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ORIGINAL RESEARCH ARTICLE

The Asian giant resin bee *Megachile sculpturalis* Smith 1853 (Hymenoptera: Apoidea: Megachilidae), a new exotic species for the bee fauna of Mallorca (Balearic Islands, Spain)

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Megachile sculpturalis Smith 1853 is found for the first time on the island of Mallorca (Balearic Islands, Spain). This is the first time that this exotic bee is reported from an island and is the southernmost record in Europe so far. Specimens were found in five distant locations throughout the island, which points out the current broad distribution of this species within the island and suggests that the introduction of *M. sculpturalis* may have happened earlier than 2020 and went unnoticed. *M. sculpturalis* females were found mainly feeding and collecting pollen from *Sophora japonica* L. 1767 (= *Styphnolobium japonicum* (L.) Schott 1830) and *Parkinsonia aculeata* L. 1753, two exotic ornamental trees. Potential entry means and impacts of this exotic bee on local biodiversity are discussed. Island ecosystems are highly vulnerable to the negative impacts produced by exotic species. Judging from the evidence of negative effects described in the literature so far, we recommend that the invasive potential and the impact of this species on native plants and pollinators within the insular context of the Balearic Islands be addressed in the future.

Keywords: Megachilidae; *Megachile*; *Megachile sculpturalis*; Balearic Islands; species introduction; invasive alien species; wild bees; island ecosystem

Introduction

The giant resin bee, *Megachile sculpturalis* Smith 1853, is a bee from the family Megachilidae native to East Asia (China, Korea, Taiwan, and Japan; Iwata, 1933; Wu, 2005) that has been accidentally introduced in America and Europe in the last decades. The first time that this species was observed outside its native range was in 1994 in North Carolina (USA). Since then, it has rapidly expanded throughout several states in North America, especially in the eastern part of the continent (Hinojosa-Diaz et al., 2005; Hinojosa-Diaz, 2008; O'Brien & Craves, 2008), becoming ultimately naturalised (Adamson et al., 2012).

The first observation of this species in Europe was in 2008 in the surroundings of Allauch, situated east of Marseille (France) (Vereecken & Barbier, 2009), becoming the first non-native bee species introduced in Europe. Since then, this species has spread throughout the continent rather quickly. The next year after its first record in France, a male *M. sculpturalis* was found in Verbania, Italy (Quaranta et al., 2014), on the other side of the Alps. However, it is not clear to which of these sites this exotic bee arrived first, nor whether this was a result of two separate introductions. Another year later, this species was found in Ascone (Switzerland) (Amiet, 2012). In 2015, it was detected in Hungary (Kovács, 2015) and a nesting population was discovered in Langenargen (Germany) (Westrich et al., 2015). In 2016, this species reached Slovenia (Gogala & Zadravec, 2018), as predicted by Gogala (2014); to be later found in Austria in 2017 (Wiesbauer, 2017), Spain in 2018 (Aguado et al., 2018) and Liechtenstein (Lanner et al., 2020), Croatia (iNaturalist, 2019), and Crimea in 2019 (Ivanov & Fateryga, 2019).

As other species in the same family, *M. sculpturalis* nests in pre-existing cavities, such as holes made by other insects or empty reeds, where brood cells are lined. Once a brood cell has been supplied with a mix of pollen and nectar and an egg has been laid, the female seals it with mud and resin (hereby its common name) (Aguado et al., 2018; Michener, 2000). It seems plausible that the arrival and dispersal of this species to and within Europe occurred by the introduction of a nest, probably through timber or ornamental garden plant trading or other commercial routes. This is also a likely feasible entry way for this species in other colonised areas, and even could explain transcontinental jumps. However, the introduction of an adult fertilised

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female cannot be completely ruled out. Moreover, judging by the separation distance of some of the observations (e.g., Crimea, with its nearest known report at 1130 km, in Hungary) it may be possible that this species be introduced more than once in Europe, or even that this exotic bee might be present in other countries and locations, yet its presence be unnoticed so far.

Materials and methods

The Balearic archipelago is located in the western Mediterranean Sea and consists of four main islands and several uninhabited islets. The main islands are Mallorca, with a surface of 3635.70 km^2; Menorca, with 694.75 km^2; Ibiza, with 571.79 km^2, and Formentera, with 82.52 km^2 (IBESTAT, 2020). Being a Mediterranean location, the climate is characterised by relatively mild winters and very warm dry summers. The most extense habitats in the archipelago are shrublands dominated by *Pistacia lentiscus* L. 1753, *Olea europaea* L. 1753, and *Ceratonia siliqua* L. 1753, as well as pine forests (mostly *Pinus halepensis* Miller 1768) and oak groves (mostly *Quercus ilex* L. 1753). Overall, the flora of the archipelago is quite rich, with around 1500 flowering plant species of which 140 are endemic (Sáez et al., 2013). Such plant diversity attracts a diverse range of pollinators, of which bees are likely the most common. So far, 236 bee species have been recorded for the archipelago (Baldock et al., 2020).

In June and July 2020, *M. sculpturalis* specimens were found for the first time on the island of Mallorca (Balearic Islands, Spain), in the cities of Palma, Portocolom, Inca, Alcúdia and Sóller. After visual identification, specimens were collected with an entomological net, killed by freezing, and pinned. Specimens were deposited at the Balearic Museum of Natural Sciences and in the authors' personal collections (see below). Coordinates were recorded with the datum WGS84 [EPSG:3857].

Results

M. sculpturalis is easily recognisable by its large size and dark wings, which make it conspicuously different from any other autochthonous bee species of the same genus present in the Balearic archipelago (Figure 1).

The following material was collected:

Megachile sculpturalis Smith 1853

- 1♀ 28.VI.2020; 2♂♂ 11.VII.2020; 2♂♂ 12.VII.2020 in Portocolom (39.409509 N, 3.254009 E, 17 m.a.s.l.), in a shrubland with an exposed bare soil area for parking purposes, feeding on *Parkinsonia aculeata* L. 1753.
- 2♀♀ and 1♂ 21.VII.2020 in Palma (39.573596 N, 2.613409 E, 68 m.a.s.l.), feeding on *Sophora japonica* L. 1767 (= *Styphnolobium japonicum* (L.) Schott 1830) trees in the surroundings of an urban area.

Figure 1. Female *Megachile sculpturalis* feeding on *Sophora japonica* in Mallorca (Balearic Islands, Spain). Its body length was approximately 23 mm.

- 1♀ 25.VII.2020 in Alcúdia (39.851101 N, 3.120609 E, 15 m.a.s.l.).
- 1♂ 25.VII.2020 in Inca (39.7338403 N, 2.9246457 E, 144 m.a.s.l.), feeding on *Parkinsonia aculeata*.

Moreover, several individuals (♂♂ and ♀♀) were observed the 5.VIII.2020 in Sóller (39.764349 N, 2.709067 E, 48 m.a.s.l.), feeding on *S. japonica* and *Vitex agnus-castus* L. 1753, yet could not be captured since they were impossible to reach. It is unknown whether females collected pollen on these plants or whether they just fed on nectar.

Voucher specimens were deposited at the Balearic Museum of Natural Sciences (MBCN), under the following deposition ID number: MBCN 23571.

Discussion

It seems likely that *M. sculpturalis* specimens found in Mallorca might belong to close-by populations and that they arrived through human activity, since this has been shown to be the factor responsible for the dispersion of this species throughout Europe (Lanner et al., 2020). Hence, the individuals of this allochthonous bee that arrived at the Balearic archipelago might belong to populations either from the Spanish north-eastern coast or from south-eastern France, based on the current distribution of this species in Europe and the touristic and commercial routes with the island of Mallorca. Furthermore, judging by the fact that *M. sculpturalis* was found at rather distant locations on the island of Mallorca (Figure 2), it could be possible that this species was actually introduced before 2020 (as a nest or an adult female) but that it had gone unnoticed until now due to low population densities. Hence, its current distribution in Mallorca might be broader than these records suggest. To the authors' knowledge, this species has not yet been introduced to the remaining islands of the archipelago. However, it seems very likely

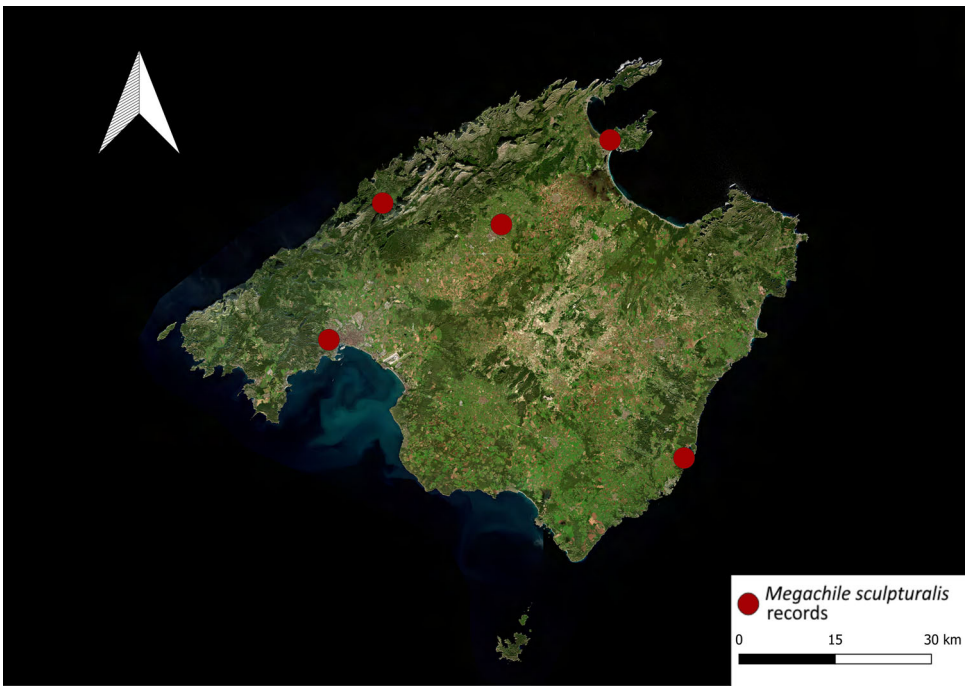

Figure 2. Locations reported in this study where *Megachile sculpturalis* was found on the island of Mallorca (Balearic Islands, Spain).

that this species will reach the other major islands in the near future, given the apparent lack of bio-safety protocols and the amount of inter-island commercial and touristic traffic. Despite this being the southernmost European record of this species so far, records of established populations even further south have been recorded in America. Thus, Mallorca's latitude might not be a restrictive factor regarding the expansion range of *M. sculpturalis* throughout Europe, which increases the chance of naturalisation of this species in the archipelago.

Due to the beneficial ecosystem services provided by pollinators, the classification of exotic bees as invasive species seems to be more controversial than that of other non-native insects. According to the Secretariat of the Convention on Biological Diversity, an invasive alien species is that one "whose introduction and/or spread outside their natural [past or present] distribution threatens biological diversity" (COP 5: Decision V/8, annex I, preamble). However, despite some increasing indicators of the negative impact of *M. sculpturalis* on local biota (e.g., Le Feon & Geslin, 2018; Roulston & Malfi, 2012; and see Russo, 2016) and even after the consideration of this species as "invasive" by some biological authorities (e.g., IUCN, 2019), this species remains not regarded as such by most governmental authorities, hence remaining unclassified. However, based on the evidence of negative impacts of this species on other autochthonous taxa (see below), we reckon *M. sculpturalis* to fit the aforementioned definition of invasive species and thus we have circumspectly considered it as such. To the authors' knowledge, no eradication, contention programmes nor management measures are being currently undertaken by any government in Europe besides the prevention of new introductions through the European regulation (EU) 2016/2031 (amended by the Implementing Directive (EU) 2019/523) on wood and plant trading and the International Standards for Phytosanitary Measures No. 15 (IPPC, 2016) on the regulation of wood packaging material in international trade. However, these measures do not target *Megachile* species and were likely already in place when the first introduction of *M. sculpturalis* occurred (IUCN, 2019).

Russo (2016) reviewed potential positive and negative impacts of non-native bees around the world and found no literature evidence of positive impacts for *M. sculpturalis*. However, negative impacts have been observed and documented at three different levels for this species so far: competition for nesting sites, pollination of invasive weeds, and the alteration of pollinator networks (Russo, 2016).

As occurs with other bees, females of *M. sculpturalis* use already-existing cavities in wooden substrates for nesting. This species seems to make use of entrance holes with a diameter of 10–16 mm (Quaranta et al., 2014), as done by other large bees such as *Xylocopa* Latreille 1802 species (Dindo et al., 1992). In fact, after the introduction of *M. sculpturalis* in the USA, Laport & Minckley (2012) and Roulston & Malfi (2012) reported the usurpation of *Xylocopa virginica* L. 1771 nests by the giant resin bee. Similarly, females of *M. sculpturalis* have been observed emptying out *Osmia bicornis* (L. 1758) and *O. cornuta* (Latreille 1805) nests to build their own in Europe (Le Feon & Geslin, 2018). *Xylocopa violacea* (L. 1758) and those *Osmia* Panzer 1806 species are

common pollinators of native plants in the Balearic Islands (Baldock et al., 2020), so these reported competition events raise the question of whether *M. sculpturalis* can have an effect on the nesting ability of Balearic native bee populations that could ultimately result in a decrease of their fitness. Moreover, many observations of this behaviour have been made at artificial nesting structures (usually referred in the literature as "trap-nests" or "bee hotels"). The increased use of this bee conservation tool in the last years might backfire and promote *M. sculpturalis*' spread and establishment (Geslin et al., 2020), unless some management measures are taken, such as the selective removal of *M. sculpturalis* nests. In fact, a possible controlling management measure to be considered would be to specifically target this species through the diameter size of the trap-nest cavities to later remove its brood. Indeed, choosing the correct diameter size in trap-nests can increase colonisation success by the species of interest (Fye, 1965), and *M. sculpturalis* showed a preference for diameters ranging from 10 to 12 mm (Quaranta et al., 2014), whilst most medium-sized bee species (e.g., *Osmia*) nest in smaller holes between 5 and 8 mm (Macivor, 2017). Nevertheless, other measures aimed at the monitorisation, contention, and eradication of this species should also be explored.

Besides competition for nesting resources, competition between *M. sculpturalis* and native bees for floral resources has also been reported. The giant resin bee is a generalist polylectic species (Quaranta et al., 2014), which means that it can potentially compete with many native species with different diet requirements (Goulson, 2003). For instance, introduced bees can prevent native pollinators from visiting their preferred sources of forage, resulting in the displacement of autochthonous species to less profitable resources (see Goulson (2003)). Also, generalist exotic species can integrate into native mutualistic interactions and even outcompete native species if resources are limiting, with the consequent disruption of current native pollination interactions (Traveset & Richardson, 2006). In fact, there is strong evidence of the inclusion of *M. sculpturalis* in native pollination networks in Europe, as suggested by plant-visit observations (Le Feon et al., 2018) and pollen analyses of brood cells and scopae from nesting females (Andrieu-Ponel et al., 2018; Quaranta et al., 2014). During our observations in Mallorca, we noticed that *M. sculpturalis* also visited native plants such as *Vitex agnus-castus*. This is not only a native plant species, but it is also considered a plant under special protection according to the Balearic list of endangered and under special protection species (Decree 75/2005 [BOIB num. 106]; note that this list includes two different categories: "endangered" and "under special protection"). Species under this category are legally protected due to their ecologic, scientific, socio-economic, or cultural importance, even though they do not necessarily need to be under any specific conservation plan. This plant species was already reported as a host plant for *M. sculpturalis* in Europe by Le Feon et al. (2018). It is likely that *M. sculpturalis* be also visiting and collecting pollen from other Balearic native plants, perhaps including endangered, vulnerable, or endemic species. The effects that this may have on local plant fitness, pollinator behaviour, and potential distribution shifts should be studied in the future. However, data on local pollinators is rather fragmentary in general, and studies in aculeate Hymenoptera, in particular, are relatively recent (e.g., Baldock et al., 2020, but see Saunders, 1904). This may present a challenge, since baseline data on Balearic wild bee diversity, abundance, and distribution is not always available or accurate. Moreover, species conservation status and population trend data at a local scale are not available beyond what is accessible at a national or European scale, which is not always necessarily relevant when extrapolating to the insular context of the archipelago.

On the other hand, the way exotic bees can shape plant-insect interactions magnifies when introduced bees indirectly modify the whole plant-pollinator network through enhancing the reproduction of allochthonous plant species. Exotic pollinators have been reported to increase seed set of a wide variety of exotic plants such as *Lupinus arboreus* Sims 1803 (Stout et al., 2002), *Lotus uliginosus* Schkuhr 1796 (Hergstrom et al., 2002), and *Lantana camara* L. 1753 in mainland Australia (Goulson & Derwent, 2004) and *Centaurea solstitialis* L. 1753 in North America (Barthell et al., 2001), among others. In Mallorca, *M. sculpturalis* was mainly found feeding and collecting pollen from *S. japonica* (a Fabaceae species native from Asia) and *P. aculeata* (an African tree also used for ornamental purposes). Several studies indicate that *M. sculpturalis* has a marked preference for *S. japonica*, albeit pollen of other exotic species has also been found to be carried by this exotic bee (Andrieu-Ponel et al., 2018; Le Féon et al., 2018; Westrich et al., 2015), suggesting that *M. sculpturalis* could increase the reproductive success of non-native plants. These results are supported by further evidence, such as the conclusions reached by Aizen et al. (2008). Their work suggests that alien species can modify the basic foundations of mutualistic networks. In their pollinator network analyses, generalist exotics became central nodes of invaded pollination webs, and links transferred from generalist native species to generalist alien species. This declined network connectivity among native species. These alterations in pollinator networks might not be enough to make native species disappear, yet native pollinator and plant species would be subject to novel evolutionary dynamics since unique ecological mutualistic interactions and evolutionary pathways could be lost forever (Aizen et al., 2008).

Islands are highly vulnerable to the impacts of exotic introductions (Simberloff, 1995), which may lead to

detrimental consequences for the island's biota. In fact, island ecosystems are characterised by poor dispersal abilities of insects, low immigration rates of pollinators, and poor insect communities (Whittaker & Fernández-Palacios, 2007). These traits enable highly generalist species to establish easier on islands than on mainland areas. Hence, given the vulnerability of insular ecosystems, it is crucial to figure out whether the new populations of *M. sculpturalis* found on Mallorca will become permanent, how they will interact with autochthonous plants and pollinators, and to what extent they will have a negative impact on native biodiversity. Plus, as much information as possible should be gathered from this introduction event in order to be able to properly manage any potential new introductions of this species from Mallorca onto the other islands of the archipelago. This would also provide valuable information that could be useful with regard to the introduction of other similar alien species such as *Megachile disjunctiformis* Cockerell 1911 (introduced in Europe in 2011 through Italy; Bortolotti et al., 2018), which are expected to arrive in the near future.

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No potential conflict of interest was reported by the authors.

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