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Rapid Communication

Occurrence of the honey bee (*Apis mellifera* L.) in the Sea of Cortés southern islands: a pathway to invasion or transient visitors?

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Abstract

The honey bee, *Apis mellifera*, is a non-native species in America that has great economic importance for crop pollination and honey exports but also is a strong competitor for the native bees. Wild colonies of honey bees may particularly impact the native bee fauna on islands negatively by competing for limited nectar and pollen resources. The southern islands of the Gulf of California were surveyed in 2018 in the most recent scientific expedition since the last one made in 1921. The presence of honey bees was recorded in twelve of fourteen sampled islands for the first time. These new records should encourage further surveys and monitoring, in order to detect if honey bees already have established viable colonies or if they are transient visitors.

Key words: Honey bees, Gulf of California, insular habitats, invasive species

Introduction

The honey bee (*Apis mellifera* Linnaeus, 1758) is a non-native species that was brought to America by European colonists and introduced in Mexico between the 16th and 17th century (Brand 1988). By the year 1889, the northern half of Baja California was already colonized by honey bees (Brandegee 1891). In 1986, for the first time, Africanized honey bees (Africanization: the process where descendants of African bees introduced in Brazil in 1951 inbred with European honey bees; Quezada-Euán 2007), were reported in southern Mexico, and in 2005 in Baja California Sur (BCS) mainland (Quezada-Euán 2007). Southern islands may have served as stepping stones for crossing from the Coast of Nayarit to the Baja California Peninsula, according to the hypothesis of Quezada-Euán (2007). Today, honey bees are considered valuable for crop pollination, contributing to an important sector of the Mexican economy (Magaña-Magaña et al. 2016), but also, they are considered an invasive species (González-Martínez et al. 2018). These bees are extreme generalists and

collect pollen and nectar from nearly every type of flower available; also their colonies may have thousands of workers (Michener 2007). Until recently, there was no evidence that wild colonies have reached the uninhabited islands of Baja California Sur, unlike of the Midriff Islands in the Northern part of the Gulf, where colonies are well established on the major islands for more than a decade (Bowen et al. 2006). *Apis mellifera* only had been recorded in one occasion in BCS islands (Espiritu Santo island – GBIF.org 2019), but now worker bees have been observed foraging on flowers in several islands. The implications of the presence of *A. mellifera* on the native bee fauna of these islands still has to be studied. Nevertheless, non-native honey bees may compete with native bees for floral resources, transmit parasites or pathogens (Guzman-Novoa et al. 2015), and they also may promote increases or decreases in seed sets of native plants as well in exotic weeds (Goulson 2003).

Materials and methods

During an expedition conducted in November 2018, an inventory of flora and fauna in fourteen islands in the Gulf of California, located between 27.46°–112.15° and 24.12°–109.77° (Figures 1, 3), was carried out by different researchers from Mexico and USA. The sampled islands were San Francisco, San Marcos, Tortuga, Carmen, Monserrate, Santa Catalina, Santa Cruz, Roca San Marcial, San Cosme, Las Galeras (right), Las Galeras (left), San Diego, San José and Cerralvo (current official name is Jacques Cousteau Island). As part of the entomological team, during this expedition two methodologies were used to sample the bee fauna on each island: (1) sweep netting on the flowering plants; and (2) trapping with bee bowls (small blue and yellow bowls filled with soapy water). Bee family and genera determination was made using the keys of Michener (2007) and Michener et al. (1994) and were corroborated by Dr. Carlos Vergara from Universidad de la Américas-Puebla. As part of the expedition, the flora of each island was inventoried by Jon Rebman and collaborators (San Diego Natural History Museum).

Results

Apis mellifera was collected in bee bowls on San Marcos (27.23°–112.09°), Cerralvo (24.15°–109.87°), and Santa Cruz islands (25.27°–110.73°), and observed foraging on plants in all visited islands, with the exception of Roca San Marcial and Monserrate islands (Figure 1C). Workers of *A. mellifera* were observed foraging on the native plants *Bourreria sonorae* (Isla Carmen), *Xylothamia diffusa* (Isla San José), *Coreocarpus dissectum,* and *Melochia tomentosa* (Isla San Marcos, Figure 3, Appendix 1 and 2).

The native bee fauna sampled in 2018 on the islands was represented by solitary species, recording ten species (*unpublished data*) from four families: Andrenidae, Apidae, Halictidae, and Megachilidae. The highest

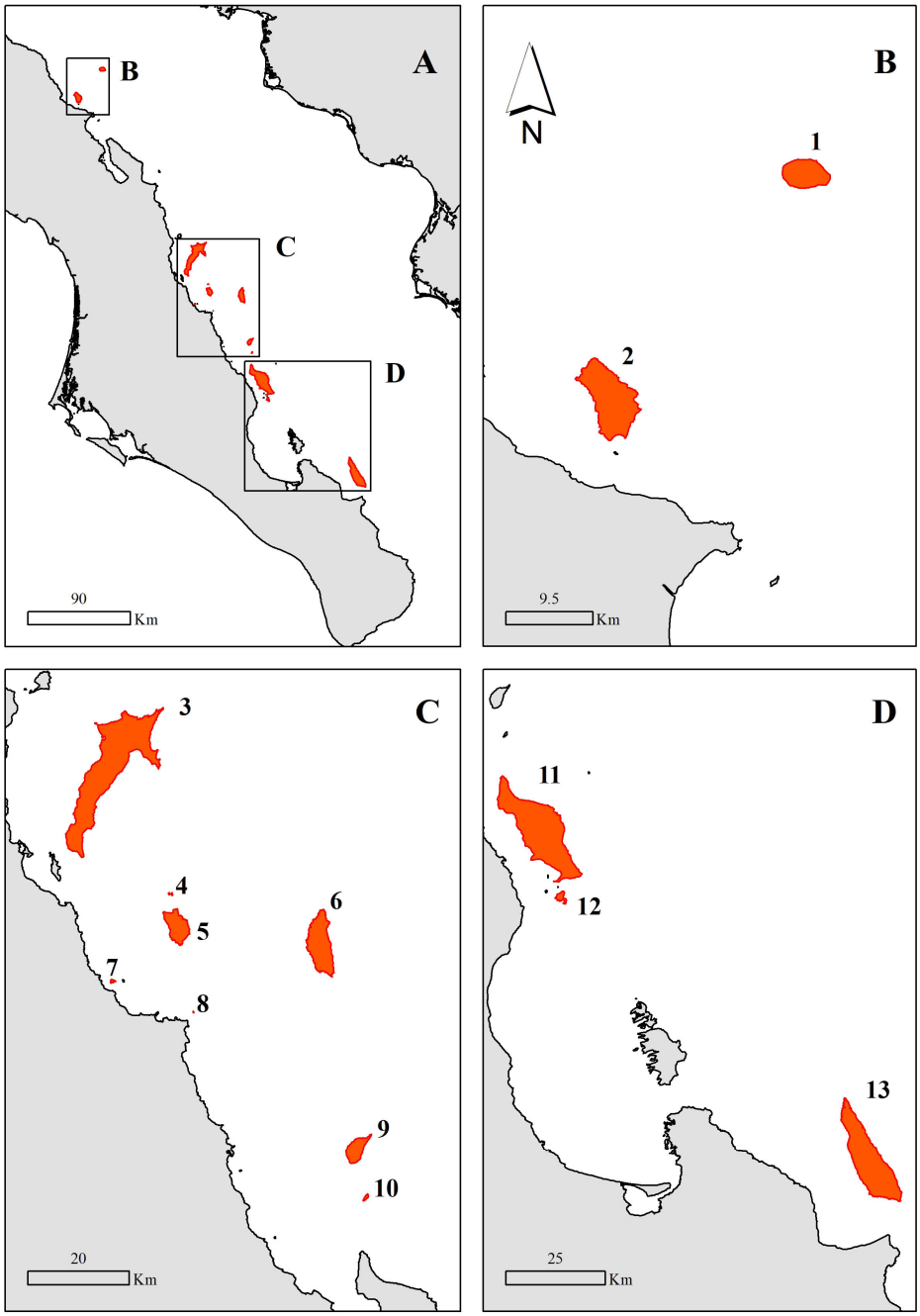

Figure 1. The Southern Gulf of California (A): Islands surveyed marked in red: B) 1. Tortuga, 2. San Marcos, C) 3. Carmen, 4. Las Galeras, 5. Monserrate, 6. Santa Catalina, 7. San Cosme, 8. Roca San Marcial, 9. Santa Cruz, 10. San Diego, D) 11. San José, 12. San Francisco, and 13. Cerralvo.

richness of bee genera was found in Cerralvo, one of the bigger islands, on San Marcos and Santa Catalina, with six genera on each island; followed by San José, Carmen and Santa Cruz islands with four bee genera each.

Surveyed islands were dominated by desert shrub vegetation. On Isla Cerralvo 254 plant species from 57 families and 171 genera were recorded, of which approximately 235 taxa might be used by bees (Jon Rebman *pers. comm.*). During the expedition, on this island at least 126 taxa had flowers (iNaturalist). On Isla San José, 65 plant families, 181 genera, and 262 species of flowering plants have been recorded (Jon Rebman *pers. comm.*).

Figure 2. *Apis mellifera* on native vegetation: a, b) *Bourreria sonorae* – Isla Carmen. Pictures by Jon P. Rebman. c) *Xylothamia diffusa* – Isla San José, d) *Coreocarpus dissectus* – Isla San Marcos, pictures by Vince Scheidt.

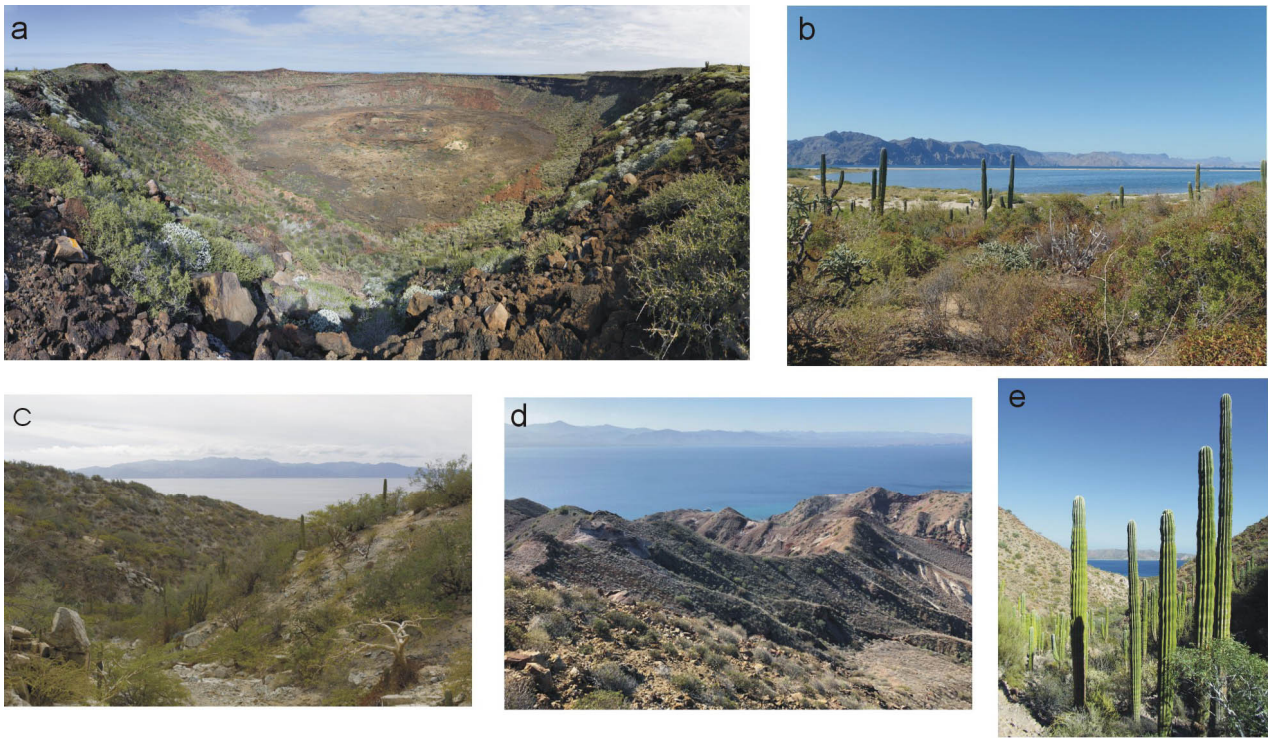

Figure 3. Island landscape where *Apis mellifera* was collected. a) Isla Tortuga, photo by Alan Harper; b) Isla San José, photo by Jim Roberts; c) Isla Cerralvo, photo by Alan Harper; d) San Marcos, photo by Jon Rebman, e) Isla Carmen, picture by Andy Pigniolo.

It is estimated that 248 plant taxa on these islands might be used by bees (Jon Rebman *pers. comm.*). According to the records in the project "Flora de Baja California" from iNaturalist, curated by Jon Rebman, 140 plant taxa were collected on San José, most of them with flowers. The number suggests ample floral resources available to bees on these islands.

Considering the number of native bee species and plants with flowers, there are many opportunities for bee-plant interactions on these islands.

Discussion

As *Apis mellifera* can rapidly colonize islands with adequate resources, its presence may present a competitive threat to native bee and/or pollinating species (e.g. The Bonin islands; Kato et al. 1999, the Midriff islands; Bowen et al. 2006). In the northern Gulf of California islands, the honey bee was reported for the first time in 1921 on Isla Tiburon (Cockerell 1923), the biggest and closest island to the mainland (ca. 1,7 km). By the end of the 1990s, the other large islands were already invaded by *Apis*, with well-established colonies (Bowen et al. 2006). Nevertheless, on the smaller islands with impoverished vegetation, honey bees were not found (Bowen et al. 2006).

A possible route of the arrival of *A. mellifera* to Sea of Cortés southern islands (BCS) is by crossing the sea from the continent. According to Bowen et al. (2006), honey bees may be easily carried long distances by the wind during storms or by hitching rides on passing boats. There is also a reasonable likelihood that because of the economic importance of beekeeping, swarms from the nearby mainland may have been the source of colonization. Likewise, these islands are on the colonization route proposed by Quezada-Euán (2007) for *Apis mellifera scutellata* (Figure S1). It is highly likely that bees observed on the islands are Africanized. Although we cannot confirm this supposition, African strains become pervasive in the populations of European honey bees as descendants of the introduced *Apis mellifera scutellata* expanded to North America from Brazil. Besides, Africanized honey bees have been present in BCS since 2005 and in Nayarit coast since 1990 (Quezada-Euán (2007), both are the possible pathway of these bees to the Sea of Cortés.

Currently, the sampled islands are not inhabited by people; however, Carmen and San José islands were inhabited by people dedicated to salt extraction in the salt ponds until the last century. Although there is no record of evidence about the presence of hives on these islands, it is possible that the Jesuits who arrived on Isla Carmen, likewise the European missionaries who introduced *A. mellifera* to America in the 1600s (Bowen et al. 2006), also have introduced hives of honey bees on the island. Currently, both Carmen and San José receive periodic visits of people for hunting and tourism.

As observed by Bowen et al. (2006) in the Midriff islands, it is possible that only the larger islands (i.e. Cerralvo and San José), or those where people arrived to settle in for hunting or living (i.e. Carmen and San José) are those that already have established wild colonies. By contrast, the smaller ones may have only transient honey bees that feed there and have

come pushed by the wind. It is also possible that the smaller islands with little or no vegetation do not have suitable habitat for honey bees. Roca San Marcial (the closest to the Peninsula), for example, is less than half a kilometer long with almost no plants, such that if honey bees arrived by wind, they would probably be unable to find sufficient food resources to become established. On Isla Monserrate, the fact that no honey bees were collected or observed does not necessarily mean they cannot arrive there, as this species was found on similar islands further away from the mainland.

Islands are vulnerable systems that often have a history of introductions that have harmed and even caused the extinction of native species (Davis 2003; Reaser et al. 2007; Aguirre-Muñoz et al. 2011). Although honey bees can coexist with native species when the conditions are favorable, *A. mellifera* may become a strong competitor for the native bees when conditions change and resources diminish, and jeopardize their reproductive success (Wenner and Thorp 1994; Thorp 1996; Paini 2004; Moritz et al. 2005; Wenner et al. 2009). On islands, such conditions could occur during long periods of drought, hurricanes, and tropical storms (Gastil et al. 1983; Mendoza et al. 2005). In addition, the honey bees may also increase the reproductive success of invasive plants, leading to a scarcity of food for native bees adapted to native vegetation of the islands, and to a decrease in mutualistic interactions (Barthell et al. 2000, 2001; Pitcairn et al. 2006; Wenner et al. 2009). On islands like Isla Carmen, Cerralvo, San José, and San Marcos, where overgrazing by introduced goats (and perhaps the bighorn sheep in Isla Carmen) reduce the native vegetation cover (Aguirre-Muñoz et al. 2011), the presence of honey bees could have an even greater negative impact on native bees.

A more exhaustive search is needed, preferably during flowering periods, to determine if *A. mellifera* has established colonies on the study islands. If so, there are risks for the native bee fauna, vegetation, and the integrity of native bee-plant interactions. Therefore, it will be necessary to develop management or eradication plans of honey bees from these islands. In Mexico, successful programs of eradication of invasive fauna on islands (not honey bees) has been developed since 1994 (Aguirre-Muñoz et al. 2011). Poisoned baits have been used at Santa Cruz island for *Apis* removal with success (Wenner 2009), a technique that could also be used in the Sea of Cortés Islands.

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Authors' Contribution:

AAJ: Was involved in the research conceptualization, sampling design, data collection, data interpretation, figures elaboration, writing, reviewing, and editing the original draft.
PAGV: Was involved in the research conceptualization, sampling design, data interpretation, writing, reviewing and, editing the original draft.

Conflict of Interest/Declaration of Interests: None

Ethics and Permits:

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Supplementary material

The following supplementary material is available for this article:

Appendix 1. *Apis mellifera* foraging on *Coreocarpus dissectus* on Isla San Marcos. Video by Austin Montero.

Appendix 2. *Apis mellifera* foraging on *Melochia tomentosa* on Isla Cerralvo. Video by Austin Montero.

Figure S1. Map that indicates the possible routes and dates for *Apis mellifera* movements towards the Baja California peninsula and the islands. Modified from Quezada-Euán (2007).

This material is available as part of online article from:
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