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Rapid Communication**Next step of the colonization of the Balearic Islands (Spain) by invasive Atlantic blue crab, *Callinectes sapidus* Rathbun, 1896 (Crustacea: Decapoda: Portunidae)**

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OPEN ACCESS**Abstract**

The arrival of invasive alien species represents key threats to native biodiversity worldwide becoming an important and growing concern. The Mediterranean Sea is a quasi-enclosed body of water connected to the Atlantic and Indian Oceans that makes it very susceptible to being affected by the arrival of invasive species. The Atlantic blue crab, *Callinectes sapidus*, with a native range along the American east coast, is a reported alien species found in Mallorca and Menorca (Balearic Islands, Spain). The current report describes the first appearance of *C. sapidus* from the Ibiza and Formentera islands (Balearic Islands). Crabs, predominantly female, were collected from high salinity waters (25–32 ‰), which could be related to the biological cycle.

Key words: colonization process, western Mediterranean, salinity

Introduction

Invasive species are a worldwide threat, and the Mediterranean Sea is one of the most affected seas (Occhipinti-Ambrogi and Savini 2003; Galil 2007). The Suez Canal is one of the main entrance pathways of marine invasive species to the Mediterranean Sea, and at least 70 invasive crustacean species have been recorded since the opening of the canal (Galil 2011), representing almost a third of the decapod crustacean species documented from the Mediterranean Sea (Garcia 2007). However, some species introductions have not been arrived at the Mediterranean Sea by the Suez Canal, such as the Atlantic blue crab *Callinectes sapidus* Rathbun,

1896 (Crustacea: Decapoda: Portunidae). This species was first reported in the eastern Mediterranean Sea in 1935, and its introduction was attributed to commercial purposes (Giordani-Soika 1951; Galil et al. 2002). The range expansion of the Atlantic blue crab in the Mediterranean Sea was very fast, becoming naturalized on the Israeli coast, Alexandria, Egypt, Rhodes Island and Gulf of Tesseloniki (Riedl 1983). Mancinelli et al. (2017) described the expansion along the southern and western Mediterranean Sea and spreading across the eastern coast of the Iberian Peninsula and the Atlantic coast of Portugal and northern Mediterranean Sea. In the Balearic Islands, the first report for the Atlantic blue crab was documented from both Mallorca and Menorca Islands in coastal lagoons of natural protected areas (Garcia et al. 2018).

Callinectes sapidus is a native species from the eastern coast of America, with a range from southern Canada to northern Argentina (Williams 1984). This crab is a very valuable crustacean for commercial and recreational fisheries in its natural distribution area (Sharov et al. 2003). The expansion of the Atlantic blue crab into the Mediterranean basin has led to the development of fisheries addressed to catch this species, such as in Turkey (Ayas and Ozogul 2011) and northern Greece (Kevrekidis and Antonadou 2018). In Spain, in 2016, the Spanish Ministry of Fisheries included *C. sapidus* in the list of commercial fishing species (BOE-A-2016-3357).

The life cycle of the Atlantic blue crab requires salinity > 20‰ for larval stages to complete development in coastal waters; however, juvenile crabs migrate back towards brackish habitats, thus becoming euryhaline during ontogeny (Millikin and Williams 1984). Both juveniles and adults can be found in freshwater areas and in high saline waters throughout their life cycle, and ovigerous females spawn in saline waters (Hines 2007; Mancinelli et al. 2013). This species is also considered eurythermal, with high fecundity, strong swimming capacity and pronounced aggressiveness, all of which may have helped this species establish in Mediterranean waters (Galil et al. 2002).

The occurrence of this species has previously been reported along the Mediterranean coast, but this manuscript presents the first report from the Ibiza and Formentera Islands, thus confirming its expansion since its first detection on June 22, 2017 (Garcia et al. 2018) to the entire Balearic Islands archipelago.

Materials and methods

Study area

The natural park of Ses Salines d'Eivissa i Formentera (SSEF) and the Marine Reserve of Els Freus d'Eivissa i Formentera (EFEF) overlap substantially, with the marine part covered by both the park and reserve and the terrestrial part only by the natural park. Additionally, these areas belong to

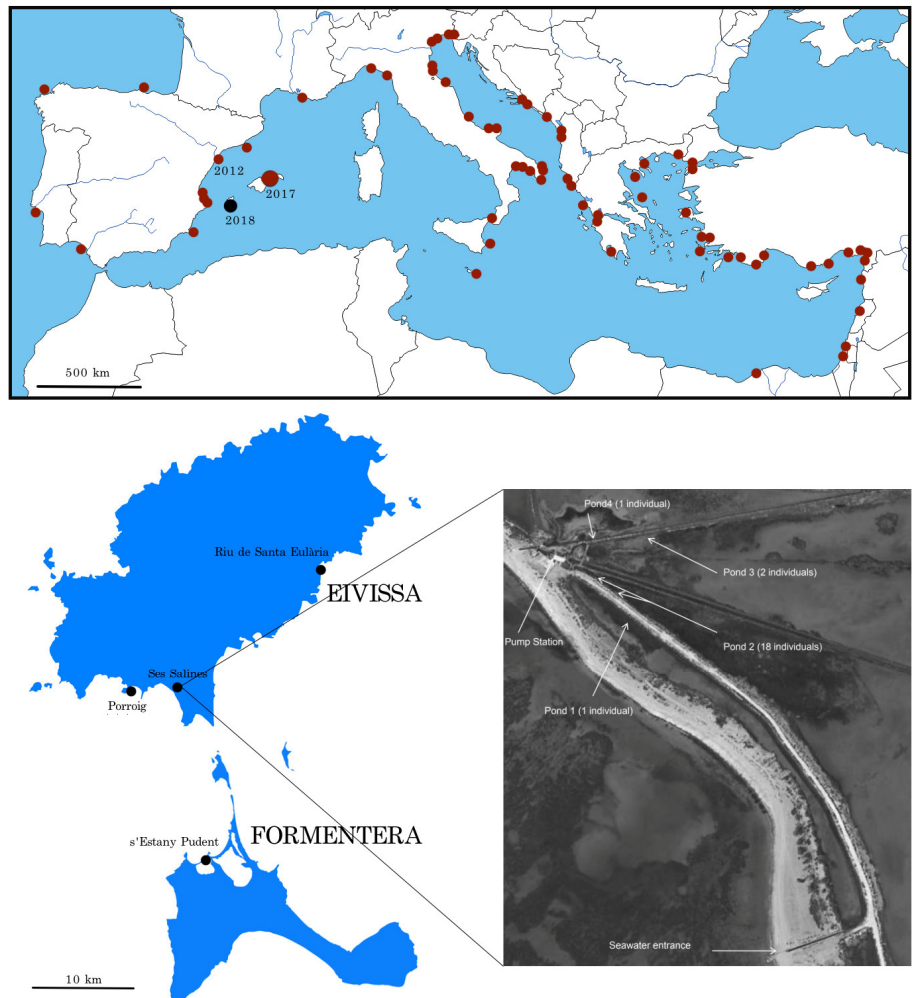


Figure 1. (A) Distribution of the records of *Callinectes sapidus* in the Mediterranean Sea based on Suaria et al. (2017) and Garcia et al. (2018) descriptions (red dots) and Ibiza and Formentera islands (black dots). (B) Distribution of the sites where *C. sapidus* was found at Eivissa and Formentera Islands. (C) Distribution of records in the salt ponds of the natural park of Ses Salines d'Eivissa i Formentera in Ibiza. Photo by Antoni Box.

European Nature 2000 under the Special Protection Areas (SPAs) for Birds and Site for Community Importance (SCI) and given the name ES000084.

On Ibiza Island, ancient and traditional salt exploitation has taken place for thousands of years (Frontera 2005) and is still running. Salt is produced through a system of ponds with different levels of salinity. Within this system, the closest tanks to the sea receive water directly from it, and, as the water evaporates, high salty water is passed to inner tanks where salt crystallizes (Figure 1). In this area *C. sapidus* specimens were found in four different ponds named from 1 to 4 (Figure 1C and Table 1). In contrast, on Formentera Island, the studied area was located at a coastal lagoon, s'Estany Pudent, with little connection with the open sea through a small channel.

Additionally, information on the occurrence of *C. sapidus* was collected from the native people of Ibiza. Therefore, the following two additional sites were included: Santa Eulària des Riu (eastern coast of Ibiza), which is a river mouth with or without water flow during most part of the year, and Porroig (Figure 1B).

Table 1. Records of *Callinectes sapidus* collected from the Ibiza and Formentera Islands (Balearic Islands) during 2018, where SSEF is the natural park of Ses Salines d’Eivissa i Formentera.

Date	N	Locality	Island	Coordinates	Raw salinity range
2018 July	1	SSEF-Pond 4	Ibiza	38.863540; 1.358930	26–30‰
2018 August	1 ♂	SSEF-Pond 1	Ibiza	38.862542; 1.359325	28–32‰
2018 August	2	SSEF-Pond 3	Ibiza	38.863356; 1.359768	27–30‰
2018 August	16 ♀, 1 ♂, 1 immature	SSEF Pond 2	Ibiza	38.863089; 1.358998	28–32‰
2018 July	1	Porroig	Ibiza	38.863056, 1.306945	27‰
2018 July	4	S’Estany Pudent, SSEF	Formentera	38.731925; 1.413664	25–26‰
2018 July	6	SSEF Ponds 1–4	Ibiza	38.862542; 1.359325	26–32‰
2018 September	3 ♂	Santa Eulària des Riu	Ibiza	38.977771; 1.530833	25–27‰



Figure 2. Image of a *Callinectes sapidus* female in the shallow waters of the salt ponds in the natural park of Ses Salines d’Eivissa i Formentera. Photo by Antoni Box.

Capture, sex determination and biometry

During algal cleaning of the closest ponds to the sea during July 2018 at the salt exploitation of the natural park of Ses Salines d’Eivissa i Formentera on Ibiza Island (pond 1 in Figure 1C), several *C. sapidus* specimens were observed in the pumping area. Due to the shallow waters and high water transparency, specimens were easily observed and hand-caught (Figure 2). In other areas such as Santa Eulària des Riu, Porroig and s’Estany Pudent specimens were hand-caught and captured with funnel traps. Captured specimens were frozen for morphological analysis and then preserved in 70% ethanol.

Captured crabs were identified according to the key and description by Williams (1974, 1984) based on characteristics of the shell, as well as the shape and arrangement of the first male pleopods. For most of the captured individuals, width (distance between the base of the marginal spines, Wc) and length of the carapace (distance from the tip of epistomial spine and the back margin of the carapace, Lc) were measured with digital calipers. Individuals were sexed, and females were recorded as ovigerous or

not. Additionally, salinity values were measured with a multiparametric probe (HANNA HI 9828) the first day of capture in each locality.

Results

During July and August 2018, 36 *C. sapidus* were reported from the Ibiza and Formentera Islands (Figure 2). Twenty-two of them were hand-caught from the salt exploitation ponds in the SSEF (19 ♀, 2♂, 1 immature). Six additional specimens were also observed in the same area, but they were not captured. Four male specimens were found in s'Estany Pudent, inside the SSEF (Formentera Island). One isolated individual was observed in Porroig, and three male individuals were found in Santa Eulària des Riu. See Figure 1C for locations of sites and Table 1 for the number of captures from each site. Ovigerous females and juveniles were found in salt ponds and at the mouth river of Santa Eulària. While the juveniles in the salt ponds occupy areas with *Cymodocea nodosa* seagrass, those reported at Santa Eulària were not found under vegetation protection.

Across all sites and dates, the measurements of captured specimens of *C. sapidus* were the following: females (n = 16), Wc: 107.27 ± 9.02 mm, Lc: 61.49 ± 6.07 mm and males (n = 5), Wc: 59.24 ± 9.99 mm, Lc: 99.11 ± 22.77 . The rest of the individuals were not measured because some spines and part of the carapace were broken. Specimens were captured in areas with salinities between 25 and 32 ‰ and water depths from 0.3 to 1.8 m. Higher salinity values corresponded to the external channels closer to the sea, while lower values corresponded to the river mouth of Santa Eulària des Riu and the coastal lagoon of s'Estany Pudent.

Discussion

In the present report, the first records of *C. sapidus* from the Ibiza and Formentera Islands are documented, although previous records exist from 2017 for the Balearic Islands, specifically from the Mallorca and Menorca Islands (Garcia et al. 2018). However this report is the first documenting the presence of *C. sapidus* in salt ponds of an industrial salt production site. On Ibiza Island, ovigerous females were found both in salt ponds at the mouth of the river of Santa Eulària, confirming the wide range of habitats and salinities which could be colonized by this species.

A rapid expansion of this species was observed in Spanish coastal waters with the first records in 2013 in Delta del Ebro (Tarragona) and only three years later in the estuary of Segura River (Alicante) (Castejón and Guerao 2013; Bañón et al. 2016). In the Balearic Islands, *C. sapidus* had previously colonized the Mallorca and Menorca Islands and now has colonized all four islands within the island chain. A more accurate study should be conducted to know the distribution of the species around the whole coast of the Balearic Islands. As Garcia et al. (2018) stated, there is no definitive evidence of one particular pathway that could explain the arrival of *C. sapidus*

to the Balearic Islands. The arrival to the Ibiza and Formentera Islands could be explained as natural dispersion of adults (due to the proximity of the species from Mallorca Island), the dispersion of larvae by sea currents or ballast tanks of ships (Garcia et al. 2018), an intentional introduction for commercial purposes (Giordani-Soika 1951), or a combination of these vectors.

Invasive species can have negative impacts not only on biodiversity but also on economic activities. Particularly, *C. sapidus* is included in the list of the 100 worst invasive alien species in the Mediterranean Sea (Streftaris and Zenetos 2006). The potential invasive behavior of *C. sapidus* and the colonization of the whole archipelago raise concerns about its impact on native biodiversity and natural and fragile insular habitats, especially in the natural protected areas. Major efforts need to be applied by environmental authorities to prevent the impact of this species, especially in those areas of special relevance for native biodiversity such as natural parks and marine reserves, but first the level and scope of the impact should be evaluated. Species monitoring is recommended in order to understand the expansion process and *C. sapidus* population dynamics around the coasts of the Balearic Islands. Then, if it is demonstrated that an impact on native biodiversity is occurring, *C. sapidus* should be declared an invasive species. However, according to the current Spanish laws, there is a problem with this scenario. While the Spanish Ministry of Fishery allows the capture of *C. sapidus* for commercial purposes (BOE-A-2016-3357), the Natural Heritage and Biodiversity Law (BOE-A-2007-21490) established that an invasive species, or any of its parts, cannot be commercialized. On the contrary, according to Regulation (EU) 1143/2014 a temporary commercial use aiming to eradicate or control an invasive species is allowed. A possible solution could be the declaration of *C. sapidus* as an invasive species by the state or European level, allowing the commercial use as a complementary mechanism for eradication or population control. Therefore, it would be necessary that local, state and European environmental authorities act accordingly against the invasion of this species in their territories.

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