

RESEARCH ARTICLE

First record of *Penaeus pulchricaudatus* (Stebbing, 1914) and the establishment of *P. aztecus* (Ives, 1891) and *P. hathor* (Burkenroad, 1959) in Cretan waters, Greece

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Abstract

Citizen science has been proven to be a valuable tool in monitoring marine biodiversity in the Mediterranean Sea contributing to the early detection and the monitoring of non-indigenous species (NIS) often by combining the use of social media and smartphone technology in data collection. In May 2016, iSea launched a relative project aiming to record the information on the occurrence, distribution and expansion of marine alien species in Greek and adjacent waters. The present paper describes the first report of the Lessepsian prawn *Penaeus pulchricaudatus* (Decapoda, Dendrobranchiata, Penaeidae) and provides strong evidence on the establishment of the alien prawns *P. aztecus* and *P. hathor* in Cretan waters based on the occurrences reported in the present study and on previous records.

Keywords: *Penaeus pulchricaudatus*, *Penaeus aztecus*, *Penaeus hathor*, decapoda, alien species, south Aegean Sea

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Introduction

Citizen science has been proven to be a valuable tool in monitoring marine biodiversity in the Mediterranean Sea (Giovos *et al.* 2018a) although there is certain limitation (Katsanevakis and Moustakas 2018). Several projects, initiatives and campaigns are currently flourishing in the basin, contributing to

the early detection and the monitoring of non-indigenous species (NIS) (Giovos *et al.* 2018a), while social media and smartphone technology are also playing an important role in improving data collection and enhancing participation (Cardoso *et al.* 2017; Sladonja and Poljuha 2018). In May 2016, iSea launched a citizen science project “Is it alien to you? Share it” aiming to record information on the occurrence, distribution and expansion of marine alien species in Greek waters and the contiguous seas. To date, the project has gathered a vast amount of information regarding the presence of NIS in Greece, including several first records, helping to further elucidate the current state of marine bioinvasions in Greece, including the expansion and the establishment of *Pterois miles* (Giovos *et al.* 2018b), the northward expansion of *Synaptula reciprocans* (Ragousis *et al.* 2017) and the first record of *Abudefduf sexfasciatus* (Lacepède, 1801) and *Acanthurus sohal* (Forsskal, 1775) in the Mediterranean Sea (Giovos *et al.* 2018a).

In 2016, an online data repository was established by iSea, in which citizen scientists could easily upload photographic materials along with information on specimen size (length and/or weight), depth, number of specimens, exact location, date and type of observation (free diving, underwater photography, shore-based fishing, boat-based fishing, spearfishing). A Google Form and a Group on Facebook were established to facilitate these reports. The project’s Facebook group currently numbers more than 5000 members, 1500 of which are actively engaged on a daily basis. The vast majority of the participants are recreational fishers, followed by scuba divers, naturalists and professional fishermen. Further, several experts on marine alien species are part of the group community offering their expertise for the identification of the specimens reported.

Penaeus pulchricaudatus (Stebbing, 1914) is a paradigm of the classification controversy and uncertainty in Dendrobranchiata- Penaeid prawns (see De Grave and Fransen 2011). Till recently, it was believed to be a junior synonym of the globally economically important *Penaeus japonicus*. *P. pulchricaudatus* demonstrates strong genetic geographical structure. It occurs in Australia, West Indian Ocean, South China and Red Seas. The population of the Mediterranean was originated from the Red Sea stock that expanded northwards, contributing to the Lessepsian migration phenomenon (Tsoi *et al.* 2014). In Greece, it was reported for the first time, as *P. japonicus*, in Rhodes Island, 1995 (Kevrekidis and Kevrekidis 1996), but it was introduced for aquaculture purposes in 1990 at Argolikos Gulf, Ionian Sea and Lagos Lagoon, Aegean Sea (Kevrekidis *et al.* 1996), and it is unknown if any individuals had escaped into the wild. ELNAIS (2018) regards the species as questionable in these areas. The species is a component of the Greek and Turkish prawn fishery locally (Can *et al.* 2004; Corsini-Foka *et al.* 2015) and it should be considered as established in the south-eastern Aegean Sea, since it was further reported in the area (Kevrekidis and Galil 2003; Corsini-Foka *et al.* 2015). Nevertheless, the species has not been reported from the Cretan waters.

Northern brown shrimp, *Penaeus aztecus* Ives, 1891, is a penaeid prawn which is indigenous to the Atlantic coast of north America from Martha's Vineyard, Massachusetts to the Yucatan Peninsula, Mexico (Cook and Lindner 1970; Lassuy 1983) and it is one of the most important fisheries part of Gulf of Mexico's prawn fishery (e.g. Holthuis 1980; Saoud and Davis 2003). Northern brown shrimp was reported from Argentinian waters, but it is unknown if it is established or not (Boschi 1968). In the Mediterranean Sea, it was recorded for the first time off Antalya (Deval *et al.* 2010) and in a short period (June 2011-November 2013) from various regions across the basin; Bay of Iskenderun in Turkey (Gökoğlu and Özvarol, 2013); Thermaikos Gulf, Greece (Nikolopoulou *et al.* 2013), Kevrekidis 2014, Minos *et al.* 2015); Southern Adriatic Sea, Montenegro (Marković *et al.* 2014), Corfu Island, Ionian Sea, Greece (Kapisir and Apostoloidis 2014). Thereupon, more occurrences were reported from north Aegean and Nestos River estuaries (Minos *et al.* 2015), south Aegean Sea, Chalki Island (Kondylatos and Corsini-Foka 2015), Gulf of Lion and southern Levantine Sea (Galil *et al.* 2016), Çandarlı Bay, Turkey (Bakir and Aydin 2016), Tyrrhenian Sea (Cruscanti *et al.* 2015), Sicily, Italy (Scannella *et al.* 2017) and recently from Nile Delta, Egypt in ponds of a shrimp farming unit and adjacent Mediterranean waters (Sadek *et al.* 2018). The northern brown shrimp is considered as an established species in the Ionian Sea (Zenetos and Giavasi 2015; Renda and Crocetta 2016) and off Aegean Sea, except Crete Island (see Kapisir and Maina 2016; ELNAIS 2018).

Penaeus hathor (Burkenroad, 1959) is found from the south eastern coasts of Africa to the Red Sea, the Persian Gulf, Gulf of Oman, Pakistani waters, India and Sri Lanka (Pérez-Farfante and Kensley 1997). Initially it was considered as a subspecies of *P. latisulcatus*, but Burkenroad (1959, cited in Miquel 1984) described important morphological differences. As most of the penaeid prawns, it is a species with commercial value. The first Mediterranean record, as *Melicertus hathor*, was made off Israeli coasts (Galil 1999). *P. hathor* expanded its distribution north to the Gulf of Antalya (Gokoglu and Kaya 2008) and to Gökova Bay (Yokes *et al.* 2007). It is established in the Turkish coast of the Levantine Sea (Çinar *et al.* 2011). In Greek waters, it is reported for the first time from the south eastern Aegean and Kastelorizo Island (Kapisir and Dogrammatzi 2013). Surprisingly, Kapisir and Chalari (2015) reported a female individual from Saronikos Gulf, showing westward geographical expansion. Lastly, Kondylatos and Corsini-Foka (2017) reported the species from Rhodes Island, revealing its invasive nature. However, ELNAIS (2018) does not report *P. hathor* from Cretan waters, inhabiting the wide area of the Heraklion Gulf (Skarvelis *et al.* 2015).

The current study describes the first record of the Lessepsian prawn *P. pulchricaudatus*, reporting the first report and the establishment of *P. aztecus* from Crete Island, based on several records from Heraklion Bay. It also provides further records of the Lessepsian *P. hathor*, that expands the species' distribution to Sitia Gulf (northeastern coast of Crete), only known from Heraklion (Skarvelis *et al.* 2015). These findings of *P. aztecus* and *P. hathor* demonstrate that the

species is established in Crete Island, at least at the northern shores. All reports are directly linked with the iSea's citizen-science project "Is it Alien to you? Share it", along with the use of social networks. Furthermore, the present study emphasizes the important contribution of citizen-scientists as previously acknowledged in earlier studies on non-indigenous species (e.g. Kondylatos *et al.* 2017; Langeneck *et al.* 2017; Ragousis *et al.* 2017; Zenetos *et al.* 2017; Giovos *et al.* 2018a; 2018b).

Materials and Methods

The online reporting system, established by iSea, in the framework of the project "Is it Alien to you? Share it", along with the use of social media were used to collect initial data from 29 May 2017 to 15 February 2018.

The individual of *P. pulchricaudatus* was identified based Tsoi *et al.* (2014), the *P. aztecus* individual was identified based on (Pérez Farfante and Kensley 1997; Bakir and Aydin 2016) and the *P. hathor* specimens according to the description provided by Galil (1999), Gokoglu and Kaya (2008), Kapiris and Chalari (2015) and Kondylatos and Corsini-Foka (2017).

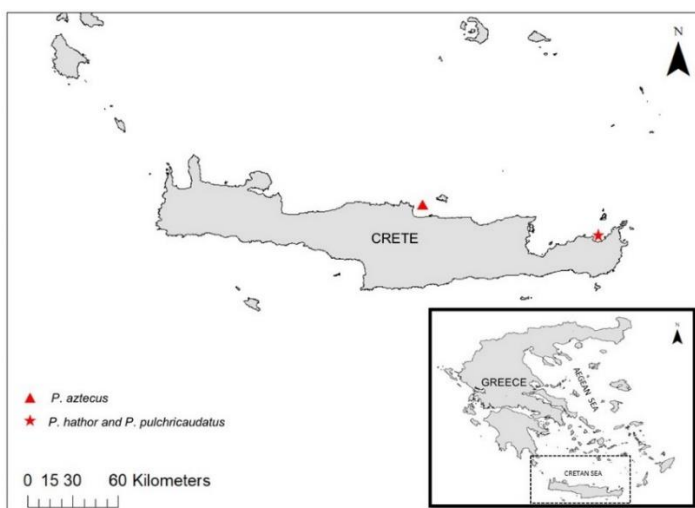


Figure 1. The capture locations of *Penaeus pulchricaudatus*, *P. aztecus* and *P. hathor* in this study

The individuals of *P. pulchricaudatus* and *P. hathor* were caught by artisanal fishermen at Sitia Gulf, approximately at 35°12' N 26°08' E, with the use of "prawn" net-trammel net (Figure 1). The mesh opening was 20-24 mm from knot to knot at depth range of 20-30 m and soak time of 12-14 h in sandy-muddy bottoms. One individual of *P. pulchricaudatus* was caught on 29 May 2017. From

21 September 2017 to 15 February 2018 four *P. hathor* individuals were caught at Sitia Gulf. *P. aztecus* were collected by commercial trawler, on 7 November 2017 and 5 May 2018, at the wide area of Heraklion Gulf, approximately 35°22' N 25°07' E (Figure 1), at depth of 80-84 m, on muddy bottoms mixed with gravel-pebbles during night operations. Two individuals were reported, one at each date.

Results and Discussion

The carapace of *P. pulchricaudatus* has well developed grooves and ridges, but transverse sutures are missing. Rostrum bears 9 well developed dorsal teeth and 1 ventral. Hepatic spine is very pronounced, and the carina is sharp. The body coloration is light yellow and brown-dark reddish transverse bands are present. The bands on the carapace extend from top to the midline. Periopods are yellow to cream-whitish and the flagella are reddish-brown. Pleopods are yellowish to reddish with white and brown spots-blotches at their bases. The distant end of uropods is yellow with a small blue blotch, while margins are red (Tsoi *et al.* 2014). *P. aztecus* differs externally by the overall uniform creamy-beige or partially orange body coloration. It has no stipes or blotches. Other anatomic features such as the epigastric tooth and abdominal cicatrices are characteristics of the species (Pérez Farfante and Kensley 1997; Bakir and Aydin 2016). *P. hathor* bears some brownish vertical stripes, an overall beige-creamy body coloration, a dark brown carina -starting from the middle of the abdomen and terminating in the middle of telson, and blue uropods, making it easy to identify it among other prawns dwelling in the Mediterranean waters (Galil 1999; Gokoglu and Kaya 2008; Kapiris and Chalari 2015).

The *P. pulchricaudatus* individual was around 17 cm in total length (Figure 2A). The *P. hathor* individuals were 12-14 cm, in total length (Figure 2C). Finally, the *P. aztecus* specimens were estimated to be at 15-30 cm in total length. All individuals of these three species were sold to the market. The *P. aztecus* individuals (Figure 2B) presented in this study are among the largest, in total length, ever reported from the Aegean coasts (27-30 cm, Gökoğlu and Özvarol 2013; 25.4 cm, Bakir and Aydin 2016) and Greek Ionia Sea (26 cm, Zenetos and Giavasi 2015). *P. hathor* specimens are in accordance, yet larger, with those described by Kapiris and Dogrammatzi (2013) (Figure 2C). the estimate for *P. pulchricaudatus* is also in accordance with the earlier studies from Rhodes Island (Kevrekidis and Kevrekidis 1996).

The present study reports for the first time two prawn species from Cretan waters, the cryptic *P. pulchricaudatus* and the alien *P. aztecus*, and also it provides strong evidence for the establishment, at least on the northern shores of Crete, of both *P. aztecus* and *P. hathor* based on several individuals, described in the present study and on earlier samples (*P. hathor*) from Heraklion Bay that were caught by artisanal fisheries (Skarvelis *et al.* 2015). In Cretan waters there are other alien crustaceans that are established or recorded such as *Percnon gibbesi*

(Katsanevakis *et al.* 2011) and the stomatopod *Erugosquilla massavensis* - described as *Oratosquilla massavensis*, (Dounas and Steudel 1994).

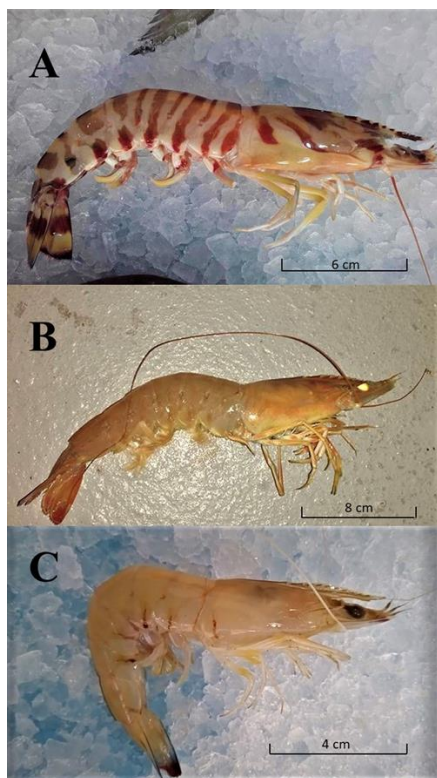


Figure 2. (A) *Penaeus pulchricaudatus* from Crete, Sitia Gulf, source: Ioanna Voulgari.
(B) *P. aztecus* Crete, wide area of Heraklion, source: Stelios F.
(C) *P. hathor* Crete, Sitia Gulf, source: Ioanna Voulgari

P. pulchricaudatus and *P. hathor* were introduced via the Suez Canal and contributing to the wider phenomenon of Lessepsian migration (Galil 1999; Tsoi *et al.* 2014). The Atlantic prawn *P. aztecus* is an alien species and both ballast water (Deval *et al.* 2010; Nikolopoulou *et al.* 2013; Kevrekidis 2014; Marković *et al.* 2014; Minos *et al.* 2015 Bakir and Aydin 2016; Scannella *et al.* 2017) and aquaculture (Crusanti *et al.* 2015; Galil *et al.* 2016; Sadek *et al.* 2018) were considered as potential vectors. Besides Lessepsian migration, shipping (ballast water and hauling) is considered to be the second most common introduction vector in the eastern Mediterranean (Katsanevakis *et al.* 2014; Zenetos 2017) not only for decapods (e.g. Kondylatos *et al.* 2017) but also for fish (e.g. Batjakas *et al.* 2015).

Although the prawn culture industry is active in Turkish coasts, it is rather limited (Bakir and Aydin 2016) and the cultivated species are *P. japonicus* and *P. semisulcatus* (Türkmen 2007). In the Mediterranean and adjacent Atlantic waters *P. japonicus* is extensively cultivated (Quigley *et al.* 2013 and references within), and it is also introduced at Lagos Lagoon (Kevrekidis *et al.* 1996), where ELNAIS (2018) reports some questionable occurrences of the species in the wider area. *P. vannamei* is cultured in Egypt (Sadek *et al.* 2018) with no reports of escapes, but there is not any evidence of *P. aztecus* cultivation in the Mediterranean waters, including Greece (Scannella *et al.* 2017). Perhaps, the scenario of more than one release incidents of ballast water (Nikolopoulou *et al.* 2013; Scannella *et al.* 2017) can explain the current species' range in the Mediterranean. Furthermore, the presence of *P. aztecus* fits well with the general distribution pattern of "several hot-spot areas", like other alien species associated with shipping, as described by Katsanevakis *et al.* (2014).

Although the presence of *P. pulchricaudatus* is verified in Mediterranean waters, it is not wise to exclude the concurrently presence of *P. japonicus*, yet further evidence and investigation is required, since the species is introduced and cultivated in the European and Mediterranean waters (Türkmen 2007; Quigley *et al.* 2013).

There is a controversy among scientists on the taxonomy of genus *Penaeus*, even on the spelling of the genus name, (see Tsoi *et al.* 2014 and references within for details). The authors of this study followed WoRMS (2018) for the taxonomy and systematics.

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