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Research Article

On the occurrence of three exotic decapods, *Callinectes sapidus* (Portunidae), *Portunus segnis* (Portunidae), and *Trachysalambria palaestinensis* (Penaeidae), in northern Tunisia, with updates on the distribution of the two invasive portunids in the Mediterranean Sea

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Abstract

The occurrence of three exotic decapods is reported from the Lagoon of Bizerte (northern Tunisia) based on records gathered from local fishermen. These three species are the Atlantic blue crab *Callinectes sapidus* Rathbun, 1896, the blue swimming crab *Portunus segnis* (Forskål, 1775), and the Lessepsian shrimp *Trachysalambria palaestinensis* (Steinitz, 1932). Our sightings confirm the establishment of *C. sapidus* and *P. segnis* in the Lagoon of Bizerte and widen the known distribution of *T. palaestinensis* to northern Tunisia. The updated distribution maps of *C. sapidus* and *P. segnis* in the Mediterranean Sea confirm the rapid expansion and colonizing behaviour of these two invasive portunid species. Finally, the potential impacts of these two latter species on the local ecosystem were discussed.

Key words: biological invasions, exotic species, crustaceans, transitional environments, Lagoon of Bizerte

Introduction

Nowadays, the Mediterranean Sea is continuously exposed to biological invasions due to the accentuation of several human factors and pressures including shipping, aquaculture trade, and creation of corridors such as the Suez Channel (Katsanevakis et al. 2014a; Azzurro et al. 2019; Morri et al. 2019). The increasing frequency in the number of introduced species has become a worrying problem since some invasive species can rapidly colonize the new habitats leading to several ecological and economic consequences (Grosholz 2002; Wallentinus and Nyberg 2007; Molnar et al. 2008; Vilà et al. 2010; Katsanevakis et al. 2014b). On the other hand, introduced species can be beneficial in the newly invaded environments,

providing additional commercially-important resources, and acting as key species playing several important ecological roles and offering numerous ecosystem services (Schlaepfer et al. 2011; Simberloff et al. 2013; Katsanevakis et al. 2014a).

Like in many other Mediterranean countries, biological invasions were reported, during the past century, along the Tunisian coasts too (Antit et al. 2011; Ounifi-Ben Amor et al. 2016). Noteworthy, according to Ounifi-Ben Amor et al. (2016), a remarkable increase in the frequency of alien species introductions and/reports was noted during the past few decades. Some of the newly arrived species to Tunisian coasts showed a remarkable invasive behavior by their rapid establishment and spread, leading to some ecological and socio-economic problems (Crocetta et al. 2015; Rabaoui et al. 2015; Stamouli et al. 2018).

In this paper, the presence of three alien decapod species is reported from the Lagoon of Bizerte based on records gathered from local fishermen. These taxa include the Atlantic blue crab *Callinectes sapidus* Rathbun, 1896, the blue swimming crab *Portunus segnis* (Forskål, 1775), and the Lessepsian shrimp *Trachysalambria palaestinensis* (Steinitz, 1932). For both *C. sapidus* and *P. segnis*, the sightings provided herein constitute additional records after recent single records along the northern Tunisian coast (Mili et al. 2019; Katsanevakis et al. 2020). As for the Lessepsian species *T. palaestinensis*, it is recorded for the first time in the northernmost lagoon of Tunisia (Bizerte Lagoon). In the case of *P. segnis*, additional records along the southern and eastern coasts of Tunisia are also provided herein, showing that the species was able to colonize the entire Tunisian coast within 6 years from its first record in the Gulf of Gabès (Rabaoui et al. 2015). Like *C. sapidus*, *P. segnis* is rapidly expanding its distribution in the Mediterranean Sea.

Materials and methods

The Lagoon of Bizerte is located in the north of Tunisia (37°8′–37°14′N; 9°46′–9°56′E). It has a total surface area of 150 km^2 and an average depth of 8 m. This water body is connected to the Mediterranean Sea through a 0.3 × 7 km straight channel, of 12 m depth. The Lagoon of Bizerte hosts very rich and diversified floristic and faunistic communities, including fisheries resources. Important mussel (*Mytilus galloprovincialis*) and oyster (*Crassostrea gigas*) aquacultures are installed in the lagoon with a total annual production that exceeds 100 tonnes. Various anthropogenic pressures, including domestic and industrial wastes and shipping activity related to the main commercial port of Bizerte, threaten the local ecosystem (Wakkaf et al. 2020a, b).

Representative specimens of the three alien species *C. sapidus*, *P. segnis*, and *T. palaestinensis* were collected between March and July 2020 by analysing

Table 1. Summary of the collection dates, collection zones of the three alien decapod species, *Callinectes sapidus*, *Portunus segnis*, and *Trachysalambria palaestinensis*, in the Lagoon of Bizerte (and Ichkeul lake, in the case of *C. sapidus*), as reported by local fishermen. Some of the environmental factors (substratum type, substratum cover, depth) and the number and gender of the collected specimens are also provided for each observation.

Species	Collection/ observation dates	Zones of observation	GPS coordinates (DD)	Substratum type	Substratum cover	Depth (m)	Number and gender of individuals caught
Callinectes sapidus	April 8th 2020	Menzel Abderrahman	37.2216833 9.8443528	sandy	*Cymodocea nodosa* seagrass	2	2 ♂
	June 10th 2020	Menzel Abderrahman	37.2096139 9.8581389	sandy	*Cymodocea nodosa* seagrass	3	1 ♀
	June 26th 2020	Menzel Abderrahman	37.2280000 9.8572528	sandy	*Cymodocea nodosa*-Algae	5	2 (gender unreported)
	June 30th 2020	Mouth of Tinja wadi in the Lagoon of Bizerte	37.1865889 9.7945194	sandy-muddy	Algae	3	3 (gender unreported)
	July 3rd 2020	Mouth of Tinja wadi in Ichkeul Lake	37.1675972 9.7529278	muddy	Bare	4	1 (gender unreported)
Portunus segnis	May 10th 2020	Menzel Abderrahman	37.2159611 9.8654722	sandy	*Cymodocea nodosa* seagrass	2	3 (1 ♂ + 2 ♀)
	June 18th 2020	Jedara	37.1880583 9.9162167	sandy-muddy	Algae	6	2 (gender unreported)
	June 23rd 2020	Menzel Bourguiba	37.1563972 9.8191167	sandy-muddy	Algae	4	1 (gender unreported)
	July 5th 2020	Oum Heni	37.1405333 9.8542639	muddy	Algae	3	2 (gender unreported)
Trachysalambria Palaestinensis	March 14th 2020	Menzel Bourguiba	37.1659583 9.8237500	sandy-muddy	*Cymodocea nodosa*-Algae	2	3 ♀
	April 6th 2020	Central Bizerte Lagoon	37.1725278 9.8533222	muddy	Bare	6	4 (gender unreported)
	June 19th 2020	NE Bizerte Lagoon	37.2023944 9.8045806	sandy-muddy	Algae	2	1 (gender unreported)

the bycatch of local fishermen operating in the Lagoon of Bizerte. In total, 9 *C. sapidus*, 8 *P. segnis*, and 8 *T. palaestinensis* specimens were collected on several occasions in 2020 (Table 1). For each species, only the specimens caught during the first collection time were obtained from fishermen (2 *C. sapidus* specimens + 3 *P. segnis* specimens + 3 *T. palaestinensis*). They were immediately preserved and transported to the laboratory, where they were measured, sexed, and identified using appropriate identification guides (Williams 1974; Sakaji and Hayashi 2003; Chan et al. 2016; Insacco et al. 2017). The information related to the subsequent records (Table 1) were later gathered based on a questionnaire survey conducted with 10 fishermen with whom the authors were cooperating from 2019. During the interview, an identification guide showing the photographs of the three decapods were shown to the interviewees to ensure their ability to identify the species and distinguish the two different portunids. The records of *C. sapidus* and *P. segnis* provided here are new, after their first single records held in 2019 (Mili et al. 2019; Katsanevakis et al. 2020).

The new records of the two invasive portunid crabs headed also to the update of the distribution maps of these two species in the Mediterranean Sea. To do so, the Mediterranean locations where *C. sapidus* was recorded from Garcia et al. (2018), Taybi and Mabrouki (2020), Katsanevakis et al. (2020), Ragkousis et al. (2020), and Falsone et al. (2020) (and references cited therein), were extracted, and a new map was created, to which the records reported during this investigation were added. For *P. segnis*, an

extensive bibliographic research was conducted and all the occurrence areas/locations where the species was recorded were collected, and a map showing the distribution of the species in the Mediterranean Sea, including the present records, in addition to others gathered from social media and fishermen along the southern and eastern coast of Tunisia, was created. The consulted literature included the following references: Fox (1924), Gruvel (1928, 1930), Steinitz (1929), Ghisotti (1966), Demetropoulos and Neocleous (1969), Corsini-Foka et al. (2004), Crocetta (2006), Crocetta et al. (2015), Rabaoui et al. (2015), Bdioui (2016), Deidun and Sciberras (2016), Shakman et al. (2017, 2019), Chebaane et al. (2019), Mili et al. (2019), and Katsanevakis et al. (2020). The record locations of *P. segnis* were inserted in the map using the GPS coordinates reported in the corresponding papers. For the records published without exact GPS coordinates, approximate locations were used based on the description given in those documents (Table S1). The map was drawn using Google Earth and ArcMap software (version 10.2.2).

Results and discussion

The photographs of the three decapod species recorded in the study area are given in Figure 1, where specimens received from local fishermen are shown. The two portunid species *C. sapidus* (Figure 1A) and *P. segnis* (Figure 1B) showed the highest occurrence frequencies in 2020 (5 observations for *C. sapidus* and 4 observations for *P. segnis*), compared to *T. palaestinensis* (Figure 1C). The three decapod species were observed and caught by local fishermen in several zones in the Lagoon of Bizerte, leading to deduce that these species are most likely well-established in the lagoon. This result was not surprizing, in particular for the two portunid species, because similar observations of rapid spread and invasion were already reported in other Mediterranean areas for both *C. sapidus* (Fuentes et al. 2019) and *P. segnis* (Crocetta et al. 2015). Figure 2 shows the localities were the three alien species were recorded/caught by local fishermen between March and July 2020.

For the Atlantic blue crab, the present records are different from those reported along the northern (Katsanevakis et al. 2020) and south-eastern (Ragkousis et al. 2020) Tunisian coasts. All these records contribute to fill the gap in the spatial occurrence of this species along the Northern African coasts, especially after its recent records in Algeria (Benabdi et al. 2019) and Morocco (Chartosia et al. 2018; Taybi and Mabrouki 2020). In addition, the species was recently recorded in the Strait of Sicily (Falsone et al. 2020). Taking into consideration that most of *C. sapidus* records in the northern and south-eastern Tunisian coasts were reported only during the past 1–2 years (Katsanevakis et al. 2020; Ragkousis et al. 2020), it can be speculated that the species reached the Tunisian shores coming from different Mediterranean regions: south-western (i.e. Algeria and Morocco) and northern (i.e. Italy and France) Mediterranean coasts. Figure 3 summarizes the occurrence area of

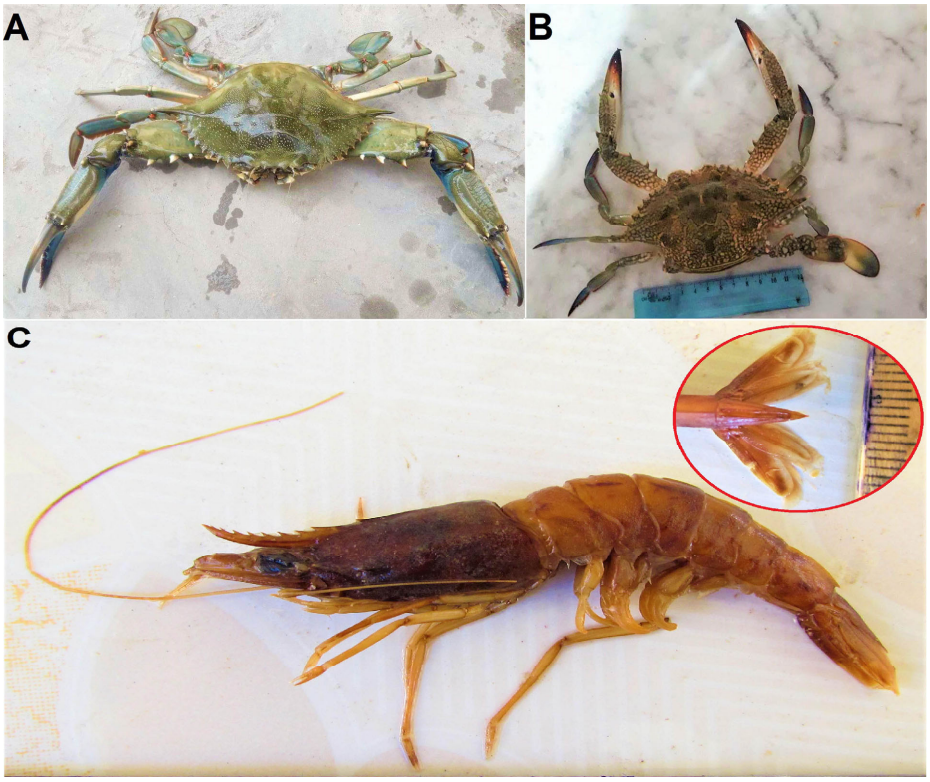

Figure 1. Photographs of the three alien crustacean species recorded in the Lagoon of Bizerte. A: *Callinectes sapidus*, B: *Portunus segnis* (note that the left 5th leg was detached from the specimen), C: *Trachysalambria palaestinensis* (the specimens received from the local fisherman were not well preserved, dried and their real color changed). Photographs by Moez Shaiek.

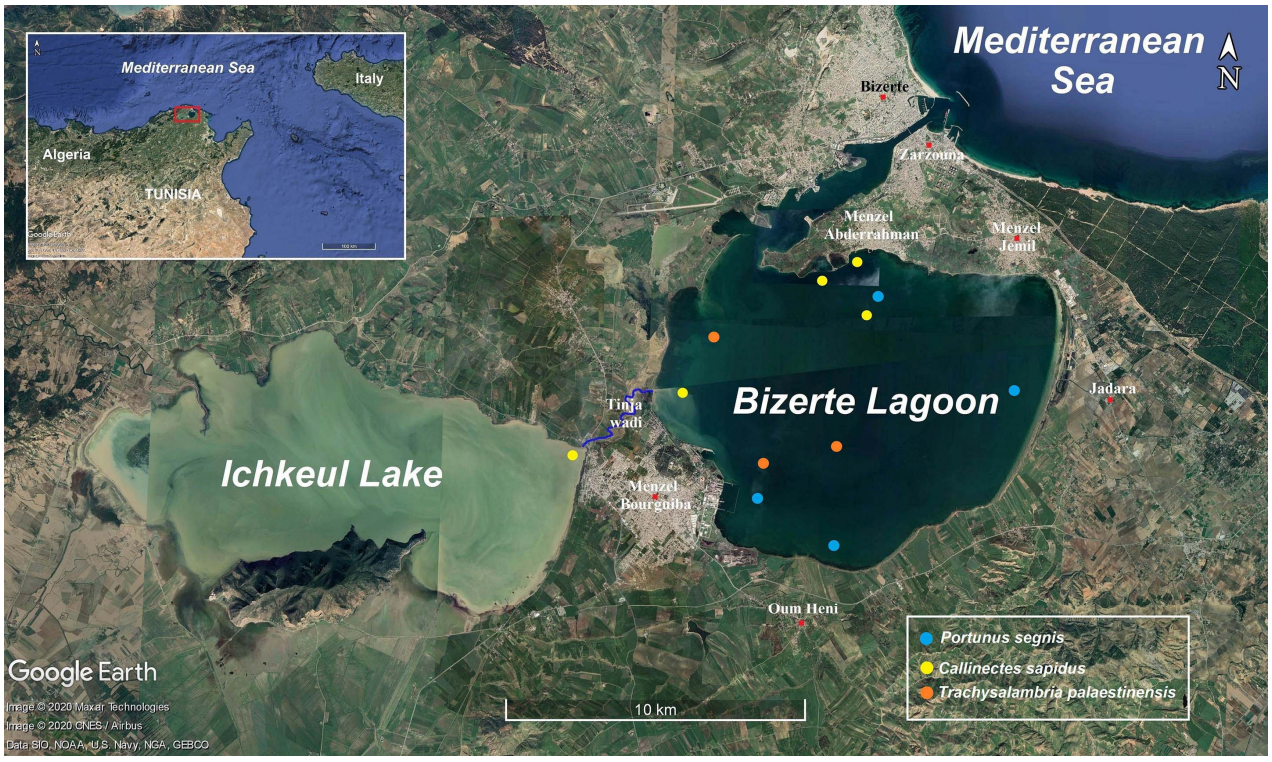

Figure 2. Locations of the occurrence of *Callinectes sapidus* (yellow dots), *Portunus segnis* (blue dots), and *Trachysalambria palaestinensis* (orange dots) in the Lagoon of Bizerte and Ichkeul Lake, recorded between September 2019 and July 2020.

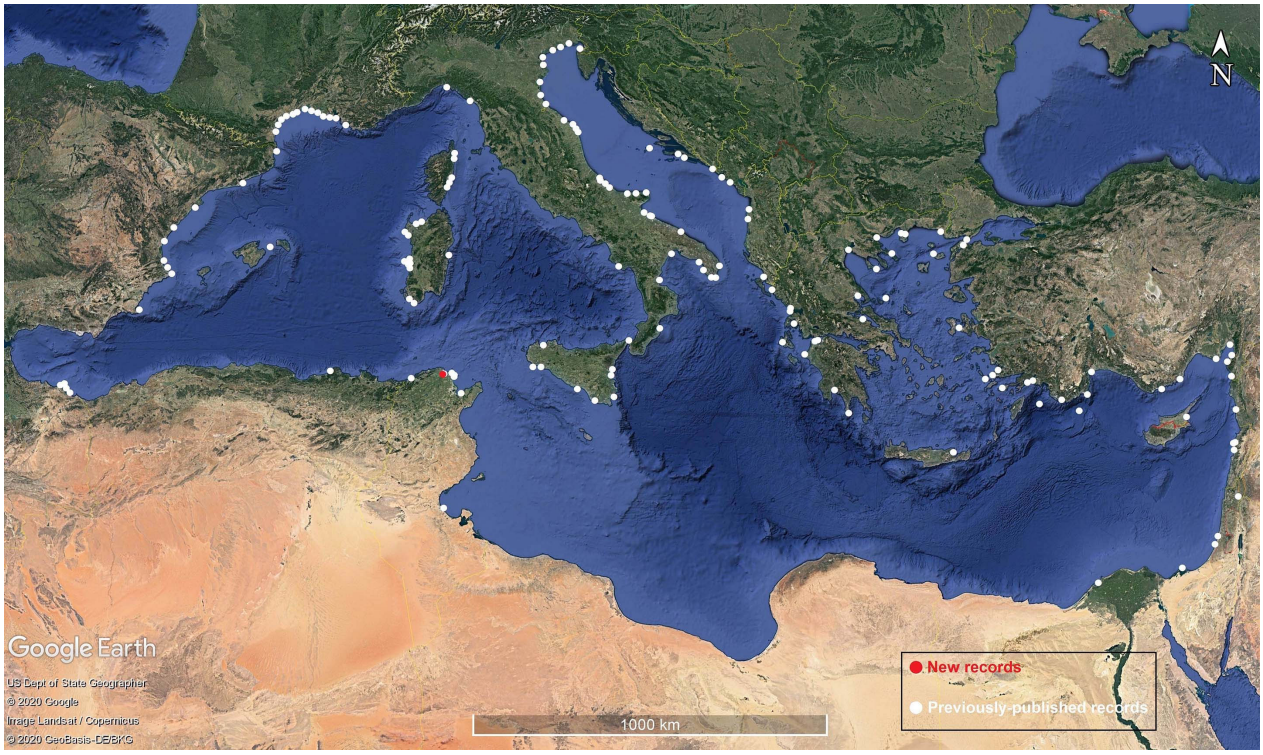

Figure 3. Updated distribution map of *Callinectes sapidus* in the Mediterranean Sea, after adding its recent records in the Lagoon of Bizerte and Ichkeul Lake (red dots). Previous records (white dots) were extracted from the maps given by Garcia et al. (2018), Taybi and Mabrouki (2020), and Falsone et al. (2020) (and references cited therein), as well as from Katsanevakis et al. (2020) and Ragkousis et al. (2020). Note that some records are overlapping.

C. sapidus in the Mediterranean Sea, updating the maps of Garcia et al. (2018), Taybi and Mabrouki (2020), and Falsone et al. (2020), and using the records recently provided by Katsanevakis et al. (2020) and Ragkousis et al. (2020). According to Benabdi et al. (2019), the occurrence of *C. sapidus* is so far confirmed in 17 out of the 23 countries surrounding the Mediterranean Sea. With the additional recent records in Tunisia, the list of Mediterranean countries hosting the Atlantic blue crab increased to 18, and the species remain absent only from 5 countries, including Libya. Considering that the first Mediterranean record of *C. sapidus* was made more than 7 decades ago in the Aegean Sea, the species has colonized almost the entire Mediterranean basin in less than 100 years. This decapod species has been recognized as an "Invasive Alien Species" (Streftaris and Zenetos 2006; Mancinelli et al. 2016) and one of the "worst invasive" species in the Mediterranean Sea and Europe (Streftaris and Zenetos 2006; Katsanevakis et al. 2014b). It is worth noting that one of the present records of *C. sapidus* was from Ichkeul Lake (a freshwater lake), in front of the channel connecting this freshwater body system to the Lagoon of Bizerte (*i.e.* Tinja wadi; Figure 2), showing therefore the ability of this species to adapt to live in wide salinity ranges. Similar observations were made by Taybi and Mabrouki (2020), who reported the occurrence of the species in similar areas in Morocco (wetland of the Moulouya mouth and Oued Kert mouth), and by Stasolla and Innocenti (2014) in the brackish waters at the mouth of the Basento River (Italy).

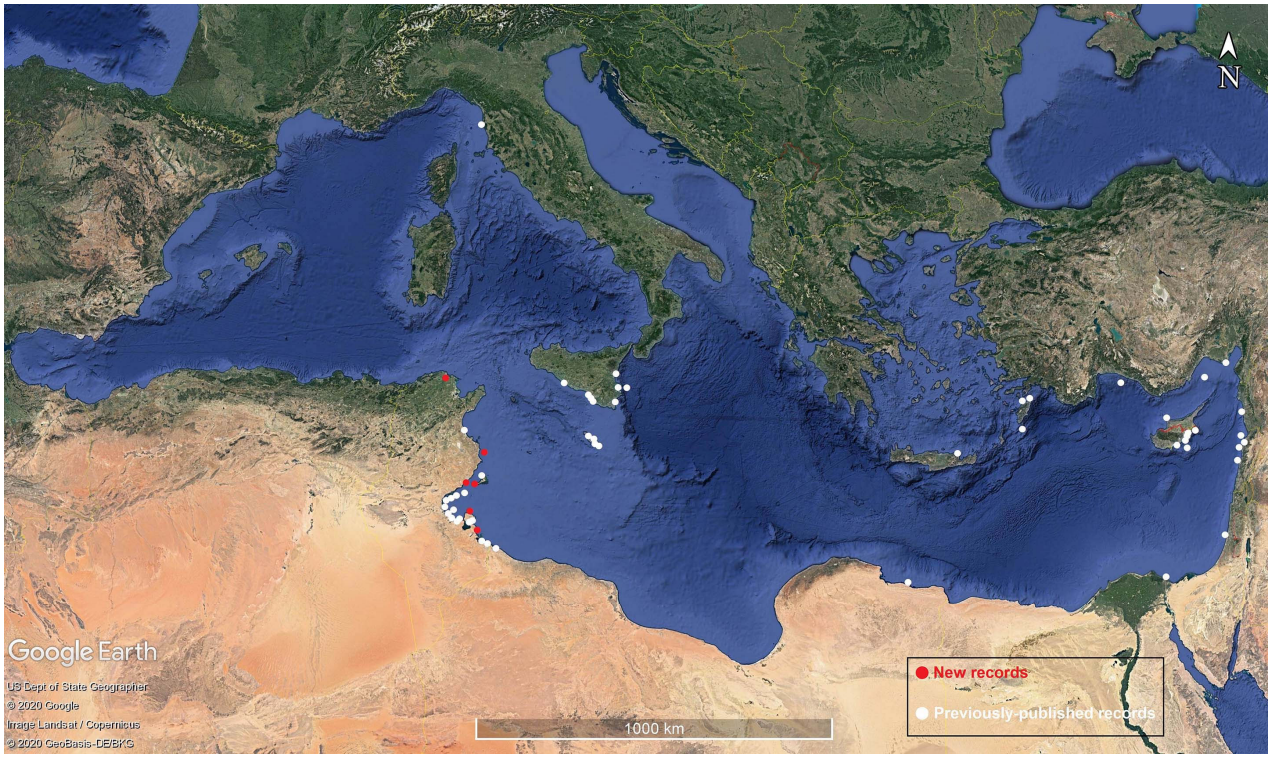

Figure 4. Updated distribution map of *Portunus segnis* in the Mediterranean Sea, after adding its recent record in the Lagoon of Bizerte (red dots). Previous records (white dots) were extracted from published literature (see Table S1). Note that some records are overlapping.

Along the Tunisian coast, *P. segnis* was first reported in the Gulf of Gabès in August 2014 (Rabaoui et al. 2015), and within just one year it invaded all the central areas of the Gulf, leading to serious socio-economic problems to local fishermen (Crocetta et al. 2015). Since that time, the species continued to spread along the Tunisian coastline reaching the southern (Djerba Island, Zarzis, and El Bibane Lagoon) and northern (Kerkennah Island and Sfax) edges of the Gulf of Gabès in 2016, eastern Tunisian coast (Mahdia, Monastir, and Sousse) in 2017, Gulf of Hammamet in 2018, and Lagoon of Bizerte in 2019 and 2020 (Table S1). Figure 4 summarizes the spread of *P. segnis* in the Mediterranean Sea, including the Tunisian coasts. Among all the colonized habitats along the Tunisian coastline, only the Gulf of Gabès (south-eastern Tunisia) was found to enhance the survival and proliferation of the blue swimming crabs. In fact, since 2014, the population of *P. segnis* has kept a continuous and increasing proliferation pattern and the species is currently being exploited by local fishermen in considerable quantities, with the catch mainly exported to other countries. The reasons behind the rapid spread of *P. segnis* in the Gulf of Gabès are still not well known since no dedicated studies have been conducted so far in this regard. However, it seems that environmental conditions in the Gulf of Gabès make it an ideal habitat for certain decapods, taking also into account the successful establishment and proliferation of *Metapenaeus monoceros* (Fabricius, 1798) and *Penaeus aztecus* Ives, 1891 (Ounifi-Ben Amor et al. 2016; El Zrelli et al. *submitted*).

To our knowledge, this is the first report of *T. palaestinensis* in the Lagoon of Bizerte. The species was previously reported (as *Trachypenaeus curvirostris*) in the Gulf of Gabès, south-eastern Tunisia (Zaouali 1993). According to Galil et al. (2002) and Chan et al. (2016), this Lessepsian Indo-Pacific species shrimp species was already reported from Turkey, Greece, Palestine, Lebanon, Syria, Egypt, and Malta, and is mainly abundant along the Levant coast, where it can be encountered at depths between 3 and 26 m (Galil et al. 2002). More recently, the species was also reported in Italian waters, where it was caught by local fishermen from southeastern Sicily (Insacco et al. 2017). The present record of *T. palaestinensis* in the Lagoon of Bizerte, together with the last record of Insacco et al. (2017), proves that this shrimp is expanding throughout the Mediterranean Sea, being presumably ready also to invade the western parts of the basin. The presence of juveniles of *T. palaestinensis* in the Lagoon of Bizerte indicates that the species is most likely to occur in the open sea areas and that the specimens caught by local fishermen might have entered the lagoon within the migration of juveniles to coastal embayment and lagoons where they can spend their early life stages in these nursery areas. According to local fishermen, *T. palaestinensis* is being caught sporadically from different zones inside the Lagoon of Bizerte, which may indicate that the species is also well established in the region. The successful establishment and spread of this species in the Mediterranean Sea seems to be enhanced by shipping activity, as it was suggested by Insacco et al. (2017).

According to local fishermen, both *C. sapidus* and *P. segnis* are accidentally captured by trammel nets, whereas *T. palaestinensis* is mostly caught with monofilament nets. These latter nets are mainly used to catch common cuttlefish (*Sepia officinalis*), Caramote prawn (*Penaeus kerathurus*), and many fish species including red mullet (*Mullus barbatus*), Senegalese sole (*Solea senegalensis*), flathead grey mullet (*Mugil cephalus*), dreamfish (*Salpa sarpa*), and some sparids and mugilids. The three crustacean species have therefore the potential of being exploited, in the future, as additional fisheries resources, and this holds particularly true for the two portunid crabs. For instance, *P. segnis* is already exploited in Tunisia and is considered as one of the new fisheries resources in the Gulf of Gabès (SE Tunisia). Most of the catch from the Gulf of Gabès is now exported to foreign countries, although the species is also commercialized and consumed by some Tunisians. In the Lagoon of Bizerte, the catch of *P. segnis* is still very low, compared to the Gulf of Gabès (nearly 30 tonnes day^{-1}), and hence the species is not commercialized locally, although it is being consumed by some fishermen and their families. In the case of *C. sapidus*, this commercially important species is still not yet abundant along the Tunisian coasts, since its introduction was recent. The species was recorded in the northern Tunisian coast since 2017 (Katsanevakis et al. 2020) and recently (August 2020) it was recorded in the Gulf of Gabès, where local fishermen are

aware of its commercial value and return all captured specimens to the sea, with the aim of enhancing its spread in the region and ensure economic benefits from its future proliferation (Ragkousis et al. 2020). The same behavior is expected to be observed in the Lagoon of Bizerte. As for *T. palaestinensis*, this shrimp species is not appreciated by locals in the Lagoon of Bizerte, mainly because of its small size compared to other exploited and edible shrimp species. However, some local fishermen consume it, mainly for curiosity about its taste.

The co-occurrence of the two portunid crabs (*C. sapidus* and *P. segnis*) in the Lagoon of Bizerte leads to deduce that the two species may enter in spatial and trophic competition in this aquatic system, especially because the two species are known to share similar niches and similar trophic resources. To our knowledge, this is one of the rarest observations of *C. sapidus* and *P. segnis* in a small waterbody such as the Lagoon of Bizerte. The record of *C. sapidus* was also recently reported in the central Gulf of Gabès which is already colonized by *P. segnis* (Ragkousis et al. 2020). Since *C. sapidus* is still less abundant in these newly colonized areas, it is very early to confirm or not about a competition between the two species.

Conclusion

Several factors can be behind the introduction of *C. sapidus*, *P. segnis*, and *T. palaestinensis* in the Lagoon of Bizerte (northern Tunisia), among which shipping activity can play the major role through the transportation of the species' eggs and/or larvae. The Lagoon of Bizerte hosts in its channel (connecting it to the Mediterranean Sea, Figure 2) one of the important commercial ports (commercial port of Bizerte, located in the channel connecting the lagoon to the Mediterranean Sea), which receives several ships coming from different Mediterranean and non-Mediterranean regions, enhancing most likely the introduction of alien species in this semi-closed water body. The two invasive portunid species *C. sapidus* and *P. segnis* have the potential of a rapid bloom in the Lagoon of Bizerte, which can lead to several ecological and socio-economic impacts on the local fisheries and aquaculture sectors. Similarly to what happened in the Gulf of Gabès during the first years of *P. segnis* colonization, these impacts may include damage of fishermen nets and their catch (fish and shellfish captured in the trammel nets and other types of nets used by local fishermen) (Crocetta et al. 2015). The Lagoon of Bizerte hosts important mussels (*M. galloprovincilais*) and oysters (*C. gigas*) aquacultures, which can be impacted by the proliferation of the newly established blue crabs. These latter are known to feed on a variety of aquatic animals including mussels, clams, oysters, small-sized crustaceans, and fishes. A significant proliferation of the two portunid crabs in the Lagoon of Bizerte will most likely lead to serious impacts on these natural resources and consequently to huge economic losses on the aquaculture and fisheries sectors in this area.

Further studies are needed to monitor the spread of these three alien species in the Lagoon of Bizerte and better understand the impacts of their establishment and proliferation on local habitats and biodiversity.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Years, areas, and countries of records of the blue swimming crab, *Portunus segnis*, in the Mediterranean Sea.