

## CORRECTED PROOF

## Data Paper

**Westward range expansion of the blue swimmer crab *Portunus segnis* (Forskål, 1775) (Crustacea, Decapoda, Portunidae) into Atlantic European waters**Gustavo F. de Carvalho-Souza<sup>1,2,\*</sup>, Jose A. Cuesta<sup>1</sup>, Diego Arana<sup>3</sup>, Cristóbal Lobato<sup>3</sup> and Enrique González-Ortegón<sup>1,\*</sup><sup>1</sup>Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC), Campus Universitario Río San Pedro, 11519, Puerto Real, Cádiz, Spain<sup>2</sup>Universidad de Cádiz, Campus de Excelencia Internacional/Global del Mar (CEI-MAR), 11510, Puerto Real (Cádiz), Spain<sup>3</sup>Agencia de Gestión Agraria y Pesquera de Andalucía, c/ Bergantín 39, 41012 Sevilla, Spain

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## OPEN ACCESS

**Abstract**

The introduction of non-indigenous species to aquatic ecosystems is one of the main threats to global biodiversity. This paper reports the occurrence of the blue swimmer crab *Portunus segnis* in southwestern European waters (i.e., the Gulf of Cadiz). We discuss the invasive potential of *P. segnis* and possible mechanisms of its expansion into this new region. The detection of this species also highlights the importance of involving citizen scientists in the reporting of non-indigenous species.

**Key words:** portunid, Iberian Peninsula, first record, gillnetter, larvae, transport, exotic, citizen science**Introduction**

The global threat of non-indigenous species (NIS), also known as non-native, exotic, allochthonous, or alien organisms, to aquatic biodiversity is well-established (Zenetos et al. 2022). Non-indigenous species can modify habitats and disrupt ecosystem functioning, resulting in significant ecological and economic impacts such as the loss of biodiversity and the alteration of trophic interactions (Katsanevakis et al. 2014; Seebens et al. 2020; Diagne et al. 2021). The increasing frequency of NIS introductions can have many impacts, ranging from negligible effects in native counterpart species (González-Ortegón et al. 2007), to introducing new diseases and parasites, outcompeting native species for resources, or disrupting trophic cascades throughout entire ecosystems (Kumschick et al. 2015; Bellard et al. 2016; de Castro et al. 2017).

In the Gulf of Cadiz (GoC), along the southwesternmost coast of Europe, records and establishment of NIS have increased exponentially since 1980 (González-Ortegón et al. 2020a). The occurrence of the so-called African Creep species, or Lessepsian migrants, are examples of NIS caused by intensified aquaculture and transoceanic shipping that transports NIS in ballast waters or biofouling assemblages, among other activities. These

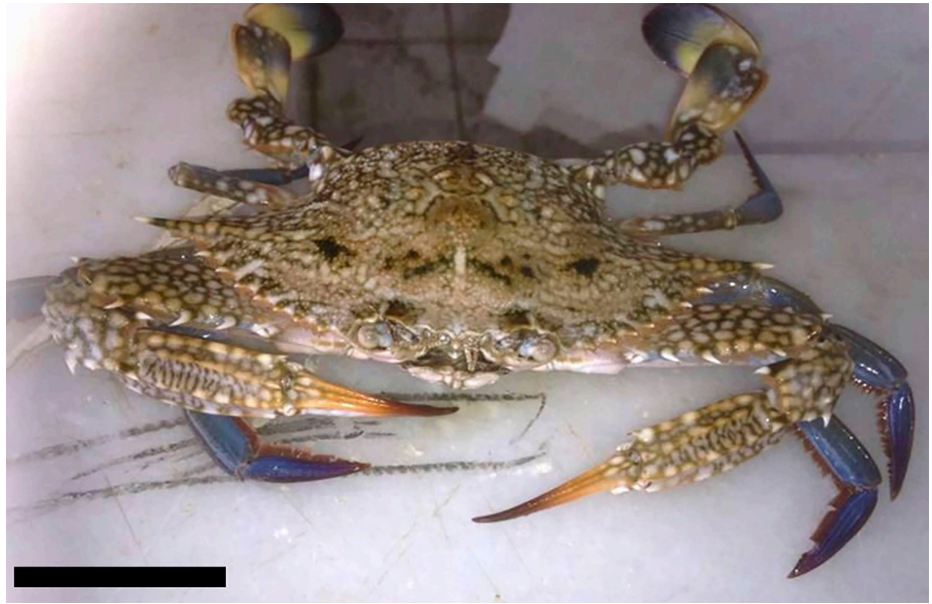
vectors have resulted in the expansion of the distribution of NIS from the extensively invaded Mediterranean Sea and African Atlantic waters to the GoC, making it one of the European ecosystems most susceptible to biological invasion (Canning-Clode and Carlton 2017; González-Ortegón et al. 2020a). One recent and emblematic example is the Atlantic blue crab, *Callinectes sapidus* Rathbun, 1896, which is native to the Western Atlantic coasts, from the Gulf of Maine (Canada) to Rio de la Plata (Argentina) and was likely introduced to the GoC via ship ballast water (Morais et al. 2019; González-Ortegón et al. 2020a, 2022; Chairi and González-Ortegón 2022). This species has successfully established and dispersed, quickly spreading throughout the Mediterranean and Iberian Peninsula, causing significant ecological impacts and loss of ecosystem services (Castejón and Guerao 2013; Mancinelli et al. 2021).

Similarly, in terms of dispersal, the blue swimmer crab, *Portunus segnis* (Forskål, 1775), native to the Western Indian Ocean, has been expanding its range to new regions, including the Mediterranean Sea through the Suez Canal. The first record for this Lessepsian species in the Mediterranean was reported in 1898 at Port Said, Egypt and Palestine (Fox 1924; Galil 2011). Subsequent records were reported from the eastern Mediterranean, including the Levantine coast of Israel, Lebanon, Syria and Turkey (Steinitz 1929; Hasan et al. 2008; Lai et al. 2010; Katsanevakis et al. 2020). Since these initial records, *P. segnis* has been observed in several areas in the Mediterranean (Castriota et al. 2022; Mancinelli et al. 2022), including the Aegean Sea (Altuğ et al. 2011; Özgül and Akyol 2019), Ionian Sea (Ghisotti 1966), and Tyrrhenian Sea (Crocetta 2006). The species has also been reported from Maltese waters, the Gulf of Gabes, northern Tunisia and the coast of Libya (Deidun and Sciberras 2016; Shakman et al. 2017; Shaiek et al. 2021; Corsini-Foka et al. 2021). These observations suggest that the species range is expanding across the Mediterranean basin, potentially aided by increasing water temperatures and other environmental factors such as salinity, precipitation and winds (Pancucci-Papadopoulou et al. 2012; Galil et al. 2018).

This paper provides the first record of the blue swimmer crab in the GoC, indicating a range expansion to the southwesternmost coast of Europe. The presence of *P. segnis* in Atlantic-Mediterranean waters raises concerns about the potential effects on native ecosystems and local economies, highlighting the need for effective management strategies to prevent its spread and control its impact.

## Materials and methods

The Guadalquivir estuary is located in the southwestern part of the Iberian Peninsula, connecting the river with the GoC. The estuary's flow (between  $< 40\text{--}400\text{ m}^3\text{ s}^{-1}$ ) is regulated by freshwater input (from a dam located 110 km



**Figure 1.** Female specimen of *Portunus segnis* recorded in the Gulf of Cadiz (Chipiona) in April 2014. Scale: 5 cm. Photo by Enrique Oliva Valle.

upstream) and water exchange with the adjacent coastal area, affecting species distribution and abundance (Cuesta et al. 2006; González-Ortegón et al. 2015; de Carvalho-Souza et al. 2019). Commercial and leisure boat traffic extend up the estuary to the Port of Seville, which has had active ship traffic since the 15<sup>th</sup> century (Crailsheim 2016). Other important ports in the region are the Port of Cadiz (40 km away from the Guadalquivir mouth), Port of Algeciras and Tangier Med (both in the Strait of Gibraltar).

The Guadalquivir estuary is considered an important nursery area and essential fish habitat for many commercial species, such as the European anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), sardine, *Sardina pilchardus* (Walbaum, 1792), seabass, *Dicentrarchus labrax* (Linnaeus, 1758) and shrimp (*Palaemon* spp.) (González-Ortegón et al. 2010; de Carvalho-Souza et al. 2019). In response to this, a fishing reserve was established in the mouth of the Guadalquivir River (<https://www.juntadeandalucia.es/boja/2004/123/3>) to ensure a sustainable exploitation of these resources and conservation of the ecosystems that support them.

One adult female specimen of the blue swimmer crab was collected at the mouth of the Guadalquivir estuary, in the Gulf of Cadiz (SW – Iberian Peninsula) by a gillnetter during a routine commercial fishing operation (Figure 1). The specimen was photographed after fishing, and the photographic record was sent by the fisher to one of the authors (CL) because it was thought to be *C. sapidus*. Unfortunately, the crab was not preserved. Total carapace width (mm) was measured as the distance between the tips of the lateral spines. The specimen was identified by the authors according to Carpenter and Niem (1998) and Lai et al. (2010).

To review the current distribution of *P. segnis*, we have compiled records through an extensive bibliographic research with the addition of previous datasets of Shaiek et al. (2021) and Mancinelli et al. (2022), which have been updated (Supplementary material Table S1). This research included literature published between 1880 and December 2022 in the Web of Science database, Scopus and Google Scholar using the following keywords (and/or): “*Portunus segnis*”, “*Portunus pelagicus*”, “swimming blue crab”, “first record”, “occurrence”, “range expansion”, “non-native”, “exotic”, “alien”, “Gulf of Cadiz”, “Iberian Peninsula”, “Atlantic”, “Strait of Gibraltar”, and “Mediterranean”. Additionally, the data were also compared to the GBIF database (<https://www.gbif.es>) and citizen science platforms (e.g. iNaturalist.com and Observadoresdelmar.es). The records presented in this dataset include the country, specific locality, latitude, longitude, year of record, consulted sources, and corresponding codes (if applicable). The data were organized according to geographical reference and assigned an accuracy rating based on the provided geographic coordinates or map included in the document. Additionally, the country of the sighting/capture site was indicated, as well as the specific or generic sighting/capture site (e.g. city name, gulf name). A map was created in R (version 4.2.1) using the packages “ggplot2”, “sf”, “rnaturalearth” and “ggspatial” (Kahle and Wickham 2013; Wickham 2016; Pebesma 2018; Massicotte and South 2023).

Furthermore, to facilitate future records of the species from citizen science sources, we describe three morphological features that can facilitate the identification of *P. segnis* in the field and for taking photographs and videos.

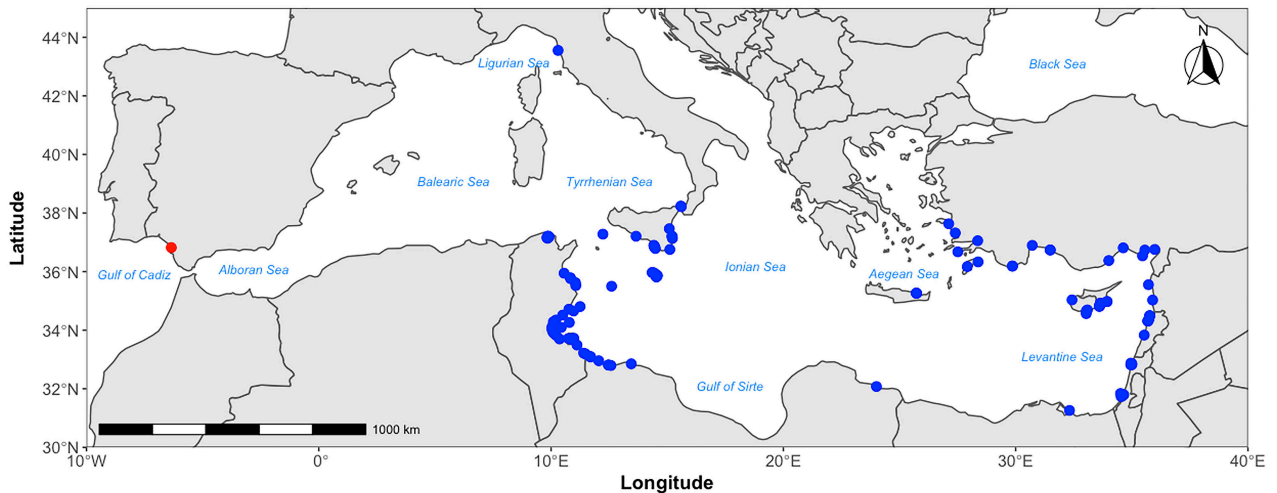
## Results

This study reports the first record of the blue swimmer crab *P. segnis* in southwestern Atlantic European waters, specifically at the mouth of the Guadalquivir estuary, Gulf of Cadiz. The report is based on a single female specimen, with a total carapace width of 170 mm, that was recorded in April 2014.

The blue swimmer crab has been reported for several localities along the Mediterranean Sea since the 19th century (Figure 2). Altogether, we found 128 records of *P. segnis* spread over 13 different countries. The records for the central Mediterranean, Italian coast, and northern Tunisia are the closest to the Gulf of Cadiz, 1400 and 1600 km away, respectively.

## Discussion

The increasing number of non-indigenous species (NIS), including *P. segnis*, in the north-eastern Atlantic and Mediterranean waters is a significant threat to the region’s biodiversity. Effective management strategies for biological invasions are required to prevent their spread and reduce their impact. At least 874 species are estimated to have already been introduced



**Figure 2.** Records of the swimming blue crab, *Portunus segnis*, in Atlantic-Mediterranean waters. The single red dot indicates the location of the record reported here of *P. segnis* on the Iberian Peninsula (Chipiona in the Gulf of Cadiz). Blue dots indicate previously reported locations of *P. segnis* in the Mediterranean Sea. The details of the records in the Mediterranean can be found in Table S1.

into European marine waters (Zenetos et al. 2022). This is clearly observed along the Guadalquivir estuary – Gulf of Cadiz ecosystem, where several NIS have been recorded in the last decades, such as *Rhithropanopeus harrisi* (Gould, 1841) (Cuesta et al. 1991), *Palaemon macrodactylus* Rathbun, 1902 (Cuesta et al. 2004), *Eriocheir sinensis* (H. Milne Edwards, 1854) (Cuesta et al. 2006), *Callinectes pallidus* (de Rochebrune, 1883) (as *C. exasperatus*, Cuesta et al. 2015), *Lysmata unicoloris* Holthuis & Maurin, 1952, (González-Ortegón et al. 2020b), *Alpheus* cf. *lobidens*, *Penaeus monodon* Fabricius, 1798, the weakfish *Cynoscion regalis* (Bloch & Schneider, 1801) and *C. sapidus* (González-Ortegón et al. 2020a; 2022). A concern that fishermen and scientists share for the GoC is that this fishing reserve could also be serving as a breeding area for these NIS. Furthermore, swimming crabs are also voracious predators, especially feeding on native bivalves (Ortega-Jiménez et al. 2022). One of the measures that could be set out to prevent and mitigate the adverse impacts would be the issuance of special licenses to allow targeting fishing for NIS within the reserve, as has been done in the same region for *C. sapidus*.

The blue swimmer crab was already included in list of potential aquatic alien species with a significant risk of invasion in Iberian waters (Oficialdegui et al. 2023). The range expansion of *P. segnis* may be due to natural dispersal mechanisms through passive larval transport or adult swimming. However, the route of arrival was probably by ballast water considering the distances from the locations where it was previously recorded (see Table S1). A route by ballast water from ships connecting important ports, such as the Port of Seville (in the Guadalquivir estuary), Port of Cadiz (40 km away from the Guadalquivir mouth), Port of Algeciras or Tangier Med (these last two in the Strait of Gibraltar), could explain the dispersal across the western part of the Mediterranean Sea for the blue swimmer crab and other NIS (González-Ortegón and Moreno-Andres 2021).



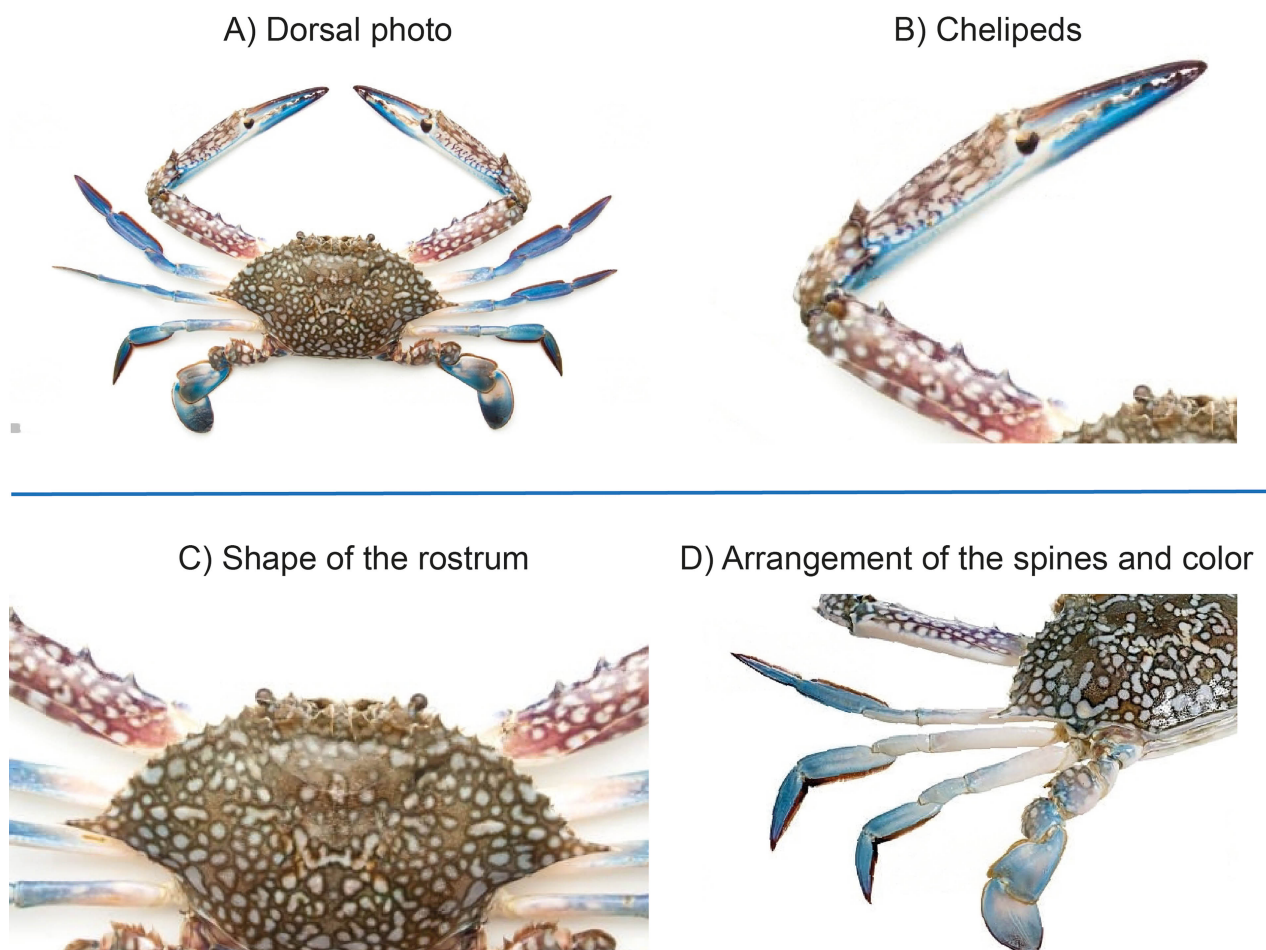
Since its arrival through the Suez Canal 125 years ago, *P. segnis* has colonized almost the entire Mediterranean basin. Castriota et al. (2022) studying this historical pattern of distribution, found that the species had an arrival phase between 1886 and 1923, a long phase of establishment between 1924 and 2001, and a recent, rapid expansion phase between 2002 and 2021.

The areas closest to the Gulf of Cadiz are located between the central Mediterranean/Italian coast and northern Tunisia. In the central Mediterranean, *P. segnis* has been recorded since the 1960s and 1970s from the coasts of Malta and Sicily (Ghisotti 1966; Crocetta et al. 2015). It was actually misidentified as *C. sapidus* in Sicily until it expanded its range and was recorded in the north Tyrrhenian Sea in 2004 (Crocetta 2006). During the last few years, it has been reported continuously in these regions (Katsanevakis et al. 2020; Table S1). Since it was recorded in Tunisia in 2014 (Rabaoui et al. 2015), *P. segnis* has shown remarkable range expansion northwards and eastwards (Shaiek et al. 2021). The blue swimmer crab has proliferated in this area and is now an essential product in local fisheries due to increases in their economic value and commercial exploitation (Ennouri et al. 2021) and is sold both locally and internationally (7,600 tonnes, worth \$24 m; Delpuech 2022).

The new record reported here, from fishermen, occurred nine years ago in 2014. The fact that no further observations of this species have been documented since then would suggest that the population of *P. segnis* may not be fully established in the Gulf of Cadiz, unlike for Tunisia, where it was recorded in 2014, or unlike *C. sapidus*, a NIS experiencing massive expansion and high abundances to support fishing activities. The difference between these two species may be due to *P. segnis* not being able to establish itself, possibly as a result of the introduction of several other exotic species. Competition for space and resources with other invasive portunids such as *C. sapidus* and native species (e.g. *Carcinus maenas* (Linnaeus, 1758) may be limiting the population growth of *P. segnis*. For instance, adult specimens of *C. pallidus* and *P. monodon* were previously recorded in the Gulf of Cadiz, and no new sightings have been reported since then (Cuesta et al. 2015; González-Ortegón et al. 2020a).

Additionally, temperature and salinity may also affect the survival, growth, and development of early stages of *P. segnis*. Temperatures below 22.5 °C and salinities outside the range of 20–35 ppt can negatively impact the larvae and juveniles of this species (Bryars and Havenhand 2006; Romano and Zeng 2006). A similar situation occurred in northern Italy where larval and adult stages of *P. segnis* were observed but the population did not increase (Pessani and Salton 1998; Crocetta 2006). Thus, the lack of appropriate environmental conditions to support larval growth and retention would be the second hypothesis which support the unsuccessful establishment

## *Portunus segnis*



**Figure 3.** Recommended sample photos that can help to identify *P. segnis*: A) Dorsal photo; B) Chelipeds and spines on the chelipeds; C) Shape of the rostrum and spines on the carapace; D) the coloration of the legs. Credit photos by S. Jiwalan.

of *P. segnis* in the gulf of Cadiz. Further studies are needed to evaluate the effects of temperature and salinity on this NIS in the study area.

To help with the correct identification of *P. segnis* through photographs, several morphological characteristics should be evident in the pictures. These include the following: (1) a dorsal photo of the carapace showing the white spots, which are characteristic of this species (Figure 3A); (2) a dorsal photograph showing the shape of the carapace, as the carapace of *P. segnis* is more triangular in shape than that of *C. sapidus*, and does not have a “V”-shaped notch in the center of its carapace; (3) a photo of the chelipeds, which are relatively narrow and elongated in this species compared to other portunid crabs (Figure 3B); and (4) additional photographs of the shape of the rostrum, arrangement of the spines on the carapace and chelipeds, and the coloration of the legs and other appendages (Figure 3C, D). Additionally, *P. segnis* present with frontal median teeth that are minute and inconspicuous, almost obsolete, or if present, always small (Lai et al. 2010; Giraldes et al. 2016).

This report also highlights the importance of citizen science information, which enables the collection and analysis of data on previously unreported species by harnessing the collective power of volunteers, particularly fishermen, who can provide observations, photos, and other valuable information (e.g. location specific data, reproductive period of the organisms, and behavior and ecological insights). However, it is important to note that there may be limitations and difficulties in determining the species from photographic materials, as some details may be difficult to discern or may require specialized knowledge. Therefore, it is recommended that citizen scientists take multiple photographs from different angles and perspectives to provide a more comprehensive view of the specimen. By involving the public in the discovery and understanding of species, citizen science can also help foster a sense of connection and responsibility towards ecosystems, inspiring greater efforts towards biodiversity conservation.

Given that *P. segnis* is not yet fully established in the GoC, it can be targeted for early control and potential eradication. This record also underscores the need for continued monitoring of the arrival and spread of NIS in the GoC and effective measures for ecosystem-based management for NIS.

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### Authors' contribution

GF de C-S and EG-O conceived the study and contributed to the study design. DA and C collected the blue swimmer crab. GF de C-S, and EG-O analyzed the data and wrote the paper. All authors contributed to drafting and editing. All authors read and approved the final manuscript.

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### Data

All data generated or analyzed during this study are included in this published article.

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## Supplementary material

The following supplementary material is available for this article:

**Table S1.** Number of records of *Portunus segnis* with additional information on the location, geographical coordinates, year of record and bibliographical reference.