ScienceDirect

Estuarine, Coastal and Shelf Science

Volume 291, 30 September 2023, 108419

Tackling bioinvasions in commercially exploitable species through interdisciplinary approaches: A case study on blue crabs in Africa's Mediterranean coast (Bizerte Lagoon, Tunisia)

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https://doi.org/10.1016/j.ecss.2023.108419

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Highlights

- Molecular taxonomy revealed uncertainties and mismatches in blue swimming crabs.
- *Callinectes sapidus* and *Portunus segnis* are now invading the Bizerte Lagoon.
- Questionnaires and participatory approaches are highly effective in monitoring NIS.

- Awareness campaigns and exchange of experiences raise the engagement in fishermen.
- Ecosystem-based management is urged to tackle blue crabs in the Bizerte Lagoon.

Abstract

The Mediterranean Sea is a well-known bioinvasion hotspot, with an increasing number of non-indigenous species spreading and becoming established. Among them, the blue crabs *Callinectes sapidus* and Portunus pelagicus have recently called the attention due to their notable ecosystem impacts but also potential economic importance. We hereby first tackled these species through interdisciplinary approaches along the Africa's Mediterranean coast (Bizerte Lagoon, Tunisia). Molecular analyses assigned *C. sapidus* specimens to the Lineage 1 *sensu* Windsor et al. (2019), while revealed uncertainties, mismatches, and low genetic distances within the *P. pelagicus* species complex, suggesting that multilocus or complete mitogenomes approaches are still needed to shed light on the taxonomy and distribution of these species worldwide. Replies to questionnaires and participatory monitoring confirmed the scattered literature data available and revealed that both species have already colonized the Bizerte Lagoon and showed similar distributions, although *P. segnis* is more abundant and is presumably sustained by the presence of nursery grounds. Awareness campaigns strongly contributed improving the level of engagement of the local community, with low catch discards and crab taste ranked as “good” to “excellent” mostly during the second phase of the project. Crab abundances significantly affected the general perception of the fishermen in considering these species as new promising fishing targets, although educational background also played a major role among the other investigated variables. As the Bizerte Lagoon hosts a wide and native biological diversity that historically sustained local communities through small scale fishery activities and aquaculture, ecosystem-based management strategies are urged ahead of the proliferation of alien species.

Introduction

Among major problems of the 21st century, marine bioinvasions represent one of the worst effects of an increasingly connected world and of a changing climate, and is commonly considered the second cause of species extinctions (Bellard et al., 2016). The Mediterranean Sea, known as an important hotspot of biodiversity with >17.000 marine species (Coll et al., 2010), is not exempt from such problem, being one of the most invaded regions in the

world, with non-indigenous species (NIS) arriving through different pathways (e.g. navigational canals, shipping, aquaculture, and aquarium trade) and displaying an array of patterns by country or ecoregion (Katsanevakis et al., 2014; Tsirintanis et al., 2022). Based on recent estimates, more than 500 NIS are established in the Mediterranean Sea (Tsirintanis et al., 2022); however, whereas the majority of them have still unknown or negligible impacts on biodiversity and economy, some raised particular awareness in local communities due to their characteristics (Kleitou et al., 2021; Tsirintanis et al., 2022). This is particularly the case of the East-African blue crab *Portunus segnis* (Forskål, 1775) and of the American blue crab *Callinectes sapidus* Rathbun, 1896.

These two taxa have different introduction histories and originate from separate localities worldwide. *Portunus segnis* is native to the Western Indian Ocean and has entered the Mediterranean Sea through Lessepsian migration since 1898, while *C. sapidus* is native to the temperate and tropical Western Atlantic and has been reported in the Aegean Sea since at least 1947, where it presumably arrived through shipping (Fox, 1924; Serbetis, 1959). Both species also share common features, having notable ecosystem impacts, including environmental and socio-economic ones (Tsirintanis et al., 2022), and widely expanded their range in the basin in the last decade, often becoming invasive (Shaiek et al., 2021). Moreover, they are also edible and particularly palatable, holding economic importance in native and invaded regions (Thomson and Farragut, 1982; Mancinelli et al., 2017b).

The management of these two NIS in the Mediterranean Sea has recently become a major challenge, highlighting the following ambiguities: (i) product or invader; (ii) threat or resource; and (iii) manage or not manage (Mancinelli et al., 2017a, 2017b; Kleitou et al., 2021). These putative ambivalences were also reflected in different approaches while proposing legislations, with the European Commission (2022) suggesting the inclusion of *C. sapidus* in the list of invasive alien species of high concern, and the General Fisheries Commission for the Mediterranean issuing the recommendation GFCM/42/2018/7, aiming to establish regional research programs to fill scientific and research gaps concerning the two blue crabs in Algeria, Tunisia, and Europe, in order to maintain the Mediterranean stocks at the maximum sustainable yield levels for the viability of their fisheries. Notwithstanding such contradictory perspectives, a species by species local approach is always necessary to tackle NIS, with diversified strategies according to different scenarios (Coutts and Forrest, 2007; Oficialdegui et al., 2020). This process always includes early detection programs aimed to assess the magnitude of the bioinvasion, often to be conducted by using interdisciplinary approaches heading toward the same direction (Reaser et al., 2020).

Tunisia is hinged between the western and the eastern parts of the Mediterranean basin and lays under the influence of the Sicily Channel. It is thus a crossroad between true NIS arriving from the Indo-Pacific, but is also subjected to the arrival of neonatives from the Atlantic (Guidetti et al., 2010). In addition, Tunisia hosts major Mediterranean harbors and several coastal lagoons — confined environments characterized by a wide and native biological diversity that sustains local communities, but also particularly prone to NIS invasions (Ounifi-Ben Amor et al., 2016, 2019). Among them, the Bizerte Lagoon has been recently invaded by both blue crabs, although no specific studies have investigated abundances or impacts so far. We hereby first tackled these species through an interdisciplinary approach, and in particular aimed to: (i) confirm preliminary morphological identifications and evaluate potential population sources through molecular analyses; (ii) raise awareness and enterprise in stakeholders at different scientific and technical levels to guarantee the success and sustainability of a participatory approach; (iii) evaluate the correct magnitude and impact of the local bioinvasion through a combined approach that included structured questionnaires and a permanent NIS survey system; (iv) test whether the level of engagement and the general perspectives of the local community (potential threat *vs* potential resource) changed after the strategies held here, evaluating also which biological and/or socio-economic variables influenced it. The present effort accounts for the first structured and articulate project targeting NIS in such a way along the Mediterranean coast of Africa and will therefore provide experiences and results that may be applied in the future to other commercially exploitable NIS invading understudied areas.

Section snippets

Study area

The Bizerte Lagoon (~37.185702°N, 9.849570°E: Fig. 1) is located in the extreme north of Tunisia and has an area of 128 km^2, with a maximum width and length of 11 and 13 km, respectively. It communicates with the Mediterranean Sea via a straight channel (6 km long and 12 m deep) situated in its northern part, whereas it is connected to Lake Ichkeul in its

western part via the Tinja river (5 km long and up to 3 m deep during flooding) (Bejaoui et al., 2010). The Lake Ichkeul is freshwater in…

Species' insight through molecular analyses

DNA barcoding on *P. segnis* specimens provided five partial COI gene sequences for both the 5′ (608 bp) and the 3′ (635 bp) ends, corresponding to two different haplotypes. BLAST hits for the 5′ end ("Folmer region") yielded high similarities (99.66–99.84%) with sequences from the Red Sea and the Arabian Sea ascribed to *P. segnis*, *P. pelagicus*, and *Portunus* sp. by different authors. Noteworthy, they also showed a slightly lower similarity value (≤97.37%), but still potentially falling within the …

Species' insight through molecular analyses

Molecular based methods are used as a powerful tool to assess correct species assignments and trace putative population sources, which, in turn, lead to improved management of NIS bioinvasions (Le Roux and Wieczorek, 2009; Darling et al., 2017). However, this implicitly relies on a clear species-specific taxonomy, on the correctness of sequences deposited in online databases, as well as on the availability of a wide pool of sequences to be used for comparisons. In the present case, the two…

Conclusions

Eradication of widely established marine NIS is generally considered difficult if not practically unrealistic (Simberloff, 2014; Giakoumi et al., 2019). The main challenge to tackle species holding invasive behaviour consists thus in limiting to the greatest extent their spread and negative impacts, whenever possible also by providing advantages or benefits to various stakeholders (Giakoumi et al., 2019; Kleitou et al., 2021). These always include professional fishermen, that may be on the one…

CRediT authorship contribution statement

Mouna Rifi: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Leila Basti:** Writing – review & editing. **Lucia Rizzo:** Writing – review & editing, Methodology, Investigation. **Valentina Tanduo:** Writing – review & editing, Methodology, Investigation. **Adriana Radulovici:**

Writing – review & editing. **Sabri Jaziri:** Writing – review & editing, Methodology, Investigation. **İrfan Uysal:** Writing – review & editing. **Nihel**…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Acknowledgments

We are grateful to Ines Zaiter Boukoum (head of fishing cell of Manzel Abderrahmen), Karima Azzouz (head of the Regional Commissariat for Agricultural Development), the fishermen of Manzel Abderrahmen (particularly Mohamed Zouaoui) and from Gulf of Gabès (Sassi Alaya and Ezzedine Mlaouah), Fethi Neloufi (Groupement Interprofessionnel des Produits de la Pêche - GIPP) and the Fishermen's Syndicates (Synagri and UTAP). The project “Halte aux espèces non indigènes”, led by the NGO Méditerranée…

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