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Trophic role and predatory interactions between the blue crab, *Callinectes sapidus*, and native species in open waters of the Ebro Delta

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Highlights

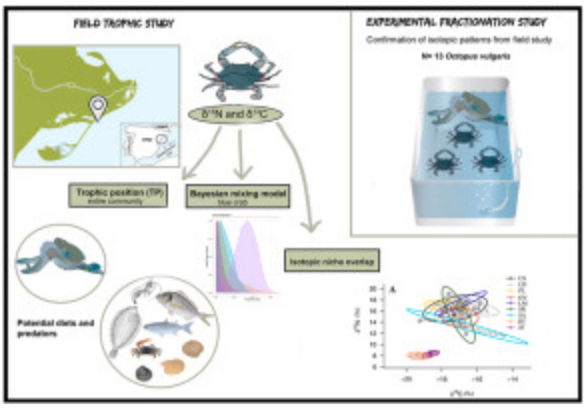
- The high trophic position of the blue crab was comparable to other native predators.
- The isotopic niche of the blue crab overlap with that of native predators.
- MixSiar models suggest that the crab predates on all available benthic resources.
- Unexpectedly, lower TP was found in *Octopus vulgaris*, a key predator of blue crab.

- Experimental work with octopus feed with blue crab draw moderate negative fractionation for $\delta^{15}N$.

Abstract

The Ebro Delta has become a major blue crab (*Callinectes sapidus*) fishery area in the NW Mediterranean, but there is limited information on factors controlling the abundance of populations in open waters, a crucial habitat for ovigerous females. Here, we use a stable isotope approach ($\delta^{15}N$ and $\delta^{13}C$), to assess blue crab trophic position, the potential consumption of food items using mixing models, and the isotopic niche overlap with local commercial species. For Octopus vulgaris, a potential blue crab key predator, a trophic enrichment experiment was also conducted to further assess predation control in wild populations. The blue crab showed 1.6 times higher trophic position than in other habitats of the Ebro Delta, and similar to that found in the harbor crab, *Liocarcinus depurator*, and several predatory fish. Additionally, the isotopic niche of blue crabs showed overlaps from 46.2 to 14.9% with native predators, and mixing models also suggest even dietary contributions throughout the food web. For *O. vulgaris*, field results showed a trophic position of 3.93, lower than that of blue crab, and lower $\delta^{15}N$ signatures were also obtained in a captivity experiment drawing negative fractionation (−1.1‰). We conclude that high dietary contribution of animal prey might provide a high protein diet that could be crucial for allowing the maintenance of a large local population, but the overall functional trophic similarity could also disfavor local native species. The similarity between experimental fractionation and field differences between predator and prey (−1.6‰) suggests that predation of blue crab is possible, but further research is needed to clarify the metabolic routes involved in octopus $\delta^{15}N$ fractionation.

Graphical abstract



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Introduction

The blue crab *Callinectes sapidus* Rathbun 1896 is a member of the Portunidae native to the Western Atlantic from Uruguay to Nova Scotia (Mancinelli et al., 2017a). The species was recorded in Europe for the first time in 1901 on the Atlantic coast of France (Bouvier, 1901), and then appeared in the Mediterranean Sea in 1948 probably introduced by ballast waters (Serbetis, 1959; Zenetos et al., 2018). Since then, it has notoriously expanded throughout the entire basin and has become one of the 100 worst invasive species despite its commercial interest (Zenetos et al., 2005). In Spain, it was first detected in the Tancada Lagoon in the Ebro Delta, Catalonia in 2012 (Castejón and Guerao, 2013), and since then, it has rapidly spread towards the Atlantic Sea reaching the Southern coast of Portugal (López and Rodon, 2018; Vasconcelos et al., 2019).

The species is a voracious generalist consumer capable of using a wide range of animal resources including mollusks, fish, crustaceans, and vegetal (plants and algae) and detrital material in the sediment, depending on availability and the stage of ontogenic development, and local availability (Laughlin, 1982; Rosas et al., 1994; Prado et al., 2021). Hence, it can affect benthic communities at multiple trophic levels, altering the functioning and biodiversity of ecosystems, and impacting native fisheries in invaded areas (Zenetos et al., 2005; Nehring, 2011; Mancinelli et al., 2017a). For instance, in the Ebro Delta, blue crab has been indicated to prey on locally abundant mollusk species, decreasing the effective size of populations until they become very rare and there is a forced trophic shift to towards other less nutritional resources such as vegetal and detrital material (Prado et al., 2021). Trophic positions (hereafter TP) of blue crab in sites already depleted from animal prey could be lower than 2.6 (Prado et al., 2021), whereas estimates in other Mediterranean regions using

the same methodology can reach values as high as 4.5 (Mancinelli et al., 2016; Aslan and Polito, 2021).

Poor nutritional conditions may have negative consequences for long-term population traits including survival and growth rates, age at first maturity, and/or fecundity (review by Metcalfe and Monaghan, 2001). Blue crab juveniles when fed on lower levels of dietary protein show lower growth rates and molting frequency than treatments featuring higher protein contents (Millikin et al., 1980). However, the Ebro Delta is the only area in the Spanish Mediterranean where abundances are large enough to sustain a targeted fishery that may reach over 2 tons of captures per day (López and Rodon, 2018; López, 2020). Hence, fishing captures also suggest a locally important reproductive output for the species. Ovigerous females, usually gather on the Ebro River mouth and open sea in front of the Ebro Delta (López and Rodon, 2018; López, 2020), an area that remains unexplored for the trophic structure and resource use of *C. sapidus*. The area hosts a diverse fishery of other commercial species, particularly benthic predatory and omnivorous fish that could overlap the functional trophic niche of blue crab, and behave either as potential predators, food resource, and/or as an active competitor (see Laughlin, 1982; Guillory and Elliot, 2001), depending on the size. For instance, the harbor crab, *Liocarcinus depurator*, has been reported to feed mainly on other decapod crustacea followed by small fishes and small cephalopods (Abelló and Cartes, 1987). Common predatory flatfish such as *Pegusa lascaris*, *Scophthalmus rhombus*, and *Solea senegalensis* might already undergo certain overlap in their trophic niche which is mostly comprised of different types of crustaceans, bivalves, polychaetes and fish (Cabral et al., 2002). Sparid fishes such as *Lithognathus mormyrus*, *Pagellus erythrinus,* and *Sparus aurata*, are also common opportunistic predators feeding on benthic invertebrates, mainly crustaceans, polychaetes, and bivalve mollusks (Kallianiotis et al., 2005; Taieb et al., 2013) that may be affected by the progressive spread of blue crab. Hence, comparative evaluation of the isotopic niche overlap and TP of these species relative to the blue crab can also provide an adequate proxy to assess functional trophic similarity.

Top-down control of blue crab has been extensively studied in native ecosystems (e.g., Heck and Coen, 1995; Guillory and Prejean, 2001; Hayes et al., 2022), but is still an unexplored ground in invaded Mediterranean regions. In the comprehensive review conducted by Guillory and Elliot (2001), authors provide a list of 93 species capable of preying on all blue crab life stages, although very few would be capable of preying on adult crabs of commercial size (ca.≥150g WW) and/or are present in a large quantity in the open waters of the Ebro Delta. Among potential candidates, the common octopus *Octopus vulgaris*, usually reaching sizes of 3–4kg and locally abundant, appear as a good model predator based on general knowledge of decapods being a favorite prey item of octopuses (e.g., Guillory and

Elliot, 2001; Leite et al., 2009; Pech-Puch et al., 2016) and on local fishermen reports of attacks to blue crab fishing traps (personal communication to P. Prado).

In this context, the main aim of this study was to determine the isotopic niche width, the TP, and the contribution of major prey items to adult female blue crab diet in the open sea of the Ebro Delta, an area that is of key importance for hatching success (females are nearly the exclusive sex in the area) in order to obtain a comprehensive picture of resource uses across the territory (provided only for males in estuarine habitats by Prado et al., 2022) that could help to assess the overall fitness of the population. A second aim was to assess the isotopic niche overlap and compare the TP of the blue crab with other commercial marine species in order to evaluate the potential effect of its introduction in the local food-web structure. A final objective was also to assess the possible role of *O. vulgaris*, in blue crab predation using a controlled manipulative experiment to assess isotopic fractionation. *O. vulgaris* has been indicated as an active predator of both the native green crab, *Carcinus mediterraneus* (Fiorito et al., 1990) and the blue crab in natural (fishermen report to P. Prado) and captivity conditions (P. Prado, personal observation). Hence, information about the specific patterns of fractionation could shed some light on the importance of trophic relationships.

Section snippets

Study sites, sample collection and processing

The study was conducted in coastal waters ca. 12–16km south from the Ebro River mouth, an area that is commonly fished for blue crab and other commercial species and features typical Mediterranean marine salinity ranges (ca. 36–37ppt; Fig. 1). Due to enhanced salinity, the local sex composition of blue crab in this area is extremely biased towards adult females which constitute the bulk of the captures (López and Rodon, 2018).

Fieldwork was conducted in five different dates from mid-October…

Isotopic signatures, TP and diet composition of blue crabs in the open sea of the Ebro Delta

Female blue crabs from the open sea featured mean isotopic signatures of −17.2±0.15 for $\delta^{13}C$ and 16.4±0.2 for $\delta^{15}N$. This resulted in a considerably high TP of 4.40±0.06 using $\delta^{15}N$ of bivalves as baseline for primary consumers. In fact, the TP of blue crabs from the open sea was also 1.4 and 1.6 times higher than that found in other habitats of the Ebro Delta, such as the Alfacs Bay and the Tancada Lagoon, respectively (Table 1).

The MixSiar model showed good performance (no variables…

Discussion

Our results evince a high blue crab trophic position (TP=4.4) in open waters of the Ebro Delta (coherent with an average total animal contribution of >80%), very similar to that found for other potential resource competitors of similar size. This situation contrasts with considerably lower TPs found in Ebro Delta Bays and the Tancada lagoon (TP=2.8), coherent with an average total animal contribution of ca. 57% (Prado et al., 2022); and even more reduced values suggested for other habitats…

Conclusions

Blue crab in open waters displayed a very high TP, comparable to that found in the harbor crab, *L. depurator*, and several predatory fish species. This contrast with TPs found in other habitats of the Ebro Delta where animal prey has become rare (Prado et al., 2022), but agrees with findings pointing to important rates of isotopic niche overlap with native predators, and with dietary modelling suggesting generalist predation. Functional trophic similarity with native species could potentially…

CRediT authorship contribution statement

Patricia Prado: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Marc Baeta:** Writing – review & editing, Resources, Methodology, Data curation, Conceptualization. **Estel Mestre:** Writing – review & editing, Resources, Conceptualization. **Marco Antonio Solis:** Writing – review & editing, Supervision, Methodology, Data…

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.…

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