SIX YEARS FROM FIRST RECORD TO POPULATION ESTABLISHMENT: THE CASE OF THE BLUE CRAB, *CALLINECTES SAPIDUS* RATHBUN, 1896 (BRACHYURA, PORTUNIDAE) IN THE NERETVA RIVER DELTA (SOUTH-EASTERN ADRIATIC SEA, CROATIA)

BY

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ABSTRACT

The data presented in this paper are based on the observation of 52 individuals of *Callinectes sapidus* Rathbun, 1896, collected in August and September 2010 by local fishermen using gillnets and traps in the area of the delta of the river Neretva (Croatian coast, south-eastern Adriatic Sea). Carapace width (CW) and carapace length (CL) frequency distributions indicate 3 age cohorts (modes) (CL: 7.2 cm, 8.4 cm, 9.0 cm; CW: 12.2 cm, 14.9 cm, 16.7 cm). The carapace width (CW)-to-weight (W) relationship was calculated (for both sexes) as $W = 0.816CW^{2.281}$ ($r^2 = 0.785$). The current substantial records, the occurrence of ovigerous females and juveniles (observations by fishermen through visual census), as well as the fact that the species was regularly caught in the estuarine area, together constitute evidence of an established population of this species in the region investigated. In future, continuous monitoring of the *C. sapidus* population, the dispersal of the species in areas adjacent to the one now investigated, as well as all along the eastern Adriatic coast, will be necessary.

RÉSUMÉ

Les données présentées dans ce papier sont basées sur l'observation de 52 individus de *Callinectes sapidus* Rathbun, 1896, collectés en Août et Septembre 2010 par des pêcheurs locaux utilisant des filets et des casiers dans la zone du delta de la rivière Neretva (côte de Croatie, sud-est de la mer Adriatique). Les fréquences de distribution de la largeur (CW) et de la longueur de la carapace (CL) indiquent 3 cohortes d'âge (CL : 7,2 cm, 8,4 cm, 9,0 cm ; CW : 12,2 cm, 14,9 cm, 16,7 cm). La relation largeur de la carapace (CW) sur le poids (W) a été calculée (pour les deux sexes) comme $W = 0{,}816CW^{2{,}281}$ ($r^2 = 0{,}785$). Ces observations substantielles, la présence de femelles ovigères et de juvéniles (observations visuelles par les pêcheurs), ainsi que le fait que cette

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espèce a été régulièrement attrapée dans la zone estuarienne constituent par leur ensemble l'évidence d'une population établie dans la région prospectée. Dans le futur le suivi continu des populations de *C. sapidus*, la distribution de l'espèce dans la zone adjacente de celle prospectée ainsi que le long de la côte adriatique Est, seront nécessaires.

INTRODUCTION

The blue crab, *Callinectes sapidus* Rathbun, 1896, is a portunid crab inhabiting estuaries and shallow coastal waters to 90 m depth. It is generally found over muddy and sandy bottoms and has a wide ecological tolerance. *C. sapidus* is a predator of fishes, molluscs, and crustaceans, and is also necrophagous and even cannibalistic. Feeding on algae as well, it can have a strong impact on natural populations of algae (Hines et al., 1987). The blue crab is characterized by sexual dimorphism in adults, with the males having blue fingers on their chelipeds and the females orange or reddish ones. It has a complex life history in which it utilizes both oceanic and estuarine habitats (Hines et al., 1987).

This species, originating from the western Atlantic, now also occurs in the Mediterranean and is here considered an invasive species (Streftaris & Zenetos, 2006). After its first Mediterranean record (in the northern Adriatic, Venice lagoon, see Giordani Soika, 1951), it has been widely reported from various different Mediterranean regions, especially in the eastern part (Galil et al., 2002). Several records have been published in recent years, with regard to the species' distribution in the Adriatic (Scaravelli & Mordenti, 2007; Florio et al., 2008; Kirinčić & Ševčić, 2008; Onofri et al., 2008; Beqiraj & Kashta, 2010; Dulčić et al., 2010) and other parts of the Mediterranean Sea (Gennaio et al., 2006; Tuncer & Bilgin, 2008), relating this expansion to the increase of maritime transportation.

This paper presents evidence of an established population of *C. sapidus*, in terms of providing additional information of blue crab specimens in the Neretva estuary in the south-eastern Adriatic Sea. Moreover, length, sex, and age composition, as well as some biological parameters of this new population are given. Since the blue crab is reported to be among the most aggressive alien species in the Mediterranean (Strefteris & Zenetos, 2006), new information on this non-indigenous species is worthy of study in order to understand the species' expansion in the new environment and its possible effects on the autochthonous flora and fauna.

MATERIAL AND METHODS

The data presented in this paper are based on the observation of 52 individuals of *Callinectes sapidus*, caught in gillnets and traps by local fishermen in August and September 2010 in the area of the Neretva River delta (fig. 1). The sediment

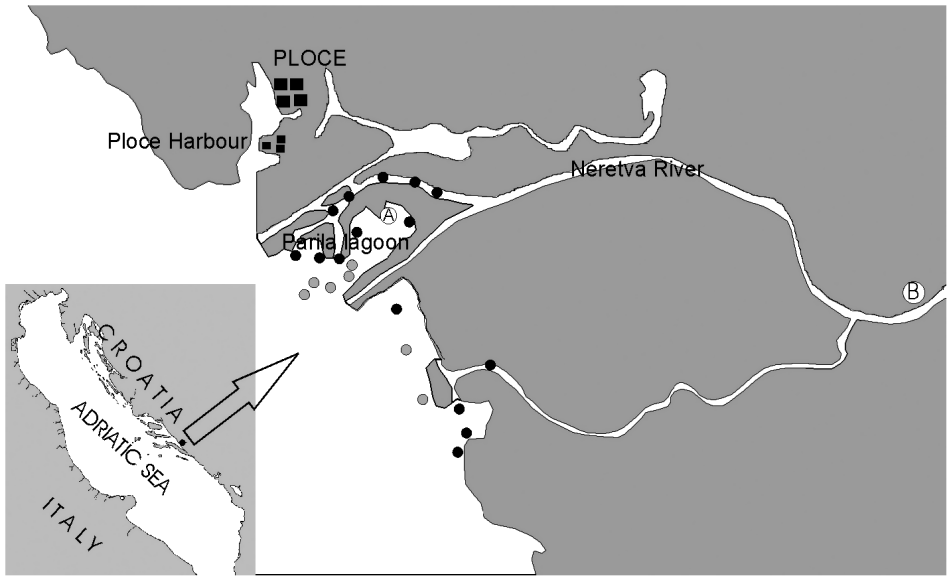

Fig. 1. *Callinectes sapidus* Rathbun, 1869. Distribution of the blue crab in the Neretva River delta, southern Adriatic Sea, Croatia; dark dots indicated males, gray dots females. A, first record by Onofri et al. (2008); B, record by Dulčić & Dragičević (2010).

in the study area is sandy-muddy and muddy (covered with photophilic algae, such as *Ulva lactuca* L., *Enteromorpha* sp., and *Cystoseira barbata* C. Agardh., as well as with meadows of *Cymodocea nodosa* (Ucria) Asch. The temperature in the Neretva River delta ranges from 9.2°C to 26.7°C, and salinity from 8.0 to 34.4 psu (in the Parila lagoon from 7.2°C to 33.4°C, and salinity from 11.4 to 34.6 psu). After collection, the specimens were identified to species level based on Galil et al. (2002).

Weight (W) and carapace measurements, inlcuding length (CL, distance between the centre of the anterior interorbital margin and the centre of the posterior margin) and width (CW, maximal distance between the posterior anterolateral spines), as well as sex, were recorded for all 52 individuals. Measurements were made with dial callipers. The carapace width-weight relationship was described by the equation:

$$W = a \times CW^b$$

where W is total weight (g), CW is carapace width (cm), and a and b are constants. The length frequency distributions (0.3 cm length classes) between sexes were analysed. Cohorts were determined through obtained modal distributions (the highest modes) according to Steele & Bert (1994).

In the laboratory, egg masses were carefully removed from the female pleopods with forceps, blotted on a paper towel, and dry weighed to the nearest 0.1 g.

To estimate the number of brooded eggs, the gravimetric method was applied. Subsamples of about 1000 eggs were taken from different parts of the egg mass, dry weighed with an accuracy of ±0.001 g, and counted under a stereomicroscope. All samples were oven-dried to a constant weight at 60°C. The absolute fecundity was then calculated from the equation:

$$F = n \times G/g$$

where F is fecundity, n is number of eggs in the subsample, G is weight of the ovaries, and g is weight of the subsample.

RESULTS AND DISCUSSION

In total, 52 specimens of *Callinectes sapidus* were examined, viz., 10 females and 42 males (overall sex ratio 4.2 : 1 males : females). CL ranged between 6.2 and 9.1 cm (Mean CL = 7.75 cm ± 0.761 SD), CW between 11.2 and 16.6 cm (Mean CW = 13.79 cm ± 1.428 SD), and weight between 158 and 520 g (Mean W = 344.08 g ± 85.969 SD). In particular, CL for males ranged between 6.2 and 7.9 cm (Mean CL = 7.13 cm ± 0.648 SD), CW between 11.2 and 14.2 cm (Mean CW = 12.69 cm ± 1.171 SD), with weight between 158 and 367 g (Mean W = 259.40 g ± 68.409 SD). For females, CL ranged between 6.6 and 9.1 cm (Mean CL = 7.90 cm ± 0.739 SD), CW between 11.8 and 16.6 cm (Mean CW = 14.05 cm ± 1.394 SD), with weight between 195 and 520 g (Mean W = 344.08 g ± 85.969 SD).

The carapace width (CW) and carapace length (CL) frequency distributions (fig. 2) indicate 3 age cohorts (modes) ($CL_{♀♂}$: 7.2 cm, 8.4 cm, 9.0 cm; $CW_{♀♂}$: 12.2 cm, 14.9 cm, 16.7 cm). The carapace width (CW)-to-weight (W) relationship was calculated (for both sexes) as $W = 0.816 \times CW^{2.281}$ ($r^2 = 0.785$). Out of the 10 females, 3 were ovigerous. The egg mass was weighed per individual: $CL_{♀}$ = 6.2 cm: 17.42 g, $CL_{♀}$ = 7.5 cm: 47.32 g, $CL_{♀}$ = 7.8 cm: 49.32 g. The egg mass was orange-yellow in colour (fig. 3) and individual fecundity ranged from approximately 1 000 000 to 1 500 000.

Among 52 individuals, 4 can be considered as medium-sized, while 48 as large, based on the classification of Harding (2003), which uses carapace width to classify blue crabs as small (CW < 80 mm), medium (CW 80-120 mm), and large (CW > 120 mm).

The current substantial records (N = 52), the indication of the presence of 3 age cohorts, the occurrence of ovigerous females and of juveniles (observed by fishermen through visual census), as well as the fact that the species was regularly caught in the estuarine area, together all constitute evidence of an established

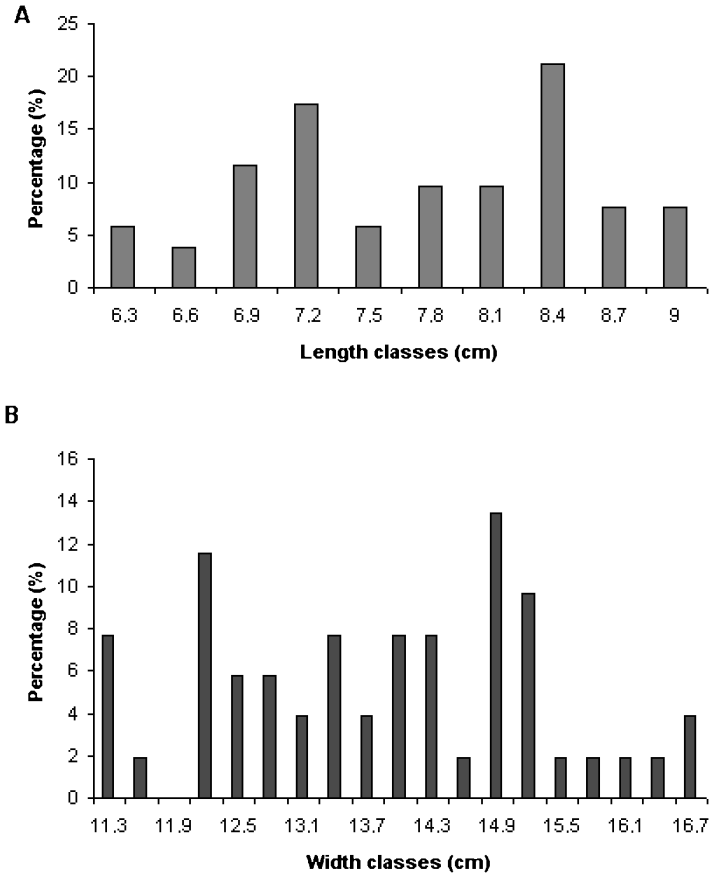

Fig. 2. *Callinectes sapidus* Rathbun, 1869. Frequency distribution of: A, CL; and, B, CW for the blue crab, Neretva River delta, southern Adriatic Sea, Croatia.

population of this species in the area investigated. Furthermore, the benthos of the Neretva delta is rich in mollusks, annelids, crustaceans, and fishes (Dulčić et al., 2007; Matić-Skoko et al., 2010), thus providing suitable feeding conditions for the blue crab as a predator. This represents the second report of an established population of the blue crab in the eastern part of the Adriatic Sea, after that from the Lagoon of Patok in Albania (south-eastern Adriatic Sea; Beqiraj & Kashta, 2010).

At least eight species of alien crabs have been recorded to date in the Adriatic Sea (Kirinčić & Števčić, 2008), and among them are two species of the genus *Callinectes*, viz., *C. sapidus* and *C. danae* S. I. Smith, 1869 (cf. Mizzan, 1993). In the eastern part of the Adriatic Sea, the blue crab was first reported in October 2004, when four specimens (2 males and 2 females) were caught near Ston in a hypersaline lagoon, and one specimen (a female) in the mouth of the river

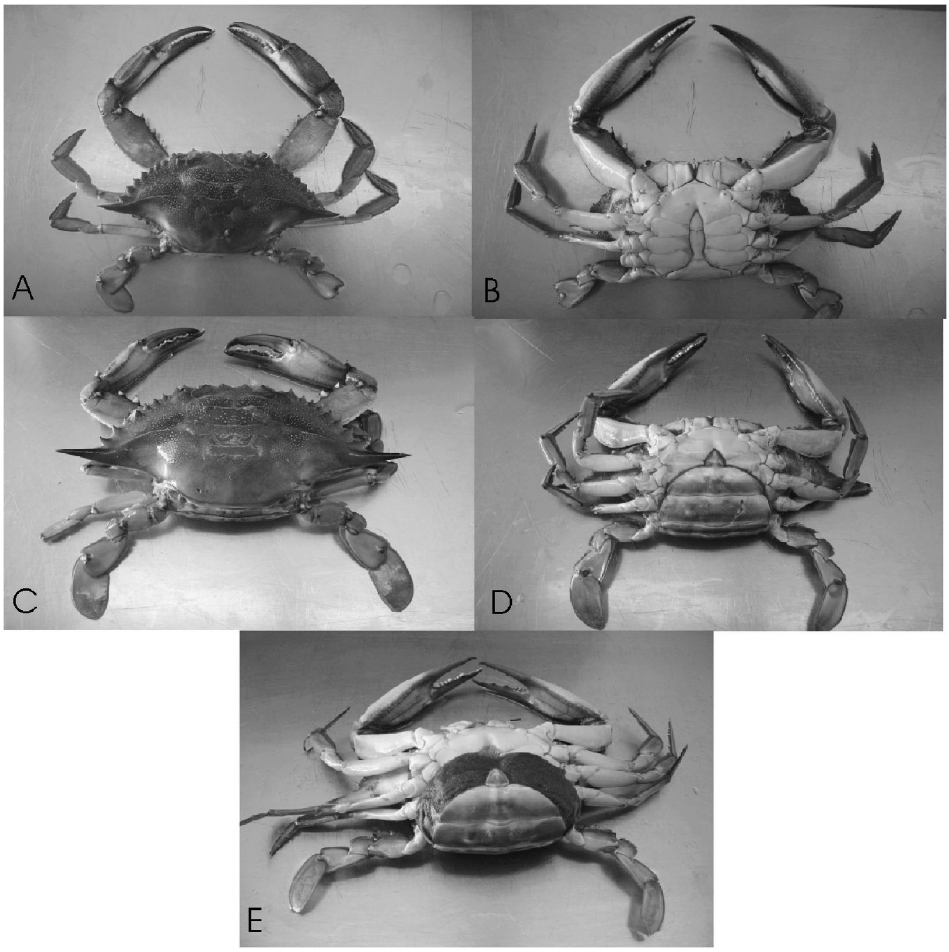

Fig. 3. *Callinectes sapidus* Rathbun, 1896: A, B, adult male; C, D, female; and, E, ovigerous female from the Neretva River delta, southern Adriatic Sea, Croatia: A-D, dorsal and ventral views, respectively; E, ventral aspect.

Neretva (Onofri et al., 2008). One additional female was recorded in the same place in December 2006 (Onofri et al., 2008), while another female was found at the mouth of the stream Norin, that flows into the river Neretva, in November 2009 (Dulčić et al., 2010). Beqiraj & Kashta (2010) reported 12 specimens (9 females and 3 males) caught in the Lagoon of Patok (Albania, Adriatic Sea). It is noteworthy to remark the current abundance of this species in the area of the Neretva delta, since most publications on the presence of the blue crab in the Adriatic have reported considerably lower numbers of individuals. Furthermore, local fishermen from the investigated area confirm the presence of many more specimens (catches varied between 40 and 50 specimens per night), so it seems that

the abundance of this species is high and that fact worries them. These fishermen often kill the crabs, because they tear their nets and damage the caught fish. This situation is not surprising because the blue crab has been reported as a highly aggresive species, and it has been selected among the 100 "worst invasive" species in the Mediterranean, with an impact on both biodiversity and socio-economics (Streftaris & Zenetos, 2006).

The blue crab is distributed throughout the Neretva River delta, with its highest abundance in the Parila lagoon (fig. 1), using various habitat types including submerged vegetation, unvegetated sediments, and marsh areas, but it seems that the populations are partitioned with respect to sex. Males prefer the brackish waters (20-25 psu) of the upper and middle parts of the lagoon, while adult females tend to concentrate in the lower reaches of the lagoon in waters of higher salinity (>30 psu). Studies also have shown that the species usually presents a differentiated distribution according to ambient environmental conditions, males occurring in higher numbers in lower salinities, while females are present in higher numbers in more saline environments, since they migrate further out into the coastal waters for spawning (Steele & Bert, 1994; Murphy et al., 2001). Salinity is an important factor in the hatching of blue crab's eggs and the survival of the larvae. Costlow & Bookhout (1959, cited in Steele & Bert, 1994) noted that larvae require salinities above 22 ppt to survive. By moving offshore to higher salinity waters before their eggs hatch, the females enhance larval dispersal and reduce osmoregulatory stress as well as predation (Hines et al., 1987, cited in Steele & Bert, 1994). Since most of our specimens were found as adults and during the spawning season, this distribution is probably related to reproductive behaviour indeed. Prey availability has been shown to be another factor influencing adult blue crab distribution in the estuarine system (Seitz et al., 2003).

The blue crab has been introduced to the Neretva River delta habitats, and now potentially represents a threat to the natural equilibrium of the delta community. It was first seen in the middle part of the Parila lagoon in 2004, and has been spreading ever since, now showing a remarkable increase in abundance. Its diverse diet makes it a possible threat to all species in the habitat, including the populations of native crabs.

In this area, a similar situation is observed with the increasing occurrence of the bluefish, *Pomatomus saltatrix* (L., 1767) during the last few years (Glamuzina & Dulčić, 2008). The bluefish is a typical predator, preying mainly on flathead grey mullet (*Mugil cephalus* L., 1758), which comprises the most important catch of the local fishery. This increase has a consequence, a decreased catch of the flathead grey mullet. Bluefish often also destroy the nets adapted to the traditional hunting of flathead grey mullet, and, moreover, damage the rest of the catch in the nets. As seen from such experience with bluefish (Glamuzina & Dulčić, 2008),

a significant increase of the blue crab may have severe consequences for the autochthonous ecological communities, and thereby deprive the local people of the benefits they are accustomed to receive from those natural communities now, in terms of changed ecological and socio-economic status.

At this point, it is not known to what extent the increase of the blue crab in the delta is related to environmental quality and to local fisheries. However, it is clear that alien predators can have significant effects on the composition of entire communities by displacement of local species with similar trophic level, by altering the behaviour or habitat selection of prey, resulting in a significant disturbance of local communities interactions (Hollebone & Hay, 2008). Understanding how alien predators affect local native communities remains a central goal of contemporary ecology, as changes in predator population densities or predator behaviour may have significant effects on entire ecosystems. To achieve the desired goal of a sustainable fishery, monitoring of the blue crab's spreading and potential effect on environment and local fishery, is strongly recommended.

The blue crab is considered as a food delicacy, being harvested not only as hard shell crabs but also as peeler crabs just prior to moulting, and soft shell crabs immediately after moulting. The large production and consumption of blue crabs in North-American and European countries as well as in Japan, is supplied by important commercial fisheries (Branco & Fracasso, 2004). Bearing this in mind, *C. sapidus* should be promoted as a new food source on the local market in terms of reducing eventual potentially negative impacts on the indigenous fauna.

Further monitoring of this population and the potential dispersal of this species in adjacent areas would be of interest, in order to provide richer information on population structure and dynamics of the blue crab in Adriatic waters along the Croatian coast.

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