

# Assessment of microbial sea water quality and health status of farmed European seabass (*Dicentrarchus labrax*) in Eastern Adriatic Sea (Montenegro and Croatia)

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Source / Izvornik: **Studia Marina**, 2019, 32, 52 - 64

Journal article, Published version

Rad u časopisu, Objavljena verzija rada (izdavačev PDF)

<https://doi.org/10.5281/zenodo.3584222>

Permanent link / Trajna poveznica: <https://urn.nsk.hr/urn:nbn:hr:184:883018>

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Download date / Datum preuzimanja: **2024-05-12**



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## Distribution and abundance of Horned Octopus (*Eledone cirrhosa* Lamarck 1798) (Cephalopoda: Octopoda) in south-east Adriatic sea

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### ABSTRACT

Specimens of *Eledone cirrhosa* were obtained from commercial bottom trawl hauls following the MEDITS protocol. Catches were standardised according to the swept area method, and the resulting values were used to calculate biomass (kg/km<sup>2</sup>) and abundance (ind/km<sup>2</sup>) indices. The results showed that *E. cirrhosa* was not found at depths below 5 m or over 500. The species is consistently present year-round only in 100–200 m stratum and its presence in shallower and deeper strata seems to be season-dependent: in spring, it is present only at 100–200 m depth, while in autumn and winter it can be found at 100–200 m and 200–500 m depth strata. Only in summer can it be found in all three depth strata (50–100 m, 100–200 m, 200–500 m). Both abundance and biomass indices were consistently most abundant in 100–200 m depth stratum.

**Keywords:** *Eledone cirrhosa*, horned octopus, distribution, abundance, biomass, south Adriatic

### INTRODUCTION

Horned, or lesser, octopus, *Eledone cirrhosa* is a medium-sized widespread octopod cephalopod species, found in shelf regions of the Mediterranean and north-east Atlantic waters (from Iceland and Lofoten Islands to Morocco (to about N33° latitude), and the Mediterranean Sea, as far east as to Marmara Sea) (Boyle, 1983; Nesis, 1987). It is found at depths from 5 to 300–500 m, but most

commonly between 60 and 120 m on the continental shelf in its entire range (Boyle, 1983; Jereb *et al.*, 2014). *E. cirrhosa* inhabits a wide range of sediments, from sand and mud, to rocks and rocky reefs. It feeds on various types of prey (shrimps, lobsters, crabs, brittlestars, polychaetes, gastropods, fish and other cephalopods). Throughout its distribution range, spawning occurs between

May and September, with a peak in July (Jereb *et al.*, 2014). However, studies in Montenegrin waters record the highest peak of sexually mature individuals in August (Ikica, 2013). Females lay from 800 to 1500–2000 eggs (Boyle, 1983; Jereb *et al.*, 2014), and the presumably benthic hatchlings emerge after about 100 days (Jereb *et al.*, 2014). Expected lifespan is 2 to 3 years in the Mediterranean, longer in colder waters of northern Atlantic (Jereb *et al.*, 2014).

## MATERIALS AND METHODS

The specimens of *E. cirrhosa* were obtained from commercial bottom trawl catches. The hauls were trawled at 10 predetermined positions, following the MEDITS protocol (MEDITS, 2007). Sampling was done using the commercial trawl in the period between 30 minutes after sunrise and 30 minutes before sunset. The trawl was hauled for 30 minutes if the sampling depth was below 200 m, or 60 minutes at depths greater than 200 m. The codend mesh size was 40 mm diamond, which was the legal minimum in Montenegro at the time (Official Gazette of Montenegro, 56/09, 8/11). Sampling was performed at depths from less than 50 m to over 200 m, here divided in four depth strata: <50 m, 50–100 m, 100–200 m, 200–500 m. The sampling was performed seasonally, from April 2009 to April 2011.

Horned octopus catches were standardised according to the swept area method (Sparre & Table 1).

*E. cirrhosa* was found in samples from all seasons at depths between 100 and 200 m. The lowest abundance index was recorded in autumn period (5.9 ind/km<sup>2</sup>), and the highest during summer (40.9 ind/km<sup>2</sup>) (Figure 2). The lowest value of biomass index was 1.1 kg/km<sup>2</sup>

Venema, 1998) using the AtrIS computer program (AdriaMed, 2007), and the swept area was calculated according to the formula:

$$P = 0.001 \times a \times s$$

where  $P$  is the surface of the swept area [km<sup>2</sup>],  $a$  is wing spread of the trawl [m], and  $s$  represents the distance travelled [km].

Obtained values of the swept area were then used to calculate biomass and abundance indices, which are used to express the catch according to area unit (kg/km<sup>2</sup> and N/km<sup>2</sup>, respectively). The mean value of the catch can be expressed as:

$$X_T = \frac{p_1 \bar{X}_1 + p_2 \bar{X}_2 + p_3 \bar{X}_3 + \dots + p_n \bar{X}_n}{p_1 + p_2 + p_3 + \dots + p_n}$$

where  $\bar{X}_T$  represents the mean value of the catch in the studied area (kg/km<sup>2</sup>, N/km<sup>2</sup>),  $\bar{X}_{1,2,3,\dots,n}$  is the mean value of the catch in a given depth stratum, and  $p_{1,2,3,\dots,n}$  is the surface area of a depth stratum (km<sup>2</sup>).

Distribution maps were made using the Surfer<sup>®</sup> 8 software from Golden Software LLC, using the haul data and Gaussian process regression (kriging) method.

## RESULTS

During the national monitoring, *E. cirrhosa* was not found on sites at depths lower than 50 m. At depths between 50 and 100 m, the horned octopus specimens were found only during the summer period, with abundance index of 15 ind/km<sup>2</sup> and biomass index of 2.3 kg/km<sup>2</sup> (

in winter, and the highest 5.4 kg/km<sup>2</sup> during summer (Figure 1).

At 200–500 m depths, no specimens of *E. cirrhosa* were found during the spring period. The lowest value of abundance index was recorded in autumn (4.8 ind/km<sup>2</sup>), and the highest in winter (216 ind/km<sup>2</sup>) (Figure 2).

Biomass index varied from 0.2 kg/km<sup>2</sup> in autumn to 14.4 kg/km<sup>2</sup> in winter (Figure 1).

Table 1. Abundance (N/km<sup>2</sup>) and biomass (kg/km<sup>2</sup>) indices of *E. cirrhosa* in Montenegrin waters according to depth during the national monitoring

Depth	Spring		Summer		Autumn		Winter	
	ind/km <sup>2</sup>	kg/km <sup>2</sup>	ind/km <sup>2</sup>	kg/km <sup>2</sup>	ind/km <sup>2</sup>	kg/km <sup>2</sup>	ind/km <sup>2</sup>	kg/km <sup>2</sup>
<50	—	—	—	—	—	—	—	—
50–100	—	—	15.0	2.3	—	—	—	—
100–200	30.4	4.9	40.9	5.4	5.9	2.4	14.0	1.1
200–500	—	—	35.4	7.3	4.8	0.2	216.0	14.4

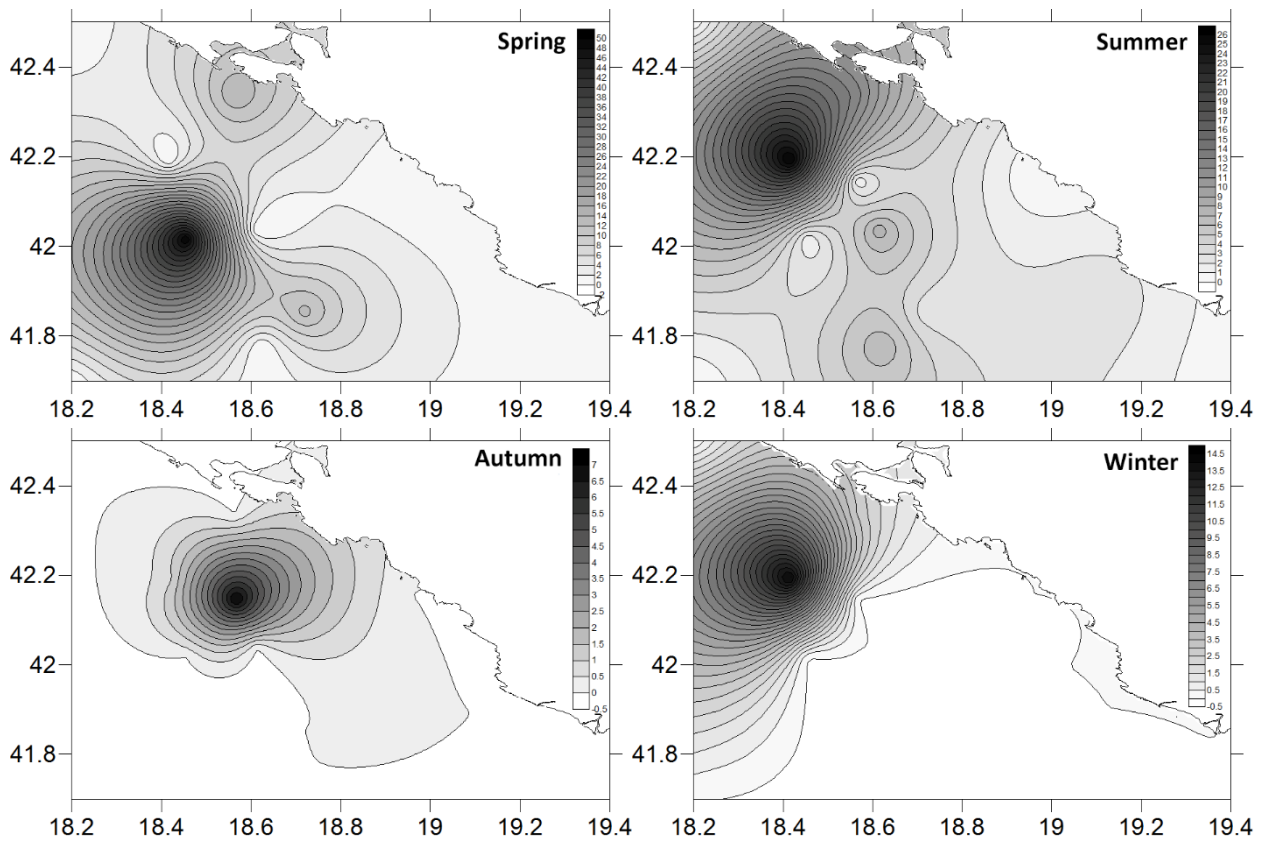


Figure 1. *E. cirrhosa* distribution and population density (kg/km<sup>2</sup>) according to season during national monitoring (2009–2011)

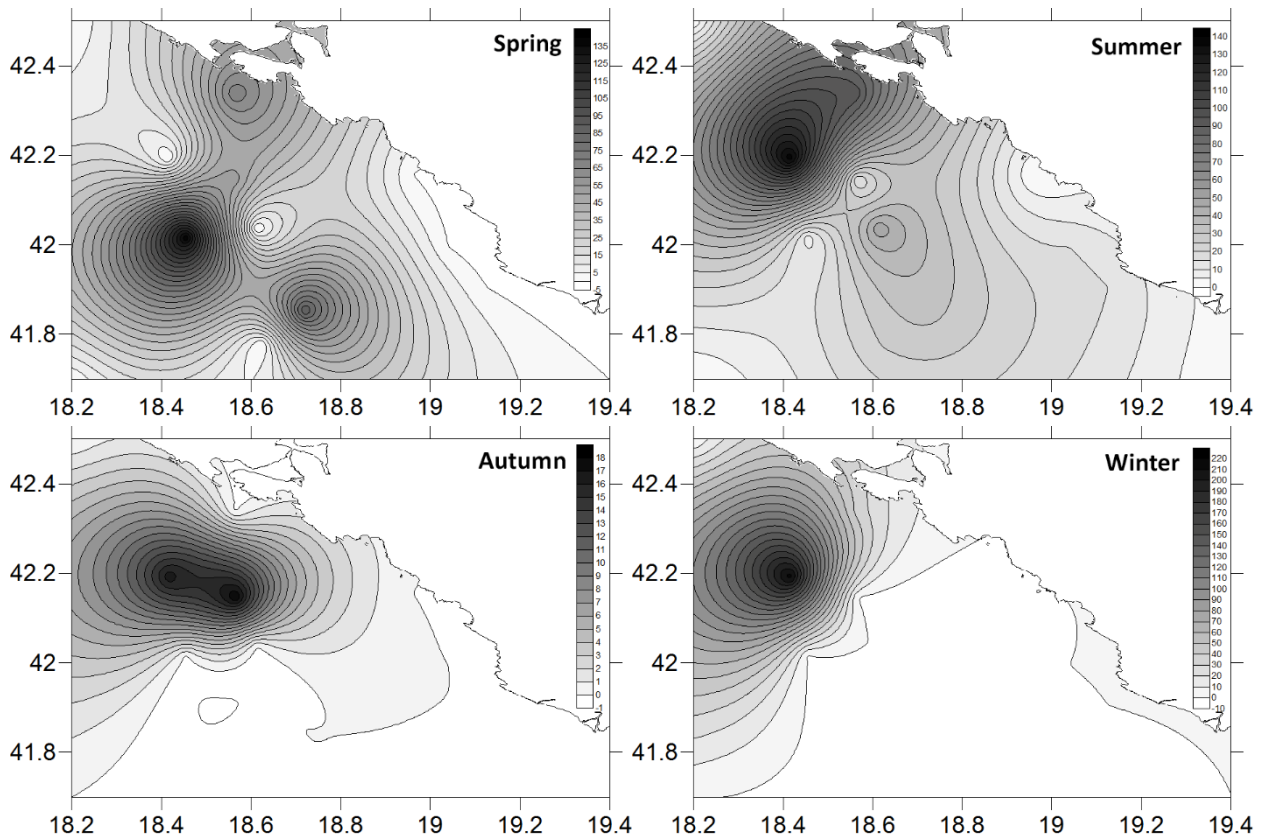


Figure 2. *E. cirrhosa* distribution and abundance ( $N/km^2$ ) according to season during national monitoring (2009–2011)

## DISCUSSION

In general, specimens of *E. cirrhosa* in Montenegrin waters were consistently present only in the 100–200 m depth stratum. No specimens were found at depths shallower than 50 m. At depths between 50 and 100 m, horned octopus was found only during the summer period, which can be tied to water temperature. In the 200–500 m stratum, horned octopus was found in all seasons except in spring. Similar results were reported by various authors across the Adriatic and Mediterranean Seas.

Mandić (1984) records horned octopus in Montenegrin waters at depths between 40 and 200 m, with the largest number of recorded individuals between 80 and 120–150 m. The author, however, notes that although the species has a relatively uniform distribution in the studied area (extreme south of Croatian

coast and the whole Montenegrin waters), it is not very abundant (accounting for 1.12% of the total cephalopod abundance, and 1.74% of the total cephalopod mass). These results were obtained using commercial catches, and serve to illustrate depth range and presence of species in 1974–1975, when there was no significant fishing activity in the investigated area. Tursi & D'Onghia (1992) report the greatest share (29.30%) of *E. cirrhosa* in the total cephalopod catch of the Ionian Sea of in the 50–100 m depth stratum – on average. The species was present at all depth ranges up to 400 m: 0–50 m (4.4%), 100–200 m (17.5%), and 200–400 m (11.3% of the total cephalopod catch). It was most well represented in summer catches (June 1989), with 37.1% of the total cephalopod catch. Sánchez & Martín (1993) report that in commercial bottom trawl catches of the Catalan Sea, *E. cirrhosa* was found at

depths from 25 to over 400 m, but was most abundant in the 50–100 m depth stratum, expressed as the number of individuals per hour of trawling ( $36.5 \pm 38.6$  ind/h) and weight of caught individuals per hour of trawling ( $3.2 \pm 5.0$  kg/h). However, at depths of 100–200 m, percentage of the species' occurrence in the total hauls performed per depth stratum was found to be the highest, reaching 66%. Krstulović Šifner *et al.* (2005) note the species in northern and central-eastern Adriatic, southeastern Adriatic and the eastern Ionian Sea, at depths ranging from 24 to 537 m. *E. cirrhosa* was most abundant on lower continental shelf and upper slope with the mean depth of 165.9 m ( $\pm 101.0$ ). Generally, the species had higher density indices in 100–200 m and 200–500 m depth strata. In the eastern part of the central and south Adriatic sub-areas, it was found only at depths greater than 80 m and 70 m, respectively. Ciavaglia & Manfredi (2009) report *E. cirrhosa* to be present in the Central Adriatic at depths from 10 to 500 m. The data is taken from GRUND and MEDITS surveys done in North and Central Adriatic from 1982 to 1995, and *E. cirrhosa* is recorded as the most abundant species, along with *E. moschata* and *I. coindetii*, in spring and summer. This is similar to data presented in this paper, where the highest occurrence was noted in the 100–200 m depth stratum. However the abundance index of 216.0 ind/km<sup>2</sup> recorded in winter period at depth range of 200–500 m, as the highest abundance index in all the studied strata, is not confirmed by other authors. This could be explained by seawater temperatures, which in winter are generally higher in deeper water layers.

Belcari *et al.* (2002) provide abundance and biomass indices covering the entire Mediterranean Sea for period between 1994 and 1999. South-eastern Adriatic is included from 1996, and the indices are the highest in

the 100–200 m depth stratum, as in this study. The highest were reported in 1996 (177 ind/km<sup>2</sup> and 39.3 kg/km<sup>2</sup>), with the lowest in 1999 (9 ind/km<sup>2</sup> and 1.6 kg/km<sup>2</sup>). Values reported in other parts of the Mediterranean can reach very high values (i.e. 1097 ind/km<sup>2</sup> recorded in western Gulf of Lions in 1995, at depths between 10 and 50 m, or 129.6 kg/km<sup>2</sup> in Argosaronikos in 1994, at depth stratum 50–100 m). Generally, the highest index values are reported for depth strata 50–100 and 100–200 m, depending on the area. Orsi Relini *et al.* (2006) report a range of abundance indices in the Ligurian Sea collected during the MEDITS expedition in period 1994 to 2003, but the highest are generally in the 100–200 m stratum and range from 82 ind/km<sup>2</sup> in 1996 to 731 ind/km<sup>2</sup> in 1994. Their results for biomass indices are similar to those of abundance indices, i.e. the highest values were registered in the 100–200 m depth stratum (range from 6.8 kg/km<sup>2</sup> in 1996 to 98.0 kg/km<sup>2</sup> in 1994). Mean abundance index for the 100–200 m depth stratum, for the entire time span, is 319 ind/km<sup>2</sup>, while the mean biomass index 29.3 kg/km<sup>2</sup>. Krstulović Šifner *et al.* (2011) give abundance index of 23 ind/km<sup>2</sup> and biomass index of 3.73 kg/km<sup>2</sup> in the Northern and Central Adriatic, based on the results of MEDITS expedition in Croatian waters from 1996 to 2004 (except 1999). The greatest abundance was recorded in 101–200 m depth stratum, 69 ind/km<sup>2</sup>, with the biomass index of 11.10 kg/km<sup>2</sup>. The lowest indices were found in the 10–50 m stratum (1 ind/km<sup>2</sup> and 0.08 kg/km<sup>2</sup>). Piccinetti *et al.* report a mean abundance index of 35 ind/km<sup>2</sup> and biomass index of 6.3 kg/km<sup>2</sup> in the north and central Adriatic, based on MEDITS expedition results for period 1996–2010. The MEDITS expedition was usually undertaken during the spring–summer period, and the results of Piccinetti *et al.* are similar to the results reported in this paper for spring and summer (

Table 1). The results given by Orsi Relini *et al.* (2006) are generally much higher, but since these are also higher than those reported by Krstulović Šifner *et al.* (2011) and Piccinetti *et al.* (2012), the difference could be attributed to the difference in geographical area (Ligurian Sea and Adriatic Sea, respectively) and the resulting difference in ecological conditions which can influence the abundance and distribution of the species. This is further supported by values reported by Belcari *et al.* (2002) for 40 sub-areas in the Mediterranean, sometimes with significant differences in index values.

## CONCLUSIONS

*E. cirrhosa* was found in the areas of Montenegrin waters from depths of 50 m to over 200 m, but the species was consistently present, and generally most abundant at 100–200 m depths. The exception was winter sampling, where the overall highest abundance index was recorded. The results of this study generally agree with the distribution data from other sources and regions, although abundance and biomass seems to be lower than in certain other areas (Ligurian Sea).

## ACKNOWLEDGMENTS

This study was performed within the frames of projects “Biological resources, edible and inedible, in bottom trawl fisheries along the Montenegrin coast”, funded by the Ministry of Science of Montenegro and implemented by the Institute of Marine Biology at the University of Montenegro and project “ADRIJA” (Analysis of the state of demersal resources along the eastern coast of the Adriatic and recommendations for sustainable exploitation and protection) funded

by the Ministries of Science of Croatia and Montenegro.

The authors would like to thank Mr Branko Vujičić and the crew of trawler “Vesna IV” for their help in sample collection, Ms Biserka Dubravčević and Ms Teodora Krivokapić for their help in processing the samples, and Mr. Vladan Vuković, B.App.Inf., for his help in data processing.

The authors are also thankful to two anonymous reviewers, whose critical comments and suggestions significantly improved the quality of this manuscript.

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Received: 09. 11. 2019.

Accepted: 11. 12. 2019.



## **Distribucija i brojnost bijelog muzgavca (*Eledone cirrhosa* Lamarck 1798) (Cephalopoda: Octopoda) u jugoistočnom Jadranu**

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### **SAŽETAK**

Uzorci bijelog muzgavca, *Eledone cirrhosa* sakupljeni su iz komercijalnih ulova pridnenom povlačnom mrežom – kočom prema MEDITS protokolu. Ulovi su standardizirani „swept-area“ metodom, a rezultati su korišćeni za izračun indeksa biomase (ind/km<sup>2</sup>) i brojnosti (kg/km<sup>2</sup>). Rezultati su pokazali da jedinke *E. cirrhosa* nisu bile prisutne na dubinama manjim od 5 m i većim od 500 m. Ova vrsta tokom čitave godine može se naći samo u dubinskom sloju 100–200 m, dok prisutnost u ostalim dubinskim slojevima najvjerojatnije zavisi o godišnjem dobu: u proljeće se može naći samo na dubinama 100–200 m, dok je tokom jeseni i zime prisutna na dubinama 100–200 m i 200–500 m. Samo ljeti može se naći u tri dubinska sloja (50–100 m, 100–200 m, 200–500 m). Najviše vrijednosti brojnosti i biomase zabiljene su u dubinskom sloju 100–200 m.

**Ključne riječi:** *Eledone cirrhosa*, bijeli muzgavac, distribucija, brojnost, biomasa, južni Jadran