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## NEW RECORDS OF *CAULERPA CYLINDRACEA* SONDER (CAULERPALES, CHLOROPHYTA) IN ISTRIA, CROATIA

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### ABSTRACT

*In this paper new records of the invasive green alga *Caulerpa cylindracea* Sonder along the Istrian coast from Vrsar to Zambratija are presented. So far, the presence of this species in Istria has been limited to a few locations in the southern part of the peninsula, with the northernmost confirmed record in Vrsar. This new data points out the continuous spread of *C. cylindracea* populations northwards.*

**Key words:** *Caulerpa cylindracea* Sonder, non-indigenous alga, spread, northern Istria

## NUOVE SEGNALAZIONI DELL'ALGA *CAULERPA CYLINDRACEA* SONDER (CAULERPALES, CHLOROPHYTA) IN ISTRIA, CROAZIA

### SINTESI

*L'articolo presenta nuove segnalazioni dell'alga verde invasiva *Caulerpa cylindracea* Sonder lungo la costa istriana, da Orsera a Zambrattia. Fino ad ora la presenza della specie in Istria era limitata a poche località nell'area meridionale della penisola, con l'avvistamento più settentrionale confermato a Orsera. I dati presentati evidenziano la continua estensione dei popolamenti di *C. cylindracea* verso nord.*

**Parole chiave:** *Caulerpa cylindracea* Sonder, alga non indigena, estensione, Istria settentrionale

## INTRODUCTION

Marine algal invasions can significantly affect benthos community structures around the world (Ribera & Boudouresque, 1995; Meinesz *et al.*, 2001; Kružić *et al.*, 2008; Antolić *et al.*, 2008; Cebrian & Balesteros, 2009). On the basis of the criteria elaborated by Boudouresque & Verlaque (2002), *Caulerpa cylindracea* Sonder, a green alga widely distributed in warm temperate and tropical seas, is one of 10 introduced macrophyte species which can be considered as the most invasive marine species in the Mediterranean Sea (Klein & Verlaque, 2008).

*C. cylindracea* was observed in the Mediterranean Sea for the first time in Libya (Žuljević *et al.*, 2007). The first occurrence of the species in the Adriatic Sea dates from the year 2000 (Žuljević *et al.*, 2003). Predominantly spread by currents, up to the end of 2006 there were more than 50 locations in the Adriatic Sea where the alga was recorded (Žuljević *et al.*, 2007). Several new investigations regarding the occurrence of *C. cylindracea* in the Adriatic Sea have been done recently. The potential impact of the species on sediments under the invasive alga was studied by Matijević *et al.* (2013), while its reproduction and the impact on other marine organisms by Antolić *et al.* (2008), Kružić *et al.* (2008) and Žuljević *et al.* (2008, 2011, 2012). So far, *C. cylindracea* has been recorded only in a few locations along the Istrian coast, at Cape Marlera in southern Istria and near Vrsar, representing the northernmost settlement of this species in the Mediterranean Sea (Iveša & Devescovi, 2006). Since these last records, the species has experienced an impressive speed of spreading northwards.

The aim of this paper is to give evidence of new records of the invasive species *C. cylindracea* along the North Adriatic coast.

## MATERIAL AND METHODS

## Study area and field methods

The present survey was conducted along the coastline from Vrsar to Zambratija, about 80 km in length. Data was collected during the summer periods of 2013 and 2014, by the use of snorkelling and professional SCUBA diving. During the summer of 2013 only sites around Poreč were examined, but the massive presence of *C. cylindracea* recorded (Fig. 1) motivated us to expand our research area during the next summer. Altogether, 12 sites from Vrsar to the Mirna River estuary were examined in 2013 and 6 more sites were examined in 2014 (Fig. 1).

Data were collected *in situ* by using the transect technique (Harmelin, 1987), a non-destructive visual census methodology. Vertical transects, 30 m in length, were laid out perpendicular to the coast, in a depth range from 0 to 15 m. At each sampling site two researchers

employed at least two diving hours for each survey. All the sites were geo-referenced by GPS coordinates (Tab. 1). GPS points corresponded to the points on the sea shore where the transect began. The coverage of the alga was estimated along the transect, 10 m to the left and 10 m to the right of the line, and classified within three levels. Levels are expressed as: 1: low abundance described sporadic algal patches not wider than 4 m<sup>2</sup> of investigated algae; 2: medium for non-continuous presence along the transect but with patches larger than 4 m<sup>2</sup>; 3: high for continuous algal covering all along the transect. On sites 3, 4, 5, 9 and 11, qualitative data about the extension of the area covered by the species was obtained over two consecutive years.

## RESULTS AND DISCUSSION

Of the 18 examined sites, *C. cylindracea* was found in 14 of them (Fig. 2). The presence of the species was confirmed at all sampling stations in the Poreč area in 2013. Moreover, the repetition of surveys at the same sites in the second year revealed wider and thicker populations of the alga. Changes in algal cover are presented in Table 1. The northernmost record of *C. cylindracea* populations appears to be the Zambratija bay. This site was not surveyed during the first year, therefore the extension of the area covered by the species was not calculated, but in 2014 the coverage of the alga was estimated to be about 800 m<sup>2</sup> (sites 17 and 18).

The results of the present study confirm the presence of *C. cylindracea* in 14 new locations along the western Istrian coast. It can be stated that this non-indigenous species has quickly spread all along the coast from Vrsar to Zambratija. Since its introduction in the 1990s, the alga has extended throughout the whole Mediterranean Sea, usually forming dense and large populations with



**Fig. 1:** The carpet of the alien algae *Caulerpa cylindracea* Sonder.

**Sl. 1:** Preproga iz alge *Caulerpa cylindracea* Sonder

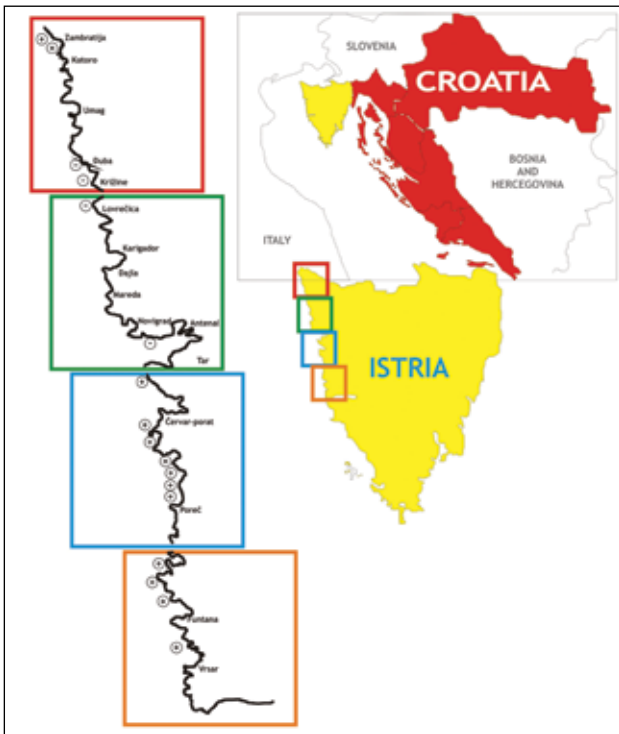
**Tab. 1: Description of investigated sites and *C. cylindracea* coverage along vertical transects in 2013 and 2014. Coverage levels are expressed as: 1: low coverage, which describes sporadic algal patches not wider than 4 m<sup>2</sup>; 2: medium coverage for non-continuous algal presence along the transect with patches larger than 4 m<sup>2</sup>; 3: high coverage for continuous algal patches along the transect; n. r.: not recorded.**

**Tab. 1: Opis vzorčevalnih mest in številčnost vrste *C. cylindracea* vzdolž vertikalnih transektov v letih 2013 in 2014. Pokrovnost je izražena kot: 1: nizka – prevleke alge, manjše od 4 m<sup>2</sup>; 2: srednja – nepovezana navzočnost alge vzdolž transekta, ki obsega prevleke, večje od 4 m<sup>2</sup>; 3: velika – neprekinjene prevleke alge vzdolž transekta; n. r.: ni zabeleženo**

Site	GPS coordinates		Site description	Bottom type	Coverage level 2013	Coverage level 2014
	Lat (N)	Long (E)				
1	45° 9' 47"	13° 36' 8"	exposed shore	rock, sand	n. r.	2
2	45° 11' 46"	13° 34' 53"	exposed shore	rock, sand	n. r.	1
3	45° 12' 18"	13° 35' 10"	exposed shore	rock, sand	2	3
4	45° 12' 44"	13° 35' 24"	sheltered bay	rock, sand	2	3
5	45° 12' 56"	13° 35' 39"	sheltered bay	seagrass bed	2	3
6	45° 13' 59"	13° 35' 54"	sheltered bay, muddy area	mud	n. r.	1
7	45° 14' 9"	13° 35' 44"	slightly exposed shore	rock, sand	n. r.	1
8	45° 14' 49"	13° 35' 34"	exposed shore	rock	n. r.	1
9	45° 14' 54"	13° 35' 29"	slightly exposed shore	rock	n. r.	2
10	45° 15' 56"	13° 34' 43"	sheltered bay	mud, seagrass bed	2	3
11	45° 16' 9"	13° 34' 48"	sheltered bay	rock	2	3
12	45° 17' 43"	13° 34' 21"	exposed shore	rock	n. r.	1
13	45° 18' 53"	13° 34' 15"	sheltered bay, brackish water	sand, mud	n. r.	-
14	45° 22' 57"	13° 32' 12"	exposed shore	rock, sand	n. r.	-
15	45° 24' 2"	13° 32' 10"	sheltered bay	rock, sand	n. r.	-
16	45° 24' 14"	13° 31' 44"	slightly exposed shore	rock, sand	n. r.	-
17	45° 28' 14"	13° 30' 35"	sheltered bay	sand, rock	n. r.	3
18	45° 28' 33"	13° 30' 16"	sheltered bay	seagrass bed	n. r.	2

an invasive behaviour (Panayotidis & Žuljević, 2001; Klein & Verlaque, 2008). During the present study *C. cylindracea* has been found on exposed shores as well as in sheltered bays, as previously found by Klein & Verlaque (2008). They also concluded that it tolerates high levels of pollution (Klein & Verlaque, 2008). During our surveys, in fact, its occurrence was not affected by the proximity of fishing and recreational boating harbours. This result does not necessarily demonstrate an affinity of the species for polluted areas, but may be a consequence of the secondary dispersal mechanisms via tourist or fishing activities (Klein & Verlaque, 2008). Regarding the impact of this invasive alga on native habitats Piazzi *et al.* (2001) observed that it causes an anoxic layer under thick algal layers. Moreover, the same au-

thors showed modifications caused by *C. cylindracea* invasion on the structure of the benthic macro algal community. The species is capable of reproducing sexually and vegetatively (Klein & Verlaque, 2008) and it is considered a strong competitor species in moderate areas (Blažina *et al.*, 2009). Its prolific development can be explained in part by the effective vegetative propagation mechanisms in addition to sexual reproduction. So far, management strategies have been concentrated on manual and chemical control of the spread of the alga. For the Adriatic Sea Žuljević *et al.* (2007) reported the successful eradication of the species in areas with small colonies. The need for researches about biological control mechanisms was underlined (Žuljević *et al.*, 2007; Klein & Verlaque, 2008).



**Fig. 2: Sampling sites and distribution of *C. cylindracea* along the western Istrian coast from Vrsar to Zambratija.**  
**Sl. 2: Vzorčevalna mesta in razširjenost vrste *C. cylindracea* vzdolž zahodne istrske obale med Vrsarjem in Zambratijo**

Further studies and monitoring are needed in order to ascertain other *C. cylindracea* locations, follow its spread in the Adriatic Sea and to establish successful prevention and perhaps eradication programmes. As this invasive species spreads steadily to almost all of the Mediterranean Sea (Cebrian & Ballesteros, 2009), it is possible that it will be soon present in the whole northern Adriatic Sea. Common efforts between Croatia, Slovenia and Italy are needed in order to complete the dataset about *C. cylindracea* spreading and to establish an effective monitoring system.

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NOVI ZAPISI O POJAVLJANJU ALGE *CAULERPA CYLINDRACEA* SONDER  
(CAULERPALES, CHLOROPHYTA) OB ISTRSKI OBALI (HRVAŠKA)

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POVZETEK

V zadnjih letih je postalo širjenje invazivnih vrst v morskem okolju zelo zaskrbljujoče. *Caulerpa cylindracea* Sonder je invazivna vrsta zelene alge, ki se razširja v Sredozemskem morju. Prvič so jo zabeležili leta 1991, v Jadranskem morju pa leta 2000. Doslej je bila navzočnost te vrste omejena na nekaj lokalitet v južnem predelu istrskega polotoka z najsevernejšo znano lokaliteto Vrsar. V tem prispevku smo želeli podati nove podatke o pojavljanju te vrste na območju od Vrsarja do Zambratije. Od 18 preiskanih lokalitet je bila na 14 potrjena navzočnost vrste *C. cylindracea*. Spričo razširjanja te vrste proti severu je smiselno pripraviti spremljanje stanja vrste na Hrvaškem, v Sloveniji in Italiji z namenom načrtovanja programov učinkovitega monitoringa, uspešnega preprečevanja in morebitnega odstranjevanja te vrste.

**Ključne besede:** *Caulerpa cylindracea* Sonder, tujerodna alga, razširjanje, severna Istra

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