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Mapping of the *Cymodocea nodosa* (Ucria) Asch. meadows in the Kotor bay and data comparison over the last four decades

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ABSTRACT

There is a huge discrepancy between different methods and periods of data collection for the seagrass *Cymodocea nodosa.* The aim of this work was to map the current distribution of the *C. nodosa* meadows in the Kotor Bay and evaluate changes over the last four decades. Seagrass *C. nodosa* was present in monospecific meadows or together with *Zostera noltei* along 22 % (7697 m) of the coastline. In total 118486 m^2 of *C. nodosa* meadows were mapped, from 1 m depth up to 5 (6) m depth on sandy-muds and muddy bottoms. The percentage of the loss of the coastline where *Cymodocea* meadows were mapped by Stjepčević and Parenzan (1980) and where they are currently present, is of 20%. Considering the vertical distribution of meadows the loss accounts for 20-40 %. In our opinion, the reports by DFS (2012) and RAC SPA (2013) concerning the distribution of the *Cymodocea* meadows in the Kotor Bay should not be taken into account in further assessments because they are not accurate.

Keywords: *Cymodocea nodosa*, mapping, regression, Adriatic Sea

INTRODUCTION

Seagrasses are distributed across the globe, but unlike 250000 terrestrial angiosperms they exhibit low taxonomic diversity (approximately 60 species worldwide) (Orth et al., 2006). Furthermore, seagrass meadows could extend for hundreds and thousands of kilometers of coastline, they have relatively low biomass compared to terrestrial ecosystems, but very high biomass compared to plankton-based oceanic communities (Short et al., 2007). Seagrasses are engineers of very important habitats in the Mediterranean Sea and they play a key role in providing ecological services such as primary production, nutrient cycling, sediment stabilization, biodiversity enhancement and habitat providers (Orth et al., 2006; Short et al., 2007). Because of all that, they are protected by different national laws

and international conventions (Official Gazette No. 76, 2006; Barcelona Convention 1976; Bern Convention 1979), as well as listed as one of the priority habitats by the EU Habitat Directive (92/43/EEC). Furthermore, following European Water Framework Directive (2000/60/EC), seagrasses could be useful indicators of ecological status, but only few indices are dealing with *Cymodocea nodosa* (Ucria) Ascherson (Orfanidis et al., 2007; 2010; Marba et al., 2013; Orlando-Bonaca et al., 2015).

Unfortunately, seagrasses inhabit coastal zones where they are under the pressures of multiple stressors such as wastewater runoff and decline in water transparency, physical disturbance, invasive species and others. Because of many negative anthropogenic impacts they are in decline globally, with rates increasing from median of 0.9% per year before 1940 to 7% after 1990 (Garrido et al., 2013). Furthermore, Telesca et al. (2015) estimated a regression of *Posidonia oceanica* (L.) Delile meadows up to 34% in the last 50 years. In developed and developing parts of the world their decline is more rapid, while mitigation and restoration efforts are only occasional (Short et al., 2007). Having in mind that reports on seagrasses in the New York Times, National Geographic and Nature are 3 to 50 times lower than those for salt marshes, mangroves and coral reefs, Orth et al. (2006) concluded that scientific understanding of the importance of the seagrass ecosystems transmitted into public awareness has not been as effective as for the other coastal ecosystems.

The Boka Kotorska Bay is a fjord-like bay on the south-eastern coast of the Adriatic Sea and the inner part of the Bay (Kotor-Risan Bay) is listed as one of the UNESCO natural and cultural heritage sites (Official Gazette No. 56/13), proclaimed also an Emerald site and most likely it will become a Natura 2000 site (MMPA 2014). In the Bay of Boka Kotorska four seagrasses are registered: *C. nodosa*., *Zostera noltei* Hornem., *Zostera marina* L. and *Posidonia oceanica* (L.) Del. (Stjepčević & Parenzan, 1980; Mačić, 2014).

C. nodosa has a tropical origin but nowadays it is restricted to the Mediterranean and several locations in the North Atlantic from Southern Portugal and Spain to Senegal, including Canary Island and Madeira (Ayala, 2010). The first record of the presence of *C. nodosa* in the Boka Kotorska Bay was by Karaman and Gamulin-Brida in 1971. They reported meadows for the Kotor Bay and particularly well developed meadows of *Zostera* sp. in the coastal area of the Kotor-Risan Bay and meadows of *Zostera* sp. and *C. nodosa* in the outer part of the Bay (Tivat-Hercegnovi Bay), while *P. oceanica* meadows were reported in several locations of the outer part of the Bay (St. Marko island, Topla, Žanjice and Mamula island).

Unfortunately, there is a huge discrepancy between different methods and periods of data collection for the *C. nodosa*. This work aims to: 1) map the present distribution of the *C. nodosa* meadows in the Kotor Bay and 2) assess the changes over the last 37 years in order to provide appropriate information as a baseline for the further monitoring and better management.

MATERIAL AND METHODS

The surveyed area has a total surface of 16.2 km^2 with an average depth of 27 m. It is characterized by a sandy-muddy bottoms and a few very small areas of rocky bottom (Lepetić 1965). Furthermore, this area is characterized,

especially in the northern part, by specific habitat "vrulja" (submarine spring of freshwater).

For the mapping of the *C. nodosa* meadows the satellite images available on the internet Google Earth application were consulted. Field work was performed by snorkeling, SCUBA diving and by a rubber boat equipped with an eco-sounder and using a "mirror". *C. nodosa* meadows coordinates were recorded by GPS Garmin 76, using the geographic coordinate datum WGS 84. Maps of *C. nodosa* meadows in the Kotor Bay were created in the Quantum GIS (2013) (Coord. Syst. WGS84 – UTM 34N) using the satellite images, data collected in the field and all available historical data. The oldest historical descriptive information together with the map of habitats for the Kotor Bay was provided by Stjepečević and Parenzan (1980), followed by DFS (2012) and RAC SPA (2013).

RESULTS AND DISCUSSION

During the field survey we observed marine habitats along 34918 m of coastline. Seagrass *C. nodosa* was present in monospecific meadows or together with *Z. noltei* along 22 % (7697 m) of the coastline. In total, 118486 m^2 of *C. nodosa* meadows were mapped, from 1 m depth up to 5 -6 m depth on sandy-muddy and muddy bottoms. *Cymodocea* meadows were more abundant along the western coast of the Bay, where several meadows a few hundred meters long were registered (Fig. 1, 2a, b). On the other hand, in the southernmost part of the Bay, only some sparse shoots of *Cymodocea* were observed (along 34 m of the coast), while in the northern part of the Bay meadows displayed a mosaic along almost 555 m of the coast. The upper limit of the meadows mapped with Google Earth coincided with the field data, while the situation for the lower limits was not always

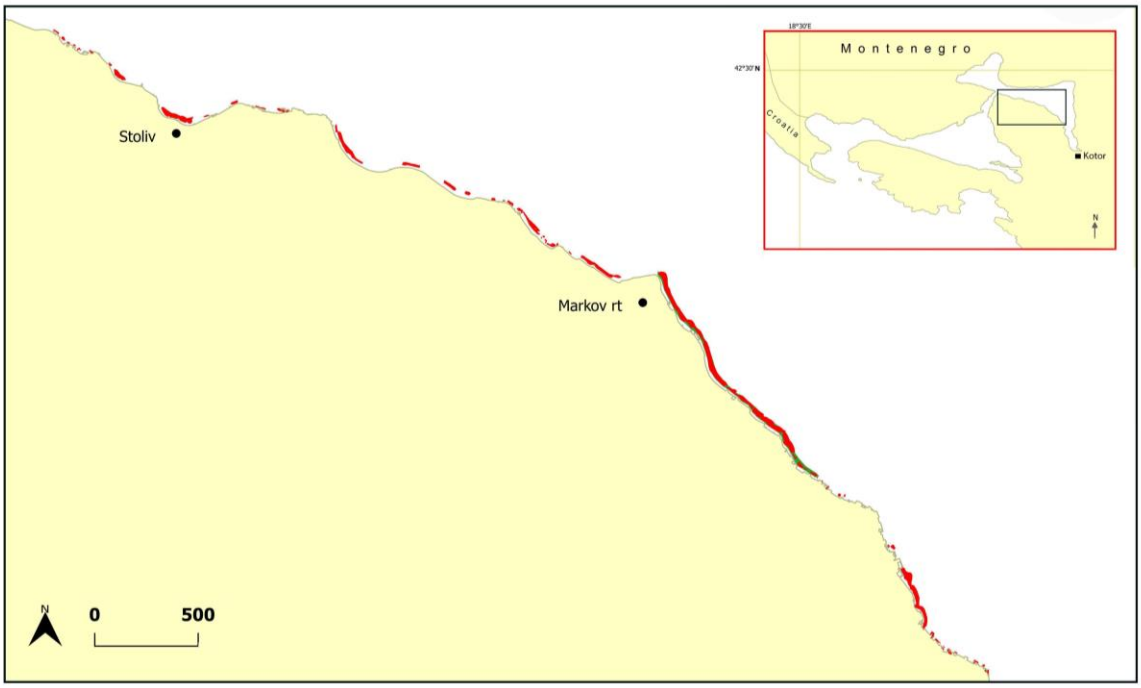


Fig. 1. Mapped *C. nodosa* meadows in the Kotor bay western part: *C. nodosa* from this study, *C. nodosa* from Stjepčević and Parenzan (1980)

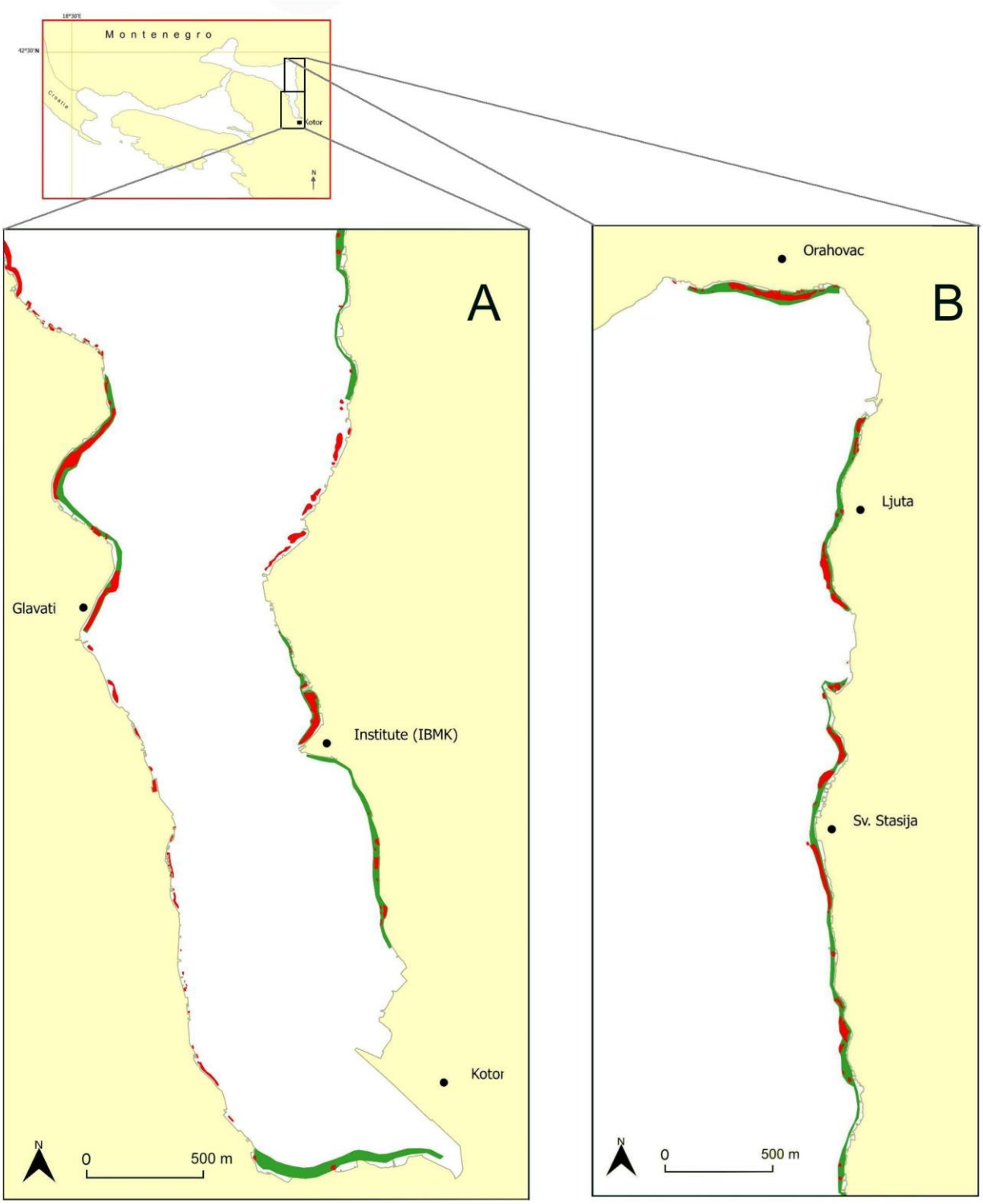


Fig. 2. Mapped *C. nodosa* meadows in the Kotor bay A) southern part, B) eastern and north part : *C. nodosa* from this study, *C. nodosa* from Stjepčević and Parenzan (1980)

the same, because of the high turbidity of the water and shadows from the surrounding mountains. Furthermore, only by SCUBA it was possible to distinguish a few meadows

where *C. nodosa* is mixed with *Z. noltei* (locations Orahovac, Sv. Stasije, Institute of Marine Biology, Markov Cape).

Mapping is not enough to evaluate the ecological status of *C. nodosa* meadows as required by the EU Water Framework Directive (WFD, 2000/60/EC). Montenegro is an EU candidate country and in the process of transposition and implementation of all EC Directives, thus, the ecological status should be assessed in the framework of the Marine Strategy Framework Directive (MSFD) and good environmental status should be achieved/maintained (MSFD, 2008/56/EC). But, in order to achieve that goal, the reference conditions of the given environment should also be defined. Due to very specific environmental conditions of the Boka Kotorska Bay the modelling of the reference condition is very difficult and the comparison with similar pristine areas is not possible. Thus, the comparison with historical data is the only remaining possibility.

Unfortunately, while analyzing the historical data we encountered the problem of different methodologies, different scales of surveys and different precision of the data provided. The oldest survey providing information on habitats as well as on habitat mapping for the Kotor-Risan Bay was provided by Stjepčević and Parenzan (1980). In this report *Cymodocea* meadows were present along 9669 m of the coast line (Table 1) and the majority of the meadows, contrary to the current situation, were present along the eastern coast of the bay (Fig. 1, 2). Comparing the length of the coast line along which *Cymodocea* meadows were present both in 1980 and nowadays, there is a 20 % of loss. The situation is even worse if we analyze only meadows reported in the 1980s and the current situation in the same microlocations, because formerly continuous meadows are now in many cases registered as mosaic or small islets of meadows. However our survey also showed *Cymodocea* meadows along 1495 m of the western coast (from Markov Cape to Stoliv) where this type of habitat was not previously reported (Stjepčević & Parenzan 1980). Based on the map of sampling stations performed in the study of Stjepčević and Parenzan (1980) we can speculate that this northernmost part of the western coast of the Kotor Bay was not analyzed in detail and these meadows could be unnoticed at that time. The loss of the coastline with *Cymodocea* meadows accounts for the 36% in 37 years. Obviously, for the time span of 37 years this is a dramatic loss.

Table 1. Coast line (in metres) along which *Cymodocea* meadows were found

Study by:	year	North	South	East	West	Total
Stjepčević & Parenzan	1980	732	759	5721	2457	9669
DFS	2012	0	0	2450	399	2849
RAC SPA	2013	0	0	448	0	448
our research	2017	555	34	2556	4552	7697
% of loss or progression from 1980 to 2017		-24%	-95%	-55%	85%	-20%

Furthermore, Stjepčević and Parenzan (1980) reported *Cymodocea* meadows from 3 m depth down to 7 m depth, while now we have registered only sparse shoots at 6 m depth. The

same authors reported several meadows wide up to 80 and 100 m, while nowadays are more reduced. If we take into consideration that the regression of this habitat is not happening only in the horizontal, but also in the vertical distribution, we can conclude that during the last four decades from 20 % to 40 % of *C. nodosa* meadows have been lost. Obviously, in this conditions, the ecosystem functions must be severely endangered.

Maps of habitats for the Kotor Bay were also developed as parts of two other projects that we have to mention here. One is „Start up of "Katič" MPA in Montenegro and assessment of marine and coastal ecosystems along the coast" (2012) and second is „Ecological quantitative description of Boka Kotorska Bay marine area (Montenegro)" (2013). These studies motivated us to work on mapping of *Cymodocea* meadows because, as it is shown in Table 1, our results are providing a completely different situation. One of the thematic maps of the submerged vegetation over the Montenegro's coast has been made on the base of satellite WorldView-2 scenes and appropriate processing (image ortho-rectification; radiometric and atmospheric correction; removal of the attenuation effect due to the water column; classification and post processing) (DFS 2012). But, we should have in mind that only one category of habitats, named "submerged vegetation" was dedicated for all types of seagrass meadows and all macro-algal habitats. Because of such inaccurate classification it was expected to have larger areas under the category "submerged vegetation" but unfortunately, for the Kotor Bay it was identified along only 2849 m of the coast line (Table 1). The reason for this situation, in our opinion, could be low transparency of the seawater and shadows from the hills that are surrounding the Kotor Bay.

Similar and even worse situation for the seagrass meadows has been reported in the RAC SPA study (2013) performed by side scan sonar (SSS). *Cymodocea* meadows in monoculture or mixed with *Z. noltei* were reported along only 448 m of the coastline (Table 1). As we were witnesses that no dramatic change in the environment of the Kotor Bay happened during the period 2012-2013, the discrepancy between this and the survey performed one year earlier (DFS, 2012) are most likely consequences of the errors in the interpretation of sonograms. In the RAC SPA study (2013) the whole coastal perimeter of the Bay was surveyed adopting a 100 m lateral range of the SSS, and the frequency of 325 kHz. It is well known that SSS is very effective tool for mapping huge areas in detail and comparison through time (Montefalcone et al., 2013). But appropriate image-processing techniques are necessary. Although the 100 kHz images usually contained more noise, they gave more information than those given by the 500 kHz (Siljestrom et al., 1996). Furthermore, the SSS survey was performed in early April 2013, when the *Cymodocea* meadows are not fully developed, which could explain possible errors in the interpretation of the SSS images.

Although *C. nodosa* is a fast growing species (Duarte, Sand-Jensen, 1990; Cancemi et al., 2002) the discrepancy between the data reported from the studies in 2011 and 2013 and our unpublished field observations during the last 20 years, the current situation seems unrealistic. Because of that, we suggest that the reports DFS (2012) and RAC SPA (2013) for the distribution of the *Cymodocea* meadows in the Kotor Bay should not be taken into account in further assessments. As regards the discrepancy between the data from 1980 and our data, we assume there are two possible reasons. First the habitat mapping described by Stjepčević and Parenzan (1980) has a low

accuracy. The second, is probably related to the impacts received by the meadows due to the current intensive coastal pressures present in Kotor Bay. The southernmost part and the east coast of the Kotor Bay are highly eutrophic (Fig. 3) even if the Municipality of Kotor constructed a wastewater pipe into the open sea in 1994, and a wastewater treatment system in 2016.

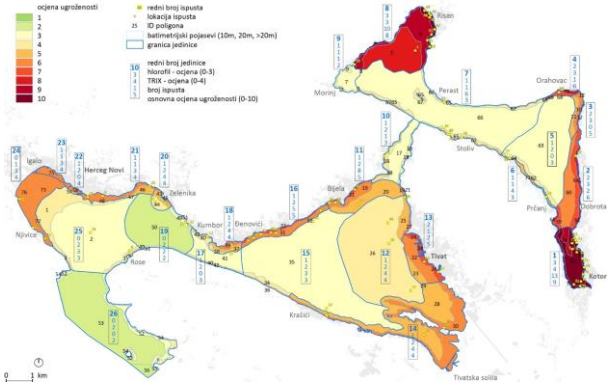


Fig. 3. Risk assessment for marine environment in terms of eutrophication effect (from Bataković et al., 2017)

But, this system still does not collect all waste waters that are partially flowing into the Kotor Bay even today. Furthermore, along all coasts of the Boka Kotorska Bay we are witnessing an intensive (very often illegal) alteration of the coast line (Fig. 4).

Numerous small piers and new beaches are constructed every year causing additional destruction of the very sensitive shallow infralittoral belt. Although the Kotor-Risan Bay is under UNESCO protection and according to the national law (Official Gazette No. 56/13) changes in the coast line are not allowed, the reality is quite different. Obviously, enforcement of this law (and several others) is urgently needed if the conservation of the marine environment is to be achieved.



Fig. 4. Example of intensive alteration of the coast line in the Kotor Bay

Furthermore, *Cymodocea* meadows in the Risan Bay have also show a strong regression (Mačić 2014) when compared to historical data of Stjepčević and Parenzan (1980). But for the outer part of the Boka Kotorska Bay (Tivat-Herceg Novi Bay) the only available map of habitats is the one by satellite imagery (DFS 2013) that was not very reliable for the Kotor Bay.

Future management and protection of the Boka Kotorska Bay has to rely on scientifically reliable cartographic data. Here we have provided some cartographic data that can be used as a baseline for further studies, but we urge the scientific community and the Administration to start long term monitorings and ecological status assessments in order to develop and implement EU Directives in the coastal waters of Montenegro.

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Mapiranje livada *Cymodocea nodosa* (Ucria) Asch. u Kotorskom zalivu i poređenje podataka iz poslednje četiri dekade

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SAŽETAK

Postoji velika razlika između različitih metoda i perioda u kojima su sakupljani podaci za morsku travu *Cymodocea nodosa.* Cilj ovog rada je bio da se mapira trenutno rasprostranjenje livada *C. nodosa* u Kotorskom zalivu i ocijene promjene tokom zadnje četiri decenije. Morska trave *C. nodosa* je bila prisutna u monospecijskim livadama ili zajedno sa *Zostera noltei* duž 22 % (7697 m) obalne linije zaliva. Ukupno je mapirano 118486 m^2 livada *C. nodosa* od 1 - 5(6) m dubine na pječano-muljevitom i muljevitom dnu. Procenat gubitka obalne linije duž koje su livade *C. nodosa* mapirali Stjepčević i Parenzan (1980) i gdje je trenutno prisutna je 20%. Kada se uzme u obzir i vertikalna disribucija gubitak je od 20 - 40 %. Po našem mišljenju, izvještaji DFS (2012) i RAC SPA (2013) za rasprostranjenje *C. nodosa* u Kotorskom zalivu u daljim analizama ne treba da se uzimaju u obzir jer nisu tačna.

Ključne riječi: *Cymodocea nodosa*, mapiranje, regresija, Jadransko more