Long-term Monitoring of Carnivorous Gelatinous Macrozooplankton in the Area of Dubrovnik-Neretva County (Croatia)

Dugotrajno praćenje želatinoznog makrozooplanktona mesoždera na području Dubrovačko-neretvanske županije (Hrvatska)

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Abstract

In the southern part the Adriatic, gelatinous macrozooplankton fauna is poorly known compared to the other taxa. Therefore, our goal was to collect and systematize all available phenological data and abundances of gelatinous organisms based on scientific surveys from 1996 to 2020 and a "citizen science" sighting program in the southern Croatian waters. The inter-annual variability and seasonality of planktonic Cnidaria and Ctenophora were described. A total of 590 reports was received from citizens, which summed up to result in 870 data together with the scientists' records. In total, 15 species were recorded. Of these, scyphomedusa *Pelagia noctiluca* accounted for 34 %, followed by ctenophora *Cestum veneris* (19 %) and the scyphomedusa *Cothylorhiza tuberculata* (17 %). Mass occurrence was most frequently found in *P. noctiluca* and then in *C. tuberculata* and *C. veneris*. Isolated mass occurrence was recorded for the freshwater hydromedusa *Craspedacusta sowerbii,* found in Lake Kuti near the mouth of the Neretva River, and for the scyphomedusa *Aurelia* cf. *solida.* The three species *A. solida, Mnemiopsis leidyi* and *C. sowerbii* are not native to European waters. Considered that alien species are invading the Adriatic Sea and human impact and global warming are increasing, it is crucial to carefully monitor the occurrence of gelatinous zooplankton taxa and to conduct studies focused on deciphering their ecological impact in marine ecosystems. Therefore, our empirical analysis of 25 years of observations provides essential information on the variation of gelatinous zooplankton in the Southern Adriatic region.

KEY WORDS

Hydrozoa
Scyphozoa
Ctenophora
blooms
Adriatic Sea

Sažetak

Fauna želatinoznog makrozooplanktona u južnom Jadranu je manje poznata i istražena u usporedbi s ostalim skupinama zooplanktona. Zbog toga je cilj ovog rada je skupiti i objediniti sve dosadašnje poznate podatke o fenologiji i brojnosti želatinoznih makroorganizama za južni Jadran. Raspoloživi podatci su dobiveni istraživanjima znanstvenika te putem dojave građana kroz organizirane inicijative praćenja u razdoblju od 1996. do 2020. Opisane su višegodišnje i sezonske promjene u distribuciji i brojnosti planktonskih žarnjaka i rebraša pri čemu je 590 nalaza prijavljeno od strane građana od ukupno 870 zabilježenih. Podatci su dani za ukupno 15 vrsta, od kojih najveći udio nalaza pripada režnjaku Pelagia noctiluca (34 %), zatim rebrašu Cestum veneris (19 %) te režnjaku Cotylorhiza tuberculata (17 %). Masovne pojave jedinki utvrđene su najčešće za režnjaka P. noctiluca, a zatim za vrste C. tuberculata i C. veneris. Opisane su kratkotrajne masovne pojave slatkovodnog obrubnjaka Craspedacusta sowerbii u jezeru Kuti u blizini delte rijeke Neretve te režnjaka Aurelia cf. solida. Istraživanjem su obuhvaćene tri alohtone vrste, režnjak A. cf. solida, rebraš Mnemiopsis leidyi te obrubnjak C. sowerbii. S obzirom na sve veći broj stranih i potencijalno invazivnih vrsta bilježenih u Jadranskom moru uslijed pojačanog antropogenog utjecaja i klimatskih promjena, izuzetno je važno pratiti promjene i prisutnost želatinoznog zooplanktona kako bi se bolje proučila njihova uloga i utjecaj u morskim ekosustavima. Naši podatci u rasponu od 25 godina sustavnog praćenja promjena pružaju jedinstvena saznanja o promjenama u populaciji želatinoznog makroplanktona južnog Jadrana.

KLJUČNE RIJEČI

obrubnjaci
režnjaci
rebraši
masovne pojave
Jadransko more

1. INTRODUCTION / *Uvod*

Gelatinous, carnivorous macrozooplankton include several organisms commonly referred to as "jellyfish" belonging to Hydromedusae, Scyphomedusae, and Ctenophora. Their populations can form massive blooms that have various negative ecological impacts, by affecting ecosystem services [13, 25, 33, 22], human health [24] and economic activities, especially fisheries and aquaculture [57, 60, 14]. Recent evidence suggests that anthropogenic stressors (overfishing, eutrophication, habitat alteration) and global climate change are driving their blooms [66, 67, 22, 85, 63].

Most of the jellyfish data in the Adriatic Sea relate to the northern and western Adriatic coasts, and there is much less information for the southern parts. Much attention has been paid only to the mass occurrences of the scyphomedusa *Pelagia noctiluca* in the 1970s and 1980s [62], as well as to the phenomenon of consistently high numbers of *Aurelia relicta* in the marine lake on the island of Mljet [10, 51, 80, 1, 44]. Apart from the studies on *P. noctiluca* blooms and the intensive research on *A. relicta* in the lake of Mljet Island, the only records of jellyfish macrozooplankton refer to the presence/absence of certain species in this region [29] and the occurrence of some species in the period 1995–2001 [9]. Recently, data about mass occurrences of Ctenophora and Scyphomedusae in a specific area of the Southern Adriatic, the Boka Kotorska Bay, have been presented [49, 84].

Due to the insufficient knowledge of the composition of the gelatinous community of the southern Adriatic, and the exposure of the area to incoming Mediterranean currents that can potentially introduce alien and invasive species, the aim of this paper is: (I) to collect and systematize all available data on the occurrence of carnivore gelatinous macrozooplankton species in the area of Dubrovnik-Neretva County; (II) to present the latest data on the phenology and abundance of gelatinous macrozooplankton in this area, (III) determine the presence and distribution of non-native gelatinous macrozooplankton species. The results of our research were preliminary presented at the congress 2nd International Conference of Maritime Science & Technology NAŠE MORE 2021 held in September 2021 in Dubrovnik.

2. MATERIAL AND METHODS / *Materijali i metode*

2.1. Study area / *Područje istraživanja*

The area of Dubrovnik-Neretva County (Fig. 1) covers a wide marine surface that is strongly influenced by incoming currents from the eastern or western Mediterranean Sea, which is related to the BIOS mechanism [88, 58, 20]. Most of the coastal area is under the direct influence of the open sea. A stronger land influence can be seen in Župa Bay, Gruž Bay and the mouth of the Ombla River. The area is markedly oligotrophic with an annual mean chlorophyll a value of 0.087±0.07 mg m-3 [83, 6]. Higher levels of chlorophyll, up to 0.7 mg m-3, are short-lived and vertically restricted [28].

The most productive area of Dubrovnik-Neretva County is the estuary of the Neretva River and Neretva Channel. The estuary is classified as a salt-wedge type where, due to small tidal currents, advection of river water is much greater than the input of seawater by tidal mixing. Mean chlorophyll a values ranged from 0.003±0.02 to 0.96±0.25 mg m^{-3} [82]. A stronger anthropogenic influence is visible in the waters of the Port of Ploče, located in the Neretva Delta.

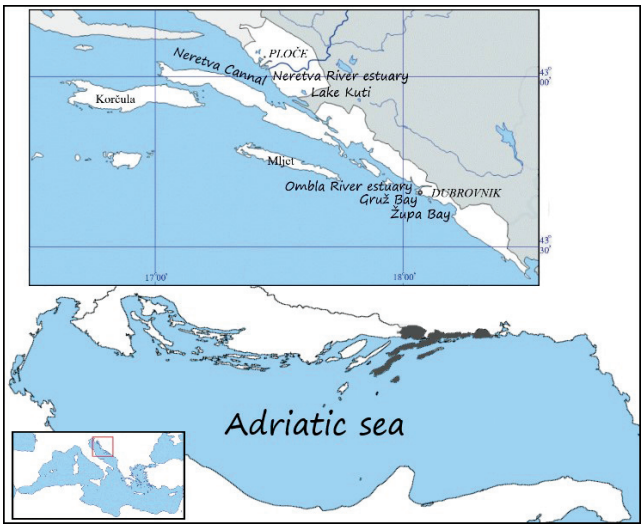

Figure 1 Map of Dubrovnik-Neretva County (Croatia)
Slika 1. Karta Dubrovačko-neretvanske županije (Hrvatska)
Source: Created by authors according to https://d-maps.com

Lake Kuti is part of the upper Neretva Delta. It belongs to the category of warm, shallow Mediterranean karst crypto-depressions (4.5 m), under minimal sea influence. According to the mean monthly values of chlorophyll a concentration and total phosphorus concentration, Lake Kuti belongs to the category of oligotrophic to mesotrophic ecosystems [64].

2.2. Data Collection / *Prikupljanje podataka*

Data on the occurrence and abundance of gelatinous macrozooplankton species, in the period from 1996 to 2020, were obtained based on research cruises and surveys conducted by scientists from several Adriatic oceanographic institutions. Additional information was obtained through the Citizen Science action "Jellywatch" (leaders A. Benović and D. Lučić). Autonomous divers, in particular, provided many accurate photographs and underwater videos. Observations for each species were pooled on a monthly basis to create a multi-year semi-quantitative dataset. Each month of the year is assigned a value between 0 and 3 according to the following criteria: 0—jellyfish not seen at all; 1—sporadic occurrence of individual organisms; 2—frequent occurrence of individual jellyfish and/or small aggregations; and 3—frequent occurrence of large aggregations. Values represent the highest frequency of jellyfish occurrence in a given month, regardless of the number of reports received. Several authors have already used similar methods to present the results of macrozooplankton research [27, 43, 16, 48, 62, 79, 54].

Furthermore, annual semi-quantitative abundance was calculated from the monthly datasets using the following equation previously used by [62]:

$$\Sigma \text{year} = [(\text{t.o. x rel. ab. 1}) + (\text{t.o. x rel.ab. 2}) + (\text{t.o. x rel.ab. 3})]$$

t.o. = times observed; rel. ab. 1, 2, 3 = relative abundance according to criteria described earlier.

3. RESULTS AND DISCUSSION / *Rezultati i rasprava*

3.1. Hydrozoa / *Obrubnjaci*

3.1.1. *Porpita porpita* (Linnaeus, 1758)

We recorded *P. porpita* only in 2018, with a single specimen in April and a large number of individuals in October. Both detections were in nearshore surface waters.

The blue button *P. porpita* is a floating colony of hydroids inhabiting mainly the superficial part of the water column as neuston. The species has been found in the Atlantic Ocean, Indo-Pacific Ocean and Mediterranean Sea [15, 38], including the Adriatic Sea [35, 69]. There are only three known records of mass occurrences of this species: stranding of large numbers of individuals along the coast of Odisha (India) during the summer season [70], high abundance (1-2 individuals/m2) along the southeast coast of Bangladesh in March/April 2014 [73], and along the northern coastal region of the Sea of Japan [46].

3.1.2. *Olindias muelleri* (Haeckel, 1879)

This hydromedusa was recorded only twice: in 2014, with a small number of individuals, and in 2017, when it was more numerous and caused inconvenience to tourists. Both findings occurred in August in shallower bays of almost the entire observed area. Gravili et al. [35] in a biogeographical monograph of widespread marine species of the Italian Sea, do not find it in the Southern Adriatic. Although *O. mulleri* could be numerous in summer in some bays along the eastern Adriatic coast, there are no published data on its biology and ecology. Its high abundance in summer is well known for Starigrad Bay on the island of Hvar (central Adriatic) [89]. Since 2014, there have been more reports from citizens about the occurrence of this jellyfish in the central and northern part of the eastern Adriatic coast. Mass occurrences were recorded in 2016 and 2017 in some localities of the Central Adriatic and in 2019 in the Northern Adriatic (Lučić, D. unpublished data).

O. mulleri is a shallow-water meroplanktonic species found in the Mediterranean Sea and tropical-Atlantic Ocean [15]. They normally reside with their tentacles among seagrasses and algae during the day, and become active in the water column after sunset. Although *O. muelleri* medusae have been recorded throughout the Mediterranean, the number of reports on their occurrence and abundance is limited [3]. Recently, there are more data on the occurrence of this jellyfish in the Mediterranean Sea, mainly because of its negative impact on tourism. Indeed, *O. mulleri* causes mild dermatitis in humans through its stings [69]. It was the third most common sting along the coasts of Salento Peninsula (Italy) [24]. This species was very common along Spanish coasts (Valencian Community) in 2009-2015 and was recorded for many stings to humans [76, 37]. Boero et al. [12] suggest that ocean warming plays an important role in the spread of this species across the Mediterranean Sea.

3.1.3. *Geryonia proboscidalis* (Forsskål, 1775)

This species has an Atlantic, Indo-Pacific and Mediterranean distribution [15]. It has been recorded in all regions of the Adriatic [8, 35], more frequently in the southern part [11, 32], always with single specimens. During our observations, we recorded a large number of individuals (~ 1 ind. 2 m^{-2}) on the southern side of the island of Mljet, from 18 to 20 March 2013. The next finding was offshore in April 2018, when it was present individually. Since 2017, the species has been frequently present in the Northern Adriatic, and in October a mass occurrence was recorded near Pula (3-4 ind. m^{-3}) [5]. In this occasion, a large number of swimmers sought medical attention after being stung by this jellyfish. In the Mediterranean Sea, a larger number of individuals (39 ind. 100 m^{-3}) has so far only been found off the coast of Egypt in summer of 2000 [86].

3.1.4. *Craspedacusta sowerbii* (Lankester, 1880)

We recorded a mass occurrence of *C. sowerbii* in September 2001 in Lake Kuti, part of the upper Neretva Delta. High numbers were again observed in January and February 2002. Thereafter, the species was no longer recorded. Our finding represents the second record of C. sowberii in Croatian waters, following the findings by Stanković and Ternjej [77] in the artificial pond Cingi-lingi (north-eastern Croatia).

C. sowerbii is one of the most successful invasive freshwater invertebrate species in the world and is still considered a cosmopolitan species [26]. This jellyfish can tolerate extreme environmental conditions and has a suitable life stage for anthropogenic transport [40]. Although it is thought to originate from South America, *C. sowerbii* is native to the Yangtze River valley in China [45]. It was first described from the "Victoria regia" tank (Victoria amazonica) in Royal Botanic Society's gardens in Regent's Park, London [47]. The most plausible vector for its introduction was water lily plants from Brazil [61]. In recent years, it has spread rapidly in the Middle East and Balkan regions [30, 41, 59].

3.2. Scyphozoa / *Režnjaci*

3.2.1. *Cotylorhiza tuberculata* (Marci, 1778)

This jellyfish was observed in the warm season, from July to October (Figs. 2). It is one of the most frequently found species during our monitoring (17% of the findings). Blooms were observed in August and September in 1998, 2003 and 2006 (Fig 2). Thereafter, *C. tuberculata* was frequently observed, but with low numbers of specimens. Higher abundances were found in summer 2019 and 2020, but mass outbreaks were not recorded.

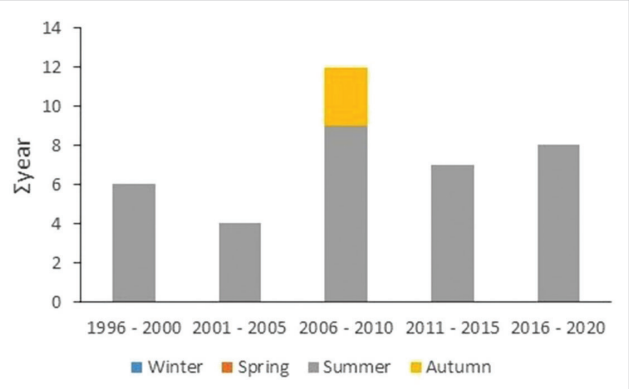

Figure 2 Temporal variability (month/year) of relative abundance of two dominant Scyphozoa taxa the Dubrovnik-Neretva County (blank-jellyfish are not seen at all; 1-sporadic occurrence of individual organisms, yellow dot; 2-frequent occurrence of individual jellyfish specimens and/or small aggregations, blue dot and 3-frequent occurrence of large jellyfish aggregations/blooms, red dot

Slika 2. Vremenske varijabilnosti (mjesec / godina) relativne brojnosti dominantnih svojti režnjaka u Dubrovačko-neretvanskoj županiji (prazno-meduze nisu primijećene; 1 - sporadična pojava pojedinačnih jedinki, žuta točka; 2 - česta pojava meduza i / ili su u manjim nakupinama, plava točka i 3 - česta pojava velikih nakupina / masa meduza, crvena točka

Based on laboratory experiments and in situ observations, Prieto et al. [65] concluded that mass outbreaks of *C. tuberculata* in the Mar Menor are associated with a trend of global warming. Mild winters and sudden warming in spring triggered strobilation,

which then led to high abundance in summer, while cold winters inhibited polyp reproduction. The influence of environmental factors on the distribution of this species in the Adriatic Sea [2] is difficult to explain, as no polyps were found in this area.

3.2.2. *Rhizostoma pulmo* (Marci, 1778)

This jellyfish was rarely found in the southern Adriatic until 2015. Since then, the number of individuals observed has become more frequent, but never more than one individual per observation. There was no difference in the seasons in which this species occurs. *R. pulmo* is one of the most abundant jellyfish in the Mediterranean Sea [13] often appearing in large numbers in recent decades, with consequences for fisheries and tourism [55]. Blooms have been recorded most frequently in semi-enclosed and highly productive marine ecosystems, such as the Northern Adriatic Sea [43, 62].

3.2.3. *Drymonema dalmatinum* (Haeckel, 1880)

During our monitoring, only one specimen of this species was found in the Neretva Channel in May 2018. Otherwise, the number and occurrence of this previously rarely seen species is increasing throughout the Mediterranean Sea, especially along the eastern Adriatic coast [52]. The largest number of finds and the greatest abundance were found in Boka Kotorska Bay [84, 62].

3.2.4. *Chrysaora hysoscella* (Linnaeus, 1767)

The frequency of findings of this jellyfish in the region Dubrovnik-Neretva coincides with the results for *R. pulmo*: increased findings since 2015, always singly, without seasonal differences. The northern Adriatic is also an area of the Mediterranean where this jellyfish has been very common and numerous since the 2000s [43]. In recent years, high abundances and frequent blooms have been found in the Boka Kotorska Bay [84, 62].

3.2.5. *Pelagia noctiluca* (Forsskål, 1775)

This jellyfish was the most frequently observed among all other gelatinous macrozooplankton species (34% of findings). The bloom was recorded periodically, approximately every 7 years: 1996-1997, 2004-2006, 2013-2014 (Fig. 2 bottom). The most recent short-term mass occurrences were recorded in spring and autumn 2018. Particularly large masses of *P. noctiluca* were recorded from 2003 to 2007. This holoplanktonic species occurred in high population densities throughout the Mediterranean almost every year during the 1970s and 1980s [81]. These were the largest and longest lasting mass occurrences of *P. noctiluca* in the Mediterranean Sea. At that time, the Adriatic Sea was particularly affected by numerous ingressions of Mediterranean water, which subsequently had a pronounced negative impact on tourism and fisheries [13].

Physical factors (currents) influence the horizontal dispersal of *P. noctiluca* and the formation of larger aggregations along the coast, and may be introduced into the Adriatic Sea by incoming currents from the Ionian Sea and the open southern Adriatic [7]. This link between Adriatic and Mediterranean metapopulations has been confirmed by genetic evidence [78]. From the coastal southern part, jellyfish were transported by currents to the central and northern Adriatic [50], where they lated longer in the plankton. According to our results, the largest masses and the longest residence time of 4-5 days near the coast fell in the winter-spring period or in autumn (Fig. 3). Therefore, they did not have a negative impact on tourism in the southern Adriatic, as was the case for the central and northern Adriatic in 2004 and 2006. Moreover, *P. noctiluca* is a large non-selective predator of zooplankton [68] and the oligotrophic Southern Adriatic certainly does not provide enough food compared to the central and especially northern regions.

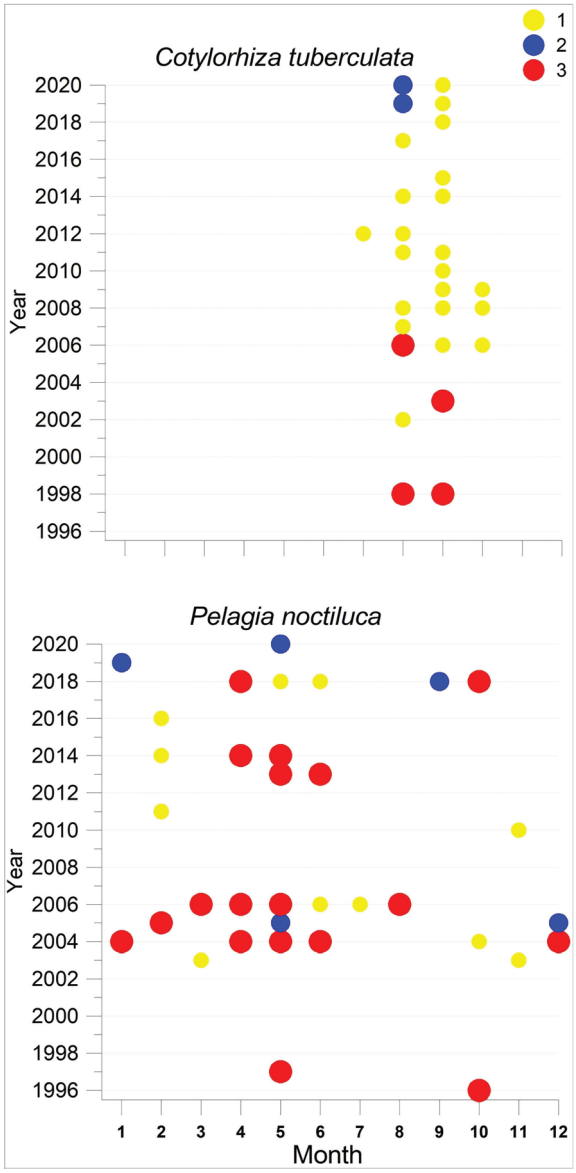

Figure 3 Occurrence and abundance of Scyphozoa *Pelagia noctiluca* in different five-year periods (1996-2020) in the Dubrovnik-Neretva County

Slika 3. Pojava i brojnost vrste režnjaka Pelagia noctiluca tijekom petogodišnjih razdoblja (1996-2020) u Dubrovačko-neretvanskoj županiji

3.2.6. *Aurelia cf. solida* (Browne, 1905)

This jellyfish was often observed in May and April, rarely in autumn or winter, always with a small number of individuals. An exception was observed in 2016 when the jellyfish was found in high population densities in April and May. The masses of individuals were then carried by the incoming current along the coast of Dubrovnik and the surrounding islands in a surface layer with lower salinity. All jellyfish were extremely compact and with firm gelatinous mesoglea with developed gonads, distinctly red-purple. The majority of individuals had bell diameters between 6 cm and 10 cm.

Significantly higher levels of *Aurelia* jellyfish have been observed in the central and especially in the northern Adriatic

Sea [62]. Therefore, according to our observations, the area of the southern Adriatic is only weakly represented by individuals of this genus. No *Aurelia* polyps were detected in the area of the southern Adriatic, except for the species *A. relicta* inhabiting the Great Lake of the Mljet island. Large colonies of these polyps were found in productive ecosystems of the northern Adriatic [71], Kaštela Bay [89] and Boka Kotorska Bay (unpublished data).

Early (19th century) records for the Mediterranean Sea referred to the species *Aurelia aurita* and followed the traditional view of its circumglobal distribution [56]. However, new molecular techniques unmasked the cosmopolitan species *A. aurita* as a species complex with several cryptic species [23]. According to Scorrano et al. [72] *Aurelia* species found in the Adriatic Sea, with the exception of species inhabiting special ecosystems of marine lakes, belong to the alien species *A. solida*. Following the recommendations for the standardization of open taxonomic nomenclature for Image-based Identifications [39], we assigned the designation "confer" (cf) to the species observed in the southern Adriatic Sea which means "to compare with".

3.3. Ctenophora / *Rebraši*

3.3.1. *Pleurobrachia rhodopis* (Chun, 1879)

A total of seven finds of this species have been recorded, exclusively in the winter-spring period. The species is known throughout the Mediterranean, in some years numerous in the western Mediterranean during spring when temperatures were between 14 and 19 °C [18].

3.3.2. *Bolinopsis vitrea* (L. Agassiz, 1860)

In September 2019, only a few individuals were found. In other Adriatic regions, this Ctenophora has recently become more common and numerous [62]. The first bloom of the species for the Mediterranean Sea was found in the Bay of Kotor [49]. In the central Adriatic, *B. vitrea* was recorded only in 2013, and the first mass occurrence was recorded in May 2017 [62].

3.3.3. *Leucothea multicornis* (Quoy & Gaimard, 1824)

The first findings of this species during our monitoring refers to the summer of 2018, when a single specimen was found. However, it was observed in much larger numbers in October 2019. In general, abundances of *L. multicornis* increased along the eastern Adriatic coast from south to north and were recorded in all seasons [62]. Blooms were recorded only in the northern region, in September 2012 and in June 2018 [62]. In past, the bloom of this Ctenophora was recorded in the central Adriatic [5].

3.3.4. *Mnemiopsis leidyi* (A. Agassiz, 1865)

This Ctenophora was observed in the waters of the port of Ploče on 12 September 2017. The individuals were 3.5 cm to 7.0 cm long. The estimated density was 1 ind. m-3. From 16 September their numbers had decreased. They were observed again from early October to late November and were present in varying densities, from single individuals to smaller clusters, depending on the local flow regime. The species was found again in September 2018, but only for a few days and in lower densities. Its occurrence in the waters of the Port of Ploče was not confirmed in the following years. We believe that the introduction of *M. leidyi* in this area is caused by the discharge of ballast water from ships coming with cargo from the northern Adriatic. Indeed, since the summer of 2016, this invasive species has been constantly present in the northern Adriatic during the warm season, often in extremely large masses and now with recognisable consequences for biochemical cycles and the food web [53, 17, 19].

In the port of Ploče, *M. leidyi* has not yet established a permanent population, although individuals have been found several times. According to our results, the species did not form gonads and quickly lost its swimming ability, and *cydippid* larvae and eggs were not found in the zooplankton samples. Given the fragile body structure of adult *M. leidyi* compared to *cydippid* larvae and fertilized eggs, which can move with cilia, we suspect that only the developmental stages could survive the treatment with ballast water. Since they were not found in the port of Ploče, it can be assumed that only adults in poor condition were brought to the area for the time being. Identical examples of failure to establish populations in the new environment can be found in the ports of Mersin in Turkey [42] and Latakia in Syria [74]. However, given the constant shipping connection of the port of Ploče with the ports of the northern Adriatic, where *M. leidyi* has been established as a permanent species, we believe that the potential threat is real. The success of this invasive species in European seas is evidenced by the establishment of its populations in very diverse environments, ranging from low temperatures and salinity to warm and highly saline waters [75].

3.3.5. *Cestum veneris* (Lesueur, 1813)

This Ctenophora was not observed in the coastal waters of the southern Adriatic until 1999 (Fig. 4), when it appeared in large numbers of individuals on the southern side of the islands of Mljet and Korčula. The sea surface temperature was 15.5 °C. The populations were mostly represented by very small specimens, only 5 cm in size, and rarely by large individuals of 50 cm. In mid-October of the same year, a large number of specimens of this species were found on the sea surface near Dubrovnik, where the sea temperature was between 20 °C and 21 °C. Since then, the species has been frequently recorded during the winter isotherms (Fig. 5). Short-lived blooms of C. veneris were again detected in February and April 2013.

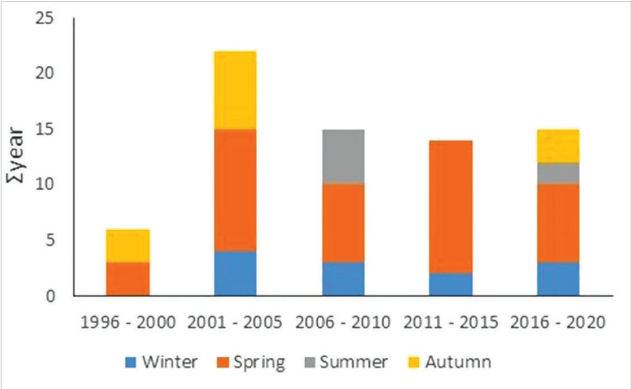

Figure 4 Temporal variability (month/year) of relative abundance of Ctenophora *Cestum veneris* in the Dubrovnik-Neretva County (blank-jellyfish are not seen at all; 1-sporadic occurrence of individual organisms, yellow dot; 2-frequent occurrence of individual jellyfish specimens and/or small aggregations, blue dot and 3-frequent occurrence of large jellyfish aggregations/blooms, red dot

Slika 4. Vremenska varijabilnost (mjesec / godina) relativne brojnosti rebraša Cestum veneris u Dubrovačko-neretvanskoj županiji (prazno-meduze nisu primijećene); 1 - sporadična pojava pojedinačnih jedinki, žuta točka; 2 - česta pojava meduza i / ili su u manjim nakupinama, plava točka i 3 - česta pojava velikih nakupina / masa meduza, crvena točka

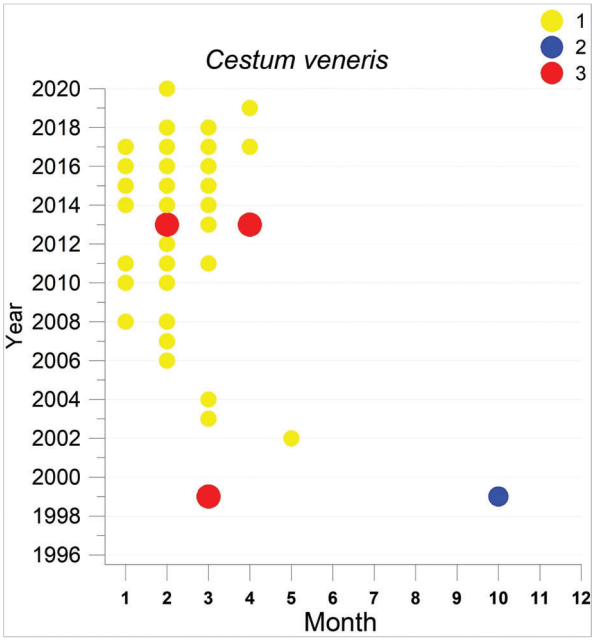

Figure 5 Occurrence and abundance of Ctenophora *Cestum veneris* in different five-year periods (1996-2020) in the Dubrovnik-Neretva County

Slika 5. Pojava i brojnost vrste rebraša Cestum veneris tijekom petogodišnjih razdoblja (1996. – 2020.) u Dubrovačko-neretvanskoj županiji

C. veneris as a common but less numerous species of the Southern and Central Adriatic [29]. However, according to our results, the occurrence of the species at the surface lasted until mid-spring or even autumn, when temperatures were significantly higher than in winter. Moreover, our results represent the first documented mass occurrence of this species in the Mediterranean region.

4. CONCLUSIONS / *Zaključci*

In this paper, we analyzed the phenological data and relative abundances of jellyfish based on scientific surveys and a "citizen science" sighting program within the Dubrovnik-Neretva County (southeast Adriatic Sea) during 1996-2020. The inter-annual variability and seasonality of macro-planktonic Hydrozoa, Scyphozoa and Ctenophora were described. Although the collected data provide only a semi-quantitative estimate of abundance, they allow temporal, large-scale coverage that would otherwise be logistically and financially infeasible. Thus, our empirical analysis of 25 years of observations provides important information on the background changes in macro-jellyfish populations.

During our monitoring 15 taxa were found. These were four hydrozoan jellyfish *Porpita porpita*, *Olindias muelleri*, *Geryonia proboscidalis*, *Craspedacusta sowerbii*, six scyphozoans *Cotylorhiza tuberculata*, *Rhizostoma pulmo*, *Drymonema dalmatinum*, *Chrysaora hysoscella*, *Pelagia noctiluca*, *Aurelia* cf. *solida*, and five ctenophores *Pleurobrachia rhodopis*, *Bolinopsis vitrea*, *Leucothea multicornis*, *Mnemiopsis leidyi* and *Cestum veneris*.

The most frequent observation was for scyphomedusa *P. noctiluca* (34%), followed by ctenophora *C. veneris* (19%) and scyphomedusa *C. tuberculata* (17%). These are also the species in which they occurred most frequently in the masses. These blooms were not even close to those observed in other Adriatic regions, especially in the Northern Adriatic [44, 62].

A marked seasonality was observed for *C. tuberculata*, which was recorded only in the warm season, from July to October. *C. veneris* dominated in winter and was never observed in summer. *P. noctiluca* is found in all seasons, most frequently in spring, rarely in summer.

An isolated mass occurrence was noted for the freshwater hydromedusa *C. sowerbii*, found in Lake Kuti near the mouth of the Neretva River, and for scyphomedusa *A.* cf. *solida*. The three species recorded are not native to European waters: *A.* cf. *solida*, *M. leidyi* and *C. sowerbii*. A large number of non-native species have been detected in the Mediterranean Sea, especially in the eastern region [87]. Six alien species of Scyphozoa and Ctenophora are currently known to inhabit the Adriatic Sea [62]. According to Gravili and Rosi [34], fifteen new species, some with high invasive potential, should be considered good candidates for future immigration into Italian waters.

The location of Dubrovnik-Neretva County in the Southern Adriatic Sea, which is directly influenced by the inflow currents into the Adriatic Sea, is an important area for monitoring and control of non-native organisms and their potential spread to other regions of the Adriatic Sea. Moreover, the potential threat of introduction of alien species into this region is the discharge of ballast water from ships in the port of Ploče, where only one of the most invasive marine species, ctenophora *M. leidyi,* has been observed so far. An example of the negative impact on the ecosystem and biodiversity as a result of ballast water discharge into this area is the establishment of a permanent population of the blue crab *Callinectes sapidus* in the Neretva Delta [31].

Our study shows that the eastern South Adriatic coast is populated by a relatively stable jellyfish fauna, whose composition and abundance have not changed significantly in the recent decades. Therefore, these results could be of particular importance as a database for future monitoring of the jellyfish communities of the Adriatic Sea in order to predict their future trends and the ecological impact of their blooms on the whole Adriatic Sea. The results are in line with the objectives of the EU Marine Strategy Framework Directive (MSFD) to achieve "good environmental status" for all water bodies where the distribution, composition and abundance of jellyfish are important components.

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