

RESEARCH ARTICLE

Contribution as to the study of Siphonophorae in the coastal waters of the South Adriatic

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Abstract

Siphonophorae were collected monthly in 2009 at four stations with different hydrographic characteristics at Bay of Boka Kotorska in the Southern Adriatic. Three of these stations were placed in the shallow part of the inner bays near the shellfish farm, and four in the Bay of Kotor, Bay of Risan, Bay of Tivat and Bay of Herceg Novi. The special ecological conditions in the Bay of Boka Kotorska are reflected on taxonomic structure, distribution and abundance, both of individual species and the zooplankton as a whole. In this paper we present the hydrographic data of Boka Kotorska Bay, together with data on presence, abundance and distribution of the six species by three genera: *Abylopsis tetragona* (Otto), *Lensia conoidaea* (Keferstein-Ehlers), *Lensia subtilis* (Chun), *Lensia fowleri* (Bigelow), *Lensia multicristata* (Moser), *Muggiaea kochi* (Will) and other *Siphonophorae* sp. Results of this research include biological monitoring at the bay, following certain species within the zooplankton diversity and communities.

Keywords: Adriatic Sea, Boka Kotorska Bay, zooplankton, Siphonophorae

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Introduction

Siphonophorae are a constant and relatively significant quantitative component in zooplankton community of many tropic and subtropic regions, and their role of secondary consumers in trophic nutrition chains is especially important. Quantitatively Siphonophorae may be important in surface waters, whereas they are increasingly less present in deeper ones in Mediterranean, as well as in other

seas (Pedenovi and Della Croce 1971). They are also important as an indicator of water masses stirring (Russel 1935; Furnestin 1957; Rottini 1969). The first Siphonophorae from Adriatic Sea was mentioned by (Will 1844) as a new species *Diphyes cochi* (*Muggiaea kochi*), our research indicates this species to be the most common Siphonophorae in the Bay of Boka Kotorska. Data for Adriatic are cited by (Will 1844; Busch 1851; Claus 1876; Graeffe 1884; Cori and Steuer 1901; Moser 1917; Bigelow and Sears 1937; Gamulin and Rottini 1966; Gamulin 1948, 1966, 1968, 1971; Hure 1955, 1961; Vukanic 2012). Surface species *Muggiaea kochi* Will, 1844 and *Lensia subtilis* (Chun, 1886) are quantitatively the most important Siphonophorae in Adriatic and East Mediterranean and very abundant in littoral waters (Hure 1961; Gamulin 1968; Rottini 1971; Vukanic 2012) what is supported by our data. Pro rata participation of species *Muggiaea kochi* ranges 90% by Rovinj (Gamulin 1979), whereas it declines towards the south owing to larger diversity of the open sea fauna. In other littoral zones of Mediterranean, like the Bay of Napoli *Muggiaea kochi* and *Lensia subtilis* have Spring maximum and they participate pro rata in Siphonophorae fauna with 82.5% (Ianora and Scotto di Carlo 1981). Gamulin (1979) cites that in Winter time in water courses of Central Adriatic there occurs open sea species *Abylopsis tetragona* Otto, 1823, which we recorded in individual specimens in Spring and in Summer at a shallow station P-IBM and at central stations P₁ and P₃ in the bays of Kotor and Tivat. The species which indicate the influence of open sea streams in the Bay of Boka Kotorska are: *Lensia conoidea*, *Lensia fowleri* and *Lensia multicristata*, characteristic for zooplanktonic community of intermediery waters on 200 – 500 meters of depth, as well as an open sea species *Abylopsis tetragona*. Only the group Calycophorae is reported in this paper. Six species have been recorded, among which only sexual and neuter specimes are the most common Calycophorae of Adriatic, *Muggiaea cochi* Will 1844, found throughout the year at all stations, and at shallow ones only in Summer. Other species *Lensia conoidea* (Keferstein and Ehlers, 1860), *Lensia multicristata* (Moser, 1925), *Lensia subtilis* (Chun, 1886), *Lensia fowleri* (Bigelow, 1911), *Abylopsis tetragona* Otto, 1823 occur rarely and in small number or in individual specimens at all sites of the Bay of Boka Kotorska (Table 1).

Table 1. Qualitative distribution of Siphonophorae at examined stations in the Bay of Boka Kotorska

Species	Stations							
	P-IBM	P-M	P-O	P ₁ -K	P ₂ -R	P ₃ -T	P ₄ -HN	
<i>Abylopsis tetragona</i> (Otto)	+			+		+		
<i>Lensia conoidea</i> (Keferstein- Ehlers)				+	+	+	+	
<i>Lensia subtilis</i> (Chun)			+	+	+	+	+	
<i>Lensia fowleri</i> (Bigelow)		+		+		+	+	
<i>Lensia multicristata</i> (Moser)						+		
<i>Muggiaea kochi</i> (Will)	+	+	+	+	+	+	+	
<i>Siphonophorae</i> sp.		+	+	+	+	+		
Total	2	3	3	6	4	6	4	

Materials and Methods

Zooplanktonic materials were sampled from January to December 2009, at 3 stations in the shallow sea in the vicinity of shellfish farms in the internal Bay of Kotor and Bay of Risan (P-IBM, P-O, P-M) on depth of 0 to 10 m, and at 4 deep sites in the middle of all the bays of the Bay of Boka Kotorska (P1-K, P2-R, P3-T, P4-HN) at depth of 0 to 30 m. The samples of zooplankton were collected by nets of type “Nansen”, 2.5 m long. Diameter of net opening was 0.5 m, whereas the mesh opening was 150 μ m. Collected material was fixed in 2.5% formaldehyde, and subsequently kept in sedimentation receptacles for 24h. Quantitative presence of zooplankton was calculated by partial counting of 1/25 of the catch, and the entire catch was examined. Variations of specific groups and zooplanktonic species in studied period were established according to the number of individuals per m³ of water, and their relations were given in arithmetic mean of pro rata participation during the year studied. Alongside with collecting of zooplankton samples there also were measured the basic hydrographic factors of temperature (T°C) and salinity (‰) by Multiline P4 probe.

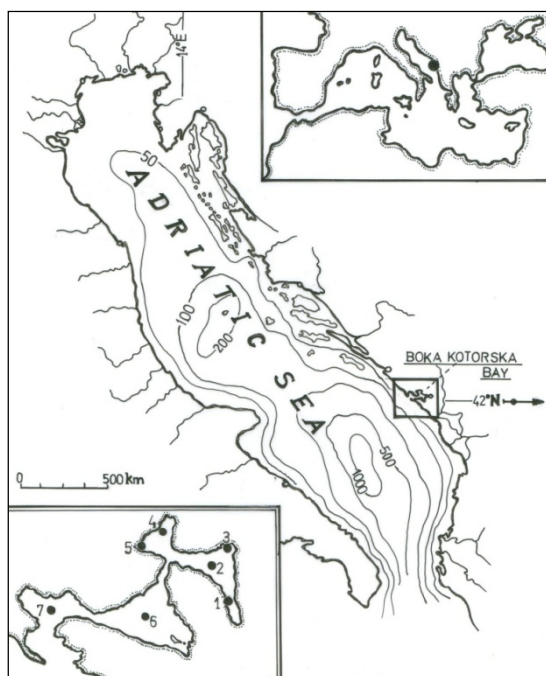


Figure 1. Map of sampling area in the southern Adriatic (NE Mediterranean)
1: (P-IBM); 2: (P1-K); 3: (P-O); 4: (P2-R); 5: (P-M); 6: (P3-T); 7: (P4-HN)

Results And Discussion

The Bay of Boka Kotorska has specific hydrographic traits, which are reflected through differences in temperature between the internal (Bay of Kotor and Bay of Risan) and the external bays (Bay of Tivat and Bay of Herceg Novi). They are seen in gradual temperature increase of surface sea water layers moving longitudinally from the Bay of Kotor, via Risan's and Tivat's Bay to the Bay of Herceg Novi and the open sea.

In our data surface temperature maximum was recorded in the Bay of Kotor (P₁) as 28.6°C in July, and at depth of 15 m it was registered in August as 22.3°C. Minimal annual temperature of surface layers in the Bay of Boka Kotorska was recorded in January as 8.2°C (P-IBM), 8.8°C (P-O) and in the middle of the Bay of Kotor (P₁) as 11.45°C. Our measurements indicated that in the period from October to May there differentiated two temperature layers, water of lower temperature in surface layers and water with higher temperatures in deeper layers (Table 2).

Table 2. Minimum and maximum values of temperatures at studied stations in the Bay of Boka Kotorska

Stations	Minimum	Maximum	Mean
P-M	9.50 (I) 0m	26.40 (VII) 2m	16.90
P-O	8.80 (I) 0m	27.40 (VII) 0m	18.60
P-IBM	8.20 (I) 0m	28.60 (VII) 0m	20.40
P ₁	11.10 (I) 0m	27.70 (VII) 0m	26.60
P ₂	10.00 (I) 0m	25.90 (VII) 0m	15.90
P ₃	11.55 (XII) 0m	23.20 (VIII) 5m i 10m	11.70
P ₄	12.57 (I) 5m	23.70 (VIII) 5m i 10m	11.10

Salinity values vary strongly in the Bay of Boka Kotorska in various seasons and years, as cited by several authors: Vukanić (1971, 1983); Regner *et al.* (1995, 2002); Vukanic (2002, 2003, 2004, 2005). Regner *et al.* (1995) emphasizes that the values of salinity vary throughout the year, especially vertically, so that the oscillations are the greatest in shallow and deeply into the land indented Bay of Kotor (8‰ to 38‰) whereas they are less expressed in the external bays - for the Bay of Herceg Novi 30.01‰ at the surface to 38.59‰ by the sea bottom.

Familia Diphyidae Quoy and Gaimard, 1827
Genus *Muggiaea* Busch, 1851

Muggiaea kochi Will, 1844 – the most common and the most abundant Calycophorae in the Adriatic and in Mediterranean, is found at depths of 0 – 100 m, and in the Bay of Boka Kotorska it is present to 30 m of depth. This is a surface water species relatively uniformly distributed in the Bay of Boka Kotorska throughout the year. Pro rata participation of this species in the total number of Siphonophorae at shallow stations amounted P-IBM 99%, P-M 38%, and P-O 43.3% and at central deep stations P₁ 15,7%, P₂ 8,9%, P₃ 30,8% i P₄ 24,4%.

Table 3. Minimum and maximum values of salinity at studied stations in the Bay of Boka Kotorska

Stations	Minimum	Maximum	Mean
P-M	4,90 (IX) 0m	38,30 (III) 10m	33,40
P-O	2,67 (XI) 0m	37,41 (VIII) 10m	28,70
P-IBM	2,30 (IX) 0m	37,80 (III) 10m	35,50
P ₁	7,90 (IX) 0m	38,10 (III) 20m	30,20
P ₂	10,50 (IX) 0m	38,30 (III) 20m	22,00
P ₃	29,32 (IV) 0m	38,71 (VIII) 10-20m	9,40
P ₄	31,32 (III) 0m	38,71 (VIII) 5-20m	7,40

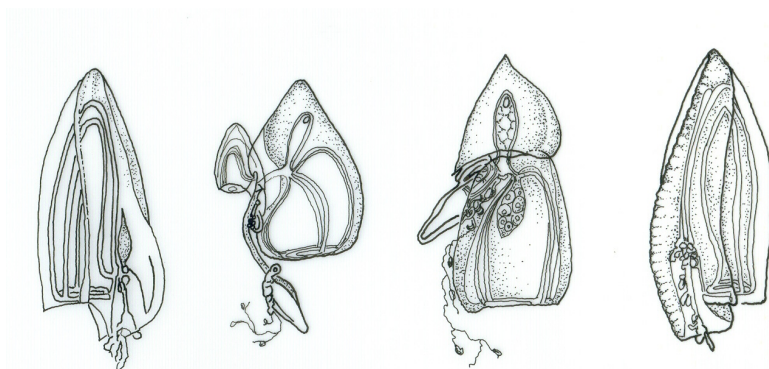


Figure 2. *Muggiaea kochi* Will, 1844 (Tregouboff and Rose 1957)

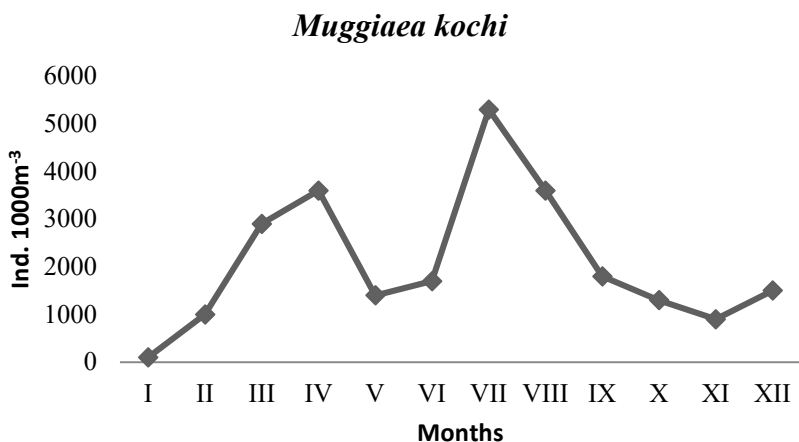


Figure 3. *Muggiaea kochi* Will, 1844 - annual quality flow during the year 2009

Genus *Lensia* (Keferstein and Ehlers, 1860)

Lensia conoidea (Keferstein and Ehlers, 1860) – At shallow stations in the Bay of Boka Kotorska (0 – 10 m) we have not registered, whereas in deeper waters it occurs occasionally, so in winter season it was found only in the Bay of Herceg Novi. Pro rata participation of this species at central stations as related to other Siphonophorae amounted P₁ 1.12%, P₂ 7.2%, P₃ 12.8% and P₄ 9.7%.

Lensia subtilis (Chun, 1886) – Surface water species which we have recorded at shallow station (0-10 m) by Orahovac in the Bay of Kotor (P-O), where, as related to other Siphonophorae, its pro rata participation was 12%. At the central stations of the Bay of Boka Kotorska its pro rata participation in Siphonophorae fauna amounted P₁ 1.7%, P₃ 0.4% and P₄ 3.7%. In the Bay of Risan we have not registered it.

Lensia fowleri (Bigelow, 1911) – This is the species of intermediate sea layers. In the internal waters it has been recorded only at the station by Morinj in the Bay of Risan (P-M) occasionally and in individual specimens. In the Bays of Tivat and Herceg Novi its pro rata participation as related to other Siphonophorae ranged P₃ 2.8% and P₄ 1.84%.

We have registered also the open sea species *Abylopsis tetragona* Otto, 1823, which we found only occasionally at some stations in the bays of Kotor and Tivat. Pro rata participation of Siphonophorae as related to total zooplankton ranged: in the Bay of Kotor 0.33%, in the Bay of Risan 0.30%, in the Bay of Tivat 1.55% and in the Bay of Herceg Novi 1.41%.

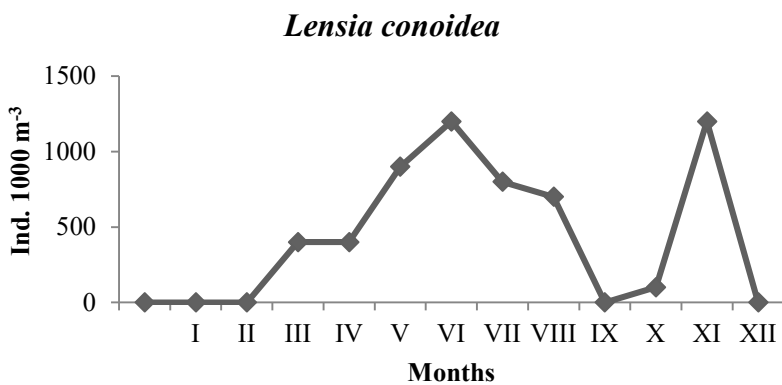


Figure 4. *Leisia conoidea* (Keferstein & Ehlers, 1860)
– annual quality flow during the year 2009

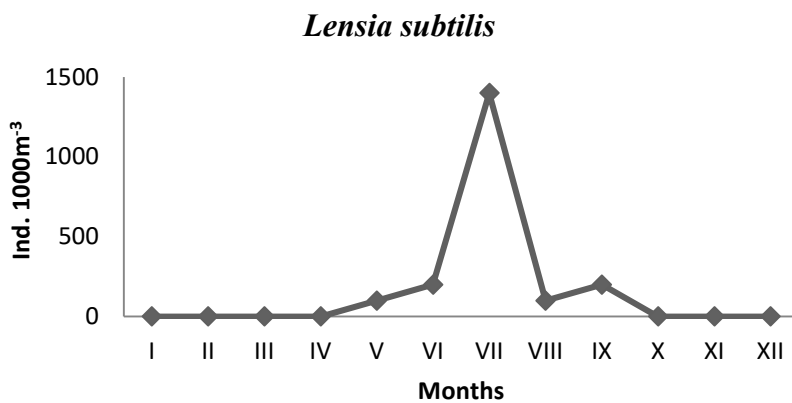


Figure 5. *Leisia subtilis* (Chun, 1886) – annual quality flow during the year 2009

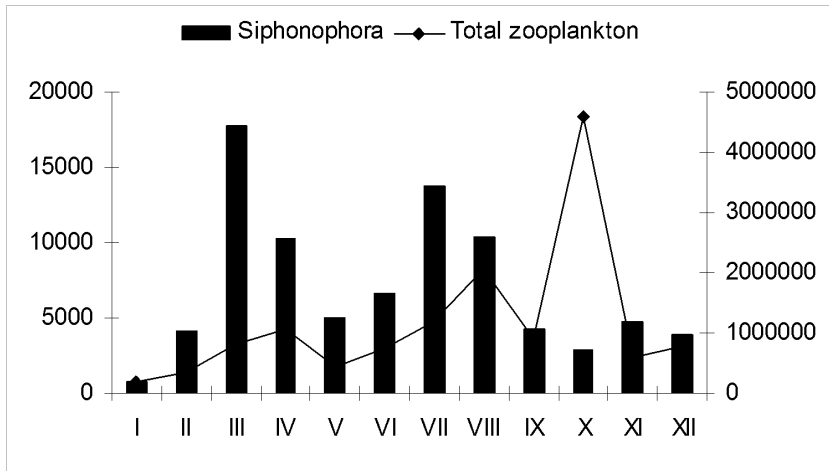


Figure 6. Logarithmic survey of quantity flow of total zooplankton and Siphonophorae in the Bay of Boka Kotorska

At shallow stations (P-IBM, P-O, P-M) species *M. cochi* is present with 100% participation in population of Siphonophorae. Pro rata participation of Siphonophorae at these stations as related to the total zooplankton amounted 0.01% (P-IBM), 0.60% (P-O) i 0.17% (P-M).

In the Bay of Kotor Siphonophorae are present with 0.33% in the total zooplankton. *M. cochi* makes 15.7% whereas juvenile and undetermined species are present in that group up to 80.3%. In the Bay of Risan Siphonophorae are present in the total zooplankton with 0.30%. In the Bay of Tivat we have registered in the group Siphonophorae a more numerous and more common species *M. cochi*, and in the total zooplankton Siphonophorae were present with 1.60%. The station at the middle of the Bay of Herceg Novi is under stronger influence from the open sea, as indicated by the occurrence of some characteristic species in the zooplankton from littoral waters of Eastern Adriatic. In this bay Siphonophorae were present with 1.14% as related to the total zooplankton.

Out of Siphonophorae only *M. cochi* is outstanding in the Bay of Boka Kotorska, it is a typical species of the Eastern coast of Adriatic (Gamulin 1948; Vukanić 1979; Onofri 1984). We register this species with an increased number of specimens from the internal waters longitudinally towards the station which is the closest to the open sea in the Bay of Herceg Novi. Annual maximum of Siphonophorae in internal waters of the Bay of Boka Kotorska was in summer, and it the external part from spring to autumn.

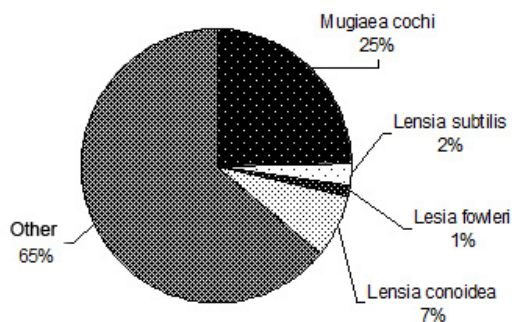


Figure 7. Pro rata participation of registered species of Siphonophorae at the stations in the Bay of Boka Kotorska

Conclusions

The water of Boka Kotorska Bay shows pronounced oscillations in values of hydrographic factors, and there are significant differences among the individual bays. In the thermal sense, Boka Kotorska Bay is not a homogenous area. The most pronounced oscillations are present in the surface layers. The temperature maximum was usually recorded in July or August, and the minimum was in January or February. The studied area has the characteristics of a shallow, semi-closed sea at the eastern coast of Adriatic, which is on one hand influenced by erosion of nearby land and influx of fresh water, and on the other hand by the open sea, as indicated by our collected hydrographic and zooplankton data.

We are also presenting the data for the group Siphonophora, collected in a one-year study. In this paper we considered only the chalicophorae, as the other Siphonophora are very rare in the Adriatic Sea. Six species were determined, while the only qualitatively important species was *Muggiaea cochi*, which was relatively uniformly distributed all over Boka Kotorska Bay. During the one-year studies it was not possible to determine periodicity and intensity of penetration of open-sea forms into the zone of coastal waters, but the results have shown that there are distinct seasonal and multi-year fluctuations.

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