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Quantitative and qualitative composition of Veneridae (Bivalvia) in Boka Kotorska Bay (south Adriatic Sea)

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ABSTRACT

In this paper data on Veneridae composition in the area of Boka Kotorska Bay are given. Sampling was done during autumn 2017 and spring 2018 by SCUBA diving. The main goal was to describe Veneridae community structure in the Bay, especially because several of those species are commercially important and present potential candidates for farming process. Total of 1754 individuals were collected, belonging to 14 different taxons. *Venus verrucosa* was the most dominant species. Species abundance regarding locations varied from 1.06 to 1.96 ind./m^2. The smallest Veneridae diversity and species richness was on Njivice location. Based on qualitative results, the highest similarity was between Sv. Stasije and Sv. Nedjelja, and the lowest between Sv. Stasije and Njivice locations. There was no statistically significant differences in Veneridae communities neither among two main sampling zone, neither among seasons.

Key words: diversity, Veneridae, Bivalvia, Boka Kotorska Bay

INTRODUCTION

Family Veneridae “Venus Clams“ is large family of Bivalvia with a world-wide distribution (Pope & Goto, 2000). It counts more than 680 different species classified in more than 90 genera (Huber, 2010). Family members inhabit different marine ecosystems up to 200 m depth (Huber, 2010; Popović, 2012). Species differ in size from small to large ones. Most of the species live burrowed in sand or mud, and species are mainly suspensions feeders, as well as dioecious (Huber, 2010). Shells are equivalve, with external ligament and three cardinal teeth. A pallial sinus is present while byssus is not (Pope & Goto, 2000). A large number of Veneridae species are commercialy important e.g. *Venus verrucosa* (Linnaeus, 1758), *Polititapes aureus* (Gmelin, 1791), *Chamelea gallina* (Linnaeus, 1758) and *Callista chione* (Linnaeus, 1758).

In total, 133 marine bivalvia species are described for the Montenegrin waters, from which 16 species belong to Veneridae family (Petović *et al*., 2017; Petović, 2018; Gvozdenović *et al*., 2019). Boka Kotorska Bay can be considered as biodiversity hot spot, with dominace of Mollusca in total zoobenthos diversity (Petović & Marković, 2016). One of the most representative Veneridae species in Boka Kotorska Bay is *Venus verrucosa*. This species has high price on market in the Montenegro, around 12 €/kg (personal observation), and despite it fact as well as high demand on market, it is still not included in mariculture process, neither in the Montenegro or other neighborhood counries (Popović, 2012). Spain is one of the Mediterranean countries where farming of *V. verrucosa* is implemented with annual production of one tonne (Popović, 2013).

Marine bivalve assemblages in the Montenegrin waters has been more detailed investigated 40-50 years ago and focus of investigation was on the Boka Kotorska Bay (Stjepčević, 1967). Karaman &Gamulin-Brida (1971) gave a contribution on benthic communities in the Boka Kotorska Bay, while Stjepčević & Parenzan (1980) described composition of benthic communities in the Kotor and Risan Bay. Quantitative and qualitative composition of benthic communities in the area of Kotor and Risan Bay is given by Stjepčević *et al*. (1982). After those studies only lists of bivalvia species were given (Petović *et al*., 2017; Petović, 2018), as well as studies related to bottom trawling and its impact on benthic assemblages (Petović *et al*., 2016), but without detailed studies on bivalvia assemblages, diversity and abundances.

The aim of present study is description of Veneridae community structure in the Boka Kotorska Bay, as much of those species are commercially important and presents potential candidates for farming process.

MATERIAL AND METHODS

Veneridae species were collected in autumn 2017 and spring 2018 on six locations (Njivice, Sv. Marko, Sv. Nedjelja, Morinj, Sv. Stasije and IMB-Institute of Marine Biology) in the area of Boka Kotorska Bay (Fig. 1). The sampling was done by SCUBA diving, collecting by hand of all visible bivalve species along a 200 m^2 transect. Because more than 99% of samples were presented by empty shells, samples were left to dry and minimum number of individuals (MNI) was calculated. MNI was estimated by determining the number of left and right hinges for each bivalve species and taking the higher of the two numbers (Mason *et al*., 1998). Collected material was identified according to Poppe & Goto (2000) and Huber (2010). Nomenclature was arranged according to the WoRMS database.

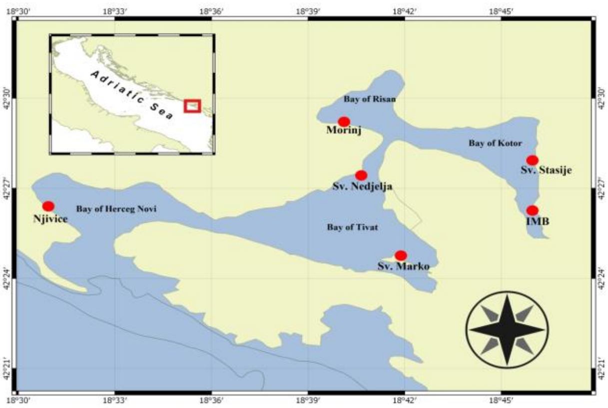

Figure 1. Map showing the sampling locations

Dominance (d) and constancy (F) were calculated as shown in equation (1 and 2) (Fritz, 1975; Krebs, 2001), where: ai is total number of individuals of one species, $\sum ai$ is total number of individuals of all species, b is number of samples in which one species was present and a is total number of samples.Species categories based on dominance and frequency are given in Table 1.

Table 1. Dominance and frequency range (Fritz, 1975; Krebs, 2001)

Dominace (d)	**Range**	**Frequency (F)**	**Range**
Eu-dominant (Ed)	d ≥ 10 %	Eu-constant (Ec)	75 % ≤ F < 100 %
Dominant (D)	5 % ≤ d < 9.9 %	Constant (C)	50 % ≤ F < 74.9 %
Sub-dominant (Sd)	2 % ≤ d < 4.9 %	Accessory (As)	25 % ≤ F < 49.9 %
Recedent (R)	1 % ≤ d < 1.9 %	Accidental (Ac)	F < 25 %
Sub-recedent (Sr)	d < 1 %		

$$d = \frac{ai}{\sum_{i=1}^{n} ai} \qquad (1)$$

$$F = 100 * \frac{b}{a} \qquad (2)$$

Abundance (ind./m^2) is calculated as ratio between total number of individuals on the transect (ait) and area of the transect(ta) (equation 3).

$$A = \frac{ait}{ta} \qquad (3)$$

Qualitative similarity index is calculated according Sorensen (1948) (equation 4), where: a is number of species in first sample, b is number of species in second sample and c is number of common species in first and second sample.

$$S = \frac{2 * c}{a + b} \qquad (4)$$

Using PRIMER 6.0 software package (Clarke & Gorley, 2006), Bray-Curtis similarity matrix was used to generate 2-dimensional ordination plots with nMDS technique. Data were transformed using fourth root transformation.1-way ANOSIM test was used for testing differences in Veneridae community structure among two main zones (inner and outer part of the Boka Kotorska Bay) as well as differences among seasons. The probability value was set at 0.05. SIMPER test was used to calculate the contribution of each species (%) to the dissimilarity between inner and outer part of the Bay. In the same program, Margalef (M), Shannon-Wiener (SW) and Simpson (S) indexes were calculated to analyze species richness and diversity.

RESULTS AND DISCUSSION

Total of 1754 individuals were collected, belonging to 14 different taxons (Tab. 2), among which five were commercially important: *Calista chione*, *Chamelea gallina*, *Popititapes* spp., *Ruditapes decussatus* and *Venus verrucosa*. In our study only few specimens were alive and more than 99% of collected material was empty shells. Empty shells provide information about presence of the species in investigated area. Most probably small number of living specimens is because of SCUBA diving methodology when living specimens, covered by sand and mud, are not detected. We should have in mind that Stjepčević (1967), who investigated bivalve assemblages in Boka Kotorska Bay during

Species	Inner Bay			Outer Bay		
	IMB	Sv. Stasije	Morinj	Sv. Nedjelja	Sv. Marko	Njivice
Callista chione (Linnaeus, 1758)		x		x		
Chamelea gallina (Linnaeus, 1758)		x	x			
Clausinella fasciata (da Costa, 1778)		x	x	x		
Dosinia exolenta(Linneus, 1758)	x	x	x	x		
Dosinia lupines (Linnaeus, 1758)	x					
Gouldia minima (Montagu, 1803)	x	x	x	x	x	x
Irus irus (Linnaeus, 1758)			x		x	x
Mysia undata (Pennant, 1777)		x		x	x	
Pitar rudis (Poli, 1795)	x	x	x	x	x	x
Polititapes spp.	x	x	x	x	x	x
Ruditapes decussatus (Linnaeus, 1758)	x	x	x	x	x	x
Timoclea ovata (Pennant, 1777)	x	x	x	x		
Venus casina (Linneus, 1758)			x			
Venus verrucosa (Linneus, 1758)	x	x	x	x	x	x

Table 2. List of Veneridae species collected in area of Boka Kotorska Bay

four years (by several different sampling methodology) also reported high percent of empty shells. Data for Rijeka Bay (north Adriatic Sea) were also collected during long study period with different sampling methodology, and for many species live individuals were not sampled (Grube, 1861). Also in other studies along Adriatic coast bigger part of the bivalve samples were presented with dead individuals (Zavodnik & Kovačević, 2000; Peharda *et al*., 2004). Kidwell & Flessa (1996) indicated that dead mollusk assemblage typically have twice as many species as live ones. According Weber & Zuschin (2013) death assemblages preserve important information on regional diversity.

Petović *et al*. (2017) reported in total 16 Veneridae species for Montenegrin coast, including *Petricola lithophaga* (Retzius, 1788) and alien *Ruditapes philippinarum* (Adrams& Reeve, 1850) which were not found in our study. Compared to that number, 14 different species found during our study presents 87.5%. Peharda *et al*. (2010) also described 14 different Veneridae species along Croatian coast, while Dhora (2009) and Paneta *et al*. (2009) reported 17 different Veneridae species along Albanian coast.

The highest number of species, 11 was found on locations Sv. Stasije and Morinj, while the lowest number was on Njivice, represented with 6 species. This is generally in coincides with results of recent studies (UNEP-MAP-RAC/SPA, 2013) which showed that inner part of the Bay (where locations Sv. Stasije and Morinj are placed) is characterized by a wealth of animal life.

Values of all three diversity indexes were the highest for location Sv. Stasije (M=1.80; SW=1.78; S=0.80), and the smallest for location Njivice (M=0.93; SW=1.18; S=0.60), indicating the highest species richness and diversity at Sv. Stasije, inner part of the Bay.The smallest Veneridae diversity and species richness at Njivice is evident. It must be noted that surveyed transect on this location is quite different compare to other five transects, both in term of maximum depth and bottom characteristics. On all investigated transects substrate type was quite similar, with dominance of mud, while just Njivice showed some differences. This transect was characterized by pebble and boulders bottom in first 40 m, while on the other 60 m of the transect muddy-sand bottom was present. Also maximum depth on this transect was just 4 m, while on other investigated locations maximum depths were in range from 10 up to 25 m. Substrate type and depth are important factors affecting bivalve distribution (Gosling, 2003). According Hubert (2010) Veneridae members prefer sandy and muddy bottoms, exept some species, as *I. irus* which inhabits hard substrates.

Eu-dominant species group (d ≥ 10 %) included: *Venus verrucosa*, *Pitar rudis*, *Polititapes* spp. and *Gouldia minima*. The same species together with *Ruditapes decussatus* belonged to eu-constant species group (75% ≤ F ≤ 100). Table 3 shows dominance and frequency of each species.

On each location species *Venus verrucosa* was present with the highest number of individuals except on IMB where that was *Polititapes* spp. (Fig. 2). Although Stjepčević (1967) indicated that number of individuals of *V. verrucosa* is lower in outer than in inner part of the Bay, in this study greatest abundance was found in outer part of the Bay. According our results *Pitar rudis* is very common species in the Bay, what is contrary to results of Stjepčević (1967) who found only three individuals in the Kotor Bay and described species as rare. Peharda *et al*. (2010) found *P. rudis* in 10 of 18 sampling locations along Croatian coast. *R. decussatus* is earlier reported as very common in the area of Boka Kotorska Bay (Stjepčević, 1967). In our study *R. decussatus* was identified on all six investigated locations, but the

Table 3. Dominance and frequency of identified Veneridae species in Boka Kotorska Bay

Species	**Dominance (%)**	**Frequency (%)**
Callista chione (Linnaeus, 1758)	0.46	33.33
Chamelea gallina (Linnaeus, 1758)	0.17	33.33
Clausinella fasciata (da Costa, 1778)	1.08	50
Dosinia exolenta (Linneus, 1758)	3.53	66.66
Dosinia lupines (Linnaeus, 1758)	0.11	16.66
Gouldia minima (Montagu, 1803)	12.94	100
Irus irus (Linnaeus, 1758)	0.23	50
Mysia undata (Pennant, 1777)	0.29	50
Pitar rudis (Poli, 1795)	21.38	100
Polititapes spp.	14.54	100
Ruditapes decussatus (Linnaeus, 1758)	2.68	100
Timoclea ovata (Pennant, 1777)	3.48	66.66
Venus casina (Linneus, 1758)	0.06	16.66
Venus verrucosa (Linneus, 1758)	39.05	100

highest number of individuals was collected in Morinj. It is not surprising, if it is known that species prefers sandy and muddy bottoms near river mouths, and those characteristics are present on Morinj location. Regarding our results species from genus *Polititapes* can be also described as common in the Bay, the highest number of individuals were found on location IMB and Morinj, what is probably due to the bottom characteristics. On those localities muddy bottom is dominant and according to Milišić (2007) species from this genus inhabits and prefers muddy bottoms. Opposite to our results, Stjepčević (1967) listed one species from this genus, *Polititapes aureus* (Gmelin, 1791) on just one location in the Bay with low number of individuals. According to Milišić (2007) species from the genus *Polititapes*, especially *P. aureus*, are common bivalve in Adriatic Sea.

Milišić (2007) reported *D. lupinus*, *C. gallina*, *M. undata* and *C. chione* as common bivalve species in the Adriatic, but in this study, small number of individuals (2, 3, 5, 8 individuals respectively) was found (Fig. 2). According to our opinion, main reason for this is sampling methodology. Although common in the Adriatic and Mediterranen seas, *C. chione* was recently reported for the first time in the open Montenegrin waters (Petović *et al*. 2017). Until our investigation, species has never before been reported for the Boka Kotorska Bay, and finding on Sv. Stasije and Sv. Nedjelja locations represents the first records for the Boka Kotorska Bay.

Abundance of Veneridae species was the highest on location Sv. Marko, 1.96 ind./m^2, and the smallest on Njivice, 1.06 ind./m^2. The highest abundance had *V. verrucosa* (0.94 ind./m^2) on location Sv. Marko. Table 4 shows the abundance of each species according sampling location.

Sorensen similarity index is qualitative index which takes just number of species in account, excluding the number of individuals. The index showed that the most similar locations were Sv. Stasije and Sv. Nedjelja, 95.24% similarity, while at least similar were Sv. Stasije and Njivice, 58.82%.

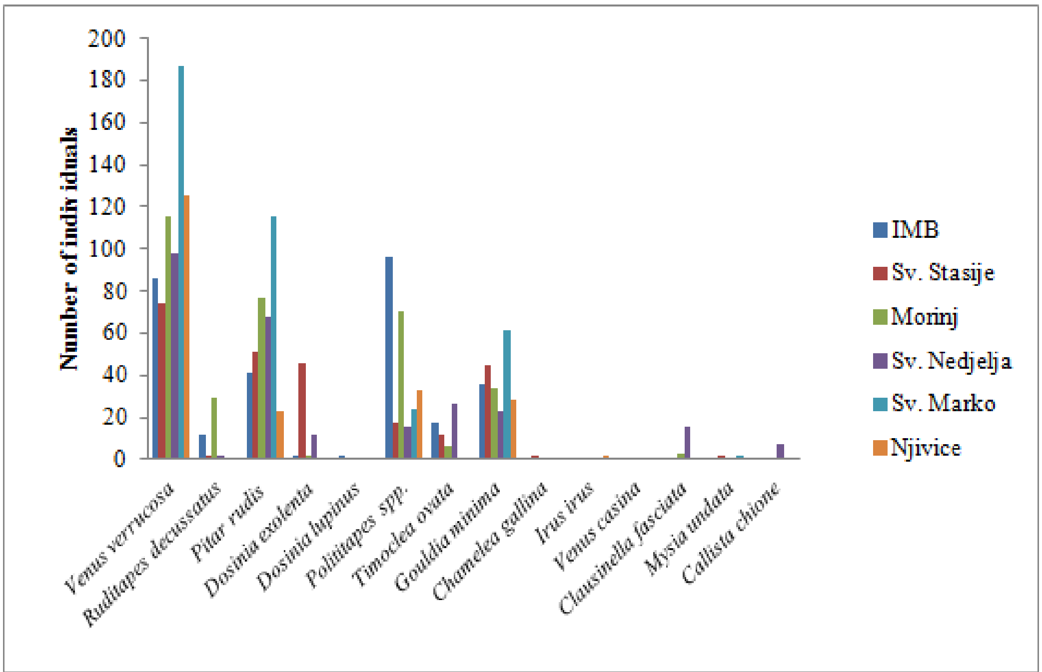

Figure 2. Number of individuals of all identified species according sampling location

Table 4. Abundance (ind./m^2) of all identified species according to sampling location

Species	IMB	Sv. Stasije	Morinj	Sv. Nedjelja	Sv. Marko	Njivice
Callista chione (Linnaeus, 1758)	0.00	0.01	0.00	0.04	0.00	0.00
Chamelea gallina (Linnaeus, 1758)	0.00	0.01	0.01	0.00	0.00	0.00
Clausinella fasciata (da Costa, 1778)	0.00	0.01	0.02	0.08	0.00	0.00
Dosinia exolenta (Linneus, 1758)	0.01	0.23	0.01	0.06	0.00	0.00
Dosinia lupines (Linnaeus, 1758)	0.01	0.00	0.00	0.00	0.00	0.00
Gouldia minima (Montagu, 1803)	0.18	0.23	0.17	0.12	0.31	0.14
Irus irus (Linnaeus, 1758)	0.00	0.00	0.01	0.00	0.01	0.01
Mysia undata (Pennant, 1777)	0.00	0.01	0.00	0.01	0.01	0.00
Pitar rudis (Poli, 1795)	0.21	0.26	0.39	0.34	0.58	0.12
Polititapes spp.	0.48	0.09	0.35	0.08	0.12	0.17
Ruditapes decussatus (Linnaeus, 1758)	0.06	0.01	0.15	0.01	0.01	0.01
Timoclea ovata (Pennant, 1777)	0.09	0.06	0.03	0.13	0.00	0.00
Venus casina (Linneus, 1758)	0.00	0.00	0.01	0.00	0.00	0.00
Venus verrucosa (Linneus, 1758)	0.43	0.37	0.58	0.49	0.94	0.63
Total abundance	**1.46**	**1.27**	**1.70**	**1.34**	**1.96**	**1.06**

Analysis of Veneridae assemblages, based on the number of individuals, between inner and outer part of the Boka Kotorska Bay showed that there was no significant differences, and that veneridae communities are similar (Global R = 0.08; p = 0.208) (Fig 3). SIMPER analysis detected low dissimilarity (28.95%) of species composition between inner and outer part of the Bay, producing mainly by the *Timoclea ovata*, *Dosinia exolenta* and *Ruditapes decusatus*.

Analysis between sampling seasons showed that there was no significant differences (Global R = -0.069; p = 0.714) (Fig. 4). In accordance to our results, Mutlu & Ergev (2012) also did not found seasonal difference, neither in adundance neither biomass of mollusks in the Mersin Bay, east Mediterranean. Silva-Calvacanti *et al*.(2018) found seasonal differences in biomass and density of Veneridae bivalve *Anomalocardia flexuosa* (Linnaeus, 1767) in the Goiana estuary in Brasil. In the Mediterranean brackish habitats seasonal differences in macroinvertebrate abundance is displayed (Mistri *et al*., 2001; Kevrekidis, 2004).

Depth is important factor which influencing the structure of demersal assemblages (Despalatović *et al*., 2009; Petović & Krpo-Ćetković, 2016). All analyzed locations in this study are shallow, up to 25 m in depth. Also most of the identified Veneridae species in this study have wide bathymetric range distribution and present common species in bathymeric range up to 25m (Hubert, 2010). Due to this fact, differences in Veneridae assemblages regarding depth were not expected. Peharda *et al*. (2004) in the area of Mali Ston found similarities in bivalve species composition between stations located in shallow part of the bay and stations located in deeper part of the bay. It must be noted that authors investigated all marine bivalve groups. Mutlu & Ergev (2012) found strong correlation between the abundance of mollusks and depth in Mersin Bay, east Mediterranean.

In total eight species identified in this study are used as food. Five species, *C. chione*, *C. gallina*, *Polititapes* spp., *R. decussatus* and *V. verrucosa* are caught from their natural habitats, but none Veneridae species is included in farming process neither in the

Montenegro neither neighbouring areas. In Montenegro only two bivalve species are farmed, *Mytilus galloprovincialis* and *Ostrea edulis* (Mandić *et al*., 2016).

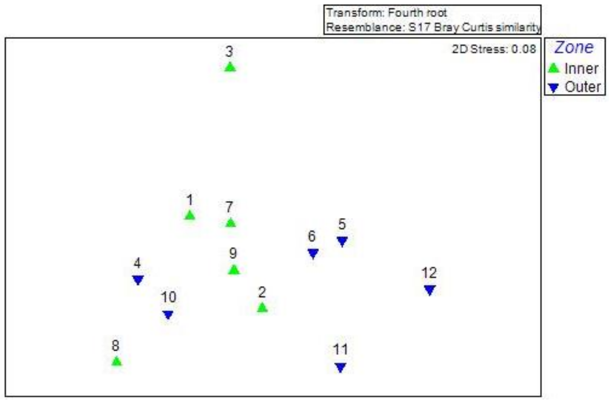

Figure 3. nMDS ordination of sampling locations with indication of two main sampling zones

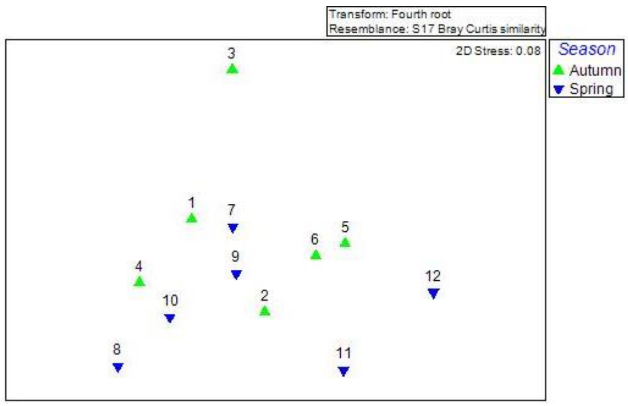

Figure 4. nMDS ordination of sampling locations with indication of two seasons

According to the FAO (2010) one of the main goals in aquaculture sector is diversification, introducing of new species in farming process, what can help in reduction of fishing pressure on natural populations. Veneridae species have great potential as candidates for farming process. Commercially farming of *V. verrucosa* exists in Spain since 2003 year, with annual production around one tone (Popović, 2013). Experimental farming of this species was conducted in Croatia, and authors reported that warty venus is very interesting shellfish for the introducing into the mariculture (Bolotin *et al*., 2011). Farming of *R. decussatus* and *R. philippinarum* is common, especially in France and Italy. Italy is second country, after China, in farming of *R. philippinarum* (Robert *et al*., 2013). Production of these two species in Europe during 2007. year was 70 703 tones, where just Italy produced 61 829 tones (Ljubičić, 2010). According Milišić (2007) farming of *Polititapes aureus* is also present in Italy.

Obtained results showed that the Boka Kotorska Bay is an area with high Veneridae diversity. Veneridae species should be considered as potential candidates for introducing into the mariculture, especially *V. verucossa*, *R. decussatus* and *Polititapes* spp.. Potential farming of those species in area of Boka Kotorska Bay should be investigated. Regarding this, future monitoring and investigation of Veneridae assemblages in the Bay should be continued in order to get more realistic picture on biomass, abundance, richness and diversity, as this study included only sampling during two seasons on small area.

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Kvantitativni i kvalitativni sastav venerinih školjki (Školjke) u Bokokotorskom zalivu (južni Jadran)

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SAŽETAK

U ovom radu su predstavljeni rezultati o zajednicama ladinki u oblasti Bokokotorskog zaliva. Uzorkovanje je sprovedeno tokom jeseni 2017. i proljeća 2018. godine metodom autonomnog ronjenja. Glavni cilj je bio opisati strukturu zajednica ladinki u zalivu, posebno zato što je nekoliko vrsta komercijalno značajno i potencijalne su vrste za uzgojni proces. Ukupno je sakupljeno 1754 jedinki, razvrstanih u 14 različitih vrsta. *Venus verrucosa* je bila dominantna vrsta. Abundanca vrsta po lokalitetima se kretala od 1.06 do 1.96 ind./m^2. Najmanji diverzitet i bogatstvo vrsta ladinki je zabilježen na Njivicama. Na osnovu kvalitativnih podataka, najveća sličnost je bila između lokaliteta Sv. Stasije i Sv. Nedjelja, dok je najmanja sličnost zabilježena između lokaliteta Sv. Stasije i Njivice. Nije bilo statistički značajnih razlika u strukturi zajednica ladinki niti između dvije glavne zone uzorkovanja, niti između sezona.

Ključne riječi: diverzitet, venerine školjke, školjke, Bokokotorski zaliv