ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 45 (2): 197-208, 2004	UDC: 597.32 (560)(262.5) Original scientific paper

A contribution to the knowledge of bivalve species diversity in Mali Ston Bay (Adriatic Sea)

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Although Mali Ston Bay is an important bivalve aquaculture area and one of the most studied areas in the Adriatic Sea, very little is known about its biodiversity. The goal of the present study was to estimate bivalve diversity in Mali Ston Bay according to the spatial distribution of live bivalves and empty shells. Samples were collected with a 0.1 m² van VEEN *grab at twelve sampling stations in the bay during June 2000. Species were determined in the laboratory and the bivalve assemblage was analyzed using the PRIMER software package. Eighty-two bivalve species were identified, indicating that Mali Ston Bay is an area of high bivalve diversity.*

Key words: bivalve diversity, Mali Ston Bay, Adriatic Sea

INTRODUCTION

Although Mali Ston Bay is an important bivalve aquaculture area and one of the most studied areas in the Adriatic Sea, very little is known about its biodiversity. Most earlier studies looked at hydrographic characteristics (e.g., BULJAN *et al.*, 1973; VUKADIN, 1981; CARIĆ *et al.*, 1992), phytoplankton and zooplankton communities (e.g., VILIČIĆ, 1989; LUČIĆ & KRŠINIĆ, 1998), or characteristics of aquacultured populations (e.g., BASIOLI, 1968, 1981; ŠIMUNOVIĆ; 1981; BENOVIĆ, 1997). Previous studies recorded only 39 species of bivalves in the bay (unpubl. data HRS-BRENKO; IGIĆ, 1981; ŠIMUNOVIĆ, 1981; BOLOTIN, 1998).

Long-term studies are highly recommended for determining bivalve diversity in a particular area. However, in many cases, such studies are unfeasible. Therefore, biologists have increasingly been studying shell accumulations as a way to extend the time frame of observations on species distribution and community structures (KIDWELL & FLESSA, 1996; KIDWELL, 2001). Naturally accumulated death assemblages provide a reliable means of acquiring data on bivalve distributions. Comparative studies in a variety of shallow marine environments typically reveal that the species composition of bivalve shell assemblages is representative of the original live community (KIDWELL & FLESSA, 1996).

The goal of the present study was to estimate the bivalve diversity in Mali Ston Bay according to the spatial distribution of live bivalves and empty shells. Such data is necessary for estimating possible environmental changes in this protected area.

MATERIAL AND METHODS

Bottom samples were collected with a 0.1-m^2 van VEEN grab at twelve sampling stations (P1-P12) in Mali Ston Bay during June 2000 (Fig.1). Three grab samples (A,B,C) were collected at each station. The sampled material was sieved through a 2-mm mesh in the field and preserved in a 4% buffered formaldehyde solution with the addition of rose Bengal. A 2-mm mesh was chosen because we were primarily interested in adult specimens. The rose Bengal solution was used to facilitate separation of live and dead material. Collected bivalves were identified in the laboratory according to TEBBLE (1966), NORDSIECK (1969), PARENZAN (1974, 1976), D'ANGELO & GARGIULLO (1987), POUTIERS (1987), and POPPE & GOTO (2000). For classification and nomenclature, SABELLI *et al.* (1990a,b) was used. Live individuals of each species were counted, while the species presence was noted for empty shells.

Sediment samples were collected from one grab sample at each station with a box core and frozen for later analysis. Sediments up to a depth of 4 cm were analyzed. Grain-size fractions were determined by sieving and aerometry. Sediment types were determined according to FOLK (1954). Organic matter content was determined according to VIDOVIĆ (1990).

The bivalve assemblage structure was analyzed with the PRIMER software package (Plymouth Marine Laboratories, UK; CLARKE & WARWICK, 1994). Data for live bivalves were transformed using 4th root transformation and the BRAY-CURTIS similarity matrix was used to generate 2-dimensional ordination plots with the non-metric multidimensional scaling (nMDS) technique. The ANOSIM 1-way test was applied to test differences in species assemblage between sampling stations (CLARKE & WARWICK, 1994). The probability value was set at 0.05. MARGALEF's index (d) was used to analyze species richness (MARGALEF, 1958), PIELOU's index to calculate evenness (PIELOU, 1969), and SHANNON-WEAVER's index (SHANNON & WEAVER, 1949) to analyze diversity. Grab samples collected at same station were grouped together to calculate the indices.

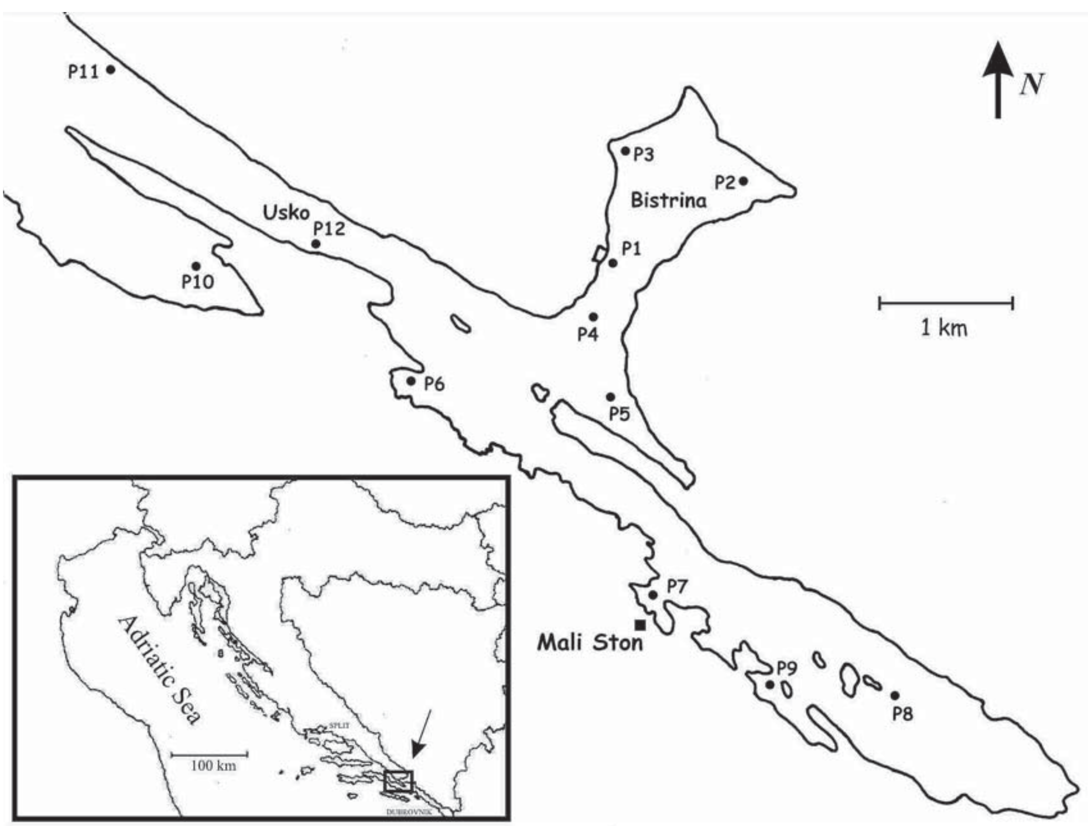

Fig. 1. Sampling stations in the Mali Ston Bay

RESULTS

There was a high content of mud particles at most sampling stations (Table 1). At stations P5, P6, P7, P8, and P12 the sediments were characterized by a high sand content and a somewhat higher content of gravel particles. Organic matter content was highest at stations P1, P9, and P11, which were located in different parts of the bay.

A total of 239 live individuals from 19 bivalve species belonging to 14 families were recorded (Table 2). The Lucinidae family was represented by four species (*Ctena decussata*, *Loripes lacteus*, *Lucinella divaricata, Anodontia fragilis*), the Tellinidae family by two (*Tellina donacina, T. serrata*), and the Semelidae family by two (*Abra nitida, A. abra*). Other families were represented by only one species. *T.*

Table 1. Granulometric characteristics of sediments and organic matter content at twelve sampling stations in Mali Ston Bay

Station	Depth (m)	Mz (µm)	Gravel (%)	Sand (%)	Mud (%)	Sediment type*	Organic matter (%)
P1	8	11.84	5	7	88	(g)M	8.18
P2	6.5	3.25	4	5	91	(g)M	7.54
P3	10	8.37	1	10	89	sM	6.86
P4	10	3.03	2	6	92	(g)M	6.35
P5	7	17.14	7	24	79	gM	5.77
P6	5.5	84.40	9	53	38	gmS	5.33
P7	4.5	50.77	6	53	41	gmS	3.33
P8	8	153.89	7	67	26	gmS	4.21
P9	5.5	5.15	3	11	86	(g)sM	8.10
P10	11	3.48	3	9	88	(g)M	6.67
P11	11.5	2.46	0	3	97	M	9.16
P12	15	50.77	9	43	48	gM	4.05

* According to FOLK (1954): (g)M – slightly gravelly mud, sM – sandy mud, gM – gravelly mud, gmS – gravelly muddy sand, (g)sM – slightly gravelly sandy mud, M – mud

Table 2. Live bivalve species (individuals 0.1 m^{-2}) collected during three samplings (A,B,C) at twelve stations (P1-12) in Mali Ston Bay

Species	P1			P2			P3			P4			P5			P6		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
		(g)M			(g)M			sM			(g)M			gM			gmS	
Nucula hanleyi	-	-	-	3	3	9	3	1	1	-	1	1	-	1	1	-	-	1
Nuculana pella	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-
Arca noae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Modiolus barbatus	-	-	-	-	-	-	7		1	-	-	-	-	-	-	-	-	-
Ctena decussata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loripes lacteus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-
Lucinella divaricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Anodontia fragilis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthocardia paucicostata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Ensis minor	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Tellina donacina	6	1	3	11	10	10	-	1	8	1	1	2	-	2	1	3	3	5
T. serrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psammobia depressa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Abra nitida	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
A. alba	-	-	-	4	1	-	1	-	4	-	-	1	-	1	-	2	-	3
Gouldia minima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corbula gibba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gastrochaena dubia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hiatella arctica	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Specimens / station	7	1	3	18	18	19	12	2	14	1	3	4	0	4	3	7	5	10
Species/station	2	1	1	3	6	2	4	2	4	1	3	3	0	3	3	3	3	4

Table 2. cont'd

Species	P7			P8			P9			P10			P11			P12		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
		gmS			gmS			(g)sM			(g)M			M			gM	
Nucula hanleyi	-	1	-	-	-	-	-	-	-	1	-	-	2	5	1	-	-	-
Nuculana pella	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-
Arca noae	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Modiolus barbatus	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Ctena decussata	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loripes lacteus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lucinella divaricata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodontia fragilis	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthocardia paucicostata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ensis minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tellina donacina	1	4	6	5	2	7	2	4	-	-	-	-	1	4	4	-	1	-
T. serrata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Psammobia depressa	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Abra nitida	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
A. alba	7	5	5	-	-	-	4	8	3	-	1	-	-	1	-	-	-	1
Gouldia minima	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Corbula gibba	-	-	-	-	-	-	-	-	-	-	-	-	4	1	2	-	-	-
Gastrochaena dubia	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hiatella arctica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specimens / station	8	11	17	6	2	7	8	12	3	1	1	0	8	12	8	1	1	2
Species/station	2	4	5	2	1	1	4	2	1	1	1	0	4	5	4	1	1	2

Sediment types according to FOLK (1954): (g)M – slightly gravelly mud, sM – sandy mud, gM – gravelly mud, gmS – gravelly muddy sand, (g)sM – slightly gravelly sandy mud, M – mud

donacina was the most abundant species with 109 individuals, then *A. alba* with 52 and *Nucula hanleyi* with 35. *T. donacina* was found in 28 samples at 11 stations, *A. alba* in 17 samples at ten stations, and *N. hanleyi* in 16 samples at eight stations. Nine species were represented by only one individual.

The number of species per station ranged from two to six and the number of specimens from two to 55 (Table 3). MARGALEF's index (species richness) ranged 0.367-1.618, PIELOU's index (species evenness) 0.353-1.0, and SHANNON-WEAVER's index 0.354-2.158.

Table 3. Number of species (S), number of individuals (N), MARGALEF's index (d), PIELOU's index (J'), and SHANNON-WEAVER's index (H') for live individuals, and number of species amongst empty shells (S empty, by sampling station)

Station	S	N	d	J'	H'	S (empty)
P1	2	11	0.417	0.440	0.434	46
P2	6	55	1.248	0.648	1.676	37
P3	5	28	1.200	0.905	2.102	40
P4	4	8	1.443	0.880	1.750	42
P5	4	7	1.542	0.921	1.842	47
P6	6	22	1.618	0.768	1.986	46
P7	6	36	1.395	0.719	1.860	42
P8	2	15	0.369	0.353	0.354	41
P9	4	23	0.957	0.651	1.301	33
P10	2	2	1.443	1.000	1.000	47
P11	6	28	1.501	0.835	2.158	42
P12	4	4	2.164	1.000	2.000	54

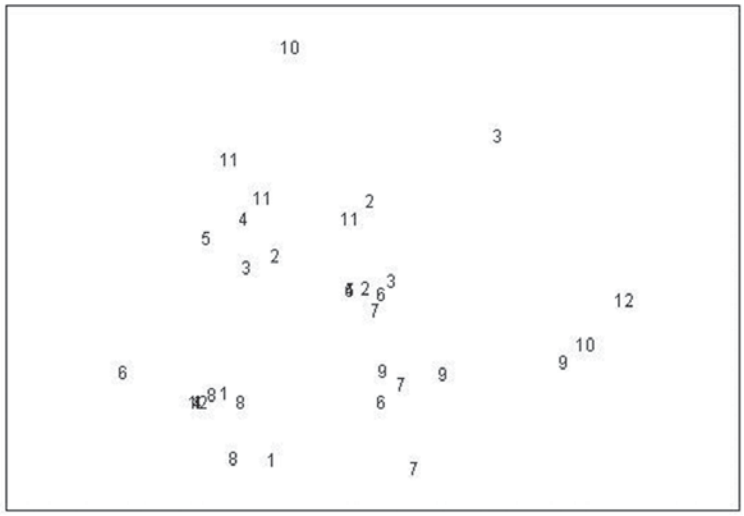

Fig. 2. Multidimensional scaling (nMDS) ordination plot of twelve sampling stations based on 4th root transformed abundances and BRAY-CURTIS similarities of live bivalves (stress = 0.13)

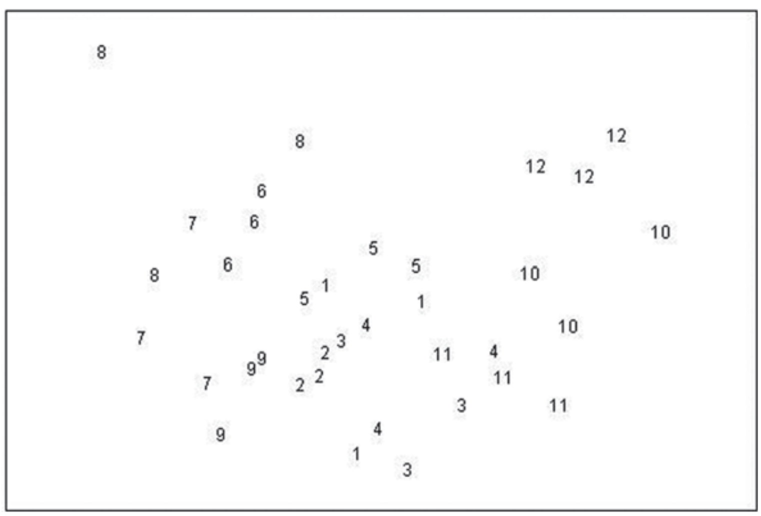

Fig. 3. Multidimensional scaling (nMDS) ordination plot of twelve sampling stations based on species presence-absence data and BRAY-CURTIS similarities of empty bivalve shells (stress = 0.19)

Due to the relatively small number of individuals collected per sample, clear differences in distribution of species were not evident between sampling stations (Fig. 2). Further, there was much variation between samples collected at same sampling station. Nevertheless, it seems that there were differences in species distribution between sampling stations, as indicated by the ANOSIM 1-way test (Global $R = 0.494$, $p = 0.001$).

The empty shells of 82 species were found (Table 4). Some kinds were found in all the stations, i.e., *Nucula* sp., *T. donacina*, *A. alba*, *Gouldia minima,* and *Pitar rudis*, while 15 species were found in only one sample. The highest number of species (54) was found at station P12 and the lowest (33) at station P9 (Table 3). The distribution of empty shells differed between stations (Fig. 3). Stations P10-12, located in the outer part of bay, seem to have a similar composition of empty bivalve shells, as do stations P6-9 in the inner bay. The stations between these two areas seem to be similar to each other and intermediate between the outer and inner areas. The ANOSIM 1-way test showed that the differences between sampling stations are statistically significant (Global $R = 0.662$, $p = 0.001$).

Table 4. Distribution of empty bivalve shells collected in three samples (A,B,C) at twelve sampling stations (P1-12) in Mali Ston Bay

	P1			P2			P3			P4			P5			P6			P7			P8			P9			P10			P11			P12		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	(g)M			(g)M			sM			(g)M			gM			gmS			gmS			gmS			(g)sM			(g)M			M			gM		
Nucula sp.	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Nuculana pella	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Arca noae	•	•	•	•	•				•		•		•	•	•		•		•	•	•	•	•	•	•	•	•				•			•	•	•
A. tetragona																																			•	
Andara diluvii												•																		•	•	•		•	•	•
Striarca lactea	•	•		•	•	•	•	•	•		•	•	•	•	•	•	•	•	•			•			•	•		•		•	•	•		•	•	•
Mytilus galloprovincialis	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•		•	•					•					
Mytilaster minimus	•						•													•																
Gregariella petagnae		•																		•			•	•												
Modiolarca subpicta	•	•	•	•	•	•	•		•	•	•		•	•	•	•		•				•	•									•	•	•	•	•
Modiolus barbatus	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•			•	•			•	•	•
M. adriaticus																•			•								•		•					•	•	•
Modiolula phaseolina																																		•		
Pecten jacobaeus		•	•					•	•	•			•		•								•		•			•	•					•	•	•
Aequipecten opercularis			•				•	•	•	•	•	•		•														•	•	•	•	•	•	•	•	•
Chlamys varia	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•
Flexopecten flexuosu	•		•	•	•	•	•	•		•	•	•	•	•	•	•	•		•	•	•				•	•	•	•	•	•	•	•			•	•
F. glaber	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•		•	•	•	•	•		•
Spondylus gaederopus																						•														
Anomia ephippium	•		•	•	•		•	•	•	•	•	•		•	•	•		•	•	•	•	•	•	•			•	•	•	•	•	•	•		•	•
Pododesmus squamula				•																																
P. patelliformis		•	•	•	•	•	•	•	•	•	•		•	•	•												•	•		•	•	•	•	•	•	•
Lima exilis	•	•		•	•	•			•		•						•		•						•	•	•									
L. hians			•											•																				•	•	•
Limea loscombi																•													•					•	•	•

Table 4. cont'd

	P1			P2			P3			P4			P5			P6			P7			P8			P9			P10			P11			P12		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
	(g)M			(g)M			sM			(g)M			gM			gmS			gmS			gmS			(g)sM			(g)M			M			gM		
Ostrea edulis	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●	●
Ctena decussata																		●			●		●	●						●						
Loripes lacteus						●										●	●	●	●	●	●			●				●	●							
Lucinella divaricata													●	●	●	●	●	●		●	●	●		●					●							
Anodontia fragilis	●	●			●			●	●		●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●									●
Myrtea spinifera		●										●	●	●	●		●											●	●	●			●			●
Thyasira flexuosa	●																				●					●		●	●	●	●	●		●		●
Diplodonta brocchi	●	●	●				●			●	●		●					●					●					●	●	●	●	●	●	●	●	●
D. rotundata		●	●				●			●	●		●	●	●	●	●	●			●		●	●				●			●			●	●	●
Chama gryphoides			●											●							●	●	●	●				●								●
Pseudochama gryphina		●				●									●								●	●		●	●									
Kellia suborbicularis																																				●
Lepton squamosum														●			●	●						●												
Mysella bidentata																●	●														●		●			
Astarte sp.																●																				
Acanthocardia paucicostata	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●		●	●
Parvicardium exiguum	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●			●
Plagiocardium papillosum	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Laevicardium crassum																																		●	●	●
Cerastoderma glaucum																														●						
Spisula subtruncata									●				●	●		●		●			●						●									

DISCUSSION

Of the total 82 bivalve species found in this study, only 19 (23%) were represented by live individuals. This value is lower than the value mentioned by KIDWELL & FLESSA (1996), who noted that dead mollusk assemblages typically have twice as many species as live ones in a single habitat at a single time. A study of live communities carried out in different seasons during several decades is required to obtain a complete and detailed list of bivalve species based on live individuals alone. However, one sampling of empty shells in the sediment can provide a realistic picture of species distribution in a given area (KIDWELL & BOSENCE, 1991).

Checklists of bivalve species for particular areas in the Adriatic contain both live individuals and empty shells. For example, 71 bivalve species from 33 families, including more than 20 species with only empty shells, were listed for Kornati archipelago and Dugi Otok (HRS-BRENKO, 1997). Also, 106 bivalve species from 40 families, with a significant number of species mentioned only as empty shells, were listed for Rijeka Bay (HRS-BRENKO *et al.,* 1998; ZAVODNIK & KOVAČEVIĆ, 2000). The data for Rijeka Bay date back to the mid-nineteenth century (GRUBE, 1861), representing a very long study period, and were collected by different sampling methods. For many of the species, live individuals were not collected.

Comprehensive studies have been conducted in parts of the northern and middle Adriatic (117 species from 39 families, LEGAC & HRS-BRENKO, 1982), Lošinj Island archipelago (38 species from 22 families, HRS-BRENKO & LEGAC, 1992), Krka River estuary (52 species from 27 families, MARGUŠ *et al*., 1991), Mljet lakes (51 species from 23 families, OREPIĆ *et al*., 1997), and Mljet National Park (114 species from 34 families, ŽERLIĆ, 1999). A review of malacological and faunistic publications since the mid-nineteenth century revealed more than 200 bivalve species in the eastern Adriatic (FREDJ, 1974; LEGAC & HRS-BRENKO, pers. comm.). Although Mali Ston Bay is an important bivalve aquaculture area, data on bivalve diversity are very scarce. Earlier studies conducted in Mali Ston Bay list only 39 bivalve species (IGIĆ, 1981; ŠIMUNOVIĆ, 1981; BOLOTIN, 1998; HRS-BRENKO, unpubl. data), of which four were determined only to the genus level. The present study, therefore, significantly increases the list of bivalves for this area.

A comparison of published and unpublished data with the present study reveals differences in the species of Mali Ston Bay (PEHARDA, 2003). For example, HRS-BRENKO (unpubl. data) found two species of the genus *Nucula*: *N. nitidosa* and *N. nucleus*, while according to the revision of Protobranchia, three species of this genus live in the Adriatic: *N. nucleus*, *N. sulcata,* and *N. nitida* (HRS-BRENKO & LEGAC, 1991). In this study, several live *N. hanleyi* were recorded in Mali Ston Bay, while a large number of empty *Nucula* shells was determined only to the genus level. *N. hanleyi* is not listed in either the revision or the checklist of Adriatic bivalves (FREDJ, 1974), but it may have been misidentified in previous studies as *N. nucleus* due to the morphological similarity of their shells. According to some authors, *N. hanleyi* is a form, subspecies, or synonym of *N. nucleus* (POPPE & GOTO, 2000). Also, four species (*Diplodonta brocchi*, *Lepton squamosum, Saxicavella jeffreysi, Thracia villosiuscula*) represented by empty shells in this study are rare for the Adriatic (DANILO & SANDRI, 1855; BRUSINA, 1896; COEN, 1937; STJEPČEVIĆ & PARENZAN, 1980; RADIĆ, 1982; ZAVODNIK & VIDAKOVIĆ, 1987).

Only two species, *A. alba* and *Corbula gibba,* are considered stress indicators by the FAO/UNEP (1986). *C. gibba* is abundant in polluted harbor environments such as Pula (HRS-BRENKO, 1981) and Trieste (GRAEFFE, 1903). In this study, *C. gibba* was found only at station P11, indicating that the Mali Ston Bay area is not undergoing strong antrophogenic perturbances.

The analysis of abundances of live individuals did not result in clear groupings of stations according to their locations in the bay. For example, in terms of species composition, samples collected at stations P1-4 in Bistrina Bay were not similar to each other. It is possible that, due to the relatively small number of species with live representatives, the results are not representative of the area. The similarity in species noted at stations P1 and P8 is probably a consequence of their dissimilarity to other stations and their small bivalve diversity values. These stations also differed with respect to sediment composition; P1 had a high organic matter content and P8 a low organic content. Results indicate that a realistic comparison of species compositions at sampling stations in Mali Ston Bay requires additional samplings, and/or samplings conducted at for a longer period.

To the contrary, analyses based on the empty shells presented in nMDS showed similarities in species composition between stations located in the shallow inner part of the bay and stations located in the deeper open part of the bay. Stations located in Bistrina Bay were near each other in the nMDS analysis, indicating similarity in species composition and a composition somewhere between the stations in the inner bay and the stations in the outer part of the bay.

In conclusion, the results of present study indicate that Mali Ston Bay is an area with high bivalve diversity. As such, it requires efficient protection and monitoring that should include detailed studies of the spatial and temporal distributions of other benthic groups. Future studies should address the effects of bivalve aquaculture on the benthic community of the bay and evaluate potential changes of these effects as bivalve production increases.

ACKNOWLEDGEMENTS

The authors would like to thank the Croatian Ministry of Science and Technology for financial support. Special thanks to Ana BRATOŠ, Marija CRNČEVIĆ, and Željko BAĆE for technical support, and Graham OLIVER, Ian KILEEN, and Henku DIJKSTA for help with species determination.

REFERENCES

BASIOLI, J. 1968. Uzgoj školjkaša na istočnim obalama Jadrana. Pomorski Zbornik, 6: 179-216.

BASIOLI, J. 1981. Uzgoj školjkaša na istočnoj obali Jadranskog mora s posebnim osvrtom na Malostonski zaljev. In: J. Roglić and M. Meštrov (Editors). Zbornik Radova Savjetovanja "Malostonski Zaljev Prirodna Podloga i Društveno Valoriziranje". JAZU. Znanstveni Savjet za Zaštitu Prirode. Dubrovnik, pp. 268-281.

BENOVIĆ, A. 1997. The history, present condition, and future of the molluscan fisheries of Croatia. In: C.L. Jr. MacKenzie, V.G. Jr. Burrel, A. Rosenfield and W.L. Hobart (Editors). The History, Present Condition, and Future of the Molluscan Fisheries of North and Central America and Europe. Vol. 3. Europe. USA Dept. Commerce, NOAA Tech Rep, 129: 217-226.

BOLOTIN, J. 1998. Ekološki i genetski aspekti prirodnih i uzgajanih populacija dagnji (*Mytilus* spp.) na istočnoj obali Jadrana. Thesis, University of Zagreb, 92 pp.

BRUSINA, S. 1896. Faunistički prilozi sa putovanja yachte "Margite" po Jadranskom moru. Glasnik Hrv. Naravosl. Društ., 9(1-6): 1-134.

BULJAN, M., J. HURE & T. PUCHER-PETKOVIĆ. 1973. Hidrografske i produkcijske prilike u Malostonskom zaljevu. Acta Adriat., 15(2): 1-60.

CARIĆ, M., N. JASPRICA & D. VILIČIĆ. 1992. Nutrient and chlorophyll *a* concentrations in Gruž and Mali Ston Bays (Southern Adriatic). Rapp. Comm. Int. Mer Médit., 33: 367.

CLARKE, K.R. & R.M. WARWICK. 1994. Change in marine communities: an approach to statistical analysis and interpretation. Nat. Environ. Res. Council, UK, Plymouth Marine Laboratory, 144 pp.

COEN, G. 1937. Nuovo saggio di una Sylloge Molluscorum Adriaticorum. R. Com. Thalassogr. It. Mem., 240: 90-167.

D'ANGELO, G. & S. GARGIULLO. 1987. Guida alle Conchiglie Mediterranee. Fabri Editori, 223 pp.

DANILO, F. & G.B. SANDRI. 1855. Elenco Nominale dei Molluschi Lamellibranchiati Marittimi Raccolti nei Contorni di Zara. – nel Programma dell' I.R. Ginnasio di Zara, 20 pp.

FAO/UNEP. 1986. Report of the FAO/UNEP Meeting on the Effects of Pollution on Marine Ecosystem. FAO Fish Rep, 352, Rome, 20 pp.

FOLK, R.L. 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. J. Geol., 62: 344-356.

FREDJ, G. 1974. Stockage et exploitation des données en écologie marine. Mém. Inst. Océanogr. Monaco, 7: 1-88.

GRAEFFE, E. 1903. Uebersichte der Seetiere des Golfes von Triest. VI. Mollusca. Arb. Zool. Inst. Wien, Zool. Sta. Trieste, 14: 89-136.

GRUBE, A.E. 1861. Ein Ausflug nach Triest und dem Quarnero. Nicolaishe Verl, Berlin, 175 pp.

HRS-BRENKO, M. 1981. Population studies of *Corbula gibba* (Olivi) Bivalvia, Corbulidae, in the northern Adriatic Sea. J. Moll. Stud., 47(1):17-24.

HRS-BRENKO, M. 1997. The marine bivalve mollusks in the Kornati National Park and the Dugi Otok Natural Park (Adriatic Sea). Period. Biol., 99(3): 381-395.

HRS-BRENKO, M. & M. LEGAC. 1991. A review of bivalve species in the eastern Adriatic Sea. 1. Protobranchia (Solemyidae, Nuculidae, Nuculanidae). Acta Adriat., 32(2): 655-670.

HRS-BRENKO M. & M. LEGAC. 1992. Prilozi morskoj flori i fauni lošinjske otočne skupine. IV. Školjkaši (Bivalvia). Otočki Ljetopis Cres-Lošinj, 8: 229-238.

HRS-BRENKO, M., M. LEGAC & M. ARKO-PJEVAC. 1998. Contributions to the marine fauna of the Rijeka Bay (Adriatic Sea). 3. Bivalvia. In: M. Arko-Pjevac, M. Kovačić and D. Crnković (Editors). Natural History Researches of the Rijeka Region. Natural History Library 1, Natural History Museum Rijeka, pp. 583-598.

IGIĆ, LJ. 1981. Obraštaj na jestivim školjkašima u Malostonskom zaljevu. In: J. Roglić and M. Meštrov (Editors). Zbornik Radova Savjetovanja "Malostonski zaljev Prirodna Podloga i Društveno Valoriziranje". JAZU, Znanstveni Savjet za Zaštitu Prirode. Dubrovnik, pp. 235-251.

KIDWELL, S.M. 2001. Preservation of species abundance in marine dead assemblage. Science, 294(2): 1091-1094.

KIDWELL, S.M. & D.W.J. BOSENCE. 1991. Taxonomy and time-averaging of marine shelly faunas. In: P.A. Allison and D.E.G. Briggs (Editors). Taxonomy: Releasing the Data Locked in the Fossil Record, Topics in Geobiology, Vol 9. Plenum Press, New York, pp. 115-209.

KIDWELL, S.M. & K.W. FLESSA. 1996. The quality of the fossil record: populations, species and communities. Annu. Rev. Earth Planet Sci., 24: 433-464.

LEGAC, M. & M. HRS-BRENKO. 1982. A contribution to the knowledge of bivalve species distribution in the insular zones of the northern and part of the middle Adriatic Sea. Acta Adriat., 23(1/2): 197-225.

LUČIĆ, D. & F. KRŠINIĆ. 1998. Annual variability of mesozooplankton assemblages in Mali Ston Bay (southern Adriatic). Period. Biol., 100(1): 43-52.

MARGALEF, R. 1958. Information theory in ecology. Gen. Syst., 3: 36-71.

MARGUŠ, D., E. TESKEREDŽIĆ, Z. MODRUŠAN, M. TOMEC, Z. TESKEREDŽIĆ & N. HACMANJEK. 1991. Školjkaši (Bivalvia) ušća Rijeke Krke. Pomorski Zbornik, 29(1): 421-436.

NORDSIECK, F. 1969. Die europäischen Meeresmuscheln (Bivalvia). Gustav Fischer Verlag, Stuttgart, 256 pp.

OREPIĆ, N., J. VIDMAR, E. ZAHTILA & D. ZAVODNIK. 1997. A marine benthos survey in the lakes of the National Park Mljet (Adriatic Sea). Period. Biol., 99(2): 229-245.

PARENZAN, P. 1974. Carta d'Identità delle Conchiglie del Mediterraneo. Vol. II. Bivalvi I. Bios Taras, Taranto, 277 pp.

PARENZAN, P. 1976. Carta d'Identità delle Conchiglie del Mediterraneo. Vol. II. Bivalvi II. Bios Taras, Taranto, 546 pp.

PEHARDA, M. 2003. Rasprostranjenost i sastav prirodnih populacija školjkaša (Mollusca, Bivalvia) u Malostonskom zaljevu. Thesis, University of Zagreb, 112 pp.

PIELOU, E. 1969. The measurement of diversity in different types of biological collections. J. Theor. Biol., 13: 131-144.

POPPE, G.T. & Y. GOTO. 2000. European Seashells. Vol. II. (Scaphopoda, Bivalvia, Cephalopoda). 2nd ed. ConchBooks, Hackenheim, Germany, 221 pp.

POUTIERS, J.M. 1987. Bivalves (Acephales, Lamellibranches, Pelecypodes). In: Fiches FAO d'Identification des Espèces pour les Besoins de la Pêche. Méditerranée et Mer Noire. FAO-ECEE, 1: 371-512.

RADIĆ, J. 1982. Contribution à la connaissance de la distribution des Mollusques (Mollusca) dans les biocoenoses benthiques du littoral du Makarska. Acta Adriat., 23(1/2): 175-195.

SABELLI, B., R. GIANNUZZI-SAVELINI & D. BEDULLI. 1990a. Catalogo annotato dei molluschi marini del Mediterraneo. Libreria Naturalistica Bolognese (Editor). 1: 273-341.

SABELLI, B., R. GIANNUZZI-SAVELINI & D. BEDULLI. 1990b. Catalogo annotato dei molluschi marini del Mediterraneo. Libreria Naturalistica Bolognese (Editor). 2: 453-498.

SHANNON, C.E. & W. WEAVER. 1949. The Mathematical Theory of Communication. Urbana, University of Illinois Press, 225 pp.

ŠIMUNOVIĆ, A. 1981. Biološko-ekološka istraživanja jestivih školjkaša Malostonskog zaljeva. In: J. Roglić and M. Meštrov (Editors). Zbornik Radova Savjetovanja "Malostonski Zaljev, Prirodna Podloga i Društveno Valoriziranje". JAZU, Znanstveni Savjet za Zaštitu Prirode. Dubrovnik, pp. 252-267

STJEPČEVIĆ, J. & P. PARENZAN. 1980. Il Golfo delle Boche di Cattaro. Condizioni generali e biocenosi bentoniche con carta ecologica delle sue due baie interne: di Kotor (Cattaro) e di Risan (Risano). Studia Marina, 10: 3-146.

TEBBLE, N. 1966. British Bivalve Seashells. A Handbook for Identification. The British Museum (Natural History), London, 212 pp.

VIDOVIĆ, N. 1990. Ovisnost specifične površine o granulometrijskom i mineraloškom sastavu sedimenta i suspendiranog materijala. Thesis, University of Zagreb, 96 pp.

VILIČIĆ, D. 1989. Phytoplankton population density and volume as indicators of eutrophication in the eastern part of the Adriatic Sea. Hydrobiologia, 174(2): 117-132.

VUKADIN, I. 1981. Hidrografska svojstva Malostonskog zaljeva i susjednog mora u periodu 1980-1981 godine. In: J. Roglić and M. Meštrov (Editors). Zbornik Radova Savjetovanja "Malostonski zaljev. Prirodna Podloga i Društveno Valoriziranje". JAZU, Znanstveni Savjet za Zaštitu Prirode. Dubrovnik, pp. 52-65.

ZAVODNIK, D. & J. VIDAKOVIĆ. 1987. Report on bottom fauna in two northern Adriatic areas presumed to be influenced by inputs. FAO Fish. Rep., 352 (Suppl.): 263-279.

ZAVODNIK, D. & M. KOVAČIĆ. 2000. Index of marine fauna in Rijeka Bay (Adriatic Sea, Croatia). Nat. Croat., 9(4): 225-379.

ŽERLIĆ, T. 1999. Školjkaši litoralnog područja nacionalnog parka "Mljet". Undergraduate thesis, University of Zagreb, 43 pp.

Received: 31 May 2004
Accepted: 20 September 2004

Prilog poznavanju raznolikosti školjkaša u Malostonskom zaljevu (Jadransko more)

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SAŽETAK

Iako je Malostonski zaljev važno područje za akvakulturu školjkaša i jedno od najistraživanih područja u Jadranskom moru, vrlo malo je poznato o njegovoj biološkoj raznolikosti. Ovo istraživanje je pokrenuto s ciljem procjene raznolikosti školjkaša u Malostonskom zaljevu na osnovi prostorne raspodjele živih školjkaša i praznih ljuštura. Uzorci su prikupljani sa 0.1 m^2 van VEEN grabilom tijekom lipnja 2000. na 12 postaja uzorkovanja smještenih u Malostonskom zaljevu. Vrste su određene u laboratoriju i sastav zajednice školjkaša je analiziran pomoću PRIMER programa. Ukupno su određene 82 vrste školjkaša što upućuje da je Malostonski zaljev područje sa visokom raznolikošću školjkaša.

Ključne riječi: raznolikost školjkaša, Malostonski zaljev, Jadran