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ECOLOGICAL STATUS ASSESSMENT OF VARNA BAY BASED ON BENTHIC INVERTEBRATE FAUNA

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ОЦЕНКА НА ЕКОЛОГИЧНОТО СЪСТОЯНИЕ НА ВАРНЕНСКИ ЗАЛИВ СПОРЕД БЕНТОСНАТА БЕЗГРЪБНАЧНА ФАУНА

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Резюме: *Целта на настоящото изледване е да се оцени екологичното състояние на Варненски залив според биологичния елемент за качество бентосна безгръбначна фауна. Установени са общо 56 вида и 3 надвидови таксона със средна численост 5 802 ind.m^{-2} и средна биомаса 146,462 g.m^{-2}, като с най-голям брой видове са представени полихетите. Клъстерният анализ диференцира определени групи от станции както според състава на бентосните съобщества, така и според типа седимент и дълбочината. Екологичното състояние на Варненския залив варира от много лошо и лошо до умерено и добро.*

Ключови думи: *енология, бентосна безгръбначна фауна, Рамкова директива за водите, крайбрежни води, биотични индекси, екологично състояние*

INTRODUCTION

Varna Bay is located in the northern part of Bulgarian Black Sea coast, locked between c. Galata and c. St. George. It is the second largest bay along Bulgarian Black Sea coast after Burgas Bay (Fig. 1). It has flat bottom sloping towards east. Its maximum depth is 18.5 m. On the west it is artificially linked by two canals to Varna Lake, which has a major impact on it. Varna, the third largest city in Bulgaria, is situated around the bay. Its population is over 300 000 inhabitants which increases considerably during the summer season. The largest sea ports of Bulgaria are located in Varna and Burgas Bays. In 2000, the Water Framework Directive entered into force. The goal of WFD is not only to prevent further deterioration of water bodies but also to protect and enhance the state of water resources to the level of quality defined as „good ecological status". Being an EU member state Bulgaria is obliged to protect, enhance and restore all bodies of surface water with the aim of achieving good surface water status before 2015.

According to WFD criteria Varna Bay is classified as moderately exposed, euhaline, shallow (< 20 m) coastal water body type. The sediments are contaminated as a result of urban and industrial activities and municipal wastewater (Shtereva *et al.*, 2004). Varna Bay is identified as a water body at risk of failing to achieve good ecological status by 2015 (Basin Directorate for Water Management in Black Sea region, 2009).

MATERIAL AND METHODS

The study area covered Varna Bay. Thirteen stations were sampled in August 2010 ranging from 3 m to 18 m depth (Table 1, Fig. 1).

Table 1. Stations, coordinates, depth and sediment type of sampled stations.

Station	Latitude	Longitude	Depth (m)	Sediment
1	43º11'49''	27º55'30''	7	sand
2	43º11'10''	27º55'30''	12	silty sand
3	43º10'41''	27º55'12''	7	sand
4	43º12'07''	27º55'47''	7	sand

5	43º11’10’’	27º56’13’’	15	silty sand
6	43º10’37’’	27º55’55’’	7	sand
7	43º12’24’’	27º56’48’’	9	sand
8	43º12’04’’	27º58’12’’	18	silt
9	43º10’34’’	27º57’00’’	17	sand
10	43º12’56’’	27º58’41’’	16	sand
11	43º11’31’’	27º55’31’’	11	sand
14	43º10’48’’	27º54’46’’	3	sand
15	43º11’42’’	27º56’24’’	13	sand

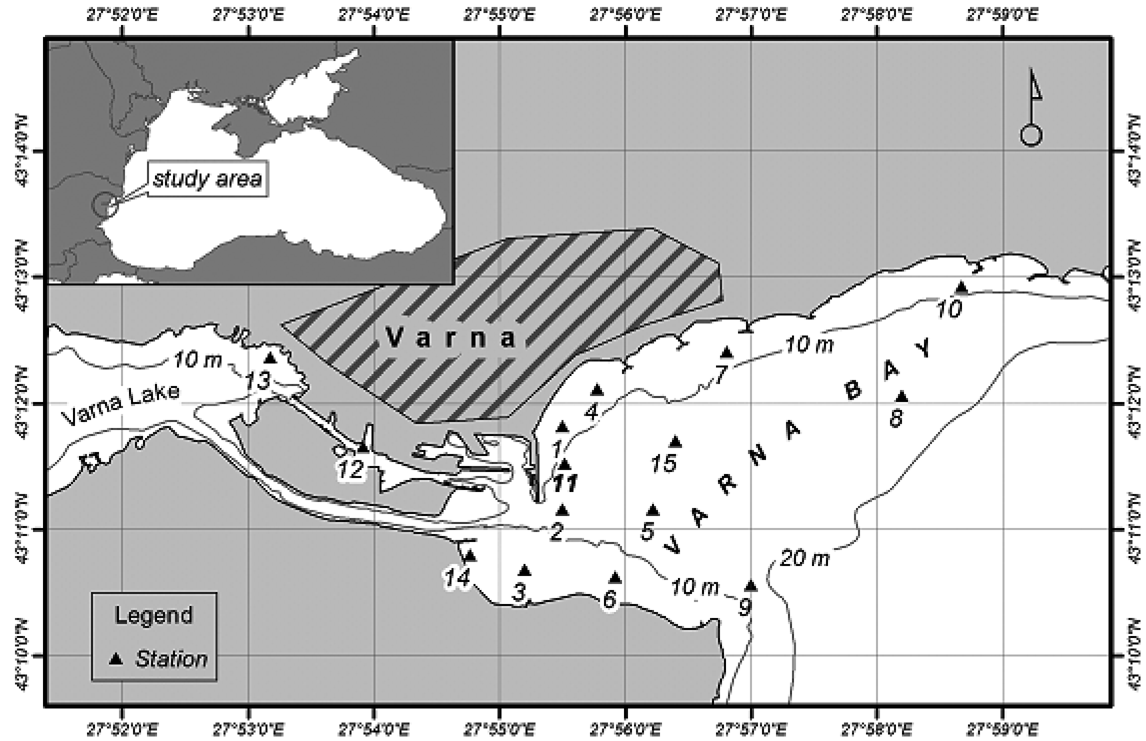

Fig. 1. Sampling network of the study area.

The samples for analysis of the benthic invertebrates were collected with van Veen grab (0.1 m^2) and gently sieved through metal gauze sieves with mesh size 1.0 x 1.0 mm and 0.5 x 0.5 mm onboard. The collected samples were fixed with 4% buffered formaldehyde and the containers were appropriately labelled for further identification. Sorting, taxonomic identification, abundance and biomass (wet weight) determination were performed in the laboratory. The procedures of collection, onboard and laboratory processing of samples were accomplished according to Todorova, Konsulova (2005).

Univariate and multivariate statistical analyses were performed on abundance and biomass datasets. Similarity pattern was examined (Clarke, Warwick, 2001). Ecological status was assessed by application of the following indices and corresponding classification scales: diversity index H’ (Shannon, Weaver, 1949), a Marine Biotic Index (AMBI) (Borja *et al.*, 2000; Borja *et al.*, 2003) and multivariate AMBI (M-AMBI) (Borja *et al.*, 2007). In the process of AMBI calculation the polychaete worm *Aricidea claudiae* Laubier, 1967 was classified as belonging to III ecological group due to statistically demonstrated species similarity (Bray-Curtis simi-larity based on log (x+1) transformed abundance) with a number of other tolerant species (Todorova *et al.*, 2008). In the process of M-AMBI calculation the reference and bad status values for species richness (S) were set sediment dependently. For water bodies with muddy sediments the boundary values for S of high and bad state were ≥ 40 and < 10, and for the stations with sandy and mixed sediments ≥ 50 and < 15 respectively (Trayanova *et al.*, 2007).

The ecological status of a particular station was assessed using M-AMBI, a combined biotic index including diversity (H'), species richness (S) and AMBI (proportion of opportunistic to sensitive taxa), into a factor analysis multivariate approach (Muxika *et al.*, 2007). The ecological class boundaries were those given by Borja *et al.* (2007). PRIMER 6 (Primer-E Ltd) and AMBI 4.0 (AZTI-Technalia) software packages were employed for statistical analyses of the data.

RESULTS AND DISCUSSION

The pool of samples yielded 56 species and 3 taxa identified at higher level (Turbellaria, Nemertini and Oligochaeta). The major groups in the taxonomic structure were polychaetes (24 species), molluscs (17 – 4 gastropods and 13 bivalves) and crustaceans (13). Group Varia included 1 phoronid, 1 cephalochordate and the higher taxa Turbellaria, Nemertini and Oligochaeta. The average number of species per sample was 17, the minimum – 8 at station 2 and the maximum - 26 species at station 7. The average abundance of macrobenthic fauna in the studied area was 5 802 ind.m^{-2} and varied in wide range with minimum 820 ind.m^{-2} at station 4 and maximum 16 870 ind.m^{-2} at station 5. The average biomass of the benthic invertebrate fauna was 146,462 gWM.m^{-2} and varied from minimum 4,464 gWM.m^{-2} at station to maximum 680,595 gWM.m^{-2} at station 6.

Hierarchical clustering procedure according to log (x+1) transformed abundance data distinguished two clusters pooling samples with similar community composition (Fig. 2).

The first cluster encompassed 5 stations with 58,16 % similarity, located in the central deeper part of Varna Bay, at depth ranging from 12 m to 18 m (average depth 15 m). Sediments varied from silt, silty sand to sand. The highest contributions to similarity belonged to polychaetes *Heteromastus filiformis* (Calaparède, 1864) and *Aricidea caludiae* Laubier, 1967 and oligochaetes. The average abundance 9 276 ind.m^{-2} was formed predominately by polychaetes (81.4%) and especially by *H. filiformis*, which average abundance was 3 574 ind.m^{-2}.

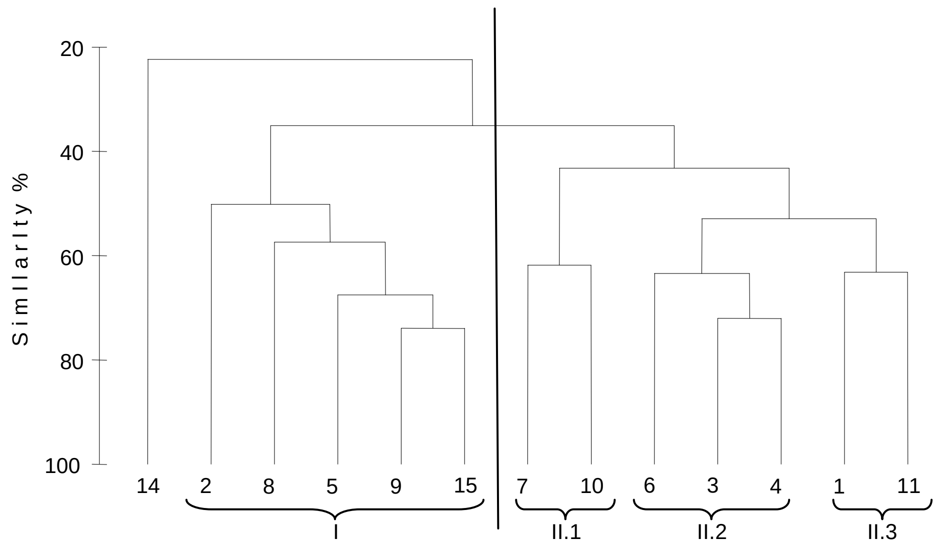

Fig. 2. Dendrogram for hierarchical clustering (group-average linking) of samples based on Bray-Curtis similarities (%) of log (x+1) transformed abundance of the macrobenthic fauna.

The second cluster included 7 stations with sandy sediments at depth range 7 to 16 m (average depth 9 m). The polychaetes *H. filiformis*, *Polydora cornuta* Bosc, 1802 and *Capitella minima* Langerhans, 1881 contributed mostly to the average similarity (51,90 %). The average abundance was 3 630 ind.m^{-2} formed by polychaetes (54,81 %) and molluscs (31,79 %). The second cluster was subdivided into three groups with higher average similarity. The first group (II.1) included two stations located in the northernmost part of the bay. The similarity within the group was 61,81 % formed by the dominance of polychaetes *P. cornuta* and *Protodorvillea kefersteini* (McIntosh, 1869) and oligochaetes in the average abundance. The second group (II.2) included three shallow stations located in the northern and southern part of the bay at the same depth (7 m). Average similarity within the group was 66,28% with the highest contribution of psamophilic bivalve *Chamelea gallina* (Linnaeus, 1758), and the polychaete worms *H. filiformis* and *Spio filicornis* (Müller, 1776). The third group (II.3) was represented by two stations with average similarity 63,14 % dominated by polychaetes *H. filiformis* and *C. minima* and crustacean *Upogebia pusilla* (Petagna, 1792).

The sallower station 14 was separated from the others because of the high abundance of psamophilic bivalve *Lentidium mediterraneum* (O. G. Costa, 1829) and polychaete worm *S. filicornis* and the abcence of oligochaetes.

Two clusters were distinguished on the dendrogram generated by the hierarchical clustering procedure according to log (x+1) transformed biomass data (Fig. 3). Samples with comparable depth and common sediment type came together in groups with similar community composition.

The first cluster included three deeper stations at average depth 15 m, located in the central part of the bay, which sediments varied from silt to silty sand. It was dominated by the polychaete *H. filiformis* and oligochaetes. The deepest station 8, characterized by silty sediments, was differentiated by the others due to the dominance of polychaete worm *Nephtys hombergii* Savigny in Lamarck, 1818. The biomass 10,571 gWM.m^{-2} was dominated by the polychaetes (76.73%).

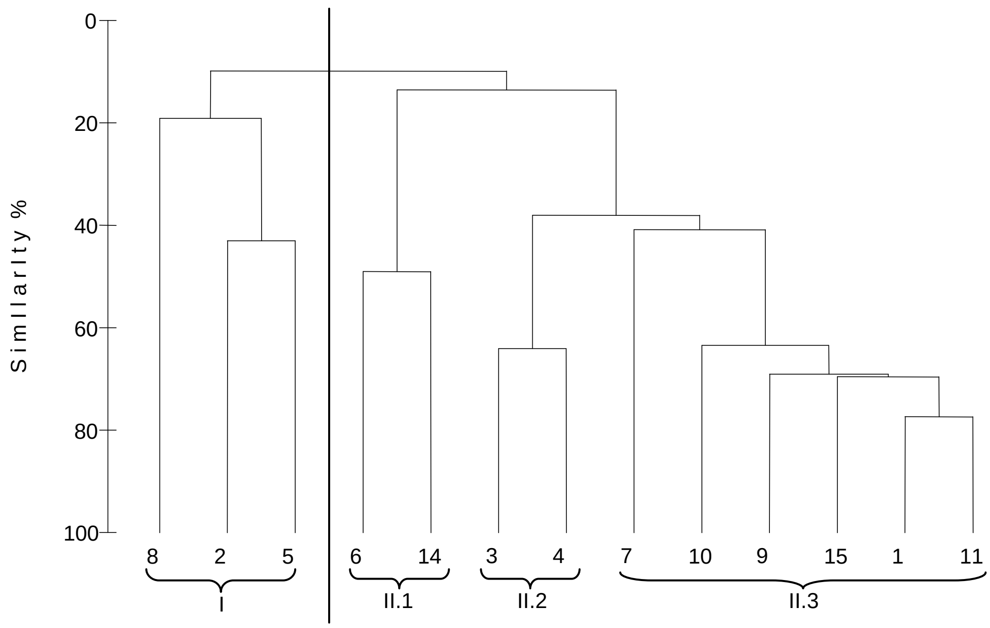

Fig. 3. Dendrogram for hierarchical clustering (group-average linking) of samples based on Bray-Curtis similarities (%) of log (x+1) transformed biomass of the macrobenthic fauna.

The second cluster pooled samples from sandy sediments at depth range 7 to 17 m (average depth 10 m). The average biomass 146,462 gWM.m^{-2} was formed predominately by molluscs (57,89 %) and crustaceans (31,69 %). The dominating species were *Ch. gallina* and *U. pusilla*, which average biomass was 40,128 gWM.m^{-2} and 44,539 gWM.m^{-2} respectively.

The average dissimilarity between the two clusters was 90,13 % because of the dominance of crustacean *U. pusilla and* psamophilic bivalves *Ch. gallina* and *Tellina tenuis* da Costa, 1778 in the average biomass within the second cluster and their absence within the first one.

The second cluster was further subdivided into three groups. The first group (I.1) was formed by two shallow stations located in the southern part of the bay. Average similarity within the group was 49,01% with the highest contribution of psamophilic bivalves *Ch. gallina* and *T. tenuis*. The second group (II.2) encompassed two stations located in the northern and southern part of the bay at depth 7 m. The similarity within the group was 64,04 % formed by the dominance of crustacean *U. pusilla* and psamophilic bivalves *Ch. gallina* and *T. tenuis* in the average biomass. The third group (II.3) was composed by six stations, at depth ranging from 7 m to 17 m, with average similarity 58,77 % dominated by crustacean *U. pusilla* and polychaete worm *H. filiformis*.

According to M-AMBI the ecological status of Varna Bay varied spatially among the categories bad, poor, moderate and good. The species richness and the diversity index increased in parallel with the improvement of ecological status (Table 2).

Table 2. Species richness (S), diversity (H'), A Marine Biotic Index (AMBI), multivariate AMBI (M-AMBI) and Ecological status based on M-AMBI values.

Station	S	H'	AMBI	M-AMBI	Ecological status
2	8	1,11	4,59	0,01	Bad
11	11	1,22	4,49	0,04	Bad
1	14	2,47	3,81	0,26	Poor
5	13	2,34	4,09	0,22	Poor
8	11	1,83	3,80	0,25	Poor
9	16	2,34	4,26	0,23	Poor
14	14	2,08	2,43	0,32	Poor
15	20	2,45	4,03	0,30	Poor
3	24	3,30	3,34	0,50	Moderate
4	20	3,66	2,61	0,55	Moderate
7	26	2,85	3,59	0,44	Moderate
10	24	3,14	4,01	0,43	Moderate
6	25	2,27	0,64	0,59	Good

Stations in bad and poor ecological status, with low species richness occupied the central part of the bay with the exception of station 14 located at southern coast. Moderate ecological status was attributed to shallower stations along the southern coast and the shallowest station 14 at the northern part of the bay. In good ecological status was classified station 6 which was characterized by high species richness, relatively high diversity and low value of AMBI resulting in high M-AMBI. It was located along the southern coast of the bay at sandy sediments and inhabited by a community identified in previous classification by Trayanova (2009) as *S. filicornis, Ch. gallina* community.

The worsening of the ecological status was reflected by the increasing of the percentage of opportunistic taxa (ecological groups IV and V) and decreasing of sensitive and indifferent taxa (ecological groups I and II) in the abundance (Fig. 4).

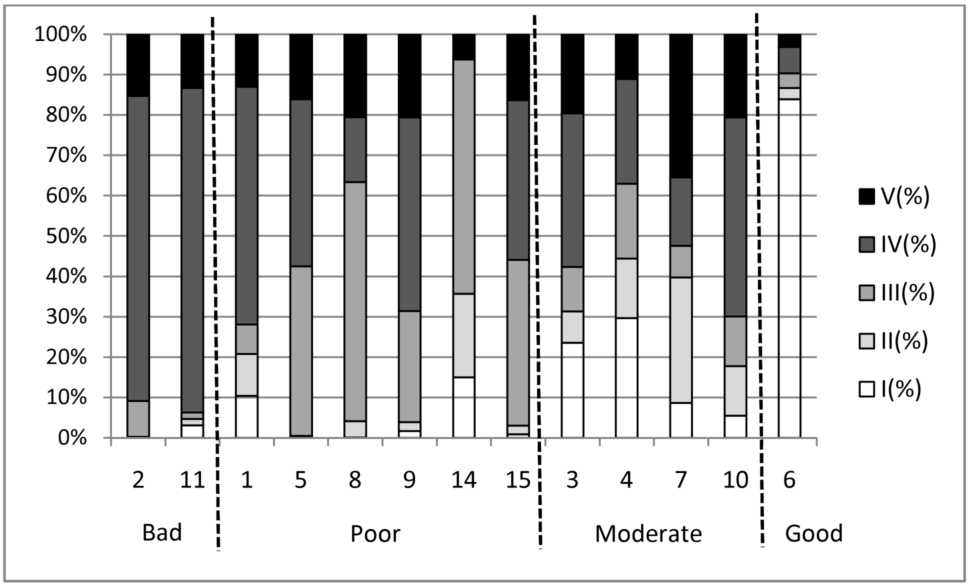

Fig. 4. Percentage of ecological groups from total abundance per station.

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