ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., Suppl. 2, 2008: 275-282

Ecological Characteristics of the Foraminiferal Fauna (Protozoa: Foraminifera) of the Bulgarian South Black Sea Area

Blagovest K. Temelkov

Department of Ecology and Environmental Conservation, Faculty of Biology, University of Plovdiv, 24 Tsar Assen Str., Plovdiv 4000, Bulgaria, e-mail: blagovest_temelkov@abv.bg

Abstract: The research provides a synecological characteristic of the foraminiferal communities inhabiting five types of sediment from the upper sublittoral (down to 20 m depth), seashore pools and river mouths of the Bulgarian South Black Sea area. It determines the species' frequency of occurrence, the dominant structure and similarity of the foraminiferal communities. In the sea samples *Ammonia tepida, Ammonia compacta* and *Elphidium macellum* are found in all sediment types, but only one of them, *A. tepida,* is found in seashore pools and river mouths. An assessment is made of the ecological conditions in the studied sediment types, using some basic characteristics of the communities' species-structure. It shows that the best conditions for foraminiferal development exist in fine-grained (predominant fraction over 50%), sandy sediment of the sea upper sublittoral.

Key words: ecology, Foraminifera, Black Sea, Bulgaria.

Introduction

There have been many publications and data regarding the species diversity of the Black Sea foraminiferal fauna, but the synecological characteristics of the separate communities have been considerably less studied (Valkanov 1957, Valkanova 1981, Janko, Troizkaya 1987, Yanko 1990). This is even more valid for the Western Shelf (the Bulgarian coast). The exact clarification of the role of foraminiferal communities in the Black sea ecosystem requires knowledge of various aspects of their ecology.

The aims of this publication are: (1) to describe the foraminifera frequency of occurrence and the dominant structure in any of the investigated sediment types, (2) to determine the faunistic similarity among the foraminiferal communities, (3) to evaluate the ecological conditions in the investigated sediments by means of several basic characteristics of the communities' species structure.

Material and Methods

The site of research is the Black Sea southern Bulgarian shore, from Nessebar Peninsula (south of Cape Emine) to the mouth of the Silistar River (just north of the boundary river of Rezovska). The material (benthos samples) was collected during the summer season (June – August) from 1997 to 2000. Those from the sea's upper sublittoral (down to the 20 m isobath) are from 16 locations (1. Nessebar Bay – UTM: NH52, 2. Pomorie Bay, - UTM:NH51, 3. Bourgas Bay (Front of Atanassovski Beach) – UTM: NH41, 4. Bourgas Bay (Front of Mandren Firth Canal) – UTM:NH30, 5. Vromos Bay – UTM:NH40, 6. Sozopol Bay – UTM:NG59, 7. Aleppu Bay – UTM:NG68, 8. Ropotamo Bay – UTM:NG68, 9. Stomoplo Bay – UTM:NG68, 10. Primorsko Bay – UTM:NG67, 11. Kiten Bay – UTM:NG67, 12. Lozenetz Bay – UTM:NG67, 13. Tzarevo Bay – UTM:NG76, 14. Nestinarka Bay –

UTM:NG76, 15. Varvara Bay – UTM:NG76, 16. Veleka Bay – UTM:NG85), from each of which 4 samples were taken; 1 sample was taken from each of another 16 locations (17. Pomorie Lake – UTM:NH51, 18. Atanassovsko Lake – UTM:NH31, 19. Bourgas Lake – UTM:NH30, 20. Mandra-Poda Lake Complex (Southeast shore) – UTM:NG39, 21. - Mandra-Poda Lake Complex (West shore) – UTM:NG39, 22. Aleppu Lagoon – UTM:NG58, 23. The Ropotamo River mouth – UTM:NG58, 24. The Ropotamo River (Left bank) 1, 5 km before river mouth – UTM:NG58, 25. The Ropotamo River (Right bank) 3 km before river mouth – UTM:NG58, 26. The Ropotamo River (left bank) 5 km before river mouth – UTM:NG58, 27. Stomoplo Lagoon – UTM:NG58, 28. Diavolsko Swamp – UTM:NG67, 29. Karaagach Swamp – UTM:NG67, 30. The Tsarevska River mouth – UTM:NG76, 31. The Veleka River mouth – UTM:NG75, 32. The Silistar River mouth – UTM:NG85) in seashore pools and river mouths (Fig.1).

Sixteen quantity samples were studied from 5 sediment types: silt-clay from seashore pools and river mouths, silt-sand, fine-grain, medium-grain and large-grain sand from the sea. They were collected by a scuba diver, using a small sampler with an opening of 120 cm^2 and depth penetration 10 cm (Jorissen 1999).

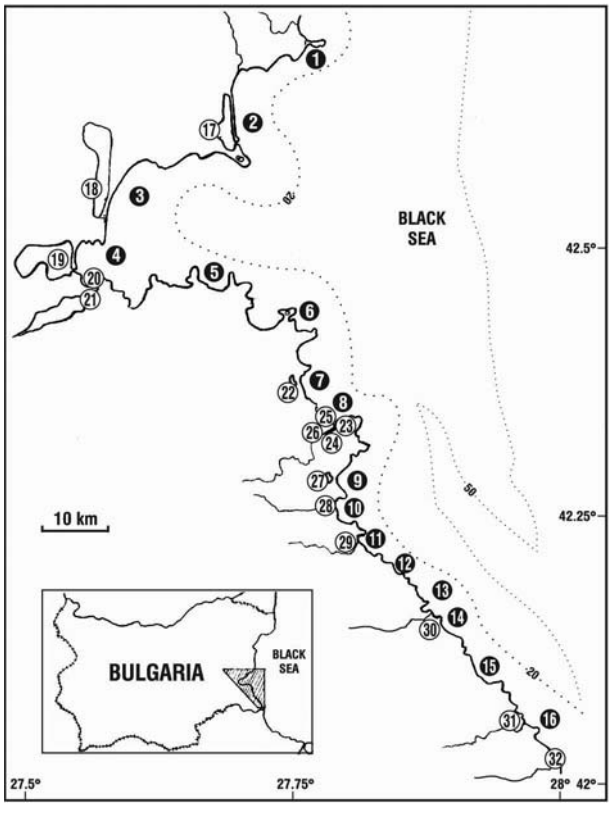

Fig. 1. Map of locations of the Bulgarian South Black Sea area.

The samples were washed on site through lab sieves and conserved in neutralized formalin. The processing of the collected samples – colouring (rose bengal) and isolating of the foraminiferas using a heavy liquid – was made in laboratory conditions, by the method published by Buzas, Severin (1982). The granulometric structure of the sediments was determined by a method, published by Schwanov (1969), and classification was made on the basis of the predominant fraction (over 50%): large-grain sand (1 – 0.5 mm); medium-grain sand (0.5 – 0.25 mm) and fine-grain sand (0.25 – 0.1 mm) (Sultanov, 1988). In the cases when the aleuritic (0.1 – 0.01 mm) and pelitic (>0.01 mm) fractions exceed 50% the sediment was marked as silt-sand or silt-clay respectively. The following keys are used in the tables and the figures in the text: m1 - Fine-grain sand; m2 - Medium-grain sand; m3 - Large-grain sand; m4 - Silt-sand sea sediment of the upper sub-littoral and m5 - Silt-clay sediment from seashore pools and river mouths.

The species' frequency of occurrence has been calculated by the formula pF = (m/N).100, where m is the number of samples in which a species was found, and N – the total sample number (Naidenov 1985). According to the values of pF the species were divided into the following categories (Bodenheimer 1955, Balogh 1958): constant – found in more than 50% of the samples; accompanying – found in 25-50% of the samples; random – found in less than 25% of the samples.

The index of Chekanowski-Sorrensen (I_{cs}) (cited by Pesenko 1982) was used for comparing the degree of similarity among the foraminiferal communities in the studied sediments.

The indices of Shannon-Weaver (H') – for information, Margalef (Dmg) – for species diversity, Simpson (C) – for concentration of domination, Fisher-Williams (α) – for species diversity and Pielou (E) – for equalization, recommended by Odum (1975), were used for analyzing the spe-

cies structure of the foraminiferal communities in the studied sediments. The mathematical formulae of all above-mentioned indices are published in the study "BIODIV Program for Calculating Biological Diversity Parameters, Similarity, Niche Overlap, and Cluster Analysis" (Baev, Penev 1995), and their values were calculated using the "BIODIV"computer programme.

Results and Discussion

Frequency of Occurrence of Species in the Studied Sediments

As a result of the faunistic research 27 species and 1 subspecies were found, belonging to 17 genera of 10 families of the following orders: Allogromiida, Astrorhizida,Lituolida,Trochamminida,Textulariida, Miliolida and Rotaliida (Loeblich, Tappan 1988, 1992, Sen Gupta 1999).

The distribution and numbers of foraminiferas in the various types of sediment were determined on the basis of the granulometric analysis results. These results are shown in Table 1.

The largest species variety was found in the fine-grain sand of the upper sublittoral, where 20 species were found. The members of the family

Table 1. Distribution of the foraminifera species depending on the sediment type, number of specimens of each species, and frequency of occurrence (the bracketed numbers in %)

Taxa	m1	m2	m3	m4	m5	Total Number
Allogromia sp.	-	-	-	-	25 (37.5)	25
Ammobaculites sp.	-	-	-	-	3 (18.8)	3
Ammonia ammoniformis	109 (75.0)	58 (68.8)	-	1 (6.3)	-	168
Ammonia compacta	148 (68.8)	495 (87.5)	19 (56.3)	2 (12.5)	-	664
Ammonia tepida	262 (100)	149 (87.5)	5 (25.0)	12 (43.8)	5 (12.5)	433
Ammonia sp.	5 (6.3)	-	-	-	1 (6.3)	6
Aubignyna perlucida	6 (12.5)	-	-	-	1 (6.3)	7
Cribroelphidium parkerae	12 (12.5)	2 (6.3)	-	-	-	14
Cribroelphidium. poeyanum	51 (43.8)	11 (25.0)	-	-	-	62
Cribroelphidium translucens	-	3 (12,5)	-	-	-	3
Elphidium cf. *sculpturatum*	8 (18.8)	-	-	-	-	8
Eggereloides scabrus	13 (18.8)	-	-	-	1 (6.3)	14
Elphidium macellum	68 (43.8)	98 (81.3)	3 (12.5)	2 (6.3)	-	171
Elphidium ponticum	18 (25.0)	34 (56.3)	-	-	-	52
Elphidium. sp.	4 (18.8)	-	-	-	-	4
Haynesina anglica	30 (18.8)	7 (18.8)	-	-	-	37
Jadammina macrescens dacica	-	-	-	-	4 (12.5)	4
Lachlanella planciana	7 (12.5)	2 (6.3)	-	-	-	9
Massilina secans	-	29 (37.5)	-	-	-	29
Miliolinella subrotunda	-	6 (12.5)	-	-	-	6
Nonion pauciloculum	4 (18.8)	-	-	-	-	4
Nonion depressula v. *matagordana*	-	5 (18.8)	-	-	-	5
Porosononion martcobi	112 (62.5)	51 (50.0)	-	5 (18.8)	-	168
Psammosphaera sp.	2 (6.3)	-	-	-	3 (12.5)	5
Quinqueloculina laevigata	3 (6.3)	17 (18.8)	-	-	-	20
Quinqueloculina lata	9 (18.8)	9 (18.8)	-	-	-	18
Quinqueloculina seminula	10 (18.8)	41 (37.5)	-	-	-	51
Trochammina inflata	-	-	-	-	6 (18.8)	6
Number of species/Number of specimens repr.	20/881	17/1017	3/27	5/22	9/49	28/1996

Elphidiidae (8 species), and family Rotaliidae (6 species), together representing 70% of the species found in this sediment, are predominant.

The middle-grain sand is also characterized by a considerably large species variety of the foraminiferal fauna. Unlike the fine-grain sand, here the number of species of the family Hauerinidae increased, but the species from the families Elphidiidae and Rotaliidae dominated here, too. The remaining two types of sediment – the large-grain sand and the silt-sand – show a marked decrease of species variety, the species number being 4 – 6 times smaller than those in the fine-grain and medium-grain sand (Fig. 2)

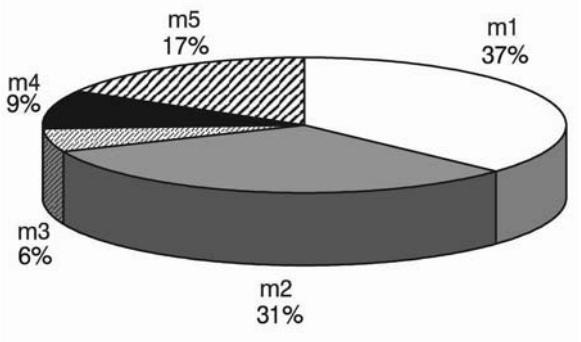

Fig. 2. Percentage quantity ratio of the number of species found in the separate sediment types.
Key: (I) Fine-grain sand; (II) Medium-grain sand; (III) Large-grain sand; (IV) Silt-sand sea sediment; (V) Silt-clay sediment from seashore pools and river mouths.

A characteristic trait of some of these species, namely *Ammonia compacta*, *Ammonia tepida* and *Elphidium macellum,* is that they are found in all of the five sediment types.

The above species are eurybionts with broad ecological plasticity and great adaptive capability. Unlike them a large part of the other species was found in only one sediment type.

An important aspect for characterizing the separate species is their frequency of occurrence (pF) in the investigated sediments. It has been shown for each species as a percentage of the total number research samples, in Table 1 (the figures in brackets).

In the fine-grain sediment the constant species are 4, one of them being present in all studied samples. Of the remaining 16 species 3 are accompanying and 13 – random.

In the medium-grain sediment the number of constant species is 5, no 100%-presence species. Accompanying – 3, random – 9.

In the large-grain sediment only one species was found for each of the three categories – constant, accompanying and random.

In the silt-sand sediment only 1 of the 5 species found is accompanying, the rest are random.

The seashore pools and river mouths also lack constant species. One of the nine species found is accompanying, the remaining 8 are random.

As seen from the review of the results, in the sea samples *Ammonia compacta*, *Ammonia tepida* and *Elphidium macellum* are found in all sediment types, but only one of them, *A. tepida,* is found in all the five biotopes.

Dominant Structure of the Foraminiferal Communities

The relative abundance n/N (where **n** is the number of individual representatives of each species; and **N** – their total number) was used to determine the dominant structure of the foraminiferal communities. All species were divided into 4 groups according to the 4-grade classification of Tischler (1955): subrecedent - n/N < 1; recedent - n/N between 1 – 2%; subdominant - n/N between 2-5%; dominant - n/N > 5%.

In the fine-grain sediment 5 species of the 20 discovered were found to have relative significance over 5%, hence, they dominante. They are: *Ammonia tepida*, *Ammonia compacta*, *Porosononion martcobi, Ammonia ammoniformis*, *Elphidium macellum* and *Cribroelphidium poeyanum*, comprising 85.4% of the total number of individual representatives for this sediment type. Two of the remaining species are subdominant, 4 – recedent and 8 – subrecedent.

In the medium-grain sediment the dominant species are 5 - 83.9% of the total number of individual representatives. They are the same as in the previous group, but differently arranged according to their relative significance, namely: *Ammonia compacta*, *Ammonia tepida*, *Elphidium macellum, Ammonia ammoniformis* and *Porosononion martcobi*. Three of the remaining 12 species are subdominant, 2 – recedent and 7 – subrecedent.

In the large-grain group the dominant species were found to be *Ammonia compacta*, *Ammonia tepida* and *Elphidium macellum.* The species found in the previous two types of sand are missing. This provides ground for the conclusion that the predominance of large grains (over 0.5 mm) in the sand sediment is a limiting factor for a large number of foraminiferal species.

In the silt-sand and silt sediment of the sea coves, out of the 5 species found only one is subdominant (*Ammonia ammoniformis*) – the rest are dominant. These are the same species (*Ammonia tepida*, *Ammonia compacta*, *Elphidium macellum* and *Porosononion martcobi*), dominant in the previous types of sediment, which shows their ability to adapt to this type of sediment, too. Here the highest percentages belong to *A. tepida* (54.6) and *P. martcobi* (22.8), as in the fine-grain sediment, whereas in the large-grain group the highest percentage is that of *A. compacta* (70.4), like in the medium grain sediment. This fact shows that *A. compacta*, the largest-sized species, is comparatively better adapted to the sands with predominantly medium- and large-grain fractions.

In the silt-clay sediment of the seashore pools and river mouths 6 species are dominant, of which *Allogromia* sp. with the highest percentage (51.1%), the remaining 3 species are subdominant.

The analysis of the dominant structure of the foraminiferal communities in the studied sediments shows that with the exception of the silt in seashore pools and river mouths, the dominant species in the remaining 4 sediment types are almost identical. Only *Ammonia tepida* is dominant in all 5 types.

A structure diagram, suggested by Couteaux (1976), was used to give a clearer idea of the dominant structure of the foraminiferal communities in the studied sediments. A histogram is given for each of the various sediment types (Fig. 3), in which the species are arranged according to their relative abundance in descending order. These histograms visualize Thieneman's first biocenotic principle, e.g. that in a favourable environment a large number of species can be found, each represented by a few specimens, whereas in unfavourable ones few species are found, but represented by a large number of specimens.

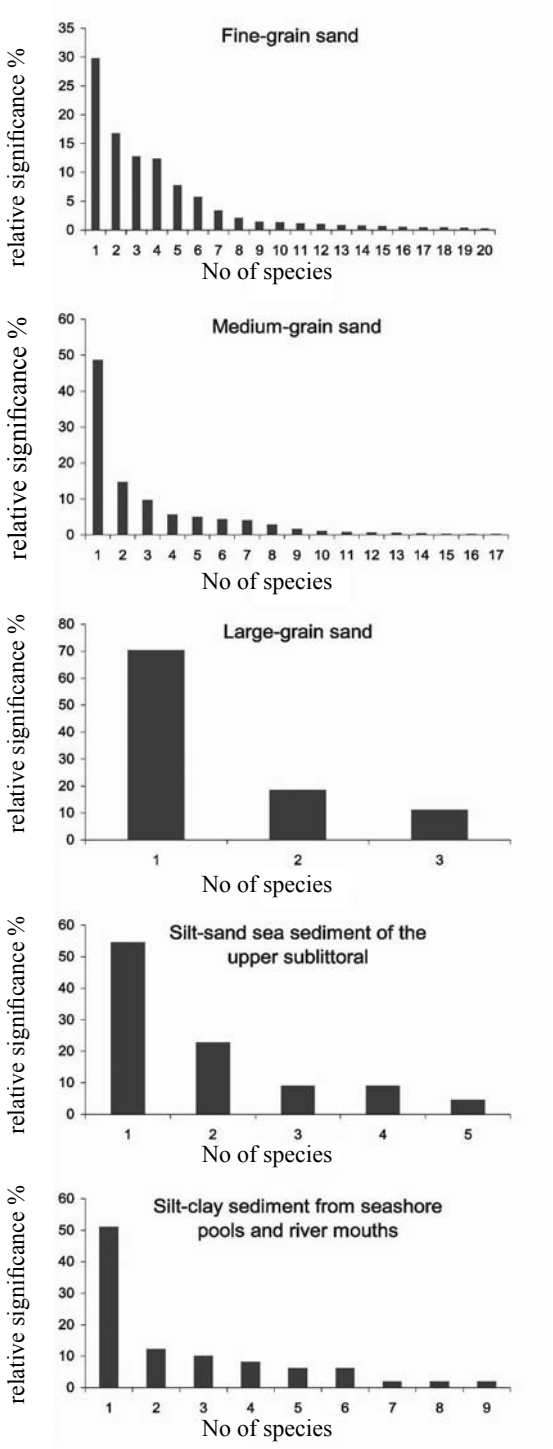

Fig. 3. Structure of the foraminifer communities in the studied sediments.

The diagrams of the studied communities show that the relatively most favourable combination of ecological factors exists in the conditions of the fine-grain sand, where the number of species is the largest, but most are represented by a few specimens. In the remaining sediment types the conditions for

foraminiferal development are comparatively less favourable, as one of the species is represented by over 50% of the total number of the individual specimens found.

Faunistic Similarities among Foraminiferal Communities

The results from the calculations of the Chekanowski-Sorrinsen index are shown in Table 2, and graphically by a dendrogram (Fig. 4). From them it can be seen, that the greatest similarity of foraminiferal populations exists between those of the fine-grain and medium-grain sand sediment on the one hand, and between the large-grain sand sediment and the silt-sand one on the other hand, the values of I_{cs} for them being between 0.375 and 0.565. Apart from that, it can also be seen that the most clearly divergent is the faunistic complex in seashore pools and river mouths, which shows the least faunistic resemblance to the ones in the other sediment types (I_{cs} is between 0.00938 and 0.143). These results are determined by the specific environmental conditions in the five sediment types and the communities related to them.

Assessment of the Ecological Conditions in the Studied Sediments Using Several Basic Indices for the Species Structure of the Communities

The indices of Shannon-Weaver (H') – for information, Margalef (Dmg) – for species diversity, Simpson (C) – for concentration of domination, Fisher-Williams (α) – for species diversity and Pielou (E) – for equalization, recommended by Odum (1975), were used for analyzing the species structure of the foraminiferal communities, and to asses the ecological conditions in the studied sediments. The calculation results are presented in Table 3.

As can be seen from the table, the index for concentration of domination (C) is the lowest in the fine-grain sand. This shows that the relatively most favourable conditions for living of the foraminiferas exist there. The values are also comparatively low for the medium-grain sand and for the silt-clay sediment from seashore pools and river mouths, which indicates that they also offer favourable conditions for foraminiferas' development. As for the remaining two sediment types (large-grain and silt-sand sediment from sea coves), this index is considerably higher. This shows that one or several factors in them acquire limiting significance, so a large part of the foraminiferas cannot find suitable conditions for their development.

Table 2. Values of I_{cs} for degree of similarity.

	m1	m2	m3	m4	m5
m1	1	0.565	0.0595	0.0466	0.0215
m2		1	0.0517	0.0405	0.00938
m3			1	0.375	0.132
m4				1	0.143
m5					1

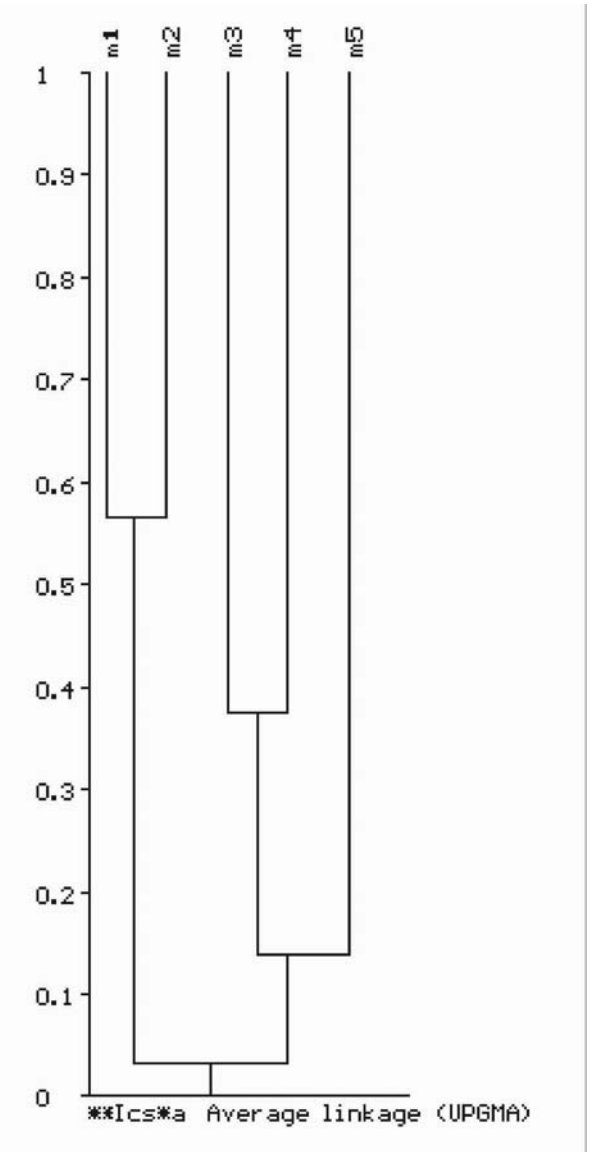

Fig. 4. Dendrogram showing the degree of similarity among the foraminifer communities from the separate sediment types.

Table 3. Indices for the species structure of the foraminiferal communities in the investigated sediments of the study Site.

Indices	m1	m2	m3	m4	m5
(Dmg)	2.8	2.31	0.607	0.985	2.06
(H')	2.18	1.81	0.804	1.11	1.62
(E)	0.729	0.638	0.732	0.8	0.736
(C)	0.16	0.278	0.542	0.401	0.301
(α)	3.64	2.9	0.864	1.47	3.24

Legend: (Dmg) – Margalef's index of species diversity; (H') – Shannon-Weaver`s information index; (E) – Pielou`s equalization index; (C) – Simpson`s index for concentration of domination; (α) - Fisher-Williams`s index of species diversity.

Contrary to (C), the indices (Dmg), (H'), (E) and (α) are comparatively highest for the fine-grain sand, and a bit less for the medium-grain sand and for the silt-clay sediment from seashore pools and river mouths. For the remaining two sediment types (large-grain and silt-sand sediment from sea coves) they have lower values. This once again proves the above conclusions, which can be summarized as follows:

- from all studied sediments the most favourable living conditions for foraminiferas exist in the fine-grain sand;

- the medium-grain sand and the silt-clay sediment from seashore pools and river mouths also offer favourable conditions for foraminiferas' development, but their species diversity is less as compared to that of the fine-grain sand sediment;

- in the large-grain sand and silt-sand sediments foraminiferas' development is limited by unfavourable factors in these sediments; because of that species diversity in them is much smaller;

- the most unfavourable conditions for foraminiferas' development are offered by the large-grain sandy sediment, where only eyrybiotic species, possessing large ecological plasticity, can develop; as a result, the species diversity there is the lowest.

References

Baev P., L. Penev 1995. BIODIV Program for Calculating Biological Diversity Parameters, Similarity, Niche Overlap, and Cluster Analysis. Version 5.1, Second edition, Published by Exeter Software, Sofia – Moscow, Pensoft. 43 p.

Balogh J. 1958. Lebensgemeinschaften der Landtiere, Berlin, 560 p.

Bodenheimer F. 1955. Precis d'ecologie animale, Paris, 315 p.

Buzas M., K. Severin 1982. Distribution and Systematics of Foraminifera in the Indian River, Florida. – *Smithson. Contrib. Mar. Sci.*, **16**: 1-73.

Coûteaux M. 1976. Dynamisme de l'équilibre des Thécamoebiens das quelques sols climatiques. - *Mém. Mus. Nat. d'Hist. Nat., Sér A, N. S.* (Zool), **96**: 1-183.

Jorissen F. 1999. Benthic foraminiferal microhabitats below the sediment-water interface. - In: Sin Gupta, B. (ed.), Modern Foraminifera, Kluwer Academic Publishers, Dordrecht, Boston, London, 161-179.

Loeblich Jr. A., H. Tappan 1988. Foraminiferal Genera and Their Classification. v. 1-2, Van Nostrand Reinhold, New York, 970 p.

Loeblich Jr., A., H. Tappan 1992. Present status of foraminiferal classification. - In: Takayanagi, Y., T. Saito (eds.), Studies in Benthic Foraminifera, Tokai University Press, Tokyo, 93-102.

Naidenow W. 1985. Die Auswirkung der Wasserbauten auf das Zooplancton im österreichischen Donauabscchnitt. - In: Die Auswirkung der Wasserbaulichen Massnahmen und der Belastung auf das Plankton und das Bentos der Donau. BAW, Sofia, 72-102.

Odum E. 1975. Fundamentals of Ecology, "Mir" Publishers, Moscow, 740 p. (In Russian).

Pesenko Y. 1982. Principles and Methods of Quantitative Analysis in Faunal Research, ASc, Zool. Inst., "Nauka" Publishers, Moscow, 288 p. (In Russian).

Schwanov V. 1969. Sand Rocks and Study Methods, "Nedra" Publishers, Leningrad, 611 p. (In Russian).

Sen Gupta B. 1999. Systematics of modern Foraminifera. - In: Sen Gupta, B. (ed.). Modern Foraminifera, Kluwer Academic Publishers, Dordrecht, Boston, London, 7-36.

Sultanov A. 1988. Practical Guidebook on Sedimentology, "Technica" Publishers, Sofia, 704 p. (In Bulgarian).

Tischler W. 1955. Synökologie der Landtiere. Stuttgart, 367 p.

Valkanov A. 1957. Catalogue of the Bulgarian Black Sea Fauna. – *Res. Mar. Biol. Stat.*, **19**: 1-61. (In Bulgarian).

Valkanova C. 1981. Recent foraminifera (Rhizopoda, Foraminifera) off the Bulgarian Black Sea Coast. - *Acta Zool. Bulg.* **18**: 3-14. (In Bulgarian).

Yanko V., T. Troizkaya 1987. Late-Quaternery Foraminifers of the Black Sea, "Nauka" Publishers, Moscow, 109 p. (In Russian).

Yanko V. 1990. Stratigraphy and Paleogeography of the marine Pleistocene and Holocene deposits of the Southern seas of the USSR. - *Mem. Soc. Geol. It.*, **44**: 167-187.

Екологична характеристика на фораминиферната фауна (Protozoa: Foraminifera) на южното българско черноморско крайбрежие

Б. Темелков

(Резюме)

Направена е синекологична характеристика на фораминиферните съобщества, обитаващи пет типа грунд от горния сублиторал (до 20 метра дълбочина), крайбрежни водоеми и речни устия от Южното българско крайбрежие на Черно море. Определена е честотата на срещане на видовете, доминантната структура и сходството на фораминиферните съобщества. В пробите от морето *Ammonia tepida, Ammonia compacta* и *Elphidium macellum* се срещат във всички типове грунд и само един от тях - *Ammonia tepida* се среща в крайбрежните водоеми и речни устия. С помощта на някои основни показатели за видовата структура на съобществата е направена оценка на екологичните условия в изследваните типове грунд. Тя показва, че най-добри условия за развитието на фораминиферите съществуват в дребнозърнестия песъчлив грунд (преобладаваща фракция над 50%) от горния сублиторал на морето.