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Morphology, biometry and ecology of *Arcella gibbosa* Penard 1890 (Rhizopoda, Testacealobosea)

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Summary

Morphology and ecology of the testate amoeba *Arcella gibbosa* Penard 1890 isolated from different microbiotops was investigated. A detailed morphometric description of *Arcella gibbosa* is presented. Size frequency distribution analysis indicates that *A. gibbosa* is a size-monomorphic species. Shell diameter and shell height are the most stable characters, whereas length of apertural collar is the most variable one. Moreover, collar length has no significant correlations with other shell measurements. The main characters determining the distinctions between populations are shell diameter and shell height. These features are stable within a separate population and various in different ones. Populations from one biotope are more similar than those from different ones. There is no discreteness in distribution of the characters between the populations, which demonstrates significant monomorphism and stability of this species. *A. gibbosa* is a highly eurybiontic species, which may dwell in both acidic and toxic conditions, in a great variety of microbiotopes.

Key words: *Arcella gibbosa*, testate amoebae, morphology, morphometry, Rhizopoda, Testacea

Introduction

The genus *Arcella* Ehrenberg 1832 is one of the most numerous testacean genera. More than 130 taxa of the genus have been described. Most of them are cosmopolitan and inhabit mainly freshwater pools, lakes, streams, moist mosses and, rarely, soils (Deflandre, 1928; Chardez, 1989). *Arcella gibbosa* Penard, 1890 is a quite well-studied species. It has been reported from Australia, West Africa, North and South America and

Europe (Ogden and Hedley, 1980). However, there are no significant biometrical and ecological data about this species. The aim of the present study is to characterise *Arcella gibbosa* Penard 1890 morphologically, biometrically and ecologically, using abundant material, collected from different biotopes in Russia.

Material and Methods

The material for the present study was collected in 2002-2003. Morphological characteristics of *Arcella gibbosa* from six populations formed in various habitats were analysed. Description of the samples investigated is given in Table 1.

Morphometric characterisation of the species and construction of an ideal individual from the median of the shell measurements were made according to Schonborn et al. (1983). The following parameters were calculated: $\bar{x}$ - arithmetic mean; M - median (the value used to construct the ideal individual); SD - standard deviation; SE - standard error of the arithmetic mean; CV - coefficient of variation in %; Min, Max - minimum and maximum values; n - number of individuals examined. Shells were isolated under the stereomicroscope at ×100 magnification and measured under light microscope at × 200 magnification. Measurements are given in mm. Frequency distribution and correlation analyses were carried out in order to describe variation of characters. Kolmogorov-Smirnov criterion was used for comparison of two populations. To reveal morphological characters that determine distinctions between populations, as well as to analyse the general pattern of interpopulation polymorphism, the step-by-step linear discriminant analysis was used. As a result of this analysis, canonical axes that in the best way explain morphological distinctions between different populations have been revealed. Cluster analysis based on the Raup-Crick (1979) similarity indices matrix was used for classification of testate amoebae community variants in lake Krugloe. Statistical analysis was performed with the aid of STATISTICA 5.5A and PAST software (StatSoft, 1999; Hammer et al., 1979).

For scanning electron microscopy the shells were isolated, cleaned by several transfers through distilled water, mounted on coverslips and air-dried. The shells on coverslips were coated with gold and examined under Leo 1420, Carl Zeiss scanning electron microscope operating at 10 kV.

Results and Discussion

Description of *Arcella gibbosa* Penard 1890. The shell is colourless in young specimens and light yellow or brown in older specimens, circular in apertural view and idomed or hemispherical, with an enlargement at the basis, in lateral view (the distinct basal border). The shell height/shell diameter ratio is in the range 0.49 - 0.88. The apertural surface and the basal border are smooth, but the aboral hemispheral part has a series of regular depressions. The aperture is invaginated, circular and has a distinct collar. The shell wall is composed of numerous alveoli 1 - 1.5 μm in diameter. They consist of proteinaceous material and are arranged in one layer (Fig. 1).

Biometric characterisation of 182 shells was carried out. The basic measurements are presented together with those by other authors (Table 2). The measurements obtained in the present survey correspond well with the values given in the literature, although the references on the shell size are restricted only to the shell diameter, shell height and aperture diameter. General shell morphology and basic morphometric characters taken into the account in our work are shown in Fig. 2.

Morphometric comparison of the populations studied. The results of morphometric characteristics of the six populations studied are given in Table 3 and Fig. 3. The ideal individual of this species constructed from median values of all characters, is represented in Fig. 4, which also shows extreme specimens. In Table 4 statistical significance (Kolmogorov-Smirnov criterion) of shell measurements between different populations of *Arcella gibbosa* is given. Patterns of variability of all shell measurements (with the exception of aperture length) between populations represent a continuous series of transition forms in the range of limits. According to aperture length, all populations can be divided into three groups. The first group is composed by the populations with the maximal value of the character (12.4 ±5.1) from sample P1. The second one

Table 1. Description of the samples investigated.

Sample	Location	Date of collection	Microhabitat
P1	Penza region, boggy lake	May, 2003	*Sphagnum* mosses, pH 5.0-5.2
P2	Penza region, lake Krugloe	May, 2002	Moss *Fontinalis hypnoides*, pH 4.4-4.8
P3	Penza region, lake Krugloe	May, 2002	Surface of the sandy sediment, pH 4.4-4.8
P4	Yaroslavl region, boggy lake	June, 2003	*Sphagnum* mosses, pH 5.4-5.5
P5	Penza region, damp meadow	May, 2003	Debris among aquatic vegetation (predominately *Carex* sp.), pH 6.5-6.6
P6	Penza region, damp meadow	June, 2003	Debris among aquatic vegetation (predominately *Carex* sp.), pH 6.5-6.6

Table 2. Measurements (in μm) of *A. gibbosa* Penard, 1890 according to different authors.

Authors	Shell diameter	Shell height	Aperture diameter	Length of preapertural cavity
Penard, 1890	80-90	50-60	—	—
Bartoš, 1954	80-90	50-60	—	—
Deflandre, 1928	70-125	49-74	21-32	—
Ogden, Hedley, 1980	90	61	19	10.5-20
Alekperov, Snegovaya, 2000	85-100	50-65	20-35	—
Present work (n=182)	79-111	48.6-76.5	17-36.6	10.2-22.5

includes populations with the average level of the measurement (7.3±1.8; 7.4±1.6, correspondingly) from samples P5 and P6. The third group, populations from the samples P2, P3, P4, is characterised by the minimal value of this character (6.2±0.8; 5.5±0.8; 5.6±1.0, correspondingly). Moreover, in populations from a consecutive sampling from the same locality (P5 and P6) there are no significant differences between the median values of the characters, which indicates stability of morphometric features.

Variability of characters. The analysis of the variation coefficients (Tables 3, 5, Fig. 5) shows that the minimal variability is noted for shell diameter (3.8 - 7.1% in different populations, average 5.4±0.50), shell height (6.0 - 9.8%, 7.9±0.56) and their proportions (shell height/shell diameter 6.1 - 8.1%, 7.2±0.77 and aperture diameter/shell diameter 6.5 - 10.2%, 8.6±1.1). These are the most stable characters in the populations. Maximal variation coefficients are noted for apertural collar length (13.3 - 40.9%, 22.1±4.10), length of preapertural cavity (9.0 - 24.0%, 14.3±2.09) and external diameter of preapertural cavity (7.5 - 14.0%, 10.7±0.91). Variability of aperture diameter is intermediate between the constant and the most variable characters (7.7 - 12.9%, 9.8±0.75). Thus, the variability of the characters investigated changes continuously from minimal values (shell diameter) to maximal values (collar length) through a number of average values (shell height, aperture diameter, external diameter of apertural cavity and length of preapertural cavity).

Variability of characters differs in various populations (Table 3, Fig. 6). Maximal values of variation coefficients of external diameter of preapertural cavity (14.0%), length of preapertural cavity (24.0%) and length of the collar (40.9%) are observed in population P1. There are individuals in this population with a long collar, which in a number of cases protrudes beyond the limits of preapertural cavity. The maximal variability of shell diameter, shell height and aperture diameter (CV - 7.1%, 9.8%, 12.9%, accordingly) is observed in population P5. Taking into account Schonborn's (1971) proposals, one can suggest that a high variability of characters is associated with the absence of rigid spatial restrictions in the biotope where the population dwells, whereas a slight variability of characters may demonstrate the presence of certain biotope restrictions. It is interesting that population P5, formed in a damp meadow in May under conditions of higher moisture content, has a significantly higher variability of the majority of the characters (shell diameter, shell height, aperture diameter) in comparison with the same population (P6) in June, under conditions of lower moisture content. Stabilisation of characters may be the evidence of spatial restrictions emerging as a result of the decrease in moisture content.

Frequency distribution of characters. Size frequency distribution analysis indicates that *A. gibbosa* is a size-monomorphic species by all characters (Fig. 7). For example, 95% of all the individuals measured have a shell diameter of 80 - 110 μm. More than 80% of them fall within the limits of 85 - 105 μm, whereas only 1% have shell diameter less than 80 μm and only 3%, more than 110 μm. Of all the individuals measured, 93% have a shell height 50 - 75 μm and about ¾ of them, 55 - 70 μm. Only 3% have a shell height less than 50 μm and 4% have a shell height exceeding 75 μm. Frequency distribution of most characters is characterised by an approximately zero level of skewness, which indicates that specimens with average measurements predominate in populations (Table 6). At the same time, skewness of frequency distribution of collar length, as well as external diameter of preapertural cavity, shows that specimens with small values of these characters predominate in populations. Only two characters (shell diameter and shell height) have negative values of kurtosis, indicating higher dispersion of average size group in populations. On the contrary, a maximal number of individuals in the populations possess values of external diameter of preapertural cavity and collar length restricted to the narrow size limits within overall size variability.

Correlation analysis of characters. Characteristics reflecting correlation between all the morphological parameters provide additional descriptors of morphological variability of the shell. Absence of a correlation represents a wider phenotypic range of adaptations than a simple proportional decrease or increase in the shell dimensions. Table 7 shows values of the Spearman

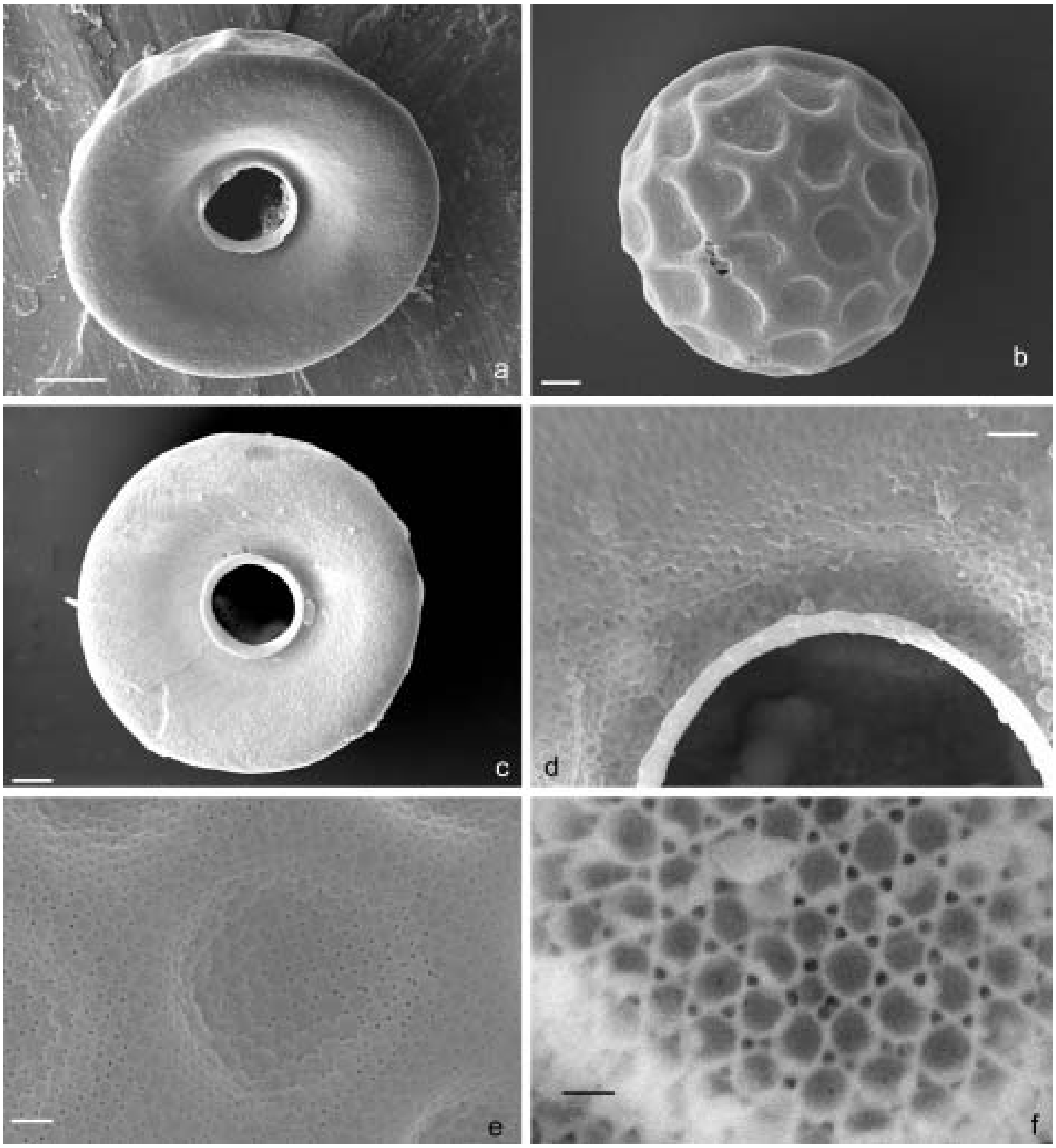

Fig. 1. Morphology of *Arcella gibbosa*, scanning electron microscopy. a - ventro-lateral view, b - aboral view, c - ventral view, d - apertural collar and pores around, e - dorsal surface, f - alveolar structure of the surface. Scale bars: a - 20 μm; b, c - 10 μm; d - 3 μm; e - 2 μm; f - 1 μm.

correlation coefficient between the morphological characters of *A. gibbosa*. Within all populations, collar length has no significant correlations with shell diameter, aperture diameter and length of preapertural cavity. All over, shell measurements have significant positive but not very strong correlations (maximal values do not exceed 0.55).

Discriminant analysis. To reveal the morphological characters which contribute essentially to differences between the populations, discriminant analysis was carried out in three variants: A) absolute values of shell measurements; B) relative values characterising the shape of the organisms; C) all characters together. The results are presented in Fig. 8 and Table 8.

Table 3. Morphometric characterisation of six populations of *Arcella gibbosa* Penard.

Character	X	M	SD	SE	CV	Min	Max	N
(1)								
P1	95.4	95.4	5.6	0.68	5.9	84.9	108.3	70
P2	99.9	100.7	6.1	0.9	6.1	86.1	111	50
P3	96.8	97.1	4.7	1.08	4.9	83.7	105.9	20
P4	105.5	105.8	4.0	0.92	3.8	96	111	20
P5	91.6	92.7	6.5	1.01	7.1	79.8	106.5	42
P6	95.6	94.8	4.2	0.97	4.4	86.4	105.5	20
P1-P6	96.7	96.4	7.2	0.53	7.4	79	111	182
(2)								
P1	66.4	66.3	5.6	0.68	8.5	53.1	75.9	70
P2	66.3	66.0	5.4	0.8	8.1	54.9	76.5	50
P3	64.3	64.2	5.3	1.22	8.3	57	75	20
P4	61.8	62.8	4.2	0.95	6.7	53.5	70.2	20
P5	59.3	60.0	5.8	0.9	9.8	48.6	74.9	42
P6	61.7	62.2	3.7	0.85	6.0	54.6	69	20
P1-P6	63.6	63	6.0	0.45	9.5	48.6	76.5	182
(3)								
P1	23.6	23.7	2.2	0.27	9.4	18.3	29.1	70
P2	25.3	25.2	2.4	0.3	9.5	22.2	36.6	50
P3	22.3	21.8	2.4	0.56	10.9	17.4	27	20
P4	24.5	24.0	1.9	0.44	7.7	21.9	28.3	20
P5	21.7	21.6	2.8	0.44	12.9	17	28.5	41
P6	23.2	23.1	2.0	0.46	8.6	20.1	27.6	20
P1-P6	23.6	23.4	2.7	0.2	11.5	17	36.6	181
(4)								
P1	58.4	57.6	8.2	0.99	14.0	43.2	74.7	69
P2	48.3	48.6	3.6	0.5	7.5	36	57.9	50
P3	48.0	47.4	4.9	1.12	10.2	37.8	59.1	20
P4	54.6	53.4	5.8	1.32	10.6	45.9	67.8	20
P5	52.3	51.0	6.4	1.0	12.2	39.9	67.5	41
P6	52.2	52.5	5.0	1.17	9.6	42.9	63	19
P1-P6	52.5	51.6	6.8	0.51	13.0	36	73.5	180
(5)								
P1	14.1	14.1	3.4	0.41	24.0	6	22.2	70
P2	16.5	16.7	1.9	0.3	11.4	12.6	22.5	50
P3	16.4	15.9	2.3	0.52	13.8	12.3	22.5	20
P4	15.7	15.9	1.4	0.32	9.0	13	18.6	20
P5	14.7	14.9	2.0	0.32	13.9	10.2	19.8	42
P6	14.8	14.9	2.0	0.46	13.5	12	18.9	20
P1-P6	15.5	15.6	2.2	0.16	14.3	10.2	22.5	182
(6)								
P1	12.4	11.6	5.1	0.61	40.9	5.4	24.3	70
P2	6.2	6.0	0.8	0.1	13.3	4.8	9.4	50
P3	5.45	5.6	0.8	0.2	15.0	3.9	6.6	18
P4	5.6	5.7	1.0	0.23	17.7	3.2	7.5	20
P5	7.3	6.9	1.8	0.29	24.0	3.9	13.5	39
P6	7.4	7.2	1.6	0.37	21.9	3.6	10.5	20
P1-P6	7.6	6.9	2.6	0.55	34.2	3.2	17.4	179
(7)								
P2	2.7	2.4	1.1	0.2	41.5	1.2	5.1	29
P3	5.8	6	1.7	0.6	29.3	3.6	8.7	9
P4	5.3	5.5	2.0	0.46	37.4	0.9	8.4	20
P5	3.6	3.6	1.0	0.25	26.8	1.5	5.7	16
P2-P5	3.7	3.3	1.8	0.21	47.6	0.9	8.4	69
proportion (2)/(1)								
P1	0.7	0.63	0.05	0.006	7.2	0.57	0.81	70
P2	0.66	0.67	0.05	0.007	7.8	0.58	0.88	50
P3	0.66	0.66	0.04	0.009	6.1	0.61	0.74	20
P4	0.59	0.6	0.04	0.010	7.5	0.49	0.66	20
P5	0.65	0.64	0.05	0.008	8.1	0.57	0.86	42
P6	0.65	0.65	0.04	0.010	6.5	0.55	0.73	20
proportion (3)/(1)								
P1	0.25	0.25	0.02	0.003	8.6	0.2	0.32	70
P2	0.25	0.25	0.02	0.003	9.1	0.21	0.34	50
P3	0.23	0.22	0.02	0.005	9.0	0.18	0.27	20
P4	0.23	0.23	0.02	0.003	6.5	0.21	0.27	20
P5	0.24	0.24	0.02	0.004	10.2	0.18	0.29	41
P6	0.25	0.24	0.02	0.004	5.5	0.22	0.27	20

Nots: 1-6 – morphometric characters. See Fig. 2 for character designation.

The first two canonical axes explain 87.3% of dispersion in variant "A" of discriminant analysis. The main morphological characters, which affect differences between populations, are (in decreasing order of importance): collar length, shell diameter, shell height, external diameter of preapertural cavity and aperture

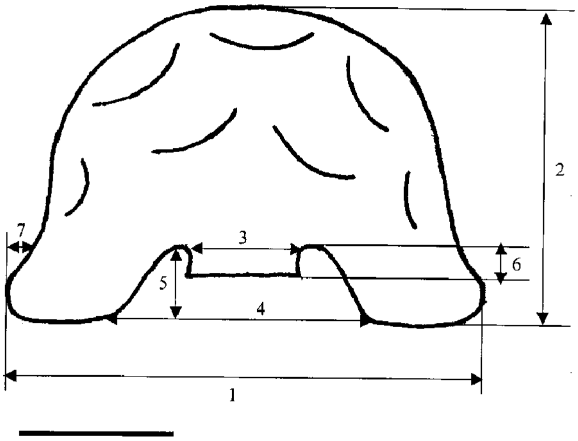

Fig. 2. Basic morphometric characters of *A. gibbosa*. 1 - shell diameter, 2 - shell height, 3 - aperture diameter, 4 - external diameter of preapertural cavity, 5 - length of preapertural cavity, 6 - collar length, 7 - length of the basal border. Scale bar 20 μm.

diameter. Table 8 shows canonical coefficients of characters describing their contribution to the canonical axes (roots). Such measurements as collar length and shell diameter make the maximal contribution to the first canonical axis, whereas shell height and external diameter of preapertural cavity, to the second canonical axis. Population P1 differs from the others in having a longer collar and a not-so-great / rather small shell diameter, while populations P2, P3 and P4 differ in having a small collar and a large shell diameter (Fig. 7). Individuals from population P2 are distinguished by a greater shell height and a not-so-large / rather small external diameter of preapertural cavity, and individuals from the populations P5 and P6, on the contrary, are distinguished by a not-so-large / rather small shell height and a large external diameter of preapertural cavity. However, there are no discontinuous differences between the populations investigated.

The first two canonical axes explain 88.0% of dispersion in variant "B" of discriminant analysis. The main morphological characters the populations differ from each other in are presented in Table 8. Such characters as the ratios collar length/shell height, collar length/shell diameter and length of preapertural cavity/external diameter of preapertural cavity make the maximal contribution to the first canonical axis, whereas the ratios length of preapertural cavity/external diameter of preapertural cavity and collar length/external diameter of preapertural cavity, to the second canonical axis. Population P1 differs from the others in having a greater ratio collar length/shell height, and populations P2 and P3 differ from each other in lesser values of the ratios collar length/shell diameter and length of preapertural cavity/external diameter of preapertural cavity. Population P4 is characterised by minimal values of the ratio length of preapertural cavity/external diameter of preapertural cavity. Moreover, as in variant "A", there are no discontinuous differences between the populations investigated.

Table 4. Statistical significance (Kolmogorov-Smirnov criterion) of shell measurements between the populations of *Arcella gibbosa*.

Shell diameter (upper line) and shell height (lower line)					
	P1	P2	P3	P4	P5
P2	** NS				
P3	NS NS	NS NS			
P4	*** NS	** *	*** NS		
P5	* ***	*** ***	*** NS	*** NS	
P6	NS NS	* *	NS NS	*** NS	NS NS

Shell height/shell diameter (upper line) and aperture diameter/shell diameter (lower line)					
	P1	P2	P3	P4	P5
P2	*** NS				
P3	NS ***	NS ***			
P4	*** *	*** ***	*** NS		
P5	*** NS	NS ***	NS NS	*** NS	
P6	*** NS	NS NS	NS *	*** NS	NS NS

Aperture diameter (upper line) and external diameter of preapertural cavity (lower line)					
	P1	P2	P3	P4	P5
P2	** **				
P3	NS *	*** NS			
P4	NS **	NS **	* *		
P5	*** ***	*** ***	NS NS	*** NS	
P6	NS +	* *	NS NS	NS NS	NS NS

Length of preapertural cavity (upper line) and collar length (lower line)					
	P1	P2	P3	P4	P5
P2	*** ***				
P3	* ***	NS NS			
P4	* ***	NS NS	NS NS		
P5	NS ***	** ***	* ***	NS ***	
P6	NS ***	* **	NS ***	NS **	NS NS

Notes: P1-P6 – populations; *** P < 0.001; ** 0.01 > P > 0.001; * 0.05 > P > 0.01; + 0.1 > P > 0.05; NS – not significant.

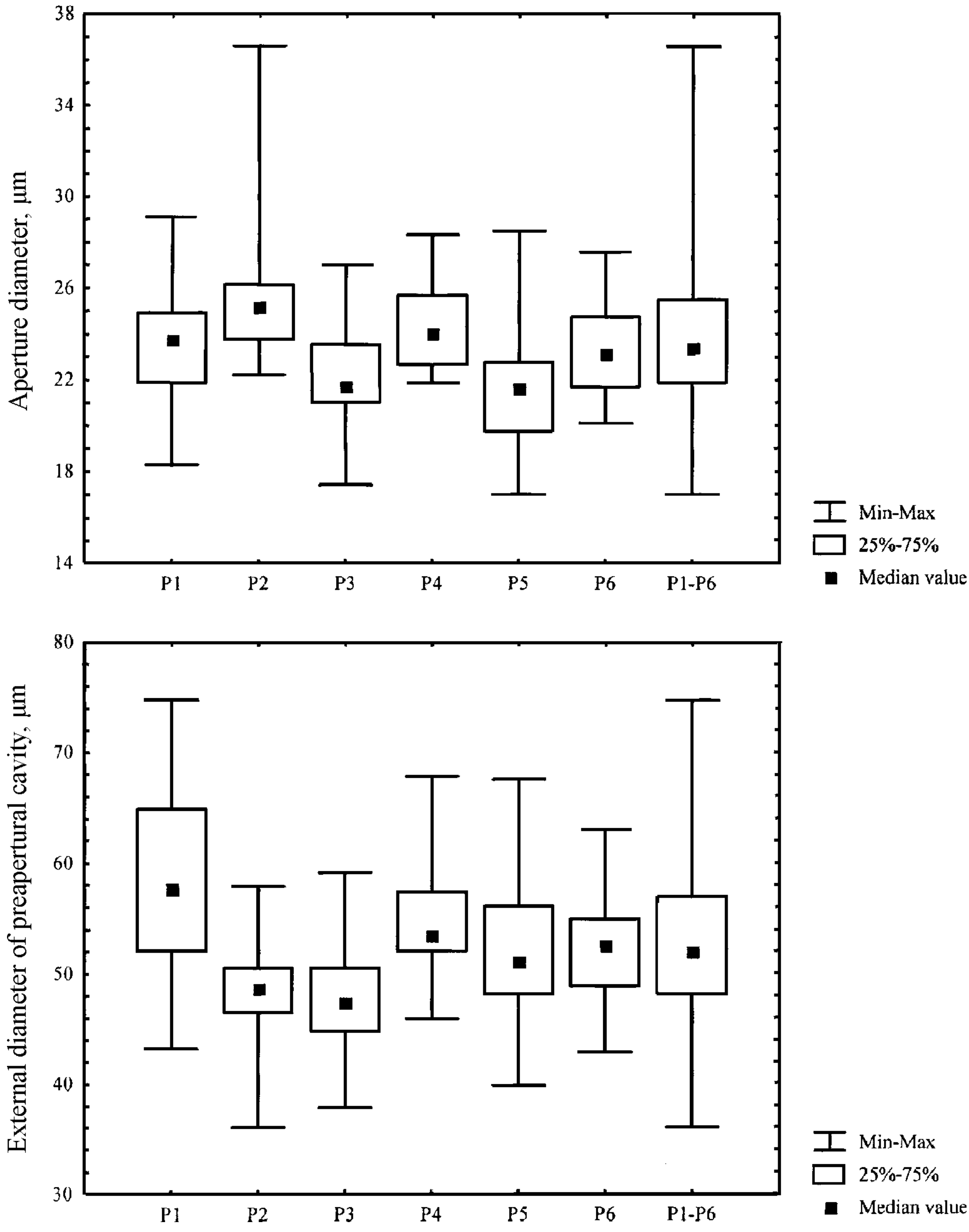

Fig. 3. Morphometry of *Arcella gibbosa* from different populations.

The first two canonical axes explain 84.4% of dispersion in variant "C" of discriminant analysis. The main morphological characters affecting differences between populations are presented in Table 8. The most essential of all are absolute values of shell diameter and shell height. Such characters as the ratios collar length/shell height, shell height, ratios collar length/shell diameter and length of preapertural cavity/external diameter of preapertural cavity make the maximal contribution to the first canonical axis whereas shell diameter, shell height, ratio shell height/shell diameter, to the second canonical axis. Population P1 differs from

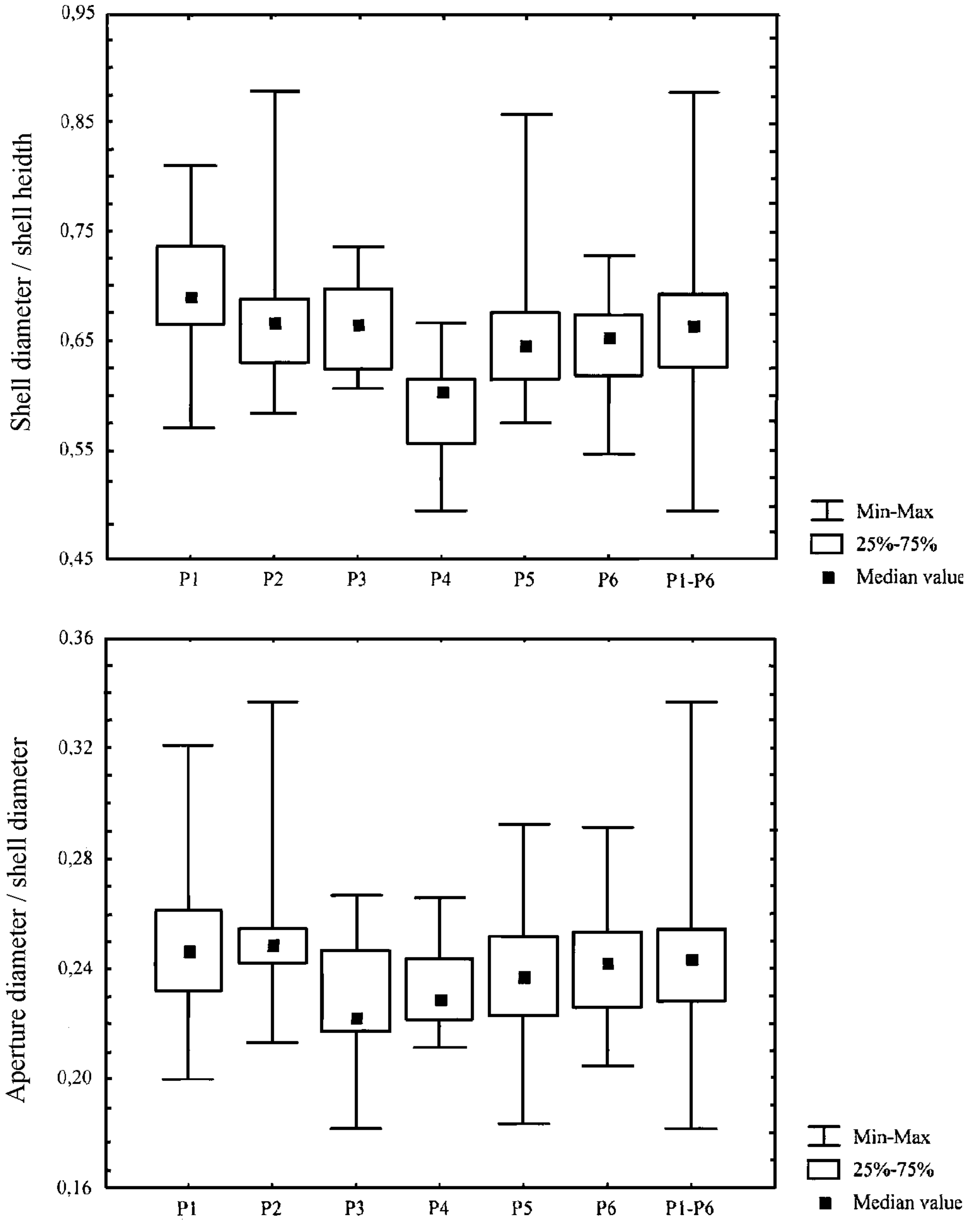

Fig. 3. (Continuation).

the others in having a greater shell length and a greater ratio collar length/shell height, and populations P2, P3 and P4 differ from each other from the others in having a small shell diameter, values ratio collar length/shell diameter and length of preapertural cavity/external diameter of preapertural cavity. Population P4 is characterised by the maximal ratio shell height/shell diameter and a greater shell diameter than populations P2 and P3, which are characterised by rather short shells.

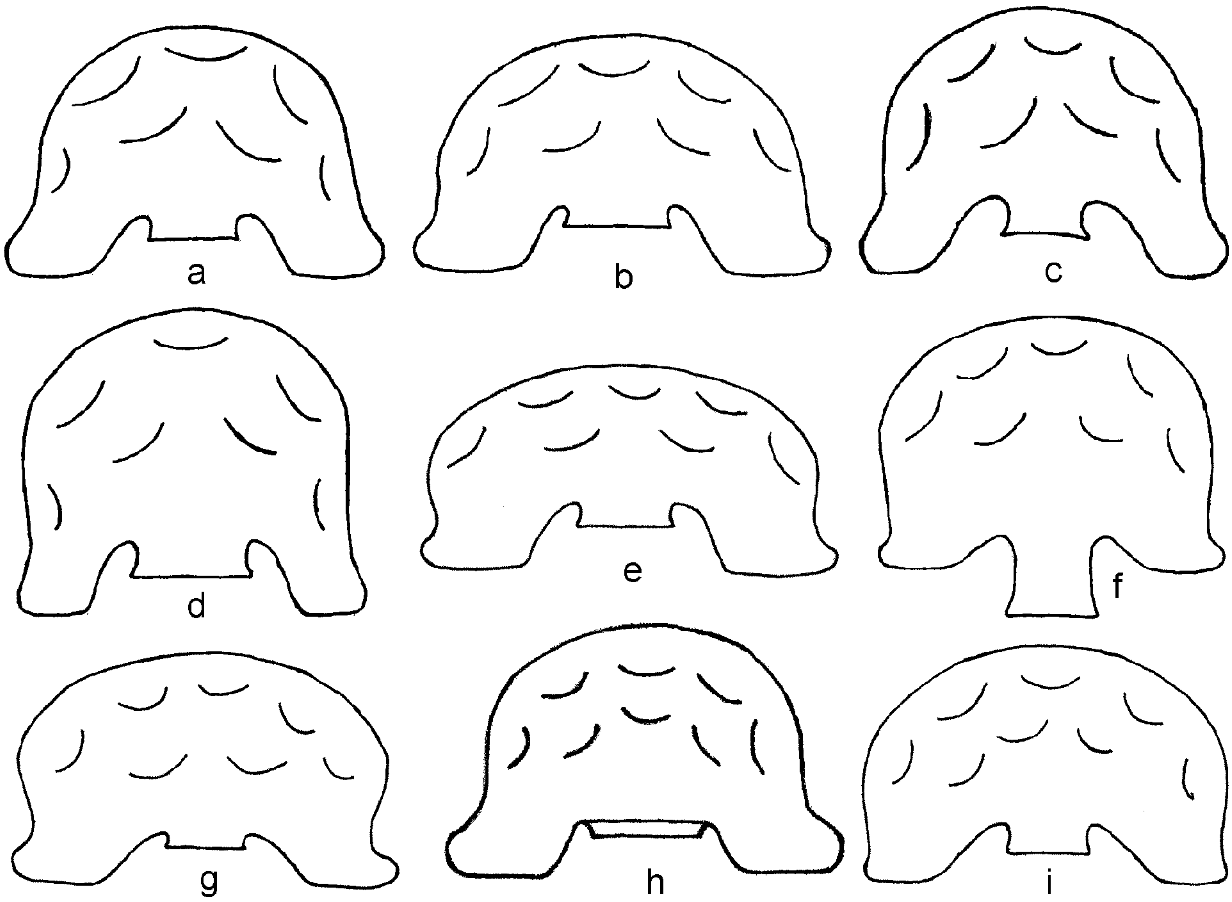

Fig. 4. Ideal individual and extreme specimens of *Arcella gibbosa* from different populations. a - ideal individual constructed from all the specimens studied, b - specimen with maximal shell diameter, c - specimen with minimal shell diameter, d - specimen with maximal proportion shell height/shell diameter, e - specimen with minimal proportion shell height/shell diameter, f - specimen with maximal collar length, g - specimen with minimal collar length, h - specimen with maximal basal border, i - specimen with minimal basal border.

Thus, the results of the discriminant analysis show that: 1) the main characters determining the distinctions between populations are shell diameter and shell height. These features are stable within a separate population and various in different ones; 2) the populations from one biotope are more similar than those from different ones; 3) there is no discreteness in distribution of the characters between the populations, which evidences significant monomorphism and stability of the species investigated.

Discussion of morphological variability of *Arcella gibbosa* and related species. The taxonomy of testate amoebae uses morphological features of their shells as a basis for differentiating species. However, many

Table 5. Statistical significance (Kolmogorov-Smirnov criterion) of the variation coefficients of the characters.

Characters	(1)	(2)	(3)	(4)	(5)	(6)	Proportion (3)/(1)	Proportion (2)/(1)
(2)	NS							
(3)	*	NS						
(4)	*	NS	NS					
(5)	*	NS	NS	NS				
(6)	*	*	*	NS	NS			
Proportion (3)/(1)	NS	NS	NS	NS	NS	*		
Proportion (2)/(1)	NS	NS	NS	NS	*	*	NS	
Proportion (5)/(2)	*	NS	NS	NS	NS	NS	NS	*

Notes: * 0.05 > P > 0.01; NS – not significant. 1-6 – shell characters.

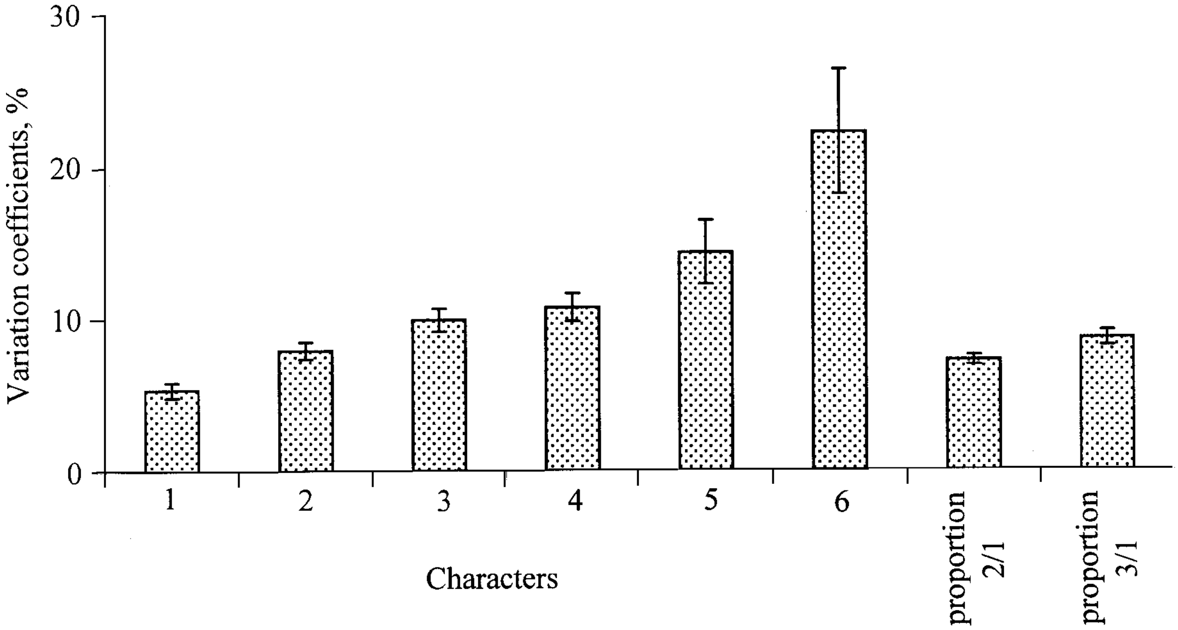

Fig. 5. Variation coefficients of different characters. 1-6 - characters (see Fig. 2 for designation). Whiskers - standard error of the mean.

authors who did detailed morphometry emphasised a high variability of metric shell characters and doubted the validity of many species, varieties and forms described (Schonborn et al., 1983, 1987; Luftenegger et al., 1988; Luftenegger and Foissner, 1991; Foissner and Korganova, 1995; Wanner, 1999). As a result, many investigations suggest an idea of lumping a vast majority of forms (Medioli et al., 1990; Foissner and Korganova, 1995). On the other hand, it has also been shown that testate amoebae shells in separate populations are not extraordinarily variable, in contrast to the widespread belief (Foissner and Korganova, 2000; Bobrov and

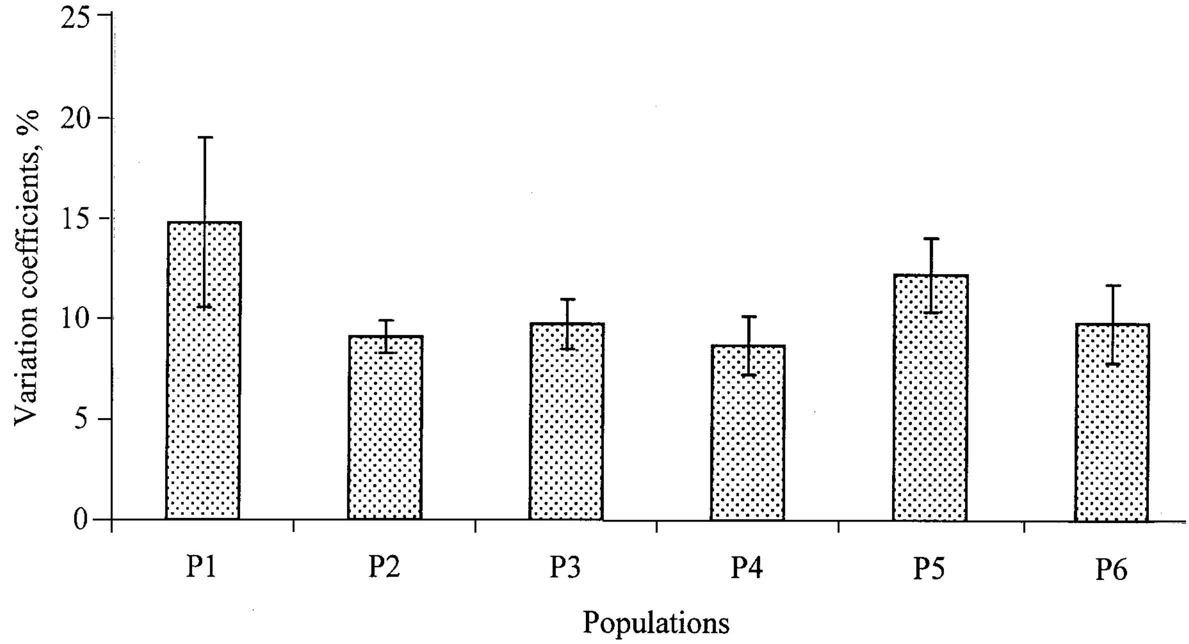

Fig. 6. Mean variation coefficients of all characters in different populations. Whiskers - standard error of the mean.

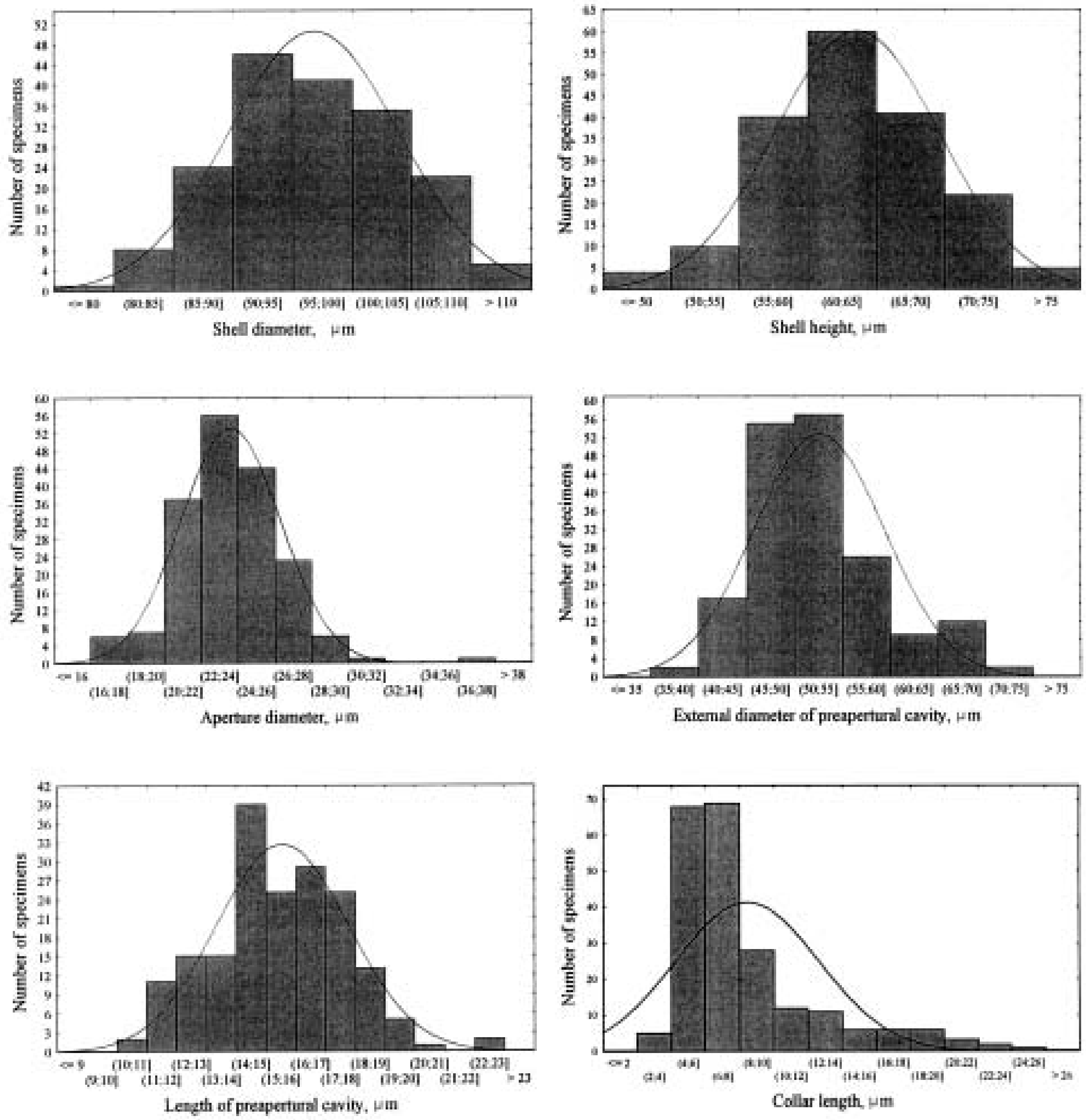

Fig. 7. Size frequency distribution of characters.

Mazei, 2004). A practical solution for the species problem in testate amoebae has recently been proposed (Foissner and Korganova, 2000). These authors suggested to lump taxa, which are morphologically and/ or morphometrically difficult to distinguish, into "complexes". Such idea was successfully applied to sibling ciliate species (Foissner and Berger, 1999).

Table 6. Skewness and kurtosis of characters' frequency distribution.

Characters	1	2	3	4	5	6
Skewness	-0.03	-0.003	0.46	0.76	-0.36	1.79
Kurtosis	-0.44	-0.35	2.00	0.26	0.77	2.65

Notes: 1-6 – shell characters.

There is a great uncertainty in distinguishing closely related forms from the genus *Arcella*, namely *A. gibbosa, A. hemisphaerica, A. jeanneli*, basing on their morphology and morphometry given by earlier authors (Deflandre, 1928, Decloitre, 1974). Five varieties of *A. gibbosa* have been described. Variation appears to be restricted to the number or presence/absence of depressions on the domed aboral region, the length of apertural collar and basal border, the ratio shell diameter/shell height. Some

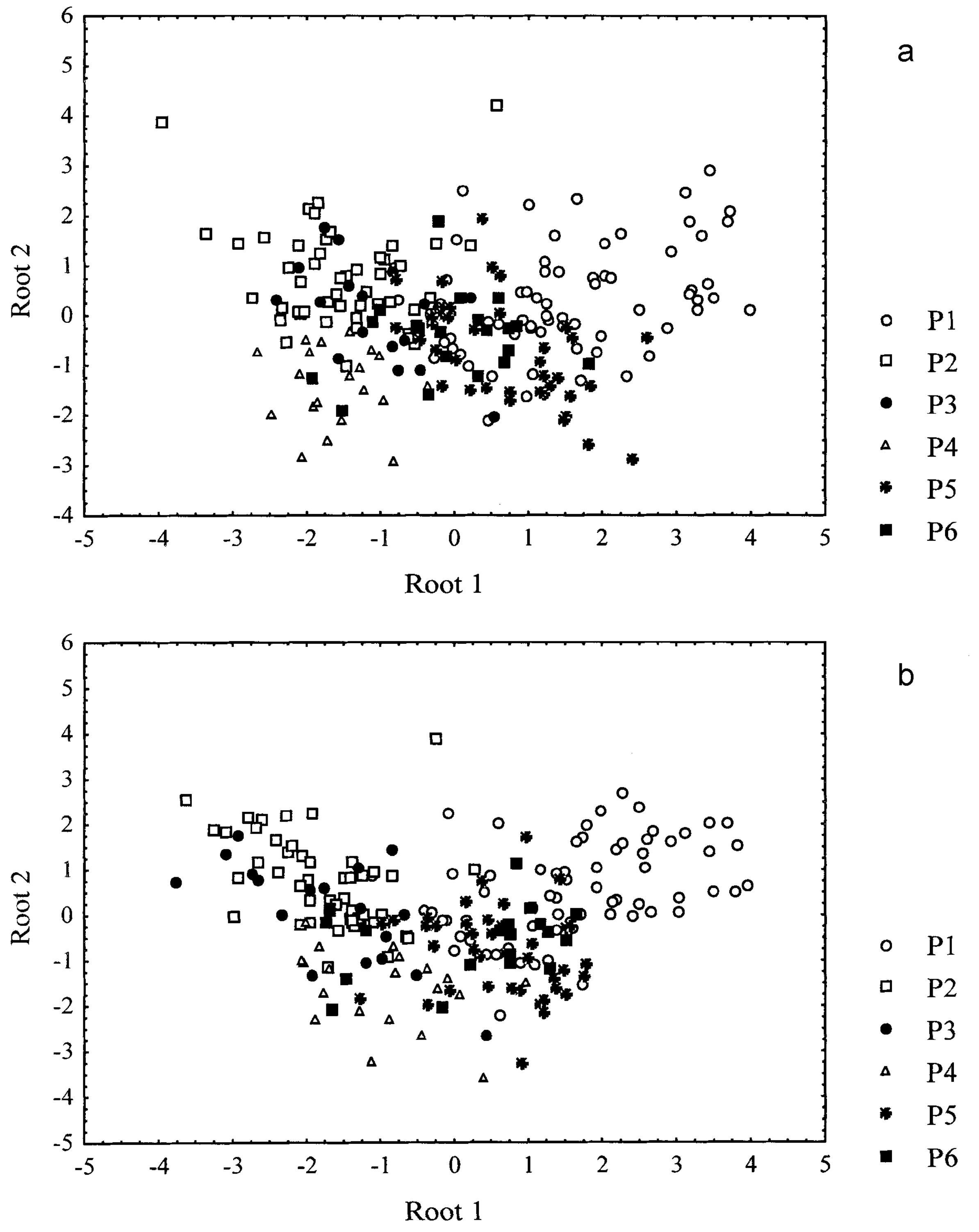

Fig. 8. Scatterplots of discriminant analysis. a-c - different variants of the analysis, P1-P6 - different populations.

of the forms, e.g., *A. gibbosa* var. *laevis* Deflandre, 1928 resemble closely *A. hemisphaerica* group, whereas *A. gibbosa* var. *mitriformis* Deflandre, 1928 tends to be associated with *A. jeanneli*. We cannot offer any taxonomic solution (either practical or theorethical) for this "problematic" species complex until accumulation of sufficient data on morphological variability of its members. Such research would be very important for making alfa-taxonomy of testate amoebae more elegant and more reliable, especially for field ecologists.

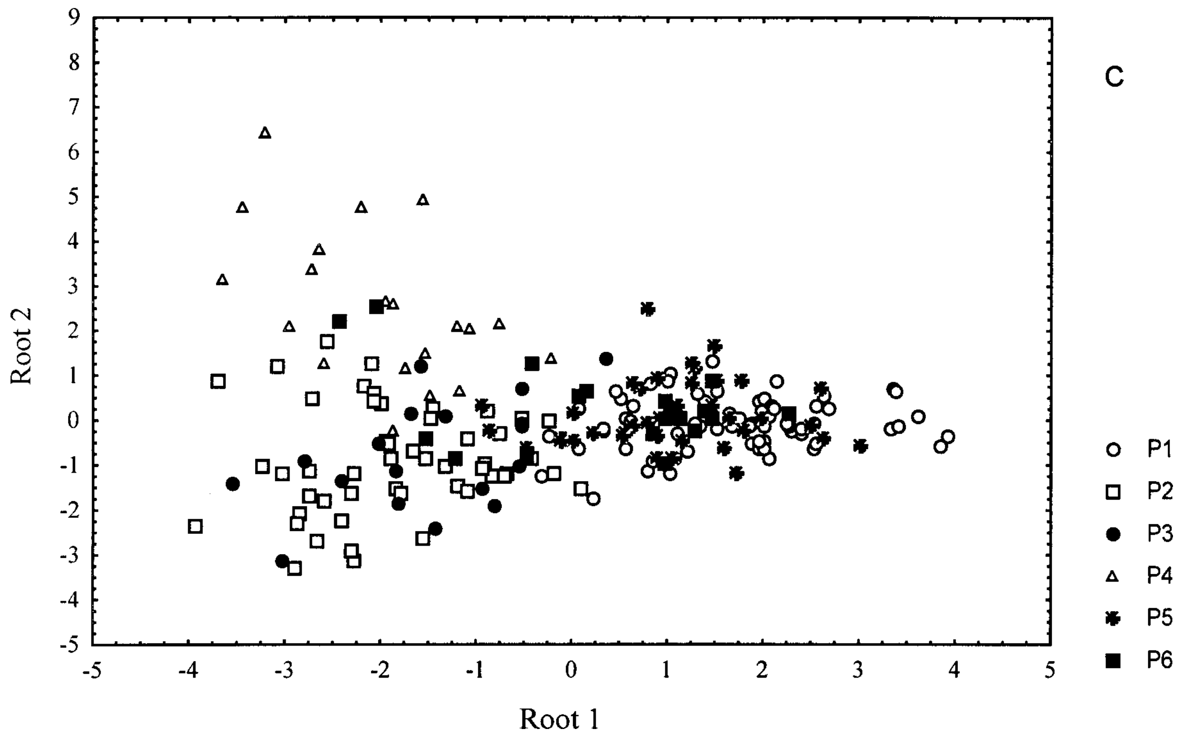

Fig. 8. (Continuation)

Ecology. *A. gibbosa* has been observed in small freshwater bodies, streams, lakes, boggy biotopes (Cash and Hopkinson, 1909; Deflandre, 1927; 1928; Moraczewski, 1961). This species prefers sites with lower mineralization and dwells predominately between aquatic vegetation (Cash and Hopkinson, 1909; Deflandre, 1928; Bartoš, 1954). The results of our investigation show that *A. gibbosa* is a frequent and characteristic species in both moss and sediment microbiotopes in different biotopes (lakes, sphagnum bogs, damp meadows). It may dwell in acidic environment. We studied in detail testate amoebae community structure in lake Krugloe. Chemical weapon destruction took place in this lake in 1960-1970s. Now there is a high content of toxic element As in the water and sediments (more than 10 time higher in comparing with undisturbed background). Common species found in this biotope together with *A. gibbosa* were: *Arcella arenaria* Greeff, *A. atava* Collin, *A. bathystoma* Deflandre, *A. conica* (Playfair) Deflandre, *A. discoides* Ehrenberg, *A. excavata* Cunningham, *A. hemisphaerica* Perty, *A. jeanneli* Virieux, *A. mitrata* Leidy, *A. polypora* Penard, *A. rotundata* Playfair, *A. vulgaris* Ehrenberg, *Centropyxis aerophila* Deflandre, *C. orbicularis* Deflandre, *C. plagiostoma* Bonnet et Thomas, *Cyclopyxis arcelloides* (Penard) Deflandre, *C. eurystoma Deflandre, C. kahli* Deflandre, *Difflugia acuminata* Ehrenberg, *D. corona* Wallich, *D. gassowskii* Ogden, *D. globulosa* Dujardin, *D. nodosa* Leidy, *D. oblonga* Ehrenberg, *D. ventricosa* Deflandre. Two successive community variants were observed (Fig. 9). In May and June *A. gibbosa* and *A. hemisphaerica* predominated, while in the second half of summer and in autumn *A. vulgaris* and *Difflugia globulosa* dominated. Moreover, *A. gibbosa* was a common component of plankton community in this lake. Therefore we conclude that *A. gibbosa* is a highly eurybiontic species, which may dwell in both acidic and toxic conditions in a great variety of microbiotopes.

Table 7. Spearman correlation coefficients between shell measurements of *A. gibbosa* in all populations.

	P1-P6				
	1	2	3	4	5
2	0.47 ***				
3	0.55 ***	0.42 ***			
4	0.19 ***	0.37 ***	0.24 ***		
5	0.34 ***	0.32 ***	0.18 ***	-0.01 NS	
6	-0.08 NS	0.36 ***	0.07 NS	0.51 ***	-0.04 NS

Notes: 1-6 – shell characters. *** P < 0,001; NS – not significant.

Table 8. Discriminant analysis results.

Variant A	F-criterion	Root 1	Root 2
Collar length	34.9	0.75	0.33
Shell diameter	31.7	-0.68	-0.50
Shell height	23.7	-0.19	0.89
External diameter of preapertural cavity	20.4	0.50	-0.72
Aperture diameter	17.1	-0.19	0.49
Cumulative percentage of explained dispersion, %		67.9	87.3
Variant B	F-criterion	Root 1	Root 2
Collar length/Shell diameter	41.1	-3.1	1.3
External diameter of preapertural cavity/Aperture diameter	15.5	-0.56	0.09
Length of preapertural cavity/Aperture diameter	9.6	1.3	-0.86
Shell diameter/Shell height	8.3	0.77	0.41
Collar length/Shell height	6.1	2.22	1.57
Length of preapertural cavity/Shell height	5.4	0.67	-1.37
Collar length/ Length of preapertural cavity	4.2	-0.99	-0.61
Collar length/ External diameter of preapertural cavity	2.9	1.93	-1.93
Degree of aperture concavity/ External diameter of preapertural cavity	2.8	-2.87	2.21
Cumulative percentage of explained dispersion, %		67.2	88.0
Variant C	F-crterion	Root 1	Root 2
Shell diameter	11.06	-1.82	5.77
Shell height	8.97	1.84	-7.85
Length of preapertural cavity/ External diameter of preapertural cavity	6.76	-2.35	-1.93
Shell diameter/Shell height	6.34	-1.03	6.23
Collar length/Shell diameter	5.15	-2.83	1.15
Collar length/ External diameter of preapertural cavity	4.99	1.32	1.09
Collar length/ Shell height	4.36	2.72	-2.17
Collar length/ Shell diameter	4.12	-1.04	-0.16
Length of preapertural cavity/ Aperture diameter	4.03	1.34	0.93
Length of preapertural cavity/ Shell height	3.22	0.23	0.63
External diameter of preapertural cavity / Aperture diameter	2.55	-0.62	-0.23
Cumulative percentage of explained dispersion, %		62.4	84.4

Variant A	Root 1	Root 2
P1	1.47	0.33
P2	-1.51	0.78
P3	-1.04	0.07
P4	-1.59	-1.41
P5	0.65	-0.69
P6	-0.03	-0.42

Variant B	Root 1	Root 2
P1	1.59	0.53
P2	-1.76	0.72
P3	-1.70	0.11
P4	-0.932	-1.60
P5	0.59	-0.81
P6	0.23	-0.56

Variant C	Root 1	Root 2
P1	1.66	-0.06
P2	-1.86	-0.89
P3	-1.51	-0.75
P4	-1.99	2.57
P5	1.01	0.13
P6	0.30	0.31

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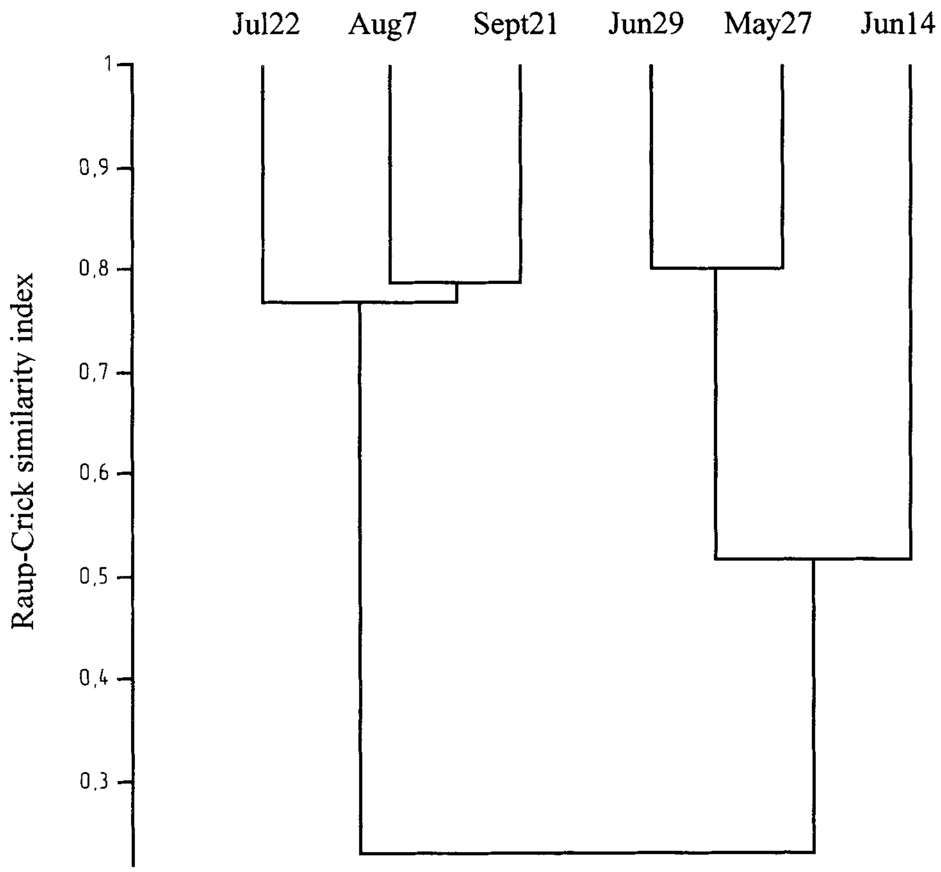

Fig. 9. Classification of testate amoebae community variants in lake Krugloe.

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