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The morphological variability of the carapace in Polish populations of *Cytherissa lacustris* (SARS) (*Ostracoda*)

Abstract. Morphological variability in lacustrine ostracode *Cytherissa lacustris* (SARS) expressed as differences in carapace size and nodation pattern as well as the carapace preservation were investigated in five physiographically similar Polish lakes.
Individuals of the populations investigated appeared to be considerably longer and less variable than individuals of the previously studied European, Arctic and North-American populations.
Considerable variation of the carapace size was found but no visible influence of the selected environmental parameters such as the depth of a lake, grain size and organic matter of sediment could be established.
The populations investigated were homogeneous in respect of nodation pattern but in respect of degree of carapace preservation there were recognized two significantly different homogeneous sets of populations.

INTRODUCTION

Ostracodes are crustaceans that seem to be physiologically and genetically predisposed to polymorphism (PEYPOUQUET et al. 1988). One of the most interesting questions of research in carapace morphology is to estimate influence of selected environmental factors on a phenotype so that this relationship could be used as a palaeobioindicator of ancient environment.

The existence of morphological differentiation is commonly observed phenomenon also in some profundal lacustrine ostracodes, in particular in *Cytherissa lacustris* (SARS). This is parthenogenetic, slowly developing, cold stenothermal species, restricted to deeper parts of well oxygenated lakes of the Holarctic Region (DANIELOPOL et al. 1990c). The variation of the carapace size and ornamentation of this species was investigated by CARBONEL et al. (1990), DANIELOPOL et al. (1985, 1988), SYWULA and GEIGER (1990), and SYWULA et al. (in press).

The present study tries to evaluate the amount of intraspecific morphological variability of the carapace of *Cytherissa lacustris* within and between isolated

lakes of similar physiographical conditions but having some slightly different sediment parameters.

The species was chosen for the following reasons:

1. in preliminary samples many specimens of this species were found in the region in question (NAMIOTKO in press, SYWULA 1990);
2. its morphology and autecology were detailed studied in the past few years (DANIELOPOL et al. 1990a), therefore there are comparable data;
3. it is known as a morphologically polymorphic species (DANIELOPOL et al. 1990a);
4. on account of its particular peculiarities, limited variations of morphological characters should be expected;
5. there was possibility of comparison between morphological and genetic polymorphism earlier investigated in the same populations (SYWULA 1990).

MATERIAL AND METHODS

Collection sites

Living and subfossil ostracodes were taken from five lakes (Gaładuś, Hańcza, Rospuda, Serwy and Szelment Wielki) within the Polish part of the Lithuanian Lake District (NE Poland). Tab. I shows some important morphometric and hydrological parameters as well as the geographical locations (longitude and latitude) of the sampled lakes.

Table I. Locations and some morphometric and hydrological parameters of five lakes studied

	Gaładuś	Hańcza	Rospuda	Serwy	Szelment Wielki
Longitude (East)	23°25′	22°49′	22°35′	23°13′	22°59′
Latitude (North)	54°11′	54°16′	54°13′	53°55′	54°14′
Altitude (m a.s.l.)	134	229	173	127	176
Surface area (km^2)	7.3	3.1	3.4	4.6	3.6
Depth max. (m)	55	108	39	42	45
Depth mean (m)	13	39	15	14	15
Drainage basin	H-BH-N	CH-N	R-Nt-B-Na-V	K-CH-N	Sl-Sp-N

Abbreviations of the names of rivers: B – Biebrza, BH – Biała Hańcza, CH – Czarna Hańcza, H – Hołnianka, K – Kalna, N – Nemunas, Na – Narew, Nt – Netta, R – Rospuda, Sl – Szelmentka, Sp – Szeszupa, V – Vistula.

The investigated lakes were for a long time oligo-mesotrophic (STANGENBERG 1936) and are still not too eutrophicated and well oxygenated, even in the deepest areas. Water quality of the lakes, however, has deteriorated slightly in the recent years (NAMIOTKO et al. 1993).

All the lakes are physiographically similar, i.e. they have comparable surface areas, maximum and mean depths (apart from the deepest Hańcza lake) and are of the similar trophic level, they differ, however, in some sediment conditions (Tab. II) and appurtenance in drainage basins (Tab. I).

Among the sublittoral and profundal ostracodes living in the lakes studied *Cytherissa lacustris* was one of the most common and abundant species (NAMIOTKO in press).

Table II. Employed in regression analyses depths and selected sediment parameters of four stations studied

	Depth	Silt and clay % d.w.*	Organic matter % d.w.**
Gaładuś	18	55.5	25.3
Hańcza	40	39.0	24.0
Rospuda	12	69.0	20.9
Szelment Wielki	13	37.3	10.9

* – percentage of particles of diameter < 0.063 mm in dry weight of the 5 cm sediment surface layer;
** – expressed by the weight loss on ignition in the 5 cm sediment surface layer.

Sampling methods

The material was collected with a triangular dredge (mesh opening 100 μm) at one sampling site within sublittoral and profundal (the depth from 12 m to 18 m) of each lake in the first half of September 1988.

All ostracodes from the preserved in neutralized formalin samples were picked up, identified and are kept in ethyl alcohol. From each sample more than 100 specimens of adult *Cytherissa lacustris* were sorted and subjected to an examination.

Living specimens from Hańcza lake did not preserve well, therefore in this case only subfossil shells taken in July 1990 from the first 5 cm layer of the sediment column of a Kajak-corer (diameter 4.4 cm) were investigated. Sediment was taken at two sampling sites: the depth of 40 m (25 valves) and 96 m (26 valves).

Morphometric analyses

More than 100 sorted valves from each lake (but Hańcza) were measured to the nearest 6 μm under a microscope (100x magnification). Maximum length (l) and height (h) of each valve were recorded and h/l ratio was calculated.

To test differences among the populations means and variances single classification analysis of variance and the F-test were used (SOKAL and ROHLF 1981). The influence of environmental parameters was checked with simple linear regression model (SOKAL and ROHLF 1981).

Ornamentation

Only the production of nodes, one of the two main recognizable type of shell ornamentation was analysed. *Cytherissa lacustris* has a carapax variously tuberculated; the species can produce up to seven nodes of different degree of strength (DANIELOPOL et al. 1988). Presence or absence of the most persistent ventro-posterior node of the adults were considered only and presented as the percentage of tuberculated (with nodes) valves. Data were tested by means of R-C test of independence and G-test of homogeneity (SOKAL and ROHLF 1981).

Carapace preservation

To test the difference between lakes of the degree of carapace preservation measured as a frequency of articulated carapaces R-C test of independence and the G-test of homogeneity with the STP (simultaneous test procedure) were employed. Only subfossil material was analysed.

RESULTS

Morphometric analyses

Size differences between right and left valves were not significant thus one valve (left or right) of each carapace or single (separated) valve were measured.

The weighted averages of the valve length and height of adult specimens of six populations from five Polish lakes were computed because of unequal sample sizes and they were 926 μm (545 measurements) and 556 μm (545 measurements) respectively.

The mean length and height varied between the studied populations. The smallest carapace in respect of both lenght and height was recorded from Hańcza lake at the depth of 40 m (station H-40), whereas the biggest one in Rospuda lake. Valves of the remaining populations had very similar dimensions.

Employing the coefficient of variation in a comparison between two measured variables one can see that the height of carapace was slightly more variable in each population than the length.

The most variable size of the carapace existed in population from Rospuda lake, whereas the least variable one was from Serwy lake and Hańcza H-40.

Maximal height at the anterior cardinal corner represented approximately 67% of the total length in each population studied.

(The morphometric data are tabulated in Tab. III).

The observed frequencies of the grouped distributions of two analysed morphological characters were unimodal, nearly symmetrical and data tended to be normally distributed. Two frequency distributions of the length (from Rospuda and Serwy), however, were bimodal, thus the mixture of two normal distributions could be suggested in these cases. Moreover, the frequency distributions of the length of the valves from Hańcza H-96 and Szelment Wielki as well as the height of the valves from Hańcza H-96 and Serwy departed from normality and were skewed to the right.

Table III. The morphometric data of six studied populations

	Mean (μm)	S.D. (μm)	S.E. (μm)	Range (μm)	C.V. (%)	N
	Length					
Gaładuś	925	25.43	2.47	866–986	2.7	106
Hańcza 40	907	20.96	4.19	877–956	2.3	25
Hańcza 96	921	27.28	5.35	870–960	3.0	26
Rospuda	938	31.70	2.56	866–1008	3.4	153
Serwy	921	19.56	1.81	877–962	2.1	117
Szelment Wielki	921	26.73	2.48	867–1000	2.9	116
	Height					
Gaładuś	552	18.59	1.85	502–598	3.4	101
Hańcza 40	541	14.89	2.98	515–581	2.8	25
Hańcza 96	552	17.06	3.35	524–588	3.1	26
Rospuda	565	21.93	1.78	506–619	3.9	152
Serwy	554	16.07	1.47	523–594	2.9	120
Szelment Wielki	553	18.57	1.64	512–613	3.4	121

Abbreviations: S.D. – standard deviation, S.E. – standard error, C.V. – coefficient of variation, N – number of measured valves.

Results of single classification anova confirmed that the variances of means of measured size characters among populations were greater than the expected on the basis of variances of these characters within the populations (F_S= 10.68; $P < 0.001$). Thus, specimens from different lakes differed morphologically more from each other than did specimens from any one population. No correlation, however, of carapace length and height with any of the measured environmental parameters could be established.

Testing the significance of differences between variances of each pair of the studied lakes one can see that the most significantly different were the following pairs of the lakes: Rospuda-Serwy, Rospuda-Hańcza H-40, Serwy-Szelment Wielki, Serwy-Hańcza H-96 and Serwy-Gaładuś.

Ornamentation

Table IV shows occurrence of nodated valves in the studied samples. The more abundant in the material right valves were always more nodated than the left ones thus only left valves were taken into consideration.

The populations from Szelment Wielki and Hańcza H-40 were characterized by the lowest ratio of nodated left valves (24% and 25% respectively) whereas Gaładuś lake showed the highest ratio of specimens with nodated left valves (55%).

Table IV. Occurrence of nodated adult and juvenile (the last stage) valves of *Cytherissa lacustris* in the samples studied

	Left valves		Right valves		Total	
	N	%	N	%	N	%
Gaładuś	42	55	64	73	106	66
Hańcza 40	12	25	13	38	25	32
Hańcza 96	13	38	13	62	26	50
Rospuda	58	38	95	76	153	61
Serwy	53	40	71	76	124	60
Szelment Wielki	50	24	72	56	122	43

Abbreviations: N – number of examined valves; % – frequency of nodated valves.

No correlation of nodation pattern of *Cytherissa lacustris* with any of the sediment parameters was found and there is a negative association between presence of the nodated valves and a given lake; G_{adj} (G value by Williams' correction) = 9.987; $P < 0.05$. There is evidence that the ratios of nodated valves were all homogeneous among the lakes studied.

Carapace preservation

Table V presents the occurrence of articulated and disarticulated carapaces of the adult and juvenile specimens at the sampling sites.

The results of R-C test of independence (using G-test) show that the carapace preservation pattern of *C. lacustris* was dependent on the lake ($G = 25.937$; $P < 0.05$). These proportions were not uniform among the lakes, thus they were said to be heterogeneous.

Table V. Occurrence of articulated and disarticulated carapaces of *Cytherissa lacustris* at the sampling sites

	Valves		Carapaces		Total number
	N	%	N	%	N
Gaładuś	90	68	42	32	132
Hańcza 40	31	84	6	16	37
Hańcza 96	51	66	26	34	77
Rospuda	30	86	5	14	35
Serwy	77	83	16	17	93
Szelment Wielki	207	86	33	14	240

Abbreviations: N – number of examined valves or/and carapaces; % – frequency of articulated carapaces or single valves.

In carrying out a simultaneous test procedure it could be find that the significance of the heterogeneity appeared to be due to differences between

Gaładuś and Hańcza H-96 stations being one homogeneous set and the remaining five samples being another homogeneous set. In Hańcza H-96 and Gaładuś the frequencies of articulated carapaces reached the highest value (34% and 32% respectively).

DISCUSSION

All (but Hańcza H-40) Polish populations of *Cytherissa lacustris* were characterized by extremely long carapaces and were less variable with respect to this character when compared with other recent European (DANIELOPOL et al. 1985, 1990b, GEIGER 1990, SYWULA and GEIGER 1990), Arctic (SYWULA et al. in press) and North-American (DELORME 1967, 1970) populations.

The mean lengths of all Polish populations studied exceeded 905 μm and the ranges were quite broad and in general broader than those known until now. The longest shell sizes were recorded in Szelment Wielki and in particular in Rospuda (1 mm and even more than 1 mm) whereas the maximum recorded to now length of *C. lacustris* do not exceed 980 μm (DELORME 1967). The reasons of the existance of such long carapaces in Polish populations is not understood now and could not be clarify in the present work.

The height range was comparable with that given by DELORME (1967, 1970) dealing to North-American populations.

Size difference in ostracodes as reviewed by SYWULA and GEIGER (1990), is related to temperature, food conditions and environmental stability.

There was noted considerable differences in carapace size among the populations studied. No relationship, however, could be established between carapace size and grain size, organic matter and depth but the sample sizes were not sufficient enough to permit assured conclusion.

It should be concluded that the more complex environmental and genetic factors that have affected each investigated population separately resulted in shifting the means of the measured morphological characters sufficiently so that the studied samples could no longer be considered as samples from the same general population.

The fact that the longest specimens of *C. lacustris* lived in Rospuda lake, which in cotrast to the remaining populations, belongs to the different main drainage basin – Vistula catchment area, could suggest geographical origin of the observed differences in the shell length most probably based on clonal differentiation and its effects on growth. The main watersheed Vistula/Nemunas, however, does not constitute a barier to the separate clones of *C. lacustris* from the lakes studied as was confirmed by SYWULA (1990) based on the distribution pattern of esterase phenotypes.

The comparison between present data of size variability and genetic variability (SYWULA 1990) is unclear and could not be simply decipher. Nevertheless among three most genetically similar pairs of populations i.e. from Rospuda-Szelment Wielki, Rospuda-Serwy and Hańcza-Serwy (Gaładuś omitted due to insufficient

material) only one pair, from Rospuda-Serwy, was significantly different with regard to the length variances.

Polymorphism in the nodation pattern of *C. lacustris* was investigated by CARBONEL et al. 1990, DANIELOPOL et al. 1985, 1988, DANIELOPOL and HANDL 1990, and SYWULA and GEIGER 1990. SYWULA and GEIGER (1990) state that there is clonal variability in the genetically determined range of the reaction norm for tuberculation and depending on the clonal composition of each population, the proportion of individuals with broad and narrow reaction norms can vary considerably in time and space. CARBONEL et al. (1990) and DANIELOPOL et al. (1985, 1988) suggest that differences in nodation pattern could be due to varied chemical environments at the water-sediment interfaces. In general the percentages of nodated specimens are higher at those sites (mostly within a littoral zone) where is a supply of allochtonous organic matter rich in silica.

As for the ratio of nodated specimens studied, no visible influx of any measured environmental factors could be detected. It is probably the type and origin of organic matter rather than the amount of this environmental factor that is important in this case. Excluding the sample from Hańcza H-40 where the organic matter could have different origin (more autochtonous ?) in comparison with the remaining stations located closer to the shore, one can notice that there is a moderate correlation between nodation and contents of organic matter ($r = 0.453$). The data obtained here, however, could not confirm such a simple association.

All the Polish populations investigated when compared with other recently studied European and Arctic ones (CARBONEL et al. 1990, SYWULA and GEIGER 1990, SYWULA et al. in press) were generally less nodated. The highest percentage of nodated specimens was recorded in Gaładuś where the ratio of recent annual sediment accumulation appears to be one of the highest within the studied lakes. This statement may be confirmed by the results obtained from the analysis of the carapace preservation. There was recorded also one of the highest percentage of articulated carapaces in this lake.

In conclusion, these investigated parameters of the morphological variability having potential application in palaeoecological studies of reconstruction of the ancient environments should be further investigated by the multivariate statistical methods.

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STRESZCZENIE

[Zmienność morfologiczna karapaksu polskich populacji *Cytherissa lacustris* (*Ostracoda*)]

Zbadano zakres morfologicznej zmienności sześciu polskich populacji słodkowodnego małżoraczka *Cytherissa lacustris*. Oszacowano zróżnicowanie

wielkości i ornamentacji karapaksu jak również zachowywanie się pancerzyków w osadach jeziornych.

Zbadane osobniki okazały się znacząco dłuższe od dotychczas zbadanych osobników z populacji europejskich, arktycznych i północnoamerykańskich.

Odnotowano statystycznie istotne różnice wielkości karapaksu między populacjami natomiast nie udało się ustalić wyraźnego wpływu wybranych czynników środowiskowych, takich jak głębokość, skład granulometryczny osadu oraz zawartość materii organicznej w osadzie.

Badane populacje były statystycznie homogenne pod względem ornamentacji pancerzyków. Pod względem stopnia zachowywania się kompletnych karapaksów wyróżniono dwie istotnie różniące się grupy populacji.

Porównanie analizowanej zmienności morfologicznej ze zmiennością genetyczną zbadaną wcześniej w tych samych populacjach nie wykazało istotnych podobieństw.

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