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Physa acuta DRAPARNAUD, 1805, *(Mollusca, Gastropoda)* from the recent Vistula sediments at Tyniec near Cracow

[With 7 text-figs]

Physa acuta* DRAPARNAUD, 1805, *(Mollusca, Gastropoda)* ze współczesnych osadów Wisły w Tyńcu koło Krakowa

Abstract. Numerous shells of *Physa acuta* are found in sand with coal grains in the Vistula river near Tyniec (South Poland). They are distinctly differentiated in size and shape so that some specimens are similar to other species of the genus *Physa*, Traces of migration and adaptation of the mentioned snail in Central Europe are discussed. Their occurrence in the Vistula river is connected with the heating of water by a power station built in 1958, which determines the lower age limit of sediments with athropogenic material.

INTRODUCTION

The genus *Physa* comprises water snails with sinistral shells, globose or elevated, thin and fragile. They are widespread in the Holarctic area. Different species of this genus live in Europe, Asia, North Africa and North America. The main European species are *Physa fontinalis* and *Physa acuta*. The first one inhabits the whole continent while the other one occurs in the Mediterranean area as well as in some countries of West- and Central Europe (JAECKEL 1967). A limited range has *Physa heterostropha* which is noted in England, Germany and Hungary (KERNEY, 1976; MACAN, 1977; EHRMANN, 1933; RICHNOVSZKY & PINTER, 1979). Another species — *Physa ancilaria* was reported from an isolated locality in Germany (BOETTGER 1930). In South England an American species — *Physa gyrina* wat noted by KERNEY (1976) at last.

In Poland *Physa fontinalis* has appeared since the beginning of the Postglacial period (PIECHOCKI, 1977; ALEXANDROWICZ, 1980, 1983) while *Physa acuta* represents a new element, known only in present century. The history of migration of the second species was described in our country by FELIKSIAK (1939) and a few new localities of its occurrence have been noted in the last 30 years by DUTKIEWICZ (1959), WIKTOR (1959), ZIĘBA & ZAĆWILICHOWSKA (1966), PIECHOCKI & POTOCKI (1976), PIECHOCKI (1979) and STRZELEC & SE-

RAFINSKI (1984). *Physa acuta* occurs as an subordinate component in assemblages of water snails, but in some localities it is represented as a dominant or even exclusive element. This is connected with the specific ecological valency of the mentioned species, living in polluted or heated water, infavourable for other molluscs. Its empty shells are accumulated in sediments of flowing or stagnated waters, in rivers, channels, ponds and lakes as well as in anthropogenic basins near factories, power stations or ironworks. The percentage of these shells in thanatocenosis reflects the number and domination of living snails in molluscan assemblages.

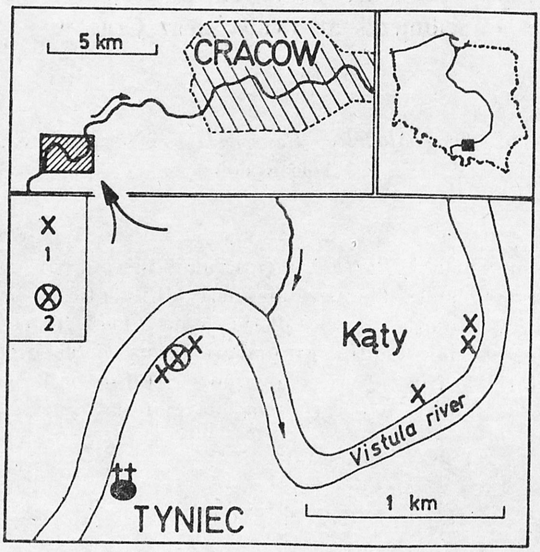

Fig. 1. Location of sands with antropogenic material and shells in the Vistula river near Tyniec
1 — Thanatocenosis with *Physa acuta*, 2 — Thanatocenosis measured

The occurrence of *Physa acuta* in the Vistula river near Tyniec was noted by ZIĘBA & ZAĆWILICHOWSKA (1966). Thanatocenosis containing mainly shells of this taxon were found by ALEXANDROWICZ & RUTKOWSKI (1984) in sand and gravel with anthropogenic material on the left river bank at Kąty. A few localities of these sediments abounded in empty shells of the mentioned snail are noted by the author on both banks of the river near the monastery at Tyniec (Fig. 1).

II. THANATOCENOSIS WITH *PHYSA ACUTA*

Recent Vistula sediments accessible in the river channel and in channel bars are developed as sand and gravel without shells. In the inner parts of meanders, even in distal ends of point bars, about half meter over the normal water level, sand with coal grains occur locally. This sand abounds in empty shells of snails, sporadically shells of bivalves can be found to. The thanatocenosis comprises following species:

— *Physa acuta* DRAPARNAUD, 1805 — shells of 4—10 mm in size are the dominant component of assemblage,
— *Lymnaea peregra* (MÜLLER 1774) — shells of different size, mainly 5—15 mm, sporadically over 20 mm, corresponding to *Lymnaea peregra peregra* (MÜLLER 1774),
— *Ancylus fluviatilis* MÜLLER 1774 — shells distinctly ornamentated, 4—6 mm in size.,
— *Planorbarius corneus* (LINNAEUS 1758) — single shells or fragments of shells,
— *Physa fontinalis* (LINNAEUS, 1758) — few small, fragile shells found in one sample only,
— *Aplexa hypnorum* (LINNAEUS, 1758) — single shells occurring in samples from Kąty on the left river bank,
— *Valvata cristata* MÜLLER, 1774 — flat shells, 2—3 mm in diameter found in almost all samples,
— *Acroloxus lacustris* (LINNAEUS, 1758) — thin and fragile shells occurring in one sample from Tyniec,
— *Pisidium personatum* MALM 1855 — few shells or fragments of shells reported from all samples.

In the thanatocenosis in question, *Physa acuta* is a clearly dominant component. Their content reaches over 90% of all shells. *Lymnaea peregra* and *Ancylus fluviatilis* occur in considerable number, the both represent 3—5% of assemblage while the remaining species are found as single specimens. In all samples this proportions are nearly the same.

Most shells are well preserved, comprising periostracum and ornamentation. Fragments of shells or even detritus occur locally mainly in sand. In samples collected on the right bank of the river between Tyniec and Kąty, over one thousand completely preserved shells of *Physa acuta* were found. From this material 200 specimens reaching more than 4 mm in size were selected as a set for biometrical investigations.

III. BIOMETRY OF *PHYSA ACUTA*

The measurement of shells comprise following indicators: H — height of shell, B — width of shell, h — heigth of aperture, w — width of aperture, α — top angle of shell, β — angle between the upper wall of aperture and the shell axis (Fig. 2). Three coefficients are calculated from these measurement: the relative height of spire $S = \frac{H-h}{H} 100$, elongation indicator $E = \frac{H}{B}$, and coefficient of aperture width $A = \frac{w}{h} 100$. All measurements were carried with

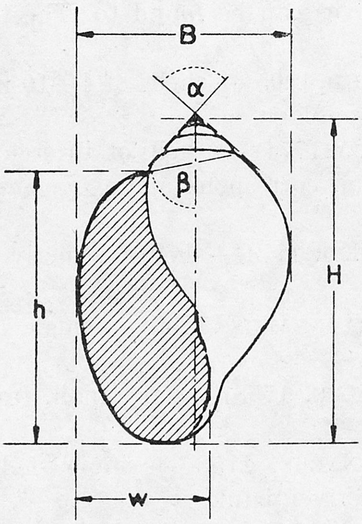

Fig. 2. Measured dimensions of the shell of *Physa acuta* (explanations in text)

accurateness up to 0,1 mm and 1°. For the values and coefficients simple statistics like arithmetic mean — x, standard deviation — s and diversity index — v are calculated (Tab. I).

Table I

Biometrical features of the population of *Physa acuta* from Tyniec

	min. size	max. size	x	s	v	λ
H (mm)	4,10	10,20	6,62	1,20	18,13	0,88
B (mm)	2,20	6,20	3,97	0,80	20,18	0,76
h (mm)	2,70	7,80	5,10	1,02	20,09	1,34
w (mm)	1,40	4,20	2,60	0,53	20,52	1,31
α	59°	96°	76°30′	7°58′	10,54	0,96
β	43°	84°	60°14′	8°39′	14,22	0,76
S	9,50	42,60	23,42	4,58	19,56	0,51
E	1,38	2,37	1,65	0,13	7,68	0,95
A	41,60	67,50	51,13	4,94	8,79	1,08

A considerable variability in size and shape of shells is clearly visible in examined collection. Beside specimens corresponding in all details to diagnosis of *Physa acuta* shells similar to other species, a. o. *Physa heterostropha* can be distinguished. In order to interprete this variability, statistical distributions of the mentioned values and coefficients were examined. In diagrams all analysed sets are unimodal, corresponding to normal distribution (Fig. 3).

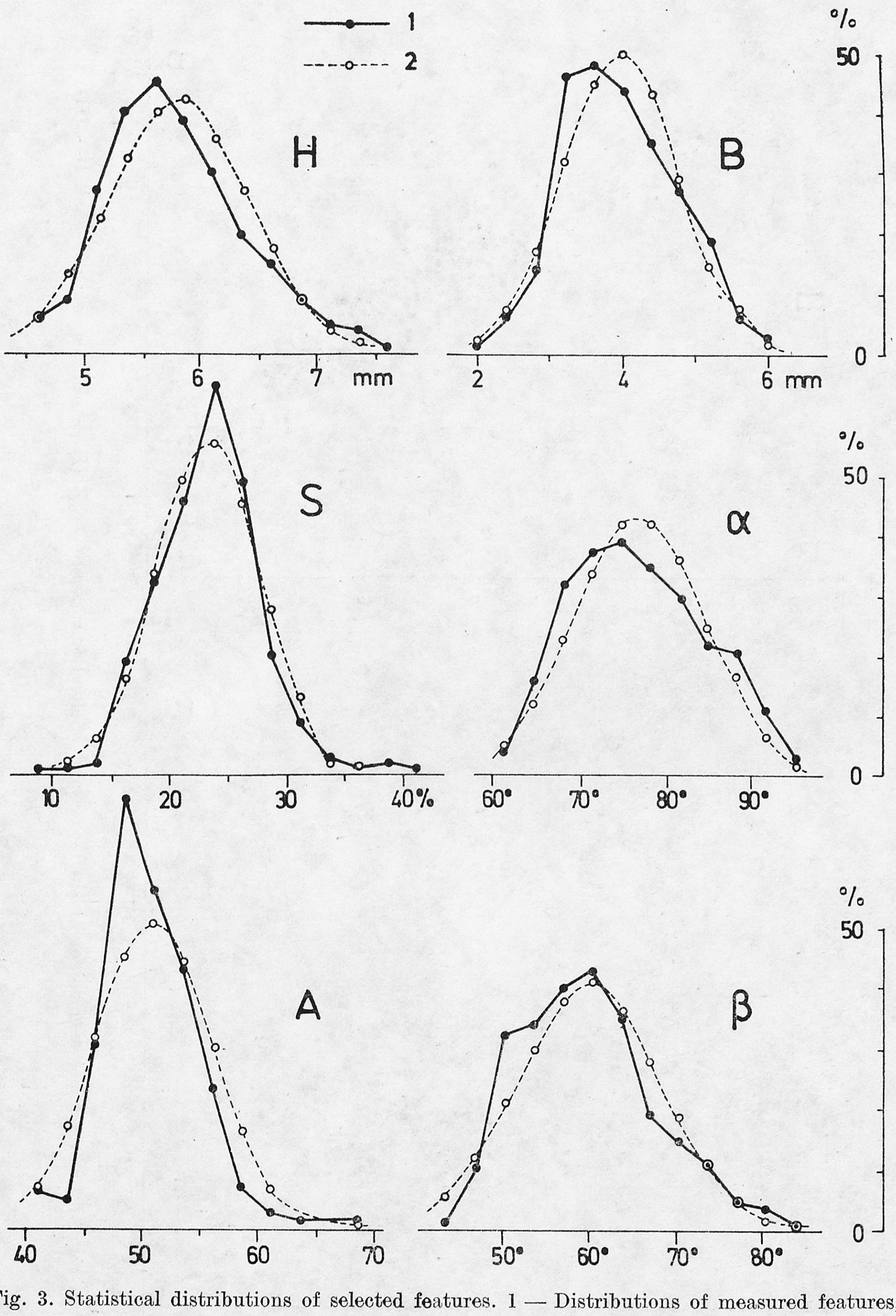

Fig. 3. Statistical distributions of selected features. 1 — Distributions of measured features, 2 — normal distribution curves, H, B, S... — features shown in Fig. 2

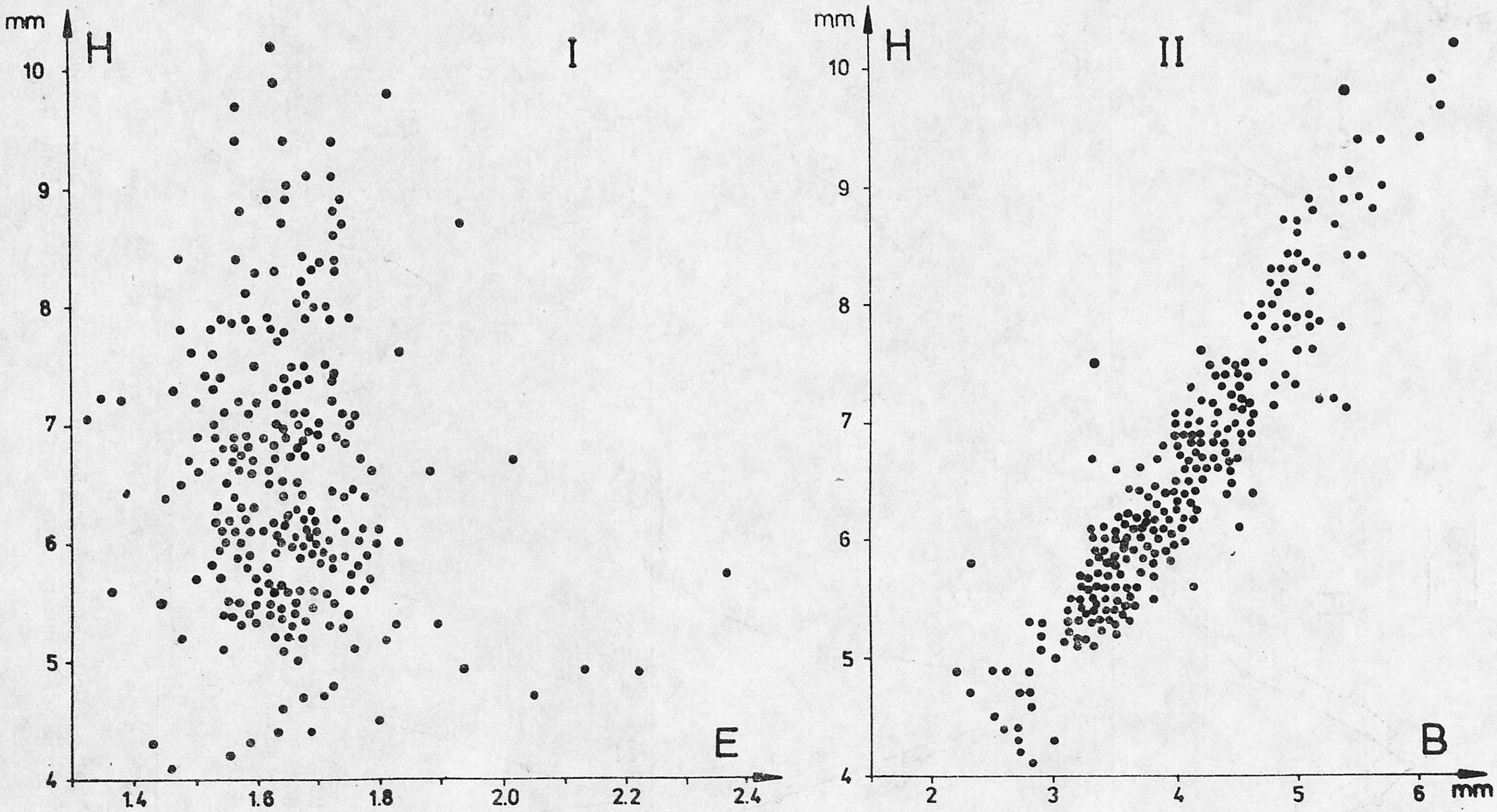

Fig. 4. Relations between height of shell — H and elongation indicator — E (I) as well as width of shell B— (II)

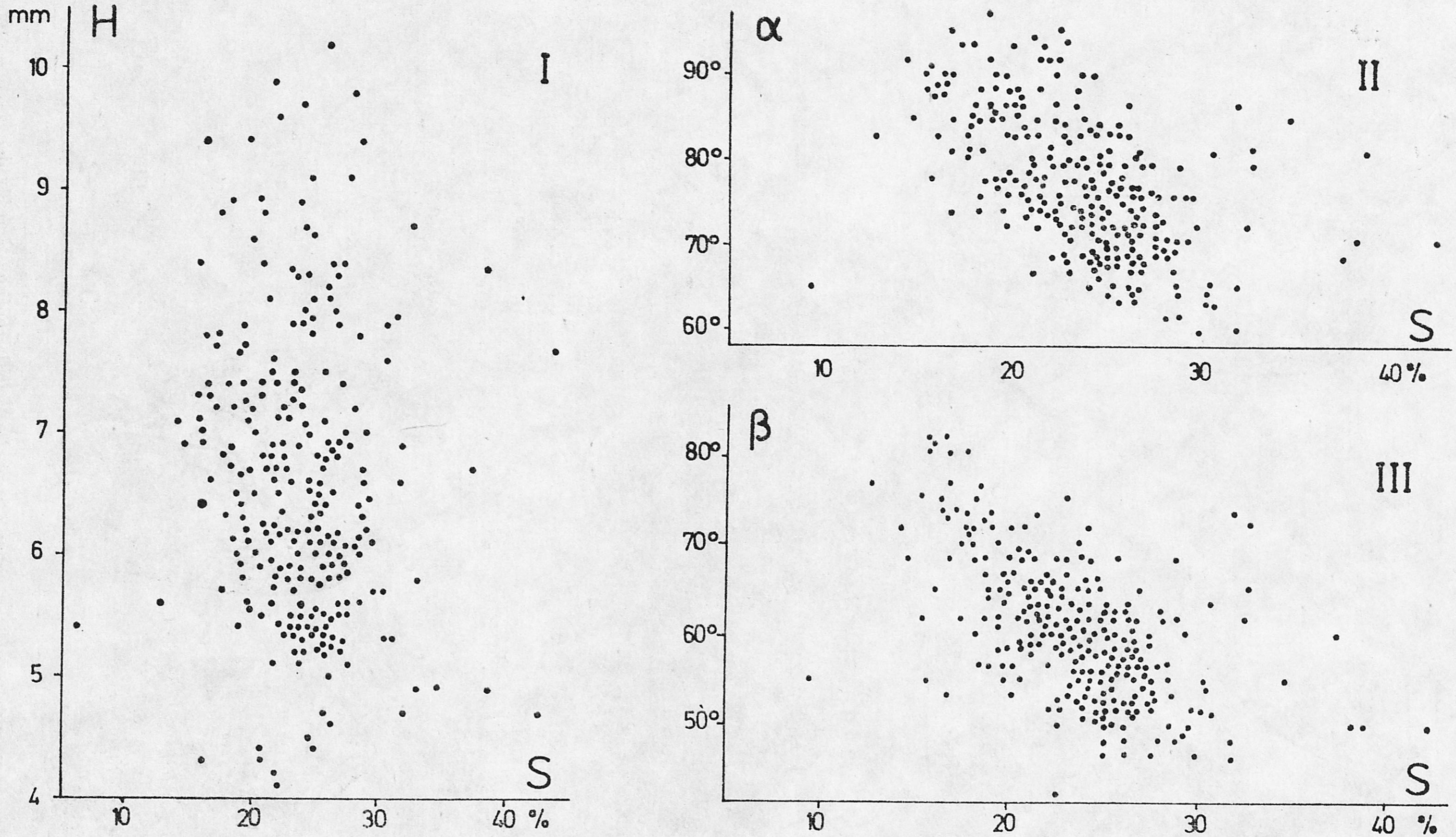

Fig. 5. Relations between height of shell — H and height of spire — S (I) as well as between two angles and height of spire (II, III)

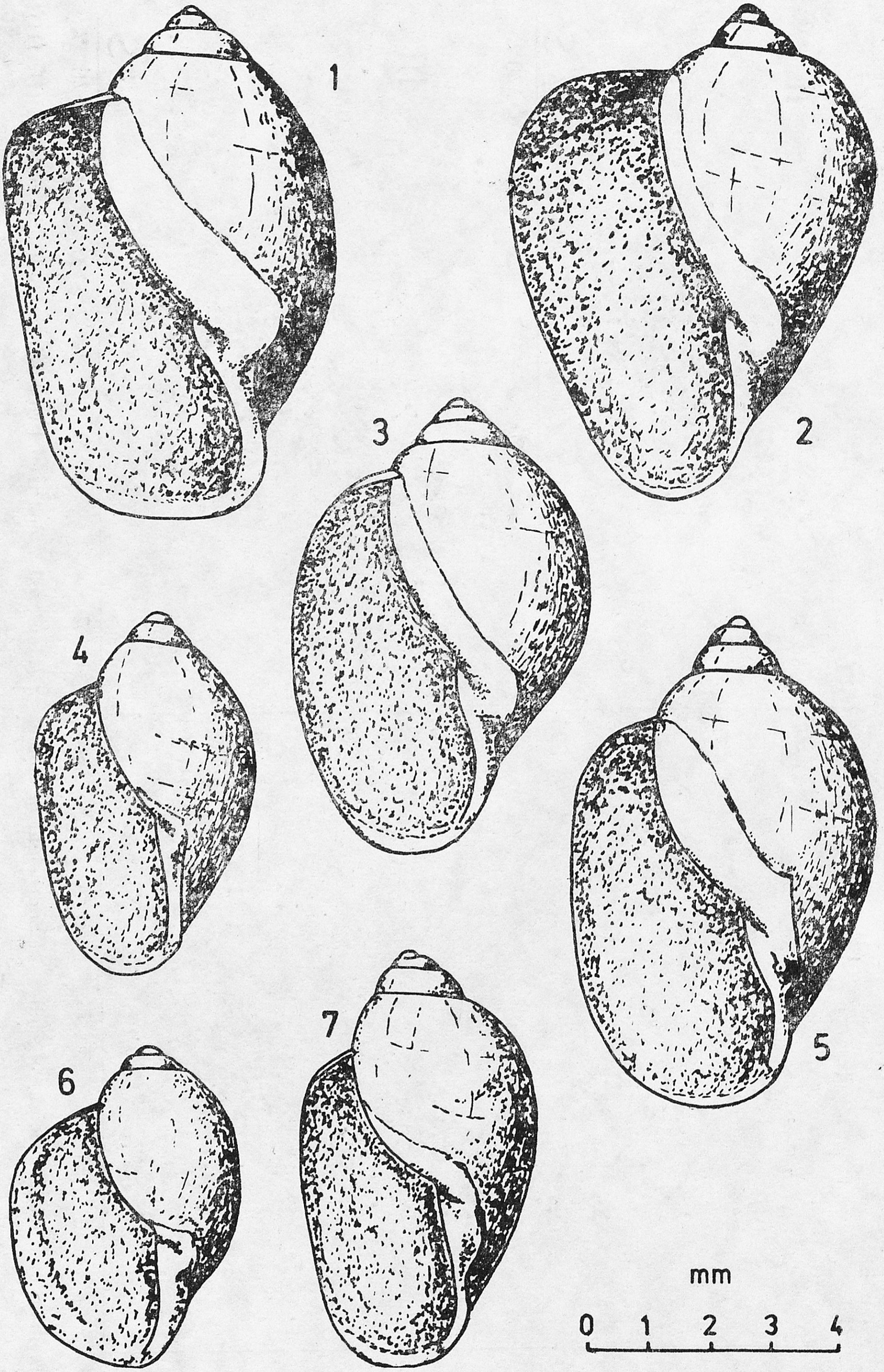

Fig. 6. Selected specimens of *Physa acuta* from the Vistula sediments at Tyniec. 1—7 — morphological type I

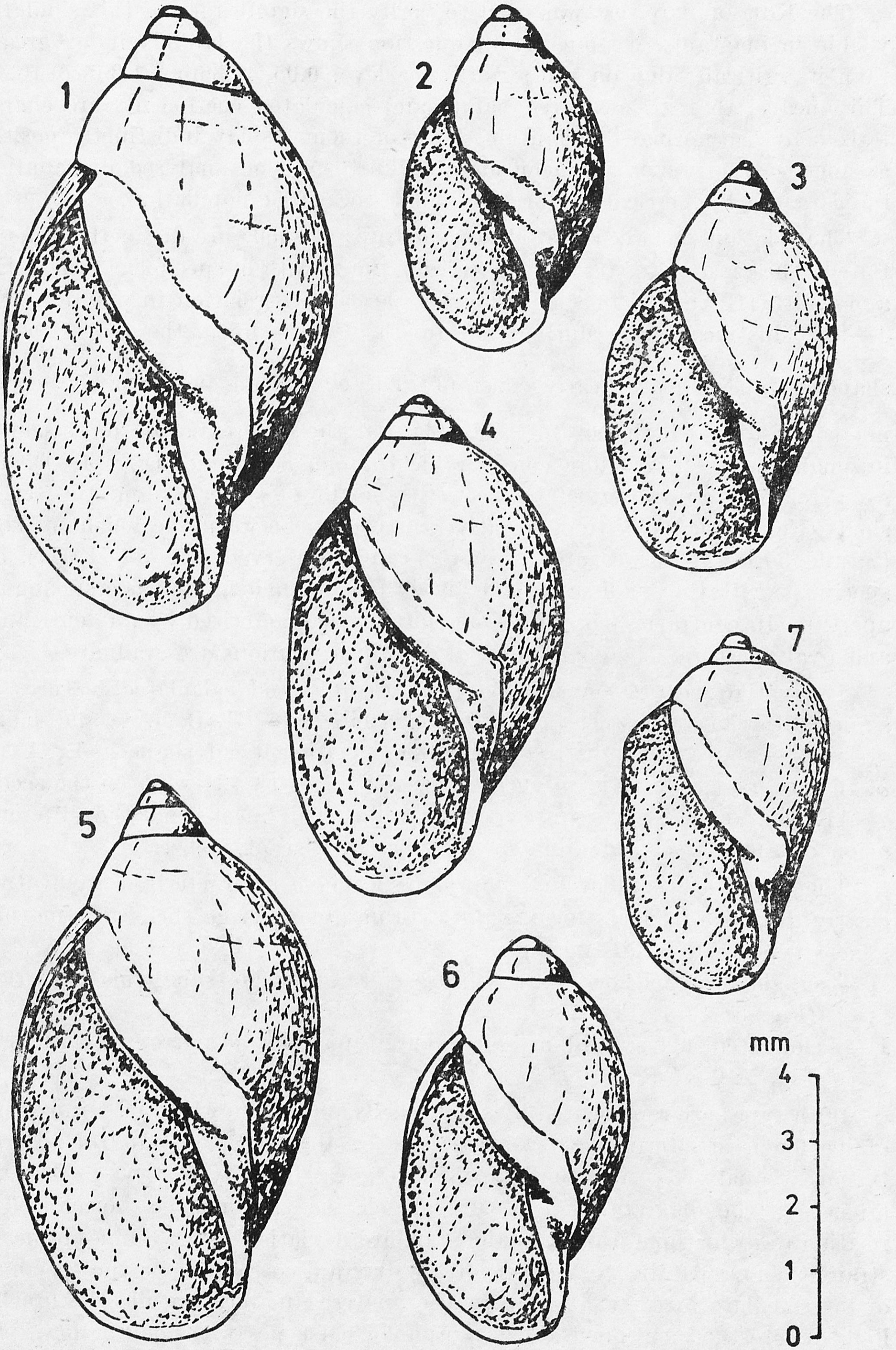

Fig. 7. Selected specimens of *Physa acuta* from the Vistula sediments at Tyniec. 1—6 — morphological type II, 7 — morphological type I

The Kolmogorov test was used to verify the significance of this similarity visible in diagrams. No one set in question shows the lambda index greater than its critical value on the significance level 0.05, reaching 1.358 (Tab. I). This means, that all measured values and calculated coefficients are characterized by the normal distribution. Most of them display indistinctly positive assimetrical curves or an inconsiderable kurtosis. The analysed distributions indicate the biometrical uniformity of the measured population.

The relations between the selected features of shells are distinctly differentiated. The most characteristic one reflects the growth of specimens. The height and width (H and B) of shells shows a positive correlation in diagram (Fig. 4—II). This means that during the growth of a specimen, the proportions of shape of the shell are nearly constant. The elongation indicator ($E = \frac{H}{B}$) is not correlated with the size of shell (H), but the differentiation of this index in small specimens is more considerable than in large ones (Fig. 4—I). The same relations are observed between the height of spire (S) and the size of shells (Fig. 5—I). A distinct negative correlation between the height of spire (S) and both angles measured (α and β) can be observed (Fig. 5—II, III). The specimens with the small spire have an obtuse top angle as well as a subangular aperture. In contrast shells with long spire are characterized by an acute angle and oval aperture. The changes of all described relations are graduate.

The variation coefficient (v) of the measured and calculated features assumed different values. The indicators of shell size as H, B, h, w and height of spire — S are more differentiated than coefficients of shape — E, A and α. In the first group of mentioned values v reaches 18—21 while in the second 7—11. The angle β shows intermediate value. This means that the differentiation of shape is considerable smaller than in size of shells.

The described population comprises specimens characterized by features clearly different from its mean values. From among large shells two morphological types can be distinguished:

I — subglobose shells with low, obtuse spire and wide subangulate aperture (Fig. 6: 1—7, Fig. 7: 7),

II — elongated shells with long spire, acute top angle and narrow oval aperture (Fig. 7: 1—6).

Both types are represented by single shells and in the whole material a bulk of specimens of intermediate character can be observed. This kind of differentiation is analysed using the shape curves described by Jentys-Szaferowa (1959). In the diagram each feature of selected specimens is normalized in relation to its arithmetical mean and standard deviation (Fig. 8). Lines of nearly straight course parallel to the axis of the diagram correspond to the specimens of intermediate features, typical for the analysed material, while the brocken lines denote the mentioned above morphological types with long or low spire.

The biometrical analysis presented above indicates, that the described

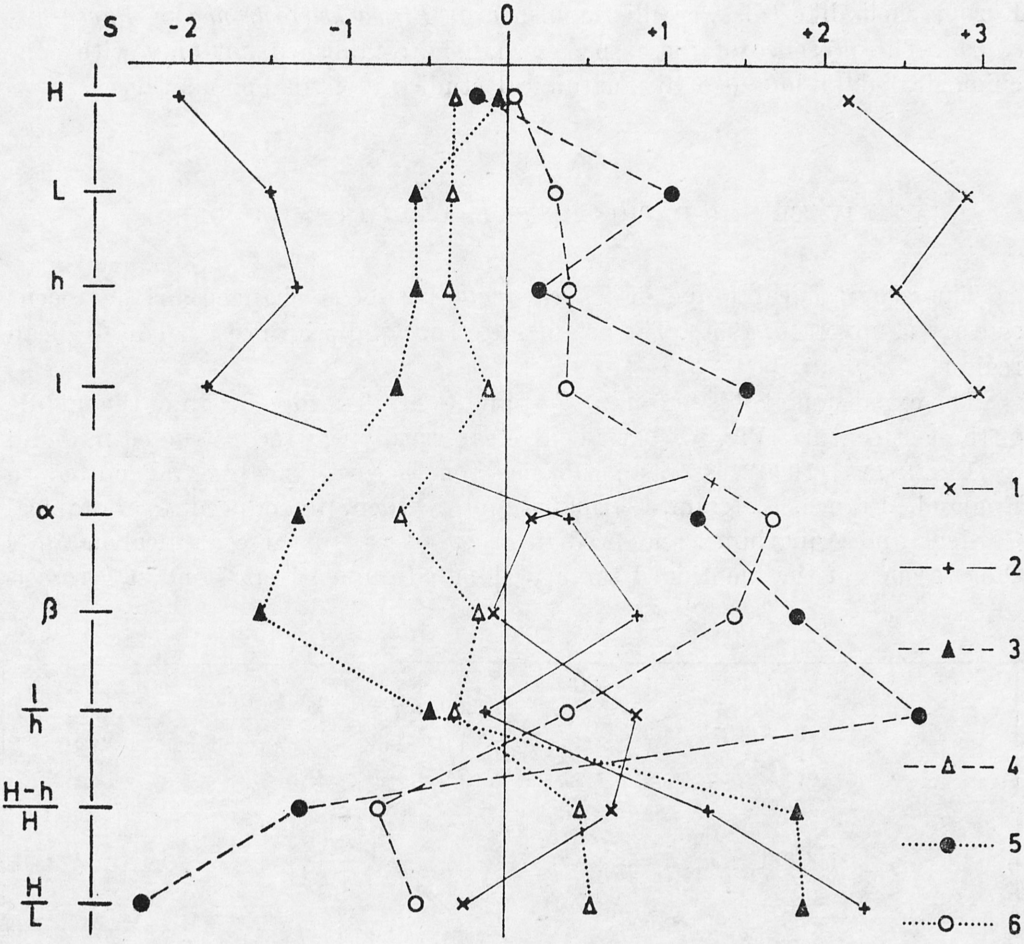

Fig. 8. Shape curves of some specimens of *Physa acuta* from Tyniec. 1 — Large specimen typical for the described population, 2 — small specimen of type II, 3 — medial specimen of type II, 4 — medial specimen of intermediate shape, 5, 6 — medial specimens of type I

population of the empty shells of *Physa* comprises only one taxon, represented by maturate and immaturate specimens. This taxon defined as *Physa acuta* is characterized by a great intraspecific variability. Due to it the presence of specimens similar to other species of *Physa* can be observed. Shells with a long spire and acute top angle described as morphological typ II resembles *Physa heterostropha* while shells of the morphological type I and of intermediate features correspond to *Physa acuta*.

It is worth noting that in specific ecological conditions, in heated and polluted waters, in artifical water basins as well as in thermal springs and small water bodies of anthropogenic origin, populations of *Physa acuta* show a great variability and clearly differ from one another. In those populations shells of extremely large size and intypical shape can exist. It is possible that in Central

Europe shells like this were distinguished as *Physa heterostropha* or *Physa ancilaria*. The presence of these species shall be established not only with conchiological data but also by anatomical studies in living populations.

IV. THE MIGRATION OF *PHYSA ACUTA* IN EUROPE

The geographical range of *Physa acuta* has been changed in the recent century (Fromming, 1956). The original area of its appearance is Mediterranean region.

The expansion of this taxon in West and Central Europe began in the middle of the last century (Fig. 9). Their course eastwardly was reconstructed in detail by Feliksiak (1939). It was performed together with plants transported to England, France, Belgium, Germany and Sweden, introduced to Botanical Gardens and Aquariums, and bred in greenhouses. In these attifical habitats the presence of the mentioned taxon was noted sequently in London, Brussels

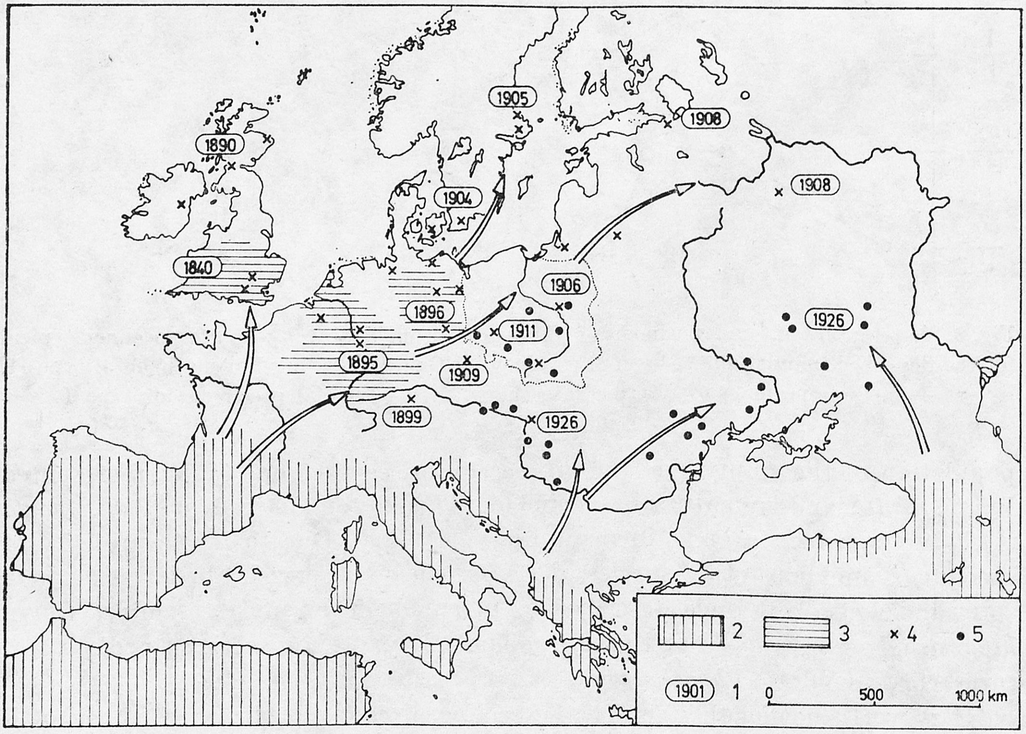

Fig. 9. Migration of *Physa acuta* in Europe. 1 — The appearance noted mainly in artificial water basins, 2 — original area of distribution, 3 — area of secondary occurrence in West Europe, 4 — localities in botanical gardens and aquariums, 5 — localities in natural environment and in industrial waste water

and Berlin, at the beginning of the current century in Warsaw and in Prague, and afterwards in Stockholm, Kaunas, Leningrad and Moscow (BABOR & NOVAK, 1909, BOETTGER, 1929; FELIKSIAK, 1939; SIVICKIS, 1960).

Apart the migration proceeding from the southwest and west, the species in quettion were extended from Balkans and Caucasus northwardly. Traces of this way were found in Hungary (SOOS, 1943; RICHNOVSZKY & PINTER, 1979), in Czechoslovakia (LOZEK, 1956, 1964) and in Ukraine (ZHADIN, 1952). The great adaptability of the mentioned snail provided facilities for inhabiting by them in natural and artifical open basins in a few countries of Central and Southwest Europe. It occurs now in many localities in South England and Germany and in isolated sites in Poland, Czechoslovakia, Hungary and Rumania, mainly in towns and in their neighbourhood, in rivers and small lakes as well as in ponds in parks and gardens, also near thermal springs.

Especially favourable conditions the species could find in reservoirs with heated water discharged from power stations and factories (FELIKSIAK, 1939). The populations of *Physa acuta* appeared in such water bodies were resistant to the pollution of the industrial waste water. Due to it they developed in conditions unfavourable for other molluscs (SCHUTT, 1977). The typical examples of such conditions are a. o. artificial reservoirs of waste water from ironwork in Nowa Huta near Cracow (DUTKIEWICZ, 1959) and considerably polluted river near Halle (MATZKE, 1964).

Recently the appearance of *Physa acuta* has been ascertained in the small pond in Łódź, frozen to the bottom every winter (PIECHOCKI & POTOCKI, 1976). Another locality of this kind is a postmining depression in Bytom — Upper Silesia (STRZELEC & SERAFIŃSKI, 1984). This fact points out for the future ability to the adaptation of this species what makes possible the next stages of the expansion by them. Consequently shells of the described snail are found also in the Skawa river near Zator (ZIĘBA & ZAĆWILICHOWSKA, 1966) and in the Ropa river near Biecz (the specimens from this site were supplied by dr W. CABAJ to the author).

In the Vistula river at first, *Physa acuta* was noted near Tyniec by ZIĘBA & ZAĆWILICHOWSKA (1966) and several years later by RUTKOWSKI (1983). At present it is the dominant element of the thanatocenosis occurring in sand and gravel with anthropogenic material (with coal grains). Its mass development has been succeeded probably in the connection with the starting of the power station in Skawina (ALEXANDROWICZ & RUTKOWSKI, 1984). The same character have the sites near other power stations as in the Nysa Łużycka river near Zgorzelec, at Siekierki near Warsaw and in channel with water discharged from power station at Kozienice (PIECHOCKI, 1979) as well as in the branch of Odra river near Opole (BOETTGER, 1911). The lack of this species in the rich complex of fauna in lakes with heated water near power station in Konin is interesting (BERGER & DZIECZKOWSKI, 1977). The appearance of it in these basins is merely a question of time.

The mass presence of the shells of *Physa acuta* in the sand and gravel with anthropogenic material makes possible the determination of the lower age limit of these sediments. On the basis of the appearance of coal grains we could suppose that they are deposited not earlier than in the middle of the XIX century. This is the time of the beginning of coal exploitation in Upper Silesia. The history of the migration of the described species considerably limits the quoted age only to the present century. The relation between the development of the abundant population of *Physa acuta* and heated waste water from the power station in Skawina precises even better the age of the deposits with shells and points out that they are not older than 25 years. This suggestion emphasizes the role of some species of molluscs in the determining of the age of the youngest sediments (Alexandrowicz & Rutkowski, 1984).

The causes of the migration of *Physa acuta* are not fully known. There are several circumstances which were making this process easier. One of them is the development of the Botanical Gardens with greenhouses and introducing there water plants from South Europe and America. This was probably the most important factor for the first stage of expansion of this species. For the next one the main role had the ability to the adaptation of the population of *Physa acuta* in the industrial heated and polluted water near power stations and factories. Due to this ability the described taxon can be defined as a synanthropic one, which develops especially in the highly industrialized regions. Even in Africa it occurs most commonly in dams and irrigation channels near human works and habitations (Brown, 1980). Recently, the life area of *Physa acuta* has covered more and more artificial and natural water basins in the moderate climate zone mainly in West and Central Europe. This process will probably proceed.

The expansion of *Physa acuta* which had been developed in the middle of the last century was not the only one. There was also noted the expansion of other animals northwards. Nowak (1971) reported the changes of the water and terrestrial animals, vertebrates and invertebrates. The cause of these migrations might have been different but the time coincidence of these changes is worth noting. In the middle of the last century the climatic conditions were changed in Europe. It was the time of the decline of so called "Small Ice Age". This was seen in the gradual growing warm and consequently in the prolongation of vegetation period as well as in the extension of the range of some plants and cultivations. It miht also have the influence on the tendency to the expansion of the areas inhabited by animals which were previously limited only to the mild climate zone. In relation to the expansion of *Physa acuta*, the coexistence of climatic and anthropogenic factors is very likely.

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STRESZCZENIE

Liczne skorupki *Physa acuta* występują w piaskach i żwirach z domieszką materiału antropogenicznego na obu brzegach Wisły koło Tyńca (rys. 1). Charakterystyka biometryczna populacji reprezentującej tanatocenozę objęła pomiary wysokości i szerokości skorupek i ujścia, kąt wierzchołkowy oraz kąt pomiędzy górną ścianką ujścia a osią skorupki (rys. 2). Wyznaczone zostały również wskaźniki liczbowe: względna wysokość skrętki (S), stopień elongacji skorupki (E) i wskaźnik szerokości ujścia (A). Dla każdej pomierzonej i wyznaczonej wielkości obliczono proste wskaźniki statystyczne: średnią arytmetyczną — x, odchylenie standardowe — s i współczynnik zmienności — v (tab. I). Analiza rozkładów statystycznych wykazała, że wszystkie badane cechy posiadają rozkład normalny, sprawdzony testem Kołmogorowa (rys. 3). Dowodzi to jednorodności zbioru, który obejmuje jeden takson o znacznej zmienności kształtu i wielkości. W obrębie tego zbioru niektóre cechy są wyraźnie skorelowane, a inne nie wykazują takiej zależności (rys. 4, 5). Zróżnicowanie wartości współczynnika v wskazuje, że takie cechy, jak wysokość i szerokość skorupki, jak też ujścia, a także względna wysokość skrętki, mają dużą zmienność, gdy współczynniki elongacji skorupki i szerokości ujścia oraz kąt wierzchołkowy są mało zmienne (tab. I). W badanej populacji można wyróżnić okazy o niskiej skrętce, szerokiej skorupce i subangularnym ujściu — typ morfologiczny I, oraz okazy smukłe o wydłużonej skrętce i wąskim ujściu — typ morfologiczny II (rys. 6, 7) Znormalizowane cechy biometryczne wybranych skorupek, obrazujące opisywane zróżnicowanie, zostały przedstawione za pomocą krzywych kształtu (rys. 8). W obrębie prezentowanej zmienności populacji mogą mieścić się okazy z rodzaju *Physa*, podobne do innych gatunków tego

rodzaju, definiowane wyłącznie na podstawie cech konchiologicznych. *Physa acuta* jest gatunkiem śródziemnomorskim, który w połowie ubiegłego stulecia zaczął rozprzestrzeniać się na obszar Europy zachodniej i środkowej. Migracja ta, opisana przez Feliksiaka (1939), objęła w pierwszym etapie akwaria i cieplarnie ogrodów botanicznych, a następnie, dzięki zdolnościom adaptacyjnym gatunku, rozserzyła się na zbiorniki naturalne (rys. 9). Obok czynników antropogenicznych przyczyną jej mogła być stopniowa zmiana klimatu, zaznaczająca się u schyłku tzw. „małej epoki lodowej". Dogodne warunki bytowania znalazł omawiany ślimak w środowiskach wodnych zanieczyszczonych ściekami przemysłowymi, a zwłaszcza zrzutami wód podgrzanych. Dzięki temu jako element synantropijny towarzyszy on obecnie elektrowniom, hutom i zgrupowaniom fabryk, tworząc silne, ale okresowo zanikające populacje w pobliżu dużych aglomeracji miejskich. Pojawienie się skorupek *Physa acuta* w osadach Wisły pod Tyńcem umożliwia datowanie piasków z materiałem antropogenicznym. Były one deponowane nie wcześniej niż 25 lat temu, to jest już po uruchomieniu elektrowni w Skawinie, położonej około 5 km na południe od opisanego stanowiska.

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