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SHELL BIOMETRICAL VARIABILITY OF *PLANORBIS PLANORBIS* (LINNAEUS, 1758) (GASTROPODA, PULMONATA) IN MAN-MADE WATER BODIES OF THE UPPER SILESIAN INDUSTRIAL REGION

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Abstract: The author has studied the effect of some environmental factors on the biometrical variability of the shell of the freshwater pulmonate snail *Planorbis planorbis* from several man-made water bodies of three types in the Upper Silesian Industrial Region. Out of the studied factors the calcium content in water did not seem to have a strong effect on the shell of the mollusc. On the contrary, a high content of magnesium ions in water seemed to inhibit the growth of the shell.

Key words: Planorbidae, shell variability, environmental factor, water pollution

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A b s t r a c t : The author has studied the effect of some environmental factors on the biometrical variability of the shell of the freshwater pulmonate snail Planorbis planorbis from several man-made water bodies of three types in the Upper Silesian Industrial Region. Out of the studied factors the calcium content in water did not seem to have a strong effect on the shell of the mollusc. On the contrary, a high content of magnesium ions in water seemed to inhibit the growth of the shell.

INTRODUCTION

Planorbis planorbis (Linnaeus, 1758) occurs in abundance in all kinds of man-made water bodies, on various bottom types, regardless of the total hardness of the water and Ca^{++} and Mg^{++} content (Strzelec and Serafiński 1984, Strzelec in press). It is a typical ubiquitous species and its occurrence is not limited by any habitat conditions (Boycott 1936, Hubendick 1947, Žadin 1952, Urbański 1957, Ložek 1964, Piechocki 1979). It appears as one of the first colonizers in industrial reservoirs and rapidly forms abundant populations.

The shell of P. planorbis is slightly variable. Its variability covers the shell size and the position of the keel on the body whorl, which is more or less shifted upwards. On the other hand, in industrial regions, the diversity of the habitats the gastropod occurs in brings about biometrical variability, both within and between populations inhabiting particular industrial reservoirs.

The aim of the present study is to give a biometrical characteristics of several populations of P. planorbis and to find the environmental factors which are responsible for interpopulation differences.

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MATERIAL AND METHODS

In order to study the infra- and interpopulation shell variability of P. planorbis living individuals of the species were collected from April to October in the following man-made water bodies in the Upper Silesian Industrial Region: Magiera in Świętochłowice, Janik in Bytom, Zagórze in Sosnowiec-Zagórze (sinkhole ponds), ZOO in Chorzów, Gliniak in Sosnowiec, Dzierżno Małe near Gliwice (sand pits), Paprocany in Tychy, power plant reservoir in Rybnik (storage reservoirs). Characteristics of the studied reservoirs are presented in Tables 1 and 2, their vegetation in Table 3.

The breadth, height and thickness of the shell were measured in specimens of all probable age classes, with 0.02 mm accuracy. All the shells measured were also weighted (Tab. 5).

In order to study the effect of enviromnental factors on the biometrical variability of the shell, about 200 shells of class IV from each reservoir were compared. Specimens at the age corresponding to that class were numerous in all the studied populations and their infrapopulation variability index was comparatively low ($i_v = \frac{SD}{x} \cdot 100\%$), which means that they were least varied in morphology (Tab. 4).

Water chemistry (total hardness, Ca^{++}, Mg^{++}, Fe^{++}, N_{NH_4}, N_{NO_3}, sulphate and chlorid content) and pH were determined using standard methods. The quantities given in the tables are the averages of three seasonal sampling resulls.

Estimation of individual age

Specimens of P. planorbis seem particularly convenient for biometrical analysis. Stripes (rest lines) appearing on their shells originate from periods of inhibited growth (Boag and Pearlstone 1979, Douglas 1981, Lutz and Phoads 1977, and Shoul and Goodwin 1982). Such stripes are commonly acknowledged to mark the termination of annual growth. However, this interpretation seems incorrect (Piechocki 1979) since it overestimates the lifetime length. Richardot (1976 and 1979) obtained some results in solving the problem. She found the deposition of calcium carbonate in the shell to be inhibited not only during dormant periods. Also in the period of reproduction, when $CaCO_3$ contained in haemolymph is used for egg capsules, thicker stripes appear on the outer shell surface, which are very similar to those originating during a dormant period.

In the studied material there were specimens with 1-6 stripes on the shell. If the stripes were considered yearly growth lines the age of the individuals would be 6 years. However, in aquarium breeding individuals of the species live at most 3 years (Piechocki 1979). It seems therefore that the stripes should be interpreted as follows: stripe I - 1st dormant period, stripe II - 1st reproduction period, stripe III --2nd dormant period, etc.

Table 1

Characterictics of studied water bodies

Reservoirs	Localization	Age (years)	Area ha	Maximum depth (m)	Bottom	Vegetation (according to Tab. 3)
"Janik"	Bytom	20	3.20	4.25	mud	4,9,10,12,15,22,23,
"Magiera"	Świętochłowice	80	6.25	2.00	mud	5,9,10,12,15,22.
"Zagórze"	Sosnowiec	50	0.10	1.00	detritus	1,4,5,7,8,9,12,13,22,24;26,
"ZOO"	Chorzów	25	0.28	0.70	mud	3,4,5,9,11,12,13,14,15,23.
"Gliniak"	Sosnowiec	30	40.00	4.70	detritus	3,4,5,9,11,12,13,15,18.
"Dzierżno Małe"	Gliwice	50	50.00	6.00	sand-clay	1,5,6,13,17,19,24.
"Paprocany"	Tychy	170	130.00	7.00	mud	4,5,6,9,12,13,15,20,21.
"Rybnik"	Rybnik	10	625.00	9.00	sand-clay	2,4,6,9,10,16,25.
"Gzel"	Rybnik	10	29.20	5.20	sand-clay	1,2,4,5,6,10,13,22.

Table 2

Water chemistry

	Reservoirs	Total hardness	Ca^{++} mg/l	Mg^{++} mg/l	Ca:Mg ratio	pH	Chlorides mg/l	Sulphates mg/l	N_{NH_2} mg/l	N_{NH_3} mg/l	Fe^{+++} mg/l
Sinkhole ponds	"Janik"	47.60	142.68	120.16	0.84	7.4	66.00	450.00	0.39	3.00	0.50
	"Magiera"	38.50	105.80	102.60	0.97	7.0	140.36	313.50	0.25	2.00	-
	"Zagórze"	51.96	171.54	42.25	0.25	6.50	37.40	425.60	0.21	1.00	0.80
Sand pits	"ZOO"	19.27	68.30	42.25	0.62	6.80	104.10	147.60	0.33	0.50	0.20
	"Gliniak"	19.26	65.73	43.74	0.67	7.20	26.40	121.70	0.29	1.50	trace
	"Dzierżno Małe"	21.20	105.00	28.20	0.27	7.20	86.40	120.60	1.06	1.00	0.375
Storage reservoirs	"Paprocany"	7.48	31.01	13.67	0.44	7.50	18.00	3.60	0.44	0.40	0.30
	"Rybnik"	13.59	80.46	10.20	0.13	7.20	160.00	107.00	0.60	0.90	0.50
	"Gzel"	6.99	36.10	8.50	0.24	8.00	96.70	71.00	0.93	0.50	0.10

Table 3

Vegetation of studied water bodies

1) _Sagittaria sagittifolia_ L., 2) _Alisma plantago-aquatica_ L., 3) _Hydrocharis morsus-ranae_ L., 4) _Elodea canadensis_ Rich., 5) _Potamogeton natans_ L., 6) _Juncus_ sp., 7) _Scirpus lacustris_ L., 8) _Carex_ sp., 9) _Phragmites communis_ Trin., 10) _Glyceria aquatica_ (L.) Whlb., 11) _Lemna trisulca_ L., 12) _Lemna minor_ L., 13) _Acorus calamus_ L., 14) _Sparganium ramosum_ Huds., 15) _Typha latifolia_ L., 16) _Polygonum amphibium_ L., 17) _Callitriche verna_ L., 18) _Batrachium circinatum_ (Sibth.) Fr., 19) _Ranunculus lingua_ L., 20) _Nymphaea alba_ L., 21) _Nuphar luteum_ (L.) Sm., 22) _Ceratophyllum demersum_ L., 23) _Myriophyllum verticillatum_ L., 24) _Myosotis palustris_ (L.) Nathorst, 25) _Bidens tripartitus_ L., 26) _Equisetum limosum_ L.

Table 4

Variability index of shells

Age class	Sinkhole ponds				Sand pits				Storage reservoirs			
	Breadth	Height	Thickness	Weight	Breadth	Height	Thickness	Weight	Breadth	Height	Thickness	Weight
I	12.1	10.0	-	39.0	16.9	10.0	-	39.0	16.9	21.0	-	57.0
II	11.8	8.0	24.0	13.0	12.3	9.0	17.0	32.0	11.3	10.0	11.0	37.0
III	9.0	9.0	15.0	29.0	8.7	8.0	15.0	22.0	16.3	11.0	17.0	36.0
IV	8.5	8.0	36.0	16.0	5.2	8.0	14.0	18.0	6.7	6.0	8.0	26.0
V	6.6	13.0	32.0	13.0	4.6	6.0	6.0	18.0	4.5	5.0	7.0	17.0
VI	5.0	6.0	15.0	29.0	4.8	6.0	23.0	22.0	4.7	7.0	6.0	19.0

The above interpretation seems to enable an age determination, observations of individual growth and biometrical comparisons of corresponding age classes.

RESULTS

The infrapopulation variability observed in the shell breadth was small there being statistically significant differences between specimens of corresponding age classes from different habitats.

The differences could be observed after the first dormant period. The individuals from the storage reservoirs were the smallest, and this difference was maintained in the next two age classes. All the differences were statistically significant (p= 0.005).

The individuals from the storage reservoirs were growing rapidly after the second dormant period, while in those from the other types of water bodies the growth rate was moderate. In classes V and VI the growth rate was similar in the storage reservoirs and sand pits (differences were insignificant, p = 0.5). The shells from the sinkhole ponds were markedly smaller and differed significantly from both the above types of water reservoirs (Fig. 1).

The specimens of class VI from the sand pits, storage reservoirs, and sinkhole ponds attained on average 14.5 mm, 14.29 mm and 12.97 mm in diameter, respectively. The largest specimen 16.3 mm in diameter has been found in a storage reservoir.

Shell height

The shell height variability among specimens from the studied water bodies was low. After the first dormant period individuals from the sand pits were the highest and this concerns all age classes, though in some cases the size differences were statistically insignificant (p 0.5).

Changes in shell height are most evident in class IV. A rapid increase in height was observed in the individuals from the storage reservoirs, the differences between them and the specimens from the sinkhole ponds being particularly sharp (Fig. 2). The shell height of the specimens from the sand pits and storage reservoirs was similar. In classes IV - VI the differences were insignificant, except for the specimens from the sinkhole ponds.

Shell wall thickness

The shell wall thickness has rarely been regarded as a diagnostic character in Planorbidae. It seems, however, that it can provide information

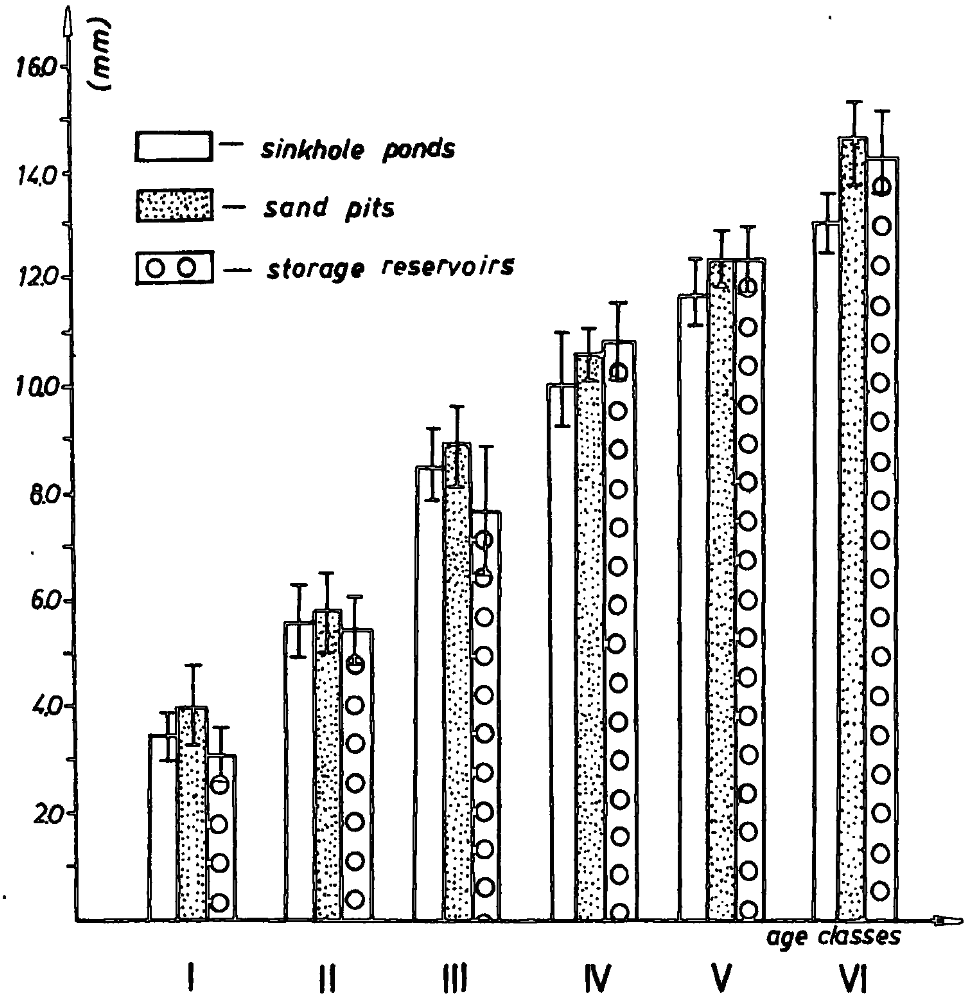

Fig. 1. Shell breadth in Planorbis planorbis

about environmental conditions in various habitats. For this reason it has been used to study ecophenotype variation (Fig. 3). In class I the shell wall thickness was not measured for technical reasons.

The measurements have revealed some regularity: in each class the individuals from the sinkhole ponds had the most thick -walled shells. The difference between them and the speciemns living in the other types of water bodies was highly significant ($p = 0.001$). The shells of classes II and III from storage reservoirs and sand pits differed insignificantly ($p = 0.5$). In higher age classes, in the storage reservoirs significant differences appeared as a result of rapid increase in wall thickness. In that period the shell wall thickness of the sand-pit individuals of class V had reached its maximum while that of the storage-reservoir ones of the same class was still increasing. It was manifested in the latter having their shells much more thick-walled than those from the other reservoir types.

Shell weight

The shell weight increased parallelly to the shell diameter, though showing a greater infrapopulation variability. In classes I - III the lightest shells were found in the storage reservoirs. After the second dormant period the shells increased in weight and in class IV became the heaviest. In classes V and VI there was almost no difference in shell weight between

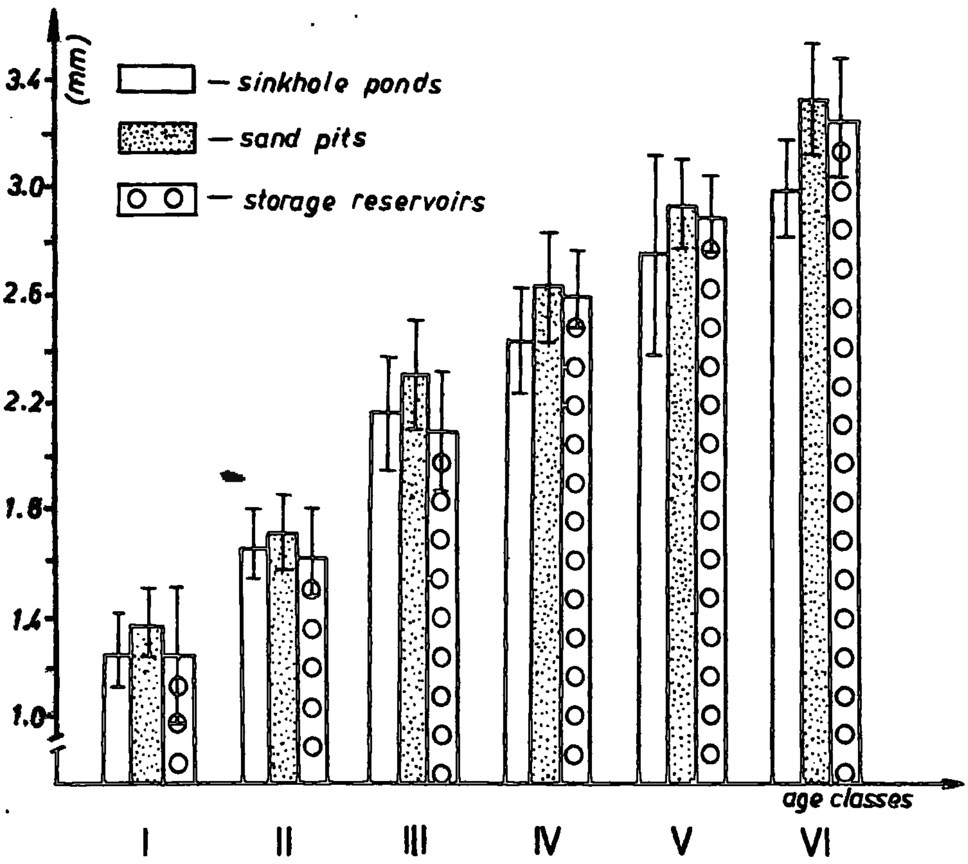

Fig. 2. Shell height in Planorbis planorbis

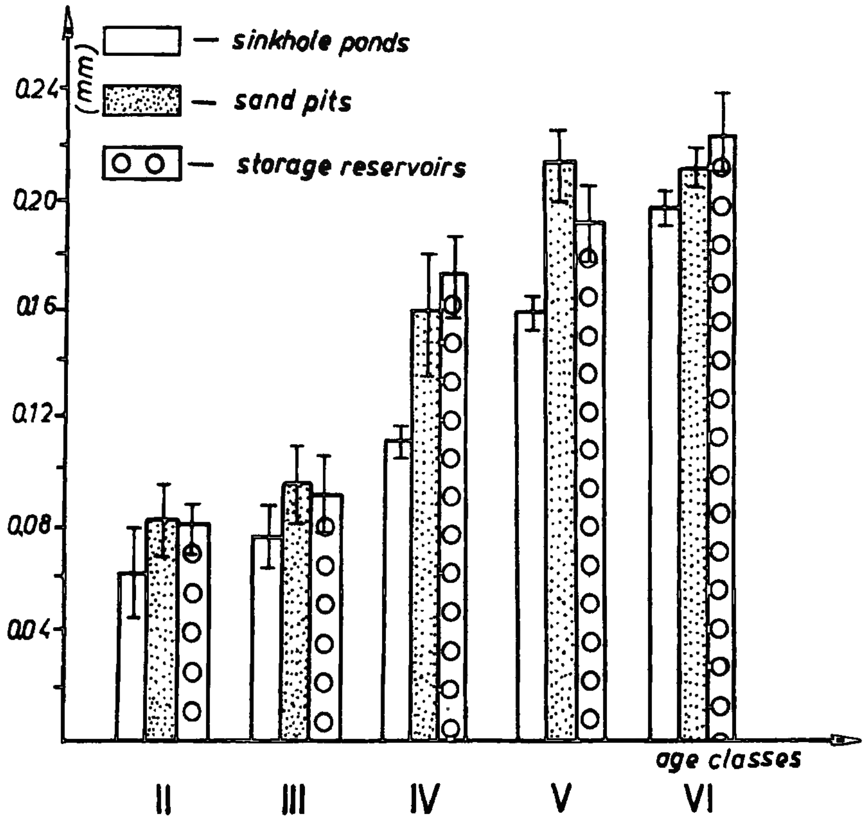

Fig. 3. Shell wall thickness in Planorbis planorbis

the storage-reservoir and sand-pit individuals. In the sinkhole-pond specimens the previous increase in weight got inhibited beginning at class IV. This resulted in significant differences between them and the specimens from the remaining water bodies. The heaviest shells were found in sand pits (173 mg) and storage reservoirs (172 mg) while in sinkhole ponds the maximum observed was 110 mg (Fig. 4).

Effects of some environmental factors on shell biometrics (Tab. 5)

According to some authors the shells of the individuals living in hard water rich in calcium are larger and heavier than those of the ones occurring in soft water. This has not been confirmed by the present study. The shell height and breadth were insignificantly correlated with total hardness and Ca^{++} content. This is the shell thickness that much surprisingly has been found negatively correlated with the total hardness (r = -0.857) as well as with the Ca^{++} content (r = -0.717).

Some authors state that the shell size is influenced by Mg^{++}: Ca^{++} ratio. This has been confirmed by the significant negative correlation calculated between the ratio and each of the measured shell parameters. The correlation coefficients are -0.76, -0.76, and -0.67 for the shell wall thickness, shell breadth, and shell height, respectively.

No significant correlation has been found between the total hardness, Ca^{++} content, and shell weight. The latter parameter, however, has been found to be negatively correlated with the Mg^{++} content (r = -0.68).

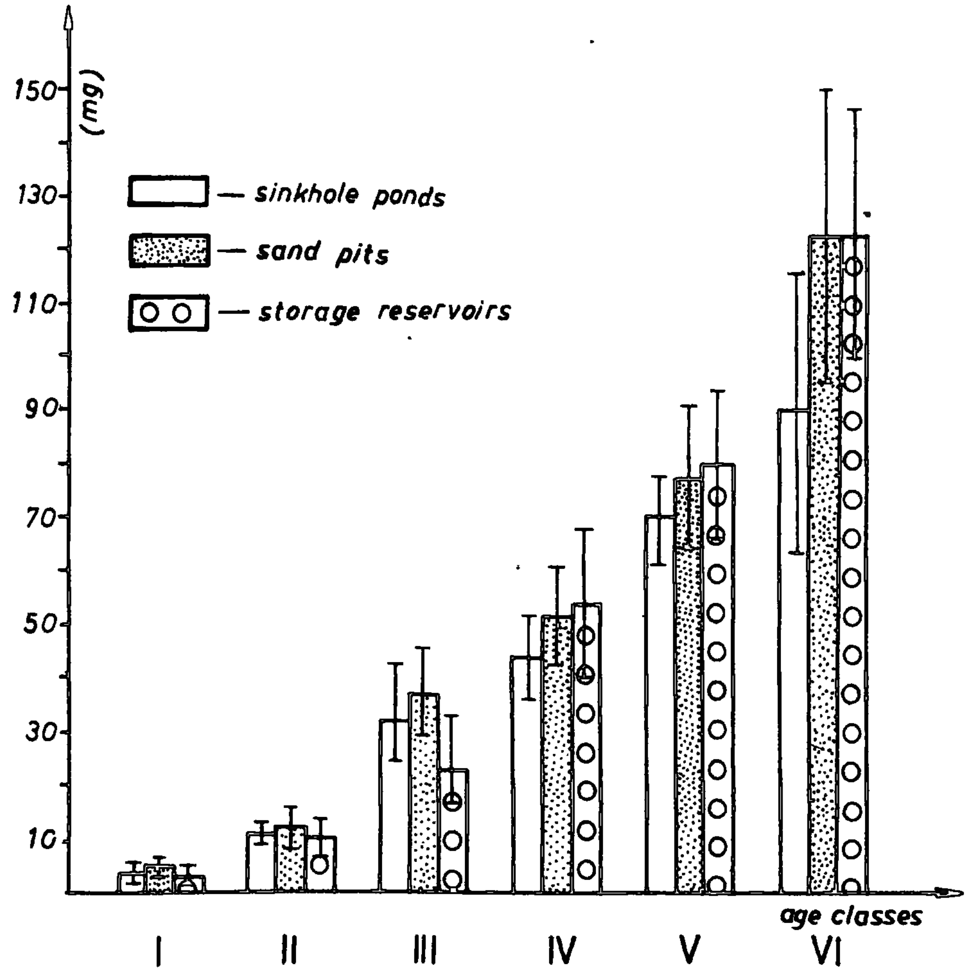

Fig. 4. Shell weight in Planorbis planorbis

Table 5

Shell measurements

CLASS	Sinkhole ponds				Sand pits				Storage reservoirs			
	Breadth	Height	Thick-ness	Weight	Breadth	Height	Thick-ness	Weight	Breadth	Height	Thick-ness	Weight
I	X = 3.54 n = 44 SD ± 0.43	X = 1.28 n = 37 SD ± 0.13		X= 3.97 n = 36 SD ± 1.58	X = 4.01 n = 51 SD ± 0.68	X = 1.38 n = 51 SD ± 0.14		X = 5.34 n = 51 SD ± 2.10	X = 3.12 n = 57 SD ± 0.53	X = 1.26 n = 47 SD ± 0.27	.	X = 2.68 n = 57 SD ± 1.54
II	X = 5.57 n = 67 SD ± 0.66	X = 1.68 n = 67 SD ± 0.14	X = 0.06 n = 30 SD ± 0.01	X = 10.66 n = 67 SD ± 1.38	X = 5.84 n = 63 SD ± 0.72	X = 1.72 n = 63 SD ± 0.15	X = 0.08 n = 30 SD± 0.01	X = 12.05 n = 63 SD ± 3.87	X = 5.46 n = 51 SD ± 0.62	X = 1.64 n = 51 SD ± 0.17	X = 0.08 n = 23 SD ±0.01	X = 6.60 n = 51 SD ± 3.58
III	X = 8.53 n = 66 SD ± 0.77	X = 2.18 n = 66 SD ± 0.20	X = 0.08 n = 30 SD ± 0.02	X = 32.60 n = 66 SD ± 9.60	X = 8.94 n = 58 SD ± 0.78	X = 2.32 n = 58 SD ± 0.19	X = 0.09 n = 30 SD± 0.01	X =36.66 n = 58 SD ± 8.24	X = 7.61 n = 61 SD ± 1.24	X =2.10 n = 61 SD ± 0.32	X =0.09 n = 30 SD± 0.01	X = 24.89 n = 61 SD ± 8.90
IV	X = 10.11 n = 66 SD ± 0.86	X = 2.44 n = 66 SD ± 0.20	X = 0.11 n = 30 SD ± 0.04	X = 49.17 n = 66 SD ± 0.04	X = 10.60 n = 65 SD ± 0.55	X = 2.64 n = 65 SD ± 0.21	X = 0.16 n = 30 SD± 0.02	X = 52.25 n = 65 SD ± 9.45	X = 10.78 n = 60 SD ± 0.72	X = 2.61 n = 60 SD ± 0.15	X = 0.18 n = 30 SD± 0.01	X = 53.90 n = 60 SD ±.13.74
V	X = 11.67 n = 59 SD ± 0.77	X = 2.76 n = 59 SD ± 0.37	X = 0.16 n = 27 SD ± 0.05	X = 69.72 n = 59 SD ± 8.98	X = 12.36 n = 67 SD ± 0.57	X = 2.94 n = 67 SD ± 0.17	X = 0.21 n = 30 SD± 0.01	X = 76.49 n = 67 SD± 13.77	X = 12.37 n = 67 SD ± 0.57	X = 2.90 n = 67 SD ± 0.15	X = 0.19 n = 30 SD± 0.01	X = 79.68 n = 67 SD ± 3.80
VI	X = 12.97 n = 54 SD ± 0.65	X = 3.03 n = 54 SD ± 0.18	X = 0.20 n = 25 SD ± 0.03	X = 89.54 n = 54 SD ±25.62	X = 14.50 n = 19 SD ± 0.70	X = 3.34 n = 19 SD ± 0.22	X = 0.21 n = 15 SD± 0.05	X =121.71 n = 19 SD ±27.00	X = 14.29 n = 65 SD± 0.67	X = 3.27 n = 65 SD ± 0.24	X = 0.26 n = 37 SD± 0.02	X =122.33 n = 65 SD± 22.84

The correlation found between the Mg^{++}: Ca^{++} ratio and shell weight is low (r = -0.56). The author supposes that the negative correlation suggests the negative influence of magnesium ions, being stronger than the positive effect of calcium salts.

Relationships between the shell parameters studied and the remaining physico-chemical factors measured are not clear considering the corresponding the correlations. The content of sulphates seems to have influenced the shell breadth negatively (r = -0.583). In the case of the Fe^{+++} content no apparent effect on the shell has been found, there being a low, positive correlation between N_{NH_4} content and shell size (r = 0.56).

It was more difficult to determine the effect of non-measurable factors, e.g. bottom type. The chi-square test having been used, only a small insignificant difference in shell breadth was found between the specimens from detritus and those inhabiting sand-clay bottom, while the individuals from muddy bottom differed significantly from the others (chi-square = 13.1 for mud and detritus, 30.4 for mud and sand-clay). The specimens from muddy bottom were remarkably smaller.

The individuals from the sinkhole ponds differed in a similar manner from those the other water bodies considered (chi^2 = 14.3 for the sinkhole ponds and sand pits, 18.6 for the sinkhole ponds storage reservoirs). The difference between the individuals from the storage reservoirs and those from the sand pits was insignificant.

DISCUSSION

Most of the present results do not confirm the common opinion that some enviromnental factors have a strong effect on the shell of freshwater snails. Haley and Gibson (1971) ascribe an important role to the total hardness and calcium content. They maintain that the amount of calcium stored by snails depends on its content in enviromnent. Our results suggest that the calcium content is not so important factor. According to Zhadin (1952) snails inhabiting soft water have smaller shells.

Thomas and Benjamin (1974) found that in water devoid of calcium snails can grow if their food is calcium-rich. Van der Borght and van Pujmbroeck (1960) found in laboratory experiments that 80% of calcium assimilated by *Lymnaea stagnalis* come from water, only 20% coming from food. Most authors agree with the latter view. Froemming (1936, 1938, 1953, 1956) is the only one convinced that food is the only source of calcium. Russel-Hunter (1970) states that differences in calcium assimilation do not depend on calcium concentration in water but have a genetic basis.

My observations do not confirm the commonly accepted opinion that snails from calcium-rich water have heavier and more thick -walled shells (Boycott 1936, Franc 1968, McMahon 1975, Russel-Hunter 1978). Unfortunately the authors cited above do not give exact but only approximate weights of shells from various habitats.

The shell weight in the studied water bodies was negatively correlated only with Mg^{++} content, no correlation being found with Ca^{++} concentration.

The shell wall thickness in the man-made reservoirs studied was not correlated with the calcium content in the habitat. This might have resulted from the fact that in living organisms the magnesium act antagonistically to the calcium ions, in competing for the same binding sites in the cell membrane (Burton 1973). An excess of magnesium probably reduces the ability to use calcium during the shell formation, though the former element has never been found a shell component (Strzelec unpublished data). Magnesium ions might inhibit the calcium transport by haemolymph, by occupying calcium binding sites.

Since calcium assimilated from enviromnent is transported by haemolymph but does not passively penetrate through the body integument as suggested by Rao and Goldberg (1959 ; Greenaway 1971, 1971a), it is obvious that the saturation of body fluids with antagonistic ions would limit the amount of calcium transported and stored in the shell. There is also another possible explanation of the smaller size of the shells from magnesium-rich water. It was found that in vertebrates a surplus of magnesium inhibits the secretion of growth hormone (Bose, Vale and Grant 1975). The same mechanism might occur in snails though no specific growth hormone has been detected in these animals so far. The present results are in agreement with those of Nduku and Harrison (1976) who found that a high Mg^{++} and Ca^{++} ratio in environment is one of the most harmful factors for snails.

Thomas, Goldworthy and Aram (1975) observed a positive correlation between the shell size of Biomphalaria glabrata and the iron content. No such correlation has been found in the present study. The suggestion that temperature has a positive effect on shell calcification (Stoor, Costa and Pravel 1982) has not been confirmed. The shells of the individuals from the storage reservoir of the power plant in Rybnik where the water temperature maintains over +5° C the year round (Krzyżanek 1979) were neither heavier nor larger than those from the other studied water bodies of the same type.

Planorbis planorbis grows throughout life, as is shown by its size increasing with the number of rest lines. According to Palmer (1982) growth is inhibited after the sexual maturity has been reached, and then variation in body weight is related only to sexual activity. That author meant probably the periodic decreases in body weight, which result from the use of part of the shell calcium for the formation of egg envelopes (Richardot 1979).

Both the present results and literature data confirm the view of Odum (1963), that size variation in organisms living in various habitats reflects specific adaptations to the set of conditions, which characterizes each particular enviromnent.

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ZMIENNOŚĆ BIOMETRYCZNA MUSZLI PLANORBIS PLANORBIS (LINNAEUS, 1758) (GASTROPODA, PULMONATA) W SZTUCZNYCH ZBIORNIKACH WODNYCH GÓRNOŚLĄSKIEGO OKRĘGU PRZEMYSŁOWEGO

S t r e s z c z e n i e : Autorka badała wpływ niektórych czynników środowiskowych na zmienność biometryczną muszli Planorbis planorbis w trzech typach sztucznych zbiorników wodnych w Górnośląskim Okręgu Przemysłowym. Spośród badanych czynników hydrochemicznych zawartość wapnia w wodzie wydawała się nie wpływać w istotny sposób na rozmiary muszli, podczas gdy podwyższona zawartość jonów magnezu w wodzie działała hamująco na wzrost muszli.