

MALACOFAUNA OF THE WAWEL HILL IN CRACOW

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ABSTRACT: A molluscan assemblage comprising 21 species was found at the Wawel Hill in the centre of Cracow. Three types of associations were distinguished using simple numerical methods. Their composition and distribution are controlled both by natural ecological conditions and by the influence of cultivation, grazing and pollution. The mentioned factors are also responsible for the differentiation of the shell size in particular populations. At the foot of the hill the allocenose of molluscs accumulated by flood of the Vistula river was observed.

KEY WORDS: comparative analysis, mollusc assemblages, Wawel Hill

Folia Malacologica 2/1988 was originally published as No. 1112 of Scientific Bulletins of University of Mining and Metallurgy, Cracow. This digitalised version was prepared by the Association of Polish Malacologists and first published on-line on December 30th, 2016.

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Abstract: A molluscan assemblage comprising 21 species was found at the Wawel Hill in the centre of Cracow. Three types of associations were distinguished using simple numerical methods. Their composition and distribution are controlled both by natural ecological conditions and by the influence of cultivation, grazing and pollution. The mentioned factors are also responsible for the differentiation of the shell size in particular populations. At the foot of the hill the allocenose of molluscs accumulated by flood of the Vistula river was observed.

THE OCCURENCE OF MOLLUSCAN ASSEMBLAGES

The castle of Wawel is situated in the centre of Cracow, at a limestone hill, about 40 m over a built-up area of the Vistula valley. The steep slopes of the hill are covered with cultivated grass but in some places, mainly at the West, North-West and East sides, there are rocky slopes, overgrown partly with bushes and deciduous trees. On the flat ridge-crest of the hill, surrounded by walls and towers, the old royal castle, the Wawel-Cathedral and some less old buildings are risen up. Among these there are lawns and flower-beds with introduced garden plants. These artificial anthropogenic habitats as well as an intensive traffic and a remarkable air and soil pollution create the unfavourable conditions for the development of the fauna, however, the molluscan assemblages found here are sufficiently rich and differentiated to be interesting as a subject of a detailed study.

Like the molluscs from other sites of the town of Cracow the malacofauna of the Wawel Hill has not been described in detail so far. A progressing pollution and changes in the natural environment in Poland make it necessary to study, like in other countries, the present conditions of the malacofauna living in towns. Snails and their empty shells were collected by the author at the Wawel Hill during three years (1983-1985), mainly in spring and autumn. Each of the nine sites described was visited 5-8 times. Besides the samples of the autochthonous fauna from these sites (the autochthonous thanato- or necrocenoses) samples from the western side of the foot of the hill (on the left bank of the Vistula river) were taken additionally just after a flood in summer 1985. In that time in the outer part of a river meander, sediments rich in shells of molluscs were accumulated, forming an allochthonous thanatocenose (allocenose). The collection comprises totally about 2000 shells; more than 1.5 thousand of them derives from the sites 1 - 9 described below (Fig. 1).

1. Lawns and flower-beds on the courtyard of the castle, between the buildings in the ridge-crest of the hill, in front of the Wawel-Cathedral. The grass is often grazed and on the cultivated flower-beds various garden plants, some of them exotic are introduced. The habitat in question is sunny and only scarce, small places within this are partly shaded by shrubs. The assemblage of gastropods found here consists of seven species, but only Cepaea nemoralis (Linnaeus) is represented by several shells (Tab. 1).

2. Small lawns and flower-beds in the western part of the ridge-crest, extending between the gate and buildings. The habitat is distinctly differentiated because the cultivated area is divided by low calcareous walls and steps partly overgrown with ivy (Hedera helix). Some places are shaded by deciduous trees and shrubs. The molluscan assemblage comprises 13 species of snails. Five of them: Vallonia costata (O.F. Müller), Vallonia pulchella (O.F. Müller), Laciniaria biplicata (Montagu), Cepaea nemoralis (Linnaeus) and Oxychilus depressus (Sterki) are represented by numerous shells (Tab. 1). The occurrence of Irunca-tellina claustralis (Gredler), a rare species found at the Wawel hill in the described locality only is noteworthy. From this site derive also single shells of two other species: Punctum pygmaeum (Draparnaud) and Aegopinella pura (Alder), absent at the other sites.

3. The North-western slope of the hill, lying under the castle-wall above the Podzamcze street. The site is shaded by numerous trees and bushes but in its lower part an open lawn predominates. Close to the

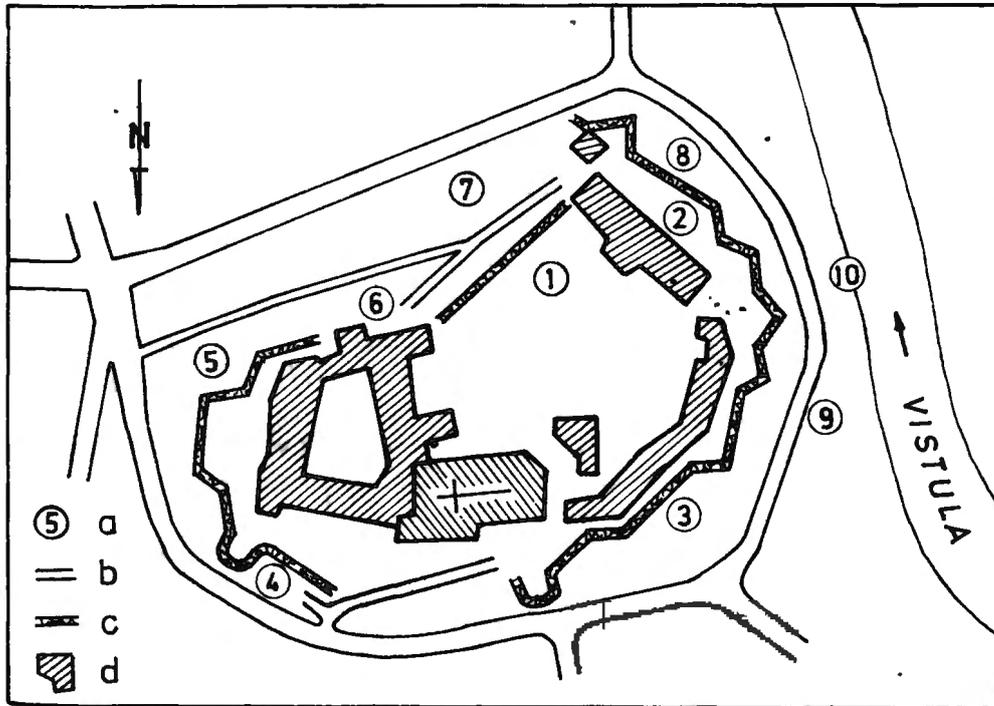


Fig. 1. The plan of the Wawel Hill, a - the localities described in the text, b - roads,

street the slope is grazed while its upper part, where small outcrops and rocks of Jurassic limestones are visible, represents a habitat resembling a natural one. The molluscan assemblage is rich. It comprises 10 taxa with the dominant component - Laciniaria biplicata (Montagu). The shells of Vallonia costata (O.F. Müller), Vallonia pulchella (O.F. Müller) and Cochlicopa lubrica (O.F. Müller) are also numerous (Tab. 1).

4. The low, eastern slope of the hill, just above the Podzamcze street. There is a small grazed lawn partly shaded by some trees. The small distance of the street causes a significant pollution of the site. The molluscan assemblage is poor and represented mainly by numerous shells of Vallonia costata (O.F. Müller). Only one specimen of Oxychilus inopinatus (Ulicný) was found also in this locality (Tab. 1).

5. The lawn covering a high, steep slope and a small part of the flat terrace in the south-eastern part of the hill, near the crossing of Grodzka and Bernardyńska streets. This is an open, sunny habitat and

Table 1

The occurrence of species at the Wawel Hill

Taxon	Samples									C	D	N
	1	2	3	4	5	6	7	8	9			
1 <u>Cochlicopa lubrica</u>	x	x	+	x		x	+	+		IV	IV	164
2 <u>Cochlicopa lubricella</u>	+	+					+			II	I	4
3 <u>Vertigo alpestris</u>							+			I	I	1
4 <u>Truncatellina cylindrica</u>					+		+	+		II	I	6
5 <u>Truncatellina claustralis</u>		+								I	I	1
6 <u>Pupilla muscorum</u>		+			+		+	+		III	II	16
7 <u>Vallonia pulchella</u>	x	x	+	x			+	x	+	IV	III	151
8 <u>Vallonia costata</u>	x	x	x	x	x	+	x	x	+	V	IV	268
9 <u>Punctum pygmaeum</u>	x									I	I	12
10 <u>Vitrina pellucida</u>			+							I	I	2
11 <u>Aegopinella pura</u>		+								I	I	1
12 <u>Oxychilus draparneudi</u>	x	+					+	+		III	II	46
13 <u>Oxychilus inopinatus</u>				+						I	I	1
14 <u>Limacidae</u>			+	+	+			+	+	III	I	9
15 <u>Cecilioides acicula</u>	+				+	+	x	x		III	II	39
16 <u>Laciniaria biplicata</u>	x	o		x	+	+	x	x		IV	IV	267
17 <u>Helicella obvia</u>	+	+			+	o	o	x	+	IV	IV	263
18 <u>Trichia hispida</u>					+					I	I	1
19 <u>Arianta arbustorum</u>	+	x	+	+			+	+		IV	II	25
20 <u>Cepaea nemoralis</u>	x	x	x	+	x	x	x	x	+	V	IV	216
21 <u>Cepaea hortensis</u>					+					I	I	1
22 <u>Helix pomatia</u>	+	+	+	+	x	+	x	+	+	V	II	65

Number of specimens: + - 1-9, x - 10-99, o - above 100

only below a big wall of the castle, overgrown with wild vine it is partly shady. In the middle, eastward exposed part of the slope, a low step built of fragments of Jurassic limestones is visible. The malacofauna is rich and differentiated. It comprises 14 taxa, four of them represented by numerous specimens: Vallonia costata (O.F. Müller), Cochlicopa lubrica (O.F. Müller), Cepaea nemoralis (Linnaeus) and Helix pomatia Linnaeus. On the mentioned small limestone wall many specimens of Laciniaria biplicata (Montagu) were found. Single shells of Cepaea hortensis (O.F. Müller) and Trichia hispida (Linnaeus) derive only from this locality (Tab. 1).

6. The southward exposed slope covered with grass, reaching just above a path leading to the principal gate of the castle. This is a xerothermic sunny and dry habitat, often grazed, unfavourable for most of the species of snails. The assemblage is poor and its dominant component is Helicella obvia (Menke). The species forms an abundant population here (tab. 1).

7. The lower part of the slope, passing southwards down to the Bernardyńska street. This is a grazed lawn partly shaded by shrubs. The assemblage of snails comprises 13 species, but only Helicella obvia (Menke) is represented by numerous specimens. The presence of several shells of Cecilioides acicula (O.F. Müller), as well as some other taxa like Cepaea nemoralis (Linnaeus), Vallonia costata (O.F. Müller) and Cochlicopa lubrica (O.F. Müller) is noteworthy. One shell of Vertigo alpestris Alder derives only from this locality (Tab. 1).

8. The western and South-western slope of the hill, below the castle wall. This is a sunny steep slope with outcrops of Jurassic limestones. In its lower part, just above the footpath leading onto a terrace covered with grass, the entrance to a cave (the so called Dragon Cave) is visible. North- and southwards from the entrance to this cave surrounded by rocks of Jurassic limestones, the slope is overgrown with grass and weeds, but locally some trees and shrubs occur. The ecological conditions are very variable here due to the existence of both sunny and shady habitats with rocks, limestone steps and block accumulations as well as grass and shrubs. The slope is not often grazed so the site in question resembles a natural habitat. The molluscan assemblage is rich and comprises 12 taxa. Laciniaria biplicata (Montagu) and Vallonia costata (O.F. Müller) are the most numerous components of this assemblage (Tab. 1).

9. Limestone rocks at the foot of the western slope of the hill, just above the Vistula and a path leading along the left bank of the river. Rocks are partly outcropped forming sunny habitats, locally overgrown with shrubs. Malacofauna is poor, it consists of 9 taxa represented by scarce shells. Only one of them - Laciniaria biplicata (Montagu) is common here (Tab. 1).

TYPES OF ASSEMBLAGES

Molluscan assemblages found in 9 localities described differ each other in the number of taxa - N_t and the number of specimens - N_i , as well as in the value of the "Taxon Diversity Index" - TDI. This index

is calculated according to the following formula, described by the author (Alexandrowicz 1985):

$$TDI = n^2 - \sum x_i^2 / n^2(n - 1)$$

where n is the number of specimens in analysed assemblage and x_i - the number of specimens representing each taxon. The value of TDI changes between 0 and 1, meaning less or more differentiated assemblages, called by Evans (1972): specialised (TDI = 0) and generalised (TDI = 1) associations.

In the diagram showing the relation between N_t and N_i two groups of assemblages can be distinguished. One of them comprises poor malacocenoses characterised by a low number of species and specimens (localities 1, 4, 9 as well as 6) while the second one - rich malacocenoses (localities 2, 3, 5, 7, 8). Both groups are distinctly separated in the mentioned diagram (Fig. 2-A).

The relation between the number of taxa - N_t and the diversity index - TDI divides the described associations into two groups (fig. 2-B). The first one is composed of two samples (1, 6) while the second one of the others. The combination of both the diagrams mentioned enables to distinguish the following types of molluscan assemblages at the Wawel Hill:

- poor specialized associations (localities 1, 6) characterizing open, sunny, less differentiated habitats;
- poor generalized associations (localities 4, 9) occurring in different habitats unfavourable for gastropods;
- rich generalized associations (localities 2, 3, 5, 7, 8) found in habitats partly shady and humid, more favourable for molluscs.

The similarity between all the assemblages coming from the localities described was analysed using two simple methods of numerical taxonomy: the qualitative and the quantitative method, both based on the formulae defined by Steinhaus (Marczewski, Steinhaus 1959) and adapted for paleontology by the author (Alexandrowicz 1977, method 1 and 7). It is worth of attention, that the qualitative analysis has given more interesting and instructive results than the quantitative one.

The dendrogram constructed for the first method divides all the material described into three groups, excluding one separate assemblage from the locality 2 (Fig. 3-A). The first group (G-I) comprises habitats corresponding with various ecological conditions, disposed on the southern and south-western slopes of the Wawel Hill. The assemblages 5, 7 and 8 are characterized by numerous taxa and specimens as well as by

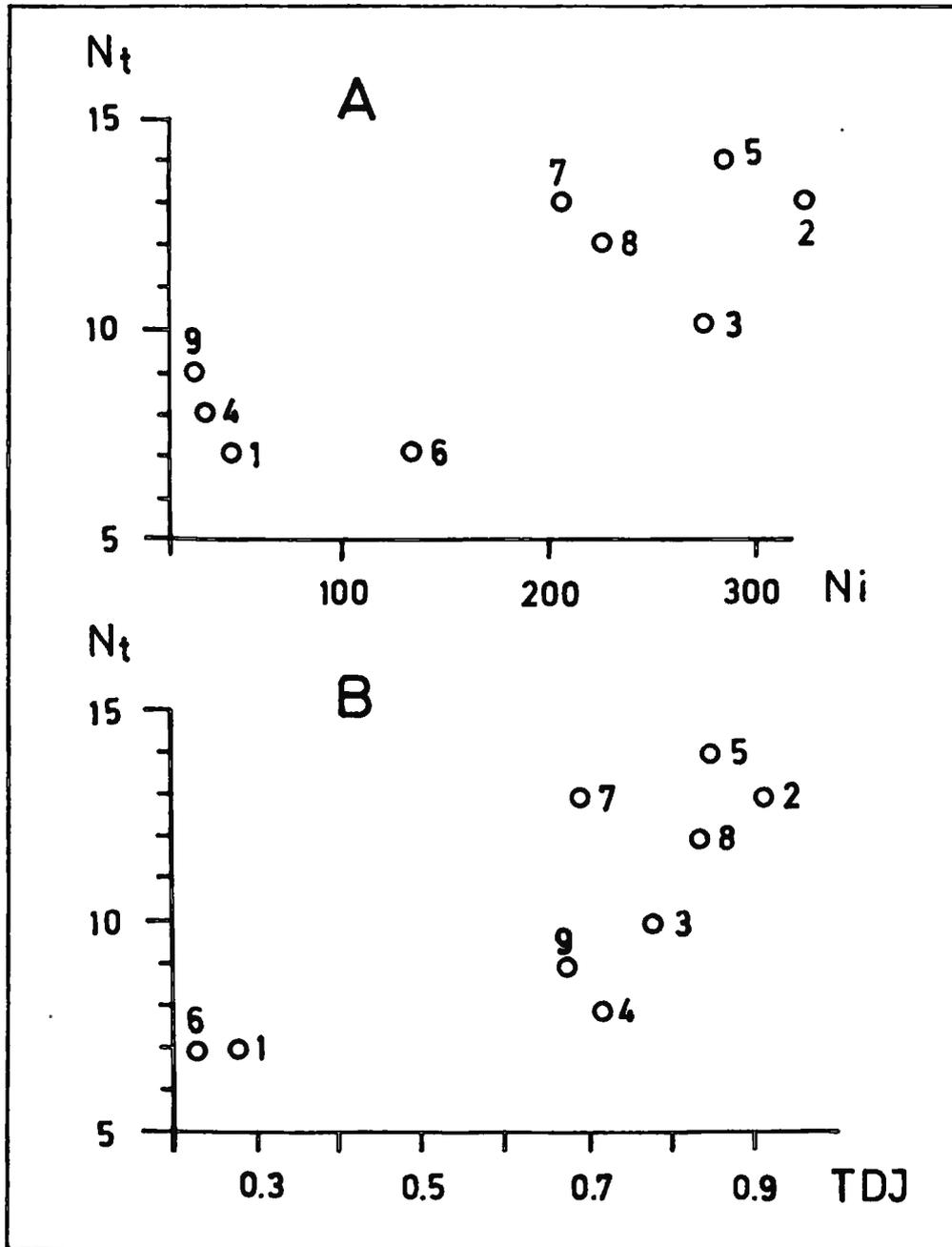


Fig. 2. The diagrams of the interrelations between the number of taxa (N_t), the number of specimens (N_i), and the taxon diversity index (TDI): 1-9 - the snail assemblages from the described localities

the high value of the diversity index (generalized associations). Three assemblages (3, 4, 9) belong to the second group (G-II). The number of species is low here, however, they can be regarded as generalized associations due to the values of TDI. The third group (G-III) is formed by the assemblages from two localities (1, 6) being sunny and intensively cultivated. The number of taxa is the lowest here and the low value of TDI defines these associations as specialized ones. The remaining assemblage (site 2) separated by the dendrogram corresponds with its markedly differentiated habitat. It is a rich generalized association, comprising the high number of taxa and specimens. It differs distinctly from the other rich associations described.

The dendrogram constructed according to the quantitative method divides all the associations into four groups (Fig. 3-B). The number of specimens seems to be the most important factor of these pattern.

It should be stressed that the malacofauna of the Wawel Hill is distinctly differentiated. This feature can be expressed by the "assemblages diversity index" - ADI used by the author as:

$$ADI = kn - \sum x_i / kn - n$$

where k is the number of samples (assemblages), n - the number of taxa in the whole analysed material and x_i - the number of taxa in each sample. Values of this index are normalized like for the TDI-index. For the association found at the Wawel Hill ADI = 0,60, this means a relatively high value of differentiation. The character and distribution of the described three groups of assemblages including the malacofauna from the locality 2 (Fig. 3-A) are controlled by such ecological factors as the plant density, the exposition and humidity of sites, the proportions of sunny and shady places as well as by the intensity of such cultivation as grazing, ploughing and fertilizing.

SPECIES DISTRIBUTION

Snails of the Wawel Hill are distributed unevenly. Four species are represented by more than 200 specimens: Vallonia costata (O.F. Müller), Laciniaria biplicata (Montagu), Helicella obvia (Menke) and Cepaea nemoralis (Linnaeus), two taxa - by more than 100 specimens: Cochlicopa lubrica (O.F. Müller) and Vallonia pulchella (O.F. Müller) and the following four - by some dozen of specimens. More than the half of all the species have been found as single or scarce shells (Tab. 1).

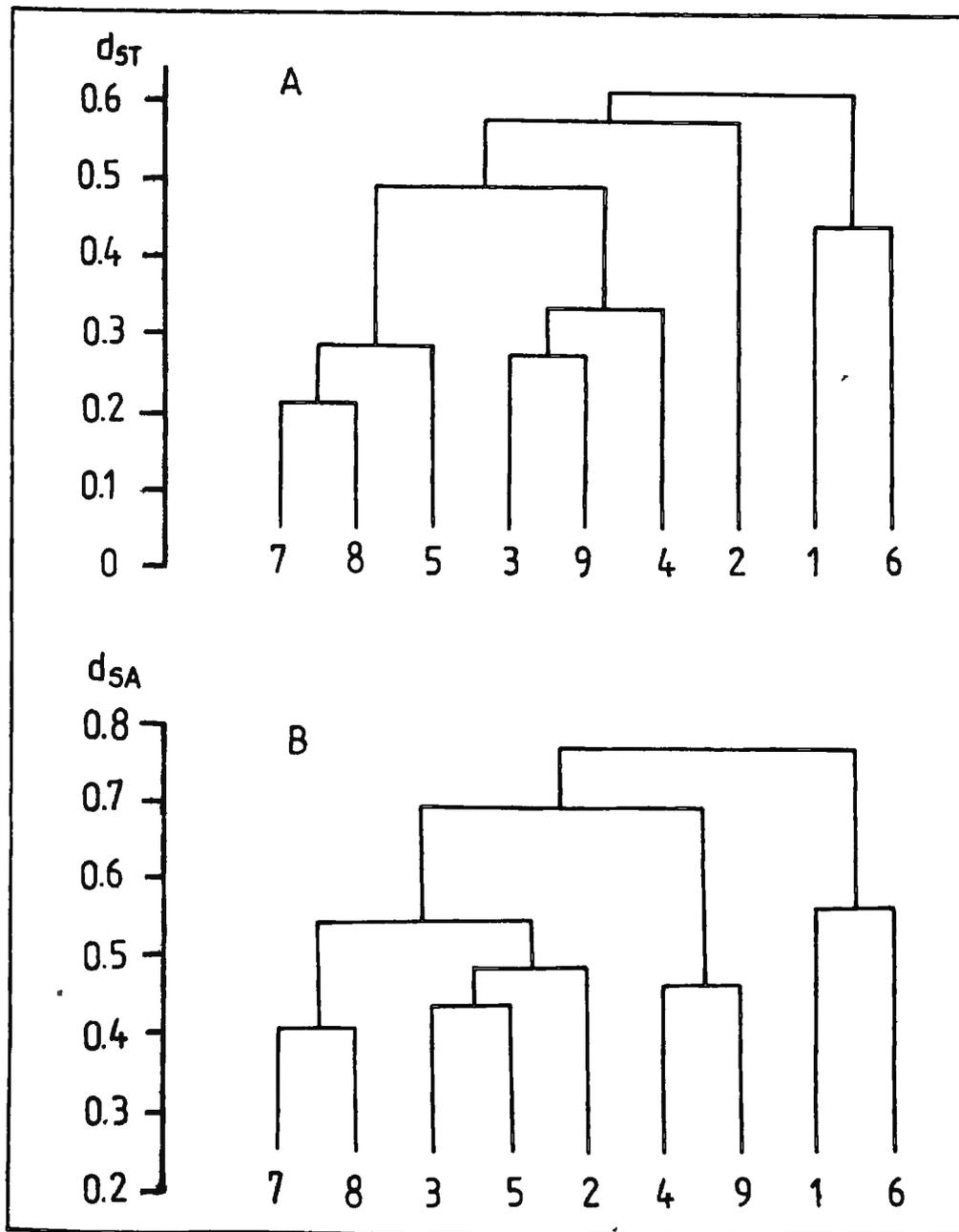


Fig. 3. The dendrograms of the taxonomical arrangement of snail assemblages: A - the dendrogram drawn according to a qualitative method (d_{ST} coefficient), B - the dendrogram drawn according to a quantitative method (d_{SA} coefficient), 1-9 - the snail assemblages from the described localities

Cochlicopa lubrica (O.F. Müller) lives in slopes around the hill and on the ridge-crest, at the site 2. It prefers somewhat humid, shady or sunny habitats and seems to be resistant to cultivation as well as pollution.

Cochlicopa lubricella (Porro) was found only in sunny cultivated sites. The species is typical of dry and even xerothermic habitats.

Vertigo alpestris Alder - a single shell was found on the southern slope of the hill. It is known as a lithophilic species living mainly on limestone rocks and walls as well as in block fields and debris covers, overgrown partly with grass and weeds.

Truncatellina cylindrica (Férussac) is a small snail preferring xerothermic habitats. It occurs on the south-eastern, southern and south-western slopes of the hill (G-I) at sunny sites, mainly in the outcrops of jurassic limestones and below the walls of the castle. Such habitats are typical of this species, known from many localities in the Cracow Upland.

Truncatellina claustralis (Gredler) was recorded from the Cracow region only in the Ojców National Park (Urbański 1973, 1977). At the Wawel Hill it occurs on a small wall and on flowerbeds at the locality 2. It was probably introduced with plants cultivated here. This mediterranean snail lives in dry sunny and warm habitats, mainly on limestones.

Pupilla muscorum (Linnaeus) occurs in the southern part of the hill (G-I) and at the site 2. This species lives in dry and somewhat humid, open habitats, mainly in meadows and grasslands. It is resistant to intensive grazing.

Vallonia pulchella (O.F. Müller) was found in all the localities excluding G-III. It is more frequent on the southern and southeastern slopes than in the northern part of the hill. This species is typical of meadows of somewhat various humidity. It seems to be resistant to grazing and pollution.

Vallonia costata (O.F. Müller) is the most frequent species of the described malacocenose, occurring in all the localities. As the previous one, it was found mainly at the sites of G-I and G-II, while within G-III its shells were noted sporadically. The ecological valency of both the species of Vallonia is similar but V. costata prefers more sunny and dry grasslands than V. pulchella. Both find favourable life conditions in habitats affected by anthropopressure.

Punctum pygmaeum (Draparnaud) is represented by some specimens only on the locality 2. This is a mesophilic taxon living in shady and sunny habitats of various humidity.

Vitrina pellucida (O.F. Müller) - two shells of this catholic species were found at the site 3, in a shady environment just below the wall of the castle.

Aegopinella pura (Alder) is represented only by a single shell in the assemblage from the site 2. It prefers shady habitats.

Oxychilus draparnaudi (Beck) occurs commonly on low walls between buildings on the ridge-crest of the hill (locality 2). Some shells were also found on other localities. This species lives in shady and sunny habitats and was reported from cultivated sites, a.o. from some towns (Matzke 1981, Streib 1984).

Oxychilus inopinatus (Uličný) - one shell of this snail derives from the north-eastern slope of the hill (locality 4). It prefers dry localities, grasslands and cultivated areas.

Limacidae - scarce shells of slugs have been found in samples taken from some localities. Living slugs were not collected.

Cecilioides acicula (O.F. Müller) was found in all the samples taken at the sites belonging to groups G-I and G-III, on dry slopes covered with grazed grass. This species is typical of such habitats, living in soil, mainly in xerothermic environments enriched in carbonates. It is resistant to grazing and cultivation.

Laciniaria biplicata (Montagu) is a single representative of the family Clausiliidae. It is common in the western part of the hill (sites 3, 8) as well as at the site 2 on the ridge-crest. The species in question lives on walls and ruins, sunny rocks as well as on trunks and rocks at shady sites. It was noted from some towns (Streib 1984, Lozek 1985), where it found favourable conditions in gardens, parks and cementaries.

Helicella obvia (Menke) occurs commonly on the southern slope of the hill at localities 6 and 7. It prefers xerothermic grasslands as well as sunny, dry ruderal habitats influenced by industry and then may be regarded as a more or less synanthropic element.

Trichia hispida (Linnaeus) is represented by a single shell found at the site 5. It is known from different types of environments, a.o. from cultivated areas.

Arianta arbustorum (Linnaeus) forms a population in the shady habitat in the north-western part of the hill and was also recorded as scarce shells in some other places. It is connected with shrubs, outcrops of limestones and debris cones, living mainly in light forests.

Cepaea nemoralis (Linnaeus) occurs in all the localities described, forming dense populations on slopes in sunny or shady grasslands and shrubs as well as on cultivated flower-beds on the ridge-crest. It finds favourable life conditions in artificial habitats like gardens, parks, cementaries, overgrown walls and ruins, therefore it seems to be a synanthropic element, well-adapted to conditions prevailing in towns.

Cepaea hortensis (O.F. Müller) is reported as a single shell from the eastern slope of the hill (locality 5). Unlike the previous one this species is more frequent in natural habitats than in cultivated areas.

Helix pomatia Linnaeus was found in all the localities of the Wawel Hill. It occurs both in sunny and shady habitats but is common only at the site 5, below the high wall of the castle. Like C. nemoralis it is well-adapted to environments of anthropogenic origin, living often in towns (Matzke 1973, Kosińska 1979, Lozek 1985).

Relations between the species of snails found at the Wawel Hill were analysed using the taxonomical method based on the Steinhaus formula mentioned above (the qualitative variant of analysis). All the species were arranged due to their occurrences using the taxonomical distances - d_{St} and as a result the dendrogram could have been drawn (Fig. 4). The whole set of the taxa can be discriminated basing on two critical values of d_{St} , defined as: $V_I = 0.67$ and $V_{II} = 0.33$. The first critical value - V_I divides the set into two groups, called A and B. One of them - group A - comprises species occurring in different localities and represented by numerous specimens, while the other - group B - species found as scarce shells at one or a few sites only. The species belonging to the second group (B) can be regarded as the accessory elements of the malacocenose of the Wawel Hill. Inside the group A the second critical value - V_{II} can be applied to distinguish three sub-units:

A_1 - grouping species living both in shady and sunny habitats, found in all or almost all the localities analysed (Helix pomatia, Cepaea nemoralis, Vallonia costata, V. pulchella, Cochlicopa lubrica);

A_2 - grouping two species typical of dry xerothermic habitats (Helicella obvia, Cecilioides acicula);

A_3 - grouping two species living in open environments (Pupilla muscorum, Truncatellina cylindrica).

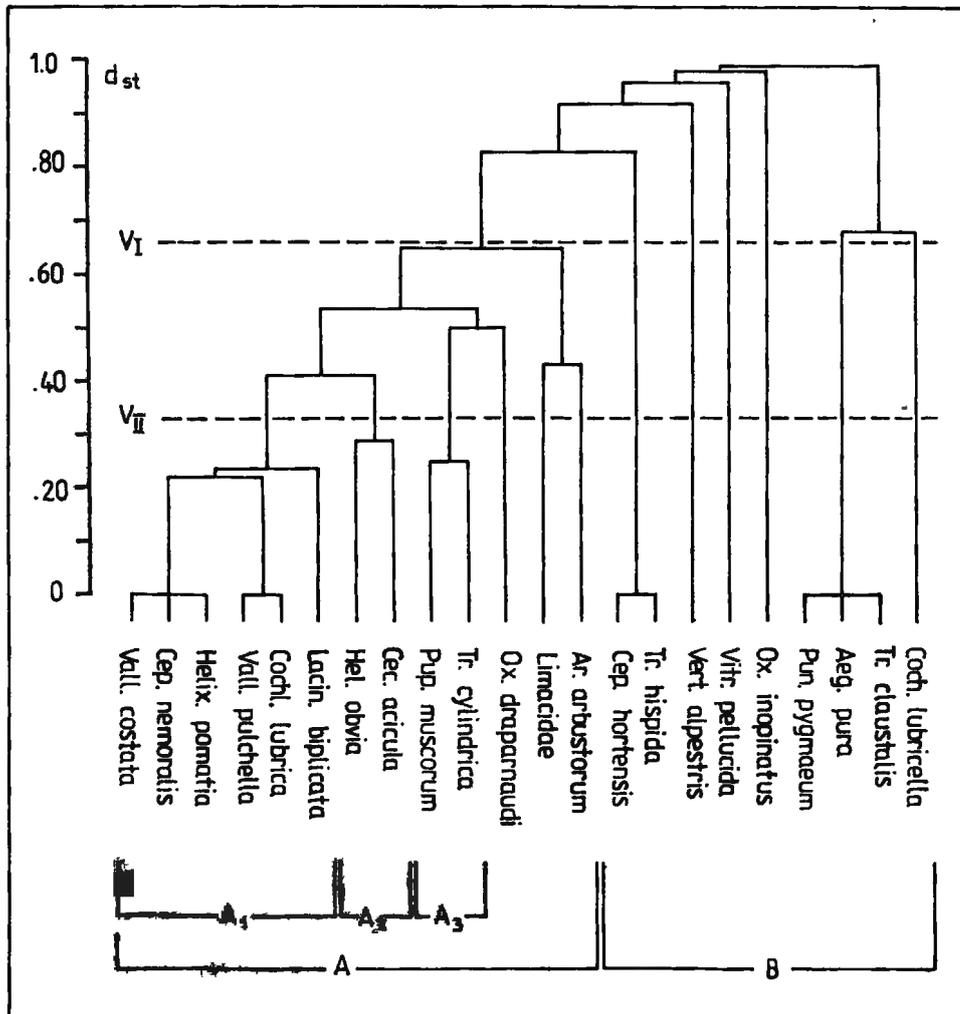


Fig. 4. The dendrogram of the taxonomical arrangement of snail species corresponding to their occurrence at the Wawel Hill: V_I , V_{II} - the critical values of the dendrogram, A(A_1 , A_2 , A_3), B - the taxonomical groups described in the text

The remaining three taxa of the group A occur in some localities and are not as common as the species mentioned above.

The dendrogram presented enables a conclusion dealing with co-occurrence of molluscs in sites under a strong pressure of human activity. There are species of snails characterized by a determined resistancy to cultivation, grazing and pollution. Like in other towns they live in some types of artificial environments and form assemblages typical of the-

se habitats (Matzke 1973, Kosińska 1979, Streib 1984, Ložek 1985). These assemblages can be somewhat different from the corresponding associations of natural habitats unaffected by anthropogenic factors.

POPULATION ANALYSIS OF SELECTED SPECIES

Four species of snails represented by considerable numbers of specimens were analysed by means of the type of statistical distribution as well as of the structure and differentiation of their populations. The height of the shells (Cochlicopa, Laciniaria) or the largest diameter of the shells (Helicella, Cepaea) are measured with the accuracy of 0.1 mm and simple statistical indicators of all the sets were calculated. These indicators concern a whole population of each species (P) found at the Wawel Hill as well as its subpopulations collected at particular sites. Each set is characterized by the number of specimens - n , the arithmetical mean of the height or diameter of the shell - \bar{x} , standard error - \bar{b} , standard deviation - \bar{s} , differentiation index - \bar{v} , the range of the mean value at the significance level .05 - \bar{X} and the range of differentiation at the same level - \bar{D} (Tab. 2). Subpopulations deriving from particular localities are also characterized by the normalized values of arithmetical mean - N_m . The differences between the distribution of the measured data (M) and the corresponding normal distribution calculated from the statistical indicators (N) were checked using the Kolmogorov test. The analysed populations of four species described below can be regarded as normally distributed.

1. Cochlicopa lubrica (O.F. Müller). The material analysed was collected in localities 2, 3, 5 and 7. At the remaining sites only a few shells of this species were found. The statistical distribution of the values of the shell height is approximate to the normal distribution (Fig. 5 - M, N). The mean value of this feature is - $\bar{x} = 5.97 \pm 0.08$ mm, therefore specimens from the Wawel Hill are relatively small in comparison with the populations described by several authors. Snails living in sites 3, 5 and 7 are somewhat smaller or larger, but they differ significantly neither among each other nor from the mentioned mean value of the whole population (N_m range between -0.18 and +0.30). In contrast, the subpopulation collected at the site 2, in sunny, cultivated habitat comprises considerably smaller shells, what is expressed by the value of $N_m = -0.80$ (Fig. 5). The difference examined by the t test can be regarded as statistically significant.

Table 2

Statistical features of populations of selected species

axon	S	n	\bar{x}	b	s	v	X	D	Nm
<u>Cochlicopa</u> <u>lubrica</u>	P	96	5.97	0.04	0.40	6.69	5.89 - 6.05	5.18 - 6.76	-
	2	20	5.65	0.07	0.30	5.31	5.51 - 5.79	5.02 - 6.28	-0.80
	3	20	6.08	0.07	0.31	5.10	5.93 - 6.23	5.43 - 6.73	+0.28
	5	43	6.09	0.06	0.40	6.57	6.03 - 6.15	5.31 - 6.87	+0.30
	7	13	5.90	0.10	0.37	6.27	5.68 - 6.12	5.10 - 6.70	-0.18
<u>Laciniaria</u> <u>biplicate</u>	P	243	15.54	0.07	1.04	6.69	15.41 - 15.67	13.49 - 17.59	-
	2	53	14.82	0.15	1.06	7.15	14.53 - 15.11	12.81 - 16.83	-0.69
	3	102	15.83	0.09	0.91	5.75	15.65 - 16.01	14.05 - 17.61	+0.28
	5	20	14.90	0.21	0.93	6.24	14.47 - 15.33	12.96 - 16.84	-0.62
	8	68	15.81	0.11	0.90	5.69	15.60 - 16.02	14.05 - 17.57	+0.26
<u>Helicella</u> <u>obvia</u>	P	102	12.67	0.12	1.21	9.55	12.54 - 12.99	10.39 - 15.13	-
	6	45	12.89	0.20	1.32	10.24	12.50 - 13.28	10.30 - 15.48	+0.11
	7	40	12.98	0.16	1.02	7.86	12.57 - 13.30	10.97 - 14.99	+0.18
	8	17	11.94	0.21	0.87	7.29	11.73 - 12.15	10.10 - 13.78	-0.68
	P	134	22.90	0.12	1.22	5.03	22.66 - 23.14	20.51 - 25.29	-
<u>Cepaea</u> <u>nemorialis</u>	1	74	23.19	0.13	1.10	4.74	22.94 - 23.44	21.03 - 25.35	+0.24
	2	34	22.18	0.17	0.98	4.42	20.26 - 24.10	21.85 - 22.51	-0.59
	7	15	23.87	0.30	1.15	4.82	23.24 - 24.50	21.42 - 26.32	+0.78
	8	11	23.09	0.41	1.38	5.78	22.19 - 23.99	20.06 - 26.12	+0.16

2. Laciniaria biplicata (Montagu). Shells taken under consideration were collected at four sites (2, 3, 5, 8). The statistical distribution of the measured character (height of shells) corresponds clearly with the normal distribution (Fig. 6—N, M). The mean value of the shell size is $\bar{x} = 15.54 \pm 0.13$ mm. This means that specimens living at the Wawel Hill are somewhat smaller than those reported from many other localities. The considerable differentiation of size in the analysed subpopulations can be observed. The shells from sites 2 and 5 ($N_m = -0.69$ and -0.62) are smaller than those from 3 and 8 ($N_m = +0.28$ and $+0.26$). The statistically significant difference between this two pairs of sets can be established using the \bar{t} test (Fig. 6).

3. Helicella obvia (Menke). The subpopulations of this species derive from sites 6, 7 and 8. The diameters of the collected shells are low in comparison with the data given in various papers. The mean value of the shell diameter is $\bar{x} = 12.67 \pm 0.22$ mm and the largest specimens reach to 15.5 mm. The whole population is characterized by a distribution approximate to the normal one (Fig. 7—M, N). At two localities (6 and 7) the size of shell is similar to the arithmetical mean cited, therefore the normalized values are: $N_m = +0.11$ and $+0.18$. At the third locality (site 8) shells of the mentioned snail are considerably smaller ($N_m = -0.68$), which is confirmed by the \bar{t} test (Fig. 7).

4. Cepaea nemoralis (Linnaeus). The population described was collected at four localities (1, 2, 7, 8). Its distribution does not differ from the normal one (Fig. 8—M, N). The diameters of shells are somewhat higher than reported by some authors, reaching the mean value $\bar{x} = 22.90 \pm 0.24$ mm. In the described subpopulations the considerable variability of this value can be observed (Fig. 8). The shell diameters of the specimens living in sites 1 and 8 are close to the mean value ($N_m = +0.24$ and $+0.16$). In contrast the specimens from the locality 7 are much larger ($N_m = +0.78$) while those from the locality 2 are remarkably smaller ($N_m = -0.59$).

The differentiation of the four populations described suggests that the shell size of the particular snail species is controlled by unstable ecological conditions in habitats of anthropogenic origin. It is worth of noting, that in intensively cultivated habitats species like Cochlicopa lubrica, Laciniaria biplicata and Cepaea nemoralis form the populations consisted of the specimens smaller than those occurring in environments of more natural character. The locality 2 may be an instructive example. In habitats less changed by the human activity (localities 3 and 8) shells reach the size similar to the mean value of

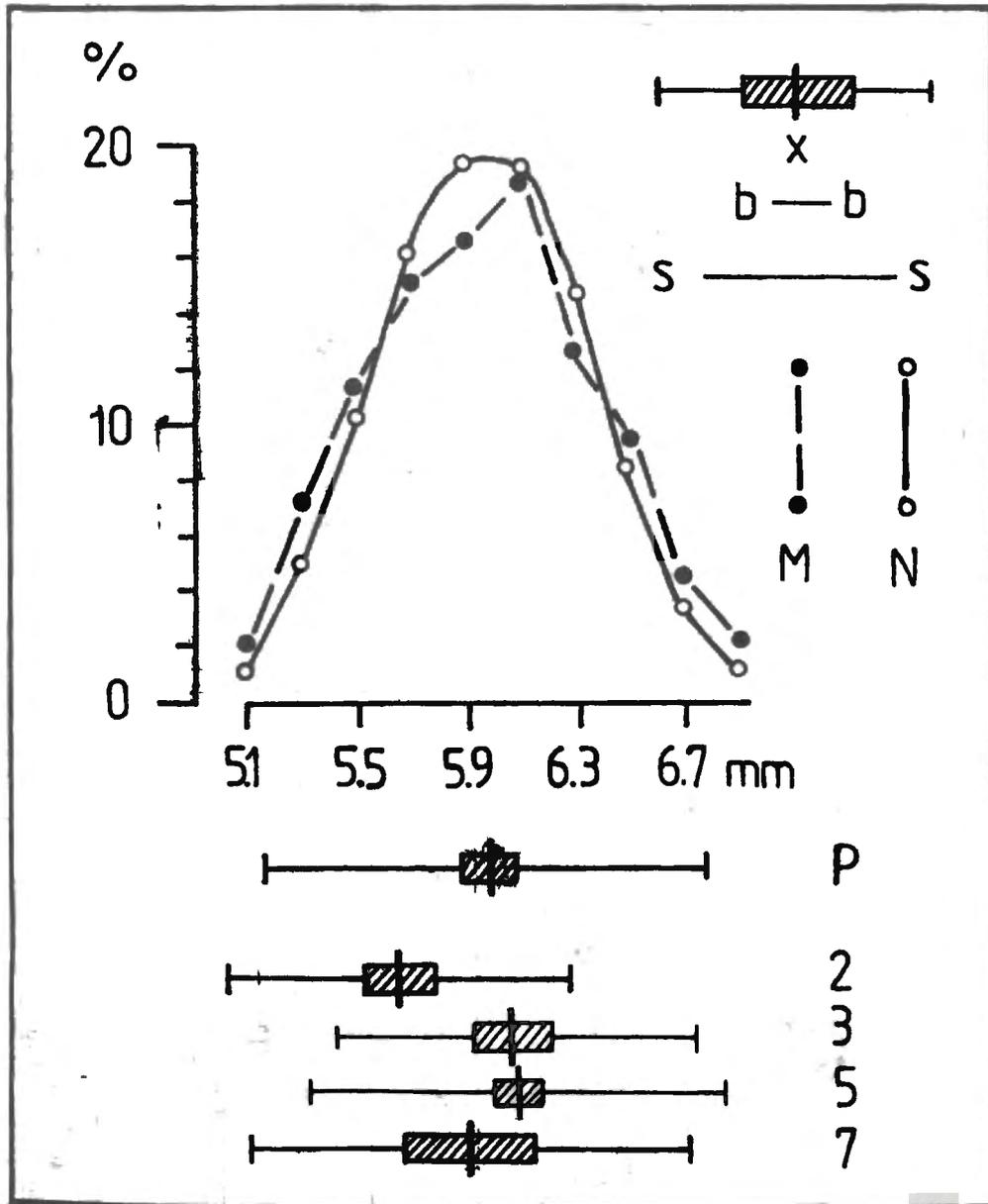


Fig. 5. The biometrical characteristics of a population of *Cochlicopa lubrica*, x - the arithmetical mean of the shell size, b-b - the range of standard error, s-s - the range of standard deviation (the significance level 0.5), M - the empirical distribution of the shell size, N - a normal distribution corresponding to the statistical characters of the studied population, P - the mean and the size variability of the whole population, 2, 3, 5, 7 - the mean values of the variability of the subpopulations from the localities indicated with the numbers

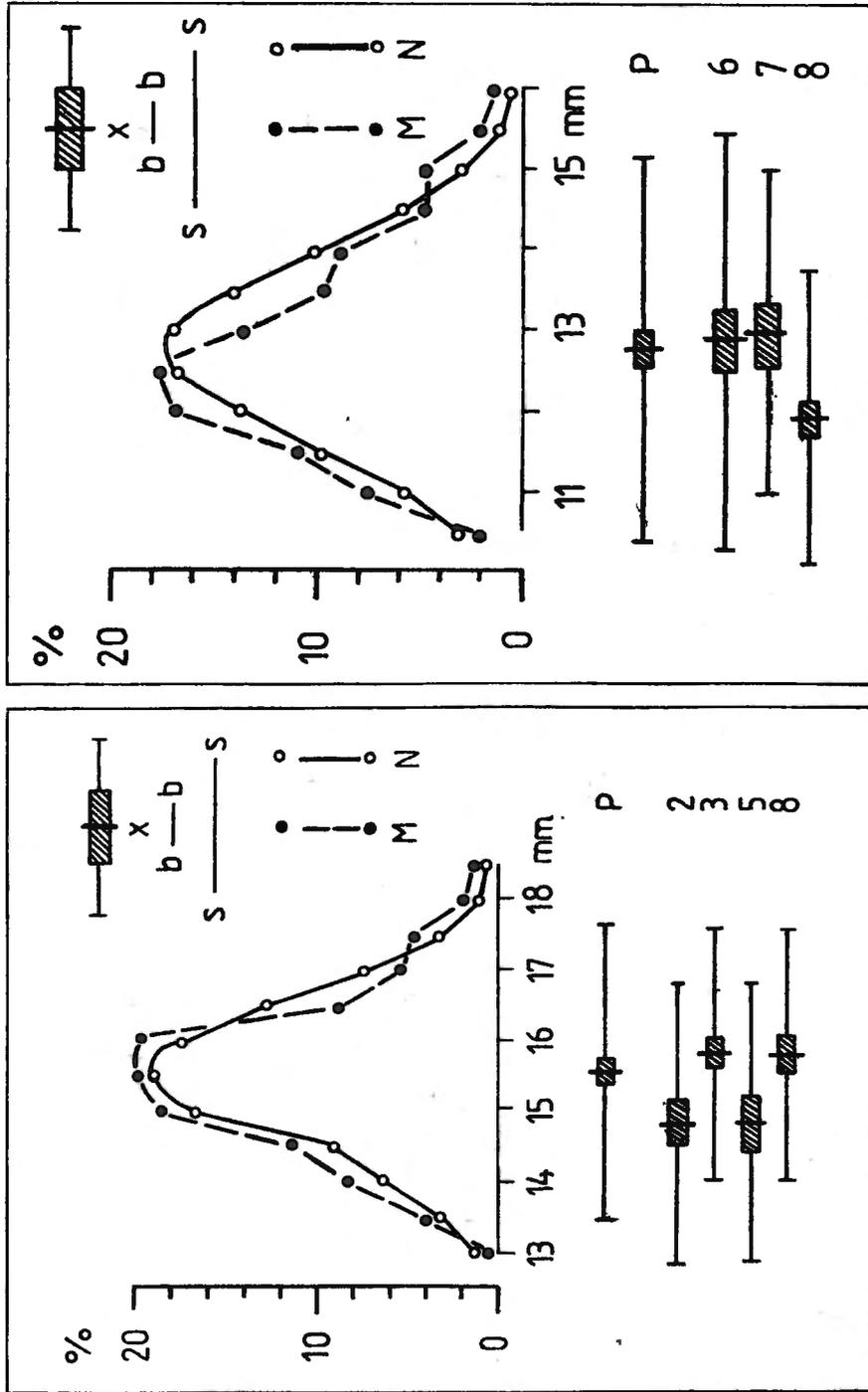


Fig. 7. The biometrical characteristics of the *Helicella obvia* population, the explanations as to Fig. 5

Fig. 6. The biometrical characteristics of the population of *Lascinaria buplicata*, the explanations as to Fig. 5

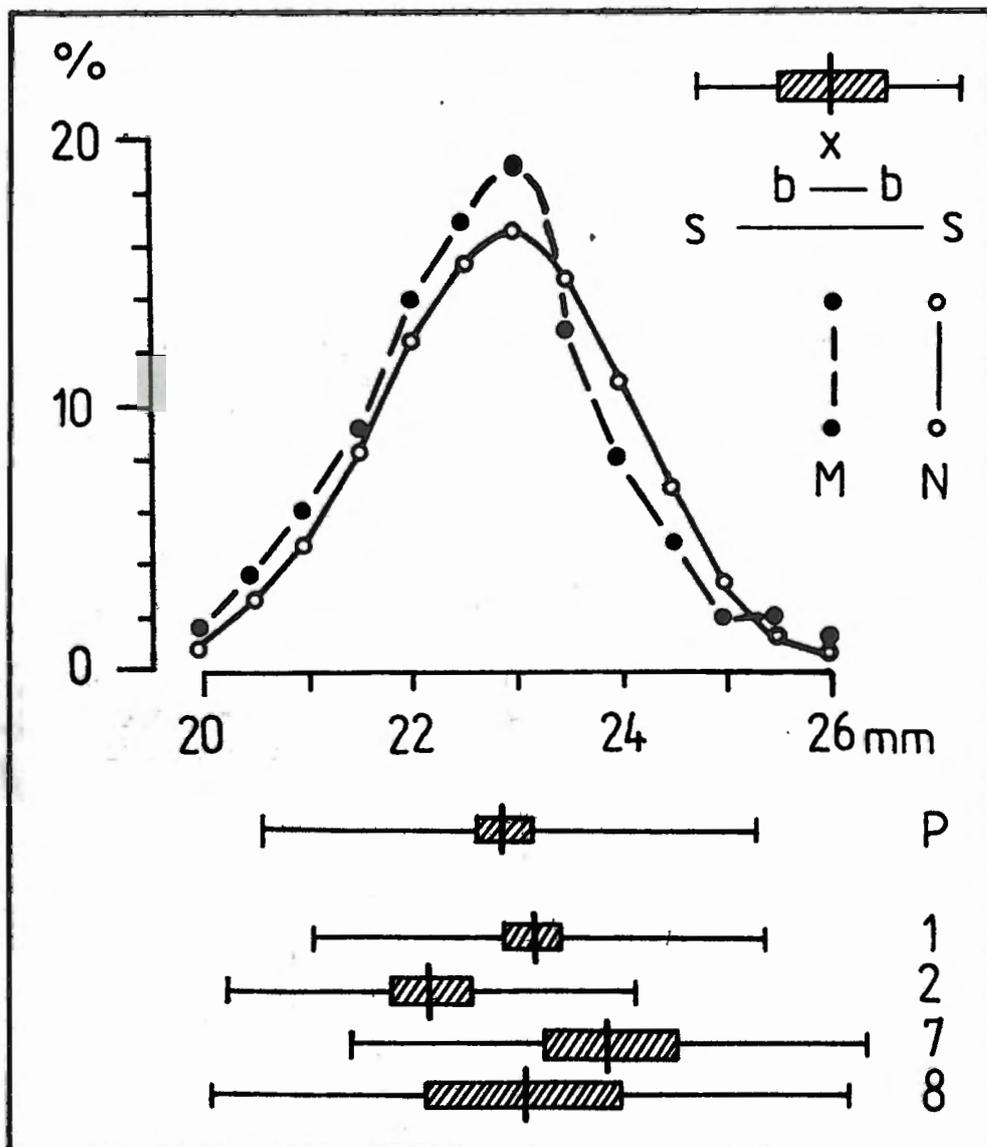


Fig. 8. The biometrical characteristics of the *Cepaea nemoralis* population, the explanations as to Fig. 5

the whole population or even larger, expressed by the positive normalized values N_m (Fig. 5, 6, 8), *Helicella obvia* can be mentioned as an exception (Fig. 7). This snail is typical of ruderal, xerothermic habitats, being quite resistant to pollution, grazing and cultivation.

FLOOD ACCUMULATION OF SHELLS

In the western part of the foot of the Wawel Hill some recent sediments rich in shells of molluscs were found. They are deposited on the left bank of the Vistula river as a result of the flood in summer 1985. Shells occurred together with fragments of timber, boughs, fruits and plants as well as with anthropogenic material. The collection derives from the locality 10, situated on the river bank (Fig. 1). Over 500 specimens of living molluscs and of empty shells were accumulated on a small bench just over the footpath. The following species were found:

Viviparus viviparus (Linnaeus), Bithynia tentaculata (Linnaeus), Bithynia operculum, Carychium tridentatum (Risso), Physa acuta Draparnaud, Lymnaea peregra (O.F. Müller), Lymnaea truncatula (O.F. Müller), Planorbis corneus (Linnaeus), Planorbis planorbis (Linnaeus), Anisus vortex (Linnaeus), Anisus leucostomus (Millet), Gyraulus albus (O.F. Müller), Ancylus fluviatilis (O.F. Müller), Succinea putris (Linnaeus), Succinea oblonga Draparnaud, Nesovitrea hammonis (Ström), Oxychilus draparnaudi (Beck), Vitrea crystallina (O.F. Müller), Zonitioides nitidus (O.F. Müller), Laciniaria biplicata (Montagu), Bradybaena fruticum (Müller), Helicella obvia (Menke), Monachoides rubiginosa (A. Schmidt), Monachoides incarnata (O.F. Müller), Perforatella bidentata (Gmelin), Trichia villosula (Rossmässler), Cochlicopa lubrica (O.F. Müller), Cochlicopa lubricella (Porro), Pupilla muscorum (Linnaeus), Vallonia costata (O.F. Müller), Vallonia pulchella (O.F. Müller), Arianta arbustorum (Linnaeus), Cepaea nemoralis (Linnaeus), Helix pomatia (Linnaeus), Sphaerium corneum (Linnaeus), Pisidium casertanum (Poli).

The assemblage in question represents the allochthonous thanatocenose, called allocenose, accumulated during a short time. Water molluscs derive mainly from the Vistula river but also from small water bodies existing on both the river banks along the valley. Hygrophilic snails live now just above the river in the flood plain and on the lower terrace. Other land snails were washed out from different habitats of the valley between Cracow and Oświęcim, flooded in summer 1985. Assemblages like this are often found in Holocene and Pleistocene river sediments. Its structure can be illustrated by double diagram according to the method described by Ložek (1964), called: MSS - malacospectrum of species and MSI - malacospectrum of specimens. It is expressed in the form of a circular diagram, in which the interior circle corresponds to the MSS spectrum while the external circle - to the MSI spectrum and the radiuses of both circles show the number of elements (species and specimens) in the logarithmic scale.

The allocenose from the Wawel Hill comprises all the ecological groups of molluscs (Fig. 9). The MSS spectrum shows, that the land snails are important components of the assemblage (67% of taxa). These are mainly the snails living in shady and partly shady environments (ecological group 2) as well as the snails of open habitats (ecological group 5), the mesophilic species from less or more humid sites (ecological group 7 and 8) and the hygrophilic snails (ecological group 9). The share of water molluscs reaches 33%. The proportions in the MSI spectrum are different. The specimens of the water molluscs are the prevailing component of the assemblage (56%). The considerable number of shells of Physa acuta Draparnaud (42%) is the most interesting feature of the assemblage in question. This snail was introduced to the Vistula due to the progressing pollution of the river and the industrial activity. It forms strong populations near the power station in Skawina, and empty shells of this taxon occur in a great number in the recent sediments near Tyniec (Alexandrowicz 1986). The considerable share of shells of hygrophilic snails (14%) represented mainly by Zonitoides nitidus (O.F. Müller), Trichia villosula (Rossmässler) and Monachoides rubiginosa (A. Schmidt) is worth of noting. These taxa can be often found on the lower terrace along the valley.

CONCLUSIONS

Malacoфаuna inhabiting the Wawel Hill in Cracow comprises more than 20 species of snails. They form some different assemblages, connected with more or less cultivated, grazed and polluted sites. The life conditions on the slopes and ridge-crest of the hill are distinctly differentiated. They control the range of poor-specialized associations, poor-generalized associations and rich-generalized associations, distinguished basing on the number of taxa and specimens as well as on the diversity index TDI. The associations mentioned were also analysed using the taxonomical method. The distribution of particular species in the localities described is clearly uneven, only three of them have been found in all the samples. The occurrence of Truncatellina claustralis (Gredler) - a species known in Poland only from scarce, isolated sites is worth of noting. Another interesting taxon - Oxychilus draparnaudi (Beck) was reported from some other towns. The populations of four selected species were analysed in details by means of simple statistical methods. The results indicate, that the size of shell is controlled partly by natural ecological conditions and partly by effects of human activity. Particular species react differently to changes caused by the

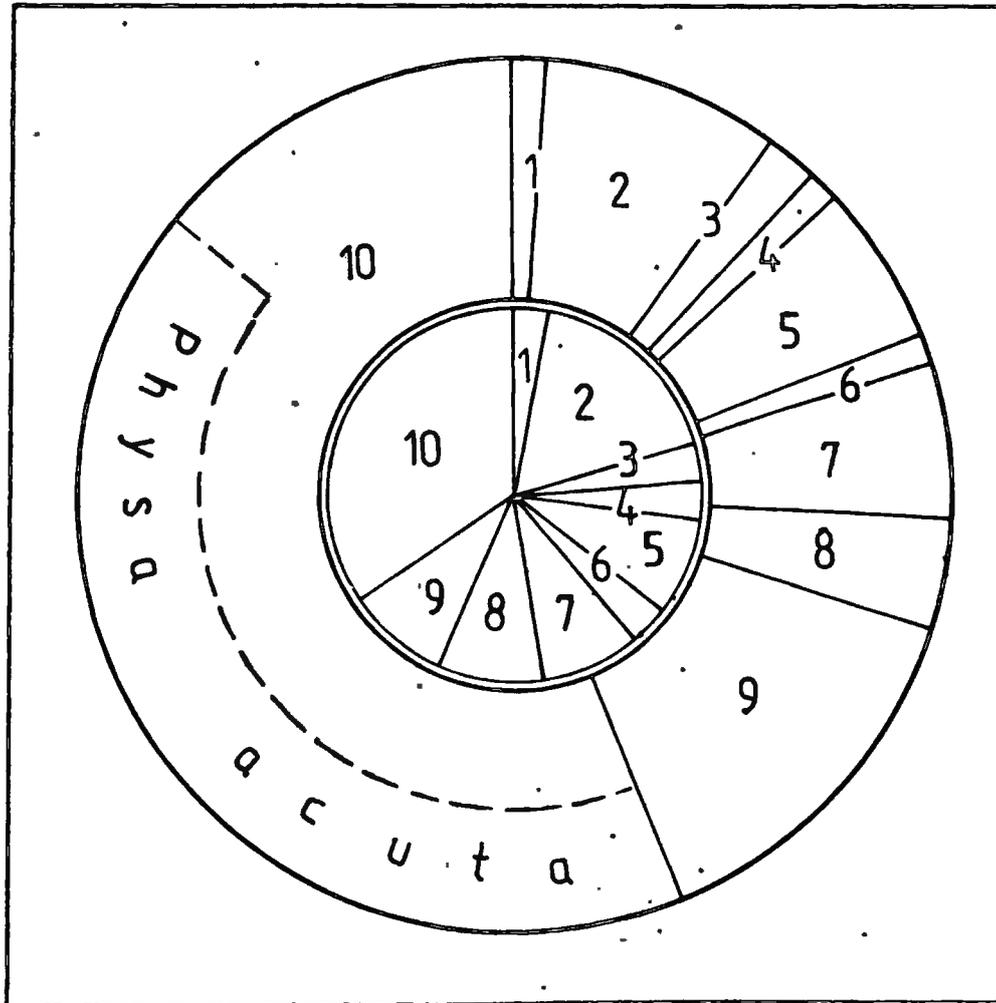


Fig. 9. The malacological spectra of the thanatocenosis from the left bank of the Vistula river at the foot of the Wawel Hill (locality 10), the inner circle - the species malacospectrum (MSS), the outer circle - the individual malacospectrum (MSI); 1-10 - the symbols of the ecological groups of molluscs after V. Lozek (1964): 1-3 - forest snails 4-6 - snails of open environments, 7-8 - mesophilic snails, 9 - hygrophilic snails, 10 - water snails

urbanisation and pollution of habitats. The assemblage comprising 35 species of molluscs was found in recent sediments accumulated during a flood below the western slope of the hill. In this way, due to redeposition, living snails can spread and inhabit new sites.

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MALAKOFAUNA WZGÓRZA WAWELSKIEGO W KRAKOWIE

Streszczenie: Malakofauna występująca na wzgórzu wawelskim w centrum Krakowa obejmuje 21 gatunków ślimaków lądowych. Na podstawie analizy statystycznej i taksonomicznej wyróżniono trzy typy zespołów. Ich skład i rozmieszczenie są uzależnione zarówno od naturalnych warunków ekologicznych, jak też od wpływów antropogenicznych, takich, jak uprawa roślin, koszenie traw oraz zanieczyszczenie środowiska. Czynniki te mają również widoczny wpływ na zróżnicowanie wielkości skorup poszczególnych gatunków ślimaków w populacjach zasiedlających wzgórze. Na lewym brzegu Wisły, tuż koło Wawelu, występuje allocenoza skorupek mięczaków akumulowana przez fale powodziowe rzeki.