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MALACOFAUNA OF THE WAWEL HILL IN CRACOW (POLAND) – A QUARTER OF A CENTURY AFTER ITS FIRST DESCRIPTION

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ABSTRACT: Mollusc assemblages found at the Wawel Hill in 2011 included 13 species; nine of the species found in 1988 were absent. Several shade-loving species had disappeared and some open-country species had increased in abundance at the expense of others. For example, *Vallonia pulchella* (Müll.) was a dominant component of the present malacofauna, while *V. costata* (Müll.) decreased in abundance. The results confirmed the environmental changes that had taken place since 1988: the negative impact of mass tourism and pollution.

KEY WORDS: comparative analysis, mollusc assemblages, Wawel Hill, environmental changes

INTRODUCTION

The Wawel Hill is located in the centre of Cracow at an altitude of 228 m a.s.l. It is built of Jurassic limestones which were uplifted during the Miocene as a tectonic framework. The hill rises above the Vistula River. Its slopes are mainly covered with planted grass; the eastern, southern and north-western slopes are partly wooded. The southern slope above the Dragon Cave is rocky. On the top of the hill, at the Wawel Castle, flowerbeds have been created. Though the limestones offer favourable gastropod habitats, the considerable air and soil pollution as well as increased traffic and urbanisation cause environmental changes which may contribute to impoverishment of the mollusc communities. The recently intensified human-induced changes result in destruction of natural habitats on the one hand and emergence of anthropogenic habitats on the other. In such places the malacofauna tends to show a different species composition, compared to the surrounding areas. Research on the malacocoenoses of castles has been conducted for many years in different countries (S. W. ALEXANDROWICZ 1995, JUŘIČKOVÁ & KUČERA 2005a, 2005b). The malacofauna of the Wawel Hill has been described by S. W. ALEXANDROWICZ (1988). The aim of this study was an attempt to specify possible changes in the malacofauna between 1988 and 2011.

MATERIAL AND METHODS

Samples containing gastropod shells were taken from nine sites at the Wawel Hill (Fig. 1) in the spring of 2011 from the surface soil layer to the depth of 3 cm. Each sample, taken with a spade and containing soil, empty shells and live individuals, was ca. 1 kg. The samples were washed, and fresh shells and their fragments were extracted. The gastropods were identified using WIKTOR's (2004) key.

The samples were taken from the central part of the hill as well as from its northern, eastern, western and southern slopes. Site 1 – partly shaded lawn and flowerbed surrounded by a low limestone wall; the

site is located among the buildings of the Wawel castle, at the top of the hill, where the grass is frequently mown and renovation works are still carried out in the courtyard. Site 2 – a smaller lawn and flowerbed situated between the Visitors Center and the castle wall in the western part of the ridge. Site 3 – north-western slope of the Wawel Hill below the castle wall; forested, with strongly polluted soil. Site 4 – north-eastern slope, well insolated and polluted because of the close proximity of the Podzamcze street. Site 5 – south-eastern forested slope and open lawn on a flat terrace; the slope is steep, with a low limestone wall in the middle. Site 6 – sward on the southern slope. Site 7 – southern slope and well insolated lawn above the Berdardyńska Street. Site 8 – south-western slope, above the entrance to the Dragon Cave; this part of the hill is rocky and built of Jurassic limestones, with both sunny and shady places; the site is littered. Site 9 – deforested western slope on the left bank of the Vistula River.

Standard methods of malacological analysis were applied as described by LOŽEK (1964), S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ (2011). The indices of diversity: TDI and ADI (S. W. ALEXANDROWICZ 1987, 1999) were calculated for the whole fauna. Similarity between the assemblages was analysed using the method described by S. W. ALEXANDROWICZ (1987). The structure of constancy (C) and dominance (D) as well as indices of normalised constancy and dominance (C_i, D_i) were also analysed (DOBROWOLSKI 1963, S. W. ALEXANDROWICZ 1987). The earlier data on the malacofauna of the Wawel Hill (S. W. ALEXANDROWICZ 1988) were used for comparison.

RESULTS

The whole analysed material comprised 13 snail taxa (1,030 specimens) (Table 1). The species were divided into three ecological groups: F – shade-loving species, O – open-country species and M – mesophile species with wide ecological tolerance. The number of species per sample ranged from 3 to 9, the number of specimens from 9 to 368.

The material used for comparison (S. W. ALEXANDROWICZ 1988), from the nine samples taken between 1983 and 1985 from the same sites (Fig. 1), included 22 species (7–14 per sample) and 1,559 specimens. This "old fauna" included three types of assemblages: 1. of open and sunny habitats (sites 1, 6); 2. of different habitats which were unfavourable for gastropods (localities 4, 9); 3. a rich assemblage of shaded and humid habitats (sites 2, 3, 5, 7, 8). The most abundantly represented species were *Vallonia costata, Alinda biplicata, Helicella obvia, Cepaea nemoralis, Vallonia pulchella* and *Cochlicopa lubrica*. Three species were found in all the samples: *Helix pomatia, Cepaea nemoralis* and *Vallonia costata*. The fauna included also *Truncatellina claustralis* which has isolated localities in Poland.

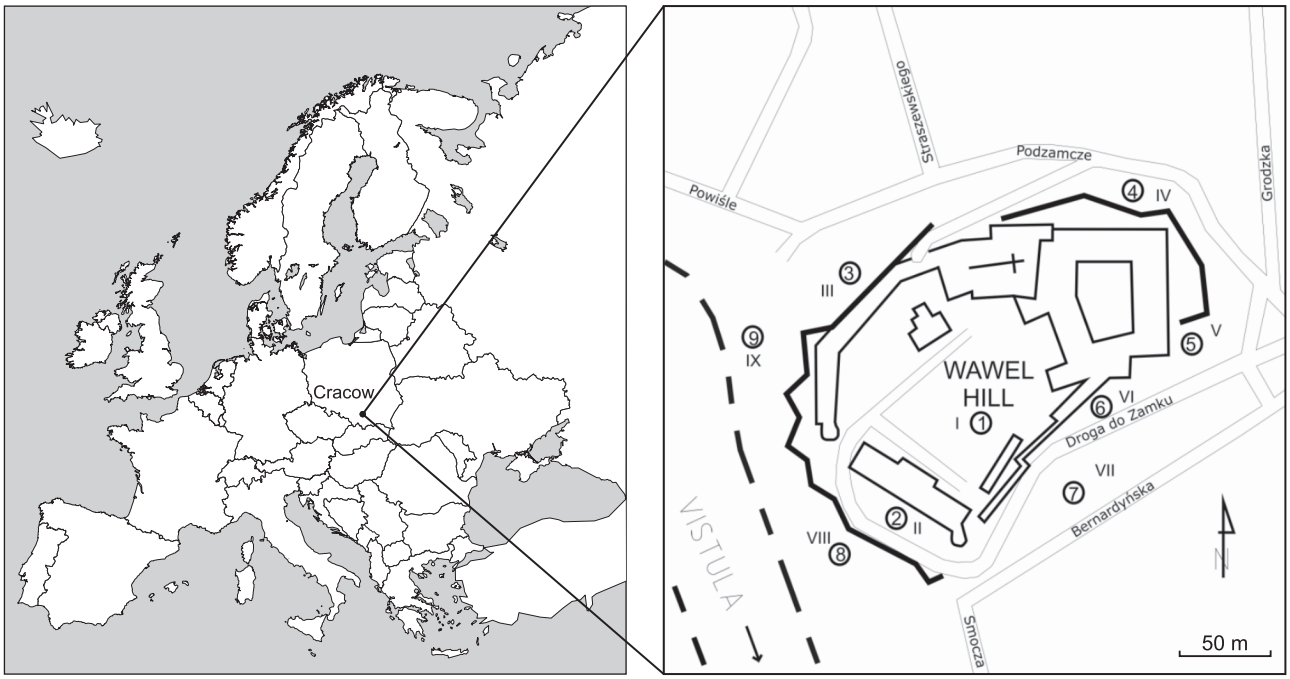

Fig. 1. The Wawel Hill in Cracow, sampling sites: 1–9 – 2011, I–IX – 1988

Table 1. List of species found at the Wawel Hill in 2011: E – ecological groups (LOŽEK 1964, S. W. ALEXANDROWICZ & W. P. ALEXANDROWICZ 2011), N – number of specimens, D – dominance, C – constancy

	E	1	2	3	4	5	6	7	8	9	N	D %	C %
Alinda biplicata (Mont.)	F	8	6	4		9	3		29		59	5.73	66.7
Cepaea nemoralis (L.)	F		1								1	0.10	11.1
Helix pomatia (L.)	F			1	1	2		1			5	0.49	44.4
Cecilioides acicula (Müll.)	O			1	2	4		2	3	3	15	1.46	66.7
Helicella obvia (Menke)	O					63	16	3	3		85	8.25	44.4
Pupilla muscorum (L.)	O	9				3			37	91	140	13.59	44.4
Vallonia costata (Müll.)	O	9			12	5	2	19	22	28	97	9.42	77.8
Vallonia pulchella (Müll.)	O	61	12		32	94	10	12	99	228	548	53.20	88.9
Cochlicopa lubrica (Müll.)	M	13			8	7	3	2	1	17	51	4.95	77.8
Vertigo alpestris (Ald.)	M	21									21	2.04	11.1
Punctum pygmaeum (Drap.)	M	2									2	0.19	11.1
Limacidae	M	1				1					2	0.19	22.2
Trichia hispida (L.)	M			3						1	4	0.39	22.2
Total taxa		8	3	4	5	9	5	6	7	6	13		
Total specimens		124	19	9	55	188	34	39	194	368	1,030		

Table 2. Constancy (C) and dominance (D) structure of mollusc assemblages for the samples; Σ_{tax} – number of species, Σ_{spec} – number of specimens, C_i, D_i, TDI and ADI – indices

	D-1	D-2	D-3	D-4	D-5		
C-5					1	*Vallonia pulchella*	(C-5; D-5)
C-4		2	2			*Pupilla muscorum*	(C-3; D-4)
C-3	1		1	1		*Vallonia costata*	(C-4; D-3)
C-2	2					*Alinda biplicata*	(C-4; D-3)
C-1	2	1				*Helicella obvia*	(C-3; D-3)

Σ_{tax}= 13 C_i = 4.75 TDI=0.944
Σ_{spec}= 1030 D_i = 6.0 ADI= 0.595

In 2011, nine of the species found in 1988 were absent. Only 65 specimens represented shade-loving species; open-country species were represented by 885 specimens, and mesophile snails – by 80 specimens. Compared to the earlier survey, the total abundance of *Vallonia pulchella* and *Pupilla muscorum* – both open-country species – increased. The number of shade-loving snails was smaller than that of the mesophiles. Sites 1, 5 and 8 contained the most diverse species combination. *Vertigo alpestris* and *Punctum pygmaeum* occurred only in the first site, while *Cepaea nemoralis* was recorded only in the second site.

The constancy and dominance structure of the fauna are presented in Table 2. Five species, four of which are open-country forms, showed the highest C-D values: *Vallonia pulchella, Pupilla muscorum, Alinda biplicata*, *Vallonia costata* and *Helicella obvia*. Five taxa were accessory components with low C-D indices. The values of normalised constancy and dominance indices were very low (C_i=6 and D_i=4.75). The taxonomic diversity index (TDI), as well as assemblage diversity index (ADI) for the whole material, reached 0.6. The TDI for individual samples varied from 0.5 to 0.7. The values correspond to relatively high diversity which is characteristic of polymictic associations. The mollusc assemblages could be divided in two categories. Poor generalised associations occurred in sites 2, 3, 4, 6 and 7, rich generalised associations were present in sites 1, 5, 8 and 9.

DISCUSSION

The 2011 malacofauna included three shade-loving species, five open-country species and five mesophiles (Fig. 2), while the previous survey revealed six shade-loving species, nine open-country species and seven mesophiles. The MSI spectrum indicates that at present the malacofauna is mainly composed of

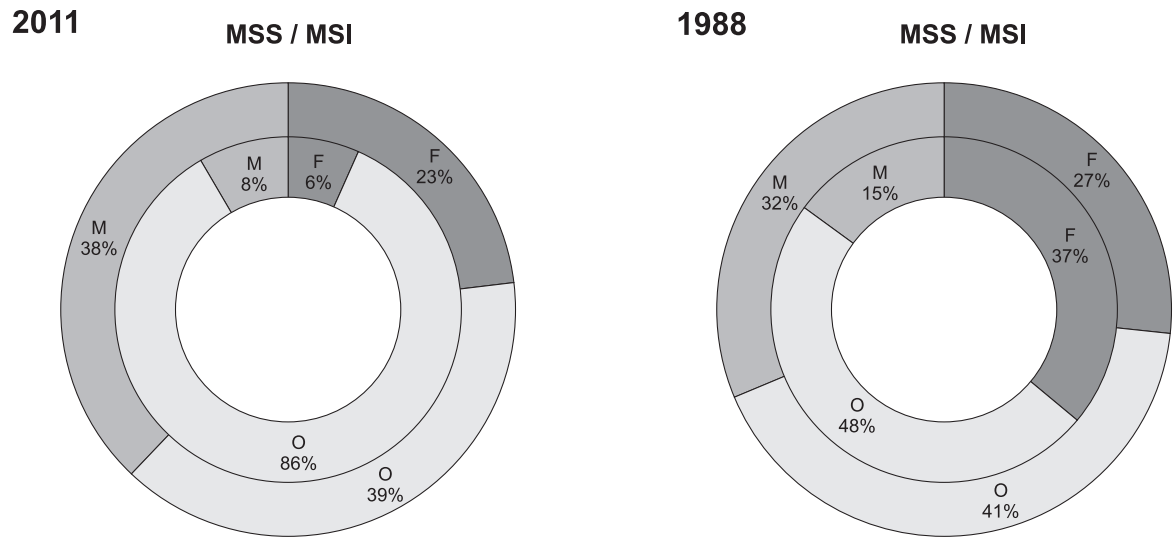

Fig. 2. Malacological species spectrum (MSS) and malacological individual spectrum (MSI) of all assemblages found in 2011 and 1988: F – shade-loving species, O – open-country species, M – mesophilic species (data for 1988 from S. W. ALEXANDROWICZ)

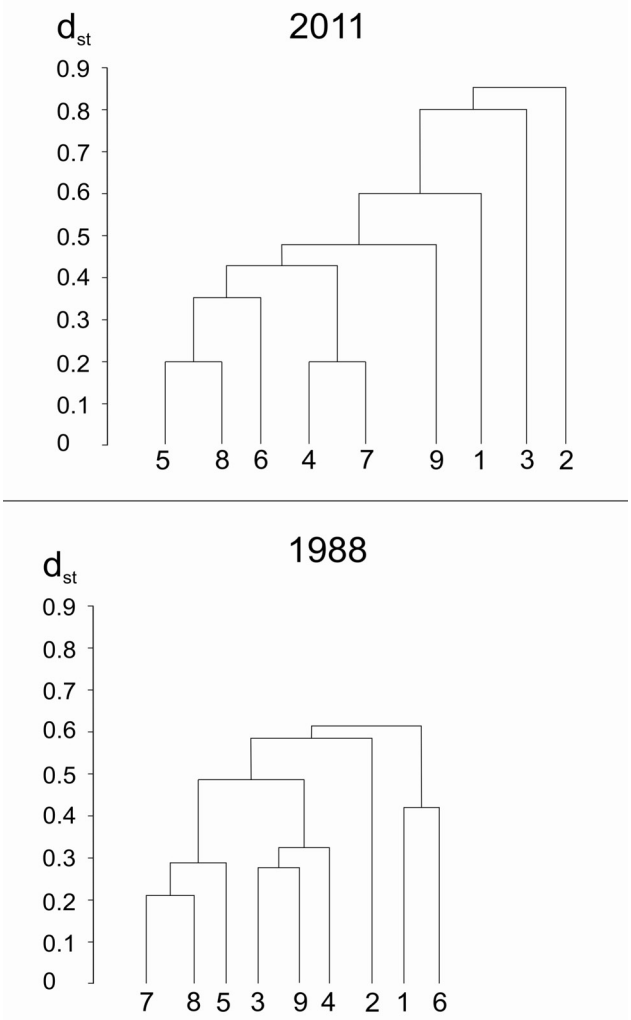

Fig. 3. Similarity dendrograms of assemblages found in 2011 and 1988 (data for 1988 from S. W. ALEXANDROWICZ)

open-country snails. The MSS spectrum shows a high diversity. Compared to the previous survey, the number of shade-loving species has become reduced. Only *Alinda biplicata* is still present in large numbers while *Helix pomatia* and *Cepaea nemoralis* have disappeared. Open-country snails remain dominant, but the abundance of *Vallonia pulchella* has increased at the expense of *Vallonia costata*, whereas *Pupilla muscorum* has become much more abundant. Mesophiles are still represented by *Cochlicopa lubrica*, but other mesophiles occur in smaller numbers. *Vertigo alpestris* was abundant (21 specimens) in site 1 (at the top of the Hill); during the previous survey it was found in site 9.

Nine of the species recorded during the previous inventory were not found in 2011: *Truncatellina cylindrica*, *Truncatellina claustralis*, *Cochlicopa lubricella*, *Vitrina pellucida*, *Aegopinella pura*, *Oxychilus draparnaudi*, *Oxychilus inopinatus*, *Arianta arbustorum* and *Cepaea hortensis*. Of these only *Oxychilus draparnaudi* and *Arianta arbustorum* were abundant; the remaining ones were represented by single or few specimens. In 2011, the most abundant species (> 50 specimens) were: *Vallonia pulchella*, *Pupilla muscorum*, *Vallonia costata*, *Helicella obvia*, *Alinda biplicata* and *Cochlicopa lubrica*.

The changes in the assemblages in individual sites were as follows. In site 1 the species composition changed completely: no mesophiles were found during the previous survey, but they were frequent in 2011. In site 2 the species composition was unchanged, but the abundance decreased. In sites 3 and 4 the 2011 species list was shorter, but included a previously unrecorded *Cecilioides acicula*. In site 5 the species composition overlapped with the corresponding sample from the previous survey and it was still the largest sample. In site 6 *Vallonia pulchella* and *Cochlicopa lubrica* appeared, as well as one mesophile.

In sites 7 and 8 the species composition remained unchanged, but the abundance was smaller. The sample from site 9 included *Cecilioides acicula*, *Pupilla muscorum* and *Trichia hispida* not recorded on the previous occasion.

The ADI values for the earlier survey and for the 2011 samples were the same: 0.6. All the studied assemblages were generalised associations. However, the mollusc assemblages changed and the poorly specialised associations disappeared, as indicated by the TDI values for individual samples. The number of molluscs living in unfavourable habitats increased, making the poor generalised associations richer than before. Moreover, the rich generalised associations were poorer.

The similarities among the assemblages changed since the previous survey (Fig. 3). Three clusters of assemblages could be distinguished in the previous survey (S. W. ALEXANDROWICZ 1988), and only two in 2011. The first group included sites 5, 6 and 8, and corresponded with various ecological conditions (partly shady) on the southern slopes of the Wawel Hill. Its TDI varied from 0.6 to 0.7, and the group was similar to that distinguished before. The second group, which differed from the group distinguished in the previous survey, included sites 4 and 7 and represented generalised assemblages of dry, sunny habitats.

The Wawel Hill with its Jurassic limestones creates favourable conditions for gastropods. However, the increased tourism at the Wawel Castle, combined with its location in the city centre, have a negative impact on molluscs due to pollution, traffic, necessity of regular fertilising and grass mowing. The malacofauna inhabiting the Wawel Hill comprises 13 gastropod taxa. The mollusc assemblages are diverse, reflecting the different habitats on the slopes. The assemblages from sites 4, 5 and 8 show no similarity with the assemblages found during the previous survey. Beside these two groups, four separate assemblages from sites 1, 2, 3 and 9 were distinguished. The species composition and abundance and their changes reflect the environmental changes. The changes in species composition in favour of open-country snails and disappearance of shade-loving ones are especially pronounced, reflecting the prevalence of open habitats.

The unfavourable living conditions have resulted in enrichment of poor generalised assemblages. This may cause further loss of species at the Wawel Hill. The dominant species is now *Vallonia pulchella*, while the abundance of *Vallonia costata* has decreased. *Cepaea nemoralis*, abundant during the previous survey, has mostly disappeared. The abundance of *Trichia hispida* and *Helix pomatia* has decreased, which may indicate a further impoverishment of mesophilic and shade-loving fauna. *Vertigo alpestris* in Poland is regarded as a rare and endangered species. It still inhabits the Wawel Hill and has even increased in abundance. The synanthropes found at the Wawel Hill (e.g. *Cepaea nemoralis, Cecilioides acicula, Helicella obvia*) may have been imported by humans.

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