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MOLLUSCAN FAUNA OF ABANDONED CRYSTALLINE LIMESTONE QUARRY IN ROGÓŻKA (LOWER SILESIA, KROWIARKI RANGE, STRONIE ŚLĄSKIE COMMUNE)

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ABSTRACT: The paper deals with succession in an abandoned quarry of crystalline limestone, located in the village of Rogóżka (Krowiarki Mts near Konradów, the northern extension of the Śnieżnik Massif). Its bottom is covered by synanthropic communities of unspecified systematic rank and communities of limestone screes as well as clumps of *Alnus incana* and *Betula* sp. The following communities, gradually entering the quarry, have been distinguished: *Dentario-Fagetum*, *Aceri-Tilietum* and *Carici remotae-Fraxinetum*. The malacofauna collected in the quarry (45 species) constitutes 50.6% of the terrestrial snails recorded from the Śnieżnik Massif (89 species) and 43.7% of those collected in the Kłodzko Region (103 species). Seven of the 15 clausiliid species recorded from the Kłodzko Region were found in the quarry (47%), which indicates considerable diversity of the microhabitats. The most important species include *Eucobresia diaphana*, *Semilimax semilimax*, *Macrogastra tumida*, *Helicigona lapicida*, and most of all *Clausilia parvula*; for the last species the quarry in Rogóżka is the only extant locality in the Kłodzko Region. The fate of the quarry's malacofauna is uncertain, since formally it has not been exluded from exploitation; measures need be taken to establish a nature reserve there.

KEY WORDS: ecology, succession, *Clausilia parvula*, *Helicigona lapicida*, pioneer and endangered species

INTRODUCTION

Succession in anthropogenic habitats has been rather little studied, especially with respect to land snail communities. Abandoned quarries, particularly those located in calcareous areas and surrounded by rich sources of potential colonisers, provide a good opportunity to study succession of terrestrial gastropod communities. The aim of this paper was to inventory the gastropod species richness on the background of plant communities which developed in an abandoned limestone quarry in south-western Poland.

The quarry is located in an area favouring development and preservation of rich malacocoenoses – the Krowiarki Mts. This range constitutes the northern extension of the Śnieżnik Massif which is one of the mesoregions of the Sudetes with the Sudete Foothills (KONDRACKI 1994) and forms the eastern border of the Kłodzko Basin. In this group of mountains altitudes range from 446 to 670 m a.s.l.; only its south-eastern part holds a few peaks exceeding 800 m, with the highest – Suchoń – of 964 m a.s.l. The Krowiarki range is mainly built of metamorphic rocks, with outcrops of Palaeozoic crystalline limestones and dolomites forming lenses and intercalations among mica schists. The carbonate rocks are especially thick in the western Krowiarki (up to 150 m). This part of the range holds hills and ridges of karstic character, such as Słupiec (531 m) and Wapniarka (518 m), whose present form is a result of karstic processes that started in the Palaeogene, Pleistocene frost erosion, and Holocene weathering and hill wash; all these phenomena made individual carbonate outcrops assume the shape of dome-like mogots, only rarely found elsewhere in Lower Silesia (Połom, Osełka, Wapienna and Miłek in the Kaczawskie Mts, and Krzyżnik in the Śnieżnik Group) (WALCZAK 1968, MIGOŃ 2009).

The Krowiarki range is surrounded by cultivated fields which separate individual hills, forming a spe-

cific system of forest islands. Spruce with admixture of beech, oak, birch and pine is the dominant component of the tree stands of the slopes of Krowiarki. In only few places (e.g. on the slopes of Słupiec, Wapniarka and Wapnisko), deciduous stands with the dominance of beech and admixture of sycamore maple, oak, hazel and linden prevail (WALCZAK 1968). Some parts of the slopes are dissected by numerous, in most cases abandoned, large quarries – characteristic components of the Krowiarki landscape and favourable gastropod habitats (MERKEL 1894, SPRICK 1921, JAECKEL 1942, WIKTOR 1960, 1964, MALTZ 2009). Previous studies, aimed at inventorying the sites of rare and endangered clausiliid *Charpentieria ornata* (WIKTOR 1960, MALTZ 2009), included only the quarries of the western and central part of the Krowiarki. The quarry in Rogóżka, located in the south-eastern part of the range and fairly remote from that group of quarries, was not studied in detail before. The only mention of the snails of the quarry is contained in WIKTOR's (1964) faunistic-zoogeographical study of the huge area of the Kłodzko Region, and his data on the quarry in Rogóżka are fragmentary.

This paper is the result of faunistic and ecological studies in the quarry; the data supplement the information on gastropod communities of the quarries of western and central Krowiarki.

STUDY AREA

The studied crystalline limestone quarry is located near the now nonexistent village of Rogóżka, south-west of Konradów (Fig. 1). It is situated on the south-western slope of mount Wapnisko (50°17'15"N, 16°48'41"E, UTM: XR27, 608.03 m a.s.l. – altitude of the quarry bottom). The quarry was established at the end of the 19th c. It was then that the Rogóżka Cave was discovered; it was damaged in the 1960s as a result of further exploitation (BIEROŃSKI 2009). Till the 1980s the limestone was quarried occasionally in the upper floors of the quarry which led to the discovery of another cave – Cave Na Ścianie. The exploitation ceased in the 1990s, but formally the quarry is still not excluded from exploitation (BIEROŃSKI J. – personal communication).

The quarry's bottom, ca. 15,000 m^2 in area, is covered by synanthropic communities of unspecified systematic rank and, in places with accumulations of rock rubble, communities of limestone screes and clumps of *Alnus incana* and *Betula* sp. (ŚWIERKOSZ K. – personal communication) (Fig. 2). The same communities are found on the northern and eastern walls of the quarry (Fig. 2A, B). The western wall, as well as a part of the western slope of mount Wapnisko, is covered by beech forest with admixture of spruce and oak (*Dentario-Fagetum*) (ŚWIERKOSZ K. – personal communication). The community *Aceri-Tilietum* (regeneration stage), occurring on the south-western slope, above the beech forest and above the north-eastern and eastern parts of the quarry (Fig. 2B, C), enters the quarry from south-east. Above the northern wall is an ovegrowing xerothermic sward, while submontane ash riverine forest (*Carici remotae-Fraxinetum*) with beds of *Petasites* sp. and *Cirsium oleraceum* (ŚWIERKOSZ

Fig. 1. Location of the abandoned quarry in Rogóżka (Krowiarki Mts, Stronie Śląskie commune)

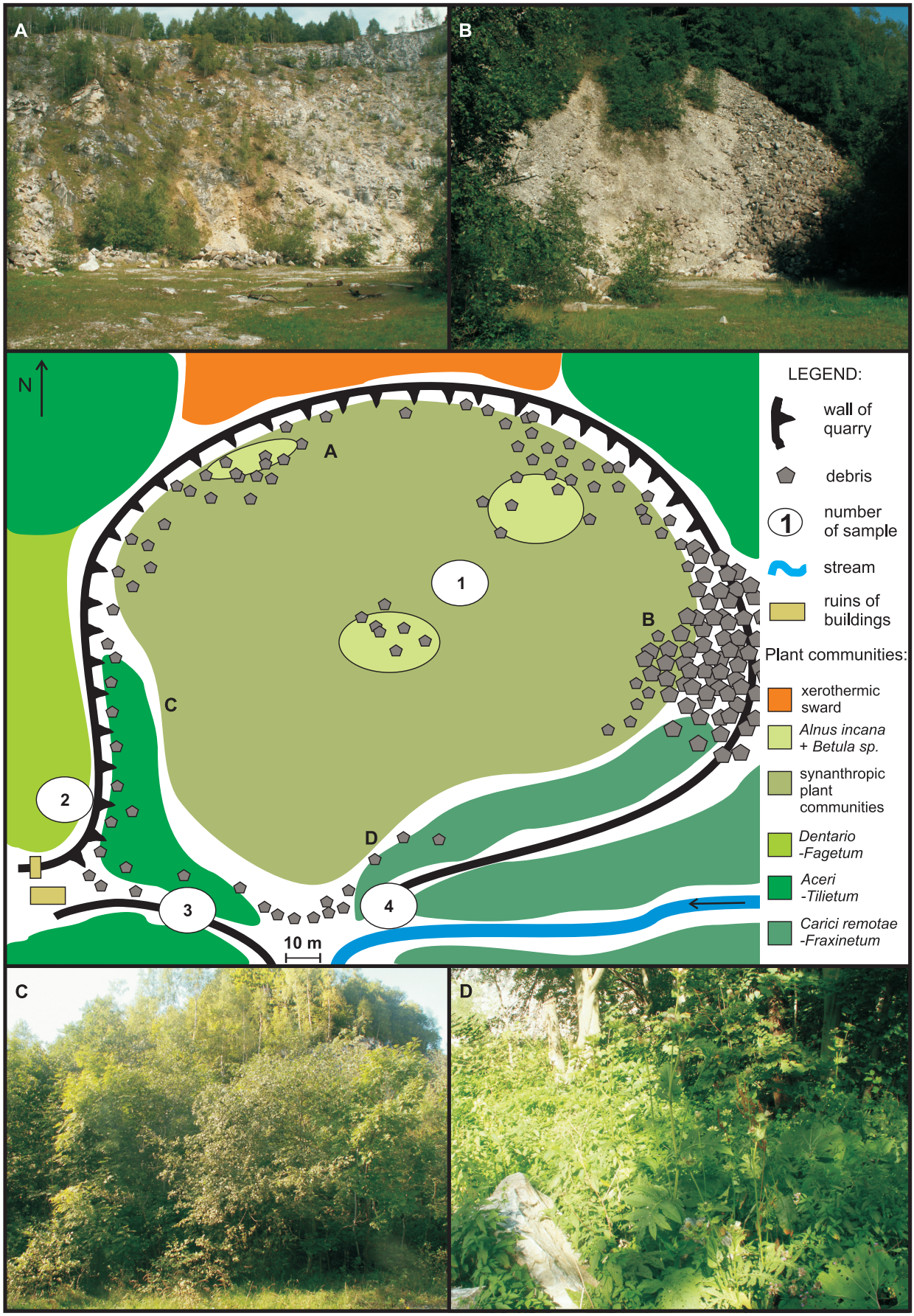

Fig. 2. Diagrammatic map of the quarry and its habitats (A–D)

K. – personal communication) (Fig. 2D), occurring on the banks of Konradka stream – the south-western limit of the quarry, enters from south-east. The stone bank closing the wide southern entrance to the quarry was built in 2009 (BIEROŃSKI J. – personal communication).

METHODS

Samples were taken from the 23rd till the 26st of August 2010. Four different habitats were distinguished in the quarry: 1. quarry's bottom (synanthropic communities, screes, clumps of alder and birch) (sample 1); 2. western wall covered by beech forest (sample 2); 3. south-western part of the quarry's bottom with a patch of linden-sycamore forest (sample 3); 4. south-eastern part of the quarry's bottom on the right bank of Konradka, with ash forest and beds of *Petasites* (sample 4) (Fig. 2). In each habitat gastropods were collected by eye for at least 2 person-hours. Litter samples, of 15 l volume each, were taken and sieved through a sieve of 10 × 10 mm mesh; after a few days' drying the samples were passed through a sieve with a smaller mesh (2 × 2 mm). Live individuals of Clausiliidae, Helicidae and slugs were identified in the field and released, the remaining material was identified in the laboratory and deposited in the collection of the Natural History Museum, Wrocław University. The nomenclature and systematic arrangement follow KERNEY et al. (1983) and WIKTOR (2004). The division into ecological and zoogeographical groups is based on RIEDEL's (1988) classification.

The analysis of the material from the four sieve samples considered constancy of occurrence and dominance; the classes were adopted after DZIĘCZKOWSKI (1972). The completeness of the results was tested with Chao index for the whole studied area and for individual samples (CAMERON & POKRYSZKO 2005).

In order to compare gastropod communities from the studied locality and from the other limestone quarries in the western part of the Krowiarki (MALTZ 2009) the following indices were used: 1) index of faunistic originality (IFO) (EJSMONT-KARABIN 1995), 2) valorisation index (RED = Σ Th_i, where Th – coefficient of danger to the species; for NT Th = 2, for Cr Th = 5), 3) index of biocoenosis value (REB = Σ Th_i/n, where n – number of all species), 4) index of "special care" species (RES = s/n × 100%, s – in this paper the number of legally protected species) (CZACHOROWSKI et al. 2004) and 5) Nei index (N) (POKRYSZKO & CAMERON 2005). Classification of endangered species for calculating the indices RED, REB and RES was adopted after WIKTOR & RIEDEL (2002).

RESULTS

A total of 45 gastropod species were collected in the quarry (Table 1). The occurrence of 13 species reported by WIKTOR (1964) was confirmed, as well as the presence of 10 species recorded by that author from the environs of Konradów. Twenty four species were recorded for the first time from the area. WIKTOR (1964) reported from the environs of Konradów also two species: *Vallonia excentrica* and *Aegopinella epipedostoma*, which were not found in the studied locality. The number of species in individual sites was: 17 (38% of 45), 29 (64%), 30 (67%) and 32 (71%) (Table 2).

Most species were collected by eye (41 out of 45; 91%); four species: *Succinea oblonga*, *Cochlicopa lubricella*, *Punctum pygmaeum* and *Macrogastra tumida* were found only in the litter samples (Table 2). The sieve samples contained a total of 2,289 specimens (mean density per 1 l litter was 38.2 specimen); the most numerous gastropods were found in sample 4 (948; 63.2 specimens/litre), the fewest – in sample 1 (376; 25.1 specimens/litre). The Chao index for the whole locality and for each site was 0 so that the collection could be regarded as complete.

Constancy of occurrence of the gastropods in the four sites in the quarry is presented in Figure 3. Only 9 out of 45 species (20%) were found in all four habitats (euryoecious species or species of wide ecological spectra), 11 species (24%) were found in three of the four habitats (most often woodland species of wide tolerance with respect to humidity changes), 13 species (29%) occurred in two habitats, and 12 (27%) – in only one habitat.

The following species formed the highest percentage of the collection (jointly for all litter samples): *Carychium tridentatum*, *Vallonia costata*, *Discus rotundatus*, *Vitrina pellucida*, *Vitrea diaphana*, *Clausilia parvula* and *Trochulus hispidus* (>5%), while 19 species constituted the smallest proportion of the collection (<1%; Fig. 4A). In sample 1 (quarry's bottom, very early succession stage), eudominants (>10%) were: *C. parvula* (27.9%), *V. costata* (18.4%) and *T. hispidus* (12.5%), while recedents (1.1–2.0%) included *C. lubricella*, *P. pygmaeum*, *Nesovitrea hammonis* and *Euconulus fulvus*, subrecedents (<1.0%) – *S. oblonga* (0.8%) and *D. rotundatus* (0.5%); the remaining spe-

Table 1. Species recorded from the studied locality and from the environs of Konradów

No.	Species	Rogóżka (WIKTOR 1964)	Konradów (WIKTOR 1964)	Rogóżka (this study)
1.	*Carychium tridentatum*			+
2.	*Succinea oblonga*			+
3.	*Succinea putris*		+	+
4.	*Cochlicopa lubrica*		+	+
5.	*Cochlicopa lubricella*	+		+
6.	*Columella edentula*			+
7.	*Vertigo pusilla*			+
8.	*Vallonia pulchella*		+	+
9.	*Vallonia costata*			+
10.	*Vallonia excentrica*		+	
11.	*Ena montana*	+		+
12.	*Punctum pygmaeum*			+
13.	*Discus rotundatus*		+	+
14.	*Arion subfuscus*			+
15.	*Arion distinctus*			+
16.	*Arion silvaticus*			+
17.	*Vitrina pellucida*		+	+
18.	*Eucobresia diaphana*		+	+
19.	*Semilimax semilimax*			+
20.	*Vitrea diaphana*	+	+	+
21.	*Aegopinella minor*	+		+
22.	*Aegopinella epipedostoma*		+	
23.	*Nesovitrea hammonis*			+
24.	*Oxychilus cellarius*	+		+
25.	*Zonitoides nitidus*		+	+
26.	*Limax cinereoniger*	+		+
27.	*Lehmannia marginata*			+
28.	*Malacolimax tenellus*	+	+	+
29.	*Deroceras agreste*		+	+
30.	*Deroceras reticulatum*	+		+
31.	*Euconulus fulvus*			+
32.	*Cochlodina laminata*	+		+
33.	*Ruthenica filograna*			+
34.	*Macrogastra plicatula*			+
35.	*Macrogastra tumida*			+
36.	*Macrogastra ventricosa*			+
37.	*Clausilia parvula*	+		+
38.	*Alinda biplicata*		+	+
39.	*Perforatella incarnata*	+		+
40.	*Perforatella vicina*			+
41.	*Trochulus hispidus*			+
42.	*Arianta arbustorum*		+	+
43.	*Helicigona lapicida*	+		+
44.	*Isognomostoma isognomostoma*			+
45.	*Cepaea hortensis*			+
46.	*Cepaea nemoralis*			+
47.	*Helix pomatia*	+		+
Total species		13	14	45

cies were dominants (2) and subdominants (3) (Fig. 4B). In sample 2 (beech forest) the eudominant was *C. parvula* (14.6%), recedents were *Vertigo pusilla*, *Oxychilus cellarius*, *Alinda biplicata*, *Perforatella vicina*, *Isognomostoma isognomostoma* and *Cepaea hortensis*, subrecedent – *V. pulchella* (0.85%) (Fig. 4C). Sample 3 (sycamore-linden forest) contained no eudominants, dominants were *V. diaphana* and *T. hispidus* (6.63%), *D. rotundatus* (6%) and *Perforatella incarnata* (5.59%), recedents – *V. pusilla*, *Cochlodina laminata*, *Macrogastra ventricosa*, *Arianta arbustorum* and *I. isognomostoma*, subrecedents – *Helicigona lapicida* (0.83%), *C. hortensis* (0.62%) and *Helix pomatia* (0.41%) (Fig. 4D). In sample 4 (submontane ash forest) the eudominant was *Carychium tridentatum* (17.45%), dominants were *D. rotundatus*, *V. pellucida*, *V. diaphana*, *Aegopinella minor* and *T. hispidus*, recedents – *Columella edentula* and *Ena montana*, subrecedents – *Succinea putris*, *Eucobresia diaphana* (0.94%), *P. pygmaeum*, *Semilimax semilimax*, *Ruthenica filograna* (0.73%), *P. incarnata* (0.63%), *S. oblonga* (0.52%), *I. isognomostoma* (0.42%), *M. tumida*, *A. arbustorum* (0.31%) and *E. fulvus* (0.21%) (Fig. 4E).

Clausiliidae are regarded as indicators of natural habitats (CAMERON & POKRYSZKO 2004). Seven species were found in the quarry. In individual samples they occurred in the following proportions. In sample 1, only *C. parvula* (100%) was present. In sample 2, *C. parvula* (51.1%) dominated, and *C. laminata* (31.9%) and *A. biplicata* (5.9%) were also present. In sample 3, *C. parvula* (21.2%) was the most abundant clausiliid, but compared to sample 2, the proportion of *A. biplicata* (18.2%) was higher; *M. plicatula* (12.1%) and *M. ventricosa* (5.1%) were also present; they were absent from the remaining samples. In sample 4, *A. biplicata* (34.5%) was the most abundant clausiliid; *R. filograna* (7.5%) and *M. tumida* (3.2%) were also recorded (Fig. 5).

The zoogeographical composition of the studied malacofauna is presented in Figure 6A. European species formed the largest group (28); they were fol-

Table 2. Number of specimens of species recorded from four different habitats in the quarry (sample 1–4). Abbreviations: ls – litter samples, sbe – searching by eye

No.	Species	Sample 1		Sample 2		Sample 3		Sample 4		Σ
		ls	sbe	ls	sbe	ls	sbe	ls	sbe	
1	*Carychium tridentatum*							167	+	167
2	*Succinea oblonga*	3						5		8
3	*Succinea putris*							9	+	9
4	*Cochlicopa lubrica*	27	+	15	+	12		28	+	82
5	*Cochlicopa lubricella*	6								6
6	*Columella edentula*							16	+	16
7	*Vertigo pusilla*	13	+	6		9				28
8	*Vallonia pulchella*	35	+	4						39
9	*Vallonia costata*	69	+	23	+	10		32	+	134
10	*Ena montana*			21	+	14	+	17	+	52
11	*Punctum pygmaeum*	6		10		18		7		41
12	*Discus rotundatus*	2		21	+	29	+	79	+	131
13	*Arion subfuscus*		+		+		+		+	
14	*Arion distinctus*				+		+		+	
15	*Arion silvaticus*				+		+			
16	*Vitrina pellucida*	13	+	18	+	21	+	92	+	144
17	*Eucobresia diaphana*							9	+	9
18	*Semilimax semilimax*							7	+	7
19	*Vitrea diaphana*			17	+	32	+	69	+	118
20	*Aegopinella minor*	15	+	23	+	24	+	52	+	114
21	*Nesovitrea hammonis*	5				14	+			19
22	*Oxychilus cellarius*			9	+	10	+			19
23	*Zonitoides nitidus*							43	+	43
24	*Limax cinereoniger*						+		+	
25	*Lehmannia marginata*						+		+	
26	*Malacolimax tenellus*				+		+		+	
27	*Deroceras agreste*				+				+	
28	*Deroceras reticulatum*		+		+				+	
29	*Euconulus fulvus*	4	+					2		6
30	*Cochlodina laminata*			15	+	7	+			22
31	*Ruthenica filograna*							7	+	7
32	*Macrogastra plicatula*					12	+			12
33	*Macrogastra tumida*							3		3
34	*Macrogastra ventricosa*					5	+			5
35	*Clausilia parvula*	105	+	69	+	21	+			195
36	*Alinda biplicata*			8	+	18	+	32	+	58
37	*Perforatella incarnata*			33	+	27	+	6	+	66
38	*Perforatella vicina*			6	+	14	+	21	+	41
39	*Trochulus hispidus*	47	+	32	+	32	+	51	+	162
40	*Arianta arbustorum*				+	5	+	3	+	8
41	*Helicigona lapicida*			12	+	4	+			16
42	*Isognomostoma isognomostoma*			9	+	6	+	4	+	19
43	*Cepaea hortensis*			5	+	3	+			8
44	*Cepaea nemoralis*				+					
45	*Helix pomatia*		+		+	2	+		+	2
	Zonitidae juv.	26		21		53		79		179
	Clausiliidae juv.			43		45		51		139
	Helicidae juv.			52		36		67		155
Σ		376		472		483		958		2,289
D (number of specimens/litre)		25.1		31.5		32.2		63.2		38.2

lowed by Holarctic species (9); 4 Euro-Siberian, 2 Carpathian, one Carpathian-Alpine and one Palaearctic species were also found. Among the ecological groups (Fig. 6B; Appendix) forest-dwellers dominated (26), the proportion of euryoecious species (8) and open country species (5) was also high; besides, 3 hygrophiles, 2 calciphiles and one xerothermophile were collected. Forest species formed the majority in samples 2–4 (Fig. 6C); in sample 3 their proportion was 70% (21 of 30 species), in sample 2 – 62% (18 of 29), and in sample 4 – 56% (18 of 32). Besides, 3 hygrophiles (9%) were found in the ash forest (sample 4), the only sample including this ecological group. Sample 1 (quarry's bottom) was ecologically

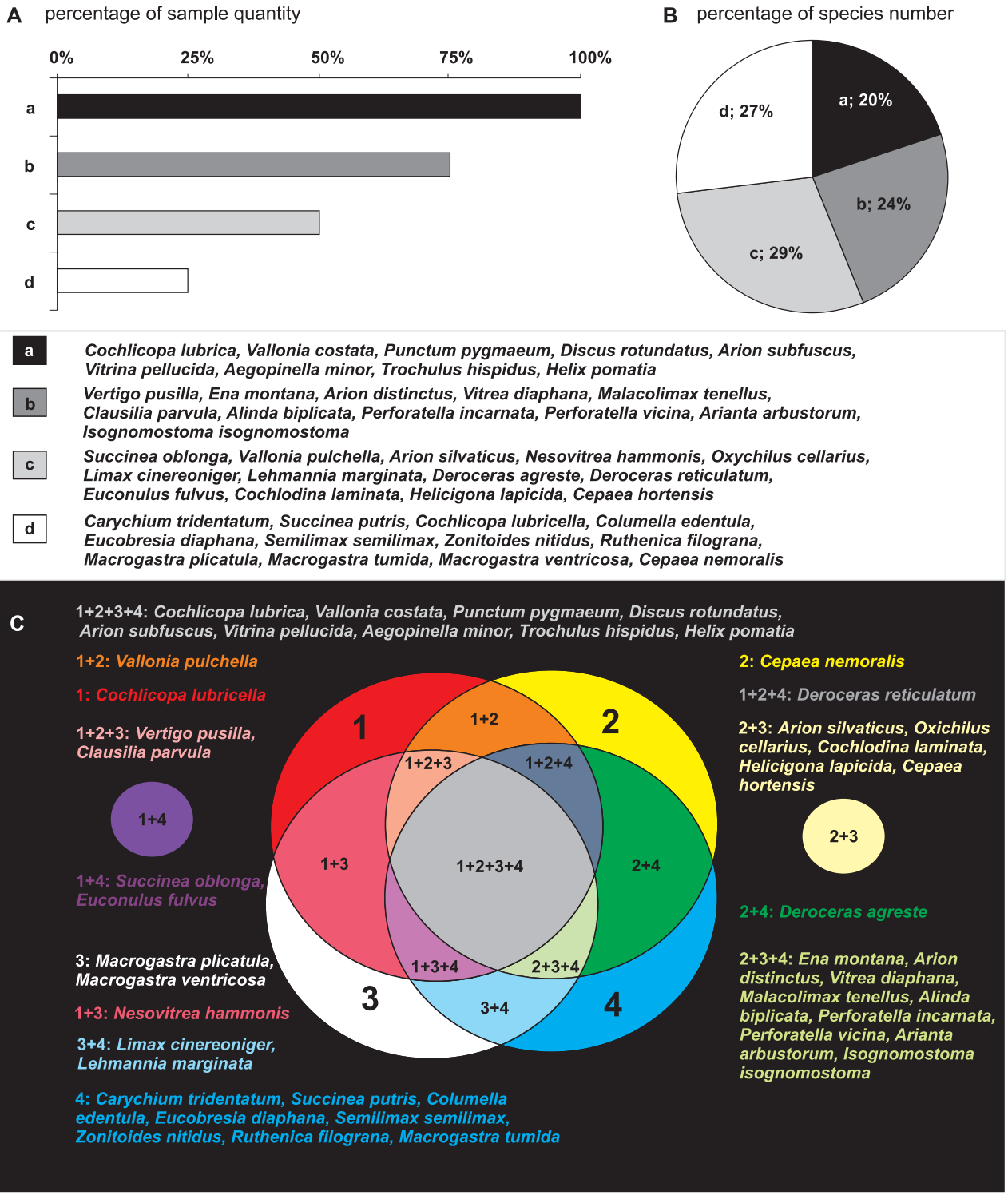

Fig. 3. Constancy of occurrence of species in four habitats in the quarry (A–B) and species common to particular habitats (Samples 1–4) (C)

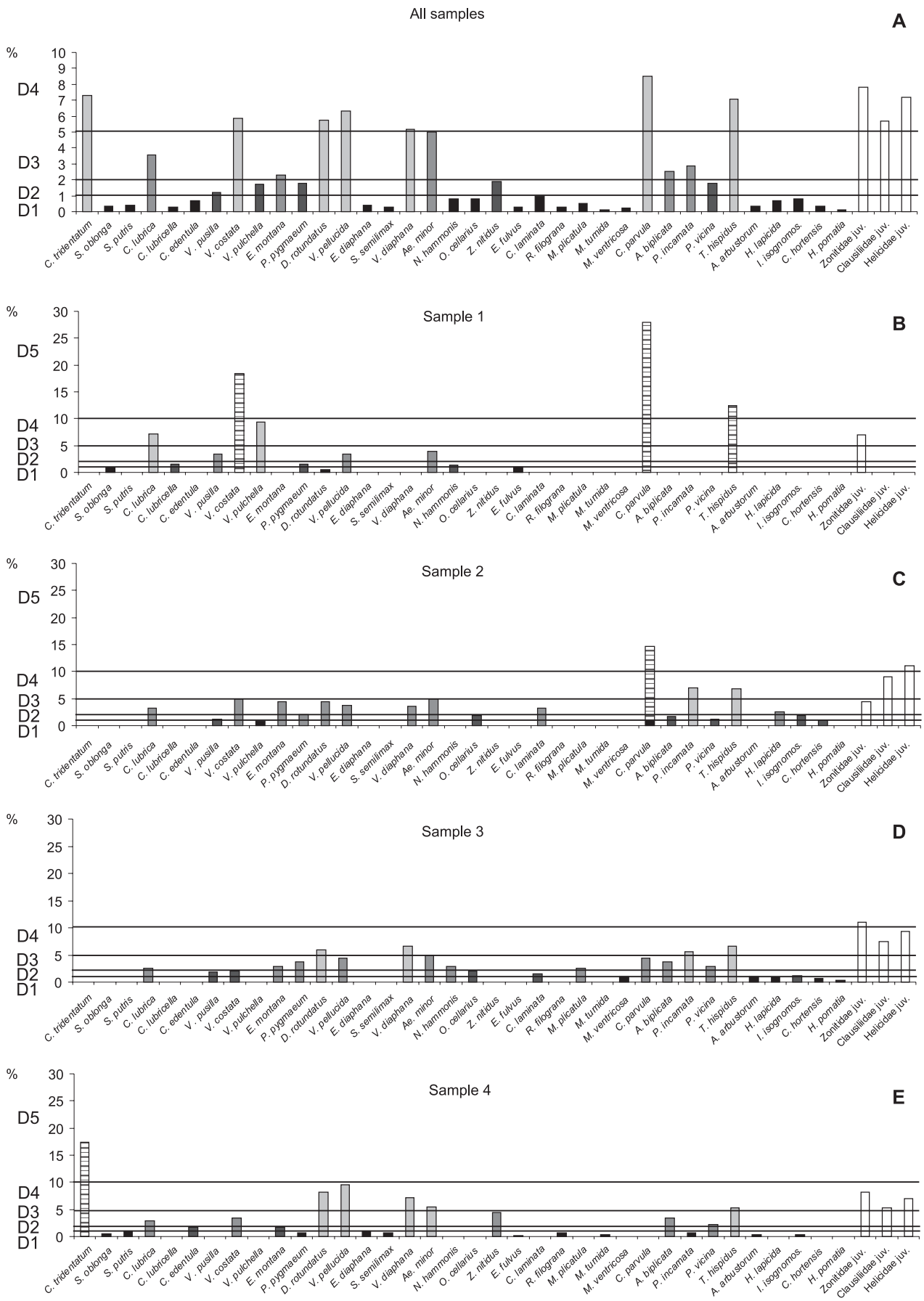

Fig. 4. Dominance of individual species in the malacocoenosis of the quarry (A) and in particular samples (B–E)

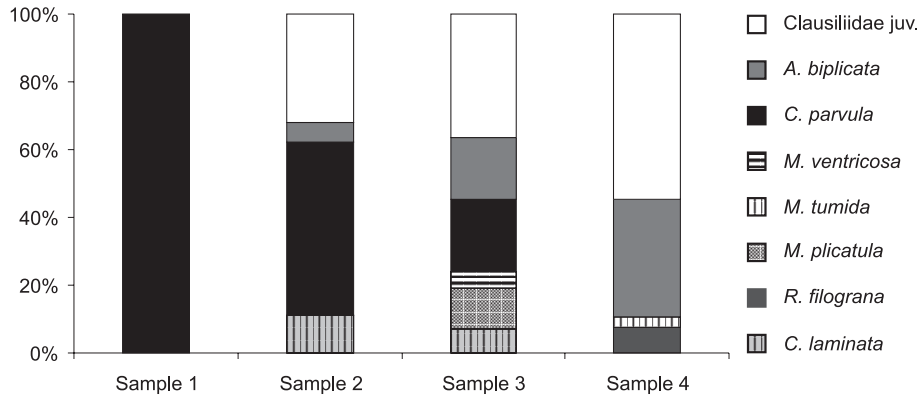

Fig. 5. Composition of clausiliid species in four samples from the Rogóżka quarry

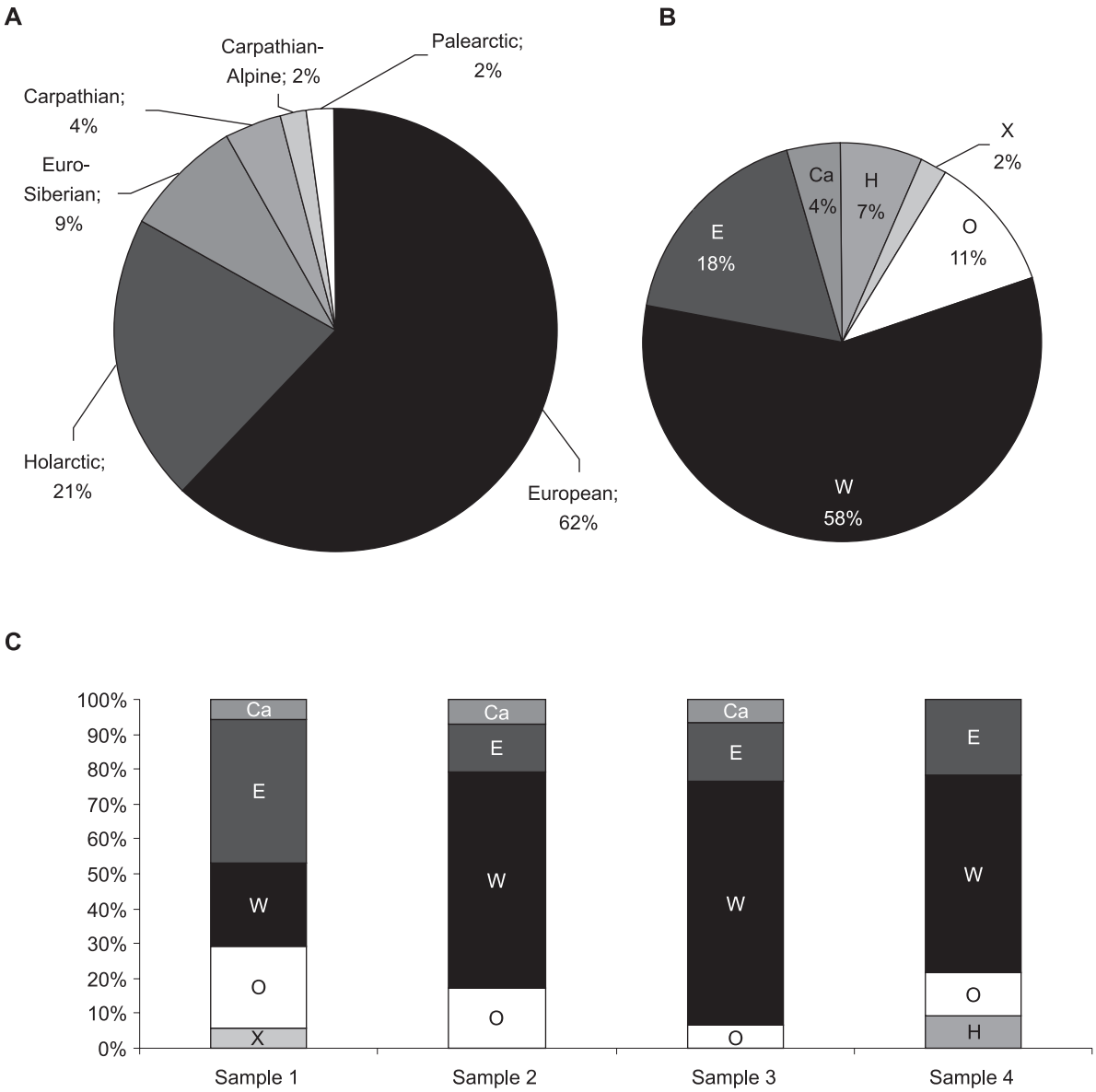

Fig. 6. Zoogeographical (A) and ecological (B – all quarry; C – particular samples) composition of the Rogóżka quarry malacocoenosis. Ecological groups: Ca – calciphilous, E – euryoecious, H – hygrophilous, O – open-country, W – woodland, X – xerothermophilous

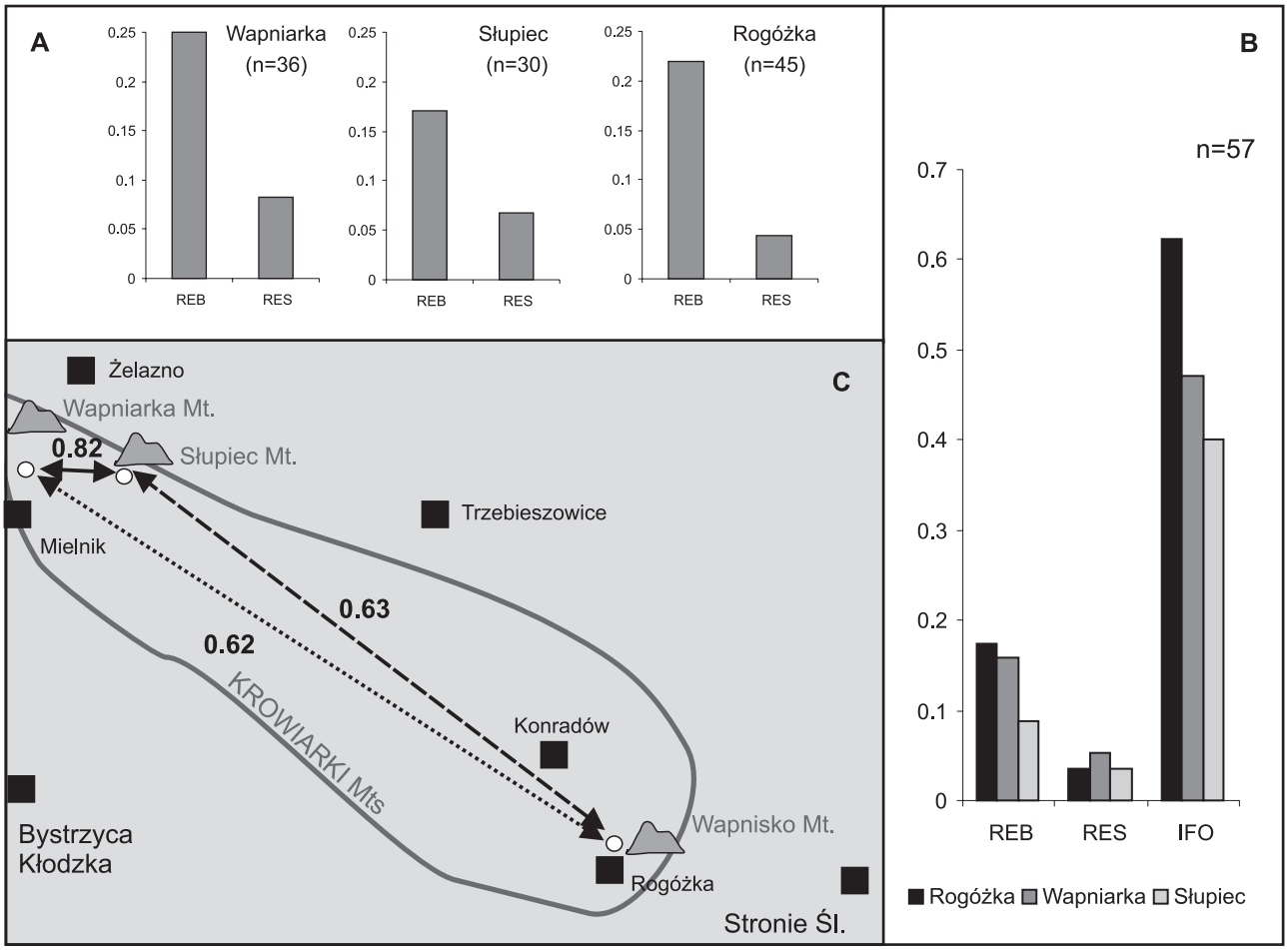

Fig. 7. Values of ecological indices: REB & RES (A) for individual malacocoenoses of quarries on Wapniarka, Słupiec and in Rogóżka; REB, RES, IFO (B) and N (C) for all species collected in abandoned quarries in the Krowiarki Mts

the most diverse, with euryoecious species forming the majority (41%; 7 of 17), forest and open country species constituting 24% each (4 species of each group); one calciphile and one xerothermophile were also found (5.5% each).

The quarry's malacofauna includes 5 species red-listed with NT category (WIKTOR & RIEDEL 2002): *E. diaphana*, *S. semilimax*, *M. tumida*, *C. parvula* and *H. lapicida*. *H. lapicida* is strictly legally protected, *H. pomatia* – seasonally protected (s = 2). The indices of faunistic value for the studied locality are: RED = 10, REB = 0.22 and RES = 0.044 (n = 45). Based on the data on the malacofauna of the quarries in the western Krowiarki (MALTZ 2009), such indices were also calculated for the quarries of Wapniarka (RED = 9; REB = 0.25; RES = 0.083; n = 36), and the quarries of Słupiec (RED = 5; REB = 0.17; RES = 0.067; n = 30) (Fig. 7A) (for detailed data on endangered and protected species see Appendix). Considering the number of all species recorded from the quarries of Krowiarki (n = 57) the indices are: 1) Rogóżka – REB = 0.175 and RES = 0.035; 2) Wapniarka – REB = 0.158 and RES = 0.053; 3) Słupiec – REB = 0.088 and RES = 0.035 (Fig. 7B). The values of the index of faunistic originality are: for the quarry in Rogóżka IFO = 0.622, for the quarries of Wapniarka – IFO = 0.472 and for Słupiec – IFO = 0.4. The similarity among the malacocoenoses in the above quarries (N) is: for Wapniarka and Słupiec N = 0.82, for Słupiec and Rogóżka – 0.63 and for Wapniarka and Rogóżka – 0.62 (Fig. 7C).

DISCUSSION

This study recorded 45 species of snails and slugs in the quarry in Rogóżka. This constitutes 50.6% of terrestrial gastropods recorded from the Śnieżnik Massif (89 species) and 43.7% of the species recorded from the Kłodzko Region (103 species) (WIKTOR 1964). The most valuable species include *E. diaphana*, *S. semilimax*, *M. tumida*, *H. lapicida*, and most of all *C. parvula*, for which the quarry in Rogóżka is the only

extant locality in the region. In the past it occurred in the quarries of Wapniarka (JAECKEL 1942), but its presence was not confirmed in more recent studies (WIKTOR 1960, MALTZ 2009). In Lower Silesia the species was found in fairly large numbers in limestone quarries of the Kaczawskie Mts (POKRYSZKO 1984), and also in the environs of Wałbrzych, mainly in the ruins of mediaeval castles (MALTZ 1999). The quarry in Rogóżka is its south-easternmost locality, isolated from other Sudetic localities of the species.

Literature information on colonisation of anthropogenic sites which undergo secondary succession by terrestrial gastropods is rather scarce (among others BARGA-WIĘCŁAWSKA 1997, BAUCZ-MALIJ 2001, MALTZ 2009). In each of those studies, the authors attempted to specify the group of pioneering species. In the case of quarry spoil heaps in the environs of Kielce, aged ca. 30–60 years, the following species were classified as pioneering: *C. lubrica*, *C. lubricella*, *C. edentula*, *Truncatellina cylindrica*, *V. costata*, *V. pulchella*, *P. pygmaeum*, *Arion subfuscus*, *V. pellucida*, *N. hammonis*, *E. fulvus*, *P. incarnata* and *T. hispidus* (BARGA-WIĘCŁAWSKA 1997). In the copses in Lower Silesia, formed in agricultural areas 50–80 years after they were excluded from cultivation, the pioneering species included *V. pellucida*, *N. hammonis*, *C. lubrica*, *P. pygmaeum*, *A. subfuscus*, *T. hispidus*, *P. incarnata*, *Aegopinella pura*, *V. pulchella*, *V. costata* and *H. pomatia* (BAUCZ-MALIJ 2001). In the quarries of Wapniarka and Słupiec the pioneer species were *Pupilla muscorum*, *T. cylindrica*, *C. lubrica*, *C. lubricella*, *V. pulchella*, *V. costata*, *A. subfuscus*, *V. pellucida*, *Ch. ornata*, *Helicella obvia*, *T. hispidus*, and also *Vertigo pygmaea*, *Ae. minor*, *E. fulvus* and *Euomphalia strigella*, followed by *V. pusilla*, *D. rotundatus*, *A. biplicata*, *H. lapicida*, *C. hortensis*, *H. pomatia*, *P. pygmaeum*, *O. cellarius*, *C. laminata*, *P. incarnata* and *I. isognomostoma* (MALTZ 2009).

Colonisation of quarries, like that of copses or spoil heaps, is random and depends directly on the kind of habitats found in the immediate vicinity (BARGA-WIĘCŁAWSKA 1997, BAUCZ-MALIJ 2001, MALTZ 2009). The quarry in Rogóżka was abandoned in the 1980s. It is an anthropogenic habitat presently undergoing secondary succession. The surrounding habitats are forests (communities *Dentario-Fagetum*, *Aceri-Tilietum* or *Carici remotae-Fraxinetum*), and consequently the dominant components of the fauna are forest-dwellers. The sparse beech forest of the quarry's western wall holds *V. pusilla*, *E. montana*, *P. pygmaeum*, *D. rotundatus*, *O. cellarius*, *C. laminata*, *A. biplicata*, *P. incarnata*, *C. hortensis* and *H. pomatia* – forest snails tolerant of humidity changes (RIEDEL 1988). In damper places *V. pellucida*, *A. silvaticus*, *V. diaphana*, *P. vicina*, *A. arbustorum* and *I. isognomostoma* can be found. According to MALTZ (2009) these species constitute the second group of colonisers. Along with the penetration of the quarry by the sycamore-linden and ash-alder forest from the south, species preferring damp forest habitats – *Limax cinereoniger*, *Lehmannia marginata*, *Malacolimax tenellus*, *Macrogastra plicatula* and *M. ventricosa* – colonise the quarry. According to MALTZ's (2009) classification they belong to the third and fourth groups of colonisers. *C. tridentatum*, *S. putris*, *E. diaphana*, *S. semilimax*, *Z. nitidus*, *R. filograna* and *M. tumida* occur next to the stream – they are typical of very damp forest microhabitats (RIEDEL 1988) and a more extensive colonisation of the quarry by such species seems unlikely. In the open part (bottom and northern wall of the quarry) there are no xerothermophiles such as *H. obvia*, *P. muscorum*, *T. cylindrica*, which live on Wapniarka (MALTZ 2009). In Rogóżka, the only such species is *C. lubricella*. It is scarce there, and with *V. pulchella* and *V. costata* it inhabits the overgrowing xerothermic sward above the northern wall; it probably penetrated the quarry from there. The remaining species co-occurring with *C. lubricella*: *C. lubrica*, *V. pulchella*, *V. costata*, *P. pygmaeum*, *A. subfuscus*, *V. pellucida*, *Ae. minor*, *N. hammonis*, *E. fulvus* or *T. hispidus*, common and of wide ecological tolerance, have great colonising abilities and are typical of early succession seral stages (BARGA-WIĘCŁAWSKA 1997, BAUCZ-MALIJ 2001, MALTZ 2009). Also *C. parvula*, the only clausiliid which is abundant in the screes of the quarry's bottom, can be included in the group of pioneer species. Besides penetration by gastropods from the adjacent natural habitats, introduction of some species by man is likely. An example is *Cepaea nemoralis*, found only in the ruins of farm buldings (Fig. 2), among farm garbage brought there. According to WIKTOR (2004), man plays the main role in the spread of this species. Other such species found in the quarry are *D. reticulatum* or *T. hispidus*.

In the litter, the dominant species were *C. tridentatum*, *V. costata*, *V. pellucida*, *V. diaphana*, *Ae. minor*, *D. rotundatus* and *T. hispidus* – snails living mainly in the litter and/or on the soil surface. Adult and subadult individuals of clausiliid species (among others *C. laminata*, *M. plicatula* or *M. ventricosa*) or Helicidae (among others *A. arbustorum*, *H. lapicida*, *C. hortensis* or *H. pomatia*), were few, though numerous small juveniles of these families were found in the samples (Fig. 4). In late summer adult and subadult clausiliids, as well as the above helicids, stay mainly on tree trunks, pieces of dead timber, rocks or tall herbs, hence their small proportion in the samples. Their hatchlings are associated with litter. *C. parvula* is exceptional in that it is abundant in various microhabitats, such as litter, tree trunks, stones or rock ledges. These observations are confirmed by the studies on the seasonal dynamics of abundance, age structure and species composition of malacofauna in litter samples taken during various seasons of the year in the nature reserve Muszkowicki Las Bukowy (KUŹNIK-KOWALSKA 1998), or population dynamics of *Helicodonta obvoluta* (MALTZ 2003) – a snail staying mainly on logs and descending to the litter only in early spring and late summer.

The rather numerous group of clausiliids (7 of 15 recorded from the Kłodzko Region; 47%) indicates considerable diversity of microhabitats of the quarry. The presence of limestone results in the population of *C. parvula* – a calciphile – being very abundant both in the open places and in the forested parts; this confirms a strict association of the species with calcium content (RIEDEL 1988, WIKTOR 2004) (the species shows a rather wide tolerance to other habitat factors, e.g. humidity, shadiness, presence of dead timber, temperature). The presence of dead timber in the sycamore-linden forest, combined with the considerable accumulation of litter, allows for the syntopic co-occurrence of five clausiliid species (the only site of *M. plicatula* and *M. ventricosa* in the quarry). Microhabitat diversity favours the occurrence of various clausiliid species because of the differences in their habitat preferences, as demonstrated for example in the studies on Carpathian forest clausiliids (SULIKOWSKA-DROZD 2005), or on the litter fauna of the forests of western and central Europe (KAPPES et al. 2009). In those studies clausiliids were found to be among the groups especially sensitive to the absence of dead timber.

Among the studied quarries in the Krowiarki range (MALTZ 2009), the quarry in Rogóżka is the richest in species. Of the 57 species collected in such habitats in the Krowiarki range as many as 45 (79%) occur in Rogóżka, including 15 species not found in the other quarries (Appendix). This results in the high value of the index of faunistic originality (IFO = 0.622) (for Wapniarka and Słupiec these values are similar, 0.47 and 0.40 respectively). Also the values of Nei index confirm the greater similarity between the communities from Wapniarka and Słupiec than between any of them and that from Rogóżka (Fig. 7C). The reasons are probably related to the way these quarries are situated. The quarry in Rogóżka is far from human habitations, located among forests which for the most part preserved their natural character. This allowed many forest species to survive and colonise the quarry with progressing succession. The quarries in Wapniarka and Słupiec are surrounded by cultivated fields and meadows, with only the higher parts of the hills covered by forests, mainly dry beech woods with admixture of spruce and oak, and hence their colonising malacofauna is much poorer, with a greater proportion of synanthropic and euryoecious species (MALTZ 2009) and only 2–3 clausiliid species. It should be noted, however, that both the quarries of the western Krowiarki range and the quarry in Rogóżka are localities of rare and endangered gastropod species, often their only remaining localities in the area. The group of quarries of Słupiec and Wapniarka holds a critically endangered clausiliid *Ch. ornata* (the only locality in Poland) (WIKTOR 1960, 1964, 2004, RIEDEL 1988, MALTZ 2009), *S. semilimax* and *H. lapicida* live in the quarries of Wapniarka and Rogóżka, while *E. diaphana*, *M. tumida* and *C. parvula* (in the last case it is the only locality in the Kłodzko Region) are found in Rogóżka.

There is a need to legally protect such abandoned limestone quarries (habitat protection), since species protection (*Ch. ornata* and *H. lapicida*) is often insufficient and ineffective as exemplified by the resumed limestone exploitation in one of the quarries in Słupiec in 2005 (MALTZ 2009) despite the presence of *Ch. ornata*. The fate of the gastropods from Rogóżka is also uncertain, since the quarry is not formally excluded from exploitation and the commune Stronie Śląskie has for several years been trying to sell the land of the former village to a private investor. This additionally speaks in favour of establishing a nature reserve in the quarry.

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APPENDIX

List of species recorded from abandoned quarries in the Krowiarki Mts. Abbreviations: EG – ecological groups: Ca – calciphilous, E – euryoecious, H – hygrophile, O – open-country, W – woodland, X – xerothermophilous (RIEDEL 1988); sites in the Krowiarki Mts.: QR – quarry on Mt. Wapnisko near Rogóżka, QW – quarries on Mt. Wapniarka (MALTZ 2009), QS – quarries on Mt. Słupiec (MALTZ 2009); TC – threat categories: CR – critically endangered, NT – near threatened, P – protected (WIKTOR & RIEDEL 2002); IFO – index of faunal originality, RED – index of biocoenosis valorisation, REB – index of biocoenosis value, RES – index of protected species

No.	List of species	EG	TC	Sites		
				QR	QW	QS
1	*Carychium tridentatum*	H		+		
2	*Succinea oblonga*	E		+		
3	*Succinea putris*	H		+		
4	*Cochlicopa lubrica*	E		+	+	+
5	*Cochlicopa lubricella*	X		+	+	+
6	*Truncatellina cylindrica*	X			+	+
7	*Columella edentula*	E		+		
8	*Vertigo pusilla*	W		+	+	+
9	*Vertigo pygmaea*	O				+
10	*Pupilla muscorum*	X			+	+
11	*Vallonia pulchella*	O		+	+	+
12	*Vallonia costata*	O		+	+	+
13	*Acanthinula aculeata*	W			+	
14	*Ena montana*	W		+		+
15	*Punctum pygmaeum*	W		+	+	+
16	*Discus rotundatus*	W		+	+	+
17	*Arion rufus*	H			+	+
18	*Arion subfuscus*	E		+	+	+
19	*Arion circumscriptus*	E			+	+
20	*Arion distinctus*	W		+	+	+
21	*Arion silvaticus*	W		+		
22	*Vitrina pellucida*	E		+	+	+
23	*Eucobresia diaphana*	W	NT	+		
24	*Semilimax semilimax*	W	NT	+	+	
25	*Vitrea diaphana*	W		+	+	
26	*Vitrea crystallina*	W			+	
27	*Aegopinella pura*	W			+	
28	*Aegopinella minor*	O		+	+	+
29	*Nesovitrea hammonis*	E		+		
30	*Oxychilus cellarius*	W		+	+	+
31	*Daudebardia rufa*	W			+	
32	*Zonitoides nitidus*	H		+		
33	*Limax cinereoniger*	W		+	+	+
34	*Lehmannia marginata*	W		+		
35	*Malacolimax tenellus*	W		+	+	+
36	*Deroceras agreste*	O		+		
37	*Deroceras reticulatum*	O		+		
38	*Euconulus fulvus*	E		+		+

No.	List of species	EG	TC	Sites		
				QR	QW	QS
39	*Cochlodina laminata*	W		+	+	+
40	*Charpentieria ornata*	Ca	CR, P		+	+
41	*Ruthenica filograna*	W		+		
42	*Macrogastra plicatula*	W		+		
43	*Macrogastra tumida*	W	NT	+		
44	*Macrogastra ventricosa*	W		+		
45	*Clausilia parvula*	Ca	NT	+		
46	*Alinda biplicata*	W		+	+	+
47	*Helicella obvia*	X			+	
48	*Perforatella incarnata*	W		+	+	+
49	*Perforatella vicina*	W		+		
50	*Trochulus hispidus*	E		+	+	+
51	*Euomphalia strigella*	O			+	+
52	*Arianta arbustorum*	W		+	+	
53	*Helicigona lapicida*	Ca	NT, P	+	+	
54	*Isognomostoma isognomostoma*	W		+	+	+
55	*Cepaea hortensis*	W		+	+	+
56	*Cepaea nemoralis*	W		+		
57	*Helix pomatia*	W	P	+	+	+
total species	57	–	–	45	36	30
snail species	47	–	–	37	30	24
clausiliid species	8	–	–	7	3	3
slug species	10	–	–	8	6	6
Ca	–	3	–	2	2	1
H	–	4	–	3	1	1
E	–	9	–	8	5	6
O	–	7	–	5	4	5
W	–	30	–	26	20	14
X	–	4	–	1	4	3
IFO	–	–	–	0.622	0.472	0.40
CR	–	–	1	0	1	1
NT	–	–	5	5	2	0
P	–	–	3	2	3	2
RED	–	–	–	10	9	5
REB	–	–	–	0.175	0.158	0.088
RES	–	–	–	0.035	0.053	0.035