Geology, Geophysics & Environment • 2012 • Vol. 38 • No. 4 • 411–425

http://dx.doi.org/10.7494/geol.2012.38.4.411

HOLOCENE MALACOFAUNA ON THE CIESZYN BEDS CALCAREOUS SUBSTRATE AT THE TUŁ HILL (FLYSCH CARPATIANS, POLAND)

Magdalena GOŁAS-SIARZEWSKA

AGH University of Science and Technology, Faculty of Geology, Geophysics and Environment Protection, Department of General Geology and Geotourism; al. Mickiewicza 30, 30-059 Krakow, Poland; e-mail: mgolas@agh.edu.pl

Abstract: The Cieszyn Beds (Jurassic/Cretaceous) in the Flysch Carpathians (Southern Poland) contain limestones, which create favourable conditions enabling the preservation of the Holocene mollusc shells in the overlying soils. The malacofauna found at the Tuł Hill in the soil underlain by the limestones, and containig their fragments, confirms the conditions enabling migration of the species between the regions located south of the Carpathian range and the lowlands to the north. The dominating species are represented by the mollusc associations living in the woodlands. This study reports the presence of a unique species Orcula doliolum (Brug.) in the Tuł Hill area. Detailed biometric measurements on the shells of this species show no variation by comparison with similar studies conducted by previous authors at other isolated localities throughout Europe.

Key words: mollusc associations, faunal analysis, Tuł Hill, Flysch Carpathians, South Poland

INTRODUCTION

The region of Flysch Carpathians is characterised by sandstone and shale complexes with low calcium carbonate content, which results in conditions unfavourable for preservation of molluscs shells in the overlying soils. At the low concentration of calcium carbonate, shells are dissolving after mollusc death, mainly due to the humic acids activity. However, in the Flysch Carpathians, there are complexes represented by sandstones with calcite cements and rare marble complexes, especially rich in calcite. The calcareous complexes occur at the Cieszyn Foothills of the Żywiec and Adrychów region. In those areas preservation and accumulation of mollusc shells was possible, as shells do not undergo rapid dissolution.

Such accumulation of empty shells is called thanatocenose (S.W. Alexandrowicz 1999, S.W. Alexandrowicz & W.P. Alexandrowicz 2011). Studies of thanatocenoses and biocoenoses from terrestrial environments were conducted in the limestone-underlain areas of the Polish Carpathians in the past (e.g. W.P. Alexandrowicz 1997, 2001, W.P. Alexandrowicz & Rudzka 2006) and also in Kraków-Częstochowa Upland (e.g. S.W. Alexandrowicz 2000, W.P Alexandrowicz 2000). Due to the presence of small isolated carbonate-underlain areas the Flysch Carpathians, synthetic regional studies of this nature are rare (W.P. Alexandrowicz 1994).

Tuł Hill lies in southern Poland at the Cieszyn Foothills (Fig. 1). This is a unique area of the Polish Flysch Carpathians because it is underlain by carbonate rocks called the Cieszyn Beds composed of marble complexes called "Cieszyn limestones" of the Jurassic and Cretaceous age. These limestones are covered by soils with high concentration of calcium carbonate. Cieszyn limestones lie within the Cieszyn shales and are the oldest sedimentary rocks belonging to the Silesian Series of the Flysch Carpathians (Słomka 2001). These limestones, due to a relatively high resistance to weathering, form isolated hills, one of which is Tuł Hill.

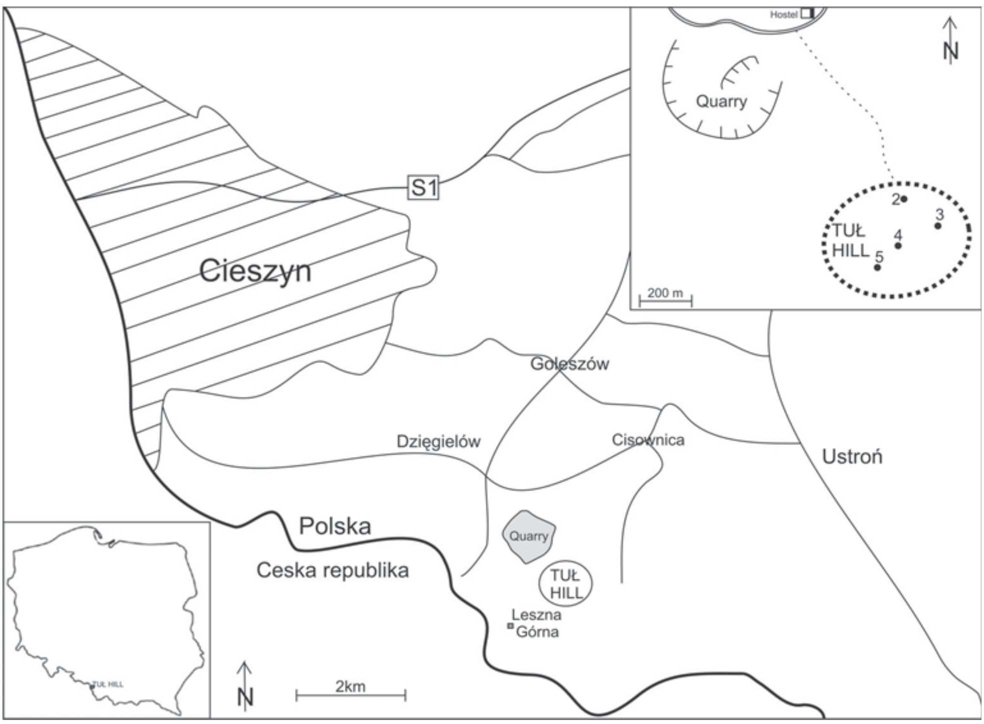

Fig. 1. Location of the sampling sites at the Tuł Hill

Tuł Hill lies in the Goleszów district, 12 km to the south-east of the Cieszyn town (Fig. 1). The hill rises 621 metres above mean see level and possesses five prominent mild brows and steep valleys with slopes inclied up to 23 degrees. The brows proceed from east, west, north and south. Northern slopes are less wooded than southern ones, and the central part of the hill is covered by grasslands. This is an important area in terms of ecological and historical interest. The florist reserve was established here in 1948 at the highest part of this hill and on its northeast slope to protect rare species of plants. In this area *Orchis pallens* (L.) are growing, as well as old *Acer campestre* (L.) on the eastern slope and *Lilium martagon* (L.) at the top of the Tuł Hill (Szlachetko 1985, Rostański et al. 1986). Moreover, archeologists found the traces of the Lusatian cultures settlement at the apex (B. Chorąży & B. Chorąży 2005). Unfortunately, the decision to treat this area as a natural reserve was made by the wrong administration organ and it was removed from the list of Polish reserves a few years ago.

Tuł Hill is a special loclity because of the calcium carbonate appearance in the ground which fosters mollusc expansion. This specific geological structure enabled mollusc studies at the Cieszyn Highland area, and several research projects were carried out by Poliński (1919, 1922, 1924), Geyer (1927), Ehrmann (1933) and Urbański (1957). However, detailed study of malacofauna were not conducted at the Tuł Hill. An occurrence of *Orcula doliolum* (Brug.) species is also interesting, due to its limited distribution in Poland.

MATERIALS AND METHODS

The presented research on thanatocenoses and biocoenoses were conducted on five samples representing different slopes of the Tuł Hill. Samples containing shells of molluscs were collected from the surface using hands and spade. The first sample was taken twenty years ago by W.P. Alexandrowicz (personal comm.) and represented mainly south eastern edge of the Tuł Hill (Fig. 1). Samples 2–5 were collected in 2010. The second sample came from a small soil outcrop in the northern slope. The outcrop was 2 metres high, and surrounded by a few trees and meadow. The third sample was taken from eastern part of the apex, which is underlain by the Cieszyn limestones covered wiht a thin solid ground and forest. From the central part of the Tuł Hill the fourth sample was collected. The last sample came from the western apex underlain by the Cieszyn limestones.

The samples were collected using the methods described by S.W. Alexandrowicz & W.P. Alxeandrowicz (2011). The average weight of the sample was about 1 kg of material taken from 25 cm × 25 cm size square. Before malacological analysis, samples were washed to extract shells and their fragments. Then, collected remains of malacofauna were identified using microscope. Fragments of shells were converted into completely preserved specimens according to the method described by S.W. Alexandrowicz & W.P. Alxeandrowicz (2011). The whole analyzed material comprised 38 species of land snails, represented by 879 specimens (Tab. 1).

Table 1

Malacofauna found at the Tuł Hill (Samples 1–5). Ecological groups (E) (based on Ložek 1964, S.W. Alexandrowicz 1987): F – shade-loving species, O – open country species, M – mesophilous species

E	Taxon	Abbrev.	1	2	3	4	5
F	*Acicula polita* (Hartmann)	Ap	2	–	–	–	2
F	*Vertigo pusilla* (Müller)	Vpu	25	1	–	–	–
F	*Orcula doliolum* (Bruguiere)	Od	125	–	–	72	12
F	*Acanthinula aculeata* (Müller)	Ac	3	–	–	–	–
F	*Ena obscura* (Draparnaud)	Eo	–	–	–	8	–
F	*Discus rotundatus* (Müller)	Dro	41	–	1	21	1
F	*Vitrea diaphana* (Studer)	Vd	20	–	2	10	3
F	*Vitrea transsylvanica* (Clessin)	Vt	8	–	–	–	–
F	*Vitrea crystallina* (Müller)	Vc	4	–	–	–	–
F	*Aegopinella minor* (Stabilne)	Am	3	2	1	17	7
F	*Aegopinella nitens* (Michaud)	An	12	–	11	–	–
F	*Aegopinella pura* (Alder)	Ap	18	4	–	–	–
F	*Oxychilus glaber* (Westerlund)	Og	2	–	–	–	–
F	*Daudebardia rufa* (Draparnaud)	Dr	2	–	1	3	–
F	*Cochlodina laminata* (Montagu)	Cl	3	2	–	4	6
F	*Ruthenica filograna* (Rossmässler)	Rf	5	–	2	1	4
F	*Macrogastra tumida* (Rossmässler)	Mt	2	–	–	–	–
F	*Macrogastra plicatula* (Draparnaud)	Mp	16	–	–	3	3
F	*Balea biplicata* (Montagu)	Bb	26	5	3	26	6
F	*Trichia unidentata* (Draparnaud)	Tu	18	4	–	–	–
F	*Monachoides incarnatus* (Müller)	Mi	8	4	2	3	2
F	*Monachoides vicinus* (Rossmässler)	Mv	25	46	35	13	8
F	*Isognomostoma isognomostomos* (Schröter)	Ii	–	7	4	1	–
O	*Truncatellina cylindrica* (Férussac)	Tc	–	–	–	1	–
O	*Vertigo pygmaea* (Draparnaud)	Vpy	–	1	–	–	–
O	*Pupilla muscorum* (Linnaeus)	Pm	2	–	–	–	–
O	*Vallonia costata* (Müller)	Vc	1	1	1	–	2
O	*Vallonia pulchella* (Müller)	Vp	14	3	5	–	–
M	*Cochlicopa lubrica* (Müller)	Clu	4	2	–	1	–
M	*Columella edentula* (Draparnaud)	Ce	–	–	4	–	–
M	*Punctum pygmaeum* (Draparnaud)	Pp	25	–	–	–	–
M	*Vitrina pellucida* (Müller)	Vpe	3	–	–	–	–
M	*Vitrea contracta* (Westerlund)	Vc	1	5	–	–	–
M	*Nesovitrea hammonis* (Ström)	Nh	2	18	–	3	–
M	*Oxychilus cellarius* (Müller)	Oc	1	–	–	–	–
M	*Clausilia dubia* (Draparnaud)	Cd	2	–	–	–	–
M	*Trichia hispida* (Linnaeus)	Th	–	6	5	–	2
M	*Carychium minimum* (Müller)	Cm	9	6	6	–	2

Standard methods of malacological analysis described by Ložek (1964) and S.W. Alexandrowicz (1987, 1999) were applied. Malacological individual spectra (MSI) and malacological species spectra (MSS) were measured to determine the structure of molluscan fauna (Figs 2–6). The found species were divided into ecological groups representing three categories: F – shade-loving species, O – open-country snails, and M – mesophilous snails with wide ecological tolerance (Tab. 1). Structure of constancy (C) and dominance (D) were measured in the whole material using the method described by Dobrowolski (1963) and S.W. Alexandrowicz (1987), and then dominant and accessory species were distinguished (Tabs 2, 3). Molluscs form the four groups: CD – common species with numerous specimens (C > 50%, D > 5%), Cd – common species with limited number of specimens (C > 50%, d < 5%), cD – rare species represented by numerous specimens (c < 50%, D > 5%), and cd – rare species and limited number of specimens (c < 50%, d < 5%). Additionally, for the whole fauna two indices of differentiation of fauna (TDI, ADI) were calculated, as well as normalized constancy, dominance indices (C_i, D_i) and Q index, which define geometric mean of constancy and dominance defined by S.W. Alexandrowicz (1987, 1999). Zoogeographical structure of mollusc associations was analysed based on traditional scheme of species classification (Jaeckel 1962, Ložek 1964, Körnig 1966) (Fig. 7). Entity HP represents widespread species: Hl – Holarctic, Pl – Palaearctic, Ep – European, Es – Euro-Siberian. Group ME indicates Middle-European taxa: Me – Central-European and Ma – Alpino-Carpathian. Species belonging to EO entity represent European species with limited distribution: Em – South-European. Detailed biometric analysis was performed for *Orcula doliolum* (Brug.), for which following parameters were measured: mean height, width and elongation of the shells and apertures (Figs 8, 9). This rare species commonly inhabits the Tuł Hill. Analysis was carried out to verify whether population of *Orcula doliolum* (Brug.) living in an isolated area had biometric features similar to those described in areas of dense presence of this species (Tab. 4).

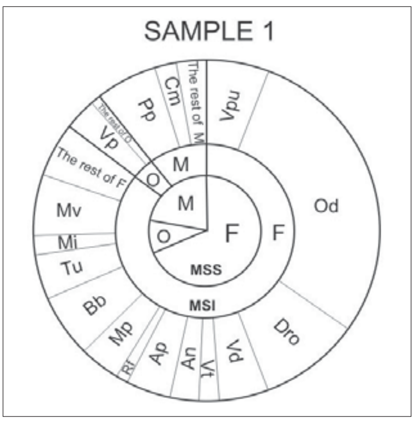

Fig. 2. Malacological spectra: individual (MSI) and species (MSS) – sample 1: F – shade-loving species, O – open-country species, M – mesophilous species (for explanation of abbreviations see Table 1)

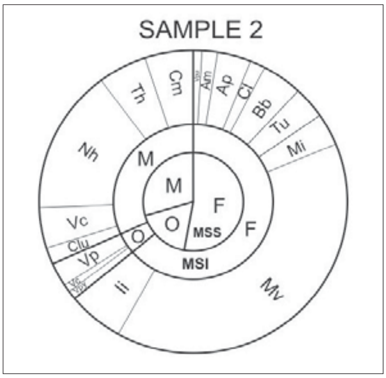

Fig. 3. Malacological spectra: individual (MSI) and species (MSS) – sample 2: F – shade-loving species, O – open-country species, M – mesophilous species (for explanation of abbreviations see Table 1)

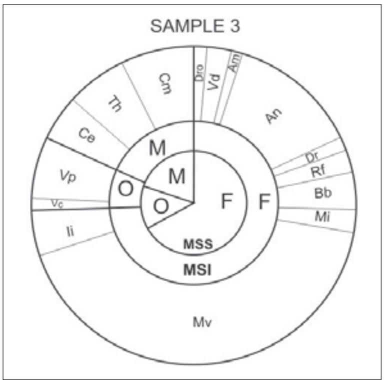

Fig. 4. Malacological spectra: individual (MSI) and species (MSS) – sample 3: F – shade-loving species, O – open-country species, M – mesophilous species (for explanation of abbreviations see Table 1)

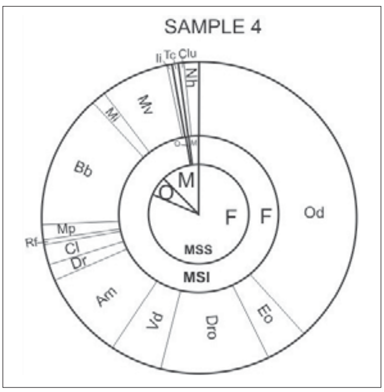

Fig. 5. Malacological spectra: individual (MSI) and species (MSS) – sample 4: F – shade-loving species, O – open-country species, M – mesophilous species (for explanation of abbreviations see Table 1)

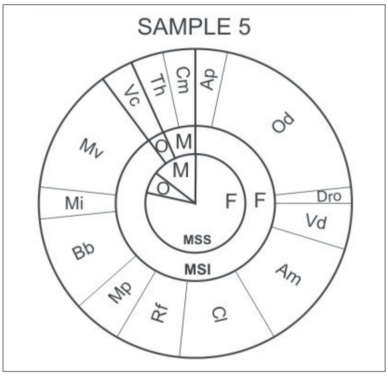

Fig. 6. Malacological spectra: individual (MSI) and species (MSS) – sample 5: F – shade-loving species, O – open-country species, M – mesophilous species (for explanation of abbreviations see Table 1)

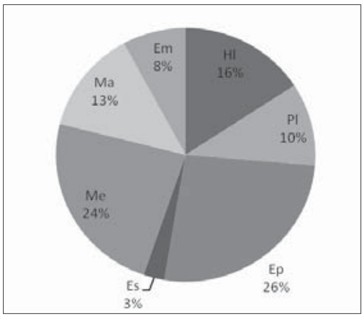

Fig. 7. Zoogeographical structure of mollusc associations from Tuł Hill: Hl – Holarctic species, Pl – Palaearctic species, Ep – European species, Es – Euro-Siberian species, Me – Central-European species, Ma – Alpino-Carpathian species, Em – South-European species

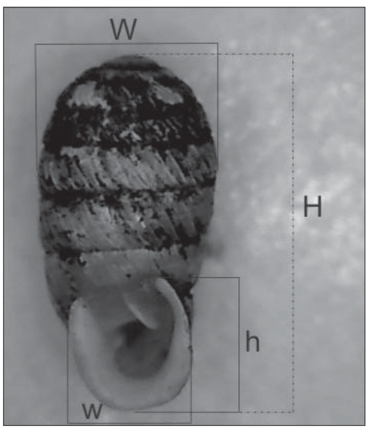

Fig. 8. Measured dimensions of Orcula doliolum (Brug.): H – height of the shell, h – height of the aperture, W – width of the shell, w – width of the aperture

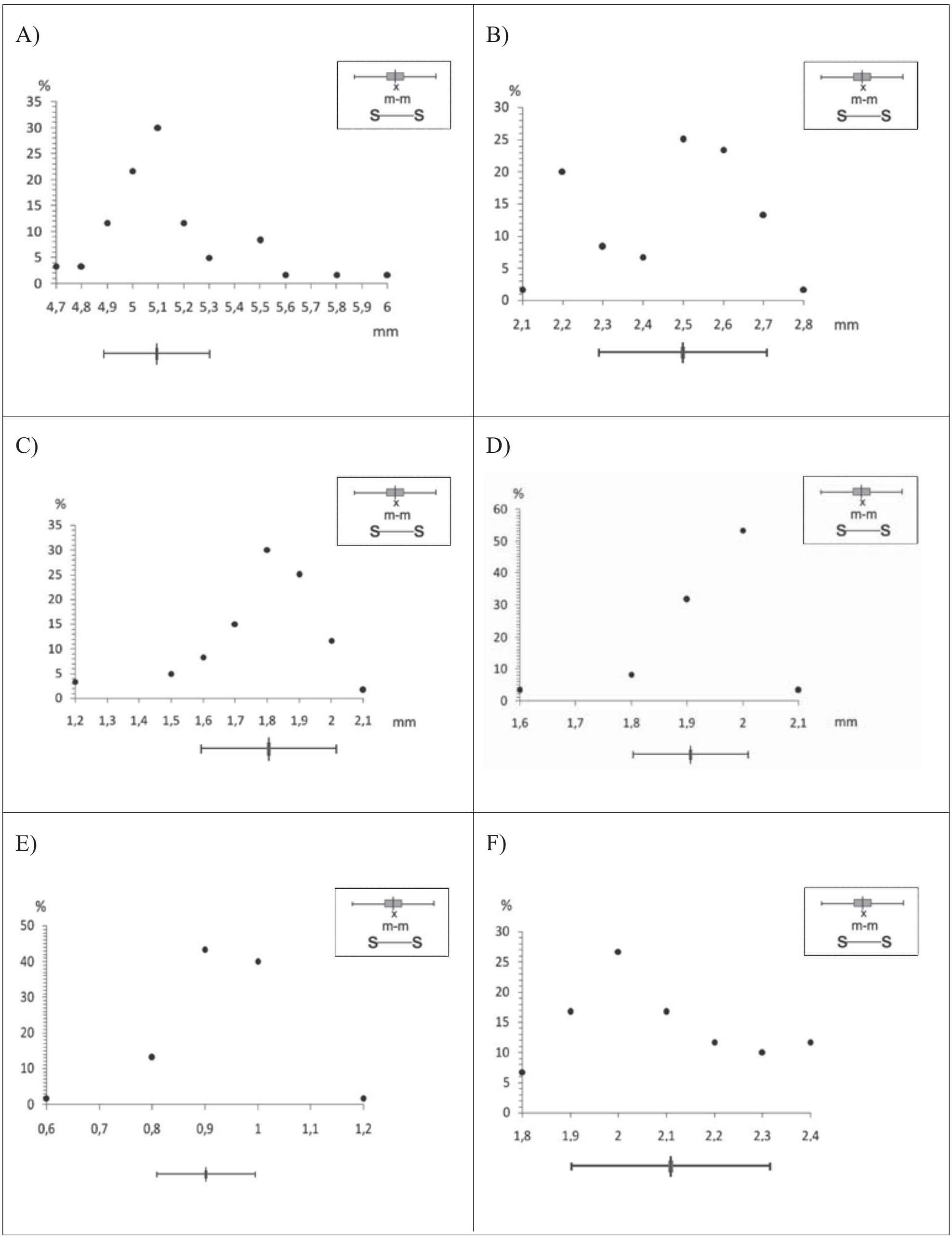

Fig. 9. Diagram presenting percentage of each Orcula doliolum (Brug.): A – shells heightness, B – shells widthness, C – aperture heightness, D – aperture widthness, E – aperture elongation, F – shells elongation, x – arithmetic mean, m – standard error, S – standard deviation

Table 2

Constancy (C) and dominance (D) structure of mollusc associations: Σ_{tax} – number of species, Σ_{spec} – number of specimens, C_i, D_i, TDI and ADI – indicators (see text)

	D-1	D-2	D-3	D-4	D-5
C-5	–	2	1	1	–
C-4	1	4	1	–	–
C-3	1	5	–	–	1
C-2	2	4	–	–	–
C-1	14	1	–	–	–

Monachoides vicinus (C-5; D-4)

Balea biplicata (C-5; D-3)

Discus rotundatus (C-4; D-3)

Orcula doliolum (C-3; D-5)

$\Sigma_{tax} = 38$ $C_i = 35.53$ TDI = 0.96

$\Sigma_{spec} = 879$ $D_i = 17.76$ ADI = 0.63

Table 3

Structure of mollusc associations (in samples 2–5): CD, Cd, cD, cd – constancy (C) and dominance (D) categories (described in text), Q – geometrical mean of C and D

CD [D ≥ 5%, C ≥ 50%]	Q	Cd [d < 5%, C ≥ 50%]	Q
Monachoides vicinus	38.0	*Aegopinella minor*	18.5
Orcula doliolum	37.8	*Vitrea diaphana*	17.8
Balea biplicata	27.4	*Monachoides incarnatus*	14.7
Discus rotundatus	24.1	*Carychium minimum*	14.5
		Nesovitrea hammonis	12.5
		Macrogastra plicatula	12.3
		Vallonia pulchella	12.3
		Cochlodina laminata	11.7
		Ruthenica filograna	10.5
		Trichia hispida	9.4
		Isognomostoma isognomostoma	9.1
		Cochlicopa lubrica	6.9
		Vallonia costata	6.7
		Daudebardia rufa	6.4

Table 3 cd.

cD [D ≥ 5%, c < 50%]	Q	cd [d < 5%, c < 50%]	Q
–	–	*Vertigo pusilla*	10.9
		Aegopinella nitens	10.2
		Aegopinella pura	10.0
		Trichia unidentata	10.0
		Punctum pygmaeum	7.5
		Vitrea contracta	5.2
		Acicula polita	4.3
		Ena obscura	4.3
		Vitrea transsylvanica	4.3
		Vitrea crystallina	3.0
		Columella edentula	3.0
		Acanthinula aculeata	2.6
		Vitrina pellucida	2.6
		Oxychilus glaber	2.1
		Macrogastra tumida	2.1
		Pupilla muscorum	2.1
		Clausilia dubia	2.1
		Truncatellina cylindrica	1.5
		Vertigo pygmaea	1.5
		Oxychilus cellarius	1.5

Table 4

Biometry of populations of Orcula doliolum (Brug.) from different regions

References	Shells height [mm]	Shells width [mm]
Geyer (1927)	4.4–5.5	2.0–2.5
Ložek (1956, 1964)	4.5–6.0	2.3–2.5
Damjanov & Likharev (1975)	4.5–5.6	2.3–2.4
Kerney et al. (1983)	4.5–6.0	2.3–2.5
Schileyko (1984)	4.0–5.0	2.2–2.4
Wiktor (2004)	5.0–6.0	2.5–3.0
Gołas-Siarzewska (this paper)	4.7–6.0	2.1–2.8

RESULTS

Malacofauna found at the Tuł Hill contained 38 species and 879 specimens (Tab. 1). Twenty-three species belong to the group of shade-loving snails (F), five taxa are open-country species (O) and ten are mesophilous ones (M). The number of taxa per sample ranged from 14 to 32, and the number of specimens ranged from 60 to 432.

The first sample contained 32 species and 432 specimens of molluscs with a domination of shade-loving species (Fig. 2). Taxa which occurred in the first sample, but were not found in the rest of samples (10 species), represented some of the rare species appearing in Poland. The second sample included 17 species and 117 specimens of malacofauna. This sample contained molluscs which mainly corresponded to shade-loving group, but also had the highest content of mesophilous snails with wide ecological tolerance (Fig. 3). The third sample was represented by 15 species and 83 specimens. Numerous species in this sample corresponded to dominant shade-loving ecological group (Fig. 4). The fourth sample contained 16 species and 187 specimens. The most frequent species were those living in forests, while mesophilous and open-country snail constituted only 3% of taxa found in the fourth sampling site (Fig. 5). The last sample contained 14 species and 60 specimens, with significant number of shade-loving species (90%) (Fig. 6). Malacological individual spectra (MSI) and malacological species spectra (MSS) made for particular samples were comparable and showed that molluscs associations living in the forest were dominating.

Structure of constancy (C) and dominance (D) of the samples is characterized by mean values (Tab. 2). Only four species represented shade-loving environment had the highest C-D values: *Monachoides vicinus* (Rossm.) (5–4), *Balea biplicata* (Mont.) (5–3), *Discus rotundatus* (Müll.) (4–3), *Orcula doliolum* (Brug.) (3–5). Twenty-one taxa could be regarded as accessory components with low C-D indices. The values of normalized constancy and dominance indicators (C_i = 35.53, D_i = 17.76) showed similar species composition found in different sampling sites, with variation of dominant species. Normalized differentiation index (TDI) equated 0.89, 0.81, 0.79, 0.80 and 0.91 for the samples 1 to 5, respectively. Value of TDI measured for the whole material achieved 0.96, while average difference index ADI was 0.63. These results corresponded to well-differentiated polymictic associations of molluscs, which confirms favorable ecological conditions for malacofauna development.

The molluscan associations belonging to three C-D categories were ordered according to Q index values (Tab. 3). The CD group consisted of four species: *Monachoides vicinus* (Rossm.), *Orcula doliolum* (Brug.), *Balea biplicata* (Mont.) and *Discus rotundatus* (Müll.). This fauna, with the highest Q index values, was considered as dominant. Fourteen species belonging to Cd class were accessorial components, while 20 of taxa occured rarely (cd class).

The whole described fauna was composed of various geographical ranges of species (Fig. 7). Zoogeographical composition of the malacofauna indicates that more than half of the species (HP = 55%) can be classified to the group of taxa which are widespread in the whole Europe. Almost half of them (Ep = 26%) were European taxa, while the lowest number belonged to Euro-Siberian class (Es = 3%). The second large group consisted of species representing middle European taxa (ME = 37%), especially those that migrated from Central Europe (Me = 24%). The rest of species (EO = 8%) are South-European taxa (Em) with limited spread.

Biometric analyses were conducted for *Orcula doliolum* (Brug.) and distributions of measured parameters were shown on the diagrams (Figs 8, 9). Sixty shells were randomly chosen and measured. The mean height (H) of shells was 5.1 mm, and the mean height of apertures (h) was 1.8 mm. The mean width (W) of shells was 2.5 mm, and the mean width of apertures (w) was 1.9 mm. The elongation of shells was 2.1, and the ratio of apertures' height to width was 0.9. Standard deviation for each measurement ranged from 0.1 mm to 0.2 mm.

DISCUSSION

The first sample from the Tuł Hill was collected 20 years before the next four samples. Thus, it was possible to recognize changes in the identified mollusc associations. Probably these changes are the outcomes of human activity, such as deforestation, mass tourism and archeological excavations in the main part of the Tuł Hill. As a result, we observe that for example *Oxychilus glaber* (Rossm.), *Daudebardia rufa* (Drap.) and *Macrogastra tumida* (Rossm.) species are disappearing. Fortunately, *Orcula doliolum* (Brug.) is still present here.

Orcula doliolum (Brug.) occurs on the Polish Red List of Threatened Animals and commonly appears at the Tuł Hill. *Orcula doliolum* (Brug.) inhabits forests of high humidity and can be found under limestone rocks. This species lives in the Eastern and Southern Europe, and extends from Iran through Mediterranean to the Pyrenees (Riedel 1988, Wiktor 2004). *Orcula doliolum* (Brug.) inhabits local limestone areas in France, Belgium, Holland, Switzerland, Germany and Czech Republic (Ložek 1956, Kerney et al. 1983). In Poland, it occurs at isolated localities in the southern part of the country, avoiding the higher and cooler mountain ranges (Riedel 1988, Wiktor 2004).

Biometric analysis provided information on the population diveristy. The results of the measurements (height and width of shells) are in accordance with minimum and maximum sizes given by Geyer (1927), Ložek (1956, 1964), Damjanov & Likharev (1975), Kerney et al. (1983), Schileyko (1984), Wiktor (2004) (Tab. 4). My results compared to previous measurments showed no variation. However, for *Orcula Doliolum* (Brug.) species, left skewed distributions of aperture heightness and widthness was shown, so that higher values occured more often. Diagrams presenting the height and elongation of shells had a right skewed distribution, which indicated higher amount of shorter shells. Only the values of aperture elongation were normally distributed. Diagram of shells width was bimodal, showing the presence of young and old snails populations at the Tuł Hill. Biometric analysis of the specimens may suggests that the shell size is controlled partly by natural ecological conditions and by the effects of human activity (deforestation). *Orcula doliolum* (Brug.) species may also reacts differently to changes caused by the diversity of slopes, forestation and insolation.

The Flysh Carpathians constitute an ecological barrier (low calcium carbonate content and climate fluctuations) especially for south European calciphile species. There are two possible routes of their migration. The first represents a natural way associated with the occurrence of limestones (Cieszyn Silesia, Andrychów region, Kraków-Częstochowa Upland). The second includes the construction of castles along the river valleys, which were the transport routes (S.W. Alexandrowicz 1995, S.W. Alexandrowicz & W.P. Alxeandrowicz 2010).

CONCLUSIONS

Outcrops of the Cieszyn limestones at the Tuł Hill create perfect environmental conditions for conservation of malacofauna shells and fragments. Nowadays, this area is covered by forests and meadows. Progressive deforestation and devastation of the Tuł Hill area may lead to extinction of the characterized species. It would, in turn, inhibit their migration from the south of Europe, which can be seen through the comparison of the samples and zoogeographical analysis. Shade-loving and mesophilous species show reduction in numbers during the last 20 years, at the expense of open-country snails. Mid- and South European taxa represent almost 50% of all found malacofauna. The collected taxa indicate that the region of the Cieszyn Silesia may be a route of the species migration because of the Cieszyn limestones occurrences. The species can migrate from the Czech Republic and Slovakia to Poland, especially to the Kraków-Częstochowa Upland and Podhale Basin. For example, *Orcula doliolum* (Brug.) species was noticed in samples from Moravian in Czech Republic (Ložek 1956) and from Dzięgielów in Poland (Riedel 1988).

Malacofauna found at the Tuł Hill, in comparison to molluscan assemblages from Pańska Góra Hill and Babia Góra Massif, represents rare species of Flysch Carpathians (W.P. Alexandrowicz 1994, 2003). Mollusc associations from the Tuł Hill are different from those observed in Pańska Góra Hill, where a unique taxon *Candidula unifasciata* (Poiret) was found (W.P. Alexandrowicz 1994). This species lived at the Tuł Hill in the past, but recent researh does not confirm its occurrence. Rare taxa from the Tuł Hill are similar to those found in the Babia Góra Massif. What is most interesting, *Orcula doliolum* (Brug.) was not recognized in mentioned areas, except the Tuł Hill. This species occurs only in several isolated areas in Poland. Research carried out at the Tuł Hill indicates the uniqueness of the Polish Carpathians malacofauna, so that Tuł Hill should be considered as a reserve of nature.

This study was sponsored by AGH University of Science and Technology through the University grant no. 11.11.140.173.

REFERENCES

Alexandrowicz S.W., 1987. Analiza malakologiczna w badaniach osadów czwartorzędowych. *Geologia* [AGH UST quarterly], 12, 3–240.

Alexandrowicz S.W., 1995. Ruins of Carpathian castles as refuges of land snails. *Ochrona Przyrody*, 52, 2–18.

Alexandrowicz S.W., 1999. Tanatocenozy muszlowe w rzecznym środowisku sedymentacyjnym – metody badań i interpretacji. *Geologia* [AGH UST quarterly], 25, 211–295.

Alexandrowicz S.W., 2000. Współczesna i subfosylna malakofauna wzgórza Kajasówka na Wyżynie Krakowskiej. *Chrońmy Przyrodę Ojczystą*, 56, 83–101.

Alexandrowicz S.W. & Alxeandrowicz W.P., 2010. Expansive migrations of molluscs during the historic period. *Biological Invasions in Poland*, 1, 23–48.

Alexandrowicz S.W. & Alexandrowicz W.P., 2011. Analiza malakologiczna. Metody badań i interpretacji. *Rozprawy Wydziału Przyrodniczego PAU*, 3, 5–302.

Alexandrowicz W.P., 1994. Współczesna i subfosylna malakofauna kamieniołomu na Pańskiej Górze w Andrychowie. *Ochrona Przyrody*, 51, 147–156.

Alexandrowicz W.P., 1997. Malakofauna osadów czwartorzędowych i zmiany środowiska naturalnego Podhala w młodszym vistulianie i holocenie. *Folia Quaternaria*, 68, 7–132.

Alexandrowicz W.P., 2000. Molluscan assemblages from cave and slope sediments of the Częstochowa Upland (Poland). *Folia Quaternaria*, 71, 113–137.

Alexandrowicz W.P., 2001. Molluscan assemblages from deposit filling small karst forms in the Tatra Mountains (Southern Poland). *Acta Carsologica*, 30, 1, 125–142.

Alexandrowicz W.P., 2003. Ślimaki (Mollusca: Gastropoda) i małże (Mollusca: Bivalvia) Masywu Babiej Góry. [in:] Wołoszyn B.W., Wołoszyn D. & Celary W. (red.), *Monografia fauny Babiej Góry*, Komitet Ochrony Przyrody PAN, Kraków, 69–97.

Alexandrowicz W.P. & Rudzka D., 2006. Molluscan communities from cave and slope deposits of the limestone rocky hills in the eastern part of Podhale Basin (Southern Poland). *Folia Malacologica*, 14, 191–201.

Chorąży B. & Chorąży B., 2005. Archeolodzy na tropie. Kim byli prehistoryczni mieszkańcy Śląska Cieszyńskiego sprzed 2,5 tysiąca lat? *Kalendarz Cieszyński*, 91–100.

Damjanov S.G. & Likharev I.M., 1975. *Fauna Bulgarica*. Gastropoda terrestria, 4, 116–117.

Dobrowolski K., 1963. Próba analizy pojęcia „rzadki gatunek". *Ekologia Polska*, B3, 207–212.

Ehrmann P., 1933. *Die Tierwelt Mitteleuropas*, *Weichtiere (Mollusca)*. Quelle & Meyer Verlag, Leipzig.

Geyer D., 1927. *Unsere Land- und Süsswasser-Mollusken*. Lutz Verlag, Stuttgart.

Jaeckel S.G.A., 1962. Ergänzungen und Berichtigungen zum rezenten und quartären Vorkommen der mitteleuropäischen Mollusken. [in:] *Die Tierwelt Mitteleuropas – Ergänzung*, Quelle & Meyer Verlag, Leipzig, 25–294.

Kerney M.P., Cameron R.A.D. & Jungbluth J.H., 1983. *Die Landschnecken Nord- und Mitteleuropas*. Verlag P. Parey, Hamburg – Berlin.

Körnig G., 1966. Die Molluskengesellschaften des mitteldeutschen Hügellandes. *Malakologische Abhandlungen*, 2, 1, 1–112.

Ložek V., 1956. *Klič Československých měkkýšu*. Vydavatelstvo Slovenskej Akademie Vied, Bratislava.

Ložek V., 1964. Quartärmollusken der Tschechoslovakei. *Rozpravy Ustředniho Ustavu Geologického*, 31, 3–374.

Poliński W., 1919. Rozsiedlenie geograficzne Helicidów w Polsce. *Przegląd Geograficzny*, 1, 269–280.

Poliński W., 1922. Recherches sur l'anatomie et la systématique des Xérophilinés de la Pologne et da la Transsylvanie. *Annales Zoologici Musei Polonici Historiae Naturalis*, 1 (4), 166–184.

Poliński W., 1924. Anatomisch-systematische und zoogeographische Studien über die Heliciden Polens. *Biuletyn International de l'Academie Polonaise des Sciences et des Lettres, Classe des Sciences et Naturelles Mathématiques*, 2, 131–279.

Riedel A., 1988. Ślimaki lądowe (Gastropoda terrestria). [in:] *Katalog fauny Polski*, PWN Warszawa, 36, 1, 1–316.

Rostański K., Sendek A., Rostański A. & Bernacki L., 1986. Projekt powiększenia rezerwatu „Góra Tuł" koło Cieszyna. *Chrońmy Przyrodę Ojczystą*, 42, 54–60.

Schileyko A.A., 1984. Nazemnye mollyuski podotryada Pupillina fauny SSSR (Gastropoda, Pulmonata, Geophila). [in:] *Fauna SSSR, Mollyuski 3(3)*, Akademija Nauk, Leningrad.

Słomka T., 2001. Early Cretaceous debris flow deposits in the Cieszyn Beds of the Żywiec region. *Geologia* [AGH UST quarterly], 27, 89–110.

Szlachetko D.L., 1985. Stanowisko storczyka bladego *Orchis pallens* na górze Tuł w okolicy Cieszyna. *Chrońmy Przyrodę Ojczystą*, 41, 73–77.

Urbański J., 1957. *Krajowe ślimaki i małże. Klucz do oznaczania wszystkich gatunków dotąd w Polsce wykrytych*. PZWS, Warszawa.

Wiktor A., 2004. *Ślimaki lądowe Polski*. Wydawnictwo Mantis, Olsztyn.