The influence of reclamation to malaco - assemblages of limestone quarry

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Abstract. Quarries fundamentally change the character of the landscape, both in the mined parts and in its immediate surroundings. Inside the mined areas, there are many different types of microbiotopes, their character is very different from the surrounding ecosystem. Destruction of original biotopes is an opportunity for settlement by new plant and animal communities. To monitor these biodiversity changes in the landscape, appropriate groups of organisms are used. Only a bioindicator that is well processable from a taxonomic point of view and its demands on the environment and its distribution are well-known, gives reliable results. For these reasons, less moving molluscs are used in many works. The territory of the southern part of the Devonian limestone of the Moravian Karst is affected by the industrial mining of limestone. There is forest quarry in Lisen, which was ended in 1997 and a few years later reclamation work was started on parts of the mined area. The study of molluscs in this model territory was used to assess the impact of reclamation methods on the malaco - assemblage’s diversity inside the quarry.

1. Introduction

The southern part of the massif of Devonian limestone of the Moravian Karst is affected by the industrial mining of limestone. Some valuable original biotopes, such as karst forest steppes, have been irreparably destroyed or preserved only on small areas (the natural monument Velka Klajdovka and Kavky). Local biodiversity is also disrupted by the Brno city district of Lisen, which is growing to foothills of Hady Hill. The increase of biodiversity through sensitive recultivation of local limestone quarries seems to be very appropriate and desirable.

Quarries, significantly affect the major ecological factors important for the occurrence of molluscs depending on the stage of succession. This is mainly the development of vegetation, the microclimate and properties of the substrate. Cover, structure, height stratification, and canopy of vegetation create a completely specific physical environment for molluscs. This environment is characterized by different types of vegetation shading, soil and air humidity, character of the plant litter, humus and soil. Molluscs are strongly bound to the habitat due to their limited mobility.

Abiotic conditions, ecological specifics and succession of vegetation in old quarries can be appropriately regulated and transformed by the reclamation techniques used. There are currently three main approaches to renewal. These are technical reclamation, spontaneous succession and controlled succession. By their proper combination and subsequent management, the mined areas can become very valuable sites as for natural value.
1.1. Characteristic of the study area

The study area is located north of Brno near the southern border of the Moravian Karst PLA. The Moravian Karst is the most extensive karst area of the Czech Republic with typical forms of surface and underground karst. From wider point of view study area is part of Macocha bioregion. The Macocha bioregion forms a narrow strip of limestone area in the centre of South Moravia and occupies the mesoregion Moravian Karst. It has an elongated shape in the north-south direction. Bioregion is created of limestone with rocky deeps. As for vegetation tiers there is oak communities of the 1st tier, but beech communities of the 4th tier and fir-beech communities of 5th tier prevail[1].

The Moravian Karst has a largely flattened surface, but it is divided by very sharp and deep valleys. Relief has the character of a plain highlands with a roughness largely of 150 to 200 m (up to 270 m only in Křtiny creek). The lowest point is the Říčky valley at Muchova bouda (about 265 m), the highest point is area nearby Sosuvka (590m). Typical height is 300-530 m, outside of canyons 400-550 m [2]. The area is created by nappes of predominantly pure Devonian limestone, there are also the Granodiorite of the Brno massif and the loess in the southern part.

Soils in the area are heavier with frequent limestone gravel, shallow and dry, mineral rich. As a typical soil type, gray to dark gray rendzins are developed, which appear mainly on the slopes of deeps where they are enriched by carbonate material.

According to Quitt (1971) [3], the bioregion lies in climatic areas from the warmest (MT11) in the south, to the coldest (MT 3) in the north. The climate around Brno is warm and relatively dry (Brno 8.6°C; 547 mm); the northern areas are cooler and humid (Olomučany 7.7°C; 620 mm). The most northern part of the region has average temperatures of 6.6°C and precipitation up to 660 mm. The local climate illustrates sharp differences, especially the contrast of the cold bottom of the canyon and warm and dry top edges. The southern edge of the bioregion has a very warm climate, enhanced by the southern orientation of the Hady Hill slopes[1].

Hydrographically and hydrologically, the Moravian Karst is different from the surrounding landscape by a whole range of peculiarities. Allochtonous waters which coming from the non-karst parts of the Drahanska vrchovina are almost immediately lost to the underground on the geological boundary of Devonian limestones, that’s why the hydrographic conditions and hydrological regime of these waters are very complex. The southern part of the Moravian Karst is drained by Ochozsky, Hadek and Hostenicky creeks. The catchment area is 76 km2 with an average annual flow of 0.16 m3.s-1. The largest cave system is the Ochoz cave, whose famous part was formed due to flood regime of Hostenicky potok. The active underground water flow is only on the lower part of the Netopyrky cave. Immersion flows rise like the Ricka Creek after go through very complex hydrographic network [2].

According to the Regional Phytogeographical Division of Czechoslovakia [4], the study area is part of the phytogeographical district of the 70th Moravian Karst and belongs to the Bohemian-Moravian Mesophytic District. There are three floral subelements in the territory. Hercyn and Carpathian forest flora are mixed here and the thermophilic and steppe flora from the Pontic-Pannonian region is acceding from the south. The natural vegetation is created oak-hornbeams with vegetation stands of the Hercyn association Melampyro nemorosi-Carpinetum and the Carpathian Cariri pilosae-Carpinetum. There are also rare tree-less habitats with species-rich communities of rock steppes and northern slopes on the carbonate soils (Seslerio-Festucion pallentis) here.

The fauna of the region has the character of Hercyn subprovince, but is heavily influenced by the Carpathian element, especially beechwoods on limestone. This effect is manifested especially on molluscs, ground beetles or flesh flies, we can observe occurrence of endemic Carpathian species (eg molluscs Monachoides vicinus, Vitrea transsylvanica). We can find also other important species as Rhinolophus hipposideros, Myotis myotis from mammals, Salamandra salamandra from amphibians, Lacerta viridis from reptiles, Aegolius funereus, Cinclus cinclus, Ficedula parva, Ficedula albicollis from birds [1].
1.2. History of landuse

The history of industrial mining of limestones on the northern outskirts of Brno dates from the end of 19th century. The first quarries at the foothill of the southernmost ridges of the Devonian limestone were the Dzungle Quarry and the Ruzenin Quarry. Both of them were interconnected by the large Haje Quarry around 1960. The ever-increasing demand for raw materials, especially for the cement industry in the first half of the 20th century, led to the opening of Lesni Quarry in Lisna, which is located in the north-eastern direction near Ruzenin quarry.

Lesni quarry in Lisna. Lesni quarry lies in the area of the southern part of the Hadecka peneplain. The area is located approximately 300 m from the edge of the southern part of the Moravian Karst PLA at an altitude of about 370 m. Part of the surrounding quarry is an agriculturally used landscape and part is forested. Deciduous forest stands of oak-hornbeam on limestone substrate prevail here [5]. Lesni quarry is divided into a total of 5 storeys. Quarrying was ended in 1997. Technical reclamation began in order to reforest part of the quarry in 2002-2003. It was approximately 20% of the area.

2. Methods

We have chosen limestone quarry near Brno with finished mining. Technical reclamation was performed on several sites of quarry. The remaining areas were left without reclamation interventions to natural spontaneous succession. The list of sampling areas with coordinates and information about reclamation techniques is summarized in table 1. Malacological samples from 14 sampling areas were collected from May to September in 2015. We observed also the link among character of biotopes, vegetation cover and reclamation techniques.

| Sampling area | Date       | Latitude       | Longitude      | Reclamation               |
|---------------|------------|----------------|----------------|----------------------------|
| 1.            | 15.2015    | 49°13’16,5”   | 16°41’43,7”   | Technical reclamation     |
| 2.            | 15.2015    | 49°13’15,6”   | 16°41’41,4”   | Technical reclamation     |
| 3.            | 15.2015    | 49°13’25,1”   | 16°41’42,5”   | Spontaneous succession    |
| 4.            | 16.5.2015  | 49°13’13,1”   | 16°41’32,3”   | Technical reclamation     |
| 5.            | 16.5.2015  | 49°13’13,4”   | 16°41’32,4”   | Technical reclamation     |
| 6.            | 16.5.2015  | 49°13’13,9”   | 16°41’37,1”   | Technical reclamation     |
| 7.            | 23.5.2015  | 49°13’20,2”   | 16°41’28,2”   | Technical reclamation     |
| 8.            | 24.5.2015  | 49°13’23,1”   | 16°41’31,7”   | Technical reclamation     |
| 9.            | 24.5.2015  | 49°13’13,3”   | 16°41’27,9”   | Technical reclamation     |
| 10.           | 30.5.2015  | 49°13’22,6”   | 16°41’51,3”   | Spontaneous succession    |
| 11.           | 5.7.2015   | 49°13’20,4”   | 16°41’49,0”   | Spontaneous succession    |
| 12.           | 19.7.2015  | 49°13’17,9”   | 16°41’40,2”   | Spontaneous succession    |
| 13.           | 18.9.2015  | 49°13’21,7”   | 16°41’42,1”   | Spontaneous succession    |
| 14.           | 24.9.2015  | 49°13’17,2”   | 16°41’43,9”   | Spontaneous succession    |

We collected zoological samples using a uniform methodology. Each of sampling area was 10 x 10 m or 20 x 5 m if was located next to the quarry wall. We collected molluscs for one hour manually by one person. Collecting of molluscs was performed on trees, on vegetation, under stones and other objects on the ground, in the plant litter, and from mosses. We thoroughly inspected the soil substrate in four squares with an edge of 30 x 30 cm to a depth of at least 5 cm on each of the sample area. We determined molluscs by Ložek [6] and Horsák et al. [7].

Ecological classification: SI 1 - silvicola (strict forest species), SI 2 - silvicola (predominantly forest species), SIh - highly humid forest species, ST - steppicola (steppe species), SS - silvisteppicola (species of xeroterm bushes and sparse groves) MS - mesicola (euryvalent species), SLP - agricola (euryvalent species living on rocks and in forests too), RP - ripicola (species with high humidity demands).

Conservation status: LC - least concern, NT - nearly threatened.
3. Results
We found 514 in total individuals of terrestrial gastropods belonging to 20 species of 6 ecological groups in Lisna Quarry. Table 2 shows a summary of all species including the number of living individuals found on individual sampling areas, ecological distribution, and conservation status.

Table 2. List of Moluscs.

| Eco-elements | Name of species                        | Status | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|--------------|----------------------------------------|--------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| 1 SI         | Aegopinella nitens (Michaud, 1831)     | LC     | 7 | ~ | ~ | 3 | ~ | ~ | ~ | 4 | 1 | ~ | ~ | ~ | ~ | ~ |
|              | Cochlodina laminata (Montagu, 1803)    | LC     | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 2 SI(MS)     | Alinda bippilata (Montagu, 1803)       | LC     | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 3 SI(MS)     | Arion fuscus (O.F. Müller, 1774)       | LC     | ~ | 5 | 8 | ~ | 7 | 4 | 2 | 1 | ~ | 2 | ~ | ~ | ~ | ~ |
| 4 SI(MS)     | Discus rotundatus (O. F. Müller, 1774) | LC     | 1 | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | 1 | ~ | ~ | 13 | 4 |
| 5 SI(MS)     | Limax cinereoniger (Wolf, 1803)        | LC     | ~ | ~ | 2 | 1 | ~ | 1 | 1 | ~ | 4 | ~ | ~ | ~ | ~ | ~ |
| 6 SI(MS)     | Monachoides incarnatus (O. F. Müller, 1774) | LC | 2 | 1 | ~ | 5 | 1 | ~ | 3 | 3 | ~ | ~ | ~ | ~ | ~ | ~ |
| 7 Sth        | Helix pomatia (Linnaeus, 1758)         | LC     | 1 | 7 | ~ | 1 | 3 | 1 | 1 | 5 | 4 | 1 | ~ | ~ | ~ | ~ |
|              | Merdigeria obscura (O. F. Müller, 1774) | LC     | ~ | ~ | 1 | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 8 Sth        | Arion rufus (Linnaeus, 1758)           | LC     | ~ | ~ | 8 | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 9 SI         | Granaria frumentum (Draparnaud, 1801)  | NT     | ~ | ~ | 6 | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 10 ST        | Xerolenta obvia (Menke, 1828)          | LC     | ~ | ~ | 1 | 8 | 6 | 7 | 15 | 5 | 9 | 6 | 2 | ~ | ~ | ~ |
| 11 ST(SI)    | Cepaea vindobonensis (Férussac, 1821)  | NT     | 2 | 4 | 7 | 2 | 1 | 8 | 6 | 7 | 15 | 5 | 9 | 6 | 2 | ~ | ~ |
| 12 SS        | Euomphalia strigella (Draparnaud, 1801)| LC     | ~ | ~ | ~ | ~ | ~ | 7 | 7 | 2 | ~ | ~ | ~ | ~ | ~ | ~ |
| 13 MS        | Arion distinctus (Mabille, 1868)       | LC     | 5 | 7 | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 14 MS        | Arion vulgaris (Moquin-Tandon, 1855)   | LC     | ~ | 1 | 1 | 1 | 4 | 3 | 1 | ~ | 12 | ~ | ~ | ~ | ~ | ~ |
| 15 MS        | Boettgerilla pallens (Simroth, 1912)   | LC     | ~ | 1 | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 16 MS        | Oxychilus cellarius (O. F. Müller, 1774) | LC | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | 2 | ~ | ~ | ~ | ~ | ~ | ~ |
| 17 MS        | Vitrina pellucida (O. F. Müller, 1774)  | LC     | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |
| 18 Stp       | Lacinariia plicata (Draparnaud, 1801)  | NT     | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | 26 | ~ | ~ | ~ | ~ | ~ |
| 19 Stp       | Limax maximus (Linnaeus, 1758)         | LC     | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ | ~ |

Σ of individuals 514

4. Conclusion
The mining in the Lesni Quarry in Lisna was ended in 1997. After the mining some areas were left to spontaneous succession and part of the quarry was technically reclaimed. Technically reclaimed areas can be described as places with predominantly bushes and trees, with lots of fallen wood with a rich herbaceous ground cover. Areas of spontaneous succession we can characterize as places with minimal occurrence of trees and discontinuous grasslands.

We found 514 live mollusc individuals belonging to 20 species of 6 ecological groups in 14 sampling areas. A relatively large diversity of microhabitats within the quarry is illustrated wide representation of ecological groups suggests. The largest group contains predominantly forest species,
followed by equivalent species and steppe species. The presence of steppe species is not surprising. Approximately 15 years have elapsed since the mining, and most of areas are in early stages of the succession. There are habitats with rather "open" character that suits steppe species in these quarry. However, steppe species probably disappear due to progressive overgrown of quarry within few decades. We found most often species *Cepaea vindobonensis*, *Xerolenta obvia* and *Helix pomatia*. According to the Red List of Endangered Species of the Czech Republic by Farkač et al., 2005 [8], the species *Granaria frumentum*, *Cepaea vindobonensis* and *Laciniaria plicata* have conservation status "Near Threatened" (NT). Other species are included in the group "Least concern" (LC). Problematic can be occurrence of invasive species *Arion vulgaris* in half of the sampling areas.

Six from 26 species of gastropods we found only on technically reclaimed areas (*Aegopinella nitens*, *Arion fuscus*, *Monachoides incarnatus*, *Arion rufus*, *Euomphalia strigella*, *Limax maximus*). Predominant frequency of occurrence on reclaimed areas have also *Helix pomatia*. Five species (*Alinda biplicata*, *Merdigera obscura*, *Granaria frumentum*, *Oxychilus cellarius*, *Laciniaria plicata*) we found on areas of spontaneous succession. As for remaining species, there is the dominant frequency of *Xerolenta obvia* or *Discus rotundatus* on open spontaneous successive areas.

The diversity of the occurrence of molluscs’s species on technically reclaimed areas and areas with spontaneous succession shows how important the heterogeneity of the environment is for regeneration and increasing the biodiversity of sites disturbed by mining.

5. References
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