Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2008, 5 A, 15–22

BIOLOGICAL DIVERSITY IN THE AREA OF QUARRIES AFTER SAND EXPLOITATION IN THE EASTERN PART OF SILESIAN UPLAND

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Summary. The objective of this paper was an attempt at defining the plant diversity and presenting the participation of protected, rare and endangered species in associations or communities which are formed in the explored quarries (Pogoria I, Siemonia, Kuźnica Warężyńska and Maczki Bór). In the parts of quarries which were not reclaimed, unique biocenotic systems are created during succession. These systems are biotopes of numerous rare and protected plant species, including those described in Polish Plant Red Data Book: *Pinguicula vulgaris, Liparis loeselii* and *Malaxis monophyllos.* The most abundant in populations of rare species are communities from *Caricion davallianae* and *Caricion nigrae* compound. The conducted research has shown that quarries may be a suitable place for survival and development of a wide range of rare and critically endangered Polish plant species.

Key words: sand quarry, rare and protected species, biodiversity, Silesian Upland

INTRODUCTION

Relatively shallow location of coal under the surface of Silesian Upland has become the primary reason of extremely drastic changes in the environment of this area. From 1769 to 1995, 9.7 million tons of coal were mined in the Upper Silesia [Pukowska-Mitka 2002]. Already at the end of 19th century, in order to prevent damage and land deformation which have been created as a result of surface deformation above the empty spaces after coal mining, the need to fill them with sand appeared. Extremely abundant amounts of sand were placed on contact of Triassic and Jurassic deposits in the eastern part of Silesian Upland. In this zone the biggest exploitation fields of filling sand are situated. The exploitation of filling sand was started in 1922 in the Pogoria area, a district of today

Dąbrowa Górnicza. After the resource exhaustion in the Pogoria complex, exploitation was started in the area of Kuźnica Warężyńska. It was one of the biggest sandpits measuring over 700 ha [Czylok 2004]. The total area of quarries after sand exploitation in the eastern part of Silesian Upland should be estimated at approximately 50 km^2 [Czylok and Szymczyk 2008].

Scientific studies on quarries after sand exploitation have focused mainly on the methods of restoring the economic virtues through land reclamation. Not many studies have been conducted on the spontaneous succession which is taking place in the area [Czylok 1997, Szymczyk 1998, 1999, 2001, Czylok and Rahmonov 2004, Rahmonov and Szymczyk 2008]. Apart from Silesian Upland, research on *Lycopodiella innundata* population has been conducted in sandpits [Cieszko and Kucharczyk 1997]. However, a few studies on rare and protected species floras have been published [Czylok and Rahmonov 1996, Czylok and Baryła 2003, Szymczyk *et al*. 2003, Czylok 2004].

This paper concerns the parts of pits in which reclamation has not been conducted and the plant encroachment has a character of primary succession. Studies and observations carried out so far in these areas [Fojcik and Szendera 1995, Czylok 1997, Szymczyk 1998, 1999] have shown that ecological systems developing here have a unique form. Numerous populations of rare and endangered species participate in this development. These species tend to disappear in more mature ecosystems.

The objective of this paper is an attempt at specifying the plant diversity in the area after sand exploitation and presentation of the role of protected, rare and endangered species in the explored plant associations or communities.

THE AREA AND METHODS OF RESEARCH

The research was conducted in the area of Pogoria I, Siemonia, Kuźnica Warężyńska and Maczki Bór sandpits located in the eastern part of Silesian Upland macro-region (Fig. 1). In these pits, sands of river and fluvial-glacier accumulation have been exploited [Gilewska and Klimek 1967]. Geological structure and the manner of sand exploitation has led to the creation of specific hydrogeological conditions in the quarries. The output in the explored sandpits caused cutting of water tables and flooding of after-exploitation surfaces which often have an increased level of calcium ions [Szymczyk 1999]. In severe winters in the spheres of seepage, vast ice-caps are created being the source of calcium carbonate of cryogenic origin. Diversified relief of tens of metres deep quarries has also a considerable influence on the creation of specific microclimate within the quarry [Szymczyk 2001].

The research was conducted in those parts of the quarries in which processes of ecosystems development were not disturbed by reclamation measures. On the basis of archival exploitation maps presenting dates of finishing the ex-

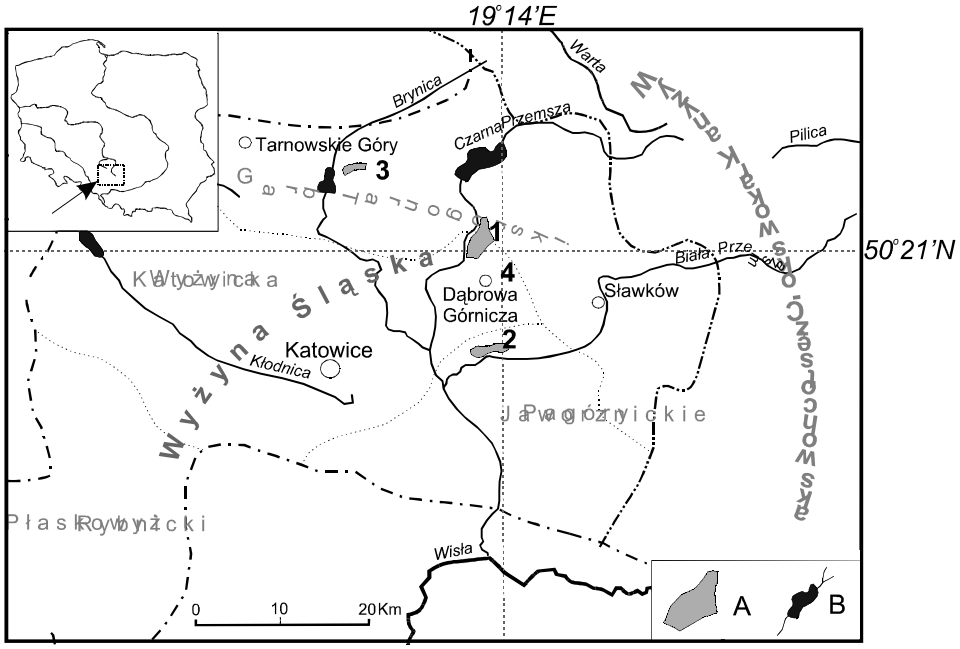

Fig. 1. The localization of sand on the background of physical and geographical division of Silesian Upland (after [Kondracki 2001]): A – the described sand excavations, B – the rivers and water reservoirs; 1 – excavation of Kuźnica Warężyńska, 2 – excavation of Maczki-Bór, 3 – excavations in Siemonia, 4 – excavation in Pogoria I

ploitation of particular scarps, the approximate dating of the explored surfaces was determined. On the selected surfaces of sandpit on which rare and protected species occur, phytosociological relevés have been taken using the Braun-Blanquet method to identify plant associations and to present the biological diversity of initial succession stages. The photographs were intentionally taken on the surfaces where one may determine the syntaxon to a particular association or compound. Most of the phytocenoses in the area of explored sandpits have not been successfully classified due to lack of characteristic species. A detailed phytosociological documentation may be found in the papers by Czylok and Rahmonov [1996] and Szymczyk [2001]. The belonging of species to particular syntaxonomic groups has been specified according to the classification by Matuszkiewicz [2001].

Materials have been gathered from 1994 to 2008 and are still being gathered. Species were determined with the help of keys to plant determination [Szafer *et al*. 1986, Rothmaler 2000] and nomenclature was accepted according to Mirek *et al*. [2002].

RESULTS

The oldest explored surfaces where succession has occurred for over 60 years were situated in the Pogoria I and Siemonia quarries. The initial succession stages (about 15–30 years) have been observed in various exploitation fields of Kuźnica Warężyńska and Maczki Bór sandpits (Tab. 1). Taking into consideration the general number of corroborated species, the floral research has shown their biggest diversity in Siemonia sandpit and the smallest in Maczki Bór (Tab. 1).

Table 1. Termination of exploitation in sand quarries under study and the number of species identified

Sand quarry	Termination of exploitation	Number of species
Kuźnica Warężyńska	1987	367
Maczki Bór	1989	266
Siemonia	1953	443
Pogoria I	1938	353

Table 2. Occurrence of plant associations & communities in the quarries and participation of protected plant species

	Determined syntaxons	P.p.	Quarries			
			K.	M.	S.	P.
Plant associations	*Phragmitetum australis* (Gams 1927) Schmale 1939	8	+	+	+	+
	Caricetum rostratae Rubel 1912	1	+		+	
	Caricetum vesicariae Br. - Bl. et Denis 1926	1			+	
	Glycerietum plicatae (Klucz.1928) Oberd. 1954	1			+	+
	Salicetum pentandro-cinereae (Almq. 1929) Pass 1961	6	+	+	+	+
	Betulo-Salicetum repentis Oberd 1964	10	+	+	+	+
Plant communities line	*Epilobion fleischeri* Br. -Bl. in. J. et G. Br.-Bl. 1931	10				
	Molinion caeruleae Koch 1926	7	+		+	+
	Rynchosporion albae Koch 1926	9	+			
	Caricion nigrae Koch 1926 em. Klika 1934	12	+	+	+	+
	Caricion davallianae Klika 1934	14	+	+	+	+
	Dicrano-Pinion Libb. 1933	12	+		+	+

+ Presence in quarries; P.p. – Number of protected plant species;
Quarries: K. – Kuźnica Warężyńska, M. – Maczki-Bór, S. – Siemonia, P. – Pogoria I

During the research conducted in the quarries, six plant associations and communities were distinguished on surfaces where land had not been reclaimed (Tab. 2). The participation of protected and rare species is different in particular associations and communities. The biggest number of their populations may be

found in communities from *Caricion davallianae, Caricion nigrae* and *Dicrano-Pinion* compound and *Epilobion fleischeri* and *Betulo-Salicetum repentis* associations (Tab. 2).

Table 3. List of recorded vascular plants under conservation

No.	Species	C.t.	Quarries			
			K .	M.	S.	P.
1.	*Carex davalliana* Sm	(2)	+			
2.	*Centaurium erythraea* Rafn		+	+	+	+
3.	*Chimaphila umbellata* W.P.C. Barton				+	+
4.	*Dactylorhiza maculata* (L.) Soó	(2)	+	+	+	+
5.	*Dactylorhiza majalis* (Rchb.) P. F. Hunt & Summ.	(2)	+	+	+	+
6.	*Drosera anglica* Huds.					+
7.	*Drosera rotundifolia* L.		+	+	+	+
8	*Epipactis atrorubens* (Hoffm.) Besser		+	+	+	+
9.	*Epipactis helleborine* (L.) Cratz s. str.		+	+	+	+
10.	*Epipactis palustris* (L.) Cratz		+	+	+	+
11.	*Equisetum variegatum* Schleich.		+	+	+	+
12.	*Gentiana pneumonanthe* L.	(2)			+	
13.	*Huperzia selago* (L.) Bernh. Ex Schrank& Mart		+		+	
14.	*Liparis loeselii* (L.) Rich.	VU, (2)	+	+	+	+
15.	*Listera ovata* (L.) R. Br.				+	+
16.	*Lycopodium clavatum* L.		+		+	
17.	*Lycopodiella inundata* (L.) Holub		+			
18.	*Malaxis monophyllos* (L.) Sw.	LR	+	+	+	+
19.	*Nasturtium officinalis* R. Br.		+	+	+	+
20.	*Ophioglossum vulgatum* L.	(2)				+
21.	*Pinguicula vulgaris* (L.) ssp.bicolor (Woł.) Löve	CR	+		+	+
22.	*Tofieldia calyculata* (L.) Wahlenb.		+	+	+	+
	Total:		17	12	18	17

+ Presence in quarries; C.t. – Category of threats; Quarries: K. – Kuźnica Warężyńska, M. – Maczki-Bór, S. – Siemonia, P. – Pogoria I; VU, CR, LR – Category of threats after Polish Plant Red Data Book [Zarzycki, Kaźmierczakowa (eds) 2001]; (2) – species requiring active conservation according to the Ordinance of the Minister of the Environment of 9th July 2004 on protected plants which occur in the wild

All in all, in the explored sandpits 22 rare and protected plant species have been observed (Tab. 3). Among them, in all the quarries *Equisetum variegatum* was dominant. Also, in all the sandpits numerous populations of *Centaurium erythraea***,** *Dactylorhiza maculata, D. majalis, Drosera rotundifolia, Epipactis atrorubens, E. helleborine, E. palustris, Liparis loeselii, Malaxis monophyllos, Nasturtium officinalis* and *Tofieldia calyculata* have been corroborated (Tab. 3).

DISCUSSION

Current law imposes the duty of land reclamation on the exploiter. Such areas are most often restored for the purposes of forestry. In the areas where land

reclamation was conducted one can observe the effect of forests consisting of species which have few biotopic needs and which are often of foreign origin. Contrary to those, in areas where biocenosis regeneration occurred spontaneously one may observe floral abundance [Czylok and Rahmonov 1996, Czylok 2004, Czylok and Szymczyk 2008].

Among those elements of flora which take part in the formation of initial communities in quarries after sand exploitation, attention must be paid to significant participation of protected, rare and even critically endangered species. From among the species described in the Polish Plant Red Data Book [Kaźmierczakowa and Zarzycki (eds) 2001] in the category of critically endangered, sites of *Pinguicula vulgaris* ssp. *bicolor* have been noted. A population of hundreds of individuals lives on the bog-spring periphery by Pogoria I, and in Kuźnica Warężyńska and Siemonia quarries less numerous populations exist. From among vulnerable species, *Liparis loeselii* has been observed. From the category of species with lower risk of extinction, in the areas after sand exploitation *Malaxis monophyllos* also grows. Populations around a dozen or dozens of individuals from this species have been observed in all quarries.

14 years of observations on protected and rare species populations have shown that with the progress of plant succession their number on some sites decreases with the development of communities. It is the consequence of replacing early succession species by late succession ones. The research conducted by Czylok and Szymczyk [2008] has shown that the most precious biocenoses are formed in places where after-exploitation grounds are flooded by seepage waters with alkaline reaction and high content of calcium carbonate and stable temperature. In recent years, in one of the seepages in Kuźnica Warężyńska quarry, a new species in the Polish flora has been observed – *Typha laxmannii* Lepech. Until recently, this species was known only from Asia and south-western part of Mediterranean area. For dozens of years it has been spreading in the north-western direction. It is already relatively frequent in Slovakia, Moravia and the Czech Republic, as well as in the southern part of Germany. It appears mainly on the banks of artificial reservoirs [Czylok and Baryła 2003].

In older stages of succession, under tufts of mature pine plantings, such typical for a coniferous forest species of undergrowth as *Pyrola minor, P. rotundifolia, P. chloranta, Orthila secunda, Vaccinium vitis-idea, V. myrtillus* appear. From among protected species *Chimaphila umbellate,* which is a species characteristic for *Dicrano-pinion* compound, often occurs here. Fragments of this type of initial pinewood ecosystems may be observed in Pogoria I quarry, in which exploitation was finished over 60 years ago [Czylok and Rahmonov 2004]. Communities with the dominance of *Equisetum variegatum* which form in sandpits belong to most often observed patterns in all of the explored quarries. In the Arctic (e.g. in Alaska and Spitsbergen island), the species together with others participates in forming the initial stages of plant succession and soil development [Crocker and Major 1955, Święs 1988]. Therefore, it can be claimed that in

the early stages of succession for a short period of time (approx. 15 years) extreme habitat conditions take place here. In the following succession stages, in flooded parts of quarry bottom, *Equisetum variegatum* participates in the formation of low-sedge bog-springs from *Caricion davallianae* compound [Czylok 1997]. In the areas where succession has occurred already for over 60 years, the species occurs in more advanced stages with birch-willow scrubs *Betulo-Salicetum repentis* and initial pinewoods.

CONCLUSION

The results show that extremely deformed areas may be substitute biotopes for endangered plants. The initial stages of succession which are formed in quarries create conditions for sustaining relatively large populations of many unique plant species. Every endeavour should be made to include the most precious parts of areas after sand exploitation in the programme of conservation of rare and endangered species which have their biotopic optimum in the early stages of plant encroachment. The fragments of quarries in which *Liparis loeselii* occurs in large numbers should be protected as Areas of Special Conservation Interest Natura 2000.

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RÓŻNORODNOŚĆ BIOLOGICZNA NA OBSZARZE WYROBISK PO EKSPLOATACJI PIASKU WE WSCHODNIEJ CZĘŚCI WYŻYNY ŚLĄSKIEJ

Streszczenie. Celem pracy była próba określenia zróżnicowania roślinności oraz przedstawienie udziału gatunków chronionych, rzadkich i zagrożonych wyginięciem w zespołach lub zbiorowiskach formujących się na badanych wyrobiskach (Pogoria I, Siemonia, Kuźnica Warężyńska i Maczki Bór). Na nierekultywowanych fragmentach wyrobisk wykształcają się podczas sukcesji unikatowe układy biocenotyczne, stanowiące siedliska licznych, rzadkich i chronionych gatunków roślin, w tym opisanych w „Polskiej czerwonej księdze": *Pinguicula vulgaris, Liparis loeselii i Malaxis monophyllos*. Najbogatsze w populacje rzadkich gatunków są zbiorowiska ze związku *Caricion davallianae* i *Caricion nigrae*. Przeprowadzone badania wykazały, że wyrobiska mogą stanowić dogodne miejsca dla

przetrwania i rozwoju szeregu rzadkich i ginących w Polsce gatunków roślin.

Słowa kluczowe: wyrobiska po eksploatacji piasku, rzadkie i chronione gatunki, bioróżnorodność, Wyżyna Śląska