THE ASSESSMENT OF FLOODED MINE SUBSIDENCE RECLAMATIONS IN THE UPPER SILESIA THROUGH THE PHYTO AND ZOOCENOSIS

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ABSTRACT

The northeaster part of the Czech Republic is since the early 19th century associated with underground coal mining. This activity brings economic benefit in addition to changes in the landscape – soil depression followed by habitat destruction. Flooded mine subsidences are an example of such degradation of native plant and animal communities, biodiversity decline and wetland and aquatic ecosystems establishment. For a long time, these ecosystems were considered worthless and unproductive [10]. The aim of the various reclaim methods was to restore the function; some flooded subsidences were on the contrary left to the process of spontaneous development. The present research was focused on comparing the effectiveness of biotechnical reclamation methods to the directed succession and to the spontaneous development of ecosystem. The main criterion was the malacocoenosis and phytocoenosis characteristics. It was found that the reclamation method has a significant influence on the emerging ecosystems. The vegetation characteristic assessment according to the phytosociological classes share confirmed the usability of the method in assessing reclamation efficiency. Data obtained on the basis of molluscs (terrestrial and aquatic species) research are more difficult to assess. The reclamation controlled by managed succession seems to be a suitable alternative to biotechnical reclamation, but the concrete used methods must be further clarified in order to achieve higher efficiency in this type of restoration.

Keywords: reclamation of postmining landscape, COBRAMAN, brownfields, spontaneous succession, managed succession, wetland, Mollusca

INTRODUCTION

As a result of underground coal mining in the area of Karviná and Katowicka Upland (Czech and Polish part of Upper Silesia), there was the formation of new aquatic, to the development accessible habitats – flooded mine subsidences. Sierka and Sierka [15] or [4] also involved the issue of development and biodiversity of such a habitats in their work.Reclamations of flooded mine subsidences in the fifties of twentieth century led to the complete removal of these objects, often by filling with tailings. In the next phase, those areas were converted to arable land or afforested [14]. In many cases, then there are at newly created flooded mine subsidences carried out different interferences with various intended objectives. For different reasons, natural values and potential production possibilities of these units are not respected [1, 2]. In principle, there are used three fundamental approaches to rehabilitation of flooded mine subsidences [11]:

-natural one - consisting on using vegetation forming in the process of spontaneous succession;

-mixed one - based on "collaboration with nature" so called, method of directed succession;

-artificial one - omitting benefits from restoration of nature, based on technical and biological treatments.

The current environmental practice has not done so far enough studies focused on combined research of plant and animal biodiversity in anthropogenically developed sites such as flooded mine subsidences. The aim of the research was to assess the effect of three different methods that deals with flooded mine subsidence reservoir banks on diversity vegetation, characteristic of malacocenosis, soil properties and water conditions in subsidence reservoir.

MATERIALS AND METHODS

Study area is situated in the Czech part of Upper Silesia – Karvinsko. There was selected two flooded subsidence reservoirs in Karvina region. The bank of first (Darkov) was reclaimed by standard biotechnical method with using barren rocks. On the eastern part of the area, there were reclaimed some bank fragments using directed succession by modification biotopic conditions. Riparian ecosystem on the second antropogenic tank (Loucky Rybnik) was formed by natural succession. The aim of this kind of natural reclamation method was to form habitats and refuges for rare, protected plants and to create biological, esthetical and scientific function [16].

The both reservoirs had almost similar area (30 and 41ha), the vegetation had corresponding age (about 5 years old). The research was held from March to November 2010 and it was focused on phyto and zoocenoses (Phyllum Mollusca) and fundament environmental factors. In total, studies were carried out in 3 sample plots (transects) localized on representative site on the banks reclaimed by different methods (more Table 1). Transects were 11m long and 2m wide. There were 6 fundamental subplots (2mx1m) in one transect where collection of *Mollusca* species were performed. In each rectangle 2 phytosociological relevés ($1m^2$) were collected. Terrestrial Molluscs assemblages were sampled in using a standard sampling procedure, i.e. one person searched by eye in all 6 rectangles for 1 hour (1 rectangle for 10minutes). Aquatic molluscs were sampled by using bowl-shaped metal sieve (kitchen strainer) with the diameter 20 cm, mesh size 0,8x0,8 mm. Vegetation edge of subsidence reservoir was washed by metal sieve in the rectangle transect (usually the 1st or 2nd section of transect). Only living specimens of molluscs were collected. The samples were then determined after throughout survey of the site. Several species were determined afterwards, in laboratory conditions using binocular magnifier. Molluscs species names are given according to [3]. Ecological elements are listed according to [7] and [5]. The value of the domination index D was divided into 5 classes according to [6].

Fig.1: Localisation of study area

Tab. 1. Characteristics of study plots

	Study plot A	**Study plot B**	**Study plot B**
Reservoir	Darkov sea	Darkov sea	Loucky pond
Slope of bank	10°	2°	3 °
Reclamation method	Biotechnical reclamation	Directed succession	Spontaneous succession
Treatments	Filling with barren rock, planting of *Cornus mas*	Habitat was prepared for development of rush vegetation	Lack
Direction	E (east)	E	E

In particular relevés species composition were estimated. Percentage cover of species in squares with a side of 1m were evaluated using the following scale 0%, 1%, 5%, 10%, 20%.......100%. In total 36 subplots were done. Plant species, with their percentage were classified into syngenetic groups follow [8]. Vegetation analysis was carried out with respect to: species composition, Shannon–Wiener's Index, cover share of ecological groups and invasive plants following [9].

To determine significant differences of species composition, species richness and diversity as well as the share of ecological groups of species between each study plot, Kruskal-Wallis one-way analysis of variance by ranks was used [13]. The correlation between phyto and malacocenosis analysed characteristic and reclamation type were tested by RDA– Redundancy analysis made with Canoco for Windows 4.5 software.

RESULTS

During the transect research in 2010, 19 species were observed (Table 2), 17 gastropods and 2 bivalve species – *Sphaerium corneum, Anodonta anatina*. There were found aquatic (8 species) and also terrestrial molluscs (11 species). The most species and also individuals were found on the transect B with the directed succession, but there were not found statistically significant differences as between study plots in the number of individuals so as in the number of species. Also all ecological groups of mallacocenosis were statistically very similar, only group 9 - PALUDICOLAE (PD) including two species *Succinea putris* and *Zonitoides nitidus* (10, 5% density) shows significant difference due to type of reclamation process (B to C, see Table 3).

There were found only species belonging to group least concerned according to the threat. Only 2 species – *Potamopyrgus antipodarum*, *Aplexa hypnorum* - are not evaluated for Czech Republic (introduced species). In the transects 5 species were found eudominant (*Physella acuta, Stagnicola corvus, Zonitoides nitidus, Cochlicopa lubrica, Anodonta anatina*) and 7 species were assessed as subrecedent (*Fruticicola fruticum, Monachoides incarnatus, Deroceras laeve, Succinea putris, Sphaerium corneum, Anisus vortex, Potamopyrgus antipodarum*) Only 2 species were found dominant (*Trichia hispida* and *Radix peregra*) and 5 species recedent (*Discus rotundatus, Arion lusitanicus, Oxychillus cellarius, Vitrina pellucida, Lymnea stagnalis*)

In total, there were found 62 vascular plant species within the three study plots including 35 species in biotechnical reclamation, 15 in directed succession and 32 in natural succession. There were in the reclaimed plot according to mean number of species, Shannon index and share of cover *Achillea millefolium*, *Festuca arundinacea* and *Erigeron annuu* significant differences than in phytocoenosis appeared by directed succession. On the vegetation created by mixed reclamation (plot B) *Phalaris arundinacea* shows the highest contribution (Table 4).

In terms of percentage participation (syngenetic groups) the vegetation underwent spontaneous succession show lower contribution of species representing the classes *Molinio-Arrhenatheretea*, and lack of species syntaxonomical affiliation – ubiquistic species (other) then in standard reclamation (see Fig. 1). There were significant differences in the contribution of *Artemisietea vulgaris* and *Phragmitetea* classes, between biotechnical reclamation and directed succession (Table 3). There was recorded one invasive plant species (*Solidago canadensis*) on biotechnical reclamation plots.

DISCUSSION

Only a few studies conducted so far [17, 11] show that reclamation has a great impact on natural habitats environment. Biotechnical reclamation type leads to the extinction of valuable plant communities, in artificial habitats is then regarded an increasing incidence of ruderal plant communities. Recent findings from [14] show, that the mining subsidence levelling has an impact on biodiversity habitats.

Table 2. List of species found in transects A,B and C, the values of the domination index of the mollusc communities (D%), ecological elements – 2 - mesophilic habitat species, 7 – euryvalent species, 8 – hydrophilic species, 9 – hydrophilic species prefering wetlands, 10 – aquatic species, **transects - A – biotechnical reclamation, B – directed succession, C – spontaneous succession, threat**

Ecological element		Species	Threat	Number of species	D(%)	Sites		
						A	B	C
2	SI(MS)	*Fruticicola fruticum* (O.F. Mïller, 1774)	LC	2	0,7	0	2	0
		Monachoides incarnatus (O. F. Müller, 1774)	LC	2	0,7	1	1	0
		Discus rotundatus (O. F. Müller, 1774)	LC	5	1,8	0	5	0
7	MS	*Arion lusitanicus* (Mabille, 1868)	LC	5	1,8	0	5	0
		*Trichia hispida (*Linnaeus, 1758)	LC	26	9,4	17	6	3
		Oxychilus cellarius (O. F. Müller, 1774)	LC	5	1,8	0	5	0
		Vitrina pellucida (O. F. Müller, 1774)	LC	5	1,8	4	0	1
		Cochlicopa lubrica (O. F. Müller, 1774)	LC	39	14,1	32	4	3
8	HG	*Deroceras laeve* (O. F. Müller, 1774)	LC	1	0,4	1	0	0
9	PD	*Succinea putris* (Linnaeus, 1758)	LC	1	0,4	0	1	0
		Zonitoides nitidus(O. F. Müller, 1774)	LC	39	14,1	10	29	0
10	SGRV	*Radix peregra* (O. F. Müller, 1774)	LC	22	7,9	0	18	4
		Physella cf. acuta (Draparnaud, 1805)	NE	45	16,2	0	23	22
		Sphaerium corneum (Linnaeus, 1758)	LC	2	0,7	0	2	0
	RV (SG)	*Anodonta anatina* (Linnaeus, 1758)	LC	30	10,8	30	0	0
	SG-PD	*Anisus vortex* (Linnaeus, 1758)	LC	1	0,4	0	1	0
	SG	*Stagnicola corvus* (Gmelin, 1791)	LC	42	15,1	0	19	23
		Lymnea stagnalis (Linnaeus, 1758)	LC	5	1,8	0	2	3
	invasive	*Potamopyrgus antipodarum* (Gray, 1843)	NE	1	0,4	1	0	0
		Total individuals 278				96	123	59

- LC – Least concerned, NE – not evaluated

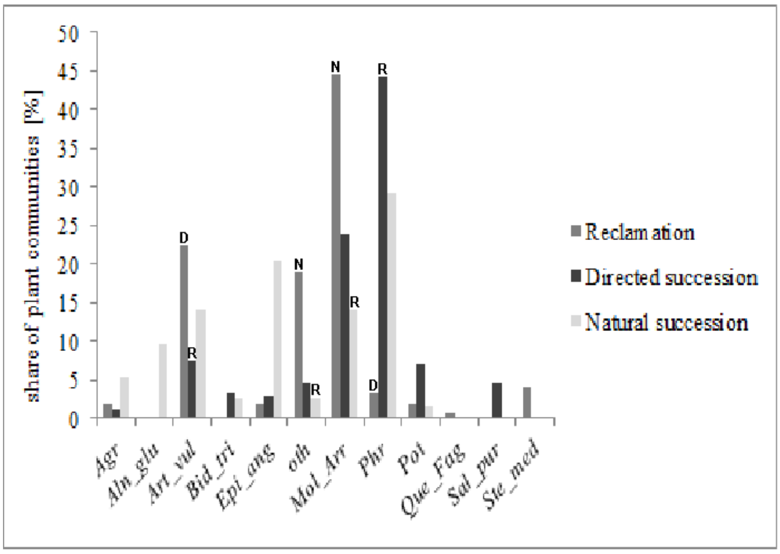
Table 3. Percentage participation of ecological elements. Values, which are the same letters are not significantly different (p<0,05 Kruskal-Wallis test)

Ecological elements	Biotechnical reclamation	Directed succession	Natural succession
2	0.17±0.28 a	1.33±1.44 a	0 a
7	8.83±3.22 a	3.33±3.11 a	1.17±0.28 a
8	0.17±0.28 a	0 a	0 a
9	1.67±1.11 ab	**5.00±5.33a**	0 b
10	5.00±8.33 a	10.83±12.1 a	8.67±9.56 a
introduced	0.17±0.00 a	0 a	0 a

Tabel 4. Comparison of effects in different reclamation manners on the vegetation. Index - Shannon–Wiener' Index, Num.Spec.- number of plant species. Values, which are the same letters are not significantly different (p<0,05 Kruskal- Wallis test)

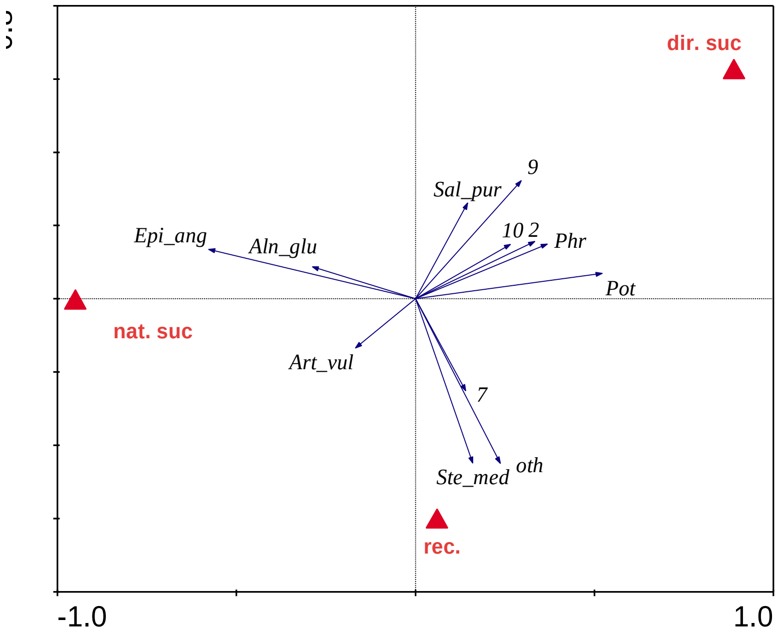
	Biotechnical reclamation	Directed succession	Natural succession
	X±SD	X±SD	X±SD
Index	0.94 ± 0.03 a	0.80 ± 0.15 b	0.90 ± 0.04 ab
Num.Spec.	8.17 ± 2.44 a	5.33 ± 1.61 b	5.58 ± 2.65 ab
Achillea millefolium	8.50±4.21a	0.00 b	0.00 b
Festuca arundinacea	8.78±6.96a	0.00 b	0.00 b
Erigeron annuus	9.33±6.82a	0.00 b	0.00 b
Phalaris arundinacea	0,00 a	21.46±22.02b	17.39±18.77ab

Fig. 2. Percentage participation of syngenetic groups in the study plots. *Agr - Agropyretea, Aln_glu- Alnetea glutinose, Art_vul - Artemisietea vulgaris, Bid_tri - Bidentea tripartiti , Epi_ang - Epilobietea angustifolii, oth – other* (species without affiliation), *Mol_Arr- Molinio-Arrhenatheretea, Phr- Phragmitetea, Pot – Potametea, Sal_pur – Salicetea purpureae, Que_Fag - Querco-Fagetea,* Ste_med - *Stellarietea mediae*. Above boxes with abbreviations for significantly different type of reclamation are shown. R- Reclamation (Technical-biological), D- directed succession, N- Natural succession) (p <0.05)



The phytocoenosis managed by biotechnical reclamation method differs mostly from directed succession communities. Vegetation had high number of species and high biodiversity with low participation of the *Phragmitetea* class and considerable contributions of classes *Artemisietea vulgaris* and species such as *Festuca arundinacea* and *Erigeron annuus* show ruderal character of man-made phytocoenosis. Analysis of vegetation established by directed succession method demonstrated the highest contribution of characteristic and distinguishing species for wetland type communities. The rush communities (the *Phragmitetea* class) is also significant in terms of appropriate area and protection, as well as space and refuge for nesting birds, amphibians, fish and reptiles. Due to high productivity, it works as a root sewage, which positively affects water conditions. *Phragmitetea* classis is characteristic for natural riparian vegetation.

Fig. 2. Ordination diagram RDA analysis - contribution of syngenetic plant species groups (*Agr - Agropyretea, Aln_glu-Alnetea glutinose, Art_vul - Artemisietea vulgaris, Epi_ang - Epilobietea angustifolii, oth – other* - species without affiliation, *Phr- Phragmitetea, Pot – Potametea, Sal_pur – Salicetea purpureae,* Ste_med - *Stellarietea mediae*) and molusco ecoelements (2,7,8,9,10) to particular reclamation manners of subsidence reservoirs (rec. – biotechnical reclamation. nat suc – natural succession, dir. suc – directed succession)



However, low biodiversity and number of plant species in direct succession confirmed, that only modification of biotopic conditions is insufficient for spontaneous vegetation development. Seeding the species characteristic for *Phragmitetea* enable biodiversity rise and became more similar to natural riparian ecosystems. Similar suggestions are given by [17]. *Phragmitetea* and *Potametea* are positively correlated to 3 ecological groups of molluscs – 2, 9, 10 and to their occurrence. Both of this plant classes can have positive effect according to hygrophilous and aquatic Molluscs species.

Initial stage of natural succession shows similarity to biotechnical reclamation method according to biodiversity, number of plant species, and ruderal classes. Share of the classes which form in the vicinity of natural water bodies was higher and was not different to directed succession. In the terms of mallacological data, there is not positive correlation between natural succession and ecological classes. Also number of species (and individuals) is the lowest in natural succession according to remaining two methods. This fact confirms that the ecosystem is young (5 years) and probably there are barriers which hinder genetic information transfer that is needed for development of wetland communities.

To assess the influence of different reclamation types is at first essential to determine the optimal reclamation aim [12]. The reference state for the purpose of rehabilitation is often recognized as the best attainable state ("best attainable condition" sensu [18]). Determination of this state enables to fully assess actual methods of reclamation in flooded subsidences and prepare such a reclamation methods, that could accelerate development of demanded ecosystems.

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