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RODENT SPECIES DIVERSITY IN THREE AREAS OF DIFFERENT RENATURALIZATION HISTORY

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Industrial waste disposal sites are subject to spontaneous succession that can also be accelerated by certain human activities. In this study we compared rodent species diversity indices, rodent abundance and species composition in three industrial sites with a different history of renaturalization: a limestone quarry at Mydlniki, post-production waste sedimentation ponds of the former Cracow Soda Factory, and ash dumps of the Cracow Combined Heat and Power Plant. All the study sites were dominated by *Microtus arvalis*. Contrary to expectations, the sites did not differ significantly in rodent abundance. Regardless of the slightly higher species diversity indices in Mydlniki, cluster analysis showed that the species composition at Mydlniki was different as compared with the other investigated sites. The results suggest that Niwa and Solvay, being distinct from Mydlniki, are at their early stages of succession. The cases of Niwa and Solvay show that rodent community reconstruction to the stage of rodent communities characteristic of urban or semi-urban areas requires more than 20 years of succession processes, even if these reclamation processes are accelerated by human activity.

Key words: rodents, industrial wastes, biodiversity

INTRODUCTION

Activities of the extractive and processing industries lead to production of significant amounts of by-products requiring extensive areas for their disposal. Due to high levels of organic and mineral pollutants these waste disposal sites are potentially harmful to free-living populations. In Poland the area allocated for disposal of post-industrial waste has gradually increased. In 2001, out of 123 million tons of industrial waste 78% was reprocessed, while the remainder was taken to waste disposal sites (ROCZNIK STATYSTYCZNY, 2002). The total amount of industrial waste landfilled in Poland is approximately 2 million tones, covering an area of 15 thousand ha (SKRZYPSKI, 1999).

Waste disposal areas are subject to natural spontaneous succession soon after they have been established. However, natural succession is usually a long-lasting process. Formation of

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a several-centimeter-thick layer of soil may last from 170 to 200 years (Gilewska, 1991). Therefore, natural processes of succession should be aided by human activities in order to accelerate the renaturalization process. The current legislative act of 3 February 1995 (Dz.U., 1995) divides the recultivation into two activities: technical recultivation covering reconstruction and maintenance of roads, terrain shaping and water regulation, and biological recultivation i.e.: planting of tolerant trees, grasses and papilionacae herbs in order to consolidate the dump slopes and to accelerate the pedogenesis process. The last stage of the reclamation process should lead to transformation of the contaminated area into spaces that satisfy the objectives of forestry, communication or recreation.

Due to their high plasticity and unspecialized feeding habits, rodents can easily colonize and maintain numerous populations in disturbed areas. The activity of the most popular species, such as the common vole, contributes to soil formation and accelerates nutrients dynamics in the ecosystem.

The aim of this study is to compare rodent communities in terms of species diversity in three industrial waste disposal sites.

MATERIAL AND METHODS

Study area

The study areas were situated in three separate sites degraded either by extraction or by post-industrial waste disposal. Characteristics of study areas are listed in Table 1.

1. The Limestone Quarry at Mydlniki (Mydlniki)

Two different biotopes can be distinguished within the perimeter of the abandoned limestone quarry at Mydlniki. The first has the form of a ca. 7-hectare basin created by the extraction of limestone. It has predominantly shallow, sandy soil, overgrown with ruderal and calciphilic vegetation. The second includes the upper portions of the quarry, covering some 40 hectares with characteristic brown rendzina (limestone) soil and typical calciphilic and xerothermic vegetation. Within the Mydlniki quarry, two transects were set out in different habitat areas: I- was laid out in the aforementioned basin of the quarry, with a low-diversity plant community;

II-was laid out in the upper part of the quarry, on limestone rocks, with a compact highly-diversified plant cover.

2. The Post-production Sediment Disposal Area of the former Cracow Soda Factory (Krakowskie Zakłady Sodowe, Solvay)

The Cracow Soda Factory (Solvay) which produced soda ash, caustic soda and sal soda was closed at the end of the 1980s because of the harm it caused to the environment. After operating unchallenged for many years, almost 5 million metric tonnes of post-production waste that had accumulated in settling ponds near the plant were left behind (chiefly calcium chloride ($CaCl_2$) and calcium carbonate ($CaCO_3$)) (Proceedings Of The III[rd] Sozology [Enviromental Protection And Management] Conference, 1993). Three transects were set out on the reclaimed sedimentation ponds of the former Cracow Soda Factory:

I-covers the area of the youngest sedimentation ponds, reclaimed in the years 1984-1994, overgrown with abundant and dense vegetation;

II-was laid down in the area of the older sedimentation ponds, where artificial experimental planting was conducted in the 1970s. This transect was overgrown with very dense and compact vegetation;

III- this study area, situated on the youngest sedimentation ponds reclaimed in the years 1984-1994, was of a typical steppe character, with not very dense but diverse vegetation.

3. The Ash Heap of the Cracow Combined Heat and Power Plant (Elektrociepłownia Cracow S.A, Niwa)

The Cracow Combined Heat and Power Plant, which is situated in the eastern part of Cracow, fires hard coal which adversely affects the environment through the release of combustion products. Until recently, up to 70% of combustion waste, in the form of ash and slag were utilized to produce building materials, with the remaining 30% directed to a waste dump at Mogiła-Niwa that had been in operation since 1971. At present, the Cracow Heat and Power Plant not only uses the ash and slag generated from its current operations, but also eliminates ash previously deposited on the dump (WWW.ECKRAKOW.PL). At the time of this study on the dump site, there were two heaps, namely: the older pile, covering an area of 8 hecta-

TABLE 1. Characteristics of the study areas. TRI, TRII, TRII – transects.

Characteristic	Solvay			Niwa		Mydlniki	
	TR I	TR II	TR III	TR I	TR II	TR I	TR II
Age	The youngest part of the deposits established in the 1980s	Old part of the deposits established in the 1960s and 70s	The youngest part of the deposits established in the 1980s	Established in the 1980s, closed since 1990	Established in the 1980s, closed since 1990	Basin created by the extraction of limestone, established in the 1920s, closed in 1950	Natural calciphilic and xerothermic vegetation on brown rendzina (limestone) soil.
Recultivation activities performed	Placing a carpet-like soil layer, sown with a mix of grasses and papilionaceous plants	Uneven covering with cinder and anthropogenic soil	Placing a carpet-like soil layer, sown with a mix of grasses and papilionaceous plants	Placing a carpet-like soil layer, sown with a mix of grasses and papilionaceous plants	Placing a carpet-like soil layer, sown with a mix of grasses and papilionaceous plants	No recultivation performed	No recultivation performed
Average thickness of soil [cm]	20	15	10	25	25	10	25
pH	8.1 – 8.4	8.6	8.2 – 8.3	7.5 – 8.7	7.5 – 8.7	7.8	7.4
Ca [mg/kg]	3,900	> 4,000	> 4,000	2,530	2,530	2,860	2,800
N [mg/kg]	100	90	90	50	50	43	15
P [mg/kg]	22	25	20	42	42	15	35
K [mg/kg]	140	270	147	47	47	105	80
Dominant plant species	*Calamagrostis epigeios, Melilotus officinalis, Melilotus albus, Medicago sativa, Tanacetum vulgare, Solidago canadensis*	*Tanacetum vulgare, Artemisia vulgaris, Elymus repns, Calamagrostis epigeios, Cirisium arvense, Trifolium pratense, Taraxacum officinale*	*Lotus corniculatus, Trifolium repens, Plantago lanceolata, Achillea millefolium, Potentilla anserina*	*Trifolium repens, Trifolium pratense, Taraxacum officinale, Dactylis glomerata, Festuca pratensis, Achillea millefolium, Lotus corniculatus, Ranunculus repens, Tripleurospermum maritimum*		*Calamagrostis epigeios*	*Dianthus carthusianorum, Fragaria vesca, Cerastium holosteoides, Rumex acetosa, Sedum acre*
The degree of vegetation density	5	5	3	4	4	4	5
Average height of plants [cm]	70 – 90	100 – 150	10 – 15	20 – 30	20 – 30	70 – 90	10 – 20
Number of rodent species	4	3	4	4	4	2	4

res and mothballed since 1986, and the current slag heap, covering 12 hectares. In 1991 the Heat and Power Plant started reclamation work on the older heap (Kraków Heat and Power Plant-Report, 1997).

Two transects were set out on the reclaimed heaps of combustion waste at Mogiła-Niwa:

I- included the area of the current ash dump, in the direction of the reclaimed part;

II- was laid out through densely overgrown escarpments on the reclaimed heap.

RESULTS

Out of the 29 rodent species reported to live in Poland, 5 species belonging to 2 families, *Muridae* and *Arvicolidae*, were captured in the investigated area. The numbers of individuals at each site, transect and season are listed in Table 2. Rodent assemblages at each site were dominated by *Microtus arvalis* and this species accounted for 87.6% of the total number of the individuals captured. *Clethrionomys glardeolus* was represented by one individual only, and therefore this species should be treated as a migrant rather than as a permanent resident of the investigated community. The comparisons of total rodent numbers did not show any significant differences between the sites (Table 3). However, cluster analysis revealed that the highest similarities were between sites with only a short history of recultivation, namely between Niwa and Solvay, which was the most distinct location (Table 4, Figure 1). Species diversity indices are listed in Table 5. Mydlniki was characterized by the highest Shannon-Wiener index and the lowest Simpson index of dominance (1.0646 and 0.561, respectively). The lowest species diversity was detected in Niwa, while for Solvay intermediate values of biodiversity indices were found.

DISCUSSION

In general, the results indicate that all the investigated sites are characterized by high dominance of *Microtus arvalis*. The fact that only five species have been recorded, and the diversity indices have reached relatively low values, indicates low species diversity in the investigated sites. While comparing the locations, Mydlniki was characterized by slightly higher Shannon-Wiener and Simpson indices, whilst no significant differences in terms of rodent abundance were found between the study sites.

The dominance of *M. arvalis* can be explained by the extraordinary adaptive plasticity of this species. Its small body size, fast development, early onset of puberty and high fertility allow this species to colonize quickly new areas, with a rapid increase in population size that may show synchronized peaks in terms of its abundance. Certain micro-evolutionary changes in the digestive tract anatomy can also contribute to the domination of *M. arvgalis* in the investigated areas. It has been proven that *M. arvalis* originating from the Solvay area exhibits a 30% increase in blind gut length at the expense of the large intestine which is reduced by about 30% when compared with individuals originating from undisturbed sites (Dobek, 2000; Vorontsov, 1962, 1979; Carleton, 1981). As rodents are herbivores, they feed on food rich in cellulose and have developed an extended blind gut that contains microsymbionts that enhance the digestion processes and are an extra source of bacterial proteins. The extension of the blind gut most likely gives *M. arvalis* advantage over other rodent species in terms of colonization and development of numerous populations in the investigated areas. The dominance of the species indicated in this study is roughly in line with the results of other authors investigating rodents in disturbed areas, and who have proven that *M. arvalis* can be considered as a typical rodent species for the early stages of succession.

The values of the species diversity indices obtained in this study were relatively low with little differences between the study sites. Only in the case of Kamieniołom the value of the Shannon-Wiener index was high enough to correspond with rodent diversity values reported for urban and semi-natural areas (Pelikàn, 1986). Cluster analysis also indicated that Mydlniki differed from Solvay and Niwa in species composition. This result can be explained by differences in the history of renaturalization between the investigated areas. Niwa and Solvay have been subject to renaturalization processes, supported by reclamation activities, for about 20 years, while in Mydlniki the history of spontaneous succession is approximately 50 years. Thus, the slightly higher species diversity

TABLE 2. Number of rodent individuals captured, analyzed by study site, season and transect.

Study areas	Season	Transect	Species					Total
			Mictotus arvalis	*Apodemus agrarius*	*A. sylvaticus*	*A. flavicollis*	*Clethrionomys glareolus*	
Solvay	Autumn 99	TR I	65	0	3	0	0	68
		TRII	49	4	4	0	1	58
		TR III	48	2	1	0	0	51
	Spring 00	TR I	12	0	4	0	0	16
		TRII	26	0	0	0	0	26
		TR III	0	0	1	0	0	1
	Autumn 00	TR I	9	2	5	0	0	16
		TRII	33	2	0	0	0	35
		TR III	7	0	0	0	0	7
	Spring 01	TR I	24	6	1	0	0	31
		TRII	37	4	0	0	0	41
		TR III	12	0	0	0	0	12
	Sum		322	20	19	0	1	362
Niwa	Autumn 99	TR I	33	0	0	0	0	33
		TR II	41	0	0	0	0	41
	Spring 00	TR I	24	1	0	0	0	25
		TR II	8	0	0	0	0	8
	Autumn 00	TR I	53	0	2	0	0	55
		TR II	33	0	0	0	0	33
	Spring 01	TR I	19	0	0	0	0	19
		TR II	13	0	0	0	0	13
	Sum		224	1	2	0	0	227
Mydlniki	Autumn 99	TR I	14	12	0	2	0	28
		TR II	13	15	0	0	0	38
	Spring 00	TR I	11	3	0	0	0	14
		TR II	12	1	0	0	0	13
	Autumn 00	TR I	11	6	3	0	0	20
		TR II	24	9	0	0	0	33
	Spring 01	TR I	4	0	0	0	0	4
		TR II	19	0	0	0	0	19
	Sum		118	46	3	2	0	169
	Total		664	67	24	2	1	758

TABLE 3. Results of between-site comparisons of capture effectiveness performed using a t-test.

Study areas		Niwa	Mydlniki	Solvay
Solvay n = 4	x = 20.105 SD = 13.3578	t = 0.1767 p = 0.8709	t = 1.2346 p = 0.3048	/ /
Niwa n = 4	x = 18.9125 SD = 9.5266	/ /	t = 2.2741 p = 0.1075	t = 0.1767 p = 0.8709
Mydlniki n = 4	x = 13.83 SD = 7.2146	/ /	/ /	t = 1.2346 p = 0.3048

TABLE 4. The Euclidean distance between the study sites.

	Solvay	Niwa	Mydlniki
Solvay	/	101.267	210.2403
Niwa	101.267	/	118.8697
Mydlniki	210.2403	118.8697	/

TABLE 5. Parameters of rodent species diversity in the investigated sites.

Parametr	Site		
	Solvay	Niwa	Mydlniki
Number of pitfalls	1 800	1 200	1 200
Number of individuals captured / 100 pitfalls	20.11	18.92	14.08
Number of species	4	3	4
Simpson's index of dominance (λ)	0.796	0.974	0.561
Simpson's index of diversity (C)	0.204	0.026	0.439
Shannon – Wiener index of diversity H'	0.6277	0.1135	1.0646
Shannon – Wiener index of evenness J'	0.314	0.179	0.532

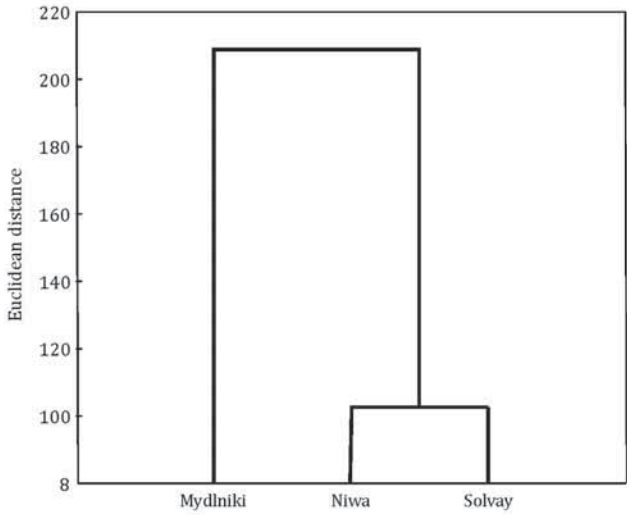

Fig. 1. The similarity of rodent communities in the study sites measured by the Euclidean distance.

and distinctive species composition are probably the result of a longer succession history.

Summing up, both the dominance of *M. arvalis* and rodent species diversity established in this study seem to suggest that Niwa and Solvay, being distinct from Mydlniki, are in the early stages of succession. The cases of Niwa and Solvay show that the reclamation of rodent community back to the stage of rodent communities characteristic for urban or semi-urban areas requires more than 20 years of succession processes, even if these reclamation processes are accelerated by man-made activities.

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