UNIWERSYTET ZIELONOGÓRSKI • ZESZYTY NAUKOWE NR 133

Nr 13 INŻYNIERIA ŚRODOWISKA 2007

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ECOLOGY OF AN ALDER CARR *RIBESO NIGRI-ALNETUM* SOL.-GÓRN. (1975) 1987 COMMUNITY IN AN AREA OF SUBSIDENCE CAUSED BY COAL MINING (CHORZÓW AREA CASE STUDY)

Key words: interior basin, surface deformations, waterlogging, ground surface depression, submergence, Upper Silesia

S u m m a r y

Studies were made of the influence of the mining industry on the floristic composition, vertical and horizontal structure, and the stand's health condition, of the alder carr Ribeso nigri-Alnetum Sol.-Górn. (1975) 1987 community, in the nature-landscape complex 'Uroczysko Buczyna' in Chorzów, Upper Silesia. A single-layered stand, of an average canopy cover reaching 65%, allows for the abundant natural regeneration of black alder. However, one may assume that very dense and concentrated patches of its seedlings will contribute to the low efficiency of the natural regeneration of the stand in the future. The most serious threat to the existence of the alder carr community is the subsidence of the ground caused by coal exploitation, resulting in the creation of a subsidence water basin. Permanent submergence, observed in some parts of the alder carr, has led to the death of many black alder trees. Partial amelioration of the study area is needed to reduce the negative effects of mining and to allow the Ribeso nigri-Alnetum community to persist in the future.

Introduction

The exploitation of minerals lasting a few centuries and the development of industry (metallurgy or smelting, fuel, chemical, and power) had a great influence on the natural environment of Upper Silesia. It led to the pollution of air and surface waters and to heavy surface deformations. It has been estimated that almost 98% of the total amount of coal in Poland is extracted from the Upper Silesian coal mines. Thus, the influence of mining is very clearly seen in

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the region [Dwucet & al. 1992]. Furthermore, Upper Silesia is one of the biggest coal exploitation areas in Europe.

The coal-mining industry leads to many undesirable changes in the natural environment, including geochemical, biogenic, hydrological and hydrogeological transformations. Both direct and indirect types of influence can be observed. The group of direct changes includes surface deformations [Ogrodowski & Kot 1988, Chwastek & al. 1990], resulting from the activity of gravitational forces over empty spaces made in the rock formation following the extraction of coal deposits. Such changes are classified as continuous deformations, which take the form of mild and extensive land depressions, so-called lowering basins or subsidence basins. Such depressions usually lead to extensive flooding [Dwucet & al. 1992], which belongs to the group of indirect effects of mining [deformations [Ogrodowski & Kot 1988]. The presence of waterlogged areas is caused by the changes in the interrelated position of ground surface (subsidence) and the level of the water table. Up to 1992, about 640km^2 of the area of Upper Silesia had been under the influence of the direct effects of mining extraction. The indirect effects, namely drainage, waterlogging and seismic shocks, had been recorded on an area of ca. 1000 km^2 [Dwucet & al. 1992]. In the rock formation, extensive, post-exploitation hollows, of a size of 110 million m^3, were created, which is equivalent to an average annual surface depression of up to 20cm on an area of 640 km^2. The deformation of surface features is one of the main consequences of mining extraction. In some parts of Upper Silesia, including Katowice and Chorzów cities, surface depressions reach a depth of five to 13 meters [Dwucet & al. 1992].

One of the consequences of the changes caused by the mining industry is shrinkage of the areas with natural and semi-natural vegetation. Among them, forests were the most heavily affected. One such area is the "Uroczysko Buczyna" forest, designated as a nature-landscape complex in the year 2001. It is characterised by high floral and faunal diversity and well-developed and well-preserved acidic lowland beech wood – *Luzulo pilosae-Fagetum* – and riverside carr – *Fraxino-Alnetum* – forest communities. However, the close proximity of industrial plants, coal mines and cities has influenced the natural features of the site. Subsidence caused by coal extraction in the Śląsk and Katowice-Kleofas coal mines, is the most drastic consequence.

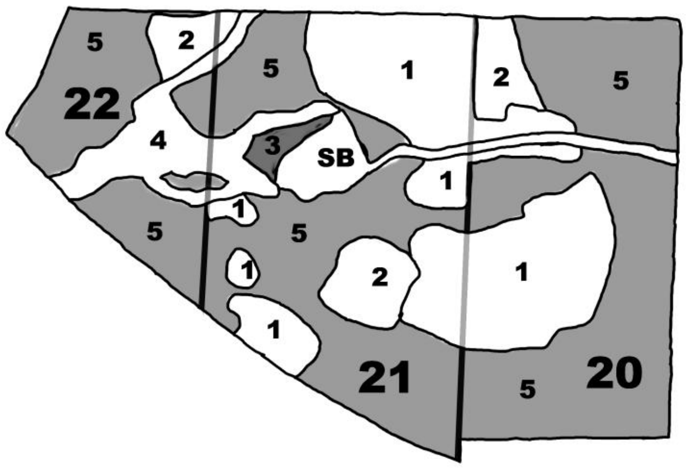
The aim of this paper is to present the influence of the mining industry on the floristic composition, vertical and horizontal structure, and the state of health of the stand of the alder carr *Ribeso nigri-Alnetum* community, developing in the Uroczysko Buczyna forest complex. Within this particular forest community, the influence of the mining industry on the natural environment is the most noticeable that we detected.

Description of the study site

The Uroczysko Buczyna nature-landscape complex is located in the Silesian voivodship, within the administrative borders of the town of Chorzów. The study area is surrounded by cities, on the south-western side by Ruda Śląska and in the east by Katowice.

According to the physio-geographical division of Poland [Kondracki 2001], the study site is located within: Polish Uplands province, Silesian-Kraków Upland subprovince, Upper Silesia macroregion, and Katowice Upland mesoregion.

The overall area of the complex is 65.32 hectares and includes three forest divisions (no. 20, 21, and 22), owned and managed by Katowice Forest District, and belonging to the state forestry (Fig. 1).



1 – *Luzulo pilosae-Fagetum*; 2 – *Querco roboris-Pinetum* 3 – *Ribeso nigri-Alnetum*; 4 – *Fraxino-Alnetum* 5 – *Tilio cordatae-Carpinetum betuli*; SB – subsidence basin

Fig. 1. Location of the study site

The study area is located within the main anticline, highly elevated tectonic-structural unit of the Upper Silesian Basin, composed of palaeozoic deposits [Fajer & Grygierczyk 1994, Parzentny & Radosz 1997].

The Uroczysko Buczyna forest has a diverse morphology. Its ground surface falls towards the west, south-west and south [Opinia 1997].

Within the area studied, brown, acidic soils and gley soils are predominant. Black half-bog (muck) soils and acidic brown, podzolic soils are also present here. Most soils are of moderate depth. Shallow soils are present only in the forest division no. 22. The soils of the Uroczysko Buczyna are a sandy mantle rock of a normal or loamy sand character. In the deeper layers, light, sandy or, less frequently, heavy clay are present [Plan urządzania lasu]. The site is located in the Odra river basin and Kłodnica river catchment [Kuczera 1995].

A few streams, some of them seasonal, flow through the area and there is a small interior water basin in forest division no. 21b. The area is under the influence of the Middle Uplands climate, belonging to the Silesian-Kraków climatic province [Romer 1949]. The average annual air temperature is 7-8 ^{0}C, and the annual precipitation is 700-800 mm. The highest rainfall occurs in July (80-100mm). The vegetation season lasts ca. 205 days [IMiGW 2000].

Within the Uroczysko Buczyna, five types of forest community were recorded: acidic, lowland beech wood (*Luzulo pilosae-Fagetum* W. Mat. et A. Mat. 1973); riverside carr (*Fraxino-Alnetum* W. Mat. 1952); oak-hornbeam (*Tilio cordatae-Carpinetum betuli* Tracz. 1962); continental, mixed conifer (*Querco roboris-Pinetum* (W. Mat. 1981) J. Mat. 1988); and alder carr (*Ribeso nigri-Alnetum* Sol.-Górn. (1975) 1987). The *Luzulo pilosae-Fagetum* and *Fraxino-Alnetum* are the most valuable and the best preserved, whereas the *Ribeso nigri-Alnetum* community is the most heavily transformed and degenerated [Cabała & Herczek 1999].

The study site is located directly above the excavation section of the Śląsk coal mine, where coal extraction started in the mid-1970s. Between 2001 and 2003, coal was extracted directly below the Uroczysko Buczyna, at a depth of 730m, from the 2.8m-thick roof layer. In the northern part of the forest, coal extraction was undertaken at a depth of 700 m, from the bottom layer of 3.5 m thickness. In the Katowice-Kleofas coal mine, extraction took place much more shallowly, at a depth of 100 m below the ground, from a layer 1.1m thick. These extraction sites were the last to continue in the area, until mining stopped completely in 2003. The mining industry led to up to 10 m-deep ground-surface depressions, which can be observed in the north-western part of the study site, and about 13-14 m deep in the central part of the area [Opinia 1997].

In 1996, as a result of subsidence, in the south-eastern part of the Uroczysko Buczyna (forest division no. 20f) an interior subsidence basin was created. Temporal submergence of an area of 1.5 hectares, damaging the forest stand, took place as a consequence. Although the waterlogged area was ameliorated and drained in 1996 [Opinia 1997], waterlogging continued subsequently. Thus, the water basin located in forest compartment no. 21b is not of natural origin; it was also created as a consequence of subsidence caused by mining. The area and the depth of the basin continue to increase: the ditches, which were supposed to ameliorate the submerged part of the forest, no longer help to reduce the excessive amount of water, since the current depth of the subsidence basin has exceeded that of the amelioration ditches.

Material and methods

In order to characterise the floristic composition of the *Ribeso nigri-Alnetum* community, three phytosociological relevés were taken by the Braun-Blanquet method.

Studies on the vertical (stand and its natural regeneration) and horizontal structure of the alder carr *Ribeso nigri-Alnetum* Sol.-Górn. (1975) 1987 community were undertaken in June 2002. Within the whole area of the community (0.0225 ha – plot 15 by 20 m) heights and diameters of trees were measured. To assess the degree of natural regeneration of the stand, seedlings up to 0.5 m high, 0.5-2.0 m and over 2 m high, but with diameter of less than 5 cm, were counted.

The horizontal structure of the herb layer was assessed within the Greig-Smith grid [Greigh-Smith 1952], 8 x 8 m in size, consisting of 16 quadrats of 2 x 2 m. Within each quadrat, the percentage cover of species of vascular plants was estimated according to the following scale: 1, 5, 10, 20 … 100%. In addition, the canopy cover index within each quadrat was measured using a spherical densiometer.

As the first step of the analysis, a numerical classification of the data on herb layer composition, with the use of the Mulva-5 package [Widli & Orlóci 1996], was undertaken. Scalar and vector transformation was applied, then the similarity correlation coefficient was calculated to assess the degree of similarity among quadrats, according to the following formula:

$$r\,(x,y) = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left(\sum xx - \frac{\sum x^2}{n}\right)\left(\sum yy - \frac{\sum y^2}{n}\right)}} \qquad (1)$$

Then, as a result of cluster analysis with the use of minimal variance,

$$Qjk = (n_j n_k / n_j + n_k)\ \delta_{jk} \qquad (2)$$

quadrats were grouped. The floristic similarity of quadrats was illustrated on a dendrogram. As a result of numerical classification, microcommunities were distinguished. Their nomenclature was given based on the names of dominant species. Spatial distribution of the microcommunities distinguished was presented on a carthogram. Nomenclature of vascular plants followed that proposed by Mirek et al. [Mirek & al. 2002].

Habitat conditions within quadrats were assessed using Ellenberg indicator values [Ellenberg & al. 1992]. The weighted means of moisture (F), reaction (R), nitrogen content (N) and light (L) indicators were calculated. Species richness (number of species) and species diversity (Shannon index) for each quadrat were measured. For both types of calculation, the Mulva-5 package was used. Ellenberg indicator values were presented as carthograms and Shannon index values as a histogram.

To examine whether there is any relationship between the canopy density and: total cover of herb layer, species richness, species diversity, and Ellenberg indicator values within each type of microcommunity, the Spearman correlation coefficient test was applied. Mean values of Ellenberg indicator values, species richness and species composition, herb layer cover and canopy cover were compared among microcommunities using the Kruskal-Wallis test. The Statistica 5.0 software was used for all statistical computations.

Results

Phytosociological characteristics

Table 1 shows the species composition of the Ribeso nigri-Alnetum Sol.-Górn. (1975) 1987 community. It is worth mentioning that a few years ago, when the relevés were taken, the overall area occupied by this community was a few times bigger than during the ecological studies on stand structure and herb layer composition. The differences that were observed were a consequence of subsidence and waterlogging.

Table 1. Ribeso nigri-Alnetum Sol.-Górn. (1975) 1987 community

Number of relevé	1	2	3
Date	6.09. 1999	6.09. 1999	7.09. 1999
Forest division	21c	21c	21c
Relevé area [m^2]	100	100	100
Tree layer cover [%]	70	60	60
Shrub layer cover [%]	20	5	5
Herb layer cover [%]	100	80	90
Number of species in relevé	17	10	15

CH.+D°. *Ribeso nigri-Alnetum + Alnetea glutinosae*				
Carex elongata L.		3.3	3.3	.
°*Carex remota* L.		1.3	.	+.3
Dryopteris cristata (L.) A.Gray		.	+.2	.
Festuca gigantea (L.) Vill.		+	.	.
Lycopus europaeus L.		.	+	.
Salix cinerea L.		.	.	+
Accompanying species		4.4		
Alnus glutinosa (L.) Gaertn.	a	+	4.4	4.4
Alnus glutinosa	b	+	+	1.1
Alnus glutinosa	c	2.2	+	.
Frangula alnus Mill.	b	2.3	1.1	+
Juncus effusus L.		1.1	4.4	1.3
Lysimachia vulgaris L.		+.2	1.1	+
Scirpus sylvaticus L.		3.3	+.2	+.2
Athyrium filix-femina (L.) Roth		2.3	+	.
Deschampsia caespitosa (L.) P.Beauv.			.	+.2

Species occurring only in one relevé:
Acer pseudoplatanus L. b 1; Agrostis stolonifera L. 1; Bidens tripartita L. 1; Calamagrostis epigejos (L.) Roth 1; Dryopteris carthusiana (Vill.) H.P.Fuchs 1; Equisetum sylvaticum L. 3; Glyceria maxima (Hartm.) Holmb. 3(1.3); Glyceria fluitans (L.) R.Br. 3(4.4); Polygonum hydropiper L. 4; Potamogeton natans L. 3(2.3); Quercus robur L. b 1; Rubus idaeus L. 3; R. plicatus Weihe & Nees 3; Sorbus aucuparia L.Emend.Hedl b 1; Urtica dioica L. 2.

Stand structure and its natural regeneration

The single-layered stand is purely composed of Alnus glutinosa with average tree cover reaching 65% and a density of 1022 specimens per hectare. Tree diameter varies between 5,5 and 38 cm, with 29,3 cm being the average. Trees reach 17-24 m in height, with 20,8 m being the average value. The presence of many dead trees, especially in the proximity of the subsidence water basin, is noted. Tree distribution within the research plot is presented in Figure 2a.

Natural regeneration of the stand is observed in the whole area studied. The most abundant are seedlings up to 0,5 m high (16666,7 specimens per hectare). Seedlings of 0,5-2,0 m high are not as numerous but they are still strongly represented. In both height classes, seedlings of black alder are the most abundant. The highest concentration of seedlings under 2 m high is found on the side of the plot adjacent to the riverside carr Fraxino-Alnetum W. Mat 1953 community, whereas seedlings over 2 m high are most numerous in the central part of the plot (Fig. 2b).

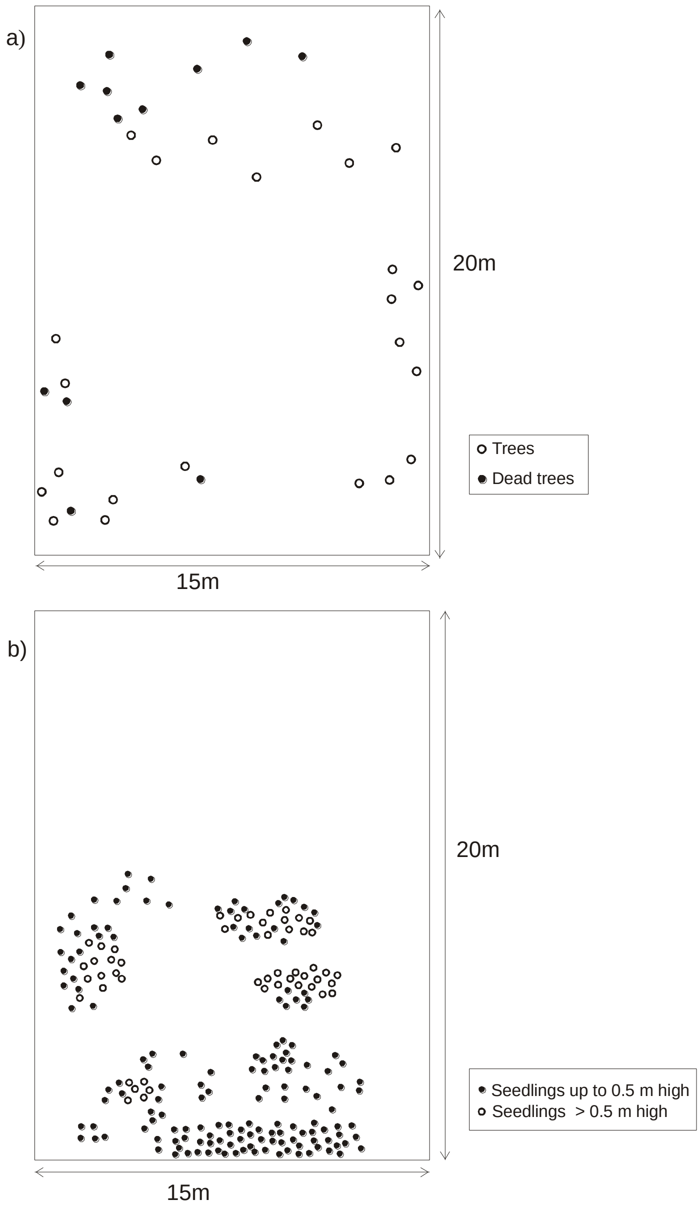


Fig. 2. Distribution of a) trees and b) seedlings of different height classes within the study site

Horizontal structure of the herb layer

Species richness and diversity

The cover of the herb layer is very high, reaching over 70% but it is very poor in species, with only 10 species of vascular plants recorded. Carex remota (16 quadrats), Juncus effusus (14), Alnus glutinosa (13), Calamagrostis epigejos (12) and Lysimachia vulgaris (11) are the most frequent, while Carex remota gives the greatest cover (32%).

The value of the Shannon diversity index varies between 0,34 and 0,85, with an average of 0,65. The most frequent are the values between 0,6 and 0,7.

Habitat conditions – Ellenberg indicator values

The mean values of the Ellenberg indicators calculated for the community allow us to describe its habitat conditions as semi-shaded sites (L=5,2), with moist (F=7,8), moderately acidic soils (R=4,5) of average nitrogen content (N=4,6).

A strong, positive correlation between the canopy index and species richness (r=0,74; p=0,001) and diversity (r=0,54; p=0,033) was observed, but no correlation between canopy index and herb layer cover (r= -0,5; p=0,051) or light indicator value (r=0,46; p=0,076) was found.

Comparative characteristics of the microcommunities

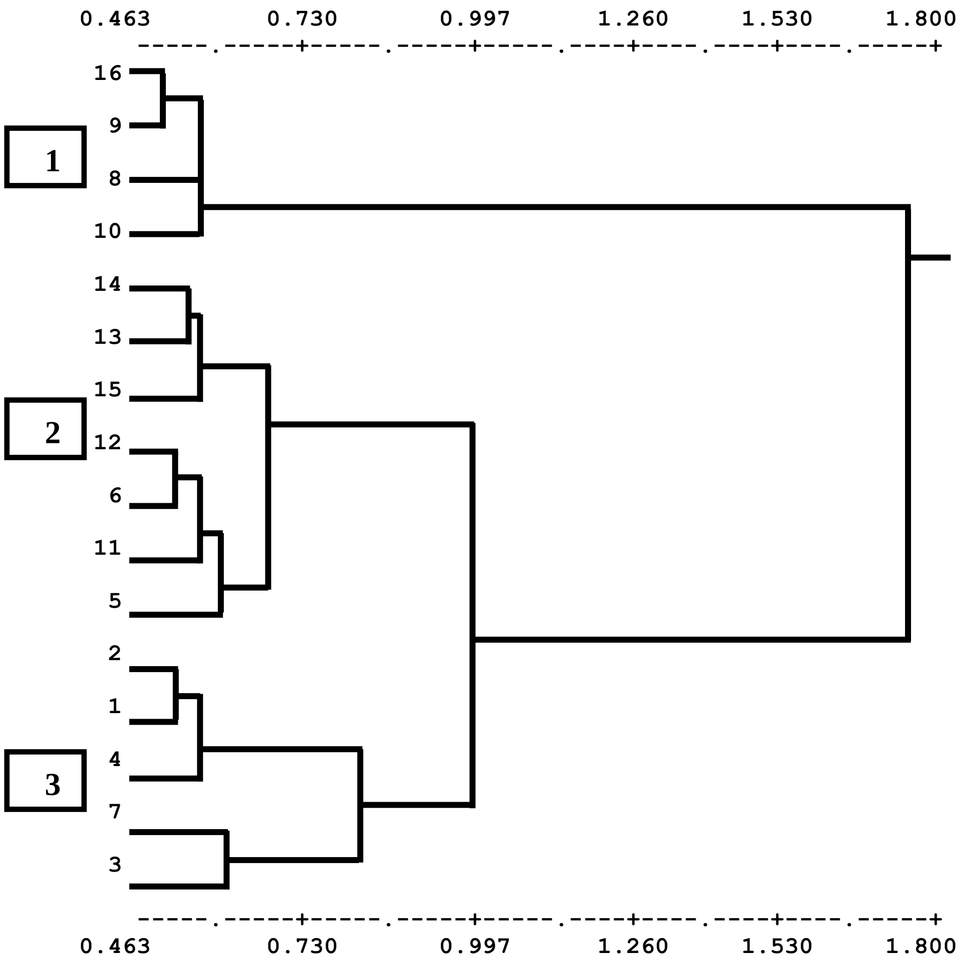
Within the research plot, three microcommunities were distinguished:

a) *Carex remota* (1), dominated by *Carex remota*, with low cover and frequency of other herb layer species;

b) *Carex remota-Alnus glutinosa-Juncus effusus* (2), where these three species play the most important role;

c) *Juncus effusus*, with abundant occurrence of Juncus effusus but also high frequency of *Carex remota*. Compared to the first two microcommunities *Calamagrostis epigejos* and *Deschampsia caespitosa* reach a higher average percentage cover here.

A full species composition and the percentage cover of each species are given in Table 2. The floristic similarity of the microcommunities distinguished in the course of our analyses is shown in the dendrogram (Fig. 3). A clear division into two main groups is noticeable, with the first branch representing microcommunity 1, and the second including microcommunities 2 and 3 clustered together. Thus, the *Carex remota* microcommunity is distinctively different in its species composition from the other two.



1) Carex remota microcommunity; 2) Carex remota-Alnus glutinosa-Juncus effusus microcommunity; 3) Juncus effusus microcommunity

Fig. 3. Dendrogram of the floristic similatiry of the microcommunities distinguished in course of analyses

A Kruskal-Wallis test did not allow us to detect any significant differences among microcommunities in the mean values of reaction and nitrogen content indicators, but confirmed that microcommunities differ in their average values of Shannon diversity index, canopy cover index, soil moisture, and light conditions indicators (Table 3).

Table 2. Average percentage cover of herb layer species within microcommunities; 1) Carex remota microcommunity; 2) Carex remota-Alnus glutinosa-Juncus effusus microcommunity; 3) Juncus effusus microcommunity

Species	Microcommunities		
	1	2	3
Carex elongata	5,000	-	1,000
Carex remota	60,000	30,000	12,000
Juncus effusus	1,500	19,300	32,000
Alnus glutinosa	1,250	20,700	6,400
Calamagrostis epigejos	2,500	5,290	9,000
Lysimachia vulgaris	1,000	1,000	1,600
Deschampsia caespitosa	1,250	2,140	5,000
Rubus idaeus	-	0,857	4,000
Dryopteris carthusiana	-	-	0,600
Rubus sp.	-	0,143	-

Table 3. Spearman correlation coefficients between different variables analysed

Variables analysed	Spearman rank coefficient	p
Canopy cover × number os species	0,74	0,001
Canopy cover × Shannon index	0,54	0,033
Canopy cover × herb layer cover	-0,50	0,051
Canopy cover × L (light) indicator	0,46	0,076

Discussion

Within the area of an alder carr community, a large number of specimens of black alder of a small diameter was recorded. Its natural regeneration was abundant. The total concentration of seedlings reached 23034 specimens per hectare. In both height classes of the seedlings, *Alnus glutinosa*, a main component of the stand, dominated. Great abundance of seedlings over 0,5 m high proved a very good natural regeneration. Low canopy cover, reaching only up to 65%, might be one of the main factors contributing to that. In comparison with the *Ribeso nigri-Alnetum* community, canopy cover of the riverside carr, adjacent to the community studied, reached a value over 20% higher. Although the stand of the *Fraxino-Alnetum* community had the most diverse structure, natural regeneration of *Alnus glutinosa*, the dominant species of the tree layer, was very limited compared to the alder carr [Badach & al. 2004]. Being a light-demanding species, black alder does not reproduce itself under a dense tree canopy [Kowalski 1975].

However, the black alder seedlings occur in very dense patches. According to Hett [1971], the mortality of young specimens of trees, growing in highly concentrated groups, reaches levels of up to 90%. Even though the total proportion of immature specimens of trees is very large, they occur in single, very dense and concentrated populations, located within the area of the mature trees. Thus, the effectiveness of its natural regeneration is very low. Sparse groups of seedlings with small concentration of specimens usually provide better conditions for the growth and development of the young generation of *Alnus glutinosa* [Symonides, Solińska-Górnicka 1991].

A characteristic feature of the herb layer in the alder carr community is its high percentage cover but low species richness. One of the reasons for this might be the low cover of the tree canopy, facilitating the domination of the herb layer by some competitive, light-demanding species. The result of a correlation test, which shows that species richness and Shannon diversity index increase when canopy cover reaches higher values, confirms that relationship. However, permanent submergence of the alder carr community seems to be the most important factor, which eliminates some species from the herb layer.

The most serious threat to the existence of the alder carr studied is the subsidence of the ground caused by coal exploitation in the two neighbouring coal mines – Śląsk and Katowice-Kleofas. This has led to a rise in the groundwater table, permanent submergence and flooding. Many mature *Alnus glutinosa* trees located either within the area of, or in the near proximity of, the subsidence water basin, are already dead. The area of the reservoir is growing and forest submergence continues to expand as a consequence.

The high percentage of dead trees no doubt is a reaction of the adult specimens of black alder to sudden and permanent submergence, as a consequence of subsidence. Although seedlings of *A. glutinosa* show a high tolerance to partial, temporal submergence and are able to endure longer periods of it compared to hardwood species [Siebel & al. 1998], they are much more sensitive to total submergence than to partial submergence and need time to build up and maintain tolerance to it [Siebel & al. 1998]. Thus, we may assume that, in the lowest located parts of the forests, in places permanently submerged throughout the year, the *Ribeso nigri-Alnetum* community will have no chance of survival.

Conclusions

1. The mining industry has influenced the floristic composition, vertical and horizontal structure of the *Ribeso nigri-Alnetum* community, and the health of its stand.
2. Coal exploitation has led to local surface depressions and flooding. As a consequence, many specimens of black alder, especially closest to the submerged area, are dead.
3. Low canopy cover, reaching up to 65%, has allowed an abundant natural regeneration of black alder. However, the subsidence water basin, causing permanent submergence of many parts of the community, will substantially limit that process in the future. Furthermore, we may assume that very dense and concentrated patches of *Alnus glutinosa* seedlings will contribute to the low efficiency of the natural regeneration of the stand in the longer-term perspective as the mortality of seedlings occurring in such highly concentrated groups is usually very high.
4. Open canopy cover resulted in a high percentage cover of the herb layer but low species richness caused by a dominance of some competitive, light-demanding herb layer species.
5. The most serious threat to the existence of the alder carr community is the subsidence of the ground caused by coal exploitation, resulting in the creation of a subsidence water basin. Permanent submergence observed in some parts of the alder carr, led to the death of many trees and eliminated some species from the herb layer.
6. Partial amelioration of the study area is needed to reduce the negative effects of mining and to allow the *Ribeso nigri-Alnetum* community to survive in the future.

Acknowledgements

The authors would like to express their gratitude to the authorities of the Kleofas coal mine for making the data on the estimations of the surface depressions accessible and to Lynn Frances for her kind help in improving the language of the paper

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EKOLOGIA ZBIOROWISKA OLSU PORZECZKOWEGO *RIBESO NIGRI-ALNETUM* SOL.-GÓRN. (1975) 1987 NA TERENACH OSIADAJĄCYCH NA SKUTEK SZKÓD GÓRNICZYCH (NA PRZYKŁADZIE OBSZARU CHORZOWA)

S t r e s z c z e n i e

Zbadano skład gatunkowy runa oraz strukturę poziomą i pionową zbiorowiska olsu porzeczkowego Ribeso nigri-Alnetum Sol.-Górn. (1975) 1987 w zespole przyrodniczo-krajobrazowym 'Uroczysko Buczyna' w Chorzowie (Górny Śląsk), pozostającym pod silnym wpływem górnictwa, powodującym osiadanie gruntów. Jednowarstwowy drzewostan, o średnim zwarciu nie przekraczającym 65%, umożliwia dynamiczne odnawianie się olszy czarnej. Wydaje się jednak, że zbyt silne zagęszczenie osobników nalotu i podrostu sprawi, że naturalna regeneracja drzewostanu nie będzie w przyszłości efektywna. Głównym źródłem zagrożenia dla trwania tego zbiorowiska jest jednak osiadanie gruntów, spowodowane eksploatacją węgla kamiennego bezpośrednio pod badanym terenem. Przyczyniło się ono bowiem do powstania zbiornika zapadliskowego, którego areał stale się powiększa. Częściowe lub trwałe podtopienie, jakie obserwuje się w niektórych partiach olsu, spowodowało śmierc wieku okazów drzewiastych olszy czarnej. Aby skutecznie zmniejszyc negatywny wpływ górnictwa na zbiorowisko olsu, potrzeba jest melioracja tego obszaru.