Short Communication

Ecohydrological Monitoring in Assessing the Mining Impact on Riverside Ecosystems

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Received: 26 September 2013
Accepted: 22 December 2013

Abstract

Ecohydrological monitoring was conducted in the period of 1999-2013 (and beyond) in the riverhead section of the Kłodnica Valley, in the riverside ecosystems in the southern part of the Silesian Upland. The aim of this study was to analyze and evaluate the impact of mining on the changes in water conditions and their impact on plant ecosystems connected with waterlogged habitats in the valley. The monitoring included observations on the variability of the water table, the size of mining subsidence and the scale of ground deformation. In order to monitor the range of *Allium ursinum* and *Veratrum lobelianum,* five permanent plots of 100 m^2 each were established.

During coal extraction (2000-06) the water table depths ranged from 0 to 2.4 m in the uplands, and from 0 to about 1 m in the valley, and the waterlogging of the substrate was dependent on precipitation conditions (amount and distribution of rainfall throughout a year). At that time, the surface of the area lowered by a maximum of 1.78 m. After the coalmine operation ceased, i.e. in the period of 2007-13, the subsidence significantly declined and did not exceed 15 cm. The monitored populations of *Allium ursinum* L. and *Veratrum lobelianum* Bernh. did not show considerable changes in terms of the area they occupied. However, a trend was observed to increase their ranges not only in the plots but also in the whole area. Local decrease in the ranges of the tested species was caused by forest management carried out at the same time. According to the results of the monitoring, the changes evoked by the mining activities are dependent on geological and lithological conditions, the position of the water table, the size of the mining operation, and ground subsidence, as well as the technology of extraction. It was found that the impact of mining on riparian ecosystems in the study area has not caused negative changes in their functioning.

Keywords: ecohydrological monitoring, mining subsidence, mining activities protected areas, *Allium ursinum*, *Veratrum lobelianum*, Kłodnica springs, Silesian Upland

Introduction

The dynamic processes occurring in ecosystems include regeneration and degeneration [1]. The changes are the result of both natural processes and human economic activity. Especially anthropogenic activities – in most cases – lead to significant changes in biocenotic systems and disturbances in ecological homeostasis. Therefore, knowledge of the rate and trends of changes in vegetation as well as water and soil conditions taking place under the influence of anthropogenic and natural processes, is very important for the assessment of changes in the dynamics of the biocenosis and its functioning under increased anthropopressure.

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Studies of ground subsidence caused by underground mining operations include aspects of changes in the relief in space and time, and their effects on the environment, both in Poland [2-5] and in the world [6, 7]. There are also studies on the impact of underground mining on the landscape in the coalfields [8-10] and those offering proposals for reclamation of post-mining areas [11].

In Poland, studies based on biological monitoring are conducted primarily in national parks [12-16], nature reserves, and landscape parks. These studies rely mostly on long-term observation of changes in plant populations, mostly under the influence of natural factors.

Since 2000 monitoring studies have also been carried out in the area of the Springs of the Kłodnica nature and landscape complex (NLC) – a protected area. In 2000-06 an underground coal mining run by the Staszic Coal Mine in Katowice took place in the area. Therefore, there were concerns that the mining industry might have led to the deregulation of ecosystem processes in this area and thus it was decided to undertake long-term observation. Monitoring included the population of protected species of *Allium ursinum* and *Veratrum lobelianum* as well as observations of changes in relief and water conditions evoked by mining activities. This comprehensive monitoring explains the causes and effects of the changes in the studied wetland ecosystem. Such studies are rarely performed due to the high costs and lack of physical abilities for such a study.

The aim of this study is to analyze and assess the impact of mining on the changes in water conditions and their impact on the functioning of plant ecosystems of wetland habitats within the river valley. Particular attention is given to the population dynamics of *Allium ursinum* and *Veratrum lobelianum*. The monitoring is to answer the question whether and how quickly the changes in the morphology of the area, together with changes in water conditions caused by underground coal exploitation, affect the functioning of the valley and the entire Springs of the Kłodnica NLC in Katowice (Silesian Upland).

Material and Methods

Study Area

The Springs of the Kłodnica NLC includes the western slope of the watershed hump (Odra-Vistula). This hump is made of a Carboniferous formation (sandstones and shales) covered locally with Tertiary clays and silts with a thickness of up to 11 m (Fig. 1). They provide an insulating and hydrophilic layer, which is essential for water retention in the bottom of the Kłodnica Valley. The surface of the area is covered with a series of Pleistocene tills and fluvioglacial sands and gravels of variable thickness (up to 15 m on the plateau). In the bottom of the Kłodnica Valley is a thin (up to 30 cm) layer of Holocene alluvial sediments overlying the clays and Tertiary silts. The area of such a geological structure is where the headwaters of the Kłodnica developed. The Kłodnica is fed by the water flowing out from sandy and sandy-clayey series of the Pleistocene deposits creating seepages and bog-springs near the outcrops of impermeable layers. The upper reaches of the Kłodnica Valley is well developed, suggesting a substantial level of water supply.

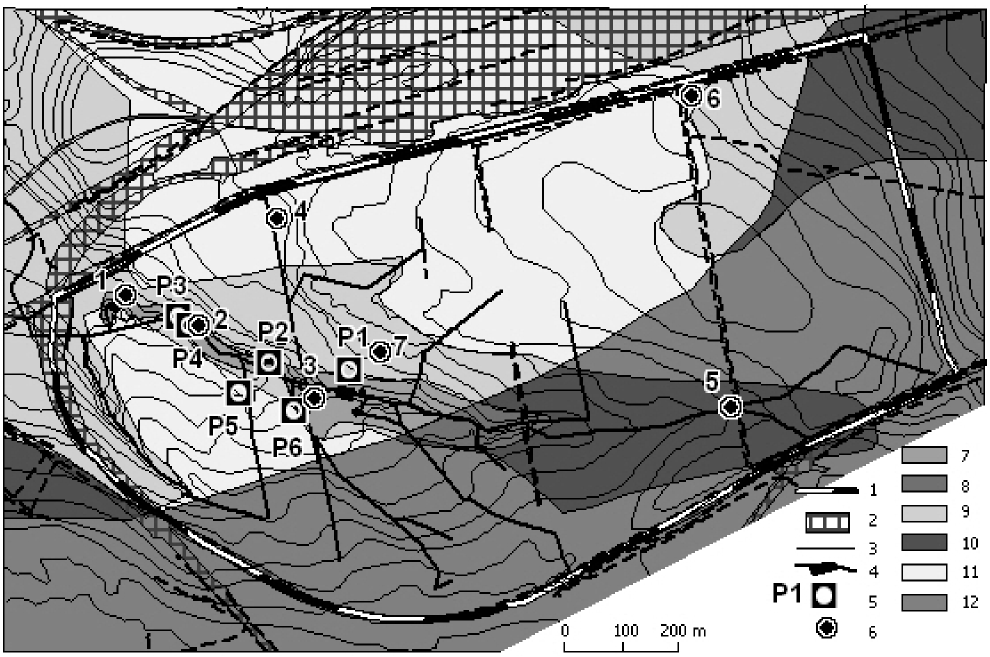

Fig. 1. The investigated area: 1 – the boarder of analyzed surface (Kłodnica River Basin), 2 – deformed surfaces with pit embankments and railroad, 3 – countur, 4 – streams, drainage ditches, water reservoirs, 5 – location of investigated plots, 6 – location of piezometers, 7 – silts on the tertiary deposits (Holocene), 8 – silts on carbon deposits (Holocene), 9 – eluvium of boulder clay on tertiary deposits (Pleistocene), 10 – eluvium of boulder clay on carbon deposits (Pleistocene), 11 – fluvioglacial sands and gravels, boulder clay on tertiary deposits (Pleistocene), 12 – the boulder clay on carbon deposits (Pleistocene).

A major part of the NLC is young forest plantations of the age 20-30 years. However, the area under protection, the riverside alder forest, takes only 6.5% of the total area of the complex. This situation is also clearly visible on aerial photographs taken in 1981, in which most of the area is devoid of vegetation. Today, the northern and southern parts of the valley – particularly in its higher parts – is taken by artificial planting, including *Betula pendula* and *Quercus rubra* [17].

The research area is dominated by the *Fraxino-Alnetum* community, especially in the valley. This community shows a typical structure, floristic composition and habitat conditions, very similar to those of natural phytocenoses. This is illustrated by a typically developed vertical structure, the species composition and of the forest and undergrowth. The undergrowth in different parts of the complex is dominated by patches of *Allium ursinum* and *Veratrum lobelianum*. Noteworthy is the presence of many monumental specimens of *Alnus glutinosa*, with a diameter sometimes exceeding 75 m. This indirectly proves the old age of these trees (about 100-120 years), which in turn points to the age diversity of individual trees within the community and, at the same time, to its character similar to the natural.

Studies of Relief Changes

The observation of relief changes was based on the network of 79 leveling points established within the Nature and Landscape Complex. The points were placed along the valley axis as well as in three transverse profiles across the valley. The height measurements were performed by the mine surveying services from the Coal Mine "Staszic" every two months in the years 2000-06, and every six months from 2007 to 2012.

Changes in the water table throughout the area were observed with the use of a network of piezometers established at select points (21 piezometers) (Fig. 1). The precipitation data, indispensable for describing water conditions, came from the precipitation gauge station Katowice-Muchowiec.

Vegetation Studies

Changes in the patches of select species within the riverside alder forest were examined by creating five permanent research plots (Fig. 1). The plots are squares of 100 m^2 each; they are divided into 2×2 m squares for detailed mapping of vegetation. The mapping considered only those species that occupied an area of at least 0.5 m^2, and thus so accurate was the mapping. The plots were permanently marked with metal tubes and extra wooden stakes with consistent numbering (letters and numbers).

The selection of the places where the plots were established was conditioned by the occurrence of patches of *Allium ursinum* (plots No. P_1, P_2, and P_3) and *Veratrum lobelianum* (P_4, P_5). These species occur on various landforms, but predominantly in the valley (in the bottom and on the slopes). When choosing plots the attention was also paid to soil moisture, as in this particular case it is one of the most important factors for the development of *A. ursinum* and *V. lobelianum*. Therefore, their habitats differed in terms of soil moisture, which had an impact on the viability of the population.

Within the test plots detailed plans of the distribution of plant populations were made (scale 1:100). The observation of the study area included an assessment of the dynamics of changes in the populations of *Allium ursinum* and *Veratrum lobelianum*. The direction and pace of change was assessed by comparison of floristic composition in annual intervals, as well as the change in coverage and ranges of the tested species. Mapping was performed each year in the first decade of May.

The measurements were taken using a GPS receiver. Based on the obtained data, maps were generated using MapInfo Professional GIS software.

Results

Relief Changes

A direct result of mining activities carried out by the caving method is ground subsidence. The greatest subsidence occurred during the exploitation of the mineral resource, 2000-06. It reached a maximum value of 1.78 m (Figs. 2 and 3), being particularly visible within the mining fields. After the operation, in 2007-13, subsidence was already small and did not exceed 15 cm. Mining subsidence resulted in a general lowering of the Kłodnica headwaters and changing the shape of the valley, at places leading to widening of its bottom.

Changes in Water Conditions

Subsidence has increased water retention of the area. In the most subsided and flattened parts of the area water appears on the surface in the form of hollows and small water reservoirs. This is especially observed in the eastern part of the area occupied by a riverside community. During the study period the water table level ranged from 0 to 2.4 m in the uplands and from 0 to 1 m in the valley within the riparian ecosystem. The highest water table level was observed in 2001, which closely correlates with the annual rainfall (Fig. 4).

In the winter-spring period very high water table levels were recorded by the piezometers. Water was often found on the surface. But in times of drought and increased spring vegetation rapid lowering of the water table level was observed.

Changes in Vegetation

Allium ursinum colonized both waterlogged and fresh habitats within the valley. During the monitoring of individual plots dominated by *Allium ursinum*, there were no significant changes observed (Fig. 5). A slight decrease in the population of *A. ursinum* was recorded in the years 2003, 2005, and 2006 in the plot P_1, where the range of its population was reduced, while in the plots P_2 and P_3 a steady increase

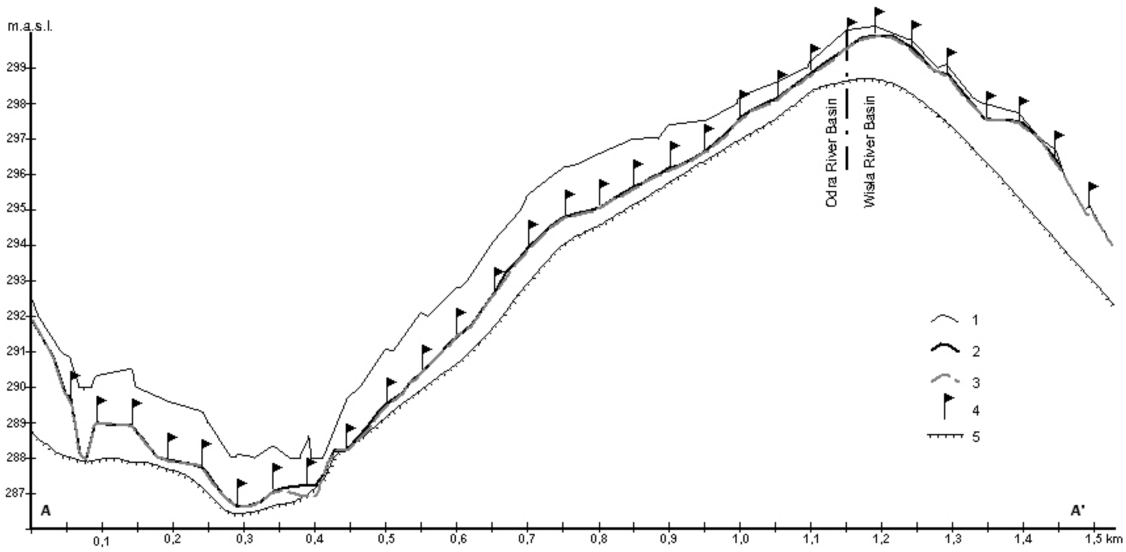

Fig. 2. The topographic profile AA' – subsidence in the period of 01.2000-09.2012 years -longitudinal profile in valley: 1 – profile line – state form 01.2000, 2 – profile line – state from 05.2006, 3 – profile line – state from 09.2012, 4 – the leveling points, 5 – the level of groundwater – state from 05.2006.

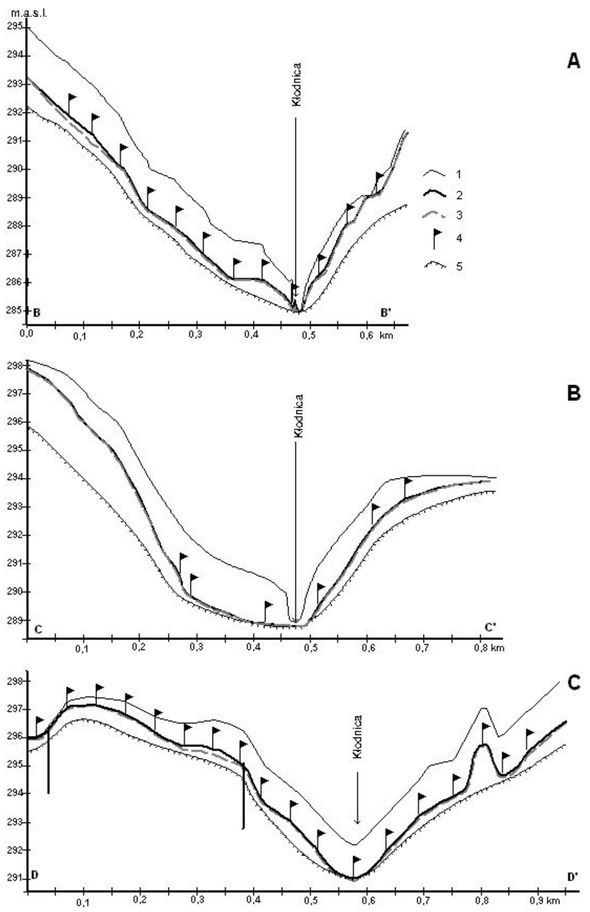

Fig. 3. The topographic profile of subsidence in the period of 01.2000. 09.2012 years- transverse profile – BB', CC', DD':
1 – profile line – state from 01.2000
2 – profile line – state from 05.2006
3 – profile line – state from 09.2012
4 – leveling points
5 – groundwater level – state from 05.2006.

with minor variations was recorded (Table 1, Fig. 5). The plots located on the valley slopes or on small swellings within the plots had a varying participation of hygrophilous or mesophilic species typical of this type of habitat, such as *Carex remota*, *Galeobdolon luteum*, *Equisetum sylvaticum*, *Scirpus sylvaticus*, and others (Table 1).

Veratrum lobelianum occurred in the study area primarily along stream banks, in the headwaters area, in the hollows of standing water often coming from precipitation, and in well-lit forest fragments. During the research the population was of almost stable character or indicated an upward trend compared to the first period of the study in the test plots (P_4 and P_5). The only decline in the population of *V. lobelianum* on both plots (by approx. 10%) was noted in 2003 (Table 2, Fig. 5). Besides *V. lobelianum* and other single species in plot P_4 *A. ursinum* coexisted, and the size of its population was continuously growing since the beginning of the study period.

Six years after coal mining ceased, significant changes were visible in the population of the tested species. *Allium ursinum* increased its surface area in comparison to previous years. Its specimens are more vital in wet habitats than at the edge of the valley.

Significant changes were observed in plots with *Veratrum lobelianum*, as in plot P_5, where coverage of this plant population doubled (Table 2, Fig. 5). However, in plot P_4 the coverage of this plant population decreased significantly due to the ground subsidence and flooding of the area previously colonized by this species.

Discussion

Changes in Relief and Water Conditions

Mining leading to the formation of ground subsidence often results in complete disappearance or transformation

Table 1. Changes in vegetation within the plots with dominance of *Allium ursinum*.

	Species	Years							
		2000	2001	2002	2003	2004	2005	2006	2013
		[%]							
Plot 1	***Allium ursinum* L.**	**80.5**	**84.5**	**85.0**	**65.0**	**83.0**	**69.0**	**58.0**	**95.0**
	Ajuga reptans L.	0.0	0.0	0.5	9.0	0.0	0.5	2.5	0.0
	Carex remota L.	0.0	0.0	0.0	0.0	0.0	9.0	7.0	0.0
	Cirsium oleraceum (L.) Scop.	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0
	Dryopteris filix-mas (L.) Schott	0.0	0.0	0.0	9.0	0.0	2.0	13.0	2.0
	Equisetum sylvaticum L.	0.0	0.0	0.0	1.0	0.0	0.0	3.5	1.5
	Eupatorium cannabinum L.	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
	Galeobdolon luteum Huds.	0.0	0.0	0.0	0.0	0.0	6.0	8.0	0.0
	Oxalis acetosella L.	0.0	1.0	0.0	3.5	0.0	0.0	0.0	0.0
	Rubus plicatus Weihe & Nees	0.0	0.0	0.0	1.5	4.5	11.0	6.5	0.0
	Scirpus sylvaticus L.	0.0	0.0	0.0	0.5	0.5	1.0	1.5	1.5
	Senecio fuchsii C.C. Gmel.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
	Organic detritus	19.5	14.5	14.0	1.0	12.0	1.0	0.0	0.0
	Stagnant water	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Plot 2	***Allium ursinum* L.**	**28.5**	**31.0**	**25.5**	**43.0**	**33.0**	**29.0**	**39.5**	**60.0**
	Quercus robur L.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Rubus plicatus Weihe & Nees	0.0	0.0	0.0	17.5	1.0	1.5	1.5	0.0
	Carex remota L.	0.0	0.0	0.0	2.0	2.5	6.0	4.0	3.0
	Veratrum lobelianum Bernh.	0.0	0.0	0.0	1.0	1.5	1.5	2.0	3.5
	Pteridium aquilinum (L.) Kuhn	0.0	0.0	0.0	0.5	0.0	0.0	1.0	0.0
	Dryopteris filix-mas (L.) Schott	0.0	0.0	0.0	0.0	1.0	0.0	0.0	3.0
	Urtica dioica L.	0.0	0.0	0.0	0.0	0.0	1.0	1.5	0.0
	Galeobdolon luteum Huds.	0.0	0.0	0.0	0.0	0.0	5.0	6.0	3.0
	Equisetum sylvaticum L.	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
	Organic detritus	70.5	68.0	73.5	35.0	60.0	55.0	42.0	25.0
Plot 3	***Allium ursinum* L.**	**79.5**	**94.0**	**95.0**	**92.0**	**95.0**	**83.5**	**85.5**	**97.0**
	Dryopteris filix-mas (L.) Schott	0.0	0.0	0.0	0.0	0.0	0.5	3.0	0.0
	Rubus plicatus Weihe & Nees	0.0	0.0	0.0	1.5	1.0	1.0	1.5	0.0
	Galeobdolon luteum Huds.	0.0	0.0	0.0	0.0	0.0	0.5	1.5	0.0
	Oxalis acetosella L.	0.0	0.0	0.0	0.0	0.5	1.0	0.5	0.0
	Urtica dioica L.	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0
	Cirsium oleraceum (L.) Scop.	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.0
	Alnus glutinosa (L.) Gaertn.	0.5	0.5	0.5	0.5	1.0	1.0	0.5	1.0
	Maianthemum bifolium (L.) F.W. Schmidt	0.0	0.0	0.0	0.0	0.0	5.5	0.0	0.0
	Paris quadrifolia L.	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0
	Pteridium aquilinum (L.) Kuhn	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
	Veratrum lobelianum Bernh.	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.5
	Polygonatum multiflorum (L.) All.	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
	Organic detritus	15.0	0.5	2.0	1.5	2.0	1.0	0.5	0.0
	Stagnant water	5.0	5.0	2.5	2.0	0.0	3.0	3.0	0.5
	Forest path	0.0	0.0	0.0	0.0	0.0	2.0	3.0	0.0

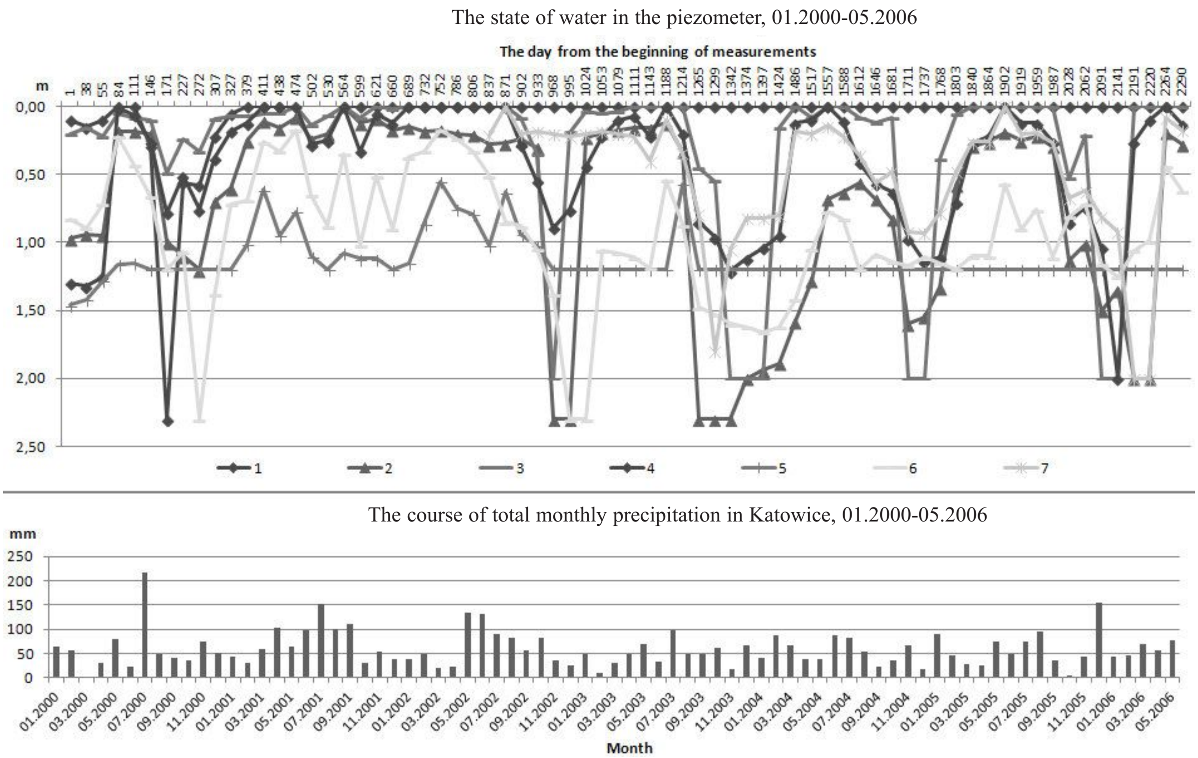

Fig. 4. The state of water in the piezometer, 01.2000-05.2006 and the course of total monthly precipitation in Katowice, 01.2000-05.2006.

of an existing ecosystem. However, there are cases that this phenomenon also contributes to the improvement of habitat conditions and, as a result, stabilization of existing ecosystems. The latter is the case of the study. This is due to the formation of depressions or hollows suitable for rainwater or groundwater retention, thus delaying its outflow outside the analyzed area.

The greatest subsidence occurs during mining exploitations. They result from deformation of the rock mass and clenching of post-exploitation underground voids. The result is a general lowering of the topographic surface area and the formation of small depressions without outflow. These processes may also lead to widening of the valleys in the reaches within the exploitation area. A variety of landforms and an increase in soil moisture creates favorable conditions for the functioning of riparian ecosystem together with its components. It should be noted that the ground subsidence did not cause a significant reconstruction of the hydrographic system in the area.

In the presented case, keeping moisture and water retention is significantly supported by the Miocene clays that prevent or reduce water infiltration into the rock formation. This process directly contributes to keeping the water table in the near-surface layer. The highest water table level is recorded in the period of spring snowmelt and increased summer precipitation. Previous observations indicate that a relatively constant flow occurs only in the main river channel of the Kłodnica. Other watercourses are seasonal,

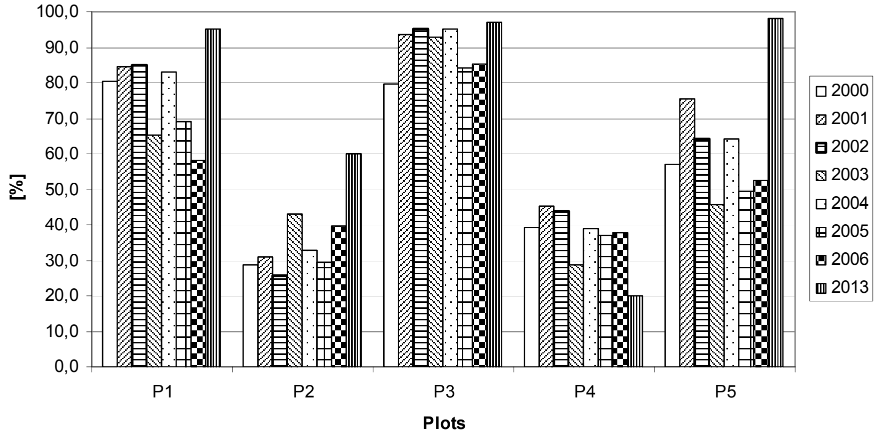

Fig. 5. The range of *Allium ursinum* (P_1_3) and *Veratrum lobelianum* (P_4_5), 2000-13.

Table 2. Changes in vegetation within the plots with dominance of *Veratrum lobelianum*.

Species	Years							
	2000	2001	2002	2003	2004	2005	2006	2013
	[%]							
Plot 4								
***Veratrum lobelianum* Bernh.**	**40.0**	**45.5**	**44.0**	**28.5**	**39.0**	**36.5**	**37.5**	**20.0**
Aegopodium podagraria L.	0.0	3.0	3.0	0.0	1.0	0.0	0.0	0.0
Ajuga reptans L.	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0
Allium ursinum L.	12.5	5.5	0.0	16.5	3.0	8.5	21.0	0.0
Carex remota L.	34.0	25.5	30.0	32.0	22.0	1.0	0.0	18.0
Cirsium oleraceum (L.) Scop.	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Dryopteris filix-mas (L.) Schott	0.0	0.0	0.0	0.0	0.0	3.5	13.0	0.0
Equisetum sylvaticum L.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Galeobdolon luteum Huds.	4.0	4.0	13.5	0.0	0.0	25.5	14.5	0.0
Polygonatum multiflorum (L.) All.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Pteridium aquilinum (L.) Kuhn	1.0	3.0	6.0	7.0	0.0	0.0	1.0	0.0
Rubus plicatus Weihe & Nees	0.0	0.0	0.0	0.0	2.0	0.5	1.0	0.0
Sambucus nigra L.	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Scirpus sylvaticus L.	2.0	1.0	0.5	0.5	1.0	0.0	0.0	15.0
Juncus conglomeratus L. emend. Leers	0.0	0.0	0.0	0.0	1.0	0.0	0.0	12.0
Organic detritus	3.5	10.0	0.0	6.0	13.0	20.0	7.5	0.0
Flowing water	3.0	2.5	3.0	8.5	3.0	3.5	4.0	0.0
Stagnic water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
Plot 5								
Veratrum lobelianum Bernh.	**57.0**	**75.5**	**64.0**	**45.5**	**64.0**	**49.5**	**52.5**	**97.0**
Alnus glutinosa (L.) Gaertn.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Carex remota L.	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dryopteris filix-mas (L.) Schott	0.0	0.0	0.5	0.0	0.5	0.0	2.5	1.0
Equisetum sylvaticum L.	6.0	2.0	4.5	3.0	4.5	0.0	0.0	0.0
Luzula pilosa (L.) Willd.	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0
Padus serotina (Ehrh.) Borkh.	0.0	0.0	0.0	0.0	0.0	3.0	5.0	0.0
Poa nemoralis L.	0.0	0.5	7.5	0.0	7.5	0.0	0.0	0.0
Rubus plicatus Weihe & Nees	0.0	0.0	0.0	1.5	0.0	0.5	1.5	0.0
Scirpus sylvaticus L.	0.0	0.5	1.0	0.5	1.0	0.5	2.5	2.0
Organic detritus	35.5	21.5	22.5	48.5	22.5	13.0	6.0	0.0
Stagnant water	0.0	0.0	0.0	1.0	0.0	24.5	29.5	0.0

dependant on rainfall and the duration of periods without precipitation [17]. Similar changes and relationships were observed in the middle reaches of the Kłodnica River in the Zabrze area [18], where the anthropogenic transformation of the surface led to the creation of valuable wetland communities.

The watercourse flowing through the Springs of the Kłodnica NLC is essential for plant growth. The necessary moisture during its scarcity in the areas located in the bottom of the valley and the areas above the bottom is accumulated by the Neogene silts. They show poor permeability and large water capacity due to a high content of colloidal clay. It is this property that determines the water retention and its capillary rising, making *Allium ursinum* grow beyond the valley zone. These deposits in the bottom of the valley are located very shallowly (up to 30 cm) and thus contribute significantly to the regulation of water conditions in the study area.

Changes in Vegetation Ranges

Species diversity, both within the valley as well as in the test plots, is determined by the topography and microtopography of the research area. Studies have shown a clear relationship between the topography and the distribution of vegetation. *Allium ursinum* specimens growing on small hills differ from those growing on waterlogged surfaces in terms of their viability (they were relatively grand and branch). The differences in the morphology of this species are largely dependent on the type of substrate and the density of vegetation, i.e. the availability of light [17], as well as the biology of the species [19]. Single plant clusters are lush and expansive. The same applies to *V. lobelianum*. Both test species generally prefer moist soil with high humus content [20]. When moving away from the river the growth of these species is much poorer; which is caused by change in the soil moisture. Its decrease may even lead to a complete disappearance of *A. ursinum*, as indicated by Tutin [21].

Essentially, during the whole study period the populations of *Allium ursinum* and *Veratrum lobelianum* did not change. The only observed changes were due to a strong gale at the beginning of March 2002. The result was a number of windfalls. A significant portion of the topmost soil layer and vegetation in the area of Nature and Landscape Complex, including some of the research plots, was completely destroyed as a result of the dumping of wood with heavy-duty vehicles by the forest service. The negative effects of transport were observed in the population of *A. ursinum* and *V. lobelianum* only in a year of devastation. In later years, these communities self-regenerated completely. Significant changes in the distribution of these species in the past six years (by 2013) are closely related to the terrain conditions. The ground subsidence that occurred in the southern part of the investigated object led to an excessive increase in the water table level and the occurrence of water on the ground surface in the case of increased rainfall, which caused changes in species composition. Such a situation was observed in the plot P_4, where *V. lobelianum* grew only on the ground swells. The relief there is of pit-mound nature. In the absence of watercourses draining the area this contributes to the swampy character of the area and leads to the transformation of the riparian habitat to the alder forests.

In 2003, as a result of the above-mentioned disorders, the *Allium ursinum* population decreased by 20% compared to 2002. The change in the test species' range is directly associated with a mechanical change in epipedon (top soil), together with the seed bank located there (including bulbs of *A. ursinum*). The damage of the humus horizon and its mixing with mineral horizons has led to changes in habitat conditions and the formation of microhabitats [22]. Another factor damaging soil cover and the associated vegetation was movement of vehicles of the forest service of the NLC. *Ajuga reptans*, *Rubus plicatus*, and other species encroached (Table 1) to the areas modified in this way.

The share of non-decomposed organic matter on individual plots had a significant impact on the development of vegetation. With a thicker detritus layer plant species could not germinate and rise to the surface. In the final period the area with organic detritus significantly decreased, which was due to higher moisture content (higher precipitation). The degree and rate of mineralization of plant litter [23] within each ecological system is critical in species diversity and abundance of habitats.

Conclusion

In the course of 13 years of observation of the dynamics of populations of *Allium ursinum* and *Veratrum lobelianum* there were no significant changes related to the operation of the mine. The watercourse flowing through the NLC shows seasonal fluctuations in water flow rate. This is often related to the amount of atmospheric precipitation. Moisture needed for plant growth during the lack of moisture in the areas bordering the watercourse is maintained by the Neogene silts characterized by poor permeability as well as high water capacity and content of colloidal clay. This is what determines the water retention and its capillary movement. Thanks to these properties of the geological structure, hygrophilous vegetation develops here. In the bottom of the valley these deposits are located very shallow (up to 30 cm) and significantly regulate the water conditions in the analyzed area.

Changes in studied populations of the monitored plant species (*Allium ursinum*, *Veratrum lobelianum*) are mostly connected with the anthropogenic factors related to the direct actions of the forest service.

The repeated floristic composition in the examined areas illustrates the stability of the habitat conditions; small differences are associated with local habitat changes, competition, and the biology of a given species.

The above facts indicate that exploitation by the Staszic Coal Mine in the monitored period of time did not have a negative impact on the functioning of the NLC. On the contrary, it helped to improve the functioning of a riparian ecosystem and thus a significant increase in the range of the observed protected species was recorded.

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