10.2478/v10067-011-0019-z

ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA
VOL. LXVI, 1 SECTIO C 2011

ANNA SOŁTYS-LELEK[1], BEATA BARABASZ-KRASNY[2]

[1]Ojców National Park, Ojców 9, Pl-32-047, e-mail: ana_soltys@wp.pl
[2]Department of Botany, Institute of Biology, Pedagogical University, Podbrzezie 3
Pl-31-054, Kraków, e-mail: beata_barabasz@poczta.onet.pl

Rebuilding of species composition of xerothermic grasslands in selected research areas in the Ojców National Park

Odtworzenie składu gatunkowego muraw kserotermicznych na wybranych powierzchniach badawczych w Ojcowskim Parku Narodowym

SUMMARY

The paper contains the results of monitoring of xerothermic grassland management conducted in the research areas Górkowa Skała and Grodzisko in the Ojców National Park. In Górkowa Skała active protection was implemented for the first time in 2005. In Grodzisko, in turn, the first protection measures were taken as early as 1982, but their systematic implementation was started only in 2000. Already at the current stage of investigation positive effects produced by these measures can be observed, especially in areas with relatively shallow soil profiles (around 30 cm). Plot monitoring results showed, among other things, an increase in the abundance and frequency of occurrence of grassland species preferring full-light conditions with periodic shading that grow in poor and dry soils. However, the obtained results also confirmed the assumption that the implementation of grass mowing, shrub clearance and plant biomass removal alone is not sufficient to ensure the restoration of a typical grassland species composition in deeper soil profile areas.Thus, it seems necessary that these protection measures should be supplemented by controlled grazing of farm animals.

STRESZCZENIE

Praca zawiera wyniki monitoringu zabiegów czynnej ochrony muraw ciepłolubnych, prowadzonego na powierzchniach badawczych „Górkowa Skała" oraz „Grodzisko" w Ojcowskim Parku Narodowym. Na „Górkowej Skale" ochronę czynną przeprowadzono po raz pierwszy w 2005 r. Z kolei na „Grodzisku" pierwsze zabiegi ochronne zastosowano już w 1982 r., ale systematyczne dopiero od 2000 r. Zwłaszcza na powierzeniach o stosunkowo płytkim profilu glebowym (ok.

30 cm) zabiegi te już na obecnym etapie obserwacji przyniosły pozytywny efekt. Na monitorowanych poletkach stwierdzono m.in. wzrost liczebności i frekwencji gatunków murawowych, preferujących warunki pełnego oświetlenia, z okresowym ocienieniem, porastających gleby ubogie i suche. Uzyskane wyniki potwierdzają również przypuszczenia, że samo koszenie, odkrzewianie i usuwanie biomasy roślinnej nie jest wystarczające do odtworzenia typowego składu gatunkowego muraw na glebie o głębszym profilu. Konieczne wydaje się uzupełnienie zabiegów ochronnych o kontrolowany wypas zwierząt gospodarskich.

Key words: xerothermic grassland, active protection of a seminatural grassland, changes of plant composition, Ojców National Park

Słowa kluczowe: murawy kserotermiczne, czynna ochrona półnaturalnych muraw, zmiany składu gatunkowego, Ojcowski Park Narodowy

INTRODUCTION

Xerothermic grasslands belong to the species-richest plant communities of the Ojców National Park (ONP). They currently occupy only 3% of its area, however they at the same time contain about 25% of all species growing in the Park. From the botanical point of view, the most valuable non-forest thermophilous communities include flowery swards with common origanum *Origano-Brachypodietum pinnati* Medw.-Korn. et Kornaś 1963, and the sward with furrowed fescue *Koelerio-Festucetum rupicolae* Kornaś 1952. About 30–35 species per a square metre can be observed in the patches of these communities (3).

Thermophilous grasslands of the ONP developed and survived thanks to pastoral farming. After the abandonment of traditional farming methods the majority of xerothermic grasslands disappeared due to secondary succession transforming themselves into thermophilous brushwood of the class *Rhamno-Prunetea* Rivas Goday et Garb. 1961, and thermophilous forms of dry-ground forest *Tilio cordatae-Carpinetum betuli* Tracz. 1962. In the early 1980s the conception of active protection of non-forest ecosystems was created in the Park (33). Since that time until the year 2010 protection measures had been introduced in twenty xerothermic grassland sanctuaries of a total area of about 39.5 acres (16 ha).

The aim of the present paper was the analysis of the floral composition of selected for monitoring xerothermic grassland plots and the changes taking place in their habitat conditions, as well as the assessment of the effectiveness of active protection methods used within their areas.

STUDY AREA

Górkowa Skała is a small rock massif of a southern exposure situated in the central part of the Ojców National Park, in the settlement of Zazamcze, nearby a field pathway called Jerzmanowska. In the 1960s the massif was overgrown with communities of flowery xerothermic swards *Origano-Brachypodietum*. However, even at that time almost half of that grassland was in the initial stage of secondary succession. The top part of the massif was then occupied by thermophilous brushwood *Peucedano cervariae-Coryletum* Kozł. 1925, and limestone rocks were dominated by rock swards *Festucetum pallentis* (Kozł. 1928) Kornaś 1950 (17). Even as recently as the early 1990s in the upper part of the massif the flowery sward *Origano-Brachypodietum* occurred, but in its lower part a community similar to *Tilio-Carpinetum* dry-ground forest developed. The thermophilous brushwood that once inhabited the hilltop has transformed itself into a community resembling mixed coniferous forest *Pino-Quercetum* Kozł. 1925 (=*Querco roboris-Pinetum* [W. Mat. 1981] J. Mat. 1988) (20). Active protection measures were for the first time introduced within the area of the massif in the autumn of 2005 (29). Trees and shrubs (mainly hornbeams, maples, oaks and spindle-trees) were then removed from an area of around 0.39 acres (0.16 ha). Monitoring of changes in the grassland species composition within permanent research areas located on the massif has been conducted since 2006.

The Grodzisko study area covers the 700-m-long section of the Prądnik Valley slope of high insolation and southern exposure, situated in the hamlet of Grodzisko, which is an administrative part of the town of Skała. The entire area is distinguished by greatly diversified relief. Vast rock complexes that occupy its western and eastern parts are dissected into groups and isolated rocks. No outcrops occur in the middle part of the area which is inclined at an angle of 25^0–40^0 (19). The soil in this area is, as in the Górkowa Skała research area, a type of limestone soil (11). According to Klein (14), almost the entire area is situated within the warmest meso- and microclimatic region distinguished by the highest insolation values (above 120%) and very high maximum and diurnal temperatures. Both microclimatic factors and the soil type create favourable conditions for the development of xerothermic vegetation.

In the early 18th century the area of Grodzisko was covered with dense brushwood and forest which became cleared while Blessed Salome's hermitage was built. At the end of the 19th century, because of intense grazing of farm animals the whole area was almost completely deforested and such a state lasted until the 1950s. Permanent and intense pastoral land use was a main factor that stabilized the species composition of the area's plant communities (19). However, since the 1980s until the end of the 1990s a significant increase in brushwood-forest surfaces could be observed in the studied area with a simultaneous decline in the participation of grasslands, mainly *Origano-Brachypodietum* swards. Even as recently as the mid-1990s the processes of succession consisting in grassland overgrowing were very intense in the area, which was favoured by a complete abandonment of grazing. The first measures of active protection were implemented in the area of Grodzisko in 1982, there is however a lack of detailed data about their use. In 1993 trees and shrubs were removed from an area of 1.48 acres (0.6 ha), and in the next year from an area of only 0.74 acre (0.3 ha) (2, 22, 23). In the winter of 1996 individual pine-trees and scattered sloe thicket were cleared from the 150-square-metre area in the upper part of the slope (24). In the years 1997–1998, after the removal of trees and shrubs, a 1.23-acre (0.5-ha) area of grass was mowed and dry biomass was then collected (25, 2, 3). Undertaken at that time active protection was however performed quite irregularly and in too small areas. Only as late as 2000 at the foot of rock outcrops a big part of the xerothermic slope of an area of 4.9 acres (2 ha) was unveiled (26). In 2001, in turn, chosen trees and shrubs growing at the foot of rocks were cleared from an area of 3.7 acres (1.5 ha) and the stems were removed. In the studied area the measures of active protection have been regularly performed only since 2003 (27, 28, 32).

METHODS

The investigations covered three permanent study plots situated in the Górkowa Skała research area and established a year after the implementation of the first measures of active protection, and three permanent study plots founded in the Grodzisko research area five years after the use of protection measures. The area of each plot was 100 sq. m and they were designated in places where the sward *Origano-Brachypodietum* formerly occurred. In the years 2006–2010 in Górkowa Skała at one-year intervals five phytosociological relevés were made based on methodology according to Braun-Blaquet. In Grodzisko, in turn, in the years 2005–2010 at the one-year and then the two-year interval four phytosociological relevés were made in each plot. The entire phytosociological material (27 relevés altogether) was included into the overall table comparing changes in the species composition within the studied plots. The list (made to meet the needs of the presentation of results) included mostly the taxa classified as xerothermic, and few forest-brushwood and ruderal species. Assigning particular species into xerothermic classes was made based on the work by Michalik (1979). The species characteristic of syntaxonomic units were determined following the work by Matuszkiewicz (2007).

In order to visualize habitat changes that occurred after the application of active protection measures, for each relevè weighted averages (based on species abundance) were calculated of the values of the following ecological indicators according to Ellenberg (9): L – light, F – soil moisture, R – soil reaction (pH), N – soil nitrogen content. Moreover, in the biotopic gradient the relevès from all plots were ordinated along the two first DCA axes – Detrended Correspondence Analysis DCA (12). This method is an especially useful tool for an indirect analysis of environmental gradients with which the differentiation of relevès from the studied plots is associated (10, 7, 13). The analysis was performed based on the species composition and the abundance of species according to the 6-degree Braun-Blanquet scale. Correlations between the values of DCA axes and the selected variables (Ellenberg's indicators, slope angle, herbaceous cover, tree and shrub cover, the number of species in a relevè) were calculated using Pearson's coefficient of correlation (r). DCA analyses were made using the CANOCO program, version 3.12 (35).

RESULTS

Significant changes in the floral composition of the studied xerothermic sward *Origano-Brachypodietum* that was subjected to active protection measures were observed in both Górkowa Skała and Grodzisko (Table 1). In Górkowa Skała within the period of monitoring an increase in the total number of recorded in relevès species was found, which was associated with the rebuilding of the species composition. In general, the species that appeared or increased their share in all three plots were: *Achillea collina, Euphorbia cyparissias, Stachys recta, Libanotis pyrenaica, Clinopodium vulgare, Coronilla varia, Origanum vulgare,* and *Verbascum lychnitis* belonging to the classes *Festuco-Brometea* and *Trifolio-Geranietea*. The relatively most considerable growth in the abundance of these species could be usually observed between the second and the fourth year of the use of protection measures. As regards forest-brushwood species, within the first five years of the application of protection measures they played no significant role in the species composition of the studied areas.

In Grodzisko, in turn, where monitoring was used during the period between the fifth and the tenth year of the protection measures application, an initial growth and then a decline in the total number of species in the relevés could be observed (Table 1). Compared with study plots located in the Górkowa Skała research area, an increase in the quantitative share of forest-brushwood species such as *Cornus sanguinea, Carpinus betulus, Fraxinus excelsior, Euonymus verrucosa,* and *Rubus idaeus* could be seen in the patches. This increase, however, did not lead to any rapid qualitative changes in the area's grassland species, whereas their

Table 1. Comparison of composition and quantitative participation of xerothermic species on renewed grasslands on permanent research plots Górkowa Skała (GS1-3) and Grodzisko (G1-3)

Relevé No.	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5	20	21	22	23	24	25	26	27	16	17	18	19	Degree of xerothermic plant vover
Study plot No.	GS2					GS3					GS1					G2				G3				G1				
Date	26. 06. 06	15. 06. 07	24. 06. 08	07. 07. 09	23. 06. 10	26. 06. 06	14. 06. 07	24. 06. 08	07. 07. 09	13. 07. 10	26. 06. 06	15. 06. 07	24. 06. 08	07. 07. 09	23. 06. 10	09. 08. 05	20. 07 06	29. 07 08	15. 07 10	03. 08. 05	11. 07 06	28. 07. 08	15. 07 10	09. 08. 05	20. 07. 06	29. 07. 08	15. 07. 10	
Slope (°)	35					45					45					40				40				40				
Cover shrubs (%)	10	10	15	15	30	5	4	3	10	30	30	10	10	10	30	10	5	10	50	5	10	10	40	10	10	30	40	
Cover herbs (%)	85	95	90	90	95	90	95	95	98	98	60	90	80	98	95	90	80	80	98	90	90	97	98	95	95	95	98	
Average thickness of soil coverage (cm)	29.8					42.8					95.4					30.4				52.0				105.6				
Number of species in relevé	43	58	65	67	68	34	43	58	55	62	34	43	55	62	63	63	87	91	82	81	88	96	83	81	89	84	61	
Ch.Cl. *Festuco-Brometea*																												
Anthemis tinctoria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	1	.	.	.	.	1	1	2	+	I
Melica transsilvanica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+	+	.	+	+	+	I
Verbascum chaixii ssp. *austriacum*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	+	+	+	+	+	+	+	II
Achillea collina	+	+	1	1	1	.	1	1	2	2	.	.	+	.	+	.	+	+	+	.	.	+	.	.	.	+	.	II
Salvia verticillata	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	I
Thymus marschalianus	.	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Brachypodium pinnatum	3	4	3	2	2	3	3	3	3	3	+	+	1	3	2	+	1	1	1	1	2	3	3	1	1	+	+	III
Euphorbia cyparissias	+	+	+	1	1	+	+	+	1	1	.	+	1	1	1	4	3	3	3	3	3	2	2	1	2	2	2	IV

Cont. Table 1

Phleum phleoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	1	1	1	1	+	+	2	2	I
Festuca rupicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	+	.	.	.	.	3	2	1	1	I
Allium oleraceum	.	.	.	+	+	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	+	+	+	+	II
Poa compressa	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	+	+	.	.	.	.	III
Helianthemum num-mularium	+	+	+	+	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	II
Stachys recta	+	+	2	2	2	+	+	+	2	2	.	+	2	2	3	.	.	.	.	.	.	.	.	.	.	.	.	II
Dianthus carthusia-norum	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Ajuga genevensis	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Ch. Cl. *Trifolio-Gera-nietea*																												
Geranium sanguineum	+	1	1	1	1	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	II
Libanotis pyrenaica	+	1	1	1	1	+	+	+	1	1	.	+	+	+	+	.	.	.	.	.	.	.	.	+	+	+	+	II
Anthericum ramosum	1	+	+	2	2	+	+	+	+	+	.	.	+	.	+	.	.	.	.	.	.	.	.	+	+	+	.	III
Trifolium rubens	+	+	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	III
Clinopodium vulgare	.	2	2	2	2	+	2	2	2	2	.	+	+	+	+	+	2	2	2	3	3	2	2	3	3	2	1	VI
Coronilla varia	.	+	2	4	2	+	+	2	4	3	.	+	3	4	3	+	+	1	2	2	1	1	2	1	1	1	1	III
Origanum vulgare	+	+	1	1	1	+	1	1	3	2	.	.	+	+	+	+	+	+	+	.	.	.	+	+	+	+	+	IV
Agrimonia eupatoria	1	1	1	1	1	+	+	+	2	1	.	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	+	III
Inula conyza	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+	+	1	1	+	+	III
Verbascum lychnitis	.	.	+	+	+	.	+	+	+	+	.	+	1	+	+	.	.	.	.	.	.	.	.	+	+	+	+	II

Cont. Table 1

Ch. Cl. *Rhamno-Prunetea*																												
Cornus sanguinea (b)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	2	3	1	1	1	1	1	2	2	4	VI
Euonymus europaea (b)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	+	1	1	1	+	+	+	1	3	-
Crataegus monogyna (b)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	+	+	1	+	+	+	V
Rosa canina (b)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	+	V
Rubus bifrons (b)	.	.	.	.	.	+	+	+	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	IV
Cotoneaster intergerrimus (b)	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	III
Rubus bifrons (c)	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	IV
Ch.Cl. *Querco-Fagetea*																												
Carpinus betulus (b)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	1	1	+	+	+	+	+	+	+	1	-
Fraxinus excelsior (b)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	1	2	-
Euonymus verrucosa (b)	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	.	.	.	.	+	+	+	+	+	1	3	3	-
Aegopodium podagraria	.	.	.	.	+	.	.	.	.	.	4	3	3	4	2	.	.	.	.	.	.	+	.	.	.	.	.	-
Ch. Cl. *Artemisietea vulgaris*																												
Picris hieracioides	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	+	.	.	+	+	.	II
Ch. Cl. *Epilobietea angustifolii*																												
Rubus idaeus (b)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	+	+	+	1	+	+	+	1	-

Cont. Table 1

Calamagrostis epigejos	.	.	+	+	+	+	1	1	.	.	.	.	.	.		.	+	2	2	+	+	1	3	+	+	2	1	-
Others																												
Chamaecytisus supinus (c)	.	+	+	+	+	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	II
Pimpinella saxifraga	+	+	+	+	+	+	+	+	+	+	.	.	.	.	.	1	1	+	+	+	+	+	+	.	.	+	.	IV
Laserpitium latifolium	.	+	+	+	+	.	.	.	+	+	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	+	IV
Vincetoxicum hirundinaria	+	+	+	+	+	.	.	.	.	.	.	.	.	+	+	+	+	+	+	.	.	.	.	+	+	+	+	IV
Verbascum nigrum	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	III
Polygala comosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	III
Potentilla collina	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	+	.	.	II
Allium montanum	.	.	.	.	.	.	.	.	.	.	+	1	1	+	+	.	.	.	.	.	.	.	.	.	.	.	.	III

abundance was subject to slight fluctuations. An alarming phenomenon was the spread of the reed grass *Calamagrostis epigejos* which quantitative share in the examined plots increased, especially between the eighth and the tenth year after the implementation of active protection measures. Despite that, the participation of grassland species in the study plots of Grodzisko was greater and their xerothermic degrees were higher compared with the plots located within the Górkowa Skała research area (Table 1).

The comparison of the species number from eight syntaxonomic classes in the restoring itself xerothermic grassland after five and ten years of the use of active protection revealed that the biggest increase in the species number took place in the classes *Molinio-Arrhenatheretea* and *Artemisietea* (Fig. 1). Within the classes such as *Festuco-Brometea, Rhamno-Prunetea,* and *Stellarietea*, this growth was slight. Among the species from the classes *Trifolio-Geranietea* and *Epilobietea* an insignificant decrease in the species number was observed. The number of forest species of the class *Querco-Fagetea* remained at the same level.

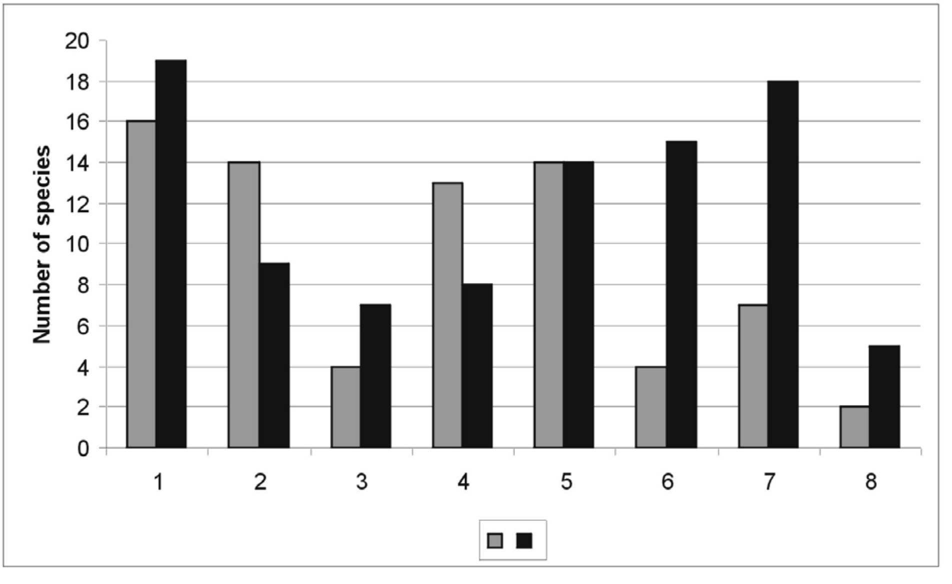

Fig. 1. Comparison of the species number from eight classes of vegetation in renewed xerothermic grassland after 5 years (Górkowa Skała – grey) and after 10 years (Grodzisko – black) from the application of active protection: 1 – *Festuco-Brometea*, 2 – *Trifolio-Geranietea sanguinei*, 3 – *Rhamno-Prunetea*, 4 – *Epilobietea angustifolii*, 5 – *Querco-Fagetea*, 6 – *Molinio-Arrhenatheretea*, 7 – *Artemisietea*, 8 – *Stellarietea mediae*

The analysis of weighted averages of Ellenberg's indicator values for light – L, soil moisture – F, soil reaction (pH) – R, and soil nitrogen content – N, showed positive habitat changes, especially during the first five years of the application

Table 2. Changes of Ellenberg's average indicator values calculated for plots on the study areas Grodzisko and Górkowa Skała

Name of area and plot No.	Year	Ellenberg's indicator values			
		light – L	soil moisture – F	soil pH – R	soil nitrogen – N
Grodzisko	2005	7.87	4.42	7.56	5.06
G1	2006	6.96	4.20	6.99	4.06
	2008	6.83	4.10	6.80	4.45
	2010	6.63	4.13	7.28	4.40
Average value G1		7.07	4.21	7.16	4.49
G2	2005	7.16	3.90	7.28	4.53
	2006	6.99	4.03	7.22	4.23
	2008	6.97	4.09	7.26	4.38
	2010	7.03	4.06	7.34	4.43
Average value G2		7.04	4.02	7.27	4.39
G3	2005	6.90	4.27	7.15	4.84
	2006	6.90	4.37	6.93	4.70
	2008	6.86	4.35	6.87	4.71
	2010	6.84	4.23	7.14	4.62
Average value G3		6.87	4.30	7.02	4.72
Górkowa Skała	2006	5.42	4.84	7.03	5.85
GS1	2007	5.69	4.64	7.17	5.14
	2008	6.22	4.47	7.28	5.03
	2009	6.33	4.41	7.43	4.67
	2010	6.49	4.27	7.35	4.40
Average value GS1		6.03	4.53	7.25	5.02
GS2	2006	6.14	4.20	7.20	4.46
	2007	6.46	4.11	7.40	4.00
	2008	6.60	4.08	7.47	3.79
	2009	6.77	4.06	7.36	3.88
	2010	6.82	4.01	8.08	3.77
Average value GS2		6.56	4.09	7.50	3.98
GS3	2006	6.18	4.14	7.42	4.15
	2007	6.50	4.09	7.39	3.86
	2008	6.57	4.40	7.35	4.21
	2009	6.85	3.99	8.07	3.68
	2010	6.83	4.13	7.48	3.89
Average value GS3		6.59	4.15	7.54	3.96

of protection measures (Table 2). In Górkowa Skała, in all three plots (GS1, GS2, GS3) a marked increase in the values of light and soil reaction (pH) indicators was observed, which was accompanied by a simultaneous decrease in the values of soil moisture and soil nitrogen content indicators. In the case of plots located in Grodzisko (G1, G2, G3), positive trends in habitat changes were not so clearly discernible and fluctuations in the values of these indicators were noted, which might be an effect of various other external factors. The analysis of ranges of average indicator values obtained from study plots located in Grodzisko and

Górkowa Skała revealed that as regards light indicators they were higher in the plots of Grodzisko (L – 6.87–7.07 G; 6.03–6.59 GS), whereas higher ranges of average values of indicators of soil moisture (F – 4.02–4.30 G; 4.09–4.53), soil reaction (pH) (R – 7.02–7.16 G; 7.25–7.54 GS), and soil nitrogen content (N – 4.39–4.72 G; 3.96–5.02) were found in the plots located within the Górkowa Skała research area.

The numerical ordination based on the species composition in phytosociological relevés performed in the years 2006–2010 in Górkowa Skała (plots GS1-3) and in the years 2005–2010 in Grodzisko (plots G1-2), made along I and II DCA axes, allowed their arrangement from the relatively species-poorest associated with the solum of the highest soil reaction, moisture and nitrogen content, and at the same time the most deficient in thermophilous species (left upper part of the graph), to the species-richest connected with the solum of a slightly lower soil reaction, moisture and nitrogen content, but the most abundant in thermophilous species (right bottom part of the graph) – Table 3, Fig. 2B. In this case, a highly negative value of the slope angle correlation with II DCA axis was also found. In the ordination of data based on the species quantitative participation, the relevés were arranged from the relatively species-poorest and at the same time containing the least number of thermophilous species (left part of the graph) to the relatively species-richest with the greatest number of thermophilous species (the right part of the graph) – Figure 2A. The second axis presented in this case no significant direction of variability (Table 3).

Table 3. Values of Pearson's correlation (r) between DCA axes, environmental variables and average Ellenberg's indicator values, calculated for phytosociological relevés from study areas in the Ojców National Park; the highest values of the correlation were distinguished in bold

Characteristics	DCA by presence of species		DCA by abundance of species	
	Axis I	Axis II	Axis I	Axis II
Aspect	-0.16	**-0.69**	-0.32	0.06
Herbaceous cover	0.18	-0.07	0.22	-0.14
Shrubs and trees cover	0.10	0.00	0.17	0.00
Number of species in relevé	**0.84**	0.08	**0.75**	-0.16
Ellenberg indicator values:				
Light L	**0.70**	0.33	**0.71**	-0.18
Soil moisture F	-0.21	**-0.69**	-0.39	-0.34
Soil reaction (pH) R	**-0.47**	0.33	-0.37	0.11
Soil nitrogen N	0.22	**-0.72**	0.00	-0.10

DISCUSSION

The results obtained from the monitoring of permanent study plots established within two study areas where active protection measures were introduced, that is Grodzisko and Górkowa Skała, confirmed a positive effect of these measures on the restoration of the xerothermic sward *Origano-Brachypodietum* species composition (Table 1). The performance of protection measures consisting in grassland mowing and regrowth removal especially during the first years results in radical changes in habitat conditions (21). The effect of this was a relatively fast species replacement process, which was particularly noticeable in the study plots of Górkowa Skała. In this case the analysis of Ellenberg's indicators very clearly showed the trend of variation in the species composition, that reflected the changes taking place in the habitat (Table 2). The uncovering of the surface increased the availability of light and decreased solum moisture allowing at the same time the encroachment of photophilous species associated with grasslands (Fig. 1–2, Table 3). In the plots located in the Grodzisko research area, where the monitoring was performed between the fifth and the tenth year of the use of active protection measures, habitat changes did not demonstrate such a clear trend. It can be assumed that other additional factors that are probably responsible for this situation might start to play a more significant role in the process within the next years of the protection measures application. Some researchers claim, for instance, that the course of weather in particular years is an essential factor in determining the composition of grassland species (31, 30, 3). It is likely that factors of this kind resulted in fluctuations in the species composition of the analyzed patches. It is also possible that this situation is a reflection of errors in the performance of protection measures.

The ordination of relevés from the plots of Grodzisko and Górkowa Skała, made along the two first DCA axes, clearly demonstrates that these plots form two separate groups as regards both the species composition and quantitative species participation in the relevés (Fig. 2). The relevés made in plots located in Grodzisko are marked by, among other things, the greater total number of species in a relevé, the bigger share of thermophilous species associated with poor soils, and the smaller participation of wet-loving species (Table 1–3). All this confirms the fact that in comparison with the plots of Górkowa Skała, they represent the older stage of regeneration of the *Origano-Brachypodiedum* sward. It is also noticeable that the species composition of the relevés performed in Górkowa Skała is less homogenous than that of the plots of Grodzisko, which is evidenced by the dissipation of relevé groups – Figure 2A.

Habitat changes caused by the implementation of protection measures initiate a rapid growth in the total number of species in patches. An increase in the species number after the removal of trees and shrubs from grasslands has

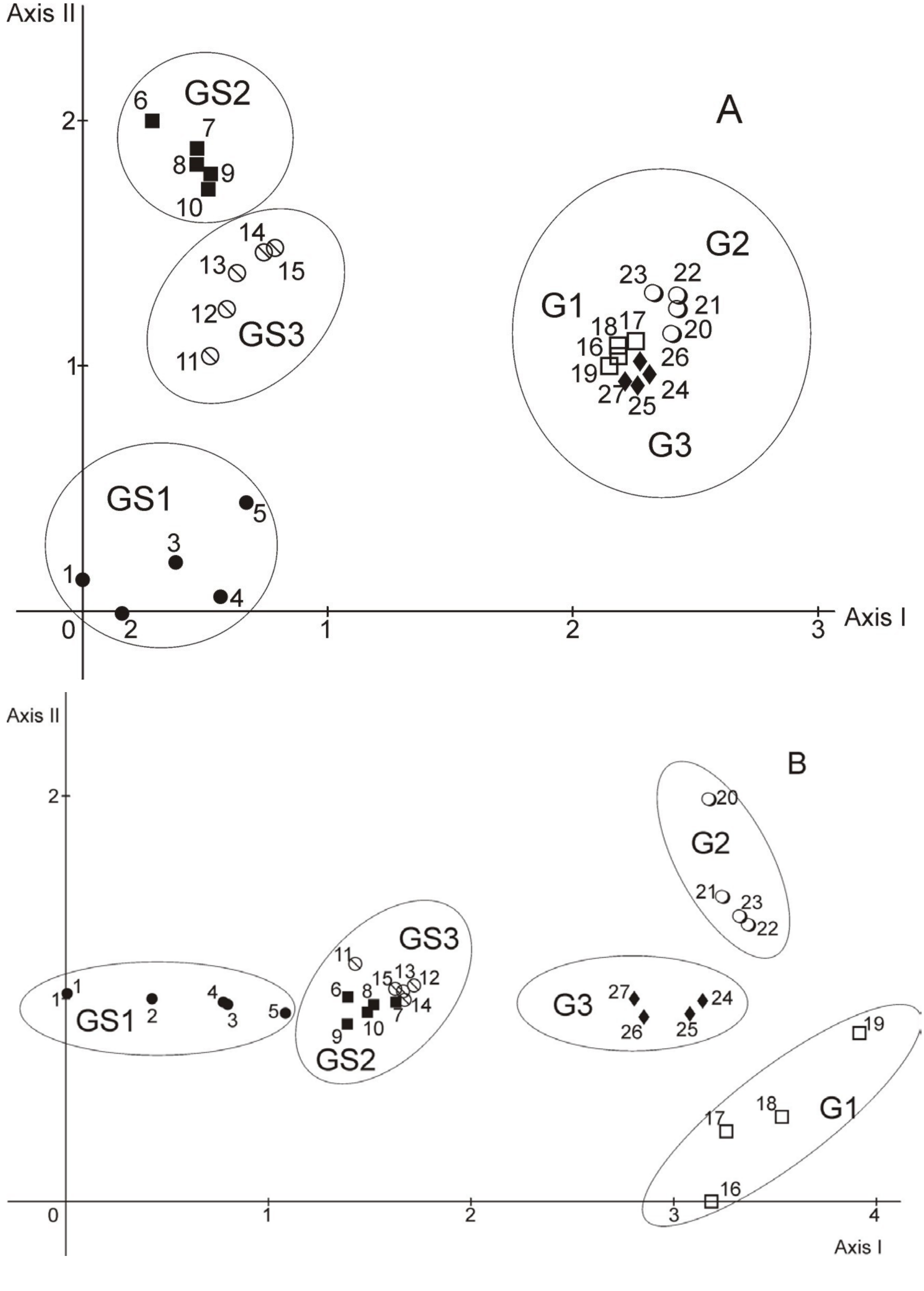

Fig. 2. Ordination of phytosociological relevés made in Górkowa Skała in 2006–2010 (plots GS1-3) and Grodzisko in 2005–2010 (plots G1-3), according to I and II DCA axes; A – based on species abundance, B – based on species presence

been observed many times (1, 8, 5, 3). This phenomenon also occurred in the plots of Górkowa Skała. It can be assumed that such a spectacular growth in the species abundance in patches was the result of the simultaneous presence of both photophilous and shade-loving species, the remains of brushwood that once occupied the area. In the plots located in the Grodzisko research area, the number of species remained at the similar, relatively high level, or demonstrated some fluctuations. Between the eight and the tenth year of the use of active protection, an increase in the forest-brushwood species quantitative participation took place, especially in distinguished by deeper soil profiles (from 52 cm to above 120 cm) plots G1 and G2, which in turn led to a decline in the total number of species in these patches. The way of protection measures performance plays a crucial role in the regeneration of sward communities, which was already pointed out by many researchers (4, 36, 34, 21). The appearance of species associated with disturbed habitats, e.g. *Calamagrostis epigejos* and *Solidago canadensis*, which, regrettably, was observed in both monitored areas, can be a signal that the used so far method of active protection is insufficient, especially in relation to swards growing in deeper profile soils.

In the course of investigations an increase was found in the number of grassland species of various xerothermic degrees (Table 1). The quantitative participation in the studied plots attained by some of these species was relatively high. This refers to, e.g.: *Brachypodium pinnatum*, *Coronilla varia*, *Clinopodium vulgare*, *Euphorbia cyparissias*, *Origanum vulgare*, and *Stachys recta.* It was at the same time determined that the rate of xerothermic species appearance and forest-brushwood species extinction was slower within the successive years of the application of protection measures. In spite of a gradual increase in the number of species typical of grasslands, meadows and thermophilous saum-communities, the participation of forest species between the fifth and the tenth year of the protection measures use remained at the same level (Fig. 1). The occurrence of a similar phenomenon in either the plots that were mowed and cleared of shrubs, or those in which only shrub clearance was performed was described by Bąba (3), who came to a conclusion that the effectiveness of the employed conservation methods was strongly dependent on the degree of grassland overgrowing. He demonstrated that in the overgrown patches of swards inhabiting deeper profile soils active protection did not lead to the restoration of typical grasslands.

The results of studies presented in this paper suggest that the implementation of active protection leads to positive changes in the grassland species composition, however, the use of mowing, shrub clearance and biomass removal as the only conservation method is not sufficient to ensure its complete restoration, especially that after five years of such protection the rate of grassland renovation is noticeably slower. It seems therefore necessary that active protection measures should be supplemented by the introduction of controlled grazing of farm animals such as sheep and goats. Extensive grazing has a positive impact on the soil structure, restrains the expansion of shrubs and brings about the disappearance of grasses which might be easily replaced by dicotyledonous plants associated with xerothermic grasslands (6, 15).

REFERENCES

1. Andrzejewski H. 1987. Changes in the species composition and structure of the herb layer of a thermophilous oak forest subject to clear cutting. Acta Soc. Bot. Pol. 56 (3), 513–525.
2. Bąba W. 1999. Murawy kserotermiczne w planie ochrony Ojcowskiego Parku Narodowego. Przegląd Przyrodniczy 10 (1/2), 129–136.
3. Bąba W. 2002/2003. Ekologiczne podstawy ochrony muraw kserotermicznych w OPN. Prądnik. Pr. i Mat. Muz. im. Prof. W. Szafera 13, 51–76.
4. Bobbink R., During H., Schreurs J., Willems J., Zielman R. 1987. Effects of selective clipping and mowing time on species diversity in chalk grassland. Folia Geobot. Phytotax. 22, 365–376.
5. Bodziarczyk J., Michalewicz J, Szwagrzyk J. 1999. Secondary forest succession in abandoned glades of the Pieniny National Park. Pol. J. Ecol. 47 (2), 175–189.
6. Bornkamm R. 2006. Fifty years vegetation development of a xerothermic calcareous grassland in Central Europe after heavy disturbance. Flora 201, 249–267.
7. Digby P. G. N., Kempton R. A. 1987. Multivariate analysis of ecological communities. [In:] Population and Community Biology Series. M. B. Usher, M. L. Rosenzweig (eds). Chapman & Hall, London, p. 206.
8. Dzwonko Z., Loster S. 1998. Dynamics of species richness and composition in a limestone grassland restored after three cutting. J. Veg. Sci. 9, 387–394.
9. Ellenberg H., Weber H., Dull R., Wirth V., Werner W., Paulissen D. 1992. Zegerverte von Pflanzen in Mitteleuropa. Scripta Geobot. 18, 1–258.
10. Gauch H. G. 1986. Multivariate Analysis in Community Ecology. Cambridge University Press, Cambridge.
11. Greszta J., Bitka R. 1977. Gleby. [In:] Przyroda Ojcowskiego Parku Narodowego. Zabierowski K. (red.) Studia Naturae ser. B. 28, 81–89.
12. Hill M., Gauch H. G. 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 42, 47–58.
13. Jongman R., ter Braak C. J. F., van Tongeren O. R. F. 1995. Data Analysis in Community and Landscape Ecology. Pudoc, Wageningen.
14. Klein J. 1974. Mezo- i mikroklimat Ojcowskiego Parku Narodowego. Studia Naturae ser. A. 8, 1–105.
15. Krasicka-Korczyńska E., Stosik T. 2010. Wpływ oddziaływań zooantropogenicznych na roślinność muraw kserotermicznych. [In:] Ciepłolubne murawy w Polsce – stan zachowania i perspektywy ochrony. H. Ratyńska, B. Waldon (eds) Wyd. Uniwersytetu Kazimierza Wielkiego, Bydgoszcz, 80–94.
16. Matuszkiewicz W. 2007. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Vademecum Geobotanicum. Wydawnictwo Naukowe PWN, Warszawa.
17. Medwecka-Kornaś A., Kornaś J. 1964. Mapa zbiorowisk roślinnych Ojcowskiego Parku Narodowego. Ochr. Przyr. 29, 17–87.
18. Michalik S. 1979. Charakterystyka ekologiczna kserotermicznej i górskiej flory naczyniowej Ojcowskiego Parku Narodowego. Studia Naturae ser. A. 19, 7–95.

19. Michalik S. 1990a. Przemiany roślinności kserotermicznej w czasie 20-letniej sukcesji wtórnej na powierzchni badawczej „Grodzisko” w Ojcowskim Parku Narodowym. Prądnik. Pr. i Mat. Muz. Prof. W. Szafera 2, 43–52.
20. Michalik S. 1991 (ed.). Zbiorowiska roślinne i waloryzacja szaty roślinnej terenu Ojcowskiego Parku Narodowego. Mskr. p. 84, Zakład Ochr. Przyr. i Zasob. Nat. PAN, Kraków.
21. Michalik S., Bąba W. 1999. Aktywna ochrona półnaturalnej murawy kserotermicznej na Skale Krukowskiego w Ojcowskim Parku Narodowym. Ochr. Przyr. 56, 51–59.
22. Partyka J. 1994 (ed.). Analiza działalności OPN za rok 1993. Mskr., Ojców, 13–14.
23. Partyka J. 1995 (ed.). Analiza działalności OPN za rok 1994. Mskr., Ojców, 17.
24. Partyka J. 1997 (ed.). Analiza działalności OPN za rok 1996. Mskr., Ojców, 10.
25. Partyka J. 1998 (ed.). Analiza działalności OPN za rok 1997. Mskr., Ojców, 40–41.
26. Partyka J. 2001 (ed.). Analiza działalności OPN za rok 2000. Mskr., Ojców, 55.
27. Partyka J. 2004 (ed.). Analiza działalności OPN za rok 2003. Mskr., Ojców, 19.
28. Partyka J. 2005 (ed.). Analiza działalności OPN za rok 2004. Mskr., Ojców, 13–14.
29. Partyka J. 2006 (ed.). Analiza działalności OPN za rok 2005. Mskr., Ojców, 23–25.
30. Peco, B., Espigares, T., Levassor, C. 1998. Trends and fluctuations in species abundance and richness. Appl. Veg. Sci. 1, 21–28.
31. Rejmanek M., Rosen E. 1992. Cycles of heterogeneity during succession: a premature generalization? Ecol. 73, 2329–2331.
32. Sołtys A., Barabasz-Krasny B. 2006. Przemiany roślinności kserotermicznej na powierzchni badawczej „Grodzisko” w Ojcowskim Parku Narodowym. Prądnik. Pr. i Mat. Muz. im. Prof. W. Szafera 16, 89–118.
33. Sołtys-Lelek A., Barabasz-Krasny B. 2009. Skuteczność dotychczasowych form ochrony flory i szaty roślinnej w Ojcowskim Parku Narodowym. Ochr. Środ. i Zasob. Nat. 39, 89–102.
34. Stampfli A. 1992. Year-to-year changes in unfertilized meadows of gread species richness detected by point quadrat analysis. Vegetatio 103, 125–132.
35. ter Braak C. J. F. 1991. CANOCO-a FORTRAN program for CANOnical Community Ordination by (partial) (detrended) (canonical) correspondence analysis, principal components analysis and redundancy analysis. 3.12. Microcomputer Power. New York.
36. Willems J. H., Peet R., Bik L., 1993. Changes in chalk-grassland structure and species richness resulting from selective nutrient additions. J. Veg. Sci. 4, 203–212.