Original Research

Flora Dynamics in a Strictly Protected Nature Reserve

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Abstract

The Świnia Góra nature reserve was established in 1938 to protect natural forest phytocoenoses. It was studied between 1964 and 1969 and during this investigation almost 350 species of vascular plants were documented. After 40 years of strict protection the studies were repeated to describe the nature reserve's flora dynamics.

A considerable decrease in number is particularly observed in the case of species belonging to *Molinio-Arrhenatheretea*, *Nardo-Callunetea*, and *Scheuchzerio-Caricetea nigrae*. The disappearance of representatives of the above socioecological groups is a result of increasing forest glade succession. Statistically relevant changes also have been noted as regards the trophic status of the nature reserve's flora, based on ecological indicators. The higher the status, the more extensive the eutrophication of the forest habitats.

Keywords: strict protection, nature reserve, succession, dynamic tendencies

Introduction

"Nature reserve" is one of 10 nature conservation designations in Poland, created to protect areas of importance for wildlife, flora, fauna, and cultural or landscape features. It can be afforded strict, active or landscape protection. Only 2% of the total area of all Polish nature reserves is strictly protected [1]. Nature reserves are set aside to protect climax species or natural processes promoting their development. Theoretically, phytocoenoses that develop within the nature reserves and the respective flora should be restored to their natural character with time. Sites afforded this kind of protection should be a perfect place to observe natural ecologic processes. However, in numerous cases the impact from the neighborhood results in natural processes being accompanied by degeneration [2-5]. The nature reserve that is positively different here is the only strict nature reserve in Świętokrzyskie Voivodeship, i.e. Świnia Góra nature reserve.

Świnia Góra strict nature reserve is one of the most precious protected forest areas in Poland. Its forest plant communities and flora are natural and the landscape is similar to that of the primeval forests found in Świętokrzyska Forest. It is located just a few kilometers from public roads and dense development. Local vegetation has been strictly protected for over 70 years. Due to this, Świnia Góra is the perfect place for naturalists to conduct multidisciplinary studies as its environment has not been influenced by human activities [6-8].

Detailed botanical studies were prepared for Świnia Góra nature reserve in the 1960s [9, 10]. After 40 years of strict protection as a nature reserve, floristic studies of the area were repeated to determine the dynamics of the vascular flora. Efficacy of the protection within the reserve also was evaluated.

The nature reserve was established on the post-mining area, when between the 17[th] and 19[th] centuries iron ores were extracted using open-cut mining techniques [11, 12]. Numerous collapsed abandoned excavation sites and adits, as well as the surrounding remains of infertile waste rock

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(dump), are signs of mining activities once carried out in this area. As a result, soil types and moisture content differ from place to place, and totally different types of vegetation may occur within a relatively small area [13]. Phytosociological studies conducted in the 1960s confirmed the above relationship. Nineteen different vegetation units were documented [9]. The area's flora is also very rich. Floristic studies conducted between 1964 and 1969 revealed 357 species of vascular plants, many of them rare and protected [10].

The nature reserve comprises three forest units: Nos. 162, 163, and 164.

Unit No. 162 is the biggest one and its plant communities are most diverse. Fir and beech stands are the most numerous, growing on the considerably damp acid sites. The northeastern part of the unit is divided by a small stream, along which a narrow strip of alder trees forms a poor riparian forest. In the 1960s, within unit No. 162, at the northern border of the nature reserve there were 3 small glades with a total area of approximately 2 ha. The glades were habitats to meadow, peat and rush communities with species composition of considerable value.

Unit No. 163, the second largest, is home to the most precious forest communities. Rich Carpathian beech forest is the dominant element here. It has grown on a bed that was largely changed due to the mining operations conducted here in the past [9]. The stand is varied in this unit regarding the number of species and their age. Massive firs, sycamore maples, beeches, oaks and larches can be found here.

Upland mixed conifer forest dominates in unit No. 164. In the southern part of the unit there is a small strip of swamp conifer forest.

Experimental Procedures

Studies were carried out during the 2008 and 2009 vegetation seasons using a route method. A floristic record was made for each of the three forest units within the nature reserve. Latin names of the plants were given after Mirek et al. [14] and phytosociological affiliation was determined according to Matuszkiewicz [15]. Species protected by law were selected according to the Ordinance on Protected Wild Floral Species of the Minister of Environmental Protection of 9 July 2004 [16]. Disappearing and endangered taxa for Poland were listed after Zarzycki and Szeląg [17]. The red list of vascular plants in the Wyżyna Małopolska upland was given after Bróż & Przemyski [18]. To determine the ecological spectrum of plant species and changes of habitat conditions, average ecological indicators for vascular plants were used [19]. Changes of light (L), moisture (M), trophy (Tr), and acidity (R) indicators were analyzed. The average values of ecological indicators were calculated using an arithmetical mean. The statistical relevance of the differences obtained was checked by Wilcoxon's signed-ranks test, at $p<0.05$ [20].

Results

294 representatives of vascular plants were identified as a result of the floristic studies conducted. From among them, 38 belong to protected or endangered categories (Table 1). Compared to the situation back in the 1960s, the nature reserve's flora has been depleted by 74 species. Among the species which have not been found in the nature reserve there are 17 protected or endangered taxa – the number of valuable species decreased from 52 to 35 (Table 1). At the same time, 11 new taxa have been found in the nature reserve's flora. Among them are three protected plants (*Aruncus sylvestris*, *Primula veris,* and *Vinca minor*) (Table 1.) and two foreign species (*Aesculus hippocastanum*, *Prunus cerasifera*). The remaining 283 species were recorded again after 40 years.

Analysis of the phytosociological affiliation demonstrated a particular decrease in the number of species belonging to *Molinio-Arrhenatheretea*, *Nardo-Callunetea*, and *Vaccinio-Piceetea* (Fig. 1). As regards *Molinio-Arrhenatheretea*, the biggest decrease was noted in the number of *Arrhenatheretalia* (Fig. 2).

Detailed comparative analysis demonstrated that there were significant changes in the floristic composition of the nature reserve's individual forest units. Considerable decrease in the number of species was observed in Unit Nos. 162 and 163. Compared with 1964-69, in Unit No. 162 there were 88 fewer species of vascular plant. Some of the species (22) were found in other parts of the nature reserve. Additionally, 36 new taxa were reported. In the part of the nature reserve in question the species that particularly decreased in number were those belonging to *Molinio-Arrhenatheretea*, *Vaccinio-Piceetea*, and *Nardo-Callunetea* (Fig. 1). Within unit No. 163 species associated with communities of non-conifer forest and conifer forest disappeared. A slight decrease in the number of species associated with peat and rush communities was noted (Fig. 1). The number of vascular plant species was observed to have risen in unit No. 164. Compared with research conducted 40 years ago, 48 new taxa were observed and 19 taxa were not found. It should be stressed that the number of plants from the dynamic eutrophic circle of non-conifer forest doubled. At the same time, the number of species characteristic of the dynamic circle of conifer forests on poor and acid sites decreased (Fig. 1). In the next stage average values of indicators for the whole nature reserve and individual values for each of the units were compared. As regards light indicator, there was a slight decrease in the number of species preferring higher solar radiation intensity. The value of the following indicators was observed to have risen: moisture, trophy, and acidity. However, the results do not reflect the changes that occurred in individual forest units which differ as regards the dynamics and nature of changes. In unit No. 162 a smaller intensity of solar radiation was observed, while the moisture, trophy, and acidity increased. Statistically relevant differences were demonstrated for the last two indicators (Table 2). A slight increase of light, trophy, and bed pH indicators were observed (statistically rel-

Table 1. List of protected and endangered vascular plants in Świnia Góra nature reserve.

No.	Species	Risk categories		Conservation status	Unit 162		Unit 163		Unit 164	
		Region	Country		1969	2009	1969	2009	1969	2009
1	*Allium ursinum*	NT	[V]	Chr.cz.	+	+	+	+		
2	*Aquilegia vulgaris*			Chr.			+			
3	*Aruncus sylvestris*	NT		Chr.		+				
4	*Asarum europaeum*			Chr.cz.	+	+	+	+	+	+
5	*Blechnum spicant*	CR		Chr.	+					
6	*Botrychium lunaria*	CR	V	Chr.	+					
7	*Cephalanthera longifolia*	VU	V	Chr.	+			+		
8	*Convallaria majalis*			Chr.cz.	+	+	+	+		
9	*Corallorhiza trifida*	EN	V	Chr.	+					
10	*Crepis mollis*	VU			+	+				
11	*Dactylis polygama*	EN					+			
12	*Dactylorhiza maculata*	VU	V	Chr.	+					
13	*Dactylorhiza majalis*			Chr.	+	+				
14	*Daphne mezereum*			Chr.	+	+	+	+	+	
15	*Dentaria enneaphyllos*	VU					+	+		
16	*Epipactis helleborine*			Chr.	+	+				+
17	*Epipactis palustris*	VU	V	Chr.	+					
18	*Frangula alnus*			Chr.cz.	+	+	+	+	+	+
19	*Galium odoratum*			Chr.cz.		+	+	+		+
20	*Gentiana pneumonanthe*	VU	V	Chr.	+	+				
21	*Gladiolus imbricatus*	VU		Chr.	+	+				
22	*Gymnocarpium robertianum*	EN			+		+	+		
23	*Hedera helix*			Chr.cz.	+	+	+	+		+
24	*Hieracium racemosum*	VU	R		+					
25	*Huperzia selago*	VU	[V]	Chr.	+	+				
26	*Iris sibirica*	VU	V	Chr.	+	+				
27	*Ledum palustre*			Chr.					+	+
28	*Leucorchis albida*			Chr.	+					
29	*Lilium martagon*			Chr.	+		+	+		
30	*Listera ovata*	VU		Chr.	+	+	+			
31	*Lycopodium annotinum*			Chr.	+	+	+		+	+
32	*Lycopodium clavatum*			Chr.		+			+	+
33	*Lysimachia nemorum*	VU			+					
34	*Melittis melissophyllum*			Chr.		+	+	+		
35	*Neottia nidus-avis*			Chr.	+	+	+	+		
36	*Ononis arvensis*			Chr.cz.	+					
37	*Ophioglossum vulgatum*	VU	V	Chr.	+	+				
38	*Orchis mascula*	EN	V	Chr.	+					
39	*Parnassia palustris*	NT			+					

Table 1. Continued.

No.	Species	Risk categories		Conservation status	Unit 162		Unit 163		Unit 164	
		Region	Country		1969	2009	1969	2009	1969	2009
40	*Pedicularis sylvatica*	VU		Chr.	+					
41	*Platanthera bifolia*			Chr.	+					
42	*Platanthera chlorantha*			Chr.	+	+		+		
43	*Polygonatum verticillatum*	NT			+	+	+	+		+
44	*Primula elatior*			Chr.cz.	+	+	+			+
45	*Primula veris*			Chr.cz.		+				
46	*Pyrola rotundifolia*	NT			+					
47	*Senecio nemorensis*	VU			+	+	+	+	+	+
48	*Streptopus amplexifolius*	CR		Chr.	+	+	+	+		
49	*Taxus baccata*	VU		Chr.			+	+		
50	*Thalictrum aquilegifolium*	LC			+	+				
51	*Thalictrum flavum*	NT			+					
52	*Trollius europaeus*	NT		Chr.	+	+				
53	*Veronica montana*	VU			+		+	+		+
54	*Viburnum opulus*			Chr.cz.	+	+	+	+	+	+
55	*Vinca minor*			Chr.cz.		+				

Risk categories: Region – according to Bróż and Przemyski [18]: CR – critically endangered, EN – endangered, VU – vulnerable, NT – near threatened, LC – least concern.
Country – according to Zarzycki and Szeląg [17]: V – vulnerable, [V] – vulnerable (at isolated sites outside of the main area of occurrence) in Poland, R – rare (potentially endangered).
Conservation status – pursuant to the Ordinance on Protected Wild Floral Species of the Minister of Environmental Protection of 9 July 2004: Chr. – strictly protected, Chr. cz. – partially protected.

evant difference) in Unit 163, with a decrease in the number of hygrophilous species noted at the same time. Unit No. 164 is better lit and its moisture content increased. Furthermore, the number of acidophilic species and those preferring sites of higher trophic status was observed to have increased. Statistically relevant differences were obtained for bed pH and light indicator.

Discussion of Results

More than 40 years ago, Świnia Góra strict nature reserve was an outstanding place because of the diversity of its vegetation that had developed partly as a result of human activity. Now, without any human activity for more than 50 years, changes have taken place that can be described as secondary succession and regeneration leading to a climax stage [21]. The effects are, among others, partial depletion of the nature reserve's flora, and less habitat heterogeneity [22] with the nature reserve being more natural at the same time. As a result, the number of vulnerable and protected species in the reserve has decreased from 52 to 35. The biggest decrease was observed in unit No. 162, where their number has fallen from 39 to 30.

The main processes in the nature reserve involve a secondary succession of glades, eutrophication of forest habitats and aging of stands.

In many cases, nature reserve conservation failed to protect precious non-forest ecosystems [23, 24]. Strict protection implemented over recent years has resulted in the disappearance of some of the glades and many precious species, which due to the lack of light gave way to species more accustomed to being poorly-lit. The species that most quickly disappeared from the glades were those related to fresh meadows and *Nardetalia* grassland. Those that have remained are species related with *Molinion* meadows, and can be quite numerous in juvenile forms of riparian, alder, and oak-hornbean forests. Use must be quickly resumed in the reserve as it is the only way to preserve precious non-forest communities, i.e. a large number of vulnerable and protected species of vascular plants. However, in the authors' opinion, the process of succession which has been going on for several years should be allowed to continue in the nature reserve, and should not be stopped even if precious species of vascular plants are to be lost. *Molinion* meadows that are still present in the nature reserve, and which will disappear as a result of succession, are relatively abundant in the Suchedniowski Sub-Plateu and

Gielniowski Hill [25, 26], and should be protected in the course of farm use.

Within the whole nature reserve, forest community eutrophication can be observed. This is evidenced by the increase of trophy and acidity index (Table 3). These tendencies have been observed across Poland in different forest units [27-31] and the process becomes more and more common, even in relatively well preserved forest biocenoses. There is much evidence that productivity of forest habitats in European forests has been noted to have increased during the last century [32]. Therefore, changes noted in Świnia Góra might result from the regeneration of forest communities and global changes. Climate changes and air pollution have a large impact on the processes observed [33-35]. Climate fluctuations facilitate the growth of species with higher thermal requirements (for example *Fagus sylvatica* and *Carpinus betulus*) and their expansion into coniferous forest habitats [36, 37]. In natural forests, these effects can be strengthened by tree fall gaps and dead wood. In Świnia Góra nature reserve numerous gaps in stands have been observed as a result of the disappearance of old trees of *Abies alba* and *Fagus sylvatica*. This results in improvement of light conditions and facilitates decomposition of organic matter. The factors discussed provide a good base for the growth of nitrophilous, gap-dependent species. Another reason behind the increased trophic status of habitats in question is the invasion of non-conifer trees to conifer forest habitats. Apart from soil trophy increase as a result of plant litter activity, the above results in a considerable decrease of available light, which in turn leads to the disappearance of acidophilic, oligotrophic species of groundcover. However, as demonstrated by research conducted in Roztocze National Park, it is not certain if the observed changes are directional and will result in transformation of *Abietetum polonicum* phytocenoses into *Tilio-Carpinetum abietosum*, or if they are fluctuating in nature [38, 39].

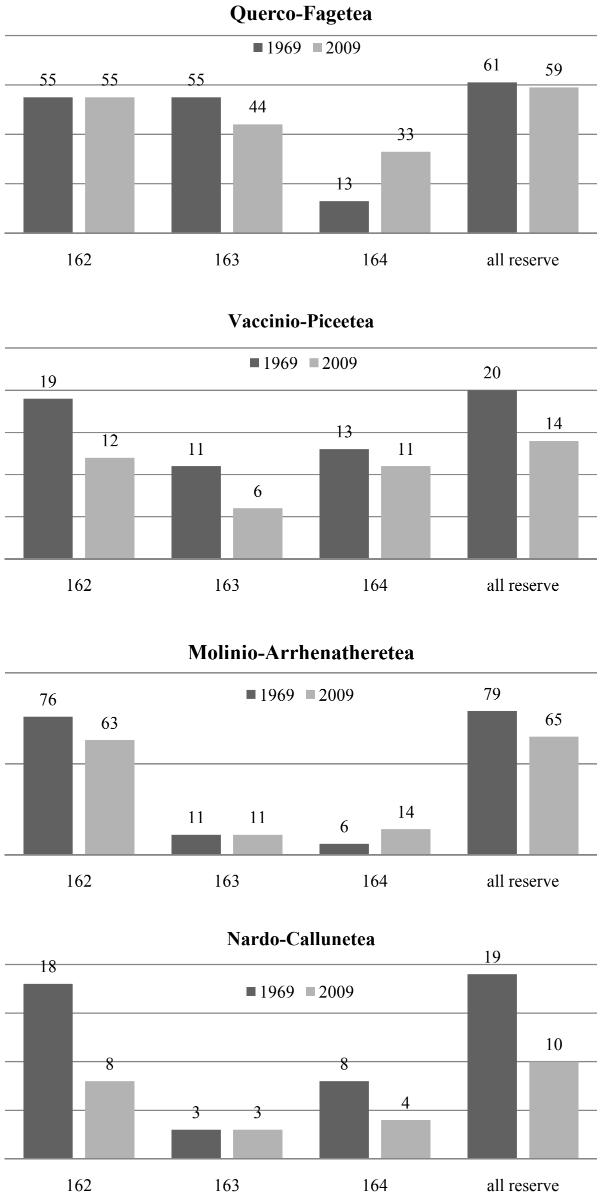

Fig. 1. Number of species characteristic of individual phytosociological classes in the years 1964-69 and 2008-09.
Mol-Arr – Molinio-Arrhenatheretea: seminatural grassland and pasture community with varying degrees of humidity
Que-Fag – Querco-Fagetea: eutrophic broadleaved forests
Vac-Pic – Vaccinio-Piceetea: coniferous forests on acid and poor habitat
Nar-Cal – Nardo-Callunetea: seminatural and antropogenic community of Nardus stricta swards and heathland
Phr. – Phragmitetea: rash community
Sch-Car – Scheuchzerio-Caricetea: lowmoor and transitional moor communities
Art.vul – Arthemisietea vulgaris: community of perennial plant on ruderal habitats
Epi.ang – Epilobietea angustifolii: clearing communities
Tri-Ger – Trifolio-Geranietea: ecotone habitats with termophilous community

Aging of stands is particularly visible in unit No. 163, where the late terminal phase covers a relatively large area. It is characterised by uneven/or dispersed stand structure. The decomposition phase is observed in a few places too. This tendency is confirmed by improvement of light conditions as shown by ecological indicators. The death of old trees (mainly *Fagus sylvatica* and *Abies alba*) is too fast a process to make self-sowing possible. This results in the occurrence of sites that are almost totally devoid of trees and inhabited mainly by herbaceous plants and bushes. The phase breaks the continuity of the forest in a given area, thus resulting in a loss of characteristics of the forest environment [40]. The increased death of old firs may be a result of the above-mentioned climate changes, because

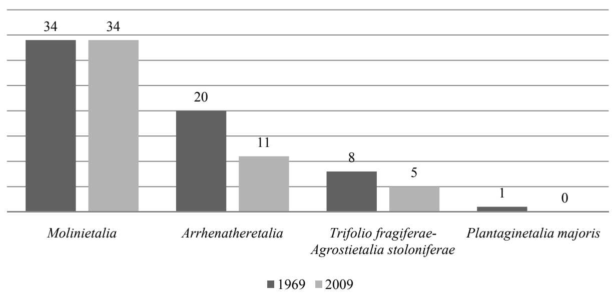

Fig. 2. Number of species characteristic of *Molinio-Arrhenatheretea* in the years 1964-69 and 2008-09.

Table 2. Changes of average values of ecological indicators of a site based on ecological indicators.

The type of ecological indicator	1969 (average value with standard error)	2009 (average value with standard error)	Difference between average value
Unit No. 162			
Light value (L)	3.58±0.05	3.52±0.05	0.06
Soil moisture value (W)	3.47±0.05	3.57±0.05	-0.10
Trophy value (Tr)	3.42±0.03	3.52±0.03	-0.10*
Soil acidity value (R)	3.82±0.04	3.86±0.04	-0.04*
Unit No. 163			
Light value (L)	3.16±0.07	3.18±0.08	-0.03
Soil moisture value (W)	3.48±0.06	3.44±0.06	0.05
Trophy value (Tr)	3.48±0.04	3.55±0.05	-0.07
Soil acidity value (R)	3.79±0.05	3.82±0.05	-0.04*
Unit No. 164			
Light value (L)	3.47±0.09	3.51±0.08	-0.04*
Soil moisture value (W)	3.63±0.10	3.68±0.08	-0.05
Trophy value (Tr)	3.55±0.06	3.49±0.06	0.07
Soil acidity value (R)	3.87±0.07	3.78±0.07	0.09*

*statistically relevant values

they have grown in different ecological conditions [41]. In places where forest regeneration is visible, there is a slight domination of *Fagus sylvatica*. Fir regeneration and growth processes may be hindered by the changed chemical composition of soils, which is a consequence of air pollution [42].

The results indicate that strict protection does not contribute to conserving fir habitat or upland fir forest, and therefore confirms that the community is not a climax one [43]. It was concluded that passive protection extended over a longer period results in the failure to maintain the community's proper condition. Nevertheless, no active protection whatsoever should be extended to fir habitat in Świnia Góra nature reserve. The only thing that is allowed is to observe natural processes at work left to their own devices.

This form of protection, however, is in conflict with the goals of protection of Natura 2000 Suchedniów Forests habitat (code: PLH 260010), which also covers the nature reserve and aims at conserving the Świętokrzyski fir forest. Yet, it is most important to preserve the continuity of natural processes occurring in phytocoenoses in this relatively small area, even if the area of legally protected habitats was to decrease.

Conclusions

During the last 40 years 74 species of the flora have disappeared from the strict nature reserve, 12 of them being endangered or protected and at the same time 11 new taxa were noted. Based on the type of changes observed within the reserve, the authors have found the following processes to occur within the reserve: secondary succession of glades, eutrophication of forest habitats and aging of stands.

Strict protection implemented over recent years resulted in the disappearance of some of the glades and many precious species, which due to the lack of light gave way to species more accustomed to being poorly-lit. The species that most quickly disappeared from the glades were those related with fresh meadows and *Nardetalia* meadows.

Forest community eutrophication can be observed within the whole nature reserve. This is evidenced by the increase of trophy and acidity index.

The changes are probably caused by two reasons, i.e. forest communities regeneration and global changes observed across Europe.

References

1. DOMAŃSKA W. (Ed.) Environment 2009. The Central Statistical Office, Warsaw, pp. 527, **2009**.
2. BOUTIN C., JOBIN B. Intensity of agricultural practices and effects on adjacent habitats. Ecol Appl **8**, 544, **1998**.
3. CULLEN L., SCHMINK M., PADUA CV., MORATO MIR. Agroforestry benefit zones: a tool for the conservation and management of Atlantic forest fragments, Sao Paulo, Brazil. Nat. Areas J. **21**, 346, **2001**.
4. GÖTMARK F., THORELL M. Size of nature reserves: densities of large trees and dead wood indicate high value of small conservation forests in southern Sweden. Biodiversity and Conservation **12**, 1271, **2003**.
5. DUGUAY S., EIGENBROD F., FAHRIG L. Effects of surrounding urbanization on non-native flora in small forest patches. Landscape Ecol. **22**, 589, **2007**.

6. FIJEWSKI Z. Breeding avifauna of the "Świnia Góra" forest reserve. Kulon **2**, (2), 195, **1997** [In Polish].
7. LEŚNIAK A. Ground beetles (*Carabidae*, *Coleoptera*) of Świnia Góra Reserve in the Świętokrzyskie Mountains. Fragm. faun. **44**, 41, **2001**.
8. LEŚNIAK A. Communities of terrestral entomofauna with special emphasis on *Carabidae* (*Coleoptera*) in the protected and managed forests in Świętokrzyski region. Leś. Pr. Bad. **3**, 75, **2004** [In Polish].
9. FABIJANOWSKI J., ZARZYCKI K. Vegetation of Świnia Góra forest reserve in the Świętokrzyskie Mountains. Acta Agr. Silv. ser. Silv. **5**, 61, **1965** [In Polish].
10. PIĘKOŚ H. The vascular plant of Chief Forestry Bliżyn in Holy Cross Mountains. Frag. Flor. Geobot. **17**, (1), 59, **1971**.
11. BARAŃSKI S. A few words on the history of Bliżyn forests in the first half of 19th century. Sylwan **103**, (8), 59, **1959** [In Polish].
12. OLACZEK R. Treasures of Polish nature and landscape. MULTICO Oficyna Wydawnicza, Warszawa pp. 765, **2008** [In Polish].
13. ADAMCZYK B. Studies in the relations between bedrock and soil. Part I. Soils of Świnia Góra forest reserve derived from variegated sandstone formations (Lower Triassic). Acta Agr. Silv. ser. Silv. **5**, 3, **1965** [In Polish].
14. MIREK Z., PIĘKOŚ-MIRKOWA H., ZAJĄC A., ZAJĄC M. Vascular plants of Poland – a checklist. IB PAN, Kraków, pp. 303, **2002**.
15. MATUSZKIEWICZ W. A guide to identification of Polish plant communities. PWN, Warszawa, pp. 537, **2005** [In Polish].
16. Ordinance on Protected Wild Floral Species of the Minister of Environmental Protection of 9 July 2004:, J.L. No. 168, item **1764** [In Polish].
17. ZARZYCKI K., SZELĄG Z. Red list of the vascular plants in Poland. [In:] Z. Mirek, K. Zarzycki, W. Wojewoda, Z. Szeląg. Red list of plants and fungi in Poland. IB PAN, Kraków: pp. 9-20, **2006**.
18. BRÓŻ E., PRZEMYSKI A. The red list of vascular plants in the Wyżyna Małopolska upland. [In:] Z. Mirek, A. Nikel. Rare, relict and endangered plants and fungi in Poland. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, pp. 123-136, **2009**.
19. ZARZYCKI K., TRZCIŃSKA-TACIK H., RÓŻAŃSKI W., SZELĄG Z., WOŁEK J., KORZENIAK U. Ecological indicator values of vascular plants of Poland. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków pp. 183, **2002**.
20. ŁOMNICKI A. Introduction to statistics for naturalists. Wydawnictwo Naukowe PWN, Warszawa, pp. 261, **2003** [In Polish].
21. WHITTAKER R. A consideration of climax theory: The climax as a population and pattern. Ecolog. Monographs **23**, 41, **1953**.
22. FALIŃSKA K. Plant Ecology. Wydawnictwo Naukowe PWN, Warszawa, pp. 511, **2004** [In Polish].
23. WILCZEK Z., BERNACKI L., ORCZEWSKA A. Conserving meadow ecosystem at "Góra Tuł" (Silesian Foothills) through nature reserve designation. Przegl. Przyr. **12**, (3-4), 223, **2001** [In Polish].
24. CIERZNIAK T., RATYŃSKA H., BANASZAK J., KACZMAREK L. Influence of strict protection on xerothermic grassland and bee fauna on the esker near the Lake Budzyńskie (Wielkopolski National Park). Przegl. Przyr. **16**, (3-4), 53, **2005** [In Polish].
25. ZIOMEK J., OLACZEK R., KOPEĆ D. Preliminary draft and principles of conservation for the Przysucha Geoparc (Central Poland). Conference materials: "Potential for geoparks establishment in the light of landscape and regional research". Kielce, **2009**.
26. PODGÓRSKA M. Endangered species of vascular plants of *Selino-Molinietum* in Garb Gielniowski. In: Z. Mirek, E. Cieślak, B. Paszko, W. Paul & M. Ronikier (Ed.), Rare, endangered and relict species of plants and mushrooms – Risks and conservation of the Polish flora. Paper and poster summaries. Institute of Botanics at the Polish Academy of Sciences and University of Agriculture in Kraków, Kraków, pp. 127, **2006** [In Polish].
27. PALUCH R. Direction and rate of successional changes in the strict reserve of the Białowieża National Park. Kosmos **51**, (4), 453, **2002**.
28. WOZIWODA B. Changes in oak-hornbeam forest in the north part of the Wysoczyzna Łaska mesoregion (Central Poland). Ecol. Quest. **2**, 117, **2002**.
29. KOPEĆ D., SIERADZKI J. Floristical change after 40 years of conservation in "Murowaniec" nature reserve Parki nar. Rez. Przyr. **25**, (3), 87, **2006** [In Polish].
30. KOPEĆ D. Dynamic tendencies in the forest communities of the "Murowaniec" nature reserve after 40 years of protection. Fol. For. Pol., ser. A, Forestry **48**, 5, **2006**.
31. BRZEZIECKI B. Long-term dynamics of natural tree stands in two forest habitats of the Białowieski National Park: *Pino-Quercetum* and *Tilio-Carpinetum*. Studia Naturae **54**, (2), 9, **2008** [In Polish].
32. SPIECKER H., MIELIKÄINEN K., KÖHL M., SKOVSGAARD J.P. Growth Trends in European Forest; EFI Research Report 5. Springer, Berlin, **1996**.
33. KOWALSKI M. Ecological succesion in Polish Forests. Fol. For. Pol., Sectio A – Forestry **34**, 5, **1992**.
34. BRZEZIECKI B. Habitat trophic level increase: myth or reality? Sylwan **143**, (11), 99, **1999** [In Polish].
35. MALZAHN E. Risks and contamination of forest environment in Białowieża Forest. Pr. IBL, Ser B, **1999** [In Polish].
36. KOWALSKI M. Climate – a changing component of forest site. Fol. For. Pol., ser. A, Forestry **33**, 25, **1991**.
37. SIWECKI R. Global climate change and oak dying. Sylwan **138**, (10), 43, **1994** [In Polish].
38. FALIŃSKI J. Ecological processes in forest habitats. Phytocoenosis 3 (N.S.) **1**, 17, **1991** [In Polish].
39. IZDEBSKI K., CZARNECKA B., GRĄDZIEL T., LORENS B., POPIOŁEK Z. Plant communities of the Roztocze National Park and habitat conditions. Wydawnictwo UMCS, Lublin **1992** [In Polish].
40. MIŚCICKI S. Natural stages in tree stand development – basics of forest reserve taxation. Sylwan **138**, (4), 29, **1994** [In Polish].
41. TREPIŃSKA J. Thermal fluctuations in Poland and in Europe. Sylwan **138**, (9) 23, **1994** [In Polish].
42. JANUSZEK K. Selected chemical properties of soils in certain fir stands (*Abies alba* Mill.) of various growth conditions in Southern Poland. Acta Agr. Silv., ser. Silv. **29**, 3, **1990** [In Polish].
43. MRÓZ W., ŁABAJ A. Świętokrzyski fir forest (*Abietetum polonicum*). In: Herbich J. (Ed.). Forests and conifer forests. Guides to Natura 2000 habitat and species protection – Teacher's handbook. Vol. **5**. Ministry of Environment, Warszawa: pp. 274-280, **2004** [In Polish].