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"Ancient forest" plant species as ecological indicators of woodland condition in parks and their implications for park restoration

Gatunki roślin „starych lasów" jako ekologiczne wskaźniki stanu zadrzewień parkowych i ich zastosowanie w rewaloryzacji parków

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ABSTRACT: Presence of plant species, associated with ancient forests (continuous existence >200 years) can be used for assessing woodland biodiversity. The aim of this study is to specify which plant species, included in the ancient forests plant species list, can indicate old woodlands in parks and what plant features are characteristic for certain habitat types. Richest in ancient forest plant species are those fragments of woodlands, which have existed continuously for at least 120 years, and their fragments suffered least from human pressure during that time, whereas recent woodlands are characterized by a small share of ancient forest indicator species and domination of nitrophilous species. Investigated plants usually propagate vegetatively, their seeds are of a small size and they have regularly, densely set leaves. Plants associated with ancient woodlands are good indicators of woodland continuity in parks so they can be used for age assessment in these areas. Accumulation of such plants can be a useful criterion in parks evaluation. Proposed idea of sustainable management of a park space, including selection of areas of a great ecological value, can be a chance to preserve woodland biodiversity.

Key words: Wielkopolska, Mazury, country parks, ancient woodland indicator species, old woodlands

Introduction and aim of the study

Vegetation of country parks was either created by men and managed according to specified composition rules, or created by adapting fragments of old natural forest ecosystems (Majdecki 1981). Parks have adjusted, in the same way as forests, to limited recreation pressure and moderate management. Intensification of any of those anthropogenic factors leads to species richness decrease and causes simplification of woodlands ecological structure. Moreover such changes are not compliant with sustainable usage of woodland vegetation patches and result in decline of most vulnerable components. In the Masurian Lakes District and Wielkopolskie Lake District extensively managed parks, under low anthropogenic pressure, were mostly destroyed in the 20th century, mainly due to ownership changes. Similar vegetation management changes and counteraction against e.g. trampling, have already been observed in the 19th-century urban parks open for general use (Siewniak, Mitkowska 1988). One of the first degeneration symptoms, resulting from excessive trampling, is decline of forest plant species (Faliński 1965, 1966). Such phenomenon in woodland parks leads directly to plant species diversity loss which results in decrease of ecological and esthetical values of these objects (Olaczek 1972, Fijałkowski, Kseniak 1982, Majdecki 1993, Fornal-Pieniak, Wysocki 2009). Woody patches of rural parks play a significant role in preservation of forest plant species populations, especially in areas where forests were entirely destroyed (Olaczek 1972). Protection of rural parks in Poland includes also their ecological values. This is why during historical parks restoration, according to the international document Burra Charter (www.icomos.org/australia), these elements should also be recreated. Even parks which structure strongly resembles natural woodlands are not as rich in species characteristic for forest plant communities as forests themselves (Sikorski, Wysocki 2003). Not all parks act as a refuge for forest plant species to the same extent. Woodland stability has a great effect on their abundance. Among plant species associated with natural forests there are also "ancient woodland" plant species, connected with areas that have been continuously forested for at leas 200 years (Dzwonko 2007). Species attachment to such stable habitats is due to their little tolerance to diverse environmental conditions and low dispersal capability when

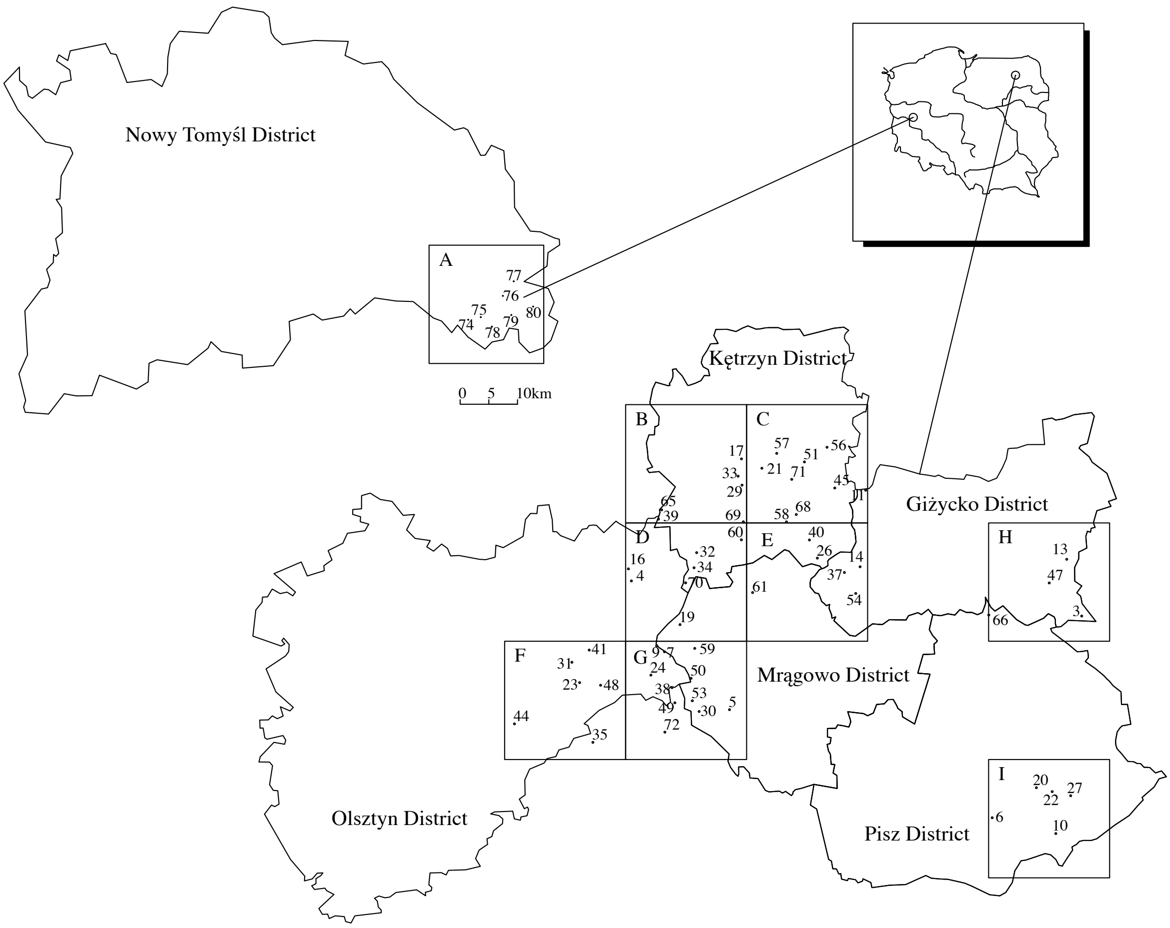

Fig. 1. Investigated rural parks located in ATPOL grid squares, names of the parks, where "old woodlands" were recorded, are in bold: *Wielkopolskie Lake District* – square A. **74. Porażyn Dwór,** 75. Porażyn Wieś, 76. Rudniki, 77. Niegolewo, 78. Sielinko, 79. Opalenica, 80. Dakowy Mokre, *Masurian Lake District* – B. 17. Grabno, 29. Kotkowo, 33. Linkowo, 39. **Mołdyty**, 42. Nisko, 55. **Samulewo**, 65. Troks, 69. Wangut, C. 11. Doba, 21. Kaskajmy, 45. Parcz, 51. Różanka, 56. **Siniec**, 57. Skierki, 58. Sławkowo, 68. Wajsznory, 71. Wopławki, D. 4. **Bęsia**, 16. Górowo, 19. **Janiszewo**, 32. **Leginy**, 34. **Łężany**, 60. Stachowizna, 70. Wola, E. 14. Głąbowo, 26. Koczarki, 37. Mleczkowo, 40. **Nakomiady**, 54. Ryński Dwór, 61. Szestno, F. 23. Kierzbuń, 31. Kramerowo, 305. Małszewo, 41. Nasy, **44. Pajtuny**, 48. **Rasząg**, G. 5. Bieńki, 7. Borki Wielkie, 9. Dąbrówka Kłobucka, 24. **Kobułty**, 30. Kozłowo, 38. **Mojtyny**, 49. Rogale, 50. Rozogi, 53. Rybno, 59. **Sorkwity**, 72. Zalesie, H. 3. Berkowo, 13. Gawliki, 47. **Ranty**, 66. **Ublik**, I. 6. **Borki**, 10. Długi Kąt, 20. Kaliszki, 22. **Kawałek**, 27. Komorowo

Fig. 2. Woodlands established in 1868 – on the basis of the park project created by J. Larras (A) and condition of recent woodlands, based on aerial images from 1997 (B). Based on these maps woodlands older than 140 years („old") can be recognized and woodland which developed later due to spontaneous regeneration (recent).

colonizing new areas. (Peterken 1974, Honnay i in. 1999a, Hermy i in. 1999, Dzwonko, Loster 2001, Dzwonko 2007).

The aim of this study was to specify which plant species, included in the ancient forest plant species list, can indicate old woodlands (continuous existence >120 years) in parks; recognition of plant features characteristic for certain habitat types and estimating possibility of using ancient woodland plant species approach in parks evaluation.

Object of the study

As object of the study, rural parks were selected, originally designed as landscape parks at the and of the 19^{th} and at the beginning of the 20^{th} century. Typical of those parks are woodlands similar to natural, what makes them well harmonized with surrounding landscape (Majdecki 1981). All 63 investigated objects were located in ATPOL system grid squares (20×20km) which were randomly selected (Fig. 1). These squares have the highest density of parks in a given region. The study was carried out in two macro-regions: Wielkopolskie Lake District and Masurian Lake District (Kondracki 2002). The dominant geological substrates are terminal and ground moraines along with their foreland. Variety of geological forms affects directly soil fertility and humidity diversification in habitats occurring here. Dominating soils are fertile brown soils (Uggla 1956).

Great climatic diversity of lake district regards mostly to temperature and precipitation. Masurian Lake District is described as a moderate warm region (mean annual temperature 6,5°C) and moderate humid (annual precipitation 550-650mm), Wielkopolskie Lake District is considered to be warm (mean annual temperature 7,7°C) and dry (annual precipitation 450-550mm) (Ziernicka-Wojtaszek, Zawora 2008, Kondracki 2002).

Methods

We studied undergrowth vegetation in woodlands which developed on fertile *Tilio-Carpinetum* and *Galio sylvatici-Carpinetum* sites. Field studies were carried out in years 2002-2008, each park was investigated at least twice – in spring and mid-summer. In every object a floristic listing of vascular plant species was conducted in 20×20m square of ground cover vegetation in the least degraded part of woodland.

According to Wulf's classification (2003), park woodlands were divided into ancient woodlands, whose habitat continuity lasts for at least 200 years, old woodlands, dating back to

Fig. 3. Painting of a Ranty Park, performed after World War I for documentary purposes (Rothgiesser R. 1916 – from „Aus den zerstörten Masuren" 36×27 cm) was used in order to identify several woodlands existing in that time.

120-200 years and recent woodlands, established during last 120 years. There is a lack of data in parks, concerning woodlands older than 200 years, so old woodlands are the patches well documented to exist before year 1888 (park project, cartographic or iconographic materials – e.g. fig. 2, drawings and photographs – e.g. fig. 3). These materials show that dense tree canopy layer has already been noticed then. Assumed stand age – 120 years – is the latest period possible to verify using land-cover and cadastral maps. In many cases it was positively verified that stands situated on hillsides (Bęsia, Zalesie) and in the neighborhood of forest complexes (Sztynort) were actually old stands, whereas most young parks were established much later, due to natural succession or by planting held since 1945. Floristic data in undergrowth were acquired in woodlands of age 120 years and older, in cases where they were lacking, younger patches were also taken into account. Age of a stand was finally determined in the field, on the basis of increment core taken with the Presler borer.

Floristic data, performed in both woodland types, were used in this study. Basing on abundance of so called "ancient woodland plant species" presented in the work of Dzwonko (2007) analysis of woodland patches age was performed. Taking into account whole floristic richness of particular objects, different indicators were calculated, concerning habitat degeneration, plant species dispersion mode, and plant morphological features (Roo-Zielińska et al. 2007). Moreover indicator values such as hemeroby and C-S-R strategy of plant species according to Grime (2001) were calculated, using BiolFlor database (Kühn et al. 2009).

Hemeroby indicators refer to transformation of flora and are adequate to plant species behavior in response to human activities which is expressed by species assignment to different categories – from least to most degraded – oligohemerob, mezohemerob, a-euhemerob, b-euhemerob, polyhemerob (Wysocki, Sikorski 2009). C-S-R strategy indicators reflect plant species reaction in relation to effect of external factors, where S indicator – reflects reaction to stress, "r" – disturbance in habitat and "c" – competition (Grime et al. 2001).

Ancient woodland species' preference of habitat condition is expressed by Ellenberg indicator values (Ellenberg et al. 1991) – for light, humidity, pH and nitrogen content. These numbers from 1 to 9 reflect strength of plants' attachment to habitat parameters mentioned. Dispersion capability of ancient woodland plant species and their ability to colonize new areas was estimated basing on parameters such as: dominating propagation mode and mean seed weight, using values given by Šerá and Šerý (2004), reproductive capacity of population (Šerá, Šerý 2004), share of plant species of certain dispersion mode (Dzwonko 2007) and distance within which 99% of a species' seeds will disperse during 1 year (Vittoz, Engler 2007).

Morphological features of ancient woodland plants occurring in parks were shown using indicators, such as mean height of particular plant species, calculated based on maximal and minimal data available (LEDA database) (Knevel i in. 2003), specific leaf area SLA (LEDA), share of plants developing different leaves distribution type – erosulate plants, hemirosette and rosette plants (Kühn et al. 2004).

Significant differences between indicator values and plant parameters were calculated using analysis of variances (one-way ANOVA) and t-test at significance level p<0,05 with STATISTICA 8 software. Floristic nomenclature was used after Rutkowski and associates (1994).

Results

Ancient woodland plant species occur in both old and younger woodlands, termed here as recent, dating back from dozens of years. However the number of such plant species is nearly twice as big (16,5) in case of old patches than in recent (8,53). Attachment to old parks is revealed by 21 out

Table 1. Mean degeneration indicator values for ancient forest plant species in recent and old woodlands, values statistically significant in bold, ns – not significant

	OLD WOODLAND	RECENT WOODLAND	p-value
Total number of ancient woodland plant species	**16,50**	8,53	**0,000**
Share [%] of mezo/oligohemerobic taxa	**0,72**	0,58	**0,000**
Share [%] of mezohemerobic taxa	0,27	**0,41**	**0,000**
Share [%] of C-strategy taxa (competitors)	0,427	**0,464**	**0,013**
Share [%]of S-strategy taxa (stress-tolerant)	**0,362**	0,325	**0,002**
Share [%] of R-strategy taxa (ruderals)	0,202	0,204	ns

Table 2. Abundance frequency of ancient forest plant species in recent and old woodlands

	OLD WOODLAND	RECENT WOODLAND	p-value
Geum urbanum	95%	93%	ns
Viola reichenbachiana	95%	77%	ns
Galeobdolon luteum	95%	33%	**0,000**
Poa nemoralis	85%	51%	**0,007**
Stellaria holostea	85%	23%	**0,000**
Mycelis muralis	75%	30%	**0,000**
Hepatica nobilis	65%	9%	**0,000**
Ficaria verna	60%	63%	ns
Festuca gigantea	60%	42%	ns
Dactylis polygama	50%	9%	**0,000**
Galium sylvaticum	5%	16%	ns
Brachypodium sylvaticum	5%	5%	ns
Melica nutans	5%	2%	ns
Moehringia trinervia	5%	2%	ns
Pteridium aquilinum	5%	2%	ns
Paris quadrifolia	5%	0%	ns
Scilla bifolia	5%	0%	ns
Pulmonaria obscura	40%	7%	**0,001**
Lathyrus vernus	40%	5%	**0,000**
Scrophularia nodosa	35%	35%	ns
Gagea lutea	35%	23%	ns
Ajuga reptans	35%	2%	**0,000**
Carex digitata	35%	2%	**0,000**
Dryopteris filix-mas	30%	9%	**0,041**
Stachys sylvatica	30%	9%	**0,041**
Sanicula europaea	30%	5%	**0,005**
Asarum europaeum	25%	5%	ns
Milium effusum	25%	5%	**0,018**
Convallaria majalis	25%	2%	**0,004**
Anemone ranunculoides	20%	16%	ns
Polygonatum multiflorum	20%	9%	ns
Ribes spicatum	20%	9%	ns
Vinca minor	20%	5%	ns
Actaea spicata	20%	2%	**0,016**
Ranunculus lanuginosus	20%	0%	**0,002**
Campanula trachelinum	15%	23%	ns
Oxalis acetosella	15%	14%	ns
Hedera helix	15%	7%	ns
Ranunculus cassubicus	15%	5%	ns
Galium odoratum	15%	0%	**0,009**
Aegopodium podagraria	100%	93%	ns
Anemone nemorosa	100%	60%	**0,000**
Adoxa moschatellina	10%	9%	ns
Corydalis solida	10%	2%	ns
Equisetum sylvaticum	10%	2%	ns
Maianthemum bifolium	10%	2%	ns
Athyrium filix-femina	10%	0%	**0,037**
Mercurialis perennis	10%	0%	**0,037**
Phyteuma spicatum	10%	0%	**0,037**
Viola mirabilis	0%	19%	ns
Stellaria nemorum	0%	7%	ns

of total 51 species noted, described as ancient woodland species. Following examples of such plants should be mentioned: *Anemone nemorosa, Galeobdolon luteum, Poa nemoralis, Stellaria holostea* and *Mycelis muralis,* which were recorded in more than 75% of all investigated woodland patches. These plants are suggested to be best indicators of old parks (Table 2).

Species composition in old woodlands is dominated by plant species associated with oligo- and mezohemeroby degree habitats, characterized by low human interference, while recent woodlands are dominated by moderately disturbed habitats. In case of old woodlands, species of high resistance to stress prevail, presenting S – strategy, on the other hand there are less species resistant to strong competition, characterized by C-strategy (Table 1).

In younger parks, in contrary to older ones, in homogenous habitats greater share of ancient woodland plant species associated with high nitrogen content and higher moisture, was recorded (Table 3). As far as species association with soil reaction and light conditions is concerned, analysis revealed no significant difference between objects.

Recent woodlands are characterized by visibly smaller number of plants using vegetative reproduction mode rather than generative, unlike old woodlands, where there are more plants using both reproduction types. In both cases plants were using similar seed dispersal modes, also dispersal effectiveness was comparable (Table 4).

Also differences in morphology of plants occurring in old and recent woodlands were recorded. Plants attached to recent woodlands are higher than in old ones and usually develop regular leaves distribution and form rosettes. There are however no significant differences as far as plants life form, such as geophytes and hemicryptophytes, is concerned (Table 5).

Discussion

In case of rural parks, similarly to isolated forest complexes, the older the stand is, the higher is the share of ancient woodland plant species (Wulf 2003). Plant species compositions occurring in parks are mostly unpredictable (Hoobs, Norton 1996). Their character and richness are dependent on woodland’s size and history, neighborhood, its isolation (colonization rate), anthropogenic interference, in the same way as it happens in case of all other habitat islands (Loster 1991; Wójcik 1991). For this reason, when using plants indicative abilities for woodland age assessment, it is recommended to base rather on plant species compositions than on presence of particular taxa.

In woodlands situated in parks, the only place where diaspores and germinules (especially seeds) of forest species, might have survived in soil, are tree clumps. In deforested parts of a park, occupied by intensively mowed grasslands or meadows, after few years of cultivation, there are no longer any seeds of forest plants in the seed bank (Dzwonko 2001). For this reason the idea of conserving plant species associated with old woodlands as biodiversity indicators, seems to be appropriate. For rural parks situated in Mazury and Wielkopolskie Lake Districts it can be assumed that plant species indicating old woodlands are those mentioned in table 2.

Table 3. Mean Ellenberg indicator values calculated for ancient woodland plant species recorded in old and recent stands

	OLD WOODLAND	RECENT WOODLAND	p-value
Light conditions [L]	3,97	4,01	ns
Moisture [F]	4,78	**5,02**	**0,021**
pH [R]	5,41	5,31	ns
Nitrogen content [N]	5,16	**5,64**	**0,005**

Table 4. Mean dispersion indicator values for ancient woodland plant species in recent and old woodlands. Seed dispersal modes (Dzwonko, Loster 2001) *Ep* – epizoochory (seeds transported by animals in fur) , *En – endozoochory* (seeds transported in vertebrate animals' guts) , *B – barochory* (seeds falling down from plant), *M – myrmecochory* (dispersal by ants), *An2 – anemochory, light or heavy seeds* (dispersal by wind), *An1 – anemochory, soaring seed, Au – autochory* (seed dispersal without external factor)

	OLD WOODLAND	RECENT WOODLAND	p-value
Share [%] of species reproducing primarily by seed, rarely vegetatively	0,22	0,26	ns
Share [%] of species reproducing primarily vegetatively, rarely by seed	0,17	**0,29**	**0,000**
Share [%] of species using equally vegetative and generative mode	**0,60**	0,45	**0,000**
Reproductive capacity of population [1/m²]	37401,2	50448,6	ns
Mean seed weight [mg]	**2,70**	2,10	**0,029**
Maximal distance within which 99% of a species' seeds will disperse during 1 year [m]	8,43	9,65	ns
Share of species using different dispersal mode [%]			
Ep	0,16	0,20	ns
En	0,07	0,04	ns
B	0,12	0,15	ns
M	0,41	0,36	ns
An2	0,16	0,17	ns
An1	0,05	0,05	ns
Au	0,16	0,20	ns

Table 5. Mean values of features and morphological parameters of ancient woodland plant species in recent and old woodlands

	OLD WOODLAND	RECENT WOODLAND	p-value
Mean canopy height [m]	**0,77**	0,54	**0,013**
Share [%] of erosulate plants	**0,48**	0,39	**0,029**
Share [%] of hemirosette plants	0,39	**0,54**	**0,001**
Share [%] of rosette plants	**0,15**	0,09	**0,006**
SLA [mm2/mg]	19,6	21,1	ns
Share [%] of hemicryptophytes	0,62	0,68	ns
Share [%] of geophytes	0,24	0,24	ns

In older parks, similarly to old forests, greater share of plants representing strategy of high stress tollerance was noted than in recent woodlands. Similar relation can be observed in both types of investigated objects as far as share of species associated with mesophilic and nutrient-rich habitats is concerned (Hermy et al. 1999). There are more nitrophilous plants in parks than in forests, in similar habitat conditions (Faliński 1966, Ratyńska, Szwed 1995, Sikorski 2002). This phenomenon is connected with stronger habitat eutrophication resulting from greater phosphorus availability for plants in more degraded objects (Sikorski 2002). Bigger canopy density in younger parks is usually due to high density of lower level and leads to decline of light demanding plants, mostly associated with edge communities (class *Trifolio-Geranietea*). Limited light reaching lower levels of phytocenosis is one of the reasons of poor plant species composition in young woodlands. Only few light demanding plants are able to survive in case of its deficiency (Sikorski 2002).

Decline in number of plant species, resulting from e.g. habitat degradation, is usually balanced by immigration of other taxa, which germinules and diaspores are available in the neighborhood (Zobere et al. 1998). It is worth mentioning, that in this case species richness of vegetation patch may remain on similar level, but is usually connected with quality changes within habitat. The ratio of plant species exchange within forest islands (park woodlands) is then dependent on the character of these habitat changes, type of neighboring phytocenosis and distance to similar environments, especially other natural forest plant communities (Honnay et al. 1999a,b).

No attachment of plants of low dispersion ability to old woodlands was recorded. This is probably an effect of distance from parks woodlands to other natural forest, which in most cases is too large for seeds to be transported. This is the reason why we recorded no relation between dispersion mode and dispersion effectiveness in parks, which might matter in case of less isolated forests (Wulf 2003).

Woodlands in parks suffering from users' pressure degenerate and undergrowth vegetation becomes more homogenous as far as habitat conditions and plant species composition are concerned (Pariente, Zhevelev 2007, Zhevelev, Pariente 2008). It can be unquestionably claimed that preserved fragments of old woodlands are particularly valuable for maintaining species richness in the whole park. In many cases the only solution for fast forest undergrowth restoration is introduction of plant species associated with this group of habitats. There are not many examples of such activities (Łaska 1997), which obstructs performing more detailed practical implications.

Taking into account all difficulties connected with rural parks preservation, which was suggested by Olaczek (1972) and Fijałkowski & Kseniak (1982), it can be suggested to leave marked biodiversity hotspot areas in parks, which should remain unmown and would be protected from trampling to preserve habitat and in consequence plant species diversity. In such countries as Germany, the Netherlands, Australia, where similar solutions are socially approved, there are places within park boundaries, where there are no standard management practices held.

Conclusions

- Ancient woodland plant species richness is greater in woodlands existing continuously for at least 120 years
- Undergrowth vegetation of recent woodlands is characterized by small share of ancient woodland plants, and those which occur commonly have regularly distributed leaves or form rosettes, are attached to nitrophilous habitats and reproduce vegetatively. If they produce seeds, they are of a small size.
- Ancient woodland species are good indicators of age and habitat condition of woodlands in parks, thus they can be applied for old woodlands identification in the field for purposes of natural parks restorations.
- To preserve biodiversity in parks, it is essential to abandon management practice within ecologically valuable fragments of woodlands and to make them local biodiversity hotspots.

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