*Folia Forestalia Polonica, series A, 2014, Vol. 56 (4), 171–178*

ORIGINAL ARTICLE

DOI: 10.2478/ffp-2014-0019

# Habitat preferences of royal fern *Osmunda regalis* L. in the 'Baszków' nature reserve

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## Abstract

The royal fern (*Osmunda regalis* L.) is a threatened species, which reaches the northeastern border of its natural range in Poland. The number of royal fern stands is decreasing due to decline of its natural habitat – alder carrs. The main aim of this paper was to compare features of stands in habitats representing different levels of anthropogenic transformation and to investigate all stands of the royal fern in the 'Baszków' nature reserve (3.76 ha; Krotoszyn Forest District, Poland). We distinguished four plant communities within the nature reserve: *Carici elongatae-Alnetum*, *Molinio-Pinetum*, *Leucobryo-Pinetum* and *Pinus-Padus*. In total, we found 144 royal fern specimens within the nature reserve area growing in 20 stands: 97 specimens in *Carici-Alnetum* (9 stands), 32 specimens in *Molinio-Pinetum* (4 stands) and 15 specimens along a drainage ditch (7 stands). Specimens from *Carici-Alnetum* had the highest proportion of sporophylles (41%), which shows the habitat preferences of the royal fern. Low proportion of sporophylles and the low number of specimens in the stands in ditches prove lower vitality of royal ferns and possibility of local extirpation in these stands. Royal fern populations in secondary habitats such as ditches and borders of forest divisions should be particularly monitored. Passive royal fern protection in the nature reserve gave positive results due to better availability of light, connected with mortality of some trees.

## Key words

anthropogenic habitats, drainage ditches, nature conservation, *Osmunda regalis*, population, drained peatlands, alder carr, species protection

## Introduction

The royal fern *Osmunda regalis* L. is the tallest native species of ferns in Poland, which reaches heights up to 1.5–2 m (Piękoś-Mirkowa and Mirek 2006; Śliwiński and Szczęśniak 2008). The species has an oceanic type of geographic range, and reaches its northeastern range limit in Poland (Zając and Zając 2001). Of 126 royal fern localities known in 1982 (historical and actual data), over 40 have not been confirmed since 1935 (Baryła and Pietras 1982), and only a few new localities have been found after this time (Kuświk *et al.*



Received 4 July 2014 / Accepted 24 October 2014

1999; Rutkowski 1999; Rostański and Cabała 2008). *Osmunda regalis* is a threatened species not only in the Wielkopolska Lowland, where it is considered a vulnerable species (V) and included in the Red List of Vascular Plants in Wielkopolska (Jackowiak and Żukowski 1995; Jackowiak *et al.* 2007), but it also is endangered at a whole country level and listed as vulnerable on the Polish Red List of Vascular Plants (Zarzycki and Szeląg 2006).

The main aspects of the protection of the royal fern are connected with decline of its primeval habitats and the use of secondary anthropogenic habitats by this species. The ecological optimum for *Osmunda regalis* are alder carrs and shrubs from the *Alnetea glutinosae* class (Matuszkiewicz 2011; Ratyńska *et al.* 2011). Ratyńska *et al.* (2011) consider this species as a differential species for wet pine forests *Molinio-Pinetum*. *Osmunda regalis* occurs in all associations from the *Alnetea glutinosae* class (Baryła and Pietras 1982; Mazur 1991; Bednarz 2004; Śliwiński and Szczęśniak 2008; Wróbel 2010; Jasnowska *et al.* 2013), in wet pine forests *Molinio-Pinetum*, peatbog pine forests *Vaccinio uliginosi-Pinetum* and peatbog birch forests *Vaccinio uliginosi-Betuletum pubescentis* (Baryła and Pietras 1982; Mazur 1991; Kuświk *et al.* 1999; Rostański and Cabała 2008; Śliwiński and Szczęśniak 2008), as well as acidophilous forests *Betulo-Quercetum* (Wróbel 2010; Jasnowska *et al.* 2013). Due to decline of royal fern associations, caused mainly by anthropogenic changes in the hydrological regime, this plant species escapes into secondary habitats, most frequently – forest division borderlines and drainage ditches (Baryła and Pietras 1982; Kuświk *et al.* 1999; Rutkowski 1999; Rostański and Cabała 2008; Śliwiński and Szczęśniak 2008; Jasnowska *et al.* 2013). Additional threat for *Osmunda regalis* is sporophytic lethality at embryonic stages of development, which considerably decreases a rate of population growth (Zenkteler 1999).

The focus of this paper was to determine the size of royal fern populations in three habitats within the 'Baszków' nature reserve, which differ regarding a level of anthropogenic transformation. We hypothesized that the royal fern in more spontaneously-created habitats will reach higher numbers of individuals and vitality than in secondary habitats.

## Material and methods

The study was conducted in the 'Baszków' nature reserve. The reserve is located in southern Wielkopolska Region (West Poland, 51°40'39''N, 17°20'32''E), in the Krotoszyn Forest District. The reserve was established in 1959 for scientific and educational purposes to allow for preservation of the section of mixed coniferous forest with localities of the royal fern growing close to its natural range limits (Baryła and Pietras 1982; Zenkteler 1999; Zarządzenie... 1959). At the present time, the main purpose of the reserve is conservation of royal fern population (Zarządzenie... 2011). The area of the reserve is 3.76 ha (Zarządzenie... 2011). The reserve is located in three forest compartments: 144d, 144f and 145c. The age of Scots pine stands which dominate in the compartment 145c is 84 years, and in 144d – 104 years. The age of alder stand in 144f is 52 years (Forest Data Bank; http://www.bdl.lasy.gov.pl/).

Forest vegetation of the 'Baszków' nature reserve consisted of four plant communities. The most extended are wet pine forests *Molinio-Pinetum*, regenerating in artificial Scots pine and Norway spruce tree stands. The central part of the reserve was covered by degenerated variants of alder carrs *Carici elongatae-Alnetum*, which developed as a result of spontaneous succession on an abandoned wet meadow (Baryła and Pietras 1982). In the eastern part of the reserve, a small area (ca. 0.3 ha) was covered by *Leucobryo-Pinetum*, in subassociation *dryopteridetosum spinulosae*, which was distinguished by massive occurrence of *Pteridium aquilinum*. In the northwestern part of the reserve, there occured forest substitutive community *Pinus-Padus*, with a dense shrub layer (over 50%) of *Padus serotina* and low cover of the herbaceous layer (25%).

During field work all localities where *Osmunda regalis* occurred were described. For each locality the number of individuals, the number of leaves (both sterile and fertile) produced by each individual and habitat conditions were recorded. For analysis, the share of fertile leaves, expressed as the percentage of leaves producing spores, and the mean number of leaves produced by individual specimens in the single stand were taken into account. These indices were taken because they show reproductive potential and vitality. There were three types of habitats where the royal fern was

found: wet pine forest, alder carr and ditches near the forest division borderline. Significance of differences between population parameters (the number of individuals in the locality, the number of leaves and proportion of fertile leaves) were tested by the Kruskal-Wallis test. To describe plant associations, 10 relevés using the Braun-Blanquet method were performed. Data from the relevés were deposited in the Polish Vegetation Database (Kącki and Śliwiński 2012). The names of phytosociological units and the system of diagnostic species were taken from Ratyńska *et al.* (2011). The borders of biochores of plant communities were drawn on a map of the reserve while in the field (fig. 1).

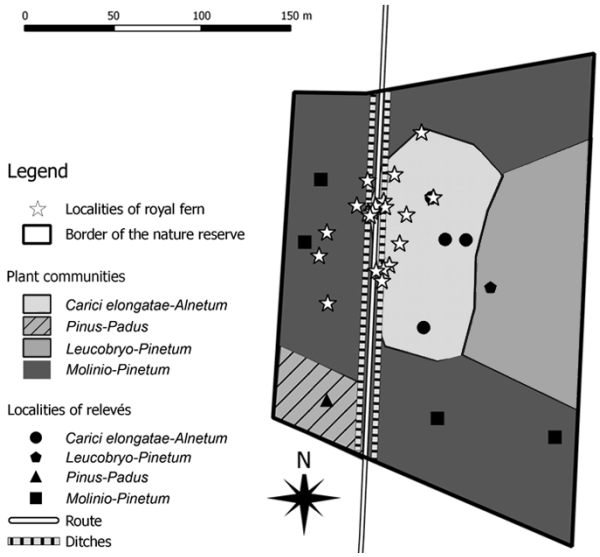


**Figure 1.** Plant community cover, localities of royal fern (*Osmunda regalis* L.) stands and relevés in the 'Baszków' nature reserve

## Results

*Osmunda regalis* occurred in three types of habitats: alder carrs *Carici elongatae-Alnetum*, wet pine forests *Molinio-Pinetum* and drainage ditches. Alder carr *Carici elongatae-Alnetum* is situated in the central part of the reserve (fig. 1). At the time of observations, the tree stand in this plant association was dominated by *Alnus glutinosa*, the shrub layer – by *Frangula alnus*, and the dominants of the herbaceous layer were *Juncus effusus* and *Molinia caerulea* (tab. 1). None of other species reached greater than 5% cover. The largest part of the reserve was covered by *Pinus sylvestris* and *Picea abies* tree stands with average canopy cover of only 60% as a consequence of windthrow. In these stands, the shrub layer was dominated by *Frangula alnus* and *Picea abies*, and less frequently – *Padus serotina*. The herbaceous layer was dominated by *Pteridium aquilinum*, with admixture of *Dryopteris carthusiana* and *Oxalis acetosella*. Plant species that are differential for *Molinio-Pinetum* were found: *Molinia caerulea* (3 of 4 relevés), *Frangula alnus* (in all relevés), *Juncus effusus* and *Osmunda regalis* (in one relevé).

**Table 1.** Phytosociological table of plant associations where *Osmunda regalis* occurred

| Successive number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Number of relevé | 1 | 2 | 5 | 7 | 8 | 10 | 9 | 3 |
| Relevé area [$m^2$] | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Tree layer cover [%] | 55 | 60 | 75 | 80 | 25 | 65 | 75 | 50 |
| Shrub layer cover [%] | 10 | 25 | 30 | 40 | 20 | 15 | 0 | 40 |
| Herb layer cover [%] | 90 | 80 | 90 | 60 | 85 | 90 | 100 | 90 |
| Moss layer cover [%] | 0 | 5 | 0 | 0 | 5 | 5 | 5 | 10 |
| Plant community[1] | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Number of species in a relevé | 8 | 15 | 8 | 9 | 18 | 15 | 13 | 9 |
| Ch. Cl. *Alnetea glutinosae* | | | | | | | | |
| *Alnus glutinosa* a1 | 4 | 4 | 4 | 5 | . | . | . | . |
| *Alnus glutinosa* a2 | . | + | 2b | . | . | . | . | . |
| *Alnus glutinosa* b | . | 1 | 1 | . | . | . | . | . |
| *Alnus glutinosa* | + | 2m | 2a | 1 | . | . | . | . |
| *Osmunda regalis* | . | 1 | . | . | . | 1 | . | . |
| *Scutellaria galericulata* | + | . | r | . | . | . | . | . |
| D. Ass. *Molinio-Pinetum* | | | | | | | | |
| *Frangula alnus* b | 2m | 2a | 2b | 3 | 1 | 2m | . | 2a |
| *Frangula alnus* | 1 | + | + | + | + | + | + | . |
| *Juncus effusus* | 5 | 3 | 4 | + | 1 | . | . | . |
| *Molinia caerulea* | . | 2m | 3 | 4 | 1 | 2b | 2b | . |
| Ch. All. *Dicrano-Pinion* | | | | | | | | |
| *Pinus sylvestris* a1 | . | . | . | . | 2a | 3 | 3 | 3 |
| *Pinus sylvestris* | . | . | . | + | . | + | . | . |
| *Betula pubescens* b | . | . | . | . | . | + | . | . |
| *Betula pubescens* | . | . | . | . | . | + | 1 | . |
| *Dryopteris dilatata* | . | . | r | . | . | . | . | . |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ch. Cl. *Vaccinio-Piceetea* | | | | | | | | |
| *Picea abies* a1 | . | . | . | . | 1 | . | . | . |
| *Picea abies* a2 | . | . | . | . | . | 2b | 3 | . |
| *Picea abies* b | . | 1 | . | . | 2a | . | . | 2b |
| *Picea abies* | . | . | . | . | + | . | . | . |
| *Pleurozium schreberi* d | . | . | . | . | + | . | . | . |
| *Pseudoscleropodium purum* d | . | . | . | . | + | . | 1 | 2m |
| Accompanying species | | | | | | | | |
| *Dryopteris carthusiana* | . | 1 | . | + | 2m | 2a | 3 | 2m |
| *Agrostis stolonifera* | 1 | 1 | + | . | . | . | . | . |
| *Lysimachia vulgaris* | + | + | r | . | . | . | . | . |
| *Deschampsia caespitosa* | . | . | . | + | 2b | . | 1 | . |
| *Padus serotina* b | . | . | . | . | r | + | . | . |
| *Padus serotina* | . | r | . | r | + | . | . | . |
| *Pteridium aquilinum* | . | . | . | . | 4 | 3 | 2a | 4 |
| *Brachythecium rutabulum* d | . | + | . | . | + | . | . | . |
| *Impatiens parviflora* | . | . | . | . | . | 1 | 2a | + |
| *Oxalis acetosella* | . | . | . | . | . | 2m | 2a | 1 |
| *Plagiomnium affine* d | . | . | . | . | . | 1 | . | + |
| *Urtica dioica* | . | . | . | . | . | + | 1 | . |
| *Betula pendula* a2 | . | + | . | . | . | . | . | . |
| *Bidens frondosa* | + | . | . | . | . | . | . | . |
| *Calamagrostis epigejos* | . | 1 | . | . | . | . | . | . |
| *Carex pilulifera* | . | . | . | . | 1 | . | . | . |
| *Elymus repens* | . | . | . | . | . | . | 1 | . |
| *Erechtites hieracifolia* | . | . | . | . | r | . | . | . |
| *Luzula pilosa* | . | . | . | . | r | . | . | . |
| *Moehringia trinervia* | . | . | . | . | r | . | . | . |
| *Pohlia nutans* d | . | + | . | . | . | + | . | . |
| *Polytrichastrum formosum* d | . | 1 | . | . | . | . | . | . |
| *Rubus fruticosus* coll. | . | . | . | . | . | 1 | . | . |
| *Rubus idaeus* | . | . | . | . | 1 | . | . | . |
| *Rubus plicatus* | . | . | . | r | . | . | . | . |
| *Rumex thyrsiflorus* | r | . | . | . | . | . | . | . |

Explanations: 1: Plant associations: 1 – *Carici elongatae-Alnetum*, 2 – *Molinio-Pinetum*.

In the study area, there were 20 localities of *Osmunda regalis*, with 144 individuals (tab. 2). The highest number of the localities occurred in *Carici elongatae-Alnetum*, where 97 royal fern individuals were recorded. Moreover, the highest number of individuals per locality (an average of 9.7) occurred within this forest community. These individuals produced the highest number of leaves (on average 6.82) and the highest proportion of fertile leaves (on average 41%). In *Molinio-Pinetum* the royal fern was found in four localities. The number of individuals per locality (on average 8) did not significantly differ from *Carici elongatae-Alnetum*. However, the average number of leaves produced per individual (5.18) was significantly lower than in both *Carici elongatae-Alnetum* and in the ditches. The mean proportion of fertile leaves (26%) in *Molinio-Pinetum* was significantly lower than in *Carici elongatae-Alnetum* ($p < 0.001$). Outside of the tree stands, seven localities of the royal fern were found in the drainage ditches, along the borderline of forest division. These localities had significantly lower ($p < 0.01$) number of individuals per locality than in tree stands (on average 2.5) as well as significantly lower ($p < 0.001$) proportion of fertile leaves (on average 6%). In the forest substitutive community *Pinus-Padus* and in *Leucobryo-Pinetum*, no royal ferns were found.

**Table 2.** Population parameters of royal fern (*Osmunda regalis* L.) in the 'Baszków' nature reserve.

| Parameter | | *Carici-Alnetum* | *Molinio-Pinetum* | Ditches |
|---|---|---|---|---|
| Number of specimens | | 97 | 32 | 15 |
| Number of specimens in a single locality | mean | 9.7 | 8.0 | 2.5 |
| $\chi^2 = 10.65399$ | SE | 1.3 | 2.4 | 0.7 |
| $p = 0.0048$ | | a | a | b |
| Number of leaves by specimen | mean | 6.82 | 5.18 | 6.00 |
| $\chi^2 = 8.896308$ | SE | 0.29 | 0.38 | 1.12 |
| $p = 0.0117$ | | a | b | ab |
| Proportion of sporophylles [%] | mean | 41.1 | 26.1 | 5.0 |
| $\chi^2 = 27.64497$ | SE | 0.1 | 0.6 | 0.3 |
| $p < 0.001$ | | a | b | c |

Values with the same letter do not differ significantly at $p$-levels presented in 'Parameter' column; values of $\chi^2$ and $p$ were obtained based on the Kruskal-Wallis test.

## Discussion

*Osmunda regalis* in the study area occurred in three habitats with different levels of anthropopressure. *Carici elongatae-Alnetum* is a plant association which developed spontaneously on the former wet meadow (Baryła and Pietras 1982) at the time when the reserve was established (1959) and meadow management was terminated, thus this association constitutes a spontaneous plant community. Although the syngenesis of plant community is spontaneous, the phytocoenoses are degenerated due to the network of drainage ditches, which is above all manifested by the dominance of plant species associated with drainage, especially *Molinia caerulea* and *Juncus effusus*. *Molinio-Pinetum* with the symptoms of degeneration connected with Norway spruce plantation may be classified as a substitutive plant community, but mortality of *Picea abies*, as well as presence of diagnostic species of *Molinio-Pinetum* in the herbaceous layer including the royal fern allows for classification of this phytocoenosis as a seminatural plant community. As a result of release from the long-term anthropopressure due to *Picea abies* planting, regeneration processes have started and are leading to a natural plant community (Faliński 2000). The drainage ditches are anthropogenic habitats. The number of royal fern individuals per locality as well as the number of leaves produced per individual decreased through the anthropopressure gradient.

The role of *Osmunda regalis* as a diagnostic species in phytosociological classification is differently described in the literature. Both Matuszkiewicz (2011) and Ratyńska *et al.* (2011) agree that the royal fern is a characteristic species for the *Alnetea glutinosae* class, but Matuszkiewicz (2011) considers it also as a characteristic species for *Myrico-Salicetum*. Baryła and Pietras (1982) as well as Ratyńska *et al.* (2011) do not agree with the latter and believe that the royal fern is a characteristic species for *Sphagno squarrosi-Alnetum* and a differential species for *Molinio-Pinetum*, which was also confirmed by Kuświk *et al.* (1999). Our observations show that the royal fern occurs in both plant associations and that it reaches its ecological optimum in the alder carr, which confirms the phytosociological properties of the royal fern proposed by Ratyńska *et al.* (2011).

The population studied here is important for conservation of *Osmunda regalis*, although it is not the largest in Poland. For example, larger populations were found in Ugoda Barczewska – 187 individuals (Woziwoda 2008), in Bratkowice – 194 individuals (Bednarz 2004), in eastern Wielkopolska – 485 and 286 individuals (Kuświk *et al.* 1999) and in Brzeziny near Kalisz – 383 individuals (Zenkteler 1999). On the other hand, the population studied is larger than that observed in all localities in Lower Silesia region (Śliwiński and Szczęśniak 2008) and populations in Mogilno and Podlubień (Woziwoda 2008). However, caution is needed when comparing the previous data on population sizes due to the dynamic nature of plant population size. In the 'Baszków' nature reserve, 78 individuals were recorded in 1950 (Czajka 1951 cited by Zenkteler 1999), but in the 1990s only 19 individuals with sporophylles were found (Zenkteler 1999). Similar population size changes over time were described by Jasnowska *et al.* (2013) in the surroundings of Zalew Szczeciński, where habitat changes were considered to be the main reason. The main factors responsible for the decrease of population size of the royal fern were changes in hydrological regime (both drainage as well as higher than required ground water level), high cover of tree canopies, competition with understory species and eutrophication (Wróbel 2010; Jasnowska *et al.* 2013).

The mortality of Norway spruce trees and renaturalization of *Molinio-Pinetum* allows to hypothesize that *Osmunda regalis* localities in this association are not threatened. The number of Norway spruce trees is decreasing in the stands, and regeneration processes have started due to spontaneous intra-community processes connected with mortality of artificially introduced Norway spruce. These regeneration processes could occur due to releasing from forest management impact, which is connected with passive nature protection. Thus, the canopy cover decreased and available light increased, which was positive for the population studied. This seems likely to be the most important factor allowing for good vitality of *Osmunda regalis*; in the 'Uroczysko Święta' nature reserve Jasnowska *et al.* (2013) found that fern populations responded positively to thinning of the tree canopy. Probably the mortality of Norway spruce trees causing gaps in the tree canopy resulted in high vitality of the royal fern in *Molinio-Pinetum*. The royal fern's vulnerability to shading is confirmed, for example in the 'Karsiborskie Paprocie' nature reserve, where the royal fern was overgrown by

dynamic natural regeneration of *Betula* spp. and *Frangula alnus*, which replaced a stand of trees that died (Wróbel 2010; Jasnowska *et al*. 2013). Also Landi and Angiolini (2011) found a negative correlation between the cover of a tree layer and proportion of generative individuals in a population of royal ferns in Italy. Pawlaczyk *et al*. (2002) argue that light availability as well as hydrological relations are key elements in conservation of this species.

Passive conservation of *Osmunda regalis* in the 'Baszków' nature reserve was successful because its aim was achieving fern population growing in specific conditions, where the releasing from long-term anthropopressure connected with forest management (renaturalization of degenerated *Molinio-Pinetum*, succession of *Carici elongatae-Alnetum* in the wet meadow) has taken place for an extended period of time. Bednarz (2004) described positive effects of anthropopressure reduction on the size of royal fern populations. Opposite to the studies of Śliwiński and Szczęśniak (2008) and Jasnowska *et al*. (2013), in the 'Baszków' nature reserve, we did not find evidence of negative influence of herbaceous plants (*Molinia caerulea*, *Pteridium aquilinum*) on the royal fern, even though these herbs had high cover in the study area. On the other hand, Landi and Angiolini (2008) studied relationships between royal ferns and other herbaceous vegetation, and found a positive correlation between the number of royal fern individuals (ramets) and occurrence of pioneer species (such as *Molinia arundinacea* and *Pteridium aquilinum*) in tree stands with low canopy cover. Tree stands with gaps are able to provide the optimum amount of light, which may allow royal ferns to survive despite competition with pioneer species. In addition, the stands in *Carici elongatae-Alnetum*, where *Molinia caerulea* dominates are the biggest stands of royal fern. It shows that notwithstanding *Molinia caerulea* competition, the royal fern may occupy these habitats.

Due to the decline in extent of primeval habitats of *Osmunda regalis* – peat bogs and alder carrs – for Poland as a whole, the species is increasingly entering and growing in habitats with higher anthropopressure, mainly forest division borderlines and drainage ditches (Baryła and Pietras 1982; Mazur 1991; Kuświk *et al.* 1999; Rutkowski 1999; Rostański and Cabała 2008; Śliwiński and Szczęśniak 2008). In 'Baszków' nature reserve, the number of leaves and share of sporophylles in these habitats were the lowest. It may show that these habitats are not suitable for *Osmunda regalis*, as well as it may be the effect of younger age of the stands. However, in Lower Silesia, the number of individuals in a single locality never exceeded 16 (Śliwiński and Szczęśniak 2008), which is comparable with the number of individuals in drainage ditches in the 'Baszków' reserve – 15. This shows that it can rather be the effect of habitat suitability than stand age (Śliwiński and Szczęśniak 2008). The problem of royal fern occurrence in anthropogenic habitats affected 34 of 74 confirmed royal fern localities in Poland (Baryła and Pietras 1982), which represent almost half of the national localities of this species. The results of this study, especially the low proportion of fertile leaves and the number of individuals in a single locality, showed that these localities had the lowest survival chances. Thus, all localities of the royal fern in anthropogenic habitats require special conservation treatment, especially more frequent monitoring of the population size.

## Conclusions

- The number of royal fern individuals per locality decreased along the increasing anthropopressure.
- Low proportion of sporophylles and low number of specimens for stands in ditches proves the lower vitality of royal ferns and possibility of local extirpation in these stands.
- Populations of royal fern in secondary habitats such as ditches and borders of forest divisions should be particularly monitored.
- Studied population, as a precious in the country -scale, requires further monitoring to assess the impact of environmental variables, as well as population's dynamics.
- Passive protection of the royal fern in the nature reserve gave positive results due to higher availability of light, connected with mortality of some trees.

## Acknowledgements

We would like to thank Dr. Lee E. Frelich (Department of Forest Resources, University of Minnesota, USA) for linguistic revision of the manuscript. We also thank Mr. Wiesław Buliński, Mr. Bogdan Staniek and Mr.

Bogdan Wiatrak from Krotoszyn Forest District for logistic help, sharing the documents and valuable remarks about the area of the study. We are also grateful to two anonymous reviewers for their valuable comments which helped us improving the manuscript.

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