Biodiv. Res. Conserv. 38: 51-56, 2015

BRC
www.brc.amu.edu.pl

DOI 10.1515/biorc-2015-0016

Submitted 25.02.2015, Accepted 30.06.2015

Synanthropization of the Baltic-type raised bog "Roby" (NW Poland)

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Abstract: Raised and transitional peat bogs, despite their considerable resistance to synanthropization, as a result of anthropogenic transformations are exposed to the colonisation by alien species. One of them is the peatland "Roby", where, in the years 2007-2009 and 2014, floristic, phytosociological and soil studies were carried out in order to record the signs of ongoing synanthropization. Conducted observations and analyses indicated that the expansion of willows has taken place and at present they occupy a large part of the bog, encroaching into bog birch forest and successfully competing with *Myrica gale*. Progressive peat mineralisation and constructed surfaced roads within the bog, contributed to the appearance and wide distribution of synanthropic species, such as: *Urtica dioica*, *Impatiens parviflora* and *Spiraea salicifolia*. Raised bog communities and their characteristic species occur on a few fragments of the bog, in north-western part, where water regime is shaped mainly by precipitation and peat deposit is fairly well-preserved. At the same time, in the patches of these communities, a distinct unfavourable increase in the share of *Molinia caerulea* is observed.

Key words: raised bog vegetation, alien species, habitat conditions, anthropogenic transformations, eutrophication

1. Introduction

Undisturbed peatland ecosystems, due to specific habitat conditions (poor nutrient content, high groundwater level, low pH) are relatively resistant to the invasion and expansion of synanthropic flora species (Budyś 2006/2007; Pawlaczyk 2009). At present, however, such intact wetlands are scarce. A definite majority of peatlands, mainly because of various kinds of human activity, has been transformed to a different degree (e.g. Jasnowski *et al.* 1968; Fojt & Harding 1995; Moen 1995; Succow & Joosten 2001; Paulissen *et al.* 2004; Prajs *et al.* 2006; Budyś 2008). In these strongly changed habitats, the retreat of stenotopic species and the reduction of the area with natural vegetation cover is observed. The most threatened species are associated with raised and transitional bogs and the vegetation characteristic of those ecosystems. Changes in environmental conditions contribute to the appearance of synanthropic plants, which is clearly visible in the most transformed sites, secondary habitats of anthropogenic nature, in particular. On the one hand, this phenomenon leads to a greater floristic diversity of peatlands, but on the other hand, is not positive, since as a result of plant competition, the richness of typical peatland flora decreases (Jasnowski 1972; Tomassen *et al.* 2004; Sotek 2010; Sadowska 2011a).

Among raised bogs, the largest areas are occupied by those of the Baltic type, mainly in Pomerania, and also Warmia and Mazury (Ilnicki 2002). They are characterised by varied habitat conditions depending on a particular peatland zone. Generally, the degree of their anthropogenic transformation also differs. In the past, peat was extracted in the majority of them, which considerably worsened soil-water relations. Water saturation and the degree of peat humification process determine the occurrence of definite kinds of plant associations.

The raised peat bog "Roby", one of the Baltic peatlands subjected in the past to strong anthropogenic pressure, has been included in nature reserve protection

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since 2007 in order to preserve the populations of valuable vascular plants and mosses (e.g. *Erica tetralix*, *Myrica gale* and *Sphagnum* spp.), as well as restore their habitats. Much earlier it had been the object of studies aimed at defining the diversity of macromycetes in peatland communities (Stasińska & Sotek 2010; Stasińska 2011). The aim of the present study was to record the manifestations of synanthropization phenomenon taking place in the Baltic-type raised bog “Roby”.

2. Study area, material and methods

The “Roby” peat-bog is located within the area of Natura 2000 “Trzebiatów-Kołobrzeg Coastal Belt” and occupies an area of 96.25 ha, of which 84.40 ha are under reserve protection (Regulation 2007). It is situated in an agricultural landscape, to the south of the village of Roby, in the West Pomeranian Province (Fig. 1). It is located in a shallow depression surrounded by arable fields and meadows, with some meadows cutting into the peat-bog area. In the past, this bog was intersected by a system of drainage ditches; moreover, peat extraction was carried out here by the manual method, the evidence of which are small areas of peat post-excavation pits. Due to drainage, the peat-bog lost its buffer zone, which usually plays an important role and protects the most valuable part of a bog, i.e., cupola, from fertilisation. Nutrient-rich waters, running off the arable fields and pastures, flow freely into the peat-bog area, providing thereby the conditions for the invasion of synanthropic species.

Floristic surveys were carried out in the reserve in 2007-2009 and 2014. They were mainly focused on the plateau, i.e. the best preserved part of the peat-bog. In the selected patches of peat-bog communities, phytosociological relevés were made with the Braun-Blanquet method. To evaluate the habitat conditions of communities, the collective samples of the substratum were collected in 2007-2009. The samples were collected three times in the vegetation season (in spring, summer and autumn) from a depth of 0-20 cm. The following parameters were determined in them: ammonium nitrogen content – by means of Kjeldahl method, nitrate nitrogen content – by means of Kjeldahl method, nitrite nitrogen content – colorimetrically by Griess method, nitrogen content – by Kjeldahl method, total phosphorus content – colorimetrically by molybdenum blue method, pH – potentiometrically, and humidity – by weight using a moisture analyser. Analyses were made at the Department of Environmental Protection and Management of West Pomeranian University of Technology in Szczecin.

The statistic correlation and one-factor analysis were performed by the Tukey test and with the Statistica 6 application.

The nomenclature for vascular plants was adopted after Mirek *et al.* (2002), for mosses after Ochyra *et al.*

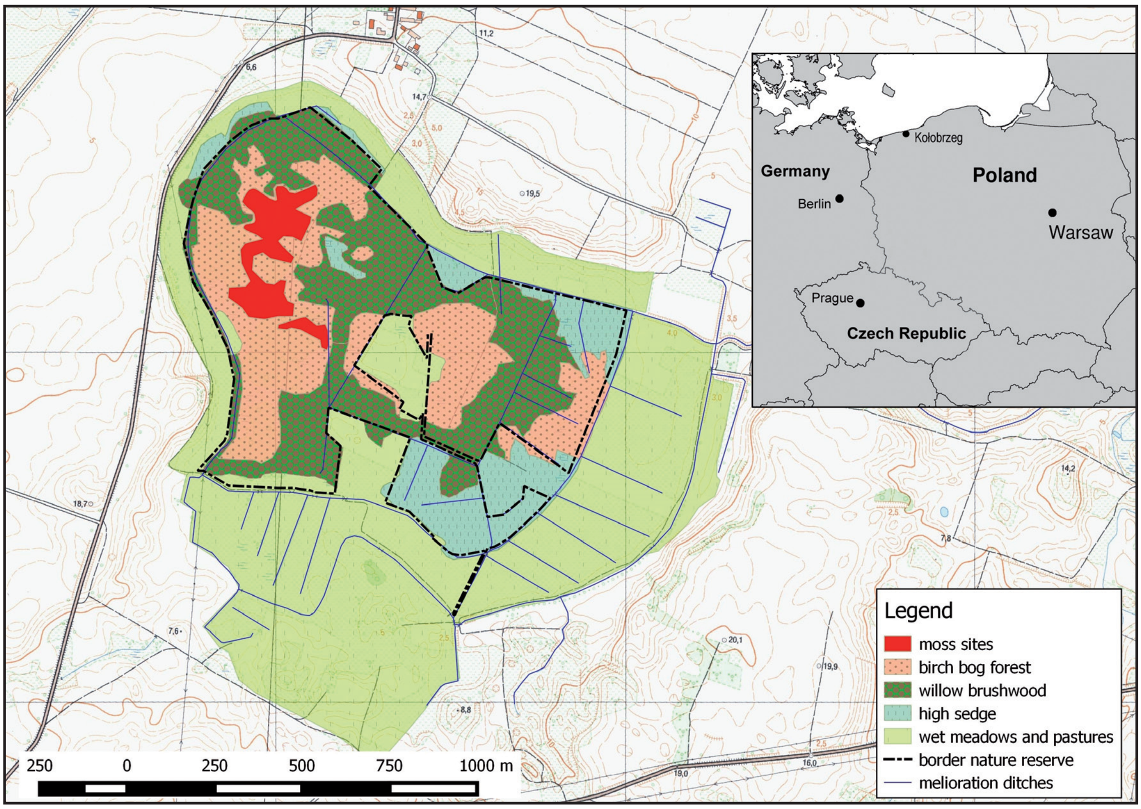

Fig. 1. Distribution of habitats in the peat bog “Roby” and around it

Table 1. Selected physico-chemical properties of the substrate

Community	Humidity (%)	pH_{H2O}	pH_{KCl}	P – P-PO_4	N total	N – N-NH_4	N – N-NO_3	N – N-NO_2
				($mg \cdot 100g^{-1}$ of dry peat)				
ErSph	85.79 a	3.86 a	2.86 a	0.21 a	1288.7 a	2.22 a	1.94 a	0.0529 a
EaSph	94.14 b	4.24 b	3.09 b	1.36 b	882.5 b	2.90 a	2.77 ab	0.084 a
VuBe	81.30 c	3.72 a	2.81 a	1.33 b	1301.5 a	3.57 a	3.80 b	0.087 a

Explanations: *ErSph – Erico-Sphagnetum medii*, *EaSph – Eriophoro angustifolii-Sphagnetum*, *VuBe – Vaccinio uliginosi-Betuletum pubescentis*; homogenous groups, $\alpha = 0.05$, Tukey's test

(2003) and lichens after Fałtynowicz (2003). The names of plant associations were given after Jasnowski *et al.* (1968) and Matuszkiewicz (2001).

3. Results and discussion

The changes in water regime in the peat bog "Roby", caused by numerous drainage ditches and peat extraction, strongly disturbed this ecosystem.

Soil studies conducted in the years 2007-2009, within the cupola of this Baltic peat bog, in the patches of the communities of *Erico-Sphagnetum medii, Eriophoro angustifolii-Sphagnetum* and *Vaccinio uliginosi-Betuletum pubescentis*, revealed considerable variations in habitat conditions. The occurrence of the above mentioned plant associations is conditioned by soil-water relations. The surface peat layer under those communities significantly differed in moisture (Table 1).

The highest humidity (94.14%, on average) was found in the peat under *Eriophoro angustifolii-Sphagnetum* and the lowest (81.30%, on average) under *Vaccinio uliginosi-Betuletum pubescentis.* Moisture conditions to a great extent determine soil chemical properties. Calculated correlation coefficients indicated a significant effect of peat moisture decrease on lowering of pH value and the increase in the total amount of nitrogen in the soil (Table 2). It may be related to a more intensive decomposition of organic matter and the formation of humic acids, rich in nitrogen and nitrogen mineral forms (Liwski *et al.* 1981). No influence of peat moisture on the content of: P-PO_4, N-NH_4, N-NO_3 and N-NO_2 was found. The content of N-NH_4 turned out to be significantly positively correlated with the content of N-NO_3 (Table 2). Maciak (1995) and Kalembasa *et al.* (2006) demonstrated that the advanced humification process under aerobic conditions brings about the loss of organic carbon but at the same time, a secondary accumulation of total nitrogen. Small quantities of N-NH_4, N-NO_3 and N-NO_2 in the total nitrogen content show that this element occurs mostly in organic form. Soil samples collected from the patch under the community *Eriophoro angustifolii-Sphagnetum* significantly differ in reaction (higher pH) and the level of total nitrogen (lower) from the soil samples collected from the patch under the associations of *Erico-Sphagnetum medii* and *Vaccinio uliginosi-Betuletum pubescentis,* which both had similar reaction and the content of total nitrogen (Table 1). It should be noted that the reaction of all soil samples under study, irrespectively of plant association, was very acid and the content of total nitrogen was typical of organic soils in Poland. The significantly lower content of P-PO_4 under the community *Erico-Sphagnetum medii* (Table 1), than in the case of communities *Eriophoro angustifolii-Sphagnetum* and *Vaccinio*

Table 2. Correlation coefficients for some physical and chemical soil properties for all studied soil samples

	Humidity	pH_{H2O}	pH_{KCl}	P – P-PO_4	N total	N – N-NH_4	N – N-NO_3	N – N-NO_2
Humidity	1.00	**0.91***	**0.78***	0.22	**-0.70***	-0.04	-0.08	0.09
pH_{H2O}		1.00	**0.92***	0.19	**-0.78***	-0.08	-0.04	0.03
pH_{KCl}			1.00	0.21	**-0.73***	-0.12	-0.01	0.03
P – P-PO_4				1.00	-0.26	0.21	0.26	**0.71***
N total					1.00	0.12	0.15	-0.07
N – N-NH_4						1.00	**0.81***	0.10
N – N-NO_3							1.00	0.01
N – N-NO_2								1.00

Explanations: **0.91*** – correlation coefficients significant at $p<0.05$, N=35 *uliginosi-Betuletum pubescentis*, in which phosphorus values were similar, deserves attention (Table 1). There was also a significant difference in the peat resources of N-NO_3 under the plant association *Erico-Sphagnetum medii* and *Vaccinio uliginosi-Betuletum pubescentis*. However, no significant differences were found in the level of N-NH_4 and N-NO_2 under the associations *Erico-Sphagnetum medii, Eriophoro angustifolii-Sphagnetum* and *Vaccinio uliginosi-Betuletum pubescentis*. Within the examined plant associations, apparent unfavourable changes were observed, e.g., in the patch with *Eriophoro angustifolii-Sphagnetum recurvi*, growing in a post-excavation pit. Over the last 7 years, it has been drying out as indicated by the smaller share of *Sphagnum* spp., *Drosera rotundifolia* and *Eriophorum angustifolium,* encroachment of *Molinia caerulea* and appearance of *Salix aurita* and the seedling of *Quercus robur* (Table 3, rel. 6). Considerable changes have been observed in one of previously studied patches of the association *Erico-Sphagnetum medii*, which not only was reduced in area but also transformed into *Ericetum tetralicis*. At present, there is a small share of *Sphagnum* spp. in that association, with a clear unfavourable increase in *Molinia caerulea* (Table 3, rel. 4). The area of the other patch of this association was also drastically reduced (Table 3, rel. 2), as a result of the damage by boars and deer, which made a muddy bathing place there. In the patch of *Vaccinio uliginosi-Betuletum pubescentis,* the species *Oxycoccus palustris* and *Ledum palustre*, are less numerous, the share of mosses is also smaller and *Molinia caerulea* forms an irregular lea (Table 3, rel. 8). Invasion of *M. caerulea* into the peatland may result from the high availability of P, and prolonged high N deposition levels (Tomassen *et al.* 2004).

Currently, a large part of the "Roby" peat bog has dried out, which is reflected in the ongoing changes in the vegetation cover of this area. Typical raised bog vegetation retreated to the wettest parts of bog cupola. The remaining area of the cupola was colonised by *Betula pubescens* and *B. pendula* (Fig. 1). Among shrubs, *Myrica gale* was a dominant species and less frequently, *Frangula alnus*. The herb layer that covered this area was exceedingly impoverished and consists mainly of *Molinia caerulea*. The vegetation in these places has been transformed into impoverished bog birch forest. The presence and wide distribution of *M. caerulea* point to the changeable water table and its tendency to fall further. Also, the signs of the advanced process of surface peat layer mineralisation and phosphorus release in the form available to plants were observed (Pawlaczyk *et al.* 2005).

Progressive peat mineralisation as well as the runoff of water rich in nitrogen and phosphorus compounds, from adjacent agricultural land, increase habitat fertility (Sotek *et al.* 2004; Sadowska 2011b). This phenomenon was also observed on the bog "Roby", especially on its margin (within the buffer zone that ceased to exist). In the habitat altered in that way, the encroachment of nitrophilous species, such as, for example, *Urtica dioica*, started. Within the peat bog, in the ecotone zone, between the meadow and alder-birch-aspen forest, there is a noticeable expansion of *Eupatorium cannabinum*, the species associated with nitrophilous fringe vegetation (Matuszkiewicz 2001). On waterlogged sites, dense rushes of large sedge and common reed began to develop. A distinct invasion of willow thicket, mainly *Salix aurita* and *S. cinerea*, to a lesser degree *Salix pentandra* and *S. viminalis*, took place. Willows colonise the stands of bog birch forest and the upper parts of raised bog cupola, gradually reducing the area of open peat moss bog. Frequently, they grow around post-extraction pits, where the process of mineralisation takes place, nutrients are released, e.g., ammonia and ions of: sulphate, nitrate and phosphorus (Herbichowa *et al.* 2007), which favours the development of these plants. Our previous observations show that willows efficiently compete with *Myrica gale* for space and the access to sunlight, gradually forcing wax-myrtle to retreat from that area. Quite often, single ramets of *M. gale* are encountered among willows. They are etiolated, of low vigour, do not flower and fruit. They are at the stage of dying out. A relatively well-preserved patches of wax-myrtle are found within the central part of cupola, in open spaces and among partially retained swamp birch woods and the area covered with sedge rushes.

Meadows within the examined peat bog (Fig. 1) are mown and in part, used as pastures. They constitute a vital source of biogenic components and as a result lead to habitat eutrophication. This, in turn, enables the encroachment of synanthrophic species on these areas. The presence of these species on anthropogenically transformed soil, had been observed before, in large complexes of raised and transitional peat bogs (Budyś 2008; Sadowska 2011a, 2011b). Surfaced roads, leading to the centre of peat bog "Roby", as in other similar objects, also contribute to the appearance of synanthrophic species in these ecosystems (Sadowska 2011b). On many sites of the bog under study, such species as: *Urtica dioica* (a clearly nitrophilous species), *Phragmites australis* and *Typha latifolia* have become widely distributed. The occurrence of *Impatiens parviflora* and *Spiraea salicifolia* on "Roby" may point to eutrophication in this part of the bog. Eutrophication is recognised as a factor facilitating the appearance and development of alien species in oligothrophic peatland (Tomassen *et al.* 2004). The dominance of *Salix aurita* and *S. cinerea* over a large area, is the sign of strong fertilisation of the bog, clearly visible in its eastern part, where the humification process of the surface layer is evident.

The species characteristic of raised peat bogs have been retained only in the small fragments of the reserve

Table 3. The plant communities of the raised bog "Roby" (NW Poland)

Successive number	1	2	3	4	5	6	7	8
Plot number	2	2	1	1	3	3	4	4
Community		*ErSph*		*Ertet*	*EaSph*		*VuBe*	
Date	07.09. 2007	19.09. 2014	07.09. 2007	04.09. 2014	27.08. 2007	04.09. 2014	17.09. 2007	19.09. 2014
Area of record [m^2]	200	60	200	80	100	100	400	400
Density of tree layer a [%]	5	5	-	-	–	-	25	25
Density of shrub layer b [%]	10	5	10	10	10	-	25	10
Cover of herb layer c [%]	80	40	60	70	80	80	80	70
Cover of moss layer d [%]	60	40	40	10	100	75	40	20
No. of species in record	16	15	15	15	14	14	21	17
Ch. *Oxycocco-Sphagnetea*								
Erica tetralix	3	2	2	2	1	.	1	1
Oxycoccus palustris	1	1	1	+	3	3	3	1
Eriophorum vaginatum	3	3	1	1	+	+	+	+
Drosera rotundifolia	1	+	1	.	3	+	+	.
Andromeda polifolia	1	+	+	+	+	+	+	.
Ledum palustre	2	.	1	+	+	+	2	1
Sphagnum capillifolium	1	1	+	.	.	.	.	+
Aulacomnium palustre	1	.	.	.	.	.	1	.
Sporadic species: *Sphagnum rubellum* 3(1)								
Ch. *Scheuchzerio-Caricetea nigrae*								
Eriophorum angustifolium	.	.	+	.	4	3	+	1
Sphagnum fallax	.	+	.	+	4	3	1	.
Rhynchospora alba	2	1	.	.	.	.	.	.
Sporadic species: *Menyanthes trifoliata* 5(+), *Sphagnum cuspidatum* 6(+)								
Ch. *Vaccinio-Piceetea*:								
Betula pubescens a	+	+	.	.	.	.	2	2
Betula pubescens b	1	+	1	1	1	1	2	1
Sphagnum palustre	1	1	.	+	1	1	.	+
Vaccinium uliginosum	+	+	+	+	+	+	1	1
Pleurozium schreberi	.	.	1	+	.	.	.	.
Frangula alnus c	.	.	.	.	+	.	.	+
Sporadic species: *Dicranum scoparium* 7(+)								
Accompanying species								
Calluna vulgaris	3	2	2	1	.	.	2	2
Molinia caerulea	+	+	+	2	.	1	3	4
Dicranum bonjeanii	1	.	1	1	.	.	.	.
Myrica gale	.	.	.	.	1	+	.	.
Salix aurita	.	.	.	+	.	+	+	.
Quercus robur	.	.	.	.	.	+	+	+
Sphagnum fimbriatum	.	.	.	.	.	.	2	2
Hypnum cupressiforme	.	+	.	.	.	.	.	+
Sporadic species: *Populus tremula* 4(+); *Calliergonella cuspidata* 4(+); *Sphagnum squarrosum* 7(+); *Straminergon stramineum* 7(1); *Luzula multiflora* 7(+); *Potentilla erecta* 7(+); *Cladonia fimbriata* 8(+)								

Explanations: *ErSph – Erico-Sphagnetum medii*, *EaSph – Eriophoro angustifolii-Sphagnetum*, *Ertet – Ericetum tetralicis*, *VuBe – Vaccinio uliginosi-Betuletum pubescentis*

"Roby", in the north-western part, i.e., in places where water relations are still shaped by precipitation, and peat deposit is fairly well-preserved.

Acknowledgements. Studies supported financially in part by the Ministry of Science and Higher Education, grant N N305 2617 33.

References

Budyś A. 2006/2007. Anthropophytisation process in vascular plants flora of peatlands in the coastal zone exemplified by the east part of Kashubian Coastal Region. In: T. S. Olszewski, R. Afranowicz & K. Bociąg (eds.). Contemporary trends of botanical research – on Professor Hanna Piotrowska 80th birthday anniversary. Acta Bot. Cassub. 6: 121-130.

Budyś A. 2008. The synanthropisation of vascular plant flora of mires in the coastal zone (Kashubian Coastal Region, N Poland) – range, reasons for, and spatial characteristics. Monogr. Bot. 98: 1-55.

Fałtynowicz W. 2003. The lichenes, lichenicolous and allied fungi of Poland – an annotated checklist. In: Z. Mirek (ed.). Biodiversity of Poland, 6, 435 pp. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Fojt W. & Harding M. 1995. Thirty years of change in the vegetation communities of three valley mires in Suffolk. J. Appl. Ecol. 32: 561-577.

Herbichowa M., Pawlaczyk P. & Stańko R. 2007. Conservation of Baltic raised bogs in Pomerania, Poland. Experience and Results of the LIFE04NAT/PL/000208 PLBALTBOGS Project. 148 pp. Published by Naturalists Club Poland (Klub Przyrodników), Świebodzin.

Ilnicki P. 2002. Torfowiska i torf. 606 pp. Wyd. AR w Poznaniu, Poznań.

Jasnowski M. 1972. Rozmiary i kierunki przekształceń szaty roślinnej torfowisk. Phytocoenosis 1(3): 193-209.

Jasnowski M., Jasnowska J. & Markowski S. 1968. Ginące torfowiska wysokie i przejściowe w pasie nadbałtyckim. Ochr. Przyr. 33: 69-124.

Kalembasa D., Becher M., Pakuła K. & Jaremko D. 2006. Wybrane właściwości fizykochemiczne i chemiczne gleb torfowo-murszowych w dolinie rzeki Liwiec na Wysoczyźnie Siedleckiej. In: T. Brandyk, L. Szajdak & J. Szatyłowicz (eds.). Właściwości fizyczne i chemiczne gleb organicznych, pp. 25-32. Wydaw. SGGW Warszawa.

Liwski S., Okruszko H. & Kalińska D. 1981. Zróżnicowanie zawartości składników chemicznych w organogenicznych utworach glebowych Bagien Biebrzańskich. Zesz. Nauk. AR we Wrocławiu, Rolnictwo 38, 134: 97-109.

Maciak F. 1995. Ocena aktywności biologicznej murszów i torfów na podstawie mineralizacji związków węgla i azotu. Rocz. Gleboz. 46(3/4): 19-27.

Matuszkiewicz W. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski. In: J. B. Faliński (ed.). Vademecum Geobotanicum 3, 537 pp. Wyd. Nauk. PWN, Warszawa.

Mirek Z., Piękoś-Mirkowa H., Zając A. & Zając M. 2002. Flowering plants and pteridophytes of Poland. A checklist. In: Z. Mirek (ed.). Biodiversity of Poland, 1, 442 pp. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

Moen A. 1995. Introduction: regionality and conservation of mires. In: A. Moen (ed.), Regional variation and conservation of mire ecosystems. Gunneria 70: 11-22.

Ochyra R., Żarnowiec J. & Bednarek-Ochyra H. 2003. Census Catalogue of Polish Mosses. In: Z. Mirek (ed.). Biodiversity of Poland, 3, 372 pp. Polish Academy of Sciences, Institute of Botany, Kraków.

Paulissen M. P. C. P., van der Ven P. J. M., Dees A. J. & Bobbink R. 2004. Differential effect of nitrate and ammonium on three fen bryophyte species in relation to pollutant nitrogen input. New. Phytol. 164: 451-458.

Pawlaczyk P. 2009. Torfowiska w obliczu zagrożeń powodowanych przez rozwój obcych gatunków inwazyjnych. In: Z. Dajdok & P. Pawlaczyk (eds.). Inwazyjne gatunki roślin ekosystemów mokradłowych Polski, pp. 19-23. Wyd. Klubu Przyrodników, Świebodzin.

Pawlaczyk P., Herbichowa M. & Stańko R. 2005. Ochrona torfowisk bałtyckich. Przewodnik dla praktyków, teoretyków i urzędników. 190 pp. Wyd. Klubu Przyrodników, Świebodzin.

Prajs B., Sotek Z. & Stasińska M. 2006. Degradation of peatland vegetation on the Reptowo bog and an attempt of its renaturalization. Polish Journal of Environmental Studies 15, 5d(1): 161-165.

Regulation 2007. Regulation of West Pomeranian Province Governor No 54/2007 of 27 September 2007 on the nature reserve "Roby". J. L. of West Pomeranian Province 2007, No 102, item 1752.

Sadowska A. 2011a. The vascular plant flora of peatlands submitted to anthropic pressure in the Równina Błot Przymorskich microregion and the Płutnica river valley (the Pobrzeże Kaszubskie region, N Poland). Acta Bot. Cassub., Monogr. 4: 1-166.

Sadowska A. 2011b. Gatunki synantropijne we florze roślin naczyniowych torfowisk wysokich i przejściowych Pojezierza i Pobrzeża Kaszubskiego (Polska północna). Acta Bot. Silesiaca 7: 79-95.

Sotek Z. 2010. Distribution patterns, history, and dynamics of peatland vascular plants in Pomerania (NW Poland). Biodiv. Res. Conserv. 18: 1-82.

Sotek Z., Stasińska M., Prajs B., Gamrat R. & Łysko A. 2004. Torfowiska śródpolne województwa zachodniopomorskiego. Woda-Środowisko-Obszary Wiejskie, 4, 2b(12): 211-224.

Stasińska M. 2011. Macrofungi of raised and transitional bogs of Pomerania. Monogr. Bot. 101: 1-142.

Stasińska M. & Sotek Z. 2010. Zróżnicowanie macromycetes mszaru wrzoścowego Erico-Sphagnetum medii (Schwic. 1933) Moore 1968 – wstępne wyniki badań. IMUZ. Woda – Środowisko – Obszary Wiejskie, 10, 3(31): 271-282.

Succow M. & Joosten H. (eds.). 2001. Landschaftsökologische Moorkunde. 2. völl. bearb. Aufl. E. Schweizerbart'sche Verl., Stuttgart.

Tomassen H. B. M., Smolders A. J. P., Limpens J., Lamers L. P. M. & Roelofs J. G. M. 2004. Expansion of invasive species on ombrotrophic bogs: desiccation or high N deposition? J. Appl. Ecol. 41: 139-150.