Biodiv. Res. Conserv. 1-2: 69-76, 2006

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Species of the type section of *Sphagnum* (Bryophyta, Sphagnaceae) in Poland

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Abstract: The paper presents data on the distribution and phytosociological preferences of species belonging to the genus *Sphagnum*, section *Sphagnum*, in Poland. The distribution maps were constructed on the basis of verified herbarium materials accessible in Polish and some German herbaria. All data were presented on the maps by using a cartogram technique in accordance with the ATMOS system. In Poland, *S. palustre* and *S. magellanicum* are the most common, widespread species, whereas *S. centrale* and *S. affine* are the rarest. *S. centrale* is found mainly in the eastern part of the country, influenced by the continental climate. Its characteristic distribution in Poland is indicative of its specific status. *S. affine* is more frequent in the northwestern part, in regions subjected to Atlantic climatic influences. *S. papillosum* is more scattered but the majority of its localities are in western Poland. So far, *S. austinii* has not been reported from any Polish locality. There are two regions with particularly high numbers of localities of the studied species: Pomerania (northwestern part of Poland) and the southern uplands.

Key words: *Sphagnum palustre, Sphagnum magellanicum, Sphagnum papillosum, Sphagnum centrale, Sphagnum affine,* distribution, Poland

1. Introduction

Within the genus *Sphagnum* L., one of the most clearly delimited sections is the section *Sphagnum* L. (syns. *Cymbifolia*, *Palustria*), which used to be frequently elevated to the rank of a separate subgenus *Inophlea* Russ. In older treatments, Demaret (1941) in a voluminous article on the subsection *Cymbifolia* Lindb. in Belgium recognized *Sphagnum palustre* as the only species, while the other taxa were treated as its varieties. *S. palustre* was described as a first species in the genus by Linnaeus, *Sp. Pl.* 1106 in 1753. In later studies, five species were distinguished: *S. palustre* L., *S. magellanicum* Brid., *S. centrale* C. Jens., *S. papillosum* Lindb., and *S. imbricatum* Hornsch *ex* Russ. (Sawitz-Lubitzkaja 1952; Isoviita 1966; Nyholm 1969).

Two species are problematic from a taxonomic standpoint: *S. centrale* and *S. imbricatum*. Within the latter species, Flatberg (1984, 1986) distinguished two European taxa: *S. imbricatum* ssp. *affine* (Ren. & Card.) Flatb., including var. *flagellare* (Roell) Card., and *S. imbricatum* ssp. *austinii* (Sull.) Flatb., including var. *arcticum* Flatb. In North America, Andrus (1984, 1987) accorded these subspecies the species status. His view was supported later by Flatberg (1994, 2002) and Thingsgaard (2001, 2002). The varieties were distinguished on the basis of several stem leaf traits. However, Andrus (1987), on the basis of specimens from eastern North America claimed that the characters are not consistent and all possible combinations can be found in different plants. He therefore failed to recognize var. *flagellare*. Also, no differences between var. *flagellare* and var. *affine* were detected in the isozyme survey by Thingsgaard (2002). The taxonomy proposed for the *S. imbricatum* complex was questioned by Crum (1997) and Daniels & Eddy (1990). With respect to the *S. imbricatum* complex, the currently recognized division into two European species *S. affine* Ren. & Card. and *S. austinii* Sull. (Andrus 1984, 1987; Flatberg 2002; Thingsgaard 2001, 2002) was followed in this work. Microscopically *S. affine* was distinguished by comb fibrils on the innermost stem cortex layer. Also, Thingsgaard (2002) treated this character as the most important and consistent.

The distribution of taxa recognized within the *S. imbricatum* complex was given by Andrus (1987), Flatberg (1984, 1986), Gauthier & Brugués (1997), and Thingsgaard (2002). The boreal-mountain species *S.*

centrale is considered by British authors (Daniels & Eddy 1985) as a variety *S. palustre* var. *centrale* C. Jens. A. Eddy. By contrast, bryologists from Eastern, Central and Northern Europe (Sawitz-Lubitzkaja 1952; Melosik 1993; Flatberg 2002), treat both these taxa as species because they differ in morphology, habitat preferences and distribution.

The remaining species (*S. palustre, S. papillosum, S. magellanicum*) are generally considered to be easy to distinguish in the field thanks to their distinct coloration and general appearance. Nevertheless, mistakes are frequent. Plants of *S. papillosum* in which papillae are very weakly developed (such forms were named in the past var. *sublaeve* Limpr.) or completely absent (var. *leave* Warnst.) are often confused with *S. magellanicum* or *S. palustre*. In turn, *S. centrale* growing in shady places in relatively base-rich habitats is frequently mistaken for green forms of *S. magellanicum* or *S. palustre,* while *S. affine* is confused with *S. palustre*.

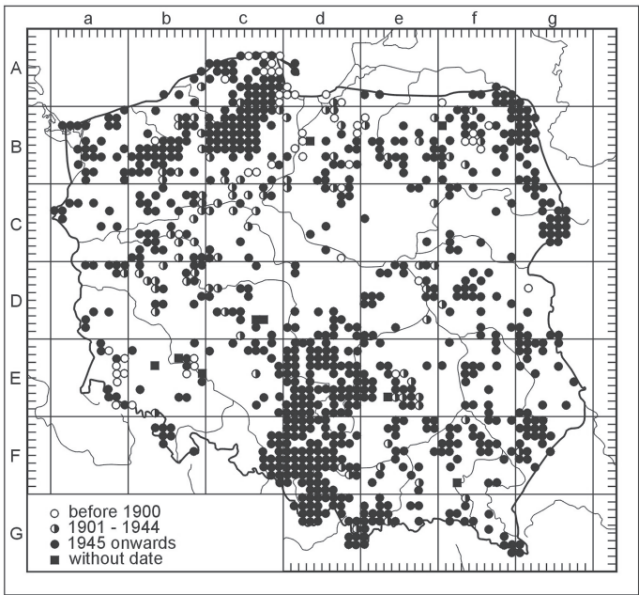

Fig. 1. Status of bryological explorations of Poland based on the distribution of *Sphagnum* species

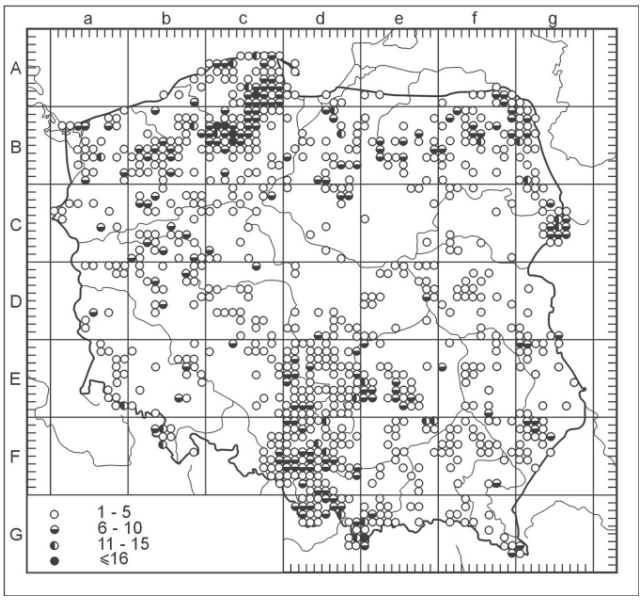

Fig. 2. Number of species of *Sphagnum* recorded in individual squares of the ATMOS grid, based on herbarium collections verified to date (sections: *Acutifolia, Sphagnum, Subsecunda, Squarrosa* and *Rigida*)

According to the map presented by Daniels & Eddy (1985), *S. papillosum* occurs only in the southwestern part of Poland, whereas *S. imbricatum* s.l. is found only in its northernmost part. On the other hand, Flatberg (1984) reported that two species of the *S. imbricatum* complex (*S. affine* and *S. austinii*) are present in Poland. Hence the aim of this study was to analyze the distribution of species from the section *Sphagnum* in Poland on the basis of herbarium collections verified by me. However, the occurrence of particular species should be referred to the status of exploration of the investigated area. Therefore, the status of bryological exploration of Poland and differentiation of regions in respect of *Sphagnum* flora are presented in this study on the basis of all the herbarium materials (from sections *Acutifolia, Squarrosa, Subsecunda, Rigida* and *Sphagnum*) that have been available and verified by me so far.

2. Material and methods

A total of 6959 samples were verified, which in most cases belonged to the following sections: *Acutifolia, Sphagnum, Subsecunda, Squarrosa* and *Rigida*. Among the samples, 2459 specimens belonging to the section *Sphagnum* were found in 18 Polish herbaria (BSG, BIL, GDMA, UGDA, KRAM, LBL, LOD, POZM, POZG, POZNF, SOSN, SZUB, SZCZ, TRN, WA, WRAB, WSRP, WRSL, Mirek et al. 1997) and 3 German herbaria (B, HAL, STU, http://sciweb.nybg.org/science2/IndexHerbariorum.asp).

The current status of explorations conducted in Poland, on the basis of all samples analyzed so far, is presented on Fig. 1, whereas differentiation of regions in respect to *Sphagnum* flora is presented on Fig. 2.

The materials subjected to verification were collected between 1853 and 2003 by German and Polish bryologists (see the legend of Fig. 1). The entire studied material was subdivided into three groups according to collection date. The fourth group consisted

Table 1. Relative distribution of localities of *Sphagnum palustre* (*pal*), *S. magellanicum* (*mag*), *S. centrale* (*cen*), *S. papillosum* (*pap*), and *S. affine* (*aff*) (as percentage of all Polish localities of each species) in Poland's physiographic subprovinces (Kondracki 1988) and their characterization (Woś 1999; Krawczyk & Błażejczyk 1999)

Subprovince	Altitude range (m)	Mean annual precipitation* (mm)	Mean January temperature* (ºC)	Percentage of localities of *Sphagnum* species				
				pal	*mag*	*cen*	*pap*	*aff*
313	0–100	527–698	-0.6 to -1.0	8.9	6.1	4.0	11.3	10.0
314	50–329	(440)-573 (794)	-3.2	30.0	30.8	13.2	37.3	46.8
315	75–312	520	-1.8 to -2.2	7.4	7.2	12.2	3.95	3.3
317	18–200	700–1000**	**	0.2	–	–	–	–
318	60–284	508–612	-1.9 to -3.4	12.0	5.5	4.0	10.2	10.0
332	>400–1603	701	-1.5 to -7.2	1.4	2.0	1.0	4.5	–
341	220–500	740	-3.0	6.0	0.8	1.0	6.8	10.0
342	180–500	649	-3.8	7.9	9.5	2.0	12.4	3.3
343	160–400	603	-3.9	2.7	2.9	4.0	–	3.3
512	200–300	678–702	-3.4 to 3.5	5.7	2.9	–	3.95	3.3
513	400–1390	1000–1300**	**	3.3	2.9	3.0	2.3	6.7
514	905–2503	700–2000	-2.0 to -11.9	0.7	3.4	2.0	2.8	3.3
521	300	600–700**	**	0.8	0.2	–	–	–
522	600–1220	700–800 (1150–1200)**	-4.8 to -5.2	0.3	0.4	–	1.1	–
841	80–216	600–700**	**	0.1	–	–	–	–
842	130–300	631	-5.3	4.6	10.5	22.3	2.3	–
843	164–241	550–600**	-5.0	5.9	12.0	29.3	–	–
845	140–210 (290)	500–600	-4.0 to -5.2	2.1	2.7	2.0	1.1	–
851	220–260	550–600**	**	–	0.2	–	–	–

* Ranges of mean values are given if data from several weather stations are available, ** Approximate data – insufficient weather station coverage or short recording periods

of specimens with no date given. Contemporary specimens (years 1944-2003) accounted for 75% of the analyzed material.

The data on distribution of species were illustrated by using the cartogram technique, employing a grid of large (100 km×100 km) and small (10 km×10 km) squares. The principles underlying the square network (ATMOS) are explained in Ochyra & Szmajda (1981). The presence of a taxon in a given small square was marked by a circle, regardless of the number of localities in the square.

To detect trends in species distribution, every locality was assigned to a subprovince by using the physiographic division of Poland (Kondracki 1988) (Table 1). As an example, for *S. centrale* (a taxon with an uncertain specific status), the proportion of localities in each subprovince, i.e. percentage of the total number of its localities in Poland, was calculated and additionally presented on Fig. 6.

Neither literature data, nor specimens with uncertain locality data were included on the maps (Figs. 1-8).

The data on peat moss occurrence in plant communities derive from herbarium labels and my field observations, both original and published (Brzeg *et al.* 1995, 1996; Borysiak *et al.* 1998; Melosik 1990, 1993, 1996; Melosik & Urbański 1997; Lisowski *et al.* 2000).

All data will be available on request as an Access 2.0 for Windows database.

3. Results

3.1. The current status of explorations conducted in Poland

The results of this study of the distribution of *Sphagnum* species in Poland, summarized on Figs. 1-2 and in Table 1, show that some regions have been comprehensively explored. These include: the lakelands, especially in the northwestern part of the country (squares Ac and Bc on Fig. 2, part of subprovince 314, and to a lesser extent on Fig. 6, part of subprovince 842), uplands (Fig. 2, square Fd and parts of squares Fe and Fg; Fig. 6, parts of subprovinces 341, 342, and 512), Tatra Mts. (Fig. 2, part of squares Gd and Ge; Fig. 6, subprovince 514), Western Beskids (Fig. 2, part of square Ge; Fig. 6, part of subprovince 513), North Polesie Lowland (mainly Bielsk Plateau, Fig. 2, part of square Cg; Fig. 6, part of subprovince 843), Sudety Mts. (Fig. 5, subprovince 332) in particular their central part, i.e. Stołowe Mts. (Fig. 2, square Fb).

For some regions, no herbarium documentation is available or the samples have not been processed yet, although the areas have been intensively studied: e.g. part of the Baltic coastland (Fig. 6, subprovince 313) and the Karkonosze Range (Fig. 6, part of subprovince 332). From subprovince 851 and the southwestern part of subprovince 318, no specimens are available.

3.2. Distribution and ecological characteristics of species from the section *Sphagnum* in Poland

***Sphagnum palustre* L.**

Distribution: Common and widespread (Fig. 3). It reaches its maximal elevation at 1410 m in Poland in the Tatra Mts.

Habitat: This predominantly mesotrophic species is a very common and important constituent of the moss flora in shady and swampy habitats in relatively dry conditions. The optimum of its occurrence is in swamp alder forests (communities of swamp alder and willow stands on peat from the class *Alnetea glutinosae* Br.-Bl. et Tx. 43). It grows predominantly in alder-ash carrs in which *Sphagnum* species are dominant in the moss layer. Common associates in this community are *S. squarrosum* Crome and *S. fimbriatum* Wils. It is also common in communities of the class *Vaccinio-Piceetea* Br.-Bl. 39, where it occurs both in mesotrophic and in oligotrophic habitats. Within other communities it can be found in subcontinental bog pine forests *Vaccinio uliginosi-Pinetum* Kleist 29, in subboreal spruce forests *Sphagno girgensohnii-Piceetum* Polakowski 62, in suboceanic bog birch stands *Betuletum pubescentis* Tx. 37, and in wet pine woods *Molinio-Pinetum* Mat. (73) Mat. 81. In these communities it usually occurs in association with *S. capillifolium* (Ehrh.) Hedw., *S. girgensohnii* Russ., and *Polytrichum commune* Hedw. It is found in older and drier parts of raised bogs, e.g. in the drier parts of the dome undergoing a gradual colonization by trees (most often by *Pinus sylvestris* L. or *Betula pubescens* Ehrh.). It grows there in various communities from the class *Oxycocco-Sphagnetea* Br.-Bl. et Tx. 43. It can also be found in the transitional zone between the open mat and the bog forest, usually among shrubs of the wet willow scrub. Besides, its self-perpetuating populations occupy some man-made or man-modified bog-like habitats, e.g. sides of drainage ditches, clearings in coniferous bog forests, peat diggings, and pond edges.

***Sphagnum magellanicum* Brid.**

Distribution: Widespread and frequent (Fig. 4). The highest stations in the Tatra Mts. are never above the altitude of 1850 m.

Habitat: This acidophilic species most often grows in drier and older parts of raised bogs, on deep peat, where it forms characteristic red-colored tufts. It occurs mainly in phytocenoses of the order *Sphagnetalia magellanici* (Pawł. 28) Moore (64) 68. The species occurs also in communities representing different stages of successional development of peat bogs, leading to boggy woods (class *Vaccinio-Piceetea* Br.-Bl. 1939). It is associated with numerous taxa, most commonly with raised bog species: *S. angustifolium* (Russ.) C. Jens., *Polytrichum strictum* Brid., *Aulacomnium palustre* (Hedw.) Schwaegr. and, to a lesser extent, *S. rubellum* Wils. and *S. fuscum* (Schimp.) Klinggr. Additionally, this peat moss often occurs on poor fens in communities of the class *Scheuchzerio-Caricetea fuscae* Tx. 37 (e.g. *Rhynchosporetum albae* Koch 26 or *Caricetum lasiocarpae* Koch 26), where it grows in drier patches. It can also be found in secondary communities that develop at the edges of ponds, dams and irrigation ditches.

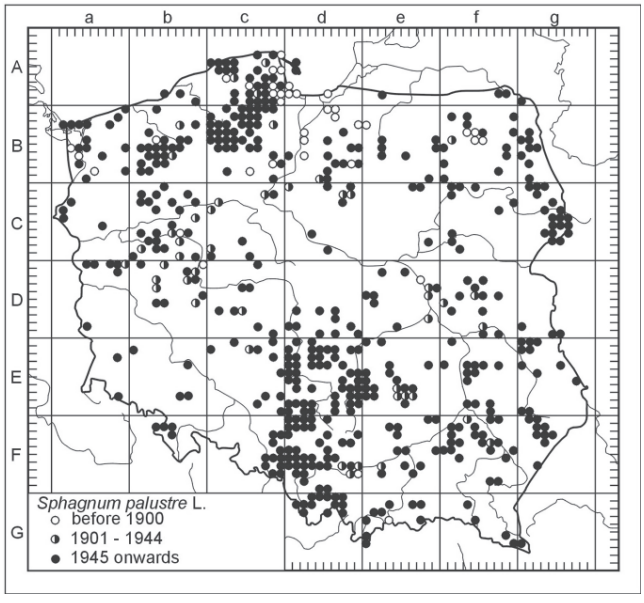

Fig. 3. Distribution of *Sphagnum palustre* L. in Poland on the basis of verified herbarium collections

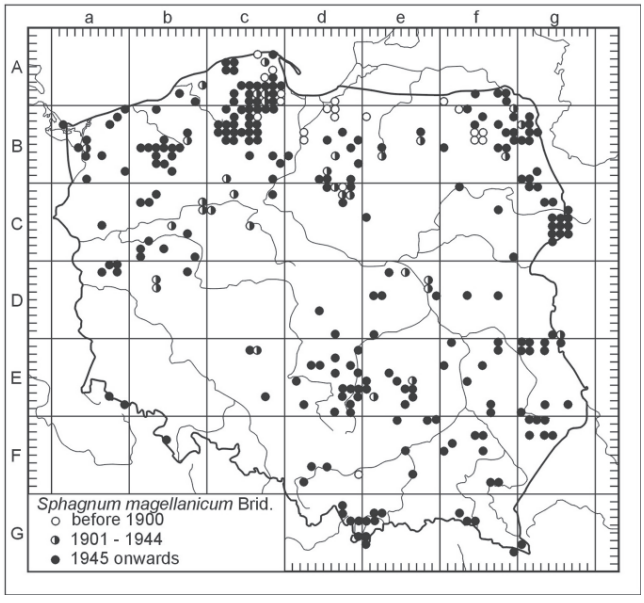

Fig. 4. Distribution of *Sphagnum magellanicum* Brid. in Poland on the basis of verified herbarium collections

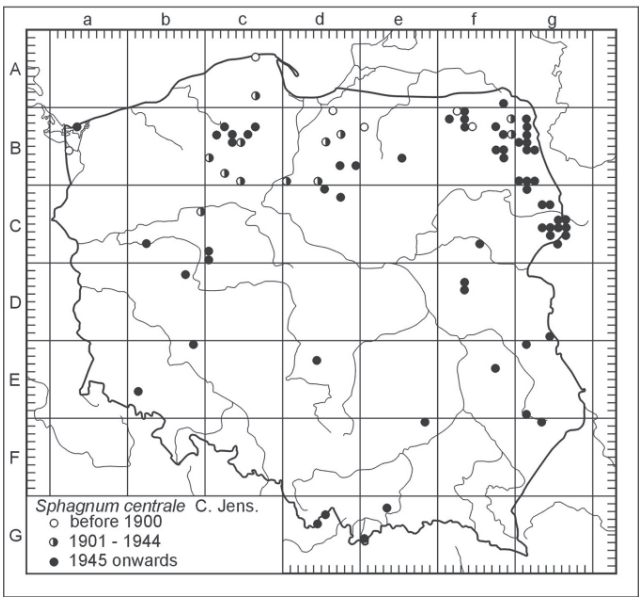

Fig. 5. Distribution of *Sphagnum centrale* C. Jens. in Poland on the basis of verified herbarium collections

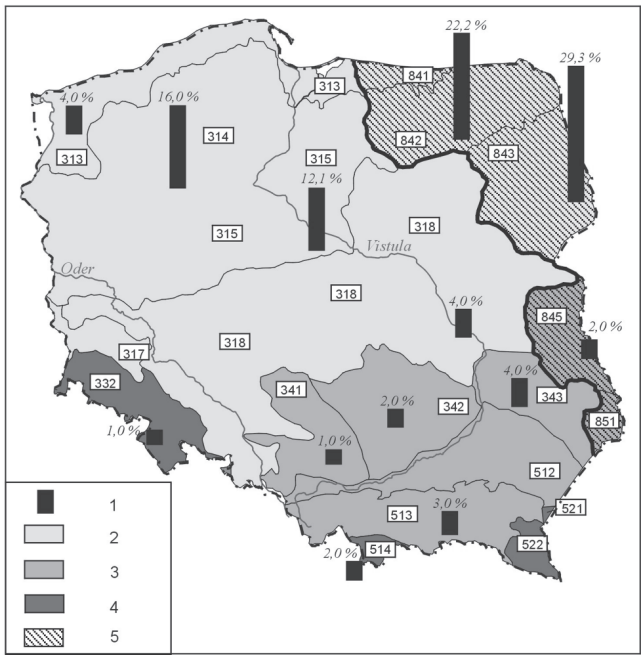

Fig. 6. Proportions of *Sphagnum centrale* C. Jens, localities in individual subprovinces of Poland: 1 – percentage of *S. centrale* localities in given subprovince; 2 – lowlands; 3 – uplands; 4 – mountains; 5 – physiographic section of Eastern Europe (see Table 1)

Sphagnum centrale C. Jens

Distribution: Generally rare (Figs. 5-6), more frequent in northeastern Poland. In the Tatra Mts. it exceeds the altitude of 1115 m.

Habitat: It is an (oligo)-mesotrophic species. Its phytocoenotic preferences have not been precisely defined, owing to the fragmentary information found on the herbarium labels. The description of communities in which it occurs is a result of my original observations. In subprovinces 843 and 314 (Fig. 6) it occurs in forest communities from the class *Vaccinio-Piceetea* (mainly in boreal spruce woods *Sphagno girgensohnii-Piceetum*, and in bog pine woods *Vaccinio uliginosi-Pinetum*) and from the class *Alnetea glutinosae* (predominantly in carrs). Occasionally, it occurs in non-forest communities (e.g. in meadows and pastures on mineral soils belonging to the class *Molinio-Arrhenatheretea* Tx. 37). The specimens from northeastern and eastern Poland have typical features of the species and their identification is easy, based on the shape and position of chlorophyllous cells in cross sections of branch leaves (Melosik 1993). It is much more vigorous in that area in comparison with specimens gathered in other parts of Poland, where it forms only tiny populations. The characteristic distribution in Poland is indicative of its specific status.

Sphagnum papillosum Lindb.

Distribution: Prevalent or locally frequent mainly in the lowlands (Fig. 7). Its highest locality in Poland is reported from the Tatra Mts. (Mt. Świstówka), from the altitude of about 1500 m.

Habitat: In Pomerania (subprovinces: 313, 314) and in the uplands (342) it is found in raised bogs, where it usually forms populations in local depressions or in the transition zone between hollows and hummocks. It occurs mainly in natural associations of the class *Oxycocco-Sphagnetea* (e.g. in *Sphagnetum magellanici* (Malc. 1929) Kästner et Flössner 1933). Its most common associates are *Polytrichum strictum*, *S. fallax* (Klinggr.) Klinggr., and *S. magellanicum*. In the extreme northwestern part of Poland (subprovinces 313, 314), apart from the above community, it is often found in Atlantic wet heaths (in communities from the order *Sphagno-Ericetalia* Br.-Bl. 48 em Moore (64) 68. In these communities it occurs together with *Erica tetralix* L., *Juncus squarrosus* L. and *Trichophorum caespitosum* (L.) Hartman, and is usually accompanied by *S. compactum* DC in Lam. & DC and rarely by *S. molle* Sull. It also occurs in communities of the class *Scheuchzerio-Caricetea fuscae*, which develop in extensive bogs.

Sphagnum affine Ren. et Card.

Distribution: Very rare countrywide (Fig. 8). It is found at scattered localities mainly in Pomerania (subprovinces: 313 and 314) becoming very rare in the remaining areas. The highest localities of this species are in the Western Carpathians within the Western Beskids (subprovince 513) and Kotlina Orawsko-Nowotarska (subprovince 514) at an altitude of 610 m.

Habitat: Because of its rarity its ecological preferences have not been precisely defined. According to herbarium labels, specimens have been gathered both

from natural ecosystems (peatlands) and from habitats that have undergone significant anthropogenic transformations (pond edges). Its most common associates are *S. papillosum* and *S. rubellum*. In the Western Carpathians it was found in a dystrophic community from the alliance *Rhynchosporion albae* Koch 1926. The following species are associated with *S. affine*: *Eriophorum angustifolium* Honck. (5.5 according to the Braun-Blanquet method), *E. vaginatum* L. (1.2), *Andromeda polifolia* L. (1.2), *Calluna vulgaris* (L.) Hull (1.2), *Drosera rotundifolia* L. (+.2), *Potentilla erecta* L. (+), *Oxycoccus palustris* Pers. (+.2), *Pinus rhaetica* Brugg. By contrast, *Sphagnum centrale* occurs predominantly (22.3-29.3% of localities) in two northeastern subprovinces (Fig. 6, 843 and 842) but is also commonly represented in subprovince 314 (13.2% of all localities) and in the immense subprovince 315 (12.2%). A high density of localities of the studied peat mosses was recorded also in the uplands (e.g. *S. palustre,* 6.0-7.9%, *S. papillosum*, 6.8-12.4 %, and *S. magellanicum*, 9.5% in subprovinces 341 and 342). Nevertheless, also in the lowlands (subprovinces 842 and 843) numerous localities of *S. magellanicum* (10.5-12.0% of the total number) are present.

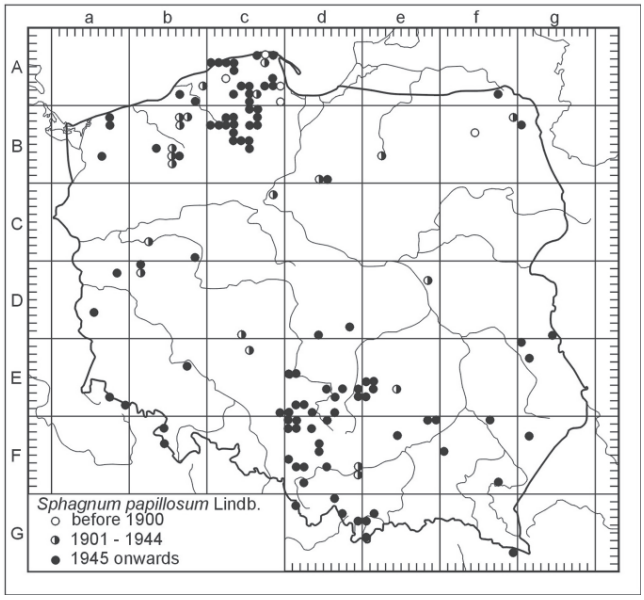

Fig. 7. Distribution of *Sphagnum papillosum* Lindb. in Poland on the basis of verified herbarium collections

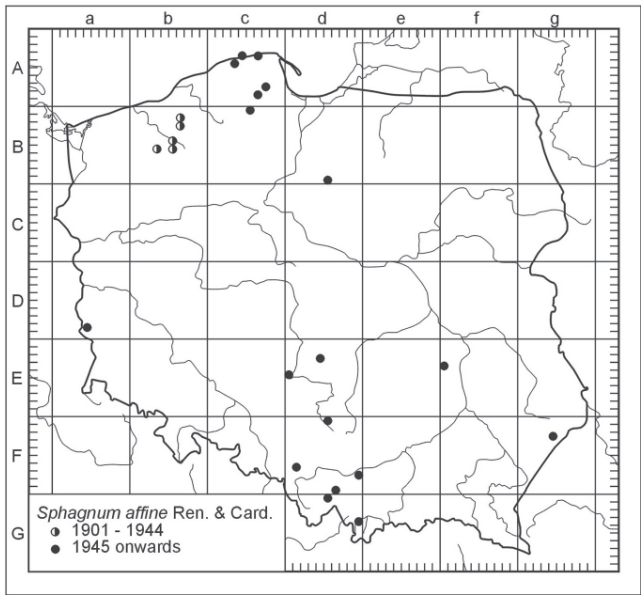

Fig. 8. Distribution of *Sphagnum affine* Ren. & Card. in Poland on the basis of verified herbarium collections

(+) (Koczura, unpubl. data). Specimens from Poland show the typical traits, i.e. 2-3 pendent branches in each fascicle, absence or presence of only a few comb-lamellae in the upper part of branch and stem leaves, very pronounced inner stem cortical comb-lamellae, several hyalocyst cells divided by septa into 2-4 parts in the upper part of stem leaf. Other characters mentioned by Flatberg (1986) as specific for *S. affine* (lack of comb fibrils in the distal part of stem leaves, color of the plants, general habit: lax mats or compact cushions) are highly variable, at least in specimens from Polish herbaria.

3.3. Frequency of species

Table 1 presents information on the proportion of localities of each analyzed species within each subprovince (according to Kondracki 1988). These data show that out of 5 analyzed species, the majority of localities (30-46.8%) of four species (*S. palustre, S. magellanicum, S. papillosum* and *S. affine*) are found in subprovince 314 (northwestern part of the country).

Only a small number of accessions originated from the mountain areas of the Sudety Mts. (subprovince 332) and the Carpathians (subprovinces 513, 514 and 522). Only *S. papillosum* has a larger representation in the Sudety Mts. (4.5% of all localities). Within the mountains, *S. palustre*, *S. centrale* and *S. papillosum* are mostly found in the submontane and the lower mountain forest zones. *Sphagnum magellanicum* is more frequent in the Carpathian coniferous forest (upper montane zone) and in the subalpine vegetation zone. However, a significant uncertainty is associated with these results, because of the frequently incomplete altitude data, and because of the fact that the majority of the verified materials originated only from the Western Carpathians (subprovinces 513 and 514). Additional studies involving more specimens, which are supplied with adequate descriptions of localities, are necessary to draw reliable conclusions.

Sphagnum austinii has not been detected among the analyzed samples. This species has been reported from

Poland only by Flatberg (1984). The locality quoted by that author, however, is outside the Polish borders. [Ostpreussen. Samland. Cranzer Hochmoore. 1922 Dietzow (H), 14. August 1932 (S)].

4. Discussion

The distribution of localities listed for species of the section *Sphagnum* reflects general preferences of species, the uneven distribution of suitable habitats, the state of bryological explorations of the different regions, and the accessibility of herbarium materials for this study (Figs. 1-8).

Most of the samples representing 4 out of the 5 taxa analyzed here originated from subprovince 314 (Table 1). It includes parts of the northwestern lake districts, which are entirely covered by landforms produced by the Pomeranian phase of the most recent Baltic glaciation (Weichselian). In geological terms, this is the youngest of the Pleistocene formations of the Polish lowland. Landforms within this area include terminal moraines abounding in lakes, outwash plains, and ground moraines, which are intersected by meltwater valley channels produced as a result of the melting glacier. Here the relative altitudinal differences are the greatest within the Polish lowland (50-329 m a.s.l.) and the landscape resembles foothills.

Another characteristic feature of this area is the large number of lakes. Nearly half (48%) of all Polish lakes are found in Pomerania (northern part of Poland) (Choiński 1991a, 1991b). Of this number, the majority (89%) are small, rather shallow water bodies without any outflow, and are overgrown to various degrees. The development of peatbogs in Pomerania, including subprovince 314, depends mainly on the process of colonization of edges of such lakes by land vegetation. Natural geological, geomorphological and hydrological conditions give rise to an outstanding diversity of peatlands (Herbichowa 1998). Besides, forests cover the largest areas in western and northwestern Poland. The climate of this subprovince is also diverse. The western and northern peripheries exhibit oceanic features, whereas the central part is cool (with a low mean January temperature of -3.2°C, and extended period of frost and snow cover). Annual rainfall ranges from 440 mm to 794 mm on western moraine slopes (Czubiński 1950).

The diverse climate, relief and hydrology of this area are responsible for the significant contributions of Atlantic, boreal and alpine-boreal species to its flora. This explains the presence in this area of relatively numerous populations of the boreal *S. centrale* (13.2%) as well as species generally considered as (sub-)Atlantic (Flatberg 1986), i.e. *S. papillosum* (37.3%) and *S. affine* (46.8%).

The distribution of localities of the studied species also reflects the fact that Pomerania has been intensively explored by Polish and German bryologists, who left abundant herbarium records.

Another area where peat moss localities are aggregated is the belt of uplands (e.g. subprovinces 341 and 342, Fig. 6). The distribution of localities, however, is not uniform there because of both natural causes and the uneven herbarium collection coverage. Peat mosses occur here in natural habitats (e.g. bogs) and secondary habitats. For example, the high density of localities in the uplands (Silesian Upland, within subprovince 341) may be explained by the vast number of mostly human-formed ecosystems available for colonization by *Sphagnum* (artificial reservoirs, such as fish pond complexes, ditches, clearings in boggy coniferous forests). All of these habitats are fed by acid rain generated by heavy air pollution in this most industrialized region of Poland. They are mostly boggy areas with a thin layer of peat, where peat-forming vegetation is predominantly in the initial stage of development. From this region a large number of herbarium specimens are available. On the other hand, Cretaceous formations generated by the karst process occur in the subsoil, creating numerous and widespread depressions filled with lakes and peatbogs (e.g. Kielce-Sandomierz Upland, subprovince 342). Accordingly, numerous peat bogs exist in this area and the number of verified specimens is relatively high. A similar aggregation within Poland is observed for *S. denticulatum*, and, to a lesser extent, for *S. inundatum* (Melosik 2000).

From the species considered here, only *S. centrale* is sparsely represented in the uplands (341 and 342). The majority of *S. centrale* sites in the country belong to Eastern Europe (subprovinces: 842, 843 and, to a lesser extent, 845).

The northeastern part of the country is also the coldest (like the highest mountains). The mean January temperature drops below -5°C. Snow cover lasts 90-110 days (compared to 40-60 days in the west) and the growing period is reduced to 180-200 days. Under these continental influences, *S. centrale* reaches its ecological optimum.

A much greater density of localities could be expected for *S. papillosum* and, presumably, for *S. affine* in the south-western part of the country (subprovince 332), where also a large number of suitable sites influenced by the Atlantic climate are available. In this case, the small number of localities reflects the fact that only some physiographic units within this province have bryological documentation in the form of available herbarium specimens.

Acknowledgments. I am very grateful to the curators of the herbaria B, BSG, BIL, GDMA, HAL, KRAM, LBL, LOD, POZM, POZG, POZNF, STU, SOSN, SZUB, SZCZ, TRN, UGDA, WA, WRAB, WSRP, WRSL for loaning herbarium materials; to K. I. Flatberg, A. Rusińska, P. Urbański for valuable suggestions, discussions and comments; and to B. Malczewska and A. Dembiński for technical assistance.

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