

## The genus *Sphagnum* L. in Portugal

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**Abstract** – The genus *Sphagnum* L. is studied through the revision of the Portuguese specimens collected in Continental Portugal, either kept in Portuguese herbaria or from author's collections. Distribution patterns are presented in individual maps for each taxon and related to climatic and topographic conditions. Twenty one taxa are reported, mainly distributed in the Northwest, in coastal lagoons and in the Central Mountain range. In the last twenty years most of the taxa had their distribution areas enlarged because of intensive fieldwork while others could not be confirmed recently. Comments on their diagnostic characters, phenology and chorology are presented, in order to emphasise the importance of studying these taxa at a regional level and at the southern limit of their European range. Their conservation status is evaluated according to IUCN categories and compared to that of the Iberian Peninsula and also the main threats are identified.

*Sphagnum* / taxonomy / distribution / ecology / conservation / Iberian Peninsula

### INTRODUCTION

In Portugal the first reference to *Sphagnum* dates from the beginning of the XIX century (Brotero, 1804). Until the beginning of the XX century others have further studied its variation and distribution (Leresche & Levier, 1880; Henriques, 1889; Sampaio, 1902; Coutinho, 1917; Machado 1913, 1917a, 1917b; Allorge, 1928), but only in 1932 (Machado, 1932) was this genus studied in Portugal according to the ongoing taxonomic criteria and integrated in a Portuguese moss flora, as Casares Gil (1925) had done before for the Iberian Peninsula as a whole. More recently important contributions about distribution areas in Portugal include the work of Sá Nogueira (1950), Sérgio (1969, 1972), the revision of the herbarium of A. Machado (PO) (Séneca, 1989; Séneca *et al.*, 1992) and Sérgio & Schumaker (1992). In Portugal, with few exceptions (Jansen, 1994), *Sphagnum* is usually absent from general ecological work either because of incomplete knowledge of the bryoflora in some areas, or because mires are not a community type with significant expression in the area. Since mires are protected habitats and *Sphagnum* has here its European southern limit, regional revisions as the one here presented are intended to help other botanists to use *Sphagnum* in their ecological and conservation assessment investigations at these latitudes.

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The aim of this work is to present distribution patterns of *Sphagnum* species known to occur in Portugal, with notes on the phenology, chorology and regional threat status as compared to that of the Iberian Peninsula.

## THE STUDY AREA

The Iberian Peninsula, in which Portugal lies at the western part, occupies a southern position in the temperate zone of the northern hemisphere (Fig. 1). Its climate is strongly influenced by the seasonal latitudinal displacements of the Polar Front and by the general atmospheric flow from West to East. The Peninsula lies almost entirely within the oscillation band of this set of climatic conditions. This determines a seasonal precipitation rhythm, less pronounced in the northwest, where the tails of the fronts still affect the area during summer so that a temperate bioclimate can be recognised (Rivas Martinez & Loidi, 1999). The strong relief and the compact form of the territory modify significantly the air masses, creating a true mosaic of regional climatic variants. The highest altitude lies in the central part of the country and is *ca* 2000 m, but the northwestern areas reach a maximum of *ca* 1500 m, though 1000 m is not unusual.

Vegetation reflects mainly climatic parameters derived from the geographic conditions described above. The potential vegetation consists mainly of woods of different species of *Quercus* that characteristically reflect the main bioclimatic domains. The *Sphagnum* taxa occur in open habitats, covering slopes, depressions or elevated plateaus mainly in areas above 500 m, and/or where the atlantic influence is stronger, like in the coastal and sub coastal plains.

## METHODS

The study area includes the continental part of Portugal. The *Sphagnum* material used was, besides from the author's own collections, kept at PO, and the Portuguese specimens kept at the following herbaria: PO, LISU, LISE, LISFA, AVE, INA, COI and G (Vitt *et al.*, 1985). This involved the study of *ca* 700 specimens collected in Portugal. The material was determined or revised mainly according to Daniels & Eddy (1985, 1990) criteria. A list of specimens list will not be presented here but is available under request.

The distribution maps (Figs 3-21) were obtained by locating every collection in a 10x10 km UTM grid. These maps also include literature references without corresponding herbarium material. The symbols used in the maps are:

- for material collected before 1950;
- for material collected after 1950;
- for literature references older than 1950;
- for literature references from 1950 onwards.

The occurrence of each taxon in Continental Portuguese provinces follows Casas *et al.* (1985,1996) (Fig. 2), and is given at the end of every taxon's comments. When the province reference corresponds only to literature references, its name is shown between brackets. For each taxon, data on distribution, ecological requirements, rarity/vulnerability are mentioned.

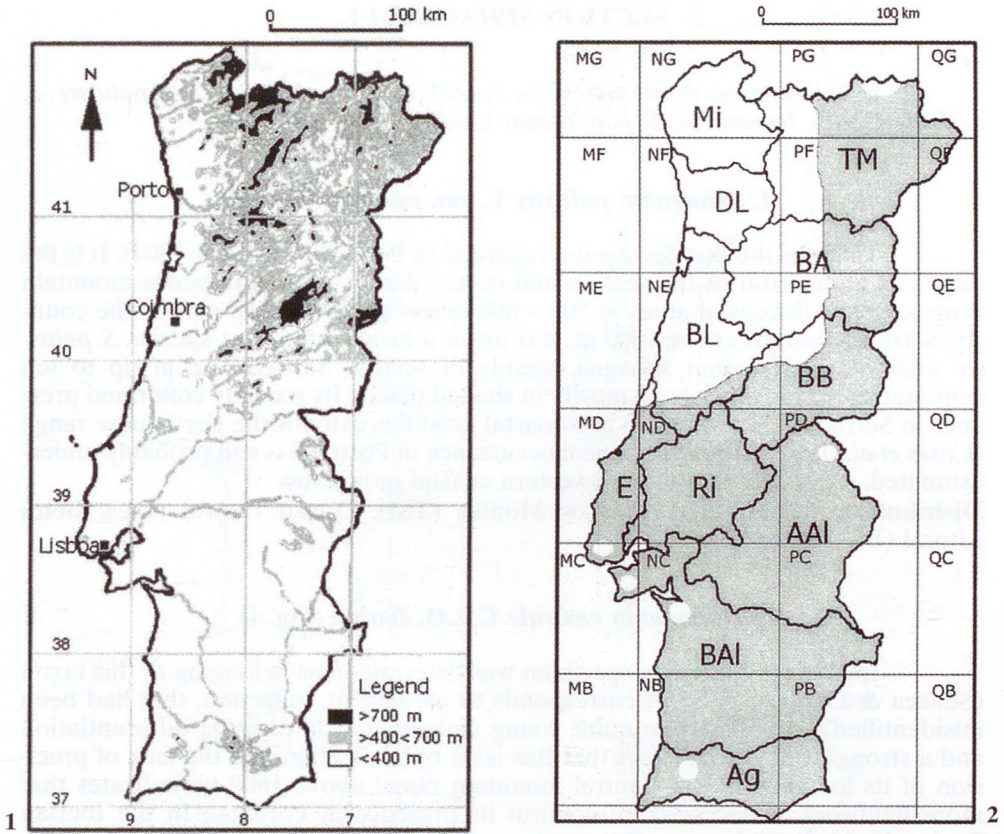


Fig. 1. Study area: hypsometric map of Continental Portugal with geographic coordinates and main towns.

Fig. 2. Map of Continental Portugal with provinces according to Casas *et al.* (1985-1996) and 50 x 50 km UTM grid; shaded areas are those where *Sphagnum* is rare. **Mi** – Minho; **DL** – Douro Litoral; **TM** – Trás os Montes; **BL** – Beira Litoral; **BA** – Beira Alta; **BB** – Beira Baixa; **Ri** – Ribatejo; **E** – Estremadura; **AAI** – Alto Alentejo; **BAI** – Baixo Alentejo; **Ag** – Algarve.

### DISTRIBUTION OF SPHAGNUM TAXA

Twenty-one *Sphagnum* taxa were identified as occurring in Continental Portugal. Some are restricted to particular relict areas while others are well - spread throughout the territory. In some areas only the taxa from the *Subsecunda* section occur. These are areas where the climate and/or topography conditions limit the occurrence of complex *Sphagnum* communities. In other areas, *Sphagnum* species are well - integrated in mire complexes represented by well-developed populations, which occur along water depth and/or altitude gradients.

## SECTION *SPHAGNUM* L.

In this section three taxa were considered: *S. palustre* L. var. *palustre*, *S. centrale* C.E.O. Jensen and *S. papillosum* Lindb.

### 1. *Sphagnum palustre* L. var. *palustre* (Fig. 3)

This was the first *Sphagnum* recorded in Portugal (Brotero, 1804). It is the most common taxon of the section and occurs mainly in northwestern mountain ranges, locally in coastal areas at 500 – 600 m and in the central part of the country, Serra da Estrela, above 1600 m. It is never a locally abundant species. *S. palustre* associates with other sphagna, mainly of section *Subsecunda*, at up to ten centimetres above water level mostly in shaded places. Its recently confirmed presence in Serra da Estrela and in two coastal localities extends the Portuguese range (Casas *et al.*, 1992). However its real occurrence in Portugal is still probably underestimated, especially in the northwestern coastal mountains.

**Distribution:** Minho (Mi), Trás os Montes (TM), Douro Litoral (DL), Beira Litoral (BL), Beira Alta (BA).

### 2. *Sphagnum centrale* C.E.O. Jensen (Fig. 4)

In Portugal only one specimen was determined as belonging to this taxon (Séneca & Daniels, 1994). It corresponds to an ancient collection, that had been misidentified. The plants are quite young and show little capitula differentiation and a strong isophylly. The fact that this is an old collection and the lack of precision of its location, in the Central mountain range above 1600 m, indicates that more fieldwork is necessary to confirm its presence in Portugal. In the Iberian Peninsula this boreal taxon with continental tendencies (Duell, 1985) seems to be rare, since it has been recorded for the Pyrenees, above 1700 m (Casas *et al.*, 1992).

This taxon has received different taxonomic treatments, so these plants are either considered to be a separate species (Crum, 1984) or a variety of *S. palustre* (Daniels & Eddy, 1990). These authors also state that these plants often present strong morphological plasticity, especially in areas with oceanic influence. On the other hand, isozyme analysis of populations of *S. palustre*, *S. centrale* and *S. magellanicum* Brid. in Poland revealed that *S. centrale* should be accepted as a distinct species, though closer to *S. magellanicum* than to *S. palustre* (Krzakowa *et al.*, 1995).

**Distribution:** Beira Alta (BA).

### 3. *Sphagnum papillosum* Lindb. (Fig. 5)

In Portugal *S. papillosum* occurs in mountainous areas: near the coast, above 700 m and inland, above 1600 m. The lack of recent collections renders its ecological characterization difficult, though the areas where it was spotted are subject to strong to mild oceanic influence. This influence can be nevertheless masked at a local topographic/microclimatic scale. The distribution of *S. papillosum* in Portugal follows the same phytogeographic and altitudinal patterns, as it does in the whole Iberian Peninsula (Casas *et al.*, 1992).



Fig. 3



Fig. 4



Fig. 5



Fig. 6



Figs 3-6 – 3. Known range of *Sphagnum palustre* in Portugal. — 4. Known range of *Sphagnum centrale*, *S. girgensohnii* and *S. angustifolium* in Portugal. — 5. Known range of *Sphagnum papillosum* in Portugal. — 6. Known range of *Sphagnum molle* in Portugal (□ before 1950; ■ collections after 1950; ○ literature references before 1950; ● literature references from 1950 onwards=).

In Portugal only epapillose forms of this taxon are present. In some cases these forms have been given the variety status and named *S. papillosum* Lindb. var. *laeve* Warnst. The occurrence of these forms in the territory and in the Iberian Peninsula was confirmed through the revision of some of the *S. palustre* material (Casas *et al.*, 1992). Nevertheless, the diagnostic morphological characters used to distinguish this epapillose variety of *S. papillosum* from *S. palustre* do not seem to be very reliable (Crum, 1984; Séneca, 1999). The European distribution and chorology of epapillose *S. papillosum* are not clearly defined as well as its ecological requirements (Nyholm, 1969; Duell, 1985; Daniels & Eddy, 1990). These forms need further morphological and ecological study in order to assess their taxonomic status. Otherwise confusion with *S. palustre* or even with *S. centrale* is possible (Crum, 1984).

**Distribution:** Minho (Mi), Beira Alta (BA).

## SECTION ACUTIFOLIA WILS.

This section includes 6 taxa out of 15 known to occur in Europe (Flatberg, 1994). Some of them are among the most common sphagna in Portugal. Most of them grow well above the water level and show mainly minerotrophic and oligotrophic affinities.

### 1. *Sphagnum molle* Sull. (Fig. 6)

This species was first collected during some phytosociological fieldwork (Braun-Blanquet *et al.*, 1952). The corresponding material was determined latter as *S. capillifolium* (Ehrh.) Hedw. Barendregt & van den Dries (1984) also reported it from Portugal, though the corresponding material could not be studied because it was not found. The presence of *S. molle* in Portugal has only been confirmed by some recent collections near the Atlantic coast (Séneca & Daniels, 1994). Its inland occurrence above 1600 m (Barendregt & van den Dries, 1984) needs further confirmation in the field. Though frequently fertile throughout its range in Europe, all the Portuguese material lacked sporophytes. In its coastal locality it was found on open soil around *Erica tetralix* bushes at the edge of a small sloppy bog, belonging to a complex of small mires on the delta of River Vouga. This confirms its sub-oceanic affinities (Duell, 1985).

**Distribution:** Beira Litoral (BL), Beira Alta (BA).

### 2. *Sphagnum subnitens* Russow & Warnst. (Fig. 7)

*Sphagnum subnitens* is the second most common *Sphagnum* species in Portugal after *S. auriculatum* Schimp. It is rather frequent in the northwest and in the sub-coastal mountain ranges, but is now apparently extinct from these areas in the southern part of the country, e.g., in Monchique (Crundwell, 1956) due to fire and anthropogenic pressure. It occurs preferentially on wet heaths, on the external hydric belt of the mire complex or as part of hummocks, and is locally abundant especially in areas with oceanic influence at low to medium altitudes. At high altitudes it is less common and the individuals are less developed. Sometimes

shoot iridescence on drying is not obvious and there exists a weak fibrillation on the stem leaf hyalocysts. The recognition of these plants or otherwise uncharacteristic individuals as *S. subnitens* makes use of a set of characters found relevant for the Portuguese material: branch leaves length, always over or at least 1,4 mm long; the diameter size of their mid leaf dorsal pores always over 15  $\mu\text{m}$ . Capsules are often present in the summer, from June to September.

**Distribution:** Minho (Mi), Douro Litoral (DL), Trás os Montes (TM), Beira Alta (BA), Beira Litoral (BL), Beira Baixa (BB), Estremadura (E), [(Algarve (Ag)].

### 3. *Sphagnum capillifolium* (Ehrh.) Hedw. var. *capillifolium* (Fig. 8)

A significant part of the material kept in Portuguese herbaria was misidentified with *S. subnitens*. This happened to the first report of this taxon from Portugal (Mitten, 1853) based on a Welwitsch's collection in Serra de Sintra [Beira Litoral (BL)]. The characters that better separate the two taxa were mentioned under the previous taxon. The present range of *S. capillifolium* in Portugal is now restricted to mountains above 1000 m, though older literature references indicate its presence near the coast. The plants were never found with sporophytes, and are seldom locally abundant. Like the previous taxon, *S. capillifolium* occurs well above the water level in heaths or rock crevices in mires where temperature amplitudes are wider than in oceanic areas. It occurs more frequently in ombrotrophic mires that seem to be restricted to the central part of the country above 1600 m (Séneca, 1999).

**Distribution:** Minho (Mi), Trás os Montes (TM), Beira Litoral (BL), Beira Alta (BA).

### 4. *Sphagnum capillifolium* (Ehrh.) Hedw. var. *tenellum* (Schimp.) Crum (Fig. 9)

Daniels & Eddy (1985, 1990) considered this variety to correspond to *Sphagnum capillifolium* (Ehrh.) Hedw. var. *rubellum* (Wils.) A. Eddy. Nevertheless, the varietal epithet *rubellum* (Wils.) A. Eddy is illegitimate according to the International Code of Botanical Nomenclature (Flatberg, pers. comm.).

It is a very frequent taxon on external wet heath belts of oligotrophic mires or as a component of hummocks, well above the water level. It is more abundant at moderate – high altitudes (700-1600m) and reaches more oceanic areas than the type variety. Portuguese plants were never found with sporophytes. Both this and the type variety are in some cases difficult to separate in the field because the capitula form and the ranked arrangement of branch leaves are often not conspicuous. The best diagnostic characters for the Portuguese material are, besides its chorological and ecological data, the lack of fibrils and the septation, sometimes multiple septation, at the apex of the stem leaf hyalocysts, together with the branch mid leaf dorsal pores diameter, always less than 12  $\mu\text{m}$  and smaller than those of *S. capillifolium* var. *capillifolium*. The occurrence of intermediate forms, particularly in oceanic areas, has been repeatedly reported (Daniels & Eddy, 1985; McQueen, 1989). There is no recent distribution map of this taxon for the European continent, which makes regional contributions (Fuertes & Munín, 1995; Séneca, 1999; Feldmeyer-Christhe *et al.*, 2001) especially important.

**Distribution:** Minho (Mi), Douro Litoral (DL), Trás os Montes (TM), Beira Litoral (BL), Beira Alta (BA).

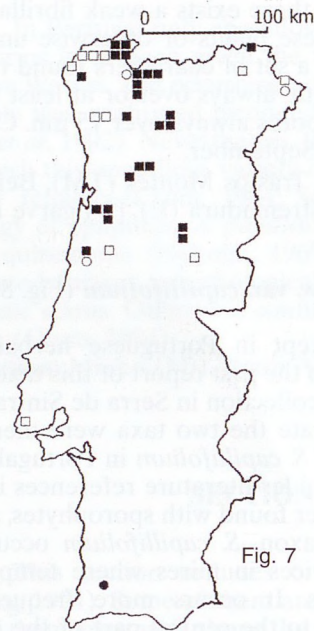


Fig. 7



Fig. 8



Fig. 9



Fig. 10



Figs 7-10 – 7. Known range of *Sphagnum subnitens* in Portugal. – 8. Known range of *Sphagnum capillifolium* in Portugal. – 9. Known range of *Sphagnum capillifolium* var. *tenellum* in Portugal. – 10. Known range of *Sphagnum russowii* in Portugal (□ collections before 1950; ■ collections after 1950; ○ literature references before 1950; ● literature references from 1950 onwards).



### 5. *Sphagnum russowii* Warnst. (Fig. 10)

This circumboreal taxon reaches Portugal at high altitudes, above 1600 m in areas with reduced oceanic influence. It apparently only occurs in Serra da Estrela mires where it forms low hummocks. It is locally abundant in moderately shaded mesotrophic fens, always above the water level. After its first reference (Séneca & Daniels, 1994) other collections were made in the same UTM 10x10 km square, confirming that it is not a rare taxon in the area, where it is integrated in well-structured communities (Jansen, 1994). It has been also reported from Montalegre, Trás os Montes (TM) (Munín & Fuertes, 1998) but these records could not be confirmed so far.

The Serra da Estrela populations could be considered a Quaternary relict due to the characteristics of the site (Janssen & Woldringh, 1981) and to the fact that it was not found elsewhere. If its presence in Trás os Montes (TM) is confirmed, the area has most probably the same geological history.

**Distribution:** Beira Alta (BA).

### 6. *Sphagnum girgensohnii* Russow (Fig. 4)

*Sphagnum girgensohnii* has the same distribution pattern as *S. russowii*. It forms small to medium sized open hummocks in minerotrophic shaded mire areas with mesotrophic characteristics, well above the water level, sometimes in association with *S. russowii*. The first record (Séneca & Daniels, 1994) consisted of plants always without capsules, growing under *Calluna vulgaris* or other species characteristic of wet heaths. Its records in Portugal fit well its chorological range, boreal - mount. (Duell, 1985) though further south than previously described for Europe (Daniels & Eddy, 1985). Together with *S. russowii* its occurrence in Serra da Estrela, above 1600 m, may well correspond to moss relict presences in the Iberian Peninsula.

**Distribution:** Beira Alta (BA).

## SECTION *SQUARROSA* RUSSOW

### 1. *Sphagnum squarrosum* Crome (Fig. 11)

The first report of *S. squarrosum* in Portugal dates from the end of the XIX century; the specimen was collected by Isaac Newton on the surroundings of Porto and was later revised by S.O. Lindberg. This collection, near the coast in Portugal, at ca 50 m, contradicts the chorological tendencies described to date, since these indicate that, in temperate areas of Central Europe, *S. squarrosum* is restricted to high altitudes (Duell, 1985). Recent collections occur, in fact, in areas above 1600 m, in Serra da Estrela where it is locally abundant in the inundated margins, or even floating in meso- to eutrophic lakes. Rarely it also occurs in mats, associated with other *Sphagnum* species in shaded areas of wet heath, and it was never found bearing capsules. The first reference could not be confirmed recently, so it would be wise to consider this taxon extinct in Porto surroundings (Douro Litoral province).

The only other taxon from this section recorded in Serra da Estrela is *S. teres* (Schimp.) Aongstr. (Barendregt & van den Dries, 1984). The material of this reference could not be confirmed and the taxon itself has never been registered in the area since then. Therefore, *S. teres* should be considered to be absent in Portugal.

**Distribution :** Douro Litoral (DL), Beira Alta (BA).

### SECTION SUBSECUNDA LINDB.

This section comprises the most widespread *Sphagnum* taxa in Portugal. They occur in every place where topographic and climate conditions favour the development of *Sphagnum* communities. These taxa exhibit a great deal of morphological plasticity (Daniels, 1985, 1990; Séneca, 1999) that sometimes makes their determination a difficult task and questions recent taxonomic treatments. According to the adopted taxonomic treatment this section includes six taxa in Portugal – *Sphagnum subsecundum* Nees subsp. *subsecundum*, *S. subsecundum* Nees subsp. *inundatum* (Russow) A. Eddy, *S. auriculatum* Schimp. f. *auriculatum*, *S. suriculatum* Schimp. f. *obesum* Warnst. and f. *crassicladum* Warnst. and *S. platyphyllum* (Lindb.) Sull.

Though *S. denticulatum* Brid. was found to be an older name for *S. auriculatum* (Dirkse & Isoviita, 1986; Duell, 1992), this and other taxonomic treatments, e.g., Corley & Crundwell (1992) and Duell (1985), that adopt the name *S. lescurii* Sull., are rejected here. The taxonomic treatment adopted (Daniels & Eddy, 1985) was found more appropriate for the following reasons: *S. lescurii* corresponds to a North American taxon, whose presence in Europe is still to be proved; this name is too agglomerative, reducing to synonymy two taxa - *S. auriculatum* and *S. subsecundum* subsp. *inundatum*; the affinities and differences of these taxa within the *S. subsecundum* complex are not taken into account if *S. lescurii* is used, at least within the complete range of the taxa's distribution. On the other hand, Warnstorf (1911), when revising the type of *S. denticulatum*, included it in *S. obesum* Warnst., confirming the agglomerative nature of that name which prevents the distinction of the *S. auriculatum* forms. In the absence of other detailed morphometric studies and population genetic and ecological investigations, it seems wiser to maintain these entities separate as stated before (Hueber, 1998).

*Sphagnum contortum* K. F. Schultz - already recorded in the Iberian Peninsula (Heras & Infante, 1997) and in studied territory - has been either included in *S. auriculatum* during this work or could not be confirmed.

#### 1. *Sphagnum subsecundum* Nees subsp. *subsecundum* (Fig. 12)

This taxon is the least frequent one from the *S. subsecundum* complex. It occurs in mesotrophic to eutrophic areas, either near the coast or in the north-western mountains, although it is never locally abundant. It colonizes inundated or simply wet areas, and forms loose tufts in exposed places, stream and river banks, or on turf soils as a first colonizer of the muddy borders of mires. Sometimes the plants bear capsules, especially in material collected between June and September. Some of the material first attributed to this taxon, particularly those of older collections, belonged to *S. auriculatum* (Séneca *et al.* 1992). Its occurrence in the central part of the country needs confirmation because the area



Fig. 11



Fig. 12



Fig. 13

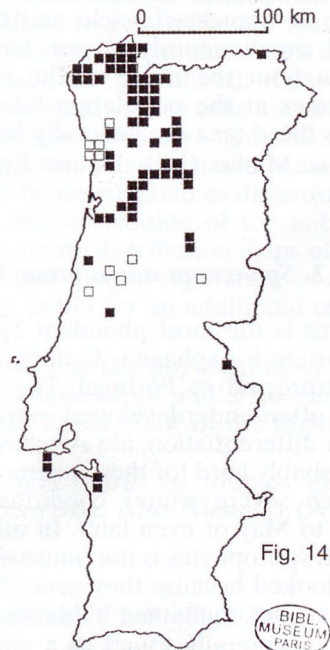


Fig. 14

Figs 11-14. **11.** Known range of *Sphagnum squarrosum* in Portugal. — **12.** Known range of *Sphagnum subsecundum* in Portugal. — **13.** Known range of *Sphagnum subsecundum* ssp. *inundatum* in Portugal. — **14.** Known range of *Sphagnum auriculatum* f. *auriculatum* in Portugal (□ collections before 1950; ■ collections after 1950; ○ literature references before 1950; ● literature references from 1950 onwards).

has been devastated by fire during the last decades. It has not been recorded in Serra da Estrela above 1600 m, an area that includes all *Sphagnum* taxa known to occur in Portugal except most of the *Subsecunda* Section.

**Distribution:** Minho (Mi), Trás os Montes (TM), Beira Litoral (BL), Beira Alta (BA).

## 2. *Sphagnum subsecundum* Nees subsp. *inundatum* (Russow) A. Eddy (Fig. 13)

This taxon occurs in areas subject to oceanic influence, from low to medium altitudes, up to 800 m. It thrives in the same type of areas as the type subspecies, though at lower water levels and in more shaded mesotrophic places, where individuals can present quite robust habits. It frequently bears capsules, especially in the summer. It is readily distinguished from the type subspecies by the form and size of the stem leaves and by its ecology (Crum, 1984; Daniels & Eddy, 1985, 1990). The taxon is frequently misidentified as *S. auriculatum* because of the liability of some morphological characters considered to be distinctive (Daniels & Eddy, 1985, 1990): the leaf number/divergent branch is a subjective character, because these leaves are not always neatly ranked so that counting is difficult, and the number of branches per fascicle, though consistent in undoubtfull specimens, can show some variation even along the same individual (Séneca, 1999). The taxon is polymorphic and the confusion with *S. auriculatum* Schimp. affects individuals with a mixed combination of characters: fibrillation of the stem leaves sometimes exceeding one third of their length together with a characteristic number of branches/fascicle and the asymmetry of the basal branch leaves maintained simultaneously or not. Unequivocal establishment of the ecological limits throughout the range of the two taxa as well as morphometric and genetic studies at the population levels are urgently needed for these taxa. In other areas these taxa are generally better individualized than in Portugal.

**Distribution:** Minho (Mi), Douro Litoral (DL), Trás os Montes (TM), Beira Litoral (BL).

## 3. *Sphagnum auriculatum* Schimp. f. *auriculatum* (Fig. 14)

This is the most abundant *Sphagnum* species. Wherever the conditions are appropriate for sphagna, *S. auriculatum* is present. Its suboceanic tendencies are well expressed in Portugal. The plants occurring in the central mountain ranges are often underdeveloped individuals, with marked isophylly and very little capitula differentiation, always sterile and having the aspect of young colonizers. It is probably hard for these plants to maintain adult colonies at these altitudes and in such severe winter conditions, where the snow cover can last from November to May or even later. In other areas in Portugal, the presence of individuals with sporophytes is not unusual, especially in the summer. The capsules are often overlooked because they generally develop from lower branches instead of capitula branches, remaining hidden from the surface of the mats.

It is generally found as a component of the centre of mire complexes where it occupies areas with meso- to oligotrophic characteristics, a few centimetres higher than the water level, infrequently floating, or as part of spring mires which is generally the case of the southernmost populations. In the Quaternary, its distribution was extended further south (Séneca *et al.*, 1992) but the post Holocene climate warmings shifted northwards the southern border of its range.

Plants of this taxon are extremely variable, showing a high degree of morphological plasticity, which is hardly correlated with main ecological factors. Most of the diagnostic characters work well for Portuguese plants, especially the percentage of fibrillated area in the stem leaves and their size. For the number of leaves/divergent branch see comments under *S. subsecundum* subsp. *inundatum* with which it often shares the same number of branches/fascicle.

**Distribution:** Minho (Mi), Douro Litoral (DL), Trás os Montes (TM), Beira Litoral (BL), Beira Alta (BA), Beira Baixa (BB), Estremadura (E), Alto Alentejo (AAI), Baixo Alentejo (BAI).

#### 4. *Sphagnum auriculatum* Schimp. f. *crassicladum* Warnst. (Fig.15)

##### *Sphagnum auriculatum* Schimp. f. *obesum* Warnst. (Fig.16)

As the type form, these occur mainly in suboceanic areas, always bordering free water, pools in the centre of mires, slow flowing stream margins and frequently floating or submerged. This particular ecology may be responsible for the occurrence of more normally developed individuals at higher altitudes than plants of the type form because of the buffering capacity of water in relation to temperature fluctuations. Plants of these forms are never found with capsules. They are extremely plastic morphologically, ranging from the normal aspect of the type form to very much loose individuals with very large leaves, either stem or branch leaves, though adult forms show marked heterophylly. The characters separating them from the type form are mainly the porosity of the branch leaves - either absent or disperse in *obesum* and *crassicladum*, respectively, and mainly ventral in *crassicladum* form. Nevertheless, other morphological characters common to both *obesum* and *crassicladum* forms should be considered: the relationship between length and width of branch leaf hyalocysts - these cells are in most cases longer and narrower than in typical forms of *S. auriculatum* - and width of chlorocysts, which are nearly always wider in these forms. These characters are quite consistent in the Portuguese material and could be investigated as diagnostic features that together with an accurate ecological characterization of the habitat would help to the delimitation of these taxa. There are no distribution maps of these taxa in Europe because, in most cases, they are not treated separately from the type form, though this information could also be useful for an additional chorological characterization.

Evaluation of the potential variability of the populations of these taxa seems to be fundamental to establish their relationships and/or to estimate their evolutionary status as separate entities. Both forms occur in the provinces mentioned below (Figs 15 and 16).

**Distribution:** Minho (Mi), Douro Litoral (DL), Trás os Montes (TM), Beira Litoral (BL), Beira Alta (BA), Beira Baixa (BB), Alto Alentejo (AAI), Baixo Alentejo (BAI).

#### 5. *Sphagnum platyphyllum* (Lindb.) Sull. (Fig. 17)

In the course of this revision most of the herbarium material previously identified as *S. platyphyllum* was transferred to *S. auriculatum*. Only one record was kept as *S. platyphyllum* with some reserves, because leaf size was not as described, though the multilayered stem hyalodermis decisively contributed to its determination. Anyway, the occurrence of this taxon should be confirmed with the

collection of further material, though the rarity of this taxon has been reported from other European regions (Daniels & Eddy, 1985; Feldmeyer-Christhe *et al.*, 2001). Its collection at ca 500 m in an oceanic area agrees with other distribution patterns of bryophytes that, in oceanic areas, can occur at lower altitudes than they normally do in more continental areas.

**Distribution:** Minho (Mi).

### SECTION *CUSPIDATA* LINDB.

From this Section only 3 taxa of the 16 recorded in Europe (Flatberg, 1994), are presently registered in Portugal. Their occurrence is mostly limited to areas above 1000 m either in the north or the central mountain ridges, Serra da Estrela. Recent fieldwork in this area suggests the occurrence of two other taxa of this section, which are currently under evaluation.

#### *Sphagnum cuspidatum* Ehrh. ex Hoffm. (Fig.18)

The plants can present terrestrial or aquatic habits, but the latter ones are the most common in Portugal. It is the most widespread taxon of the section, colonizing the margin of oligotrophic lakes at the centre of mires or even submerged and floating. In these conditions the plants were never found with sporophytes. In one of the rare cases of detected terrestrial forms, the plants bore capsules, which is a very uncommon event in Portugal. Although described to have distinct oceanic tendencies (Daniels & Eddy, 1985), in Portugal *S. cuspidatum* only occurs above 1000 m, and in sites where this influence is weak: areas where annual mean temperature varies between 6 and 12 °C and/or winters are more severe (Séneca, 1999). Munín & Fuertes (2000) drew the Iberian map of *S. cuspidatum* though the recent collections in the northern part of the country were not included.

The recently described *Sphagnum viride* Flatb. (Flatberg, 1988) could be included in the *S. cuspidatum* collections, or be present in Portugal, as suggested by some collections under study and also because it occurs in Spain (Munín & Fuertes, 1999). The close relation of the two taxa at morphological and, in some cases, ecological level, makes further study necessary for their separation as different taxa. Although intermediate forms in northern Europe and in North America are not known (Flatberg, 1988), isozymic evaluation of differences fails to support this treatment, even in northern Europe (Hanssen *et al.*, 2000).

**Distribution:** Minho (Mi), Trás os Montes (TM), Beira Alta (BA).

#### 2. *Sphagnum flexuosum* Dozy & Molk. (Fig. 19)

The occurrence in Portugal of *S. flexuosum* agrees with its chorological tendencies (Daniels & Eddy, 1985) because at these latitudes the taxon only occurs at high altitudes, where it forms extensive carpets far from the water level in mainly ombrotrophic grazed mires, being locally abundant. Its temperature requirements are even tighter than the previous taxon, since recent collections only refer it for areas with mean annual temperature of up to 9° C. Nevertheless it tends to occupy places or niches where the oceanic influence is slightly higher.



Figs 15-18. **15.** Known range of *Sphagnum auriculatum* f. *crassicladium* in Portugal. — **16.** Known range of *Sphagnum auriculatum* f. *obesum*. — **17.** Known range of *Sphagnum platyphyllum* in Portugal. — **18.** Known range of *Sphagnum cuspidatum* in Portugal (□ collections before 1950; ■ collections after 1950; ○ literature references before 1950; ● literature references from 1950 onwards).

Old records in areas other than the central mountain ridges are still to be confirmed. In these mountains it seems to substitute the taxa of the *S. recurvum* complex at the community level (Séneca, 1999). The presence of *S. recurvum* P. Beauv. or taxa belonging to the *S. recurvum* complex has been reported (Jansen, 1994; Greven & van Melick, 1994) from Serra da Estrela, but the material is still under study.

**Distribution:** Minho (Mi), Trás os Montes (TM), Beira Alta (BA).

### 3. *Sphagnum angustifolium* (Russow) C.E.O. Jensen (Fig. 4)

*S. angustifolium* occurs in areas with strong continental influence. It is a rare taxon that has been recorded only in the central mountain ridges above 1600 m. It grows normally associated with other sphagna, above the water level and tolerates moderate shade. Temperature requirements, which seem to follow those of *S. flexuosum*, and its chorological tendencies, severely restrict the number of potential areas for its occurrence in Portugal. Plants were never found with capsules. Its morphological similarity with *S. flexuosum* may cause some difficulties in the field, and thus an underestimation of their presence in the studied territory. The available Iberian distribution map (Munín & Fuertes, 2000) does not mention any record of this taxon in Portugal though its presence has been known in Serra da Estrela since 1916 (Machado, 1932).

**Distribution:** Beira Alta (BA).

## SECTION MOLLUSCA SCHLIEPH.

### *Sphagnum tenellum* (Brid.) Brid. (Fig. 20)

*S. tenellum* is rather frequent in Portugal. Frequently the plants bear capsules being the first plants of *Sphagnum* to have mature sporophytes in the year, generally around May. It integrates wet heaths in oligotrophic areas, in pure mats or together with *S. subnitens*, *S. capillifolium* var. *tenellum* or *S. compactum*, always above the water level. It is a locally abundant taxon occurring mainly in sub-oceanic areas. It occupies a rather wide range of altitudes, generally above 900-1000 m, though near the coast it can grow at much lower altitudes. Its Portuguese range has been very much expanded by recent fieldwork and the present distribution map (Fig. 20) updates the Iberian cartography of *S. tenellum* presented by Munín & Fuertes (2000).

**Distribution:** Minho (Mi), Douro Litoral (DL), Trás os Montes (TM), Beira Alta (BA).

## SECTION RIGIDA LINDB.

### 1. *Sphagnum compactum* Lam. & DC. (Fig. 21)

The occurrence of *S. compactum* in Portugal is restricted to the driest parts of wet heaths well above the water level, mostly in association with *S. tenel-*





Fig. 19



Fig. 20



Fig. 21

Figs 19-21. **19.** Known range of *Sphagnum flexuosum* in Portugal. — **20.** Known range of *Sphagnum tenellum* in Portugal. — **21.** Known range of *Sphagnum compactum* in Portugal (□ collections before 1950; ■ collections after 1950; ○ literature references before 1950; ● literature references from 1950 onwards).

*lum* or other peat mosses. In other cases the plants can also be found growing in wet rocks crevices probably because the plants are quite tolerant to summer drought. They are generally found with capsules around July. In some cases the plants develop large rounded capitula, mainly at higher altitudes, which contradicts the capitulum morphology generally presented in common descriptions. The taxon is usually locally abundant at all altitudes, from the coast to nearly 2000 m in the central mountain ridges.

**Distribution:** Minho (Mi), Trás os Montes (TM), Beira Alta (BA), Beira Litoral (BL).

## DISCUSSION

### Distribution data analysis

Early *Sphagnum* collections (before 1950) indicate that early sphagnological work was made either around the biggest urban areas or in areas where these taxa showed *a priori* a greater probability to occur (Fig. 22): the northwestern and central mountain ridges. Between 1950 and 1980, 30 new other 10x10 km UTM squares were recorded with *Sphagnum* species. These mainly corresponded to the central area of the country, either near the coast or inland. After 1980, *Sphagnum* species were recorded in 29 new 10x10 km UTM squares, corresponding mainly to inland collections especially in the north. The collection of *Sphagnum auriculatum* in southern areas like Setúbal Peninsula and Sado estuary, and particularly in inland sites are also important contributions from a chorological point of view.

Current data reveal an obvious and generalized expansion of the distribution areas of the different *Sphagnum* species in Portugal (Fig. 22). Before 1950 only 39 10x10 km UTM squares had registered sphagna occurrences, against the 100 squares that presently record *Sphagnum* presences. Despite this, it should be considered to be extinct from five squares. These correspond to urban areas where building has had a strong effect on the destruction of the sphagna habitats. Other areas, particularly in the northwest, also suffered a vulgarisation of the bryological and sphagnological flora due to anthropogenic influence, mainly drainage for agriculture purposes, a practice that began in the Quaternary. The most recent probable case of extinction is the southernmost record of *Sphagnum* in Portugal that corresponds to *Sphagnum subnitens* in Serra de Monchique (Crundwell, 1956), which has no longer been found. The area has been strongly devastated by fire in the last decades, which probably caused its extinction. The other case is the Welwitsch collection of *S. subnitens* in the Serra de Sintra (Estremadura) that could not be found in the place for several years and thus also probably extinct in the area. The occurrence of this taxon in these southern locations is a significant indicator of the bioclimate characteristics of these mountain ridges, and also reveals that climatic parameters are key ecological factors supporting mire communities in the core of the Mediterranean Region in Portugal.

The Portuguese sphagna occur mainly in the Eurosiberian region (Sérgio & Draper, 2001) and, in scattered spots, high enough or damp enough so that minimum moisture/low temperature conditions exist. The species chorological character is mainly oceanic and suboceanic, lacking all species in areas with marked continental tendencies.

As shown in Fig. 23, the greatest diversity of *Sphagnum* taxa is achieved in mountain areas, especially in the northwest and central mountain ridges. Annual precipitation can reach 3000 mm in the northwest, and the central mountains rely on the snow cover as an important reservoir of water available for these plants during warmer seasons. Both correspond to areas where vestiges of the Würmian glaciation period have been identified (Janssen & Woldringh, 1981; Coudé-Gaussen, 1981), which confers a relict character to some of the taxa and to the communities as well. Vestiges of *Sphagnum* material from this Ice Age were collected at more southern latitudes than present collections (Séneca *et al.*, 1992), which helps to characterize the climate of the area by that time. Areas with fewer *Sphagnum* species are also interesting either because of the floristic composition of their bryophyte communities (Séneca, 1999) or because of the climatic indicator value of taxa, which helps to characterize small areas with oceanic characteristics as enclaves in the Mediterranean region.

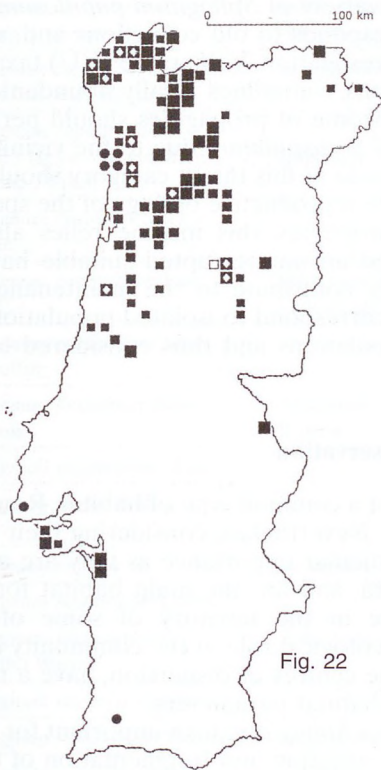


Fig. 22



Fig. 23

Fig. 22 – Occurrence of *Sphagnum* species in Portugal during three periods of time: ■ collections before 1950; ■ collections between 1950 and 1980; ■ collections after 1980; □ literature references; locations where *Sphagnum* is known to occur from early collections until now; ◊ locations where *Sphagnum* is likely extinct.

Fig. 23 – Number of *Sphagnum* taxa registered in each 10 x 10 km UTM square: ● 1; ● 2-4; ● 5-7; ● 10; ● >10

### Vulnerability of *Sphagnum* taxa

The evaluation of *Sphagnum* regional conservation status under Red List Categories and criteria (IUCN, 2000) following the guidelines of Hallingbäck *et al.* (1998) at a regional level (IUCN/SSC, 1999) indicates that 10 taxa should integrate a list of threatened species (Table 1). The critically endangered (CR) taxa correspond to unique isolated populations that, at least in the case of *S. molle*, are at considerable risk due to land use in the area. At the same time, considering reproduction strategies, distance and the habitat requirements for settlement, there will hardly be any income of propagules from other Iberian populations.

*Sphagnum angustifolium* was not included in the Iberian Red List (Sérgio *et al.*, 1994), although more recent collections have confirmed both its existence and low frequency in its classical collection site. The case of *S. centrale* and *S. platyphyllum* is rather the same, but further field effort should confirm other occurrences, otherwise they could be considered extinct. The two considered endangered (EN) taxa correspond to two different situations: *S. girgenshonii* has a restricted occurrence and is not abundant in the area. At the same time, it occupies an area severely grazed. The epillose variety of *Sphagnum papillosum* has not been evaluated before. Its material corresponds to old collections and, additionally, its taxonomic status needs further investigation. Vulnerable (VU) taxa are mainly taxa represented by several populations, sometimes locally abundant, but restricted to few areas in the country. The income of propagules should perhaps only be considered to be likely in the case of *S. cuspidatum* due to the vicinity of the Galician populations. In this case, an upgrade of this threat category should be evaluated. On the other hand, according to the reproductive biology of the species (McQueen, 1985) that rarely produces sporophytes, this income relies almost exclusively on vegetative diaspores that need an uninterrupted suitable habitat across the geographical border to effectively contribute to the maintenance of population levels. The other vulnerable taxa correspond to isolated populations at one site, which can be considered relict populations and thus considered to be endemics (IUCN/SSC, 1999).

### Threats and Conservation

Mires in Continental Portugal are not a common type of habitat. Roughly they occupy ca. 0,01% of the whole territory. Nevertheless, considering their geographical position, these habitats assume particular importance as they are made of patches of communities with peculiar flora, and are the main habitat for the Portuguese *Sphagnum* species. The absence in the territory of some of the European *Sphagnum* taxa means that their ecological role at the community level is taken over by others that, in areas near the centres of dispersion, have a more discriminative behaviour in relation to microhabitat parameters.

Another important feature that makes *Sphagnum* taxa important for conservation at this regional scale is the relative isolation and fragmentation of their populations and the relict character of some of them.

Although the Portuguese sphagna occupy a very restricted part of the global *Sphagnum* range and none of the taxa has a significant proportion of the global population in this country, they are taxa with small distribution areas included in mire communities at the southwestern border of their European range. In this case, though the Portuguese populations are unlikely to be important for the global survival of these *Sphagnum* species, these and the mire com-

Tabl. 1. *Sphagnum* taxa recognized in Portugal with synonyms used in ancient bryological Portuguese literature (Machado, 1932. Classification of the threat status according to IUCN Red List Categories and Criteria (IUCN, 2000) and compared to the one published in the Iberian Red List (Sérgio *et al.*, 1994) for Portugal (between brackets). **NT** – Not Threatened; **VU** – Vulnerable; **EN** – Endangered; **CR** – Critically Endangered; **R** – Rare; **Ex** – Extinct; **K** – Insufficiently known species; **?** - Conservation status not mentioned.

List of <i>Sphagnum</i> taxa occurring in Portugal	Ancient synonyms (Machado, 1932)	Threat status (IUCN, 2000)	Threat status (Sérgio <i>et al.</i> , 1994)
<i>Sphagnum angustifolium</i> C.E.O. Jensen	<i>Sphagnum amblyphyllum</i> Russow var. <i>parvifolium</i> Warnst.	CR B2a	VU (?)
<i>Sphagnum auriculatum</i> Schimp	<i>Sphagnum auriculatum</i> Schimp.	NT	NT
<i>Sphagnum auriculatum</i> Schimp. f. <i>crassicladum</i> Warnst.	<i>Sphagnum rufescens</i> Limpr., <i>Sphagnum crassicladum</i> Warnst.	NT	NT
<i>Sphagnum auriculatum</i> Schimp. f. <i>obesum</i> Warnst.	<i>Sphagnum obesum</i> Warnst.	NT	NT
<i>Sphagnum capillifolium</i> (Ehrh.) Hedw. var. <i>capillifolium</i>	<i>Sphagnum acutifolium</i> Ehrh.	NT	NT (R)
<i>Sphagnum capillifolium</i> (Ehrh.) Hedw. var. <i>tenellum</i> (Schimp.) Crum .	<i>Sphagnum rubellum</i> Wils	NT	NT
<i>Sphagnum centrale</i> C.E.O. Jensen		CR B2a	VU(Ex)
<i>Sphagnum compactum</i> Lam. et DC.	<i>Sphagnum compactum</i> Lam. et DC.	NT	NT
<i>Sphagnum cuspidatum</i> Ehrh. ex Hoffm.		VU B2a	R (VU)
<i>Sphagnum flexuosum</i> Dozy & Molk.	<i>Sphagnum amblyphyllum</i> Russow	VU B2a	NT (EN)
<i>Sphagnum girgensohnii</i> Russow		EN B2a	NT (VU)
<i>Sphagnum molle</i> Sull.		CR B1ab(iii); B2ab(iii)	VU(EN)
<i>Sphagnum palustre</i> L.	<i>Sphagnum cymbifolium</i> Ehrh.	NT	NT (R)
<i>Sphagnum papillosum</i> Lindb.		EN B2a	?
<i>Sphagnum platyphyllum</i> (Lindb.) Warnst.	<i>Sphagnum platyphyllum</i> Warnst.	CR B2a	NT (K)
<i>Sphagnum russowii</i> Warnst.		VU B2a;D2	NT (VU)
<i>Sphagnum squarrosum</i> Crome	<i>Sphagnum squarrosum</i> Pers.	VU B2a;D2	VU(VU)
<i>Sphagnum subnitens</i> Russow & Warnst.	<i>Sphagnum plumulosum</i> Röll	NT	NT
<i>Sphagnum subsecundum</i> Nees	<i>Sphagnum subsecundum</i> Nees	NT	NT
<i>Sphagnum subsecundum</i> Nees. subsp. <i>inundatum</i> (Russow) A. Eddy	<i>Sphagnum inundatum</i> Warnst.	NT	NT
<i>Sphagnum tenellum</i> (Brid.) Brid.	<i>Sphagnum molluscum</i> Brid	NT	NT

munities they integrate deserve conservation and monitoring as they represent, in many cases, unique and representative communities in the country and even in the whole Iberian Peninsula.

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