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Review

The Use of Plant Macrofossils for Paleoenvironmental Reconstructions in Southern European Peatlands

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Abstract: The analysis of plant macrofossils in peatland ecosystems has been widely used for the climatic and ecological reconstruction of the Holocene in the high latitudes of the northern hemisphere. By contrast, perhaps associated with rarity of these ecosystems, this proxy has barely been explored for southern Europe. In this work, a compilation and review of existing knowledge on the study of plant macrofossils of peatlands in southern Europe has been carried out, both from a paleoenvironmental perspective and in terms of biodiversity dynamics. Although small in surface area, the peatlands of southern Europe stand out for their diversity (botanical, edaphogenic, morphological, etc.), which has allowed the recovery of a large number of macrofossils from both vascular plants and bryophytes. The southern zone of Europe contains refuge zones with a high plant diversity that have not suffered the intense glaciation of the northern zones, this allows a continuous record since the beginning of the Holocene and the detection of climatic events in lower latitudes, where the ice recession was earlier.

Keywords: paleobotany; paleoclimatic reconstructions; plant remains; mires; bogs

1. Introduction

Peatland ecosystems occupy 3% of the Earth's surface, around 420 million ha. mostly in the boreal zone of the northern hemisphere [1]. The distribution of these habitats has been reduced especially in southern Europe; c. 60% of European peatlands have been destroyed due to human activities [2,3]. The Habitats Directive 92/43/EEC of the European Union [4], considers peatlands as ecosystems of priority community interest, for which it is necessary to designate areas for their conservation.

Peatlands provide a detailed record of the climatic and ecological changes that occurred during the Holocene, because they preserve a continuous record of fossil remains in very good state of conservation [5,6]. There is a rich history of paleobotanical research in Europe focused on plant macrofossils, however, most of these studies consider fossils that are older than Holocene. The analysis of plant macrofossils has been commonly used in oceanic regions of Europe, mainly in Great Britain; however, despite the potential wealth of information there are few studies in peatlands of southern Europe. This region has a variety of peatlands, which provide habitats for numerous relict, disjunct and endemic species, and communities.

Holocene plant macrofossils in southern Europe are generally related to archaeological studies on the beginnings of agriculture, the expansion of different cereals, the diversity of food of different cultures, etc. In recent decades the interest in paleoenvironmental studies and the recognition of the value of information on flora and vegetation of past times, has led to increased studies on plant macrofossils, within the time frame of the Holocene.

Plant macrofossil records are spatially much more precise than the pollen data. They present great taxonomic resolution, if the samples are well preserved, they can be identified at species level such as *Carex* or *Potamogeton* [7,8]. They are a valuable tool for obtaining good radiocarbon dating [9,10] and are very helpful in the reconstruction of the forest development, tree and, timber line shifts in the mountain ecosystems [11] or to reconstruct trails of plants spreading and migration. Another use of these macrofossils is to deliver reference conditions during reconstruction of the vegetation population, that is necessary for restoration process [12,13]. Southern Europe is heavily populated and in recent decades many of these ecosystems have been exposed to human land use change (peat bedding, grazing, fuel, acidifying, etc.), which has affected species composition.

Analyses of plant macrofossils from peat cores provides a high-resolution record of vegetation change through time. The study of peat slices 1 or 2 cm thin, allows to obtain data for very small time escals. This is especially valuable to reconstruct local plant development. Peat accumulation is primarily the result of the slow decay rate of the species in the plant communities under certain climate and anoxic conditions [14,15]. The more decomposition, the less identifiable macrofossils remain in the peat, however a biochemical footprint remains, and in recent decades numerous works have focused on identifying some of the major changes in vegetation by analyzing these biomarkers by pirolisis-GC/MS [16–21].

In this paper, we will focus on plant macrofossils data. The existence of common or biogeographically conditioned patterns and the relevance of the data from the botanical and paleoenvironmental standpoint will be explored.

2. Material and Methods

Peatlands are widely distributed across northern Europe, however in the southern part its extension is much smaller, occupying mainly mountainous areas. We review the various types of peatland and lake systems along the continuum of terrestrialization. Occasionally some peaty paleo-deposit has been included, due to the paleoenvironmental interest of the identified macrofossils. Figure 1 shows the distribution of peatlands in Europe according to Moen et al. [22] the numbers refer to Table 1. All localities below 50° N parallel have been considered and a summary of basic core data grouped by zone is given in Table 1.

Only those studies that have explicitly processed and identified plant macrofossils have been included, excluding data provided by coals, oospores of *Characeae,* and invertebrate remains. The summary Tables 2–4 group the macrofossil taxa identified in each work and include the type of remains found through a series of abbreviations for vascular plants: Leaf (LF), stomata (ST), epidermis (E), needles (NE); rhizome (R), wood (W), cones (C), bud scales (BS), bark (BK), roots (R), seeds (S), fruit (F), these last two concepts appear often confused in the different identifications, are considered fruits, achenes, or nuts (nutles) of all *Cyperaceae* and many *Rosaceae*, as well as the cariopsis of Poaceae. In the case of Bryophyta, the filidia are more abundant in the remains and only in very well conserved peat do filidia, caulidia, or large fragments of moss appear and very rarely capsules and the term vegetative part (VP) has been chosen. Data referring to sclerotia (SCL) of fungi have been included, as they are large and common in numerous papers.

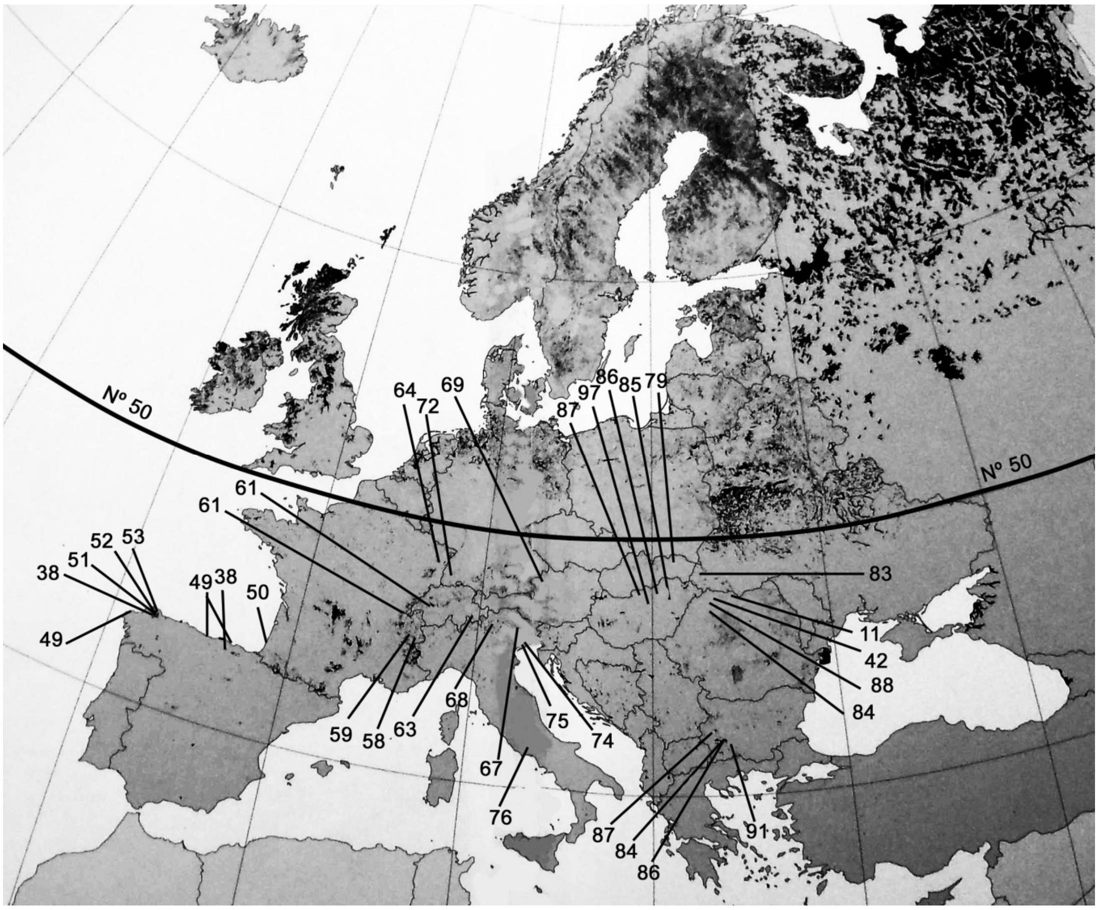

Figure 1. Distribution of peatlands in Europe and the location of sites mentioned in the text. The references correspond to the numbering in the bibliography (modified from Moen et al. 2017).

Table 1. Description of sites mentioned in the text. Ref: The references correspond to the numbering in the bibliography.

SITE LOCATION	DEPTH (cm)	Yrs. Cal. BP	MATERIAL	ALT (m a.s.l.)	REF	AUTOR
		WEST ZONE				
Zalama, De Ordunte Mts. (ES)	226	8000	Peat	1330	38	Souto, 2018
Borralleiras, Cabaleiros Mts. (ES)	230	5500	Peat	600	38	Souto, 2018
Pena da Cadela, Serra do Xistral (ES)	183	5500	Peat	970	51	Castro et al., 2015
Chan de Veiga Mol, Serra do Xistral (ES)	845	8000	Peat	695	52	Castro, 2017
Pedrido, Serra do Xistral (ES)	250	4750	Peat	770	53	Stefanini et al., 2018
Noja, Cantabric Coast (ES)	100	3200–4600	Coast peat deposit	50	49	García et al., 2008
Merón, Cantabric Coast (ES)	20	6000–7000	Coast peat deposit	50	49	García et al., 2008
Baldaio, Cantabric Coast (ES)	30	870	Coast peat deposit	25	49	García et al., 2008
Le Moura, Cantabric Coast (FR)	600	10,000	Peat		50	Oldfield, 1964

Table 1. *Cont.*

SITE LOCATION	DEPTH (cm)	Yrs. Cal. BP	MATERIAL	ALT (m a.s.l.)	REF	AUTOR
		CENTRAL ZONE				
Grande Basse, Vosges Mts. (FR)	200	3000	Peat	945	64	Kalis et al., 2006
Canard Ib, Taillefer Massif (FR)	125	10,000	Peat	2200	58	Ponel et al., 1992
Lac Lauzons, Hautes-Alpes (FR)	170	10,000	Peat	2180	59	Ponel et al., 2011
Egelsee-Moor Mire, Salzburg (AT)	600	10,000	Peat	700	69	Krisai et al., 2016
Fuorn Mire, Fuorn Valley (CH)	255	8500	Peat-Gyttja	1805	63	Stahii et al., 2006
Lac de Fully, Rhône Valley (CH)	270	11,000	Gyttja	2135	62	Finsinger and Tinner, 2007
Gerzensee (CH)	190–200	11,500	Gyttja	630	61	Tobolski and Ammann, 2000
Leysin (CH)	320–350	10,850–12,050	Gyttja	1230	61	Tobolski and Ammann, 2000
Northern Black Forest (GR)	80	2000	Peat	430	72	Hölzer and Hólzer, 2000
Palughetto, Lapisina Valley (IT)	50	12,200	Paleo peat	1040	67	Avigliano et al., 2000
Totenmoos, South Tyrol (IT)	800	15,000	Peat	1718	68	Heiss et al., 2005
Paludetto S2, Venetian plain (IT)	500–1050	8700	Peat	50	75	Miola et al., 2010
Fiorentina, Venetian plain (IT)	1100–1800	3000–17,000	Peat-clay-silt	50	74	Miola et al., 2006
La Rota, Posta Fibreno (IT)	400	600	Peat		76	Zaccone et al., 2017
		EAST ZONE				
Begbunar, Osogovo Mts (BG)	105	5000	Peat	1800	95	Lazarova et al., 2015
Lake Ostrezko, Rila Mts (BG)	200	6000	Peat	2340	92	Tonkov and Marinova, 2005
Lake Besbog, Pirin Mts (BG)	380	15,000	Peat-Gyttja	2200	94	Stefanova et al., 2006
Vodniza, Rila Mts (BG)	500	9500	Peat-Gyttja	2113	91	Tonkov et al., 2018
Tara, Mts. (RS)	270	9000	Peat	1600	97	Fisinger et al., 2017
Nagymohos (HU)	140–280	4000–7500	Peat	300	85	Magyari et al., 2001
Báb-tava, Bereg Plain, (HU)	142–176	1000–2300	Peat	100	86	Magyari et al., 2008
Sirok Nyírjes-to, Mátra Mts, (HU)	400	9000	Peat	250 m	42	Jakab & Sümegi, 2010
Gärgäläu fen, Rodna Mts. (RO)	150	9500	Peat	1810	11	Feurdean et al., 2016
Valea Morii, North western (RO)	100	1100	Peat	640	88	Galka et al., 2018
Tăul Muced, Rodna Mts. (RO)	500	9000	Peat	1360	84	Galka et al., 2016
Belanské Lúky, Tatra Mts. (SK)	230	10,000	Peat	700	79	Hájková et al., 2012
Nádas Lake, Cserhát Mts. (HU)	340	8000	Peat-Clay	360	87	Sümegi et al., 2009
Starunia, Carpathos (UA)	300–500	12,000	Peat-Clay	400	83	Stachowicz-Rybka et al., 2009

3. Results and Discussion

Southern Europe contains numerous refugia with a high plant diversity that did not suffer the intense glaciation of the northern areas. The long persistence of peat "islands" has allowed the development of endemic plants and communities. The age of many of these peatlands, with records beginning before the Holocene (Table 1), allows a continuous recording and detection of climatic events in lower latitudes, where the ice recession was earlier. We can define three basic areas of study: A western area where most peatland habitats are mainly on the Iberian Peninsula; a central area in the Alps; and an eastern area that encompasses the Carpathians and Balkans.

3.1. Problems in the Identification of Plant Macrofossils

The analysis of macrofossils is not a technique with a complicated methodology, nor does it require great investment, or equipment, but it does require expert knowledge in botany (taxonomy), plant histology (morphology), and plant ecology.

The identification of plant macrofossils is based on comparisons with published descriptions and illustrations and the use of reference material. Few publications cover the range of plant material found in peatlands and in many cases corresponds to works from Russia [23–26] or northern Europe [27–31].

An important component of the remains preserved in peat are seeds and fruits, whose identification is easy from monographs of each botanical group; some families or typical genus of peatlands have been studied from this point of view, as for example *Cyperaceae* [32]; *Juncus* [33]; *Vaccinium* [34]; *Menyanthes* [35]; or *Betula* [36].

Some species are only represented by fruits and seeds (e.g., *Drosera*). These are often herbaceous species with small or delicate vegetative tissues (Figure 2). Other species, such as *Eriophorum* have resistant and perennial organs; the macrofossils found in the fossil record correspond mainly to remains of subterranean organs, roots, rhizomes, or basal areas of aerial parts and occasionally fruits (Figure 2), its identification depends on the epidermal cell pattern, stomas, hairs, or foliar margin and when not enough diagnostic characters of the species are preserved its identification results more difficult. For plant macrofossils found in ombrophic peatlands, descriptive and illustrated work by Souto et al. [37] can be consulted.

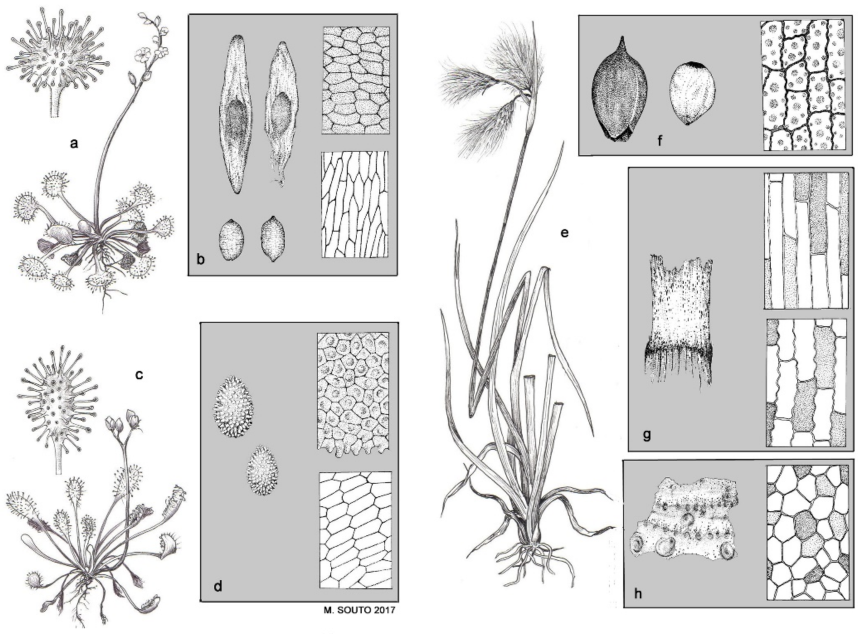

Figure 2. Fresh plants and corresponding macrofossils: *Drosera rotundifolia* (**a**) habit, (**b**) seeds; *Drosera intermedia* (**c**) habit, (**d**) seeds; *Eriophorum* sp (**e**) habit, (**f**) achenes, (**g**) remains of stems, (**h**) remains of rhizomes (Souto, 2018) [38].

The bryophytes are relatively easy to identify, since the determination of material in vivo is based mainly on the anatomy of the leaves and on their small size and it is common that they are well conserved in the peat. Sometimes they are altered by decay, keeping only certain parts, such as the zones of insertion of filidia or only the caulidia (Figure 3). They are important components of peatland flora, so their identification in macrofossil studies is vital to the interpretation of these habitats [39–42]. A detailed description of fossil bryophytes for ombrotrophic peatlands of the Cantabrian coast can be found in Souto et al. [43].

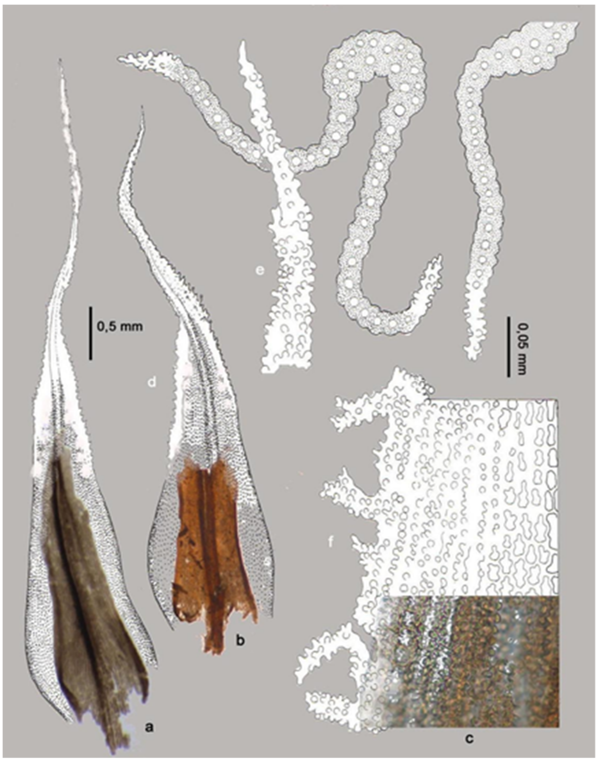

Figure 3. Example of differential degradation in *Racomitrium. lanuginosum*: (**a**,**b**) central parts of fossil leaves, (**c**) mid-leaf cells (fossils), (**d**,**e**,**f**) current leaves, hyaline apex and papillary rim (Souto, 2018) [38].

3.2. Macrofossils: West Zone (Iberian Peninsula)

In the Iberian Peninsula, the first studies of macrofossils in peatlands consisted of specific identifications, the works of Maldonado et al. [44] in Sierra de Gredos stand out. They prospected a wide area of peatlands and small lakes, located between 1100 and 1840 m a.s.l., collecting a great quantity of samples, among which stand out stumps in position of life, trunks of up to 5 m of length and 40 cm of diameter and numerous strobilus, dated between 850 and 5500 years cal BP. Other sampling areas include a synthesis on macrofossils collected in coastal areas, from the Cantabrian region to southern Portugal [45–48], the quaternary sediments that preserve peat bog deposits found in Noja, Oyambre-Merón, and Baldaio [49] stand out for their diversity in species. Although these works improve knowledge in the Iberian Peninsula mainly of forest species, they are not paleoenvironmental reconstructions of the same ecosystem over time. The work in the peatland of Le Moura [50] (Biarritz, south-west France), is the first that conserves a continuous sample of the flora since 10,000 years cal BP.

In the last decade, more precise paleobotanical investigations have been carried out, based on the analysis of plant macrofossils extracted from peat samples from different ombrotrophic peatlands in the north of the Peninsula [37,38,43,51–53]. These works provide a precise vision of the vegetation in each peatland, and the similarities between different proxy can offer more solid data for this region.

In the Iberian Peninsula, the different types of peatlands of the Atlantic region and some types of the Mediterranean and alpine region are present [54–57]. In the northwest of the Iberian Peninsula, the largest area is located, forming a complex system (macrotope) (Serras Septentrionais of Galicia, about 10,000 hectares). In this area, blanket bogs find their most southwestern distribution limit in Europe, they are currently restricted to mountain oceanic sectors, under an Atlantic hyperhumic climate very similar to that of northwestern Europe. Due to their ombrotrophic these peatlands are excellent paleoenvironmental archives and have been the subject of numerous studies from a multiproxy approach [37,38,43,51–53].

The high resolution at which these analyses have been carried out (peat samples were studied every 1 cm deep), has made it possible to study the transition of the different plant communities over time, whether or not they represent autogenic successions. The different macrofossils found in these bogs (Table 2) allowed us to reconstruct with great accuracy the plant communities that developed in the peat bog over time. Highlighting that there are no remains of vegetation that may have reached the bog by transport from other places, such as pollen. All the taxa found correspond to species that are currently present in these peatlands. In these ombrotrophic peatlands, plant macrofossils show a great diversity of bryophytes, an herbaceous stratum dominated by Cyperaceae and Poaceae that accompanies different species of Ericaceae shrubs (Table 2). The quotation from *Andromeda polifolia* L. [53], a species not present in the peninsula, stands out, so this quotation is of doubtful interpretation. Many of these peatlands have a strong component of Poaceae and Cyperaceae. Their greatest contribution to the fossil record is in the form of remains of rhizomes, however these are difficult to identify at the species level. Future studies should focus on these structures due to the importance of this group of plants.

Table 2. Macrofossil taxa for ombrotrofic mires in North of Spain. Abbreviations: S—seeds, SCL—sclerotia, LF—leaf, F—fruit, R—Rhizome, W—wood, VP—vegetative part. Ref.: The references correspond to the numbering in the bibliography.

REF. BIBLIOGRAPHY	**[53]**	**[52]**	**[38]**	**[51]**	**[38]**
MACROFOSSIL TAXA					
Betula pubescens		S			
Ericaceae	LF, F, W		LF, F, W		
Erica tetralix	LF				LF, S
Erica mackaiana	LF, S	LF, S	LF, S	LF, S	
Calluna vulgaris	S	LF, S	LF, S	LF, S	LF, S
Andromeda polifolia	LF, S				
Daboecia cantabrica		S			S
Vaccinium myrtillus	LF				LF, W
Poaceae	LF				
Agrostis curtisii				LF,R	LF,R
Molinia caerulea		LF,R,F	LF,R,F	LF,R,F	LF,R,F
Potentilla erecta			LF, F	F	LF, F
Drosera intermedia		S			
Drosera rotundifolia		S	S	S	S
Narthecium ossifragum		S		S	S
Caltha palustris			S	S	
Cyperaceae	LF	LF, R	LF, R	LF, R	
Eriophorum sp.	S, LF	LF, R, S	LF, R, S	LF, R, S	S, LF, R
Carex echinata			F		
Carex demissa				F	
Carex binervis			F		
Carex durieui		F		F	
Rhynchospora alba		F			
Trichophorum sp	LF				

Table 2. *Cont.*

REF. BIBLIOGRAPHY	[53]	[52]	[38]	[51]	[38]
Luzula multiflora				S	
Juncus bulbosus		S	S	S	
Juncus squarrosus			S	S	S
BRYOPHYTA					
Aulacomnium palustre		VP			VP
Calliergonella cuspidata					VP
Campylopus sp	VP		VP		
Dicranum scoparium					VP
Hypnum cupressiforme	VP	VP	VP	VP	VP
Leucobryum juniperoideum		VP	VP	VP	
Polytrichum sp.					VP
Racomitrium lanuginosum		VP		VP	VP
Spagnum capillifolium	VP				
Spagnum tenellum	VP	VP		VP	
Sphagnum acutifolia	VP				
Sphagnum compactum		VP		VP	
Sphagnum cuspidatum		VP			
Sphagnum molle				VP	
Sphagnum papillosum		VP		VP	
Sphagnum sec. acutifolia		VP	VP	VP	VP
Sphagnum sec. cuspidata	VP				VP
Thuidium tamariscinum				VP	
Calypogeia sphagnicola				VP	
Odontochisma sphagni		VP			
FUNGI					
Cenoccocum geophilum	SCL		SCL		SCL

3.3. Macrofossils: Central Zone (Alps)

In France there are few works based on plant macrofossils. In most of the cases they have not been carried out in peatlands, among them, it can be highlighted from the work of Ponel et al. [58,59] in the French Alps above 2000 m a.s.l. It is based on multiproxy analysis that combined palynology with identification of plant macrofossils and insects remains (mainly Coleoptera) this significantly improved the interpretations based on pollen analysis.

The Val-de-Lans basin (western French Alps) provides a rare opportunity to study Middle Pleistocene interglacial sediments, in this lacustrine interglacial deposit a rich flora of wetlands has been sampled [60]. Moreover, lacustrine deposits in Switzerland have recovered an important representation of the flora between the Younger Dryas and the Preboreal [61–63]. In the Vosges an interesting work [64] reconstructs fossil phytosociological communities, comparing groups of plant macrofossils to current communities.

In this central zone, many of the macrofossils are the remains of trees (Table 3) and in many of the peat cores one of the most studied groups is that of the Pinaceae [65,66]. The remains of conifers found in the excavation of a paleo-peatland near Venice [67] and in South Tyrol [68] with dates around the Younger Dryas stand out for their good conservation and abundance.

Table 3. Macrofossil arboreal taxa for central zone. Abbreviations: S—seeds, F—fruit, W—wood, BS—bud scales; NE—needles; BK—bark; ST—stomata. Ref.: The references correspond to the numbering in the bibliography.

REF. BIBLIOGRAPHY	**[50]**	**[64]**	**[58]**	**[69]**	**[63]**	**[62]**	**[61]**	**[61]**
MACROFOSSIL TAXA								
Pinus sp.					ST	S		
Pinus cembra			BS, NE		NE	NE, S, W		
Pinus mugo					W, NE			
Pinus uncinata			NE, S					
Pinus sylvestris							NE, BS,S	NE,BS,S
Picea abies		NE, S		NE, W, S	NE, ST	S		
Abies alba		NE	NE					
Juniperus sp.						W		NE
Juniperus communis			NE, S			NE, W		
Larix sp.			Ne					BS,BK
Larix decidua					NE, ST	NE, S, W		
Salix sp.	BS							BS
Populus tremula							BS,F	BS,F
Alnus glutinosa		S, BS		S, W				
Betula sp.	F, W		BS	S, W				
Betula alba			F			F, BS	F, BS	F
Betula carpatica			F					
Betula pendula		S, BS						F
Betula pubescens							F, BS	F
Betula nana								F
Sambucus racemosa		S						
Fagus sylvatica		BS, W, F						

On the other hand, it is remarkable the absence of identified remains of bryophytes, of all the works studied in the area of the alps, only four [69–72] offer data of mosses. For the reconstructions based on the ecological needs of moss communities, Mitchell et al. [73] used bryophyte presence/absence data from sub-alpine peatlands in the SE Swiss Alps, and bootstrapping cross-validation showing that the best performing single-proxy transfer functions for both DWT (deep water table) and pH were those based on mosses.

In Italy marine transgression has been studied during the last 8000 BP and as an effect on the development of marsh plant communities, in samples of more than 10 m the layers of peat were much rich in plant remains (Cyperaceae and Poaceae) [74,75]. "La Rota" a free-floating mire in lake of Posta Fibreno is an exceptional case of relic mire in central Italy, the top 220–230 cm of this free-floating mire consists almost exclusively of *Sphagnum palustre* [76].

3.4. Macrofossils East Zone

The numerous peatlands studied in the Carpathian area have provided a large amount of bryophyte data, both from the genus *Sphagnum* and Amblystegiaceae (Table 4.) Recent advances in biogeography include the application of macrofossil analysis to study the past distribution of many species and determine if a current species is relict. These models have made it possible to compare current distributions with past distributions, for example, relict bryophytes in the Czech Republic and Slovakia [77–79] and know the degree of regression that some taxa shows today [79]; in some cases it has been demonstrated the existence of an entire community that at present no longer exists as the case of *Stygio-Caricion limosae* alliance [80].

The diversity of peatlands in this area and the good conservation of aquatic and wetland taxa, has allowed us to reconstruct changes in the different paleoecosystems, based on the preferences of the different species [81–83]. These species indicate periods of temporary flooding or fluctuations of the water table, processes of terrestrialization or eutrophication, and autogenic plant succession [84–88].

The highest mountains of Bulgaria (Rila, Pirin, and the Rhodopes) with glacial relief forms with cirques, lakes, moraines, and trough river beds [89–91] where numerous fens are preserved, many of them above 2000 m a.s.l. These peatlands have been the subject of numerous studies [92–95]. That have shown the importance of plant macrofossil analyses in mountainous areas for the estimation of presence or absence of arborea taxa and reconstruct the history of the tree-line fluctuations [91,96,97]. The conclusions from pollen studies alone are more difficult in mountains than in the lowlands because of the importance of pollen transported over long distances [98].

Table 4. Bryophyta macrofossil. Abbreviations: VP—Vegetative parts. Ref.: The references correspond to the numbering in the bibliography.

COD. SITE LOCATION	[79]	[85]	[97]	[87]	[86]	[84]	[88]
MACROFOSSIL TAXA							
Amblystegium kochii					VP		
Amblystegium serpens					VP		
Anomodon sp.					VP		
Aulacomnium palustre		VP			VP		
Brachythecium mildeanum					VP		
Bryum pseudotriquetum	VP						VP
Calliergon giganteum	VP						
Calliergonella cuspidate	VP						
Campylium stellatum	VP						VP
Campylopus sp.						VP	
Depranocladus							VP
Depranocladus aduncus				VP	VP		
Herzogiella seligeri					VP		
Leucodon sciuroides					VP		
Meesia cf hexasticha				VP			
Meesia longiseta		VP	VP	VP	VP		
Meesia trinquetra			VP				
Philonotis calcarean	VP						
Polytrichum strictum	VP					VP	
Scorpidium cossonii	VP						
Scorpidium revolvens					VP		
Sphagnum sp.	VP	VP		VP			
Sphagnum acutifolia				VP		VP	
Sphagnum angustifolium						VP	
Sphagnum cuspidatum					VP		
Sphagnum fuscum	VP						
Sphagnum magellanicum					VP	VP	
Sphagnum obtusum					VP		
Sphagnum palustre	VP	VP	VP	VP	VP		
Sphagnum sec. cuspidate		VP	VP	VP		VP	
Sphagnum squarrosum				VP	VP		
Sphagnum subsecundum					VP		
Thuidium recognitum					VP		
Warnstorfia exannulata		VP	VP				VP
Warnstorfia fluitans			VP				

4. Conclusions

In the studies analyzed for southern Europe we find a great diversity of plant macrofossils. Around 200 taxa of vascular plants and around 50 of bryophytes. With the exception of arboreal and shrub taxa, which present a great diversity of preserved remains, most herbaceous species leave only seeds and fruits in the fossil record. The differential preservation of the different parts of each species must be taken into account for the correct identification of taxa.

High resolution sampling offers the possibility of studying the processes of autogenic succession in these ecosystems. The comparison of the evolution of the different types of peatlands could allow to find patterns and to separate these autogenic changes from climatic or anthropogenic changes. Future studies in the different areas where peatlands abound may help to consolidate the information offered by the different species.

Identification of indicator species, observations, and relationships between current vegetation can be used as a model analogous to past conditions, at least during the Holocene. The European Vegetation Archive (EVA: [99]) and European Vegetation Classification (EVC: [100]) are tools that allow us to know and classify the different groups of European habitats. Another model are macrofossil databases tracing the species distribution dynamics during glacial/interglacial cycles (http://www.sci.muni.cz/bot-any/mirecol/paleo [101]) and making the information more widely accessible to botanists and increasing confidence in paleoecological reconstructions and interpretations.

The study of current species based on their nutritional, environmental, or competitive requirements has provided very useful data for interpreting the different plant communities of the past, especially highlighting the data offered by bryophytes. The works where different proxies are used; allowing to test from different points of view the different hypotheses formulated on the observed environmental changes. In recent years, numerous investigations have been conducted in analyzing other proxy evidence include diatoms, mollusca, fungal remains, ostracods, cladocera, insect remains, and tecameba.

The rarity of these habitats in southern Europe, makes them a valuable resource for study and their present and past diversity must be preserved. All this information obtained from plant macrofossils, apart from studying the dynamics of the vegetation of the past, can also serve to discover future changes and develop programs for the restoration of ecosystems that are realistic and viable over time [102,103]. These habitats are very scarce and are in serious danger in southern Europe.

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