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THREATENED BRYOPHYTES OCCURRENCE IN PORTUGUESE STREAM HABITAT

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Abstract: Bryophyte species are often conspicuous elements of the macrophyte vegetation in mountain streams. Their community structure, habitat tolerances and niche relationships are extremely specialized and correlated with structural and physiological adaptations. The destruction of naturally vegetated mountain environments and flow regulation has caused the disappearance or modification of aquatic and semi-aquatic habitats in many Portuguese streams. This work presents new data concerning threatened bryophyte species distribution and ecology in the mountain streams of the North-West of Portugal, contributing to improve the knowledge of the occurrence of *taxa* evaluated in the Iberian Peninsula and Europe Red Lists of bryophytes.

INTRODUCTION

Stream ecosystems maintain unique and diverse assemblages of species due to high spatial and temporal heterogeneity and their considerable disturbance. Organisms living in these habitats, particularly in mountain areas, must tolerate extreme physical fluctuations and bryophyte species are often conspicuous elements of the vegetation in this habitat (Vitt *et al.*, 1986).

At a regional scale, in this habitat, bryophyte species richness depends mainly on biogeography and historic events, which are reflected in the diverse bryoflora of the Iberian Peninsula (Allorge, 1947; Sérgio, 1990; Sérgio, 2001). Furthermore, at this scale, fluvial geomorphology and catchment geology of the territory will determine the occurrence, distribution and structure of biotic communities on the freshwater ecosystem (Poole, 2002; Ward *et al.*, 2002).

At a local scale the distribution of bryophyte species within the stream and its seasonally emergent zones reflects the patterns of flow velocity, water level fluctuation, detritus

occurrence, substrate nature, heterogeneity and stability, water chemistry, catchment area land use and disturbance events. Moreover, bryophyte community structure, habitat tolerance and niche relationships are extremely specialized and correlated with structural and physiological adaptations of the species to this extreme environment (Glime & Vitt, 1984; Vitt & Glime 1984; Slack & Glime 1985).

In stream ecosystems, bryophytes play an important role, interfering in nutrient dynamics and changing the structure and abundance of stream biodiversity. Additionally they have the potential to compete effectively for resources such as space, nutrients and light and their primary production can equal or exceed that by epilithic and periphytic algae (Bowden *et al.*, 1999).

Springs, flushes and rivers are important habitats in mountain environments but because of their relative small size these habitats are often vulnerable to destruction and disturbance, including drainage, losses to forestry and agriculture, heavy grazing, water pollution (both acidification and nutrient enrichment), riverbank and water flow management. The destruction of naturally vegetated mountain and stream environments have caused the disappearance or modification of aquatic and semi-aquatic habitats in many streams, and the specific requirements of some bryophytes have disappeared as natural flowing waters are modified (Stewart, 1995). In Portugal aquatic ecosystems are among the most threatened by human pressure and many of the aquatic bryophytes are present in the Red List (Sérgio *et al.*, 1994).

STUDIED AREA

Bioclimatic characterization and potential vegetation

North-West Portuguese territories are the most meridional of the Eurossiberian Region and correspond to the transition zone to the Mediterranean Region, which encloses most of the Portuguese territories (Costa *et al*.,1998).

With a predominant temperate and rainy climate, strongly influenced both by the soothing effect of the Atlantic Ocean presence and the Mediterranean influence, this territory has a great phytogeograghic significance, presenting a rich bryophyte and vascular plant catalogue enriched by the migration routes and the diverse types of distributions occurred during geological periods of the Iberian Peninsula formation (Sérgio, 1990).

The typical woodland vegetation includes *Quercus robur* L. and *Betula celtiberica* Rothm. & Vasc. in the most atlantic and rainy areas and *Quercus suber* L. and *Arbutus unedo* L. in the termophilous and driest areas. The tree species most frequently found in the North-West riparian ecosystems are *Alnus glutinosa* (L.) Gaertn., *Betula celtiberica* and *Salix atrocinerea* Brot. (Costa *et al.*, 1998).

METHODS

Sampling strategy

This work presents new data concerning bryophyte species distribution and ecology in the mountain streams of the North-West "Natura 2000 Network Sites" of Portugal (Figure 1). These data were collected during fieldwork (2002-2004) in mountain stream environments subjected to different levels of human pressure and with dissimilar streambed structure and water quality.

The bryophyte communities were sampled using sample plots (0,5mx0,5m) placed in different micro-habitats recognized in the streambed structure and with different levels of submersion and substrate stability (Table 2). Different variables concerning surrounding landscape characteristics, water quality and streambed structure were evaluated in order to relate them with bryophyte communities and threatened species occurrence.

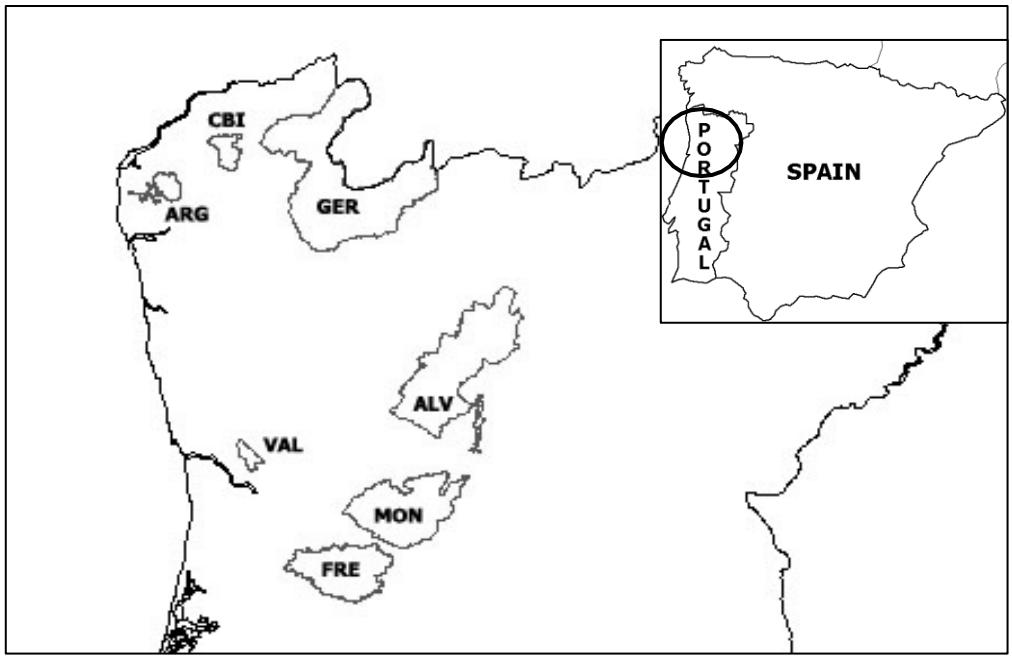


Figure 1. Studied areas and Provinces included in each of these areas (North-west *Natura 2000 Sites*). Côrno do Bico (**CBI**) - Minho province (Mi); Serra d'Arga (**ARG**) - Minho province; Peneda-Gerês (**GER**) - Minho and Trás-os-Montes e Alto Douro (TM) provinces; Valongo (**VAL**) - Douro Litoral province (DL); Alvão-Marão (**ALV**) - Trás-os Montes e Alto Douro province; Montemuro (**MON**) - Trás-os Montes e Alto Douro, Douro Litoral and Beira Alta (BA) provinces; Serras da Freita e Arada (**FRE**) - Beira Alta and Douro Litoral provinces.

Data study

The nomenclature of species is according to Sérgio & Carvalho (2003), except for *Platyhypnidium* genus which follows Ochyra & Bednarek-Ochyra (1999). The authors of species names are cited as proposed by Brummit & Powell (1992).

The biogeographic considerations of the main chorological elements represented in the studied area were made through the percentage analysis of the different chorological types, following Düll (1983, 1984, 1985). The ecological affinities of the species follow Dierβen (2001).

Table 1. Stream bryophytes, their micro-habitats (according to Table 2) and threatening status (Eur= Europe, Lu= Portugal, IP= Iberian Peninsula; Ex= extinct or probably vanished, E=endangered, V= vulnerable, R= rare).

Species	Micro-habitat	Threatening status		Endemic
		Eur	Lu	
Amblystegium riparium (Hedw.) Schimp	(1, 2, 6, 7)	-	-	-
Amphidium mougeotii (Bruch & Schimp.) Schimp.	(10)	-	R	-
Aneura pinguis (L.) Dumort.	(10)	-	-	-
Brachythecium plumosum (Hedw.) Schimp.	(8, 9)	-	-	-
Brachythecium rutabulum (Hedw.) Schimp.	(8, 9)	-	-	-
Brachythecium rivulare Schimp.	(6, 7, 8, 9)	-	-	-
Bryum alpinum With.	(1,3)	-	-	-
Bryum pseudotriquetrum (Hedw.) P. Gaertn., B. Mey. & Scherb.	(6, 8, 10)	-	-	-
Chiloscyphus polyanthos (L.) Corda	(1, 6)	-	-	-
Cinclidotus fontinaloides (Hedw.) P. Beauv.	(1, 6)	-	-	-
Conocephalum conicum (L.) Dumort.	(5, 10)	-	-	-
Dumortiera hirsuta Nees	(10)	R	E	-
Eurhynchium praelongum (Hedw.) Schimp. var. *stokesi* (Turner) Dixon	(8, 9, 10)	-	-	-
Fissidens bryoides Hedw. var. *caespitans* Schimp.	(5, 10)	-	-	-
Fissidens polyphyllus Wilson ex Bruch & Schimp.	(1, 3, 5, 6, 8, 10)	-	-	-
Fisidens pusillus (Wilson) Milde	(2, 7)	-	-	-
Fissidens rivularis Brch & Schimp.	(2, 7)	-	R	-
Fissidens serrulatus Brid.	(10)	-	-	-
Fontinalis antipyretica Hedw. v*ar. antipyretica*	(2, 7)	-	-	-
Fontinalis antipyretica Hedw. v*ar. gracilis* (Lindb.) Schimp.	(2, 7)	-	-	-
Fontinalis squamosa Hedw. var. *dixonii* (Cardot) A. J. E. Sm.	(2, 7)	-	-	-
Grimmia lisae De Not.	(3, 8)			
Gymnomitrion crenulatum Gottsche ex Carrington	(3)	-	V	Eur
Heterocladium heteropterum Bruch & Schimp. *s. l.*	(8)	-	-	-
Hookeria lucens (Hedw.) Sm.	(10)	-	-	-
Hygrohypnum ochraceum (Wilson) Loeske	(1, 6)	-	-	-
Hyocomium armoricum (Brid.) Wijk & Marg.	(3, 6, 8)	-	-	-
Isothecium holtii Kindb.	(3, 8)	-	-	Eur
Jungermannia gracillima Sm.	(8, 10)			
Jungermannia hyalina Lyell	(8, 10)	-	R	-
*Lejeunea lamacerina (*Steph.) Schiffn.	(8, 10)	-	R	-
Lejeunea cavifolia (Ehrh.) Lindb.	(8, 10)	-	-	-

Marchantia polymorpha L.	(8, 10)	-	-	-
Marsupella emarginata (Ehrh.) Dumort. var emarginata	(3, 4, 8, 9)	-	-	-
Marsupella emarginata (Ehrh.) Dumort. var. *aquatica* (Lindb.) Dumort.	(1, 6)	-	-	-
Marsupella sphacelata (Gieseke ex Lindenb.) Dumort.	(1, 3)	-	-	-
Nardia compressa (Hook.) Gray	(1, 3, 6, 8)	-	R	-
Pallavicinia lyelli (Hook.) Carruth	(5, 10)	V	V	-
Pellia endivifolia (Dicks.) Dumort.	(10)	-	V	-
Pellia epiphylla (L.) Corda	(8, 10)	-	-	-
Philonotis fontana (Hedw.) Brid.	(5, 10)	-	-	-
Plagiochila porelloides (Torrey ex Nees) Lindenb.	(8, 10)	-	V	-
Plagiomnium undulatum (Hedw.) T. J. Kop.	(10)	-	-	-
Plagiothecium nemorale (Mitt.) A. Jaeger	(10)	-	-	-
Plagiothecium succulentum (Wilson) Lindb.	(10)	-	R	-
Platyhypnidium lusitanicum (Schimp.) Ochyra & Bednarek-Ochyra	(1, 3, 6, 8)	-	-	Eur
Plathypnidium riparioides (Hedw.) Schimp.	(1, 3, 6, 8)	-	-	-
Polytrichum commune Hedw.	(3, 4, 8, 9)	-	-	-
Porella pinnata L.	(8, 9)	-	Ex	-
Racomitrium aciculare (Hedw.) Brid.	(3, 4, 8, 9)	-	-	-
Racomitrium aquaticum (Schrad.) Brid.	(3, 4, 8, 9)	-	-	-
Racomitrium hespericum Sérgio, Muñoz & Ochyra	(3, 4, 8, 9)	-	-	IP
Racomitrium lamprocarpum (Müll Hal.) Jaeger	(3, 4, 6, 8, 9)	R	-	-
Racomitrium lusitanicum Ochyra & Sérgio	(8, 9)	R	R	IP
Radula holtii Spruce	(10)	R	Ex	Eur
Rhizomnium punctatum (Hedw.) T. J. Kop.	(10)	-	-	-
Riccardia chamaedryfolia (With.) Grolle	(6, 7, 10)	-	-	-
Riccardia multifida (L.) Gray	(10)	-	-	-
Riccia huebeneriana Lindenb.	(5)	R	E	-
Saccogyna viticulosa (L.) Dumort.	(10)	-	R	Eur
Scapania undulata (L.) Dumort.	(11, 3, 6, 8)	-	-	-
Schistidium apocarpum (Hedw.) Bruch & Schimp.	(8)	-	R	-
Schistidium rivulare (Brid.) Podp.	(8)	-	Ex	-
Sphagnum auriculatum Schimp.	(5, 10)	-	-	-
Thamnobryum alopecurum (Hedw.) Gangulee	(6, 8, 10)	-	-	-
Trichocolea tomentella (Ehrh.) Dumort.	(10)	-	E	-
Tritomaria quinquedentata (Huds.) H. Buch	(10)	-	-	-

RESULTS AND DISCUSSION

Aquatic and semi-aquatic communities' diversity

The list of the species found in Portuguese streams of the studied area is presented in Table 1, which shows that aquatic and semi-aquatic communities are rich in endemic and threatened

species at the Portuguese and European level, according to ECCB (1995) and Sérgio *et al.* (1994).

Threatened species

The total number of aquatic a semi-aquatic *taxa* found in North-west Portuguese streams (60% mosses and 40% hepatics) corresponds to 10% of the total *taxa* listed for Portugal (Sérgio & Carvalho, 2003). The number of *taxa* found in the stream habitat that are considered as "threatened" in the Europe or in the Iberian Peninsula Red Lists sums 19 *taxa*, 67% of which are liverworts and 33% are mosses. Together they correspond to 7% of the total list of "threatened" *taxa* in Portugal (Sérgio *et al.*, 1994). There are also to consider 5 *taxa* endemic at the European level and 2 *taxa* endemic to the Iberian Peninsula.

The next list of *taxa* is presented in order to discuss some examples of threatened species which occurrence in the stream habitat is dissimilar. Their habitat, associated species, vitality and reproduction observations are discussed and new localities or distribution are presented (Provinces are marked with a (*) when it is the first report of a certain species).

***Amphidium mougeotii* (Bruch & Schimp.) Schimp.**

Habitat: It was found in two distinct situations: (1) in the margins of waterfalls in seasonally splashed steep surfaces and (2) in the streambed boulders, above the mean water level were it is very rarely subjected to the direct impact of water flow, except during extreme floods. In both situations it occurs in stream segments shaded by riparian or woodland vegetation between 700 and 900 m. It is not a frequently found species, even in suitable habitats and the tufts usually accumulate sand and soil beneath. Frahm (1996) has found populations in similar habitat conditions in Vosges Mountains (France). **Associated species**: When in waterfalls the most frequent associated species are *Fissidens serrulatus* and *Lejeunea cavifolia*. When it is found in the streambed boulders associated with *Marsupella emarginata* and *Diphyscium foliosum*, the transition to terricolous communities is evident. **Vitality and reproduction**: The populations found were small and formed dense tufts, always sterile. **New localities**: Mi: NG6146, 800 m (PO6958); NG6520, 490 m (PO3503); NG6747, 760 m (PO7037); NG7023, 780 m (PO4924); NG7227, 690 m (PO4820, 4917); TM: NG8825, 740 m (PO1010), NG9328, 880 m (PO3282); NF9641, 700 m (PO7233); *DL: NF7939, 690 m (PO7430); NF8744, 880 m (PO7297).

***Dumortiera hirsuta* (Sw.) Nees**

Habitat: It was frequently collected in steep water dripping granite surfaces next to waterfalls, but it was also found in the margin of a fast flow in a streambed, being easily submerged for long periods. The species always occurs in shaded and fresh environments, in stream segments that cross oak forested hills, between 240 and 670 m. Similar habitat conditions, except for altitude were described for Italy in Calabria Mountains (Alefi *et al.*, 1998). **Associated species**: It is often associated with *Plagiothecium nemorale, Aneura pinguis, Pellia epiphylla* and *Riccardia multifida*. **Vitality and reproduction**: The populations found were not extensive but they seemed stable, provided that growth conditions are maintained. It was found with female and male receptacles and sporophytes in June. **New localities**: Mi, NG4343, 240 m (PO7596); NG4443, 250 m (PO7621); NG6517, 390 m (PO957, 961, 964, 986, 4285, 4288); NG7023, 670 m (PO4868).

***Gymnomitrion crenulatum* Gottsche ex Carrington**

Habitat: The species develops in bare boulders, above low flow water level in exposed streambed conditions. The studied population occurs at 700 m, in moderately stable boulders easily submergible by acid waters. **Associated species**: It occurs together with *Marsupella emarginata* var. *emarginata* and *Pseudophebe pubescens* (L.) Choisy. **Vitality and reproduction**: Although it was locally abundant, the population studied was drastically reduced after the surrounding mountains suffered a strong fire and rock sediments were drawn to the streambed eroding the bryophyte communities (C. Sérgio, *pers. com.*) Now the species population is reduced to the places protected from the direct impact of low and high flow currents. There it occurs in dense patches, but it was not found fertile. **Distribution**: Mi: NG7219, 700 m (PO6799, 6802).

***Jungermannia hyalina* Lyell**

Habitat: Species collected in the vertical faces of boulders subjected to splashes or constant drippings and in the margin of waterfalls. It has been collected since 270 m to 970 m. **Associated species**: *Scapania undulata*, *Hyocomium armoricum, Fissidens polyphyllus* and *Platyhypnidium lusitanicum.* **Vitality and reproduction**: It has always been found sterile in pure or mixed well developed patches. **New localities**: Mi: G7022, 790 m (PO4856, 4858); NG7317, 265m (PO5225, 5230); TM: PF0480, 930 m (PO4960); PF0479, 958m (PO5051); PF0378, 966m (PO5057); BA: NF7725, 680 m (PO5809); NF7828, 480 m (PO5795).

***Nardia compressa* (Hook.) Gray (Figure 2a)**

Habitat: Species present in the granite slabs of the streambed, almost constantly immersed and subjected to fast flowing acid waters. It is most common in high mountain streams, often in exposed peat bog areas (700 m to 1400 m) but it has been also collected at 200 m. **Associated species**: *Scapania undulata*, *Marsupella sphacelata*, *Marsupella emarginata* var. *aquatica, Fissidens polyphyllus* and *Platyhypnidium lusitanicum*. **Vitality and reproduction**: It forms quite extensive populations, being the dominant species in most of the communities in which it develops. It was never found fertile. **New localities**: It is a commonly found species in acid streams of mountain ranges. As examples of localities for each Province: Mi: NG2131, 919m (PO5131); *BA: NF7020, 909m (PO5248); NF9163, 750 m (PO7516); DL: NF6826, 270 m (PO7490); TM: PF0288, 930 m (PO6110).

***Pallavicinia lyelli* (Hook.) Carruth**

Habitat: Collected in steep water dripping schist surfaces or moist clayey stream banks between herbs, in shaded or moderately exposed places in low altitudes. **Associated species**: It was found with *Aneura pinguis*, *Jungermannia hyalina* and *Fissidens polyphyllus.* **Vitality and reproduction**: It grows in small patches mixed with other bryophytes. It was found fertile with mature perigonia and sporophytes in March. **Distribuion**: DL: NF4259, 240 m (PO1259, 1260); NF4357, 60 m (PO1217); NF4358, 80 m (PO5565) (Vieira *et al.*, 2004a).

***Plagiochila porelloides* (Torrey ex Nees) Lindenb.**

Habitat: Collected in seasonally emerged and vertical stony stream banks or in waterfall margins. **Associated species**: *Thamnobryum alopecurum* and *Lejeunea cavifolia*. **Vitality and reproduction**: It was found forming sterile and pure patches, most of the times not extensive, but well developed. **New localities**: TM: NF9641, 700 m (PO7231); BA: NF7933, 716m (PO7352); DL: NF8338, 950 m (PO7455).

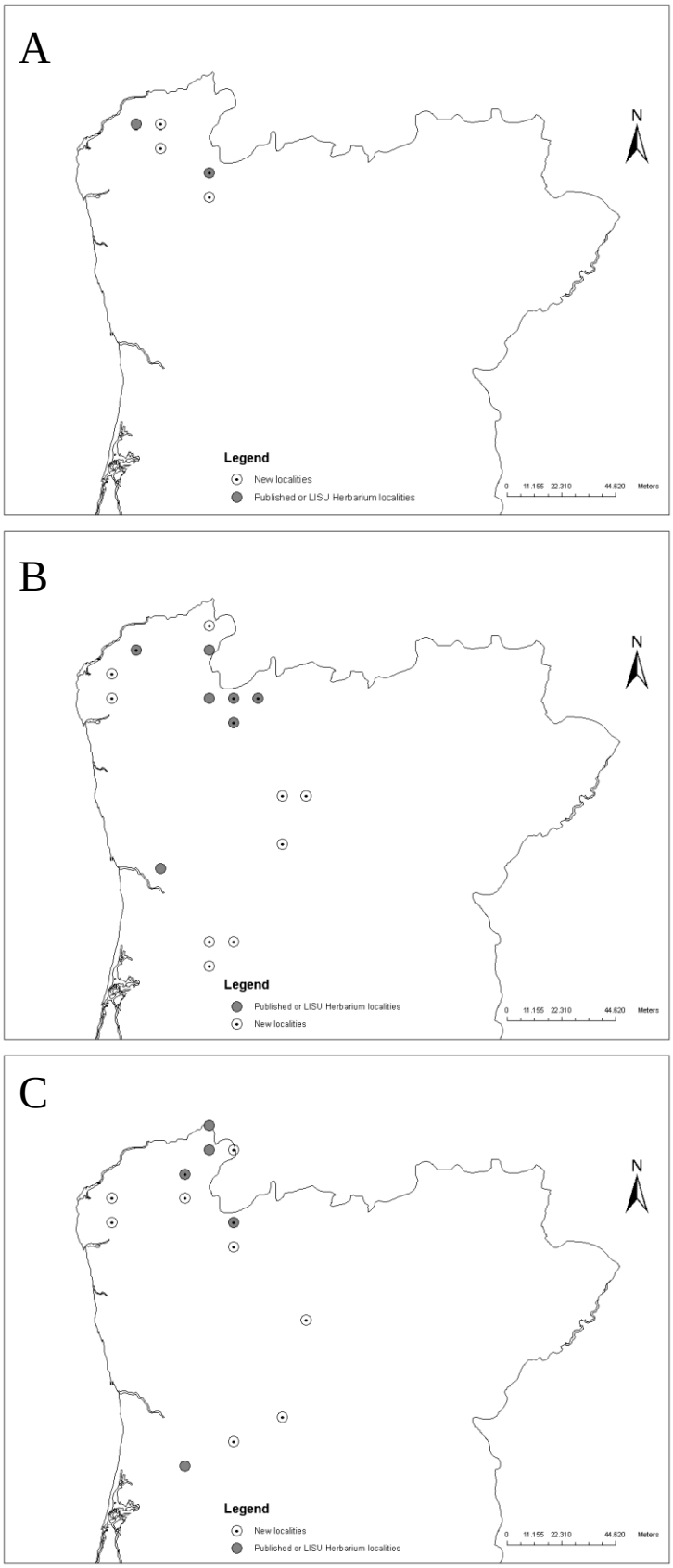


Figure 2. Distribution maps of A) *Nardia compressa*, B) *Racomitrium lusitanicum* and C) *Radula holtii*. Symbols in the maps correspond to new localities (⊙) for each species resulting from this work, to published localities (●) –compiled in Sérgio & Carvalho, 2003–; and references from LISU Herbarium or to the coincidence of the two types of information.

***Porella pinnata* L.**

Habitat: It was collected in seasonally emerged stony stream banks and riparian tree roots along a lowland river flowing trough an area where agriculture and natural forest formations still co-exist. **Associated species**: *Fontinalis squamosa* var. *dixonii.* **Vitality and reproduction**: The population found seemed well developed and formed mixes patches. It was not found fertile. **New locality**: Mi: NG3038, 130 m (PO6719).

***Racomitrium lamprocarpum* (Müll. Hal.) A. Jaeger**

Habitat: Species present in seasonally inundated or frequently splashed stable boulders of the streambed. Sometimes it can also be found in submerged fast flowing granite or schistose blocks. It often dominates the communities of streambed boulders, just above the minimum water level, in mountain exposed or shaded environments. It has been collected mostly in the higher parts of the mountains (500 to 1000 m) but it was also found at 80 m. **Associated species**: Often associated with *Racomitrium aciculare*, *Polytrichum commune* and *Hyocomium armoricum.* **Vitality and reproduction**: It is a very abundant species in the studied area and forms extensive populations, most often mixed with other *Racomitrium* species. It was constantly found with sporophytes in different stages of maturation as stated by literature references (Ochyra *et al.,* 1988). **New localities**: It is widely distributed in the North-West mountain streams. As examples of new localities for each Province: BA: NF7018, 780 m (PO5837); DL: NF7026, 280 m (PO7507); Mi: NG2127, 200 m (PO5910); TM: NF9881, 950 m (PO6635).

***Racomitrium lusitanicum* Ochyra & Sérgio (Figure 2b)**

Habitat: The species habitually colonizes the stones and slabs of the streambed, which are emerged during low flow periods but are often splashed by turbulent water. It occurs in exposed streambeds as well as in the ones shaded by surrounding vegetation, from low (80 m) to high (930 m) altitudes, mainly in pure water hill streams. **Associated species**: It can be found with *Racomitrium lamprocarpum* and *Racomitrium aciculare* in the wetter zones and with *Isothecium holtii* and *Heterocladium heteropterum* in the drier parts of the streambed rocks. **Vitality and reproduction**: It is an easily overlooked species in the field because it repeatedly occurs in small quantities and mixed with other species, and the collected specimens were, most often, only found with lens, mixed with other *Racomitrium* sp. specimens. The collected specimens were never found fertile, but the species has been found with sporophytes before (Ochyra & Sérgio, 1992). **New localities**: Mi: NG2230, 514m (PO5517); NG2429, 791m (PO5489); NG5543, 500 m (PO1598); NG5830, 80 m (PO7148, 7149); NG7053, 950 m (PO4365); NG7227, 690 m (PO4817); NG7518, 369m (PO6807); *TM: NG7929, 1400 m (PO4702); NF9641, 700 m (PO7244); PF0288, 930 m (PO6130); BA: NF7935, 710 m (PO7368).

***Radula holtii* Spruce (Figure 2c)**

Habitat: Hepatic collected in water splashed or dripping granite steep surfaces deeply shaded by surrounding vegetation. Although it was known for North-West of the country, this species was not found during 50 years and, consequently, considered extinct (Sérgio *et al.,* 2001). Recently some of the known populations were found again (Vieira *et al*, 2004b), and others are published in this work for the first time. All this populations are very important since the species is only reported for the British Islands, Macaronesia and Iberian Peninsula (Söderström *et al.,* 2002). **Associated species**: *Thamnobryum alopecurum, Dumortiera hirsuta, Pellia epiphylla, Plagiothecium nemorale, Fissidens polyphyllus.* **Vitality and reproduction**: The size of the populations varies between localities but the species always forms medium sized pure patches in the vicinity of other hygrophilic and hydrophilic

species. It was found with perianths and immature sporophytes between June and August. **New localities**: Mi: NG6136, 235m (PO7072); NG6616, 180 m (PO 2466); NG6517, 390 m (PO 4285); NG6920, 350 m (PO 4890); NG4234, 250 m (PO 7588); NG4343, 240 m (PO7617).

***Riccia huebeneriana* Lindenb.**

Habitat: It was collected in steep water dripping schist surfaces in the margin of a small exposed stream, but it was also found in the seasonally emerged loamy margin of a river. **Associated species**: It was found associated with *Fissidens bryoides* var. *caespitans* and *Bryum pseudotriquetrum*. **Vitality and reproduction**: The populations found were small (<0,5m^2) and they can be easily dragged with strong water current. It was found with sporophytes in March. **Distribution**: It is not a common species and it was reported for Douro Litoral (Vieira *et al.*, 2004) and for Beira Litoral Provinces (Sérgio, 2002), after more than 100 years without being reported for Portugal. **New localities**: DL: NF4358, 110 m (PO5550) (Vieira *et al.*, 2004a).

***Saccogyna viticulosa* (L.) Dumort.**

Habitat: Its habitat is not within the aquatic environment, but in small crevices with humus and humidity in the stream or waterfall margins, that may be subjected to inconstant splashes or inundation. **Associated species**: *Pellia epiphylla*, *Fissidens polyphyllus*, *Hyocomium armoricum*, *Plagiothecium nemorale* and *Riccardia multifida* are the species more often associated in wetter situations. *Radula holtii* also appears associated in dripping conditions. **Vitality and reproduction**: Populations found were never extensive, and the species always grows mixed with other bryophyte populations in smaller quantities. It was never found fertile. **New localities**: Mi: NG4020, 250 m (PO4460); NG4343, 240 m (PO7616); NG6136, 235m (PO7072); NG6146, 800 m (PO6976); NG6735, 360 m (PO7126); NG7023, 760 m (PO2264); NG6517, 390 m (PO960); NG6616, 200 m (PO4275); NG6735, 360 m (PO2956); NG7023, 670 m (PO4865, 4866); NG7027 630 m, (PO4841, 4843); NG7127, 650 m (PO1573, 4555, 4557); NG7515, 329m (PO5235); NG7516, 200 m (PO4242); *TM: NG8825, 740 m, (PO923, 937, 2242, 2245); NF9477, 550 m (PO6142, 6144); *DL: NF6829, 240 m (PO7488)

***Schistidium rivulare* (Brid.) Podp. and *Schistidium apocarpum* (Hedw.) Bruch & Schimp.**

Habitat: Both these species occur in the centre or margins of the streambed, in the drier and higher parts of stable boulders, which possibly will be immersed or splashed during high flow seasons. Species were found between 300 m and 700 m, constantly shaded by riparian vegetation. **Associated species**: Although once these species were found together, they usually grow separately with *Racomitrium lamprocarpum*, *Racomitrium aciculare* and *Isothecium holtii*. **Vitality and reproduction**: The populations found of both species were locally abundant forming pure or mixed patches with the associated species. They were found fertile (with sporophytes of different growth seasons) in July and August. **New localities**: *Schistidium rivulare*: Mi: NG3840, 370 m (PO7677); *TM: PF0169, 650 m (PO7539); *DL: NF8544, 640 m (PO7309); NF7943, 300 m (PO7473).
Schistidium apocarpum: *DL: NF9145, 710 m (PO7222); NF9146, 500 m (PO7207); NF7943, 300 m (PO7403).

***Trichocolea tomentella* (Ehrh.) Dumort.**

Habitat: It was collected in dripping and steep granite slabs in fresh environments. **Associated species**: *Sphagnum auriculatum, Fissidens polyphyllus* and *Radula holtii.* **Vitality and reproduction**: Some of the populations found are currently threatened by human trampling in easily accessed areas, but it has

persisted since it was first found in 2001. It was never found with fertile. **New localities**: Mi: NG6616, 166m (PO2461); NG7227, 700 m, (PO1015); NG7023, 760 m, (PO2267)

***Tritomaria quinquedentata* (Huds.) H. Buch**

Habitat: It was collected in a dripping granite surface in the margin of a permanent waterfall in a shaded environment. **Associated species**: It was found with *Chiloscyphus polyanthus* and *Aneura pinguis.* **Vitality and reproduction**: The population found in the North-West of Portugal is currently threatened by the road situated immediately beside the waterfall. It is a small population mixed with populations of other bryophytes. There is also the threat of the population being dragged if the water flow increases as it is only loosely attached to the steep rock surface. **Distribution**: This species does not possess a threatening status in Portugal because it had not been found by the time Iberian Red List was compiled. However, afterwards, it was found in two different Provinces of the country. Erroneously it was considered to be present in Minho Province (Séneca & Vieira, 2002), but actually the cited population develops in a locality in the Trás-os-Montes Province. However, a population was recently found in Peneda-Gerês in drier situations, and consequently this species is currently known for Beira Alta, Trás-os-Montes and Minho Provinces. **New locality**: TM: NG8825, 740 m (PO936).

Micro-habitat characterization and preferences

Stream segments can be quite different depending on macro-, meso- and micro-scale variables that rule the streambed structure. Macro-scale variables, topography and land use, determine the aquatic communities exposure and geology determines much of the geomorphologic characteristics of the streambed. Hydrology and water quality, acting as meso-scale variables, will greatly influence the species ability to colonize a certain micro-habitat. As micro-scale variables, the heterogeneity, stability and nature of the substrate, and local water level and velocity play major roles on the distribution of bryophyte species (Suren, 1996).

In fact, threatened species occurrence in Portuguese mountain streams is unquestionably related with the most preserved and stable stream segments with unpolluted (or almost unpolluted) waters and the particular micro-habitats typified for this work's purpose assume the conservation of the streambed structure and pure to almost pure water quality. Therefore, in the North-west of Portugal, the "stream" habitat can be divided into several other particular micro-habitats, which are typified according with field observations and are directly or indirectly related to the streambed and water flow (Table 2).

In the context of mountain streams, rheophytes, species that are confined to the beds of swift-flowing streams and tolerate the direct effects of high velocity and sometimes turbulent waters, can be considered aquatic or facultative aquatic depending on their tolerance to seasonal drought. Most of the rheophilous environments are colonized by facultative aquatic species because of the high water level fluctuations (micro-habitat 3 and 8), and aquatic rheophyte species are often restricted to the permanently submerged streambed (micro-habitat 1 and 6).

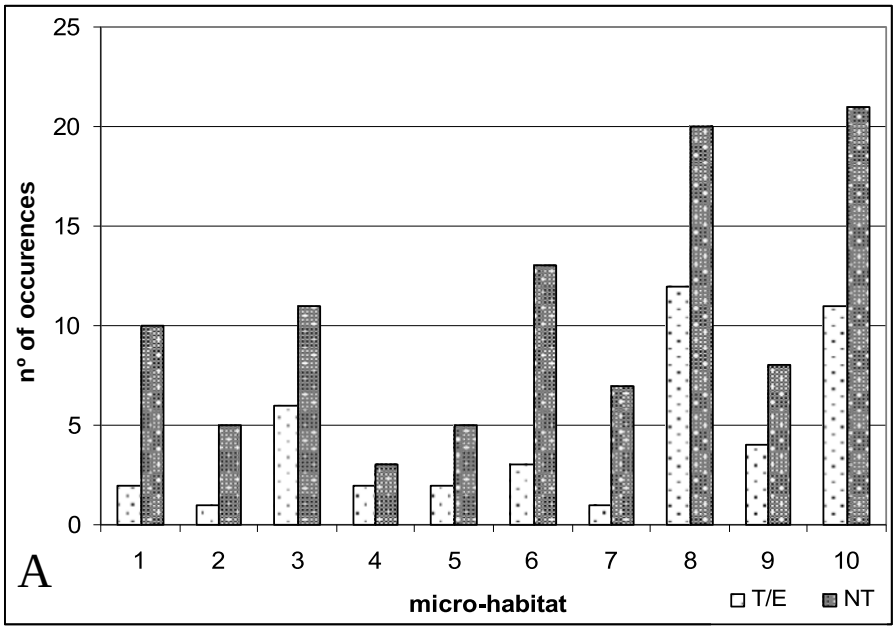
Stream segments with stable rocky sub-strate	exposed situation	constantly immersed	rheophilous (1) limnophilous (2)
		seasonally immersed	rheophilous (3) limnophilous (4)
		splashed or water dripping	(5)
	shaded situation	constantly immersed	rheophilous (6) limnophilous (7)
		seasonally immersed	rheophilous (8) limnophilous (9)
		splashed or water dripping	(10)

Table 2. Stream aquatic and semi-aquatic micro-habitat types.

On the other hand, limnophilous species, the ones characteristic of still waters, are adapted to being totally submerged, and although they may tolerate short-term xerophilous situations (micro-habitats 4 and 9), they are more frequently found in small "ponds" within the streambed, in ditches and dam's reservoirs which hold water during all the time (micro-habitats 2 and 7).

In the direct dependence of the rheophilous stream segments, the permanently splashed or water dripping surfaces are a specific micro-habitat for many bryophyte species (micro-habitats 5 and 10). Being aquatic, facultative aquatic or only dependent of the high air humidity, many bryophytes find refuge in these restrict environments. The controlled humidity allied to the possibility of some humus accumulation and the irregular stone surface micro-topography frequently results in the colonization by species that depend on small water fluctuations and don't tolerate the strong impact of flowing water.

Micro-habitat preferences among threatened and endemic species can be observed in Figure 3a, where it can be seen that these *taxa* are mostly present in shaded situations (micro-habitat 6 to 10) and preferably in seasonally immersed rheophilous or splashed or water dripping situations (micro-habitats 8 and 10). This is also true for non-threatened *taxa*, which are also very frequent in these micro-habitat. This can be explained by the characteristics of these types of micro-habitats, which allow a great variety of hygrophilous and hygrophilous *taxa* to occur, at the same time as aero-hygrophilous *taxa* that are only dependent of the high air humidity and are not in direct contact with stream's water. In addition, shaded situations are preferred, since 84% of the *taxa* found in Portuguese mountain streams are considered considerably to highly sciophytic (Dierβen, 2001).



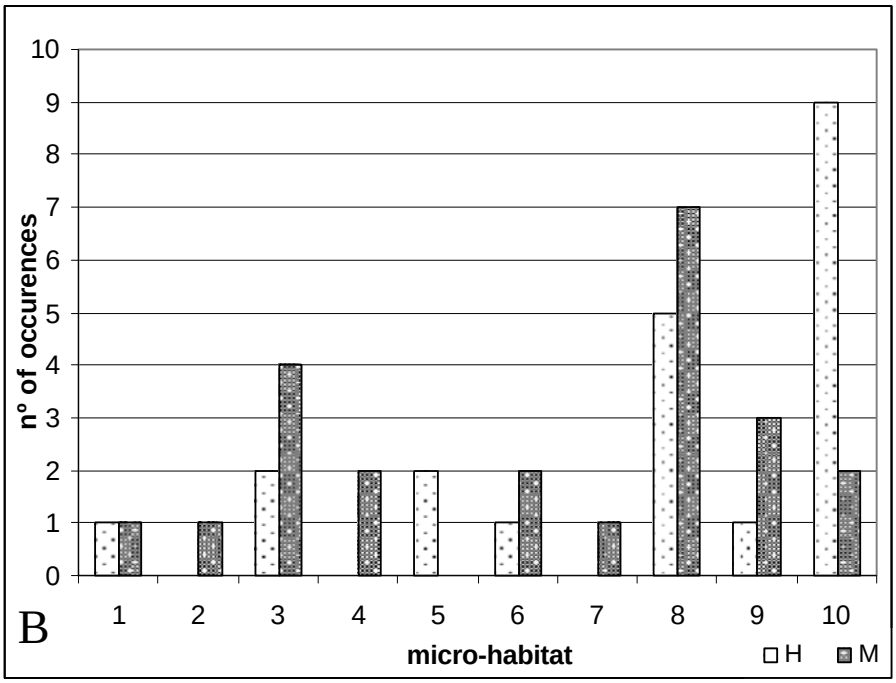


Figure 3. Differences of micro-habitat preferences between **A**: threatened or endemic *taxa* (T/E) and non-threatened *taxa* (NT); **B**: threatened or European and Iberian endemic hepatics (H) and mosses (M) (see table 2 for 1-10 micro-habitat details).

On the other hand, Figure 3b shows that threatened and European and Iberian endemic hepatics have somewhat different micro-habitat preferences than mosses, since most of the hepatics are typically associated with splashed or water dripping shaded situations and most of the mosses typically develop in seasonally immersed rheophilous shaded situations. The fact that most of the hepatics, and not only threatened *taxa*, are intolerant to high drag coefficients

and long periods of submersion in streams and that the majority prefers hygrophilous to hydrophilous situations and seasonally immersed situations, has been previously pointed out (Martínez-Abaigar & Núñez-Olivera, 1991).

Chorological approach

The distribution of the chorological elements was the expected considering the climate, the proximity to the ocean and the intermediate position between Temperate and Mediterranean territories. Regarding the chorological spectrum of the total *taxa* (Figure 4), it is possible to observe that oceanic elements are distributed in several categories of which the sub-oceanic is the most abundantly represented. The presence of these elements is undoubtedly related with the strong Atlantic influence on the climate of this part of the country.

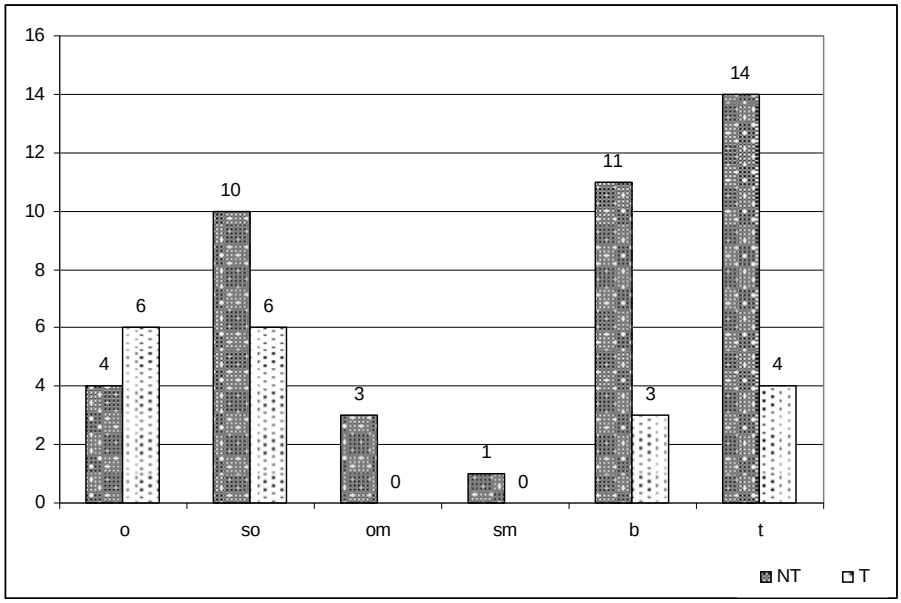


Figure 4. Number of non-threatened (NT) and threatened (T) *taxa* of each chorological element found in stream habitat (o: oceanic + euoceanic + euoceanic relic; so: sub-ocenic + sub-oceanic relic; om: oceanic-mediterranean + oceanic-sub-mediterranean + mediterranean-oceanic; sm: submediterranean; b: boreal + sb: sub-boreal; t: temperate).

Comparing the chorology of threatened and non-threatened *taxa*, the most outstanding feature is the dominance of temperate elements for non-threatened bryophytes and the abundance of oceanic and sub-oceanic threatened bryophytes. In fact many of the threatened taxa are euocenic elements (*Lejeunea lamacerina*, *Porella pinnata*, *Radula holtii* and *Saccogyna viticulosa*) or euoceanic relics (*Dumortiera hirsuta* and *Gymnomitrion crenulatum*).

Another conspicuous evidence regarding chorology is the abundance of mountainous elements, since 44% of the *taxa* found in the North-west Portuguese streams are considered characteristic of the higher altitudes (Düll, 1983, 1984, 1985). This can easily be explained, for the reason that the methodology of this study aimed mainly the study of the streams in the higher altitudinal ranges of the North-west mountains.

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