Cryptogamie, Bryologie, 2007, 28 (3): 211-236

Contribution to the biodiversity conservation in Morocco (North Africa): important areas for epiphytic bryophytes

Isabel DRAPER[a], Belén ALBERTOS[b], Ricardo GARILLETI[b], Francisco LARA[a] and Vicente MAZIMPAKA[a]*

[a]Departamento de Biología (Botánica). Facultad de Ciencias. Universidad Autónoma de Madrid. Campus de Cantoblanco. E-28049 Madrid, Spain.
isabel.draper@uam.es; francisco.lara@uam.es; vicente.mazimpaka@uam.es.

[b]Departamento de Botánica. Facultad de Farmacia. Universidad de Valencia. Av. Vicente Andrés Estellés s/n. E-46100 Burjasot, Spain.
belen.albertos@uv.es; ricardo.garilleti@uv.es.

(Received 30 March 2006, accepted 7 September 2006)

Abstract – Richness and endemicity rate of vascular plants in Morocco have lead to the establishment of hot-spot areas in the Rif, Middle Atlas and High Atlas mountains. Recent studies on the epiphytic mosses and liverworts in Morocco have yielded sufficient knowledge for also evaluating the importance of the Moroccan mountains for the conservation of the epiphytic bryoflora. The selection of hot-spot areas for the epiphytic bryophytes has been made on the basis of species richness, number of rare taxa and singularity or representative nature of the epiphytic bryophyte communities. Eighteen localities throughout the country have been selected as specially relevant: 9 belong to the Rif mountains, 6 to the Middle Atlas, 2 to the High Atlas and 1 to the Antiatlas.

Atlas mountains / conservation / epiphytic communities / floristic singularity / hot-spots / rarity / representative flora / richness / Rif mountains

INTRODUCTION

Northern Africa has a rich and singular biodiversity, partly due to its geographical location between the Mediterranean sea, the Atlantic ocean and the Saharo-Arabian Region, and to being subject to complex climatic influences. In the case of Morocco, its orography and territorial extension contribute to a considerable enrichment of its flora. In addition, the role played by this area as refuge for holarctic taxa during glacial periods is also important to understand its singularity nowadays. All these factors are materialized in complex and, in many occasions, exclusive ecosystems in Morocco. Regarding the vascular plants, richness and high endemicity rate, together with the consciousness of the degradation of the ecosystems due to overgrazing, land clearance and anarchical deforestation, lead to the definition of hot-spot areas in the Rif, the Middle Atlas

* Correspondence and reprints: vicente.mazimpaka@uam.es

and the High Atlas mountains (Médail & Quézel, 1997). As for the bryophyte flora, few studies have been made for the definition of hot-spot areas in the Mediterranean basin. The situation in Morocco is specially worrying, since the bryophytes have been only partially studied. Nevertheless, as a result of recent studies on this area (Draper *et al.*, 2003, 2005 and 2006), the epiphytic bryoflora of this territory is currently well known. The country has been thoroughly explored, especially the mountainous areas, and there is quite an accurate knowledge of the distribution areas of each of the epiphytic bryophytes: both the typical composition and the floristic variations of the most representative communities are known, and the different distribution patterns of the species have been established, which enables an accurate approach to the hot-spot areas of these organisms. Available data have been used to select areas with the most relevant epiphytic bryoflora, according to the criteria of species richness, number of rare taxa, floristic singularity and representativeness of the flora in a regional context.

Some of the here applied criteria, such as species richness and rarity, have been traditionally used for the definition of hot-spot areas. Nevertheless, there is still some controversy on the methodology to be used for the selection of specially important areas (e.g. Orme *et al*., 2005). As an example, the exclusive use of these two criteria would preferentially situate the worldwide important plant areas in temperate humid areas, in detriment to other biomes such as the boreal or arid ones, whose native communities would unlikely be remarked (Mutke & Barthlot, 2005). Other important IUCN criteria that have been used for vascular plants, such as endemicity and number of endangered species are difficult to apply when evaluating the bryophyte flora. In the first case, the usually wide distributional ranges of the bryophytes involve the lack of endemics in most areas. As for the distribution of endangered species – another criterion widely used in the selection of important plant areas (e.g. Myers *et al*., 2000; Bañares *et al*., 2004) –, in Morocco, as well as in many other countries, the lack of national red lists and the insufficient floristic knowledge make the use of this criterion almost impossible. In this study, two criteria have been additionally used: the singularity and representativity of the flora. Their use allows to emphasize other important aspects that should be considered for the conservation of the ecosystems. These aspects have already been considered in other studies (Albertos *et al.*, 2005). However, the methodology here proposed is original since an extensive study of the epiphytic bryophyte communities was previously made, in order to assess their structure, composition and geographic extension, and hence, their singularity and representative character.

METHODS

Study area

The study area comprises the four main mountain ranges of Morocco: Rif, Middle Atlas, High Atlas and Antiatlas (Fig. 1). The Rif is the northernmost range of Morocco. Its mean altitude is 2,000 m and it is mostly composed of siliceous materials (except for the calcareous outcrops northern Bab Taza). The Middle Atlas, High Atlas and Antiatlas mountains are disposed along a NE-SW axis, and separate the plain called Meseta (sited northwest) and the Sahara

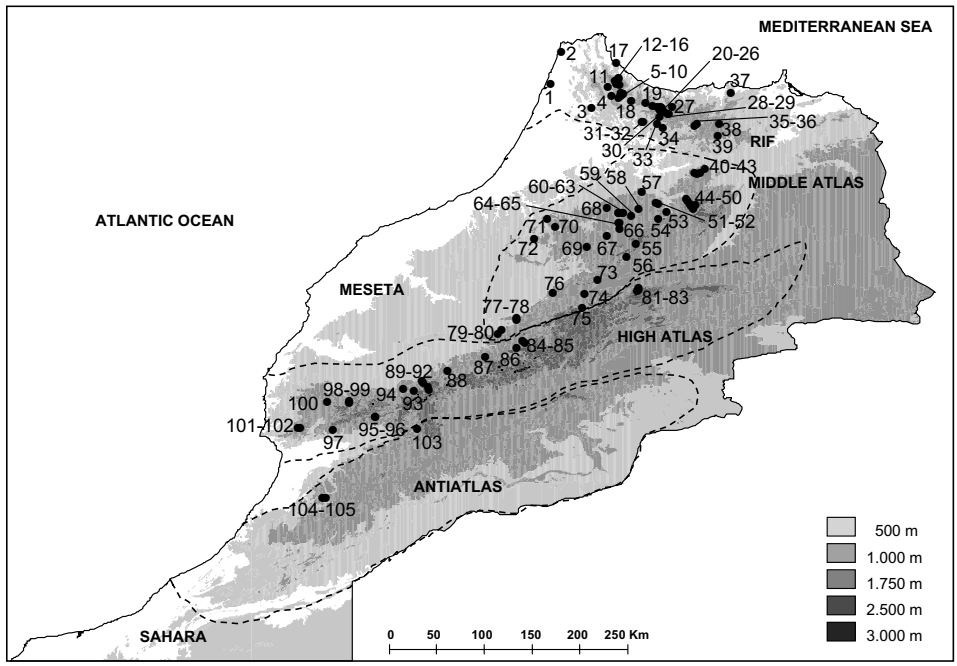

Fig. 1. Location of the study area and sampling sites. Locality numbers appear in the appendix.

desert (at the southeast). The Middle Atlas has its highest altitudes in the oriental part of the range (Jbel Bu-Naceur, 3,340 m), and is also basically siliceous, except for the surroundings of Taza (calcareous) and for southern El-Hajeb (volcanic). In the High Atlas, calcareous and siliceous mountains alternate, all of them generally higher than 3,500 m. The Antiatlas is the southernmost mountain range. Its mean altitude is 3,000 m, and it is mostly composed of siliceous materials.

Morocco is subject to a great variety of Mediterranean climatic thermotypes. The oceanic exposure softens the climate all along the Atlantic coast, while the proximity to the Sahara desert makes hard the establishment of the vegetation in the east and south-eastern areas, both for vascular plants and bryophytes. Most of the rainfall is provided by the Atlantic winds, and humidity drastically decreases from the north southwards and from the west towards the east, from a maximum of nearly 2,000 mm annual average in several sites of the Rif mountains down to a minimum of 150 mm in some parts of the occidental Antiatlas.

The variety of substrata and micro-climates in Morocco favour the development of a great diversity of forest types. Considering the whole extension of the country, *Quercus rotundifolia* Lam. is probably the tree species that finds more suitable areas for its development, and the woods dominated by this species are those with the largest extensions in Morocco (1,432,000 ha). In addition, *Quercus suber* L., *Q. canariensis* Willd., *Q. faginea* Lam., *Q. pyrenaica* Willd., *Abies maroccana* Trab. and *Cedrus atlantica* (Endl.) Manetti ex Carrière

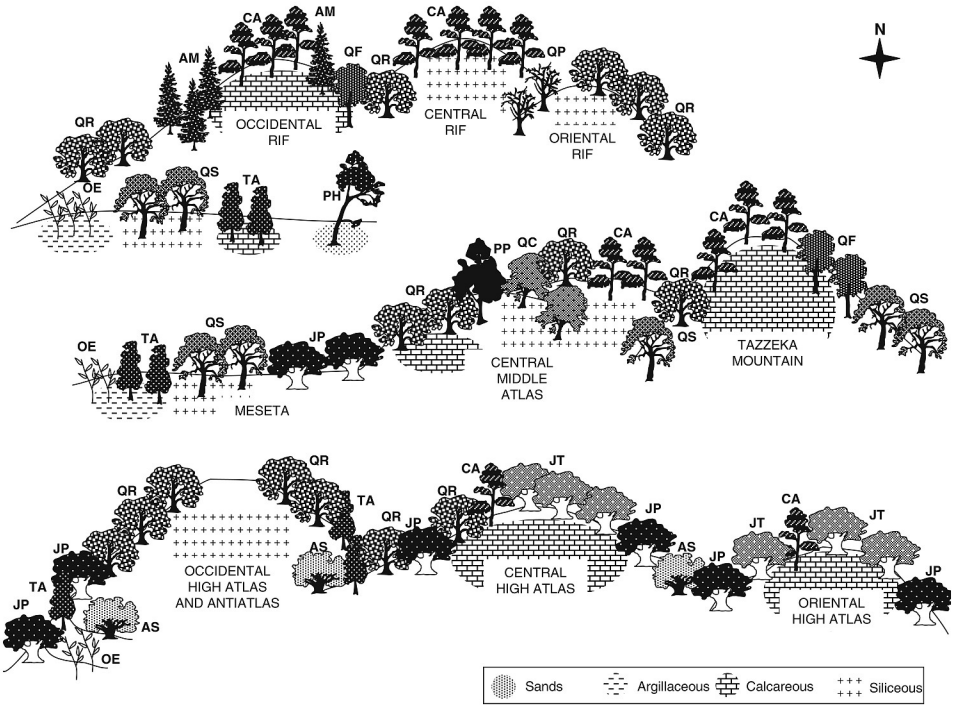

Fig. 2. Schematic representativeness of types of forest in the study area, according to their location on the mountain slopes: AM – *Abies maroccana* Trab., AS – *Argania spinosa* (L.) Skeels, CA – *Cedrus atlantica* (Endl.) Manetti ex Carrière, JP – *Juniperus phoenicea* L., JT – *Juniperus thurifera* L., OE – *Olea europaea* L., PH – *Pinus halepensis* Mill., PP – *Pinus pinaster* Aiton, QC – *Quercus canariensis* Willd., QF – *Quercus faginea* Lam., QP – *Quercus pyrenaica* Willd., QR – *Quercus rotundifolia* Lam., QS – *Quercus suber* L., TA – *Tetraclinis articulata* (Vahl) Mast.

form important forests in the most humid areas, while *Tetraclinis articulata* (Vahl) Mast., *Juniperus phoenicea* L., *J. thurifera* L. and *Argania spinosa* (L.) Skeels form open forests in the most arid ones. Finally, *Olea europaea* L., *Pinus halepensis* Mill. and *P. pinaster* Aiton are also locally abundant. The basic scheme of altitudinal distribution of these woods in the different mountain ranges is presented in Figure 2. Because of different human activities, many of the forests in Morocco have been disturbed: flat and humid areas such as *Quercus suber* habitats, have been deforested in favour of agriculture development; some dry accessible areas of *Q. rotundifolia* forests have been altered due to overgrazing, and timber forests, such as *Cedrus atlantica*, *Juniperus thurifera*, *J. phoenicea* or *Tetraclinis articulata* forests, have been overexploited (Charco, 1999). Nevertheless, well preserved forests still remain, especially in the most mountainous areas, which have been prospected for the present study.

Data collection

Field work was carried out in 105 localities, visited between 1994 and 2004 (Fig. 1; Appendix). Samples of 20 × 20 cm were taken off both from tree bases and trunks on all type of phorophytes. A list of the epiphytic bryophytes found in the study area is presented in alphabetical order in Table 1. The nomenclature is based on Ros, Cano and Guerra (1999), except for the genera *Brachytheciastrum* Ignatov & Huttunen (Ignatov & Huttunen, 2002), *Didymodon* Hedw. (Jiménez, 2004), *Kindbergia* Ochyra (Smith, 2004), *Microbryum* Schimp. (Zander, 1993), *Orthotrichum* Hedw. (Cortini Pedrotti & Lara, 2001), *Syntrichia* Brid. (Gallego, 2002), *Tortella* (Lindb.) Limpr. (Puche, 2004) and *Tortula* Hedw. (Cano, 2004). For each taxon, the sites where it has been recorded are given according to the locality numbers in the appendix.

Table 1. Epiphytic bryophytes recorded in Morocco. Sites are given according to the locality numbers in the appendix. Affinity of taxa for the epiphytic habitat in Morocco is coded as: E for "customary epiphytes"; CS for "cortico-saxicolous"; I for "indifferent"; and NO for "preferentially not corticolous".

Species	*Localities*	*Habitat affinity*
Antitrichia californica Sull.	4; 6-9; 18-22; 24; 26; 31; 32; 34; 40-42; 60; 65; 67; 70	CS
Antitrichia curtipendula (Hedw.) Brid	19; 21	CS
Barbula unguiculata Hedw.	3; 69; 88; 94; 95; 102; 105	NO
Brachytheciastrum dieckei (Roll) Ignatov & Huttunen	6; 18; 22; 23; 25; 29; 47; 64; 75	I
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen	3; 6-9; 18; 20-24; 26; 28; 29; 38; 41-44; 49; 51; 58; 59; 62-65; 67; 71; 75; 76; 82; 88; 99; 104; 105	I
Bryum capillare Hedw.	1-3; 11; 34; 37; 51; 59; 63; 64; 70-72	NO
Ceratodon purpureus (Hedw.) Brid.	6; 78; 95	NO
Cryphaea heteromalla (Hedw.) D. Mohr	1; 3; 4; 18; 19; 34	E
Dialytrichia mucronata (Brid.) Broth.	3; 34	I
Dicranoweisia cirrata (Hedw.) Lindb.	1; 6; 21-23; 25; 26; 30; 33; 34; 42; 64; 67; 71	E
Didymodon australasie (Hook. & Grev.) R. H. Zander	81	NO
Didymodon fallax (Hedw.) R. H. Zander	37	NO
Didymodon insulanus (De Not.) M. O. Hill	9; 23; 26; 40; 51; 70; 76; 99; 100	NO
Didymodon vinealis (Brid.) R. H. Zander	41; 70; 99; 100	NO
Fabronia pusilla Raddi	3; 4; 6; 7; 31; 33; 34; 40-42; 50; 51; 62; 69-72; 76; 78-80; 90-92; 94; 99; 105	E
Fissidens taxifolius Hedw.	50	NO
Frullania dilatata (L.) Dumort.	1-4; 6-10; 15; 19; 20-22; 24; 31; 34; 37; 41; 43; 71	E
Grimmia laevigata (Brid.) Brid.	71; 88	NO
Grimmia pulvinata (Hedw.) Sm.	7; 35-37; 44; 47; 50; 51; 63; 66; 69; 71; 72; 76; 80; 88; 94; 95; 97-99; 103-105	NO
Grimmia trichophylla Grev.	4; 6; 9; 19; 20; 22; 23; 25; 26; 29; 31; 36; 43	NO
Habrodon perpusillus (De Not.) Lindb.	1; 3; 4; 7-9; 32; 34; 36; 40; 41; 50; 60; 82	E
Homalothecium aureum (Spruce) H. Rob.	3; 6-9; 26; 34; 37; 70; 72; 77; 78	NO
Homalothecium philippeanum (Spruce) Schimp.	49	NO
Homalothecium sericeum (Hedw.) Schimp.	1; 3; 6-11; 18-22; 24; 27; 32; 37; 41-43; 45; 59; 60; 62-65; 67; 76; 85; 90; 99	I

Table 1. *(continued)* Epiphytic bryophytes recorded in Morocco. Sites are given according to the locality numbers in the appendix. Affinity of taxa for the epiphytic habitat in Morocco is coded as: E for "customary epiphytes"; CS for "cortico-saxicolous"; I for "indifferent"; and NO for "preferentially not corticolous".

Species	*Localities*	*Habitat affinity*
Hypnum cupressiforme Hedw.	3; 4; 6; 8; 9; 19; 21; 24; 31; 37; 65; 70; 71	I
Hypnum resupinatum Taylor	1; 3; 4	I
Isothecium alopecuroides (Lam. ex Dubois) Isov.	8; 21; 24	I
Isothecium myosuroides Brid.	4; 8; 24	CS
Kindbergia praelonga (Hedw.) Ochyra	3; 7; 25	NO
Lejeunea cavifolia (Ehrh.) Lindb.	3; 16	CS
Leptodon smithii (Hedw.) F. Weber & D. Mohr	1; 2-4; 8; 16; 19; 21; 24; 34; 43	CS
Leucodon sciuroides (Hedw.) Schwägr.	6; 8-10; 34; 42; 59; 65; 70	CS
Leucodon sciuroides var. *morensis (*Schwägr.) De Not.	8; 9; 34; 42; 48; 63; 67	CS
Metaneckera menziesii (Hook.) Steere	8	CS
Metzgeria furcata (L.) Dumort.	3; 19	CS
Microbryum starkeanum (Hedw.) R. H. Zander	103	NO
Neckera pumila Hedw.	19-21; 24	E
Orthotrichum acuminatum H. Philib.	3; 6-10; 13; 20-24; 26; 28; 31-36; 40-50; 56; 58-78; 80; 82; 84-88; 90-92; 94-96; 101; 102; 104	E
Orthotrichum affine Brid.	1; 6-10; 18; 20-24; 26-28; 31; 32; 36; 40-47; 50; 56; 58-68; 76; 84; 86	E
Orthotrichum cupulatum Brid.	9; 35; 38; 46; 56; 60; 82; 83; 85; 86; 88; 90; 91; 94; 95; 101	NO
Orthotrichum diaphanum Brid.	1-3; 12; 13; 14; 16; 23; 34-40; 44-55; 57-62; 68-70; 72; 74-76; 78-80; 82-86; 90-102; 104; 105	E
Orthotrichum ibericum F. Lara & Mazimpaka	7-9; 20; 23; 26; 28; 32	E
Orthotrichum lyellii Hook. & Taylor	1; 3-10; 13; 18-28; 30-37; 40-43; 45; 49; 50; 59-68; 71; 72; 74-76; 81; 86; 88; 95; 96; 99; 101-105	E
Orthotrichum macrocephalum F. Lara, Garilleti & Mazimpaka	36; 40; 44; 47-51; 54; 56-63; 68; 69; 72; 73; 75-86; 88-97; 101; 102; 105	E
Orthotrichum obtusifolium Brid.	61; 64	E
Orthotrichum pallens Bruch ex Brid.	8; 9; 20; 21; 24; 28; 33; 40; 42-44; 47; 49-51; 55; 56; 58-69; 72; 74-76; 82; 84-86; 94; 96; 99; 104	E
Orthotrichum philibertii Venturi	34; 36; 40; 42; 50; 51; 68; 70	E
Orthotrichum pumilum Sw.	42-44; 51; 55; 61; 66; 67; 80; 81; 90; 91; 95; 96; 99; 102	E
Orthotrichum rupestre Schleich. ex Schwägr.	3; 6-10; 19-29; 31; 38; 40-45; 47; 49-51; 59-68; 71; 74-76; 78; 81; 82; 85; 86; 88; 90; 95; 96; 99; 103-105	CS
Orthotrichum scanicum Grönvall	6-10; 13; 20-24; 40-42; 47; 62; 64; 65; 67	E
Orthotrichum schimperi Hammar	41; 44-46; 49; 50; 56; 59; 61-64; 68; 72; 73; 75; 76; 79; 85; 86; 94; 96; 97; 99	E
Orthotrichum shawii Wilson in Schimp.	8	E
Orthotrichum speciosum Nees in Sturm	8; 9; 21; 24	E
Orthotrichum speciosum var. *brevisetum* F. Lara, Garilleti & Mazimpaka	5; 7-10; 20-24; 28; 36; 40-44; 47; 58; 59; 62-65; 67; 76	E
Orthotrichum stramineum Hornsh. ex Brid.	62	E
Orthotrichum striatum Hedw.	5-10; 13; 18-26; 28; 31; 32; 36; 40-45; 47; 50; 56; 58-60; 62-65; 67; 68; 86	E

Table 1. *(continued)* Epiphytic bryophytes recorded in Morocco. Sites are given according to the locality numbers in the appendix. Affinity of taxa for the epiphytic habitat in Morocco is coded as: E for "customary epiphytes"; CS for "cortico-saxicolous"; I for "indifferent"; and NO for "preferentially not corticolous".

Species	*Localities*	*Habitat affinity*
Orthotrichum tenellum Bruch ex Brid.	1; 3; 4; 6; 8; 9; 13; 20; 21; 23; 31; 34-37; 40-42; 44; 49; 50; 62; 68; 71; 72; 88	E
Orthotrichum tortidontium F. Lara, Garilleti & Mazimpaka	41; 44; 45; 49; 56; 58-60; 62-64; 66-68; 76; 86	E
Orthotrichum urnigerum Myrin	44; 101; 102	CS
Orthotrichum vittii F. Lara, Garilleti & Mazimpaka	38; 44; 55; 81; 82; 85; 86; 99; 102	E
Pleurochaete squarrosa (Brid.) Lindb.	98	NO
Porella platyphylla (L.) Pleiff.	8; 9; 64; 90	CS
Pterigynandrum filiforme Hedw.	3; 5; 6; 8-10; 20-24; 26; 28; 29; 42-45; 59; 64-67; 81	CS
Pterogonium gracile (Hedw.) Sm.	3; 4; 6; 8; 9; 19; 22; 34	CS
Radula complanata (L.) Dumort.	3; 19; 21; 24	CS
Radula lindenbergiana Gottsche ex C. Hartm.	3; 4	CS
Rhynchostegiella litorea (De Not.) Limpr.	3; 4; 11; 14-17	CS
Rhynchostegium confertum (Dicks.) Schimp.	3; 4; 34; 59; 72	NO
Schistidium confertum (Funck) Bruch & Schimp.	44	NO
Schistidium crassipilum H. H. Blom	9	NO
Schistidium singarense (Schiffner) Lazarenko	50	NO
Scleropodium touretii (Brid.) L. F. Koch	3; 4; 6; 20; 23; 26	NO
Scorpiurium circinatum (Brid.) M. Fleisch. & Loeske	3; 14; 16	NO
Sematophyllum substrumulosum (Hampe) E. Britton	1; 3; 4; 24; 64	I
Syntrichia laevipila Brid.	1; 3; 4; 6; 7; 12; 16; 23; 26; 31; 34; 36; 39; 40-45; 68; 77; 80; 88; 90-96; 100; 102	E
Syntrichia montana Nees.	9; 32; 41; 42; 50; 51; 58; 59; 63; 64; 69; 85; 95	NO
Syntrichia papillosa Jur.	91; 94	E
Syntrichia princeps (De Not.) Mitt.	8; 38; 44-46; 50; 51; 55; 56; 59; 60; 62-67; 69-72; 76; 78; 81-83; 88; 90; 91; 95; 98; 99; 101; 102; 104; 105	I
Syntrichia virescens (De Not.) Ochyra	44; 55; 61; 64; 67; 86	CS
Thamnobryum alopecurum var. *maderense* (Kindb.) Stech, Ros & O. Werner	3	NO
Tortella flavovirens (Bruch) Broth.	2; 3; 15; 79	NO
Tortella humilis (Hedw.) Jenn.	3; 14; 51	NO
Tortella inflexa (Bruch) Broth.	51	NO
Tortella tortuosa var. *fragilifolia* (Jur.) Limpr.	9; 12; 51; 76; 78	NO
Tortula atrovirens (Sm.) Lindb.	91; 100	NO
Tortula inermis (Brid.) Mont.	38; 44; 49; 50; 82; 83; 95; 98; 99; 103	NO
Tortula israelis Bizot & F. Bilewsky	36	NO
Tortula subulata Hedw.	23; 26; 64	NO
Trichostomum brachydontium Bruch	15; 17; 37	NO
Trichostomum crispulum Bruch	15	NO
Weissia controversa Hedw.	6; 50	NO
Zygodon catarinoi C. García, F. Lara, Sérgio & Sim-Sim	8; 34; 41; 63	E
Zygodon rupestris Schimp. ex Lorentz	1-4; 9; 11; 12; 14; 16; 19; 21; 24; 74	E

The taxa affinity for the epiphytic habitat in Morocco was studied on the basis of local occurrence on different substrata (bibliographic data and field observations), and is indicated for each taxon in Table 1. Classes based on the groups established by Mazimpaka and Lara (1995) were defined as follows: "customary epiphytes", which include strict epiphytes and facultative epiphytes preferentially found on bark; "cortico-saxicolous", which include facultative epiphytes that colonize both bark and rock in the same way; "indifferent", for taxa that occur similarly on bark, rock and soil; and "preferentially not corticolous", for bryophytes that occasionally appear on bark but are commoner on other substrata.

Selection criteria

The epiphytic flora of Morocco was hereby treated in four different ways and considering two different scales of analysis, that is at national and regional levels. The distribution of the total number of species found in each locality, the number of rare species, and the singularity of the flora were treated at a national scale, while the representativeness was considered at a regional scale because of the great heterogeneity of the country. In the following sections, the methodology for the application of these criteria in the study area is explained.

Species richness – In order to select specially rich areas, the species occurring in each of the sampled sites were quantified. Hot-spots of richness were defined as those sites with more than 3/5 of the total range of the richness value, that is: a site will be considered hot-spot if its number of species (N) matches the following richness criterion

$$N > \frac{3}{5}(M - m) + m$$

where **M** and **m** refer to the maximum and minimum number of species in the epiphytic communities in a site in the considered area.

Rarity – Customary epiphytes occurring in less than 10% of the sampled localities were considered as "rare". In the case of cortico-saxicolous and indifferent taxa, the distributional area in all the different habitats in Morocco was considered. Thus, cortico-saxicolous and indifferent taxa were considered as "rare" when, being also scarce on rocks and soil, they were found in less than 5% of the sampled localities. Both saxicolous and terricolous habitats have been only partially studied in Morocco. Therefore, the status of the species considered to be rare is subject to possible changes with a more complete knowledge of these habitats. For this reason, none of the facultative epiphytes that are preferentially not corticolous have been used for the quantification of rarity criteria. Similarly to the richness criterion, hot-spots of rarity were defined as those sites containing 3/5 or more of the number of rare species recorded in the site with the highest number of rare species in Morocco.

Singularity and representativeness of the flora in a regional context – Other important criteria for the flora and habitats conservation are the

singularity and representativeness of the flora at one locality. Singular communities are those that, due to their floristic composition, are unique in a given region. The interest for the conservation of the localities holding singular communities lies on their originality and exclusivity. On the contrary, representativeness applies for those areas that exhibit most typical communities in a given territory. Both are therefore excluding criteria: those localities that hold singular communities are never representative of the typical communities of a region and vice versa.

For the application of these criteria, we have excluded forests barely colonized by epiphytic bryophytes whose communities can hardly be defined. The epiphytic communities were characterized, in order to afterwards select both the singular and representative localities of the regional flora and vegetation. For the identification and description of the epiphytic bryophyte communities, we followed this procedure:

1) The abundance of the species was estimated by the Index of Ecological Significance (Lara & Mazimpaka, 1998; Albertos *et al.*, 2001):

$$IES = \frac{100}{n}(x + \sum c_i)$$

where **n** is the total number of samples collected in the locality, **x** is the number of samples containing the species and $\mathbf{c_i}$ are the cover classes attributed to the species in each sample. These cover classes correspond to the following cover percentages: 0.5 (< 1%); 1 (1-5%); 2 (6-25%); 3 (26-50%); 4 (51-75%); 5 (76-100%). Abundance values for all the species are presented in table 2.

2) The obtained IES values were used to perform the classification of the samples with a TWINSPAN analysis (Hill, 1979). Pseudospecies cut levels were 0, 7, 35, 75 and 150, which represent the limits among the qualitative classes "present", "scarce", "frequent", "abundant" and "dominant" in the study area. The TWINSPAN analysis was carried out with the computer software Community Analysis Package 1.52.

3) Complementarily to the classification analysis, an ordination analysis was performed, in order to better understand the biogeographical relationships among the considered groups. Detrended correspondence analysis (DCA; Hill & Gauch, 1980) was chosen because of the wide gradient shown in the samples along the first axis (5 SDU) which produced an arch effect in the correspondence analysis (Ter Braak & Šmilauer, 2002). This analysis was performed with the computer software Canoco for Windows 4.5.

4) Based on the classification and ordination analysis, localities with a remarkably singular community in Morocco were selected for the singularity criterion.

5) For the representative criterion, the presence of the most common epiphytic communities in Morocco was analysed in the geographical areas of the Rif, Middle Atlas, High Atlas and Antiatlas ranges. Those communities that fulfilled the richness criteria (see Species richness above) in each of the geographical areas and for each community type were selected as representative.

Table 2. Taxa abundance (IES values) on tree trunk communities in selected localities with well developed epiphytic habitat. Taxa abundance in localities 69, 82, 99 and 104 has been estimated for tree base communities, which are better developed than tree trunk epiphytic communities.

	3	*6*	*7*	*8*	*9*	*10*	*21*	*24*	*27*	*31*	*32*	*34*	*40*	*41*	*42*	*43*	*44*	*50*	*55*
A. californica	0	63	91	209	33	0	19	17	0	87	136	20	12	93	64	0	0	0	0
A. curtipendula	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0
B. unguiculata	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. velutinum	4	0	0	6	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
B. capillare	3	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0
C. purpureus	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. heteromalla	212	0	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0
D. mucronata	18	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
D. cirrata	0	0	0	0	0	0	19	0	0	0	0	0	0	0	4	0	0	0	0
D. insulanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. vinealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F. pusilla	39	0	0	0	0	0	0	0	0	0	0	225	65	30	4	0	0	30	0
F. dilatata	110	0	7	41	41	10	69	13	0	107	0	50	0	9	0	9	0	0	0
G. pulvinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	0
G. trichophylla	0	0	0	0	4	0	0	0	0	10	0	0	0	0	0	22	0	0	0
H. perpusillus	16	0	9	36	17	0	0	0	0	0	10	55	32	30	0	0	0	0	0
H. aureum	72	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
H. sericeum	16	0	23	45	12	0	56	57	20	0	14	0	0	59	9	25	0	0	0
H. cupressiforme	54	0	0	23	6	0	31	35	0	33	0	0	0	0	0	0	0	0	0
H. resupinatum	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I. alopecuroides	0	0	0	0	0	0	37	115	0	0	0	0	0	0	0	0	0	0	0
L. smithii	76	0	0	0	0	0	12	0	0	0	0	34	0	0	0	12	0	0	0
L. sciuroides	0	0	0	5	6	0	0	0	0	0	0	55	0	0	9	0	0	0	0
L. sciuroides var. *morensis*	0	0	0	17	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
M. menziesii	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M. furcata	68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N. pumila	0	0	0	0	0	0	59	259	0	0	0	0	0	0	0	0	0	0	0
O. acuminatum	10	120	16	18	48	24	84	26	0	33	24	48	162	146	147	125	50	273	0
O. affine	0	40	16	17	41	71	31	63	20	10	31	0	26	22	104	19	33	13	0
O. cupulatum	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. diaphanum	32	0	0	0	0	0	0	0	0	0	0	64	68	0	0	0	125	240	128
O. ibericum	0	0	25	0	13	0	0	0	0	0	14	0	0	0	0	0	0	0	0
O. lyellii	41	337	364	306	301	248	331	226	225	327	467	189	312	352	266	206	0	120	0
O. macrocephalum	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	28	233	0
O. obtusifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 (cont.). Taxa abundance (IES values) on tree trunk communities in selected localities with well developed epiphytic habitat. Taxa abundance in localities 69, 82, 99 and 104 has been estimated for tree base communities, which are better developed than tree trunk epiphytic communities.

	3	*6*	*7*	*8*	*9*	*10*	*21*	*24*	*27*	*31*	*32*	*34*	*40*	*41*	*42*	*43*	*44*	*50*	*55*
O. pallens	0	0	0	5	4	0	59	22	0	0	0	0	18	0	47	81	61	47	31
O. philibertii	0	0	0	0	0	0	0	0	0	0	0	14	21	0	4	0	0	13	0
O. pumilum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	19	156	0	172
O. rupestre	8	40	23	27	76	14	78	87	117	53	0	0	65	102	166	297	22	120	0
O. scanicum	0	20	18	9	47	50	69	15	0	0	0	0	53	30	159	0	0	0	0
O. schimperi	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	78	27	0
O. shawii	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. speciosum	0	0	0	6	17	0	31	9	0	0	0	0	0	0	0	0	0	0	0
O. speciosum var. *brevisetum*	0	0	7	6	184	193	66	26	0	0	0	0	18	26	103	259	0	0	0
O. stramineum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. striatum	0	23	293	208	196	150	150	43	0	10	43	0	85	148	243	212	39	27	0
O. tenellum	62	37	0	5	4	0	12	0	0	113	0	86	218	9	36	0	17	80	0
O. tortidontium	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	114	0	0
O. urnigerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0
O. vittii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	142	0	84
P. platyphylla	0	0	0	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. filiforme	6	0	0	26	87	145	234	230	0	0	0	0	0	0	24	150	0	0	0
P. gracile	100	0	0	15	4	0	0	0	0	0	0	118	0	0	0	0	0	0	0
R. complanata	175	0	0	0	0	0	28	48	0	0	0	0	0	0	0	0	0	0	0
R. lindenbergiana	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. litorea	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. confertum	37	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
S. crassipilum	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. touretii	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. circinatum	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. substrumulosum	22	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0
S. laevipila	11	27	9	0	0	0	0	0	0	27	0	205	118	43	21	9	0	0	0
S. montana	0	0	0	0	0	0	0	0	0	0	29	0	0	0	9	0	0	0	0
S. papillosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. princeps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	67	162
S. virescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	87
T. humilis	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0
Z. catarinoi	0	0	0	0	0	0	0	0	0	0	0	20	0	39	0	0	0	0	0
Z. rupestris	62	0	0	0	6	0	31	17	0	0	0	0	0	0	0	0	0	0	0

Table 2 (cont.). Taxa abundance (IES values) on tree trunk communities in selected localities with well developed epiphytic habitat. Taxa abundance in localities 69, 82, 99 and 104 has been estimated for tree base communities, which are better developed than tree trunk epiphytic communities.

	59	*60*	*62*	*64*	*65*	*67*	*69b*	*70*	*72*	*75*	*76*	*80*	*82b*	*86*	*94*	*96*	*99b*	*104b*
A. californica	0	0	0	0	25	76	0	53	12	0	11	0	0	0	0	0	0	0
A. curtipendula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. unguiculata	0	0	0	0	0	0	27	0	0	0	0	0	0	0	24	0	0	0
B. velutinum	0	0	0	9	0	0	0	0	0	0	0	0	103	0	0	0	9	193
B. capillare	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. purpureus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. heteromalla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. mucronata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. cirrata	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D. insulanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
D. vinealis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
F. pusilla	0	0	21	0	0	0	203	288	59	0	11	65	0	0	74	0	6	0
F. dilatata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G. pulvinata	0	0	0	0	0	0	33	0	12	0	0	0	0	0	12	0	74	36
G. trichophylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. perpusillus	0	11	0	0	0	0	0	0	0	0	0	0	63	0	0	0	0	0
H. aureum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. sericeum	14	233	0	0	112	24	0	0	0	0	8	0	0	0	0	0	47	0
H. cupressiforme	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0
H. resupinatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I. alopecuroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L. smithii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L. sciuroides	0	0	0	0	19	0	0	29	0	0	0	0	0	0	0	0	0	0
L. sciuroides var. *morensis*	0	0	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0
M. menziesii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M. furcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N. pumila	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. acuminatum	171	72	164	200	119	156	173	0	232	220	283	155	26	150	100	103	0	14
O. affine	164	292	311	224	287	168	0	0	0	0	50	0	0	100	0	0	0	0
O. cupulatum	0	50	0	0	0	0	0	0	0	0	0	0	142	0	12	0	0	0
O. diaphanum	36	50	14	0	0	0	207	0	382	285	0	212	68	9	412	39	88	11
O. ibericum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. lyellii	100	33	129	121	131	188	0	0	53	50	178	0	0	73	0	269	18	100
O. macrocephalum	21	64	43	0	0	0	180	0	12	235	22	165	174	141	276	68	0	0
O. obtusifolium	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 (cont.). Taxa abundance (IES values) on tree trunk communities in selected localities with well developed epiphytic habitat. Taxa abundance in localities 69, 82, 99 and 104 has been estimated for tree base communities, which are better developed than tree trunk epiphytic communities.

	59	*60*	*62*	*64*	*65*	*67*	*69b*	*70*	*72*	*75*	*76*	*80*	*82b*	*86*	*94*	*96*	*99b*	*104b*
O. pallens	157	97	86	129	44	150	23	0	206	260	11	0	74	55	21	32	6	29
O. philibertii	0	0	0	0	0	0	0	144	0	0	0	0	0	0	0	0	0	0
O. pumilum	0	0	0	0	0	24	0	0	0	0	0	10	0	0	0	19	6	0
O. rupestre	14	19	93	71	25	100	0	0	0	15	106	0	32	27	0	6	253	357
O. scanicum	0	0	43	18	94	24	0	0	0	0	0	0	0	0	0	0	0	0
O. schimperi	93	0	114	18	0	0	0	0	12	45	50	0	0	41	9	6	6	0
O. shawii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. speciosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. speciosum var. *brevisetum*	107	0	86	59	56	0	0	0	0	0	11	0	0	0	0	0	0	0
O. stramineum	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. striatum	11	17	14	141	84	71	0	0	0	0	0	0	0	14	0	0	0	0
O. tenellum	0	0	29	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
O. tortidontium	214	56	14	32	0	88	0	0	0	0	61	0	0	23	0	0	0	0
O. urnigerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O. vittii	0	0	0	0	0	0	0	0	0	0	0	0	63	0	0	0	6	0
P. platyphylla	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P. filiforme	36	0	0	74	62	53	0	0	0	0	0	0	0	0	0	0	0	0
P. gracile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. lindenbergiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. litorea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R. confertum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. crassipilum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. touretii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. circinatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. substrumulosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. laevipila	0	0	0	0	0	0	0	0	0	0	0	70	0	0	109	0	0	0
S. montana	0	0	0	9	0	0	13	0	0	0	0	0	0	0	0	0	0	0
S. papillosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0
S. princeps	0	128	43	0	47	9	247	247	153	0	28	0	50	0	0	0	71	193
S. virescens	0	0	0	29	0	9	0	0	0	0	0	0	0	0	0	0	0	0
T. humilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. inermis	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	56	0
Z. catarinoi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z. rupestris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

RESULTS AND DISCUSSION

Species richness

The number of species recorded in each locality ranged from 1 to 35 (Fig. 3). According to the richness criterion eight sites with more than 21 species were considered to be hot-spots. All of them are located in the northern mountain ranges (Rif and Middle Atlas mountains): sites 3, 6, 8, 9, 21, 24, 44 and 64 (Table 3). The climate in all these localities is humid Mediterranean, although they are sited at various altitudes, from 125 to 2,100 m. As a consequence to the wide altitudinal range, the forests growing in these localities are also heterogeneous: they are mostly dominated by *Quercus suber* and *Q. rotundifolia* at the lowest altitudes, *Q. canariensis* at middle altitudes and *Abies maroccana* and *Cedrus atlantica* at the highest altitudes. An exception to this altitudinal scheme is site 44, a forest dominated by *Quercus rotundifolia*, which is sited between 1,800 and 2,100 m in the Middle Atlas mountains.

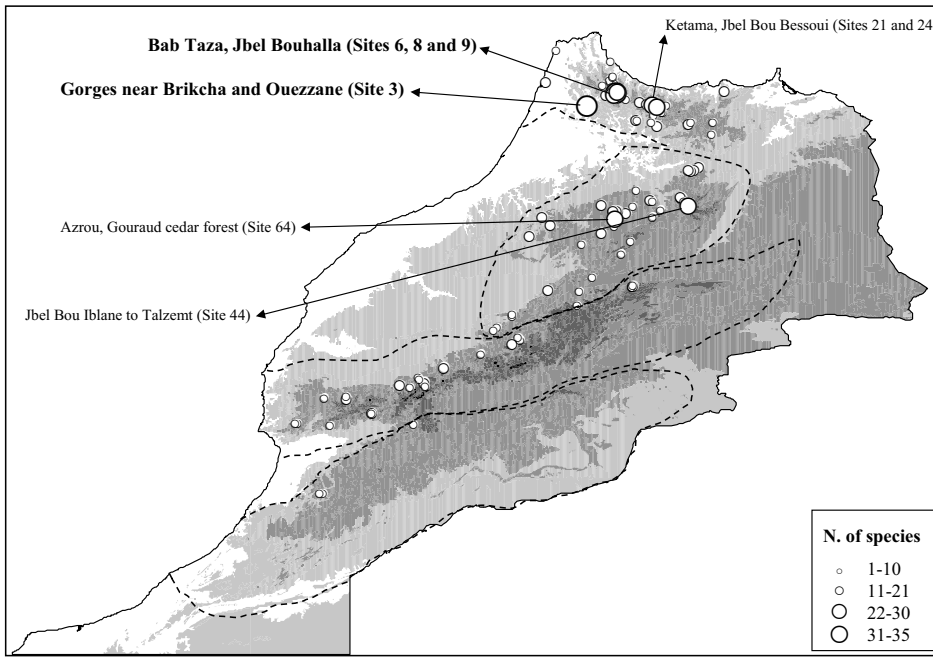

Fig. 3. Distribution of species richness in the area. Labelled sites are those with more than 21 species, in bold those with more than 30 species.

Number of rare taxa

The number of uncommon species occurring in some of the localities raises the interest of these localities for conservation purposes. The known distribution of the fifteen species selected as "rare" for Morocco are commented below.

Table 3. Sites selected as hotspots for epiphytic bryophytes in Morocco. Sites are given according to the locality numbers in the appendix.

Site	*Mountain range*	*N. of species*	*N. of rare species*	*Singularity*	*Floristic-geograpic representativeness*	*N. of fulfilled criteria*
8. Bab Taza: Jbel Bouhalla, 1,350 m	Rif	31	*Isothecium alopecuroides* *Orthotrichum ibericum* *Orthotrichum shawii* *Orthotrichum speciosum* *Zygodon catarinoi*		X	3
21. Ketama: Jbel Bou Bessoui	Rif	23	*Antitrichia curtipendula* *Isothecium alopecuroides* *Neckera pumila* *Orthotrichum speciosum*		X	3
24. Ketama: Jbel Bou Bessoui	Rif	22	*Isothecium alopecuroides* *Neckera pumila* *Orthotrichum speciosum*		X	3
34. Al Haddada, Jbel Tifelloust	Rif	21	*Cryphaea heteromalla* *Orthotrichum philibertii* *Zygodon catarinoi*	X		2
3. Gorges near Brikcha and Ouezzane	Rif	35	*Cryphaea heteromalla* *Hypnum resupinatum*	X		2
9. Bab Taza: Jbel Bouhalla, 1,550m	Rif	24	*Orthotrichum ibericum* *Orthotrichum speciosum*		X	2
44. from Jbel Bou Iblane to Talzemt	Middle Atlas	22	*Orthotrichum urnigerum* *Orthotrichum vittii*		X	2
64. Azrou, Gouraud cedar forest	Middle Altas	23	*Orthotrichum obtusifolium*		X	2
6. Bab Taza: Jbel Bouhalla, 1,075m	Rif	25			X	2
19. Tafira, Jbel Tafirane	Rif	16	*Antitrichia curtipendula* *Cryphaea heteromalla* *Neckera pumila*			1
42. Taza, Bab Bou Idir to Jbel Tazzeka	Middle Atlas	21	*Orthotrichum philibertii*		X	1
50. In the way up to Taffert	Middle Atlas	20	*Orthotrichum philibertii*		X	1
41. Taza, Bab Bou Idir to Jbel Tazzeka	Middle Atlas	20	*Zygodon catarinoi*		X	1
99. Jbel Tichka	High Atlas	15	*Orthotrichum vittii*		X	1
70. 10 km from Oulmes	Middle Atlas	13	*Orthotrichum philibertii*	X		1
86. Between Âït Mhmed and Agouti	High Atlas	13	*Orthotrichum vittii*		X	1
104. Jbel Lekst	Antiatlas	8			X	1

Antitrichia curtipendula – Cortico-saxicolous species known in Morocco only from two sites in the Rif mountains, where it grows as epiphyte on bases of *Quercus suber* (site 19) and trunks of *Prunus lusitanica* (site 21).
Cryphaea heteromalla – Customary epiphyte known in Morocco only from six sites in the Rif mountains (1, 3, 4, 18, 19 and 34), where it grows on bases and trunks of different phorophytes.
Hypnum resupinatum – Indifferent species known in Northern Africa only from three sites in the Rif mountains (1, 3 and 4), where it has been generally found on bases and trunks of *Quercus suber*.
Isothecium alopecuroides – Indifferent species known in Morocco only from three sites in the Rif mountains (8, 21 and 24), and one site in the High Atlas (Jelenc, 1955). As epiphyte, it has been generally found on bases and trunks of *Prunus lusitanica*.
Neckera pumila – Customary epiphyte known in Morocco only from four sites in the Rif mountains (19, 20, 21 and 24), where it generally grows on bases and trunks of *Prunus lusitanica*.
Orthotrichum ibericum – Customary epiphyte known in Morocco only from eight sites in the Rif mountains (7, 8, 9, 20, 23, 26, 28 and 32), where it generally grows on bases and trunks of *Quercus rotundifolia* and *Populus nigra*.
Orthotrichum obtusifolium – Customary epiphyte known in Northern Africa only from two sites in the Middle Atlas mountains (61 and 64), where it generally grows on trunks of *Quercus canariensis*.
Orthotrichum philibertii – Customary epiphyte known in Morocco only from two sites in the Rif mountains and six sites in the Middle Atlas (34, 36, 40, 42, 50, 51, 68 and 70), where it generally grows on bases and trunks of *Quercus rotundifolia*.
Orthotrichum shawii – Customary epiphyte known in Northern Africa only from one site in the Rif mountains (8), where it grows on trunks of different phorophytes between 1,300 and 1,400 m.
Orthotrichum speciosum var. ***speciosum*** – Customary epiphyte known in Morocco only from four sites in the Rif mountains (8, 9, 21 and 24), where it grows on bases and trunks of different phorophytes.
Orthotrichum stramineum – Customary epiphyte known in Morocco only from one site in the Middle Atlas mountains (62), where it grows on trunks of *Quercus rotundifolia*.
Orthotrichum urnigerum – Cortico-saxicolous species known in Morocco from two localities in the Middle Atlas (44; Jelenc, 1955) and two sites in the High Atlas (101 and 102). As epiphyte, it has been found on bases and trunks of *Juniperus oxycedrus* and *Quercus rotundifolia*.
Orthotrichum vittii – Customary epiphyte known from nine Moroccan sites in Northern Africa (38, 44, 55, 81, 82, 85, 86, 99 and 102). It has been found on bases and trunks of different phorophytes.
Syntrichia papillosa – Customary epiphyte known in Northern Africa only from two sites in the High Atlas mountains (91 and 94), where it grows on bases and trunks of *Quercus rotundifolia*, *Tetraclinis articulata* and *Juniperus phoenicea*.
Zygodon catarinoi – Customary epiphyte known in Northern Africa only from two sites in the Rif mountains and two sites in the Middle Atlas (8, 34, 41 and 63), where it generally grows on bases and trunks of *Quercus rotundifolia*.

In addition to these taxa, *Dialytrichia mucronata*, *Isothecium myosuroides*, *Lejeunea cavifolia*, *Metaneckera menziesii*, *Metzgeria furcata*, *Porella platyphylla*, *Radula complanata* and *Radula lindenbergiana* are scarce in the epiphytic habitat in Morocco, but they have not been considered to be rare species in this context, since they are frequent in other habitats. Finally,

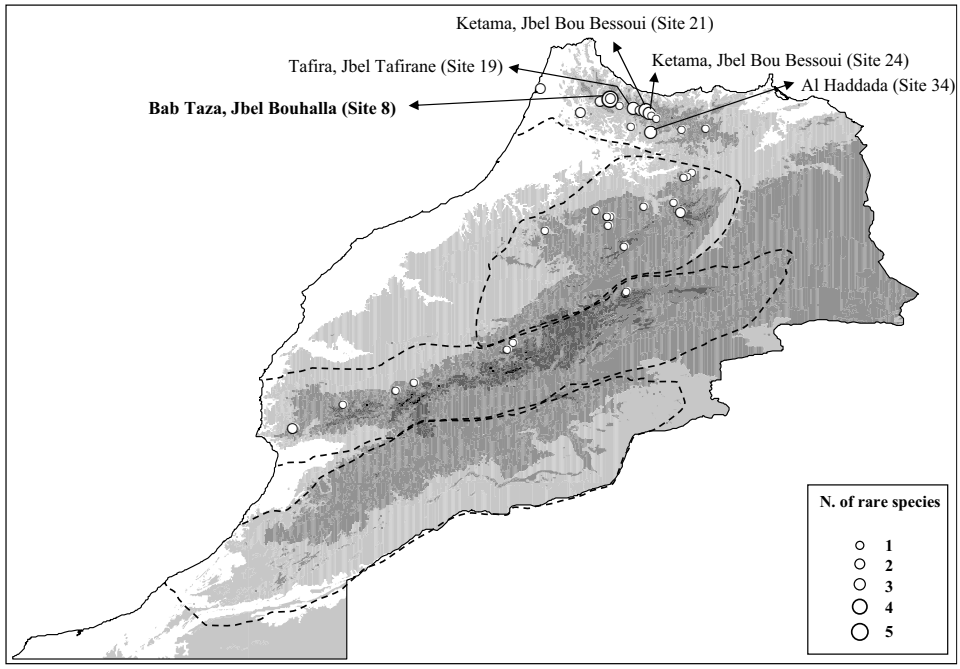

Fig. 4. Distribution of rare species in the area. Labelled sites are those with 3 or more rare species, in bold the locality with 5 rare species.

considering their currently known distributional area, some facultative epiphytes, namely *Tortula israelis* and *Thamnobryum alopecurum* var. *maderense*, could be considered as rare taxa, but the lack of knowledge in other than the epiphytic habitats in Morocco prevents a realistic analysis of their situation. Nevertheless, the ecological situation where *Thamnobryum alopecurum* var. *maderense* was found is not frequent in Morocco (Jiménez *et al.*, 2000) and this supports its rarity.

The number of rare taxa occurring in each studied site ranged from 0 to 5. The number of localities containing at least one rare species in the study area was 40, but only five of them had three or more and were considered to be hot-spots of rarity. These localities are concentrated in the Rif mountains (Fig. 4): sites 8, 19, 21, 24 and 34 (Table 3).

Singularity and floristic-geographic representativeness of the epiphytic bryophyte communities

The communities classification (Fig. 5) clearly segregated three singular communities, namely sites 3, 34 and 70 (groups 1, 2 and 5), while the remaining sites form more heterogeneous groups (3 and 4). Subsequent divisions of these groups are less significant and hardly coherent with the DCA and have not been considered to be informative. The ordination diagram (Fig. 6) showed a gradual succession along the first axis for most of the samples, with the exception of sites 3, 34 and 70, that appeared separated from the others along the second axis.

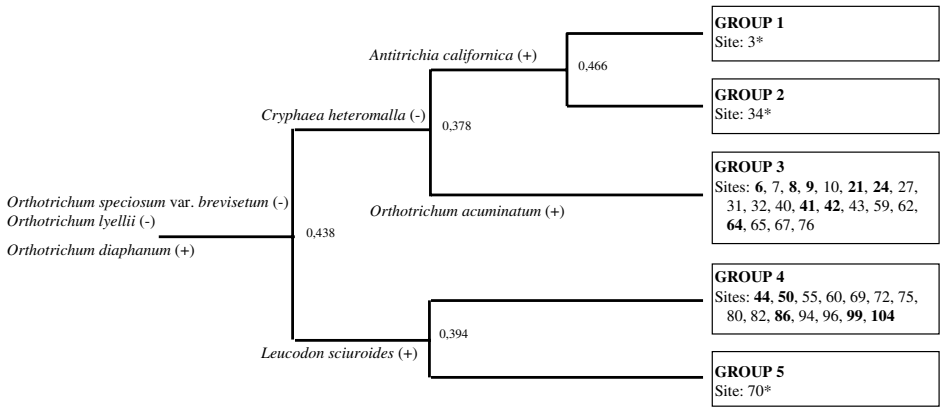

Fig. 5. Classification dendrogram (TWINSPAN) of the localities with well developed epiphytic communities (locality numbers appear in the appendix). The eigenvalues of each division are indicated in the nodes. The indicator species are commented in the text. Localities marked with* are remarkable because of the singularity of their epiphytic communities. Localities marked in bold have been selected as representative of each group.

Groups 3 and 4 of the classification are connected in the DCA analysis, showing a gradual transition among them. From this analysis, it was inferred that the bryophyte epiphytic communities in Morocco belong to five main types, although two of them are most frequent, highly variable and gradually connected.

The communities belonging to groups 1, 2 and 3 of the classification were separated by the presence of the indicator species *Orthotrichum speciosum* var. *brevisetum* and *O. lyellii,* while the presence of *O. diaphanum* segregates groups 4 and 5 (Fig. 5). The succession along the first axis drew a general geographic pattern, which is probably correlated with the decreasing humidity gradient from the north southwards, that appears in the different mountain ranges in Morocco. This gradient is also suggested by the mesophytic preferences of *Orthotrichum lyellii* and *O. speciosum* var. *brevisetum*, conversely to the drought tolerance of *O. diaphanum*. In the following sections we comment the floristic composition of the different community types that have been found in the study area.

Singularity – Three localities were identified to have community types with an exceptional floristic composition, as deduced from the DCA and TWINSPAN analysis (Figs 5 and 6): sites 3, 34 and 70.

Site 3 is a *Quercus suber* forest of the Rif mountains, located between Brikcha and Ouezzane (Figs 1 and 4). The singularity of its epiphytic bryophyte community lies in the abundance of some hygrophytic taxa that are otherwise scarce in Morocco, and here codominate with some thermophilous taxa. This community is characterized by the presence of *Cryphaea heteromalla*, *Radula complanata*, *R. lindenbergiana*, *Scorpiurium circinatum*, *Frullania dilatata* and *Pterogonium gracile*. Other common species are *Leptodon smithii*, *Homalothecium aureum*, *Metzgeria furcata* and *Orthotrichum tenellum*.

Site 34 corresponds to a *Quercus rotundifolia* forest located near Al Haddada (Figs 1 and 4) in the Rif mountains. The community developed on trunks in this locality is singular in Morocco due to the abundance of mesophytic taxa. The physiognomy of this community is determined by the abundance of the

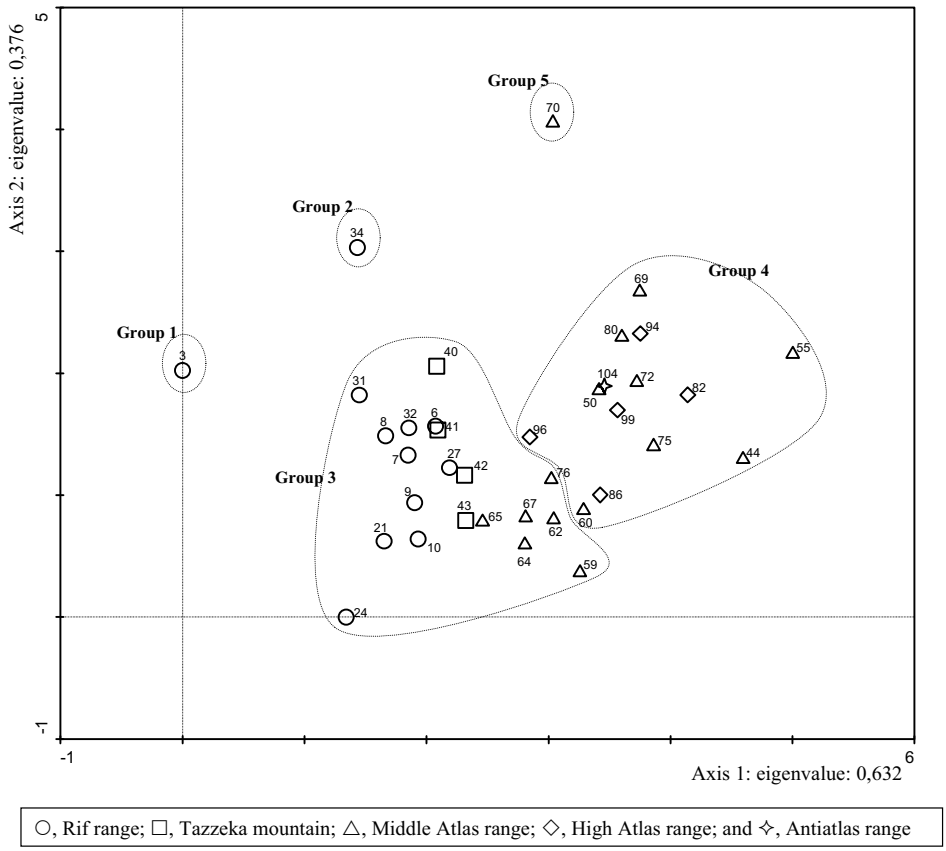

Fig. 6. Detrended Correspondence Analysis (DCA) ordination of the localities with well developed epiphytic communities (locality numbers appear in the appendix). Groups correspond to those defined by the Twinspan analysis.

pleurocarpous *Fabronia pusilla* and *Pterogonium gracile*. In addition, like in other epiphytic communities of the territory, the acrocarpous *Syntrichia laevipila* and *Orthotrichum lyellii* are abundant. Other common species are *Orthotrichum tenellum*, *O. diaphanum*, *Habrodon perpusillus*, *Leucodon sciuroides* and *Frullania dilatata*.

Site 70 is a *Quercus rotundifolia* forest located in the surroundings of Oulmes (Fig. 1) in the Middle Atlas mountains. This community is quite poor when compared to others in Morocco. However, it is exceptional due to the abundance of the acrocarpous *Orthotrichum philibertii*, which is very scarce in the study area. In Oulmes, this species codominates the epiphytic communities with *Syntrichia princeps* and *Fabronia pusilla*. Other species that grow on trunks in this forest are *Antitrichia californica* and *Leucodon sciuroides*.

Floristic-geographic representativeness – From the DCA and TWINSPAN analysis, it was inferred that most of the epiphytic communities in Morocco can

be grouped into two types (Figs. 5 and 6): groups 3 and 4. Both community types have been respectively named "*Orthotrichum lyellii* communities of the Rif and Middle Atlas mountains" and "*Orthotrichum diaphanum* communities of the Atlasic mountain ranges". After the description of each community type, the selection of some localities for the representativeness criterion will be discussed.

***Orthotrichum lyellii* communities from the Rif and Middle Atlas mountains**: this community type constitutes a relatively homogeneous community, which is characterized by the abundance of different *Orthotrichum* species, among which *O. lyellii* plays a chief role in the community characterization. The abundance of other species varies, generally according to an altitudinal gradient that has already been suggested in previous studies (Draper *et al.*, 2003 and 2005). Thus, the highest forests, dominated by *Cedrus atlantica* and *Abies maroccana*, shelter epiphytic communities dominated by *Orthotrichum speciosum* var. *brevisetum* and *Pterigynandrum filiforme*, with the constant presence of *O. lyellii*, *O. striatum* and *O. rupestre*. Forests at middle altitudes in the Rif and the Middle Atlas mountains are dominated by different *Quercus* species. The epiphytic communities in these forests are dominated by *Orthotrichum lyellii*, with the constant presence of *O. acuminatum*, *O. striatum*, *O. rupestre* and *O. affine* among the most abundant species. In addition, in some of the *Quercus rotundifolia* forests of the Middle Atlas, the presence of *Orthotrichum pallens* and *O. tortidontium* is also important.

The species richness of this community type per locality in the Rif mountains ranged from 4 to 31 species. According to the selection criteria explained above, five sites with more than 20 taxa were considered to be representative in this geographic area: they are sites 6, 8, 9, 21 and 24 (Table 3). At the Middle Atlas, this type of community exhibited richness values from 15 to 23. So, three sites with more than 19 taxa were considered to be representative: sites 41, 42 and 64 (Table 3).

***Orthotrichum diaphanum* communities from the Atlas mountain ranges**: the communities included in this group are more heterogeneous, but they all share the importance of *Orthotrichum diaphanum* and *O. acuminatum*. Both species codominate the communities together with different taxa, depending on the altitude and forest type. Thus, the mixed forests of *Quercus rotundifolia*, *Tetraclinis articulata* and *Juniperus phoenicea* hold epiphytic communities dominated by *O. diaphanum*, *O. acuminatum*, *O. macrocephalum* and *Fabronia pusilla*. The importance in the communities of the most oceanic taxa decreases with the altitude. Conversely, more continental species such as *Orthotrichum pallens*, become important in communities at higher altitude. In addition, *Orthotrichum lyellii* and *O. rupestre* can be abundant in relatively humid areas. At the top of the Atlas mountains, the extreme temperatures and drought make hard the establishment of the epiphytic communities. There, the epiphytic bryophytes look for shelter in the lowest parts of the trees, where the communities become richer in cortico-saxicolous and indifferent taxa, such as *Orthotrichum rupestre* or *Brachytheciastrum velutinum*. Finally, the communities developed on *Juniperus thurifera* are somehow particular because of the codominance of *Orthotrichum diaphanum* with *Syntrichia virescens*, *Orthotrichum pumilum* and *O. vittii*.

The species richness of this community type per locality in the Middle Atlas varied from 6 to 22. According to the richness criteria explained above, two sites with more than 15 taxa were selected as representative: sites 44 and 50 (Table 3). At the High Atlas, this type of community exhibited lower richness values, that ranged from 9 to 15. So, two sites with more than 12 taxa were considered to be representative in this geographic area: sites 86 and 99 (Table 3). Finally, only site 104 in the Antiatlas exhibited this type of community (Table 3).

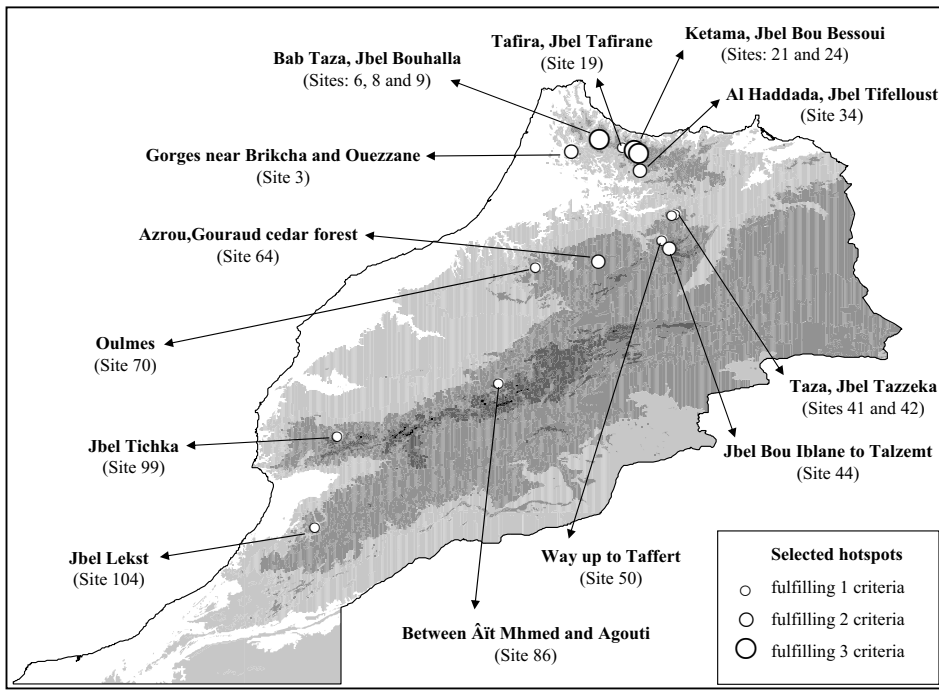

Fig. 7. Geographic location of the sites selected as hot-spots (criteria in text).

CONCLUSIONS

The four applied criteria emphasize different aspects of the interest of a territory and are not necessarily concordant in all the localities (Table 3). Some of the localities fulfil three criteria, while others match only one. When combined, all these criteria allow to propose the hot-spot areas for each of the mountain ranges.

The Rif mountains harbour the highest number of hot-spot areas (Fig. 7; sites 3, 6, 8, 9, 19, 21, 24 and 34), which include the richest communities, some important localities for rare species, two sites with exclusive epiphytic communities and several sites with representative communities of the *Orthotrichum lyellii* epiphytic communities (Table 3). Because of the warm temperatures and relatively high humidity conditions, this range constitutes a specially favourable area for the development of the epiphytic bryophytes, and numerous taxa exclusively grow in these mountains in Morocco.

In the Middle Atlas mountains, six localities are proposed as hot-spots (Fig. 7; sites 41, 42, 44, 50, 64 and 70). Most of these localities stand out for the representativeness of their epiphytic communities. Some of these communities are dominated by *Orthotrichum lyellii*, while others are dominated by *O. diaphanum*. The presence of both types of communities in this mountain range reveals the transitional character of the Middle Atlas mountains, from the humid Rif to the

dry Atlas mountains. The climatic conditions in some areas of the Middle Atlas, especially in the northernmost part, are particularly favourable to the epiphytes development, and some of the selected localities also stand out due to their species richness (Table 3). However, the number of rare taxa decreases and none of the localities has been selected as hot-spot of rarity. The importance of Ifrane (site 70) should be emphasized since this is the only known locality for *Orthotrichum stramineum* in Morocco.

With the latitude decrease the climatic conditions become harder for the establishment of the epiphytic bryophytes, which is captured in the lower species number. The High Atlas mountains are markedly poorer than the northern ones (Rif, Tazzeka and Middle Atlas). However, they harbour some localities that have been considered to be representative of the epiphytic *Orthotrichum diaphanum* communities (Fig. 7; sites 86 and 99). Even though none of the localities in this mountain range can be considered as a hot-spot of rarity, the importance of Ourika valley (site 91) and Asni (site 94) deserves some emphasis, since these are the only known localities for *Syntrichia papillosa* in northern Africa. The presence of exclusive taxa in these mountains reveals the importance of protecting, not only the richest areas, but also those which, in spite of being poorer, represent the different native ecosystems. This is well illustrated by the only selected hot-spot in the Antiatlas mountains (Fig. 7; site 104). Current data suggest that this mountain range constitutes the southern limit for the development of the epiphytic bryophytes above the Sahara desert, and the selected site is the only locality in these mountains that exhibits a good development of this type of community.

Although further studies are needed to understand what happens in other habitats, it can be concluded that the protection of the here selected sites would assure a minimum conservation of the epiphytic bryophytes, since the applied criteria cover most of the important aspects of the territory.

Acknowledgements. This work was partly funded by the National Geographic Society (Grants 5860-97 and 6708-00), the Spanish Ministry of Science and Technology (BOS2000-0296-CO3-02), and the Spanish Ministry of Education and Science (grants AP2001-0540 and CGL2004-03513). Thanks are addressed to Rosa Ros for critical comments on an earlier version of the manuscript.

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APPENDIX – Localities and phorophytes studied

1. Sidi Hassain, 10 km from Larache, 29SQV6606, 200 m, on *Quercus suber.*
2. Jbel Dahar Zhirou, Chaka, 30STE3452, 20 m, on *Quercus suber* and *Olea europaea.*
3. Gorges near Brikcha and Ouezzane, 30STD6868, 125 m, on *Quercus suber*, *Q. coccifera*, *Arbutus unedo* and *Pistacia lentiscus.*
4. Ouara affluent valley, 5 km north from Bab Taza, 30STD9386, 450 m, on *Quercus suber* and *Arbutus unedo.*
5. Bab Taza: Tala Semtan, 30SUD0687, 1,700 m, on *Abies maroccana.*
6. Bab Taza: Jbel Bouhalla, 30SUD0284, 1,075 m, on *Quercus suber.*
7. Bab Taza: Jbel Bouhalla, 30SUD0385, 1,225 m, on *Quercus rotundifolia*, *Q. faginea* and *Q. suber.*
8. Bab Taza: Jbel Bouhalla, 30SUD0588, 1,350 m, on *Quercus faginea*, *Q.rotundifolia* and *Abies pinsapo.*
9. Bab Taza: Jbel Bouhalla, 30SUD0590, 1,550 m, on *Abies maroccana* and *Q. rotundifolia.*
10. Bab Taza: Jbel Bouhalla, 30SUD0490, 1,750 m, on *Abies maroccana*, *Cedrus atlantica* and *Acer opalus.*
11. Dar Akoubaa, Talembote dam, 30STE8901, 300 m, on *Olea europaea* and *Chamaerops humilis.*
12. Jbel Tassaot, 30STE9804, 650 m, on *Tetraclinis articulata.*
13. Jbel Tassaot, 30SUE0303, 1,180 m, on *Quercus rotundifolia.*
14. Tarhzoute, 30STE9708, 350 m, on *Quercus rotundifolia.*
15. Ibouharane, Laou valley, 30SUE0111, 250 m, on *Tetraclinis articulata.*
16. Es-Sebt-de-Saïd, Oued Laou road, 30STE9009, 200 m, on *Quercus coccifera.*
17. Tamrabete, 30STE9934, 150 m, on *Quercus rotundifolia* in *Pinus halepensis* environment.
18. Bab Beren, between Koudiet es Sbaa and Jbel Beni Salah, 30SUD1777, 1,400 m, on *Quercus pyrenaica.*
19. Tafira, Jbel Tafirane, 30SUD3374, 1,300 m, on *Quercus suber* and *Q. rotundifolia.*
20. Ketama, Jbel Bou Bessoui, 30SUD4271, 1,600 m, on *Salix pedicellata* and *Quercus canariensis* near fountain.
21. Ketama, Jbel Bou Bessoui, 30SUD4769, 1,650 m, on *Cedrus atlantica* and *Quercus rotundifolia.*
22. Ketama, Jbel Souk Tahomar, 30SUD5168, 1,700 m, on *Cedrus atlantica* and *Quercus rotundifolia.*
23. Ketama, Jbel Dedokh, 30SUD5367, 1,500 m, on *Cedrus atlantica* and *Quercus coccifera.*
24. Ketama, Jbel Bou Bessoui, 30SUD4769, 1,650 m, on *Prunus lusitanica* and *Ilex aquifolium.*
25. Tetla Ketama, 30SUD5069, 1,450 m, on *Betula pendula.*
26. From Ketama to Azila, near the cross to Tawnat, 30SUD5562, 1,400 m, on *Cedrus atlantica* and *Populus nigra.*
27. Ketama, Jbel Tidirhine, 30SUD6568, 1,680 m, on *Quercus rotundifolia.*
28. Ketama, Jbel Tidirhine, 30SUD6259, 1,800 m, on *Salix atrocinerea* and *Ilex aquifolium.*
29. Ketama, Jbel Tidirhine, 30SUD5958, 1,800 m, on *Cedrus atlantica.*
30. Hachkor, Koudiat Tighighine, 30SUD4653, 1,145 m, on *Quercus suber.*
31. Ghafsäi, Lalla Outka to Jbel Oudka, 30SUD3048 to 30SUD2746, 1,100 to 1,300 m, on *Quercus suber.*
32. Ghafsäi, Lalla Outka to Jbel Oudka, 30SUD2947, 1,300 m, on *Quercus pyrenaica.*
33. Between Bab Imatene and Bab Jbah, 30SUD4744, 850 m, on *Quercus suber.*
34. Al Haddada, Jbel Tifelloust, 30SUD5439, 400 m, on *Quercus rotundifolia*, *Pistacia lentiscus*, *Erica arborea* and other phorophytes in disturbed forest.
35. Bou Imechouene, Aknoul to Tahar Souk, 30SUD9543, 850 m, on *Quercus rotundifolia.*
36. Maret, 30SUD9241, 1,090 m, on *Ulmus minor* and *Populus alba* in *Pinus halepensis* environment.
37. Irazzoükene to Al Hoceima, 30SVD3688, 780 m, on *Quercus suber.*
38. Jbel Berkane, 30SVD2242, 1,450 m, on *Quercus rotundifolia.*

39. Jbel Berkane, 30SVD2025, 925 m, on *Tetraclinis articulata.*
40. Taza, Bab Bou Idir to Jbel Tazzeka, 30SUC9168, 1,500 m, on *Quercus suber.*
41. Taza, Jbel Bou Mess'Oud to Jbel Tazzeka, 30SVC0477 to 30SUC9873, 1,200 to 1,325 m, on *Quercus rotundifolia.*
42. Taza, Bab Bou Idir to Jbel Tazzeka, 30SUC9369, 1,425 m, on *Quercus canariensis.*
43. Taza, Bab Bou Idir to Jbel Tazzeka, 30SUC9172, 1,700 to 1,800 m, on *Cedrus atlantica* and *Taxus baccata.*
44. From Jbel Bou Iblane to Talzemt, 30SUC8919 to 30SUC9426, 1,800 to 2,100 m, on *Quercus rotundifolia* and *Juniperus thurifera.*
45. Taffert, 30SUC9124, 1,850 m, on *Cedrus atlantica*, *Quercus rotundifolia* and *Juniperus oxycedrus.*
46. Near Taffert, 30SUC8823, 1,700 m, on *Fraxinus angustifolia.*
47. Taffert, 30SUC8723, 1,630 m, on *Quercus rotundifolia.*
48. Bou Iblane mountain, valley between Tizi n'Tiskine and Taffert, 30SUC8426, 1,300 m, on *Quercus rotundifolia.*
49. In the way up to Taffert, 30SUC8231, 1,500 to 1,600 m, on *Quercus rotundifolia.*
50. In the way up to Taffert, 30SUC8033, 1,200 m, on *Quercus rotundifolia.*
51. From Tazouta to Sefrou, 30SUC4429, 1,180 m, on *Quercus rotundifolia* and *Phyllirea angustifolia.*
52. From Tazouta to Sefrou, 30SUC4627, 1,085 m, on *Pistacia lentiscus.*
53. From Skoura to Tazouta, near Skoura, 30SUC5615, 895 m, on *Juniperus phoenicea.*
54. From Bouleman to Ifrane, 30SUC4605, 1,250 m, on *Buxus sempervirens.*
55. Surroundings of Timahdite, from 30SUB1062 to 30SUB1970, 2,000 to 2,100 m, on *Juniperus thurifera.*
56. Zad pass, 30SUB0655, 2,170 m, on *Quercus rotundifolia* and *Cedrus atlantica.*
57. Sefrou city, 30SUC2744, on *Celtis australis.*
58. From Sefrou to Ifrane, 30SUC2121, 1,600 m, on *Quercus rotundifolia.*
59. Vallee des Roches, near Ifrane, 30SUC1310, 1,750 m, on *Quercus rotundifolia*, *Cedrus atlantica* and *Acer monspessulanum.*
60. Ifrane, des Vierges gorges, 30SUC0215 to 30SUC0314, 1,500 m, on *Fraxinus angustifolia*, *Quercus canariensis* and *Q. rotundifolia.*
61. Ifrane, 30SUC0215, 1,675 m, on *Ulmus minor.*
62. Ifrane, 30STC9814, 1,550 m, on *Quercus rotundifolia.*
63. Ifrane, Jaaba forest, 30STC9714, 1,500 m, on *Quercus canariensis.*
64. Azrou, Gouraud cedar forest, 30STC9901, 1,700 m, on *Cedrus atlantica*, *Quercus canariensis* and *Q. rotundifolia.*
65. Azrou, Midelt road, 30STC9701, 1,625 m, on *Quercus rotundifolia*, *Ilex aquifolium* and *Sorbus torminalis.*
66. Jbel Hebri, 30STB9893, 2,050 m, on *Cedrus atlantica* and *Quercus rotundifolia.*
67. Azrou, Afenouir lake, 30STB8283, 1,700 to 1,950 m, on *Quercus rotundifolia*, *Cedrus atlantica* and *Juniperus oxycedrus.*
68. Ifrane, El Hajeb road, 30STC8322, 1,200 m, on *Quercus rotundifolia.*
69. 27 km north from Kenifra, 30STB5865, 1,100 m, on *Quercus rotundifolia*, *Tetraclinis articulata* and *Pistacia lentiscus.*
70. 10 km from Oulmes, 29SQS7896, 1,000 m, on *Quercus rotundifolia.*
71. Near Oulmes, 29SQS6807, 1,050 m, on *Quercus suber* and *Q. rotundifolia.*
72. Surroundings of Molay Bouazza, from 29SQS5277 to 29SQS6378, 800 to 1,100 m, on *Quercus rotundifolia.*
73. Tanout ou Fillet pass, 30STB6918, 2,070 m, on *Quercus rotundifolia.*
74. Arhbala, 30STA5398, 1,850 m, on *Quercus rotundifolia.*
75. Surroundings of Cherket, from 30STA4081 to 30STA4977, from 1,480 to 1,550 m, on *Quercus rotundifolia* and *Buxus sempervirens.*
76. Tizi-n'Âït-Ouira, 29SQS7800, 1,475 m, on *Quercus rotundifolia* and *Q. canariensis.*
77. 12 km from Afourer to Bin el Ouidane, 29SQR3459, 1,450 m, on *Quercus rotundifolia.*
78. Ravine in the road from Afourer to Azilal, 29SQR3363, 1,300 m, on *Pistacia lentiscus* and *Quercus rotundifolia.*
79. Ouzoud gorges, 29SQR1544, 700 m, on *Olea europaea.*

80. Surroundings of Ouzoud, 29RQR1138, 950 m, on *Tetraclinis articulata.*
81. Jaffar circle, 30SUB1902, 2,100 m, on *Cedrus atlantica.*
82. Jaffar circle, 30SUB2002, 2,000 m, on *Quercus rotundifolia* and *Fraxinus dimorfa.*
83. Canyon in the entrance of Jaffar circle, 30SUB1904, 1,900 m, on *Fraxinus dimorfa* and *Juniperus oxycedrus.*
84. Way up to Azourki mountain, northern slope, between Âït Mhmed and Tamda, 29RQR4425, 1,900 m, on *Quercus rotundifolia.*
85. Way up to Azourki mountain, northern slope, near Âït Mhmed, 29RQR4128, 1,725 m, on *Fraxinus dimorfa.*
86. Way up to Azourki mountain, northern slope, between Âït Mhmed and Agouti, 29RQR3519, 1,950 m, on *Quercus rotundifolia.*
87. Near Tifni, in the road to Imi-n'Ifri, 29RPR9605, 1,500 m, on *Quercus rotundifolia.*
88. Toufliht, 29RPQ5083, 1,500 m, on *Quercus suber*, *Q. rotundifolia* and *Juniperus oxycedrus.*
89. Setti Fatma, 29RPQ2655, 1,500 m, on *Juglans regia.*
90. Ourika valley, passed Oulmes, 29RPQ2460, 1,200 m, on *Quercus rotundifolia* and *Juniperus phoenicea.*
91. Ourika valley, 29RPQ1769, 1,000 m, on *Tetraclinis articulata*, *Juniperus phoenicea* and *J. oxycedrus.*
92. Ourika valley, Arhbalou, 29RPQ1964, 1,000 m, on *Fraxinus angustifolia* and *Populus nigra.*
93. Toubkal National Park, Oukaimeden, Tizi-n'Tizrag, 29RPQ0752, 2,600 m, on *Juniperus thurifera.*
94. Near Asni, 29RNQ9356, 1,200 m, on *Quercus rotundifolia*, *Juniperus phoenicea*, *Tetraclinis articulata* and *Pistacia lentiscus.*
95. Tizi-n'Test, northern slope, from 29RNQ5915 to 29RNQ6519, from 1,850 to 2,090 m, on *Quercus rotundifolia.*
96. Tizi-n'Test, southern slope, 29RNQ5914, 2,025 m, on *Quercus rotundifolia.*
97. Near Tamsoult, 29RNP0597, 1,500 m, on *Juglans regia.*
98. Way up to Tichka mountain from Imi-n'Tanoute, 29RNQ2738, 1,400 m, on *Juniperus oxycedrus.*
99. Way up to Tichka mountain from Imi-n'Tanoute, from 29RNQ2536 to 29RNQ2635, from 1,750 to 1,900 m, on *Quercus rotundifolia.*
100. Surroundings of Imi-n'Tanoute, 29RMQ9737 to 29RMQ9838, from 1,200 to 1,250 m, on *Tetraclinis articulata* and *Juniperus phoenicea.*
101. Jbel Touchka, 29RMQ6400, 1,600 m, on *Quercus rotundifolia.*
102. Jbel Touchka, 29RMP6199, 1,650 m, on *Juniperus oxycedrus.*
103. Jbel Siroua, 29RPP1298, 1,750 m, on *Juniperus oxycedrus.*
104. Jbel Lekst, 29RMN9798, from 1,800 to 1,900 m, on *Quercus rotundifolia.*
105. Tizi-n'Tagounit, 29RMN9398, 1,600 m, on *Quercus rotundifolia* and *Crataegus monogyna*.