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BIOLOGICAL VALUATION IN MOUNTAIN LANDSCAPES AS A TOOL FOR THE CONSERVATION OF BRYOPHYTES IN BAIXO-TÂMEGA, PORTUGAL

C. Vieira[1], H. Hespanhol[1], J. Gonçalves[1], J. Marques[1,2] and A. Bota[2]

[1]*Centro de Investigação em Biodiversidade e Recursos Genéticos (CIBIO)*
Faculdade de Ciências da Universidade do Porto
Edifício FC4, Rua do Campo Alegre, s/nº, 4169 – 007 Porto, Portugal; ccvieira@fc.up.pt
[2]*Faculdade de Ciências da Universidade do Porto*

Tendencies in landscape use in Portugal, such as abandoning agricultural land, accompanied by the intensification of urbanization, resulted in the development of highly heterogeneous land mosaics in most cases with dissimilar conditions for bryophytes. The study area, located in mainland Portugal, known as the "Baixo-Tâmega" Region, was the target of a project aimed at evaluating the territory as nature conservation and management value area. A methodology of land cover evaluation for this mountainous area is presented here, based on expert knowledge and the results shown in a map according to aspects of conservation for bryophytes. A positive correlation between the highly valued areas and the total and threatened bryophyte species richness provided evidence that biological valuation can be a useful tool for conservation and management of semi-natural areas. Furthermore, we showed that landscape configuration (*e.g.* heterogeneity, size and ecotones of natural and semi-natural mosaics) and landscape composition (*e.g.* low scrublands) are relevant for the occurrence of threatened bryophyte taxa and these must be taken into account in conservation management and planning at the landscape scale.

Key words: conservation value maps, expert knowledge, hotspots, land cover, threatened species

INTRODUCTION

The valuation of biodiversity (sensu "ecological valuation" and, in a more strict sense, "biological valuation") can be a useful tool in the reconciliation of the efforts of nature conservation versus the changing demands on land use and natural resources, all connected to the issue of the adequate implementation of the Convention on Biological Diversity from either global, regional, or local aspects (Markussen 2005). In the absence of detailed studies on natural values, at a regional scale, valuation of natural and semi-natural landscapes based on expert knowledge can be a strategic tool for planning and conserving "habitat functions", i.e., of the spatial conditions needed to preserve biotic (incl. genetic) diversity, refuge and reproduction habitats (De Groot 2006, De Groot *et al.* 2003, 2010).

In the European context, Portugal is considered a hotspot since it has rich flora and fauna, enriched both by Atlantic and Mediterranean elements, endemisms and species considered to be relics (Costa *et al.* 1998). The biological diversity of Portuguese mountain landscapes depends greatly on the degree of natural and anthropogenic exploitation that its ecosystems have historically been subjected. Nowadays, and mainly due to human activities such as agriculture, plantation forestry and urbanisation of major mountainous areas, mountain landscapes are heterogeneously spotted with mosaics of natural and semi-natural areas with different levels of complexity. This situation resulted in the threatening of many species and causes fragility in the ecosystems, also influenced by biological invasion or forest fires.

Recently, a pioneer project was established in a Portuguese mountainous territory ("Baixo-Tâmega" Region), involving several municipalities and a team of experts of geological, biological and human sciences. It had the objective of proposing a good model of management and conservation of the natural and cultural resources, based on spatially-explicit biological valuation methodologies, through a spatial summary of the relevance of each landscape unit for the conservation of biological elements. A sub-team of biologists had the task of attributing a biological value to each unit of the territory – i) by considering the regulation and habitat functions of a given land cover category from the aspect of the conservation of fauna or flora elements and communities, and also ii) by assessing the rarity of the ecosystem in context of the regional and national context.

In this mountainous territory, bryophytes are often conspicuous elements of many natural and semi-natural ecosystems. The current rural landscape is composed of extensive mosaics of agriculture (i.e. grazing lands, patches of woodland with random management practices and villages with rustic constructions), which present niches both for common and threatened species. With regard to the bryophytes in this overall project we were faced with financial constraints in performing a highly detailed study, so we undertook the task of valuating the land cover classes from the aspect of the conservation of bryophytes, based on existing knowledge and a limited number of visits to the territory.

The main objectives of this study were to: i) formulate a methodology of land cover valuation in mountainous areas based on expert knowledge, which should result in a "conservation value map" for bryophytes; ii) compare these findings with data on total and threatened bryophyte species richness; and iii) discuss the importance of landscape composition and configuration for the preservation of threatened bryophyte taxa. Furthermore, we assess the importance of biological valuation methods as tools for conservation and management of semi-natural areas.

Study area

The study area is composed of several mountain ranges (Montedeiras, Aboboreira, Castelo, Marão) located between two Natura 2000 sites (Alvão-Marão and Montemuro – Fig. 1). Located at 32 km from the seashore, lined with several other mountain ranges, this area acts like a barrier zone for oceanic winds. The surrounding valleys of Douro (NE–NW orientation) and Tâmega (NE–SW

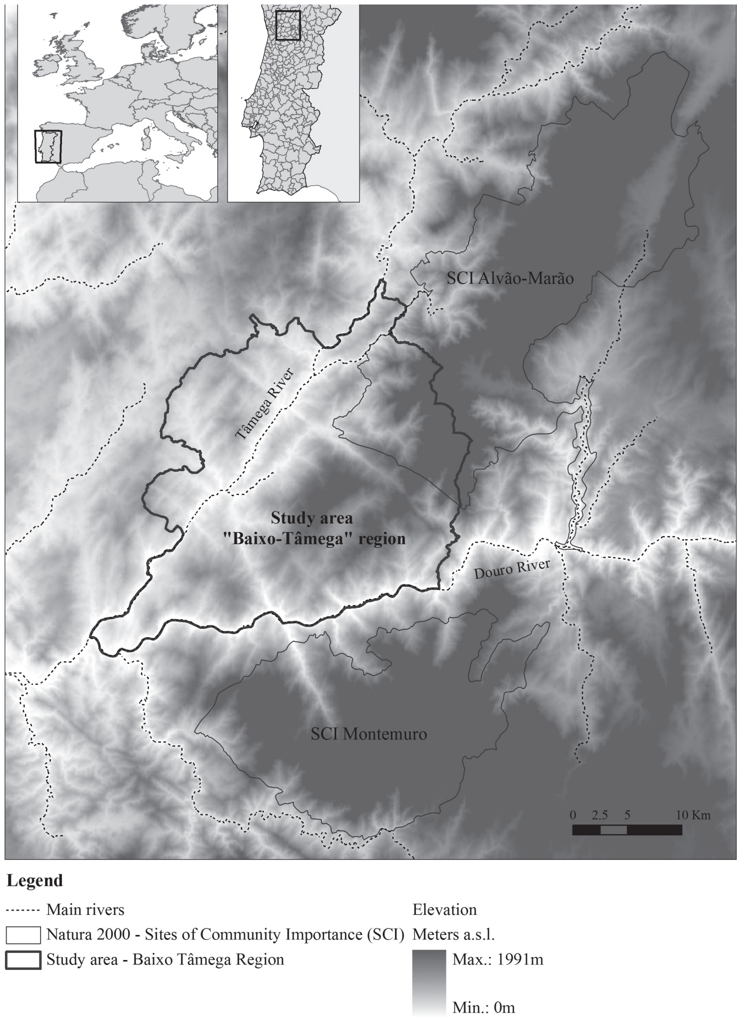

Fig. 1. Study area location.

orientation) rivers are mainly running below 400 m a.s.l. The mountain slopes are generally high (up to 28.9%) predominantly of southern exposure, ranging from 400 to 700 m, and having yearly mean temperatures between 12.5 °C and 14 °C. Elevations between 600 and 1,000 m a.s.l. are somewhat cooler with annual mean temperatures of 10.5–12.5 °C. Above 1,000 m (4.2% of the study area; complex of Alvão/Marão/Aboboreira with the highest point at Marăo at 1,443 m) annual mean temperatures below 10.5 °C and precipitations above 2400 mm/year prevail. Granitic and schistose (Schist-Greywacke Complex) substrates are dominant. The semi-natural habitats and overall cultural landscape add great importance to these areas in both the conservation of biodiversity and the ecological processes in the landscape, providing the frame in the concept of "High Nature Value Farmlands" (Santos *et al.* 2010). Moreover, about two dozen habitat types of Annex I of EU Directive "Habitats" (including two priority ones), various species of flora and fauna of Annexes II, IV and V, and numerous bird species of Annex I of EU Directive "Birds" can be found here (Honrado and Vieira 2009).

The vegetation reflects a transitional character, influenced by oceanic (from west) and continental (from east) climate regimes, reflected in the distinctive dominance of *Quercus robur* in the "oceanic woodlands" and *Quercus pyrenaica* in the more "continental woodlands". To a less extent, transition between the Euro-Siberian (from north) and Mediterranean (from south) climate is observed, marked by the "mesotemperated" and "termotemperated" oak forests *Rusco aculeati-Quercetum roboris quercetosum suberis,* enriched both by atlantic (*e.g. Acer pseudoplatanus, Anthoxanthum amarum, Carduus gaianus, Centaurium scillioides* and *Cytisus striatus*) and by numerous Mediterranean elements (incl. *Daphne gnidium, Arbutus unedo*, *Laurus nobilis*, *Ruscus aculeatus*) (Costa *et al.* 1998).

METHODS

Biological valuation

The territory was studied using an agglomerative methodology of land cover assessment, using the classification of natural and semi-natural classes presented in Table 1. The biological valuation of each of these classes was based on the expert judgment by the team that had previously visited the studied area during a limited number of generalist surveys or sporadic visits, and mainly based on the knowledge acquired from the studies of the surrounding Natura 2000 Sites, since no specific bibliographic references were found for this area.

To produce a conservation value matrix for bryophytes, a numerical value was assigned to each natural and semi-natural land cover class, based on three criteria: bryophyte richness (SR); bryophytes listed in Directives, Red Lists or known as singular/locally rare/sporadic/endemic (RLS); bryophyte functional richness understood as the diversity of life forms and life strategies (FR). A scale ranging from 1 to 5 (1 = very low; 2 = low; 3 = moderate; 4 = high; 5 = very high) was used to value the importance of each class, according to each criterion. The final conservation value for each class was obtained by the sum of values obtained for each criterion. At the same time, other teams developed conservation value matrices for groups other than bryophytes, namely for vascular plants and their habitats, lichens, macrofungi, invertebrates and vertebrates, based on the same valuation methodology in order to obtain an overall matrix of biological valuation.

Spatialization and calculation of statistics and metrics

Using GIS software, biological valuation matrices were linked to land cover maps enabling the spatial representation of biological conservation value at the patch level. In order to aggregate biological matrices at the scale of the UTM

Table 1. Methodology used to estimate a conservation value for bryophytes of natural and semi-natural class; (SR) species richness; (RLS) species listed in directives, red lists or known as singular/locally rare/sporadic/endemic; (FR) functional richness; (Σt) total sum of the values of SR, RLS, FR.

Natural and semi-natural classes	SR	RLS	FR	Σt
Native broadleaf forests (*Quercus robur*, *Q. suber* mixed or pure stands)	5	5	5	15
Other broadleaf stands (*Castanea sativa*, olive groves)	4	3	3	10
Rock outcrops	4	3	2	9
Mosaics of annual cultures and oak stands/edges	3	2	3	8
Mosaics of coniferous forests (*Pinus pinaster*, *Pinus sylvestris*, *Pseudotsuga menziesii*)	3	2	3	8
Low scrublands	3	2	3	8
Mosaics of extensive agriculture with forest stands of *Pinus* spp., *Eucalyptus* spp., *Castanea sativa* or other broadleaf trees	3	3	2	8
Orchards (arboreal fruit trees including isolated olive trees)	2	2	2	6
Complex mosaics of annual cultures and tree formations	2	1	2	5
Vineyards	2	1	2	5
Eucalyptus spp. plantations	2	1	2	5
High scrublands (with sporadic regeneration of trees)	2	1	1	4
High scrublands (with degraded forest)	2	1	1	4
Annual cultures mosaics (no forest edges)	1	1	1	3
Artificial areas (gardens, infra-structure and equipment, urban and semi-urban spaces)	1	1	1	3

grid (1 km × 1 km quadrate) several statistics were calculated (*e.g.* mean, area-weighted mean, median, standard deviation and the median absolute deviation for each quadrate). The 40 statistics concerning biological valuation are presented in Table 3. Using the available land cover maps, 9 landscape configuration metrics (Lcf) and 16 landscape composition metrics (Lcp) were also calculated for each UTM grid unit (or quadrate) (Table 3).

Herbarium bryological data

To obtain a realistic source of bryological data for the studied territory we used the herbarium specimens of Oporto Herbarium (OPO, including CIBIO collections) obtained in several campaigns, between 2000 and 2010, with different purposes (mountain stream environments subjected to different levels of human pressure and with dissimilar streambed structure and water quality; distinctive outcrops visited in different mountain ranges; epiphytic communities in oaklands; terricolous bryophytes from agricultural and forest mosaics) (Marques *et al.* 2005, Vieira 2008, Cruz 2009, Hespanhol 2010). A sampling effort was also associated to each quadrate since different numbers of specimens were available from each location ranging from 1 (less than 7 specimens) to 6 (more than 30 specimens).

All the specimens (numbers ranging from 6,671 to 13,937 and a total of 450 specimens) were referenced at the scale of the UTM grid (1 km × 1 km quadrate) and reviewed. The nomenclature of mosses follows Hill *et al.* (2006), and hornworts and liverworts follows Ros *et al.* (2007). The threat status follows IUCN categories and is according to the new Portuguese Red List that is currently in preparation. For the purpose of this work, the "threatened taxa" concept includes species with threat categories (EN, VU), species with fewer information available (DD) and species regarded as non-threatened but endemic or of particular phytogeographical importance to which attention should be paid (LC-att) (Sérgio *et al.* 2007).

Exploratory statistical analysis

We used Spearman rank correlation as an exploratory technique, in order to relate response variables (total and threatened species richness data obtained from the herbarium collection) to the surrogate variables (statistics calculated to summarise biological value at the quadrate level). Additionally, we used the same correlation test to explore the relationships between bryophyte occurrence and explanatory variables (landscape composition and configuration metrics). Only significant values (p-values: * = 0.05; ** = 0.01; *** = 0.001) obtained from the correlation test are shown and discussed.

RESULTS

In total, 167 bryophyte taxa (2 hornworts, 38 liverworts and 127 mosses) were recorded in 27 different 1 km × 1 km UTM quadrates (Appendix 1 and 2). From the total number of species, 15% are "threatened taxa" (Table 2).

The spatialization of bryophyte conservation value at land cover class level (Σt) for the entire territory is shown in Figure 2. Positive correlations were found between bryophyte valuation parameters (namely, the mean and median quadrate values) and the total and threatened bryophyte species richness (Table 3). In the same way, we found positive correlations between total bryophyte species richness and median and mean values for lichens and invertebrates valuations and between threatened bryophyte species occurrence and median and mean values for invertebrates and vertebrate valuations. On the other hand, the total bryophyte richness is negatively correlated with the quadrates' median absolute deviation value of habitats valuation.

Concerning landscape composition, only one positive correlation was found between quadrates with higher percentage of low scrublands and total bryophyte richness (Table 3). Negative correlations were found between quadrates with modified land covers (*e.g.* annual cultures, vineyards and artificial areas) and total and threatened bryophyte richness; and also between quadrates with semi-natural forest formations (other broad-leaf stands) and total bryophyte richness.

In relation to landscape configuration, total and threatened bryophyte richness are positively correlated with landscape mosaics displaying larger patches, higher variability in patch size distribution and higher mean patch edge (Table 3). Conversely, a negative correlation with landscape mosaics with a higher number of patches was found. Threatened species occurrence is also positively correlated with quadrates where land cover patches display lower core area index and higher mean shape index.

Table 2. Number of species and frequency values in the study area; species are classified according to their IUCN category.

IUCN categories	Number of species	%	Number of occurrences	%
Endangered (EN)	5	3	6	1
Vulnerable (VU)	4	2	5	1
Least concern – attention (LC-att)	6	4	8	1
Data-deficient (DD)	7	4	13	2
Least concern (LC)	145	87	578	95

Table 3. Spearman correlation values between response variables (NTBS = number of threatened bryophyte species; TNBS = total number of bryophyte species) and sampling effort (SE), explanatory variables (Lcp = landscape composition; Lcf = configuration metrics) and surrogate variables (Bv = biological valuation parameters). Only significant correlation values are shown. p-values: * = 0.05; ** = 0.01; *** = 0.001

		NTBS		TNBS		SE	
EXPLANATORY VARIABLES							
Lcp	Quadrate % of orchards						
	Quadrate % of native broadleaf forests						
	Quadrate % of annual cultures	−0.40	***				
	Quadrate % of other broadleaf stands			−0.52	**	−0.52	***
	Quadrate % of complex mosaics of annual cultures and tree formations						
	Quadrate % of vineyards	−0.64	*	−0.53	**	−0.68	*
	Quadrate % of complex mosaics of annual cultures and tree formations	−0.40	***	−0.50	**	−0.53	**
	Quadrate % of *Eucalyptus* spp. plantations					−0.53	**
	Quadrate % of other broadleaf stands						
	Quadrate % of water						
	Quadrate % of high scrublands (with degraded forest)						
	Quadrate % of low scrublands			0.41	***	0.59	*
	Quadrate % of high scrublands (with sporadic regeneration of trees)						
	Quadrate % of artificial areas			−0.43	**		
	Quadrate % of rock outcrops						
	Quadrate % of mosaics of coniferous forests						
Lcf	Core Area Index (m^2)	−0.42	***			−0.57	*
	Number of patches	−0.50	**	−0.47	**	−0.48	**
	Mean Patch Size (m^2)	0.43	**	0.46	**	0.55	*
	Median Patch Size (m^2)			0.42	***		
	Patch size coefficient of variation						
	Patch size standard-deviation (m^2)	0.39	***	0.42	***	0.56	*
	Edge density ($m.m^{-2}$)			−0.40	***	−0.37	***
	Mean Patch Edge (m)	0.55	*	0.52	**	0.55	*
	Mean Shape Index	0.68	*				

Table 3 (cont.)

		NTBS		TNBS		SE	
SURROGATE VARIABLES							
Bv	Quadrate median absolute deviation value of all biological elements valuation						
	Quadrate median absolute deviation value of bryophyte valuation						
	Quadrate median absolute deviation value of habitats valuation			–0.44	**		
	Quadrate median absolute deviation value of invertebrate valuation						
	Quadrate median absolute deviation value of lichens valuation						
	Quadrate median absolute deviation value of macrofungi valuation						
	Quadrate median absolute deviation value of vertebrate valuation						
	Quadrate mean value of all biological elements valuation			0.46	**		
	Quadrate mean value of bryophytes valuation			0.44	**		
	Quadrate mean value of habitats valuation					0.38	***
	Quadrate mean value of invertebrates valuation			0.50	**		
	Quadrate mean value of lichens valuation			0.37	***	0.46	**
	Quadrate mean value of macrofungi valuation						
	Quadrate mean value of vertebrates valuation						
	Quadrate median value of all biological elements valuation	0.48	**	0.40	***		
	Quadrate median value of bryophytes valuation	0.48	**	0.43	**	0.47	**
	Quadrate median value of habitats valuation						
	Quadrate median value of invertebrates valuation	0.44	**	0.46	**	0.40	***
	Quadrate median value of lichens valuation			0.56	*	0.57	*
	Quadrate median value of macrofungi valuation						
	Quadrate median value of vertebrates valuation	0.38	***			0.41	***

Table 3 (cont.)

	NTBS		TNBS		SE	
Quadrate percentage classified as "high value" for bryophyte conservation						
Quadrate percentage classified as "low value" for bryophyte conservation			−0.39	***	−0.63	*
Quadrate percentage classified as "moderate value" for bryophyte conservation					0.54	**
Quadrate percentage classified as "very low value" for bryophyte conservation	−0.36	***				
Quadrate percentage classified as "very high value" for bryophyte conservation						
Quadrate standard deviation value of all biological elements valuation						
Quadrate standard deviation value of bryophyte valuation						
Quadrate standard deviation value of habitats valuation						
Quadrate standard deviation value of invertebrates valuation						
Quadrate standard deviation value of lichens valuation						
Quadrate standard deviation value of macrofungi valuation						
Quadrate standard deviation value of vertebrates valuation						
Quadrate area-weighted mean value of all biological elements						
Quadrate area-weighted mean value of bryophytes					0.41	***
Quadrate area-weighted mean of habitats					0.38	***
Quadrate area-weighted mean of invertebrates			0.37	***	0.39	***
Quadrate area-weighted mean of lichens			0.46	**	0.50	**
Quadrate area-weighted mean of macrofungi					−0.38	***
Quadrate area-weighted mean of vertebrates					0.36	***

DISCUSSION

Regarding total bryophyte species richness, herbarium data showed that the total number of bryophyte species is mostly due to occurrences in natural formations, but it is also enhanced by the presence of species related with low impact traditional cultures. The number of threatened species richness is mostly related with the remaining natural formations and undisturbed substrates, such as in the microhabitats of oak stands, watercourses and rock outcrops.

Spatial patterns of total and threatened bryophyte species richness seem spatially congruent with bryological valuation, since quadrates rich in threatened or total species are located in highly valued areas (Fig. 2, Table 3). However, this consideration can only be supported by herbarium data on the eastern part of the studied area (due to biased representation of the territory by herbarium collections). The western part, although presenting low-valued mosaics and quadrates with less threatened species and lower overall richness, is represented by a very limited number of quadrates, and therefore the spatial evaluation of congruency between the bryological valuation and collections is not entirely reliable.

In general, quadrates with higher mean or median value for lichens, invertebrates or biological elements (as overall biodiversity) also present higher numbers of bryophytes or, even in some cases, threatened bryophyte species, which shows that these valuations are also congruent with field data for bryophytes. This indicates that somehow bryophyte data (and valuation) might be a surrogate for other biological groups responding to small-scale variation in habitat, such as invertebrates and lichens.

Overall richness of bryophytes and threatened species are negatively correlated with artificial and modified land use/land cover classes. On the other hand, the negative correlation found between total bryophyte richness and the median absolute deviation of habitat types valuation shows that quadrates with heterogeneously valued mosaics are not favourable for the occurrence of high number of bryophyte species. In the studied area, these two results might correspond to quadrates with highly modified mosaics where few species can tolerate human impact and eutrophication related to non-traditional agriculture and artificialization of natural land cover. In the same way, quadrates with other broad-leaf stands (mainly *Castanea sativa* plantations and olive groves) tend to present low overall bryophyte richness, which might be explained by the disturbance caused by management in these formations.

Nevertheless, and once more, the fact that areas with highly modified landscapes (quadrates with higher percentage of annual cultures, vineyards and artificial areas) and other broad leaf stands are not intensively represented by herbarium data (as shown by negative correlations between sampling effort and quadrates with high percentage of these land covers) might bias any extensive conclusion. Conversely, low scrublands, represented by a high amount of herbarium data (as shown by positive correlations between sampling effort and quadrates with this land cover), were found to be important for the preservation of a high number of bryophytes in the studied area.

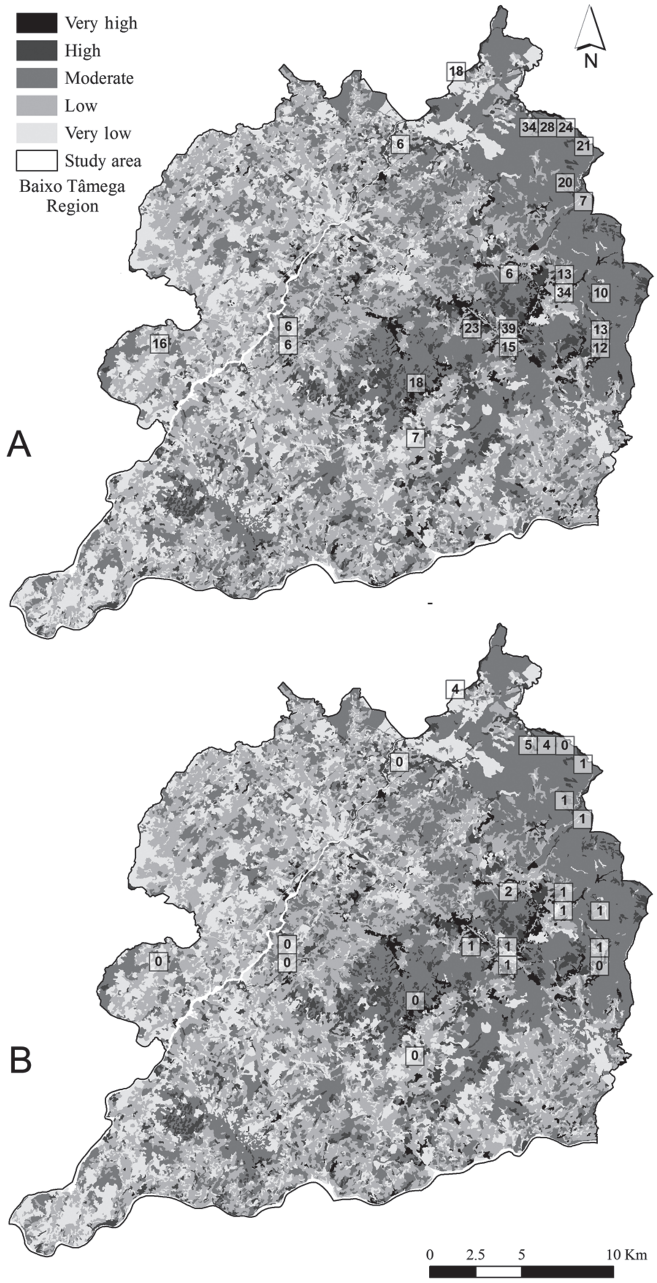

Fig. 2. Map of conservation value for bryophytes in the region of Baixo-Tâmega, superimposed with total bryophyte richness (a) and threatened bryophyte species richness (b). Values inside the quadrate represent the number of species.

Higher values of total and threatened bryophyte species richness are associated with distinct types of quadrates: either with low number of patches, bigger patches (mean patch size), highly heterogeneous sizes (patch size standard-deviation), or with intricate edges (mean patch edge/edge density). Furthermore, a higher number of threatened species richness is usually found in irregular patches with higher mean shape index and smaller core area index that reflect spatial heterogeneity (Table 3). In the study area, this might correspond to two ecologically distinct situations: i) nonfragmented landscapes presenting large patches of scrublands in mountainous areas (some of which include calcareous outcrops with many threatened species) or ii) complexes of mosaics of annual cultures and remnant oak stands with longer and intricate ecotones intertwined with linear features – small watercourses – where many hygrophilous threatened species thrive.

In this project, the exercise of biological valuation proved to be a useful tool for conservation and management of semi-natural areas, especially in the case of bryophytes and when only scarce biological data is available. Although some assumptions about the value of each land cover class can be reductionist, there are some important advantages in the bryophyte valuation methodology, such as the rapid assignment of conservation value to different land cover types and the generalist and informative overview of the territory hotspots.

Landscape configuration and composition must also be taken into account in conservation management and planning at the landscape scale, since we found that heterogeneity, patch size and ecotones of natural and semi-natural mosaics can be as important as the presence of certain land cover classes (low scrublands) for the preservation of national threatened bryophyte taxa.

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Appendix 1. List of localities studied (locality number: UTM quadrate, mean altitude).

1: 29TNF6762, 200 m	**10**: 29TNF8377, 100 m	**19**: 29TNF8974, 610 m
2: 29TNF7463, 100 m	**11**: 29TNF8463, 500 m	**20**: 29TNF9070, 852 m
3: 29TNF7665, 200 m	**12**: 29TNF8562, 650 m	**21**: 29TNF9073, 1,000 m
4: 29TNF7869, 200 m	**13**: 29TNF8663, 750 m	**22**: 29TNF9162, 500 m
5: 29TNF8058, 190 m	**14**: 29TNF8666, 346 m	**23**: 29TNF9163, 750 m
6: 29TNF8073, 70 m	**15**: 29TNF8774, 540 m	**24**: 29TNF7462, 200 m
7: 29TNF8157, 400 m	**16**: 29TNF8874, 550 m	**25**: 29TNF8662, 700 m
8: 29TNF8160, 750 m	**17**: 29TNF8965, 900 m	**26**: 29TNF8971, 1,168 m
9: 29TNF8264, 700 m	**18**: 29TNF8966, 626 m	**27**: 29TNF9165, 1,215 m

Appendix 2. List of bryophytes found in the study area (species name: localities numbers, microhabitat)

Species are listed according to their IUCN categories and the localities numbers correspond to Appendix 1. The microhabitat where species were found was only specified for species with a threat status (EN, VU); DD: species with fewer information available; LC-att: species regarded as non-threatened but endemic or of particular phytogeographic importance to which attention should be paid.

EN – Liverworts: *Jungermannia pumila* With.: 20; semi-immerged granite bank; *Preissia quadrata* (Scop.) Nees: 15; calcareous outcrops and crevices. – Mosses: *Encalypta streptocarpa* Hedw.: 15; crevices of exposed calcareous outcrops; *Fissidens rivularis* (Spruce) Schimp.: 16; semi-immerged granite or schist rocks in streambeds; *Mnium stellare* Hedw.: 14; granite and earth banks.

VU – Liverworts: *Dumortiera hirsuta* (Sw.) Nees: 16; granite waterfall margins. – Mosses: *Porella pinnata* L.: 10; semi-immerged rocks in river margins; *Orthotrichum rivulare* Turner: 10; semi-immersed riparian trunks; *Schistidium rivulare* (Brid.) Podp.: 10; semi-immerged rocks in streams.

DD – Liverworts: *Aneura maxima* (Schiffn.) Steph.: 25; drippings in an earth bank. – Mosses: *Dichodontium pellucidum* (Hedw.) Schimp.: 16; semi-immersed schist rock in watercourse; *Grimmia tergestina* Tomm. ex Bruch et Schimp.: 15; surfaces of exposed calcareous outcrops; *Hedwigia striata* (Wilson) Bosw.: 13, 17; granite banks in pathways and oaklands; *Fissidens pusillus* (Wilson) Milde: 18; semi-immerged granite or schist rocks in streambeds; *Schistidium apocarpum* (Hedw.) Bruch et Schimp.: 15, 16; earth banks and surfaces of exposed calcareous outcrops. *Tortella tortuosa* (Hedw.) Limpr.: 15; surfaces or cavities of exposed calcareous outcrops.

LC-att – Liverworts: *Barbilophozia hatcheri* (A. Evans) Loeske: 21, 26; crevices of exposed schist outcrops; *Plagiochila porelloides* Torrey ex Nees) Lindenb.: 14; fresh granite wall. – Mosses: *Andreaea heinemannii* Hampe et Müll. Hal. subsp. *crassifolia* (Luisier) Sérgio: 27; surfaces of exposed schist outcrops; *Dendrocryphaea lamyana* (Mont.) P. Rao: 10; semi-immersed riparian trunks; *Dicranum crassifolium* Sérgio, Ochyra et Séneca: 11; oakland soil and earth banks; *Racomitrium lamprocarpum* (Müll. Hal.) A. Jaeger: 23; semi-immerged rocks in streams.

LC – Hornworts: *Anthoceros punctatus* L.: 25; *Phaeoceros laevis* (L.) Prosk.: 25. – Liverworts: *Aneura pinguis* (L.) Dumort.: 17; *Calypogeia fissa* (L.) Raddi: 11; *Cephaloziella baumgartneri* Schiffn.: 15; *C. divaricata* (Sm.) Schiffn.: 21, 26; *C. turneri* (Hook.) Müll. Frib.: 1; *Chiloscyphus polyanthos* (L.) Corda: 16; *Conocephalum conicum* (L.) Dumort.: 5, 16; *Diplophyllum albicans* (L.) Dumort.: 11, 12, 27; *Douinia ovata* (Dicks.) H. Buch: 13, 17; *Fossombronia angulosa* (Dicks.) Raddi: 22; *Frullania dilatata* (L.) Dumort.: 7, 8, 11, 13, 15, 17, 25; *F. tamarisci* (L.) Dumort.: 13, 21, 25; *Jungermannia gracillima* Sm.: 12, 19; *J. hyalina* Lyell: 11, 18, 19, 23; *J. sphaerocarpa* Hook.: 23; *Lejeunea cavifolia* (Ehrh.) Lindb.: 14; *L. lamacerina* (Steph.) Schiffn.: 16; *Lophocolea bidentata* (L.) Dumort.: 8, 13; *L. heterophylla* (Schrad.) Dumort.: 11; *Lophozia bicrenata* (Schmidel ex Hoffm.) Dumort.: 17; *Lunularia cruciata* (L.) Lindb.: 6, 8, 10, 15, 16, 22; *Marchantia polymorpha* L. : 16; *Marsupella emarginata* (Ehrh.) Dumort.: 11, 12, 13, 21,23, 26, 27; *M. funckii* (F. Weber et D. Mohr) Dumort.: 21; *Metzgeria furcata* (L.) Dumort.: 8, 21, 13; *Pellia epiphylla* (L.) Corda: 16, 19, 23, 25; *Porella obtusata* (Taylor) Trevis.: 1, 13, 14; *Radula complanata* (L.) Dumort.: 13, 14; *Reboulia hemisphaerica* (L.) Raddi: 6, 8, 22; *Scapania compacta* (A. Roth) Dumort.: 8, 11, 12, 13, 17, 19, 22, 24, 26, 27; *S. undulata* (L.) Dumort.: 18, 19, 20, 23; *Southbya nigrella* (De Not.) Henriq.: 15. – Mosses: *Amphidium mougeotii* (Schimp.) Schimp.: 22; *Andreaea rothii* F. Weber et D. Mohr subsp. *falcata* (Schimp.) Lindb.: 21, 26, 27; *A. rothii* F. Weber et D. Mohr subsp. *rothii*: 21; *Anomobryum julaceum* (Schrad. ex P. Gaertn. et al.) Schimp.: 4, 16; *Antitrichia curtipendula* (Hedw.) Brid.: 13, 17; *Atrichum undulatum* (Hedw.) P. Beauv.: 13, 24; *Bartramia pomiformis* Hedw.: 8, 11, 21, 22, 24; *B. stricta*

Brid.: 13; *Brachythecium rivulare* Schimp.: 10, 16, 25; *B. rutabulum* (Hedw.) Schimp. : 9, 17; *Bryum alpinum* Huds. ex With.: 10, 16, 19; *B. argenteum* Hedw.: 9, 13, 17; *B. capillare* Hedw.: 1, 8, 15, 17, 19, 22; *B. gemmiparum* De Not.: 16, 18; *B. pseudotriquetrum* (Hedw.) P. Gaertn. et al.: 10, 16, 18, 23, 25; *Calliergonella cuspidata* (Hedw.) Loeske: 10, 16; *Campylopus fragilis* (Brid.) Bruch et Schimp.: 21; *C. introflexus* (Hedw.) Brid.: 1; *C. pilifer* Brid.: 1, 16, 18, 19, 26; *C. pyriformis* (Schultz) Brid.: 13; *Ceratodon purpureus* (Hedw.) Brid. subsp. *purpureus*: 2, 4, 8, 13, 16, 26; *Cheilothela chloropus* (Brid.) Broth: 15; *Cinclidotus fontinaloides* (Hedw.) P. Beauv.: 2; *Cryphaea heteromalla* (Hedw.) D. Mohr: 7; *Cynodontium bruntonii* (Sm.) Bruch et Schimp.: 13, 19, 21, 26, 27; *Dialytrichia mucronata* (Brid.) Broth.: 10, 15; *Dicranella heteromalla* (Hedw.) Schimp.: 27; *Dicranum scoparium* Hedw.: 11, 13, 17; *Didymodon insulanus* (De Not.) M. O. Hill: 16; *Diphyscium foliosum* (Hedw.) D. Mohr: 27; *Encalypta vulgaris* Hedw.: 15; *Epipterygium tozeri* (Grev.) Lindb.: 16; *Fissidens bryoides* Hedw. var. *caespitans* Schimp.: 16, 17, 18, 19, 20; *F. dubius* P. Beauv.: 15, 22; *F. polyphyllus* Wilson ex Bruch et Schimp.: 19, 23; *F. serrulatus* Brid.: 18; *F. taxifolius* Hedw.: 16; *F. viridulus* (Sw. ex anon.) Wahlenb.: 17; *Fontinalis antipyretica* Hedw.: 7, 23; *F. squamosa* Hedw. var. *dixonii* (Cardot) A. J. E. Sm.: 18; *F. squamosa* Hedw. var. *squamosa*: 2, 6, 10; *Funaria hygrometrica* Hedw.: 19; *Grimmia decipiens* (Schultz) Lindb.: 19, 26; *G. laevigata* (Brid.) Brid.: 8, 13; *G. montana* Bruch et Schimp.: 8, 13, 19, 21, 26, 27; *G. orbicularis* Bruch ex Wilson: 15; *G. pulvinata* (Hedw.) Sm.: 13, 15; *G. trichophylla* Grev.: 13, 15, 19, 26; *Gymnostomum calcareum* Nees et Hornsch.: 15; *Hedwigia ciliata* (Hedw.) P. Beauv.: 1; *H. ciliata* (Hedw.) P. Beauv. var. *leucophaea* Bruch et Schimp.: 17; *H. stellata* Hedenäs: 7, 8, 13, 17, 21, 26; *Homalothecium sericeum* (Hedw.) Schimp.: 1, 13, 15, 22, 25; *Hygrohypnum ochraceum* (Turner ex Wilson) Loeske: 18; *Hyocomium armoricum* (Brid.) Wijk et Margad.: 18, 19, 20, 23; *Hypnum andoi* A. J. E. Sm.: 11, 13, 17, 25; *H. cupressiforme* Hedw. var. *cupressiforme*: 1, 8, 11, 13, 15, 17, 21, 24, 25, 26; *Isothecium holtii* Kindb.: 10; *I. myosuroides* Brid.: 13, 17; *Kindbergia praelonga* (Hedw.) Ochyra: 6, 10, 16, 17, 25; *Leptodictyum riparium* (Hedw.) Warnst.: 7, 10; *Leptodon smithii* (Hedw.) F. Weber et D. Mohr: 1; *Leskea polycarpa* Hedw.: 10; *Leucodon sciuroides* (Hedw.) Schwägr.: 2, 15; *Neckera pumila* Hedw.: 11; *Orthotrichum affine* Schrad. ex Brid.: 17, 22; *O. lyellii* Hook. et Taylor: 8, 11, 13, 17, 25; *O. rupestre* Schleich. ex Schwägr.: 9, 13, 15, 17; *O. speciosum* Nees : 11, 13, 17, 25; *O. striatum* Hedw.: 7; *Philonotis caespitosa* Jur.: 9; *P. fontana* (Hedw.) Brid.: 19; *Plagiomnium affine* (Blandow ex Funck) T. J. Kop.: 6; *P. undulatum* (Hedw.) T. J. Kop.: 16; *Plagiothecium nemorale* (Mitt.) A. Jaeger: 11, 17, 20; *Platyhypnidium lusitanicum* (Schimp.) Ochyra et Bednarek-Ochyra: 18, 19, 20, 23; *P. riparioides* (Hedw.) Dixon: 2, 3, 5, 6, 7, 10, 16, 17, 22; *Pleurochaete squarrosa* (Brid.) Lindb.: 15; *Pogonatum aloides* (Hedw.) P. Beauv.: 11, 26; *Pohlia annotina* (Hedw.) Lindb.: 19; *P. cruda* (Hedw.) Lindb.: 16; *P. elongata* Hedw. var. *elongata*: 26; *Polytrichastrum formosum* (Hedw.) G. L. Sm.: 11, 24; *Polytrichum commune* Hedw.: 1, 17, 19, 23; *P. juniperinum* Hedw.: 1, 13, 22; *P. piliferum* Hedw.: 1, 2, 4, 8, 13, 17, 21, 26; *Pseudoscleropodium purum* (Hedw.) M. Fleisch.: 1, 8, 11, 17, 24; *Pseudotaxiphyllum elegans* (Brid.) Z. Iwats.: 11, 17, 26, 27; *Pterogonium gracile* (Hedw.) Sm.: 8, 11, 13, 17, 25; *Racomitrium aciculare* (Hedw.) Brid.: 16, 18, 19, 20, 23; *R. affine* (F. Weber et D. Mohr) Lindb.: 13, 21, 26; *R. elongatum* Ehrh. ex Frisvoll: 1, 8, 11, 13, 17; *R. heterostichum* (Hedw.) Brid.: 1, 13, 15, 17, 19, 21, 26; *R. lanuginosum* (Hedw.) Brid.: 1, 13, 21; *Rhabdoweisia fugax* (Hedw.) Bruch et Schimp.: 21; *Rhynchostegium confertum* (Dicks.) Schimp.: 17; *Scleropodium touretii* (Brid.) L. F. Koch: 10; *Scorpiurium circinatum* (Bruch) M. Fleisch. et Loeske: 15; *Sphagnum auriculatum* Schimp.: 19; *Syntrichia* montana Nees: 15; *Thamnobryum alopecurum* (Hedw.) Gangulee: 10, 14, 16; *Thuidium tamariscinum* (Hedw.) Schimp.: 19; *Tortella nitida* (Lindb.) Broth.: 15; *Tortula muralis* Hedw.: 13; *Trichostomum brachydontium* Bruch: 15; *T. crispulum* Bruch: 15; *Ulota crispa* (Hedw.) Brid.: 11, 17; *Weissia condensa* (Voit) Lindb.: 15; *Zygodon rupestris* Schimp. ex Lorentz: 13.