Portugaliae Acta Biol. **20**: 37-48. Lisboa, 2002

HOW TO EVALUATE SPECIES WHEN DISTRIBUTION IS POORLY UNDERSTOOD.

THE USE OF PREDICTIVE STUDIES FOR IBERIAN BRYOPHYTES

Cecília Sérgio[1] & David Draper [2]

[1] Jardim Botânico (M.N.H.N.) / Centro de Ecologia e Biologia Vegetal (FCUL). Rua da Escola Politécnica 58, 1250 - 102, Lisboa, Portugal. Email: csergio@fc.ul.pt

[2] Jardim Botânico (M.N.H.N.), Rua da Escola Politécnica 58, 1250 - 102, Lisboa, Portugal. Email: ddraper@fc.ul.pt

Sérgio, C. & Draper, D. (2002). How to evaluate species when distribution is poorly understood. The use of predictive studies for Iberian bryophytes. *Portugaliae Acta Biol.* **20**: 37-48.

With more than 1100 bryophyte species, the Iberian Peninsula harbours one of the most diverse floras of Europe, including important endemics and elements of phytogeographic interest.
The lack of knowledge in important areas, particularly for historical reasons, makes conservation action very difficult. Another consequence of this is the idea that some of the species that are in regression in Europe appear to be in expansion in the Iberian Peninsula.
These facts complicate the evaluation of the threatened status of Iberian bryophytes, particularly when using the new IUCN criteria (World Conservation Union 1994).
The examination of the relationships between the environmental variables and the loca ity of each species, using GIS, may be useful in predicting the distribution of bryophyte taxa in the Iberian Peninsula.
The applied methodology presents good results and can give suggestions for the identification of the location of threatened species that need nature conservation plans.

Key words: Bryophytes, distribution, GIS, conservation, Iberian Peninsula.

Sérgio, C. & Draper, D. (2002). Como avaliar espécies de distribuição pouco conhecida. O uso de estudos preditivos para os briófitos Ibéricos. *Portugaliae Acta Biol.* **20**: 37-48.

A Península Ibérica é uma das regiões da Europa mais rica quanto à sua brioflora, integrando mais de que 1100 espécies,

além de incluir importantes endemismos ou elementos com manifesto interesse fitogeográfico.
No entanto, a falta de conhecimento de algumas áreas, em particular por razões históricas, e por falta de estudos antigos, dificulta a promoção de acções de conservação. Uma outra consequência desta falta de conhecimento é a ideia que, uma determinada espécie, pareça estar em expansão na Península Ibérica enquanto no resto da Europa pode ser considerada em regressão.
Estes factos dificultam o conhecimento do estado de ameaça de uma determinada espécie na Península Ibérica, em particular quando se pretende aplicar os critérios da IUCN (World Conservation Union 1994).
A obtenção das relações entre as diferentes variáveis estacionais e as localidades onde se conhece a ocorrência de determinada espécie, por meio de SIG, pode tornar possível a sua distribuição predictiva, tendo como base a maior probabilidade de ocorrência em todo o território.
Esta metodologia foi aplicada em espécies seleccionadas, os exemplos apresentados dão bons resultados, podendo dar sugestões fundamentadas na identificação de novas áreas de ocorrência de espécies, que necessitam de planos específicos de conservação.

Palavras chave: Briófitos, distribuição, SIG, conservação, Península Ibérica.

INTRODUCTION

One of the principal objectives of the ECCB is to develop a complete resource network, which is gradually emerging from first publication of the Red Data Book of European Bryophytes (ECCB 1995). This project has also provided opportunities for applying the same criteria in different countries and to work in collaboration with others bryologists. Also it has provided the opportunity for preparation of the first Iberian Red List (SÉRGIO *et al.* 1994).

With more than 1100 bryophyte species, the Iberian Peninsula harbours one the most diverse floras in Europe, including important endemic species and elements of phytogeographic interest (SÉRGIO 1990).

Recent publication of taxonomic revisions and other identification works in poorly studied areas have led to many modifications to this work. Therefore, the update of numerous distribution maps of Iberian species (CASAS *et al.* 1985, 1989, 1992 and 1996) are needed.

Some species are easily overlooked and difficult to find in Mediterranean habitats, or not easy to identify, so there has not been a significant increase in their records. However for particular groups such as the genus *Orthotrichum*, *Racomitrium*, *Hedwigia*, *Schistidium* and *Grimmia*, there has been considerable improvement.

On the other hand, recent floristic studies are in some cases concentrated in areas which were very under recorded, such as Serras da Arrábida, Candeeiros, S. Mamede and Estrela,in Portugal and Pyrenees, Gredos, Sierra Nevada, etc. in Spain. Others, such as the North Iberian Peninsula in the region of Galicia and Minho, extensively surveyed up to the 1950's, are now much altered due to the pressure of extensive industrial and society development, and are now being considerably less studied.

However it can be said that in the last 5 years there has been a big improvement in recording the Iberian bryoflora. More than 22 species of mosses have been added (CASAS 1999) to the Spanish list, and about 20 bryophytes to the Portuguese list. With this result a question can be asked: is the Iberian bryoflora now well known? We think the answer is "Not yet".

The conservation of a particular species begins with recording its distribution and studying its bioclimatic affinities and environmental requirements. The establishment of correlations between distribution patterns and environmental factors could be an appropriate tool for management and conservation programmes (BEGON *et al.* 1990). In a further step, if we know the relationships between the organism and the environmental variable we can predict its distribution (JOHNSTON 1993).

Our knowledge of the environmental needs of most species is extremely inadequate and the necessity for the implementation of a new approach, particularly in the Iberian peninsula, has become urgent. The application of predictive maps presents a new way to use the taxa distribution. These predictive maps are commonly applied in other species groups such as vascular plants (GUISAN & THEURILLAT 2000) or animals (PEREIRA & ITAMI 1987).

In the specific case of bryophytes, scarce knowledge is translated into a low number of records over a wide area. There is a strong limitation due to the low fitness of the statistical methods employed to obtain the predictive models. Another restriction is scale, several authors have pointed out the need for a particular scale for each survey or objective on each species (GASTON & LAWTON 1990, MAY 1994). Several factors could limit the spatial distribution of a species in different parts of its geographical distribution (BROWN & GIBSON 1983).

The objective of this work is to give a new approach to the biogeographical distribution of bryophytes in the Iberian Peninsula that can help the identification of areas for threatened species and give information about their macro-environmental requirements.

METHODOLOGY

All data was obtained from bibliographic references and recent published data, with some others from our own unpublished results as well as from information from herbarium material. The occurrence of species was recorded in 10x10 km squares (UTM).

The bryophyte species were selected, for the most part, from the taxa that need revision for the new European Red Data Book (ECCB 1995).

The software package used to create the digital terrain model (DTM) was IDRISI (Ver. 2.0) GIS software. The pixel dimension of the model is 500 x 500 m.

The predictive method was the multiple linear regression (MLR) and after that a logistic transformation (HILL & DOMINGUEZ 1994). The variables used were: Altitude; Slope; Aspect; Latitude; Longitude; Radiation; Rainfall; Temperature; Thermal amplitude; Angstrom Index; Angot Index; Dantin Index; Emberger Index; Giacobbe Index; Lang Index; Martonne Index; Number of frost days/year; Soil pH. Bioclimatic indexes were calculated from TUHKANEN (1980). The predictive maps of selected bryophytes in the Iberian Peninsula, based on ecoclimatic variables, are made using a Geographic Information System (GIS). A digital Terrain Model (DTM) of all territory was used in order to obtain geographical and meteorological information for each plant locality. All the records known at present were used to calculate the ecological models.

CASE STUDIES

As we said before, the principal limitation, which complicates the evaluation of threat status of the Iberian bryophytes using the IUCN categories (World Conservation Union 1994) and HÄLLINGBÄCK *et al.* (1998) criteria, is the deficit of old studies for many taxa, particularly before 1950 (fig. 1 to 12 and table 1). This is the case for some endemic or endangered species of the Iberian Peninsula, such as *Anomobryum lusitanicum* (I. Hag. in Luis.) Ther., *Bryum minii* Podp., *Triquetrella arapilensis* Luis., *Schizymenium pontevedrensis* (Luis.) Casas, Sérgio, Cros & Brugués *Racomitrium hespericum* Sérgio, Muñoz & Ochyra and *Sphagnum pylaisii* Brid. One of the other consequences of this lack of knowledge is the idea that some species that are in regression in Europe appear to be in expansion in the Iberian Peninsula. This the case for *Andreaea frigida* Hueb., *Frullania fragilifolia* (Taylor) Gottsche *et al.* (fig. 1, 9 and table 1) and *Cryphaea lamyana* (Mont.) C. Müll. This last species has been recorded from 29 squares, but with only 14 of them after 1950 (fig. 4 and table 1). There is some evidence that this moss has declined or disappeared in an important area in the North Atlantic part of Portugal, where river bank alterations and water pollution may be the cause.

To illustrate the possibilities of having better knowledge of distribution patterns of some Iberian bryophytes we can present some illustrative cases, giving predictive maps of the following species: *Frullania fragilifolia* (Taylor) Gottsche et al., *Marsupella profunda* Lindb., *Brachythecium dieckii* Roell and *Bruchia vogesiaca* Schwaegr.

Frullania fragilifolia

This species is widely distributed around the central-North and north-eastern coast of Portugal (SIM-SIM 1999). In the Iberian Peninsula it has been recorded from about 75 squares 10x10 km (fig. 9A and CASAS *et al.* 1995). *Frullania fragilifolia* avoids areas with high Potential Evapotranspiration values and it has a slight positive relation to altitude, Mean temperature, Thermical amplitude and Martonne Index (table 2). The predictive model is shown in fig. 9B. The two scattered localities in the central part of the Iberian region give a strong probability that the species is continuously distributed in Sistema Central (Estrela-Gredos-Guadarrama). It is also possible to infer its occurrence in restricted areas in the South Mountains, as in the Algeciras region, where enclaves with strong oceanic influence exist. This species is known from restricted sites in Macaronesia.

As was analysed by SIM-SIM *et al.* (1995) based on DCCA ordination, the distribution of this species in Portugal is correlated with a climate with higher precipitation levels, corresponding to mountains under Atlantic influence.

Marsupella profunda

In the Iberian Peninsula this liverwort is restricted to a small number of localities from Minho in the North to the centre-eastern part of Portugal (SÉRGIO & PIERROT 1997). It is locally frequent, even abundant in the Serra da Estrela, but it is apparently confined to Portugal in the Iberian Peninsula (fig. 10A).

With the small number of sites the model remains deficient and the predictive map shows a very wide area in Spain (fig. 10B). *Marsupella profunda* tolerates a high humidity (Lang and Martonne Indexes) as shows table 2.

This species is rarely recognised in the field and may be more widespread in the Iberian Peninsula. However, it always has a very particular ecology, needing natural erosion of unstable granite cliffs, to benefit the colonisation of the plants. Knowing this ecological requirement may help new the detection of new records in Spain.

It is an Euoceanic species restricted to a very few sites in Britain, Portugal and Macaronesia (Madeira and Canary Islands). It is an endangered species in Europe and is included in Appendix I of the Bern Convention and on Annex 2 of the EC Habitats and Species Directive.

Brachythecium dieckii

The taxonomic status of *Brachythecium dieckii* was not clarified until HEDENÄS (1993) studied the type material. Its critical nature has meant that this taxon has been considered a Data Deficient moss in the European Red Data Book (ECCB, 1995). The species was refound in new areas of North Africa (SÉRGIO & JANSEN 2000) and about 8 squares (10x10 km) are known in the Iberian Peninsula. At present *B. dieckii* has been recorded in only 4 main areas (fig. 11A), but the predictive map, though not strongly predictive, suggests that the species may be present in a larger region in the North as well as in scattered areas in the South. *Brachythecium dieckii* has a low dependence on altitude and exposure, but a positive relation with Potential Evapotranspiration (table 2) as illustrated in figure 11. Scattered records from others areas of the Peninsula, where it has probably been confused with *B. velutinum*, are likely. This species has been recorded recently at two new sites: Sierra Nevada, Laguna de la Caldera 1997 (Brugués *et al.* in press) and Cantabria, Vega de Liébana 1994 (Sérgio 9143, LISU), that are coincident with areas predicted to have a high probability of occurrence of the species (fig. 11B). The predictive map is therefore supported by these new localities, and is a good example to demonstrate the methodology.

Bruchia vogesiaca

Records of this species in the Iberian Peninsula are restricted to the North and a few sites in the central area near the border between Portugal and Spain. The species has a wide range in Central Europe but a disjunct distribution in only very few sites (SÉRGIO *et al.* 1998). By this fact and its specialised ecology and climatic requirements, *Bruchia vogesiaca* is considered an Endangered species in Europe and is included in Appendix I of the Bern Convention and on Annex 2 of the EC Habitats and Species Directive. It often occurs in areas with an oceanic or sub-oceanic climate and has a very restricted ecology. It grows in small niches, including open acid grassland, on bare turned tussocks or on the banks of small intermittent rivulets, always on black well-humified organic soils. *Bruchia vogesiaca* is strongly dependent on humidity (Dantin and Martonne Indexes), but there is less relation to the Potential Evapotranspiration, and this species avoids areas with a high January temperature (table 2). With these requirements, the modelling map is preliminary. The inclusion of geological factors in this analysis can give more precise predictive maps. However figure 12 (A and B) shows an important area in Cantabria were the plant may be present.

CONCLUSION

In conclusion the applied methodology for predicting bryophyte distribution presents good results and can give suggestions for the identification of the location of species of nature conservation importance. It also gives the possibility to analyse the relationships between levels of different environmental variables and the occurrence of a species to determine the main ecological requirements. We can also analyse how environmental conditions can influence the distribution of a particular species. If we can know these relationships it will be much easier to find new populations. In particular cases, it could be a useful increment to our knowledge and in future may contribute to the removal of species from Red Lists.

With this knowledge we can make a renewed effort to refind species considered Extinct or Critically Endangered in the Iberian Peninsula, not only in classic localities, currently much altered or destroyed, such as Atlantic western areas of the Iberian Peninsula, but also in new areas.

From another perspective, as some bryophytes can be potential monitors of the effects of environmental alterations or climatic changes, in future this methodology will provide good prospects for new monitoring studies.

Better results could be obtained when new variables are used. The inclusion of geological variables or anthropogenic influence such as demographic growth or industrialization could explain the regression of sensitive species.

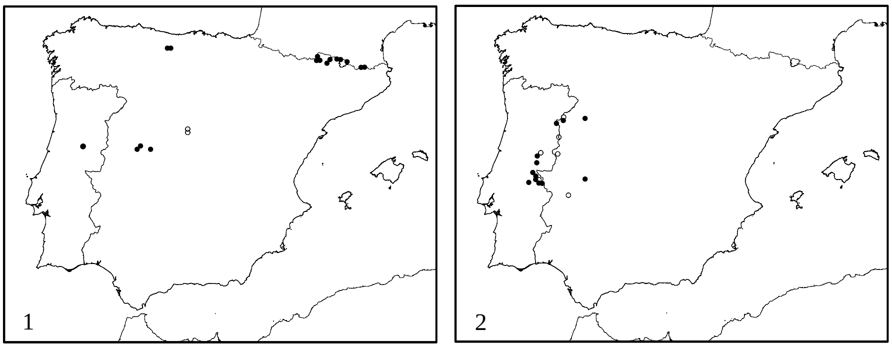
As a conclusion we suggest that more links between taxonomy, floristics, biogeography and climatology are required, and are important to support conservation programmes.

Table 1. Status of knowledge of selected species in the Iberian Peninsula based on the Iberian Red List (SÉRGIO *et al.* 1994) and Red Data Book of European bryophytes (ECCB 1995). Note: New = not included in these Red Lists. Also number of UTM 10x10 km squares, before and after 1950 and references to representative maps.

Species	<1950 UTM 10 km	>1950 UTM 10 km	Red List I P	Red List Eur	Figure
Andreaea frigida Hueb.	3	12	N	R	1
Anomobryum lusitanicum (I. Hag. in Luis) Ther.	6	10	R	R	2
Brachythecium dieckii Roell	3	5	K	K	12
Bruchia vogesiaca Schwaegr.	7	3	V	E	11
Bryum minii Podp.	4	15	new	new	3
Cryphaea lamyana (Mont.) C. Muell.	15	14	V	V	4
Frullania fragilifolia (Taylor) Gottsche *et al.*	12	65	N	N	9
Marsupella profunda Lindb.	1	8	R	V	10
Racomitrium hespericum Sérgio, Muñoz & Ochyra	2	19	new	new	5
Schizymenium pontevedrensis (Luis.) Casas *et al.*	1	19	N	R	6
Sphagnum pylaisii Brid.	4	9	N	V	7
Triquetrella arapilensis Luis.	20	37	N	R	8

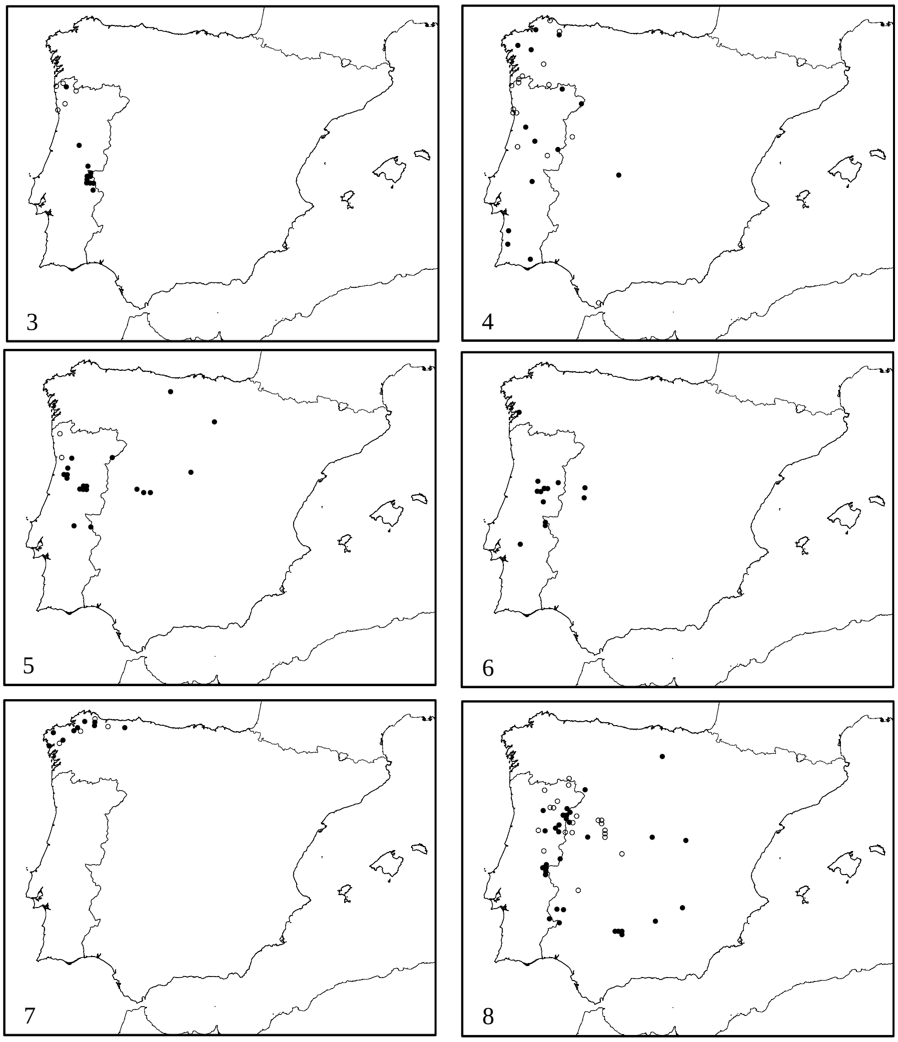
Table 2. Coefficients obtained by the MLR according to the variables used. Specific variables are selected for each considered species.

	Brachythecium dieckii	*Bruchia vogesiaca*	*Frullania fragilifolia*	*Marsupella profunda*
Intercept	0.30451	0.09135	0.22656	0.61645
Altitude	0.00022		0.000057	
Exposure	0.00062			
January temperature		-0.00004		
Mean temperature			0.0309	
Thermical amplitude			0.01483	
Dantin		0.40514		
De Martonne		-0.05308	0.02520	0.01491
Lang				-0.00475
PEV	0.0182	0.036929	-0.13712	
	R^2=0.66 P<0.000	R^2=0.90 P<0.000	R^2=0.76 P<0.000	R^2=0.36 P<0.000



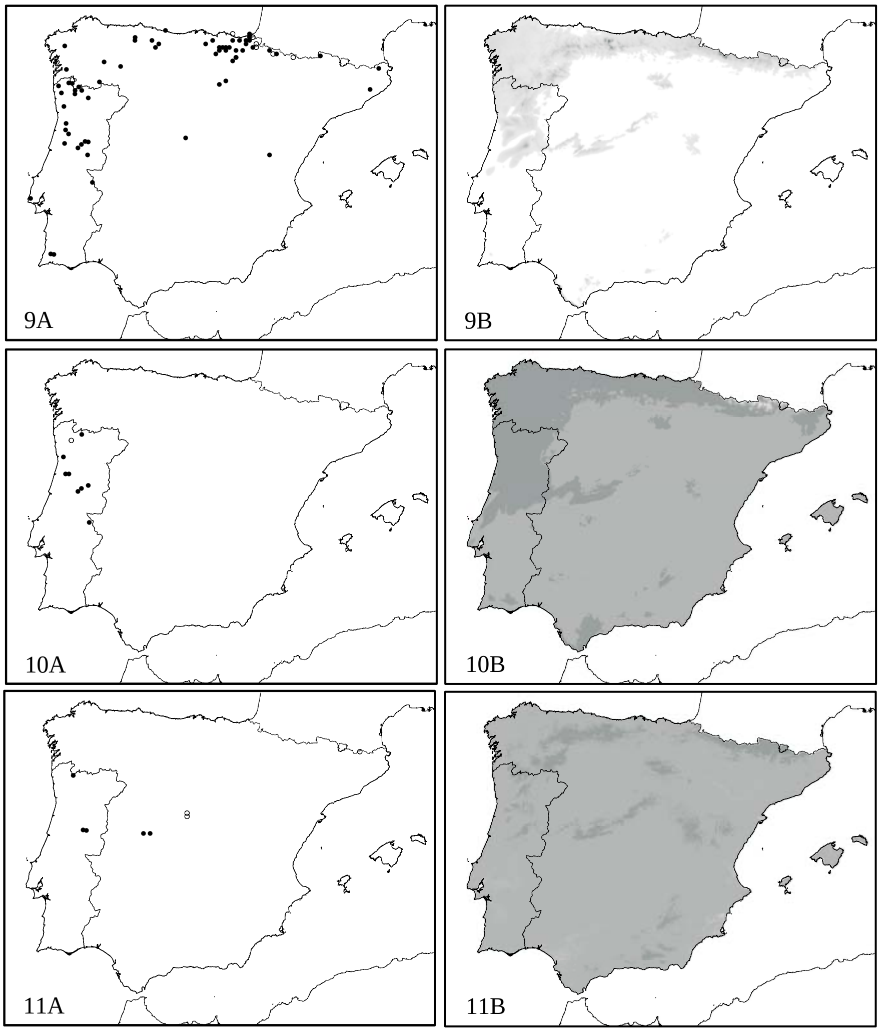
Figures 1-2. 1. Distribution map of *Andreaea frigida* Hueb. in the Iberian Peninsula (UTM 10x10 Km). 2. Distribution map of *Anomobryum lusitanicum* (I. Hag. in Luis.) Ther., in the Iberian Peninsula.

o - before 1950 • - after 1950. UTM grid 10 × 10 km.



Figures 3-8. 3. Distribution map of *Bryum minii* Podp. in the Iberian Peninsula. 4. Distribution map of *Cryphaea lamyana* (Mont.) C. Müll. in the Iberian Peninsula. 5. Distribution map of *Racomitrium hespericum* Sérgio, Muñoz & Ochyra in the Iberian Peninsula. 6. Distribution map of *Schizymenium pontevedrensis* (Luis.) Casas, Sérgio, Cros & Brugués in the Iberian Peninsula. 7. Distribution map of *Sphagnum pylaisii* Brid. in the Iberian Peninsula. 8. Distribution map of *Triquetrella arapilensis* Luis. in the Iberian Peninsula.

o - before 1950 • - after 1950. UTM grid 10 × 10 km.



Figures 9-11. 9A. Distribution map of *Frullania fragilifolia* (Taylor) Gottsche *et al*. in the Iberian Peninsula. 9B. Predictive map obtained from the coefficients of table 2. The darkest areas have the highest values of occurrence probability. 10A. Distribution map of *Marsupella profunda* Lindb. in the Iberian Peninsula. 10B. Predictive map obtained from the coefficients of table 2. The darkest areas have the highest values of occurrence probability. 11A. Distribution map of *Bruchia vogesiaca* Schwaegr. in the Iberian Peninsula. 11B. Predictive map obtained from the coefficients of table 2. The darkest areas have the highest values of occurrence probability.

O - before 1950 • - after 1950. UTM grid 10 × 10 km.

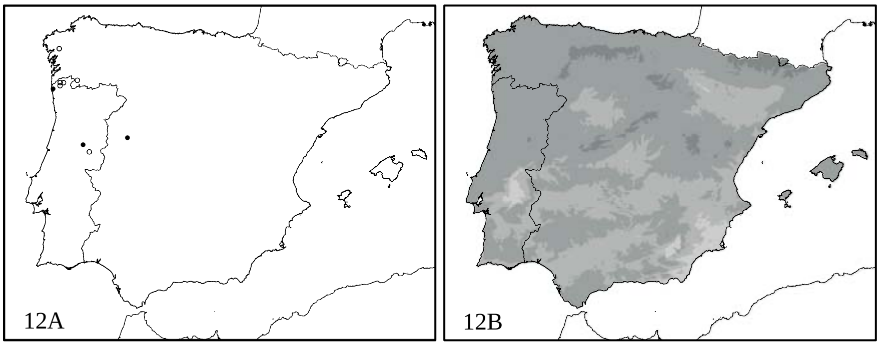


Figure 12. 12A. Distribution map of *Brachythecium dieckii* Roell in the Iberian Peninsula. 12B. Predictive map obtained from the coefficients of table 2. The darkest areas have the highest values of occurrence probability.

o - before 1950 • - after 1950. UTM grid 10 × 10 km.

REFERENCES

BEGON, M., HARPER, J. L. & TOWNSEND, C. R. (1990). *Ecology. Individuals, populations and communities*. Blackwell Scientific Publications, Boston.

BROWN, J. H. & GIBSON, A. C. (1983). *Biogeography*. Mosby, St. Luis, 643p.

BRUGUÉS, M., CROS, R. M., SÉRGIO, C. & CASAS, C. (2002). Los briófitos de las zonas culminales de Sierra Nevada (SE de España). *Boletín de la Sociedad Española de Briología* (in press).

CASAS, C. (1999). Modificaciones a "New Checklist of Spanish Mosses" IV. *Boletín de la Sociedad Española de Briología* 14:13-15.

CASAS, C., BRUGUÉS, M., CROS, R. M. & SÉRGIO, C. (1985). *Cartografia de Briòfits. Península Ibèrica i les Illes Balears, Canárias, Açores i Madeira*. Institut d'Estudis Catalans 1: 1-50. Barcelona.

CASAS, C., BRUGUÉS, M., CROS, R. M. & SÉRGIO, C. (1989). *Cartografia de Briòfits. Península Ibèrica i les Illes Balears, Canárias, Açores i Madeira.* Institut d'Estudis Catalans 2: 51-100. Barcelona.

CASAS, C., BRUGUÉS, M., CROS, R. M. & SÉRGIO, C. (1992). *Cartografia de Briòfits. Península Ibèrica i les Illes Balears, Canárias, Açores i Madeira*. Institut d'Estudis Catalans 3: 101-150. Barcelona.

CASAS, C., BRUGUÉS, M., CROS, R. M. & SÉRGIO, C. (1996). *Cartografia de Briòfits. Península Ibèrica i les Illes Balears, Canárias, Açores i Madeira*. Institut d'Estudis Catalans 4: 151-200. Barcelona.

ECCB edt. (1995). *Red Data Book of European bryophytes. Part. 1-3: Threatened mosses and liverworts in Europe including Macaronesia.* ECCB. European Committee Conservation of Bryophytes. Trondheim. 291 pp.

GASTON, K. J. & LAWTON, J. H. (1990). Effects of scale and habitat on the relationship between regional distribution and local abundance. *Oikos* 58: 329-355.

GUISAN, A. & THEURILLAT, J. P. (2000). Equilibrium modelling of alpine plant distribution, how far can we go? *Phytocoenologia* 30: 353-384.

HALLINGBÄCK, T. (1998). The new IUCN threat categories tested on Swedish bryophytes. *Lindbergia* 23: 13-27.

HEDENÄS, L. (1993). The identity of *Brachythecium dieckii* and *B. salteri. Journal of Bryology* 17: 627-631.

HILL, M. O. & DOMINGUEZ LOZANO, F. (1994). A numerical analysis of the distribution of liverworts in Great Britain. *In:* HILL, M. O., PRESTON, C. D. & SMITH, A. J. E. *Atlas of the Bryophytes of Britain and Ireland*, vol. 3 Mosses, Part 2, Diplolepideae. Colchester.

IUCN (1994). World Conservation Union. Red List categories. Gland, IUCN.

JOHNSTON, C. A., (1993). Introduction to quantitative methods and modelling in community, population, and landscape ecology. *In:* GOODCHILD, M. F., PARKS, B. O., STEYAERT, L. T. (eds.). *Environmental Modelling with GIS*. pp. 276-283. Oxford University Press, New York.

MAY, R. M., (1994). The effects of spatial scale on ecological questions and answers. *In:* EDWARDS, P. J., MAY, R. M., WEBB, N. R. (eds.). *Large-scale ecology and conservation biology*. pp. 41-58. Blackwell Scientific Publications, London.

PEREIRA, J. M. C. & ITAMI, R. M. (1987). GIS-based habitat modeling using logistic multiple regression: a study of the Mount Graham red squirrel. *Photogrammetric Engineering and Remote Sensing* 57 (11): 1475-1486.

SÉRGIO, C. (1990). Perspectiva Biogeográfica da Flora Briológica Ibérica. *Anales del Jardín Botánico de Madrid* 46:371-392.

SÉRGIO, C., CASAS, C., BRUGUÉS, M. & CROS, R. M. (1994). *Lista Vermelha dos Briófitos da Península Ibérica / Red List of Bryophytes of the Iberian Peninsula*. pp. 1-50. Lisboa.

SÉRGIO, C., JANSEN, J. & SÉNECA, A. (1998). *Bruchia vogesiaca* Schwaegr. (Musci, Dicranales) in Portugal. New remarks on morphology, ecology, distribution and conservation. *Lindbergia* 23: 55-61.

SÉRGIO, C. & JANSEN, J. (2000). On the presence of *Brachythecium dieckii* in Portugal and Morocco. *Journal of Bryology* 22: 239-241.

SÉRGIO, C. & PIERROT, R. B. (1997). Duas novas localidades para Portugal de *Marsupella profunda* Lindb. *In:* SÉRGIO, C. Notulae Bryoflorae Lusitanicae VI. 5. *Portugaliae Acta Biologica (B)* 17: 275-276.

SIM-SIM, M. (1999). The genus *Frullania* Raddi (Hepaticae) in Portugal and Madeira. *Cryptogamie, Bryology* 20 (2): 83-144.

SIM-SIM, M., REGO, F. & SOUSA, A. (1995). Epiphytic bryophyte communities of Olea europaea in Portugal. A background survey for future evaluation of environmental quality. *Cryptogamica Helvetica* 18: 18-25.

TUHKANEN, S. (1980). Climatic parameters and indices in plant geography. *Acta Phytogeographica Suecica* 67: 1-109.