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Bryophyte diversity in the Peneda-Gerês National Park (Portugal): selecting Important Plant Areas (IPA) based on a new survey and past records

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Abstract: Sérgio, C.; Garcia C. A.; Hespanhol, H.; Vieira, C.; Stow, S. & Long, D. 2012. Bryophyte diversity in the Peneda-Gerês National Park (Portugal): selecting Important Plant Areas (IPA) based on a new survey and past records. *Bot. Complut*. 36: 39-50.

The Peneda-Gerês National Park (PNPG) in North-western Portugal has been the subject of many bryological studies although there remain unstudied areas. We here present a summary of current knowledge using data from recent fieldwork and past data which comprises ca. 11000 records. Using this data twelve Important Plant Areas (IPAs) were selected. The PNPG is an area exceptionally rich in bryophytes as shown from current species richness distribution maps. There has been a significant increase in the level of bryophyte of the PNPG since 1980. From recent fieldwork, two new species to Portugal were found and fourteen species are reported as new to this National Park. Future studies in relatively unknown areas will most likely lead to the discovery of further bryophytes of conservation importance. The IPAs mapped can be useful in guiding conservation planning.

Key words: bryophyte diversity and richness, Important Plant Areas, Peneda-Gerês National Park, Portugal.

Resumen: Sérgio, C.; Garcia, C. A.; Hespanhol, H.; Vieira, C.; Stow, S. & Long, D. 2012. Diversidad de briófitos en el Parque Nacional Peneda-Gerês (Portugal): seleccionando áreas importantes de plantas "Important Plant Areas (IPA)" basado en nuevos datos y anteriores referencias. *Bot. Complut.* 36: 39-50.

En el Parque Nacional Peneda-Gerês (PNPG) situado en el noroeste de Portugal se han realizado numerosos estudios briológicos, sin embargo todavía quedan áreas poco conocidas. En este trabajo se presentan nuevos datos que junto con los datos anteriores alcanzan unas 11000 referencias. Con esta información se han establecido 12 nuevas áreas importantes (IPA). El PNPG es un área excepcionalmente rica en briófitos como se muestra en los mapas de distribución de riqueza. Ha habido un aumento significativo de referencias de briófitos desde 1980. Debido a nuevas recolecciones efectuadas se han encontrado dos especies nuevas para Portugal y 14 novedades para el PNPG. Estudios futuros en zonas relativamente poco estudiadas permitirán encontrar nuevos briófitos importantes para la conservación. Las zonas IPA (Áreas de Importancia en Plantas) reflejadas en los mapas serán herramientas útiles en los futuros planes de conservación.

Palabras clave: diversidad, riqueza, briófitos, Áreas de Importancia en Plantas, Parque Nacional Peneda-Gerês, Portugal.

INTRODUCTION

The Peneda-Gerês National Park (PNPG) is one of the best studied areas in Portugal for bryophytes and one of the first areas in the country with bryophyte collections, for example, *Mnium fontanum* L. collected by Brotero (1804), "*Ad fontes et in udis subalpinis Gerez, et alibi*". Almost two centuries afterwards, Sérgio & Schumacker (1992) presented an extensive bryophyte catalogue for this National Park summarizing old and current data, but there still persisted significant knowledge gaps concerning several areas and *taxa*. Following this, Hespanhol *et al.* (2005) provided an updated distribution of bryophytes to this area, including potential areas of occurrence for some threatened/rare bryophyte species.

Despite these studies, the knowledge of bryophyte distribution in this National Park varies considerably between areas. For some there are recently published distribution maps and detailed species lists including conservation status, habitat quality and new species (Hespanhol *et al.*

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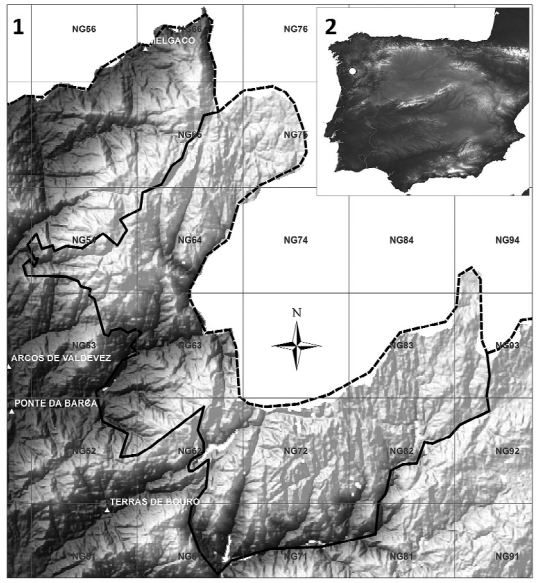
2005), yet there remain enclaves with high-quality habitats that need to be studied as they could hold bryophytes that are very rare or considered extinct, not only in PNPG, but also in Portugal. Species with few records in this region are either common species that are overlooked when collecting or important *taxa* that have been under-collected. It is therefore important to focus new fieldwork on areas with fewer records and target rare species.

Despite the low detectability of some bryophytes and the lack of knowledge concerning particular species, the evaluation of red-listed *taxa* in a particular area is so far considered the most effective conservation tool (Butchart *et al.* 2005). Considering this and the reality of PNPG, a new bryophyte survey was undertaken by the authors in June 2010 to record species considered endangered or extinct in Portugal as well as *taxa* expected to be present as predicted by previous distribution models (Sérgio & Draper 2002). Some distribution models from this work allowed barely visible species to be located, especially ones whose auto-ecology or distribution pattern is poorly known. Some of these species are listed in the Annexes of the Habitat Directive: *Bryoerythrophyllum campylocarpum* (Müll. Hal.) H. A. Crum*, Marsupella profunda Lindb.* or *Frullania oakesiana* Austin.

The identification of biodiversity hotspots can be achieved through the use of bryophytes as shown by Sérgio *et al*. (2000), since generally there is a good correlation between bryophyte richness and high diversity of other taxonomic groups. Given this, and after the analysis of data obtained from the 2010 bryophyte survey and past data, we aimed to select Important Plant Areas (IPA) for plant conservation based on all currently known bryophyte species distribution in PNPG and taking into account objective criteria related to total and threatened bryophytes richness. Three main criteria were used for IPA selection based on floristic richness, threatened bryophytes of the Portuguese flora (red-listed species) and species of national interest or geographic singularity such as Iberian endemics.

MATERIALS AND METHODS

Study Area. The PNPG (Figs. 1-2) is the only National Park in Portugal and its total area is approximately 70000 ha. Due to its topography there are strong climatic contrasts ranging from the thermophytic and humid conditions in the Rio Homem valley to areas with warm and heavy rainfall in the high mountains and interior (Honrado *et al.* 2001). The PNPG has a typical Atlantic climate with an annual precipitation that varies from 1600 to 3000 mm and average annual temperatures usually ranging between 10 °C and 16 °C. The underlying geological structure is mainly dominated by granites.



Figs. 1-2– **1:** Relief map of PNPG area with UTM 10 km squares labelled. **2:** Location of the PNPG in the Iberian Peninsula.

Data source. All of the bryophyte information used (except data from the most recent study, see below) was taken from University of Lisbon (LISU) and Porto (PO/PO-CIBIO) herbaria database which host c. 5000 specimens from PNPG resulting from sporadic surveys, projects and PhD studies (Garcia 2006; Vieira 2010; Hespanhol 2011). A bibliographic database that has been continuously updated was also used and, when possible, all the available data was georeferenced. In total, *ca.* 11000 records were used. It is important to note that the degree of knowledge of the studied localities is not homogeneous due to irregular historical sampling efforts, resulting in some areas being better surveyed than others. However, all localities have been included in this study in order to use all available data on the distribution of *taxa* in PNPG for subsequent selection of the IPAs.

Recent Survey. The localities of the most recent bryophyte survey (June 2010) are presented in Table 1. All localities correspond to Braga district in the Minho province. The catalogue of Portuguese bryophytes (Sérgio & Carvalho 2003) was used to evaluate new chorological records and new species to this area. Bryophyte taxonomy and nomenclature largely follows Sérgio & Carvalho (2003) as well as Hill *et al.* (2006) for mosses and Grolle & Long (2000) for liverworts and hornworts. All specimens are placed in the herbarium collections of LISU, PO/PO-CIBIO and E. For each bryophyte *taxon* its threat category is given, according to the Iberian Red List (Sérgio *et al.* 2007) using the following threat categories: critically endangered (CR); endangered (EN); vulnerable (VU); near threatened (NT); low risk species which require special attention (LC-Att);

Table 1
The nine study localities in the June 2010 survey with altitude, 1 km UTM coordinate, date and collectors

1	**Portela de Leonte**, Fonte e caminho para Cabeços de Cancelo, 864 m, 29TNG7024, 07-06-2010, C. A. Garcia, C. Sérgio, S. Stow, C. Vieira, H. Hespanhol, D. Long & D. Bell.
2	**Próximo de Cabeços de Cancelo**, 959 m, 29TNG7025, 07-06-2010, C. A. Garcia, C. Sérgio, S. Stow, C. Vieira, H. Hespanhol, D. Long & D. Bell.
4	**Ribeira de Água de Aldeia**, 836 m and 854 m, 29TNG7125, 07-06-2010, C. Sérgio, S. Stow, C. A. Garcia, C. Vieira, H. Hespanhol, D. Long & D. Bell.
5	**Leonte-Albergaria** (308-1), 854 m, 29TNG7124, 07-06-2010, C. Sérgio, S. Stow, C. A. Garcia, C. Vieira, H. Hespanhol, D. Long & D. Bell.
6	**Cascata e Ponte do Arado**, 718 m, 29TNG7219, 08-06-2010, C. A. Garcia, C. Sérgio, S. Stow, C. Vieira, H. Hespanhol, D. Long & D. Bell.
7	**Fonte das Letras**, 774 m, 29TNG7219, 08-06-2010, C. A. Garcia, C. Sérgio, S. Stow, C. Vieira, H. Hespanhol, D. Long & D. Bell.
8	**Ribeira de Freitas**, 836 m, 29TNG6517, 08-06-2010, C. Sérgio, S. Stow, C. A. Garcia, C. Vieira, H. Hespanhol, D. Long & D. Bell.
9	**Rio Caldo**, Ponte da Seara, 155 m, 29TNG6616, 08-06-2010, C. A. Garcia, C. Sérgio, S. Stow, C. Vieira, H. Hespanhol, D. Long & D. Bell.
s/n	**Bridge between Paradela and Outeiro**, 734m, 29TNG8725, 05-06-2010, D. Bell & D. G. Long.

species with insufficient data (DD e DD-n) and species of low concern (LC).

***Database records*.** All database records, herbarium (old records and recent survey) and bibliographic, are georeferenced at a 1x1 km scale (in MGRS UTM coordinates). For records that had insufficient location information a cross-reference was undertaken with herbarium specimens to ensure that georeferencing was as accurate as possible. Records without a precise indication of locality (e.g. those that only had "Gerês") were not included in this study.

Selection of Important Plant Area (IPA). We applied a method similar to the one used for the area of Murcia by García-Fernández *et al.* (2010), that is based partly on the IPA program of Plantlife International (Anderson, 2002), with some changes and adaptations, including not taking into account habitat quality due to the large variation within each 1km UTM square in PNPG. The criteria used to select important areas are as follows:

Criterion 1 (C1) – based on floristic richness and corresponding to the total number of species (including subspecies) in each 1 km UTM square. Each UTM was assigned a richness class and value (given in brackets): more than 100 taxa - especially rich (4); 51 to 100 taxa - rich (3); 11 to 50 taxa - moderately rich (2); 1 to 10 taxa - poor (1).

Criterion 2 (C2) – based on the number of threatened bryophytes (CR, EN and VU) in each 1 km UTM square using the 2006 Iberian Red List (Sérgio *et al.* 2007), as well as the new Portuguese Red Book (*in prep*). Each threatened species is given a value of 1.

Criterion 3 (C3) – based on species of national and international importance in each 1 km UTM square, Habitat Directive and LC-Att or NT Red List categories (Sérgio *et al.* 2007), and geographic singularity (such as Iberian endemics). Species listed in the Habitat Directive are given a value of 3 and other species a value of 1.

First, each 1km UTM square was assigned a value for the three criteria. Then, the sum of the scores of each criterion (C1+C2+C3) were calculated for each UTM square giving the Area Importance Index. UTM squares with an Area Importance Index equal to or greater than 9 and with more than 50 *taxa* were considered to be areas of importance for bryophytes. IPAs were selected using these UTM squares and each IPA can include one or more of these UTM squares.

RESULTS AND DISCUSSION

New Survey. Data collected in the June 2010 survey are presented in Table 2; new *taxa* to PNPG are indicated with an asterisk (*) and species which are new to Portugal are indicated with two asterisks (**). A total of 482 new georeferenced bryophyte specimens were recorded (Table 2). In total, 179 *taxa* (species and subspecies) from 101 genera of bryophytes are reported. A total of 126 moss species and 53 liverwort species (but no hornworts) were recorded. In addition, 16 taxa were recorded for the first time in PNPG including two Habitat Directive species and two new species to Portugal. The total list of species identified is in alphabetical order, with mosses first followed by liverworts.

Table 2
List of species collected in the PNPG, with study localities (1 to 9). Threat status is taken from the 2006 Iberian Red List (Sergio *et al*. 2007). ▲ Directive species, * new *taxa* to PNPG, ** new *taxa* to Portugal.

	Mosses	**Localities**
	Amphidium mougeotii (Schimp.) Schimp.	1; 2; 4; 5; 8; 9
VU	*Andreaea heinemannii* Hampe & Müll. Hal. subsp. *heinemannii*	1
	Andreaea megistospora B. M. Murray	1; 4
	Andreaea rupestris Hedw.	6
	Anomobryum julaceum (Schrad. ex P. Gaertn. *et al.*) Schimp.	2; 6; 8; 9
	Antitrichia curtipendula (Hedw.) Brid.	1; 4
	Atrichum androgynum (Müll. Hal.) A. Jaeger	8
	Atrichum angustatum (Brid.) Bruch & Schimp.	8; 9
	Atrichum undulatum (Hedw.) P. Beauv.	8
	Bartramia pomiformis Hedw.	8; 9
	Brachythecium albicans (Hedw.) Schimp.	8
	Brachythecium rutabulum (Hedw.) Schimp.	8
*	*Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp.	8
EN *▲	*Bryoerythrophyllum campylocarpum* (Müll. Hal.) H. A. Crum	8; 9
	Bryum alpinum Huds. ex With.	1; 6; 7; 9
	Bryum capillare Hedw.	1; 4; 6; 8
	Bryum donianum Grev.	6; 7
	Bryum pseudotriquetrum (Hedw.) P. Gaertn. *et al*.	5
*	*Bryum subapiculatum* Hampe	9
	Campylopus flexuosus (Hedw.) Brid.	1; 6; 9
	Campylopus fragilis (Brid.) Bruch & Schimp.	5; 8
	Campylopus introflexus (Hedw.) Brid.	1; 2; 4; 9
	Campylopus pilifer Brid.	1; 2; 6; 7; 9
	Campylopus subulatus Milde	6
	Cirriphyllum crassinervium (Taylor) Loeske & M. Fleisch.	8
VU	*Cyclodictyon laetevirens* (Hook. & Taylor) Mitt.	8
	Cynodontium bruntonii (Sm.) Bruch & Schimp.	2
	Dicranella heteromalla (Hedw.) Schimp.	1; 9
	Dicranoweisia cirrata (Hedw.) Lindb.	2
	Dicranum crassifolium Sérgio, Ochyra & Séneca	1
	Dicranum scoparium Hedw.	1; 2; 4
	Didymodon insulanus (De Not.) M. O. Hill	1; 8
	Diphyscium foliosum (Hedw.) D. Mohr	1; 5; 9
	Ditrichum subulatum Hampe	1; 8
	Entosthodon attenuatus (Dicks.) Bryhn	6; 8
*	*Entosthodon fascicularis* (Hedw.) Müll. Hal.	1; 6
	Entosthodon obtusus (Hedw.) Lindb.	6; 7
	Epipterygium tozeri (Grev.) Lindb.	8
	Eurhynchium striatum (Hedw.) Schimp.	8; 9
	Fissidens bryoides Hedw. var. *caespitans* Schimp.	1; 6; 8
	Fissidens crispus Mont.	9
	Fissidens dubius P. Beauv.	6; 8; 9
	Fissidens polyphyllus Wilson ex Bruch & Schimp.	1; 2; 4; 5; 6; 7; 9
	Fissidens serrulatus Brid.	1; 2; 6; 7; 8; 9

	Mosses	**Localities**
	Fissidens taxifolius Hedw.	8
	Grimmia lisae De Not.	8
	Grimmia montana Bruch & Schimp.	2; 7
	Grimmia trichophylla Grev.	9
	Gymnostomum calcareum Nees & Hornsch.	6; 9
	Gymnostomum viridulum Brid.	6
	Hedwigia ciliata (Hedw.) P. Beauv.	1
	Hedwigia striata (Wilson) Bosw.	1
	Heterocladium heteropterum (Brid.) Schimp.	4
	Homalothecium sericeum (Hedw.) Schimp.	9
	Hookeria lucens (Hedw.) Sm.	5; 8
	Hygrohypnum ochraceum (Wilson) Loeske	9
	Hyocomium armoricum (Brid.) Wijk & Margad.	1; 2; 4; 5; 6
	Hypnum andoi A. J. E. Sm.	5; 9
	Hypnum cupressiforme Hedw.	4; 7
EN	*Hypnum imponens* Hedw.	1
	Hypnum jutlandicum Holmen & E. Warncke	9
* EN	*Hypnum uncinulatum* Jur.	8
	Isothecium alopecuroides (Lam. ex Dubois) Isov.	1; 2
	Isothecium myosuroides Brid.	1; 8
	Kindbergia praelonga (Hedw.) Ochyra	8
	Leptodon smithii (Hedw.) F. Weber & D. Mohr	1; 8
	Leucobryum juniperoideum (Brid.) Müll. Hal.	9
	Loeskeobryum brevirostre (Brid.) M. Fleisch.	s/nº
	Mnium hornum Hedw.	8; 9
	Neckera complanata (Hedw.) Huebener	5; 9
	Neckera crispa Hedw.	5; 9
	Neckera pumila Hedw.	2; 4; 5; 8; 9
	Orthotrichum lyellii Hook. & Taylor	1; 2; 9
	Orthotrichum striatum Hedw.	2
*	*Oxyrrhynchium hians* (Hedw.) Loeske	8
	Oxyrrhynchium pumilum (Wilson) Loeske	8
	Philonotis arnellii Husn.	8
	Philonotis rigida Brid.	7; 8; 9
	Plagiomnium affine (Blandow ex Funck) T. J. Kop.	1
	Plagiomnium undulatum (Hedw.) T. J. Kop.	8; 9
	Plagiothecium denticulatum (Hedw.) Schimp.	1
	Plagiothecium succulentum (Wilson) Lindb.	8
	Platyhypnidium lusitanicum (Schimp.) Ochyra & Bednarek Ochyra	8
*	*Pleurochaete squarrosa* (Brid.) Lindb.	5
	Pogonatum aloides (Hedw.) P. Beauv.	1; 6; 8
	Pogonatum nanum (Hedw.) P. Beauv.	1; 9
	Pogonatum urnigerum (Hedw.) P. Beauv.	9
*	*Pohlia annotina* (Hedw.) Lindb.	1; 4; 6; 8
	Pohlia elongata Hedw.	1
	Polytrichastrum formosum (Hedw.) G. L. Sm.	5; 7
	Polytrichum alpinum Hedw.	7

	Mosses	**Localities**
	Polytrichum commune Hedw.	1; 2
	Polytrichum piliferum Hedw.	9
	Pseudotaxiphyllum elegans (Brid.) Z. Iwats.	4
	Pseudotaxiphyllum laetevirens (Dixon & Luisier ex F.Koppe & Düll) Hedenäs	1
	Pterogonium gracile (Hedw.) Sm.	4; 9
	Ptychomitrium polyphyllum (Dicks. ex Sw.) Bruch & Schimp.	8; 9
	Racomitrium aciculare (Hedw.) Brid.	1; 6; 8
	Racomitrium aquaticum (Brid. ex Schrad.) Brid.	1; 9
	Racomitrium hespericum Sérgio, J. Muñoz & Ochyra	1
	Racomitrium heterostichum (Hedw.) Brid.	1; 4; 9
	Racomitrium lamprocarpum (Müll.Hal.) A. Jaeger	4
	Racomitrium lanuginosum (Hedw.) Brid.	1; 2; 7; 9
	Racomitrium lusitanicum Ochyra & Sérgio	6
	Racomitrium macounii Kindb. subsp. *alpinum* (E. Lawton) Frisvoll	1
	Rhabdoweisia fugax (Hedw.) Bruch & Schimp.	2
	Rhizomnium punctatum (Hedw.) T. J. Kop.	5
	Rhynchostegium confertum (Dicks.) Schimp.	8
	Rhytidiadelphus squarrosus (Hedw.) Warnst.	8
	Rhytidiadelphus loreus (Hedw.) Warnst.	1; 8
	Schistidium apocarpum (Hedw.) Bruch & Schimp.	9
	Sphagnum auriculatum Schimp.	1; 2; 6; 7; 9
	Sphagnum compactum Lam. & DC.	2; 7
	Sphagnum subnitens Russow & Warnst.	1; 5
	Thamnobryum alopecurum (Hedw.) Gangulee	8; 9
	Thuidium tamariscinum (Hedw.) Schimp.	5; 8; 9
*	*Tortella humilis* (Hedw.) Jenn.	7
	Tortella tortuosa (Hedw.) Limpr.	5
	Tortula muralis Hedw.	9
*	*Tortula subulata* Hedw.	1
	Trichostomum brachydontium Bruch	8; 9
	Ulota bruchii Hornsch. ex Brid.	1; 2; 4; 9
	Ulota crispa (Hedw.) Brid.	2; 4
	Ulota hutchinsiae (Sm.) Hammar	1
	Weissia controversa Hedw.	8; 9
	Zygodon rupestris Schimp. ex Lorentz	2; 5; 9
	Liverworts	
	Aneura maxima (Schiffn.) Steph.	5; 9
** VU	*Barbilophozia atlantica* (Kaal.) Müll. Hall	7
	Calypogeia arguta Nees & Mont.	4
	Calypogeia fissa (L.) Raddi	2
	Cephalozia bicuspidata (L.) Dumort.	1; 2; 6
	Cephaloziella divaricata (Sm.) Schiffn.	2
	Cephaloziella stellulifera (Taylor ex Spruce) Schiffn.	1
	Cephaloziella turneri (Hook.) Müll. Frib.	8; 9
	Cololejeunea minutissima (Sm.) Schiffn.	4
	Conocephalum conicum (L.) Dumort.	8
	Diplophyllum albicans (L.) Dumort.	1; 2; 4; 5; 6; 7; 9

	Mosses	Localities
**	*Diplophyllum obtusifolium* (Hook.) Dumort.	1
	Douinia ovata (Dicks.) H.Buch	1
	Dumortiera hirsuta (Sw.) Nees	8
	Fossombronia angulosa (Dicks.) Raddi	8; 9
	Frullania dilatata (L.) Dumort.	2
	Frullania fragilifolia (Taylor) Gottsche *et al*.	1; 2
	Frullania microphylla (Gottsche) Pearson	1; 4
	Frullania tamarisci (L.) Dumort.	2; 5
	Gongylanthus ericetorum (Raddi) Nees	9
	Gymnomitrion crenulatum Gottsche ex Carrington	1; 6
	Harpalejeunea molleri (Steph.) Grolle	2; 9
	Jungermannia gracillima Sm.	4
	Jungermannia hyalina Lyell	4; 5; 6
	Lejeunea cavifolia (Ehrh.) Lindb.	1; 5; 8; 9
*	*Lejeunea eckloniana* Lindenb.	8; 9
	Lejeunea lamacerina (Steph.) Schiffn.	6
	Lophocolea bidentata (L.) Dumort.	8; 9
	Lophocolea heterophylla (Schrad.) Dumort.	8
	Lophozia bicrenata (Schmidel ex Hoffm.) Dumort.	8
	Marchantia polymorpha L.	8
	Marsupella emarginata (Ehrh.) Dumort.	1; 2; 4; 6; 8; 9
*▲	*Marsupella profunda* Lindb.	8
	Marsupella sphacelata (Gieseke ex Lindenb.) Dumort.	5
	Metzgeria furcata (L.) Dumort.	8; 9
	Microlejeunea ulicina (Taylor) A. Evans	1; 4
	Nardia compressa (Hook.) Gray	4
*	*Pallavicinia lyellii* (Hook.) Carruth.	9
	Pellia epiphylla (L.) Corda	4; 5; 6; 8; 9
*	*Porella canariensis* (F. Weber) Underw.	8
	Porella obtusata (Taylor) Trevis.	1; 6; 9
	Porella platyphylla (L.) Pfeiff.	1
VU	*Radula holtii* Spruce	8
	Radula lindenbergiana Gottsche ex C.Hartm.	8
	Reboulia hemisphaerica (L.) Raddi	8
	Riccardia multifida (L.) Gray	8; 9
	Saccogyna viticulosa (L.) Dumort.	8
	Scapania compacta (A. Roth) Dumort.	2
	Scapania gracilis Lindb.	2
	Scapania nemorea (L.) Grolle	9
	Scapania subalpina (Nees ex Lindenb.) Dumort.	6; 7
	Scapania undulata (L.) Dumort.	1; 2; 6
	Trichocolea tomentella (Ehrh.) Dumort.	9; 1

Important Plant Areas. The PNPG has 374 recorded bryophyte *taxa*, collected from 263 UTM squares, with the highest total richness in a single UTM square being 174 species. Following the parameters of criterion 1, three UTMs are especially species rich (more than 100 *taxa*), 19 are rich (with between 50 and 100 *taxa*), 125 are moderately rich (between 11 and 49 *taxa*) and the remaining 116 have less than 11 *taxa* (Table 3 and Fig. 3).

Table 3
Species richness of PNPG UTM squares grouped in four richness classes with corresponding values within criterion 1

Number of species	Number of 1km UTMs	Richness class	C1 Value	Variation in number of species
1-10	116	Poor	1	1-10
11-50	125	Moderately Rich	2	11-49
51-100	19	Rich	3	52-99
>100	3	Especially Rich	4	122-174

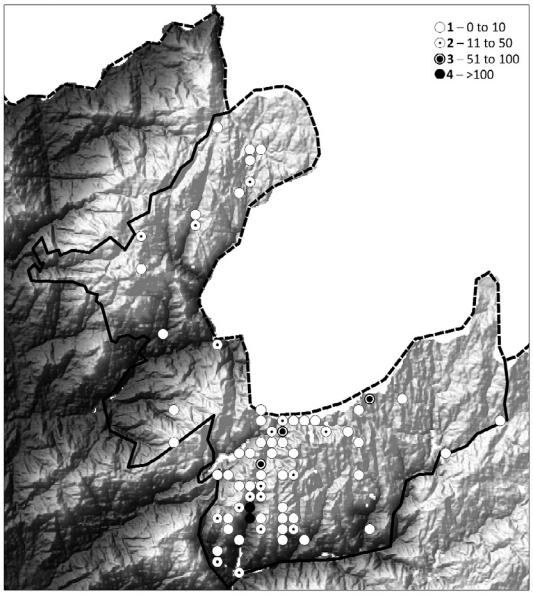


Fig. 3– *Taxa* richness distribution in PNPG from collections made before 1980. Species richness class (1 to 4) of each UTM square represented by circles (see legend on map).

Based on the 2006 Iberian Red List (Sérgio *et al.* 2007), as well as the new Portuguese Red Book (*in prep*), 65 threatened bryophyte *taxa* were found in PNPG and, although more than half of the sampled UTMs have no threatened species, 5 UTMs have more than 10.

Based on the three criteria, 12 IPAs were identified (those with an Area Importance Index value equal to or greater than 9 and with more than 50 *taxa*) (Table 4 and Fig. 5). Three levels of importance can be identified based on the Area Importance Index Value, with the most important areas having a value greater than 31, followed by areas with 15 to 30 and then those with a value less than 15. The IPA with the highest species richness was Caldas do Gerês (220 species, corresponding to two UTM squares, Table 4), which also has the highest number of threatened *taxa* (25 *taxa*). Selecting areas with a higher number of threatened species identifies vulnerable areas such as the Rio Homem valley (Fig. 5) which has over 100 *taxa*, of which 19 are red-listed (Criterion C2).

In general, species richness (C1) seems to be associated with the Area Importance Index, as the presence of threatened and important bryophytes is more likely the larger the number of species an area holds. However, this is not always the case, as shown by the Sobreiral da Ermida IPA which has one of the lowest species richness but an Area Importance Index value of 20 (the 5th highest value) due to the large number of threatened species (12). Similarly, the Ribeira de Freitas IPA, despite being the fourth richest IPA, has the second highest Area Importance Index Value (36) due to the presence of several important *taxa* including two Habitat Directive species, giving a very high C3 value of 20. This shows that the Area Importance Index is not merely highlighting species-rich areas but also sensitive ones (those with high C2 and C3 values) and can therefore be used to determine areas of conservation importance.

Some of these IPAs include classic localities which have been well studied since 1980 (Fig. 4), but others only recently have been studied (Fig. 3). Comparing the number of species collected in PNPG before and after 1980 (Figs. 3 and 4, respectively) provides evidence not only of the importance of these classical locations, but also shows that, with new studies, further important areas (Table 4) can be found such as Ramiscal, Serra da Peneda and the region of Planalto da Mourela (Montalegre) which remained practically unexplored before 1980 (Fig. 3).

Distribution of selected species. The distribution of new *taxa* not reported before 1980 *(e. g. Andreaea megistospora* B. M. Murray, *Pogonatum urnigerum* (Hedw.) P. Beauv. and *Racomitrium lusitanicum* Ochyra & Sérgio) is

Table 4

Important Plant Areas identified based on the established criteria. The 1km UTM squares found within these IPAs are given in parentheses. Criterion 1 (C1), species richness, has 4 classes and values; criterion 2 (C2), number of red-listed species; criterion 3 (C3), number of species of geographic singularity, LC-Att and NT *taxa* (which includes endemic species) and species listed in the Habitats Directive (indicated with ▲). The Area Importance Index value is the sum of the three criteria (C1+C2+C3) and there are three levels of importance: most important areas with a value greater than 31, followed by areas with 15 to 30 and then those with a value less than 15

IPA Areas (UTM 1x1km)	Criterion C1 Species Richness			Criterion C2 2012 Red List		Criterion C3 Important *taxa*	Area Importance Index
	Number *taxa*	Richness	Value	Number *taxa*	Level of threatened *taxa*	Number *taxa*	C1+C2+ C3
1 Caldas do Gerês (NG6920, NG6919)	220	Especially Rich	4	25	Very High	14	43
2 Albergaria, Portela do Homem e Leonte (NG7227, NG7127, NG7228, NG7025)	165	Especially Rich	4	19	Very High	8	31
3 Preguiça e Ribeira da Lage (NG7023, NG7022, NG7024)	162	Especially Rich	4	20	Very High	12	36
4 Ribeira de Freitas, São Bento da Porta Aberta e Calcedonia (NG6517, NG6616, NG6518, NG6619)	136	Especially Rich	4	14	Very High	20▲▲	38
5 Cascata do Arado, Fonte das Letras e **Malhadoura** (NG7219, NG7319)	99	Rich	3	5	High	8	16
6 Ramiscal (NG5743, NG5944)	97	Rich	3	7	High	8	18
7 Planalto da Mourela (Carvalhal de Sezelhe, Pitões das Junias, Montalegre e Paradela) (NG9129, NG9228)	92	Rich	3	8	High	12▲	23
8 Carris (NG8030)	91	Rich	3	8	High	3	14
9 Sobreiral da Ermida e Pedra Bela (NG7217, NG7018)	88	Rich	3	12	Very High	5	20
10 Serra da Peneda (NG6446)	82	Rich	3	4	Moderate	8	15
11 Mesio e Banda da Travanca (NG5737, NG5638)	68	Rich	3	4	Moderate	6	13
12 Cabril e Lagoa do Marinho (NG7923)	54	Rich	3	4	Moderate	2	9

due to the evolution of both taxonomic knowledge and sampling effort (Figs. 6, 8, 11). The importance of areas and habitats within the PNPG is illustrated through particular species of conservation value such as *Dumortiera hirsuta* (Sw.) Nees and *Microlejeunea ulicina* (Taylor) A. Evans (Figs. 7 & 10.).

The European neophyte and aggressive invasive species *Campylopus introflexus* (Hedw.) Brid., which was first reported to Portugal in 1997 by Sérgio, is now a frequent species in the PNPG (Fig. 9) and consequently it may be a negative impact on the region's bryoflora.

CONCLUSIONS

At the National, Iberian and International scales the PNPG holds a significant number of important bryophyte species. Over time the knowledge of this area has increased as more explorations have been undertaken in new areas. Until 1980 a total of *ca*. 260 taxa had been reported to PNPG, in 1992, 285 were reported by Sérgio and Schumacker and after 2005 *ca.* 316 are given (Hespanhol *et al.* 2005). Now we can indicate *ca*. 375 *taxa*, including 16 new species to PNPG from the most recent collection in June

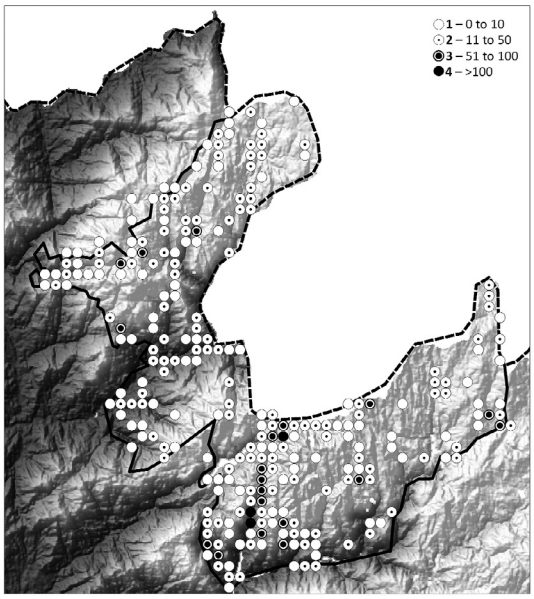


Fig. 4– Total *taxa* richness distribution in PNPG. Species richness class (1 to 4) of each UTM square represented by circles (see legend on map).

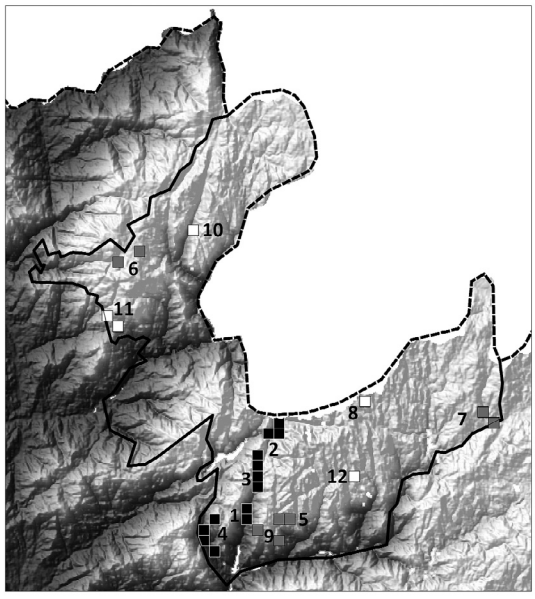


Fig. 5– Distribution of IPAs, shown as 1 km UTM squares, in the PNPG with three levels of importance based on the Area Importance Index Value: the most important areas have a value greater than 31 (■), followed by areas with 15 to 30 (■) and then those with a value less than 15 (□). According table 4.

2010 to this National Park. Over 50% of all species recorded for Portugal are found in the PNPG, confirming that it is an important area for the national bryoflora and comparable to the Natural Park of Serra da Estrela (PNSE) in terms of the species richness and singularity (Garcia *et al.* 2008). Although the PNSE has a higher number of species (402), the PNPG has the same level of species richness per UTM, as both parks have squares with more than 100 species.

One of the IPAs selected is the area of Albergaria which is part of a Biogenetic Reserve (131775) incorporated within the European Biogenetic Reserves Network (European Environment Agency 2012) providing further evidence that the Area Importance Index based on bryophyte diversity can be used to select sites of conservation importance.

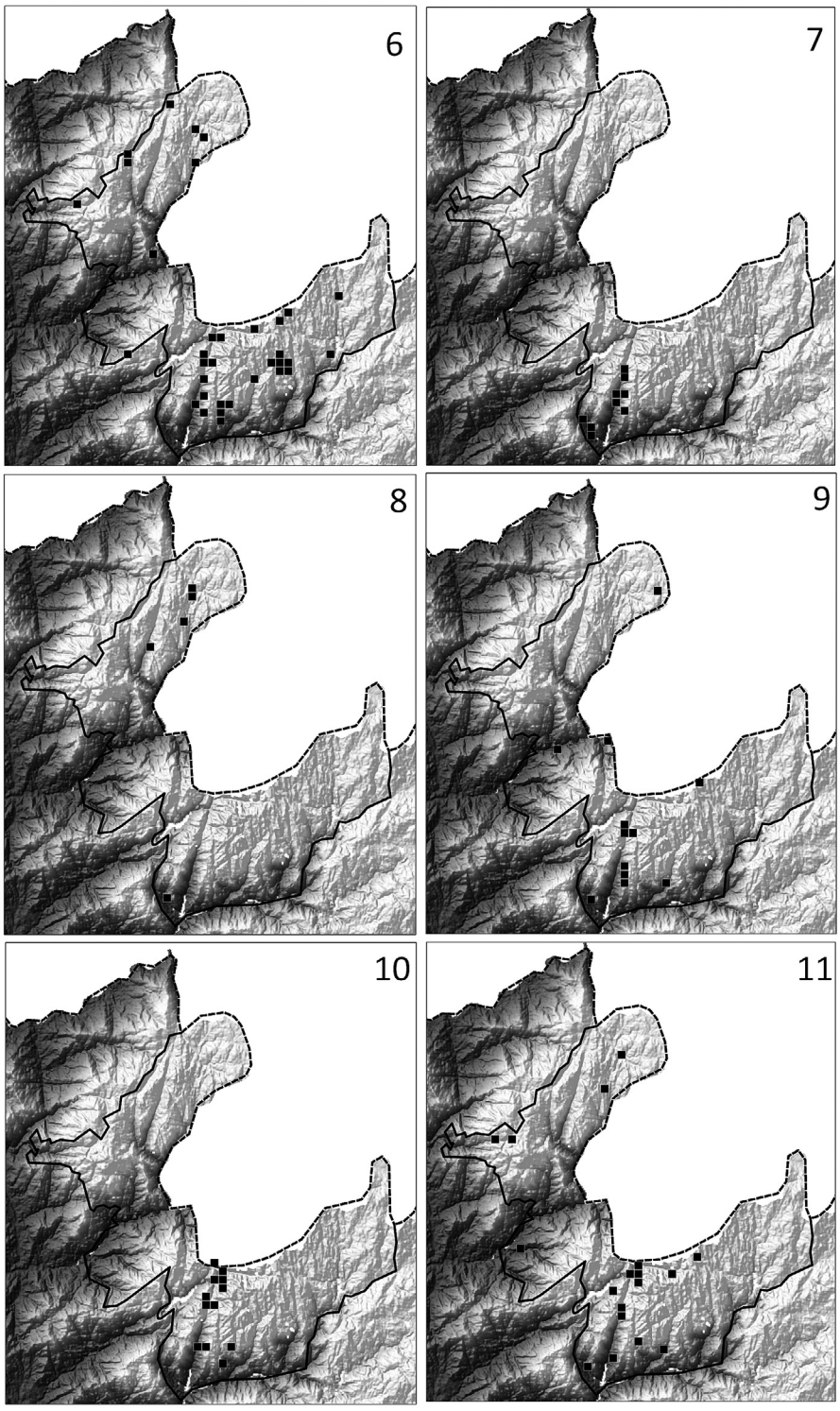
Excluding the single historical collection of *Bartramia ithyphylla* Brid., collected by Welwitsch in the 19th century and not re-found since, and *Telaranea europaea* Engel & Merr., only reported in Portugal from Caldas do Gerês by P. & V. Allorge (1944), a large number of *taxa* are repeatedly reported in different collections and dates. *Loeskeobryum brevirostre* (Brid.) M. Fleisch. has only been collected once by Machado in 1916 and was considered to be an extinct moss (Sérgio & Carvalho 2003) but was re-found in the recent survey.

Our results suggest and highlight the following:

In the recent survey two new Habitat Directive species were recorded in PNPG (*Bryoerythrophyllum campylocarpum* (C. Muell.) Crum. and *Marsupella profunda* Lindb.), highlighting the probable existence of other areas containing important species.

Some *taxa* that are only present in Portugal in the PNPG should be monitored, such as: *Barbilophozia atlantica* (Kaal.) Müll. Hall, *Diplophyllum obtusifolium* (Hook.) Dumort. (new species to Portugal, Garcia *et al.* 2011) *Gymnomitrium crenulatum* Gottsche ex Carrington, *G. obtusum* Lindb., *Trichocolea tomentella* (Ehrh.) Dumort. and *Cyclodictyon laetevirens* (Hook. & Taylor) Mitt.

The exceptional level of bryophyte diversity in the area, with 3 UTM squares that comprise more than 100 bryophytes species, and the 12 IPAs identified are important conservation data. As demonstrated by Sérgio *et al.* (2000), bryophytes are reliable indicators and so the IPAs selected are likely to be important for other organisms and can be used to support the establishment of a new Portuguese IPA network.



Figs. 6-11– Distribution patterns in PNPG of six different species. **6:** *Andreaea megistospora* B.M.Murray. **7:** *Dumortiera hirsuta* (Sw.) Nees. **8:** *Pogonatum urnigerum* (Hedw.) P. Beauv. **9:** *Campylopus introflexus* (Hedw.) Brid. **10:** *Microlejeunea ulicina* (Taylor) A. Evans. **11:** *Racomitrium lusitanicum* Ochyra & Sérgio.

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