

Bryophytes of Lava Tubes and Volcanic Pits from Graciosa Island (Azores, Portugal)

Rosalina Gabriel¹, Fernando Pereira^{1,2}, Sandra Câmara¹, Nídia Homem¹, Eva Sousa¹, and Maria Irene Henriques¹

¹ Universidade dos Açores, Departamento de Ciências Agrárias, CITA-A, Centro de Investigação de Tecnologias Agrárias dos Açores, 9700-851 Angra do Heroísmo, Açores, Portugal.

² “Os Montanheiros”, Rua da Rocha, 9700 Angra do Heroísmo, Terceira, Açores, Portugal.

Abstract

Mainly due to historical reasons, the bryophyte flora of Graciosa Island is the poorest of the Azores (119 species), and it is especially scarce of rare and endemic species. However, Lava Tubes (Furna da Maria Encantada, Furna do Abel, Galeria Forninho) and Volcanic Pits (Furna do Enxofre) seem to offer refuge to some interesting plants. Previous studies have recorded, among others, the European endemic moss, *Homalia webbiana*, present only in four of the nine Azorean Islands and with a distribution of less than 10 localities known in the archipelago. The main purposes of this

project were: i) to update with field work, the bibliographic records of bryophytes that may be observed in the volcanic formations of Graciosa; ii) to identify, in those formations, endemic bryophyte species (from the Azores, Macaronesia and Europe) and species with a conservation risk associated, according to the European Committee for the Conservation of Bryophytes (ECCB). The results show that although no endemic plants from the Azores were found at this point, six European and four Macaronesian endemic species were confirmed in the entrances of these volcanic formations, including one Vulnerable species and three rare species, according to ECCB criteria. In

conclusion, besides the rich geological interest of the caves in Graciosa, their entrances continue to harbour rare or endemic bryophytes, not commonly found on other parts of the island, possibly due to the greater stability of these habitats. This is an additional reason to preserve the caves and a further possible motive of interest to all that visit them.

Introduction

Bryophytes include mosses (Bryopsida), liverworts (Marchantiopsida) and hornworts (Anthocerotopsida), all of which are small primitive plants that occupy a wide variety of habitats and substrates. Bryophytes assume an important

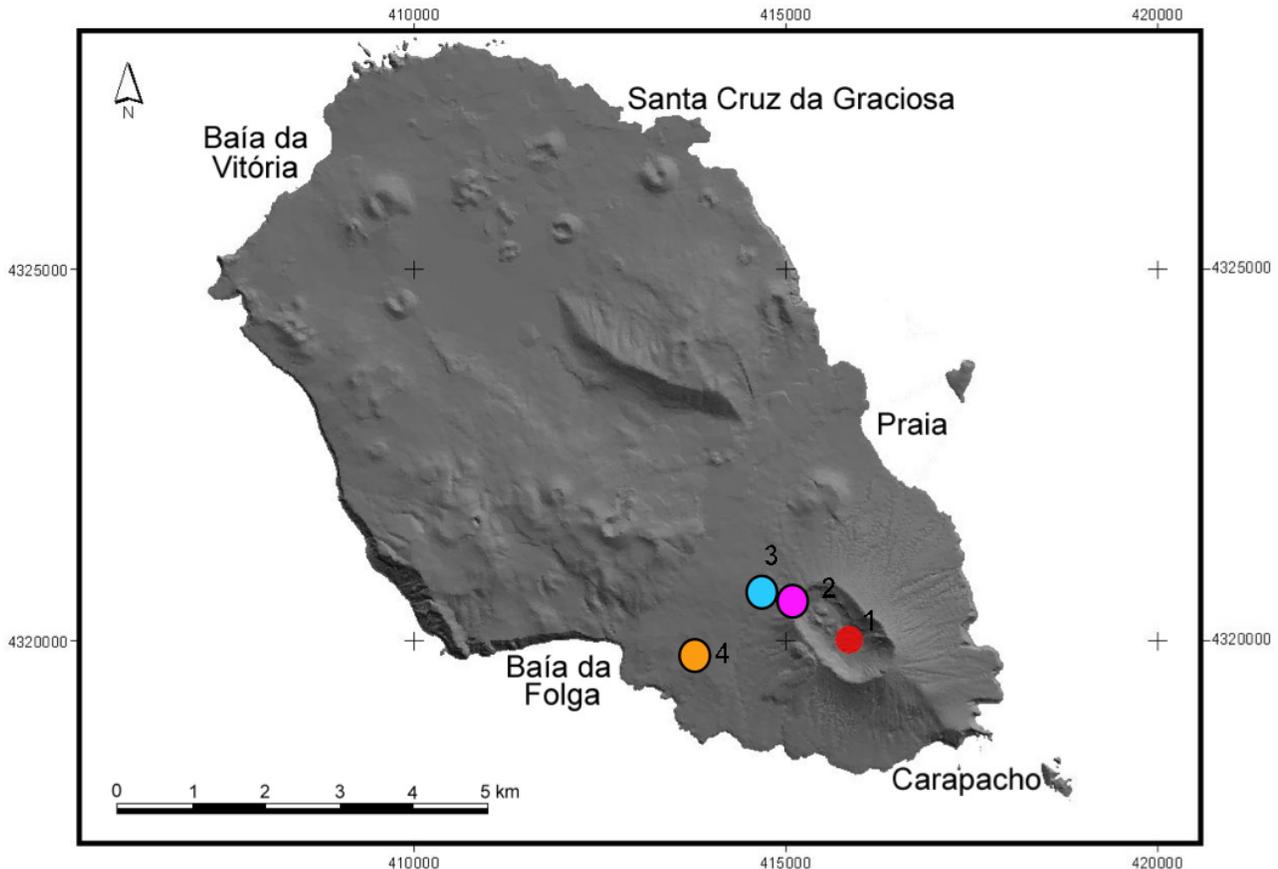


Figure 1. Sampled cave sites of Graciosa Island (Azores archipelago, Portugal). (1, Furna do Enxofre; 2, Furna da Maria Encantada; 3, Furna do Abel; 4, Galeria Forninho).

functional role in the ecosystems where they occur, performing water interception, accumulation of water and their mineral contents, decomposition of organic matter and physical protection of soils. Many bryophyte species are used as bioindicators, and their presence is associated with atmospheric and aquatic purity (Gabriel *et. al.*, 2005).

The Azores Archipelago offers a great variety of habitats for bryophytes, due to the diversity of microhabitats and available substrata, and to the hyper-humid conditions they provide (Gabriel & Bates, 2005). Mainly due to historical reasons, Graciosa Island is the poorest island of the Azores regarding the number of bryophytes (119), especially of rare and endemic species. However, Lava Tubes (Furna da Maria Encantada, Furna do Abel, Galeria Forninho) and Volcanic Pits (Furna do Enxofre) seem to offer refuge to some interesting plants. Previous studies have recorded, among others, the European endemic moss, *Homalia webbiana*, present only in four of the nine Azorean Islands and with less than 10 localities recorded in the archipelago.

The main purposes of the project were: i) to update with field work, the bibliographic records of bryophytes that may be observed in the volcanic formations of Graciosa; ii) to identify in those formations, endemic bryophyte species (from the Azores, Macaronesia and Europe) and species with a conservation risk associated, according to the European Committee for the Conservation of Bryophytes (ECCB).

Material and methods

Graciosa is the northernmost island of the central group of the Azorean archipelago (39°05'N, 28°00'W), and the second smallest of the Azores (61.7 km²). This is the most levelled surface island of the archipelago, with more than 90 % of its surface below 300 m; its highest point is Pico Timão, at 398 m altitude. The island has four villages: Luz, Gualupe, Praia and Santa Cruz, which is the largest and most important one.

Four cave entrances from Graciosa were purposefully sampled by one of us (FP) during June and July of 2005 (Figure 1): Furna do Enxofre; Furna da Maria Encantada; Furna do Abel and Galeria Forninho. All bryophytes were collected to newspaper bags, with

Table 1. List of bryophyte species found in the entrance of four caves in Graciosa Island in June and July 2005. Their rarity value (#) is specified in Table 2.

Cave	Species
Furna da Maria Encantada	Anthoceros punctatus
	Bryum canariense
	Campylopus polytrichoides
	Fossombronia caespitiformis
	# Frullania azorica
	Frullania tamarisci
	Lejeunea lamacerina
	Lunularia cruciata
	# Marchesinia mackaii
	# Myurium hochstetteri
	Porella obtusata
	Pterogonium gracile
# Radula wichurae	
Scorpiurium circinatum	
Furna do Abel	Conocephalum conicum
	Epipterygium tozeri
	# Fissidens coacervatus
	# Frullania azorica
	# Frullania microphylla
	Hypnum cupressiforme
	Porella obtusata
	Radula lindenbergiana
	# Radula wichurae
	Scorpiurium circinatum
# Tetrastichium fontanum	
Furna do Enxofre	Calypogeia arguta
	# Fissidens luisierii
	Heterocladium wulfsbergii
	# Homalia webbiana
	Lejeunea lamacerina
	Leucobryum juniperoideum
	Plagiochila bifaria
	Plagiothecium nemorale
	Riccardia latifrons
	# Tetrastichium fontanum
# Tetrastichium virens	
Thamnobryum maderense	
Galeria Forninho	Chiloscyphus coadunatus
	Epipterygium tozeri
	Lejeunea lamacerina

Table 2. Status and endemic area of the bryophyte species found on Graciosa cave entrances. Status according to the European Red List of Bryophytes (ECCB, 1995) (K, unknown status; R, rare species; V, vulnerable species; NT, not immediately threatened in Europe); endemism area (Macaronesia, Mac; Europe, Eur).

Status	Endemic	Species
NT	Eur	Frullania azorica
	Eur	Frullania microphylla
	Eur	Homalia webbiana
	Eur	Marchesinia mackaii
	Eur	Myurium hochstetteri
K	Mac	Fissidens luisierii
R	Eur	Tetrastichium fontanum
	Mac	Fissidens coacervatus
	Mac	Tetrastichium virens
V	Mac	Radula wichurae

reference of place and date of collection, substrate, and different observations concerning the ecology of the plant. Bryophyte samples were air dried.

The specimens were identified in the laboratory of the Departamento de Ciências Agrárias, University of the Azores. Nomenclature follows Gabriel *et al.* (2005). The following floras were used for the identification: Hedenäs (1992) and Smith (1978) for mosses and Schumacker and Vânia (2000), Smith (1990) and Paton (1999) for liverworts and hornworts. The confirmation of the identification of some species was done by Dr.^a Cecília Sérgio (LISU, University of Lisboa, Portugal), Professor René Schumacker (University of Liège, Belgium) and Professor Erik Sjögren (University of Uppsala, Sweden).

Results and discussion

Thirty two species of bryophytes may be found at the entrances of the four caves surveyed in Graciosa Island (Table 1), which corresponds to more than a quarter of all the bryophytes known to that island (26.9 %). The large volcanic pit, “Furna do Enxofre” and the small cave “Furna da Maria Encantada” are the richest caves surveyed with 12 and 14 bryophyte species, respectively.

The results show that although no endemic plants from the Azores were

found at this point, six European and four Macaronesian endemic species were found at the entrances of these volcanic formations, including one Vulnerable species and three rare species, according to ECCB criteria. Hence, ten bryophytes are listed in the European Red List of Bryophytes (ECCB, 1995), either due to their rarity or to their biogeographically restricted area, endemic species (Table 2).

Those ten species may be found in other islands and habitats, however it is important to note the presence of the vulnerable Macaronesian endemic liverwort, *Radula wichurae* and the European endemic moss *Homalia webbiana*, that is very rare in the Azores. The moss may only be found at four of the nine islands of the Archipelago (Flores, Graciosa, S. Jorge and Santa Maria) and has been recorded for less than ten localities in them.

Conclusions

About a quarter of the bryophyte flora of Graciosa Island may be found at the cave entrances accessed in this study. Although this habitat harbours mostly species found on other habitats, it also serves as a refuge to ten species, currently listed in the European Red List of Bryophytes (ECCB, 1995).

In particular, the presence of *Homalia*

webbiana was confirmed at the entrance of Furna do Enxofre, a classical locality, previously referred by González-Mancebo, Losada-Lima & Hernández-García (1991). This European endemic moss is very rare on the Azores, where there are less than 10 localities known for the species.

In conclusion, besides the rich geological interest of the caves in Graciosa, their entrances continue to harbour rare or endemic bryophytes, not commonly found on other parts of the island, possibly due to the greater stability of these habitats. This is an additional reason to preserve the caves and a further possible motive of interest to all that visit them.

Acknowledgements

We wish to thank to the following entities:

The project - “SOSTENP- *Estratégias de desenvolvimento económico, social e ecológico sustentável em espaços naturais protegidos da Macaronésia: Biodiversidade de briófitos na ilha Graciosa.*” INTERREG – IIIB.

The Azorean Government, for supporting the trip to Mexico of Rosalina Gabriel and Fernando Pereira, in order to participate on the XIIth International Symposium on Vulcanospeleology (Tepoztlan, Morelos, México, July 2006);

The “Centro de Investigação e Tecnologia Agrária dos Açores (CITAa/UAçores)” for supporting Nídia Homem and Sandra Câmara by the means of scientific grants;

The kind staff of the “Ecoteca da Graciosa”, for all the facilities granted while we were doing our fieldwork on Graciosa Island.

References

- ECCB. 1995. *Red data book of European bryophytes*. European Committee for the Conservation of Bryophytes. Trondheim.
- Hedenäs, L. 1992. Flora of Madeiran pleurocarpous mosses (Isobryales, Hypnobryales, Hookeriales). *Bryophytorum Bibliotheca*, **44**: 1-165.
- Gabriel, R. & Bates, J. W. 2005. Bryophyte community composition and habitat specificity in the natural forests of Terceira, Azores. *Plant Ecology*, **177**: 125-144.
- Gabriel, R., Sjögren, E., Schumacker, R.,

- Sérgio, C., Frahm, J. P. & Sousa, E. 2005. Bryophyta. In: Borges, P.A.V., Cunha, R., Gabriel, R., Martins, A.F., Silva, L., and Vieira, V. (eds.) *A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. pp. 117-129, Direcção Regional do Ambiente and Universidade dos Açores, Horta, Angra do Heroísmo and Ponta Delgada.
- González-Mancebo, J. M., Losada-Lima, A. & Hernández-García, C. D. 1991. A contribution to the floristic knowledge of caves on the Azores. *Mémoires de Biospéologie*, **17**: 219-226.
- Paton, J. A. 1999. *The Liverwort Flora of the British Isles*. Harley Books. Colchester. England.
- Schumacker, R. & Váña, J. 2000. Identification keys to the liverworts and hornworts of Europe and Macaronesia (Distribution & Status). *Documents de la Station Scientifique des Hautes-Fagnes*, **31**: 1- 160, Robertville.
- Smith, A. J. E. 1978. *The moss flora of Britain and Ireland*. Cambridge University Press. Cambridge.
- Smith, A. J. E. 1990. *The liverworts of Britain and Ireland*. Cambridge University Press. Cambridge.