Zeitschrift: Cryptogamica Helvetica
Herausgeber: Schweizerische Vereinigung für Bryologie und Lichenologie Bryolich
Band: 18 (1995)

Artikel: Bryophyte survey for a first planning of conservation areas in Terceira Island (Azores)
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DOI: https://doi.org/10.5169/seals-821130

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BRYOPHYTE SURVEY FOR A FIRST PLANNING OF CONSERVATION AREAS IN TERCEIRA ISLAND (AZORES)

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SUMMARY — Fifty-seven bryophyte species, mostly Macaronesian endemics and threatened species in Europe were surveyed from natural and semi-natural areas on Terceira Island (Azores). Based on recent field data and previous information, their conservation status is briefly discussed. The distribution of these selected species was mapped using a 1 km x 1 km UTM grid. The richest species squares, considered hot-spots, were used as indicators to define sites of special interest for bryophytes that should be included in conservation programmes.

KEYWORDS — Azores, bryophytes, endangered species, conservation, hot-spot

ZUSAMMENFASSUNG — Mooskartierung für eine erste Planung von Schutzgebieten auf Terceira (Azoren)

Siebenundfünfzig Moosarten, meist makaronesische Endemiten und in Europa gefährdete Sippen, wurden in natürlichen und naturnahen Gebieten der Insel Terceira (Azoren) kartiert. Auf der Basis von neuen Funddaten und älteren Angaben wird der Naturschutz-Status dieser ausgewählten Arten kurz diskutiert. Ihre Verbreitung wurde im 1-km-UTM-Netz festgestellt. Die artenreichsten Quadrate ('hot spots') dienten der Festlegung von Orten, die in bezug auf Moose von besonderem Interesse sind.

Introduction

The Azores archipelago is situated in the Atlantic Ocean, Macaronesian Region. Terceira Island is one of the nine islands of this archipelago. In spite of its small size (397km^2), its geomorphology, recent volcanic origin (2 million years), altitudinal range (1021m) and its mild oceanic climate, provide a considerable number of habitats for endemic and relict species. It is well known that the Macaronesian flora is particularly rich in those important taxa (Sunding 1979).

The floristic studies of the Azorean vegetation started more than 200 years ago (Adanson 1757), but the principal references to bryophyte species are much more recent. The most relevant works started with the Allorge and Persson expeditions in the thirties (Allorge & Allorge 1950, 1952 and Buch & Persson 1941). More recent publications (Sjögren 1978, 1990, 1993) cover most of the Azorean islands using ecological and phytosociological studies. However, previous data from Terceira are incomplete.

The basic aim of this project was to compile and co-ordinate information on the bryoflora and the status of rare and endemic taxa of Terceira. Another objective was to use a system to identify sites with potential bryological richness, using a relatively short list of species. With knowledge of these selected areas it is possible to provide guidelines for the improvement of the conservation policy and management of the existing natural areas important for bryophytes.

Methods

From the 249 known bryophytes of Terceira (Gabriel & Sérgio, in preparation), 57 species were selected. This short list includes the Azorean and Macaronesian endemic taxa as well as the endangered, vulnerable or rare species in Europe.

In order to assess the status of the selected species, two years of fieldwork (1991-1992) were carried out. During this period both, classical sites and other natural habitats were surveyed. Other sources of information, such as bibliographic, herbarium and personal knowledge have also been used. The status of the bryophytes was assessed using adapted IUCN criteria (**Ev** -

TABLE 1. Selected bryophyte species of Terceira (Azores), in alphabetical order, including hornworts and liverworts (a) and mosses (b), which are either endemic (*sensu lato*) or threatened in Europe.

(1) End: * European endemics. ** Macaronesian endemics. *** Azorean endemics.

(2) Taxon: The nomenclature generally follows Grolle (1983) for hornworts and liverworts and Corley & al. (1981) and Corley & Crundwell (1991) for mosses. Some modifications were based on recent works: Gabriel (1994), Hedenäs (1992), Jovet-Ast (1986) and ECCB (in press).

(3) Records: B: Bibliographic references; H: Herbarium specimens.

(4) Status: Eur: status in Europe including Macaronesia according to a draft of ECCB (in press); Ter: status in Terceira. For categories see text (Methods).

(5) h-spots: + = Taxa present in the hot-spots; - = Taxa not present in the hot-spots.

End (1)	Taxon (2)	Records (3) <1950 B	<1950 H	>1950 B	>1950 H	Status (4) Ter	Status (4) Eur	h-spot (5)
	(a) Hornworts and Liverworts							
*	Anthoceros caucasicus Steph.			1	5	R	V	+
**	Aphanolejeunea madeirensis (Schiffn.) Grolle			2		E	V	-
***	Aphanolejeunea teotonii V. Allorge & Jov.-Ast			2	7	NT	V	+
	Asterella africana (Mont.) Evans	1			1	E	V	-
***	Bazzania azorica Buch & H. Perss.	2		3	9	NT	R	+
***	Calypogeia azorica Bischler			3	1	V	R	+
	Calypogeia fusca (Lehm.) Steph.	1		2	2	V	R	+
***	Cheilolejeunea cedercreutzii (Buch & H. Perss.) Grolle	1		1	1	E	E	+
**	Cololejeunea azorica V. Allorge & Jov.-Ast				2	E	V	+
	Colura calyptrifolia (Hook.) Dum.			4	5	R	RT	+
	Dumortiera hirsuta Nees	2		3	2	R	R	+
	Exormotheca pustulosa Steph.	1				Ev	V	-
*	Frullania azorica Sim-Sim et al.				3	V	T	-
***	Herbertus azoricus (Steph.) Richards	1		1	3	V	R	+
	Lejeunea eckloniana Lindenb.		1		1	E	R	+
*	Lejeunea flava (Sw.) Nees			1	3	V	R	+
*	Lejeunea hibernica Grolle	1				Ev	R	-
***	Lepidozia azorica Buch & H. Perss.	1		2	2	R	V	+
***	Leptoscyphus azoricus (Buch & H. Perss.) Grolle	1				Ev	E	-
	Marchantia paleacea Bertol.	1		1		E	K	-
	Pallavicinia lyellii (Hook.) Carruth.	1			3	V	V	+
***	Plagiochila allorgei Herz. & H. Perss.				1	E	V	+
*	Porella canariensis (F. Web.) Bryhn	1				K	T	-
*	Radula carringtonii Jack			3	7	NT	R	+
**	Radula holtii Spruce	1				Ev	R	+
	Radula wichurae Steph.	2			1	E	V	+
	Riccia huebeneriana Lindenb.				1	E	V	-
*	Riccia ligula Steph.				1	E	E	-
	Riccia perennis Steph.	1				Ev	R	-
	Telaranea nematodes (Aust.) Howe	1		5	6	NT	R	+
***	Tylimanthus azoricus Grolle & H. Perss.	1		1	3	V	V	+

TABLE 1 continued

End (1)	Taxon (2)	Records (3) <1950 B	Records (3) <1950 H	Records (3) >1950 B	Records (3) >1950 H	Status (4) Ter	Status (4) Eur	h-spot (5)
	(b) Mosses							
**	Alophosia azorica (Ren. & Card.) Card.	2			14	NT	R	+
**	Andoa berthelotiana (Mont.) Ochyra	4		1	15	NT	R	+
*	Bryum platyloma Schwaegr.	1			5	V	T	+
	Campylopus cygneus (Hedw.) Brid.	1			2	E	K	+
	Campylopus shawii Wils.	1			4	V	R	+
	Cyclodictyon laetevirens (Hook. & Tayl.) Mitt.			1	7	R	R	+
	Daltonia splachnoides (Sm.) Hook. & Tayl.	1		2	1	E	V	+
*	Dicranum scottianum Turn. var. canariense (C. Müll.) Corb.	1		1	9	T	T	+
**	Echinodium prolixum (Mitt.) Broth.	3		2	9	NT	R	+
**	Echinodium renauldii (Card.) Broth.				2	E	V	+
*	Fissidens asplenioides Hedw.	3		1	8	NT	R	+
**	Fissidens coacervatus Brugg.-Nann.				1	E	R	-
	Hypnum uncinulatum Jur.	2		1	9	NT	RT	+
	Isopterygium tenerum (Sw.) Mitt.				1	E	E	-
	Microcampylopus laevigatus (Thér.) Giese & Frahm	1			5	R	V	+
	Neckera intermedia Brid.	1			1	E	R	+
	Philonotis hastata (Duby) Wijk et Marg.	2				E	K	-
**	Pseudotaxiphyllum laetevirens (Kop. & Düll) Hedenäs				7	R	R	+
*	Ptychomitrium nigrescens (Kunze) Wijk & Marg.	2		1	2	V	RT	-
**	Ptychomitrium polyphyllum (Sw.) B. & S. var. azoricum (Card.) Düll	2			7	R	T	+
*	Rhamphidium purpuratum Mitt.	2			9	NT	V	+
***	Sphagnum nitidulum Warnst.	1	1		2	T	T	-
**	Tetrastichium fontanum (Mitt.) Card.	1		1	8	R	R	+
**	Thamnobryum maderense (Kindb.) Hedenäs	1			2	E	R	+
	Tortula solmsii (Schimp.) Limpr.	1			3	V	R	-
	Weissia triumphans (De Not.) M. Hill	1			1	E	K	-

vanished: not located in the field for the last 40 years, or more recent localities destroyed. **E** - endangered: in danger of extinction; survival unlikely if causal factors continue operating; taxa whose population numbers have been reduced to a critical level, or whose habitats or localities have been drastically reduced, or species known from two or fewer localities in the island. **V** - vulnerable: expected to move into category E soon if the causal factors continue operating, or 1/3 to 1/2 of the known populations have disappeared, or species known from three to five localities, with small populations on the island. **R** - rare: taxa localized within restricted geographical areas, or habitats, often with small populations, at present not E or V, but at risk, or species known from six to 10 localities, with small populations on the island. **RT** - regionally threatened: taxa not threatened in Europe but under severe stress, or already disappeared in part of the natural area of distribution. **NT** - not threatened: taxa presently not threatened even if they show some signs of regression in some areas. **T** - taxonomical problems: taxa with taxonomical problems in their definition, or insufficiently known taxa. **K** - insufficiently

known status: taxa having a restricted distribution but needing further field studies for attribution to the appropriate threat category).

Biological richness is used to identify sites of potential high conservation interest (Hodgetts 1992, Prendergast & al. 1993). To select the richest bryophyte areas on Terceira Island the 57 species were mapped on a UTM grid (1km x 1km). The number of selected species present in each square was sorted into three classes: **hot-spots** – at least 10 of the selected species present; **intermediate zones** – squares with 5 to 9 of the selected species; **cold-spots** – squares with fewer than 5 of the selected species present.

Results and Discussion

Table 1 shows the results including the conservation status of the selected bryophytes on Terceira and their level of threat in Europe.

From the selected species, 5 are considered to have disappeared, 18 are endangered, 11 are vulnerable, 9 are rare, 3 are taxonomically problematic and 11 are not threatened. The species considered vanished have been searched for during the period of field work, especially in the classical sites. However, further studies should proceed in suitable habitats and especially for *Exormotheca pustulosa* and *Riccia perennis*, in the proper season.

Thirty-four European endemic species are listed including 22 exclusive to Macaronesia. Among these Macaronesian elements, 12 taxa are threatened (Ev, E, V) on the Island, for example *Calypogeia azorica, Cheilolejeunea cedercreutzii* and *Cololejeunea azorica.*

Some species that are not in imminent danger (R) or not threatened (NT) in Terceira Island are threatened (Ev, E, V) in Europe as a whole. For this group it is important to propose special guidelines for the selection of sites or habitats to assure their survival. Some of them, excluding Macaronesian endemics, are *Anthoceros caucasicus*, *Colura calyptrifolia*, *Hypnum uncinulatum*, *Microcampylopus laevigatus* and *Rhamphidium purpuratum*. Among the endemics we may

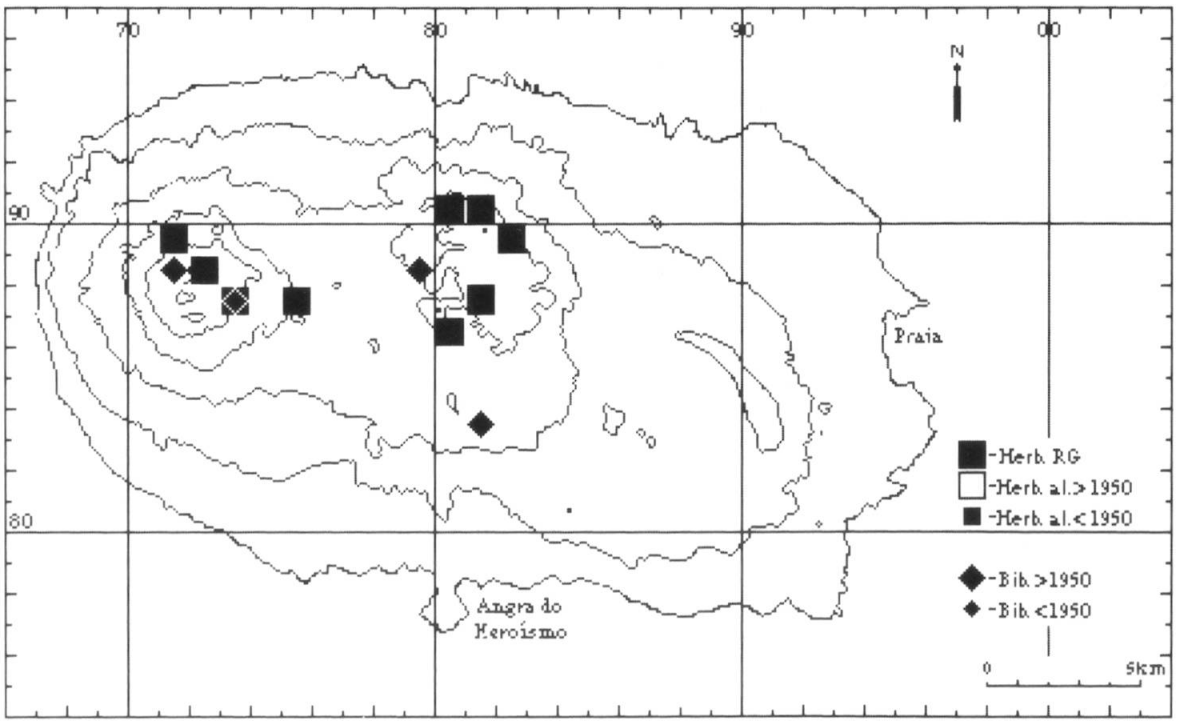

FIGURE 1. Distribution map of *Bazzania azorica* Buch & H. Perss. on Terceira Island. (Herb. RG - collected by R. Gabriel from 1991 to 1993. Herb. al. >1950 - collected by others, since 1950; seen by the authors. Herb. al. <1950 - collected by others, before 1950; seen by the authors. Bib. >1950 - bibliographical reference after 1950; Bib. <1950 - bibliographic reference before 1950).

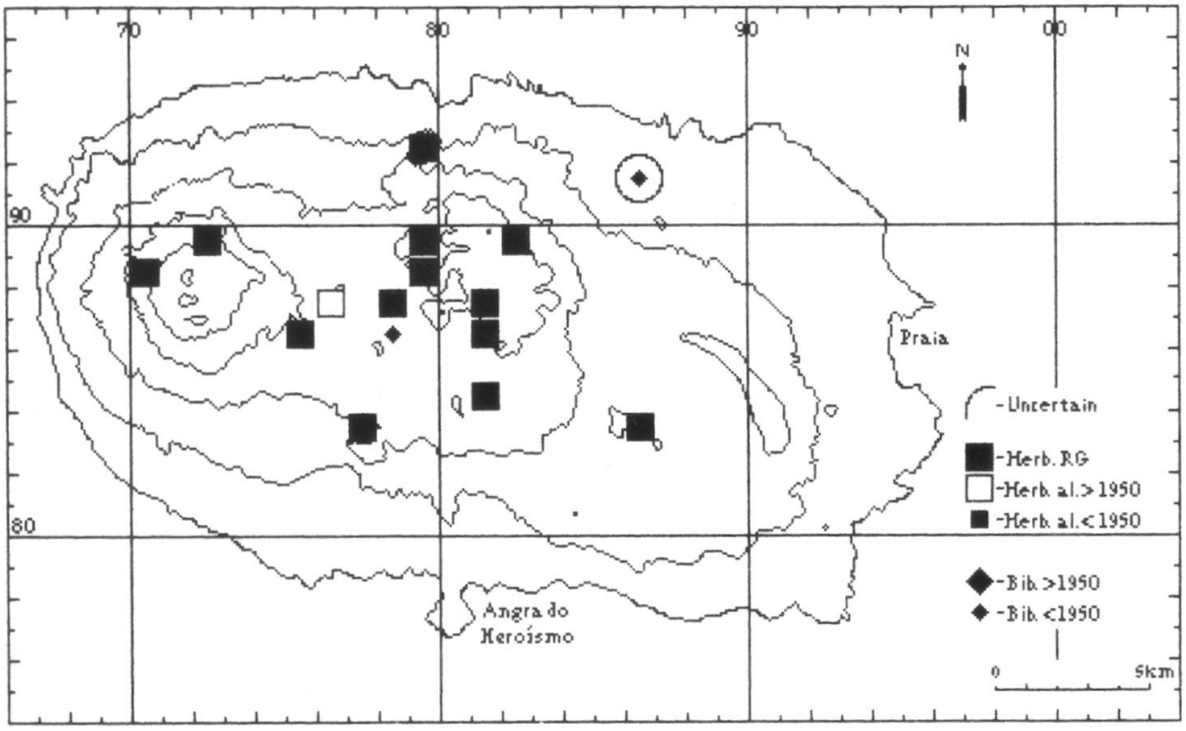

FIGURE 2. Distribution map of *Alophosia azorica* (Ren. & Card.) Card. on Terceira (uncertain - approximate position. Herb. RG - collected by R. Gabriel from 1991 to 1993. Herb. al. >1950 - collected by others, since 1950; seen by the authors. Herb. al. <1950 - collected by others, before 1950; seen by the authors. Bib. >1950 - bibliographical reference after 1950; Bib. <1950 - bibliographic reference before 1950).

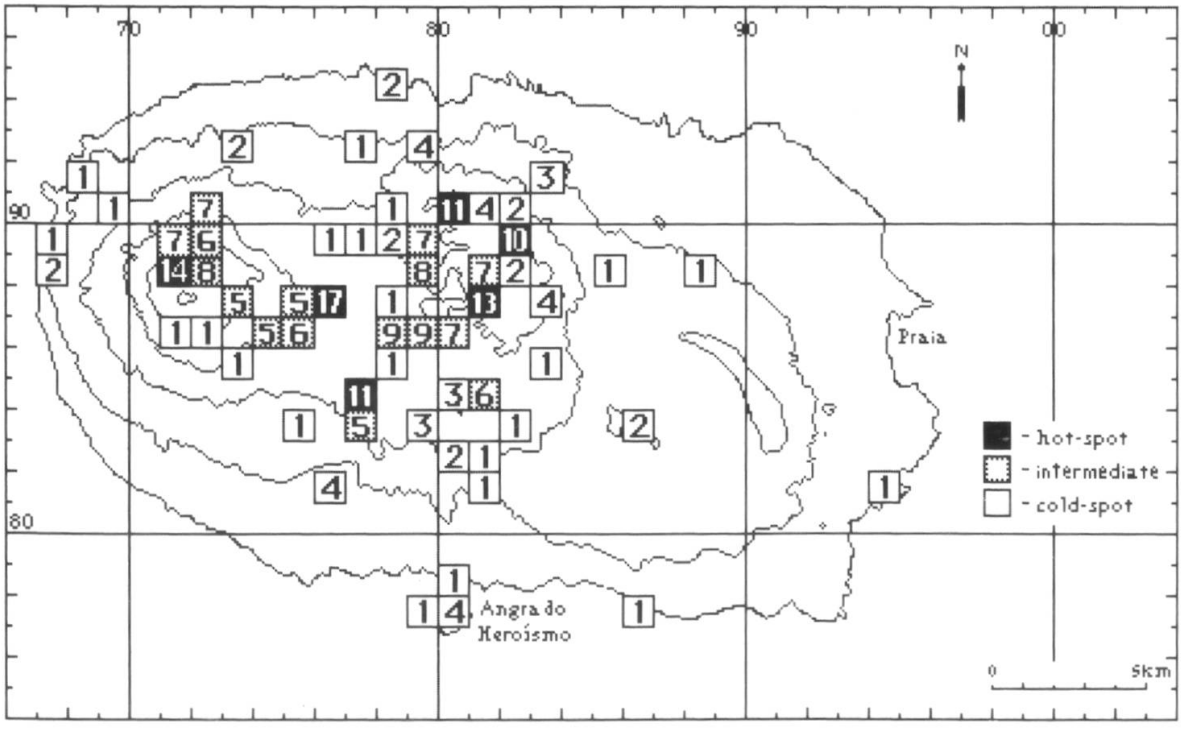

FIGURE 3. Figure 3. Terceira Island map with the distribution of the number of selected species for each UTM square (1kmx1km) (hot-spot - area with more than 9 of the selected species; intermediate - area with 5 to 9 of the selected species; cold-spot - area with less than 5 of the selected species).

mention *Andoa berthelotiana, Aphanolejeunea teotonii, Bazzania azorica* (Fig. 1), *Alophosia azorica* (Fig. 2) and *Echinodium prolixum*, which have now been found to be quite abundant on the island.

A more critically threatened group includes species in the Red-List of Europe (ECCB, in press) that are also threatened on Terceira, as *Asterella africana, Exormotheca pustulosa, Pallavicinia lyellii, Radula wichurae, Riccia huebeneriana, R. ligula, Daltonia splachnoides, Fissidens coacervatus* and *Isopterygium tenerum*. For these bryophytes, most of which have Mediterranean tendencies, it is essential to continue with further studies, including new visits, in the proper season, to areas where the most representative habitats exist.

Special attention should be given to these two groups of bryophytes and to the selection of sites in which they grow.

Species like *Lejeunea hibernica, Ptychomitrium nigrescens, Tortula solmsii* and *Weissia triumphans* which have quite generalized distributions, may be at the limit of their range in the Azores. For this reason they should be monitored there, where they are generally scarcer than in the rest of Europe.

The number of records of the selected species in each UTM square and the mapped information of the different species (for example, Figs 1 and 2) were used to select the bryological hot-spots on the island (Fig. 3). In this figure it is possible to define six hot-spot areas with a great richness of bryophytes. These are often surrounded by intermediate richness zones, where the diversity is also quite important, and may in future become recognized as hot-spots as a result of more exhaustive field studies (Gabriel 1994).

In general, these hot-spot areas do not only house the largest number of selected species but also the species being among the most endangered in Europe as well as the Macaronesian endemics. Two exceptions are *Sphagnum nitidulum*, an endemic of the island, and *Isopterygium tenerum* which,in the Azores, are known only from one locality. Although not present in one of the six hot-spots considered, these species are found in a special area with a particular ecology, sulfurous fumaroles, an intermediate richness zone (9 species). This place should obviously be regarded as a hot-spot.

Vouchers of all the species collected, with precise geographical information, are kept in AZU and some duplicates in LISU. All the information gathered is in a database, available for future studies. This methodology may be important for the selection of areas with bryophytic interest at a regional level, allowing the classification of these sites on a European scale. The same system of site identification could be implemented in other Azorean islands.

Acknowledgements

We wish to thank Dr. Urmi, Prof. Sjögren and two anonymous referees for helpful comments on an earlier draft of the manuscript.

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