# Liverworts of *Sphagnum magellanicum* Brid. raised bogs from Tierra del Fuego National Park, Ushuaia (Argentina)

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At present, the available information about the liverworts of *Sphagnum magellanicum* Brid. mires from South America is very limited. The main aim of this paper is to present a comprehensive study of the liverwort flora of this habitat, as well as details on the chorology and ecology of the taxa involved. Four different environmental units were examined, based on the water table level and plant cover, in three representative raised bogs from Tierra del Fuego National Park (Ushuaia). Floristic relevés were recorded in 93 square plots ($0.50 \times 0.50$ m$^2$), distributed at random in the environmental units. Twenty-four liverwort species have been identified; the majority have a Subantarctic distribution and there were a remarkable number of Magellanean endemics (11 species). Among the rare species, there were two new records for the Argentinian Province of Tierra del Fuego, *Cephaloziella byssacea* and *Chiloscyphus notophyllus*. The ecological preferences of the species were analysed based on their frequencies in the four environmental units examined. Only six species demonstrated significant correlation with some of the environmental units. *Riccardia pallidevirens, R. georgiensis, R. alcicornis*, and *Cephaloziella varians,* showed a preference for waterlogged and wet habitats, while *Calypogeia sphagnicola* and *Cephalozia chilensis* were linked to dense carpets of *Sphagnum magellanicum.*

**Keywords:** Liverworts, Magellanean, Mire, Peatland, Subantartic

## Introduction

The available information about the liverwort flora of *Sphagnum magellanicum* Brid., dominated mires in South America is very limited. Moreover, the literature is dispersed, and incomplete in the case of Tierra del Fuego where most of the references cover the Chilean area, the Subantarctic Islands (Hässel de Menendez & Rubies, 2009) and Antarctica (Bednarek-Ochyra *et al.*, 2000). Many of the studies that have analysed the vegetation of these ecosystems have focussed on the vascular plants (San Martín *et al.*, 1999; Teneb & Dollenz, 2004), despite the considerable interest of: (i) this type of wet habitat; (ii) the huge mire area in the Argentinean area of Tierra del Fuego (more than 20 000 ha on Isla Grande, according to Roig *et al.* 2004); and (iii) the fact that recent analyses have shown that the Subantarctic Magellanean area constitutes a hotspot of worldwide bryophyte diversity (Rozzi *et al.*, 2006).

The main aim of this paper is to present a comprehensive study of the liverworts of raised bogs from Tierra del Fuego National Park, Ushuaia, in order to improve knowledge about the flora, as well as the geographic distribution and the ecological behaviour of the liverwort taxa.

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## Materials and Methods

### Study area

Tierra del Fuego National Park is located in the southwestern Tierra del Fuego Province (Argentina), next to the border with Chile. Raised bogs dominated by *S. magellanicum* are the main mire type in this Park. These mires are linked to the water bodies in the area and lie between Roca Lake and Lapataia Bay, where three mires Laguna Negra, (LN; 54°50′S, 68°35′W); 'Laguna Pequeña' (LP; 54°50′S, 68°30′W) and Lapataia, (LT; 54°51′S, 68°35′W) were sampled for this study (Figure 1).

### Field sampling

A total of 93 floristic relevés (square plots $0.50 \times 0.50$ m$^2$) were recorded. Sampling points were distributed at random in four different environmental units, defined by mire heterogeneity and microtopography. The main criteria used to define these environmental units were the water table level and the principal plant cover components, as follows (Figure 2):

U1: Hollows and flooded areas with *Warnstorfia* Loeske sp. and *Tetroncium magellanicum* Willd.


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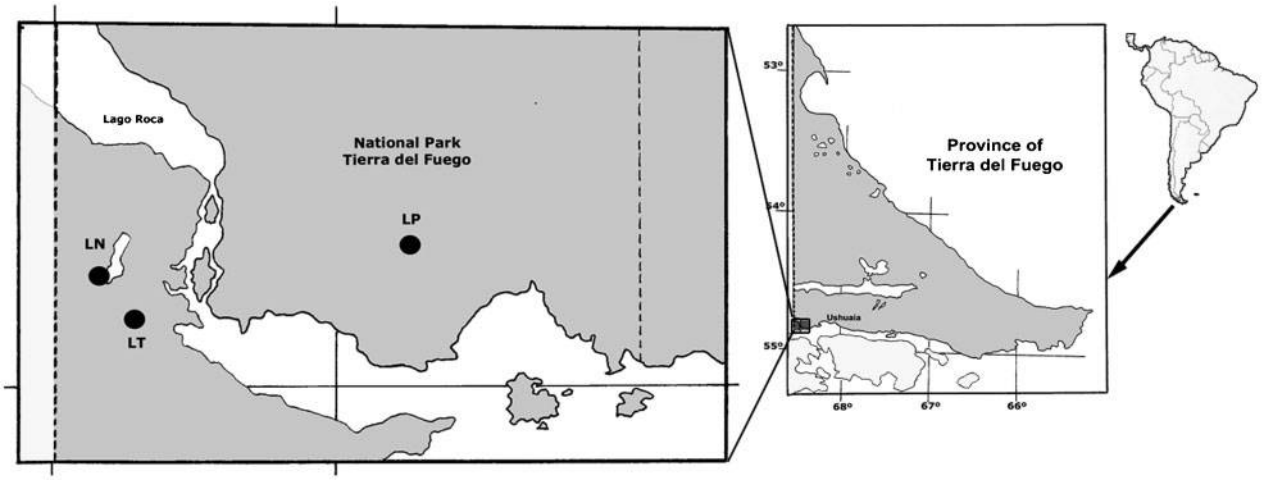


**Figure 1 Location of three surveyed bogs from Tierra del Fuego National Park.**

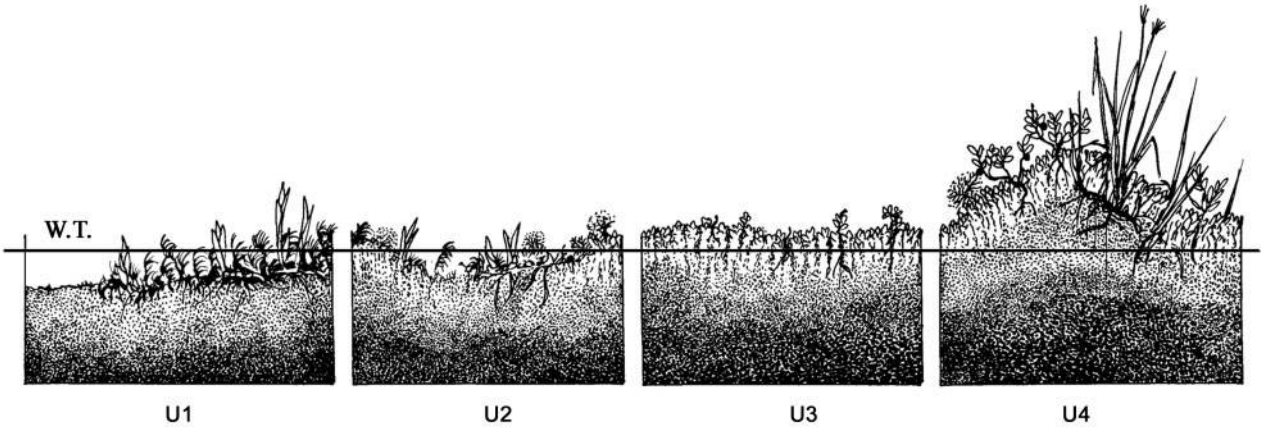


**Figure 2 Ecological units established on the basis of water table level and principal plant cover components (see text for explanations). W.T.: Water Table.**

**Table 1 Species frequencies for each environmental unit**

| | Fr-T | Fr-U1 | Fr-U2 | Fr-U3 | Fr-U4 |
|---|---|---|---|---|---|
| *Riccardia georgiensis* (Steph.) Hässel | 50.5 | 66.7 | 60 | 66.7 | 23.3 |
| *Pseudocephalozia quadriloba* (Steph.) R.M.Schust. | 32.3 | 5.6 | 43.3 | 53.3 | 26.7 |
| *Blepharidophyllum densifolium* (Hook.) Ångstr. *ex* C.Massal. | 31.2 | 22.2 | 46.7 | 33.3 | 20 |
| *Lepidozia laevifolia* (Hook.f. & Taylor) Gottsche, Lindenb. & Nees | 29 | 0 | 56.7 | 20 | 23.3 |
| *Fuscocephaloziopsis pleniceps* (Austin) Váňa & L.Söderstr. | 26.9 | 38.9 | 30 | 20 | 20 |
| *Calypogeia sphagnicola* (Arnell & J.Perss.) Warnst. & Loeske | 26.9 | 0 | 23.3 | 46.7 | 36.7 |
| *Adelanthus linderbergianus* (Lehm.) Mitt. | 25.8 | 0 | 60 | 13.3 | 13.3 |
| *Cephalozia chilensis* (J.J.Engel & R.M.Schust.) R.M.Schust. | 22.6 | 0 | 20 | 46.7 | 26.7 |
| *Leptoscyphus chilensis* (De Not.) Grolle | 21.5 | 16.7 | 33.3 | 6.7 | 20 |
| *Hyalolepidozia bicuspidata* (Mass.) S.Arnell *ex* Grolle | 16.1 | 0 | 26.7 | 40 | 3.3 |
| *Pseudolepicolea quadrilaciniata* (Sull.) Fulford & J.Taylor | 15.1 | 5.6 | 40 | 0 | 3.3 |
| *Kurzia setiformis* (De Not.) J.J.Engel & R.M.Schust. | 12.9 | 5.6 | 23.3 | 20 | 3.3 |
| *Riccardia pallidevirens* (Steph.) Evans | 10.8 | 22.2 | 13.3 | 6.7 | 3.3 |
| *Cephaloziella varians* (Gottsche) Steph. | 9.7 | 22.2 | 10 | 0 | 6.7 |
| *Cephaloziella byssacea* (Roth.) Warnst. | 8.6 | 0 | 13.3 | 13.3 | 6.7 |
| *Leptoscyphus antarcticus* (C.Massal) Solari | 7.5 | 5.6 | 13.3 | 0 | 6.7 |
| *Clandarium clandestinum* (Mont.) R.M.Schust. | 4.3 | 0 | 6.7 | 13.3 | 0 |
| *Chiloscyphus notophyllus* (Hook.f. & Taylor) Gottsche, Lindenb. & Nees | 4.3 | 5.6 | 10 | 0 | 0 |
| *Riccardia alcicornis* (Hook.f. & Taylor) Trevis. | 3.2 | 11.1 | 3.3 | 0 | 0 |
| *Syzygiella jacquinotii* (Mont.) Hentschel, K.Feldberg, Váňa & J.Heinrichs | 2.2 | 0 | 0 | 0 | 6.7 |
| *Aneura pinguis* (L.) Dumort. | 1.1 | 0 | 0 | 0 | 3.3 |
| *Ptilidium ciliare* (L.) Hampe | 1.1 | 0 | 0 | 0 | 3.3 |
| *Temnoma quadripartitum* (Hook.) Mitt. | 1.1 | 0 | 3.3 | 0 | 0 |
| *Temnoma pilosum* (A.Evans.) R.M.Schust. | 1.1 | 0 | 0 | 0 | 3.3 |
| Species number | 24 | 12 | 20 | 14 | 20 |

Note: Fr: relative frequency (Fr %); T: total plots; U1, U2, U3, & U4: environmental units (see text for explanations).

U2: Irregular ground surface and water table close to or above the ground surface. *S. magellanicum* usually scarce and damaged, in contrast with the abundance of other bryophytes and lichens.

U3: Dense carpets of *S. magellanicum,* water table close to or below the ground surface. *Empetrum rubrum* Vahl. *ex* Willd, present, but scarce.

U4: Hummocks, water table below the peat surface. Abundant *S. magellanicum* and vascular plants (*Nothofagus antarctica* (G.Forst.) Oerst, *Empetrum rubrum*, *Marsippospermum grandiflorum* (L.f.) Hook.f.).

Species cover was estimated for each sampling plot, by eye or, where necessary, later in the laboratory, by counting or estimating % plant cover from photographs taken in the field. Authorities for plant names are given in Table 1.

### *Laboratory study*

An Olympus SZ30 stereomicroscope and an Olympus CX40 microscope were used for microscopic analysis of the samples. The mounting medium for microscope slide preparations was Hoyer's solution (Anderson, 1954). Species identifications and nomenclature are mainly based on Schuster (2000, 2002), Engel (1978, 1990), Engel & Schuster (2001), Hässel de Manendez (2001), Hässel de Manendez & Solari (1975), Hässel de Manendez & Rubies (2009), and Bednarek-Ochyra *et al.* (2000).

All reference material from this study (herbarium specimens and permanent microscopic slides), are stored in the herbarium of the Museum of Natural History of the University of Santiago de Compostela (MHN-TDF). There are also duplicates in the herbarium of the Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia', Buenos Aires (MACN) and in the herbarium of the CADIC (Centro Austral De Investigaciones Científicas, Ushuaia, Argentina).

Hässel de Manendez & Rubies (2009), Grolle (2002), Schuster (2000, 2002), and Bednarek-Ochyra *et al.* (2000) have been the main bibliographic sources used for chorological analysis. According to Grolle (2002),

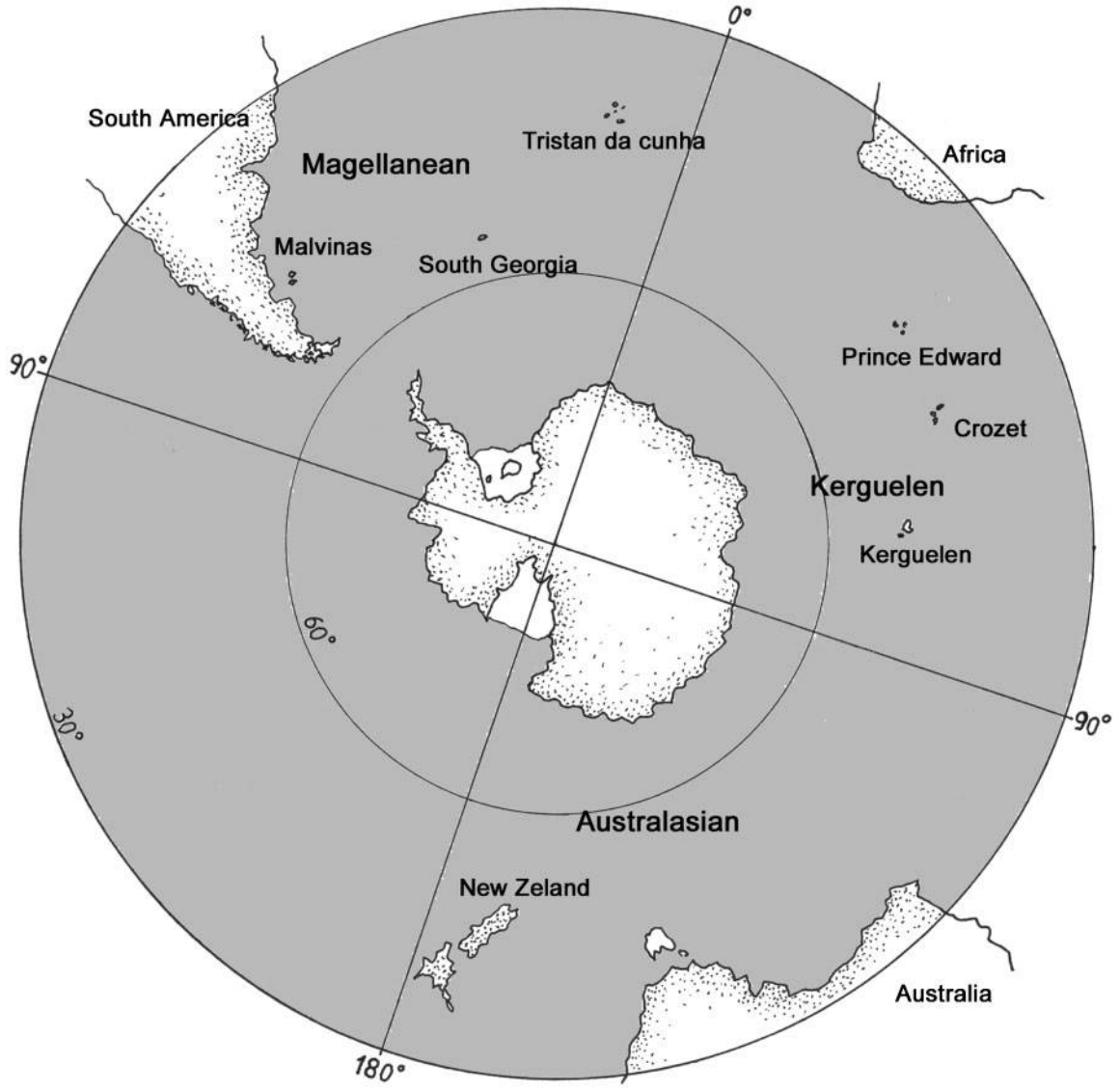


**Figure 3 Subantartic zone sectors according to Grolle (2002).**

for practical reasons, three sectors have been differentiated in the Subantarctic Zone (Figure 3): (i) Magellanean (0°–90°W: Tierra del Fuego, South Georgia, Falkland Islands, Tristan da Cunha Islands, and Gough Islands); (ii) Kerguelen (90°E–0°: Crozet Islands, Kerguelen Islands and Prince Edward Islands); and (iii) Australasian (180°–90°E: Tasmania, New Zealand, Auckland Islands, and Campbell Islands).

### *Statistical analysis*

Bivariate correlation analysis (Spearman correlation tests, $P<0.05$) and Hierarchical Cluster Analysis (based on the Chi-square test) were performed to assess the species ecological preferences and to determine the natural groupings of species, according to their relative frequencies in the four environmental units established, using IBM SPSS Statistics 20 Package.

## Results

Twenty-four liverwort species (20 Jungermanniopsida and 4 Marchantiopsida) were identified. In most samples, the liverworts are the dominant bryophytes, after *S. magellanicum*. The liverwort flora was very similar for the three sampled mires. According to the phytogeographical attributes of the recorded taxa, most of the species have a Subantarctic distribution (Figure 4), with a high number of endemic species exclusive to the Magellanean Sector (11 species). *Cephaloziella byssacea* and *Chiloscyphus notophyllus* were recorded for the first time in the Argentinian Province of Tierra del Fuego, and *Aneura pinguis* and *Cephalozia chilensis* were recorded for the second time in this province.

The species frequencies for each environmental unit give an indication of their ecological preferences (Table 1). Hummocks of *S. magellanicum* with vascular plants (environmental unit U4) and areas of irregular surface and water table close or above the ground surface (environmental unit U2) have the greatest species richness (20 species). The lowest number of species (12) was found in the hollows and flooded areas (environmental unit U1), a slightly lower total than that observed in the dense carpets of *S. magellanicum* (14 species, environmental unit U3)

Hierarchical cluster analysis reveals natural groupings according to the species relative frequencies in each environmental unit (Figure 5). The initial splitting of the dendrogram forms two main clusters. The upper main cluster comprises the species that, except for *Pseudolepidozia quadriloba*, do not grow in the flooded habitats (U1), while those that have been recorded in flooded environments are included in the lower main cluster. The first group includes rare species only recorded in U4 (*Ptilium ciliare*, *Temnoma pilosum*, *Syzygiella jacquinotii*, and *Aneura pinguis*. The other groups of the upper half of the dendrogram differ in their relative frequencies in each environmental unit; higher in: U3 and U4 (*Calypogeia sphagnicola* and *Cephalozia chilensis*), U3 and U2 (*P. quadriloba* and

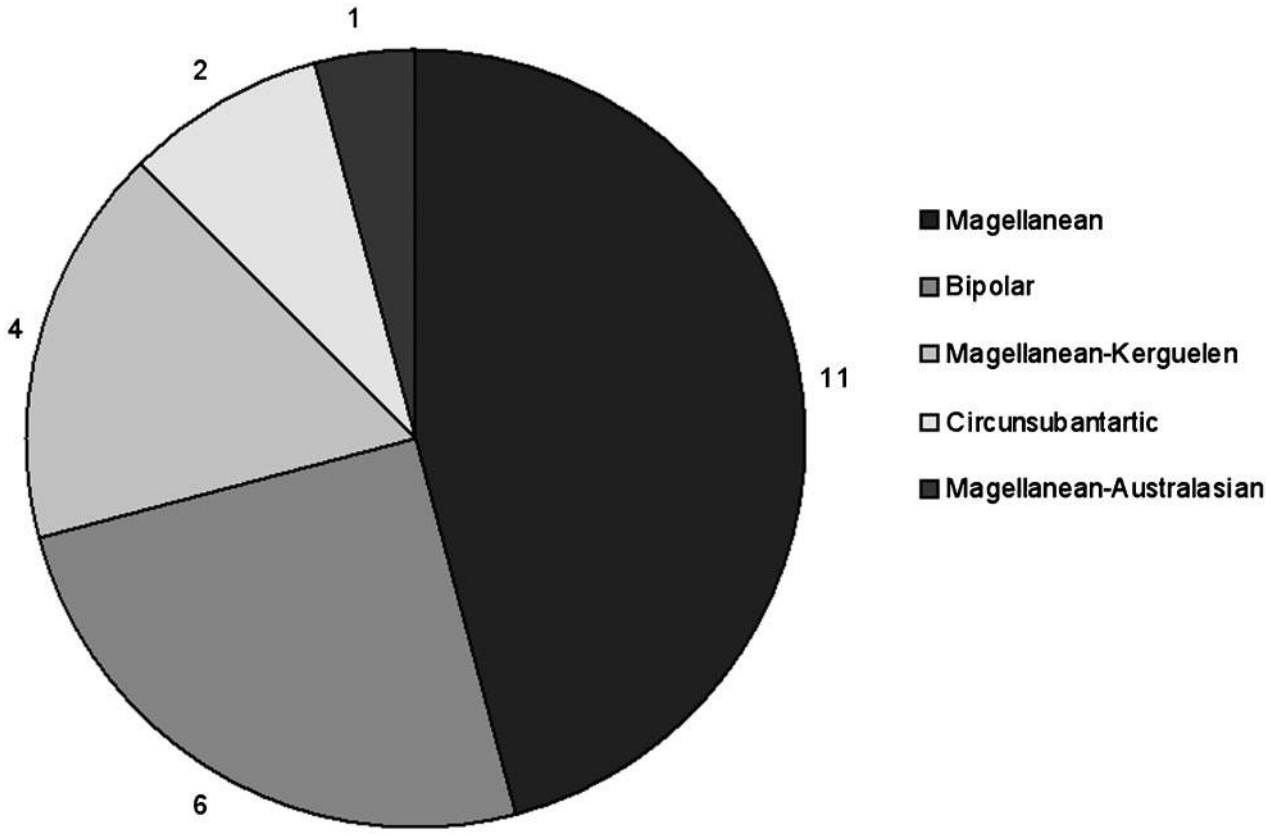


**Figure 4 Chorological spectrum. The number of species recorded for each sector is shown.**

*C. byssacea*), U2 (*Lepidozia laevifolia* and *Adelanthus linderbergianus*), and U3 (*Hyalolepidozia bicuspidata* and *Clandarium clandestinum*).

In a similar way, the lower main cluster is subdivided into groups: the first branch separates the groups of species with higher frequency in U1 from the most frequent species in U2. In the first group, the species with a higher frequency in U1 (*Cephaloziella varians* and *Riccardia alcicornis*) differ from those with higher frequencies in U1 and U2 (*Fuscocephaloziopsis plenicepes* and *R. pallidevirens*) or in U1, U3, and U2 (*R. georgiensis*). In the last group, corresponding to the most common species in U2, there are species with unclear trends, as their relative frequencies in U1 and U4 are similar (*Leptoscyphus chilensis* and *L. antarcticus*) and species never recorded in U3 (*Pseudolepicolea quadriciliata*) or absent in U3 and U4 (*Chiloscyphus notophyllus*). There is also the rare species, only recorded in U2 (*Temnoma quadripartitum*).

## Discussion

Generally peatlands are considered habitats with low floristic diversity, because non-vascular plants are often poorly studied or ignored. Nevertheless, several studies show that in some specific areas, such as the Magellanean region, peatlands can host high bryophyte diversity (Rozzi *et al.*, 2006) and the liverworts present a high rate of endemism (Hässel de Manendez & Rubies, 2009). In terms of species richness, excluding vascular

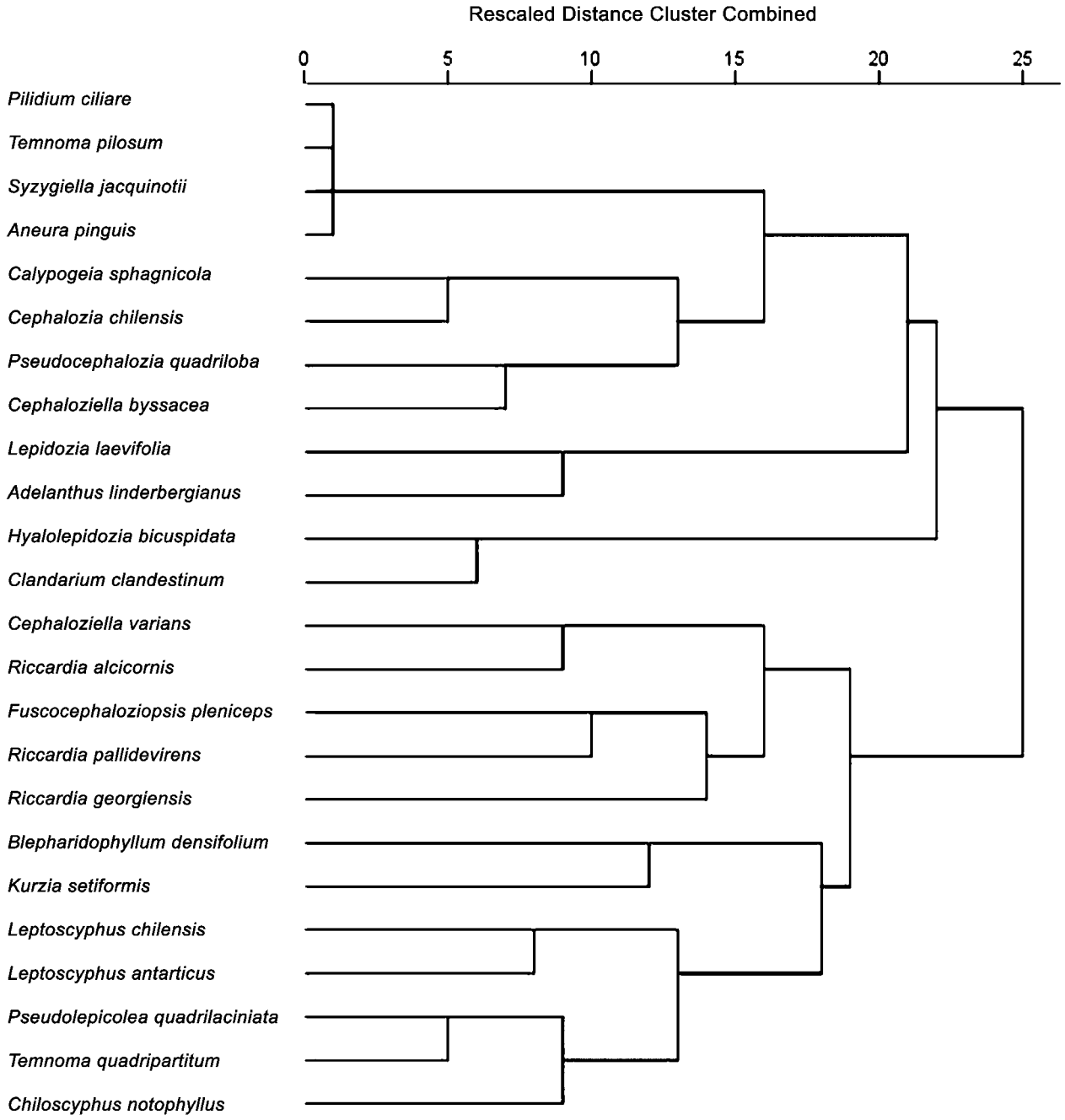


**Figure 5 Species clusters established on the basis of their ecological preferences.**

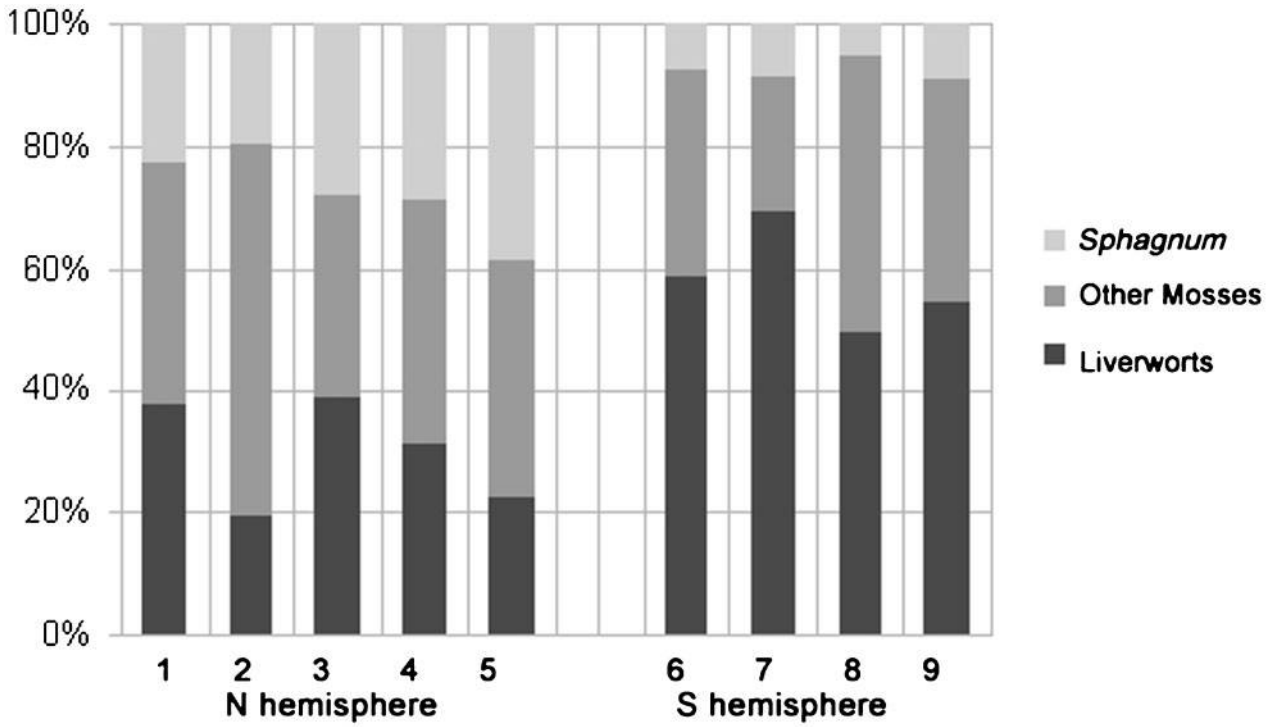


**Figure 6 Proportion of liverwort numbers in relation to mosses, in different areas of the N and S hemispheres. See Table 3 for details of sites 1–9.**

plants, in *Sphagnum*-raised bogs in Tierra del Fuego National Park, we have previously recorded 51 non-vascular plant species (Souto, 2008), of which 24 were liverworts, 17 mosses and 10 lichens. Other studies on Tierra del Fuego bogs also showed a predominance of liverworts over other non-vascular plants (Kleinebecker *et al.*, 2007) or a greater liverwort species richness (33 species; Engel, 1978) in *Sphagnum* bogs from Bahia San Nicolas and Laguno El Parrillar, Brunswick Peninsula, Chile. Fourteen species recorded by Engel (1978) were also present in Tierra del Fuego National Park, of which seven (*Riccardia georgiensis*, *Pseudocephalozia quadriloba*, *Blepharidophyllum densifolium*, *Lepidozia laevifolia*, *Calypogeia sphagnicola, Fuscocephaloziopsis pleniceps*, and *Adelanthus linderbergianus*) were very common. However, of the 29 liverwort species recorded in the natural peatlands of the Isla Grande de Chiloé, by León Valdebenito (2012), only four were recorded in this study, probably because of the distance (1400 km) and differences in environmental characteristics between Chiloé and Tierra del Fuego. In contrast, Diaz *et al.* (2008) only listed six liverwort species from Isla Grande de Chiloé which is considerably lower than in this or the León Valdebenito's (2012) study.

According to Moen (2005), Tierra del Fuego is one of the few areas in the southern hemisphere with environmental conditions comparable to northern Europe. Comparing the bryophytic richness of *Sphagnum* bogs from South America and from Europe and North America, the number of liverwort species is lower than moss species (including *Sphagnum* spp.) in the northern hemisphere, while in the southern hemisphere, the general rule is a dominance of liverworts over mosses (Table 3 and Figure 6). Only five species are found in both hemispheres.

The heterogeneity of the microhabitats appears to make an important contribution to the number of taxa of bryophytes in Tierra del Fuego National Park. Kleinebecker (2007) examined different microhabitats, very similar to those used in this paper and based on the vegetation and water table levels in *Sphagnum* bogs from Chile. Kleinebecker (2007) found a difference in the distribution and abundance of liverworts and a lower diversity of taxa, with only one species in hollows (U1), 10 species in wet *S. magellanicum* habitat type (U2), 10 in dry *S. magellanicum* habitat type (U3), and 14 in *S. magellanicum* hummocks (U4). The biggest contrast in liverwort flora compared to this study is related to the hollows.

The results of Spearman's Correlation analysis allow a more accurate and objective assessment on ecological preferences of the species (Table 2). Among the species with a frequency >3% for all the plots, only six demonstrate significant correlation with the environmental units. *Riccardia pallidevirens*, *R. alcicornis*, and *Cephaloziella varians* showed a clear preference for flooded and wet habitats (U1), while *Calypogeia sphagnicola* and *Cephalozia chilensis* are linked to dense carpets of *S. magellanicum* (U3). The most common species, *R. georgiensis*, is significantly correlated with both environmental units U1 and U3.

Considering the two environmental units with the highest number of species: in U4, the lower level of the water table allows the entry of species from the drier

**Table 2 Species correlation with the environmental units U1, U2, U3, and U4**

| | Correlation with the environmental units (Spearman Rho) |
|---|---|
| *Riccardia georgiensis* | −0.320** |
| *Pseudocephalozia quadriloba* | 0.150 |
| *Blepharidophyllum densifolium* | −0.075 |
| *Lepidozia laevifolia* | −0.036 |
| *Fuscocephaloziopsis pleniceps* | −0.138 |
| *Calypogeia sphagnicola* | 0.348** |
| *Adelanthus linderbergianus* | −0.083 |
| *Cephalozia chilensis* | 0.289** |
| *Leptoscyphus chilensis* | −0.073 |
| *Hyalolepidozia bicuspidata* | −0.037 |
| *Pseudolepicolea quadrilaciniata* | −0.133 |
| *Kurzia setiformis* | −0.106 |
| *Riccardia pallidevirens* | −0.214* |
| *Cephaloziella varians* | −0.311** |
| *Cephaloziella byssacea* | 0.078 |
| *Leptoscyphus antarcticus* | 0.004 |
| *Clandarium clandestinum* | 0.019 |
| *Chiloscyphus notophyllus* | −0.079 |
| *Riccardia alcicornis* | −0.216* |

Note: Spearman bivariate correlation test: **correlation is significant at the 0.01 level (two-tailed); *correlation is significant at the 0.05 level (two-tailed).

**Table 3 Comparison of the numbers of liverwort and moss species in *Sphagnum* bogs from different areas of the northern and southern hemispheres**

| Liverworts | Mosses | Sphagnum | Total | Locality | Author |
|---|---|---|---|---|---|
| 20 | 21 | 12 | 53 | 1. Western Canada | Vitt & Belland, 1995 |
| 8 | 25 | 8 | 41 | 2. Duck Mountain, Manitoba | Locky & Bayley, 2006 |
| 14 | 12 | 10 | 36 | 3. Central Sweden | Sjors, 1948 |
| 12 | 15 | 11 | 38 | 4. Xistral, Galicia, Spain | Fraga *et al.*, 2008 |
| 7 | 12 | 12 | 31 | 5. Asturias, Spain | Fernandez Prieto *et al.*, 1987 |
| 24 | 14 | 3 | 41 | 6. Tierra del Fuego, Argentina | Souto, 2008 |
| 16 | 5 | 2 | 23 | 7. XII th Region, Chile | Kleinebecker *et al.*, 2007 |
| 29 | 27 | 3 | 59 | 8. Is. Chiloé, Chile | León Valdebenito, 2012 |
| 6 | 4 | 1 | 11 | 9. Is. Chiloé, Chile | Díaz *et al.*, 2008 |

surrounding habitats (such as *Ptilidium ciliare* and *Temnoma quadripartitum* that usually grow in forest habitats and are very rare in *Sphagnum* bogs), while in the case of U2, the ground surface irregularities and the existence of bare peat patches favour a greater floristic diversity, mostly of pioneer liverwort species that may occasionally form dense carpets.

Liverworts face heavy competition from *Sphagnum* for light and space, so flagelliform growth forms are common. As Duckett & Clymo (1988) pointed out, these flagelliform forms can utilize asexual reproduction, which favours their survival against strong competition for environmental resources from *S. magellanicum* and other mosses.

In conclusion, these *Sphagnum* bogs host an abundant liverwort diversity that is not usually considered in terms of conservation or exploitation regulations. Further ecological studies would broaden our understanding of this important bryophyte group, resolving ecological and chorological questions.

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Taxonomic Additions and Changes: Nil.

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