

BRYOPHYTE FLORA AND VEGETATION ON THE ISLAND OF GRACIOSA (AZORES), WITH REMARKS ON FLORISTIC DIVERSITY OF THE AZOREAN ISLANDS

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ARQUIPÉLAGO



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The bryoflora of Graciosa was earlier documented to be 17 spp. This figure has now been changed to 107 spp. The documentation of the bryoflora of Graciosa has provided new knowledge on the autoecology of several bryophytes; several have got wider altitude ranges; substratum preferences are more pronounced at low altitude levels than in the cloud-zone forest; high altitude species have more pronounced demands for shelter and substratum moisture on Graciosa than at high altitudes on other islands in the archipelago. Bryophyte communities distinguished: The epiphytic *Frullanietum microphyllae*; the epilithic-epigeic *Tetrastichium-Dumortiera* - association; the epilithic *Grimmia azorica*-*Ptychomitrium* - alliance (including the *Grimmietum azoricae* and *Ptychomitrium polyphyllae* by V. HÜBSCHMANN 1974); the epigeic *Myurium-Allorgea-Fissidentetum pallidicaulis* - all. (comprising the mini-associations *Fissidentetum serrulati*, *Fissidentetum pallidicaulis*, *Diphyscietum foliosi* by V. HÜBSCHMANN 1974). Plant diversity on the Azorean islands is not positively correlated to island size or topographical features. But high altitude provides high and equally high diversity figures on islands of widely different size. Richly varied habitat conditions within the coastal zone on Graciosa helps to explain the high vascular plant diversity of the island, widely differing from that of other Azorean islands, if their size and altitude are considered. The bryophyte diversity on Graciosa is unexpectedly high, as most parts of the island are species-poor.

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Para a brióflora da Graciosa estavam referidas 17 espécies. Este valor é agora alargado para 107 spp. Os dados recolhidos fornecem novos conhecimentos sobre a autoecologia de alguns briófitos: novos limites de altitude para algumas espécies; as preferências de substrato mostraram ser mais acentuadas a baixas altitudes do que na zona da "floresta húmida"; as espécies de altitude mostram, nesta ilha, maiores exigências de ensombramento e de substrato húmido do que as suas populações, em maiores altitudes, noutras ilhas do arquipélago. Distinguem-se as briocomunidades como epífita, *Frullanietum microphyllae*; associação *Tetrastichium* - *Dumortiera* como epilítica - epigeica, a aliança *Grimmia azorica* - *Ptychomitrium* como epilítica (incluindo o *Grimmietum azoricae* e o *Ptychomitrium polyphyllae* de V. HÜBSCHMANN 1974); e a aliança *Myurium* - *Allorgea* - *Fissidentetum pallidicaulis* como epigeica (compreendendo as mini-associações *Fissidentetum serrulati*, *Fissidentetum pallidicaulis* e *Diphyscietum foliosi* de V. HÜBSCHMANN 1974). A análise de diversidade florística das ilhas dos Açores mostra não haver uma correlação positiva desta com o tamanho da ilha ou com os factores topográficos. Por outro lado as ilhas com altitude mais elevada mostram possuir valores de diversidades altos e semelhantes entre si, independentemente da área. Para a ilha da Graciosa, a grande variedade de habitats costeiros ajuda a explicar a alta diversidade relativa da sua flora vascular acima dos valores esperados, se considerarmos a sua área e altitude. Igualmente, a diversidade da sua brióflora é, inesperavelmente, elevada, já que grandes extensões da ilha são pobres em espécies.

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INTRODUCTION

From the very beginning botanical investigations in the Azorean archipelago have been centred on the largest, most densely populated and economically developed islands. The vascular flora and vegetation of the small islands of Corvo, Santa Maria and Graciosa did not become thoroughly documented until after the 1930s.

The bryological field work on Corvo and Graciosa, carried out in 1978 by E. and J. Sjögren, was inspired by the fact that these two islands were at that time almost unknown as to their bryophyte flora and vegetation. The aims were to collect autecological, synecological and sociological data, which could be compared with results obtained earlier from the islands of S. Miguel, Terceira, Faial, Pico and S. Jorge (SJÖGREN 1978).

The island of Graciosa is situated in the central group of Azorean islands. Its size is 61 km² and the highest point of the rim of the caldeira is at 402 m a.s.l. (Fig. 1). Today most of the island area is cultivated land and grazing land. A small part of about 4 km² is covered by a semi-natural forest of *Persea*, *Pittosporum* and *Acacia* in an area of abandoned fields on the lava stream between Pedras Brancas and Praia. A small area to the SW of Serra Branca is covered by a low scrub of *Erica* and *Myrsine*.

At the time of discovery, Graciosa was

covered by indigenous forest composed by "cedro", "sanguinho" and "louro" (*Juniperus brevifolia*, *Frangula azorica*, *Laurus azorica*) according to COSTA (1845). This forest was progressively felled and nothing was left by the middle of the 19th century. At that time, plantation of "faias", "álamos" and "pinheiros" (*Myrica faya*, *Populus*, *Pinus pinaster*) had already been in progress for 30 years.

This valuable information may suggest that the flora of Graciosa was richer in Azorean cloud-zone plants about 200 years ago, whereas the coastal zone flora may have been much more species-poor than nowadays. The consequence of these far-reaching changes of the landscape of Graciosa has been a progressive reduction in the number of localities with suitable habitat conditions for colonization and survival of shelter-demanding bryophytes. They now have to be looked for in deep ravines, in the Furna of the Caldeira and in the shelter provided by forest plantations. Consequently, such localities had to be intensively investigated and they were also found to be very rich in species that had not formerly been documented on the island.

A few climatological data ought to be given. Mean precipitation for the period 1971-1977 was 820 mm/yr (Sta. Cruz) and mean relative humidity for the same period was 77%. Coastal rainfall is thus only about 100 mm higher than on S. Miguel and about 200 mm lower than at sea level on Faial and S. Jorge. An increase of rainfall/100 m by 20% would mean that the highest altitudes on Graciosa would at least get 1450 mm/yr. The base level of completely developed *Juniperion brevifoliae* (on other Azorean islands at altitudes with a rainfall of 2200 - 2400 mm/yr) is consequently not reached on Graciosa. The presence of cloud-zone bryophytes on the island is thus possible only in places where efficiently compensating habitat conditions are available (shelter from desiccating insolation and wind, permanently moistured substrates, permanently high air humidity).

BRYOPHYTE FLORA

The bryophyte flora of Graciosa is, as documented in this paper (sampling areas in Fig. 1), made up of 40 hepatics and 67 mosses (17 spp. listed by EGGERS 1982). A lower percentage of hepatics (28%) is only available on the comparatively dry island of Santa Maria. On the other high-altitude islands of the central Azorean group, the proportion of hepatics is 46 - 51% of the total number of bryophytes. On the highly exploited islands of Flores and S. Miguel there is a percentage of 40% of hepatics. Among hepatics, there is a much higher proportion of shelter-and moisture-demanding species than among mosses. Consequently, the proportion of hepatics is lower on the dry low altitude islands and on the islands with small remnants of sheltering cloud-zone forest. Only Pico, with large reforested areas and the largest remaining areas of *Juniperion brevifoliae*, has a higher number of hepatics than mosses (99 and 96 spp.).

The proportion of bryophytes on Graciosa, which in other parts of the archipelago preferentially grow in the cloud-zone, is low (19%). Only 10 hepatics and 11 mosses belong to that group. The localities of those species are few and concentrated to the Pedras Brancas forest, to the Furna of the Caldeira and to some deep ravines in the SW part of the island. Most of the cloud-zone species on Graciosa have been documented in the epiphytic moss cover (*Frullanieta microphylla*) on *Persea*, *Acacia* and *Pittosporum* and in associations on moist, sheltered soil escarpments (which belong to the *Myurium*-*Allorgea*-*Fissidens pallidicaulis* - all.). The proportion of hepatics in these associations is much higher than in other bryo-communities on the island.

Only a few of the bryophyte species on Graciosa reach high cover percentages, such as: (1) *Frullania microphylla* and *Lejeunea lamacerina* on sheltered rock surfaces and stem bases in forests, indicating favourable habitat conditions for several of the shelter-demanding hepatics

documented on the islands; (2) *Thuidium tamariscinum*, *Scleropodium* spp. in open grasslands at all altitude levels, with few associated species; (3) *Nardia scalaris*, *Philonotis rigida*, on moist sheltered soil escarpments with a wide range of accompanying hepatics; (4) *Ptychomitrium nigricans* and *Grimmia trichophylla* spp. *azorica* on fully exposed surfaces, indicating presence of several drought-tolerant coastal-zone mosses (few hepatics); (5) *Myurium hochstetteri*, *Allorgea berthelotiana* and *Fissidens taxifolius* spp. *pallidicaulis* on permanently moist and sheltered soil escarpments, where highly moisture demanding hepatics occur frequently.

BRYOPHYTE VEGETATION

Bryophyte communities on Graciosa were studied using altogether 82 sample plots (size 4 dm²). The sampling areas are shown in Fig. 1. A selection of the investigated plots has been presented in Tables 1-4. Only presence of the documented species has been given, as cover degrees in Azorean bryophyte communities are most variable and mainly accidental (cf. SJÖGREN 1978). The communities have been compared with those distinguished earlier from other parts of the archipelago.

Epiphytic

The *Frullanieta microphylla* Sjn. 90 nov. ass. (Table 1; F=epiphytic) grows on Graciosa on stems of *Pittosporum undulatum*, *Acacia melanoxylon* and *Persea indica* at altitudes between 100 - 200 m, frequently fragmentarily developed such as in plot 9. Species with fairly strong differential value (a) and also high frequency are only *Frullania microphylla* and *Cololejeunea minutissima*. Both species occur, although not frequently, in the Azorean epiphytic and epixylic bryo-communities of the cloud-zone forest. They are frequent only in the epiphyllous *Cololejeuneetum azoricae*. Group (b) includes species with low differential value, namely *Cololejeunea azorica* (diff. sp. of the epiphyllous



Fig. 1 - Black dots: sampling areas. The lines of short dashes: occasionally water-bearing ravines. Thick lines of long dashes: roads.

ass.) and *Harpalejeunea ovata*, which has only got a diff. val. towards epigeic and epilithic communities. The number of accompanying species (c), most of them hepatics, is fairly low and the association has a low mean number of species. It is restricted to tree species with smooth bark surfaces, where it forms the primary stage of moss colonization. It becomes fairly rapidly succeeded by a dense carpet of highly competitive species such as *Frullania tamarisci*, *Porella canariensis* and *Hypnum uncinatum*.

A similar *Frullania microphylla*-community from S. Miguel has been shortly commented (V. HÜBSCHMANN 1974), with suggestions that it should be made up of several associations. Such associations would, however, exist only on the level of mini-associations, mainly distinguished

by some species which may accidentally reach high cover degrees.

The *Frullanietum microphyllae*, typical of dense forests of mainly introduced species, below the cloud-zone forests, was recorded by the author in 1965-1978 (not published) on Terceira, Faial and Pico. As compared with the *Cololejeuneetum azoricae* and the epiphytic *Echinodio-Lepidozietum cupressinae* it is possible to regard the *Frullanietum microphyllae* as a less distinctly distinguished association, to some extent formed by a stable but impoverished group of species, which is also present in those two endemic cloud-zone associations of the *Juniperion brevifoliae*. Some of the accompanying species, however, preferentially occur below the cloud-zone forest, namely

Table 1. Epiphytic moss-vegetation on the island of Graciosa (Azores).
Frullania microphylla - ass.

signum	2:	3:	4:	4:	4:	4:	8:	8:	2:	5:
	36	30	1	18	19	22	4	26	23	8
date (1978)	6/	7/	8/	8/	8/	8/	12/	12/	6/	9/
	6	6	6	6	6	6	6	6	6	6
substrate	F	F	F	F	F	F	F	F	F	F
altitude	200	100	200	200	200	200	200	200	140	150
number of species	5	6	4	5	7	5	4	7	4	4
No. in table	1	2	3	4	5	6	7	8	9	10
a.										
<i>Frullania microphylla</i>	x	x	x	x	x	x	.	x	.	.
<i>Cololejeunea minutissima</i>	.	x	x	x	x	.	x	x	.	x
b.										
<i>Cololejeunea azorica</i>	.	.	.	.	.	.	x	x	.	x
<i>Harpolejeunea ovata</i>	x	.	.	x	x	x	.	.	x	.
c.										
<i>Frullania tamarisci</i>	x	.	.	.	x	x	x	.	x	.
<i>Lejeunea ulicina</i>	x	.	.	.	.	.	.	.	.	.
<i>Lophocolea fragrans</i>	x	.	.	.	.	.	.	.	.	.
<i>Radula carringtonii</i>	.	x	x	.	x	.	.	x	.	.
<i>Lejeunea lamacerina</i>	.	x	x	x	x	.	x	x	x	x
<i>Zygodon viridissimus</i>	.	x	.	.	.	.	.	.	.	.
<i>Sematophyllum substrumulosum</i>	.	.	x	.	.	.	.	.	.	.
<i>Radula lindenbergiana</i>	.	.	.	x	.	.	.	.	.	.
<i>Porella canariensis</i>	.	.	.	.	x	.	.	x	.	.
<i>Hypnum uncinatum</i>	.	.	.	.	.	x	.	x	.	.
<i>Radula wichurae</i>	.	.	.	x	.	x	.	.	.	.
<i>Frullania dilatata</i>	.	.	.	.	.	.	.	.	.	x

Radula wichurae, *Frullania dilatata*, *Radula lindenbergiana*.

Their frequency is low in the sample plots from Graciosa but further investigations on other Azorean islands may eventually rank them as additional differential species of the *Frullania microphylla*, which would considerably strengthen the value of this association, new to the Azores.

Epilithic

The epilithic moss vegetation in the Azores is richly varied. There are several associations from the coast to the highest altitudes. Most associations are not strictly epilithic as they generally grow on stones or rock surfaces covered by a more or less thick layer of soil and litter. They may be regarded as epilithic-epigeic. Strictly epilithic communities are largely found in the coastal zone of the islands. In the cloud-zone they occur principally on fully exposed lava field surfaces.

In general, the epiphytic, epixylic and epi-

phyllous communities are fairly easily separated from the epilithic and epigeic ones. Within these two community groups, transitions become progressively more frequent towards altitudes of potential growth of the cloud-zone forest (*Juniperion brevifoliae*). Even below the cloud-zone, such transitions may be frequent in very sheltered habitats, providing places with cloud-zone conditions, such as in ravines, in deep crevices and explosion holes in lava streams, etc.

The epilithic bryo-communities on Graciosa are few and easily separated from others, mainly due to the scarce presence of cloud-zone species on the island. Only two communities will be treated below.

The *Tetrastichium-Dumortiera* - ass. Sjn. 90 nov. ass. (Table 2) has been documented in several localities between 140 - 300 m, on moist sheltered rock surfaces. The four differential species, (a) *Tetrastichium fontanum*, *Riccardia latifrons*, *Dumortiera hirsuta* and *Lepidopilum virens* may all occur as dominants as well as some of the accompanying species listed in the table, such as *Thamnobryum alopecurum*, *Fis-*

Table 2. Epilithic-epigeic moss-vegetation on the island of Graciosa (Azores). *Tetrastichium-Dumortiera* - ass.

signum	3:	3:	3:	9:	2:	9:	9:	10:	10:
	8	10	20	17	31	13	17	9	16
date (1978)	7/	7/	7/	13/	6/	13/	13/	14/	14/
	6	6	6	6	6	6	6	6	6
altitude m a.s.l.	140	140	140	300	140	300	300	275	275
number of species	4	8	10	4	3	5	4	6	4
No. in table	1	2	3	4	5	6	7	8	9
a.									
<i>Tetrastichium fontanum</i>	x	x	x	*	x	*	*	*	*
<i>Riccardia latifrons</i>	x	x	x	x	*	*	x	*	*
<i>Dumortiera hirsuta</i>	*	x	x	*	x	x	*	*	*
<i>Lepidopilum virens</i>	*	x	x	x	*	*	x	x	x
c.									
<i>Lejeunea lamacerina</i>	x	*	x	*	*	*	*	x	*
<i>Thamnobryum alopecurum</i>	x	x	x	*	*	*	*	*	*
<i>Fissidens tax.v. pallidicaulis</i>	*	x	x	*	*	x	*	x	*
<i>Eurhynchium praelongum</i>	*	x	x	*	*	x	*	*	*
<i>Marchantia paleacea</i>	*	x	*	*	*	x	*	*	*
<i>Hypnum uncinatum</i>	*	*	x	*	*	*	*	*	*
<i>Heterocladium heteropterum</i> sim.	*	*	x	*	*	*	*	*	*
<i>Brachythecium populeum</i>	*	*	*	x	*	*	x	*	*
<i>Lophocolea fragrans</i>	*	*	*	x	*	*	x	*	*
<i>Rhynchostegiella tenella</i>	*	*	*	*	x	x	*	x	x
<i>Marchesia mackayii</i>	*	*	*	*	*	*	*	x	*
<i>Fissidens crassipes</i>	*	*	*	*	*	*	*	x	x
<i>Epipterygium tozeri</i>	*	*	*	*	*	*	*	*	x

sidens taxifolius var. *pallidicaulis* and *Eurhynchium praelongum*. The association is probably endemic to the Azores.

The *Dumortiera hirsuta* - *Jubula hutchinsiae* - ass. Allorge 1947 was recorded by v. HÜBSCHMANN (1974) on S. Miguel, with the *Tetrastichium fontanum* community as a facies constituent without *Jubula hutchinsiae*. In my opinion, there is good justification to treat this so-called facies as an association being supplied with two additional differential species. The *Tetrastichium-Dumortiera* - ass. exist on all the Azorean islands, except Corvo and Santa Maria (cf. SJÖGREN 1978, p. 124). In several localities the association has no strict limits towards the fragmentarily documented and most - probably in the Azores - weakly differentiated associations *Fegatellum conicae* and *Thamnetum alopecuri* (v. HÜBSCHMANN 1974).

The *Grimmia azorica*-*Ptychomitrium* - all. (Table 3) includes the *Grimmietum azoricae*

and the *Ptychomitrium polyphyllae* by v. HÜBSCHMANN 1974. These two associations are frequently present on Graciosa, from the coast up to 200 m a.s.l. They occur in fully exposed localities, providing the first colonization of a moss-carpet on slightly, or not at all, soil covered stone surfaces.

Character species of the alliance are (a) *Ptychomitrium nigrescens* and *Tortella nitida*. Five species of lower differential value have been referred to group (b). The number of accompanying species (c) is very large. Several species occur accidentally and microhabitats supporting their presence are frequently present, even within the small sample plot size of 4 dm².

In the *Grimmia azorica*-*Ptychomitrium* - all. on Graciosa some differential species of its two associations have not been documented, namely *Grimmia trichophylla*, *Ptychomitrium polyphyllum* and its local var. *azoricum*. The *Grimmietum azoricae* is most probably a coastal-zone

Table 3. Epilithic moss-vegetation on the island of Graciosa (Azores). *Grimmia azorica* - *Ptychomitrium* - all.

signum	1:	2:	2:	2:	2:	2:	2:	2:	2:	3:	3:	3:	4:	4:	4:	4:	5:	7:	10:	10:	13:	4:
	8	2	13	16	21	23	27	46	47	23	24	25	21	24	27	28	2	1	1	15	3	20
date (1978)	5/	6/	6/	6/	6/	6/	6/	6/	6/	7/	7/	7/	8/	8/	8/	8/	9/	11/	14/	14/	17/	8/
	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
altitude m a.s.l.	20	140	140	140	140	140	140	200	200	10	100	100	200	200	200	200	150	130	275	275	200	200
number of species	5	6	7	6	4	10	5	8	5	4	5	9	6	8	6	4	5	4	10	9	6	5
No. in table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
a.																						
<i>Grimmia azorica</i>	x	x	*	x	x	x	x	x	x	x	x	x	x	x	*	x	x	x	x	x	x	x
<i>Ptychomitrium nigricans</i>	x	x	*	x	*	*	x	*	*	x	*	*	x	*	x	*	x	x	*	*	*	x
<i>Tortella nitida</i>	*	*	x	*	x	x	*	*	*	*	x	x	x	x	*	x	*	x	*	*	*	x
b.																						
<i>Frullania dilatata</i>	x	x	*	*	*	x	x	x	x	x	*	x	*	*	*	*	x	x	x	*	x	*
<i>Leucodon canariensis</i>	x	x	*	*	*	x	*	*	*	*	*	*	*	*	*	*	*	*	*	x	*	*
<i>Brachythecium populeum</i>	*	*	*	*	*	*	*	x	*	*	x	x	*	*	*	*	*	x	x	*	*	*
<i>Scorpiurium circinatum</i>	*	x	x	x	*	*	*	*	*	*	*	*	*	*	x	*	*	*	*	*	x	*
<i>Campylopus pilifer</i>	*	*	x	x	x	*	*	*	*	*	*	*	x	*	x	*	*	*	*	x	x	x
c.																						
<i>Hypnum jutlandicum</i>	*	x	*	*	x	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
<i>Allorgea berthelotiana</i>	*	*	x	*	*	*	*	*	*	*	*	*	*	x	*	*	*	*	*	*	*	*
<i>Frullania tamarisci</i>	*	*	x	*	*	x	*	x	x	*	*	*	*	x	*	*	*	*	x	x	*	*
<i>Radula carringtonii</i>	*	*	x	*	*	x	*	*	*	*	*	x	*	x	*	x	*	*	x	x	x	*
<i>Radula wichurae</i>	*	*	x	*	*	*	x	x	*	*	*	x	*	x	*	x	*	*	*	*	*	*
<i>Hypnum resupinatum</i>	*	*	*	x	*	x	*	*	*	x	*	*	*	*	*	*	*	*	*	*	x	*
<i>Porella canariensis</i>	*	*	*	*	*	x	*	*	*	*	*	x	*	x	*	*	*	*	x	*	*	*
<i>Eurhynchium praelongum</i>	*	*	*	*	*	x	*	x	*	*	*	*	*	*	*	*	*	*	x	*	*	*
<i>Lejeunea lamacerina</i>	*	*	*	*	*	*	x	*	*	x	x	*	*	*	*	*	*	*	x	*	*	*
<i>Pterogonium gracile</i>	*	*	*	*	*	*	*	x	x	*	*	*	*	*	*	*	*	*	*	*	*	*
<i>Harpalejeunea ovata</i>	*	*	*	*	*	*	*	x	x	*	*	*	*	x	*	*	*	*	x	x	*	*
<i>Radula lindenbergiana</i>	*	*	*	*	*	*	*	*	*	*	*	x	*	*	x	x	*	*	*	*	*	*
<i>Hypnum uncinatum</i>	*	*	*	*	*	*	*	*	*	*	*	x	*	x	*	*	*	*	*	*	*	*
<i>Bryum</i> sp.	*	*	*	*	*	*	*	*	*	*	*	*	x	*	*	*	x	*	*	x	*	x

Other accompanying species: *Fissidens bryoides* (1), *Homomallium incurvatum* sim. (4), *Saccogyna viticulosa* (6), *Herzogiella striatella* (13), *Bryum donianum* (15), *Philonotis rigida* (15), *Brachythecium plumosum* (17), *Zygodon viridissimus* (19), *Plagiochila spinulosa* (20), *Campylopus fragilis* (20).

Table 4. Epigeic moss-vegetation on the island of Graciosa (Azores). *Myurium-Allorgea-Fissidens pallidicaulis* - all.

signum	2:	2:	8:	8:	8:	8:	8:	8:	8:	9:	9:	9:	2:	2:	2:	4:	8:	8:
date (1978)	6/	6/	12/	12/	12/	12/	12/	12/	12/	13/	13/	13/	6/	6/	6/	6/	8/	12/
substrate	G	L	G	G	L	G	G	G	G	G	G	G	G	G	G	L	L	G
altitude m a.s.l.	140	140	220	220	220	220	220	220	220	300	300	300	140	140	140	200	200	220
number of species	5	6	9	9	10	8	6	8	5	8	8	8	8	7	6	8	6	7
No. in table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19
a.																		
<i>Myurium hochstetteri</i>	*	x	x	x	x	*	x	x	x	*	*	*	*	*	*	*	x	x
<i>Allorgea berthelotiana</i>	x	x	x	*	*	*	*	*	*	x	x	x	x	x	x	x	x	*
<i>Fissidens tax.v. pallidicaulis</i>	*	*	*	x	*	*	*	*	x	*	x	x	*	x	*	*	x	*
b.																		
<i>Saccogyna viticulosa</i>	x	x	*	x	x	x	x	x	x	x	*	*	x	x	x	*	*	*
<i>Calypogeia fissa</i>	*	*	x	x	*	x	x	x	x	x	*	*	*	*	*	x	*	*
<i>Scleropodium touretii</i>	*	*	*	x	*	x	x	*	*	*	*	*	*	*	*	*	*	*
<i>Epipterygium tozeri</i>	*	*	*	*	*	x	*	*	*	x	x	x	*	*	*	*	*	*
c.																		
<i>Frullania tamarisci</i>	x	x	x	x	x	x	x	x	*	x	*	*	x	*	x	x	x	x
<i>Hypnum uncinatum</i>	x	*	*	*	*	*	*	*	*	*	*	*	*	*	*	x	x	*
<i>Radula carringtonii</i>	x	x	x	*	x	x	*	x	*	*	*	*	*	*	x	*	x	*
<i>Hypnum resupinatum</i>	*	x	*	*	*	*	*	*	*	*	*	*	x	x	*	*	*	x
<i>Porella canariensis</i>	*	*	x	x	x	x	*	*	*	*	*	*	*	x	*	*	*	*
<i>Plagiochila spinulosa</i>	*	*	x	x	x	x	*	x	*	*	*	*	*	*	*	x	*	*
<i>Lejeunea lamacerina</i>	*	*	x	x	x	*	*	*	*	*	*	x	*	*	*	x	*	*
<i>Harpalejeunea ovata</i>	*	*	*	*	x	*	*	x	*	*	*	*	x	*	*	*	x	x
<i>Campylopus pilifer</i>	*	*	*	*	x	*	*	*	*	*	*	*	*	*	*	*	*	x
<i>Campylopus fragilis</i>	*	*	*	*	x	*	*	*	*	*	*	*	*	*	*	*	*	x
<i>Porella obtusata</i>	*	*	*	*	*	*	x	x	*	*	*	*	*	*	*	*	x	*
<i>Eurhynchium praelongum</i>	*	*	*	*	*	*	*	*	x	*	*	x	*	*	*	*	*	*
<i>Tortella nitida</i>	*	*	*	*	*	*	*	*	x	*	*	*	*	x	*	x	*	*
<i>Fossombronia</i> sp.	*	*	*	*	*	*	*	*	x	x	*	*	*	*	*	*	*	*
<i>Fissidens bryoides</i>	*	*	*	*	*	*	*	*	*	*	x	x	*	*	*	*	*	*
<i>Reboulia hemisphaerica</i>	*	*	*	*	*	*	*	*	*	*	x	x	*	*	*	*	*	*
<i>Weissia</i> sp.	*	*	*	*	*	*	*	*	*	*	x	x	*	*	*	*	*	*
<i>Anthoceros punctatus</i>	*	*	*	*	*	*	*	*	*	*	*	*	*	*	x	*	*	*
<i>Ptychomitrium nigricans</i>	*	*	*	*	*	*	*	*	*	*	*	*	x	x	*	x	*	*
<i>Radula wichurae</i>	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	x	*	x

Other accompanying species: *Plagiochila corniculata* (3), *Nardia scalaris* (10), *Marchantia paleacea* (11), *Fissidens asplenioides* (13), *Radula lindenbergiana* (13), *Riccardia latifrons* (15), *Drepanolejeunea hamatifolia* (20), *Cephaloziella divaricata* (20).

association whereas the *Ptychomitrium polyphyllae* occurs from the coast up to the cloud zone. Further investigations may accentuate the difficulties in maintaining these two associations as separate units in the Azores, already documented by the author. Their spectra of accompanying species are locally very similar, frequently with *Campylopus pilifer* reaching high cover percentages.

Epigeic

The epigeic moss vegetation of sheltered moist

soil escarpments has been described in Table 4 (substrate: G = epigeic, L = epilithic). The sample plots have been analysed in localities between 140-300 m. The suggested *Myurium-Allorgea-Fissidens pallidicaulis* - all. has three characterizing species, (a) *Myurium hochstetteri*, *Allorgea berthelotiana* and *Fissidens taxifolius* var. *pallidicaulis*. These species are preferentially epigeic and epilithic. The substratum preference is weaker at cloud-zone altitudes, where at least *Myurium* and *Allorgea* may also occur epiphytically on *Erica* and *Juniperus*.

Frequently associated species with weaker differential value are, (b) *Saccogyna viticulosa*, *Calypogeia fissa*, *Scleropodium touretii* and *Epiphygium tozeri*. Also these four species are preferentially epigeic (epilithic) but tend to become progressively more frequent also on other substrates towards altitudes of potential cloud-zone forest. The number of accompanying species (c) is very high within the alliance. Some of these species also occur within the earlier - described epilithic communities.

Several associations of the Myurium - Allorgea - Fissidens pallidicaulis - all. may be distinguished if maintained at a level of mini associations such as the Fissidentetum serrulati, Fissidentetum pallidicaulis, Diphyscietum foliosi (cf. v. HÜBSCHMANN 1974). These associations are extremely difficult to maintain as they occur frequently in all the Azorean islands in a dense mixture, with the species spectrum and the cover of the species correlated to altitude (rainfall), shelter, coarseness of substrate, inclination and aspect.

A well-documented investigation of the associations of the alliance, avoiding mini-associations distinguished by only one or two frequently dominating species, will probably lead to the differentiation of just a few large-scale associations. They may be endemic to the Azores islands and characterized by quite a few bryophytes endemic to the Azores or to Macaronesia as a whole, such as the hepatics *Calypogeia azorica*, *Chiloscyphus denticulatus*, *Plagiochila allorgei*, *Tylimanthus azoricus*, and the mosses *Alophozia azorica*, *Allorgea berthelotiana* and *Breutelia azorica*.

REFLECTIONS ON PLANT DIVERSITY

This chapter was inspired by the recently greatly improved knowledge of the vascular and bryophyte flora of the small islands in the Azores, earlier forgotten by botanists. Until the investigations by Palhinha, Graciosa was only extensively known as to its vascular flora, and the

bryoflora has remained almost unknown before the publication of this paper. Also, the vascular and bryophyte flora of Graciosa were found to be amazingly large, considering the small size of the island.

The floristic composition of the Azorean vegetation has been intensively studied for almost 150 years. The main interest among botanists has been attributed to vascular plants and bryophytes. Some of the islands, however, namely Graciosa, S. Jorge and Corvo, remained only superficially known as to their vascular plants until the beginning of this century. The more comprehensive knowledge about bryophytes of the islands is of much later date, starting in the 1930s (Allorge, Persson, Sjögren, v. Hübschmann). At an early stage bryophytes were studied mainly on S. Miguel, Terceira, Faial and Flores. The bryophyte flora of S. Jorge, Santa Maria and Pico has become better known only after the 1950s. This paper was aimed to provide better knowledge of the bryophyte vegetation and flora of Graciosa and will be followed shortly by a similar one dealing with Corvo, both being reports of the author's investigations in 1978. Whereas the vascular flora of the nine islands may now be considered as being fairly well known there are certainly numerous bryophytes to be discovered, even on the islands that were earlier the most intensively investigated.

The vascular plants in the Azores number about 960 spp. (cf. HANSEN & SUNDING 1985) and there are about 450 bryophytes, of which 175 are hepatics (cf. EGGERS 1982). The number of vascular plants has recently been estimated to 1011 spp. (HANSEN 1988). The largest numbers of vascular plants and bryophytes have been recorded on the largest island of S. Miguel, the fewest on the very small island of Corvo. The known plant diversity on the Azorean islands is somewhat confusing if only the size of the islands is considered. The diversity will therefore be treated below, taking into consideration some aspects such as: (1) size of the is-

land, (2) altitude, (3) topographic features, (4) cultural influences and remains of cloud-zone forests, (5) communications between the islands and with the continents, (6) earlier investigations.

The numbers of endemic plants will also become commented. There are 53 vascular plant taxa (incl. 7 subspecies) endemic to the Azores and 14 taxa endemic to the Azores including at least one other Macaronesian island group. The respective numbers for bryophytes are 15 and 32 taxa (11 taxa at the level of subsp. and var. are endemic to Macaronesia).

S. MIGUEL (M): 684 vascular plants (HANSEN & SUNDING 1985), 348 bryophyte species (EGGERS 1982). 42 of the vascular plant taxa are endemic to the Azores, 10 to Macaronesia; of the bryophytes 13 and 19 respectively (including 5 taxa at the level of subsp. + var., endemic to Macaronesia). Size of the island 747 km², max altitude 1103 m. Richly varied topography with several caldeiras, volcanic cones and deep river ravines, especially in the W and E parts of the island. One of the main centres of communication in the archipelago. Cultivation has left larger areas of the endemic cloud-zone forest unspoiled only in the E part of the island. Intense botanical investigation.

The species numbers of S. Miguel (0.91/km² of vascular plants and 0.47/km² of bryophyte taxa) will here be used for comparison (cf. Table 5). The survival of several cloud-zone forest plants, both vascular plants and bryophytes, is now threatened by reforestation with foreign tree species. Further invasion of species into the cultivated landscape may take place.

PICO (P): 506 vascular plants (HANSEN & SUNDING 1985), 195 bryophyte species (EGGERS 1982). 45 of the vascular plant taxa are endemic to the Azores, 9 to Macaronesia; of the bryophytes 9 and 16 (including 4 taxa at the level of subsp. + var.) respectively.

Size of the island 433 km², altitude 2351 m.

Richly varied topography, with a large number of caldeiras, volcanic cones, caves and ravines all over the island. Comparatively scarce communications, except with the nearby island of Faial. In the coastal zone rich cultivation and reforestation, in the cloud-zone large seminatural grasslands and also the largest remains of natural forest in the archipelago. Intense botanical investigation mainly after 1897 (Trelease).

Vascular plant diversity 1.26 x higher than on M, bryophyte diversity 0.95 x, considering the size of the island. The high-altitude areas above the cloud-zone forest (above 1200 m) do hardly increase the plant diversity of the island, as mainly occupied by a vegetation which becomes a progressively depoverished towards the top of the volcano. The large areas of grazing-land decrease the possibilities for colonization of several species. The species diversity on the island is, however, strongly differentiated, being exceptionally high in the dense natural forest areas and very low in fully exposed habitats as well as in reforested places on the lava fields at low altitudes. The vascular plants of Pico are now well known and only few species may eventually become added to the flora (such as more or less accidental weeds). The bryophyte flora, composed of about 50% hepatics, is not as well known, mainly due to the large number of difficultly accessible localities, such as caves, explosion holes and large areas of almost impenetrable *Juniperion brevifoliae* forests on very rough lava fields.

TERCEIRA (T): 620 species of vascular plants (DIAS 1988), 218 bryophyte species (EGGERS 1982). 42 of the vascular plant taxa are endemic to the Azores, 10 to Macaronesia; of the bryophytes 10 and 13 (including 4 taxa at the level of subsp. + var.) respectively. Size of the island 397 km², max. altitude 1021 m. The topography is rough, with caldeiras, volcanic cones and ravines, principally in the W and central parts of the island. One of the three principal communication islands in the archipelago. The

main parts are cultivated (fields, reforestation, grazing land), but large areas of unspoiled cloud-zone forest still remain in the area of Santa Barbara and to the N of Furnas do Enxofre. The vascular plant flora and the bryophytes have been intensively investigated (in recent times especially by I.B. Gonçalves and by Eduardo Dias).

Vascular plant diversity is 1.71 x higher than on M, bryophyte diversity 1.15 x. The reason for these figures is most probably the high altitude of the island, the sheltered biotopes in the big caldeira (and to some extent the frequent communications with other islands and the continents, increasing the number of introduced plants). The number of vascular plants may remain fairly stable, provided that the presently existing areas of natural forests do not become further exploited.

S. JORGE (J): 424 vascular plants (HANSEN & SUNDING 1985), 214 bryophyte species (EGGERS 1982). 43 of the vascular plant taxa are endemic to the Azores, 10 to Macaronesia; of the bryophytes 9 and 17 (including 5 taxa at the level of subsp. + var.) respectively.

Size of the island 238 km², max. altitude 1053 m, with large parts of the island above 500 m. The topography is extremely rough with numerous ravines around the island and a large number of volcanic cones. Communications have been even less frequent than between Pico and the other islands. Large areas are cultivated mainly as semi-natural grazing land. There are only small remnants of the former cloud-zone forests at high altitudes, now restricted to ravines. The vascular flora became thoroughly known only after the investigations by Palhinha since the 1930s. The bryophytes were only extensively known before the 1940s.

Vascular plant diversity is 1.95 x higher than on M, bryophyte diversity 1.91 x. The steep coasts all around the island, the comparatively small areas of fields and the large areas of grasslands will probably eventually result in only a

small stable addition of new plants to the island. The diversity of the bryophyte flora may become lower, as several species of the cloud-zone forest are now growing in ravines, where only a small decrease of sheltering trees and shrubs may threaten their survival. This will also have a negative effect on several of the vascular plants that are sparsely present today, and which are differential species of the endemic cloud-zone forest.

FAIAL (F): 594 vascular plants (HANSEN & SUNDING 1985), 224 bryophyte species (EGGERS 1982). 44 of the vascular plant taxa are endemic to the Azores, 10 to Macaronesia; of the bryophytes 9 and 15 (including 4 taxa at the level of subsp. + var.) respectively.

The size of the island is 172 km², max. altitude 1043 m. The topography is rough with numerous small and large ravines at high altitudes around the main caldeira and in areas with some volcanic cones in the westernmost part of the island. One of the principal communication islands in the archipelago. The main parts of the island are cultivated. Small remnants of the cloud-zone forest are retreating to the interior of the main caldeira. The vascular and bryophyte flora have been intensively investigated.

Vascular plant diversity is 3.79 x higher than on M, bryophyte diversity 2.77 x higher. Reasons for these unexpectedly high figures are the altitude of the island, the rich number of biotopes in the very deep and large caldeira, which is not very accessible. The introduction, deliberately or not, of a large number of plants to the cultivated parts of the island also explains the high diversity. The large number of bryophytes is due to the rich variation of biotopes and probably to some extent to the intense investigations. The number of bryophytes may eventually suffer a decrease, as several species may now occur as unstable relicts under marginal habitat conditions in a landscape deprived of most of its cloud-zone forest.

FLORES (L): 320 vascular plants (HANSEN & SUNDING 1985), 241 bryophytes (EGGERS 1982). 37 of the vascular plant taxa are endemic to the Azores, 10 to Macaronesia; of the bryophytes 5 and 16 (including 5 taxa at the level of subsp. + var.) respectively.

The size of the island is 143 km^2 , max. altitude 914 m, with large parts of the island above 300 m. The topography is rough with numerous volcanic cones, caldeiras and ravines. The isolated position of this westernmost island has always meant sparse communication with other islands in the archipelago. Large areas are now transformed to grazing land, which has mostly turned into grasslands of inferior quality as a result of being invaded by *Sphagnum* species, where the cloud-zone forests have been totally felled and where vascular plants have not been able to compete with the mosses (precipitation higher than 3000 mm/yr). Fortunately there are still fairly large remains of the cloud-zone forest at the highest altitudes. The vascular plants have been well known since the 1870s (WATSON 1870). The bryoflora became thoroughly investigated mainly due to the important work carried out since the 1930s by P. and V. Allorge.

Vascular plant diversity is $3.01 \times$ higher than on M, bryophyte diversity $3.60 \times$ higher. The number of vascular plants and bryophytes is exceptionally high, if only size and altitude of the island are considered. However, most of the island area is above the lower altitude limit for potential growth of a richly developed *Juniperion brevifoliae*, due to the considerably higher rainfall than on other Azorean islands (cf. SJÖGREN 1978, p. 18). This fact may be the main reason for the high diversity figures, also being positively influenced by the rich differentiation of biotopes, linked to the rough topography of the island. Unfortunately, a decrease of the plant diversity on Flores is highly probable, due to the destruction of cloud-zone forest. An equally important transformation of the landscape in the Azores has taken place on C and J.

SANTA MARIA (S): 422 vascular plants (HANSEN & SUNDING 1985), 110 bryophytes (EGGERS 1982). 25 of the vascular plant taxa are endemic to the Azores, 5 to Macaronesia; of the bryophytes 0 and 5 (including 3 taxa at the level of subsp. + var.) respectively.

The size of the island is 97 km^2 , max. altitude 587m. The topography is fairly even in large parts of the island. Fairly high communication frequency with other islands in the archipelago and the most frequently communicated island by air until a few years ago. The low, comparatively dry, S parts are heavily overgrazed and deprived of shrubs and trees. Fractions of the cloud-zone forest remain only in small parts at high altitudes. Investigation of the vascular flora has been intense only since the beginning of this century (several recent recordings by D. Pombo and A. Hansen). The bryoflora is still incompletely known.

Vascular plant diversity is $4.78 \times$ higher than on M, bryophyte diversity $2.40 \times$ higher. The large number of vascular plants is partly due to a rich presence of weeds in the lower areas of the island. The number of bryophytes is as low as on G, although some calcicolous species occur, which are absent or rare on other islands in the archipelago. The lack of cloud-zone forest is most probably the reason for the low bryophyte diversity. The vascular flora may eventually become slightly increased as a result of invasion by drought-tolerant species to the lower parts of the island. The bryoflora, more intensively investigated, may be found to be about 50% larger than recorded today.

GRACIOSA (G): 324 vascular plants (HANSEN & SUNDING 1985), now 44 more species after the recordings of E. and J. Sjögren in 1978 (unpublished). 107 bryophytes (EGGERS 1982, incl. species new to the island, listed in this paper). 13 of the vascular plant taxa are endemic to the Azores, 3 to Macaronesia; of the bryophytes 2 and 10 (including 2 taxa at the level of subsp. + var.) respectively.

The size of the island is 61 km², max. altitude 402 m. The lowest island in the Azores, with unusually even topography especially in the W part; in the S and SE with a few volcanic cones, one small and one large caldeira; few deep ravines. Fields and grazing land dominate the island. An *Erica*-dominated scrub is still left in small areas, with a severely impoverished type of flora, including a few plants of the cloud-zone forest. There are a few reforested areas, the largest one (partly spontaneous) on a formerly cultivated lava-field to the NE of Pedras Brancas. A sparsely communicated island, although close to P, J, T and F. The vascular flora was only extensively known before TRELEASE (1897), and the bryoflora was very poorly known before 1978 (4 hepatics, 13 mosses).

Vascular plant diversity is 5.83 x higher than on M, bryophyte diversity 3.72 x higher. The vascular flora of G is most unexpectedly large, as compared with the more than 12 x larger island of M. Approximately 50 vascular plants typical of the cloud-zone forest communities are not present on G and at least an equally large number of bryophytes. Considering precipitation and relative humidity, the coastal climate is not very different from that on the other islands of the central group, which may contribute to the high number of vascular plants. The bryophyte diversity is positively influenced by the presence of ravines. Several of the species not tolerant to drought have their only locality in the Furna of the Caldeira. Both the vascular and bryophyte flora may now be regarded as fairly stable. Several bryophytes may, however, still be under-recorded or not yet documented.

CORVO (C): 300 vascular plants (HANSEN & SUNDING 1985) + 6 species recorded by the author in 1978, see SJÖGREN 1979). 29 bryophytes (EGGERS 1982). 34 of the vascular plant taxa are endemic to the Azores, 6 to Macaronesia.

The size of the island is 17 km², max. altitude 718 m. Topography is fairly rough due to

numerous ravines in the E part of the island. The coasts are steep all around the island except in the southernmost part. About 9 km² are occupied by intensively grazed seminatural grassland, other parts by the steep coasts, the ravines, lakes and by grazing land of inferior quality, as on L invaded by *Sphagnum* species. Fractions of cloud-zone forest exist in some ravines. Communications between C and other islands are still scarce. The number of vascular plants recorded did not reach close to today's figures until the investigations by Palhinha. The bryophyte flora with only hepatics and 22 mosses documented, is still poorly known. Vascular plant diversity is 19.3 x higher than for M. The large number of vascular plants is, as on Flores, most probably due to extremely high amounts of precipitation, which means that most parts of the island, above 200 m, are potentially available for colonization of plants of the cloud-zone forest. The determination of a bryophyte material collected in 1978 by E. and J. Sjögren, will most probably increase the number of bryophytes on the island to at least 125 spp. (78 species determined in the field). In that case, the bryophyte diversity will rise to a figure approximately 15 x higher than for M. Invasion of vascular plants will probably be small. Some of the today very small remaining relicts of cloud-zone forest plants, may become extinct. The most demanding bryophytes as regards shelter and humidity are probably not threatened in their presently colonized small-scale biotopes in deep and narrow ravines.

Concluding remarks

The diversity figures of the nine Azorean islands (Table 5), related to their size, range from 0.91 - 17.6 spp./km² for vascular plants, with the lowest figure for S. Miguel and the highest for Corvo. As compared with S. Miguel, Pico has a diversity/km² 1.27 x higher and Corvo 19.3 x higher. The figures for bryophytes range from 0.45 on Pico to 1.75 spp./km² on Graciosa (Corvo not included). The bryophyte diversity

on Pico is thus only 0.95 x as high as on S. Miguel and the highest value is 3.72 x for Graciosa.

There is apparently in the Azorean archipelago no positive correlation between island size and plant diversity if the numbers of plants/km² are considered. If the size of the islands is not considered, a fairly good correlation can be found between altitude and vascular plant diversity. The number of vascular plants/100 m of altitude ranges from 40 - 81 spp. on the islands (mean 55 spp.). The high islands of S. Miguel, Terceira and Faial have 56 - 62 spp./100 m of altitude. The figures for Corvo, S. Jorge and Flores are only 40 - 43 spp., probably due to a suppressed number of coastal zone species. The low value of 42 spp. for Pico (only counting the altitude range 0 - 1200 m, as there are few additional species above that altitude), may be due to a reduced number of coastal plants as well. On Graciosa and Santa Maria, on the other hand, the figures are 81 and 72 spp. respectively, probably due to favourable conditions for a large number of coastal plants with varied habitat demands.

The bryophyte figures of the islands range from 16 - 32 spp./100 m (mean 22 spp.). The lowest figure is 16 spp. on Pico and the highest is 32 spp. on S. Miguel probably due to insufficient and intense investigation respectively. On the other islands, the range is 20 - 27 spp. (Corvo not included), thus giving a fairly good correlation to altitude.

Frequently communicated islands (Faial, Terceira) have higher numbers of species than the sparsely communicated ones of approximately the same size (S. Jorge, Flores). The very rough topography of the islands of Pico and S. Jorge does not provide these islands with a compensating rise in numbers of species.

The particularly species-rich high islands are provided with a richer supply of climatically differentiated biotopes. However, the equally, high precipitation at 800 m on S. Miguel, at 500 m on Terceira and Pico and at about 250 m on Flores and Corvo should be taken into consideration.

The westernmost islands thus get a lower position of the basal limit for potential presence of cloud-zone forest and there is consequently less space for a richly varied coastal vegetation consisting of plant groups with different habitat demands. The almost equally large number of vascular plants on Santa Maria and on S. Jorge is due to a rich presence of coastal-zone species on Santa Maria but of cloud-zone species on S. Jorge. There is always a much larger number of Bryophytes within the altitude range for potential growth of the cloud-zone forest than within the coastal zone of the *Festucion petraeae*, which explains the more than 100 % larger number of bryophytes on Flores than on Santa Maria.

Graciosa is an extraordinary island as to diversity, which must be looked upon as unexpectedly high considering its low altitude, small size, sparse communications, fairly even topography, large areas of cultivated land and rare presence of efficiently sheltered habitats as well as absence of cloud-zone forest. The still smaller island of Corvo is characterized by even more extreme diversity figures, which are, however, more easily correlated to altitude, climate and its large areas available for potential growth of cloud-zone forest.

Still, the plant diversity on Graciosa and Corvo, in comparison with the other islands of the archipelago, clearly shows that all vegetation features cannot be explained or correlated. There is, for example, frequently a lack of necessary knowledge on the long-term development of vegetation during times of cultivation, information of major importance when treating aspects of existing vegetation.

The numbers of vascular plant taxa endemic to the Azores and to Macaronesia are almost the same on M P T J F (42 - 45 and 9 - 10). For bryophytes these figures for the same islands range between 9 - 13 and 13 - 19 taxa respectively. The diversity figures for endemic plants are apparently not positively correlated to island size but rather to altitude of the islands. The

Table 5. Diversity of vascular plants and bryophytes, including taxa at the level of subsp., on the Azores islands. Figures of diversity/km² as times higher than on S. Miguel (bryophyte figures of Corvo insufficiently known).

island	area (km ²)	altitude (m)	vascular plants			bryophytes			diversity	
			total	endemic (Az.)	endemic (Macaronesia)	total	endemic (Az.)	endemic (Macaronesia)	vascular plants	bryophytes
S. Miguel	747	1103	684	42	10	348	13	19		
Pico	433	2351	506	45	9	195	9	16	1.27	0.95
Terceira	397	1021	620	42	10	218	10	13	1.71	1.15
S. Jorge	238	1053	424	43	10	214	9	17	1.95	1.91
Taial	172	1043	594	44	10	224	9	15	3.79	2.77
Flores	143	914	320	37	10	241	5	16	3.01	3.60
Santa Maria	97	587	422	25	5	110	0	5	4.78	2.80
Graciosa	61	402	368	13	3	107	2	10	5.83	3.72
Corvo	17	718	306	34	6	--	--	--	19.30	

high islands with large parts within the cloud-zone forest range have large numbers of endemic species. For the low islands of Graciosa and Santa Maria the numbers are much lower, especially for the bryophytes. Most of the endemic Azorean bryophytes are confined to the cloud-zone forest communities of the *Juniperion brevifoliae* (Table 5).

BRYOPHYTES OF GRACIOSA, WITH REMARKS ON THEIR PRESENCE, ECOLOGY AND SOCIOLOGY

Introductory remarks

Samples: Several Azorean bryophytes, both hepatics and mosses, are difficult to determine in the field. They have therefore been sampled and determined at the Institute of Ecological Botany and the Institute of Systematic Botany, Uppsala. They are now kept and registered in UPSV. Localities for sampling have been given with brief notes on habitat such as altitude, substrate and shelter. Some easily determined, generally very frequent species, were not sampled. The altitude range of the localities where they have been recorded has been given. Numbers of sam-

ples have been added only if more than one was taken in the respective localities. Earlier documented presence of the species in the Azorean islands is according to the very informative and up to date list by EGGERS (1982).

Habitat: Some habitat preferences of the species on G principally as to substrate, altitude and shelter, have been treated. Comparisons with earlier suggestions as to preferences of the species in other parts of the archipelago (SJÖGREN 1978) were important to provide, being valuable also in sociological aspects. Altitude ranges of several species have become much wider in the archipelago after the documentation of localities on Graciosa. The unexpected presence of several cloud-zone species at low altitudes on Graciosa is, however, due to extremely efficient shelter and consequently attractive habitat conditions, such as in deep ravines, in dense forest stands and especially in the Furna do Enxofre of the main caldeira.

Sociology: Most of the Azorean bryophytes occur with indistinct confinement to other species and their range of habitats including substrate is frequently very wide. Consequently

they are not particularly suitable as differential species of one or a group of bryo-communities. Some species, on the other hand, with very restricted habitat preferences, usually appear more or less strictly associated with a group of species and may thus be given a certain differential value. Sociological affinities of the respective species were treated in this section. Differential values earlier suggested (SJÖGREN 1978) have been discussed. In some cases these values have become less pronounced after the recordings on Graciosa. The application of some differential species of small-scale associations, described earlier (V. HÜBSCHMANN 1974) has been criticized.

Nomenclature: Hepatics and mosses are treated in alphabetical order, with family names mentioned. Nomenclature of the hepatics is according to GROLLE (1983) and that of the mosses according to CORLEY & al. (1981). For some species, names frequently applied earlier, are given as synonyms.

Abbreviations:

- Mac - Macaronesia
- Az - Azores islands
- S - Santa Maria
- M - São Miguel
- T - Terceira
- J - São Jorge
- P - Pico
- G - Graciosa
- F - Faial
- L - Flores
- C - Corvo
- C Az - Central island group (TJPGF)
- E Az - Eastern island group (MS)
- W Az - Western island group (LC)
- Hüb. - A.v. Hübschmann
- Sjn. - E. Sjögren
- ass. - association
- all. - alliance
- diff. sp. - differential species

- diff. val. - differential value
- leg. - collected by
- pref. - preferentially
- spls. - samples

HEPATICAEE

Anthoceros punctatus L.
= *Anthoceros husnotii* Steph.
(Anthocerotaceae)

Samples. G: Furna, 140 m, on soil sheltered by boulder, on road escarpment and on volcanic ash (4 spls.). - Close to Furna, 200 m, on soil in rock crevices. Pico Timão, 300 m, on volcanic ash. Fajã, Serra Branca, 200 m, on strongly exposed soil escarpment.

Azorean distrib.: S M T J F L.

Habitat. Pref. epigeic on G, as on other islands in the Az., and pref. on moist fine soil escarpments.

Sociology. Occurs in the Myurium-Allorgea-Fissidens pallidicaulis - all. but with no diff. val.

Aphanolejeunea teotonii Jov.-Ast. et V. Allorge
= *Cololejeunea teotonii* (Jov.-Ast. et V. Allorge) Grolle
(Lejeuneaceae)

Samples. G: Pico Timão, 200 m, sheltered habitat on stone wall. Serra Branca, 300 m, in ravine on *Trichomanes*; on base of *Pittosporum* and on stones (2 spls.). Ibid., 275 m, on stones in the bottom of narrow ravine (2 spls.).

Azorean distrib.: M T J P F L. A fairly recently distinguished endemic member of the Azorean bryoflora (cf. ALLORGE & JOVET-AST 1950).

Habitat. On G recorded at exceptionally low altitudes. In C Az pref. epiphyllous, generally between 600 - 900 m. However, all the localities on G are very much sheltered.

Sociology. Earlier treated as diff. sp. with strong diff. val. of the *Cololejeuneetum azoricae* Sjn. 78. The diff. val. of the species will be kept unchanged, considering its presence in the whole archipelago.

Calypogeia arguta Nees et Mont.

(Calypogeiaceae)

Samples. G: Caldeira, 200 m, epiphytic on *Cryptomeria japonica*, in forest plantation.

Azorean distrib.: MTJPL.

Habitat: Apparently no substratum preference in the Az. Earlier also recorded in forest plantations at altitude levels below the *Juniperion brevifoliae* (cf. SJÖGREN 1978).

Sociology. No sociological affinity in the Az.

Calypogeia fissa (L.) Raddi

(Calypogeiaceae)

Samples. G: A fairly large number of records, between 200 - 300 m.

Azorean distrib.: S M T J P F L.

Habitat. Generally as epigeic, in sheltered places below *Erica azorica*, but also as epiphytic on *Erica* and as epilithic on sheltered stone surfaces. Earlier not recorded below 475 m in the Az.

Sociology. On G low diff. val. of the epigeic Myurium- Allorgea - Fissidens pallidicaulis - all. (Table 4).

Cephaloziella divaricata (Sm.) Schiffn.

(Cephaloziellaceae)

Samples. G: Pico Timão, 220 m, as epigeic. Probably still under-recorded in the Az.

Azorean distrib.: S M L.

Cololejeunea azorica V. Allorge & Jov. Ast.

(Lejeuneaceae)

Samples. G: Carapacho, 150 m, on base of *Eucalyptus* stem. Pico Timão, 220 m, on *Pittosporum* stem. Close to Pico Timão, 200 m, on *Persea indica*.

Azorean distrib.: M J P F L. A fairly recently distinguished species (cf. ALLORGE & JOVET-AST 1955), now known to exist on 7 of the Azorean islands and on Madeira (SJÖGREN 1975). Endemic to the Azores and Madeira.

Habitat. On other Azorean islands rarely epi-

phytic or epixylic. Still to be treated as pref. epiphyllous in the Az.

Sociology. Diff. sp. of the *Cololejeuneetum azoricae* Sjn. 78, although now with slightly weaker diff. val. (Table 1). *C. a.* is on G a member of the epiphytic *Frullania microphylla* - ass., with weak diff. val.

Cololejeunea minutissima (Sm.) Schiffn.

(Lejeuneaceae)

Samples. G: A large number of records, between 100 - 275 m. Epiphytic on *Cryptomeria*, *Acacia*, *Persea*, *Eucalyptus*, *Pittosporum*, in dense forest stands. Three samples of the species as epilithic in the Pedras Brancas forests close to Pico Timão.

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. Earlier records of *C.m.* in the Az. between 250-1050 m. Generally epiphyllous; also growing on other bryophytes such as *Porella* spp. The preferred habitats of the species thus differ on G.

Sociology. Diff. sp. of the epiphytic *Frullania microphylla* - ass. (Table 1) as well as of the epiphytic cloud-zone ass. *Echinodio - Lepidozietum* Sjn. 78 and the epiphyllous *Cololejeuneetum azoricae* Sjn. 78.

Conocephalum conicum (L.) Underw.

(Conocephalaceae)

Samples. G: Serra Branca, 275 m, on soil in a deep ravine together with the fern *Trichomanes speciosum*, also new to the island.

Azorean distrib.: S M T J P F L.

Habitat. In the Az. mostly on moist fine soil escarpments, efficiently shaded.

Sociology. No diff. val. It is impossible to distinguish a small scale association like the *Fegatelleetum conicae* in the Az. (cf. v. HÜBSCHMANN 1974). There are no means of distinguishing it, for example, from the *Tetrastichium-Dumortiera* - ass. which is also epilithic-epigeic (Table 2).

Drepanolejeunea hamatifolia (Hook.) Schiffn.
(Lejeuneaceae)

Samples. G: Serra Branca, 275 m, on soil in a deep ravine. Pico Timão, 220 m, on soil.

Azorean distrib.: M T J P F L.

Habitat. *D.h.* is apparently very rare on G, which was not expected, considering the frequent presence of, for example, *Cololejeunea minutissima*, which is also a pref. epiphyllous species in the archipelago.

Dumortiera hirsuta (Sw.) Nees
(Wiesnerellaceae)

Samples. G: Fairly common species, both as epilithic and epigeic. Recorded between 100 - 300 m.

Azorean distrib.: M T J P F L.

Habitat. Mostly in sheltered places, especially if the substrate is not permanently moist. Large-grain volcanic deposits become colonized only if strongly sheltered and preferably also permanently moistened.

Sociology. Diff. sp. of the epilithic-epigeic *Tetrastichium-Dumortiera* - ass. (cf. SJÖGREN 1978, p. 124). See Table 2. This association is more richly developed in other Azorean islands, where it also includes e.g. *Jubula hutchinsiae* (although not frequently), a species not yet recorded on G.

Fossombronia angulosa (Dicks.) Raddi
(Codoniaceae)

Samples. G: Furna, 140 m, epilithic on sheltered rock escarpment; idem, epigeic under *Myrica*.

Serra Branca, 300 m, epigeic on eroding soil escarpment; idem, epilithic, on strongly sheltered rock surface in ravine.

Azorean distrib.: M T P G F L.

Habitat. On moist soil escarpments, both on fine and coarse volcanic deposits.

Sociology. See *Nardia scalaris*.

Fossombronia husnotii Corb.
(Codoniaceae)

Samples. G: Not recorded in 1978.
Azorean distrib.: M T G F.

Fossombronia pusilla (L.) Nees
(Codoniaceae)

Samples. G: One record, W of St. Cruz, sterile specimen, which makes the determination not completely reliable.

Azorean distrib.: M L (var. *decipiens* Corb. on L).

Frullania dilatata (L.) Dum
(Frullaniaceae)

Samples. G: Several records, between 50 - 275 m. The species generally appears as epilithic but has also been recorded as epigeic and epiphytic (on *Eucalyptus*, *Cryptomeria* and *Pittosporum*).

Azorean distrib.: S M T J P G F L.

Habitat. The substratum preference of *F.d.* is approximately the same on G as on other Azorean islands, where most localities are below the cloud-zone.

Sociology *F. d.* has a weak diff. val. of the epilithic *Grimmia azorica*-*Ptychomitrium* - all. (Table 3). See also *Radula lindenbergiana*.

Frullania microphylla (Gott.) Pears.
(Frullaniaceae)

Samples. G: Several records, between 100 - 200 m. As epiphytic, except in one record.

Azorean distrib.: M T J P F L.

Habitat. Considering all the Azorean islands, *F.m.* is pref. epiphyllous, at least at altitudes above 500 m (SJÖGREN 1978). However, the epiphytic presence of the species in G is the same as at low altitudes on the other islands.

Sociology. Diff. sp. of the epiphytic *Frullania microphylla* - ass. (cf. v. HÜBSCHMANN 1974, SJÖGREN 1978, p. 127). *F. m.* is highly frequent and appears locally even with high cover percentages. It colonizes pref. in the primary stages of development of a moss carpet on almost all sorts of tree species in dense forests of G. The *Frullanietum microphyllae* (Table 1) may poss-

ibly be regarded as an impoverished association which, as to altitude increases, progressively develops into the Echinodio - Lepidozietum cupressinae, an association where *F. m.* has very much reduced diff. val.

Frullania tamarisci (L.) Dum.
(Frullaniaceae)

(incl. *F. nervosa* Mont., see GROLLE 1970, VANDEN BERGHEN 1976).

Samples. G: A large number of records, between 140 - 300 m, on all sorts of substrates.

Azorean distrib.: S T M J P F L C.

Habitat. The altitude range of *F. t.* has become considerably widened and the substratum preference made weaker in the Az. after the addition of records from G.

Sociology. *F. t.* has no diff. val. in the Az., not even at the level of alliance and order (epiphytic + epilithic cloud-zone associations) as suggested by v. HÜBSCHMANN (1974). *F. t.* is, for example, frequent in epiphytic, epilithic as well as epigeic low-altitude associations in the Az.

Harpalejeunea ovata (Hook.) Schiffn.
(Lejeuneaceae)

Samples. G: A large number of records between 140 - 275 m. The species appears generally as epilithic and epiphytic, e.g. on *Erica*, *Pittosporum*, *Persea*, but also as epigeic in some records.
Azorean distrib.: S M T J P F L.

Habitat. The earlier suggested weak substratum preference of *H. o.* has been confirmed by the records on G. The species is, however, confined to weakly exposed habitats at almost all localities on G.

Sociology. A weak diff. val. of the epiphytic *Frullania microphylla* - ass. may be suggested for *H. o.* (Table 1).

Heteroscyphus denticulatus (Mitt.) Schiffn.
= *Chiloscyphus denticulatus* Mitt.
(Geocalycaceae)

Samples. G: Furna, 140 m, as epilithic.

Azorean distrib.: M J P L.

Habitat. Earlier known as a species growing up to 600 m, with no substratum preference.

Sociology. No diff. val.

Lejeunea lamacerina (Steph.) Schiffn.
(Lejeuneaceae)

Samples. G: A very large number of records, between 100 - 300 m. Generally epiphytic and epilithic, occasionally epigeic and in one sample epiphyllous on *Trichomanes*.

Azorean distrib.: M T J P F L (+ C; leg. Sjn. 78). var. *azorica* (Steph.) Greig-Smith (= *L. azorica* Steph.) on M J L.

Habitat. The known weak substratum preference of *L. l.* in the Az. has become further weakened, taking into consideration the epilithic and epigeic records of the species on G.

Sociology. *L. l.* has a very weak diff. val. towards epigeic associations. The presence of *L. l.* on G has further strengthened the statement (SJÖGREN 1978, p. 137) that this very frequent hepatic, with almost no substratum preference, has no diff. val. in the Az.

Lejeunea ulicina (Tayl.) Gott. et al.
= *Microlejeunea ulicina* (Tayl.) Evans.
(Lejeuneaceae)

Samples. G: Caldeira, 200 m, on *Cryptomeria* (2 spls.). W Praia, 100 m, on *Pittosporum* and on sheltered boulder (2 spls.).

Azorean distrib.: T M J P L.

Habitat. The species occurs on other Azorean islands pref. at low altitudes and, as on G, also with no pronounced substratum preference. The species may be under-recorded in the archipelago as, in many cases, it is difficult to separate from *Cololejeunea minutissima* at least in the field.

Lophocolea bidentata (L.) Dum.
(Geocalycaceae)

Samples. G: Caldeira, 200 m, on *Cryptomeria* (2 spls.). Pedras Brancas, 175 m, epixylic (2 spls.).

Azorean distrib.: M J L.

Habitat. No distinct substratum preference. Probably under-recorded in the archipelago.

Lophocolea fragrans (Moris et De Not.) Gott. et al.

= *Chiloscyphus canariensis* Bryhn
(Geocalycaceae)

Samples. G: Caldeira, 200 m, on *Cryptomeria*. Pedras Brancas, 200 m, epixylic and at 175 m epilithic (2 spls.). Serra Branca, 300 m, epigeic and as epilithic (2 spls.), in ravine.

Azorean distrib.: M T J P F L.

Habitat. No clear substratum preference but still, as in other parts of the archipelago, rarely epigeic.

Lophocolea heterophylla (Schrad.) Dum.
(Geocalycaceae)

Samples. G: Pedras Brancas, 175 m, as epixylic.

Azorean distrib.: M T F L.

Habitat. The epixylic substratum preference in the Az. is weak. Not recorded as epigeic. The species seems to avoid the cloud-zone forests.

Lunularia cruciata (L.) Lindb.
(Lunulariaceae)

Samples. G: Furna, 140 m, epigeic in cave.

Furna, 200 m, epigeic.

Azorean distrib.: S M F L (+ J, C; leg. Sjn. 78).

Habitat. Probably under-recorded in the archipelago. Pref. epigeic, in sheltered places. In strongly exposed places needing moist substrates.

Sociology. See *Nardia scalaris*.

Marchantia paleacea Bertol.
(Marchantiaceae)

Samples. G: Furna, 140 m, epilithic and epigeic (2 spls.). Serra Branca, 300 m, epilithic and epigeic in ravine (2 spls.).

Azorean distrib.: S M T P F L.

Habitat. Probably pref. epigeic-epilithic.

Sociology. In the Az. as a whole probably most frequent in the *Plagiochasma-Targionia* - ass. (v. HÜBSCHMANN 1974). This ass. also exists on Madeira but without *M. p.* (v. HÜBSCHMANN 1971).

Marchesinia mackaii (Hook.) Gray
(Lejeuneaceae)

Samples. G: Serra Branca, 275 m, epilithic on sheltered boulder in bottom of ravine.

Azorean distrib.: S M T J P F L.

Nardia scalaris S.F. Gray
(Jungermanniaceae)

Samples. G: Furna, 140 m, epilithic on sheltered stones. Pico Timão, 300 m, epigeic on rough volcanic ash; idem, 200 m, on fairly strongly exposed steep soil escarpment. Serra Branca, 300 m, on eroding soil escarpment.

Azorean distrib.: M T J P F L.

Habitat. Pref. epigeic and epilithic, on moist substrates.

Sociology. On steep soil escarpments in the Az. *N. s.* is frequently associated with e.g. *Diplophyllum albicans*, *Diphyscium foliosum*, *Philonotis rigida* and *Frullania tamarisci*. The *Diphyscium foliosum* (v. HÜBSCHMANN 1974) was not, however, recorded on G, in the archipelago becoming frequent above 500 m, at least in C Az. The association, although somewhat difficult to distinguish, may be present on all the islands in the Az. but is most probably also characterized by *Philonotis rigida* and *Diplophyllum albicans* as diff. spp. Transitions are certainly, on the other hand, most frequent towards such small-scale associations as those described by v. HÜBSCHMANN (1974, Tables 13-19), generally characterized by only one diff. sp. ("Kennart") namely *Lunularia cruciata*, *Fossombronia angulosa*, *Anthoceros husnotii*.

Plagiochasma rupestre (Forst.) Steph.
(Aytoniaceae)

Samples. G: No samples were taken.

Azorean distrib.: M.

Habitat. the species is fairly common on G., in several places growing together with *Targionia hypophylla* in coastal localities.

Sociology. See *Targionia hypophylla*.

Plagiochila corniculata (Dum.) Dum.

(Plagiochilaceae)

Samples. G: Pico Timão, 220 m, epigeic in strongly sheltered crevices between stones (3 spls.).

Azorean distrib.: M T J P F L.

Habitat. *P. c.* is a species with weak substratum preference in the archipelago, which has been additionally confirmed by the records obtained on G. Earlier not recorded below 475 m. The presence on G at such a low altitude is motivated by the strongly sheltered habitat.

Plagiochila spinulosa (Dicks.) Dum.

(Plagiochilaceae)

Samples. G: (var. *macaronesiana* not distinguished from var. *spinulosa*). A large number of records, between 175-275 m, only as epigeic and epilithic.

Azorean distrib.: M T J P F L (+ C; leg. Sjn. 78).

Habitat. Earlier known as pref. epiphytic, epiphyllous and epixylic. Records of the species on G as epilithic and epigeic have weakened that preference and also widened the altitude range of the species within the archipelago.

Sociology. No diff. val.

Porella canariensis (F. Web.) Bryhn.

(Porellaceae)

Samples. G: A large number of records, between 100 - 300 m, on all sorts of substrates, but generally growing as epilithic and epigeic. As epiphytic on *Erica*, *Persea*, *Pittosporum*.

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. Earlier not recorded below 400 m. Apparently resists desiccation, as recorded on

G in extremely exposed habitats such as on top of boulders in field walls.

Porella obtusata (Tayl.) Trev.

= *Madotheca thuja* (Dicks.) Dum.

(Porellaceae)

Samples. G: Pico Timão, 220 m, epigeic under *Erica* (3 spls.).

Azorean distrib.: J.

Habitat. Probably under-recorded in the Az. No strictly defined habitat preference (cf. SJÖGREN 1978, p. 161).

Radula carringtonii Jack.

(Radulaceae)

Samples. G: A very large number of records, between 100 - 300 m. Epigeic, epilithic and epiphytic (on *Acacia*, *Erica*, *Persea*, *Pittosporum*). The most frequent *Radula* species on G.

Azorean distrib.: S M T J P F L.

Habitat. On G, as also on other islands in the archipelago, with no pronounced substratum preference.

Radula complanata (L.) Dum.

(Radulaceae)

Samples. G: Pedras Brancas, 175 m, on stone wall. Fontes, 130 m and 200 m, on boulders (2 spls.).

Azorean distrib.: M T J P L.

Habitat. Rare species with unclear habitat preferences in all the archipelago. Pref. growing below the cloud-zone forest zone.

Sociology. See *Radula lindenbergiana*.

Radula lindenbergiana Gott. ex Hartm.

(Radulaceae)

Samples. G: Furna, 140 m, epigeic between boulders. W of Praia in forest, 100 m, epilithic (2 spls.). Pedras Brancas, 150 m, epilithic (2 spls.). NW of Carapacho, 160 m, in forest on *Pittosporum* and on boulder (2 spls.).

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. No decided substratum preference in the Az. On G, however, clearly pref. epilithic. The earlier supposed preference of the species to grow at altitudes below 500 m (SJÖGREN 1978, p. 166) has become strengthened after the recorded presence of the species on G.

Sociology. The diff. val. for the epilithic associations *Cryphaetum arboreae* and *Echinodietum prolixum*, suggested by v. HÜBSCHMANN (1974), becomes still more doubtful after recordings on G (cf. SJÖGREN *op. cit.*). Those two associations are made up of several species which, on G, are also present in the *Frullanietum microphyllae*, such as *Frullania dilatata*, *Zygodon viridissimus*, *Radula complanata*, *Frullania tamarisci*.

Radula wichurae Steph.
= *Radula limbata* Schiffn.
(Radulaceae)

Samples. G: A fairly large number of samples and records, between 100 - 200 m, as epigeic and epiphytic but generally as epilithic.
Azorean distrib.: S M T J P G L.

Habitat. Pref. epilithic on G but considering the presence in the whole archipelago, no substratum preference and, furthermore, characterized by an unusually wide ecological range.

Sociology. Only very weak diff. val. of the low-altitude epiphytic and epilithic associations towards epigeic ones.

Reboulia hemisphaerica (L.) Raddi
(Aytoniaceae)

Samples. G: Several records between 140 - 300 m; epigeic and epilithic.
Azorean distrib.: S M T J F L.

Habitat. *R.h.* is pref. epigeic, growing on fine-soil escarpments and even on coarse soil if at least occasionally moistened. Locally, the species may be dominant on large surfaces, in an easily eroding moss-carpet. Also on soil-covered boulder and rock surfaces.

Sociology. A diff. val. of *R.h.* can be maintained only towards epiphytic and epiphyllous com-

munities, as well as towards epigeic-epilithic cloud-zone communities (SJÖGREN 1978, p. 168).

Riccardia latifrons (Lindb.) Lindb.
(Aneuraceae)

Samples. G: Several records, between 140 - 300 m; epigeic and epilithic.

Azorean distrib.: M T J P F L.

Habitat. Pref. on moist substrates. Earlier not recorded as epilithic, and now also with extended altitude range.

Sociology. Diff. sp. of the epilithic-epigeic *Tetrastichium-Dumortiera* - ass. (Table 2). Earlier not given any diff. val. Fairly frequent in premature stages of the epixylic *Lepidozietum azoricum*, thus only weak diff. val. of the *Tetrastichium-Dumortiera* - ass.

Saccogyna viticulosa (L.) Dum.
(Geocalycaceae)

Samples. G: Several records between 140 - 220 m; epigeic and epilithic.

Azorean distrib.: S M T J P F L.

Habitat. In the Az. as a whole no substratum preference. On G pref. epigeic and epilithic. Several species with a very wide altitude range in the Azorean islands, like *S. v.*, tend to progressively decrease their substratum preference towards the cloud-zone.

Sociology. No diff. val. (cf. v. HÜBSCHMANN 1974; SJÖGREN 1978, p. 171). Most of the species suggested together with *S.v.* as diff. spp. of alliance and order, comprising the epilithic *Bazzanio-Hymenophylletum tunbrigensis*, are highly frequent in the Az., at least within the cloud-zone, on almost all sorts of substrates.

Targionia hypophylla L.
(Targioniaceae)

Samples. G: A fairly common species on G, especially on soil in strongly exposed places from the coast to 150 m. No samples were taken.

Azorean distrib.: S M T J F L.

Habitat. Pref. epigeic species, highly resistant to desiccation.

Sociology. The most frequently associated species are treated as diff. spp. in records of the Plagiochasmo-Targionietum hypophyllae (v. HÜBSCHMANN 1974), an epigeic association confined to the coastal zone in the Az. as well as on Madeira (v. HÜBSCHMANN 1971).

MUSCI

Allorgea berthelotiana (Mont.) Ando
= *Gollania berthelotiana* (Mont.) Broth.
(Hypnaceae)

Samples. G: A very large number of records, between 140-300 m, only as epigeic and epilithic.

Azorean distrib.: S M T J P F L.

Habitat. The records on G help to maintain *A.b.* as a pref. epigeic and epilithic species in the Az. Sociology. Some species frequently associated with *A.b.* have been listed by SJÖGREN (1974, p. 179). Records on G have motivated *A. b.* as a diff. sp. of the Myurium-Allorgea-Fissidens pallidicaulis - all. (Table 4), made up of species available on most of the Azorean islands, at altitudes below the level of the typically developed cloud-zone forest. Associations of the alliance are principally confined to sheltered fine soil escarpments, if strongly exposed, preferably where they are permanently moistened.

Anomobryum julaceum (Gaertn., Meyer et Scherb.) Schimp.
= *Anombryum filiforme* (Dicks.) Husn.
(Bryaceae)

Samples. G: Furna, 140 m, on stone wall and on road cutting (2 spls.). Serra Branca, 300 m, epigeic (3 spls.).

Azorean distrib.: M L.

Habitat. Strongly drought-tolerant species, growing at low altitudes in the Az. Not epiphytic or epiphyllous.

Barbula unguiculata Hedw.
(Pottiaceae)

Samples. G: Ajuda, 100 m, on moist soil escarpment. Sta. Cruz, 50 m, on soil (2 spls.).

Azorean distrib.: S M P F L.

Bartramia stricta Brid.
(Bartramiaceae)

Samples. G: Sta. Cruz - Praia, Quitadouro, 25 m, on soil escarpment.

Azorean distrib.: S M T L.

Habitat. Pref. epigeic.

Brachythecium plumosum (Hedw.) B.S.G.
(Brachytheciaceae)

Samples. G: Several records, between 50 - 300 m, as epigeic and epilithic, only in one locality as epiphytic, on *Pittosporum*.

Azorean distrib.: S M J P F L.

Habitat. Wide altitude range in the Az. Pref. epilithic.

Sociology. In the Az. as a whole frequently associated with *Rhynchostegium riparioides* and *Thamnobryum alopecurum* of the Platyhypnidietum riparioidis Gams 1927 (see v. HÜBSCHMANN 1974). The composition of the ass. in the Az. and in western Europe is very similar, which is rarely the case with other bryo-associations of the archipelago, supposed to exist also on the European continent.

Brachythecium populeum (Hedw.) B.S.G.
(Brachytheciaceae)

Samples. G: Several records, between 100 - 300 m, only as epilithic.

Azorean distrib.: M T J P F L.

Habitat. The epilithic substratum preference is much more pronounced on G than on other Azorean islands, where the preference of the species to grow on stone surfaces is much weaker at altitudes above 500 m.

Sociology. Weak diff. val. of the epilithic low-altitude *Grimmia azorica* - *Ptychomitrium* - all. (Table 3). This diff. val. may later become verified also on other islands, at altitudes below the cloud-zone forest.

Brachythecium rivulare B.S.G.

(Brachytheciaceae)

Samples. G: Serra Branca, 275 m, on boulder in deep ravine.

Azorean distrib.: M F.

Habitat. Pref. on boulders in deep ravines.

Sociology. In the Az. pref. associated with species of the *Platyhypnidietum rivularis* (see *Brachythecium plumosum*).

Brachythecium salebrosum (Web. et Mohr) B.S.G.

(Brachytheciaceae)

Samples. G: Caldeira, 200 m, in cave in the caldeira, as epigeic,

Azorean distrib.: S M T P L.

Bryum canariense Brid.

(Bryaceae)

Samples. G: Not recorded on G in 1978. Probably under-recorded in the Az.

Azorean distrib.: S M T G J F L.

Bryum donianum Grev.

= *B. pachyloma* Card.

(Bryaceae)

Samples. G: Pedras Brancas, 150 m, on basal stones in stone wall in strongly exposed habitat.

Azorean distrib.: M T P L.

Campylopus fragilis (Brid.) B.S.G.

(Dicranaceae)

Samples. G: Several records, between 200 - 300 m, as epigeic and epilithic.

Azorean distrib.: M T J P F L.

Habitat. The species should not be treated as pref. growing above 500 m, as earlier stated by SJÖGREN (1974).

Campylopus pilifer Brid.

= *C. polytrichoides* De Not.

(Dicranaceae)

Samples. G: A very large number of records, be-

tween 25 - 300 m, as epigeic and epilithic.

Azorean distrib.: S M T J P G F L.

Habitat. *C. p.* is a species with a fairly wide ecological range. The species is strongly drought-tolerant and prefers to colonize in early stages of bryo-succession on soil and boulders.

Sociology. Fairly strong diff. val. of the epilithic *Grimmia azorica*-*Ptychomitrium* - all. towards low-altitude associations on other substrates (Table 3). Strong diff. val. towards epiphytic, epixylic and epiphyllous associations at high altitude levels. *C.p.* may appear also in the *Myurium*-*Allorgea*-*Fissidens pallidicaulis* - all. on moist soil but not very frequently and always with low cover degree as a consequence of strong competition from species more adapted to habitats preferred by that alliance.

Ceratodon purpureus (Hedw.) Brid.

(Dicranaceae)

Samples. G: Furna, 140 m, epigeic. Serra Branca, 300 m, on soil in cliff crevices.

Azorean distrib.: S M T J P G F L.

Habitat. In the Az. pref. below the cloud-zone forest.

Didymodon luridus Hornsch. ex Spreng.

(Pottiaceae)

Samples. G: Sta. Cruz, 50 m, on moist soil in shallow ravine.

Azorean distrib.: M.

Didymodon tophaceus (Brid.) Lisa

= *Barbula tophacea* (Brid.) Mitt.

(Pottiaceae)

Samples. G: NW of Carapacho, 150 m, on strongly exposed soil escarpment. Furna, 140 m, epilithic and also on soil escarpment (2 spl.).

Azorean distrib.: S M T L.

Diphyscium foliosum (Hedw.) Mohr

(Buxbaumiaceae)

Samples. G: Serra Branca, close to the lake, 300 m, epigeic on soil escarpment. Idem. 350 m, epigeic. Under-recorded on G.

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. Pref. epigeic, frequently on soil escarpments.

Sociology. *D. f.* belongs to the epigeic moss cover frequently present on more or less steep soil escarpments of fine soil, starting to appear in the C Az. at about 500 m and getting progressively more frequent toward higher altitudes. Associated species are frequently *Diplophyllum albicans*, *Nardia scalaris*, *Philonotis rigida* and *Saccogyna viticulosa*. *D.f.* has been treated by v. HÜBSCHMANN (1974) as a diff. sp. of the *Diphyscium foliosum* (Amann 1928) Philippi 1963, an association which, in the Az., may be very difficult to separate from other small-size epigeic associations described by the same author.

Echinodium prolixum (Mitt.) Broth.

(Echinodiaceae)

Samples. G: Not sampled. The species is fairly frequent as epiphytic above 200 m.

Azorean distrib.: M T J P F L (+ C; leg. Sjn. 78).

Habitat. Pref. epiphytic on G as also at low altitudes on other islands in the Az. Principally a bryophyte of the cloud-zone forest.

Sociology. Not present in the epiphytic low-altitude *Frullanietum microphyllae*, as also in other parts of the archipelago.

Epipterygium tozeri (Grev.) Lindb.

(Bryaceae)

Samples. G: several samples, between 140 - 300 m, only as epigeic.

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. Pref. epigeic in the Az. Pref. on moist fine-soil escarpments. Low competitive ability in moss carpets dominated by hepatics.

Sociology. This small-size bryophyte, somewhat resembling a small *Mnium* species, has certainly been under-recorded in the Az. and consequently became too rarely represented in earlier

described bryo-communities. *E.t.* is a diff. sp. with weak diff. val. of the *Myurium-Allorgea-Fissidens pallidicaulis* - all. (Table 4).

Eurhynchium hians (Hedw.) Sande Lac.

= *E. swartzii* (Turn.) Curn.

(Brachytheciaceae)

Samples. G: Furna, 140 m, epigeic and epilithic (3 spls.). W of Praia, 100 m, epigeic in forest. Pedras Brancas, 150 m, epigeic (2 spls.)

Azorean distrib.: S M T J P F L.

Eurhynchium praelongum (Hedw.) B.S.G.

= *E. stokesii* (Turn.) B.S.G.

(Brachytheciaceae)

Samples. G: A very large number of records, between 50-300 m, as epilithic and epigeic, occasionally as epiphytic on bases of trees.

Azorean distrib.: S M T G P F L (+ C; leg. Sjn. 78).

Habitat. This species, in several European countries on the continent regarded as pref. epigeic, has lost all its substratum preference in the Az.

Eurhynchium pumilum (Wils.) Schimp.

(Brachytheciaceae)

Samples. G: Caldeira, 200 m, as epigeic in a *Cryptomeria* plantation. Furna, 140 m, as epilithic.

Azorean distrib.: S M T J P F L.

Fissidens asplenioides Hedw.

(Fissidentaceae)

Samples. G: Furna, 140 m, epigeic. Fontes, 200 m, epigeic. Pico Timão, 300 m, epigeic on lapilli. Serra Branca, 300 m, on soil escarpment.

Azorean distrib.: S M T J P F L. (in Europe confined to the Azores islands, according to CORLEY & al., 1981)

Habitat. Fairly frequent on G between 140 -300 m. On other islands progressively more frequent towards altitudes of the cloud-zone forest.

Sociology. Frequently present in a fairly large

number of epigeic bryo-associations, from the coast up to the endemic forest of the Juniperion brevifoliae. Thus hardly suitable as diff. sp. of an association, such as the Fissidentetum asplenoidis (v. HÜBSCHMANN 1974).

Fissidens bryoides Hedw. ssp. *bryoides*
(Fissidentaceae)

Samples. G: Several records between 50 - 300 m, as epigeic and epilithic.

Azorean distrib.: M T J P F (var. *inconstans* (Schimp.) Ruthe also on L; ssp. *tamarindifolius* (Turn.) Podp. also on S).

Fissidens crassipes Wils. ex B.S.G.
(Fissidentaceae)

Samples. G: Serra Branca, 275 m, epigeic in ravine and on thickly soil covered boulder (2 spls.)

Azorean distrib.: M T J F L.

Fissidens serrulatus Brid.
(Fissidentaceae)

Samples. G: Recorded in several localities above 200 m, generally as epigeic and epilithic in strongly sheltered places.

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. Pref. epigeic and epilithic as on other Azorean islands.

Sociology. See SJÖGREN (1978, p. 200). *F. s.* may be treated as a diff. sp. with weak diff. val. of the Tetrastichium-Dumortiera - ass. and also of the Fissidentetum serrulati Hüb. 74 of the Myurium-Allorgea-Fissidens pallidicaulis - all. (Tables 2, 4).

Fissidens taxifolius Hedw. ssp. *pallidicaulis* (Mitt.) Amann
(Fissidentaceae)

Samples. G: A large number of records, between 140 - 300 m, only as epigeic and epilithic. The most frequent *Fissidens* species on G.

Azorean distrib.: S M T J P F L.

Habitat. The preference of this taxon to grow at altitudes below the cloud-zone forest, suggested earlier (SJÖGREN 1978, p. 201), has been confirmed by the recorded presence of the species on G. On G pref. growing as epilithic and epigeic. Less pronounced substratum preference has been documented on other islands, at higher altitudes.

Sociology. Diff. sp. of the epigeic-epilithic Myurium-Allorgea-Fissidens pallidicaulis - all. The diff. val. of the mini-association Fissidentetum pallidicaulis Hüb. 1974, becomes difficult to maintain, confirmed by the frequent presence of the species on G together with such species as *Myurium hochstetteri*, *Allorgea berthelotiana*, *Saccogyna viticulosa* and *Epipterygium tozeri*.

Fissidens viridulus (Sw.) Wahlenb.
(Fissidentaceae)

Samples. G: Furna, 140 m (3 spls.). NW of Carapacho, 160 m, epigeic.

Azorean distrib.: S M L.

Grimmia laevigata (Grid.) Brid.
(Grimmiaceae)

Samples. G: Not recorded on G in 1978.
Azorean distrib.: G J.

Grimmia montana B.S.G.
(Grimmiaceae)

Samples. G: Not recorded on G in 1978.
Azorean distrib.: G.

Grimmia trichophylla Grev. ssp. *azorica* (Ren. et Card.) Luis.
= *Grimmia azorica* Ren. et Card.
(Grimmiaceae)

Samples. G: A very large number of records, between 5 - 275 m. As epilithic. Only one record on soil.

Azorean distrib.: S M T J P G F L.

Habitat. Strongly drought-tolerant species. Almost obligatory epilithic, which is an extraordinarily strong substratum preference among Azorean bryophytes. Pref. at altitudes below the

cloud-zone forest.

Sociology. Strong diff. val. of the *Grimmia azorica*-*Ptychomitrium* - all., which has become further confirmed by the records on G (Table 3). The alliance comprises the two epilithic associations *Grimmietum azoricae* and *Ptychomitrium polyphyllae* (v. HÜBSCHMANN 1974).

Haplodontium notarisii (Mitt.) Broth.
(Bryaceae)

Samples. G: Furna, 140 m, as epigeic.
Azorean distrib.: M L.

Herzogiella striatella (Brid.) Iwats.
= *Dolichoteca striatella* (Brid.) Loeske
(Plagiotheciaceae)

Samples. G: Pedras Brancas, 150 m, as epilithic.
Azorean distrib.: F.

Heterocladium heteropterum B.S.G.
(Thuidiaceae)

Samples. G: Furna, 140 m, epilithic (2 spls.).
Azorean distrib.: M T J P F L.
Habitat. Pref. epilithic in the Az. Probably under-recorded, at least at altitude levels below 600 m.
Sociology. No diff. val. of the *Thamnetum alopecuri* (v. HÜBSCHMANN 1974), at least not towards other epilithic bryo-associations at various altitude levels.

Homomallium incurvatum (Brid.) Loeske
(Hypnaceae)

Samples. G: Furna, 140 m, epilithic on sheltered dry rock surface.
Azorean distrib.: New to the archipelago.

Hypnum cupressiforme var. *resupinatum* (Tayl. ex Spruce) Schimp.
(Hypnaceae)

Samples. G: Several records, between 5-220 m, generally as epilithic, a few samples on soil.
Azorean distrib.: S M T J G F L.

Hypnum jutlandicum Holmen et Warncke
= *H. cupressiforme* var. *ericetorum* B.S.G.
(Hypnaceae)

Samples. G: Furna, 140 m, as epilithic on strongly exposed boulder in stone wall (2 spls.).
Azorean distrib.: M T P F L.

Hypnum uncinulatum Jur.
= *H. canariense* (Mitt.) Jaeg.
(Hypnaceae)

Samples. G: Several records, between 100 - 200 m, generally as epiphytic and epilithic, occasionally as epigeic. The most frequent of the *Hypnum* species on G as well as on other islands in the Az.
Azorean distrib.: S M T J P G F L (+ C; leg. Sjn. 78).

Lepidopilum virens Card.
= *Plagiothecium argyrophyllum* Geh.
= *Pseudolepidopilum virens* (Card.) Luis.
(Daltoniaceae)

Samples. G: Furna, 140 m, epilithic in dark sheltered places (3 spls.). Serra Branca, 300 m, epilithic on boulder in bottom of ravine. Idem, 275 m, as epilithic in ravine (3 spls.).
Azorean distrib. M T J P F L.
Habitat. This species has been treated as pref. epigeic and epilithic. It is one of several Azorean bryophytes with this pronounced type of substratum preference. *L.v.* needs shelter. On rock slopes, generally where they are moistened and where covered by a more or less thick cover of fine soil, which helps to retain the moisture.
Sociology. Diff. sp. of the epigeic - epilithic *Tetrastichium-Dumortiera* - ass., although described as a diff. sp. of the epigeic *Isopterygium laetevirens*-*Lepidopilum virens* - ass. (v. HÜBSCHMANN 1974). The latter mentioned ass. of *Cryptomeria* - plantations on S. Miguel has not yet been encountered on other islands in the archipelago.

Leucobryum juniperoideum (Brid.) C. Müll.
(Dicranaceae)

Samples. Furna, 140 m, epilithic.
Azorean distrib.: S M T J P F L (+ C; leg. Sjn.
78).

Leucodon canariensis (Brid.) Schwaegr.
= *L. treleasei* (Card.) Par.
(Leucodontaceae)

Samples. G: Several records, between 50-275 m,
always as epilithic.
Azorean distrib.: M. Probably under-recorded
in the Az.
Habitat. Probably strongly pref. epilithic.
Strongly drought-tolerant species.
Sociology. Weak diff. val. of the *Grimmia azorica*-*Ptychomitrium* - all. (Table 3).

Myurium hochstetteri (Schimp.) Kindb.
= *M. hebridarum* Schimp.
(Myuriaceae)

Samples. G: Several records, between 140 - 220
m, as epigeic and epilithic.
Azorean distrib.: S M T J P F L (+ C; leg. Sjn.
78).
Habitat. Weakly pref. epigeic and epilithic at
altitudes below the cloud-zone forest. Within the
cloud-zone also frequently as epiphytic.
Sociology. Diff. sp. of the epigeic *Myurium*-*Al-
lorgea*-*Fissidens pallidicaulis* - all. Associations
of this all., typical of moist soil escarpments
(Table 4) are found at altitudes below the
Juniperion brevifoliae. Within the cloud-zone
forest the diff. spp., including *Myurium*, tend to
lose their diff. values.

Neckera intermedia Brid.
= *N. laeviuscula* Geh.
(Neckeraceae)

Samples. G: Furna, 140 m, as epilithic (2 spls.).
Azorean distrib.: M T J P F L (+ C; leg. Sjn.
78).
Habitat. In the Az., at least in C Az., pref. above

500 m. Habitat conditions at the locality on G, at
remarkably low altitude, provide permanently
high air humidity and shelter against desiccating
winds.

Neckera webbiana (Mont.) Düll.
= *Homalia webbiana* (Mont.) Schimp.
= *Neckera besseri* (Lob.) Jur.

(Neckeraceae)

Samples. G: Furna, 140 m, as epilithic on very
sheltered cliffs (4 spls.).
Azorean distrib.: S L. Probably under-recorded
in the Az.

Habitat. *N. w.* is a probably pref. epilithic
species of the cloud-zone forest, even there con-
fined to dark sheltered habitats, such as in cre-
vices of lava flows with dense tree layer. The
locality on G is at exceptionally low altitude (cf.
Neckera intermedia).

Philonotis rigida Brid.
(Bartramiaceae)

Samples. G: Several records, between 100 - 350
m, as epigeic except in one record.
Azorean distrib.: S M T J P F L.
Habitat. Frequent on all the islands including G,
pref. growing on moist soil escarpments, even
where they are richly water soaked.
Sociology. It has not been possible to record any
particular affinity to an epigeic or epilithic asso-
ciation. The diff. val. towards epiphytic, epixylic
and epiphyllous associations must, however, be
regarded as very strong at all altitude levels on
all the Azorean islands.

Plagiothecium succulentum (Wils.) Lindb.
(Plagiotheciaceae)

Samples. G: Furna, 140 m, as epilithic.
Azorean distrib.: J.
Habitat. See SJÖGREN (1978, p. 225).

Polytrichum juniperinum Hedw.
(Polytrichaceae)

Samples. G: Not recorded on G in 1978.

Azorean distrib.: S M T G J P L.

Polytrichum piliferum Hedw.

(Polytrichaceae)

Samples. G: Not sampled but recorded in several localities from the coast to 350 m, as epigeic on dry soil.

Azorean distrib.: S M T J P G L.

Pterogonium gracile (Hedw.) Sm.

= *P. ornithopodioides* (Web. et Mohr) Lindb.

(Leucodontaceae)

Samples. G: Furna, 140 m, as epilithic on stone wall. Caldeira, 200 m, as epilithic on sheltered boulder surfaces (2 spls.).

Azorean distrib.: M G L.

Ptychomitrium nigrescens (Kunze) Wijk et Marg.
= *P. nigricans* Schimp.

(Ptychomitriaceae)

Samples. G: The species has been sampled in a large number of localities between 5 - 300 m, generally as epilithic, rarely as epigeic.

Azorean distrib.: S M T G J P F L.

Habitat. *P.n.* is a very drought-tolerant species, with strong preference to grow as epilithic, on poorly soil-covered or uncovered stone surfaces. The species occurs primarily in the primary stages of colonization of strongly exposed boulder and rock surfaces at altitudes below the cloud-zone forest. The Azorean forms of *P. polyphyllum* (also treated as *P. azoricum* (Card.) Par.) are quite similar to *P.n.*, even considering ecological preferences. However, *P. azoricum* has a much wider altitude range.

Sociology. *P.n.* is a diff. sp. with strong diff. val. of the *Grimmia azorica*-*Ptychomitrium* - all. (Table 3). *P. azoricum* may eventually also become treated as a diff. sp. of this all. The all. includes the two mini-associations *Grimmiatum azoricae* and *Ptychomitrium polyphyllae* (v. HÜSCHMANN 1971, 1974).

Rhynchostegiella tenella (Dicks.) Limpr.

(Brachytheciaceae)

Samples. G: Furna, 140 m, epilithic and epigeic (2 spls.). NW of Carapacho, 150 m, epilithic in forest. Serra Branca, 275 m, epilithic and epigeic in ravine (2 spls.).

Azorean distrib.: M F.

Habitat. Insufficiently known preferences but probably pref. epilithic and epigeic.

Rhynchostegium riparioides (Hedw.) Card.

= *Platyhypnidium riparioides* (Hedw.) Dix.

(Brachytheciaceae)

Samples. G. Furna, 140 m, epilithic on moist rock surface.

Azorean distrib.: S M J F L.

Habitat. On G, as on other Azorean islands, pref. epilithic, on moist and sheltered stone surfaces in ravines (cf. SJÖGREN 1978, p. 236).

Rhytidiadelphus squarrosus (Hedw.) Warnst.

(Hypnaceae)

Samples. G: W of Sta. Cruz, 25 m, epigeic in strongly exposed habitat.

Azorean distrib.: M T J P F L.

Scleropodium purum (Hedw.) Limpr.

= *Pseudoscleropodium purum* (Hedw.) Fleisch.
ex Broth.

(Brachytheciaceae)

Samples. G: Furna, 140 m, epigeic in open grassland and in scrub of *Erica* (3 spls.). Serra Branca, 300 m, in open grassland with *Thymus* and on fine sand deposits on steep coast cliffs (2 spls.).

Azorean distrib.: S M T J P F L (+ C; leg. Sjn. 78).

Habitat. Pref. epigeic, in open grassland vegetation below the cloud-zone forest.

Sociology. No diff. val. in the Az.

Scleropodium touretii (Brid.) L. Koch

= *S. illecebrum* B.S.G.

(Brachytheciaceae)

Samples. G: Pico Timão, 220 m, epigeic in places sheltered by *Erica* (5 spls.).

Azorean distrib.: M T P F. Probably under-recorded in the Az.

Scorpiurium circinatum (Brid.) Fleisch. et Loeske

(Brachytheciaceae)

Samples. Several samples, between 50 - 200 m; mostly as epilithic but also as epigeic and epiphytic.

Azorean distrib.: S M T J P F L.

Habitat. Strictly coastal species in the whole archipelago. Pref. epilithic. *S. c.* is a characteristic species of the endemic *Festucion petraeae* Sjögren 1973, along the Azorean coasts.

Sociology. *S. c.* is a diff. sp. of the *Grimmia azorica*-*Ptychomitrium* - all. (Table 3). The diff. val. is weaker than that of *Grimmia azorica* and *Ptychomitrium nigricans* and its frequency is lower. It is also more frequent in epigeic communities. *S.c.* has, however, a strong diff. val. towards Azorean bryo-associations of the cloud-zone forest.

Sematophyllum substrumulosum (Hampe) Britt.

(Sematophyllaceae)

Samples. G: Several samples, between 100 - 300 m, on all sorts of substrates.

Azorean distrib.: S M T J P F L.

Habitat. Samples of *S. s.* on G have considerably extended the earlier known altitude range of this species, which was earlier known principally from localities above 500 m.

Sociology. Earlier stated diff. val. of *S. s.* towards epigeic and epilithic bryo-associations has become weakened after the recording of the species on G, where it grows fairly frequently on soil as well as on cliffs and boulders in strongly sheltered places.

Tetrastichium fontanum (Mitt.) Card.

= *Lepidopilum fontanum* Mitt.

(Hookeriaceae)

Samples. G: Furna, 140 m, as epigeic; as epilithic (4 spls.) on moist and sheltered rock surfaces.

Azorean distrib.: S M T J P F L.

Habitat. This remarkable species, endemic to the Macaronesian island groups, has a wide altitude range. The substratum preference of *T.f.* is fairly weak if its presence also in the cloud-zone forest is considered. On G, as on other islands in the Az., however, pref. epilithic-epigeic.

Sociology. Diff. sp. of the epilithic-epigeic *Tetrastichium* - *Dumortiera* - ass. (Table 2). Frequently growing together with *Dumortiera hirsuta*, *Lepidopilum virens* and *Riccardia latifrons*, which have also been suggested as diff. spp. of the association.

Thamnobryum alopecurum (Hedw.) Nieuwl.

= *Thamnium alopecurum* (Hedw.) B.S.G.

(Thamniaceae)

Samples. G: Furna, 140 m, as epilithic (6 spls.)

Azorean distrib.: M T J P F L (+ C; leg. Sjn. 78).

Habitat. Wide altitude range and weak substratum preference.

Sociology. No diff. val. in the Azores.

Thuidium tamariscinum (Hedw.) B.S.G.

(Thuidiaceae)

Samples. G: Pico Timão, 220 m, as epigeic.

Azorean distrib.: M T J P F L (+ C; leg. Sjn. 78).

Tortella flavovirens (Bruch) Broth.

(Pottiaceae)

Samples. G: Furna, 140 m, epigeic in open grassland and as epilithic on sheltered rock surfaces (2 spls.)

Azorean distrib.: S M J.

Habitat. Coastal species, very drought-tolerant.

Sociology. Diff. sp. of the *Festucion petraeae* but with weaker diff. val. than the much more frequent *Tortella nitida*, which is also a diff. sp. of the *Grimmia azorica*-*Ptychomitrium* - all.

Tortella nitida (Lindb.) Broth.

(Pottiaceae)

Samples. G: Several samples, between 50-300 m, generally as epilithic but also as epigeic.

Azorean distrib.: S M T J F L.

Habitat. *T. n.* is strongly pref. epilithic-epigeic on G. Confined to the coastal zone, pref. growing at altitudes below 200 m.

Sociology. *T.n.* is most frequently associated with *Grimmia azorica* and *Ptychomitrium nigricans* on G, which confirms its earlier supposed diff. val. of the *Grimmia azorica*-*Ptychomitrium* - all. (Table 3). *T.n.* belongs to the primary stage of succession, becoming frequently outcompeted by pleurocarpous mosses as well as by highly competitive hepatics such as *Frullania tamarisci* and *Porella canariensis*.

Tortula muralis Hedw.

(Pottiaceae)

Samples. G: Sta. Cruz, 50 m, as epilithic on top of stone wall and as epigeic (2 spls.). Furna, 140 m, as epilithic. Ajuda, 100 m, as epilithic on strongly exposed stone wall (2 spls.)

Azorean distrib.: S M T J F L.

Habitat. Almost only as epilithic, in strongly exposed habitats at low altitudes.

Trichostomum brachydontium Bruch

(incl. var. *litorale* (Mitt.) C. Jens.)

(Pottiaceae)

Samples. G: Sta. Cruz, 50 m, on coastal cliffs. Very frequent all over the island along the coasts.

Azorean distrib.: S M T J P F L.

Habitat. Pref. epilithic coastal species in the Az.

Weissia brachycarpa (Nees et Hornsch.) Jur.

= *W. ludwigii* Crum

(Pottiaceae)

Samples. G: W of Sta. Cruz, 50 m, on moist sand in shallow ravine near the coast.

Azorean distrib.: T.

Weissia controversa Hedw.

(Pottiaceae)

Samples. G: Several records, between 50 - 300 m, as epigeic, occasionally as epilithic.

Azorean distrib.: S M T J P F L.

Zygodon viridissimus (Dicks.) Brid. var. *viridissimus*

(Orthotrichaceae)

Samples. G: W of Sta. Cruz, 50 m, at a distance of 200 m from the coast, as epilithic on top of stone wall. W Praia, 100 m, in forest as epilithic on *Persea*.

Azorean distrib.: S M T J F L.

Habitat. The species has a restricted altitude range in the Az., rarely growing above 500 m. The substratum preference is weak. It grows in strongly as well as weakly exposed places. The epiphytic preference of *Z.v.* on the European continent is not maintained in the Az.

Zygodon viridissimus (Dicks.) Brid. var. *vulgaris* Malta

(Orthotrichaceae)

Samples. G: Serra Branca, 275 m, as epilithic on strongly exposed stone wall.

Azorean distrib.: S M T F.

INDEX OF SPECIES

Hepaticae and Musci of Graciosa, treated in this paper

(x = earlier not documented on G).

HEPATICAE

x *Anthoceros punctatus*

x *Aphanolejeunea teotonii*
 x *Calypogeia arguta*
 x *Calypogeia fissa*
 x *Cephaloziella divaricata*
 x *Cololejeunea azorica*
 x *Cololejeunea minutissima*
 x *Conocephalum conicum*
 x *Drepanolejeunea hamatifolia*
 x *Dumortiera hirsuta*
 Fossombronia angulosa
 Fossombronia husnotii
 Fossombronia pusilla
 Frullania dilatata
 x *Frullania microphylla*
 x *Frullania tamarisci*
 x *Harpalejeunea ovata*
 x *Heteroscyphus denticulatus*
 x *Lejeunea lamacerina*
 x *Lejeunea ulicina*
 x *Lophocolea bidentata*
 x *Lophocolea fragrans*
 x *Lophocolea heterophylla*
 x *Lunularia cruciata*
 x *Marchantia paleacea*
 x *Nardia scalaris*
 x *Plagiochasma ripetere*
 x *Plagiochila spinulosa*
 x *Porella canariensis*
 x *Porella obtusata*
 x *Radula carringtonii*
 x *Radula complanata*
 x *Radula lindenbergiana*
 x *Radula wichurae*
 x *Reboulia hemisphaerica*
 x *Riccardia latifrons*
 x *Saccogyna viticulosa*
 x *Targionia hypophylla*

MUSCI

x *Allorgea berthelouiana*
 x *Anomobryum julaceum*
 x *Barbula unguiculata*
 x *Bartramia stricta*
 x *Brachythecium plumosum*

x *Brachythecium populeum*
 x *Brachythecium rivulare*
 x *Brachythecium salebrosum*
 Bryum canariense
 x *Bryum donianum*
 x *Campylopus fragilis*
 Campylopus pilifer
 Ceratodon purpureus
 x *Didymodon luridus*
 x *Didymodon tophaceus*
 x *Diphyscium foliosum*
 x *Echinodium prolixum*
 x *Epipterygium tozeri*
 x *Eurhynchium hians*
 Eurhynchium praelongum
 x *Eurhynchium pumilum*
 x *Fissidens asplenioides*
 x *Fissidens bryoides*
 x *Fissidens crassipes*
 x *Fissidens serrulatus*
 x *Fissidens taxifolius* ssp. *pallidicaulis*
 x *Fissidens viridulus*
 Grimmia laevigata
 Grimmia montana
 Grimmia trichophylla ssp. *azorica*
 x *Haplodontium notarisii*
 x *Herzogiella striatella*
 x *Heterocladium heteropterum*
 x *Homomallium incurvatum*
 Hypnum cupressiforme var. *resupinatum*
 x *Hypnum jutlandicum*
 Hypnum uncinulatum
 x *Lepidopilum virens*
 x *Leucobryum juniperinum*
 Leucodon canariensis
 x *Myrium hochstetteri*
 x *Neckera intermedia*
 x *Neckera webbiana*
 x *Philonotis rigida*
 x *Plagiothecium succulentum*
 Polytrichum juniperinum
 Polytrichum piliferum
 Pterogonium gracile
 Ptychomitrium nigrescens
 x *Rhynchostegiella tenella*

- x *Rhynchostegium riparioides*
- x *Rhytidiadelphus squarrosus*
- x *Sceropodium purum*
- x *Scleropodium touretii*
- x *Scorpiurium circinatum*
- x *Sematophyllum substrumulosum*
- x *Tetrastichium fontanum*
- x *Thamnobryum alopecurum*
- x *Thuidium tamariscinum*
- x *Tortella flavovirens*
- x *Tortella nitida*
- x *Tortula muralis*
- x *Trichostomum brachydontium*
- x *Weissia brachycarpa*
- x *Weissia controversa*
- x *Zygodon viridissimus* var. *viridissimus*
- x *Zygodon viridissimus* var. *vulgaris*

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SEI WHALES (*BALAENOPTERA BOREALIS*) ENCOUNTERED IN THE AZORES: A NEW RECORD FOR THE REGION

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ARQUIPÉLAGO



GORDON, JONATHAN, LISA STEINER & JOÃO M. GONÇALVES 1990. Sei whales (*Balaenoptera borealis*) encountered in the Azores: a new record for the region. - *Arquipélago*. Life and Earth Sciences 8:97-100. Angra do Heroísmo. ISSN 0870-6581.

The sei whale is recorded for the first time in Azorean waters. Five individuals were observed in the channel between S. Jorge and Pico on 16 July 1989 heading North, which does not agree with the present knowledge of the migratory behaviour of this species. It is unlikely that sei whales would visit the archipelago to feed.

GORDON, JONATHAN, LISA STEINER & JOÃO M. GONÇALVES 1990. Baleias sardinheiras (*Balaenoptera borealis*) observadas nos Açores: primeira referência para a Região. - *Arquipélago*. Ciências da Natureza 8:97-100. Angra do Heroísmo. ISSN 0870-6581.

A baleia sardinha ou rorqual de Rudolphi é pela primeira vez referido para as águas dos Açores. Cinco indivíduos foram observados no canal entre as ilhas de S. Jorge e Pico a 16 de Julho de 1989, dirigindo-se para Norte, o que não está de acordo com os actuais conhecimentos sobre o comportamento migratório desta espécie. Não é provável que estas baleias visitem o arquipélago para se alimentarem.

Jonathan Gordon, Wildlife Conservation Research Unit, Department of Zoology, South Parks Road, Oxford, OX1 3PS. - Lisa Steiner, International Fund for Animal Welfare, Tubwell House, New Road, Crowbrough, East Sussex, TN6 2QH, U. K. - João M. Gonçalves, Department of Oceanography and Fisheries, University of the Azores, P-9900 Horta, Azores, Portugal.

The sei whale (*Balaenoptera borealis*) is the third largest of the rorqual whales. Females grow to around 15.5 m with males being about 0.5 m shorter (HORWOOD 1987). They have sleek streamlined bodies and are believed to be the swiftest of the great whales, capable of speeds as high as 20 knots. Sei whales are found in all of the world's oceans. In the Western North Atlantic sei whales were caught by whalers off Nova Scotia and Labrador (JONSGÅRD 1977) and strandings have occurred on the eastern seaboard of America from Massachusetts to Mexico (MEAD 1977). In the Eastern North Atlantic they have been caught by whalers off Scotland, Ireland, the Faroes, Iceland, and Norway as well as off the coasts of

Spain and Portugal. In Iberian waters small numbers of sei whales were caught off NW. Spain (AGUILAR & SANPERA 1982) though they are thought not to be common there. 66 sei whales were caught from shore stations in Portugal between 1925 and 1927 and sei whales were also caught from shore stations around the straits of Gibraltar (TØNNESSEN & JOHNSSEN 1982). Three solitary sei whales were spotted during a whale marking cruise off Spain (AGUILAR & al. 1983). Sei whales were never taken during traditional whaling operations in the Azores or Madeira (JONSGÅRD 1977) and there are no confirmed sightings of sei whales in the Azores.

Five sei whales in one group of three and

another group of two individuals were sighted between 07.10 and 08.30 on 16 July 1989 at 38°43.0'N 28°22.6'W, in the channel between S. Jorge and Pico, about 3 miles south of S. Jorge (Fig.1). Weather conditions were good during the encounter. The wind was an easterly force 3, and visibility was greater than 15 miles.

The sea surface temperature was 22.6°C. The whales were making dives lasting 2-3 minutes and blowing once at the surface between them. The dives appeared to be shallow. "Footprints", small slicks caused by the wash from the beat of the whale's flukes, could be seen at the surface allowing the whales to be followed while they were submerged. All the whales were heading 300° at a speed of about 5.5 knots and maintained this heading and speed throughout the encounter. The whales in each group were swimming roughly abreast. The second group (of two whales) followed an estimated 1.5 to 2 nautical miles directly behind the first (three

whales). Whales were approached closely to allow them to be observed and photographed to confirm their identity. Body length was estimated by eye and by comparison with the length of the research vessel, to be 14 m.

Sei whales can be readily distinguished from fin whales, which are typically larger and have a characteristic white lower jaw on the right hand side. However they are difficult to distinguish from Bryde's whales which have a more tropical but overlapping range. The most useful identification features are the ridges on the dorsal surface of the head. Sei whales have only one of these which runs forward along the mid-line from the blow hole to the tip of the rostrum. In Bryde's whales there are also two smaller ridges on either side of the main median ridge making a total of three. Photographs taken during this encounter (e.g. Fig. 2) shows only one ridge confirming that the animal is indeed a sei and not a Bryde's whale.

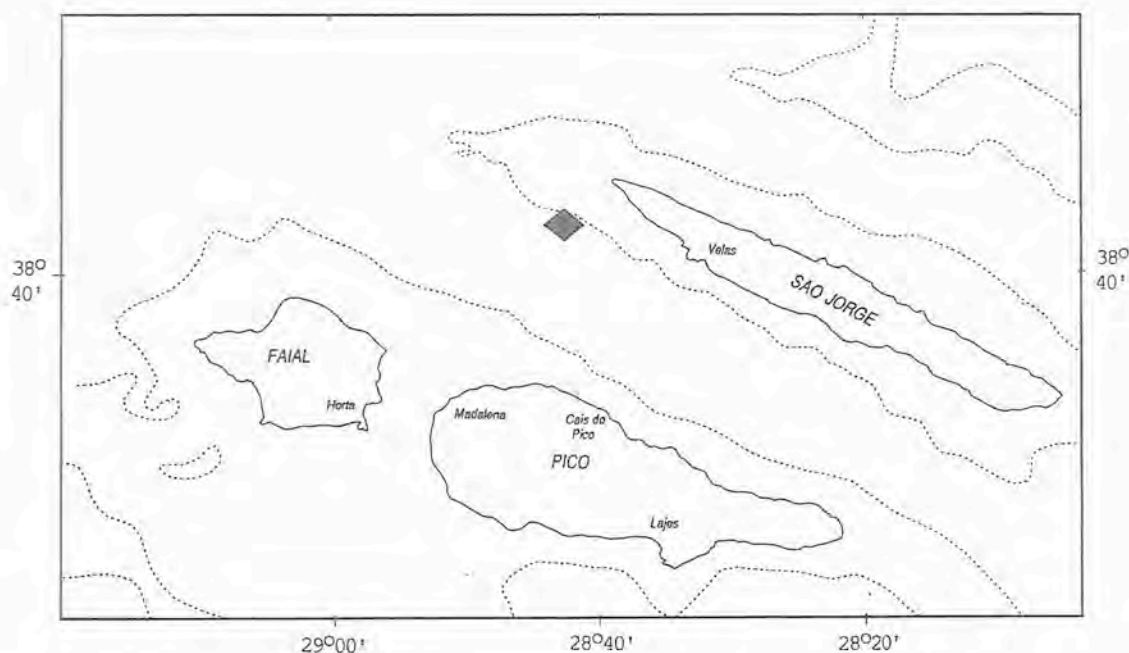


Fig. 1 - Position of sei whale sighting on 16 July 1989. Position of encounter marked (◆). Broken line (----) shows 1 000 m depth contour.