STUDIES ON THE LICHENS OF THE AZORES. PART 3. MACROLICHENS OF RELICT CLOUD FORESTS

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With 4 figures and 1 table

ABSTRACT. Azorean lichens have been relatively poorly studied with little attempt having been made to describe the communities of the major vegetation types, in particular the epiphytes in endangered relict woodlands. Lichen communities from selected, distinctive habitats within the cloud-zone woodlands in the Azores, many now greatly fragmented, are described with emphasis on the macrolichen flora of three areas on Pico and the principal caldeira on Faial. Lichen communities occurring within cloud forest vary considerably in species composition and abundance in relation to moisture regimes, altitude and substrate and are characterised by a high proportion of species known to be rare and endangered elsewhere in Europe. 49 red data book species listed for the European Community are present in the Azorean cloud forests accounting for 22% of the total listed for Europe. Five endemic lichen taxa have been described so far, in *Nephroma, Ochrolechia, Peltigera* and *Ramonia,* and several more await description. Lichens are extremely sensitive to habitat disturbance. The Azorean cloud forest lichens are unique assemblages which merit a high conservation priority.

INTRODUCTION

The Azores lichen flora has been relatively poorly studied and, except for a few papers on the discovery of particular species, there has been little attempt to describe the major lichen communities. Apart from a number of recent monographic and other taxonomic studies and floras (e.g. AHTI 1961, HALE 1965, JAMES & WHITE 1987, JØRGENSEN 1974 & 1978, KROG & SWINSCOW 1978, MOBERG 1989, PURVIS *et al.* 1992) which include reference to Azorean lichens, most of the literature was published over 50 years ago, including DES ABBAYES (1946, 1947), CROMBIE (1878), NAVAS (1909), NYLANDER (1895, 1898), SEUBERT (1844) and STIRTON (1875). DEGELIUS (1941) published a catalogue of 157 lichens

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for the Azores, mainly collected by the bryologist H. Persson. Four recent papers add a further 95 species to the flora (APTROOT 1989, ARVIDSSON 1990; PURVIS & JAMES 1993; PURVIS *et al.* 1994). Contributions on Macaronesian lichens, including some reference to the Azores, have been prepared (e.g. TAVARES 1952, 1953, 1958, 1964; KALB & HAFELLNER 1992). Although the lichen flora thus documented appears relatively impoverished, totalling some 375 taxa, many crustose lichens have been hardly examined, some names may have been wrongly applied and further taxa await description including several relatively common species belonging to the genera *Gyalideopsis, Heterodermia, Phaeographis, Peltigera* and *Thelotrema*. Five Azorean endemic cloud forest lichens have been described: *Nephroma hensenniae* P. James & F. J. White (JAMES & WHITE 1987), *Ochrolechia azorica* Purvis, P. James & Brodo (PURVIS *et al.* 1994), *Peltigera dissecta* Purvis, P. James & Vitik., *P. melanorhizza* Purvis, P. James & Vitik.) and *Ramonia azorica* P. James & Purvis (PURVIS & JAMES 1993).

Ancient woodlands are widely recognised throughout W. Europe, N. America and elsewhere as supporting important and often endangered lichen communities (ROSE 1988, SMITH 1993). The composition of these lichen communities is used to assess the age and continuity of these woodlands and may be an important tool in the choice of areas having high conservation priority (ROSE 1976). Cloud forests are one of the most threatened types of forest in the world (HAMILTON *et al.* 1993) but differ greatly in their moisture regime. Cloud forests in areas such as the Azores which do not have a marked seasonal rainfall are characterised by the frequency of cloud cover with heavy and sometimes persistent orographic rainfall and high annual precipitation (HAMILTON *et al.* 1993). The Azorean cloud forests are defined in the present paper as relict woodlands occurring above an altitude of 550 m, areas in which *Pittosporum undulatum* is unable to invade, largely on account of excessive moisture (E. Dias, pers. comm.). There are two major objectives of the present study: (1) a description of the main lichen communities occurring within the cloud forests with an emphasis on macrolichen floras, and (2) a discussion of the vulnerability of these lichen floras and the importance of their conservation.

Study area

The Azorean archipelago in the Atlantic Ocean 1480 km west of the nearest continental land in Portugal lies between 36° 59' and 39° 44' north latitude and 24° 41' and 31° 16' west longitude. There are three separate island groups of which Faial is the westernmost of the central islands, being separated from Pico by the 7 km wide Faial channel (Fig. 1). Faial from north to south is about 14 km, while at its widest the island is 21 km across; Pico is c. 15 by 45 km. Both islands are dominated by volcanoes. The principal physical feature of Faial island is Cabeço Gordo (1043 m) more-or-less in the centre of the island. This symmetrical volcanic mountain was last active in 1672 and has a steep-sided crater with a floor more than 4.5 km in diameter. The crater floor is c. 350 m below the rim and contains

a shallow lake which varies in size according to rainfall and which is slowly silting up. On the adjacent island of Pico the active volcano, O'Pico (2351 m) (Fig. 2), is the highest mountain in the Azores.

Sites studied:

Cerrado de Sonicas

6.5 km N of Pico summit, Testados dos Baldios do Concelho, by roadside, alt. 890 m, 6 April 1992, O.W. PURVIS & P.W. JAMES; 4 km NW of Pico summit, alongside road to aerial, 900 m alt., 6 April 1992, O.W. PURVIS & P.W. JAMES; c. 200 m along track leading off road EN3 to aerial, 900 m alt., 11 April 1992, O.W. PURVIS & P.W. JAMES; NW slopes of Pico, c. 3 km S of road EN3, S of track leading to aerial,1000-1150 m alt., 11 April 1992, O.W. PURVIS & P.W. JAMES; 11 km SE of Madalena, 1-1.5 km S. of road EN-3, 1050-1150 m alt., 25 April 1993, O.W. PURVIS & P.W. JAMES.

Cabeço do Caveiro

7 km SSE of Prainha, by roadside, 900 m alt., elfin cloud forest dominated by *Frullania* sp. and mosses, 9 April 1992, O.W. PURVIS & P.W. JAMES; 3.5 km N of Ribeiras, by roadside, 900 m alt., wet cloud forest with *Juniperus* and large *Sphagnum* tussocks, 27 April 1993 and 16 May 1994, O.W. PURVIS & P.W. JAMES (Fig. 3.).

Bosque da Junqueria / Redondo

Between Lajes do Pico and S. Roque do Pico, c. 100 m from beginning of road to Lagoa do Caiado, 1 km SE of Cabeço da Cruz, 700 m alt.; 12 km NNE of S. João, Bosque da Junqueria near road EN-2; 770 m alt., 9 April 1992, O.W. PURVIS & P.W. JAMES; 8 km NW of Lajes do Pico, 0.5 km along road to Lagoa do Caiado from intersection with EN-2, Cabeço do Redondo, 700 m alt., rocky outcrop with well developed *Juniperus* scrub etc, in boggy pasture, 27 April 1993, O.W. PURVIS & P.W. JAMES; 10 Km NW of Lajes do Pico, SW margin of Bosque da Junqueria, c. 300 m west of Cabeço do Vermelho, 700 m alt., mixed cloud forest adjacent to pasture, 6 May 1993, O.W. PURVIS, P.W. JAMES & C.W. SMITH (Figs 2 & 4).

Faial Caldeira

Faial Caldeira, alongside track from Canto dos Saquinhos to base, 562-922 m alt., 14 April 1992, O.W. PURVIS & P.W. JAMES.

Climate

The climate of the Azores is oceanic with comparatively small seasonal fluctuations in temperature and rainfall at sea level. Annual precipitation is c. 1054 mm at sea level in Faial (the adjacent island to Pico) increasing some 16% for every 100 m increase in altitude

(SJÖGREN 1978) up to a more-or-less well-developed inversion layer. However, rainfall is very low towards the summit above the cloud layer (PURVIS *et al.* 1994). The mean high temperatures in the Azores range between 15-23°C at sea level and the diurnal variation rarely exceeds 7°C (Anon 1945). In the three coldest months, January to March, frosts occur regularly above 1860 m, occasionally down to 1200 m and very rarely as low as 600 m (TUTIN 1953).

The diurnal formation of tradewind-induced, orographic clouds is a well known and easily observed phenomenon. Throughout the warmer months the cloud base tends to ascend during daylight hours, and the afternoon and evenings are usually less cloudy than during the early morning (ANON 1945). Cloud commonly forms a ring around the cone of Pico, at 900 - 1370 m on the northern slopes with a thinner layer, at 1370 - 1520 m on the southern side creating a rain-shadow effect. Though the peak often appears concealed by cloud when viewed from lower altitudes, in fact the upper third of the mountain often rises well above the main cloud layer. Cloud often persists on the high W-E ridge east of Pico, particularly at Cabeço do Caveiro and also around the rim of Caldeira do Faial (H. MARTINS, pers. comm.).

Vegetation

The characteristic evergreen forests of the Azores, together with those of the Canaries and Madeira, are considered to be relicts of the now largely lost Tertiary forests of southern Europe (GODMAN 1870, HAGGAR 1984, 1988; TUTIN 1953) traditionally referred to as "Laurissilva" (e.g. VIRVILLE 1965). They support 53 endemic vascular plant taxa and 15 endemic bryophytes (SJØGREN 1990). The special interest of the vegetation is reflected in that eight of the eleven native trees are endemic to the Azores: *Erica azorica, Frangula azorica, Ilex perado* ssp. *azorica, Juniperus brevifolia, Picconia azorica, Prunus lusitanica* subsp. *azorica, Vaccinium cylindraceum* and *Viburnum tinus* subsp. *subcordatum*, and two other species, *Laurus azorica* and *Myrica faya,* are endemic to the Azores and Madeira (SJØGREN 1973, 1984). Now, virtually no natural forest with native trees exists below 500 m, having completely been replaced by the exotic *Pittosporum undulatum.* At higher altitudes there has been wide-scale clearance for pasture (Fig. 4). There have been various attempts to classify the vascular plant vegetation (e.g. SJØGREN 1973, Dias 1991), though much remains to be done to resolve factors responsible for the development of different types of forest as well as the study of succession.

METHODS

Author citations follow BRUMMIT & POWELL (1992); full author citations are also given for lichens the first time they are mentioned in the text. Higher plant nomenclature follows SJÖGREN (1973, 1984) and that for lichens conforms to the most recent taxonomic

papers.

Two islands in the central island group, Pico and Faial, with significant relict cloud forest vegetation above an altitude of 550 m, were studied in areas severely threatened by agriculture. The lichen communities in recently examined, important cloud forests on Terceira will be the subject of a future paper. Sites were selected after consultation with local botanists and knowledgeable persons and in our opinion are representative types in the area. Most were easily accessible either by road or track. Each site was thoroughly searched to provide as complete a sample as possible over a 2 year period; details of site visits are included under 'study area'. Substrate type and species abundance according to the DOMIN scale were noted in the field. All species recorded have voucher specimens at BM, HAW, LIS and TERCEIRA. Standard methods for identifying lichen material were applied in accordance with those outlined in PURVIS & JAMES (1993).

The results presented here describe the diversity of a selected number of the more distinctive habitats with an emphasis on macrolichens. A fuller study of the lichen communities of relict woodlands on Pico including coastal vegetation will be the subject of a future paper with a greater emphasis on crustose species, once the more critical crustose genera have been more fully studied.

RESULTS

PICO

Cerrado de Sonicas: upper altitude lichen-rich forest

A series of gulleys and craters run SSE of wireless mast at Sonicas on the ENE-facing ridge of O'Pico at an altitude between 1050-1150 m. Large areas cleared for pasture are dominated by *Anthoxanthemum odoratum* with other aliens including *Lotus corniculatus*; stands of rative scrub occur on higher, more exposed parts of ridges reduced to a dense, short canopy of *Calluna vulgaris, Vaccinium cylindraceum* and *Erica azorica* with scattered *Ilex perado* subsp. *azorica* and *Juniperus brevifolia,* at higher elevations reaching no more than 0.5 m tall. Here extensive areas of dead wood in various stages of decay provide further habitats for bryophytes and lichens. The vegetation has suffered extensively from shrub clearance. The best-developed cloud forest is now ± confined to sheltered craters and gulleys, supporting much taller and mostly denser vegetation to c. 5 m tall with *Euphorbia stygiana, Juniperus brevifolia, Ilex perado* subsp. *azorica, Vaccinium cylindraceum* and *Erica azorica* and an understorey of *Myrsine africana* often smothered with *Rubia peregrina* and *Holcus rigidus.* In sheltered craters pendulous mosses are conspicuous. The deep craters are virtually inaccessible and are lined with large fronds of the fern *Woodwardia radicans.*

Pastureland supports few lichens, although *Peltigera lactucifolia* (With.) Laundon is frequent on raised grass tussocks and by paths. Stony areas support abundant *Placopsis*

gelida (L.) Lindsay, *Stereocaulon azoreum* (Schaer.) Nyl., *S. macaronesica* Purvis & P. James, and a few crustose species, including *Baeomyces rufus* (Huds.) DC., *Gyalidea hyalinescens* (Nyl.) Vězda and *Porpidia*. The corticolous flora of the cloud forest includes *Hypotrachyna taylorensis* (M. Mitchell) Hale and *H. endochlora* (Leighton) Hale dominant on *Juniperus*, and *Parmelia saxatilis* (L.) Ach. and *Platismatia glauca* (L.) Culb. & C. Culb. on both *Juniperus* and *Erica*; *Hypotrachyna sinuosa* (Sm.) Hale is rare (its only known site on Pico). On dead *Erica* wood, lichen cover ranges from 30-50 % in drier, better illuminated sites. *Loxospora elatinum* (Ach.) Massal. and *Mycoblastus caesius* (Coppins & P. James) Tønsb. are particularly frequent, the latter often fertile. The newly described *Ochrolechia azorica* Purvis, P. James & Brodo and *Lecanora farinaria* Borrer are also present. *Sphaerophorus globosus* (Huds.) Vainio is also locally frequent at an altitude of 1000 m. A number of crustose species are frequent on moss tufts including: *Gomphillus calycioides* (Del.) Nyl. *Graphis triticea* Nyl. and *Gyalideopsis muscicola* P. James & Vězda. *Polychidium dendriscum* and *Stenocybe bryophila* W. Watson are rare. *Erioderma leylandii* (Taylor) Müll. Arg. and *Ramonia azorica* P. James & Purvis are occasionally seen, the latter confined to *Juniperus*. Ancient *Ilex* supports a very diverse flora including *Lobaria scrobiculata* (Scop.) DC., not seen elsewhere and earlier considered a doubtful record (Degelius 1941), though here confirmed.

Some slight evidence of eutrophication through the application of fertilisers in pastureland is apparent. For instance *Lobaria pulmonaria* (L.) Hoffm. was observed covered with a surface layer of alien algae on several occasions, particularly on isolated trees in improved pasture and at wood margins.

Cabeço do Caveiro: mid-altitude wet bryophyte-rich forest

An extensive area consisting mainly of *Juniperus brevifolia, Ilex perado* subsp. *azorica* and *Vaccinium cylindraceum* scrub with scattered *Erica azorica, Laurus azorica* and *Myrsine africana* as an understorey (Fig. 3). Large hummocks of *Sphagnum* and *Polytricum* species are locally present, mostly confined to valley bottoms, often associated with vascular plants including *Cardamine calderianum, Luzula purpureo-splendens, Lysimachia nemorum* subsp. *azorica, Rubia peregrina, Sibthorpia europaea* and *Viola palustris;* the large, rare umbellifer *Melanoselinum decipiens* is locally frequent in sheltered situations. Ferns are also conspicuous including *Culcita macrocapa, Elaphoglossum hirtum, Hymenophyllum* species and *Trichomanes speciosum. Daboecia azorica* is present in more open situations such as by roadsides. Pendulous bryophytes hang from all trees apart from *Vaccinium*, *Frullania* species clothe the branches and trunks of *Ilex* particularly. Dead branches of *Juniperus* often have extensive bare patches, lacking even mosses.

The terricolous lichen flora is generally sparse, although species of *Cladonia* may be well-developed on the tops of *Polytrichum* and *Sphagnum* hummocks as well as on rotting wood. *Frullania* hanging from *Ilex* branches in more open situations supports a range of

mainly foliose lichens typically with cyanobacterial photobionts, which though well-developed are often lacerated, including: *Leptogium burgessii* (L.) Mont., *L. cyanescens* (Rabenh.) Körber, *Peltigera dissecta* Purvis, P. James & Vitik., *P. melanorrhiza* Purvis, P. James & Vitik., *Pseudocyphellaria intricata* (Del.) Vainio, *P. lacerata* Degel. and *Sticta canariensis* (Bory) Bory ex Delise (blue-green photosymbiodeme). Apart from *Vaccinium* which supports a range of mainly pyrenocarpous lichens, bryophyte cover is high accounting for some 70-90% cover. Crustose species are few and generally not well represented although *Pannaria pezizoides* (Weber) Trevisan is frequent on mosses and an undescribed species of *Thelotrema* containing protocetraric acid frequent on *Vaccinium* in sheltered, moist situations near the ground. Species of *Hypotrachyna* are poorly represented here, with the exception of *H. endochlora.*

Bosque da Junqueria / Redondo: mid-altitude lichen-rich forest

Bosque da Junqueria is the most intact, mid-altitude, cloud forest remaining occupying the floor basin of the Cabeços da Junqueria / Cabeço do Vermelho / Cosme and Cabeço do Sintroa peaks (Fig. 4). Long-established, it contains many trees several hundred years old. The woodland shows considerable diversity in structure with shaded areas of dense canopy and areas where there is a more open glade structure. Surrounded by extensive pasture, these remnants mostly occupy rocky outcrops and often boggy ground on extremely uneven terrain. There is open access to cattle in many areas, though the rocky terrain and its boggy nature makes penetration difficult. Important outliers of Bosque da Junqueria occur east of the main road (EN2) as at Cabeço do Redondo. The vegetation consists of mixed *Juniperus brevifolia, Erica azorica, Vaccinium cylindraceum* and *Laurus azorica* scrub with scattered *Ilex perado* subsp. *azorica* and *Frangula azorica* as well as an understorey of *Myrsine africana* and *Rubus* spp. *Euphorbia stygiana,* a species characteristic of the more recent lava flows, was not seen.

This lichen-rich habitat has well over 100 species. Elements of the *Lobarion* community are widespread, including all species of *Sticta* and *Pseudocyphellaria* recorded in Azores, *Pseudocyphellaria lacerata* also being seen on rocks; *Sticta weigelii* (Ach.) Vainio is rare. Parmelioid species are also well represented. Some crustose, foliicolous species occur on leaves of *Laurus* and *Ilex.* Several lichens are apparently restricted to this type of forest including *Menegazzia terebrata* (Hoffm.) Massal. and *Leptogium cochleatum* (Dickson) P.M. Jørg. & P. James which were only found at Redondo. *Erioderma mollissimum* (Samp.) Du Rietz is frequent on all phorophytes, and especially so at the bases of *Erica, Myrsine* and *Vaccinium* in more open sites; *E. leylandii* (Taylor) Müll. Arg. is occasional in more sheltered sites, preferring the upper boughs of *Erica* and *Juniperus.* The diversity of species falls dramatically in the shadier parts of the woodland where *Lobaria virens* (WITH.) Laundon, *Sticta fuliginosa* (Hoffm.) Ach. and *Leptogium cyanescens* are the most frequent. *Psilolechia leprosa* Coppins & Purvis occurs in the sheltered rock underhangs and is locally frequent.

Herteliana taylorii (Salwey) P. James is ubiquitous on damp rocks.

FAIAL

Faial Caldeira

The interior slopes towards the upper part consist mainly of *Juniperus brevifolia* with scattered *Erica azorica, Hypericum foliosum, Vaccinium cylindraceum* and *Myrsine africana.* Lower down the tree diversity increases and *Laurus azorica* and *Ilex perado* subsp. *azorica* become more frequent. There is some evidence of cutting above, principally of *Juniperus* and in such places *Pteridium aquilinum* has invaded. The floor of the Caldeira is characterised by a mosaic of vegetation defined largely by local hydrology. Here the most abundant shrub is *Erica azorica* and *Hypericum foliosum* is also frequent. The crater floor contains a shallow lake which is slowly silting up; drier areas support almost pure stands of *Erica azorica* with little diversity in shrubs (PURVIS & JAMES 1993).

(a) Upper, wet, bryophyte-dominated cloud forest (800-922 m)

This upper, mist-enshrouded zone in which *Juniperus brevifolia* predominates is notable for the luxuriance of bryophytes, lichens being neither conspicuous nor numerous. Here macrolichens are typical including frequently: *Heterodermia japonica* (Sato) Swinscow & Krog, *Hypotrachyna endochlora, H. rockii* (Zahlbr.) Hale and *Parmelinopsis horrescens* (Taylor) Elix & Hale as well as several species of *Cladonia* mainly occurring on partly rotted wood. Crustose species present occur principally on bare bark or ± overgrowing mosses and include *Pannaria pezizoides* (Web.) Trev. and *Ramonia azorica* whilst a few also grow directly on wood, particularly species of *Micarea, Trapelia* and *Trapeliopsis. Baeomyces rufus* is frequent on the ground and *Thrombium epigaeum* (Pers.) Wallr. was recorded on disturbed soil by the path. Few species were noted on rocks though *Rhizocarpon hochstetteri* (Körber) Vainio was rather frequent, together with *Leptogium cyanescens* and species of *Trapelia.*

(b) Middle, lichen-rich cloud forest (600-800 m)

Lichens are most frequent and conspicuous within this zone, the commmunities being dominated by complex associations of foliose species of the *Lobarion*, including: *Coccocarpia palmicola* (Spreng.) L. Arvidss. & D. J. Galloway, *Degelia atlantica* (Degel.) P.M. Jørg. & P. James, *Leptogium cyanescens, Lobaria pulmonaria, L. virens, Nephroma helveticum* Ach., *N. hensseniae* P. James & F. J. White, *N. laevigatum* Ach., *N. venosum* Degel., *Normandina pulchella* (Borrer) Nyl., *Pannaria conoplea* (Ach.) Bory, *Pannaria rubiginosa* (Ach.) Bory, *Parmeliella jamesii* S. Ahlner & P. M. Jørg., *Pseudocyphellaria aurata* (Ach.) Vainio, *P. intricata, P. lacerata* and *Sticta fuliginosa. Parmelinopsis horrescens* is particularly abundant. Macrolichens do not appear to be host-specific, occurring on a wide range of substrates, often entangled amongst mosses. By contrast, crustose species are

also more conspicuous here than in the upper zone, though they are more host-specific. Smooth-barked *Vaccinium cylindraceum* and *Ilex perado* subsp. *azorica* support distinctive communities dominated by a species of *Melaspilea* and several pyrenocarpous lichens including species of *Arthopyrenia* and *Pyrenula.* By contrast, *Erica azorica* and *Juniperus brevifolia* with a more friable, peeling, acidic bark have no pyrenocarpous lichens, but *Micarea* spp., *Mycoblastus caesius*, *Pertusaria pulvinata* Erichsen and species of *Thelotrema* are present. *Myrsine africana* is a particularly rich substrate for lichens. The foliicolous *Byssoloma subdiscordans* (Nyl.) P. James and *Tapellaria epiphylla* (Müll. Arg.) R. Sant. were collected from *Laurus* and *Ilex* leaves; both phorophytes and also the endemic *Euphorbia stygiana* were noted to be rather rare.

(c) Lower, lichen-poor cloud forest (562-600 m)

This area is floristically less diverse and members of the *Lobarion* are correspondingly scarcer here, though *Cococcarpia palmicola*, *Lobaria pulmonaria* and *Sticta fuliginosa* are frequent. Species of the Parmeliaceae including *Usnea* are well-represented, particularly *Hypotrachyna microblasta* (Vainio) Hale, *Parmotrema robustum* (Degel.) Hale, *Rimelia subisidiosa* (Müll. Arg.) Hale & A. Fletcher and *Usnea flammea* Stirton. Crustose species present include *Byssoloma subdiscordans*, *Catillaria pulverea* (Borrer) Lettau, *Pyrenula dermatodes* (Borrer) Schaerer and unidentified species of *Thelotrema* and *Pyrenula.*

DISCUSSION

Our studies on the lichen flora of Faial Caldeira (PURVIS & JAMES 1993) showed a clear correlation between altitude and species abundance and composition of lichen communities attributable to precipitation and particularly persistence of mist. In Faial Caldeira, the upper zone, where cloud persists, is wettest and the one which favours a rich development of moss cover whilst the zone below contains the most diverse range of lichens, notably the *Lobarion* community where mosses are less dominant. However, the topography of Pico is more varied and the persistence of mist is here not solely a function of altitude. Whilst detailed meteorological data is lacking, the wetter areas are immediately obvious as being those dominated by luxuriant growths of pendulous bryophytes, particularly *Frullania,* hanging from trees, with as well formation of substantial mats of *Sphagnum* on the ground, as seen at Cabeço do Caveiro. Moreover, the summmit of Pico (2350 m) is more than twice the height of that of Faial and well-developed woodland occurs to above 1000 m in altitude, therefore presenting a greater diversity of habitat. Variations in the abundance of species in a particular zone must also be considered in relation to the availabilty of phorophytes which is particularly important in the case of crustose lichens which share a more intimate association with their substrate. Substrate factors such as pH, texture, stability and the water holding

capacity can strongly influence the development of lichen communities (BARKMAN 1958, JAMES *et al.* 1977); this aspect will be considered further in a future paper.

The most lichen-rich habitats in the Azorean cloud forests are undoubtedly those occupying intermediate altitudes where there is a wide diversity of tree species and varied niche structure. These habitats are also intermittently subjected to mist and where the water table is permanently high allowing the development of well-developed *Sphagnum* hummocks. The mid zone (800-600 m) in Caldeira Faial is characterised by a rich flora where lichens are conspicuous and similar to, though probably less diverse than those occurring in the more extensive, mid-altitude, lichen-rich forest on Pico, as exemplified by the Bosque da Junqueria - Redondo area (700-770 m). The *Lobarion* occurring in these areas is generally accepted as being the major climax alliance of lichen epiphytes on the trunks of mature trees in the forests of the Post-glacial in Europe (JAMES *et al.* 1977, ROSE 1988). The *Lobarion* includes not only large foliose lichens: *Lobaria*, *Sticta* and *Pseudocyphellaria*, smaller foliose species from *Nephroma*, *Pannaria*, *Parmelia*, *Parmeliella* and *Peltigera*, but also many crustose lichens and a number of bryophytes. The *Lobarion* is oceanic-montane comprising a complex of associations. That occurring within the mid-altitude Azorean cloud forests clearly most closely resembles the western *Nephromaetum lusitanicae* (BARKMAN 1958), which has as faithful species, *Degelia plumbea*, *Lobaria virens*, *Nephroma laevigatum* Ach., and species of *Pseudocyphellaria* and *Sticta*, all of which also occur in the Azores. This oceanic association is also well-represented in W. Scotland, W. and S. England, W. Wales, S.W. Ireland, S.W. Norway, W. and N.W. France and the Western Pyrénées (JAMES *et al.* 1977, ROSE 1988). However, additional species are present in the Azores, e.g. *Erioderma leylandii*, *E. mollissimum*, *Nephroma helveticum*, *N. hensseniae*, *Peltigera dissecta* and *P. melanorrhiza* which are important endemic components of the *Lobarion* in the Azores. The Pico localities are important for the additional presence of *Menegazzia terebrata* and *Leptogium cochleatum*.

The upper altitude lichen-rich forest at Cerrado de Sonicas on O'Pico (890 - 1150 m) comprises sheltered (gulleys and craters) as well as more exposed (ridges) habitats. Lichens are here well-developed and form unique communities, otherwise not represented elsewhere in the Azores as this area represents the highest occurring *Juniperion* forest. Amongst species restricted to this region are: *Hypotrachyna sinuosa*, *Lecanora farinaria*, *Lobaria scrobiculata*, *Ochrolechia azorica*, *Sphaerophorus globosus* and *Stenocybe bryophilus*. Here species of *Hypotrachyna*, particularly *H. taylorensis*, reach their maximum development.

The wetter areas are correspondingly poorer in lichens owing to the dominance of mosses. Under these conditions few lichens can compete with them, e.g. *Gomphillus*, *Gyalideopsis* and *Ramonia* which directly overgrow mosses; foliose lichens such as *Hypotrachyna* grow less well owing to the instability of their moss substrate which they eventually kill. In these wet conditions crustose lichens are best developed on smooth-barked trees, such as *Ilex*, *Vaccinium* and *Myrsine*, the trunks or stems of which usually support fewer mosses. The upper, mist-enshrouded zone on Caldeira do Faial (800-922 m) is most

similar to Cabeço do Caveiro (900 m) on Pico which both have *Pannaria pezizoides* and a well-developed *Cladonia* community. Sheltered areas within Cabeço do Caveiro contain a large number of foliose, cyanobacterial lichens such as *Degelia, Leptogium, Nephroma, Pannaria, Parmeliella, Pseudocyphellaria* and *Sticta*, the lobes often thin, elongate and lacerate due to the very high, constant humidity. The basidiolichen *Dictyonema interruptum* is also conspicuous and abundantly fertile, a species otherwise recorded only elsewhere in Europe from S.W. Ireland, now considered as extinct in S. England, S. Wales and W. Scotland (PURVIS *et al.* 1994, Sérusiaux 1989). This community represents an extreme facies of the *Lobarion* restricted to moist, sheltered habitats in which *Lobaria pulmonaria* itself is rare. The abundance of lichens here with cyanobacterial photobionts is not surprising considering their physiological requirement for liquid water to reactivate photosynthesis (LANGE *et al.* 1993). Their relative scarcity in the Caldeira, is perhaps due to the rarity of *Ilex* and *Laurus*, the dominance of *Juniperus*, as well as the more open woodland structure owing to selective logging. The lichens occurring in these wetter areas are characteristic of hyperoceanic areas of W. Britain, S.W. Ireland and other parts of W. Europe including W. Brittany. The distinctive alliance, *Parmelion (Hypotrachynon) laevigatae*, was described from these areas, all of which are characterised by high rainfall (129-229 cm $year^{-1}$) and a tendency for bark to become leached and more acidic with a pH for this community of between 3.75 - 4.60 (JAMES *et al.* 1977). This community is best developed in the upper part of Caldeira do Faial, though also occurs at Caveiro. A similar situation of the juxtaposition of these two alliances has been frequently observed in W. Scotland and is considered to relate to variation in the substrate bark pH (JAMES *et al.* 1977). Amongst the parmelioid lichens belonging to the *Parmelion laevigatae, Hypotrachyna endochlora* is best-developed in this wet zone, and also seems to have the widest ecological amplitude.

A notable feature of the cloud forests is the general scarcity of fruticose lichens. However, several species of *Usnea* may occur at forest margins and in windy, exposed situations such as upper branches of *Erica azorica*, which often protrude above the canopy, particularly at Bosque da Junqueria. Species of *Usnea* are most frequent in mid-altitude, lichen-rich sites. The genus *Ramalina* was not observed, though several species were seen by the authors at lower altitudes, especially by the coast. *Teloschistes flavicans* is also coastal on Pico, though was not seen in the cloud forests. *T. flavicans* is abundant in forests on Hawaii above an altitude of 1200 m, as a result of frequent cloud; elsewhere in Hawaii *Teloschistes* is normally found well below this altitude (SMITH, 1993). Perhaps the scarcity of these species in the Azorean cloud forests is due to the wetter conditions and relative infrequency of drying out periods.

The scarcity of lichens growing on rocks within the cloud forests on both Pico and Faial is also notable, though *Herteliana taylorii* is ubiquitous and *Baeomyces rufus*, *Leptogium cyanescens*, *Rhizocarpon hochstetteri* and species of *Trapelia* less frequent. In W. Scotland, e.g. on the island of Mull a similarly poor saxicolous lichen flora on basalt was noted (EDDY

& JAMES 1978). As lichens usually need environments subject to greater fluctuations in humidity and light than is usual for many mosses and algae, in the more sheltered, damp habitats, lichens tend to come into direct competition with cyanobacteria and mosses which often overgrow or make initial colonisation difficult for the crustose and smaller foliose species. The importance of moisture as a principal factor in controlling the distribution of other plant communities is particularly apparent in the case of bryophytes (SJÖGREN 1978) who considers annual rainfall largely responsible for the zonation of plant communities as well as individual species in the Azores. However, the lichen communities, in contrast, appear to be more sensitive to a climatic gradient, involving humidity, temperature and illumination, but a more detailed survey will be necessary to confirm this. The degree of exposure plays an important role in determining the relative periods of desiccation and hydration essential to the physiology of these poikilohydric organisms (LANGE *et al.* 1993). This observation is not unexpected in view of the very different physiologies exhibited by bryophytes and lichens.

Azorean cloud forests are remarkable for the presence of a large number of rare, vulnerable, or endangered macrolichens which are listed in the Red List of the European Community (SÉRUSIAUX 1989). Out of a total of 220 species, 65 are found in the Azores, 49 (22%) of which occur within the cloud forests (Table 1). 11 species are considered as endemic to the European Community and Macaronesia whilst a further two recently described endemic macrolichens, *Peltigera melanorrhiza* and *P. dissecta* (PURVIS & JAMES 1993) should now be added to this list. There are also 12 disjunct Macaronesian taxa which occur nowhere else in Europe. Amongst these, some such as *Erioderma leylandii* may possibly be regarded as distinct taxa since Azorean populations differ chemically from Chilean specimens (ELIX *et al.* 1986). We believe further species should be added to the Red List including *Leptogium cochleatum* and *Sticta weigelii*; further work is needed in certain critical macrolichen genera, particularly *Cladonia, Heterodermia* and *Usnea,* where it is probable that further taxa remain to be described. Significantly, several of the Red List species are frequent in at least certain cloud forests in the Azores which therefore represent major strongholds for many species which are now rare or extinct elsewhere in Europe. For instance *Pseudocyphellaria lacerata*, originally described from the Azores (São Miguel) is elsewhere (N. Wales, S.W. Ireland, W. Scotland, Faroe Islands and Madeira) regarded as being genuinely rare (GALLOWAY 1994), though on Pico it is present at all sites surveyed where it is well-developed.

The sensitivity of the *Lobarion* to habitat destruction is well-documented in Europe where the *Lobarion* was formerly widespread throughout much of lowland north and north-west Europe on the bark of most broad-leaved species. It has declined significantly in many regions owing to pronounced changes in forest management and deforestation and the additional effect of atmospheric air pollution, including both sulphur dioxide and acid rain (HAWKSWORTH *et al.* 1973; JAMES *et al.* 1977, ROSE 1988). The inability of many lichens to grow in secondary vegetation is well documented, even though perhaps adjacent to primary

woodland relics with old trees (JAMES *et al.* 1977; ROSE 1976). The extreme sensitivity of certain lichens to environmental change is well illustrated by the probable extinction of *Erioderma pedicellatum* (Hue) P.M. Jørg. in Nord Trøndelag, Norway and Värmland, Sweden (JØRGENSEN 1990). Although protected by law in Sweden, reserves were too small in both countries and the destruction of native woodlands in adjacent areas to the reserves is considered to have caused the local environment to become too dry to allow their survival.

Traditionally Macaronesia has been regarded as a separate biogeographical region for more more than a century, though this has recently been criticized due to the floristic heterogeneity of the region (NICOLAS *et al.* 1989). Origins of the Azorean cloud forest lichens pose intriguing problems which can be satisfactorily addressed only when the critical, corticolous crustose species, as well as terricolous and saxicolous communities are identified. These must in turn be compared with other floras both in Macaronesia and beyond. The majority of the lichens recorded to date occur also in W. Europe, though others are pan-tropical or cosmopolitan (*Coccocarpia palmicola*, *Hypotrachyna microblasta*, *H. rockii*, *H. sinuosa*, *Rimelia subisidiosa*). An analysis of the biogeographical affinities of the Azorean lichen flora will be presented in a future paper.

Azorean cloud forests are important remnants of Laurissilva in Macaronesia with a rich and varied lichen flora which were formerly more widespread prior to wide-scale deforestation and industrialisation in Europe. Further phytosociological studies are needed to define the communities more precisely, particularly in relation to the crustose species present as well as the importance of individual phorophyte species. Forests are not only important for the conservation of rare organisms such as lichens and beetles (BORGES 1992) etc. Without forests and their associated mosses, liverworts and lichens, the water budget of the islands will become severely curtailed. Grasslands simply do not intercept sufficient cloud resulting in the drying up of streams and springs leading to an over-all deficit for the island and all its habitants, including humans. Lichens, because of their dual nature and sensitivity to environmental change, are well-placed to help monitor the health of the Azorean cloud forests and ecosystem as a whole.

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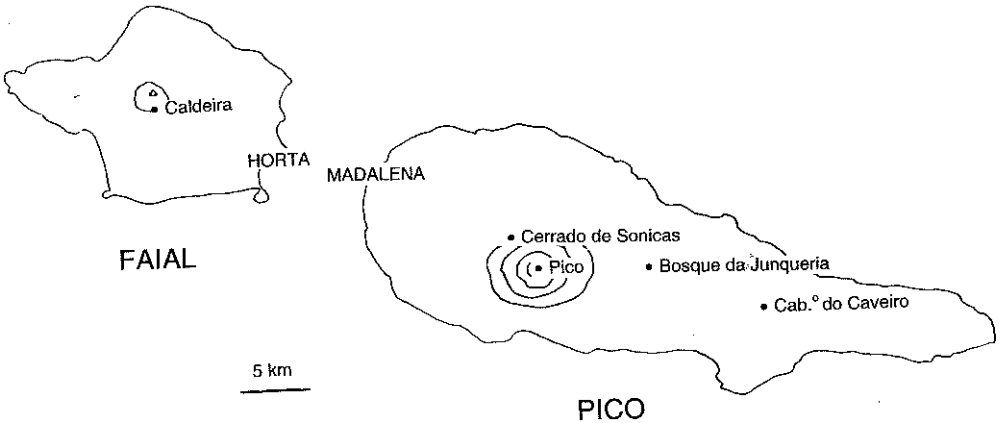

Figure 1 - Sites studied on Pico and Faial.

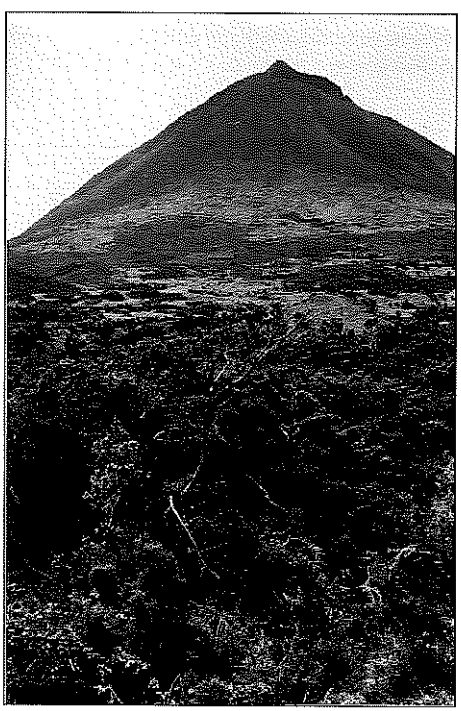

Figure 2 - Pico Mountain with a relict scrub outlier of Bosque da Junqueria in foreground of *Erica azorica*, *Juniperus brevifolia*, *Ilex perado* subsp *azorica* and *Laurus azorica*.

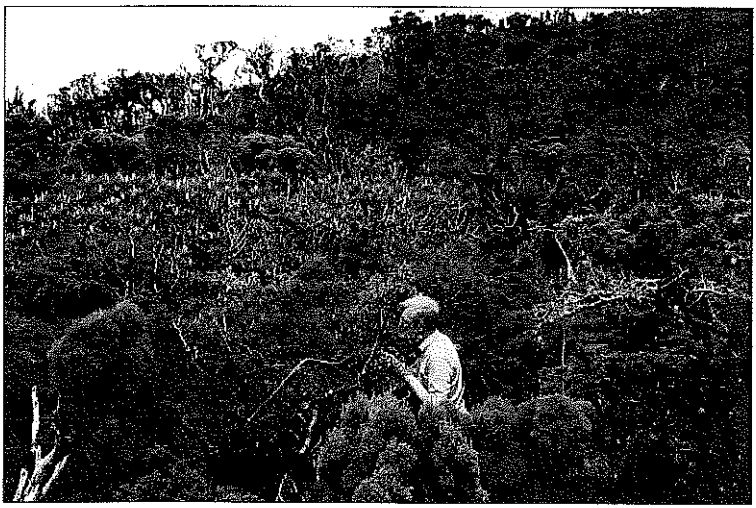

Figure 3 - Close-up of cloud forest vegetation with *Erica azorica*, *Ilex perado* subsp. *azorica*, *Juniperus brevifolia* and *Vaccinium cylindraceum*, Cabeço do Caveiro, April 1992.

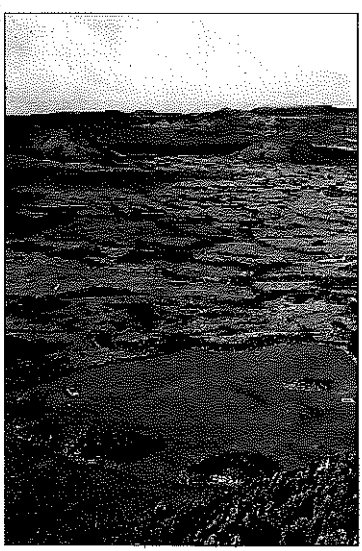

Figure 4 - Fragmented landscape with Bosque da Junqueria in background showing extensive land clearance and relict scrub forming hedges and shelter belts. Taken from Pico da Urze, May 1993.

TABLE 1 - Distribution within study sities of Azorean cloud forest lichens included in European Community Red List of macrolichens (adapted after SÉRUSIAUX 1989)

	Junqueria / Redondo	Cerrado de Sonicas	Caveiro	Caldeira Faial
Cladonia azorica Ahti*	f	a	r	o
C. barbonica (Del.) Nyl.§				
C. macaronesica Ahti*				
C. stereoclada des Abb. *	f	r	r	o
C. subradiata (Vainio) Scriba§				
C. vulcanica Zollinger §				
Degelia atlantica (Degel.) P.M. Jørg. & P. James	o	r	r	f
D. plumbea (Lightf.) P.M. Jørg. & P. James		r		
Dictyonema interruptum (Carm ex Hook) Parm.*ex	o		o	o
Erioderma leylandii (Taylor) Mull. Arg. §	f	r		
E. mollissimum (Samp.) Du Rietz	o	o	r	
Heterodermia japonica (Sato) Swinscow & Krog§		r		f
H. lutescens (Kurokawa) Follman†*				
Hypotrachyna endochlora (Leighton) Hale	a	r	o	o
H. imbricatula (Zahlbr.) Hale§	o			
H. microblasta (Vainio) Hale§	o	r	r	
H. pseudosinuosa (Asah.) Hale§				
H. pulvinata (Fée) Hale§				
H. rockii (Zahlbr.) Hale§	a	f		f
H. sinuosa (Sm.) Hale		o		
H. taylorensis M. Mitchell	f	a		
Leptogium burgessii (L.) Mont.			a	
L. coralloideum (Mey. et Flot.) Vain	o	o		
L. hibernicum Mitchell ex P.M. Jørg.				
Lobaria immixta Vainio*† - possibly *L. pulmonaria*				
L. scrobiculata (Scop.) DC.		r		
L. virens (With) Laundon	f			
Nephroma helveticum Ach. ex		f		f
N. henssenіae P.James & F.J. White*	f	f	o	f
N. venosum Degel. *	f	r	o	f
Pannaria conoplea (Ach.) Bory	o	r	o	f
P. leucosticta (Tuck.) Nyl.				
Pannaria rubiginosa (Ach.) Bory	r	f		o
Parmeliella jamesii S. Ahlner & P.M. Jørg.	f	r		o
Parmelinopsis horrescens (Tayl.) Elix & Hale	f	f		a
Parmotrema arnoldii (Du Rietz) Hale	f			f
P. mellissii (Dodge) Hale §	r ?			
Pseudocyphellaria aurata (Ach.) Vainio	o	r		o
P. crocata (L.) Vain.		o		
P. intricata (Del.) Vainio	f	f	f	f
P. lacerata Degel. *	o	o	f	f
Stereocaulon atlanticum (Lamb) Lamb §				
S. azoreum (Schaer.) Nyl. *	o	o	o	
S. macaronesica Purvis & P. James [as *S vulcani* (Bory) Ach.] *		o	o	
Sticta canariensis (Flörke) Delise				
S. fuliginosa (Hoffm.) Ach.	f	f	o	a
S. limbata (Sm.) Ach.				
S. sylvatica (Huds.) Ach.				
Usnea articulata (L.) Hoffm.§				

Key - a abundant; f frequent; o occasional; r rare; * endemic within European Community (including Macaronesia) † doubtful record - record(s) on which based require further study; § disjunct species. Only recorded in Macaronesia in European Community - otherwise mostly tropical; ex extinct outside Macaronesia