STUDIES IN THE LICHENS OF THE AZORES. PART 5. A COMPARISON BETWEEN THE LICHEN FLORAS ASSOCIATED WITH *JUNIPERUS BREVIFOLIA* IN RELICT WOODLAND IN SELECTED SITES ON TERCEIRA AND FLORES

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With 5 figures and 1 table

ABSTRACT. Lichen comunities associated with relict *Juniperus* woodland on the Azorean islands of Flores and Terceira are discussed in relation to phorophyte composition, water regime and altitude. *Juniperus* supports contrasting communities as a direct response to varying environmental regimes. The endemic *Ramonia azorica* is restricted to *Juniperus* in relict stands where it is characteristic of a distinctive community reaching its maximum development in humid sites above 650 m alt. on the island of Flores. The vulnerability of this unique community to habitat disturbance is discussed and recommendations for conservation of selected areas of *Juniperus* forest presented.

INTRODUCTION

This paper is the fifth in a series on the taxonomy, ecology and biogeography of lichens in the Azores. The characteristic evergreen forests of the Azores, together with those of the Canaries and Madeira, are considered relicts of the now largely lost Tertiary forests of southern Europe traditionally referred to as "Laurisilva" (see DIAS 1991). However, these forests are complex in structure consisting of a mosaic of vegetation types according to succession, altitude and geology (e.g. HAGGAR 1988, DIAS 1991). Indeed *Laurus azorica* itself may be absent from many forests, especially in the wetter sites above an altitude of 800 m where *Juniperus brevifolia* predominates. The relict forests are noteworthy in that they support 53 endemic vascular plant taxa, 15 endemic bryophytes (SJØGREN 1990), although only 7 endemic lichens have been described so far: *Nephroma hensenniae* P. JAMES & F.J.

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WHITE (JAMES & WHITE 1987), *Ochrolechia azorica* PURVIS, P. JAMES & BRODO (PURVIS *et al.* 1994), *Peltigera dissecta* PURVIS, P. JAMES & VITIK., *P. melanorrhiza* PURVIS, P. JAMES & VITIK.), *Ramonia azorica* P. JAMES & PURVIS (PURVIS & JAMES 1993) and *Thelotrema antoninii* PURVIS & P. JAMES and *T. perforatum* var. *pauciseptatum* PURVIS & P. JAMES (PURVIS *et al.* 1995); several more await description. Eight of the native trees including *Juniperus brevifolia* are endemic, with a further two species endemic to the Azores and Madeira (SJÖGREN 1973, 1984). Little forest with native trees, particularly containing *Juniperus*, now exists below 500 m, having either been felled for firewood or building purposes. Often such cleared sites are invaded by dense stands of the exotic *Pittosporum undulatum* with continuous thickets of *Hedychium gardneranum* as an understorey. On São Miguel *Clethra arborea* is an ever increasing problem (L. SILVA pers. comm.). At higher altitudes there has been a wide-scale clearance of the forests for pasture.

The climate of the Azores is oceanic with rather small seasonal fluctuations in temperature and rainfall at sea level. Annual precipitation is *c.* 1054 mm at sea level in Faial increasing some 16% for every 100 m increase in altitude (SJÖGREN 1978). Rainfall also increases from east to west of the archipelago (Fig. 1). The mean high temperatures in the Azores range between 15-23°C at sea level and the diurnal variation rarely exceeds 7°C (ANON 1954). 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).

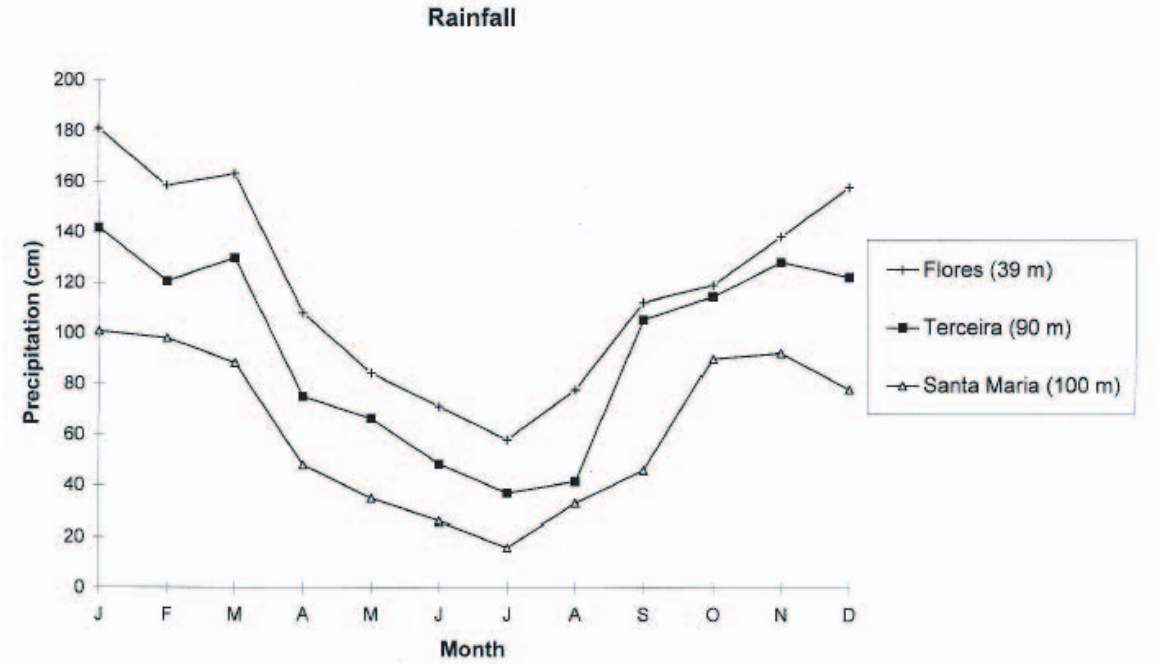

Fig. 1 - Annual precipitation on Santa Cruz, Flores (1931-1960), Angra do heroismo, Terceira (1931-1960) and Aeroporto, Sta. Maria (1947-1969). Data from Instituto Nacional de Metereolgia e Geofisica (BETTENCOURT 1979).

Previous studies by the authors on relict cloud forests in the Azores have demonstrated that their lichen communities 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 (PURVIS *et al.* 1996).

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 may be used to assess the age and continuity of these woodlands and is an important tool in the choice of areas for conservation (ROSE 1976, TIBELL 1992). Forty-nine red data book macrolichen species listed for the European Community are present in the Azorean cloud forests accounting for 22% of the total listed in Europe (SÉRUSIAUX 1989). 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). There are three major objectives of the present study (1) a description of the main lichen communities occurring on *Juniperus* and associated phorophytes within selected *Juniperus* forests, (2) a discussion of the vulnerability of these lichen floras and the importance of their conservation and (3) recommendations on sites for conservation.

METHODS

Areas with significant relict *Juniperus* forest vegetation along an altitudinal gradient from 440 m to the highest peak on Terceira in the central island group, and on the slopes of the highest mountain, Morro Alto on Flores, the most westerly of the islands of the Azores, were studied (Fig. 2). Most areas were severely threatened by encroaching agriculture, particularly cattle grazing and are easily accessible either by road or track. Each site was thoroughly surveyed to provide as complete a sample as possible during May 1994 and May 1995; 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 are represented by voucher specimens at BM, HAW, LIS and Herbario da Universidade dos Açores (AZU). Standard methods for identifying lichen material were applied in accordance with those outlined in PURVIS & JAMES 1993, PURVIS *et al.* 1992). Author citations follow BRUMMIT & POWELL (1992); nomenclature and full author citations for lichens are according to HAFELLNER (1995). Higher plant nomenclature follows SJÖGREN (1973, 1984). In this paper we refer to species by the generic name after the first citation of the name except where it is necessary to distinguish between two congeneric species.

A small number of critical species remain to be determined pending critical taxonomic evaluation, mainly within the genera *Cladonia, Heterodermia* and *Usnea.*

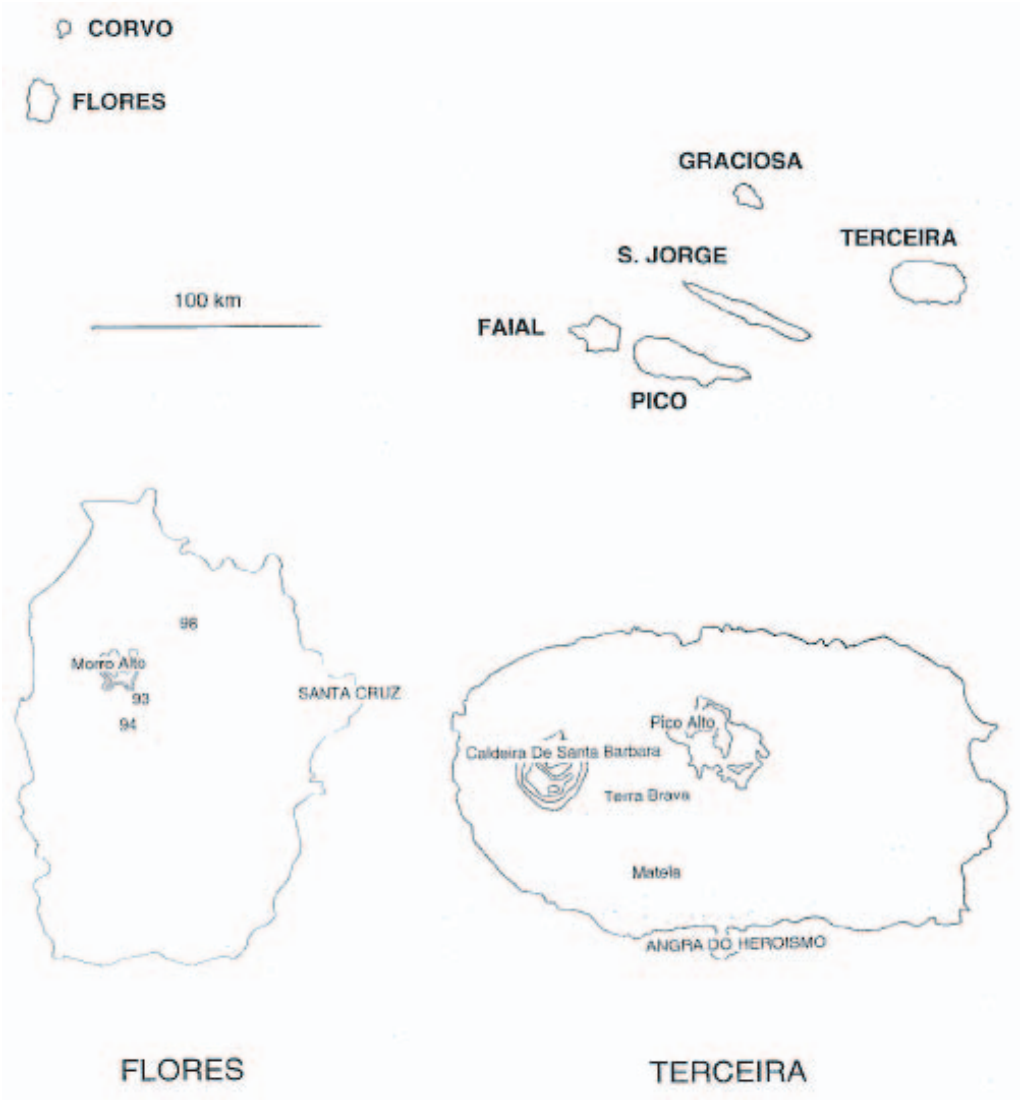

Fig. 2 - Relict *Juniperus* forest sites studied.

Study area

Terceira

Matela

Four km NW of S. Bartolomeu, east of road, alt. 400 m, 6 May 1994, O.W. PURVIS & P.W. JAMES [site 67] Scattered *Juniperus* forming tall, erect standards to 5(-6.5) m tall in pasture with *Erica azorica, Laurus azorica, Myrica faya, Pittosporum* with *Cryptomeria japonica* plantation on opposite side of road. *Hedera helix* and *Rubus* spp. are abundant. This is a rare remnant of lowland *Juniperus* forest which elsewhere has been virtually eliminated through selective removal as timber and following invasion by exotic species (Fig. 3).

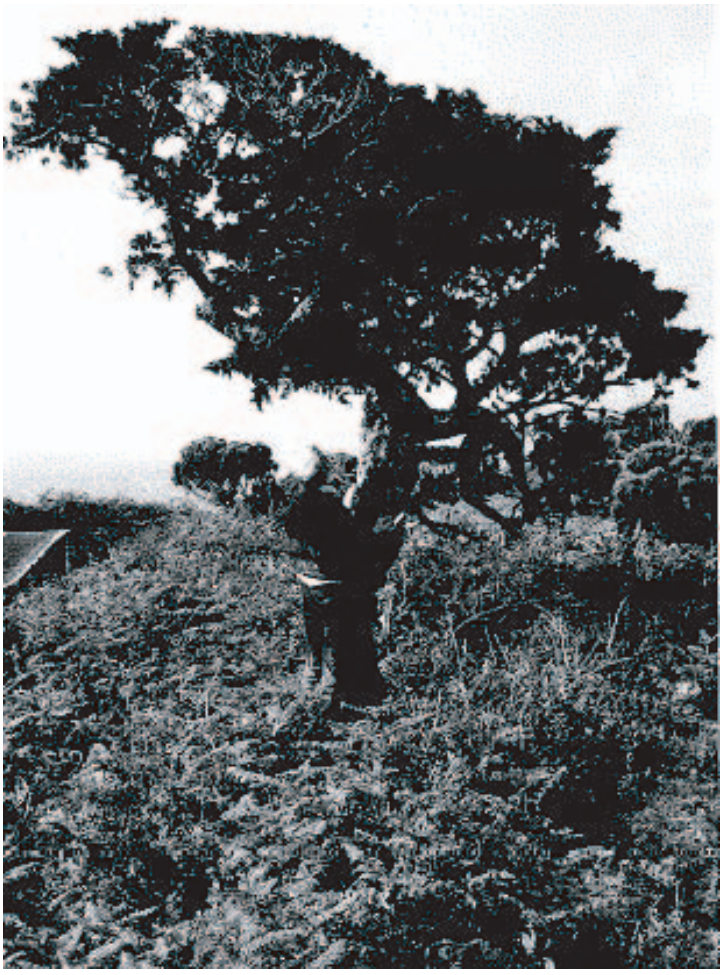

Fig. 3 - Isolated *Juniperus brevifolia* at Matela, Terceira.

Terra Brava

East side of Terra Brava, 6.5 km S of Quattro Ribeiras, 675 m alt., 9 May 1994, O.W. PURVIS & P.W. JAMES [site 74] An extensive open area of low hills covered with *Juniperus/Laurus /Vaccinium cylindraceum* scrub forest amidst large *Sphagnum* hummocks, associated with a wide diversity of phanerogams including *Erica azorica, Calluna vulgaris, Hedera, Holcus rigidus, Hypericum foliosum, Myrsine africana, Luzula azorica* and the ferns *Culcita macrocarpa, Elaphoglossum hirtum. Ilex perado* subsp. *azorica* is rare and where it occurs by road margins is much damaged due to selective cropping for cattle feed and bedding, as are other shrubs, especially *Juniperus.* This area is surrounded by *Cryptomeria* forest *c.* 1 km to the west.

Santa Barbara Mountain

Five km NW of Santa Barbara, summit of Santa Barbara Mountain, 1000 m alt., 6

May 1994, O.W. PURVIS & P.W. JAMES [site 69]. Windswept *Juniperus* elfinwood to *c.* 1 m tall, rarely to 2 m in protected, deep rock crevices with *Calluna*, *Myrsine*, *Deschampsia foliosa*, *Holcus* and rarely *Vaccinium cylindraceum*. The bryophytes *Campylopus carreiroanus* and *Polytrichum commune* are frequent. This is the most exposed site on Terceira where winds in excess of 140 km/h regularly occur (DIAS 1991).

Flores

Morro Alto [94]

About 500 m W of Pico dos Sete Pes, SW-facing, sheltered slope, 720 m alt., 5 May 1995, O.W. PURVIS, P.W. JAMES & C.W. SMITH [site 94] *Juniperus* dominant, 1-2 m tall, forming dense, interlocking stands, more rarely as isolated individuals amongst notably deep and ± continuous *Sphagum* hummocks. An extremely species poor community with occasional *Vaccinium* but notably lacking *Erica*, *Laurus* and other characteristic elements of the Laurisilva. The associated bryophyte flora is well developed on *Juniperus* with *Frullania* dominant. The ferns *Blechnum spicant* and *Elaphoglossum hirtum* are frequent; few associated herbaceous plants are present apart from *Potentilla erecta* and *Luzula azorica*. The site is in pristine condition with no evidence for disturbance by cattle (Fig. 4).

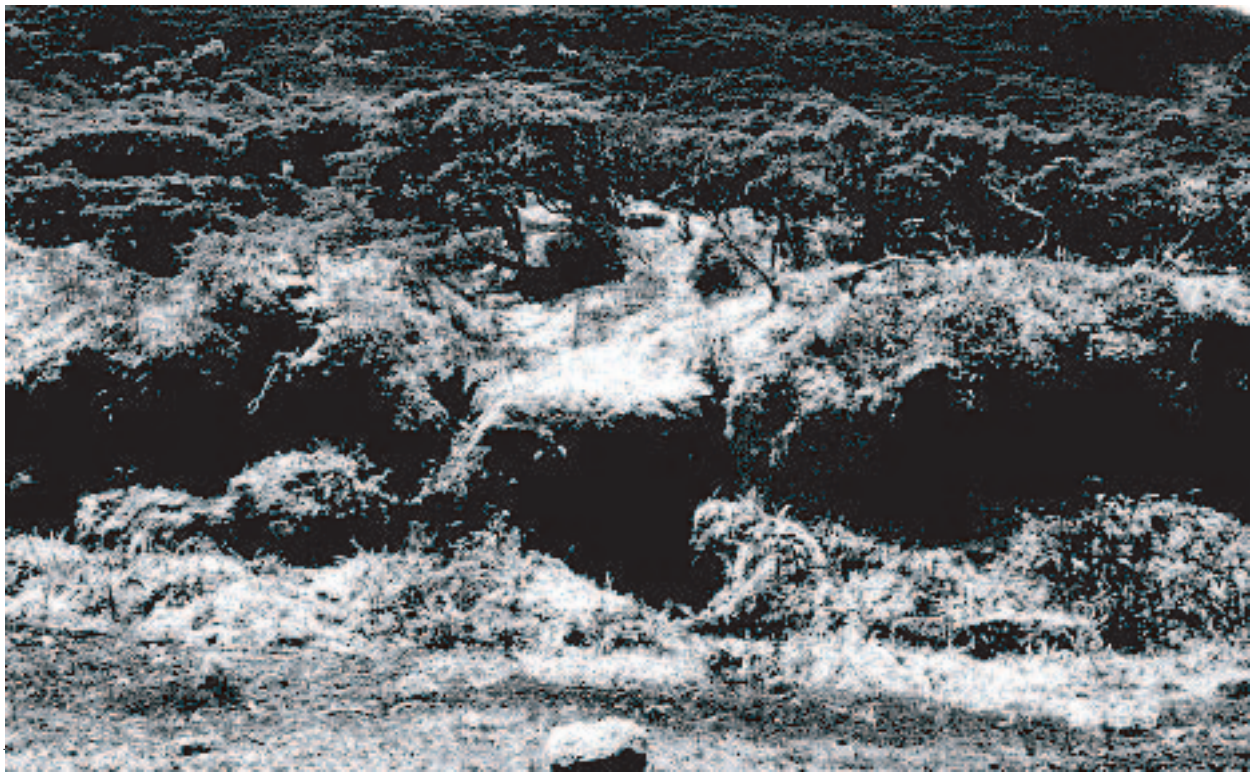

Fig. 4 - *Juniperus brevifolia* at Morro Alto (site 94) amidst *Sphagnum* humocks.

Morro Alto [98]

Three km NNE of Morro Alto, N-planeze of Morro Alto, by forestry road, 650 m alt., 7 May 1995, O.W. PURVIS, P.W. JAMES & C.W. SMITH [site 98] Fragmented stands of erect, mature *Juniperus* to 2(-3) m tall forming moderately dense stands or more rarely as isolated clumps with *Vaccinium*, *Frangula azorica* and *Laurus* scrub amidst large *Sphagnum* cushions. *Ilex* is rare and mostly badly damaged due to cropping, though some young individuals persist. There is evidence of extensive, long-term extraction of timber, particularly *Juniperus* and disturbance by cattle.

Morro Alto [93]

About 0.5 km SE of Morro Alto, off forestry road, *c.* 750-850 m alt., 5 May 1995, O.W. PURVIS, P.W. JAMES & C.W. SMITH [site 93]. The site is a windswept, poorly drained plateau with dwarf, prostrate *Juniperus* scrub to 1(-2)m tall in the more sheltered sites amongst low *Sphagnum* hummocks; *Vaccinium* is rare. Small rock outcrops and water-filled hollows are present with grasses and patches of *Sibbaldia procumbens Hypericum elodes* is abundant and indicative of poor drainage. *Daboecia azorica* is locally present. There is considerable evidence of disturbance by cattle in the area.

RESULTS AND DISCUSSION

The lichens present within *Juniperus*-dominated forest in the Azores are variable in terms of diversity and species composition according to the nature of the site, particularly with regard to the diversity of phorophytes present (Table 1). Significantly, no single site contains all the lichen species associated with *Juniperus* thus emphasising the need to conserve diverse fragments of the forest.

On Terceira the three sites are lowland (400m, Matela), intermediate (675m, Terra Brava) and high altitude (1000 m, Sta Barbara). The greatest diversity of species occurs in lowland and intermediate altitude sites. Altitude has a direct effect on moisture regime and temperature. Lowland remnants of relict forest, such as that at Matela which is virtually unique in the Azores, contain a range of essentially lowland species: *Cladonia nana, Pyxine sorediata* and *Pyrrhospora lusitanica* and more dry bark species like *Calicium* sp., *Chyrysothrix chlorina* and *C. chrysophthalma.* At the intermediate altitude site at Terra Brava there is also a diverse flora, including significant elements of the *Lobarion* community, such as the endemic *Nephroma hensseniae*, and is similar to those documented at similar altitudes on Pico (PURVIS *et al.* 1996). On the wind-exposed summit of Sta Barbara a relatively species poor flora occurs, mostly on bryophytes. On Flores all studied sites occur within a narrower altitudinal range on the slopes and plateau of Morro Alto, an acid, water-logged area with abundant mounds of *Sphagnum.* Although significantly lower in altitude than Sta Barbara on Terceira, the lichen floras at the Flores sites are broadly similar (Table 1).

TABLE 1 - Lichens recorded in *Juniperus* woodland at selected sites on Flores and Terceira.

ISLAND	FLORES			TERCEIRA		
Locality	Morro Alto	Morro Alto	Morro Alto	Matela	Terra Brava	Sta Barbara
Site no.	98	94	93	67	74	69
Altitude (m)	650	720	c. 800	400	675	1000
Agonimia tristicula				r; C		
Arthonia elegans						
Arthopyrenia antecellans					r; V	
A. carneobrunneola				r; I		
A.sp. 1	o; F					
A.sp. 2					o; I	
Bacidia c.f. arcentina				r; P		
B. cf. lauroceraxi				r; Mf		
B. spiohica				r; Mf, C, L		
Baeomyces rufus				+	+	
Buellia erubescens				o; Mf,J		
Byssoloma leucoblepharum				o; L	o; L	
B. subdiscordans				r; L	r; L	
Calicium sp.	r; E			r; E,J		
Catillaria pulvera						r,J
Celothelium ischnobelum				r; V		
Chrysothrix candelaris				r; J	r; E	
C. chrysophthalma				r; J		
Cladonia azorica	+	+	+	+	+	+
C. cervicornis				+	+	
C. chlorophaea				r; E	r; E	o;J
C. coniocraea				r; E	r; E	r; J
C. diversa				+	+	r; J
C. fimbriata				r; E, J	r; E	
C. foliacea				+		
C. humilis				+		
C. nana				+		
C. polydactyla				r; lig,J	r; lig	
C. pyxidata		r; J	r; J	r; E		
C. stereoclada	r; J	r; J		E,J	E	r; J
C. vulcanica				r; E,J	+	
C. sp 1	r; J	r; J	r; J			r; J
C. sp 2				+		
C. sp 3					+; lig	
Cliostomum griffithii				r; Mf		
Coccocarpia palmicola	r; J					
Collema furfuraceum				r; C		

TABLE 1 - (cont.)

C. nigrescens				r; C		
C. subflaccidum				r;P		
Degelia atlantica				r; E,C		
D. plumbea				o; E,C,P,I	r; I	
Dictyonema interruptum	r;J				r;L	
Dimerella cf pineti	r;J			o; J	r;L	
Erioderma leylandii	r;J				r;J,E	r;J
E. mollissimum					r; Mf	
Flavoparmelia caperata				r; E,J		
Fuscidea arboricola	r;V	r;V	r;V	r;V	r;V	
Gomphillus calycioides	r;J	r;J	r;J		r;J	r;J
Graphis elegans				r;P		
G. scripta	r;I,V				r;I	r;I,V
G. tritícea	r;J,E	r;J	r;J		r;J,I	r;J,E
G. sp.				r;E		
Gyalideopsis muscicola	r;J		r;J			r;J
Gyalideopsis sp.	r;J	r;J	o;J			r;J
Herteliana taylorii	+			+	+	
Heterodermia japonica	r;J	r;J	o;J		r;L	r;J
H. leucomelos	r;J			o;E	r;L	
H. lutescens				r;E,J		
Hyperphyscia adglutinata				r;E,P		
Hypotrachyna costaricensis				r;E,J	r;L	
H. endochlora	r;J,E	r;J	r;J		r;E	r;J
H. microblasta	o;J				r;J	
H. pseudosinuosa					r;E	
H. pulvinata				r;J	r;E	
H. rockii				r;E,J	r;E,J	
Lecanora cf albella				r;Mf		
L. chlarotera agg.				o;Mf,P,I	r;I	
L. confusa				r;E		
L. jamesii				r;P		
L. symmicta				r;lig		
Lepraria incana	r;E			r;E,J	r;E	
L. lobificans				o;J	r;I	
L. umbricola				E,J,E	r;I	
L. sp 1					r;I	
L. sp 2					r;I	
Leptogium brebissonii					r;I	
L. burgessii					r;I	
Leptogium cyanescens	o;J			r;E,J,P	r;E	r;V
Lobaria pulmonaria	r;V			r;P,E	r;L,V	
L. virens					r;L	
Loxospora elatinum	r;J,E			r;J,E	r;V,L	r;J
Megalaria puverea	r;J		r;J		r;J,E,L	r;E,J

TABLE 1 - (cont.)

Megalaspora tuberculosa	o:J,E	o:J	o;J	r:J	r:E	o:J,E
Melaspilea ? diplaciospora	r:I					
Micarea alabastrites				r:C		
M. lignaria	r;lig	r;lig	o;J,lig			o;lig,Ma
M. peliocarpa				r;C		
M. prasina	r:J			r:J,E	r:J,E	r:J
M. synotheoides				r;C		
M. sp.				r;C		
Mycoblastus caesius	r:J,lig	r;J,lig	r:J,lig	r;J	r:J,E,lig	r:J,lig
Nephroma helveticum					r:I	
N. hensseniae	r:E				r:L,V	
N. laevigatum				r:E		
Normandina pulchella				o:J,E,Mf		r;J
Ochrolechia inversa				r:J,E		
Opegrapha sp.					r:I	
Pannaria conopiea	r:J	r:J	r:J		r:J,E	r:J
P. pezizoides		r:J	r:J			r:J
P. rubiginosa			r:J		o:L,V	
Parmeliella parvula				r:C		r:J
Parmelinopsis horrescens	r:J			r:J,E,Mf	r:E	
P. minarum						
Parmotrema chilensis	o:I				o:L,V	
Parmotrema chinense	o;E			r;J,E,Mf,P	r;I,E	
P. crinitum				r;E		
P. robustum				r;E,J	r;E	
Peltigera dissecta	r;J,E				r;J,E	r;J
P. melanorrhiza			r;J			
P. sp					r;E	
Pertusaria maximilliana				r;I,P		
P. pulvinata	r;J,E		r;J		r;E	r:J
P. sp 1				r;I		
P. sp 2				r;P		
P. sp 3				r;I,P		
Phaeographis dendritica				r;P		
Placopsis gelida						
Placynthiella icmalea						
Platismatia glauca						r;J
Pseudocyphellaria aurata	r;E			r:E,L	r:E	
P. crocata					r:L	
P. intricata	r:L			r:E	r:L	
P. lacerata					r:L	
Pyrenula dermatodes	r;V,I	r;V	r;V,I	r;V	r;V,I	r;E,V,I
P. harrisii				r;P,J		
P. macrospora					r;V	
P. sp. 1					r;I	

TABLE 1 - (cont.)

P. sp. 2					r;I,E	
Pyrrhospora lusitanica				r;J		
Pyxine sorediata				r;J		
Ramalina cf peruviana				r;J,E		
Ramonia azorica	r;J	a;J	r;J			r;J
Rimelia reticulata				r;Mf,E,J	r;E	
R. subisidiosum				r;E,J	r;E	
Rinodina sp.				r;P		
Schismatomma decolorans				r;C		
Scoliciosporum umbrinum				r;E,lig		
Sticta canariensis (foined photomorph)				r;L		
S. dufourii				r;L	r;Ma	
S. fuliginosa	r;J	r;J	r;J		r;E	r;J
S. limbata				r;L		
Stereocaulon azoreum				+	+	
S. macaronesicum	+				+	
S. vesuvianum				+		
Strigula cf nitidula				r;L		
Tapellaria epiphylla				r;L	r;L	
Thelotrema antoninii	r;J	r;J	r;J	o;J,E	r;J,E	r;J,E
T. isidioides	r;J,E	o;J	r;J			
T. lepadinum	r;J,V		r;J,E	o;J,E	r;V	r;V
Trapelia corticola	r;E,J		r;J	r;J	o;J,E	
Trapeliopsis flexuosa	r;lig					r;lig
T. granulosa			+	o;E		
T. pseudogranulosa					r;lig	
Umea cornuta				r;E,J		
U. madeirensis				r;E		
U. rubicunda				r;J		
U. sp 1					r;E	
U. sp 2					r;E	
U. sp 3					r;E	
Total no. species recorded	48	20	27	102	84	35
Total no. species on Juniperus	31	17	23	38	15	30
Total no. phorophytes present	5	2	4	8	7	5
Ratio lichens/no. phorophytes	10	10	7	13	12	7

Cry = *Cryptomeria*, E = *Erica*, F = *Frangula*, I = *Ilex*, J = *Juniperus*, Mf = *Myrica*, Ma = *Myrsine*, P = *Pittosporum*, V = *Vaccinium*, lig = on wood (*Juniperus* or *Erica*), + = on soil or rock

a= abundant, f= frequent, o= occasional and r= rare.

In addition to altitude, three further factors essentially control the distribution of lichens within these woodlands: (i) types of phorophyte present, (ii) moisture regime resulting from a combination of precipitation and persistence of cloud as well as exposure and (iii) disturbance.

Juniperus is an evergreen typically forming a dense canopy. Three growth habits occur forming the basis for the delimitation of three distinct vegetation facies (DIAS 1991). In extreme, wind-exposed situations it is typically ± low-spreading and prostrate in habit to 1 m tall, as on the summit of Santa Barbara Mountain and below the summit of Morro Alto, at middle to lower altitudes *Juniperus* more typically occurs in distinct groups forming a spreading canopy to 1.5 m tall with interlocking limbs; at the lowest altitudes it may exceptionally have an erect trunk and assume a tree-like habit, 3(-4) m tall, as at Matela. In the first two cases where *Juniperus* forms a dense canopy, lichens are either confined to those areas where there is a break in the canopy where light can penetrate or else occur on exposed outer branches and smaller twigs. *Juniperus* has a spongy, ± water-retaining, resinous bark containing phenolic substances and has an acidic pH (3.5-4.2) (BARKMAN 1958). In the wettest situations moss cover is usually high, often greater than 50%, with only very few lichens able to compete e.g. the crustose *Ramonia azorica, Gomphillus calycioides, Gyalideopsis muscicola* and an unidentified species of *Gyalideopsis* with long hyphophores. *Hypotrachyna endochlora* and *Graphis triticea* also occur on wood, bark and mosses and *Erioderma leylandii* on bark. Conversely dead and drier *Juniperus* supports different communities including *Mycoblastus caesius* and species of *Cladonia* on decorticated areas. Different assemblages may occur on the same tree according to microenvironmental considerations there being distinct difference between lichen distribution on upper and lower branches according to the degree of illumination and dryness. *Ramonia* and *Loxospora elatinum* have a preference for drier situations and *Lepraria, Micarea prasina* and *Trapelia corticola* on the undersides of branches. *Coccocarpia palmicola, Erioderma, Thelotrema antoninii* and *T. isidioides* tend to occur on twigs and small branches within the canopy.

Periods of desiccation are essential for the long-term survival of most lichens, particularly those with green algal photobionts (LANGE *et al.* 1993). Thus the most luxuriant and species-rich areas occur in the lower altitude sites studied in the present survey which receive less direct precipitation but are also subject to the important influence of low cloud. Frequent periods of mist blowing through a tree canopy can promote prolific lichen growth and an abundance of fruticose lichens generally indicates such cloud forest conditions as at Matela where luxuriant growths of *Usnea* occur.

Where few lichens are present the conditions may be either too wet or dry or else the site is disturbed. Thus at higher elevations where there is both high mist and rainfall, mosses and liverworts predominate and only a few specialised lichens are able to compete by either growing on or over mosses or colonising lower surfaces of smooth, moss-free terminal branches where there is minimal competition. Specific data on the relative significance of

precipitation versus persistence of cloud cover is unfortunately lacking and urgently needed. However, local areas where significant amounts of *Sphagnum* occur indicate persistently high levels of humidity. These areas have significantly lower amounts of lichen biomass. Thus the wettest area studied in this survey are those on the island of Flores, below the summit of Morro Alto (Fig. 4) where the most species-poor phanerogamic assemblages occur are those with the lowest lichen diversity. Although species diversity is traditionally considered to be an important criterion in selecting areas for nature conservation, Morro Alto (site 94) perhaps represents the least disturbed remnant of near uniform *Juniperus* forest in the Azores and is here regarded as representing the climax of a specialised, species-poor and unnamed, lichen association dominated by the endemic *Ramonia azorica*. Extensive thalli, to 20 cm diam. of this species indicate the suitablility of this site as it is often under 3 cm across elsewhere (PURVIS & JAMES 1992) and also markedly demonstrates its ability to parasitise, overgrow and kill associated mosses and liverworts (Fig. 5). *R. azorica* occupies an extremely specialised ecological niche being restricted to *Juniperus*. It is, however, an indicator of very specialised environmental conditions requiring near undisturbed *Juniperus*, abundant rainfall and cloud cover, maintaining consistently high levels of humidity throughout the year. On Flores it occurs at lower altitudes than on Terceira, Pico (PURVIS *et al.* 1996) and Faial (PURVIS & JAMES 1993) due to the overall higher rainfall levels on this island (Fig. 1).

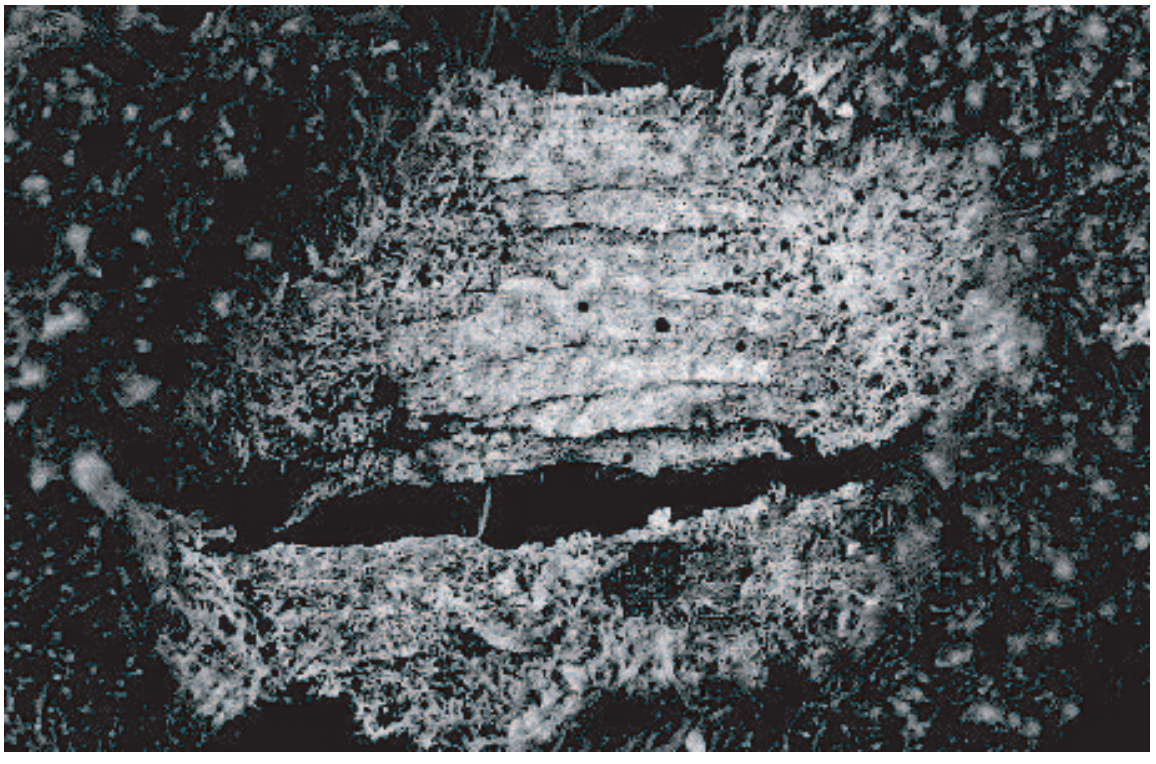

Fig. 5 - *Ramonia azorica* overgrowing and killing leafy liverworts.

Conservation Recommendations

In our report on the endangered forests on Pico to Amigos dos Açores via Dr H.R. Martins and the data presented here and in PURVIS & JAMES (1993) we conclude the *Juniperus* forests in the Azores are in need of special protection: We recommend the following sites - **Flores**: southern slopes of Morro Alto including substantial areas of the northern plateau of Morro Alto. **Faial**: Caldeira do Faial (PURVIS & JAMES 1993). **Pico**: Bosque do Junqueria / Redondo, Cabeço de Caveiro, Cerrado de Sonicas (PURVIS *et al.* 1996). **Terceira**: Santa Barbara, Matela, Terra Brava following the recommendations for conserved areas (see DIAS 1991). A recent visit by the authors to **São Miguel** forest reserve, Plan Alto dos Graminhais, Pico da Vara, suggest this area is also in need of protection. Here there was considerable evidence of cattle grazing within the reserve. Apart from protecting the *Juniperus* forest this is the only known site of *Ramonia azorica* on this island.

Juniperus forest is rapidly being destroyed, there now appear to be few undisturbed areas remaining in the Azores overall. Consequently there is an urgent need to protect the remaining few large tracts. This is important for several reasons: (i) to conserve endemism through such species as *Ramonia azorica* which forms part of a fast diminishing Azorean natural heritage (ii) the loss of *Juniperus* has important consequences for other associated species and specific to or dependent on *Juniperus* (iii) *Juniperus* forests are unique and (iv) are important as water catchment areas maintaining the overall health of the forests.

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