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Soil surface lichens on a 1500 kilometre climatic gradient in subtropical eastern Australia

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Abstract: Soil lichens are taxonomically diverse in subtropical eastern Australia. A total of 61 species in 25 genera is reported from a transect 1500 km long, running from the humid sub-tropical coast to the arid interior of the continent. The distribution of the lichen species and genera is associated with climatic pattern and with the growth form of the species. The total number of species found in bands of one degree of longitude along the transect decreases from the wet coastal region to the arid interior. Fruticose and foliose species dominated the flora in wetter regions and squamulose species in the dry interior.

Key words: arid, Australia, distribution, morphology

Introduction

Soil surface biotic crusts are a significant part of the biodiversity of many ecosystems, especially those in semi-arid areas. These crusts comprise a diversity of photosynthetic organisms and systems including lichens, mosses, liverworts, cyanobacteria and algae (Eldridge 2001). These photosynthetic components are in turn hosts to a diversity of microfauna (Wood 1970), fungi and bacteria (Fletcher & Martin 1947). The soil surface lichens of Australia have been the subject of a series of studies (Rogers & Lange 1970, 1972; Rogers 1971, 1972, 1973; Rogers 1973; Eldridge & Green 1994; Hodgins & Rogers 1997). With the exception of Hodgins & Rogers (1997), all of these refer to studies in the southern half of the continent, and to vegetation formations that are arid or semi-arid shrublands.

Apart from taxonomic studies, accounts of lichen distribution patterns in Australia are few. Rogers (1972) dealt with distribution patterns of soil lichens in arid south-eastern Australia. Rogers & Stevens (1981) discussed distribution patterns of a range of Australian lichens, and Rogers (1992) expanded that discussion. It is apparent that climatic factors are the primary determinant of distribution patterns, especially rainfall. The impact of stocking is locally important (Rogers & Lange 1971; Eldridge & Greene 1994; Hodgins & Rogers 1997), as trampling destroys crusts. There is some evidence that lichens are particularly sensitive to heat when wet (Rogers 1971), a factor of particular significance in arid and semi-arid tropical and subtropical Australia where most rain falls in the summer and shade is often sparse.

Hodgins & Rogers (1997) demonstrated the existence of a sparse lichen cover in grassland near Cunnamulla (Fig. 1) in south-western Queensland that was heavily influenced by stock. A small number of soil surface lichen collections in the Queensland Herbarium (BRI) confirmed the existence of a soil surface lichen flora across southern Queensland.

This paper documents the occurrence and distribution pattern of soil surface lichens along a 1500 km transect across southern Queensland linking to the area in New South Wales and South Australia studied by Rogers & Lange (1972). This transect extends from the humid subtropical coast

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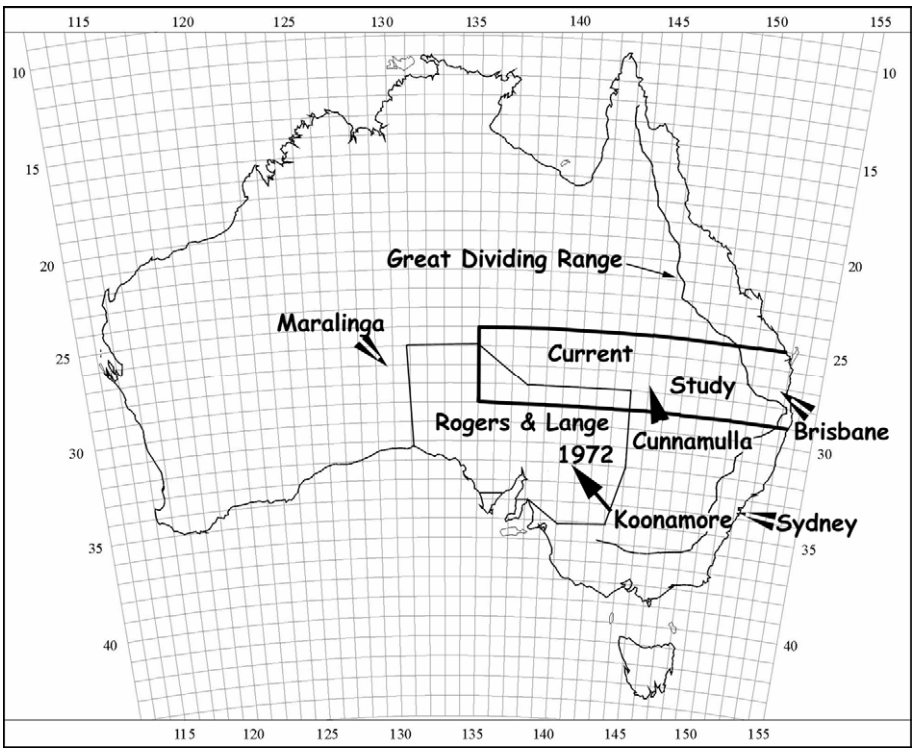


FIG. 1. Map of Australia indicating the study area in relation to other studies of soil surface lichens in Australia and the Great Dividing Range. Studies at Maralinga were undertaken by Eldridge (1998), at Koonamore by Rogers (1974) and at Cunnamulla by Hodgins & Rogers (1997). The extensive study area of Rogers & Lange (1972) is also marked.

near Brisbane to arid Lake Eyre in central Australia.

Methods

Study area

The transect (Fig. 1) includes some of the very driest and hottest parts of the Australian continent at its western extreme, and some of the moister, warm subtropical coasts in the east. The altitude within 150 km of the coast ranges from sea level to about 1000 m. The geology and soils in this area are complex and the rainfall closely related to altitude. As a result the vegetation includes low sand-heaths, eucalypt woodlands and forests with a high light penetration to the understorey, and subtropical to cool temperate rainforests which have very low light levels within the canopy. Eucalypt communities tend to accumulate a deep, dry litter layer that periodically carries fire (Rogers & Westman 1977).

Proceeding inland beyond the watershed of the Great Dividing Range, the altitude falls away for about 1400 km, finishing below sea-level in the Lake Eyre basin. The rainfall also falls proceeding inland, and salinity levels of the soil tend to rise. Many of the inland soils are self-mulching clays that have an extremely unstable surface that churns with alternate wetting and drying periods. The vegetation immediately beyond the watershed is eucalypt woodland merging into *Acacia* woodlands (common beyond 300 km inland) and ultimately into low open shrublands and grasslands often with very widely spaced low *Acacia* trees. Litter accumulation under these communities is very sparse.

Rainfall is regular and seasonal east of the watershed, predominantly falling in the summer. West of the Great Dividing Range rainfall decreases, but is predominantly summer rainfall until about 800 km inland. In the far west of the transect rainfall is equally unlikely at all times of the year. Climatic summaries are provided in Table 1.

Methods

Soil surface lichens were collected from remnant natural vegetation and other areas with protected soil surfaces from the coast near Brisbane to the Grey Range, over 1000 km inland. In the west the study area partially overlaps the study area of Rogers & Lange

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TABLE 1. *Climatic summary for the region between latitudes 25°S and 29°S and longitude 153°E and 136°E in Eastern Australia*

Longitude	*n**	rainfall†	range‡	t_{max}	t_{min}
135	1	175		37·6	7·4
138	1	162		37·7	4·8
139	1	169		38·8	6·7
142	1	227		36·1	5·4
143	1	286		36·9	5·6
144	3	337	276–391	36·6	5·1
145	3	360	332–375	35·9	4·7
146	2	495	491–499	35·5	4·1
147	2	515	462–568	34·7	3·5
148	5	569	506–632	34·4	4·2
149	3	614	585–677	33·7	4·5
150	4	647	625–668	33·1	4·3
151	12	739	643–950	30·4	4·3
152	17	1081	670–1709	32·1	6·2
153	19	1332	916–1695	29·1	8·5

*Number of meteorological sites from the area; † mean annual rainfall in mm; ‡ range of mean annual rainfall in the relevant sites; t_{max}=mean maximum temperature (°C) for the hottest month and t_{min}=mean minimum temperature (°C) for the coldest month.

1972 (Fig. 1), with lichen collections from that area available.

Collection of materials was opportunistic both in selection of locations and collecting within locations. It was sometimes difficult to find areas with soil surfaces sufficiently intact to support lichens, and within such locations the soil-surface lichens were often very patchy. To ensure the most complete representation of the soil surface lichen flora, the area was searched and bulk samples taken from a variety of soil surface habitats that bore lichens. This included searching along fence lines, around the base of trees and shrubs, on the near vertical banks of tracks and drainage lines and amongst tangles of garbage. Only strictly terricolous lichens were collected: those on fallen timber, emergent roots and termitaria (whether distinct mounds or low domes) were not included in the survey.

The lichens were all determined in the laboratory using current literature with nomenclature following McCarthy (2005). Collections made from within the transect held in the Queensland Herbarium (BRI) were added to the data block. The distribution pattern of the lichen species was summarized by grouping them into intervals of one degree of longitude, and tabulated. Collections of the same species from sites less than 5 km apart were considered to be a single location for the purposes of analysis. Specimens identified are housed in Queensland Herbarium (BRI) or the South Australian Herbarium (AD).

Distribution of species and genera were analysed by arranging both in order of tolerance for coastal regions and in the reverse order of tolerance for inland regions. The distribution of thallus forms and photobiont were also analysed along the transect.

The long-term climatic data (years 1960–1990) for each degree of longitude was summarized from the Australian Bureau of Meteorology (2004). This summary was made by collating all data for the relevant degree interval for locations within the transect and calculating the mean average annual rainfall, mean maximum temperature for the hottest month, and mean minimum temperature for the coldest month.

Linear regressions were calculated between the number of species present in any one degree interval and number of collections, mean annual rainfall, maximum temperature in the hottest month and longitude. A more rigorous quantitative analysis of the data is not appropriate because of the broad-scale nature of the survey in which many sites examined had no lichens and many more sites presumed to have no lichens were not examined at all. The very nature of the sampling, which made the study practicable, prevents some otherwise interesting analyses.

Results

Preliminary observations

A total of 328 records were documented from the vast amount of material returned to the laboratory and from the herbarium material consulted, representing 61 species of lichen in 25 genera (Table 2). The most common species (*Heterodea muelleri*) was found 32 times and a number of species were found only once. Stocking and agriculture appear to have impacted severely on soil surface lichens. In many areas lichens were found on the soil only in road or railway reserves, and at one site, only in a 10 cm wide band immediately below an unusually low bottom strand of barbed wire in a fence. The soil surface biotic crust was usually very fragmented but in a few well-protected sites extensive areas with a diverse lichen flora and almost continuous lichen cover were found. In addition, in some disturbed roadside areas growth of lichens was found over long-abandoned road-works.

The number of species found in any one-degree interval was strongly significantly associated with rainfall (F=39·05, P<0·0001), longitude (F=27·38, P=0·0001), maximum temperature (F=21·82, P=0·0003) and number of specimens observed (F=80·25, P<0·0001).

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TABLE 2. *Number of collections for a given degree of longitude of each soil surface lichen species found in a transect between latitudes 25° S and 29° S and longitude 153° E and 136° E in eastern Australia (see Fig. 1)*

Longitude (°E)	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	*n**	Form†
Aspicilia sp.										1	1								2	C
Buellia subcoronata (Müll. Arg) Malme									1	1	2	1	1						6	S
Buellia 10654									3	3	2	1	3	4		2			18	F
Cladia aggregata (Sw.) Nyl.												1			1	4	7	7	20	F
C. schizopora (Nyl.) Nyl.																		1	1	F
Cladonia cervicornis (Ach.) Flot.																1	2		3	F
C. corniculata Ahti & Kashiw.																	1		1	F
C. corymbescens Nyl. ex Leight.																		3	3	F
C. fimbriata (L.) Fries																	1		1	F
C. floerkeana Flörke																2	9	5	16	F
C. furcata (Huds.) Schrad.																	2	1	3	F
C. kuringaiensis A. W. Archer																	1	1	2	F
C. macilenta Hoffm.																		1	1	F
C. merochlorophaea Asahina																		1	1	F
C. ochrochlora Flörke														1			2	1	4	F
C. pertrichosa Kremp.																	2	1	3	F
C. praetermissa A. W. Archer																	2	1	3	F
C. rigida (Hook. f. & Taylor) Hampe																	4	1	5	F
C. subradiata (Vain.) Sandst.																		1	1	F
C. tesselata Ahti & Kashiw.																1			1	F
Collema coccophorum Tuck.		1	1	2			1	2		3		4	2	2		1			19	L,cyan
C. pustulatum Ach.																	3		3	L,cyan
Dibaeis arcuata (Stirt.) Kalb & Gierl																	2		2	F
D. sorediata Kalb & Gierl																	8	1	9	Lep
Endocarpon aridum P. M. McCarthy									1				1			2			4	S
E. pallidum Ach.								1	1										2	S
E. pusillum Hedw.	1			1				3	3		4			1					13	S
E. rogersii P. M. McCarthy								1		1	1								3	S
E. simplicatum (Nyl.) Nyl.								2		1	2		2	1					8	S
Heppia lutosa (Ach.) Nyl.	1							2	1	1	2		3	1		2			13	S,cyan
Heterodea beaugelholii Filson									1	1	1	1	2	3	2	2	2	1	16	L
H. muelleri (Hampe) Nyl.										1	1	1	3	3	4	5	11	3	32	L
Lecidea ochroleuca Pers.									2	1		2	5	1	1		1	1	14	C
L. terrena Nyl.																	2		2	C
Lepraria sp.																		3	3	Lep
Leprocaulon arbusculum (Nyl.) Nyl.																	2		2	Lep

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TABLE 2. *Continued*

Longitude (°E)	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	*n**	Form†
Leproloma membranaceum (Dicks.) Vain.																		1	1	F
Paraporpidia leptocarpa (C. Bab. & Mitt.) Rambold & Hertel																		1	1	C
Peltigera dolichorrhiza (Nyl.) Nyl.																	1	2	3	L,cyan
Peltula obscurans (Nyl.) Gyeln.								1	1		1								3	S,cyan
P. patellata (Bagl.) Swinscow	1		1					2	3		5			2					10	S,cyan
Placidium lacinulatum (Ach.) Bruess			1											1		1			3	S
P. pilosellum (Bruess) Bruess								2							1				3	S
P. squamulosum (Ach.) Bruess	1		1	1				1	1	1	1			2		1	1		11	S
Placynthium nigrum (Huds.) S. F. Gray											1								1	S,cyan
Psora crenata (Taylor) Reinke								1	1	2	3	2	2						11	S
P. crystallifera (Taylor) Müll. Arg				2					1		2								5	S
P. decipiens (Hedw.) Hoffm.			1	1															2	S
Ramalinora glaucolivida (Müll. Arg) Elix															1		4	1	5	S
Trapelia coarctata (Sm.) M.Choisy													1						1	C
Xanthoparmelia adusta (Kurok.) Elix & J. Johnst.																	1		1	L
X. pulla (Ach.) Elix & J. Johnst.																	1		1	F
X. reptans (Kurok.) Elix & J. Johnst.																1			1	L
X. substrigosa (Hale) Hale																	1		1	L
X. semiviridis (Nyl.) Elix										1	2			1		3			7	L
X. terrestris (Kurok. & Filson) Elix & J. Johnst.																		1	1	L
X. versicolor Hale									2	1									3	L
X. willisii (Kurok. & Filson) Elix & J. Johnst.														1	1				2	L
Number of specimens seen	4	1	4	7	0	0	1	18	22	18	30	14	25	24	11	28	80	41	328	
Number of species	4	1	4	5	0	0	1	11	14	14	17	7	12	15	7	14	25	24	59	

*Number of occurrences of each species; †C=crustose, S=squamulose, F=fruticose, L=leafy (foliose); cyan indicates that the photobiont is a cyanobacterium, if not indicated photobiont is a green alga.

The simple bipolar nature of the data taken with very high levels of internal correlation makes the application of multidimensional ordination analyses such as Principal Components Analysis redundant.

Distribution patterns

Soil surface lichens are found in both disturbed and natural habitats, but are not common in the coastal strip (long. 152°E and 153°E). Some species (especially the crustose and squamulose species) are found on compacted earth near paths and tracks or on vertical soil banks, being excluded from most areas by accumulated leaf litter. Foliose and fruticose species, especially *Heterodea* and *Cladonia* spp., tended to occur on nutrient poor, well-drained skeletal soils.

The flora of the coastal strip and the Great Dividing Range (long. 152°E and 153°E) is particularly rich in species, with many species of *Cladonia* present that are not found further west. Other less common genera including *Dibaeis*, *Lepraria* and *Peltigera* are also to be found in this narrow hilly strip. Only 15 species were found west of longitude 144°E and no soil surface lichens were found along the transect between longitude 140°E and 142°E although searches were made in this interval.

If the species are arranged in descending order of occurrence in relation to proximity to the coast (at higher longitudes) a pattern becomes clear (Table 3). Many species are restricted to the region near the coast with high annual rainfall, and relatively mild temperatures. *Heterodea beaugelholii* and *Lecidea ochroleuca*, however, occur both in the coastal strip and penetrate as far inland as 142°E. On the other hand, no species are confined to the very dry far western region, although *Endocarpon rogersii*, *Peltula obscurans*, *Psora crystallifera* and *Xanthoparmelia versicolor* occur only west of latitude 150°E with mean annual rainfall less than 647 mm and a mean maximum temperature in the hottest summer month >33°C. Similar patterns are also clear at the generic level (Table 4).

Growth forms

The growth forms of soil-surface lichens are strongly patterned along the transect (Table 5). It is striking that the number and proportion of foliose and fruticose lichens decreases from the coast inland to longitude 143°E, whereas the number and proportion of squamulose lichens increases along this section of the transect. Further west than 143°E the squamulose lichens are the most common growth form, although all growth forms are rare. Leprose lichens are confined to the coastal strip. Lichens with cyanobacterial symbionts occur across the range of habitats, but they are present in higher numbers and as a higher proportion of species in the centre of the transect and in the west than in the wetter east.

Commonness and distribution

The proportion of infrequently collected lichens (i.e. those species occurring less than three times overall) in the flora of each degree of longitude decreases with distance from the coastal strip inland (Fig. 2). This reduction is evident both as a proportion of the number of species reported and as a proportion of the number of collections made. No infrequently collected species occur in the very dry inland region.

Discussion

Distribution patterns

Field observations suggest that a subcontinuous biotic crust with a substantial lichen component once covered much of the semi-arid zone of southern Queensland, although the crust apparently was never as well developed as in the winter rainfall regions of South Australia discussed by Rogers (1972). In the moister coastal areas it appears that accumulated leaf litter and wildfire prevent the development of extensive soil surface lichen populations in most areas, but that lichens do colonize areas of soil that remain bare for an extended time.

The relationship between climate and distribution pattern observed here is consistent

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TABLE 3. *Soil surface lichens* that occurred at least three times on a transect between latitudes 25° S and 29° S and longitude 136° E and 153° E in eastern Australia arranged in order of occurrence in relation to proximity to the coast*

Longitude (°E)	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	Form†
Cladonia corymbescens																		3	F
Lepraria																		3	Lep
Peltigera dolichorrhiza																	1	2	L
Cladonia kuringaiensis																	1	1	F
C. furcate																	2	1	F
C. pertrichosa																	2	1	F
C. praetermissa																	2	1	F
C. rigida																	4	1	F
Dibaes sorediata																	5	1	Lep
Cladonia floerkiana																2	8	5	F
Ramalinora glaucolivida															1		4	1	S
Cladonia ochrochlora														1			2	1	F
Cladia aggregata												1			1	4	7	7	F
Heterodea muelleri										1	1	1	3	3	4	5	11	3	L
H. beaugelholii									1	1	1	1	2	3	2	2	2	1	L
Lecidea ochroleuca									2	1		2	5	1	1		1	1	C
Cladonia cervicornis																1	2		F
Collema pustulatum																	3		Lcyan
Placidium squamulosum	1		1	1				1	1	1	1			2		1	1		S
Xanthoparmelia semiviridis										1	2			1		3			L
Buellia 10654									3	3	2	1	3	4		2			C
Endocarpon aridum									1				1			2			S
Placidium lacinulatum			1											1		1			S
Collema coccophorum		1	1	2			1	2		3			2	2		1			S
Heppia 'lutosa'	1							2	1	1	2		3	1		2			S
Placidium pilosellum								2							1				S
Peltula patellate	1			2				3	4		5			2					S
Endocarpon simplicatum								2		1	2		2	1					S
E. pusillum	1			1				3	3		4			1					S
Buellia subcoronata									1	1	2	1	1						S
Psora crenata								1	1	2	3	2	2						S
Endocarpon rogersii								1		1	1								S
Peltula obscurans								1	1		1								S
Psora crystallifera				2					1		2								S
Xanthoparmelia versicolor									2	1									L

*Numbers in the body of the table refer to the number of collections of that species for the given degree of longitude; †C=crustose, S=squamulose, F=fruticose, L=leafy (foliose), cyan indicates that the photobiont is a cyanobacterium, if not indicated photobiont is a green alga.

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TABLE 4. *Soil surface lichen genera* that occurred at least three times on a transect between latitudes 25° S and 29° S and longitude 137° E and 153° E in eastern Australia arranged in order of occurrence in relation to proximity to the coast*

Longitude (°E)	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153
Lepraria																	3
Peltigera																1	2
Dibaeis																7	1
Ramalinora													1		3	1	
Cladonia													1		4	25	17
Cladia											1			1	4	7	8
Heterodea								1	2	2	2	5	6	6	7	10	4
Lecidea								2	1		2	5	1	1		3	1
Xanthoparmelia							2	2	2			2	1	4	2	1	
Collema	1	1	2			1	2		3			4	2		1	2	
Placidium		1	1				3	1	1	1			3	1	2	1	
Buellia								4	4	4	2	4	4		2		
Endocarpon		1				7	5	2	7		3	2		2			
Heppia							2	1	1	2		3	1		2		
Peltula							3	4		6			2				
Psora		1	3				1	2	2	5	2	2					
Total number of species	1	4	5	0	0	1	11	14	14	17	7	12	15	7	14	25	24

*Figures indicate the number of collections of species in the genera that were observed.

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TABLE 5. *The number and proportion* for a given degree of longitude of soil surface lichen species with various life-forms and with a cyanobacterial photobiont in a transect latitudes 25° S and 29° S and longitude 153° E and 136° E in eastern Australia*

Longitude	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153
Fruticose	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	4	12	13
Foliose	0	1	1	1	0	0	1	1	2	5	3	2	4	5	3	5	7	6
Crustose	0	0	0	0	0	0	0	0	2	3	3	2	3	2	1	1	2	3
Squamulose	4	0	3	4	0	0	0	10	10	6	11	2	5	6	2	4	1	1
Leprose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Cyanobacterial	2	1	1	1	0	0	1	4	3	2	5	0	3	3	0	2	2	2
Total no. species	4	1	4	5	0	0	1	11	14	14	17	7	12	15	7	14	25	24
% fruticose	0		0	0				0	0	0	0	14	0	7	14	29	**48**	**54**
% foliose	0		25	20				9	14	**36**	18	29	**33**	**33**	**43**	**36**	28	25
% crustose	0		0	0				0	14	21	18	29	25	13	14	7	8	13
% squamulose	**50**		**75**	**80**				**91**	**71**	**43**	**65**	29	**42**	**40**	29	29	4	4
% leprose	0		0	0				0	0	0	0	0	0	0	0	0	8	8
% cyanobacterial	**50**		25	20				**36**	21	14	29	0	25	2	0	14	8	8

*Proportions are not shown for those cells in which the number of species is less than 4; proportions equal to 33% or greater are shown in **bold**.

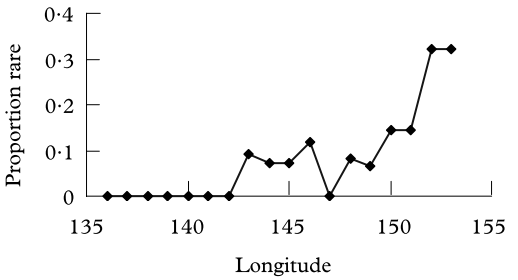


FIG. 2. The proportion of rarely collected species of lichen expressed as a fraction of all species of soil surface lichens found in each degree of longitude on a longitudinal transect in subtropical eastern Australia.

with that found by Rogers (1973) in southern Australia, with the number of lichen species decreasing with decreasing rainfall. However, that study covered low rainfall mediterranean and winter-rainfall semi arid to extremely dry a-seasonal areas. A study comparable in scale to the present study was carried out in southern Africa by Zedda & Rambold (2004) who examined soil surface lichens on a north-south transect almost 2000 km long with contrasting soils and rainfall (winter rain predominating) along its length. It is striking, however, that Zedda and Rambold (2004) found that the number of species of soil surface lichens in an area was negatively related to rainfall, whereas in Australia it is positively associated with rainfall. The African data also show that the greatest number of lichen species is found in the winter rainfall areas, whereas all of the areas studied in this transect fall into areas with either summer rainfall or year-round rainfall.

The negative impact of stocking by domesticated animals (mostly cattle) is also in accordance with previously observed patterns (Rogers & Lange 1971; Eldridge & Green 1994; Hodgins & Rogers 1997; Eldridge 2001). A long history of grazing by sheep and cattle ensures that many square kilometres of eastern Australian rangeland have no soil surface lichens present despite the presence of a cover of native shrublands and woodlands: many such sites were examined.

Diversity is statistically linearly related to the number of collections made in one degree of longitude intervals suggesting in the first instance that the number of species found is simply dependent on the intensity of collecting. The species found in the inland regions, however, were all relatively frequently collected, whereas the coastal flora is rich and contains a relatively large number of uncommon species. It appears that severe and relatively uniform inland habitats do not provide sites in which more specialized species can develop. Unfortunately, all of the attributes investigated were very strongly related to the number of species found, and also to each other. It is therefore not possible to ascribe a statistical effect on species richness to any single parameter examined in this study.

Rogers (1974) drew attention to the high proportion of crustose and squamulose lichens found in arid environments compared with other habitats. In this study these observations are borne out, in particular by the strong presence of squamulose thalli. It is evident that thalli of soil-surface lichens tend to become more and more prostrate in drier and more exposed habitats.

At species and genus level, however, it is apparent that while the same strongly correlated environmental attributes impact on distribution patterns, different species respond in different ways. It is traditional in studies of Australian vegetation to ascribe an overwhelming impact to quantity of rainfall (epitomized by Specht 1981), and it is likely that on this particular transect it is rainfall that is the principal environmental factor influencing large-scale patterns. However, Rogers (1971) and Lange *et al.* (1970*a*, 1970*b*) have argued that factors other than mean annual rainfall, including temperature and insolation at the time of rainfall, frequency of rainfall and dew frequency, may be critical factors for lichen populations in Australia. Furthermore, Rose's (1968) discovery that dew formation can occur beneath the upper surface of an arid soil from water reserves deeper in the soil is surely a matter of significance for soil surface lichens; but is an observation that as

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yet does not appear to have been followed up.

Taxonomic notes

Psora crenata has been recorded in Australia only rarely in the past (Schneider 1979; Eldridge 1998). It is now clear that it is quite common in the subtropical part of the semi-arid region. This taxon has sometimes been confused with *Psora decipiens* and *P. crystallifera* by Australian lichenologists. *Psora crenata* is separated from *P. decipiens* by the absence of secondary chemicals and a brown rather than pink to red upper surface that is deeply cracked. *Psora crenata* is separated from *P. crystallifera* in that it has a brown not grey upper surface, has irregular cracks and not a regular crystalline upper surface, has marginal not laminal apothecia and by the absence of coarse rhizoids joining the squamules.

The species name *Heppia lutosa* has been used as a name for the *Heppia* collections from the area, but this taxon appears to be very variable and may include more than one species.

Buellia 10654 is an apparently undescribed species that is unusual in that it is crustose but produces coarse rhizines up to 2 cm long that penetrate the soils on which it grows. As a consequence of the growth of the rhizines the circular crustose thalli become domed in the centre as the rhizines push into the soil. Squamulose species of *Endocarpon* and *Siphula* in the area also produce such coarse rhizines, apparently an adaptation to life on somewhat unstable, dry soils.

Prospects for conservation

The conservation of soil surface lichens requires undisturbed soil surfaces. The exclusion of all domestic stock from conservation areas is therefore a high priority, as soil surfaces recover only slowly from trampling.

In many areas soil surface lichens are now confined to roadside and railway reserve vegetation. This habitat, however, is usually heavily disturbed. In times of drought stock graze on the roadsides and therefore trample the surface of the soil thus destroying lichen populations and any other organisms dependent on the lichen stabilized crust. The use of fire to control vegetation in railway reserves is common, and this too has a destructive effect on soil surface lichens. Along roadsides it is rare to find areas more than ten metres square that have not been at least somewhat disturbed by road-making or other human activities. These activities include drainage lines, borrow-pits for materials, trees cleared for road building dumping of old road building materials and garbage. An important biodiversity reserve is being lost by attrition. The evidence of regrowth of lichens over some abandoned road-works suggests, however, that if protection is put in place now the redevelopment of these floras with their associated biota is still possible.

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