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RESEARCH ARTICLE

Species diversity and altitudinal preferences of lichens on selected substrata in Ritigala Strict Natural Reserve

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Abstract: The objective of this research was to study corticolous and saxicolous lichen diversity and distribution in Ritigala Strict Natural Reserve (SNR). For this survey, 34 plots, covering different forest types at different elevations: < 300 m, between 300 m and 500 m and > 500 m were established. The plot area was 250 m × 250 m except above 500 m, where it was smaller (10 × 10 m). Trees selected to register lichens were *Drypetes sepiaria* and *Ficus microcarpa* at lower elevation (< 300 m), *Diospyros affinis* and *Dimocarpus longana* at mid elevation (300–500 m) and *Pterospermum suberifolium*, *Syzygium zeylanicum* and *Neolitsea cassia* at high elevations (< 500 m). Coverage and frequency of lichens were recorded by randomly placing a 250 cm^2 quadrate on bole of each tree. Morphology, anatomy, reproductive structures and biochemistry of lichens were examined for their identification. Shannon's diversity index was used to determine the lichen diversities at different elevations. Data were statistically analysed to reveal the distribution pattern of lichens with change in elevation. Two hundred and eighty-six different lichens collected represented 27 families, 72 genera and 152 species. The distribution pattern of species reflected variability in environmental conditions at different elevations. Higher lichen diversities (1.48 and 1.45) were recorded at higher and lower altitudes than at mid altitudes (1.14). It is envisaged that microclimatic conditions at lower altitudes have encouraged the growth of lichens with trebouxioid photobionts, while shady and cooler niches supported those with cyanobacterial photobionts. Trentepohlioid lichens dominated at mid-elevations. At higher elevations, sunny locations encouraged the growth of trebouxioid folioses while shady and wet places supported cyanobacterial photobionts. Distinct species assemblages at different elevations showing restrictive species distribution signifies the need of protection of Ritigala SNR for lichen conservation.

Keywords: Altitudinal preferences, lichen diversity, Ritigala Strict Natural Reserve.

INTRODUCTION

Ritigala is the highest mountain range in the Anuradhapura district with the geographic coordinates 80° 38'–80° 40 ' E and 8°0'–8°9'N which is included under the Strict Natural Reserve category. It is situated 27 km N of Dambulla and 36 km SE of Anuradhapura and covers an area of 1,528.2 ha. The terrain is hilly with an elevation of 766 m above sea level at the highest peak. This isolated hill ranges 6.5 km long on its north-south axis and about 3 km wide at its widest point. It is divided into northern and southern blocks by the shallow Maha-Degala gorge (Central Cultural Fund, 1983). This isolated hill range is in the dry zone of the island where the climate is characterised by a bimodal pattern of rainfall and uniformly high temperature throughout the year. The total annual rainfall is around 1,500 mm and relative humidity ranges between 60 % and 90 %. Prolonged dry period prior to the rainy season and desiccating winds during the long, hot south-west monsoon subject the vegetation to severe moisture stress.

Many botanists have studied the vegetation of Ritigala, commencing with Trimen in 1889 followed by Wills in 1906 and Jayasuriya in 1984. The vegetation of the area can be divided into several clear altitudinal zones: (i) Disturbed dry-mixed evergreen (lower

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elevation < 300 m), (ii) Dry-mixed evergreen (old-growth) (middle elevation 300–500 m) and (iii) Short-stature forest (high elevation > 500 m) occurring along the ridge tops (DWC, 2008). The dominant vegetation in Ritigala is dry-mixed evergreen forest. However, a clear altitudinal zonation is visible on the upper slopes except un-vegetated butte slopes on the eastern-side and on the summit of the reserve where one could observe a short-stature forest. This unique vegetation may be due to cloud cover and the mist that cloth the summit most of the year, which is closely comparable to the humid sub-montane and montane vegetation in the Highlands (DWC, 2008). According to Trimen (1889) the top of Ritigala represents 'a characteristic little oasis of vegetation distinct from the dry zone vegetation surrounding it'.

Understanding the diversity and distribution of organisms is the key aspect in conservation and management of a natural resource. Preliminary investigation on lichens in the area revealed that Ritigala hill range is not only distinct with respect to higher plants but also with respect to lichens. Seventeen species of lichens had been recorded by Jayasuriya (1984) in a study of the flora of Ritigala. Apart from that there are no published data on lichens of Ritigala. It is envisaged that there are patterns of lichen distribution and high species richness in this unique ecosystem.

The objectives of this study were (1) to understand and describe lichen diversity and distribution in this strict natural reserve in which the vegetation shows a clear pattern of altitudinal zonation (2) to suggest factors that may be important in influencing the distribution and abundance of lichens and (3) to provide baseline information with respect to corticolous and saxicolous lichens in areas that may be threatened by development activities such as extraction of phosphate deposit in the vicinity of Ritigala mountain range.

METHODOLOGY

Study site

Thirty four plots were established in Ritigala Strict Natural Reserve (Figure 1) at three elevations, covering three different forest types; dry mixed evergreen forest below 300 m with an open canopy (disturbed area), dry mixed evergreen forest with a fairly closed canopy between 300 m and 500 m elevation (undisturbed) and exposed mountain forest above 500 m. At lower and mid

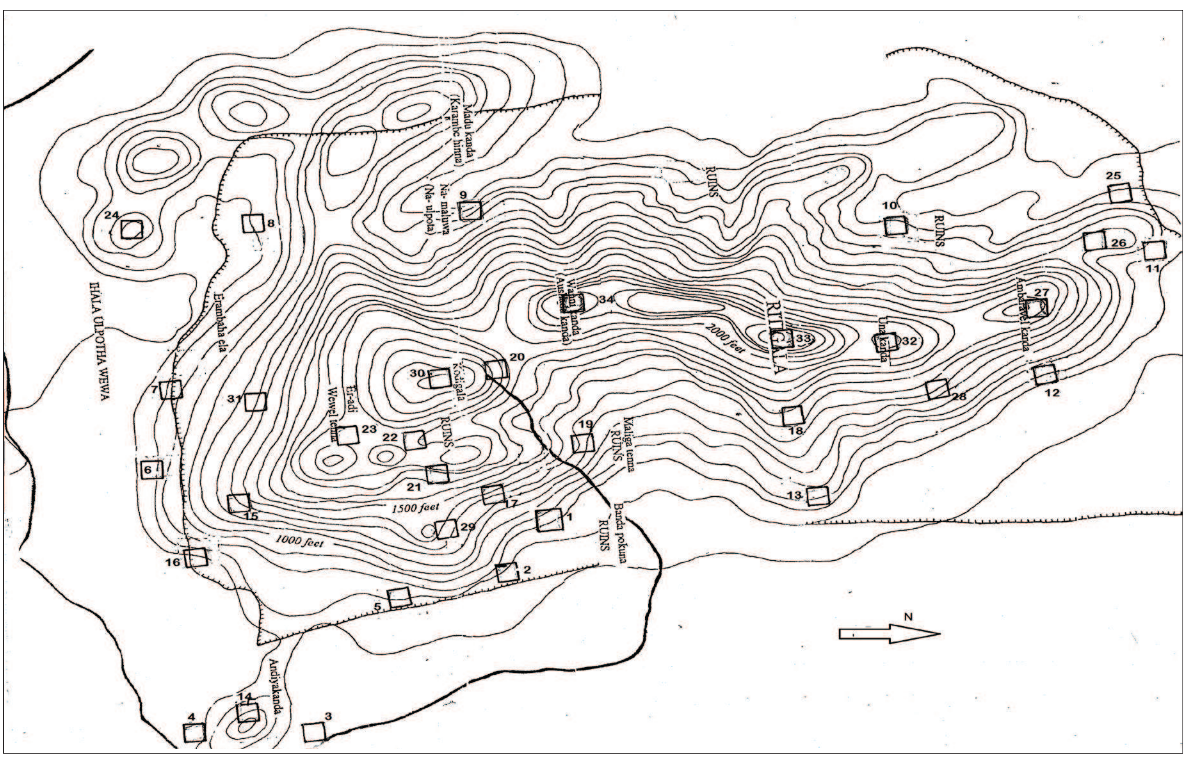

Figure 1: A contour map of Ritigala hill range depicting the 34 sites that were used in the lichen diversity monitoring study

elevations the plot area was 250 m × 250 m but above 500 m the plot area was smaller (10 × 10 m) due to practical problems. Lichens were recorded on selected substrata (trees and rocks) at different elevations.

Tree species examined for recording lichens

The method used for recording of lichens was largely based on the German guidelines (VDI, 1995) with few modifications with respect to selection of sampling trees. By carrying out a preliminary investigation, trees that would be suitable for studying lichen diversity were selected by avoiding trees having peeling barks or grooved barks. Rocks were selected randomly to record lichens. This preliminary survey revealed that some tree species carried more lichens than others. Therefore, for registration of lichens at different elevations, trees having a greater diversity of lichens were selected. At lower elevation *Drypetes sepiaria* and *Ficus microcarpa* species and at mid elevation, *Diospyros affinis* and *Dimocarpus longana*, all of which had diameter at breast height (DBH) great than 30 cm were selected to record lichen diversity. In each plot, three trees from each species were examined to record lichens. As occurrence of boulders and rocks carrying a great number of lichens were common in all sites, three rocks were also selected for examination of saxicolous lichens in each plot. As the vegetation changes at high elevations, *Pterospermum suberifolium*, *Syzygium zeylanicum* and *Neolitsea cassia* were examined to record lichens. As the DBH of these trees were less than 30 cm, more trees were examined per plot. On short-stature trees, the lichen recording was done not only on the main stem but also on small branches and twigs.

Registration of lichens

For the registration of lichens on tree trunks, height between 0.5 m from the base to a height up to 1.5 m was selected as the sample area. Coverage and frequency of lichens were recorded by placing a 250 cm^2 quadrate (25 cm × 10 cm) randomly on the bole at four different places facing different aspects within the sampling area of each tree (Figure 2). On boulders, the quadrates were randomised with respect to aspect. In the case of shrubs, cover values of lichen taxa were calculated using the length of the twig and its average diameter. Each one-meter segment of a branch was considered as a micro plot. Twelve micro plots were considered as equivalent to one tree examined in a plot as the total circumference of 12 branches /twigs was roughly equal to 25 cm, length of one side of the quadrate used.

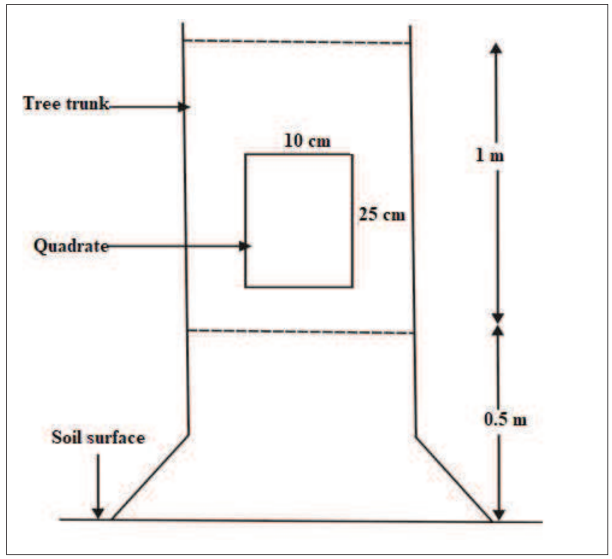

Figure 2: Registration of lichens on a tree trunk

Measurement of bark pH

The bark pH values of trees examined for lichens were determined using the method adopted by Farmer *et al.* (1990). Samples of bark were removed from each sampled tree at the height of about 1.5 m on the tree trunk. Two small pieces of bark with a total surface area of approximately 1 cm^2 were cut from the collected samples and dipped in hot wax to expose only the outer surface. These waxed bark pieces were kept overnight in a 25 mmol KCl solution. Then the pH of the solution was determined after removing the bark pieces.

Identification of lichens

Microscopic examinations of the specimens were done with respect to morphology, anatomy and reproductive structures if present. Macro lichens that did not have reproductive structures were subjected to thin layer chromatograpy to obtain information with respect to their chemistry. After studying the morphological, reproductive and chemical characters, lichens were identified using standard taxonomic keys (Awasthi, 1988, 1991; Sipman, 1996).

Lichen diversity

Lichen diversity of each lichen community at different elevations was determined using Shannon's diversity index (Batten, 1976).

$$H' = -\sum p_i (\log p_i)$$

Where, H' = Diversity
p_i = the proportional abundance of the i^{th} site = n_i / N.
n_i = Number of species found in a site
N = Total number of species recorded in all sites of a particular elevation
Evenness J′ = H′/ H′ max
where H′max = log N
Dominance = 1-J

Lichen distribution in relation to exposure levels

General exposure of the site to light was recorded as open, semi-shade or shade (categorised according to the observations) in the field. The three exposure levels were coded as, open-1; semi-shade-2; shade-3.

Data analysis

Diversity was measured as species richness and Shannon's Index was calculated for each lichen community at different elevations. Lichen coverage data of different elevations were analysed using one-way ANOVA at 5 % level of significance to find out whether a correlation exists between coverage values and elevations.

RESULTS AND DISCUSSION

Types of lichens recorded

A total of 286 different lichens based on morphology, anatomy and reproductive structures were recorded during this study. Among the lichen growth forms, crustose lichens (65 % of all species) were predominant followed by foliose (29 %), fruticose and squamulose (3 % in both types) (Figure 3). These values are very much similar to values reported by Pinokiyo *et al*. (2008) for a protected biodiversity hot spot in north-east India. They recorded 56.5 % crustose, (34.5 %) foliose, 8.5 % fruticose and 0.6 % squamulose in the area studied. Abundance of crustose species in several other protected areas in India has also been recorded by a number of researchers (Balaji & Hariharan, 2004; Nayaka *et al*., 2004; Phatak *et al*., 2004).

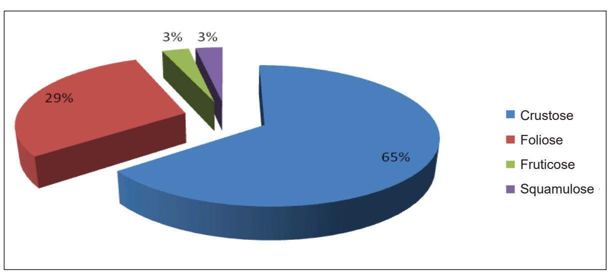

Figure 3: Percentages of different lichen types recorded in Ritigala mountain range

Identification of lichens

Out of the total of 286 lichens, those which had either sexual or asexual structures were identified at least to the generic level and wherever possible to species level. These lichens represented 27 families, 72 genera and 152 identified species. It was not possible to identify sterile crustoses even to the genus level. Therefore, they were designated as sterile crustose with code numbers. This is the first instance that a high lichen diversity was recorded from a natural reserve in the Dry Zone of Sri Lanka. However, it should be emphasised that the number of species reported here are only corticolous and saxicolous lichens and the actual number of species would be much greater if the canopy is also examined. According to Cornelissen and Gradstein (1990), in tropical forests, 86 % of macrolichens occurred exclusively in the canopy. Therefore, the recorded diversity in this study is a small part of the whole diversity. Nevertheless, total numbers of identified lichens signify that Ritigala SNR possesses a rich lichen diversity which may include new species. Of the thirty five species in Table 1 the first report of *Thelotrema minisporum* as a new species was by Wijeyaratne *et al*. (2012).

Lichen diversity and their coverage values at different elevations

Based on the percentage coverage values of lichen genera recorded, it was possible to put them into four categories; very common (percentage cover >1), common (percentage cover 0.99 – 0.5), occasional (percentage cover 0.49 – 0.1) and rare (percentage cover < 0.1). Table 2 shows the genera and species that were recorded listed under these four categories.

Ecological factors play an important role in the growth, development, distribution and diversity of lichen species (Brunialti & Giordani, 2003). Microclimatic conditions, particularly light, moisture and nutrients can influence distribution of lichens (Jonsson & Jonsell, 1999). In Ritigala mountain range, the variation in the distribution of lichen species reflected variability in the environmental conditions at different elevations. At higher and lower elevations a greater lichen diversity was recorded than mid elevations (Table 3).

Table 1: List of new records of lichens from Ritigala Strict Natural Reserve

Bulbothrix atrichella (Nyl.) Hale
Bulbothrix fungicola (Lynge.) Hale
Chiodectan leptosporum (Müll.) Arg.
Collema quadriloculare F. Wilson
Dichosporidium nigrocinctum (Ehrenb.) G. Thor.
Dirinaria complicata D.D. Awasthi
Dirinaria confluence (Fr.) D.D. Awasthi
Escatagonia prolifera (Mont.) R. Sant comb. Nov
Haematomma collatum ((Stirt) C. W. Dogge
Heterodermia obscurata (Nyl.) Trevisan
Lecanactis concordans (Nyl.) Zahlbr.
Leptogium marginellum (Swartz) S.F. Gray
Leptogium azureum (Sw. ex Ach.) Mont.
Letrouitia transgressa (Malme) Hafe. & Bellem
Ocellularia allosporoides (Nyl.) Patw. & Kulk.
Parmotrema andium (Müll. Arg.) Hale
Parmotrema durumae (Krog & Swinscow) Krog & Swinscow
Parmotrema gardneri (C.W. Dodge) Sérus
Parmotrema ravum (Krog & Swinscow) Sérus
Parmotrema sulpuratum (Nees & Flot.) Hale
Pertusaria granulate (Ach.) Mull. Arg.
Pertusaria kodaikalensis M. Choisy
Pertusaria quassiae (Fee.) Nyl.
Porina guentheri (Flot.) Zahlbr.
Porina nuculastrum (Müll.Arg.) R.C.Harris
Pyrenula carya R.C. Harris
Pyrenula kurzii Ajay Singh & Upreti
Pyrenula nodulata (Stirt.) Zahlbr.
Pyrenula submarginata Vain.
Pyrenula subnitida Müll. Arg.
Pyxine austroindica D.D. Awasthi
Pyxine himalayensis D.D. Awasthi
Ramalina peruviana Ach.
Relicina abstrusa (Vain.) Hale
Roccella phycopsis (Ach.)
Thelotrema minisporum Wijeyaratne, Lucking & Lumbsch sp. nov.

At lower elevation, the microclimate is hot and dry and trees received more light, encouraging the growth of photophilus lichen species with trebouxioid photobionts, e.g. *Dirinaria* spp., *Parmotrema* spp. (Figure 4a), and *Pyxine* spp. (Figure 4b), while lichens that have cyanobacterial photobionts, e.g. *Leptogium cyanascence*, (Figure 4c) and *Parmeliella nigrocincta* were confined to shady cool and moist places at lower elevations.

At mid elevation, light is a limiting factor due to the fairly closed canopy and high humidity (> 85 %) and provides conditions suitable for lichens with trentepohlioid photobionts such as *Myriotrema* spp., *Thelotrema* spp. (Figure 4d), *Porina* spp., *Pyrenula* spp. and *Anthracothecium* spp.. Considerable numbers of sterile crusts that were not identified to genera were recorded in majority of the sites in mid elevations. The lower diversity observed in mid elevation could be mainly due to the presence of sterile crustoses that were not identified to genus level, which covered large areas, mostly rock and boulders. Foliose lichens that were recorded in lower elevation sites were absent in the sites of mid elevation. However, fallen branches of trees of mid elevations revealed evidence for the presence of photophilous lichens such as *Parmotrema* spp., *Rocella* spp., *Relicina* spp. and *Ramalina* spp. in the canopy. According to Groombridge (1992) and Cornelissen and Gradstein (1990), in tropics the lichen biodiversity tends to be richest in the canopy vegetation.

The role of temperature and moisture on the diversity and distribution of lichens has been discussed by several researchers (Lesica *et al*., 1991; McCune & Geiser, 1997; Pinokiyo *et al*., 2008). On Ritigala mountain range, at higher elevations (> 500 m) the environment is cooler and fairly damp compared to any part of the dry zone which surrounds it. This unusual climate at higher elevations supports a wide variety of higher plant species quite distinct from the flat drier areas below draped with pendent masses of mosses and lichens similar to those in higher mountains (Wills, 1906). The short stature vegetation at higher elevations is due to the prevailing strong winds. Although ridge tops are exposed to sunlight at mid-day, mist and clouds envelop the crest in the evenings and at night, particularly during the south-west monsoon, ensuring high vapour condensation. Thus, during the early hours of the day, ridge tops are damp and cooler when compared to lower elevations. These unique microclimatic conditions at higher elevations support photophilus foliose and fruticose lichen genera with trebouxioid photobiont species: *Heterodermia* spp., *Bulbothrix* spp., *Parmotrema* spp. and *Usnea* spp., which are absent at lower elevation. Such epiphytic macrolichens are known for their drought tolerance and high light requirement (Pentecost, 1998). Lichens with cyanobacterial photobiont e.g. *Pseudocephellaria* sp., *Sticta* sp., *Leptogium* spp. and *Coccocarpia* spp. that are able to fix nitrogen were recorded in shady, cool and fairly wet places on rocks and on soil. The twigs and branches of short stature vegetation were mostly wrapped up with *Collema* sp., *Coenogonium linkii* and *Heterodermia* sp.. The findings of the present study agreed with the results and conclusions drawn from similar studies carried out in temperate and tropical countries (Wolseley & Aguirre-Hudson, 1997; Pinokiyo *et al*., 2008).

Table 2: Lichen genera and species in four different categories: very common, common, occasional and rare based on the percentage cover

Very common (% cover >1)	Common (% cover 0.99 -0.5)	Occasional (% cover 0.49 – 0.1)		Rare (% cover <0.1)
Unidentified Sterile Crust (white hypothallus)	*Graphis* sp. 1	*Anthracothecium subvenosum*	*Parmelia atrichella*	*Bacidia* sp. 3
Leptogium cynescens	*Graphis* sp. 2	*Bacidia corolloid*	*Parmelia fungicola*	*Byssaloma* sp.
Pseudocypellaria sp.	*Dirinaria aegialita*	*Bacidia* sp. 2	*Parmotrema andium*	*Collema pulcellum*
Phyllospora pannosa	*Dirinaria picta*	*Buellia* sp. 2	*Parmotrema complicata*	*Collema quadrilocularia*
Arthopyrenia ceylonensis	*Graphis* sp. 3	*Bulbothrix atrichella*	*Parmotrema gardneri*	*Gyrostomum* sp.
Leptogium denticulatum	*Sticta* sp. I	*Canoparmellia* sp.	*Ocellularia orthomastia*	*Heterodermia obscurata*
Buellia posthabita	*Graphina* sp. 2	*Caloplaca* sp.	*Ocellularia* sp.	*Lecanora sufusca* 1
Porina mastoidea	*Hetrodermia diademata*	*Coccocarpia palmicola*	*Ochrolechia* sp.	*Leptogium azureum*
Porina luteopallens	*Porina guentheri*	*Crustose*	*Parmotrema ravum*	*Lithothelium* sp.
Myreotrema glaucescens	*Thelotrema* sp.	*Dirinaria papulifera*	*Pertusaria* sp.	*Parmotrema sulphuratum*
Porina tetracerae	*Lecanora subfusca*	*Dirinaria complicata*	*Physcia dilatata*	*Parmelia isidiza*
Coenogonium linkii	*Crustose* (ash colour)	*Drinaria* sp.*(isidia)*	*Physcia* sp. 2(saxicolous)	*Pertusaria isidiosa*
Aspicilia sp.	*Crustose* (white colour)	*Graphis* sp. 1	*Phyllospora* sp.	*Phaeographis* sp.
Lecanora subfusca	*Lecanactis* sp.	*Graphina* sp.	*Porina* sp.	*Phaeographina* sp.
Parmotrema praesorediosum	*Coccocarpia erythroxili*	*Haematomma collatum*	*Psilolechia* sp.	*Pyrenula* sp.
Pyxine subcinera	*Dirinaria applantata*	*Heterodermia diademata*	*Pyrenula caryae*	*Pyxine coccifera*
Pyxine himalayensis	*Myreotrema wightii*	*Heterodermia microphylla*	*Pyrenula kurzii*	*Heterodermia comosa*
Relicinopsis sp.	Crustose 12	*Heterodermia speciosa*	*Pyrenula nodulata*	*Toninia* sp.
Buellia sp. 2	Crustose 14	*Heterodermia* sp.*(rock)*	*Pyrenula submarginata*	*Trypethelium eluteriae*
Pyrenula subnitida	*Pyxine consocians*	*Lecidia* sp.	*Pyxine berteriana*	
Caloplaca sp.	*Parmotrema durumae*	*Lecanactis* sp.	*Pyxine petricola*	
Lepraria sp.	*Crustose* (with isidia)	*Lecanactis* sp. (saxicolous)	*Ramalina* sp.	
Graphina sp.1	*Sarcographae* sp.	*Lecanora subfusca*	*Ramalina peruviana*	
Graphis duplicata	*Parmeliella nigrocincta*	*Leptogium juvanicum*	*Roccella montagnei*	
Pyrenula caryae	*Pertusaria kodaikalensis*	*Leptogium marginellum*	*Roccella phycopsis*	
Parmotrema tinctorum	*Caloplaca* sp.	*Leptogium (isidia)* sp.	*Sticta weigelii*	
	Anthracothecium pustuliferum	*Letrouitia domingensis*	*Thelotrema platysporum*	
	Parmotrema tabacina	*Letrouitia transgressa*	*Thelotrema* sp.	
	Dirinaria confluens	*Letrouitia vulpina*	*Trypethilium tropicum*	
	Haematomma sp.	*Megalospora* sp.	*Xanthoparmelia* sp.	
	Phyllospora sp. 3	*Myreotrema* sp.		
	Pyxine berteriana			

Table 3: Diversity indices of lichen communities at different altitudes of Ritigala SNR

Elevation	Diversity	Evenness	Dominance
High > 500 m	1.48	0.92	0.08
Mid 300–500 m	1.14	0.82	0.18
Lower < 300 m	1.45	0.88	0.12

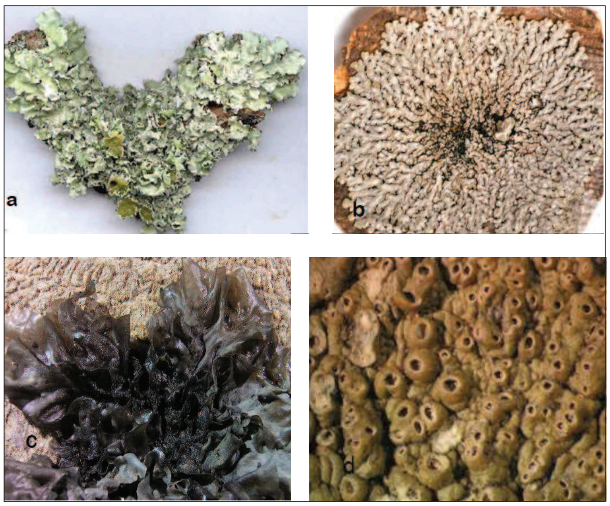

Figure 4: a) *Parmotrema* sp. and b) *Pyxine subcinera*, with *Trebouxia* as the photobiont; c) *Leptogium cyanascens* with *Nostoc* as the photobiont; d) *Thelotrema minisporum* with *Trentepholia* as the photobiont

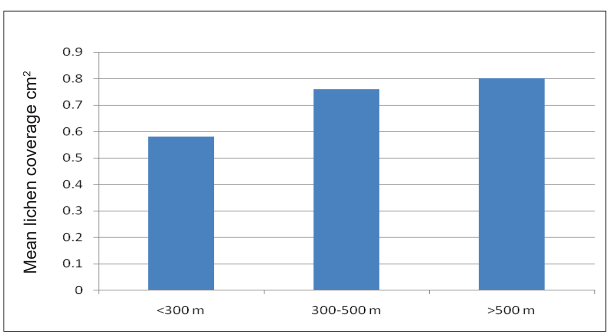

Figure 5: Lichen coverage at different elevations

When Pearson correlation coefficient was used at 1 % level of significance, a positive correlation was found to exist between lichen coverage and the elevation. Lichen coverage increased with the increase in elevation (Figure 5). One way ANOVA test performed at 5 % level of significance revealed that there is no significant difference between the lichen diversity of low and higher elevations although the plot size was smaller and the DBH of trees were lesser in short stature forests at higher elevations (> 500 m). The diversity of mid elevation was significantly different to those of lower and higher elevations (Table 3).

Effect of Bark pH on lichen distribution

The bark pH values of all trees used to monitor lichens were not significantly different and were all in the range 5–6. Therefore, the lichen community differences observed on different trees could not be due to the pH of barks of trees.

Lichen coverage and exposure to light

The trees examined for recording of lichens were categorised according to the degree of exposure to light. Thus, trees that were in open places, which received light almost equally throughout the day were included in the open category, those that did not get the full light regime in the semi-exposed category and those that were in shade most of the time in the shade category. There were no significant differences among the lichen coverages in the three different light regimes (open, semi and shade) when data were analysed using one-way ANOVA at 5 % level of significance. While sites having different exposure levels were present across the elevational gradients, tree species composition and other environmental conditions mainly humidity varied across the elevation, which may have been important factors in the distribution and abundance of lichens in Ritigala mountain range.

CONCLUSION

Investigation of lichens of Ritigala mountain range revealed the presence of extremely interesting and remarkable diversity, which may not be seen anywhere else in Sri Lanka as their distribution strongly associated with elevation and other environmental gradients present. Presence of a large number of critical lichen families (>50 %) indicate that Ritigala is relatively undisturbed and embraces highly vulnerable lichen communities, which are susceptible to environmental changes.

The presence of distinct species assemblages at different elevations showing restricted species distribution signifies the need for protection of Ritigala Natural Reserve for lichen conservation.

A study of canopy lichen diversity would enable a more accurate picture of the diversity and distribution in this unique biogeographic area, which is a strict natural reserve of Sri Lanka.

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