Inventory List of Epiphytic Lichens Inhabiting Low and High Altitude Environment

Asmida Ismail[1,2], Aini Nadhirah Nor Azian[1], Nur Syafiqah Abd Hakim[1], Faezah Pardi[1,2], Khairul Adzfa Radzun[1], Faeiza Buyong[3] & Nurul Aida Kamal Ikhsan[4]

[1] School of Biology, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia
[2] Institute for Biodiversity & Sustainable Development, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[3] School of Chemistry & Environment, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[4] Centre of Foundation Studies, Universiti Teknologi MARA, Cawangan Selangor, Kampus Dengkil 43800 Dengkil, Selangor, Malaysia.
asmida@uitm.edu.my

Abstract. Lichens, taxonomically classified as lower plants due to their basic morphological traits, are easily affected by climate. Interactions between microclimatic factors such as temperature and humidity are particularly important in determining local differences in lichen species composition and coverage. Coupled with other abiotic components, the nature of the habitat may cause a certain species of lichen to thrive better. For the purpose of the study, two different sampling locations with differing elevations were adopted. Sampling stations in UiTM Shah Alam represent lichens in low elevation while sampling stations in Fraser's Hill represent lichens in high elevation. The study was conducted using 15cmx15cm quadrats, laid on 60 selected trees. Microclimatic factors such as temperature and humidity were recorded using a hygro-thermometer. The average temperature of 33.0°C ± 0.2 and 22.9°C ± 0.2 were recorded in low and high elevation, respectively. This is inversely proportional to the humidity level where the low and high elevation recorded 66.2% ± 1.2 and 78.0% ± 1.0 of humidity, respectively. A total of 29 species of lichens from 14 families were recorded in the study sites. The low and high elevation each dominating by different species of lichens; *Chrysothricaceae* exhibit the highest frequency in low elevation (28.2%) while *Parmeliaceae* exhibit the highest frequency in high elevation (54.8%). For lichens species coverage, *Chrysothrix flavovirens* exhibit the highest percentage coverage in low elevation (18.7%) while *Lepraria* sp. exhibit the highest coverage in high elevation (20.3%). It is evident that high elevation habitat is more favourable for lichens due to low temperature and high humidity which help the lichens from desiccation. This study also showed that different elevation will support different types of lichens; the foliose and fruticose lichens are more abundant in high elevation while the crustose lichens are more abundant in low elevation. The findings of this study highlighted the role of microclimatic factors and how it affects the survivability of epiphytic tropical lichens.

S. Gandaseca et al. (eds.), *Proceedings of the International Conference on Science, Technology and Social Sciences – Biology Track (ICONSTAS-BIO 2023)*, Advances in Biological Sciences Research 43,
https://doi.org/10.2991/978-94-6463-536-2_19

Keywords: Lichen, elevation, microclimatic factors, species coverage

1 Introduction

Lichens are symbiotic relationship made up of different organisms, including the mycobiont, algae and cyanobacteria [1]. Due to the incorporation of algae and cyanobacteria, lichens portray a plant-like look and possess a photobiont component to carry out photosynthesis and produce its own food. The algae are responsible for the photosynthesis process while cyanobacteria are responsible to fix the nitrogen in the air for lichen development [2]. Lichens can be classified into three common types which are crustose, foliose and fruticose.

Lichens are sensitive towards the environment, hence its famous use as a bioindicator to detect pollution in the environment [3]. Lichens distribution may also be affected by the levels of temperature and humidity of its surroundings. For instance, a study by reference [4] highlights the increasing number of lichen species in warmer regions along the elevational gradient of Gunung Nuang. Another study by reference [5] showed distribution of lichen species at different altitudes in Gunung Machinchang, in which crustose are abundant in the lower elevation of the mountain and foliose dominates the higher regions of the mountain. Lichens thrive better in warm surroundings as higher temperatures may promote the rate of photosynthesis [6]. Despite the warm condition which may be drying, lichens are organisms that need moisture. Thus, it is expected that lichens will favor areas with a relatively higher humidity. However, in studies conducted by reference [4,5], the results showed the opposite, in which lichen species are higher in areas with lower humidity.

There are about 250 species of freshwater lichens as of the year 2000 as studied by reference [7]. Meanwhile, for marine lichens, the exact number of lichen is not identified. However, between the years of 2000 to 2003, there are about 122 species in the White sea, 122 species in the Baltic Sea coast, and 27 species in the Pacific coast [8]. Lichens have high adaptability and resistance against factors that may affect them. Some lichens can thrive in extreme conditions such as dry and cold weather. For instance, around 400 species of lichens recorded in Antarctica [9]. Marine lichens too, are able to adapt to a rather extreme environment like solar radiation fluctuations, strong waves and wind, dryness as humidity becomes lower under the scorching sun at noon, rising and falling of the temperatures and the water salinity [10]. This results in morphological adaptation as the lichens are usually crustose, densely cortical and scaly, which is when the lichens are joined together and attach strongly to the substrate [8].

Lichen is a natural bio-indicator which can be found in undisturbed places with conditions that are favourable for their growth. Though lichen favours places with high humidity and lower temperature, species of lichens have adapted to the tropical climate in Malaysia. In fact, there are over a hundred species of lichen in Malaysia. From past observations in Pulau Pangkor and Selangor, there are 12 species of lichen observed in Pulau Pangkor, Perak [11] and 44 species of lichen in Selangor [4]. In Gebeng, Pahang, 11 lichen species were observed with the most abundant species being *Graphis scripta* [12]. Not long ago, an additional of 126 species of lichen were discovered in Kinabalu,

Sabah in which 15 species of the lichen were new to Southeast Asia [13]. The most common lichen that is endemic and can be found in Malaysia is *Dirinaria sp*. which is also especially abundant in countries with tropical climates [14].

The objectives of the study are to determine the effects of variation in temperature and humidity on lichens and to examine species coverage and speciescomposition of lichens in selected study sites.

2 Research Methodology

This study was conducted at 2 sites namely UiTM Shah Alam and Fraser's Hill, Pahang. UiTM Shah Alam is located in Shah Alam, Selangor with a warm climate. The average minimum temperature in Shah Alam is 23°C and the average maximum temperature is 33°C [15]; highest relative humidity is 81% in December and lowest relative humidity is 71% during August and September [16]. Meanwhile, Fraser's Hill has a relatively colder climate with the average temperature of 22°C and average relative humidity of 92% [17]. In this study, UiTM Shah Alam will be referred to as Site 1 that represents the lowlands with higher temperature and lower relative humidity while Fraser's Hill will be referred to as Site 2 that represents the highlands with lower temperature and higher relative humidity.

2.1 Quadrat Sampling

The quadrat sampling method was conducted on 30 tree barks in each site. The trees that are selected have a diameter larger than 30cm. The size of the quadrat was 15cm X 15cm, and were laid on the tree. The quadrats are positioned away from the sunlight. Quadrat sampling was used in this study to estimate the species coverage, abundance of the lichens, their density and their frequency by using the formula listed below.

$$Species\ Coverage = \frac{Total\ number\ of\ species}{Total\ area} \quad (1)$$

$$Percentage\ Frequency = \frac{Number\ of\ quadrants\ with\ the\ species}{Total\ number\ of\ quadrats\ used} \quad (2)$$

The temperature and the relative humidity were recorded using an electronic portable hygro-thermometer. The hygro-thermometer was held in a clear space near the area of the lichen growth on the tree barks and away from heat sources like direct sunlight. An average of three measurements of temperature and humidity were used in this study.

A set of tools consisting of a knife and paper envelope were brought along for lichen collection. The knife was used to collect only lichen samples that are in loose form like foliose and fruticose. For crustose lichen samples which are attached tightly to the substrate, the substrate (thin layer of tree bark) was taken along. For lichens that are too dry, small spritz of water are sprayed onto the lichen to ease peeling of foliose lichen. The lichen that were scraped were stored in a paper envelope and labeled by its sampling site, identification of lichen, date of collection and name of collector. For

preservation of the lichens before analysis under the microscope, the lichens will be transferred to another paper bag to be kept dry to avoid molding.

2.2 Lichen species identification

Lichen species can be determined on site by observing its growth form which are crustose, foliose and fruticose. Crustose lichen attaches tightly to the substrate, foliose lichen looks similar to the appearance of leaves and fruticose lichen branches out or may look hairy. Lichen samples were also compared with lichen pictures in an online database which is in the Wisconsin State Herbarium, Department of Botany website. To further identify and confirm the species of lichen, samples of the lichen were collected and taken to the laboratory at UiTM Shah Alam to be observed under the stereoscopic microscope. The morphological structure of lichen that was observed is the thallus, which is by its colour, texture- granules, powdery and dotted, and finger-like projections or hairs [18]. In cases of fruticose lichens, the ascocarp, the colour and shape of apothecia will also be noted.

To further identify the lichen species, four spot tests were conducted. The spot tests use 10% KOH solution (K test), chlorine (C test), Lugol's solution (I test) and combination of K test and C test (KC test). For every spot test, a drop of the solution was put on the surface of the lichen. Colour changes of the lichen were noted for every test as a positive reaction. In addition to the spot tests, the lichen was examined under a UV lamp to see their fluorescence properties. The common colour changes (positive reactions) are tabulated as shown in Table 1.

Table 1. Positive reactions of K test, C test, KC test, I test and UV lamp towards lichen

Test	Positive reaction
K test	Yellow, Red, Microscopic crystal
C test	Pink, Red, Orange, Green (rare)
KC test	Red, Orange, Violet
I test	Blue, Violet, Red (rare)
UV lamp	Fluorescent

Source: Reference [19,20]

2.3 Data Analysis

To compare the lichen coverage between two sampling sites, t-test was conducted. In this study, lichens are identified through morphological characteristics and percentage coverage.

3 Results and Discussion

3.1 Temperature and Humidity Affecting Lichen Composition in Low and High Altitudes

Lichens species distributions are influenced by the temperature of the surrounding, along with the ambient humidity levels. Figure 1 showed an average temperature of 33.0°C ± 0.2 and 22.9°C ± 0.2 for Site 1 (low altitude) and Site 2 (high altitude), respectively. An average relative humidity of 66.2% ± 1.2 and 78.0% ± 1.0 were also recorded in low and high altitude. The temperature and relative humidity of the two sites varied significantly (T-test, $p<0.001$), with Site 1 recording the higher temperature and lower relative humidity.

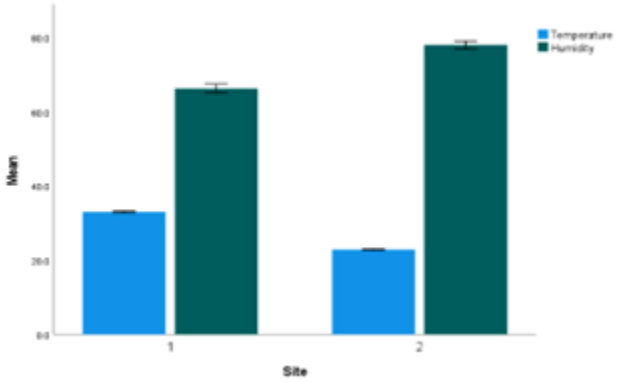


Fig. 1. Temperature and relative humidity in Site 1 (low altitude) and Site 2 (high altitude)

3.2 Elevation levels

Besides temperature and humidity, the elevation levels of the two sites were also recorded since elevation, temperature and humidity are correlated with each other.

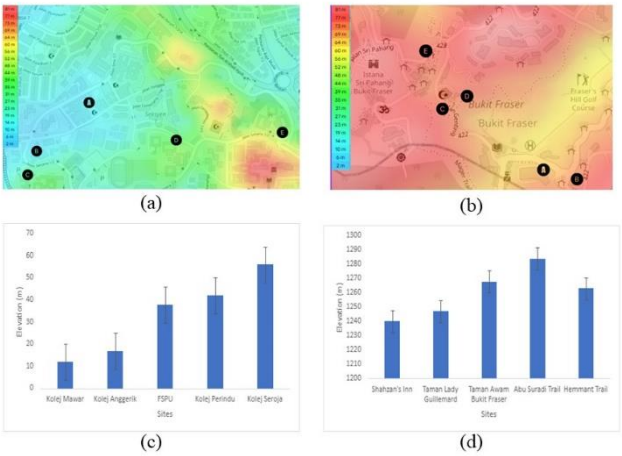


Fig. 2. Contour map of Site 1 (a) and Site 2 (b), along with the elevation levels of the five locations in Site 1 (c) and Site 2 (d)

Site 1 represents the lowland which typically has higher temperatures and lower relative humidity while Site 2 represents the highland which in contrast have lower temperatures and higher relative humidity. The range of elevation levels in Site 1 and Site 2 are 12 m to 56 m and 1240 m to 1280 m, respectively. Site 1 has an average elevation of 32.0 m ± 3.0 while Site 2 has an average elevation of 1260.4 m ± 2.9.

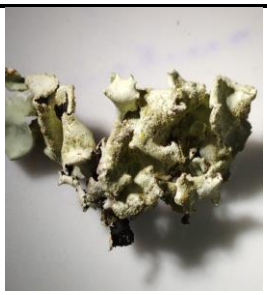
In Figure 2 (a) and (b), the contour map showed a contrast of colors between the two sites, in which Site 1 is mostly covered with blue and green, which as shown in the indicator, agrees that Site 1 is a lowland as it has lower elevation levels. Site 2 is portrayed with red color as it is located in the highlands, in which the elevation levels are higher.

A study conducted by reference [4], species distribution of lichens increases as temperature levels of the surrounding increases. In contrast, as humidity level decreases, the species coverage of lichens increases. According to a study by reference [21], exposure of high humidity on lichens for a long period of time decreases the growth rate of lichen, suggesting that varying humidity levels are suitable for lichens. Plus, lichens are small organisms that can find source of hydration from night dew and light rain instead of continuous hydration from the high relative humidity level in the ambience [21].

3.3 Lichen Inventory List

Table 2. Description of lichen species

 *Anisomeridium polypori*	Family Monoblastiaceae; Thin crustose; Whitish gray in colour with hints of yellow; Ascomata scattered dark flask-shaped fruiting body (perithecia); No secondary metabolites
 *Bryoria sp.*	Family Parmeliaceae; Fruticose growth form, Colour light green; Slender and ciliated; Secondary metabolites not identified.
 *Buellia griseovirens*	Family Caliciaceae; Crustose growth form; Green in colour; Rounded soredia forms on thallus of lichen; Secondary metabolites include major traces of atranorin and norstictic acid [22].
 Chrysothrix chlorina [23]	Family Chrysothricaceae; Leprosy crustose growth form; Bright yellowish green in colour; Secondary metabolites include calycin and pulvinic acid [22].



Parmotrema reticulatum

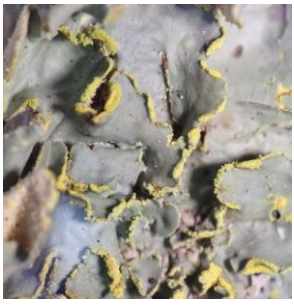
Family Parmeliaceae; Foliose with simple cilia, upper surface pale greenish, lower surface smooth dark brown; Contains secondary metabolites atranorin, chloroatranorin (in upper cortex) and salazinic acid and consalazinic acid (in medulla).

Parmotrema bangii

Family Parmeliaceae; contains secondary metabolites salazinic acid in medulla [14], atranorin and chloroatranorin (in upper cortex) [22]

Lepraria finkii

Family Stereocaulaceae; Thallus corticolous, leprosy crustose; Colour pale yellowish green and appear fluffy and cottony; Secondary metabolites include atranorin, zeorin, stictic, cryptostictic and constictic acids [22]



Crocodia aurata

Family Peltigeraceae; Foliose growth form; Thallus undulating, and irregular spread; Coloured green with bright yellow outline; Contains secondary metabolites pulvinic acid, pulvinic dilactone and calycin [24]

Sticta sylvatica

Family Peltigeraceae; Foliose growth form; Brown in colour; Fan shaped thallus with minute isidia; No secondary metabolites; Has a distinct smell.

Coccocarpia pellita

Family Coccocarpiaceae; Foliose growth form; Coloured grey; Irregular outlines and coarse granulated growth near the centre of the lichen; No reported secondary metabolites.

Usnea rubicunda

Family Parmeliaceae; Fruticose growth form; Coloured light green with hints of reds; Branchy; Secondary metabolites include usnic, stictic, constictic, and salazinic acid [24]

Usnea flammea

*This picture was not taken under a microscope.

Family Parmeliaceae; Fruticose growth form, yellowish green with tapering branches; Long branching; Secondary metabolites include stictic, norstictic, constictic, cryptostictic and menegazziaic acids [22]

Hypotrachyna sp.

Family Parmeliaceae; Foliose growth form; Light green in colour; Ciliated; Secondary metabolites not identified.

Pectenia plumbea

*This picture was not taken under a microscope.

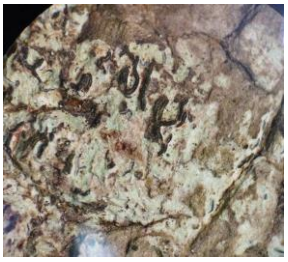
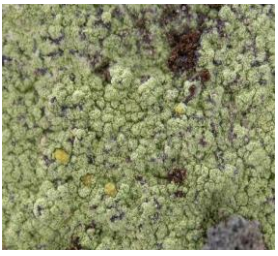
Family Pannariaceae; Foliose growth form; Bluish grey in colour; Irregularly distributed growth with orange lobes; No reported secondary metabolites.

Usnea fragilescens

Family Parmeliaceae; Fruticose growth form; Green in colour; Branchy with soredia scattered [22]

Scutula effusa

Family Ramalinaceae; Crustose growth form; White with hints of green colour; No secondary metabolites reported.

 *Parmelia sulcata* [25]	Family Teloschistaceae; Foliose growth form; Yellow in colour with orange lobes; Secondary metabolites include parietin, fallacinal, emodin, teloschristin, parietinic acid [22]
 *Graphis scripta*	Family Graphidaceae; Crustose growth form; Coloured pale whitish green; Thin and continuous growth; No secondary metabolites reported.
 *Psilolechia lucida* [26]	Family Psilolechiaceae; Leprosy crustose growth form; Green and yellow in colour; Secondary metabolites include rhizocarpic acid [27]
 *Phlyctis argena* [28]	Family Phlyctidaceae; Crustose growth form with soredia; White or grey in colour; Secondary metabolites include norstictic acid [22]

Myelochroa aurulenta
[29]

Family Parmeliaceae; Foliose growth form; Green with slight yellow colour; Secondary metabolites include atranorin, chloroatranorin, secalonic acid (in upper cortex), zeorin and leucotylic acid (in medulla) [22]

Pyxine cocoes
[30]

Family Caliciaceae; Foliose growth form; Black disk-like apothecia; Yellowish green with white parts; Secondary metabolites include lichexanthone (upper cortex) and terpenes (in medulla) [22]

Chrysothrix flavovirens
[31]

Family Chrysothricaceae; Leprosy crustose growth form; Yellowish green in colour; No secondary metabolites reported.

Flavoparmelia baltimorensis
[32]

Family Parmeliaceae; Foliose growth form; Yellowish green in colour; Isidia present; Secondary metabolites include usnic acid (in upper cortex) and protocetraric acid (in medulla) [32]

 *Parmeliopsis ambigua* [33]	Family Parmeliaceae; Foliose growth form; Yellowish green in colour; Soredia laminal; Secondary metabolites include usnic acid and divaricatic acid [33].
 *Parmeliopsis hyperopta* [34]	Family Parmeliaceae; Foliose growth form; Pale green in colour; Soredia present; Secondary metabolites include atranorin and divaricatic acid [33].
 *Pertusaria amara* [35]	Family Pertusariaceae; Crustose growth form; Whitish green in colour; White soredia present; Secondary metabolites include oxalic acid.
 *Lepraria lobificans* [36]	Family Stereocaulaceae; Crustose growth form; Green in colour; Granulats with soredia present; Secondary metabolites include atranorin, zeorin, stictic acid [22]

*All pictures are of own property unless stated otherwise.

* Species identification is based on morphological observation and chemical reactions with 10% KOH solution, Lugol's solution and bleach.

* All pictures are taken under a stereoscopic microscope with a range of 10X to 40X magnification, unless stated otherwise.

3.4 Lichen Species

Table 3. Lichen Species in Site 1 and Site 2, with Family, Genus and their growth form

Type	Family	Genus	Species	Site 1	Site 2
Crustose	Caliciaceae	*Buellia*	1. *Buellia griseovirens*	-	+
	Chrysothricaceae	*Chrysothrix*	2. *Chrysothrix chlorina*	+	-
			3. *Chrysothrix flavovirens*	+	-
	Graphidaceae	*Graphis*	4. *Graphis scripta*	-	+
	Monoblastiaceae	*Anisomeridium*	5. *Anisomeridium polypori*	-	+
	Physciaceae	*Dirinaria*	6. *Dirinaria picta*	+	-
	Psylolechiaceae	*Psylolechia*	7. *Psylolechia lucida*	+	-
	Ramalinaceae	*Scutula*	8. *Scutula effusa*	-	+
	Stereocaulaceae	*Lepraria*	9. *Lepraria finkii*	-	+
			10. *Lepraria lobificans*	+	-
			11. *Lepraria* sp.	-	+
			12. *Lepraria usnica*	+	-
Total:			12 species (6 species in Site 1, 6 species in Site 2), 8 families		
Foliose	Caliciaceae	*Pyxine*	1. *Pyxine cocoes*	+	-
	Coccocarpiaceae	*Coccocarpia*	2. *Coccocarpia pellita*	-	+
	Lobariaceae	*Crocodia*	3. *Crocodia aurata*	-	+
	Parmeliaceae	*Flavoparmelia*	4. *Flavoparmelia baltimorensis*	-	+
		Hypotrachyna	5. *Hypotrachyna* sp.	-	+
		Parmelia	6. *Parmelia sulcata*	-	+
		Parmeliopsis	7. *Parmeliopsis hyperopta*	-	+
			8. *Parmeliopsis ambigua*	+	-

		Parmotrema	*9.*	*Parmotrema bangii*	-	+
			10.	*Parmotrema reticulatum*	-	+
			11.	*Parmotrema* sp.	-	+
	Pannariaceae	*Pectenia*	*12.*	*Pectenia plumbea*	-	+
	Peltigeraceae	*Sticta*	*13.*	*Sticta sylvatica*	-	+
	Physciaceae	*Dirinaria*	*14.*	*Dirinaria* sp.	+	-
	Teloschistaceae	*Xanthoria*	*15.*	*Xanthoria parietina*	-	+
Total:			15 species (4 species in Site 1, 11 species in Site 2), 8 families			
Fruticose	Parmeliaceae	*Bryoria*	*1.*	*Bryoria sp.*	-	+
		Usnea	*2.*	*Usnea flammea*	-	+
			3.	*Usnea fragilescens*	-	+
			4.	*Usnea rubicunda*	-	+
Total:			4 species (all in Site 2), 1 family			
Grand total:			27 species, 13 families			

A total of 29 species were sampled in both sites comprising of 14 families which are Caliciaceae, Chrysothricaceae, Graphidaceae, Monoblastiaceae, Physciaceae, Psylolechiaceae, Ramalinaceae, Stereocaulaceae, Coccocarpiaceae, Lobariaceae, Parmeliaceae, Pannariaceae, Peltigeraceae and Teloschistaceae. Out of the 29 species, 12 are crustose, 13 are foliose and four are fruticose.

There was a difficulty in identifying the species for the genus *Lepraria* as they are similar lookwise, thus the species is listed as *Lepraria sp*. Lichens from the genus *Lepraria*, specifically *L. incana, L. achariana* and *L. lendemeri* are morphologically similar to each other, in which they are a light green crustose lichen with granules [22]. To further identify the lichens up to the species level, DNA analysis is needed.

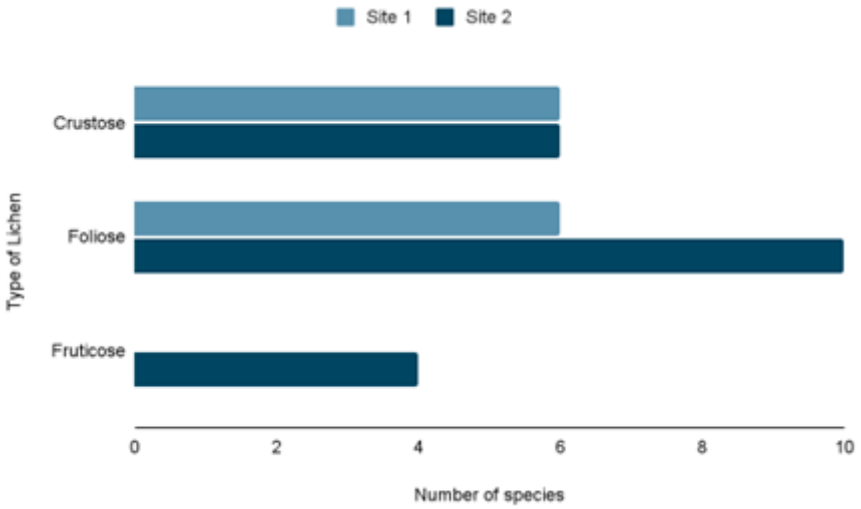


Fig. 3. Frequency of lichens according to the types of lichen

As shown in Table 3, the same number of crustose species are found in both sites, while the number of foliose species increase exponentially in Site 2 where temperature is lower and relative humidity is higher. 6 foliose species were recorded in Site 1 while 10 foliose species were recorded in Site 2. Generally, it is noted that crustose species are more robust and more tolerant to abiotic factors which include levels of temperature and relative humidity [37]. However, foliose lichens are more competitive [38] and are more effective at dominating the space [39], hence they outgrow and limit the growth of crustose lichens.

Fruticose lichens are only present in Site 2, which agrees with past studies like reference [40], in which fruticose lichens are mainly sampled in locations with higher elevation. This may be due to the presence of fog and mist in higher elevations [41] which helped the absorption of water on fruticose lichens.

3.5 Lichen Frequencies Based on Family

To further analyse the lichen species composition, pie charts were produced, with percentage of the lichen frequencies based on their Family in Figure 4 for Site 1 and Figure 5 for Site 2.

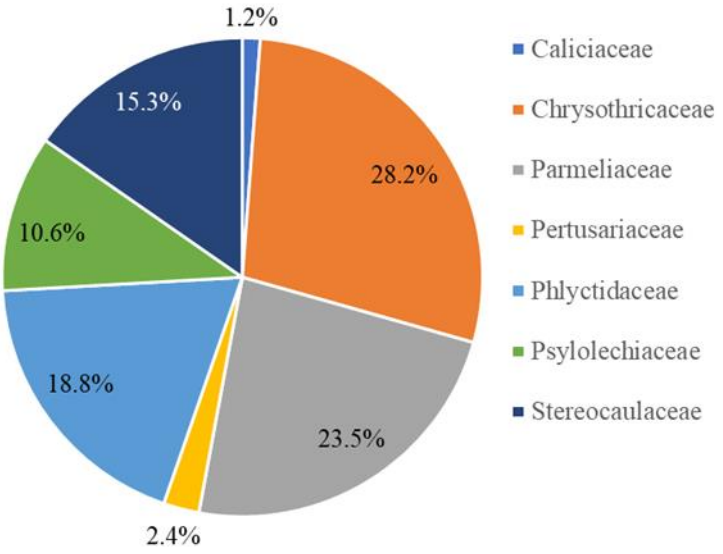


Fig. 4. Lichen frequencies based on family in Site 1

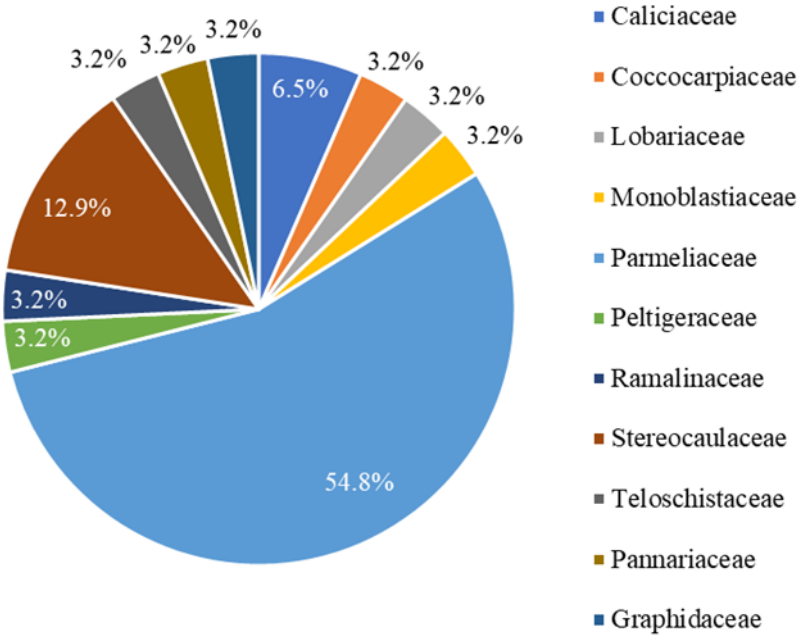


Fig. 5. Lichen frequencies based on family in Site 2

In Site 1, the lichen family that exhibits the highest frequency is Chrysothricaceae which consists of crustose lichens such as *Chrysothrix chlorina* and *Chrysothrix flavovirens.* In Site 2, the family Parmeliaceae dominates the lichen distribution, which mostly consists of foliose and fruticose types such as *Hypotrachyna sp., Parmotrema bangii, Parmotrema reticulatum, Parmotrema sp., Bryoria sp., Usnea flammea, Usnea fragilescens,* and *Usnea rubicunda*. This agrees with the theory that fruticose types are more abundant in places with lower temperatures and higher relative humidity [12]. Fruticose lichens are also noted to favor those conditions as they have the characteristics of having a higher surface to air ratio, causing it to undergo desiccation and rehydration faster [42].

3.6 Percentage Coverage of Lichen Species

Bar chart was produced to analyse the percentage coverage of lichen species according to sites. However, the bar chart shows that the species do not overlap which indicates that not one species found in Site 1 can be found in Site 2.

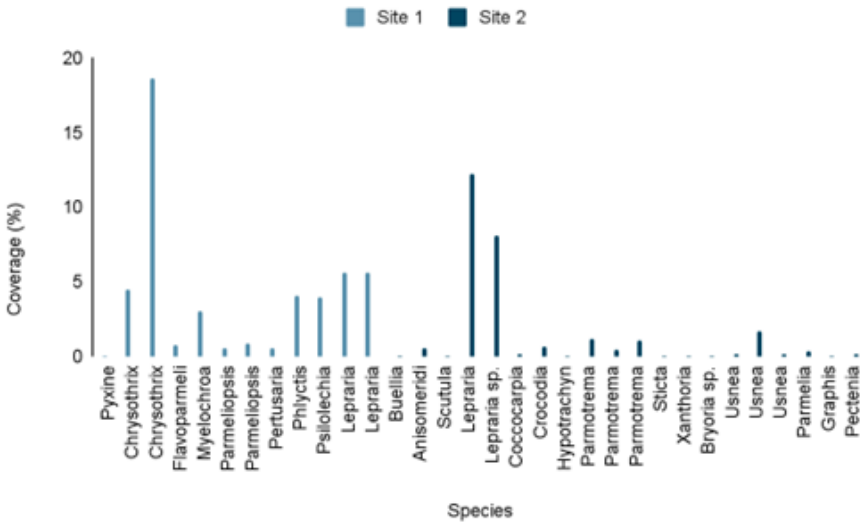


Fig. 6. Percentage coverage of lichens according to species in both sites

Depicted above is the percentage coverage of lichens in Site 1 and Site 2. The distribution of lichens in the aspect of percentage coverage showed a significant difference between the two sites, with a t-test result of $p<0.05$ ($p=0.039$, d.f.=30). For instance, in Site 1, *Chrysothrix flavovirens* exhibit the highest percentage coverage in Site 1 (18.7%). As highlighted in Figure 4, lichens from the family Chrysothricaceae exhibit the highest frequency of lichens from the 30 quadrats sampled. This agrees with the study by [43] which stated that *Chrysothrix flavovirens* typically found in the microclimates that have a lower relative humidity and in the warmer regions. Next, the

Genus *Lepraria* exhibits 5.7% of coverage in Site 1, followed by *Chrysothrix chlorina* (4.5%), *Psilolechia lucida* (3.9%), *Phlyctis argena* (4.1%) and *Myelochroa aurulenta* (3.1%). The rest of the lichen species sampled in Site 1 has a coverage of less than 1%. In Site 2, the Genus *Lepraria* dominates the coverage of lichens with 12.2% for *Lepraria finkii* and 8.1% for *Lepraria* sp. Next, Usnea fragilescens has a coverage of 1.7% followed by Genus *Parmotrema* with a range coverage of 1.1% to 1.2%. The rest of the lichen species sampled in Site 2 yields a coverage of less than 1%.

Therefore, from this observation, lichen coverage of the species is higher in warmer regions with lower relative humidity, with an average coverage of 4.04% ± 1.46. In contrast, lichen coverage of the species is lower in colder regions with higher relative humidity, with an average coverage of 1.37% ± 0.69. Generally, lichen coverage is higher in places with lower relative humidity [44]. However, it is also noted that Site 1 is less diverse than Site 2 as there were low number of species found despite the higher coverage of lichens. For instance, there were 21 species recorded in Site 2 but only 10 species recorded in Site 1.

4 Conclusion

Higher lichen species were recorded in lower temperature and higher relative humidity by 8 species. Family Stereocaulaceae thrives in both sites albeit the significant differences in temperature and relative humidity. This study presents evidence that crustose lichens are more abundant in lower elevations (12m-56m) which typically have a warmer temperature and lower relative humidity. Meanwhile, foliose and fruticose lichens increase along with the elevations. In higher elevations, temperatures are lower and relative humidity are higher. For instance, *Chrysothrix flavovirens*, a type of crustose lichens that had the highest frequency in Site 1, was absent in Site 2. Meanwhile, the foliose with genus *Parmotrema* that were the most abundant in Site 2 and fruticose lichens were absent in Site 1. From the analyses, foliose and fruticose lichens increase as the temperature decreases. Conversely, foliose and fruticose lichens decrease by 66% as relative humidity decreases.

Acknowledgements. We would like to express our gratitude to Universiti Teknologi MARA for providing the financial support under the research grant funded by Universiti Teknologi MARA 600-RMC/MYRA 5/3/LESTARI (070/2020), 600-RMC/SRC/5/3 (007/2020), and a national grant funded by the Ministry of Higher Education, Malaysia 600-RMC/FRGS 5/3 (139/2023).

References

1. Morillas, L., Roales, J., Cruz, C., Munzi, S.: Lichen as Multipartner Symbiotic relationships. Encyclopedia **2**(3), 1421–1431 (2022)
2. Cruz, C., Vishwakarma, K., Choudhary, D. K., Varma, A.: Soil Nitrogen Ecology. Soil Biology **62** (2021)
3. Zaghloul, A., Saber, M., Gadow, S. Awad, F.: Biological indicators for pollution detection in terrestrial and aquatic ecosystems. Bulletin of the National Research Centre (2020)

4. Abas, A., Din, L.: Diversity, composition and distribution of lichens along elevational gradients in the tropical mountain forest of Gunung Nuang, Selangor, Malaysia. Eco.mont **13**(1) (2021a)
5. Zulkifly, S., Kim, Y. S., Majid, M. A., Merican, A. F.: Distribution of Lichen Flora at Different Altitudes of Gunung Machincang, Langkawi Islands, Malaysia. Sains Malaysiana **40**(11), 1201–1208 (2011)
6. Baldauf, S., Porada, P., Raggio, J., Maestre, F. T., Tietjen, B.: Relative humidity predominantly determines long-term biocrust-forming lichen cover in drylands under climate change. Journal of Ecology **109**(3), 1370–1385 (2020)
7. Hawksworth, D. L.: Freshwater and lichen-forming fungi. Fungal Diversity 5(1), 1–7 (2000)
8. Sonina, A. V., Androsova, V. I.: Coastal Lichens. 1st eds. Springer, Cham (2020)
9. Sancho, L. G., Pintado, A., Green, T. G. A.: Antarctic Studies Show Lichens to be Excellent Biomonitors of Climate Change. Diversity **11**(3), 42 (2019)
10. Markovskaya, E., Sonina, A., Sergienko, L., Morosova, K., Elkina, N.: Morphological and functional peculiarities of saltmarsh plants and epilithic lichens in tidal conditions of Russian Arctic Seas. Czech Polar Reports **4**(2), 168–177 (2014)
11. Abas, A., Khalid, R. M., Rosandy, A. R., Sulaiman, N.: Lichens of Pulau Pangkor, Perak, Malaysia. The Malaysian Forester **82**(1), 59–66 (2019a)
12. Abas, A., Asnawi, N. H., Aiyub, K., Awang, A., Abdullah, S. R.: Lichen Biodiversity Index (LBI) for the Assessment of Air Quality in Industrial City in Pahang, Malaysia. Atmosphere 2022 **13**(11) (2022)
13. Paukov, A., Sipman, H. J. M., Kukwa, M., Repin, R., Teptina, A.: New Lichen Records from the Mountains Kinabalu and Tambuyukon (Kinabalu Park, Malaysian Borneo). Herzogia **30**(1), 237–252 (2017)
14. Abas, A., Sulaiman, N., Adnan, N. R., Aziz, S. A., Nawang, W. N. S. W.: Using Lichen (Dirinaria sp.) as Bio-Indicator for Airborne Heavy Metal at Selected Industrial Areas in Malaysia. Environment Asia **12**(3) (2019b)
15. Malaysian Meteorological Department.: Climate Information (2023)
16. Yearly & Monthly weather - Shah Alam, Malaysia, Weather Atlas, https://www.weather-atlas.com/en/malaysia/shah-alam-climate
17. Musthafa, M. M., Abdullah, F.: Beetles Species Richness along Environmental Gradients at Montane Ecosystem in Fraser's Hill, Peninsular Malaysia. Sains Malaysiana **48**(7) (2019)
18. Nayaka, S.: Methods and techniques in collection, preservation and identification of lichens. ResearchGate (2014)
19. McCune, B., Geiser, L.: Macrolichens of the Pacific Northwestm 2nd Ed. Oregon State University Press (2009)
20. Orange, A., James, P. W., White, F. J.: Microchemical methods for the identification of lichens (2010)
21. Bando, M., Sugino, M.: Effect of Low-Humidity Treatment on Growth of the Lichen Parmotrema tinctorum in a Growth Cabinet. Journal of Plant Research **108**(4), 527–529 (1995)
22. Consortium of Lichen Herbaria, https://lichenportal.org/portal/
23. Brinker, Consortium of Lichen Herbaria, https://lichenportal.org/portal/
24. Fungi of Great Britain and Ireland, https://fungi.myspecies.info/
25. Bibimoncada iNaturalist Luxembourg, https://inaturalist.lu/
26. Fungi of Great Britain and Ireland, https://fungi.myspecies.info/all-fungi/psilolechia-lucida
27. Taylor, J. A., Fourie, M., Powell, M., Chianella, I.: Evidence for some antimicrobial properties of English churchyard lichens. Access Microbiology **5**(6) (2023)
28. British Lichens, http://www.britishlichens.co.uk/index.html

29. Consortium of Lichen Herbaria, https://lichenportal.org/portal//collections/individual/index.php?occid=4936244
30. Consortium of Lichen Herbaria, https://lichenportal.org/portal//collections/individual/index.php?occid=4935001
31. Diederich, P. (2006), http://www.lichenology.info/doc/images/CHFL3966.jpg
32. iNaturalist Luxembourg, https://www.inaturalist.org/guide_taxa/225387
33. McCune, B., Geiser, L.: Macrolichens of the Pacific Northwest. 2nd edn. Oregon State University Press (2009)
34. Fungi of Great Britain and Ireland, https://fungi.myspecies.info/file-colorboxed/21117
35. Ways of Enlichenment - Lichens of North America, https://www.waysofenlichenment.net/lichens/Pertusaria%20amara
36. Lichens of Belgium, Luxembourg and Northern France, http://www.lichenology.info/cgi-bin/baseportal.pl?htx=atlas_frm&newId=1246
37. Nascimbene, J., Marini, L.: Epiphytic lichen diversity along elevational gradients: biological traits reveal a complex response to water and energy. Journal of Biogeography 42(7), 1222–1232 (2015)
38. Welch, A. R.: The effect of anthropogenic nutrient addition on the growth and competitive abilities of selected lichen species. [Doctoral thesis]. The Open University (2003)
39. Saiz, H., Dainese, M., Chiarucci, A., Nascimbene, J.: Networks of epiphytic lichens and host trees along elevation gradients: Climate change implications in mountain ranges. Journal of Ecology **109**(3), 1122–1132 (2020)
40. Cleavitt, N. L., Clyne, A. B., Fahey, T. J.: Epiphytic macrolichen patterns along an elevation gradient in the White Mountain National Forest, New Hampshire. The J. of the Torrey Botanical Society **146**(1), 8–17 (2019)
41. Bässler, C., Cadotte, M. W., Beudert, B., Heibl, C., Blaschke, M., Bradtka, J., Langbehn, T., Werth, S., Müller, J.: Contrasting patterns of lichen functional diversity and species richness across an elevation gradient. Ecography **39**(7), 689–698 (2015)
42. Čabrajić, A. J.: Modeling Lichen performance in relation to climate: Scaling from Thalli to Landscapes. [Doctoral dissertation]. Swedish University of Agricultural Sciences (2009)
43. Tripathi, M., Joshi, Y.: Future perspectives and challenges. Endolichenic Fungi: Present and Future Trends, 171-180 (2019)
44. Pearson, L. C.: Influence of temperature and humidity on distribution of lichens in a Minnesota bog. Ecology **50**(4), 740–746 (1969)