DIVERSITY, ECOLOGY AND ALTITUDINAL DISTRIBUTION OF CORTICOLOUS LICHENS IN MOUNT KENYA TROPICAL MONTANE FOREST

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DECLARATION

"This thesis is my original work and has not been presented for a degree in any other university or for any other award."

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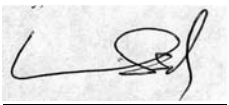

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DEDICATION

Dedicated to my wife, Jennifer W. Muigai and our daughters: Beth Wambui, Martha Wairimu and Linet Mumbi for their support during the entire duration of my studies. You have always been a source of my inspiration.

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ABBREVIATIONS AND ACRONYMS

ACE	Abundance Based Coverage Estimator
ANOVA	Analysis of Variance
GLM	Generalized Linear Model
ICE	Incidence Coverage Estimator
ICN	International Code of Botanical Nomenclature for Algae, Fungi and Plants
ISA	Indicator Species Analysis
IV	Indicator Value
MMMeans	Michaelis-Menten Means
MRPP	Multi-Response Permutation Procedure
NMS	Non-metric Multi-dimensional Scaling
TLC	Thin Layer Chromatography
UNESCO	United Nations Scientific and Cultural Organization
USA	United States of America

ABSTRACT

While recent studies indicate a high diversity of lichens in the tropical regions of the world equaling or even surpassing that of temperate areas, studies of lichens in these regions remain rare and Kenya is no exception. The aim of this study was to enhance our knowledge of lichen diversity in Mt. Kenya forest. Diversity, composition and altitudinal distribution of corticolous lichens was evaluated in Chogoria a wet forest type and Sirimon a dry upland forest. At every 200m elevation starting from the lower forest edge plots measuring 10 × 200m were established, these were further subdivided into 10 × 20m subplots from which two host trees were randomly selected for sampling. Ten sites were studied, six in Chogoria and four in Sirimon using stratified random sampling method. Four ladder quadrats measuring 10 × 50 cm were placed on the tree trunks 1.5m from the ground on the four compass directions and all lichens occurring inside these quadrats collected. In total 113 host trees of 13 species were sampled, Chogoria recorded higher diversity of host trees than Sirimon. A total of 245 taxa were recorded from 1007 specimens collected, these were classified into 73 genera and 38 families. Sixteen species were new for Africa while seventy three were first records for Kenya, seven new species were discovered. Majority of taxa in the dataset were rare, recorded only once or twice in the samples. Chogoria forest had higher species richness (150) than Sirimon (91). Rarefaction curves were used to compare species richness and abundance in the two forest areas and among study sites. Eight non parametric species estimators were used to approximate the number of species expected from each forest. Sampling effort computed revealed adequate sampling with 67% completeness. To test for differences in lichen assemblages among study sites, MRPP was used while ordination of study sites was performed using NMS. Altitude and vegetation type had a significant influence on lichen richness, abundance and occurrence. Chogoria recorded high abundance of crustose micolichens at lower elevation whereas at higher altitudes macrolichens were more abundant. Beta diversity was high for the two forest areas as well as among the study sites indicating high heterogeneity. Subtle lichen preference for the tree host species was revealed through ISA. Overall high family, generic and species diversities were observed. Lichen identification was done using morphological and anatomical characters of lichen thalli, apothecia and ascospores in addition to chemistry. Presence of chemical substances on lichen thalli was detected by spotting reagents that give characteristic colour changes and by exposure to UV light to detect substances that fluoresce under UV light giving characteristic colours. Standardized TLC was performed in identification of specific lichen substances. To enable biomonitoring and comparative studies more lichen biodiversity research covering other montane ecosystems is recommended. Lichen metabolites and their derivatives have great potential use in pharmaceutical and agrochemical industries, more research to determine their use in medicine and crop protection is therefore stongly recommended.

CHAPTER ONE

1. INTRODUCTION

1.1 Background

Lichens are a highly diverse group of composite organisms consisting of a fungal (the mycobiont) and a photosynthetic partner (the photobiont) living in a symbiotic association with each other to form a discrete structure (the thallus). The lichen thallus is a relatively stable and well-balanced system that has distinct structure and morphology that is often species-specific. The photobiont contains chlorophyll and may be either a member of the chlorophyta (green-algae) in about 90% or a cyanobacterium (blue-green algae) in about 10% of the total lichens (Rogers, 1992). In the lichen association the photobiont is known to provide the energy for maintaining life and growth of the structure, while the mycobiont offers protection to the photobiont by reducing the light intensity to which the photobiont is exposed and is also thought to enhance water uptake (Nash, 2008). Lichens are therefore autotrophic organisms, living a life similar to green plants (Will-Wolf *et al*., 2004). Lichen thalli may sometimes contain additional lichenicolous fungi that are different from the dominant mycobiont, the relationship of the lichenicolous fungi with the lichen thalli may either be parasitic, commensalistic, mutualistic or saprophytic (Nash, 2008).

Lichens constitute a significant portion of forest biodiversity worldwide (Debolt *et al*., 2007; McCune, 2000), forming a vegetation cover of about 8% of the earth's terrestrial surface (Brodo *et al*., 2001; Purvis, 2000). Globally there are an estimated 14,000 species of lichens, diverse in size, form and colour (Brodo *et al*., 2001). While lichens are generally believed to be more diverse in cool temperate climates, studies indicate that lichen diversity in the tropics may

equal or even surpass that found in non-tropical areas (Lücking, 1999). Tropical montane forests are typically characterized with a high diversity of epiphytes, both of higher plants and lichens (Gradstein *et al.,* 1996; Komposch and Hafellner, 2000; Lücking and Matzer, 2001). However little is known about their diversity in the tropical areas due to limited studies and lack of inventory data for most areas, consequently large areas remain largely under-explored especially the paleotropics making it difficult to make accurate estimates of lichen diversity (Caceres *et al.,* 2008a; Feuerer and Hawksworth, 2006; Lücking and Matzer, 2001; Lücking *et al.,* 2009; Lücking, 1999; WCMC, 1992). Yeshitela (2008) attributed the low study of lichens in Africa to the lack of expertise in the region, a lack of reference materials and also the fact that most botanists in Africa prefer to work on vascular plants. Recent studies in the tropical regions are revealing a much higher diversity than previously envisaged (Caceres *et al.,* 2008a and b). In a recent publication of one hundred new species of lichenized fungi, Lumbsch *et al.* (2011) placed the estimates of the undescribed lichens at about 10,000 species, most of which he asserts are likely to be found in the tropical areas of the world. For complete global lichen diversity, more focus should therefore be placed on the tropical regions especially in the primary forests (Sipman and Aptroot, 2001).

Our current knowledge of lichens in Africa is among the poorest in the world and studies in lichen diversity and its ecology are rare. For example, currently, there is no known study of altitudinal distribution of lichens in Africa at least to the best of my knowledge. In addition the entire East African region covering Kenya, Uganda, Tanzania and Ethiopia has only one comprehensive reference book (Swinscow and Krog, 1988) which covers only the macrolichens, little information is therefore available on the microlichens diversity and the ecology of lichens in the region. In Kenya only a small part of the country has been covered in lichen inventories,

which means that even the better known macrolichens are still poorly documented. The total lichen mycobiota for Kenya is projected to be in the range of 1400-2000 species (Fischer and Killmann, 2008; Feuerer, 2009). Currently, only less that half (30-43%) of these have been recorded and therefore majority of the species are yet to be documented. Recent studies of foliicolous lichens carried out in Kakamega forest by Yeshitela (2008) recorded 77 new records of foliicolous lichens for Kenya bringing the number of known foliicolous lichens to 171 which is the highest number recorded for a single country in tropical Africa. While an earlier study of macrolichens in the alpine and sub-alpine zone of Mt. Kenya by Frisch and Hertel (1998) recorded 155 species, nine (9) of which were new records for Kenya.

Corticolous lichens lichens grow epiphytically on the bark of trees and shrubs forming one of the most striking characteristics of tropical montane forests (Gradstein *et al*., 2003). They play an important role in water balance and nutrient cycle in these forests; their value is exemplified by their usefulness as ecological indicators of climate and forest type (Gradstein *et al.,* 2003; Brodo *et al*., 2001; Aptroot and van Herk, 2007). As such describing and analyzing these communities is a research priority for conservation of biodiversity and a prerequisite for sustainable management of tropical montane forests (Holz and Gradstein, 2005). This study is aimed at enhancing our current knowledge on the diversity of lichens in the tropics by assessing the distribution of the corticolous lichens along an altitudinal gradient in Mt. Kenya tropical forest. The lichen diversity data generated will constitute important baseline information for future use in biomonitoring studies.

1.2 Problem statement and justification

Although it is currently difficult to give an accurate estimate of lichens in most tropical areas due to inadequate inventory data, it is estimated that about 50% of the total lichen species,

especially corticolous lichens occur in the tropics (Lücking *et al.,* 2009). This inadequacy of data on lichens from tropical forests has been identified as a major hinderance in conservation planning and biodiversity assessments (Fischer and Killmann, 2008; Musila *et al*., 2009).

Kenya is endowed with a wide diversity of ecosystems ranging from the lowland coastal forests, the savannas with occasional inselbergs to the high montane forests with alpine vegetation. A large number of species of lichens are therefore expected for the country, the current estimates of the total lichen species richness for Kenya is between 1400 to 2000 species (Fischer and Killmann, 2008; Feuerer, 2009). However, the existing preliminary checklist records only 594 species (Feuerer, 2009). This therefore indicates that the lichen flora of Kenya is poorly known and a large number of taxa (57-70%) remain largely un-documented.

Mt Kenya ecosystem is an important reservoir for biodiversity, is one of the major water towers and a key tourist attraction in the country. It has also been inscribed by UNESCO as a world heritage site. A lack of comprehensive biodiversity information on the Mt Kenya ecosystem has already been identified as an impediment to its proper management and a thorough biodiversity assessment encompassing the whole ecosystem has been recommended (Musila *et al*., 2009). Despite these efforts and the fact that lichens are major components of the Mt. Kenya forest ecosystem their diversity and ecology remain largely under-studied and even the recent biodiversity inventories did not cover lichen flora (Musila *et al.,* 2009), therefore the lichen mycobiota of the ecosystem remains poorly known. This study is therefore aimed at enhancing our knowledge of the lichen diversity in Mt. Kenya ecosystem and will contribute important biodiversity information for better management of the ecosystem besides complementing the ongoing biodiversity documentation efforts. Since a good understanding of

the biodiversity and the ecology of an ecosystem is an important prerequisite for its prudent management.

1.3 Hypotheses

- The diversity of corticolous lichens in Mount Kenya montane forests is influenced by changes in altitude.
- The lichen community structure and distribution is affected by changes in vegetation composition or the forest type.
- The lichen occurrence and distribution is affected by the host tree species.
- The diversity of lichens in Mount Kenya forest is greater than shown by existing records.

1.4 Objectives

1. 4.1 Main objective

The aim of this study is to enhance our knowledge of lichen diversity in Kenya for the broader picture of enhancing knowledge on biological diversity.

1.4.2 Specific objectives

i. To document the diversity and altitudinal distribution of corticolous lichens in Mount Kenya tropical montane forest.
ii. To assess host specificity of the corticolous lichens in Mount Kenya montane forest.
iii. To evaluate the diversity and the differences in the lichens assemblages within the different forest types in Mount Kenya forest.

1.5 Significance and expected outputs

To the best of my knowledge, this is the first study focusing on vertical distribution of lichens in a tropical montane forest in Africa. So far, most studies on altitudinal zonation are from temperate regions and the few studies in tropical areas are almost exclusively from the Neotropics. This study will therefore not only enhance our knowledge of the lichen flora in a tropical montane forest but will also provide important baseline information required for better management and conservation of biodiversity in Mt. Kenya ecosystem. With the current interest and concern on issues pertaining to climate change, the findings from this study will constitute important information for the future detection and monitoring of environmental changes in the Mt. Kenya montane forest ecosystem. Some of the outputs from this study include;

i. a checklist of the corticolous lichens of Mt. Kenya montane forest.

ii. herbarium voucher specimens of collected lichens.

iii. scientific publications on the ecology and taxonomy of lichens of Mt. Kenya (Kirika *et al.*, 2012a; Kirika *et al.*, 2012b).

iv. an electronic database of the corticolous lichens of Mt. Kenya montane forest.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Structure of lichens and thallus morphology

The structure of a lichen thallus is primarily determined by the mycobiont which forms the greater part of lichen thalli (80%) with the photobiont accounting for 20% (Purvis, 2000). There are only a few exceptional cases where the photobiont is known to determine the habit of the whole thallus (Nash, 2008). The fungal components of lichens are mainly taxa classified under Ascomycota, which occur in about 98% of the lichenised fungi, the rest comprising of Basidiomycota (Hawksworth and Rose, 1976). The scientific names given to lichens under the rules of International Code of Botanical Nomenclature for Algae Fungi and Plants (ICN) are treated as referring to the mycobiont (Nash, 2008).

The morphology of lichen thalli may be classified into five general morphological categories: (i) crustose, which has the lower surface of the thalli tightly embedded on or in the surface of the substratum as species *Pertusaria scaberula* A.W.Archer (Fig. 4.1A) ii) leprose, composed of granular particles of intertwined fungal hyphae and algal cells without an organized thallus and lacking a distinct fungal or algal layer as *Chrysothrix xanthina* (Vain.) Kalb (Fig. 4.1B) iii) squamulose type that is composed of small flakes or scale like thallus as *Phyllopsora santensis* (Tuck.) Swinscow & Krog (Fig. 4.1C) (iv) foliose type that has leaf-like thalli with a distinct upper and lower surface and as in *Lobaria pulmonaria* (L.) Hoffm. (Fig. 4.1D) and (v) fruticose type which is either shrubby or comprises of string-like structures with a radial symmetry as in *Usnea* spp. (Fig. 4.1E and F). The foliose and fruticose lichens are usually

referred to as macrolichens, while the other forms of crustose lichens that are less conspicuous are called microlichens (Gradstein *et al.,* 1996).

2.2 Reproduction in Lichens

Most of the lichenized fungi have both sexual and asexual life cycles. The majority of lichens bear fungal components belonging to the phylum Ascomycota and thus the sexual phase produces fruiting bodies known as ascomata. The fruiting bodies (ascomata) are of two basic types: apothecial, which are disc or cup shaped with an exposed spore producing layer (hymenium) and the perithecial type which has flask-shaped structures enclosing the hymenium and opening through an ostiole (Brodo *et al.,* 2001; Nash, 2008). The hymenium layer bears sac-like structures called asci in which meiosis occurs with subsequent development of spores (ascospores) (Brodo *et. al*., 2001). The ascospores vary greatly in shape, size, septation and colour depending on the species. In most cases an ascus contains eight ascospores, although this can vary from one to 300 in some rare cases (Filson, 1992). The asci and ascospore structures are of primary importance in the classification of ascomycetes.

Asexual reproduction in lichens is mainly through the production of vegetative propagules that contain both the fungus and photobiont cells in form of powdery structures called soredia and the thalline outgrowths called isidia. Soredia are clusters of photobiont cells intertwined with fungal hyphae that develop on the upper surface of the lichen thallus while isidia are thalline propagules with the fungal and the photobiont cells.

2.3 Lichen substrates and habitat preferences.

Lichens grow on different kinds of substrates, which include both natural and man-made. The natural lichen substrates include tree bark, wood, rock, soil, peat mosses, other lichens, shells of living tortoises, the backs of certain insects and broad evergreen leaves in humid

tropics, while the man-made substrates include glass, metal, plastic and cloth (Brodo *et al.,* 2001). Lichens can be grouped according to the type of substrates they grow on such as (i) corticolous lichens that grow on the bark of living plants as epiphytes, (ii) terricolous lichens that grow on soil, (iii) saxicolous lichens that grow on rock, and (iv) foliicolous lichens, which grow on the leaves of higher plants (Brodo *et al*., 2001; Will-Wolf *et al*., 2004). Other terms have been described by Lücking (1998) such as 'plasticolous' referring to the lichens growing on plastic surfaces. The major substratum factors affecting the growth and abundance of lichens are the chemistry, stability and longevity (Will-Wolf *et al*., 2004).

Lichens are successful colonizers and are practically found in all ecosystems from the tropics to the polar region and even in aquatic and marine environments, some are often found in toxic and mineralized environments, a feature attributed to their stable symbiosis (Nash, 2008; Caceres *et al.,* 2007). As a result of the symbiosis, both photobiont and mycobiont have expanded into many habitats, where separately they would be rare or nonexistent (Nash, 2008). In the temperate and arctic regions of the world, rocky landscapes are covered with lichens.

2.4 Chemical compounds in lichens

Lichens have an extraordinary chemical diversity, producing over 700 secondary chemical compounds, almost all of which are unique to lichens. These lichen substances comprise a multitude of different classes of chemical compounds; they include amino acid derivatives, sugar alcohols, aliphatic acids, macrocyclic lactones, monocyclic aromatic compounds, quinones, chromones, xanthones, dibenzofuranes, depsides, depsidones, depsones, terpenoides, steroids and carotenoides (Huneck and Yoshimura, 1996; Nash, 2008). Some of these compounds are by-products which are deposited on the outer surface of the hyphae, mainly the cortex where they are thought to act as light screens or foul tasting deterrents to browsing

invertebrates (Purvis, 2000; Brodo *et al*., 2001; Nash, 2008). In addition, these chemical compounds may form insoluble crystalline materials that help to repel water and provide air spaces within the lichen, which is critical for gaseous exchange needed for photosynthesis. Lichens and lichen substances have a number of biological activities for example depsides, depsidones and usnic acids are acitive against gram-positive micro-organisms while protolicheristerinic acid, usnic acids, polyporic acid and derivatives, lichen glucans have antitumor and antimutagenic activities (Huneck and Yoshimura, 1996). Other chemical substances of lichens have antibiotic properties that can inhibit the growth of soil fungi and seeds of vascular plants, thereby giving the slow growing lichen some competitive advantage (Brodo *et al*., 2001; Nash, 2008).

The chemical substances contained in many lichen species are more or less constant for that species (Orange *et al.,* 2010), these substances therefore provide useful chemical fingerprints in the identification and classification of lichens (Purvis, 2000). Chemistry has always played a role in the circumscription of taxa, even before the chemical basis was discovered, such as when lichens were characterized by their bitter taste or differences in colour caused by some secondary metabolites (Lumbsch, 1998). The secondary metabolites data in over 5000 lichen species (33%) are extensively used in routine identification of lichens (Nash, 2008). Spot tests for colour reactions of lichen tissues are universally used as a rapid, nonspecific, means for detecting unspecified lichen substances (Orange *et al*., 2010). These colour reaction are often mentioned in identification keys (Orange *et al*., 2010). Lichens have certain properties such as the presence of usnic acid which absorbs and transmits light differently from plants thus enabling the use of remote sensing techniques such as landsat to monitor, for example the arctic ecosystems which are extremely fragile and sensitive to disturbances and pollution (Purvis, 2000).

2.5 Importance of lichens

Lichens has been used as a source of food for man for example *Umbilicaria esculenta* (Miyoshi) Minks is eaten in Japan as a delicacy (Pulvis, 2000), while *Byoria fremontii* (Tuck.) Brodo & D. Hawksw., were eaten by the native people in America (Brodo *et al*., 2001). In temperate regions lichens are an important source of food for mammals, they offer shelter for birds, invertebrates and other microorganisms while man has over centuries used them for, food, poisons, medicine, clothing, fibre, decorations, tannins and dyes (Brodo *et al*., 2001; Nash, 2008) . Lichen species *Letharia vulpina* (L.) Hue, has traditionally been used as poison for foxes and wolves in Europe (Nash, 2008). This is because it contains pulvinic acid derivative, vulpinic acid which is poisonous to all meat eaters, insects and mollusks (Nash, 2008). The production of alcohol using lichens is recorded as early as 1868 (Filson, 1992). In Siberia and Russia lichens were used in the brewing of highly potent beer, which was served to travelers by monasteries, while during the Second World War alcohol for the military was prepared from glucose molasses made from *Cetraria islandica* (L.) Ach. and *Alectoria ochroleuca* (Hoffm.) A. Massal. (Filson, 1992; Brodo *et al*., 2001). More recently lichens have been employed mainly in the manufacture of perfumes and antibiotics (Brodo *et al*., 2001; Nash, 2008; McCune, 2000; Purvis, 2000; Filson, 1992). It is estimated that about 9,000 tones of lichen species *Evernia prunastri* (L.) Ach. and *Pseudevernia furfuracea* (L.) Zopf., are processed annually for the production of perfumes in France (Huneck and Yoshimura, 1996; Brodo *et al*., 2001). The ethanol extract from these lichens has a flavour used as a component for certain perfumes in addition to their use as fixatives for the longevity of perfume flavours (Nash, 2000). Lichens are also used as sources of pharmaceutically active compounds and therefore enhanced knowledge of occurrence and species richness of tropical lichens is important for pharmaceutical research (Lücking *et al*., 2009).

Lichens are often used to evaluate air quality, climate change, as well as an effective early-warning system to detect accumulation of heavy metals and radioactive materials in terrestrial ecosystems (Aptroot and van Herk, 2007). Their use as environmental phytometers (Boonpragop and Polyiam, 2007) is due to their specialized ecological and physiological requirements making them very sensitive to environmental changes and are therefore excellent indicators of ecosystem health (Gradstein *et al*., 2003; Aptroot and van Herk, 2007; Wolseley, 2002).

Lichens form an important component of the tropical ecosystem, playing a significant role in nature, influencing soil fertility through nutrients and nitrogen fixation, in addition to water cycles (Gradstein *et al.*, 1996, 2003; Lücking *et al*., 2009; McCune, 2000). They also contribute to soil formation by breaking down rock minerals both physically and chemically (Purvis, 2000). They have been referred to as 'nature's pioneers' because of their ability to colonize bare rock as they are often the first plant-like life forms to be established on newly exposed surfaces (Brodo *et al*., 2001). This is because of their ability to withstand long periods of drought, their reliance on ambient dust and moisture for their mineral requirement and their efficient dispersal mechanism through tiny propagules. Besides, lichens with cephalodia containing cyanobacteria are able to fix atmospheric nitrogen and therefore provide their own source of nitrogen in nitrogen-poor substrates, such as newly exposed rocks (Brodo *et al*., 2001). Lichens therefore form an important component of the complex web of life and their disappearance affects the balance of nature to a great extent, but despite their importance in nature their conservation has not been given much emphasis (Nash, 2008). Lichen flora therefore continue to decline leading to reduction of their biodiversity, mainly as a result of human destruction of the ecosystems worldwide through deforestation, agricultural practices,

urbanization, pollution of air, water, soil and in the exploitation of natural resources (Nash, 2008).

2.6 Changes in lichen mycobiota with altitude.

Tropical regions are known to be richer in species than temperate areas but documentation of diversity patterns, particulary for the epiphytic cryptogams is still rare with inventory data and ecological studies lacking for most areas (Wolf, 1993a). Lücking (1999) attributed the lack of detailed analysis of lichen associations in the tropics to the poor taxonomic background coupled with high diversity. A study of species richness for various organisms along altitudinal gradients in Northern Andes by Wolf (1993) demonstrated an increase of lichen species richness with increase in altitude. Other studies show that epiphytic macrolichen species richness appears to be greater in the tropical montane forests (Wolf, 1993a). The lichen flora is known to change dramatically in relation to altitude (Dietrich and Scheidegger, 1997; Dolezal and Srutek, 2002; Hansen, 1996; Leuckert *et al.,* 1981; Loppi *et al.,* 1997; Mucina *et al.,* 2000; Pintado, 2001; Pirintsos *et al.,* 1993, 1995). This pronounced variation in lichens and other poikilohydric organism's results from differences in humidity and temperature along an altitudinal gradient (Kurschner *et al.,* 1999; Kurschner and Parolly 1998; Zotz, 1999; Zotz *et al.,* 2003). There are numerous studies in temperate regions documenting changes in the lichen composition in relation to altitude, but studies in the tropics are rare and the few that have been done are largely restricted to the Neotropics (Kessler, 2000; Plata *et al.,* 2008; Wolf, 1993a, b), with only one study in the Palaeotropics region of Thailand (Wolseley and AguirreHudson, 1997). Lichens are often abundant in habitats with distinct humid and dry conditions (Wolseley and AguirreHudson, 1997). Such conditions are often found along altitudinal gradients on the different orientations of montane areas in the tropics. Therefore this study is likely to reveal a

large number of lichen species resulting from the wide range of micro-habitas under investigation. Data from this study will contribute important information of lichen diversity and occurence in the tropics.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Study area

The study was carried out in two forest areas within Mt. Kenya indigenous forest, Chogoria on the Southeastern side and Sirimon to the Northwestern side of the mountain (Fig. 3.1). Mount Kenya is the second highest mountain in Africa, located in the central part of Kenya, approximately 00° 10'S and 37° 20'E (Fig. 3.1), about 180 km northeast of Kenya's capital city, Nairobi. The mountain is of volcanic origin and has two main peaks, Batian (5199 m) and Nelion (5188 m) which are remnants of the hard volcanic plug (Bussman, 1994). It experiences two distinct rainy seasons; the long rains between March and June and the short rains between October and November. The mountain experiences two dry seasons from December to February and July to September. The amount of annual average rainfall ranges between 900 mm in the north to 2300 mm in the southeastern slopes (Bussman, 1994). The lower slopes of the mountain are covered by dense montane forest reaching up to about 3400 m in the south and 3000m in the north with a sharp boundary separating the forest from the lower alpine zone (Bussman, 1994). The climate of Mount Kenya is characterized by large daily temperature fluctuations with a small variation in the mean monthly temperatures that is largely influenced by altitude. Temparature decreases at a rate of 0.56˚C per every 100 m, with frost expected above an altitude of 2500 m. During the two wet season's low clouds and mist are very common all around the mountain, while in the dry season in July and August, mist and clouds are common on the southeastern slope only (Bussman, 1994).

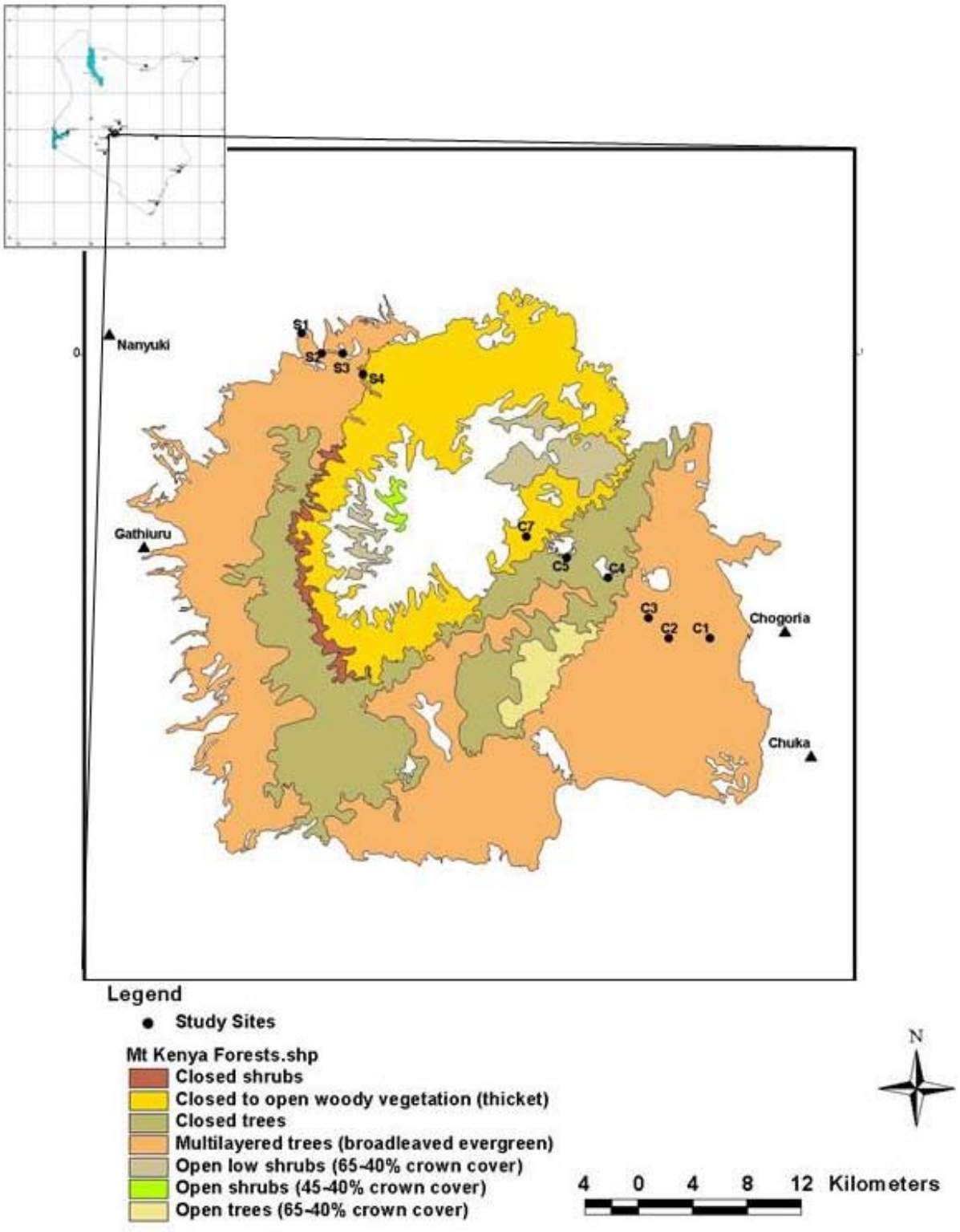

Figure 3.1: Map of Mt. Kenya forest showing the location of the study sites

A total of 10 sites were sampled, six in Chogoria (C1 - C5 and C7) between altitudes 1827m and 3043m above sea level and four sites in the Sirimon (S1 - S4) between altitudes 2464m and 3060m above sea level (Table 3.1 and Fig. 3.1).

Table 3.1 Study sites details; altitude location and vegetation type

Study Site	Altitude	Route	Location	Habitat
C1	1827m	Chogoria	00˚ 14´ S, 37˚ 34´ E	Mixed montane forest dominated by *Podocarpus falcatus* Mirb., *Neoboutonia macrocalyx* Pax, *Strombosia scheffleri* Engl., *Harungana madagascariensis* Poir.
C2	2018m	Chogoria	00˚ 14 S, 37˚ 32' E	Mixed forest dominated by *Strombosia scheffleri* Engl., *Lasianthus kilimandscharicus* K.Schum., *Tabernaemontana stapfiana* Britten, *Syzygium guineense* (Willd.) DC., *Podocarpus latifolius* (Thunb.) Mirb., *Neoboutonia macrocalyx* Pax and *Ocotea usambarensis* Engl.
C3	2232m	Chogoria	00˚ 13 S, 37˚ 31' E	Mixed forest dominated by *Macaranga* spp., *Neoboutonia macrocalyx* Pax, *Xymalos monospora* (Harv.) Warb., *Psychotria* spp. and *Podocarpus latifolius* (Thunb.) Mirb.
C4	2475m	Chogoria	00˚ 11' S,	Mixed forest, closed canopy dominated by *Podocarpus latifolius* (Thunb.) Mirb.,, *Afrocrania*

			37˚ 29' E	*volkensii* (Harms) Hutch.*, Lepidotrichilia volkensii* (Gürke) Leroy, *Cassipourea malosana* (Bak.) Alston and *Psychotria* spp.
C5	2687m	Chogoria	00˚ 10' S, 37˚ 27' E	Bamboo dominated forest with scattered *Podocarpus* trees mainly along the edges of the forest.
C7	3043m	Chogoria	00˚ 09' S, 37˚ 25' E	Patches of open forest dominated by *Hagenia abyssinica* (Bruce) J.F. Gmel., *Hypericum revolutum* Vahl. and *Juniperus procera* Endl.
S1	2465m	Sirimon	00˚ 01' N, 37˚ 14' E	Disturbed dry upland forest with *Juniperus procera* Endl., *Dodonaea angustifolia* L.f., *Faurea saligna* Harv., *Rhus natalensis* Krauss and *Rhamnus prunioides* L'Hérit.
S2	2660m	Sirimon	00˚ 00' S, 37˚ 15' E	Mixed forest with *Juniperus procera* Endl.*, Podocarpus spp. Agarista salicifolia* (Lam.) G. Don and *Faurea saligna* Harv.
S3	2870m	Sirimon	00˚ 00' S 37˚ 16' E	Montane forest with *Podocarpus latifolius* (Thunb.) Mirb., *Juniperus procera* Endl., *Olea europaea* L. , *Hypericum revolutum* Vahl. and *Arundinaria alpina* K.Schum.

S4	3080m	Sirimon	00˚ 01' S, 37˚ 17' E	Open patches of grasslands intermixed with open forest with *Juniperus procera* Endl., *Podocarpus latifolius* (Thunb.) Mirb., *Hagenia abyssinica* (Bruce) J.F. Gmel. and *Arundinaria alpina* K.Schum.

3.2 Sampling and data collection

Studies were carried out on sampling plots placed on linear transects along altitudinal gradient in both Chogoria and Sirimon forests. Sampling plots were placed at intervals of 200m elevation along each transect starting from the lower forest zones towards the upper forest limit in the afro-alpine zone (Fig. 3.1 and Table 3.1).

Stratified random sampling and non-quantitative opportunistic methods were applied for data collection. For each study site large rectangular plots measuring 10 × 200 m were established, every 200m elevation these were further subdivided into 10 × 20 m subplots from which two trees were randomly selected for sampling. To ensure mature trees of comparable age were sampled, undamaged free-standing trees with a girth equal or greater than 70 cm were selected (Asta *et al.,* 2002). The location of each study site was geo-referenced using a Global Position System (GPS) receiver and the altitude also recorded. The vegetation type for each site was subsequently described using the dominant tree species and each host tree sampled was identified at least to genus level and to the species level where possible (Table 3.1).

Four metal ladders measuring 10× 50cm and each having five 10×10cm contiguous quadrants were used to sample lichens on the tree trunks (Fig. 3.2) as outlined by Asta *et al.*

(2002) and Scheidegger *et al*., (2002). Each ladder was placed on the tree trunk, in each of the four compass directions (determined using a magnetic compass). The metal ladders were secured on tree trunks using small nails such that the upper edge of each ladder was 1.5m above the highest point on the ground (Fig. 3.2). All the lichen species and their frequencies within each of the five quadrants of the ladder were recorded. In order to capture as much species diversity as possible within each study site, opportunistic collecting was carried out from trees that were not sampled. Only one site was studied in the bamboo zone in Chogoria forest since no trees with the required DBH (DBH > 70cm) were observed, consequently lichen specimens were collected from the standing bamboo trees in each of the 10 × 20m subplots.

Herbarium voucher specimens were obtained for all lichens encountered in each ladder and preserved using standard herbarium voucher specimen collecting and preservation techniques for lichens (British Columbia, 1996).

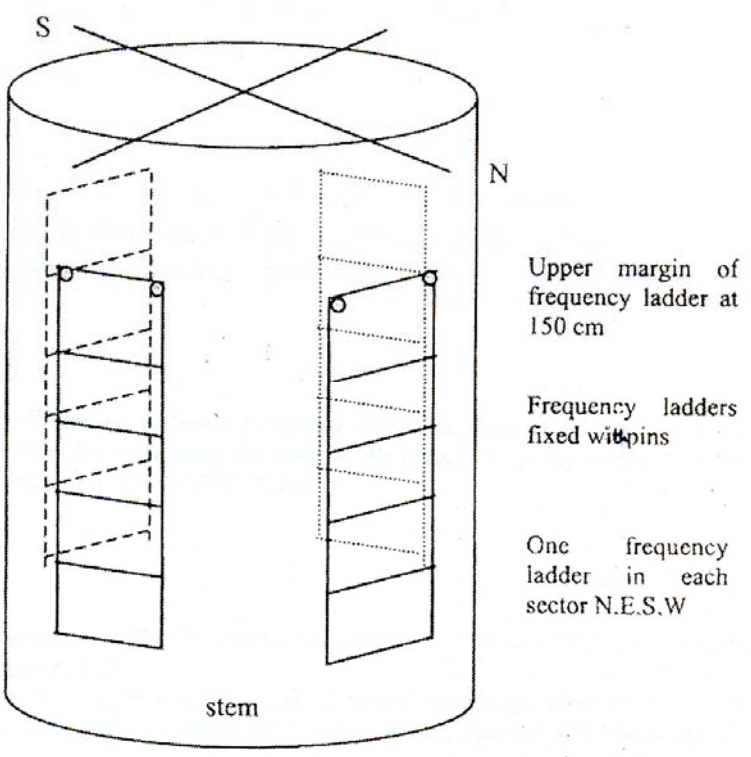

Figure 3.2: Micro-plots sampling on bark of a tree trunk. Adopted from Scheidegger *et al*., (2002)

3.3 Lichen Identification

Specimen identification was initially carried out at the East African Herbarium and further evaluations undertaken with the help of lichen experts at the Field Museum of Natural History at Chicago, USA. Identification was initially done through observation of morphological features of lichen thalli and apothecia using binocular and compound microscopes. Thin free hand sections of the thalli and squash preparations of the ascomata were made to observe the micro-morphological characteristics under a compound microscope. Macrolichen identification was done using keys in Swinscow and Krog (1988).

Lichens contain over 700 secondary metabolites belonging to diverse classes of chemical compounds (Purvis, 2000). These substances have great significance in the taxonomy of lichens since many are species-specific (Lumbsch, 1998). Spot tests involve the use of reagents that are

able to detect various lichen substances by producing characteristic colour change without necessarily identifying the lichen substance but serves as an indicator of certain group of substances (Swinscow and Krog, 1998). These reagents included iodine solution (turns blue with certain polysaccharides), potassium hydroxide (distinctive colors with some depsides and depsidones), and calcium hypochlorite solution (pink or red with some depsides) (Orange *et al*., 2010; Brodo *et al*., 2001). Spot tests were carried out under a binocular microscope, by first scraping the cortex of the lichen specimen with a scapel to expose the medulla and then applying the reagent using a drop bottle then observing the colour reaction. Some lichen substances produce fluorescence under ultra-violet (UV) light as a result of the presence of pigments in the cortex, such as xanthones, which fluoresce shades of yellow, orange and red and depsidones which fluoresce blue or white (Orange *et al*., 2010). The presence and absence of chemical substances was determined by using both the chemical reagents and by exposure of specimens to ultraviolet light as outlined in Orange *et al*., 2010. On the other hand standardized Thin Layer Chromatography (TLC) tests were carried out on lichen samples that could not be positively identified using the morphology and simple spot test procedures described above. Lichen substances for TLC were extracted using acetone and the extracts spotted on glass plates coated with silica gel, then eluted in an organic solvent of toluene and acetic acid (170: 30); this solvent is considered stable and more reliable (Orange *et al*., 2010). Plates were then air dried and the location of colourless lichen substances observed under the shortwavelength UV light. For the colourless substances to develop characteristic spot colour, plates were sprayed with 10% Sulphuric acid and heated in an oven for 10-15 minutes at 100˚C. Interpretation of the TLC profiles of developed plates was done by comparing R_f values, colour and fluorescence characteristics of the spots with published TLC data (Orange *et al*., 2010).

3.4 Data analysis

The sampling effort (percentage of completeness) was computed as a percentage of the number of species observed in each forest and for every study site to the average number of species expected as given by the eight species richness estimators.

The study of communities requires an understanding of the number of species present and their abundance distribution (Chazdon *et al*., 1998). Species richness or the number of species of a given taxon in a sample unit is commonly used by ecologists as a measure of diversity because of its simplicity, is easy to calculate and is readily appreciated (McCune and Grace, 2002; Magurran, 2004). The species richness for the sampled sites was estimated using eight nonparametric species estimators namely; Incidence Coverage Estimator (ICE), Abundance Based Coverage Estimator (ACE), Chao 1 and 2, first and second order Jacknife (Jack 1 & 2), Bootstrap estimator and Michaelis-Menten Means (MMMean). Since most of the estimators use rare species recorded to describe the overall species richness (Chao *et al*., 2000), their success depends on sample size, abundance and distribution pattern of the organisms under consideration (Chao *et al*., 2006).

EstimateS® version 8.0 Software was used to compute the estimates of the expected species richness for the two forests and for all the ten study sites (Colwell, 2006).

Rarefaction curves are used to assess species richness between samples of different sizes by scaling down the collections to the same sample size and therefore permitting meaningful standardization and comparison of datasets (Gotelli and Colwell, 2001). To compare species richness of the different forests and the various study sites, rarefaction curves were used for this study. Rarefaction curves record the total number of species revealed during data collection as additional samples are added to the pool of all previously observed samples (Gotelli and Colwell,

2001). Sample–based rarefaction curves were generated using Coleman's 'random placement' method (Coleman *et al*., 1982). The curve has the advantage of being closely related to a species accumulation curve.

To quantify diversity, Shannon index of species richness and Pielou's index of species evenness which are commonly used measures of diversity were computed. The Shannon index uses the formula: (***H***):= - $\sum^{s}_{i=1}$ ($\rho_{i)}$ ($\log_i \rho_i$), pi=n_i /N, ***H'*** = index of species diversity, where ρ_i= proportion of total sample belonging to the i^{th} species; N= total number of species; ni = individual number of species i. The value of the index falls between 1.5 and 5.0 with the higher values indicating higher diversity and the lower value indicating lower diversity.

The formula used to calculate Pielou's evenness is as follows: $J' = H'/\text{Log}_e S$

Where *J'* = Pielou's evenness, S= Total species

Beta diversity is the difference in species composition (species turnover) between two or more spatial areas or sites, which is used as a measure of heterogeneity (Magurran, 2004). Beta diversity was calculated using Whittaker's index of diversity (Whittaker 1960); $\beta_w = S/\alpha$ where; β_w = Whittaker's index of diversity, S = total number of species in a forest and α = mean sample species number.

To determine whether the three ecological factors (altitude, tree host and the forest type) examined significantly influenced lichen species composition and distribution, analysis of variance (ANOVA) using the nested Generalised Linear Model (GLM) in STATISTICA software was used. In addition, the similarity in species composition of the study sites was further analysed using the Bray Curtis coefficient of similarity in PRIMER software version 5 (Clark and Gorley, 2001).

To determine the effect of altitude and the species distribution patterns within the study sites non-metric multi-dimensional scaling (NMS) was performed in PCORD version 6.0 (McCune and Mefford, 2011). NMS was performed with quantitative Sörensen distances and random starting configuration, the final stress for the best 50 runs with real data were evaluated using 50 runs of randomized data. To assess whether NMS was extracting stronger axes than expected by chance, a Monte Carlo test was performed.

Further multivariate tests for differences in lichen community composition and richness between the two forest types and among the ten study sites non-parametric Multi-response Permutation Procedure (MRPP) was performed in PCORD version 6.0. MRPP is a procedure for testing the hypothesis of no difference between two or more groups of entities (McCune and Grace, 2002). The MRPP method uses a chance corrected within-group agreement (*A*-statistic) to describe the strength of the differences among groups. When all items in a group are the same *A* statistic is equal to one and the more distinct the groups are the higher the *A* statistic. A p-value estimates the likelyhood that an observed difference between groups is due to chance alone based on randomized data (Debolt *et al*., 2007).

To assess whether lichen species had preference for certain tree host species, the Indicator Species Analysis (ISA) was carried out, which calculates an indicator value for each species based on their relative abundance and relative frequency on each group or the host tree. A perfect indicator of a group should be faithful to that group (always present) and should be exclusive to the other groups. To test whether the maximum indicator (IV) values calculated was larger than expected by chance, a Monte Carlo test of significance for the IV for each species, based on 1000 randomizations was performed.

CHAPTER FOUR

4. RESULTS

4.1 Species richness and assemblages in Mount Kenya forest

A total of 1007 lichen specimens were collected during the study, consisting of 245 distinct taxa (Appendix 1) representing 73 genera and 38 families from the two forest areas (Table 4.1). Of these, 197 taxa were identified to species level, 40 to genus level and 8 distinct taxa that could not be positively identified and were denoted as crust 1 – 8 (Appendix 1). Two hundred and three (203) taxa were collected from 113 sampled host trees while 42 were non quantitative opportunistic collections from within and outside the sampled plots. Chogoria forest recorded the highest number of taxa (187) of which 150 were identified to species level, 30 to genus level (Table 4.1), while seven (7) taxa could not be identified and were denoted unknown crust 1-7. Sirimon recorded a total of 113 taxa, 91 were identified to species level, 21 to the genus level (Table 4.1) and one unknown was denoted crust 8. Thirty one (31) taxa were collected opportunistically within the study sites while 11 species were collected form the areas adjacent to the sampled plots. Thirty three (33) species in 29 genera and 16 families occurred in both forests.

Sixteen (16) species were new records for the African continent while a total of 73 species belonging to 30 genera and 22 families were first records (Appendix 1) for Kenya. Seven (7) species were confirmed to be new to science and are in the process of being described, named and published. Six of the new species were recorded from Chogoria forest; *Graphis* sp. nov., *Hemithecium* sp. nov., *Heterodermia* sp. nov., *Porina* sp. nov., *Strigula* sp. nov., *Thelotrema* sp. nov., while only one species, *Lecanora* sp. nov., was recorded as new from Sirimon forest.

Twenty two (22) families were represented by less than two species (Table 4.1). Parmeliaceae was the most dominant family in terms of the number of species (46) and genera (11) followed by Graphidaceae (21), Physciaceae (14) and Pertusariaceae (13). Parmeliaceae were more dorminant in Sirimon with 32 species as compared to 27 species in Chogoria (Table 4.1).

Amongst the study sites C1, C2 and S3 recorded the highest number of species with 55, 58 and 53 species respectively (Table 4.3). While site C5 was the most species poor recording only 15 species followed by S4 with 24 species. In Sirimon sites S1 and S3 were the most species rich (Table 4.3).

Analysis of variance (ANOVA) using the generalised model did not detect significant differences in species richness between Chogoria and Sirimon forests (F 2.4, p=0.120). While ANOVA of combined data for the the study sites showed a highly significant difference of species richness among the ten study sites (F 64.38, p=0.000). However separate within forest analysis showed significant difference in species richness for sites in Chogoria (F 61.7 p=0.000) but not in Sirimon (F 1.09, p=0.777) at $p<0.05$.

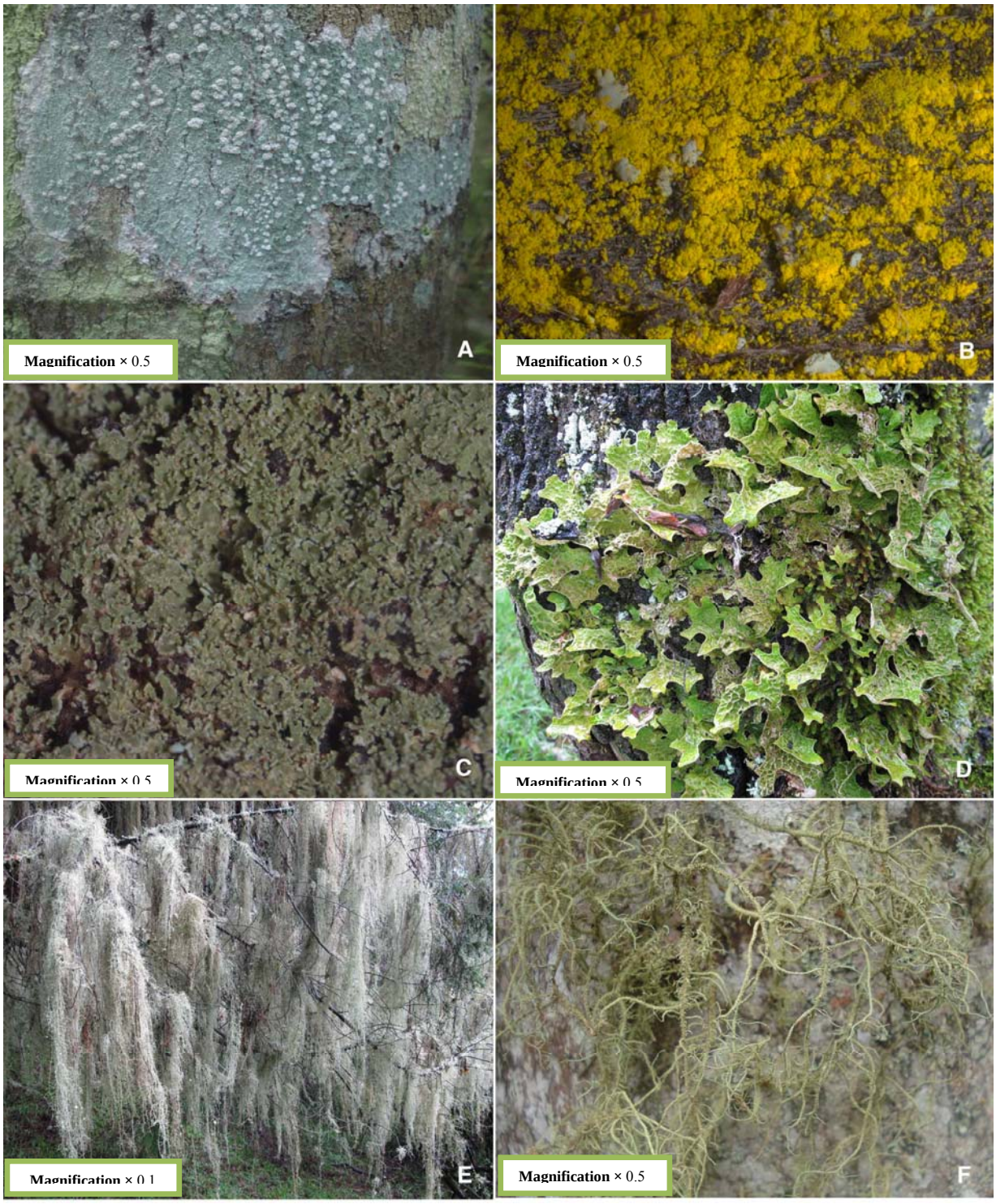

Figure 4.1: Morphological types of lichen thalli

A. *Pertusaria scaberula*- Crustose , **B**. *Chrysothrix xanthina*- Leprose, **C**. *Phyllopsora santensis*- squamulose, **D**. *Lobaria pulmonaria*- Foliose, **E**. *Usnea* spp. & **F**. *Usnea bicolorata*–Fruticose

Table 4.1: Number of species, genera and the new records recorded in each family

			Chogoria		Sirimon	
Family	**Total species collected**	**New records for Kenya**	**No. of genera**	**No. of species**	**No. of genera**	**No. of species**
Agyriaceae	1	1	1	1		
Arthoniaceae	1	1			1	1
Biatorellaceae	1	1	1	1		
Brigantiaeaceae	1		1	1		
Chrysotrichaceae	1				1	1
Cladoniaceae	2	1	1	1	1	1
Coccocarpiaceae	3		1	2	1	1
Coenogoniaceae	8	4	1	6	1	3
Collemataceae	10		1	9	1	8
Graphidaceae	21	20	9	20	1	1
Gyalectaceae	1		1	1		
Haematommataceae	1	1	1	1		
Lecanoraceae	2	1	1	1	1	1
Letrouitiaceae	1	1	1	1	1	1
Lobariaceae	9	1	2	8	3	5
Malmideaceae	2	2	1	2	1	
Megalariaceae			1			
Megalosporaceae	2	2	1	2		
Mycoporaceae	1	1	1	1		
Nephromataceae	1		1	1		
Pannariaceae	2				2	2
Parmeliaceae	46		9	27	9	31
Peltigeraceae	3		1	3	1	1
Pertusariaceae	13	8	1	11	1	7
Phlyctidaceae			1			
Physciaceae	14	4	3	9	6	11
Pilocarpaceae	2		3	2	1	
Porinaceae	9	9	1	9		
Pyrenulaceae	10	10	1	10		
Ramalinaceae	9		3	8	4	4
Roccellaceae	1	1	1	1		
Sphaerophoraceae	1		1	1		
Sphinctrinaceae	1				1	1
Stereocaulaceae	7	6	1	5	1	6
Strigulaceae	1	1	1	1		
Teloschistaceae	4	1			3	4
Tephromelataceae	1	1	1	1		

Thelotremataceae	5	5	2	4	1	1
Verrucariaceae	4	3	2	2	1	1
Totals	**197**	**81**	**56**	**150**	**43**	**91**

4.2 Sampling effort and completeness of lichens survey

Using the combined species data for Chogoria and Sirimon forests the sampling effort was adequate with a completeness of 68% and 67% respectively (Table 4.2). This was despite the wide variations in the performance of the species richness estimators.

Table 4.2: Number of; samples, species observed, and the species estimated, the percentage sampling effort, mean species per sample and diversity indices for each forests.

	Chogoria **(C)**	Sirimon (S)
Samples	259	134
Species observed (a)	156	94
ACE	180	113
ICE	307	187
Chao 1	168	103
Chao 2	264	157
Jack 1	230	141
Jack 2	279	171
Bootstrap	188	114
MMMeans	218	134
Average sampling effort (%)	68	67
Lowest and highest sampling effort (%)	51-93	50-91
Shannon diversity (***H'***)	4.318	3.598
Pielou's evenness (***J'***)	0.8675	0.8712
Mean No. of species per sample (b)	5.47	6.06
Beta diversity (a/b)	28.52	15.51

Five study sites in Chogoria (C1-C4 and C7) showed adequate sampling with each site recording more than 65% coverage except for site C5 (bamboo zone) which recorded 39% coverage (Table 4.3). All the study sites in Sirimon (S1-4) forest recorded an average sampling completeness of more than 50% (Table 4.3).

Table 4.3: Number of: samples, species expected, species observed, samples and new records, altitude, sampling effort, Shannon index, Pileou's index, mean species number and beta diversity observed from each site.

	Chogoria forest						Sirimon forest			
Study site	**C1**	**C2**	**C3**	**C4**	**C5**	**C7**	**S1**	**S2**	**S3**	**S4**
Altitude (m)	1827	2018	2232	2475	2687	3043	2465	2660	2870	3080
No. of Samples	49	72	72	24	10	29	30	34	53	17
No. of Individuals	364	352	300	114	20	245	148	188	352	124
Observed species	55	58	47	37	15	34	39	34	53	24
ACE	59	63	51	39	93	37	62	38	61	28
ICE	112	121	82	90	97	56	113	54	193	51
Chao 1	56	59	48	35	48	35	52	35	56	25
Chao 2	91	99	67	68	45	45	87	44	150	38
Jack 1	83	88	72	52	26	48	65	47	87	37
Jack 2	102	108	83	68	34	55	85	54	116	45
Bootstrap	67	70	58	40	20	40	50	41	67	30
MMMeans	99	100	80	86	52	52	101	60	92	56
Sampling effort (%)	65.8	65.5	69.5	61.9	39.3	73.9	50.7	72.9	51.6	62.1
Degree of lichen collection	49-98%	48-98%	57-98%	41-95%	16-75%	61-97%	35-78%	57-97%	27-93%	43-86%
Shannon index (***H'***)	3.672	3.649	3.141	3.404	2.597	2.958	3.375	3.192	3.455	2.917
Pielou's evenness (***J'***)	0.916	0.902	0.816	0.943	0.959	0.839	0.921	0.905	0.870	0.918

Mean species number per sample(b)	7.43	4.88	4.17	4.75	2.00	8.45	4.93	5.53	6.64	7.29
Beta diversity (a/b)	7.4	11.7	11.3	7.8	8.5	4.0	7.9	6.1	7.9	3.3
New Records of species for Kenya	33	26	19	27	4	7	7	10	12	6

Except for C5, all the other sites had more than 50% of the estimated numbers of species collected and therefore adequately sampled. Collection of more than 50% of the total number of species known to occur in a given area is usually considered satisfactory (Heck *et al.,* 1975).

4.3 Estimation of species richness

The performance of the various species estimators varied widely, Chao 1 gave the lowest estimates of species richness in both forests (Chogoria=168, Sirimon=103). Moderate estimates of richess for Chogoria forest were given by the Abundance Coverage Estimator (ACE) (180), Bootstrap (188), MMMeans (218) and Jacknnife 2 (230) while the highest estimates were given by the Incidence Coverage Estimator (ICE) (307), Jacknife 2 (279) and Chao 2 (264) (Table 4.2). Similar trend in the perfomance of the various estimators was also observed for Sirimon (Table 3). The performance of the estimators again showed huge variation in estimates of species richness for the study sites. The highest variation between the estimated and observed species richness was observed in S3 (137 species) and C5 (77) while the lowest variation was observed in S2 (25) (Table 4.3).

4.4 Rarefaction curves

Rarefaction curves are closely related to species accumulation curves and are used in the comparisons of species richness between different sites or sample units. The rarefaction curves

generated for the two forests indicated higher species richness for Chogoria compared to Sirimon forest (Fig. 4.2). Although the rarefaction curves have not completely reached an asymptote they have leveled off.

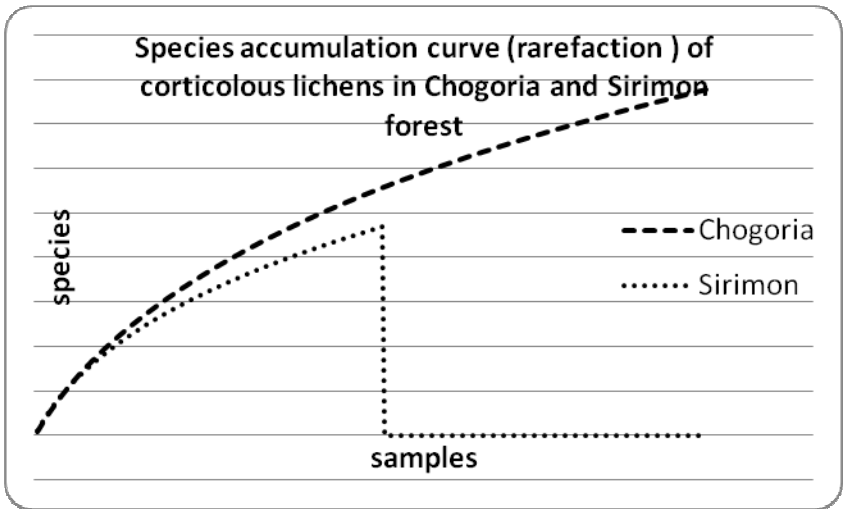

Figure 4.2: Sample based rarefaction curves of the corticolous lichens for Chogoria and Sirimon forests.

Species rarefaction curves were also computed for the six study sites in Chogoria (Fig. 4.3) and four sites in Sirimon (Fig. 4.4). The species curves for each study site did not reach an asymptote and continue to rise as more samples are accumulated a trend indicative of increased species numbers with continued sampling (Fig. 4.3 & 4.4).The curves for sites C1 and C2 rises above the curves for the other sites suggesting a higher species diversity of corticolous lichens as compared to the other sites in Chogoria while while C5 has the least species diversity (Fig. 4.3).

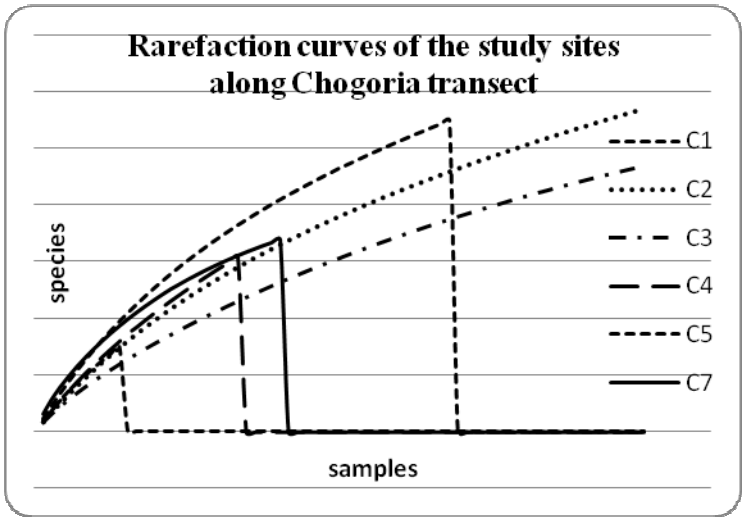

Figure 1.3: Sample based rarefaction curves for the six study sites in Chogoria forest

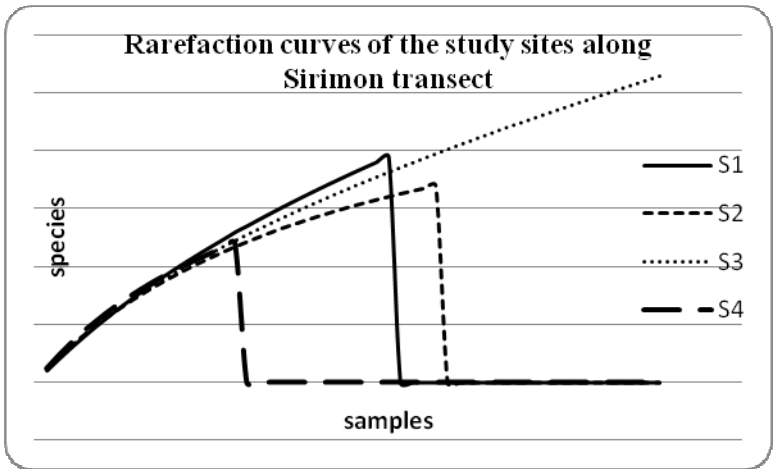

Figure 4.4: Samples based rarefaction curves for the four study sites in Sirimon forest.

4.5 Comparison of lichen assemblages between Chogoria and Sirimon forests

Generally Chogoria forest had higher species richness and diversity than Sirimon, with an average of 41 species per site as compared to 37.5 species in Sirimon. The Shannon index of species diversity was 4.3 and 3.6 for Chogoria and Sirimon forests, respectively (Table 4.2). Sirimon forest shows a slightly higher species evenness as indicated by Pielou's index of evenness (Table 4.2). Eighteen families (18) of lichenized fungi were unique to Chogoria forest. Lichen assemblages between the two forests showed a significant difference in species

composition, with analysis performed using MRPP (A = 0.025, p< 0.0001), with a p-value smaller than expected by chance. Pairwise comparison of study sites showed significant difference (at p<0.05) in lichen assemblages in majority of the study sites except for C1 vs. C2 (p=0.348) and S2 Vs S3 (p=0.167) (Appendix 2). Further comparisons of lichen assemblages among study sites done using Bray-curtis similarity coefficient indicated huge dissimilarities (70%) in lichen assemblages for the sites (Table 4.4).

Table 4.4: Percentage similarity matrix for the ten study sites computed using Bray-Curtis similarity coefficient.

	C1	**C2**	**C3**	**C4**	**C5**	**C7**	**S1**	**S2**	**S3**
C2	40								
C3	44	44							
C4	18	21	22						
C5	4	14	7	14					
C7	4	10	6	9	12				
S1	6	8	6	20	9	28			
S2	8	16	10	28	16	36	40		
S3	9	18	12	23	8	23	28	43	
S4	9	15	9	17	10	16	25	26	34

4.6 Effect of altitude on corticolous lichens in Chogoriaand Sirimon forests

Lichen species richness and distribution along the altitudinal gradient in Chogoria and Sirimon forest responded in slightly different ways. Higher species richness was observed at lower elevation in Chogoria forest 1827m to 2018m (Table 4.3 and Fig. 4.5). This decreased with further increase in altitude, reaching the lowest species richness in the bamboo zone at 2687m then increasing again towards the upper forest limit 3080m (Table 4.3). There was a

general decrease in the number of recorded genera and families with increase in altitude for plots in Chogoria forest (Fig. 4.5). The species diversity given by the Shannon index also demonstrated a decline in species richness with increase in altitude (Table 4.3).

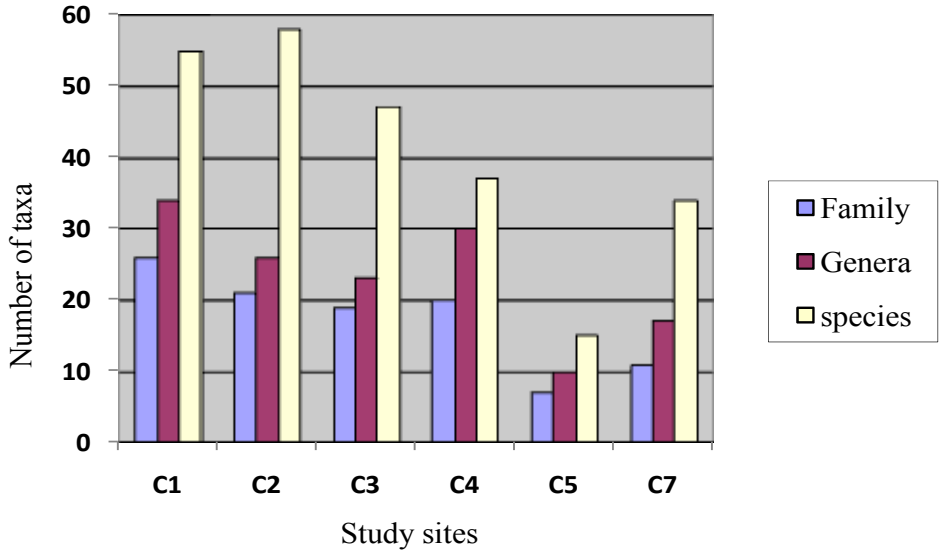

Figure 4.5: Distribution of families, genera and species of corticolous lichens in the six study sites in Chogoria

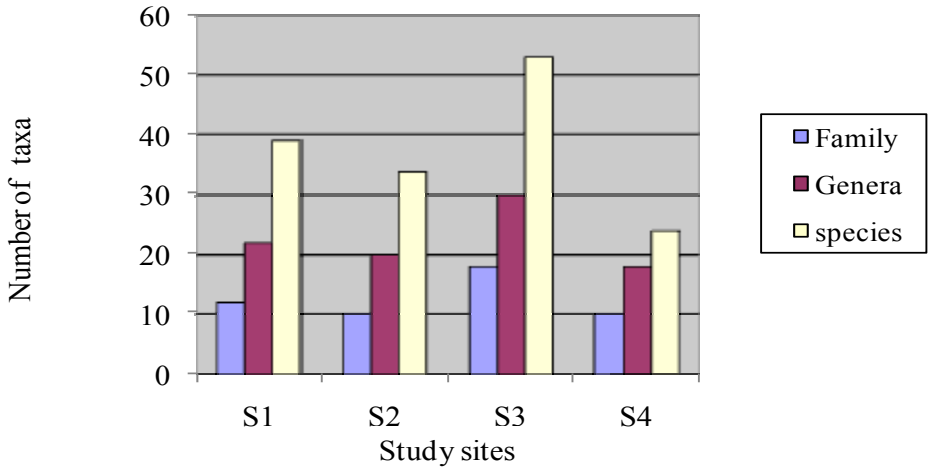

Figure 4.6: Distribution of families, genera and species of corticolous lichens in the four study sites in Sirimon

Sirimon forest showed a mixed response of species richness to increase in altitude. There was sharp increase in species richness from the lower elevations S1and S2 (2465m – 2670m) 30 and 34 species respectively to mid elevation S3 2870m (53 species). This was followed by a decrease towards the upper forest limit S4 at 3080m (Table 4.3 and Fig. 4.6). The number of genera and families recorded in the three sites in Sirimon forests S1, S2 and S4 remained relatively constant with increase altitude (Fig. 4.6). The Shannon index of diversity demonstrated a pattern where lower elevation (S1 and S2) had relatively constant values while S3 at 2870m had the highest diversity (*H'*=3.455). The upper forest limits S4 at 3080m (*H*'=2.917) had the lowest diversity values (Table 4.3). The species evenness was lowest (*J'*=0.8701) at S3 (2070m) and was highest at S1 (2465m) and S4 (3080m) corresponding to *J'*=0.9212 and *J'*=0.9180), respectively (Table 4.3). The rate of species tunover is high for various study sites with the highest turnover observed in Chogoria, C2 and C3 (β= 11.7; β =11.3) and the lowest turnover is observed in C7 (β=4) and S4 (β=3.3) (Table 4.3).

Generally the number of new records of lichens decreased with increase in altitude, their distribution followed the observed trend for species richness with the most species rich sites recording higher numbers of new records.

The effect of altitude on lichen distribution for the two forests was assesed using generalized model in ANOVA. The results indicated that altitude significantly influenced (F-64, p = 0.000) species distribution in Chogoria (F 61.72, p=0.000) but not in Sirimon (F 1.09, p= 0.777) at $p<0.05$.

4.7 Ordination

Non-metric Multidimensional scaling (NMS) stabilized on 2-dimension solution that explains 65.7% of the variation in lichen community composition. The ordination had a final stress of 7.018 and a final instability of 0.00001. The structure observed was stronger than expected by chance (p=0.0040). The effect of altitude on lichen community composition was explained by Axis 1 with 32.6%. A strong negative correlation of lichen community composition with elevation was revealed by the Pearson correlation coefficient (r= -0.843) on Axis 1 of the ordination.

The sites formed groupings on the ordination plot depending on their species composition. Four groupings were formed, C1, C2 and C3 grouped together forming a single group, and C4 separated alone forming another group. Sites S1 and S2 from Sirimon grouped with C7 from Chogoria in the ordination plot, while S3 and S4 formed a separate group. Site C5 was an outlier that separated from the other sites (Fig. 4.7) an indication that the site had different lichen assemblages. The study sites close to each other on the ordination plot have more similar species composition than sites that are far apart.

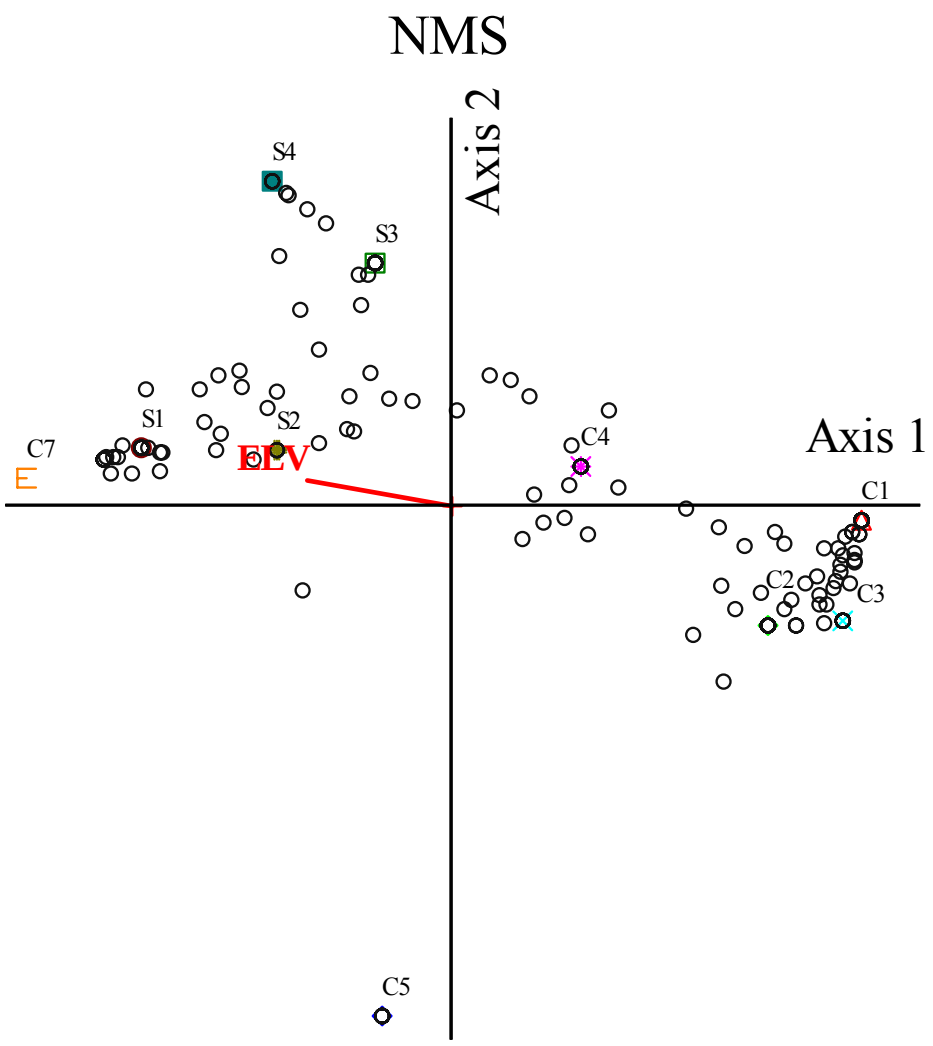

Figure 4.7: Ordination (NMS) of study sites in species space with join overlay of elevation (ELV) indicated as a vector in the ordination

4.8 Effect of tree host on lichen assemblages

A total of 72 individual trees were sampled from Chogoria and 41 from Sirimon. The average number of lichen species collected on each tree ranged between 2 to 13 species with an average of 5.9 species per tree. High lichen species richness within the study sites coincided with sites having a high diversity of host tree species. In Chogoria the lower forest zone which comprised mixed forest, had a higher diversity of host trees and consequently recorded higher

lichen diversity. Only two species of host trees (*Podocarpus latifolius* and *Juniperus procera*) occurred in both forests with *Podocarpus latifolius* being more abundant in Sirimon forest. A total of 38 *Podocarpus* spp. trees were sampled in both forests, Chogoria (13) and Sirimon (25). In total, *Podocarpus* spp. recorded the highest number of corticolous lichen species followed by *Macaranga kilimandscharica* Pax and *Juniperus procera.* The highest number of corticolous lichens (13) from a single tree was recorded from *Hypericum revolutum* in C7, followed by *Syzygium guineense* and *Macaranga kilimandscharica* in C1, which supported eleven species each. In Sirimon forest (S1and S2) *Juniperus procera* supported the highest number of lichens with eleven (11) species.

The ANOVA test was performed using generalised linear model to determine if tree host had influence on lichen assembalages**.** In Chogoria the host tree showed a significant influence on lichen assemblages ($F=38.485$, $p=0.051$) while in Sirimon the host tree did not significantly influence the lichen assemblages ($F=2.75$, $p=0.738$) at $p<0.05$.

The Indicator Species Analysis (ISA) was used to determine lichen preference towards the tree host. Only twelve (12) species of lichens showed significant level of specificity to tree host (at $p<0.05$). Five lichen species showed significant level of specificity towards *Juniperus procera*, three towards *Hypericum revolutum,* two towards *Strombosia scheffleri* and one each towards *Neoboutonia macrocalyx* and *Macaranga kilimanscharica* (Table 4.5).

Table 4.5: Lichen species that showed significant level of specificity towards tree hosts (at p<0.05) in the indicator species analysis (ISA).

Lichen species	Tree host	Observed indicator value (IV)	P*(significant level)
Heterodermia japonica (M. Satô) Swinscow & Krog	*Hypericum revolutum*	64.7	0.0042
Leptogium cochleatum (Dicks.) P.M. Jørg. & P. James	*Hypericum revolutum*	41.2	0.0060
Lobaria pulmonaria (L.) Hoffm.	*Hypericum revolutum*	63.0	0.0038
Heterodermia allardii (Kurok.) Trass	*Juniperus procera*	50.0	0.0274
Leptogium burnetiae C.W. Dodge	*Juniperus procera*	50.0	0.0274
Pertusaria endoxantha Vain.	*Juniperus procera*	50.0	0.0334
Pertusaria krogiae A.W. Archer, Elix, Eb. Fischer, Killmann & Sérus.	*Juniperus procera*	100.0	0.0008
Usnea exasperata (Müll. Arg.) Motyka	*Juniperus procera*	41.1	0.0330
Graphis illinata Eschw.	*Macaranga kilimanscharica*	37.5	0.0386
Brigantiaea leucoxantha (Spreng.) R. Sant. & Hafellner	*Neoboutonia macrocalyx*	57.1	0.0026
Porina sp.	*Strombosia scheffleri*	66.6	0.0002
Porina sp. nov.	*Strombosia scheffleri*	44.4	0.0156

The total number of species collected on each of the four compass directions of the tree trunk was similar (North 100, East 100, West 99 and South 101) differing only slightly. The Shannon index of diversity was 4.2 for all the four aspects of the tree trunk. However, the analysis (ANOVA) to determine if aspect significantly influenced lichen assemblages using the nested Generalised Linear Model (GLM) results indicated significantly difference (F,40.08, p=0.02) in Chogoria forest whereas it did not significantly affect assemblages in Sirimon (F 15.75, p=0.15) at p<0.05.

CHAPTER FIVE

5. DISCUSSION, CONCLUSIONS AND RECOMENDATIONS

5.1 Sampling effort and the species estimators

Total enumeration of all the species occurring in a community is not possible in most cases; hence estimation of species richness is achieved by extrapolating from samples. Consequently, it is essential to first assess the completeness of sampling (sampling effort) in order to make conclusions regarding the community under investigation using data collected from samples. The percentage of sampling effort calculated using the average richness estimates given by the estimators showed adequate sampling (67%) in both forests (Table 4.2). All study sites were adequately sampled with a completeness of more than 65% for sites in Chogoria and 50% in Sirimon, except for the bamboo zone (C5) in Chogoria where the sampling effort was estimated at 39% (Table 4.3). Heck *et al*. (1975) asserts that when 50-75% of the total species occurring in an area have been collected the sampling effort is considered adequate.

The non-parametric species estimators used gave varied estimates of species richness for the two forests. Chao 1, ACE and Bootstrap gave the lowest estimates while Jack 2 and ICE gave the highest. Moderate estimates were given by MMMeans, Jack 1 and Chao 2 in both forests (Table 4.2). Estimates of species richness for the study sites also varied with the estimator in question. ACE and Chao 1 gave estimates that were almost equivalent to the observed species numbers, suggesting a near complete sampling effort (90-98%) for majority of the sites (Table 4.3). These estimators were therefore considered not good for this dataset since it was unlikely that all the species expected in the sites were collected. ICE, Chao 2, Jack 2 and Michaelis-Menten Means (MMMeans) estimators gave the highest estimates therefore denoting a relatively

lower sampling effort of between 16-61% (Table 4.3). These estimators seem to over estimate the species richness, similary they are considered not good estimators of true richness for this dataset. First Order Jacknife (Jack 1) and Bootstrap gave moderate estimates and could be considered as good estimators of the true richness for this dataset. However, it should be noted that the species estimators have not been used much in lichenological literature and their true performance is not well known. To evaluate their true performance complete and well known lichenology data sets should therefore be used.

5.2 Species richness

This study has greatly enhanced our knowledge of the lichen mycobiota for Kenya with a total 1007 voucher specimens representing 245 species collected (Appendix 1). To the best of my knowledge, this is the first study on altitudinal distribution of lichens in tropical Africa with comparable studies having been carried out in the Neotropics and Asia. The species richness reported for this study may not be directly compared with the results from other tropical regions because of the differences in the sampling methods. In this study, only part of the host tree trunk was sampled while in other studies whole tree trunks including the tree canopies were sampled. However, the number of species observed for the study is considered high compared with the total site values obtained from other studies carried out in the tropics. The total number of lichens recorded for the study area is among the highest reported in the tropics. It compares with the 270 species reported by Boonpragop and Polyiam (2007) from two host species in Khao Yai National Park in Thailand, 250 and 173 species observed by Komposch and Hafellner in 2000 and 2003 respectively from Venezuelan tropical lowland rainforest, 209 species by Moontfoort and Ek (1990) recorded from 28 trees, 168 species reported by Holtz and Gradstein (2005) from 15 trees in Costa Rica, 150 species of microlichens reported by Caceres *et al.* (2007) from 47

host trees in Atlantic forest in Brazil and 178 species observed by Wolf (1993a) from altitudinal gradient in Northern Andes. The finding of this study reveal rich lichen diversity in tropical montane forests and thus supports the assertion by Lücking (1999) that tropical regions support high lichen diversity equaling or even surpassing that of the well known temperate regions.

Through this study the number of lichenized fungi known for Kenya has increased by 73 species, a 10% increase from 712 (Kirika and Lumbsch, 2011 unpublished) currently known for the country. The number of genera known from Kenya increased from 150 to 164, a 9% increase while the number of families was raised to 57 from 50, a 14% increase. Seven species new to science were also discovered and are in the process of being described and named. The number of new taxa is likely to be higher but the accurate number will be known when all the specimens are fully identified to the species level. The results are indicative of a rich but less known lichen mycobiota thus calling for intensified inventories to cover more regions of the country. A similar trend was recorded in a recent study of the foliicolous lichens for Kakamega by Yeshitela (2008) who reported 77 new records of foliicolous and lichenicolous fungi for Kenya and discovered 5 species new to science while in an earlier study of macrolichens in the alpine and subalpine zone of Mt. Kenya, Frisch and Hertel (1998) made 9 new records for Kenya and 7 to East Africa. Their study recorded a total of 155 species which were classified into 47 genera.

Majority of the new records (76%) for Kenya in this study were crustose microlichens in Graphidaceae, Coenogoniaceae and Pyrenulaceae, besides five out of six of the six new species confirmed so far are microlichens, a clear indication that the group is poorly known. More new records of crustose taxa are therefore expected as inventories are intensified to cover more areas.

A high proportion of rare species was recorded, 75% of the total species occurred only once or twice in the samples which is comparable to results obtained by Caceres *et al*. (2007) who recorded up to 86% rare species in their dataset. Caceres *et al*. (2007) hypothesized the rarerity as a strategy by the species to have low population densities and a high spatial dispersion to escape competition from the dominant lichens. However this rarity could be the result of many interacting factors that were not investigated in this study, e.g site conditions, pollination, light intensity, life history of the species among other factors. It is therefore difficult to speculate on the possible reasons underlying this observation.

5.3 Lichen distribution and diversity in Chogoria and Sirimon forests

Krog (1987) noted that the local composition of lichens in the tropics is determined by a number of interacting factors the most impotant being humidity and temperature. Lichens are therefore abundant and diverse in areas where humidity is high even though actual precipitation may be occasional. In the high montane forests where temparatures are low and humidity high the diversity of lichens found in these areas tend to be high as well. The disparity in lichen compostion between Chogoria and Sirimon forests could be attributed to the difference in their climatic condition and hence differences in the two most important factors, i.e temperature and humidity. This inturn influences the vegetation distribution patterns and consequently the diversity of lichens. Chogoria forest is wetter with higher diversity of host tree species and a closed canopy at lower and mid elevation. This diversity of host trees decreases with increase in altitude up to the upper forest limit, which comprises scattered trees intermixed with patches of bushed grassland.

Higher species richness and diversity were observed in Chogoria than in Sirimon as exhibited by the species numbers recorded and the higher values of Shannon index (Table 4.2

and 4.3). The species rarefaction curve for the two forests further demonstrated a higher richness for Chogoria than Sirimon (Fig. 4.2). The higher species richness could be attributed to the higher precipitation and consequently high humidity therefore creating good conditions for the growth of lichens. In addition, Chogoria side has a wider forest block, forest starts at a much lower altitude than Sirimon, besides, the gradient rises gradually therefore covering a longer distance, more sites were therefore studied here (Fig. 3.1 and Table 3.1). On the other hand Sirimon forest starts at a much higher altitude than Chogoria with the gradient rising steeply, up to the upper forest limit, fewer sites were therefore studied (Fig. 3.1 and Table 3.1). The rarefaction curves for study sites in Sirimon indicated that species richness among the sites were similar differing only slightly with more sampling (Fig. 4.4).

Comparison of the lichen assemblages between the two forests using Bray-Curtis index revealed a high dissimilarity (70 %) in species composition. This observation is further corrobated by the high values of beta diversity (Chogoria=28.52; Sirimon 15.51), an indication of high heterogeneity between the two forests (Table 4.2). Similary, majortity of the study sites had less than 30% similarity in their lichen assemblages except for a few sites that had between 40 and 44% similarity (Table 4.4). In addition pairwise comparison of species composition between the study sites using MRPP showed significant differences among majority of the sites (Appendix 2).

The study sites in Chogoria forest were highly heterogenous, for example no single species occurred in all the six sites. Four of the sites (C1-C4) had species assemblages comprising mainly microlichens, in the genera *Arthonia*, *Bacidia*, *Graphis*, *Lepraria*, *Malmidea*, *Porina* and *Pyrenula*, while the other two sites (C5 and C7) were dominated by macrolichen species in the genera *Parmotrem*a, *Usnea*, *Heterodermia*, *Punctelia*, *Sticta*, and *Leptogium*

(Appendix 3). The most abundant species in C7 (Fig. 4.8 D) were *Heterodermia japonica*, *H. leucomelos* (L.) Poelt, *Parmotrema reticulatum* (Taylor) M. Choisy, *Leptogium* spp and *Lobaria pulmonaria* which were also abundant in majority of the study sites in Sirimon forest with the exception of *Lobaria pulmonaria* which was present in C7 and S3 only (Appendix 3). The similarity in species assemblages of C7 with sites in Sirimon is the reason why the site grouped together with S1 and S2 in the ordination plot (Fig. 4.7).

Sirimon, which is drier, was largely dominated by macrolichens, mainly of the families Parmeliaceae, Physciaceae, Collemataceae and Lobariaceae, with Pertusariaceae and Coenogoniaceae being the only abundant microlichen families in this forest. In particular, *Flavopunctelia flaventior* (Stirt.) Hale, *Parmotrema reticulatum, Heterodermia japonica*, *Pertusaria krogiae* occurred in all the four study sites in this forest (Appendix 3).

5.4 Effect of altitude on lichen assemblages

Multivariate analysis of the species richness, diversity and lichen assemblages in different forest types revealed significant differences among the sites. Altitude therefore has influence on lichen occurrences and distribution. Higher species richness was recorded on the lower mixed forest in Chogoria, decreasing with increase in altitude. This was followed by an increase in richness towards the upper forest margin (Table 4.5). The lowest species richness was recorded in the bamboo zone (C5), an observation similar to that by Krog (1987) who also termed the zone as "lichenologically of little importance" (Fig. 10C). Though, the site had a number of species unique to the zone, for example *Punctelia semansiana* (W.L. Culb. & C.F. Culb.) Krog, *Sticta kunthii* Hook. f., *Coenogonium subfallaciosum* (Vezda & Farkas) Lücking, Aptroot & Sipman and a new species of *Strigula* were exclusively recorded in this zone (Appendix 3). Difference in species richness among the sites in Chogoria was further demonstrated by the

rarefaction curve for the sites (Fig. 4.3). The curves suggest higher species richness for samples in C1 and C2.

The lichen richness in Chogoria was highly correlated with the diversity of the host tree species, which also followed a similar pattern, of decrease with increase in altitude. The lower elevation 1800-2400m comprises mixed forest with a high diversity of host trees, this declined with altitude, with the lowest diversity recorded at the bamboo zone. Sites in the lower altitude in Chogoria were dorminated by microlichens, which are more tolerant to shade resulting from the closed forest canopies. At the mid and higher altitude, species of *Usnea* that are characteristic of mist forests were more common. Their abundance was evident from the masses of these species hanging from tree branches (Fig. 4.1 E).

Cyanolichens were more abundant at high altitude, above 2500m. Species, mainly in the genera *Leptogium, Peltigera* (Fig. 4.8A and B) and *Sticta,* seemed to have preference for open forest types with the exception of *Leptogium cyanescens* (Pers.) Körb., *Sticta weigelii* Isert and *S. tomentosa* (Sw.) Ach., which were more abundant at lower altitudes and therefore seem to have preference for more closed forest (Appendix 3). The differences in lichen assemblages could be attributed to the differences in the microhabitats created by factors that are determined by altitude, e.g temperature and humidity.

Figure 4.8: A. *Peltigera praetextata* B. *Leptogium burgessii*- Cyanolichen found at high altitude in both Chogoria and Sirimon forests C. Lichen poor bamboo zone D. Abundance in macrolichens at high altitude in Chogoria (C7)

5.5 Host specificity and lichen richness

The indicator species analysis (ISA) showed subtle tree host specificity. Out of the total taxa collected, only twelve species (12) showed a significant level of specificity towards the host tree species (Table 4.5). Particularly, only one species, *Pertusaria krogiae* exclusively occurred on *Juniperus procera* with an indicator value (IV) of 100 (Table 4.5). Similar results of sublte host specificity were found in other studies by Moontfoot and EK (1990), Wolf, (1993a), and Holtz and Gradstein, (2005). However, it should be noted that the bark parameters of the host trees such as bark pH, degree of bark shedding, density and size of bark lenticels, and presence of milk sap (Caceres, *et al.,* 2007), which are known to be important in influencing lichen communities, were not assessed in this study. The average number of lichen species recorded for each individual tree was 5.8. The maximum number recorded from a single tree was 13 while majority of trees had between 4-8 species. This was lower compared to Caseres *et al*. (2007) who recorded between 8-24 species per tree with an average of 8.6 per tree and a maximum of 24 in the study of Atlantic rainforest of northeastern Brazil. The low number of lichen species recorded could be attributed to the sampling procedure employed in this study where only part of the tree trunk was surveyed. Komposch and Hafellner (2000) estimated that between 80-90% of the effective species diversity could be overlooked since a large number of species is hidden in the upper forest regions, out of reach for unequipped collector. Since different lichen species are known to inhabit different zones of the tree trunk and pronounced vertical gradients exists on the tree trunks (Komposch and Hafellner 2000, 2003; Boonpragop and Polyiam, 2007) it is imperative to suggest that substantial number of lichen species were missed and therefore the reason why few species were recorded per host.

5.6 Conclusions and Recomendations

- This study has greatly enhanced our knowledge of lichens in Africa. It is particular evident that tropical montane forests support a high diversity of corticolous lichens, that was observed at the species, genus and family levels. The result supports my hypothesis that the diversity of lichens in Mt. Kenya is greater than shown by the existing records. This study also seems to confirm recent assertions that suggest higher lichen diversity in the tropical regions than thought before (Sipman and Aptroot, 2006). However substantial number of taxa may have been missed due to the sampling method used that covered only parts of host trees, besides only corticolous lichens were assesed. The species estimators predicted higher richness, while rarefaction curves did not reach horizontal asymptote. Future studies should therefore be designed to cover all substrates and the entire range of microhabitats. In addition entire host trees should be sampled using the right tree climbing gear so as to capture the entire diversity of the lichen mycobiota of the host trees.

- The forest type has great influence in lichen species richness, occurrence and abundance in the tropical montane areas. Their occurrence is therefore largely dependent on the site microhabitats conditions since they are specific to the sites conditions and their occurrence are influenced by the microclimate of the sites. The two forest types had a contrasting lichen species composition and abundances. Higher diversity of crustose microlichens species was observed at lower altitudes in the closed wet forest contrasting to the drier forest type, which had a higher abundance of the macrolichen species. The finding supports the hypothesis that suggests influence of vegetation composition on

lichen community structure and distribution. Therefore to conserve lichen biodiversity as much of the habitats as possible must be conserved.

- Altitudinal changes have a significant influence in the lichen species richness, diversity and composition in the tropical montane forests, therefore supporting the hypothesis suggesting influence of altitude on lichen diversity. Study sites in the wetter forest exhibited diffences in lichen structure, composition and numbers. However, for a more elaborate structure on altitudinal distribution of lichens, all substrates where lichens are known to grow should be sampled. In addition to sampling other forest blocks which were not covered by this study and which may have different lichen assemblages.

- Subtle lichen preference to the host species was detected, only one species showed 100% specificity. Lichens in tropical montane forests therefore seem to have little preference for the host tree. The results of this study therefore do not support the hypothesis suggesting that the host tree species has influence on lichen occurrence and distribution. In future studies the bark characteristics that are known to be important in influencing lichen occurrence should be investigated so as to shed more light on the relationship of lichens with the tree host.

- Lichen richness and abundance is highly correlated with the diversity of host trees. Sites with a higher tree diversity also recorded higher species richness while sites with less diversity of trees recorded less species numbers. The results of this study affirm a rich but under studied lichen diversity in the tropical montane forests. In addition to further strengthening the prediction that tropical regions have a high lichen diversity that equals or even surpases that of the temperate regions of the world. Inventories should therefore

be intensified to cover the other major montane ecosystems so as to allow for comparative studies in future, and also to inform conservationist besides generating data useful in future biomonitoring studies.

- Lichen metabolites and their derivatives have great potential use in the pharmaceutical and agrochemical industries, more research to determine their use in medicine and crop protection is therefore stongly recommended.

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APPENDICES

Appendix 1: List of taxa collected from Chogoria and Sirimon forests arranged according to their respective families following taxonomy by Lumbsch and Hundorf (2010)

(* = new records for Kenya; ** = new records to Africa).

Family	Species
Agyriaceae	**Trapeliopsis gelatinosa* (Flörke) Coppins & P. James
Arthoniaceae	**Arthonia complanata* Fée
Arthoniaceae	*Cryptothecia* sp.
Biatorellaceae	***Piccolia elmeri* (Vain.) Hafellner
Brigantiaeaceae	*Brigantiaea leucoxantha* (Spreng.) R. Sant. & Hafellner
Chrysotrichaceae	*Chrysothrix xanthina* (Vain.) Kalb
Cladoniaceae	**Cladonia insolita* Ahti & Krog
Cladoniaceae	*Cladonia leucophylla* Ahti & Krog
Coccocarpiaceae	*Coccocarpia erythroxyli* (Spreng.) Swinscow & Krog
Coccocarpiaceae	*Coccocarpia palmicola* (Spreng.) Arv. & D.J. Galloway
Coccocarpiaceae	*Coccocarpia pellita* (Ach.) Müll. Arg.
Coenogoniaceae	*Coenogonium fallaciosum* (Müll. Arg.) Kalb & Lücking
Coenogoniaceae	*Coenogonium geralense* (Henn.) Lücking
Coenogoniaceae	***Coenogonium kalbii* Aptroot, Lücking & Umaña
Coenogoniaceae	**Coenogonium luteum* (Dicks.) Kalb & Lücking
Coenogoniaceae	**Coenogonium nepalense* (G. Thor & Vezda) Lücking, Aptroot & Sipman
Coenogoniaceae	*Coenogonium siquirrense* (Lücking) Lücking
Coenogoniaceae	***Coenogonium stenosporum* (Malme) Lücking, Aptroot & Sipman
Coenogoniaceae	*Coenogonium subfallaciosum* (Vezda & Farkas) Lücking, Aptroot & Sipman
Collemataceae	*Leptogium austroamericanum* (Malme) C.W. Dodge
Collemataceae	*Leptogium azureum* (Sw. ex Ach.) Mont.

Collemataceae	*Leptogium burgessii* (L.) Mont.
Collemataceae	*Leptogium burnetiae* C.W. Dodge
Collemataceae	*Leptogium cochleatum* (Dicks.) P.M. Jørg. & P. James
Collemataceae	*Leptogium coralloideum* (Meyen & Flot.) Vain.
Collemataceae	*Leptogium cyanescens* (Pers.) Körb.
Collemataceae	*Leptogium furfuraceum* (Harm.) Sierk
Collemataceae	*Leptogium marginellum* (Sw.) Gray
Collemataceae	*Leptogium phyllocarpum* (Pers.) Mont.
Graphidaceae	**Cladestinotrema cladestinum* (Ach.) Rivas Plata,Lücking and Lumbsch
Graphidaceae	***Diorygma minisporum* Kalb, Staiger & Elix
Graphidaceae	*Fissurina* sp.
Graphidaceae	**Fissurina triticea* (Nyl.) Staiger
Graphidaceae	*Graphis acharii* Fée
Graphidaceae	***Graphis consanguinea* (Müll. Arg.) Lücking
Graphidaceae	***Graphis illinata* Eschw.
Graphidaceae	**Graphis macella* Kremp.
Graphidaceae	**Graphis proserpens* Vain.
Graphidaceae	**Graphis* sp. nov.
Graphidaceae	**Graphis streblocarpa* (Bél.) Nyl.
Graphidaceae	**Graphis subtenella* Müll. Arg.
Graphidaceae	***Hemithecium chlorocarpum* (Fée) Trevis.
Graphidaceae	*Hemithecium* sp.
Graphidaceae	**Hemithecium* sp. nov
Graphidaceae	**Ocellularia pluripora* Hale
Graphidaceae	***Phaeographis dendritica* (Ach.) Müll. Arg.
Graphidaceae	**Phaeographis girringunensis* A.W. Archer & Elix
Graphidaceae	**Platygramme caesiopruinosa* (Fée) Fée

Graphidaceae	**Thelotrema canarense* Patw. & C.R. Kulk.
Graphidaceae	**Thelotrema diplotrema* Nyl.
Graphidaceae	**Thelotrema lepadinum* (Ach.) Ach.
Graphidaceae	**Thelotrema* sp. nov.
Gyalectaceae	*Cryptolechia caudata* Kalb
Haematommataceae	**Haematomma collatum* (Stirt.) C.W. Dodge
Lecanoraceae	**Lecanora leprosa* Fée
Lecanoraceae	*Lecanora* sp.
Lecanoraceae	*Lecanora* sp. 1
Lecanoraceae	*Lecanora* sp. 2
Lecanoraceae	**Lecanora* sp. nov.
Letrouitiaceae	**Letrouitia flavocrocea* (Nyl.) Hafellner & Bellem.
Lobariaceae	*Lobaria patinifera* (Taylor) Hue
Lobariaceae	*Lobaria pulmonaria* (L.) Hoffm.
Lobariaceae	*Lobaria retigera* (Bory) Trevis.
Lobariaceae	*Pseudocyphellaria aurata* (Ach.) Vain.
Lobariaceae	*Sticta ambavillaria* (Bory) Ach.
Lobariaceae	*Sticta fuliginosa* (Dicks.) Ach.
Lobariaceae	**Sticta kunthii* Hook. f.
Lobariaceae	*Sticta tomentosa* (Sw.) Ach.
Lobariaceae	*Sticta weigelii* Isert
Malmideaceae	**Malmidea ceylanica*
Malmideaceae	**Malmidea gyalectoides*
Malmideaceae	*Malmidea* sp.
Megalariaceae	*Catillochroma* sp.
Megalosporaceae	**Megalospora coccodes* (Bél.) Sipman
Megalosporaceae	*Megalospora* sp.

Megalosporaceae	**Megalospora tuberculosa* (Fée) Sipman
Mycoporaceae	**Mycoporum sparsellum* Nyl.
Nephromataceae	*Nephroma tropicum* (Müll. Arg.) Zahlbr.
Pannariaceae	*Pannaria conoplea* (Pers.) Bory
Pannariaceae	*Parmeliella pannosa* (Sw.) Müll. Arg.
Parmeliaceae	*Anzia afromontana* R. Sant.
Parmeliaceae	*Canoparmelia texana* (Tuck.) Elix & Hale
Parmeliaceae	*Cetrariastrum sorocheilum* (Vain.) W.L. Culb. & C.F. Culb.
Parmeliaceae	*Cetrelia braunsiana* (Müll. Arg.) W.L. Culb. & C.F. Culb.
Parmeliaceae	*Flavoparmelia caperata* (L.) Hale
Parmeliaceae	*Flavoparmelia soredians* (Nyl.) Hale
Parmeliaceae	*Flavopunctelia flaventior* (Stirt.) Hale
Parmeliaceae	*Hypotrachyna afrorevoluta* (Krog & Swinscow) Krog & Swinscow
Parmeliaceae	*Hypotrachyna croceopustulata* (Kurok.) Hale
Parmeliaceae	*Hypotrachyna immaculata* (Kurok.) Hale
Parmeliaceae	*Hypotrachyna microblasta* (Vain.) Hale
Parmeliaceae	*Hypotrachyna minarum* (Vain.) Krog & Swinscow
Parmeliaceae	*Hypotrachyna orientalis* (Hale) Hale
Parmeliaceae	*Hypotrachyna polydactyla* (Krog & Swinscow) T.H. Nash
Parmeliaceae	*Hypotrachyna* sp.
Parmeliaceae	*Parmotrema abessinicum* (Nyl. ex Kremp.) Hale
Parmeliaceae	*Parmotrema austrosinense* (Zahlbr.) Hale
Parmeliaceae	*Parmotrema cetratum* (Ach.) Hale
Parmeliaceae	*Parmotrema chinense* (Osbeck) Hale & Ahti
Parmeliaceae	*Parmotrema commensuratum* (Hale) Hale
Parmeliaceae	*Parmotrema cooperi* (J. Steiner & Zahlbr.) Sérus.
Parmeliaceae	*Parmotrema gardneri* (C.W. Dodge) Sérus.

Parmeliaceae	*Parmotrema hababianum* (Gyeln.) Hale
Parmeliaceae	*Parmotrema indicum* Hale
Parmeliaceae	*Parmotrema lophogenum* (Abbayes) Hale
Parmeliaceae	*Parmotrema reticulatum* (Taylor) M. Choisy
Parmeliaceae	*Parmotrema sancti-angelii* (Lynge) Hale
Parmeliaceae	*Parmotrema* sp.
Parmeliaceae	*Parmotrema subarnoldii* (Abbayes) Hale
Parmeliaceae	*Parmotrema subisidiosum* (Müll. Arg.) Hale
Parmeliaceae	*Parmotrema subschimperi* (Hale) Hale
Parmeliaceae	*Parmotrema subtinctorium* (Zahlbr.) Hale
Parmeliaceae	*Pseudoparmelia ecaperata* (Müll. Arg.) Hale
Parmeliaceae	*Pseudoparmelia nairobiensis* (J. Steiner & Zahlbr.) Hale
Parmeliaceae	*Pseudoparmelia* sp.
Parmeliaceae	*Pseudoparmelia sphaerospora* (Nyl.) Hale
Parmeliaceae	*Punctelia neutralis* (Hale) Krog
Parmeliaceae	*Punctelia rudecta* (Ach.) Krog
Parmeliaceae	*Punctelia semansiana* (W.L. Culb. & C.F. Culb.) Krog
Parmeliaceae	*Punctelia* sp.
Parmeliaceae	*Punctelia subrudecta* (Nyl.) Krog
Parmeliaceae	*Usnea albomaculata* Motyka
Parmeliaceae	*Usnea articulata* (L.) Hoffm.
Parmeliaceae	*Usnea bicolorata* Motyka
Parmeliaceae	*Usnea exasperata* (Müll. Arg.) Motyka
Parmeliaceae	*Usnea firmula* (Stirt.) Motyka
Parmeliaceae	*Usnea picta* (J. Steiner) Motyka
Parmeliaceae	*Usnea rubicunda* Stirt.
Parmeliaceae	*Usnea* sp.

Parmeliaceae	*Usnea trichodeoides* Motyka
Parmeliaceae	*Usnea undulata* Stirt.
Peltigeraceae	*Peltigera polydactyloides* Nyl.
Peltigeraceae	*Peltigera praetextata* (Flörke ex Sommerf.) Vain.
Peltigeraceae	*Peltigera ulcerata* Müll. Arg.
Pertusariaceae	*Pertusaria* cf. *krogiae* A.W. Archer, Elix, Eb. Fischer, Killmann & Sérus.
Pertusariaceae	*Pertusaria* cf. *melanostoma* Nyl.
Pertusariaceae	**Pertusaria* cf. *scaberula* A.W. Archer
Pertusariaceae	*Pertusaria endoxantha* Vain.
Pertusariaceae	**Pertusaria fosseyae* A.W. Archer, Elix, Eb. Fischer, Killmann & Sérus.
Pertusariaceae	*Pertusaria krogiae* A.W. Archer, Elix, Eb. Fischer, Killmann & Sérus.
Pertusariaceae	**Pertusaria lambinonii* A.W. Archer, Elix, Eb. Fischer, Killmann & Sérus.
Pertusariaceae	**Pertusaria maritima* A.W. Archer & Elix
Pertusariaceae	**Pertusaria microstoma* Müll. Arg.
Pertusariaceae	**Pertusaria pilosula* A.W. Archer & Elix
Pertusariaceae	**Pertusaria scaberula* A.W. Archer
Pertusariaceae	*Pertusaria* sp.
Pertusariaceae	*Pertusaria* sp. 1
Pertusariaceae	*Pertusaria* sp. 2
Pertusariaceae	*Pertusaria* sp. 3
Pertusariaceae	**Pertusaria subrigida* Müll. Arg.
Pertusariaceae	**Pertusaria velata* (Turner) Nyl.
Phlyctidaceae	*Phlyctis* sp.
Physciaceae	*Calicium salicinum* Pers.
Physciaceae	*Calicium* sp. B
Physciaceae	*Calicium* sp. C
Physciaceae	***Heterodermia allardii* (Kurok.) Trass

Physciaceae	**Heterodermia casarettiana* (A. Massal.) Trevis.
Physciaceae	*Heterodermia hypoleuca* (Mühl.) Trevis.
Physciaceae	*Heterodermia japonica* (M. Satô) Swinscow & Krog
Physciaceae	*Heterodermia lepidota* Swinscow & Krog
Physciaceae	*Heterodermia leucomelos* (L.) Poelt
Physciaceae	*Heterodermia microphylla* (Kurok.) Skorepa
Physciaceae	**Heterodermia reagens* (Kurok.) Elix
Physciaceae	*Heterodermia* sp.
Physciaceae	**Heterodermia* sp. nov.
Physciaceae	*Phaeophyscia hispidula* (Ach.) Essl.
Physciaceae	*Physcia albata* (F. Wilson) Hale
Physciaceae	*Physcia dilatata* Nyl.
Physciaceae	*Physcia* sp.
Physciaceae	*Physconia muscigena* (Ach.) Poelt
Physciaceae	*Rinodina* sp. 1
Pilocarpaceae	*Byssoloma leucoblepharum* (Nyl.) Vain.
Pilocarpaceae	*Fellhanera fragilis* (Vezda) Lücking & Kalb
Pilocarpaceae	*Micarea* sp.
Porinaceae	**Porina brisbanensis* Müll. Arg.
Porinaceae	**Porina conspersa* Malme
Porinaceae	**Porina distans* Vezda & Vivant
Porinaceae	***Porina exocha* (Nyl.) P.M. McCarthy
Porinaceae	**Porina imitatrix* Müll. Arg.
Porinaceae	***Porina internigrans* (Nyl.) Müll. Arg.
Porinaceae	**Porina nucula* Ach.
Porinaceae	**Porina nuculastrum* (Müll. Arg.) R.C. Harris
Porinaceae	*Porina* sp.

Porinaceae	*Porina* sp. 1
Porinaceae	**Porina* sp. nov.
Pyrenulaceae	**Pyrenula acutispora* Kalb & Hafellner
Pyrenulaceae	**Pyrenula* cf. *cruenta* (Mont.) Vain.
Pyrenulaceae	**Pyrenula cruenta* (Mont.) Vain.
Pyrenulaceae	*Pyrenula globifera* (Eschw.) Aptroot
Pyrenulaceae	*Pyrenula macrocarpa* Massal.
Pyrenulaceae	**Pyrenula mastophora* (Nyl.) Müll. Arg.
Pyrenulaceae	**Pyrenula nitidula* (Bres.) R.C. Harris
Pyrenulaceae	**Pyrenula platystoma* Müll. Arg.
Pyrenulaceae	**Pyrenula pyrenuloides* (Mont.) R.C. Harris
Pyrenulaceae	**Pyrenula quassiaecola* Fée
Pyrenulaceae	**Pyrenula santensis* (Nyl.) Müll. Arg.
Pyrenulaceae	*Pyrenula* sp.
Ramalinaceae	*Bacidia* aff. *Medialis* (Tuck.) Zahlbr.
Ramalinaceae	*Bacidia* sp.
Ramalinaceae	*Bacidiopsora* sp.
Ramalinaceae	***Eschatogonia triptophyllina* (Nyl.) Kalb
Ramalinaceae	*Phyllopsora albicans* Müll. Arg.
Ramalinaceae	*Phyllopsora chlorophaea* (Müll. Arg.) Zahlbr.
Ramalinaceae	*Phyllopsora confusa* Swinscow & Krog
Ramalinaceae	*Phyllopsora mediocris* Swinscow & Krog
Ramalinaceae	*Phyllopsora santensis* (Tuck.) Swinscow & Krog
Ramalinaceae	*Phyllopsora* sp.
Ramalinaceae	*Phyllopsora* sp. 1
Ramalinaceae	*Ramalina celastri* (Spreng.) Krog & Swinscow
Ramalinaceae	*Ramalina pollinaria* (Westr.) Ach.

Ramalinaceae	*Ramalina pusiola* Müll. Arg.
Ramalinaceae	*Ramalina* sp.
Roccellaceae	***Lecanactis platygraphoides* (Müll. Arg.) Zahlbr.
Sphaerophoraceae	*Sphaerophorus melanocarpus* (Sw.) DC.
Sphinctrinaceae	*Sphinctrina tubiformis* A. Massal.
Stereocaulaceae	**Lepraria* cf. *caesioalba* (B. de Lesd.) J.R. Laundon
Stereocaulaceae	**Lepraria* cf. *incana* (L.) Ach.
Stereocaulaceae	***Lepraria coriensis* (Hue) Sipman
Stereocaulaceae	**Lepraria cupressicola* (Hue) J.R. Laundon
Stereocaulaceae	**Lepraria incana* (L.) Ach.
Stereocaulaceae	**Lepraria lobificans* Nyl.
Stereocaulaceae	*Lepraria* sp.
Stereocaulaceae	*Lepraria* sp. 1
Stereocaulaceae	*Lepraria* sp. 2
Stereocaulaceae	*Lepraria* sp. 3
Stereocaulaceae	*Lepraria* sp. 4
Stereocaulaceae	**Lepraria usnica* Sipman
Strigulaceae	**Strigula* sp. nov.
Teloschistaceae	***Caloplaca brebissonii* (Fée) J. Sant. ex Hafellner & Poelt
Teloschistaceae	*Caloplaca* sp. 1
Teloschistaceae	*Teloschistes exilis* (Michx.) Vain.
Teloschistaceae	*Xanthoria candelaria* (L.) Th. Fr.
Teloschistaceae	*Xanthoria parietina* (L.) Beltr.
Tephromelataceae	**Tephromela atra* (Huds.) Hafellner
Unknown	Unknown Crust 1
Unknown	Unknown Crust 2
Unknown	Unknown Crust 3

Unknown	Unknown Crust 4
Unknown	Unknown Crust 5
Unknown	Unknown Crust 6
Unknown	Unknown Crust 7
Unknown	Unknown Crust 8-isidiate
Verrucariaceae	***Agonimia pacifica* (H. Harada) Diederich**
Verrucariaceae	*Agonimia papillata* (O.E. Erikss.) Diederich & Aptroot
Verrucariaceae	**Agonimia tristicula* (Nyl.) Zahlbr.

Appendix 2: Pairwise comparison of lichen assemblages among study sites using MRPP, the *A*-statistic and significant level.

Study sitess	A	p-value
C1 vs. C2	0.0013	0.3483
C1 vs. C3	0.0142	0.0065
C1 vs. C4	0.0262	0.0008
C1 vs. C7	0.0912	0.0000
C1 vs. S1	0.0423	0.0000
C1 vs. S2	0.0570	0.0000
C1 vs. S3	0.0565	0.0000
C1 vs. S4	0.0400	0.0001
C2 vs. C3	0.0068	0.0579
C2 vs. C4	0.0174	0.0047
C2 vs. C7	0.0673	0.0000
C2 vs. S1	0.0312	0.0000
C2 vs. S2	0.0403	0.0000
C2 vs. S3	0.0430	0.0000
C2 vs. S4	0.0253	0.0012
C3 vs. C4	0.0260	0.0006
C3 vs. C7	0.0784	0.0000
C3 vs. C7	0.0418	0.0000

Study sitess	A	p-value
C3 vs. S2	0.0545	0.0000
C3 vs. S3	0.0567	0.0000
C3 vs. S4	0.0342	0.0002
C4 vs. C7	0.0834	0.0001
C4 vs. S1	0.0219	0.0122
C4 vs. S2	0.0309	0.0028
C4 vs. S3	0.0383	0.0000
C4 vs. S4	0.0348	0.0046
C7 vs. S1	0.0694	0.0001
C7 vs. S2	0.0585	0.0001
C7 vs. S3	0.0668	0.0000
C7 vs. S4	0.0754	0.0007
S1 vs. S2	0.0179	0.0250
S1 vs. S3	0.0295	0.0003
S1 vs. S4	0.0258	0.0061
S2 vs. S3	0.0066	0.1672
S2 vs. S4	0.0314	0.0089
S3 vs. S4	0.0200	0.0243

Appendix 3: Distribution of corticolous lichens within the study sites, and the opportunistic collections made near the sites in Chogoria and Sirimon forests. (1 = presence, 0 = absence)

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
Agonimia pacifica	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agonimia papillata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Agonimia tristicula	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anzia afromontana	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Arthonia complanata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bacidia aff. *medialis*	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacidia sp.	1	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0
Bacidiospora sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Brigantiaea leucoxantha	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Byssoloma leucoblepharum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calicium salicinum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Calicium sp. B	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Calicium sp. C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Caloplaca brebissonii	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Caloplaca sp. 1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Canoparmelia texana	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Catillochroma sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetrariastrum sorocheilum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetrelia braunsiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chrysothrix xanthina	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Cladestinotrema cladestinum	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Cladonia insolita	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cladonia leucophylla	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coccocarpia erythroxyli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Coccocarpia palmicola	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Coccocarpia pellita	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenogonium fallaciosum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenogonium geralense	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Coenogonium kalbii	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Coenogonium luteum	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Coenogonium	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
nepalense																				
Coenogonium siquirrense	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenogonium stenosporum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenogonium subfallaciosum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptolechia caudata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptothecia sp.	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diorygma minisporum	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eschatagonia triptophyllina	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fellhanera fragilis	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fissurina triticea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flavoparmelia caperata	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Flavoparmelia soredians	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Flavopunctelia flaventior	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Graphis acharii	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Graphis consanguinea	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Graphis illinata	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Graphis macella	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Graphis proserpens	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Graphis sp. nov.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Graphis streblocarpa	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphis subtenella	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haematomma collatum	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Hemithecium chlorocarpum	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemithecium sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemithecium sp. nov.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterodermia allardii	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Heterodermia casarettiana	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Heterodermia hypoleuca	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Heterodermia japonica	0	1	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Heterodermia lepidota	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Heterodermia	0	0	0	0	0	1	0	1	1	0	0	1	0	1	0	0	0	0	0	1

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
leucomelos																				
Heterodermia microphylla	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Heterodermia reagens	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterodermia sp.	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Heterodermia sp. nov	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hypotrachyna afrorevoluta	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna croceopustulata	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna immaculata	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0
Hypotrachyna microblasta	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna minarum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna orientalis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna polydactyla	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanactis platygraphoides	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora leprosa	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lecanora sp.	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Lecanora sp. 1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lecanora sp. 2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora sp. nov.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lepraria cf. caesioalba	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria cf. incana	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria coriensis	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria cupressicola	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria incana	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria lobificans	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Lepraria sp.	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria sp. 1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria sp. 2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria sp. 3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria sp. 4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepraria usnica	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Leptogium austroamericanum	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Leptogium azureum	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
Leptogium burgessii	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Leptogium burnetiae	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	1
Leptogium cochleatum	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptogium coralloideum	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Leptogium cyanescens	1	1	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Leptogium furfuraceum	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Leptogium marginellum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Leptogium phyllocarpum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Letrouitia flavocrocea	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Lobaria patinifera	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lobaria pulmonaria	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Lobaria retigera	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Malmidea ceylanica	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malmidea gyalectoides	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
Malmidea sp.	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Megalospora coccodes	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Megalospora sp.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megalospora tuberculosa	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micarea sp.	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Mycoporum sparsellum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephroma tropicum	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocellularia pluripora	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pannaria conoplea	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmeliella pannosa	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema abessinicum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema austrosinense	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Parmotrema cetratum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema chinense	0	0	0	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Parmotrema commensuratum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema cooperi	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Parmotrema gardneri	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema hababianum	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Parmotrema indicum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Parmotrema	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
lophogenum																				
Parmotrema reticulatum	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Parmotrema sancti-angelii	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Parmotrema sp.	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Parmotrema subarnoldii	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Parmotrema subisidiosum	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema subschimperi	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema subtinctorium	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Peltigera polydactyloides	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peltigera praetextata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1
Peltigera ulcerata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria cf. krogiae	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Pertusaria cf. melanostoma	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria cf. scaberula	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria endoxantha	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Pertusaria fosseyae	0	1	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Pertusaria krogiae	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Pertusaria lambinonii	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria maritima	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria microstoma	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pertusaria pilosula	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Pertusaria scaberula	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Pertusaria sp.	1	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Pertusaria sp. 1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Pertusaria sp. 2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria sp. 3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria subrigida	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pertusaria velata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Phaeographis dendritica	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Phaeographis girringunensis	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phaeophyscia hispidula	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
Phlyctis sp.	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllopsora albicans	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Phyllopsora chlorophaea	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllopsora confusa	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Phyllopsora mediocris	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllopsora santensis	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllopsora sp.	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Phyllopsora sp. 1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia albata	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Physcia dilatata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Physcia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Physcornia muscigena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Piccolia elmeri	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platygramme caesiopruinosa	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Porina brisbanensis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina conspersa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina distans	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina exocha	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina imitatrix	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina internigrans	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina nucula	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina nuculastrum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina sp.	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina sp. 1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porina sp. nov.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudocyphellaria aurata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pseudoparmelia ecaperata	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudoparmelia nairobiensis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudoparmelia sp.	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0
Pseudoparmelia sphaerospora	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Punctelia neutralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Punctelia rudecta	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
Punctelia semansiana	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Punctelia sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Punctelia subrudecta	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0
Pyrenula acutispora	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	2	3	4	5	7	1	2	3	4	1	2	3	4	5	7	1	2	3	4
Pyrenula cf. cruenta	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula cruenta	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula globifera	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula macrocarpa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula mastophora	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula nitidula	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula platystoma	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula pyrenuloides	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula quassiicola	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula santensis	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrenula sp.	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ramalina celastri	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ramalina pollinaria	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ramalina pusiola	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ramalina sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Rinodina sp. 1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerophorus melanocarpus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphinctrina tubiformis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Sticta ambavillaria	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	1
Sticta fuliginosa	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Sticta kunthii	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticta tomentosa	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Sticta weigelii	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Strigula sp. nov	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Teloschistes exilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Tephromela atra	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Thelotrema canarense	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelotrema diplotrema	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thelotrema lepadinum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Thelotrema sp. nov.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trapeliopsis gelatinosa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 2	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 6	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown crust 8-isidiate	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Usnea albomaculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Species	Taxa from the study sites										Opportunistic collections									
	Chogoria						Sirimon				Chogoria						Sirimon			
	1	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**7**	**1**	**2**	**3**	**4**
Usnea articulata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Usnea bicolorata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Usnea exasperata	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0
Usnea firmula	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Usnea picta	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Usnea rubicunda	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Usnea sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Usnea trichodeoides	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Usnea undulata	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Xanthoria candelaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Xanthoria parietina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1