

Some environmental factors influencing diversity of corticolous
lichens in selected disturbed and undisturbed vegetation types in
Knuckles Mountain range in Sri Lanka.

by

Weerakoon Mudiyanseelage Gothamie Sagalika Kumari Weerakoon



A thesis submitted to the University of Sri Jayewardenepura for
the award of the Degree of Doctor of Philosophy in Botany on
Lichenology.

Declaration

The work described in this thesis was carried out by me under the supervision of Prof. S.C. Wijeyaratne and Dr P.A. Wolseley and a report on this has not been submitted in whole or in part to any university or any other institution for another Degree/Diploma.

Author's name : W.M.G.S.K.Weerakoon

Date : 31. 01. 2013

Signature

:  Weerakoon

We certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University for the purpose of evaluation.

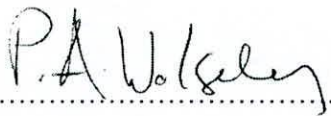
Supervisor 1 : Name : Prof. S.C.Wijeyaratne

Date : 31. 01. 2013

Signature: 

Supervisor 2 : Name : Dr. P.A.Wolseley

Date : 31. 01. 2013

Signature: 

We certify that the candidate has incorporated all corrections, additions and amendments recommended by the examiners.

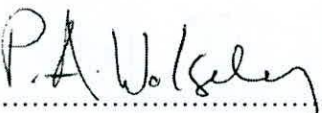
Supervisor 1 : Name : Prof. S.C.Wijeyaratne

Date : 11. 11. 2013

Signature: 

Supervisor 2 : Name : Dr. P.A.Wolseley

Date : 11. 11. 2013

Signature: 

TO you.....

With my endless love.....

you,

always stood by me

With love, courage and support,

May you see from somewhere,

I am where you wanted me to be,

Your dream has come true.....

Table of Contents

	<i>Page</i>
Table of Contents	i
List of Figures	v
List of Tables	vii
Abbreviations	viii
Acknowledgements	ix
Abstract	xii
Chapter 1: Introduction	1-25
1.1. Lichen as an organism	1
1.2. The lichen symbionts	3
1.2.1. The mycobiont	3
1.2.2. The photobiont	4
1.2.3. The growth forms of lichens	5
1.2.4. Thallus structure	7
1.2.5. Reproduction in lichens	9
1.3. Ecology and Diversity of lichens	12
1.3.1 Substrates of lichens	13
1.3.2 Main ecological factors influencing lichens	14
1.3.3 Lichens as environmental indicators	16
1.4. Lichens and Environmental monitoring	18
1.4.1. Why use lichens as environmental monitors	18

1.4.2. Purposes for which environmental monitoring of lichens is used	19
1.4.3. Methods used	20
1.5. Rationale and Objectives	22
1.5.1. Rationale	22
1.5.2. Objectives of the study	24
1.5.3. Specific Objectives	25
 Chapter 2 : Literature Review	 26-46
2.1 Study area - Knuckles Mountain Region (KMR)	26
2.2. Vegetation types of Knuckles Mountain Region	30
2.3. Floral studies in Knuckles Mountain Range	38
2.4. Tropical Lichens	41
2.5. Earlier records of Lichens in Sri Lanka	44
 Chapter 03 : Methods and Materials	 47-83
3.1. Study area and establishment of sites	47
3.2. Lichen survey and sampling method	58
3.2.1. Preparing lichen inventory	58
3.2.2. Quantitative sampling of corticolous lichens	59
3.3 Registration and collection of corticolous lichens for the quantitative study	63
3.4. Measurement of Microclimatic and phorophytic parameters	67
3.4.1. Phorophyte parameters	67
3.4.2. Measurement of Microclimate parameters	69
3.5. Morphological, anatomical and chemical identification	70

3.6. Data Analysis	76
3.6.1. Corticolous lichen diversity in different vegetation types	76
3.6.2. Relationship of ecological and phorophyte characters to corticolous lichen distribution	78
3.6.3. Diffrence of vegetation types related to lichen composition and possible indicator species of corticolous lichens in different vegetation types	81
Chapter 4 : Results	84-159
4.1. Corticolous lichen diversity across sites and by vegetation type	84
4.1.1. Quantitative analysis of corticolous lichen diversity	84
4.1.2. Comparison of corticolous lichen cover of family and genera	90
4.1.3. Distribution of corticolous lichen family and genera in 16 different vegetation types	93
4.2. Effect of ecological and phorophyte characters on distribution of corticolous lichen	106
4.2.1. The non-metric multidimensional scaling (NMS)	106
4.2.2. Two-way cluster analysis	113
4.2.3. Lichen composition in relation to different vegetation in KMR	120
4.2.4. Possible indicator species of corticolous lichens in different vegetation types	125
4.3. Taxonomic diversity	129
4.3.1. Characters of new species recorded during the present study	137
4.3.2. Identification key to the genera of lichen family Graphidaceae	153

4.3.3. Other possible new lichen species	157
Chapter 5 : Discussion	160-192
5.1. The factors identified affecting distribution and diversity of lichens	162
5.2. Diversity of lichens	169
5.3. Correlation of corticolous lichens with sites and vegetation types	174
5.4. Lichen cover values at family and generic level and association with vegetation types	179
5.5. Distribution of photobionts across vegetation types	183
5.6. Potential indicator species of corticolous lichens in KMR	187
5.7. Taxonomic diversity	190
Chapter 6 : Conclusions	193-195
References	196-225
Appendix 1 List of Publications and Communications from thesis	226
Appendix 2 Lichen genera list used for analysis	228
Appendix 3 Ecological data of 48 sampling sites	243
Appendix 4 Check list of identified lichens of the present study	246

List of Figures

		Page
Figure 1.1	Cross section of the thallus	10
Figure 3.1	Location of the Knuckles Mountain Region	49
Figure 3.2	Site map of Knuckles Mountain Region	55
Figure 3.3	Different vegetation types	56 -57
Figure 3.4	Species-area curve	61
Figure 3.5	Transparency graph sheet	62
Figure 3.6	Registration of corticolous lichens for quantitative survey	66
Figure 3.7	Bark types	69
Figure 3.8	Herbarium label for lichen specimens	75
Figure 4.1	Percentage number of corticolous lichen genera and families	85
Figure 4.2	Graphical depiction of average diversity index values	90
Figure 4.3	Total lichen cover of the corticolous lichen families	92
Figure 4.4a	Total lichen cover of the corticolous lichen genera	93
Figure 4.4b	Distribution of Photobionts in habitat clusters	94
Figure 4.5	Distribution of corticolous lichen families in the sampling sites	98
Figure 4.6	Distribution of corticolous lichen genera in the sampling sites	104
Figure 4.7	NMS ordination of 48 sampling sites in 16 different vegetation types	110
Figure 4.8	NMS ordination joint plot a) axis 1 vs. 3, b) axis 2 vs. 3	111
Figure 4.9	Overlay of lichen genera on the joint plot of NMS	113

Figure 4.10	Two-way cluster analysis dendrogram of 48 sites and 32 crustose lichen genera	119
Figure 4.12	Status of the lichen species collected from Knuckles Mountain	131
Figure 4.13	<i>Chapsa wijeyaratniana</i>	138
Figure 4.14	<i>Chapsa wolseleyana</i>	140
Figure 4.15	<i>Fissurina srilankensis</i>	142
Figure 4.16	<i>Graphis allugallenensis</i> , <i>Graphis dotalugensis</i> , <i>Graphis knucklensis</i>	148
Figure 4.17	<i>Graphis srilankensis</i>	150
Figure 4.18	<i>Thelotrema pseudosimilans</i>	152
Figure 5.1	Average no. of different trees in each vegetation type	163

List of Tables

	<i>Page</i>
Table 3.1. Details of the three sampled sites in each vegetation type	50
Table 3.4.1. Data entry sheet for corticolous lichens	64
Table 3.4.2. Data entry sheet for environmental and phorophyte measurements	65
Table 4.1. Alpha, Beta, Gamma Diversity and Half Changes of the 48 sampling sites for 32 genera and 201 species	85
Table 4.2. Diversity indices of each vegetation type	88
Table 4.3. The corticolous lichens recorded from the sampling sites	91
Table 4.4. Correlation of ecological and phorophyte factors with NMS ordination axes	108
Table 4.5. Pairwise comparison of species composition among vegetation types based on MRPP	123
Table 4.6. Lichen indicator species for vegetation type	127
Table 4.7. Systematic arrangement of the identified specimens	132
Table 4.8. Possible specimens in their families and genera that need further analysis to confirm as new lichen species	157
Table 6.1. Summary of the taxonomic diversity of the present study	195

Abbreviations

KMR	- Knuckles Mountain Region
DBH	- diameter at breast height
PDA	- National Herbarium of the Peradeniya, Sri Lanka
BM	- Natural History Museum, London
F	- Field Museum, Chicago
TLC	- Thin Layer Chromatography
NMS	- Non-metric multidimensional scaling
MRPP	- Multi-Response Permutation Procedure
IV	- indicator value
SL	- Sri Lanka
IAP	- Indices of Air Pollution
VDI	- Verein Deutscher Ingenieure
msl	- mean sea level

Acknowledgements

I wish to offer gratitude to Prof. S.C. Wijeyaratne, Chair of Botany, Department of Botany, University of Sri Jayewardenepura, for her supervision and valuable advice during the course of this investigation. Special thanks for my chief supervisor for facilitating the opportunity to study the Ph.D degree where she is the grantee of the research project ASP/06/2008/11 funded by University of Sri Jayewardenepura-SL.

It is a great pleasure to express my deepest gratitude to Dr. P.A. Wolseley, Scientific Associate, Natural History Museum, London, for supervising this study with invaluable guidance, support, encouragement, taxonomic expertise, insight in to my study and future direction in lichen ecology. I would not be here without your spirits during rainy days. I have no words to thank you Pat !!!

I am most thank full to Prof. S.Piyasiri, Dean , Post Graduate faculty who always pushed and advised me for completing the work in very difficult times during the final year. I gratefully acknowledge Prof. N. Salime, Head, Department of Botany, University of Sri Jayewardenepura, and all the academic and non-academic staff of the Department for their willing co-operation throughout this research study. This work was carried out with the assistance of funds from the University of Sri Jayewardenepura-SL, grant no. ASP/06/2008/11.

The analysis of this huge dataset in the research would not be possible without Prof. Bruce McCune, Oregon State University, providing the opportunity to follow the

Community Structure and Analysis course in 2011. His invaluable suggestions in data analysis and hospitality of Dr. Patricia will never be forgotten.

I am also deeply indebted to Dr. Andre Aptroot, providing many useful suggestions that improved my manuscripts, for thorough editing and for checking species lists many times and assistance given in specimen identification. Most of all being a close friend during difficult times.

I wish to offer my special gratitude to Drs. Thorsten Lumbsch, Robert Lucking, Eimy Rivas Plata of Field Museum-Chicago, Drs. Cécile Gueidan, Holger Thus of Natural History Museum-London, Drs. Monika Shaffer-Fehre, Heidi Doring of Kew, Dr. Phillipe Clerc and Dr. Gintaras Kantvilas for providing me with the research facilities, assistance in identification of specimens, sending me published papers and books, introducing me to molecular techniques and helping to get overseas grants to carry out this investigation successfully. A major part of this work was carried in Field Museum and Natural History Museum under the supervision of expertise. Many many thanks!

I am also thankful to Dr. S.Somaratne, Lecturer, Department of Botany, Open University of Sri Lanka, for his valuable support in statistical analysis. Special thanks are expressed to friends and staffs of Department of Botany and Plant Pathology of Oregon State University, National Herbarium, Singapore, Lichenology Department of Ramkhamhaeng University of Thailand for their support and help.

My gratitude is also due to the staff at National Herbarium, Peradeniya for their support and permission given me to use plant specimens for specimen identification. All the people full of smiles and endless hospitality in deeply hidden villages of Knuckles Mountain range will never be forgotten for fulfilling my dream.

I wish to express my heartfelt gratitude to my brothers, Nilantha malli and my field assistant Vimukthi malli, who shared my life and worked with me endlessly during long hours in the Knuckles with laughter and helped me to remember that there was more to life everywhere when we did field work. Vimukthi will be always remembered sharing long hours in the lab, helping me in everything, handling specimens carefully. You did a very good job! Warm and very special thanks to my loving friends, Ranil, Dinarzarde, Vishan, Wasana, Kangmin, Shawn Lum and Ranjie. Thank you very much Maduranga malli, for assisting me for typesetting the thesis. My aunts in London and Prof. Logen and family in Oregon supported me by accommodating and taking care of me during my visits without any expense. Many thanks to you all!

I am also indebted to my beloved father, husband and two sons who have been incredibly patient and have given me unconditional love, encouragement, sage advice and unlimited financial support throughout the study and especially in every difficult moment since January 2012. They turned the whole house to a lichenological laboratory, a library and to a herbarium since then. In every turn, told me that only few more miles are ahead towards THE END, held my stress and disappointments, encouraged me saying that life is always not a fantasy as at home but full of cruelty. With my love to you all !!

**Some Environmental Factors influencing Diversity of Corticolous Lichens in
selected disturbed and undisturbed vegetation types in Knuckles Mountain range
in Sri Lanka.**

Weerakoon Mudiyanseelage Gothamie Sagalika Kumari Weerakoon

ABSTRACT

This study was conducted in Knuckles mountain range, Sri Lanka in order to assess corticolous lichen diversity and distribution in a range of forest types under different environmental conditions and management, and to investigate these lichens as potential bioindicators of environmental alteration. Data were collected from 48 sampling sites in 16 different vegetation types and analyzed using multivariate analysis to assess the relationship between lichen communities, diversity and environmental factors and to select potential lichen bioindicators. The total number of corticolous lichen species, 448, was among one of the highest reported for a tropical forest. These taxa encompass 92 genera, 34 families, 10 orders, and four classes of the phylum Ascomycota (412 species) and one species of the phylum Basidiomycota. Significantly, 159 species were new records for Sri Lanka (46 new records for Indian subcontinent) including 10 species new to science. Graphidaceae (127 species) was the most dominant family, while *Graphis* represented highest corticolous lichen cover. This family has undergone recent taxonomic revision and an identification key to the 21 genera is presented.

The highest alpha diversity (14), Shannon's diversity (2.11) and Simpson's diversity (0.84) was recorded in Cardamom plantation, undisturbed sub-montane forest (α diversity= 12) and undisturbed montane forest (α diversity= 10). Lowest diversity values (α diversity= 2, Shannon's diversity=0.16, Simpson's diversity =0.1) were recorded for the riverine forest. Highest evenness values were found in the *Pinus*

plantation (0.91) associated with dominance of few common species on even-aged *Pinus* contrasted with increasing numbers of rare species on a variety of tree species in montane sites. The NMS identified major factors affecting the distribution and diversity of lichen communities including altitude and phorophyte factors; diameter (DBH), trunk inclination and bark pH. The cluster analysis of lichen genera with >3 occurrences resulted in two major habitat clusters separating undisturbed montane forests from managed and disturbed forests with < 50% dissimilarity and two further clusters within the managed and disturbed sites. Nine lichen groups were distinguished with two distinct groups identified in the montane sites and a larger number of similar groups widely distributed. Pairwise comparison of species composition among vegetation types, based on MRPP showed undisturbed submontane forest to be significantly different from other forest types but did not distinguish significant relationships between lichen communities and other forest types. Analysis of photobionts showed a tendency for disturbed and managed sites to have a higher percentage of trebouxoid species and undisturbed sites to have a higher percentage of trentepohlioid photobionts with a low percentage of cyanobacterial photobionts at high altitudes. Analysis of species components using PC-ORD identified 59 potential bioindicators for eleven vegetation types including species associated with Cardamom plantations and undisturbed montane forest and species associated with tea and Acacia plantations and/or disturbance.

This study has documented the extraordinary diversity of lichens in KMR, and identified factors associated with high diversity in montane forest vegetation, suggesting that many more species await discovery and could provide substantial additions to the under explored tropical lichen flora of the world as well as contribute to conservation of rapidly degrading forest cover in SL.