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Journal of Biogeography

Supporting Information

Community change and species richness reductions in rapidly advancing treelines

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Supporting Information

Appendix S1

Table S1: Explanation of treeline forms/structures used in the sampling design.

Treeline form	Description	Transects	Sampling locations along transects	Mean transect length (m)
Abrupt advancing	Treelines with an abrupt edge that show evidence of advance. A dense band of young trees is apparent at the edge of the forest and aerial photograph analysis shows advances of treeline in recent decades (Greenwood et al. 2014).	11	3: Interior forest, mid forest, treeline	50
Diffuse advancing	Treelines that show evidence of recent advance occurring in a diffuse manner; regeneration has occurred over a long distance at low density. Young trees can be seen scattered upslope at very low density beyond the treeline, forming the tree-limit at their upper limits. Aerial photographs provide evidence of recent advances of treeline (Greenwood et al. 2014)	11	4: Interior forest, mid forest, treeline, tree limit	100
Static	Treelines that show no evidence of recent advance. Mature trees occur at the edge of the forest and the treeline is abrupt in nature, no evidence of advance is apparent in aerial photographs (Greenwood et al. 2014).	11	3: Interior forest, mid forest, treeline	50

11 **Appendix S2**

12 **Literature and methods for lichen identification and accession numbers for GenBank**

13 **Literature used for species identification**

- 14 Aproot, A., Lai, M-J. & Sparrius, L. B. (2003) The genus *Menegazzia* (Parmeliaceae) in Taiwan. *The*
15 *Bryologist*, **106**, 157- 61.
- 16 Aproot, A. & Sparrius, L. B. (2009) Additions to the lichen flora of Vietnam with an annotated checklist and
17 bibliography. *The Bryologist*, **109**, 358-371.
- 18 Aproot, A. & Sparrius, L.B. Pictures of tropical lichens (<http://www.tropicallichens.net/>)
- 19 Elix, J.A. (2009) *Pyxine*, *Flora Australia*, **57**, 517-533
- 20 Elix, J. A. (2011) *Heterodermia*, Australian Physciaceae (lichenised Ascomycota).
21 <http://www.anbg.gov.au/abrs/Heterodermia.pdf>
- 22 Kurokawa, S. & Lai, M-J. (2001) Parmelioid lichen genera and species in Taiwan. *Mycotaxon*, **77**, 225-284.
- 23 Lai, A., Aproot, A. & Sparrius, L. B. (2004) Checklist of lichens and lichenicolous fungi of Taiwan. Version 1
24 April 2005. <http://checklists.de>
- 25 Lin, C-K. (2007) The lichen Genus *Usnea* at Meifeng, Central Taiwan. *Coll. and Res*, **20**, 1-7.
- 26 Liu, H. (2009) A brief overview of and key to species of *Collema* from China. *Mycotaxon*, **108**, 9-29.
- 27 Luo, H., Wei, X.L., Han, K.S., Koh, Y.L. & Hur, J-S. (2007) Taxonomic study of the lichen genus *Cetrelia*
28 (Lecanorales, Ascomycotat) in South Korea. *Mycobiology*, **35**, 117-123.
- 29 McCune, B. (2009) *Hypogymnia* (Parmeliaceae) species new to Japan and Taiwan. *The Bryologist*, **112**, 823-
30 826.
- 31 Myllys, L., Velmala, S. Holien, H., Halonen, H, Wang, L-S & Goward, T. (2011) Phylogeny of the genus
32 *Bryoria*. *The Lichenologist*, **43**, 617-638.
- 33 Obermayer, W. & Elix, J.A. (2003) Notes on chemical races in *Sulcaria sulcata* from south-eastern Tibet and
34 adjacent regions. *Bibliotheca Lichenologica*, **86**, 33-46.
- 35 Ohmura, Y. (2012) A synopsis of the lichen genus *Usnea* (Parmeliaceae, Ascomycota) in Taiwan. *Mem. Natl.*
36 *Mus. Nat. Sci.*, Tokyo, **48**, 91-137.
- 37 Orange, A., James, P.W. and White, F.J. (2010) Microchemical methods for the identification of lichens. British
38 Lichen Society. ISBN 978 0 9540418 9 2.
- 39 Park, Y. S. (1991) The macrolichen flora of South Korea. *The Bryologist*, **93**, 105-160
- 40 Ren, M-R., Wang, X.Y., Koh, Y.J. & Hur, J-S. (2012) Taxonomic study of the lichen genus *Lobaria* in South
41 Korea. *Mycobiology*, **40**, 1-7.
- 42 Sipman, H. (1986) Notes on the genus *Everniastrum* (Parmeliaceae). *Mycotaxon*, **26**, 235-251.
- 43 Thell, A., Randlane, T., Saag, A and Karnefelt, I. (2005) A new circumscription of the lichen genus
44 *Nephromopsis* (Parmeliaceae, lichenized Ascomycetes). *Mycological Progress*, **4**, 303-316.

- Verdon, D. (1992) *Leptogium*, *Flora Australia*, **54**.
- Wang, X.Y., Wei, X.L., Han, K.S., Koh, Y.J. and Hur, J-S. (2007) Taxonomic study of the lichen genus *Coccocarpia* (Lecanorales, Ascomycotata) in South Korea. *Mycobiology*, **35**, 174-179.
- Wang, X.Y., Joshi, Y. and Hur, J-S. (2011) The genus *Cladonia* (lichenized Ascomycota, Cladoniaceae) in South Korea. *Mycotaxon*, **117**, 405-422.
- Wei, X.L. and Hur, J-S. (2007) Foliose genera of Physciaceae (lichenized Ascomycota) of South Korea. *Mycotaxon*, **102**, 127-137.
- Wei, X. L., Luo, H., Koh, Y.J. and Hur, J.S. (2008) A taxonomic study of *Heterodermia* (Lecanorales, Ascomycota) in South Korea based on phenotypic and phylogenetic analysis. *Mycotaxon*, **105**, 65-78.
- Wei, X.L., Wang, X.Y., Koh, Y.K. and Hur, J-S. (2009) Taxonomic study of *Peltigera* (Peltigeraceae, Ascomycota) in Korea. *Mycobiology*, **37**, 189-196.

Barcoding methods

Thin layer chromatography was conducted following the methods of Orange, James and White (2010). Solvent G was used on a glass plate and plates were sprayed with sulphuric acid and water and observed under UV light as well as natural light.

Methods of extraction, amplification and purification for DNA barcoding followed those described by Kelly *et al.* (2011). Purified PCR product was sequenced in forward and reverse directions via a commercial service (Macrogen Europe). Contigs were edited and assembled using BioEdit software (Hall, 2013). Most specimens were successfully barcoded and at least one example of each species yielded useable sequence data except for three species of *Usnea*, one *Heterodermia*, one *Cetrelia*, one *Lobariella* and one *Hypotrachyna* for which specimens either yielded low concentration DNA after extraction or failed to yield useable sequence data (see Table S1 in Appendix S2). These un-barcoded species were all rare in the sample sites, both in terms of occurring in small number of sites and being at very low abundance in the occurring sampling areas. BLASTN searches in GenBank (www.ncbi.nlm.nih.gov/genbank/) were used for initial sequence identity and top hits were recorded for comparison with the morphological species identification. In most cases this revealed a close match between sequence ID and morphological ID and where these did not

agree specimens were reclassified as appropriate. Voucher specimens of the species identified in this study are stored in the herbarium of The Royal Botanic Garden Edinburgh and associated sequence data are stored in GenBank, for accession numbers/sequence IDs see Table S1.

References

- Hall, N. (1999) Bioedit: a user-friendly biological sequence alignment editor and analysis program for windows 95/98/NT. *Nucleic Acids Symposium Series*, **41**, 95-98
- Kelly, L.J., Hollingsworth, P.M., Coppins, B.J., Ellis, C.J., Harrold, P., Tosh. J. & Yahr, R. (2011) DNA barcoding of lichenized fungi demonstrates high identification success in a floristic context. *New Phytologist*, **191**, 288–300
- Orange, A., James, P.W. & White, F.J. (2010) Microchemical methods for the identification of lichens. British Lichen Society. ISBN 978 0 9540418 9 2.

Table S1: Lichen species list and accession numbers for GenBank and RBGE Herbarium.

<i>Species name</i>	<i>In GenBank (number of replicates)</i>	<i>In RBGE</i>	<i>Voucher specimen (RBGE)/ Accession number (GenBank)</i>
<i>Allocetraria madreporiformis</i>	2	0	KU862932 KU862933
<i>Anzia formosana</i>	2	2	C8 32 HYPB3/ KU862934 S4 31 HYPB5/ KU862935
<i>Bryoria bicolor</i>	1	1	S5 11 BB2/ KU862936
<i>Cetrelia braunsiana</i>	-	-	-

<i>Cetrelia cetraoides</i>	1	1	S9 11 PAP1/ KU862937
<i>Cetrelia chicitae</i>	1	1	S5 31 PEX1/ KU862938
<i>Cetrelia japonica</i>	1	1	C1 21 PSA3/ KU862939
<i>Cetrelia olivetorum</i>	1	1	S3 22 PAU1/ KU862940
<i>Cetrelia pseudolivetorum</i>	2	2	D4 32 PT2/ KU862941 C10 32 PT3/ KU862942
<i>Cladonia spp</i>	-	-	-
<i>Coccocarpia erythoxyli</i>	1	1	S9 22 COP2/ KU862943
<i>Coccocarpia palmicola</i>	1	1	S5 21 COE3/ KU862944
<i>Everniastrum cirrhatum</i>	2	2	D11 42 EVC1/ KU862945 D3 22 EVC2/ KU862946
<i>Fuscopannaria ahlneri</i>	2	2	S6 11 PNSP4/ KU862947 S8 11 PNSP2/ KU862948
<i>Fuscopannaria leucostica</i>	2	2	S10 31 GR1/ KU862949 S3 32 GR4/ KU862950

<i>Heterodermia boryi</i>	2	2	D3 42 HL2/ KU862951 S2 11 HL3/ KU862952
<i>Heterodermia casarettiana</i>	2	2	D3 32 HS1/ KU862953 C3 22 HO1/ KU862954
<i>Heterodermia isidiophora</i>	2	2	S5 12 HI3/ KU862955 S4 11 HI2/ KU862956
<i>Heterodermia japonica</i>	2	2	C6 21 HJ2/ KU862957 S4 22 HJ3/ KU862958
<i>Heterodermia microphylla</i>	-	-	-
<i>Heterodermia subascendens</i>	1	0	KU862959
<i>Hypogymnia flavida</i>	1	2	C6 12 HYF3/ KU862960 S11 12 HYF2
<i>Hypogymnia hengduanensis</i>	1	1	C9 12 HYH4/ KU862961
<i>Hypogymnia pseudoenteromorpha</i>	2	3	C11 11 HYPE1 S5 31 HYPE2/ KU862962 C4 12 HYPE3/ KU862963

<i>Hypogymnia stricta</i>	1	0	KU862964
<i>Hypogymnia subarticulata</i>	1	1	S3 11 HYS2/ KU862965
<i>Hypogymnia taiwanalpina</i>	1	0	KU862966
<i>Hypogymnia vittata</i>	1	1	D4 21 HYT2/ KU862967
<i>Hypotrachyna majoris</i>	-	-	-
<i>Hypotrachyna sinuosa</i>	1	1	D7 12 HYSi1/ KU862968
<i>Leptogium burnetiae</i>	1	1	D6 32 LEPB3/ KU862969
<i>Leptogium furfaraceum</i>	2	2	S10 31 LEPA4/ KU862970 S5 21 LEPA3/ KU862971
<i>Lobaria quercizans</i>	1	1	D3 41 LD2/ KU862972
<i>Lobaria retigera</i>	1	1	D6 31 LI1/ KU862973
<i>Lobariella wrightii</i>	-	-	
<i>Menegazzia anteforata</i>	2	1	D4 12 MAN1/ KU862974 S8 11 MAN2/ KU862975
<i>Menegazzia primaria</i>	1	1	C5 12 MPS3/ KU862976
<i>Menegazzia pseudocyphellata</i>	1	1	D5 11 MPS2/ KU862977

<i>Menegazzia terebrata</i>	1	2	D1 11 MPR1/ KU862978
<i>Myelochroa irrugans</i>	2	2	C5 12 MYI1/ KU862979 S1 11 MYI5/ KU862980
<i>Nephroma helveticum</i>	1	1	S9 11 PPR1/ KU862981
<i>Nephromopsis laureri</i>	2	2	S7 32 NP1/ KU862982 S5 21 NP2/ KU862983
<i>Nephromopsis morrisonicola</i>	0	1	S6 12 NM4
<i>Parmelia adaugescens</i>	2	2	S9 11 PAAD3/ KU862984 D3 12 PAAD5/ KU862985
<i>Parmelinopsis afrorevoluta</i>	2	2	D3 22 CTX1/ KU862986 S1 12 CTX4/ KU862987
<i>Parmeliella parvula</i>	2	2	S11 31 GR2/ KU862988 S4 32 GR3/ KU862989
<i>Peltigera polydactyla</i>	2	2	D8 42 PHO3/ KU862990

			S3 31 PPR3/
			KU862991
<i>Phaeophyscia hirtuosa</i>	1	0	KU862992
<i>Physconia muscigena</i>	1	0	KU862993
<i>Pseudocyphellaria desfontainii</i>	1	1	D11 41 PDE1/
			KU862994
<i>Sphaerophorus taiwanensis</i>	1	1	C1 31 ST4/
			KU862995
<i>Sticta filicina</i>	1	1	C8 32 SF2/
			KU862996
<i>Sticta nylanderiana</i>	1	1	S10 32 SPL4/
			KU862997
<i>Sticta wrightii</i>	2	0	KU862998
			KU862999
<i>Sulcaria sulcata</i>	1	1	S9 12 BB1/
			KU863000
<i>Usnea articulata</i>	-	-	-
<i>Usnea diffracta</i>	-	-	-
<i>Usnea himalayana</i>	-	-	-
<i>Usnea longissima</i>	1	1	D11 11 UL4/
			KU863001
<i>Usnea malmei</i>	2	2	S3 11 UN3/ KU863002
			D11 22 UN4/ KU863003
<i>Usnea pycnoclada</i>	-	-	-
<i>Usnea trichoideodes</i>	0	2	S2 11 UL1 S7 11 UL2

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Appendix S3

Size age relationships of trees and the influence of altitude.

The relationship between tree age and size was determined across all transects through ring data obtained by random tree core sampling. Cores were collected from adult trees over an altitudinal gradient great than that of any single transect; the mean altitudinal range covered by individual transects was 27 m, the maximum covered by a single transect was 134 m, whereas the range covered by tree core sampling was 167 m. Linear modelling suggests a strong and significant relationship between tree size and age ($R^2 = 0.86$, $p < 0.001$). The effect of altitude was not significant when included as an interaction term in the model ($P > 0.05$) and did not improve the R^2 value.

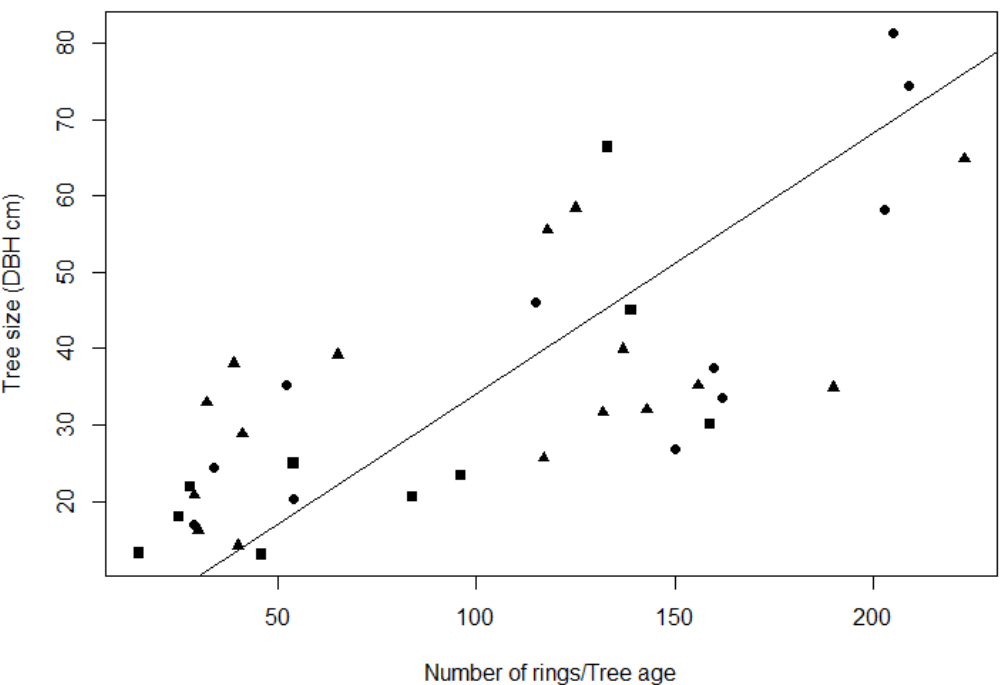


Figure S3: The relationship between tree age (number of rings) and size (DBH (cm)). Symbols represent altitude, split into three levels: (low (squares), mid (circle) and high (triangle)). The linear regression line is shown, the R^2 value is 0.86, the F value is 243.9 on 35 degrees of freedom, and the p value is < 0.001 .