2004

The effect of climate change on Antarctic terrestrial flora

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The Effect of Climate Change on Antarctic Terrestrial Flora

A thesis submitted in fulfilment of the requirements for the award of the degree

Doctor of Philosophy

from

UNIVERSITY OF WOLLONGONG

by

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School of Biological Sciences

2004

Certification

I, Jane Wasley, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Biological Sciences, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Jane Wasley.

22rd July 2004

Acknowledgements

I would firstly like to thank Sharon Robinson and Cath Lovelock, who have been exceptionally supportive and inspirational supervisors. Sharon and Cath have been far more than just supervisors to me, providing a wealth of support and guidance beyond the realms of this thesis - thanks to both of you, your lessons have been priceless.

Eternal thanks goes also to the other "Moss Girl", Johanna Turnbull, whose dedication to this work over three Antarctic summers and, importantly, also her friendship has made this thesis possible – I don't think I will ever be able to thank you enough Wan. Thanks too to Jodie Dunn, who also assisted with field and lab work in Antarctica, and to other ANARE members who helped with various aspects of this work. I am also very grateful to those who assisted with other analyses: Prof. Marianne Popp, Dr. Andreas Richter, Dr. Wolfgang Wanek and Sabine Maringer assisted with IRMS and GC analyses; Dr Lixia Lui performed lipid analyses; Joanne George assisted with phosphorous analyses; and Assoc. Prof. Ken Russel and Prof. David Griffith provided statistical advice. Feedback on earlier drafts, and on the manuscript that forms the basis of chapter 1, was provided by Rob Whelan, Jodie Dunn, Sue Fyfe and Margie Law. Andrew Netherwood produced Figs. 1.1 and 1.2 (and many delicious meals).

Finally a very special thank you to all my friends and family who have shown me endless love and support and who have kept me in touch with the things that really matter in life. You know who you all are… I can only list a few here…. The girls from the Gong (especially Susie Brooks and Ali Findlay), Andy Cianchi (yes, I have finally "pulled my finger out" and got this thing finished!), Rachel Cianchi (for the many life-enriching phone calls), Letitia Bright (for helping get the final stages of the "fashion parade" underway) and Margie Law (for surviving the endless "school nights"). And of course thank you Mum and Dad, for giving me the confidence, encouragement and support to "be anything I want to be".

Funding and logistic support was provided by the Australian Antarctic Division and an Australian Postgraduate Award.

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List of Special Names or Abbreviations

A	Algae
ASPA	Antarctic Specially Protected Area
B	Bryophytes
C	Cyanobacteria
CA	Continental Antarctic
CV	Coefficient of Variation
CRT	Critical Recovery Time
CWC	Critical Water Content
D	Day
DR	Dark Respiration
dwt	Dry weight
ETR	Electron Transport Rate
F	Fungi
FB	Field Based
FC/L	Field Collected / Laboratory Analyses
F_v/F_m	Ratio of variable to maximum fluorescence
L	Lichen
LB	Laboratory Based
L(P)	Lichen Phycobiont
M	Moss
MA	Maritime Antarctic
M-FD	Model, based on field data
M-LD	Model, based on laboratory data
MUFA	Monounsaturated fatty acid
P_n	Net Photosynthesis
PS	Photosynthesis
PUFA	Polyunsaturated Fatty Acid
R	Review
RGR	Relative Growth Rate
S	Soil
SFA	Saturated Fatty Acid
Sn	Snow
SSSI	Site of Special Scientific Interest
temp	Temperature
TWC	Turf Water Content
V	Vascular plants
veg	Vegetation
WC	Water Content
X2, X3, X4	Unidentified soluble carbohydrate compounds
$\delta\ ^{15}N$	Abundance of ^{15}N stable isotope (relative to ^{14}N)
$\delta\ ^{13}C$	Abundance of ^{13}C stable isotope (relative to ^{12}C)
ΦPSII	Quantum yield of PSII
↑	Increasing
↓	Decreasing
‰	Parts per thousand

Abstract

Climate change is expected to affect the high latitudes first and most severely, rendering Antarctica one of the most significant baseline environments for the study of global climate change. The indirect effects of climate warming, including changes to the availability of key environmental resources, such as water and nutrients, are likely to have a greater impact upon Antarctic terrestrial ecosystems than the effects of fluctuations in temperature alone. Water availability is the focus in this thesis for two main reasons; firstly, there is a wealth of evidence to suggest water is currently limiting to Antarctic plant distributions and productivity, and secondly, availability of this key resource is predicted to change with the onset of climate change. Nutrient availability is a second variable considered in this work, as there is evidence to suggest that nutrients also play a role in determining plant species distributions, and changes to nutrient balance and turnover rates are also expected in response to climate change.

This work was conducted in the floristically important Windmill Islands region of East Antarctica, with the three Windmill Islands moss species *Bryum pseudotriquetrum*, *Ceratodon purpureus* and *Grimmia antarctici* forming its focus. A combination of field ecology, ecophysiology and laboratory studies were used to determine fine-scale patterns of present species distributions and their relationship to naturally occurring water and nutrient resource gradients, the impact of increased water and nutrients on a range of cryptogamic communities, and tolerance of desiccation biological profiles.

A survey-based approach was used to determine species level patterns in bryophyte species distributions, and identify correlations with resource availability. Ten replicate transects, along community gradients, from pure bryophyte stands, through transitional moribund bryophyte zones, to lichen-dominated communities, were surveyed at two sites. The physical environment at each site was characterised by measurement of site soil properties, along with individual transect aspects and slopes. To determine the relationship between resource gradients and community patterns water and nutrient availability, along with a range of plant biochemistry measures indicative of the growth environment, were measured using a series of quadrats along each transect. Percent

abundance for each species and/or vegetation category was determined for each quadrat by microscopic examination of field samples.

The community gradient, covering the entire ecological range of past and present bryophyte occupation, was found to be accompanied by resource gradients that operated in opposing directions. Pure bryophyte communities existed under conditions of high water availability and low nutrient availability. Crustose lichen-dominated communities persisted under opposing environmental conditions, of low water availability and high nutrient availability. *Grimmia antarctici* dominated the wettest habitats but its distribution extended into the dry moribund zones, albeit in low levels of abundance. *Bryum pseudotriquetrum* occurred in consistent levels of abundance across the entire gradient, whilst *C. purpureus* was restricted to the driest habitats. Live bryophyte material was found to occur in moribund turf, supporting the potential for bryophyte regeneration under a future wetter climate. Regenerating turf showed potential to support high species diversity, as all four bryophytes survive in this zone.

To investigate the likely impacts of a wetter climate on Antarctic terrestrial communities, four cryptogamic communities, pure bryophyte, moribund bryophyte, crustose and fructicose lichen-dominated communities were subject to a multi-season manipulative field experiment. Within each community type, eight replicate quadrats received increased water and/or nutrient availability over two consecutive summer seasons. A range of physiological and biochemical measurements were conducted in order to quantify the community response to the treatments and determine the extent of any nutrient and water limitation. Few multi-season manipulative field experiments have been conducted in continental Antarctica. Whilst an overall increase in productivity in response to water and nutrient additions was supported, productivity appeared to respond more strongly to nutrient additions than to water additions. Pure bryophyte and fructicose lichen communities also showed stronger positive responses to additions, identifying some communities that may be better able to adapt and prosper under the ameliorating conditions associated with a warmer, wetter future climate.

Using a range of morphological, biochemical and physiological techniques, biological profiles related to desiccation tolerance were developed for the three bryophyte study species, providing measures of relative abilities to avoid, tolerate, recover from and survive desiccation. *Ceratodon purpureus* showed good desiccation avoidance characteristics, its photosynthetic efficiency remained high at low water contents and it was lipid rich, suggesting that this species is well adapted to survive a drying climate. *Bryum pseudotriquetrum* is also likely to survive drier conditions, as this species showed good desiccation avoidance, had a plastic response to desiccation, and contained stachyose, which is likely to assist in its survival of desiccation events. Conversely, *G. antarctici* showed poor desiccation avoidance, as photosynthetic efficiency required highest water contents and it contained few protective substances, this species is therefore least likely to survive a drying environment.

This study provides a baseline from which future changes to the Windmill Islands cryptogamic communities can be monitored. A baseline incorporating fine-scale bryophyte species patterns is particularly useful, as this component of the cryptogamic community is likely to be highly sensitive to even small shifts in water availability and detection of change is likely to be more sensitive at fine- rather than broad-scales. Both water and nutrient resource availability was found to underlie regional bryophyte species distributional patterns. The dynamics of the Windmill Islands flora is therefore likely to shift in response to climate change as the availability of these key resources is altered. Under a wetter future climate, productivity is overall likely to increase but only certain cryptogamic communities are likely to thrive. Regeneration of moribund bryophytes appears likely only if the future moisture regime creates consistently moist conditions. *Bryum pseudotriquetrum* is most likely to survive both a drying climate and also a fluctuating climate, which is a highly likely scenario for the region. Under a drier climate, the Antarctic endemic, *G. antarctici*, is likely to be most adversely affected, as it dominates only the wettest communities and generally shows poor tolerance of desiccation. Conservation issues are therefore raised for this species, if the current drying trend continues, creating overall biodiversity concerns.