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Understanding the tolerance of Antarctic mosses to climate change

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Understanding the tolerance of Antarctic mosses to climate change

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. Despite this, there have been few long-term studies of the response of Antarctic vegetation to climate change. The Windmill Islands region supports some of the most extensive and best developed vegetation on continental Antarctica, with lush, green mossbeds along many of the lakes and melt streams close to Casey station. Over the past 12 years my University of Wollongong colleagues and I have studied the mosses of this region to better understand how they are responding to climate change.

Keywords
Antarctic • Bryum pseudotriquetrum • cell wall • Ceratodon purpureus • confocal microscopy • ozone depletion • Schistidium antarctici (Grimmia antarctici) • UV-screening compounds

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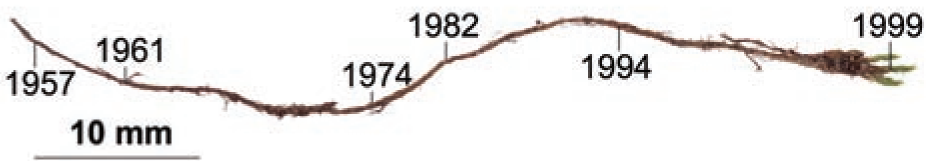
UNDERSTANDING THE TOLERANCE OF ANTARCTIC MOSSES TO CLIMATE CHANGE

A typical moss turf from Antarctic Specially Protected Area 135 near Casey station. The undulations are caused by frost heaving. Most of the moss shown here is the endemic Schistidium antarctici *(olive green in colour), which is the dominant moss species in the area. The bright green mosses at the front of the image are* Bryum pseudotriquetrum *and the red patches on the ridge tops are likely to be* Ceratodon purpureus. S. antarctic *and* C. purpureus *are hard to tell apart in the field and microscopic analysis is usually required to confirm identity.*

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.

Despite this, there have been few long-term studies of the response of Antarctic vegetation to climate change. The Windmill Islands region supports some of the most extensive and best developed vegetation on continental Antarctica, with lush, green mossbeds along many of the lakes and melt streams close to Casey station. Over the past 12 years my University of Wollongong colleagues and I have studied the mosses of this region to better understand how they are responding to climate change.

Our research has provided evidence that the Antarctic endemic moss *Schistidium antarctici* is likely to be more susceptible to climate change than two co-occurring cosmopolitan species *Ceratodon purpureus* and *Bryum pseudotriquetrum*. Initially we focused on how increasing springtime UV-B radiation, caused by the 'Antarctic ozone hole', was affecting these three mosses. We found that *S. antarctici* was more susceptible to UV-B-induced DNA damage than the cosmopolitan moss species. This is probably due to the endemic moss having the lowest concentration of sunscreen compounds of the three mosses. *C. purpureus* is the most UV-tolerant of the three mosses and PhD student, Laurence Clarke, has shown that although *C. purpureus* and *B. pseudotriquetrum* contain similar overall levels of sunscreen compounds, the location of the compounds varies between the two species. *C. purpureus* concentrates the sunscreens in its cell walls, whereas in *B. pseudotriquetrum* they are distributed evenly between the cytoplasm and cell walls. We think that wall-bound sunscreens offer a more spatially uniform and potentially more effective UV screen, which may explain why *C. purpureus* is so tolerant of UV-B radiation.



Radiocarbon isotope analysis has allowed researchers to determine the age and growth rate of moss shoots.

Work by Jane Wasley showed that whilst the endemic species thrives in melt streams and melt lakes, it is less able to cope with drier environments. In contrast, the two cosmopolitan species are much more tolerant of drier conditions. One of the impacts of climate change in this region of Antarctica is a drying trend – evidenced by the increased salinity of terrestrial lakes over past decades. Our results suggest that the two cosmopolitan species may out-compete the endemic one as the climate continues to change.

A collaboration with David Fink and Quan Hua at the Australian Nuclear Science and Technology Organisation (ANSTO) has allowed us to determine the age of these moss shoots and determine accurate growth rates using radiocarbon isotope analyses. Our results show that the oldest moss shoot sections predate the 1960s peak in atmospheric 14C due to nuclear testing, indicating average growth rates between 0.4 and 1.6 mm per year. We were also able to detect changes in growth rate over the last 50 years, allowing the influence of environmental variables on growth rates and water relations of Antarctic mosses to be explored over time periods not possible using other techniques.

Our results suggest that high wind speeds and ozone depletion typically have negative impacts on the growth of these mosses, whereas temperature tends to have a positive effect. Stable carbon isotope ($\delta^{13}C$) signatures in the mosses reveal when mosses were exposed to wetter and drier periods in the past, and also suggest that the growth rate of some species is water-limited. Recovery of the ozone layer and warming predicted for the Antarctic are likely to increase growth rates, whereas the already observed increase in wind speeds may negatively impact the growth of Antarctic mosses. These studies of past growth rates are consistent with results from other studies, which indicate moss communities are retracting into the wetter microhabitats.

Whilst short-term manipulative experiments are important in enabling us to predict the likely impacts of climate change, actual community change can only be determined by rigorous, long-term monitoring. To address this we have established a long-term monitoring program at Casey. We will determine how environmental change affects the terrestrial vegetation of the Windmill Islands by measuring how biodiversity is changing along a set of permanent vegetation transects established in 2002-03. This project has the potential to validate our hypotheses by measuring actual community change.

In the 2007-08 season we collected samples and photographed the quadrats from these transects at Robinson's Ridge (10 km from Casey) and in Antarctic Specially Protected Area 135, near the station. The samples and photographs are currently being analysed and will be compared to those collected in the 2002-03 season to see if our predictions for moss survival are sound.

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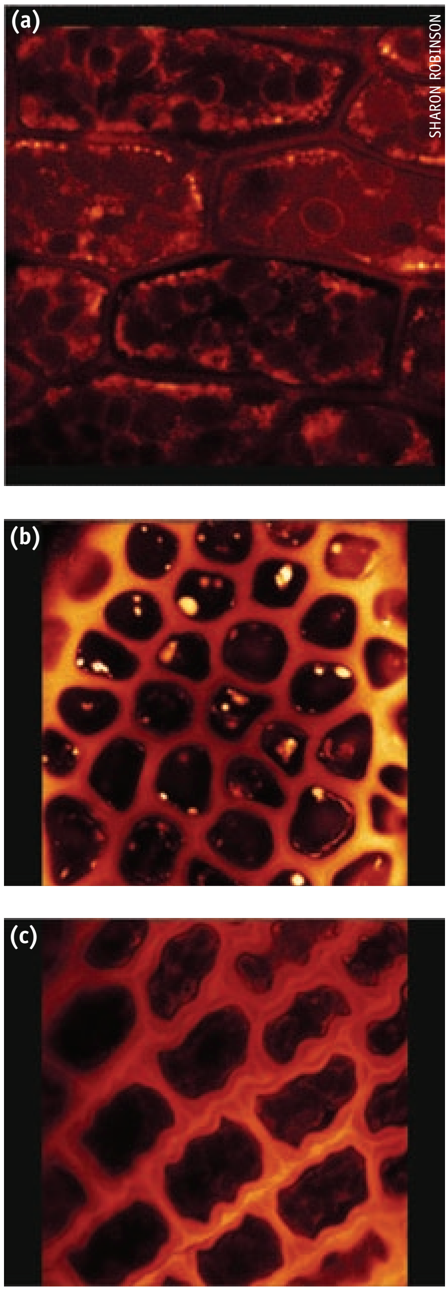

Confocal images of leaves from (a) Bryum pseudotriquetrum, *(b)* Ceratodon purpureus *and (c)* Schistidium antarctici *stained with Naturstoffreagenz A to show the localisation of UV-screening compounds in each species. Orange fluorescence indicates the presence of phenolic compounds.*

Genetic adaptation to climate change

Previous studies of Antarctic moss populations have reported extraordinarily high levels of genetic variation, possibly as a result of UV-induced mutation. We used microsatellite DNA markers to compare the genetic variation present in continental Antarctic, sub-Antarctic and temperate populations of the moss *Ceratodon purpureus*. In contrast to previous studies, we found continental Antarctic *C. purpureus* displays less intra-population genetic diversity and lower levels of inter-population gene flow compared to populations from a range of temperate and sub-Antarctic sites. Our data provide no evidence of elevated mutation rates in the Antarctic, and imply climate change will present ongoing challenges for continental Antarctic moss populations with less potential than temperate populations to adapt to environmental change.