PROCEEDINGS OF THE AUSTRALIAN RANGELAND SOCIETY BIENNIAL CONFERENCE
Official publication of The Australian Rangeland Society

Copyright and Photocopying

© The Australian Rangeland Society. All rights reserved.

For non-personal use, no part of this item may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior permission of the Australian Rangeland Society and of the author (or the organisation they work or have worked for). Permission of the Australian Rangeland Society for photocopying of articles for non-personal use may be obtained from the Secretary who can be contacted at the email address, rangelands.exec@gmail.com

For personal use, temporary copies necessary to browse this site on screen may be made and a single copy of an article may be downloaded or printed for research or personal use, but no changes are to be made to any of the material. This copyright notice is not to be removed from the front of the article.

All efforts have been made by the Australian Rangeland Society to contact the authors. If you believe your copyright has been breached please notify us immediately and we will remove the offending material from our website.

Form of Reference
The reference for this article should be in this general form;

Author family name, initials (year). Title. *In*: Proceedings of the *n*th Australian Rangeland Society Biennial Conference. Pages. (Australian Rangeland Society: Australia).

For example:

Anderson, L., van Klinken, R. D., and Shepherd, D. (2008). Aerially surveying Mesquite *(Prosopis* spp.) in the Pilbara. *In*: 'A Climate of Change in the Rangelands. Proceedings of the 15th Australian Rangeland Society Biennial Conference'. (Ed. D. Orr) 4 pages. (Australian Rangeland Society: Australia).

Disclaimer
The Australian Rangeland Society and Editors cannot be held responsible for errors or any consequences arising from the use of information obtained in this article or in the Proceedings of the Australian Rangeland Society Biennial Conferences. The views and opinions expressed do not necessarily reflect those of the Australian Rangeland Society and Editors, neither does the publication of advertisements constitute any endorsement by the Australian Rangeland Society and Editors of the products advertised.

The Australian Rangeland Society

CYANOBACTERIA WELL ADAPTED TO RESPOND TO DROUGHT AND CLIMATE CHANGE

*Wendy J. Williams[1], David J. Eldridge[2], Burkhard Büdel[3]

[1]The University of Queensland, Gatton, Queensland, 4343, Australia
[2]Depart. of Environment and Climate Change, c/- School of Biological, Earth and Environmental Sciences, University of NSW, Sydney, 2052, Australia
[3]Depart. of Biology, University of Kaiserslautern, Kaiserslautern, Germany

Email: wendyjwilliams@bigpond.com

ABSTRACT

Cyanobacteria-dominated soil crusts are a significant component of Australian arid and semi-arid landscapes. Morphogenetic adaptation has enabled cyanobacteria to respond to both short- and long-term changes in their environment. Cyanobacteria thrive on intermittent ‘nuisance’ rain and have the capacity to withstand inundation by sand, excessive temperatures and long periods of desiccation. They respond to moisture within a few seconds of wetting where respiration commences with as little as 0.5 mm precipitation. Cyanobacterial soil crusts attained positive net photosynthesis at 37°C. Certain species appeared to respond differently to the effects of drought. Our data showed that following two years of severe drought, four species of cyanobacteria responded well to rain, recovering close to pre-drought levels after the first year. Two other species were much slower to recolonise, taking up to two years to recover. Species such as *Microcoleus* and *Schizothrix* were observed to have high motility, moving 10-20 mm to the surface in response to gradients in light and moisture. In contrast, *Stigonema, Scytonema* and *Porphyrosiphon* were surface dwellers, with the strong pigmentation in their outer sheaths providing UV protection. We conclude that changes in species composition of cyanobacterial soil crusts over time may be important indicators of changes in soil nutrient gradients and rainfall patterns.

Key words: *Cyanobacteria, cyanobacterial soil crusts, biological soil crusts, drought, soil nutrients, bio-indicators.*

INTRODUCTION

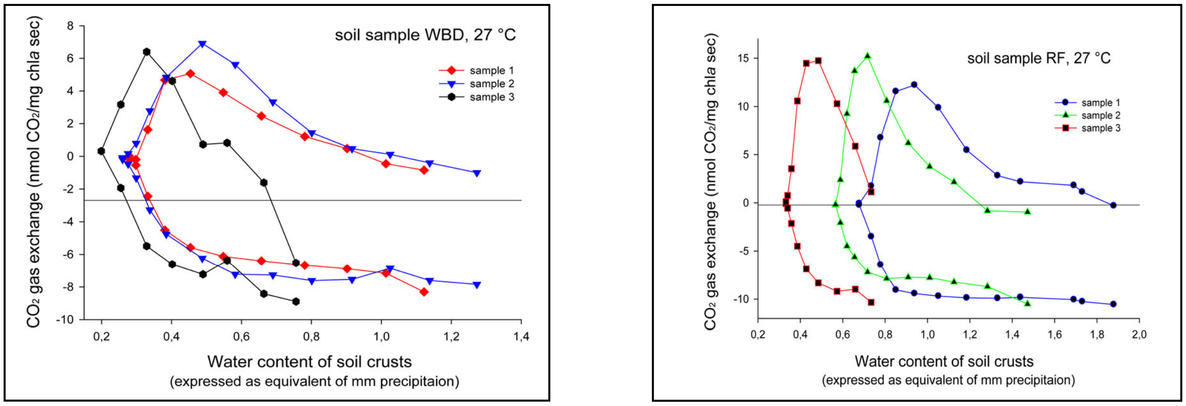
Cyanobacteria are one of the most primitive plant forms that inhabit harsh terrestrial environments where other vegetation often struggles to survive. These prokaryotic micro-organisms frequently occur as masses of colonial cells or bundles of filaments and are an integral component of soil and rock biofilms (Büdel, 2003) and biological soil crusts (lichens, cyanobacteria, liverworts, mosses, algae, fungi and bacteria). Biogenic crusts colonise bare ground or micro-patches between tussock grasses across arid and semi-arid landscapes and perform a functional role in surface stability and nutrient flows (West, 1990). Cyanobacteria are resilient to climatic variability and have the capacity to withstand exceptionally long dry periods (Mann, 2001). They carry out photosynthesis under low light conditions, and with limited moisture across a broad range of temperatures (Rascher *et al.*, 2003).

We examined cyanobacteria-dominated soil crusts from a semi-arid mulga woodland (Glencoban Paddock, 28°10’S; 146°02’E, SW QLD) over four years in contrasting climatic phases that included pre-drought (2002), drought (2003), post-drought recovery (2004) and seasonal drought (2005). In this paper we demonstrate evidence of the resilience and functional capacity of cyanobacteria-dominated soil crusts to remain photosynthetically productive even in drought cycles.

METHODS AND RESULTS

At Glencoban Paddock whole samples of cyanobacterial soil crusts (7 cm x 7 cm x 1 cm depth) were collected from two contrasting landscape zones – run-on (WBD) and runoff (RF), and of different cyanobacteria/crust compositions. Under controlled laboratory conditions these crusts were subjected to a range of light, temperature and moisture regimes using an Automatic Cuvette System (ACS, Walz Company, Germany). Photosynthetic performance (and productivity) under these varying conditions is expressed as CO_2 gas exchange rates and shown in Figures 1-4.

We also recorded the frequency (on a presence/absence basis) of cyanobacterial species at the research site over the four years. A total of 540 crust samples (2 cm x 2 cm) were collected from quadrats located adjacent to permanent transects situated across the paddock (Williams *et al*., 2008), but not in areas < 200 m from stock watering points. Five cyanobacteria species that showed significant changes over time are represented in Figures 5-9.



Figures 1 and 2. Photosynthesis (expressed by rate of CO_2 gas exchange) in relation to water content of cyanobacterial soil crust samples from two different sites.

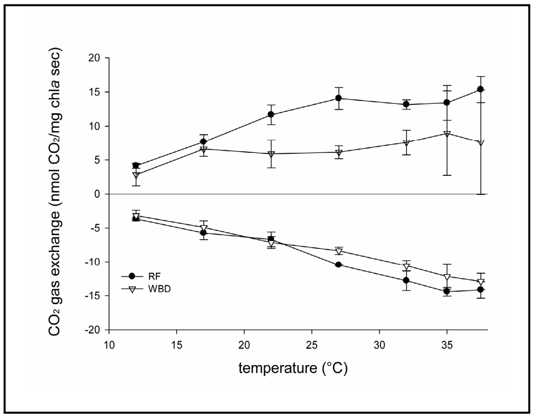


Figure 3. CO_2 exchange rates at rising temperatures.

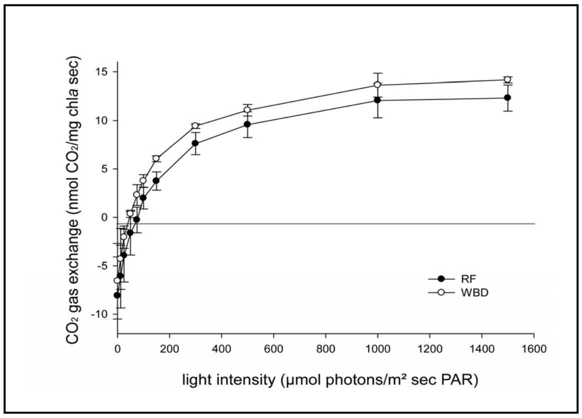
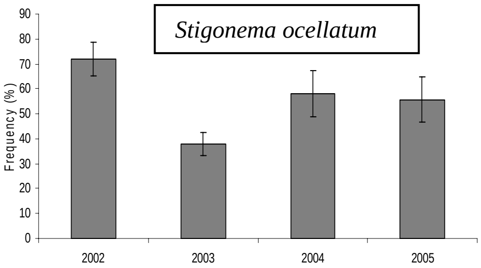
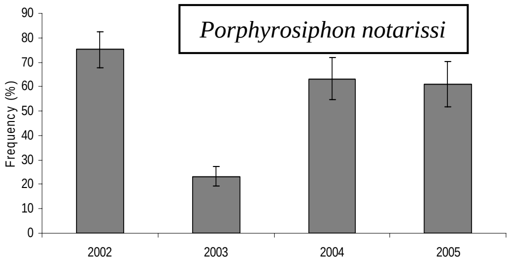
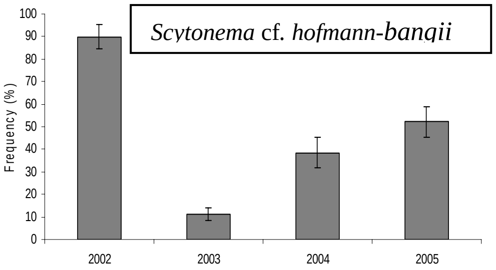
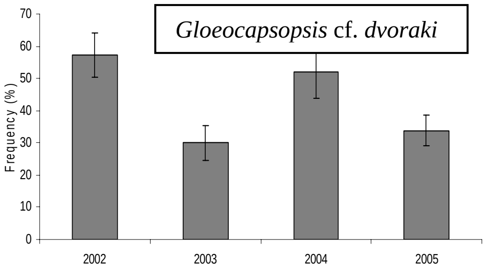


Figure 4. CO_2 exchange rates in relation to light intensity









Figures 5-9. Frequencies of five cyanobacteria species over four years (2002-2005) of changing climatic conditions

DISCUSSION

This is the first time that photosynthetic productivity has been measured for Australian cyanobacteria-dominated soil crusts and it clearly demonstrates their low moisture requirements and adaptation to high temperatures. Soil-resident cyanobacteria have the capacity to commence respiration after about 0.5 mm of rain (Figures 1 and 2), and under exceptionally low light conditions (Figure 4). Productivity of these crusts peak at 37^{o}C; within the range of soil surface temperatures regularly experienced at the research site (unpublished data). CO_2 uptake responses of crusts from both zones were similar with regard to light intensity and temperature. However, the run-on (WBD) crust type needs less water to become activated than the runoff (RF) crust type. Nevertheless, runoff crusts reached higher rates of net photosynthesis while the activity of run-on crusts was depressed by over-saturation of water much sooner than the runoff crusts. We cannot explain this fully without further investigation.

At the study site we found that cyanobacteria were adapted to survive being covered by broad deposits of sand (Williams, 2004). Naturally, surface-dwelling cyanobacteria such as *Stigonema* and *Scytonema* contain high levels of scytonemin in their outer sheaths that provided protection from UV damage. Other cyanobacteria such as the filamentous *Microcoleus* are highly mobile when moist and have the capacity to move between the surface environments or to seek sub-surface refuge, thereby gaining protection from potentially damaging environmental conditions. Our data also showed that the recovery of different cyanobacteria occurred at different rates (Figures 4-9) suggesting a diversity in their water requirements, as demonstrated by the contrasting respiratory activity of the two crust types.

Based on the CO_2 exchange data and the different responses of the two crust types to similar moisture regimes (Figures 1 and 2), it appears that species will vary in their vulnerability to altered rainfall patterns likely to be associated with global climate change. It follows that persistent changes in rainfall gradients would more than likely bring about a change in cyanobacteria species composition of soil crusts, and it is also likely that lichens and mosses would be highly susceptible to climate change (Belnap *et al.*, 2008). Although biological crusts are generally resilient and adaptable, any compositional changes would potentially result in critical changes to soil nutrient pools and ecosystem stability and have flow-on effects to landscape function. Biological soil crusts are integral components of the landscape, and in the Australian context, occur over extensive areas of southern Australia. Cyanobacterial crusts are critically important terrestrial biota as they are also widespread in northern Australia, south of the tropics. The challenge will be to adequately assess their roles in terms of carbon sequestration given climate change predictions over large areas of the continent. The first step however is the establishment of a continent-scale comprehensive biogeographical database of soil crust species in order to underpin any future research.

REFERENCES

Belnap, J., Phillips, S.L., Flint, S., Money, J., Caldwell, M., (2008). Global change and biological soil crusts: effects of ultraviolet augmentation under altered precipitation regimes and nitrogen additions. *Global Change Biol.* 14: 670-686

Büdel, B., (2003). Diversity and ecology of biological crusts. *Progress in Botany* 63: 396-404

Mann, N.H., (2001). Detecting the environment. *In*: ‘The ecology of cyanobacteria.’ (Eds., B.A. Whitton, M. Potts). Kluwer Acacdemic Publishers, Dordrecht, The Netherlands. Pp. 367-395

Rascher, U., Lakatos, M., Büdel, B., Lüttge, U., (2003). Photosynthetic field capacity of cyanobacteria of a tropical inselberg of the Guiana Highlands. *Eur. J. Phycol*. 38: 247-256.

West, N. E. (1990). Structure and function of microphytic soil crusts in wildland ecosystems of arid and semi-arid regions. *Adv. Ecol. Res.* 20: 179-223.

Williams, W.J., (2004). Cyanobacteria – silent survivors in droughts. *In*: Australian Rangeland Society 13th biennial Conference “Living in the outback”. (Eds., G. Bastin, D. Walsh, S. Nicolson). CSIRO Publishing, Canberra, Australia, pp 401-402.

Williams, W.J., Eldridge, D.J., Alchin, B.A., (2008). Grazing and drought reduce cyanobacterial soil crusts in an Australian *Acacia* woodland. *J. Arid Environs*. 72: 1064-1075.