EFFECTS OF ALTERED PRECIPITATION PATTERNS ON SOIL FAUNA IN AN AUSTRALIAN GRASSLAND

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Introduction

Climate change is considered one of the greatest threats to Earth's ecosystems, and changes in temperature and precipitation have been observed to impact ecosystems around the world (Nielsen et al., 2015). Soils support highly diverse communities whose intricate interactions govern essential ecosystem processes and the delivery of ecosystem services. Many processes are controlled by microbial activities, but larger soil fauna moderate microbial biomass and activity via microbial grazing, impact plant communities through belowground herbivory, fragment and incorporate litter into the soil matrix, build and maintain soil structure and, in this way, influence key processes such as decomposition and nutrient cycling (Nielsen et al., 2015). Water availability is a key constraint on soil faunal communities and changes in precipitation regimes could have substantial impacts on these communities and, therefore, ecosystem functioning (Nielsen and Ball, 2015). A recent meta-analysis of published rainfall manipulation studies indicates that altered rainfall regimes do indeed influence soil faunal communities. In particular, drought was found to reduce microarthropod and nematode abundances, while, conversely, irrigation increased nematode abundance (A'Bear et al., 2014). However, observed responses are highly variable across sites and there are few studies on the impact of changes in rainfall seasonality and frequency. Hence, further data are required to improve our capacity to predict the potential impacts of future climate change scenarios on belowground faunal communities. Here we present short-term (two years) responses of soil fauna (microarthropods and nematodes) to a range of future rainfall scenarios in a south-east Australian grassland.

Methods

The rainfall manipulation facility DRI-Grass (**D**rought and **R**oot herbivore **I**nteractions in **Grass**lands) was initiated in June 2013 in an old pasture near Richmond, New South Wales, Australia (Power et al., 2016). The site is on an alluvial floodplain with low-fertility sandy loam soils, and the climate is sub-humid temperate with a mean annual temperature of 17°C. The mean annual rainfall is *ca* 800 mm, but the rainfall pattern is highly variable both within and between years. Natural rainfall is excluded using slanted, clear polycarbonate roofs, and then water is added to the plots to create five rainfall treatments: ambient amount (shelter control), increased amount (ambient + 50%), reduced amount (ambient – 50%), altered frequency (fewer, larger events but same overall amount; rain once every three weeks), and summer drought (three months with complete removal). The facility also contains an outside control treatment (without shelters; procedure controls) used to investigate potential shelter effects. Six replicate plots of all treatments were sampled for this study. The facility further includes three rainfall × herbivore addition treatments, but these plots were not sampled for this study.

On April 7, 2015 two composite samples, each comprising two soil cores (3 cm diameter, 10 cm depth; collected from opposite sides of the treatment plots), were collected for extraction of microarthropods and nematodes, respectively. Microarthropods were extracted using modified Tullgren funnels (Tullgren, 1918) by gradually increasing the temperature to 40°C over 8 days. Extracted fauna were then sorted into springtails, oribatid mites, mesostigmatid mites, and other mites, using an Olympus SZX10 dissection microscope and counts converted to individuals m^{-2}. Nematodes were extracted from *ca* 50 g (fresh weight) of gently homogenized soil over three days, using modified Baermann funnels (Baermann, 1917). Extracted nematodes were then sorted into trophic groups based on morphological characteristics under an inverted microscope (Olympus CKX41; up to 400 x magnification), and counts converted to individuals kg^{-1} dry soil. Differences in abundance between treatments were assessed using a one-way analysis of variance. Abundances were log(x + 1) transformed prior to analyses to satisfy assumptions of normal distribution of data. All statistical analyses were performed in SPSS Statistics 22.0 (IBM, USA). Additionally, approximately 50 individuals from ambient and summer drought plots (n = 3 plots for each) were mounted on slides, identified to genus or species level where possible, and used for calculations of nematode community and soil–food-web diagnosis indices using the Nematode INdicator Joint Analysis (NINJA; Ferris et al., 2001; Sieriebriennikov et al., 2014).

Results

There were no significant differences in total or group abundances of microarthropods between treatments (Figure 1a). Similarly, there were no significant differences in total or trophic group abundances of nematodes (Figure 1b). However, the more detailed nematode community analyses of ambient and summer drought plots revealed significant differences between treatments, including lower biomass ($p<0.001$; data not shown), a reduction in plant parasitic feeding guild diversity (Figure 2a) and increased dominance of opportunistic nematodes (i.e. colonizer-persister group 2; Figure 2b) in the summer drought plots. We also observed a lower enrichment index ($p<0.01$) and reduced composite metabolic footprint ($p<0.001$) in the summer drought plots. The enrichment index is a measure of soil nutrient flow calculated using weighted abundances of nematode life history traits (i.e. growth rate, fecundity, life span) and the composite metabolic footprint is a measure of carbon cycling calculated based on known respiration and metabolic rates of nematodes (Ferris et al., 2001).

Figure 1.
Graphs showing average abundances of a) microarthropod groups, and b) nematode trophic group across treatments (mean ± s.e.).

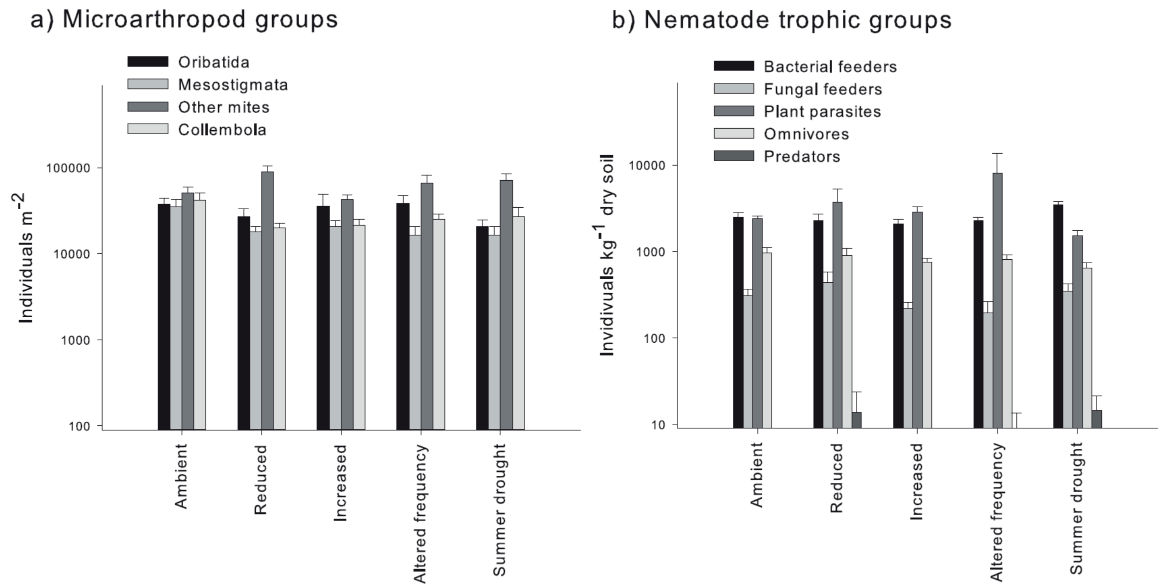
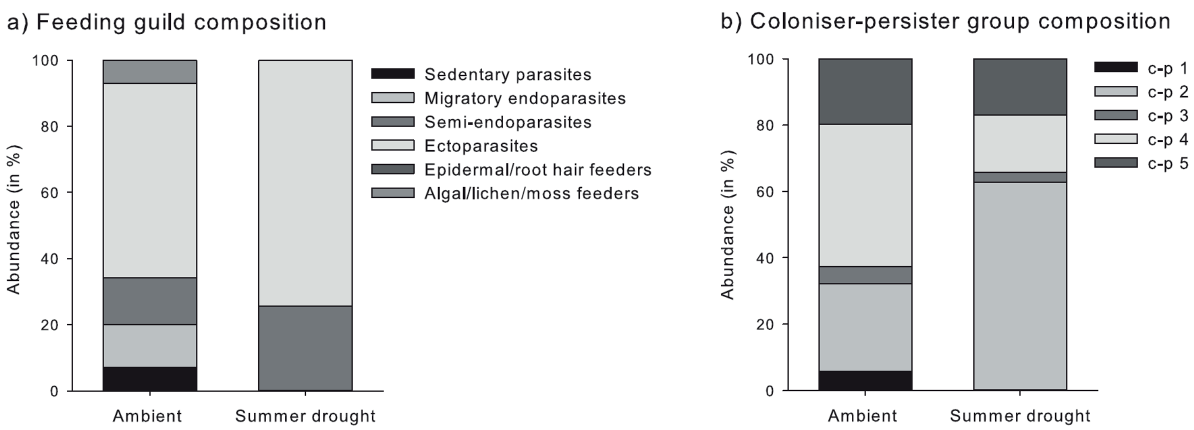


Figure 2.
Graphs showing a) feeding guild composition of plant parasitic nematodes, and b) coloniser-persister group composition of free-living nematodes. Lower c-p values indicate opportunistic genera with short generation time and high fecundity, and higher c-p values indicate persisters with longer generation time and lower fecundity. Genera of c-p 2 are known to be particularly tolerant of adverse conditions (Ferris et al., 2001).



Discussion

Strong rainfall treatment effects on soil properties and vegetation were observed within DRI-Grass at the time of sampling, with a particularly large reduction in soil moisture content and growing season net primary productivity in the summer drought treatment (Power et al., 2016); it was, therefore, expected that these effects would be reflected belowground. We found no significant differences in total or group abundances of microarthropods, or total or trophic group abundances of nematodes, in response to rainfall treatment. However, a more in-depth analysis of nematode community responses to summer drought revealed changes in nematode community structure that indicate changes in soil food web structure and possibly ecosystem function. Similarly, Cesarz et al. (2015) found negative effects of reduced summer precipitation on nematode communities, with functional guilds reflecting changes in soil food web structure and processes. We observed an increased dominance of opportunistic nematode genera of the c-p 2 group in summer drought plots. Genera of this group are generally very tolerant to disturbance and environmental stress (Ferris et al., 2001). We also observed a lower biomass of nematodes and plant parasitic feeding guild diversity in the summer drought plots indicating a change in nematode community composition likely linked to reduced growing season plant productivity (Power et al., 2016). The enrichment and composite metabolic footprint indices have been linked to nutrient availability and soil carbon turnover, respectively (Ferris et al., 2001). The lower enrichment and composite metabolic footprint in summer drought plots thus indicates nutrient depletion and reduced soil carbon flow.

Soil fauna abundances appear to be fairly robust to altered rainfall regimes, but the observed impacts of summer drought on nematode communities indicate that the system has been disturbed. These responses may be amplified over the longer term and could contribute to greater ecosystem sensitivity to human-induced impacts. Hence, there is a need for more long-term studies that investigate global change impacts, including the interactions between multiple global change drivers, to establish general patterns of drought impacts belowground. A theoretical framework that identifies possible mechanisms underlying these patterns should be developed. We stress that nematode communities are sensitive to global change and that shifts in their communities might provide an early 'warning system' for potential ecosystem level tipping points. However, it is clear that high resolution (at least genus level) identification is essential for the use of nematodes as bio-indicators and more research is needed before nematode-based indices can be used confidently for this purpose.

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