



Soil microarthropods are only weakly impacted after 13 years of repeated drought treatment in wet and dry heathland soils



Martin Holmstrup^{a,*}, Jesper G. Sørensen^a, Inger K. Schmidt^b, Pia L. Nielsen^b, Sharon Mason^c, Albert Tietema^c, Andrew R. Smith^{d,e}, Thomas Bataillon^f, Claus Beier^g, Bodil K. Ehlers^a

^a Department of Bioscience, Aarhus University, Vejlsovej 25, 8600 Silkeborg, Denmark

^b Department of Geoscience and Natural Resources, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg, Denmark

^c Earth Surface Science, Institute for Biodiversity and Ecosystem Dynamics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

^d Centre for Ecology and Hydrology, Environment Centre Wales, Deiniol Road, Bangor LL57 2UW, UK

^e School of Environment, Natural Resources and Geography, Bangor University, Bangor LL57 2UW, UK

^f Bioinformatics Research Center (BiRC), Aarhus University, C.F. Møllers Allé 8, 8000 Aarhus C, Denmark

^g Department for Chemical and Biochemical Engineering, DTU – Technical University of Denmark, Anker Engellundsvej 1, DK-2800 Lyngby, Denmark

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ABSTRACT

Studies of biological responses in the terrestrial environment to rapid changes in climate have mostly been concerned with aboveground biota, whereas less is known of belowground organisms. The present study focuses on mites and springtails of heathland ecosystems and how the microarthropod community has responded to simulated climate change in a long-term field experiment. Increased temperature and repeated drought was applied for 13 years to field plots located in Wales, The Netherlands and Denmark representing sites of contrasting climatic conditions with respect to precipitation and temperature. This approach provided an opportunity to study biological responses on a local (within sites) and regional scale. Warming treatments increasing night time temperature (0.3–1 °C higher than ambient at 5 cm soil depth) had no detectable effects on the microarthropod communities. Increased intensity and frequency of drought had only weak persistent effects on springtail species composition, but practically no effect on major mite groups (Oribatida, Prostigmata or Mesostigmata) suggesting that ecosystem functions of microarthropods may only be transiently impacted by repeated spring or summer drought.

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1. Introduction

The climate of northern Europe is undergoing rapid changes characterized by rising temperature and altered precipitation patterns resulting in the more frequent occurrence of drought events (IPCC, 2007a; Orlowsky and Seneviratne, 2012). Several studies have shown the ecological consequences of climatic change by shifting the geographic distributions of many animal and plant species (Parmesan and Yohe, 2003; Sandel et al., 2011; Walther et al., 2002). These climatically driven perturbations may have profound effects on ecosystem functions and biogeochemical processes.

* Corresponding author.

E-mail address: martin.holmstrup@dmu.dk (M. Holmstrup).

Aboveground responses to global change have been intensively studied in terrestrial ecosystems, whereas belowground organisms and processes have received less attention. However, both rising temperature and increased occurrence of drought can directly or indirectly affect the biodiversity and the function of soil fauna (Blankinship et al., 2011; Eisenhauer et al., 2012; Larsen et al., 2011; Petersen, 2011; Swift et al., 1998; Taylor et al., 2004). Recent reports show that species with limited migratory capacity are the most vulnerable to climate change (Sandel et al., 2011). Soil microarthropods, which we are concerned with in the present study, have only limited capacity to actively migrate over long distances and may therefore be at particular risk in a climate change scenario. In the present study we report responses to predicted future climate change scenarios of soil microarthropods of temperate heathland ecosystems.

Microarthropods (here: springtails and mites) can be very abundant in decomposer communities of temperate heathland

ecosystems, and in many cases they have important roles in the trophic relationships of soil communities, as in heathlands the functional role of earthworms and macroarthropods in decomposition processes are often reduced (Bardgett, 2005; Petersen and Luxton, 1982; Scheu, 2002). Springtails and oribatids are important grazers of fungi and contribute to fragmentation of dead plant material thereby enhancing decomposition processes in the soil (Faber, 1991; Seastedt, 1984; Verhoef and Brussard, 1990). Further, predacious soil mites exert top-down control of secondary decomposer organisms which can also have influence on decomposition rates (Hedlund and Öhrn, 2000; Karg, 1961; Koehler, 1997). Thus, assessment of effects on microarthropods is needed to improve the understanding of ecological effects of future climate change.

Short-term laboratory experiments suggest that euedaphic springtails (i.e. those living in the deeper soil layers) may have little resistance to evaporative water loss compared to epedaphic springtails (those species living on the soil surface). However, they can be equally tolerant to drought conditions in the soil (Kærsgaard et al., 2004), and may not experience as harsh drought as surface dwelling species due to their deeper distribution in the soil profile (Haarlov, 1955). Many soil mites, in particular Oribatids, have a rather impermeable exoskeleton and are even more resistant to desiccation than springtails (Madge, 1964; Vannier, 1987). Nevertheless, field experiments have shown that both springtails and mites are reduced during drought conditions (Lindberg et al., 2002). In general, most field and semi-field studies show that microarthropods are negatively influenced by reduced precipitation, whereas ecologically relevant warming treatments have little, if any, effect on microarthropods (see meta-analysis by Blankinship et al. (2011)). Long-lasting impacts of an increased frequency and intensity of drought events (as predicted by climate change scenarios) on the community structure of microarthropods have rarely been studied in field trials as the current body of evidence is skewed towards experiments of short duration, or assessments have been made shortly after drought treatments were terminated (Eisenhauer et al., 2012; Lindberg et al., 2002). However, predictions of the consequences of climate change should rely on long-term experiments. Indirect effects mediated through changes in vegetation composition or net primary productivity may alter the quality and quantity of substrates entering the soil (e.g. changes in root exudation and litter production) which may take several years to become established (Peñuelas et al., 2007; Prieto et al., 2009). Assessments of ecological effects should reflect both immediate effects during stressful conditions (e.g. extreme drought), but also the situation when the microarthropod communities have had the possibility to recover in-between repeated drought treatments (see e.g. Holmstrup et al. (2012)).

The present study utilises the EU FP7-INCREASE infrastructure to assess the long-term response of the microarthropod community to simulated climate change in a field setting. The INCREASE infrastructure project provides a platform to investigate the impact of simulated future climate change scenarios at three climatically contrasting sites in north-western Europe. Further details are described elsewhere (Beier et al., 2004; Emmett et al., 2004), and at the project homepage (www.increase-infrastructure.eu). Passive night-time warming and drought experimental treatments have been applied since 1999 providing a unique opportunity to study the long-term impact of climate change on the shrubland ecosystems on a local (within site) and regional scale. Our main hypothesis was that increased occurrence of drought has had higher impact than warming, and that drought has decreased both abundance and species richness of microarthropods.

2. Materials and methods

2.1. Study sites and experimental treatments

The study was carried out at three heathlands located near Cloacaenog Forest in NE Wales (Cloacaenog), near the town of Oldebroek in the central part of The Netherlands (Oldebroek) and in Mols, East Jutland, Denmark (Mols). The dominant plant species at Cloacaenog and Oldebroek sites was *Calluna vulgaris*, while at the Mols site the grass *Deschampsia flexuosa* was co-dominant with *C. vulgaris*. The soil at Cloacaenog was an organic-rich humo-ferric podzol, and sandy podzols at Oldebroek and Mols. Soil pH was similar in all the sites being approximately 3.9. The water table was below the root zone of the plants at all three sites. Further details of the locations and description of the sites are given in Sowerby et al. (2008) and Beier et al. (2009).

Field scale experimental manipulations of temperature (warming) and drought were initiated in three replicated 20 m² (4 × 5 m) plots of each site in 1999. The experiments were laid out in randomized block designs at each site. Light scaffolding was built over both the control, warming and drought plots, to ensure that any impact from the scaffolding (e.g. shading and sheltering) occurred in all three treatments. The warming treatment was achieved using a passive night-time warming method designed to mimic an increased minimum night temperature rather than the general diurnal temperature. Predicted global warming is expected to occur both during night-time and day-time, and it has been shown that over land, average minimum night-time temperatures have increased at twice the rate of day-time maximum temperatures (IPCC, 2007b). These increases in minimum (night-time) temperature are related to increased cloudiness (Alward et al., 1999). The advantage of passive night-time warming is that it minimizes unintended artifacts with respect to water balance, moisture conditions and light (Beier et al., 2004). The warming system infrastructure was identical to the drought plots differing only in the roof material which was made of high-density polyethylene mesh, capable of reflecting 97% of direct infrared radiation and 96% of diffuse infrared radiation. The warming roofs were extended over the plots at night when light intensities fell below 0.4 W m⁻², but were retracted during rain events to reduce artefacts to a minimum. Drought treatment was imposed for 1–2 month periods in the spring/summer seasons (at Cloacaenog an extended drought from May to September) from 1999 to present. Rain exclusion was achieved using an automated system that extended a transparent waterproof material over the plots creating a roof during rain events greater than 0.2 mm (Beier et al., 2004). In order to reduce experimental artefacts introduced by changes in wind, temperature and light conditions, the drought plot covers were retracted immediately after rain events. For the part of year without drought treatment, the drought plots were managed identically to the control plots. Soil temperature and moisture was measured using in-situ thermocouple and time domain reflectometry sensors installed 5 cm below the soil surface, sensor data was recorded on an hourly basis using CR1000 data loggers (Campbell Scientific Ltd, UK).

2.2. Sampling of soil microarthropods

Microarthropods were sampled in late April and early May, 2011, before the drought treatment of that year. In order to reduce edge effects as much as possible the samples were taken at random, but within a 50 cm buffer of the plots. For this purpose a cylindrical soil corer with an inner diameter of 6 cm was used. Two samples were taken randomly from each plot to a depth of 10 cm. At Cloacaenog and Oldebroek samples were taken adjacent to *Calluna* plants

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