Applied Soil Ecology 121 (2017) 20–30

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Badger (*Meles meles*) disturbances affect oribatid mite (Acari: Oribatida) communities in European temperate forests

Kaja Rola[a], Przemysław Kurek[b], Piotr Skubała[c,*]

[a] Institute of Botany, Jagiellonian University, Kopernika 27, 31-501 Kraków, Poland
[b] Department of Plant Ecology and Environment Protection, Faculty of Biology, Adam Mickiewicz University, Umultowska 89, 61-614 Poznań, Poland
[c] Department of Ecology, Faculty of Biology and Environmental Protection, University of Silesia, Bankowa 9, 40-007 Katowice, Poland

ARTICLE INFO

Keywords:
Forest soil
Disturbance
Soil patchiness
Community structure
Ecological groups

ABSTRACT

Burrowing mammals living in forests are one of the important disturbance factors driving changes in species community and diversity on the forest floor. In the present study we examined the impact of soil mounds created by badgers (*Meles meles*) on species richness and the community structure of oribatid mites, which constitute one of the most numerous components of soil mesofauna. We compare oribatid communities between forest soils disturbed by badgers in 1-year-old mounds and 5-year-old mounds as well as undisturbed forest soil to get an insight into the direction of temporal changes. The study plots were situated in pine forests within the Kampinos Forest (Poland). The soil parameters created by badgers and ecological groups in the oribatid fauna were analysed. The results showed that distinct oribatid communities occur in badger mounds when compared with adjacent undisturbed forest soil. It appeared that badgers have the potential to substantially affect the soil environment in forest ecosystems and finally influenced mite abundance and community composition. Initial badger disturbance caused a significant decline in the abundance and biodiversity of oribatid mites, but within a few years the oribatid fauna was restored. Our results supported the intermediate disturbance hypothesis. Badger activity affected the composition of ecological groups of mites, toward surface dwelling, primary decomposers and sexually reproducing species. It can be concluded that badger mounds serve as microhabitats for some soil mites and contribute to the patchiness and heterogeneity of the forest floor. Finally, oribatid community structure proved to be a good indicator of soil disturbance caused by mammal activities involving deep digging in soil and heaping mounds in temperate forests.

1. Introduction

It is widely believed that the key to ecosystem diversity is habitat heterogeneity (Freemark et al., 2002; Benton et al., 2003; Hoste-Danyłow et al., 2010) which typically depends on the presence of many marginal habitat patches. Disturbances in forests constitute a major force influencing, even determining, the structure and functions of populations, communities and ecosystems. The ability to stand a disturbance without loss is defined as resistance, whereas resilience is the ability to recover from a disturbance after incurring losses, which may be considerable (Attiwill, 1994; Lake, 2013). A certain degree of disturbance can affect species numbers positively ("intermediate disturbance hypothesis"). Connell (1978) postulated that intermediate degrees of biotic or abiotic disturbances reduce the intensity of competition between species and hence the competitive exclusions of species. Disturbance is a key process in understanding density and diversity of plant and animal species (Pickett and White, 1985). Soil mixing and displacement by living organisms, called bioperturbation, are examples of biotic disturbances in forest ecosystems. Ecosystem engineers were defined by Jones et al. (1994) as organisms that indirectly or directly affect the availaby of resources to other organisms through modifications of the physical environment. They can alter fundamental soil properties such as porosity, particle-size distribution or nutrient contents (Wilkinson et al., 2009).

Burrowing mammals living in forests are one of the important disturbance factors driving changes in species community and diversity on the forest floor (Brown, 1995; McLean and Parkinson, 1998; Kurek et al., 2014a, 2014b; Kurek and Cykowska-Marzencka, 2016). They create patches of freshly disturbed soil through their digging and burrowing activities (Pickett and White, 1985). Eurasian badger (*Meles meles*) is known for intensive soil exploitation, especially when badgers live in big social groups. The badger activity associated with the digging of setts simultaneously causes various soil disturbances such as mounds, well-trodden paths and latrines (Neal and Roper, 1991; Kowalczyk

* Corresponding author.
E-mail address: piotr.skubala@us.edu.pl (P. Skubała).

http://dx.doi.org/10.1016/j.apsoil.2017.09.013
Received 14 June 2017; Received in revised form 1 September 2017; Accepted 6 September 2017
Available online 22 September 2017

et al., 2004). The size of a disturbed area ranges from tens to hundreds of square meters (Obidziński et al., 2013). Such small and patchily distributed disturbances are thought to be the main factors influencing soil characteristics and vegetation, driving changes in soil physical and chemical properties and are usually noted as having a positive impact on the richness of herbaceous plant species (e.g. Goszczyńska and Goszczyński, 1977; Alkon, 1999; Whitford and Kay, 1999; Canals and Sebastiá, 2000; Kerley et al., 2004; Bruun et al., 2005; Obidziński and Głogowski, 2005; Eldridge and Whitford, 2009; Whitford and Steinberger, 2010; Kurek et al., 2014a, 2014b; Fedriani et al., 2015). Our study concerns dome-shaped soil mounds built at burrow entrances. It has been shown that buried sandy mounds among badger setts cause great habitat heterogeneity in forests and, they increase species diversity of bryophytes and vascular plants (Kurek et al., 2014a, 2014b; Kurek and Cykowska-Marzencka, 2016). Since badgers are real ecosystem engineers, completely overturning soil, their activity alters local habitat conditions and modifies some topsoil chemical properties (Kurek et al., 2014a, 2014b). Thus, it could be assumed that burrowing animals could have an impact not only on organisms living on the soil surface, but also on soil fauna.

The oribatid mites are numerically dominant in mature forest soil and are "key industry" animals due to their relative abundance as compared to other soil arthropods (Wallwork, 1983). They form a gradient from phytophagous species over primary and secondary decomposers to predators and scavengers (Schneider et al., 2004). In forest ecosystems they play an important role in organic matter decomposition and nutrient cycling − two key processes of ecosystem functioning (Luxton, 1981). Oribatids are connected with primary decomposers through complex bottom-up and top-down effects (Marshall, 2000). Among soil decomposing invertebrates, oribatid mites representthe quite striking group with an estimated 10% of all species reproducing via parthenogenesis (Cianciolo and Norton, 2006), which is generally assumed to facilitate establishment of populations (Norton, 1994) and fast recovery after disturbance (Prinzing et al., 2002; Lindberg and Bengtsson, 2005). Apart from fundamental biotopes of oribatid mites, they also utilize products associated with the activity of mammals and birds, e.g. burrows and nests, as habitats.

Oribatid mites serveas a pivotal element in detrital food chains (Lebrun, 1979) and can be used as indicators of changes in the environment (e.g. Niedbała, 1983). It is believed that oribatid mites are representatives of soil mesofauna that are highly sensitive to soil disturbance and unfavorable soil conditions (Wallwork, 1983; Norton and Palmer, 1991). Their low metabolic rate, slow development and low fecundity (for sexual species) are characteristics that render them unable to respond quickly to short-term hard stresses (Behan-Pelletier, 1999). Several studies tried to determine the changes in oribatid communities caused by various kinds of disturbance in forest habitats (e.g. Marra and Edmonds, 1998; Maraun et al., 2003; Battigelli et al., 2004; Lindo and Visser, 2004; Cameron et al., 2013). Studies on bioturbation by earthworms proved that densities of most groups of oribatid mites declined in disturbance treatments (McLean and Parkinson, 1998; Scheu et al., 1999; Maraun et al., 2001, 2003; Starý and Pižl, 2007). Silvicultural practices proved to reduce oribatid mite species richness and changed the structure of their communities (Battigelli et al., 2004; Berch et al., 2007). Similarly different intensities of agricultural disturbances change the community structure of oribatid mites (Crossley et al., 1992; Scheu and Schulz, 1996; Maraun and Scheu, 2000; Cole et al., 2008). Different authors underlined that the effect of bioturbators on oribatid mites in forest soils is more complicated and specifically dependent on the autecology of individual oribatid species (McLean and Parkinson, 1998; Maraun and Scheu, 2000). According to our knowledge the mite fauna in the products of badger activity has not been the object of acarologists' research so far.

In the present study we examined the impact of badger mounds on species richness and the structure of oribatid communities. We compare oribatid communities between forest soils disturbed by badgers in fresh, at most 1-year-old mounds and formerly created, approximately 5-year-old mounds as well as undisturbed forest soil to get an insight into the direction of temporal changes. We also aimed at linking the changes in the soil parameters in the mounds generally recognized as affecting soil mites with the changes in the structure of oribatid mites communities. This study was designed to test the following hypotheses: (1) Bioturbation by badgers reduces locally the abundance and species richness of Oribatida; (2) Oribatid mite communities differ between badger mounds and typical forest soil, and some species show preference for one of the habitats; (3) Surface dwelling, eurytopic, primary decomposers and parthenogenetic species significantly increased at sites disturbed by badgers.

2. Materials and methods

2.1. Study area

The study was done in the Kampinos Forest, one of the largest (ca. 385 km^2) lowland forests in central Poland. It is situated in the Vistula River Valley, north-west of Warsaw (52.26°–52.40° N, 20.28°–20.88° E; 68–106 m a.s.l.). A transitional climate (with continental and marine influence) dominates here, with weather conditions being highly variable across months and years. The average annual temperature is 7.7 °C, and average annual precipitation amounts to 546 mm (Andrzejewski, 2003). Sand of glaciofluvial and fluvial origin is the dominant substrate. A large part of the terrain is formed by wind-blown sand, creating dunes overgrown mostly with pine and mixed oak-pine forests. We searched for badger burrows (as presented in: Kurek, 2011; Kurek et al., 2014a, 2014b; Kurek and Cykowska-Marzencka, 2016) over the entire forest area during the 2009–2011 spring seasons. The burrows were identified as badger setts from observations of tracks, evidence of burrow cleaning, paths, and the animals themselves (Kowalczyk et al., 2000). In 2015 we randomly selected 14 badger burrows to establish our study plots.

2.2. Sampling design and data collection

The study plots were situated in mixed oak-pine forests within a compact forest patch. We analysed three types of study plots: 1-year-old mounds (M1) that are freshly raised mounds which were shaped by badgers not earlier than the last year, characterized by bare soil, not trodden and not covered by plants; 5-year-old mounds (M5) that were shaped about 5 years ago with trodden soil mostly covered by vascular plants and bryophytes (data from personal observations) and control plots (C) representing the same type of habitat, but having no visible signs of animal-caused disturbance. Control plots were established 50 m away in a random direction from badger setts. Each plot has an area of 5 m^2 ($r = 1.26$ m). We collected a total of $N = 3$ sites × 14 samples = 42 soil samples to a depth of 7 cm for extraction and species identification of mites and further 42 samples for soil chemical analysis. Soil samples were taken after removing the part of organic horizon consisting of visually recognizable fresh organic residues of litter. Each soil sample (ca. 250 cm^3) constituted composite soil material that was mixed from three subsamples collected at a particular study plot.

2.3. Extraction and species identification

We extracted mites (Acari) by placing 274 ± 8.5 g of soil (mean ± S.E., dry weight) in Berlese modified Tullgren funnels. Mites were extracted over six days. Mites were fixed in 75% ethyl alcohol. Oribatid mites were further identified to a species level. When possible, oribatid juveniles were also identified, counted and added to the respective adults. The classification proposed by Weigmann, (2006) was followed. The identification of oribatid mites to species was based on the following authors: Olszanowski, (1996), Weigmann, (2006) and Niedbała, (2008). All observations were performed on specimens