SOIL ORGANISMS 92 (2) · August 2020 pp. 109–119

Addition of polyester in soil affects litter decomposition rates but not microarthropod communities

Carlos Barreto[1,2,*], Matthias C. Rillig[2,3] and Zoë Lindo[1]

[1] Department of Biology, The University of Western Ontario, 1151 Richmond Street, N6A 3K7 London, Ontario, Canada
[2] Freie Universität Berlin, Institut für Biologie, Plant Ecology, Altensteinstraße 6, 14195 Berlin, Germany
[3] Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Königin-Luise-Str. 2-4, 14195 Berlin, Germany
* Corresponding author: cbarreto@uwo.ca

Received 23 April 2020 | Accepted 30 June 2020
Published online at www.soil-organisms.de 1 August 2020 | Printed version 15 August 2020
DOI 10.25674/so92iss2pp109

Abstract

Microplastics are defined as plastic particles that are <5mm. Manufactured in the production of many commercial products, microplastics have become an environmental threat for many organisms. Microplastics can be highly abundant in soil, and given their size, can interact with soil microarthropods. But how microplastics affect soil-dwelling organisms (mites and collembolans) and their role in ecosystem services such as decomposition is largely unknown. We studied the effects of polypropylene and polyester microfibers of two different lengths (2–3mm and 5–6mm) on microarthropod communities and decomposition rates in a sandy soil. Microplastic addition showed no effects on soil microarthropod communities for the groups Oribatida (abundance and species richness), Prostigmata, Astigmata and Mesostigmata, Collembola, nor other invertebrates present in the soil samples (abundance), and no significant differences were found on feeding rates measured by bait-lamina sticks. Permanova results for microarthropod community structure among treatments were not significant, although non-metric multidimensional scaling analysis (NMDS) found that communities were less similar to one another in polypropylene addition treatments compared to polyester addition and to control treatments. However, the addition of microplastics in the soil did affect litter decomposition rates for litterbags on the soil surface; higher mass loss (i.e. decomposition) was found in polyester treatments compared to control and polypropylene treatments, regardless of the length of the fibers. This study is the first to test the effects of microplastics on soil microarthropod communities, and we find no direct negative effects of microplastic addition.

Keywords microplastics | litterbags | bait-lamina-test strip | Acari | soil organisms

1. Introduction

With the fate of globalization and a consequent increase on the dependence of society on plastics, this material can be found virtually everywhere, from fresh waters (Mason 2019) and marine environments (Andrady 2011), to soils (Dioses-Salinas et al. 2020) and air (Bergmann et al. 2019). Different types of plastics are used in a vast array of products due to their durability, lightness, stability, and low cost (Shen et al. 2020). Despite their benefits, plastic pollution is an environmental issue worldwide, and numbers are quite impressive, with more than 240 million tons of plastic estimated to be used annually (Thompson et al. 2009). In just a few years, the production of plastics has spiked to 380 million tons and the total amount produced until the year 2015 has been estimated to exceed 8300 million tons (Geyer et al. 2017). Same authors estimated the global plastic waste to be 6300 million tons between 1950 and 2015, from which 79% has accumulated in landfills and other environmental compartments, rendering plastics a major environmental issue.

ISSN 1864-6417 (print) · **ISSN** 2509-9523 (online)

The term microplastics was first coined by Thompson et al. (2004) for the microscopic pieces of plastics found in European waters. Since then, its definition has changed (Arthur et al. 2009, Cole et al. 2011, GESAMP 2015, 2016), but the most common iteration of microplastics is by Arthur et al. (2009), that considers microplastics as plastic particles smaller than 5mm. Several studies have adopted this definition (e.g. Rillig 2012, Duis & Coors 2016, Rillig et al. 2017), even though the concept of microplastics is subject to intense discussion (see Frias & Nash 2019, Hartmann et al. 2019, Kooi & Koelmans 2019).

During the past 50 years, the effects of microplastics have been extensively studied in aquatic systems, with the first pieces of evidence of pollution by plastics dating back to the 70's (see Buchanan 1971, Colton et al. 1974). Studies on microplastics have largely investigated their effects on marine organisms and the possibility of transfer through the food chain (Wright et al. 2013, Ivar do Sul & Costa 2014, Duis & Coors 2016), with potentially serious consequences to life on land as well. Furthermore, microplastic contamination on land is suggested to be 4-23-fold larger than in the ocean (Nizzetto et al. 2016a,b). Among organisms that live in soil, specific groups like earthworms have been studied in depth (see Gaylor et al. 2013, Huerta Lwanga et al. 2016, Cao et al. 2017, Hodson et al. 2017, Rodriguez-Seijo et al. 2017, Rodríguez-Seijo et al. 2018), while other groups like microarthropods such as oribatid mites (Acari: Oribatida) and springtails (Collembola) have not (but see Selonen et al. 2020, and Zhu et al. 2018b, Ju et al. 2019, Kim & An 2019, Selonen et al. 2020, respectively). The consequences of microplastic contamination in soil systems on soil organisms are yet not well understood, but inhibition of growth, increased mortality, and detachment or atrophy of the gut epithelium have been observed in the earthworm *Eisenia andrei* Bouche, 1972 (Rodriguez-Seijo et al. 2017).

Microplastics may cause changes within the soil food web as they can be small enough to potentially be ingested by microarthropods, which may lead to accumulation in different trophic levels (Huerta Lwanga et al. 2017) with potentially cascading consequences at the ecosystem level, for instance, through altering nutrient cycles, carbon storage and decomposition rates. Other potential negative effects of microplastics on soil microarthropods are determined through changes in soil properties (de Souza Machado et al. 2018b). Alternatively, it is possible that microplastics impact soil organisms directly through sorbing pollutants on their surfaces, which makes them toxic (Rillig 2012).

Since Rillig (2012), increasing evidence has shown that microplastics are ubiquitous in soils and are largely influenced by anthropogenic activities including the application of biosolids and mulching with plastic films in agriculture (Duis & Coors 2016), domestic sewage (Mason et al. 2016), fertilizers (Nizzetto et al. 2016a), tire abrasion (Wagner et al. 2018), and atmospheric particles transported over long distances (Dris et al. 2016). With a multitude of paths for soil pollution by microplastics, many species that depend on soils for their survival are under potential threat (de Souza Machado et al. 2018a).

The persistence of microplastic pollution in soil systems might qualify these particles to be drivers of environmental change, since they affect soil bulk density, water holding capacity, soil aggregate formation, soil porosity and soil structure (de Souza Machado et al. 2018b, Lehmann et al. 2019), increase soil water evaporation (Wan et al. 2019), besides serving as vectors for metal exposure in soils (Hodson et al. 2017). Considering that soil fauna is exposed to these changes in soils, and at the same time, are involved in ecosystem processes, like decomposition, that occur in soil systems, it is important to investigate the impacts of microplastics on microarthropod communities. Here, we used polyester and polypropylene microfibers in two different lengths each added to meadow soil in a microcosm experiment to determine whether microplastic addition have effects on litter decomposition rates, soil fauna feeding rates, and soil microarthropod community structure.

2. Materials and methods

Study site

The test soil used in this microcosm experiment was a loamy sand soil collected in a meadow at Freie Universität Berlin – Institute of Biology (52.45°N, 13.30°W; Berlin, Germany) in June 2019. Berlin has a moderately continental climate (Cfb in the Köppen Climate Classification), with mean annual temperature of 9.1°C and a precipitation of 570 mm (climate-data.org 2019).

Soil (an Albic Luvisol, including the litter layer) was collected manually using shovel and hand trowel to sample the top 10cm of a 1×0.5m plot. Roots thicker than 1cm and aboveground vegetation were removed. After collection, the soil was kept at ambient temperature for 24 hours until the microcosms were prepared and established. Leaves of *Plantago lanceolata* L. were handpicked from the same location to be used as substrate in litterbags, since this is a very common species in our site. Leaves were dried in the oven at 60ºC for 72 hours.

Before the microcosms were established, in order to characterize the soil and the litter used in the litterbags, we homogenized both soil and litter samples, separately,

using a mixer mill for three minutes (Retsch MM400). Carbon (C) and nitrogen (N) contents from the initial homogenized soil and litter samples (six soil and six litter samples) were analyzed using a combustion autoanalyzer (EuroVector EA3000 Elemental Analyzer) to determine carbon and nitrogen contents. Soil samples had on average 0.2g N / 100g soil dw, 60°C and 3.39g C / 100g soil dw, 60 °C and litter samples had 1.33g/100g N and 44.12g/100g C. Moisture content of initial soil was measured as the difference in mass of the soil samples prior to and following samples were put in the oven at 60ºC for 72 hours; this was on average 12.1 % dry weight (dw). The pH from six soil samples was measured in a weak solution of calcium chloride (0.01 M $CaCl_2$) and this was on average 6.81.

Experimental design

Soil from the meadow was homogenized by hand and used to fill 50 microcosms [100.01g ± 0.005g SE wet weight (ww)] in 550ml mason jars that were placed in a climate chamber at 24°C in the dark during four weeks at the Institut für Biologie, Plant Ecology at Freie Universität Berlin. All microcosms had a rectangular hole (2.5 × 1 cm) with a small piece of foam inserted in the lid to allow air exchange and prevent organisms from leaving the system. Two different types of microfiber plastics cut to two different lengths were considered as treatments, making a nested statistical experimental design (i.e. the two different lengths were nested within each of two different plastic types). The microfibers were created by manually by cutting 100 % polyester (PE) white 'Paraloc Rope' (product number 8442173, Mamutec), and 100 % polypropylene (PP) orange 'Paraloc Rope' (product number 8442202, Mamutec) to a length of either 2–3mm or 5–6mm; the average diameter of fibers was 22.92 ± 0.17 µm for PE and 33.33 ± 0.07 µm for PP fibers. Fibers were manually separated before mixing into the soil to help achieve an equal distribution. The amount of microplastics added was 0.4 % of the soil dry weight (0.351–0.352g) mixed over a period of 90 seconds; each microplastic type was added separately. We also manually mixed the soil in control microcosms to create the same disturbance applied to the microplastic addition treatments. The amount of microplastics added is based on de Souza Machado et al. (2018b) and corresponded to the maximum amount of linear microplastic fiber addition that caused minor changes in soil volume in that study.

Each microcosm also contained one bait-lamina test strip with bait substrate (Terra Protecta GmbH, Berlin, Germany) that was vertically inserted in the soil at the start of the experiment, and one litterbag (5cm × 5cm with 1mm mesh, average weight 0.3g) containing oven-dried leaves of *Plantago lanceolata* L. that was placed on the top layer of the soil inside each jar. Soil moisture content was maintained in the microcosms gravimetrically during the experiment with deionised H_2O added equal to the weight lost during each week, meaning that water content was kept at the level of sampling. The experiment was built as a nested design with 10 replicates per treatment (n=10 for fiber-less control and n=10 for each of the four plastic addition treatments, i.e. two lengths for each fibre type). Microcosm setup sequence and jar location in the climate chamber were randomized, and the experiment lasted four weeks.

Variables measured

Decomposition rates were measured by mass loss from the litterbags (on soil surface) using the following equation:

$$Mass\ loss = \frac{initial\ dry\ weight\ (g) - final\ dry\ weight\ (g)}{initial\ dry\ weight\ (g)} \times 100$$

Feeding activity of microbial and microarthropod communities was measured as a proxy for biological activity with bait-lamina tests (Kratz 1998) (in soil profile) following the equation:

$$Feeding\ rate = \frac{number\ of\ holes\ with\ entirely\ consumed\ bait}{total\ number\ of\ holes\ inserted\ in\ soil}$$

Soil fauna were extracted from the soil using a modified MacFadyen apparatus into 75 % EtOH at the end of the experiment. The MacFadyen apparatus extracts fauna from soils by creating a temperature/moisture gradient, inducing the soil fauna to actively move lower into the soil profile, and where the bottom of the sample container is mesh, allowing the fauna to pass through and into the EtOH collection. The temperature/moisture gradient was established by increasing the temperature of the extraction chamber in +3°C increments from 30°C to 50°C over a period of one week. Microarthropods collected in EtOH were sorted into major taxonomic groups and counted under a dissecting microscope. As the dominant group, oribatid mites (Acari: Oribatida) were identified to the species level, where possible using descriptions from (Weigmann 2006, Bayartogtokh & Schatz 2008, Krantz & Walter 2009, Seniczak et al. 2015). Representative oribatid mite specimens were slide mounted using Hoyer's medium for the identification process under 200-600× magnification.

Statistics

All analyzes were conducted in R using RStudio (version 1.1.463) and results were considered significant at $P<0.05$. Because the experimental design was nested, and in order to account for microfiber length effects, we initially tested the effects of microplastic type (polyester and polypropylene) and microfiber length (2–3mm and 5–6mm) on Oribatida richness, decomposition rates (as measured by mass loss) and feeding activity (measured as consumed substrate in bait-lamina) using a nested Anova. As no significant effects of fiber length (Oribatida richness $F_{2,45} = 0.345$, $P= 0.71$, decomposition rates $F_{2,45} = 3.115$, $P= 0.06$, and feeding activity $F_{2,45} = 0.671$, $P = 0.51$) were detected, we grouped treatments by plastic type only (i.e. control, polyester, polypropylene). Oribatida richness, decomposition rates, and feeding activity were then analyzed for differences between plastic treatments using a one-way type II Anova (control, polypropylene, polyester treatments) to account for the unbalanced design. Tukey HSD post-hoc test was applied where applicable.

To further evaluate the total number of Oribatida (adults + immatures), and the abundance of immature Oribatida, adult Oribatida, Collembola, Mesostigmata, Prostigmata, Astigmata, Acari (all mites together), 'other' invertebrates, as well as total microarthropod abundance based on treatments (plastic type, microfiber length) (all standardized by # ind. g^{-1} dw), we used the package 'mvabund' (Wang et al. 2012) to create univariate generalized models. It returns a table summarising the statistical significance of a fitted manyglm model (Warton 2011). This package allows us to overcome the statistical issues that occur with a high number of zeros (Wang et al. 2012), which is a common feature in ecological community data (i.e. not all species will occur in all samples). The models were conducted using the {anova.manyglm} function assuming a negative binomial distribution, resampled 999 times (Warton 2011) to test whether there is significant treatment effect.

Microarthropod community composition was assessed using nonmetric multidimensional scaling (NMDS) (Clarke 1993) with Permanova to compare community structure among treatments (in this case, plastic addition and microfiber length). To further describe the oribatid mite community, we ran correspondence analysis (CA), an ordination technique that plots species in multivariate space and allows inferences about how much of the variation in the dataset can be explained by treatments (Deville & Saporta 1983). In the CA plot, the closer the samples are to one another, the more similar they are in terms of their residuals. The same applies to species with other species in ordination space. Comparisons between samples and species are based on the angle between the lines from the origin to the location of a sample and of a species; the smaller the angle, the higher the association (0 to 90 degrees).

3. Results

Decomposition and feeding rates

Microplastic type had a significant effect on the rate of decomposition measured as percent mass loss in litterbags ($F_{2,47} = 4.83$, $P = 0.01$), with the highest mass loss observed in polyester-addition (0.11g lost on average), followed by polypropylene-addition (0.09g lost on average) and control (0.08g lost on average) (Tukey HSD, $P = 0.02$) (Figure 1). Microplastic addition ($F_{2,47} = 0.40$, $P = 0.67$) showed no significant effect on feeding activity in the soil profile measured as the number of consumed baits in a bait-lamina. The soil microarthropod community exhibited very low feeding activity assessed in bait-laminas, with only nine of the 50 laminas having baits entirely eaten, with an average 1.4 baits/lamina consumed.

Microcosm microarthropod diversity

We identified eight species of oribatid mites at the end of the experiment: *Tectocepheus velatus* (Michael, 1880), *Oppiella nova* (Oudemans, 1902), *Moritzoppia unicarinata* (Paoli, 1908), *Suctobelbella* sp., *Scheloribates* sp. nr. *laevigatus*, *Minuthozetes semirufus* (C.L. Koch, 1841), *Trichoribates* cf. *novus* and *Eupelops* cf. *curtipilus* (Table S1). Oribatida species richness was not significantly affected by microplastic addition ($F_{2,47} = 1.53$, $P = 0.22$).

In total, 2663 oribatid mite specimens were collected, of which 1454 were immatures. Oribatid mites were the most abundant group across all treatments; their total abundance, including immatures, represented 86% in control, 90% in polypropylene 2–3mm, 94% in polyester 2–3mm, 88% in polypropylene 5–6mm and 90% of total abundance in polyester 5–6mm microcosms. The abundance of all individuals of oribatid mite (adults and immatures together) was not significantly affected by microplastic addition (LRT = 37.79, $P = 0.47$) or microfiber length (LRT = 54.15, $P = 0.28$) based on the mvabund analysis. The abundance of immatures did not significantly differ with plastic addition (LRT = 6.36, $P = 0.58$) or microfiber length (LRT = 14.98, $P = 0.22$). Microplastic addition (LRT = 31.42, $P = 0.46$) and microfiber length (LRT = 39.17, $P = 0.36$) did not have any significant effect on the abundance of adult oribatid mites.

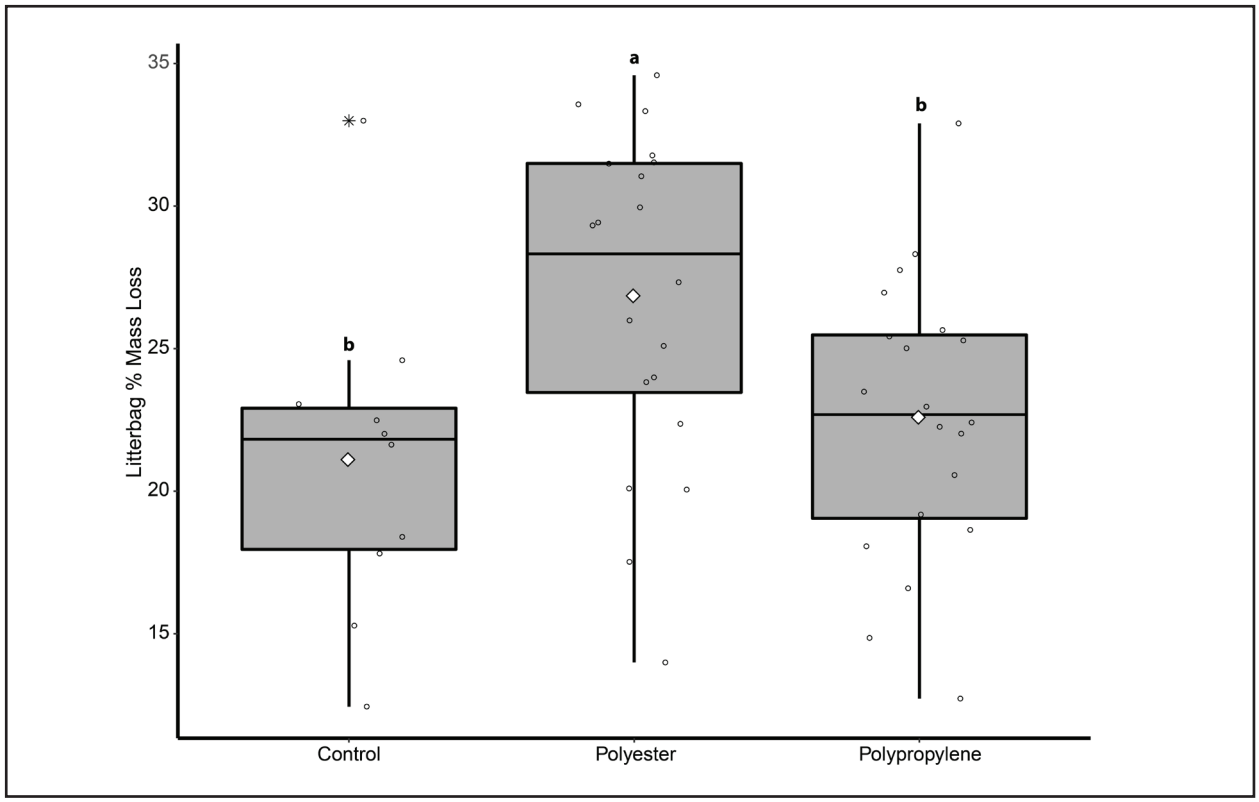

Figure 1. Boxplot of the litter decomposition measured as litterbag % mass loss after four weeks of experiment in control and microplastic-addition treatments. Values are averaged over two microfiber lengths (2–3mm and 5–6mm) for plastic-addition treatments. Sample sizes were n=10 for control, n=20 for polyester and polypropylene. Lower and upper box boundaries are 25th and 75th percentiles, respectively; the line inside box is the median, asterisk refers to data falling outside the 90th percentile (outlier) and the diamond shape is the mean. Open circles represent samples. Different letters above whiskers mean significant differences based on Tukey HSD post hoc test.

Microplastic addition had no significant effects on Collembola abundance (LRT = 9.57, P = 0.30), Mesostigmata abundance (LRT = 20.04, P = 0.13), Prostigmata abundance (LRT = 7.61, P = 0.11), Astigmata abundance (LRT = 2.34, P = 0.50), Acari abundance (LRT = 67.78, P = 0.36), other invertebrates abundance (LRT = 23.14, P = 0.24) and total microarthropod abundance (LRT = 100.5, P = 0.37).

In addition, microfiber length did not have significant effects on Collembola abundance (LRT = 8.10, P = 0.41), Mesostigmata abundance (LRT = 23.17, P = 0.06), Prostigmata abundance (LRT = 4.67, P = 0.38), Astigmata abundance (LRT = 6.02, P = 0.13), Acari abundance (LRT = 88.03, P = 0.18), other invertebrates abundance (LRT = 28.22, P = 0.08) and total microarthropod abundance (LRT = 124.3, P = 0.15).

Community composition

Permanova results were not significant for the effect of microplastic addition ($F_{2,47}$ = 1.11, P = 0.31) on microarthropod communities, although the NMDS plot demonstrates communities were less similar in polypropylene addition treatments compared to polyester addition and control treatments (Figure 2A). Permanova results were not significant for different lengths of plastic microfiber addition on microarthropod communities either ($F_{2,47}$ = 0.60, P = 0.81), and no specific patterns can be seen in the NMDS plots (Figure 2B). In the correspondence analysis we conserved the first two axes, which explained, respectively 34.5 % and 18.8 % of the variance in microarthropod communities (Figure S1). Most species of oribatids had relatively similar residuals, and thus were grouped near the origin of the plot. However, three oribatid species were plotted away from the origin; *Suctobelbella* sp. was a singleton present in a polypropylene-5mm sample, *Moritzoppia unicarinata* and *Oppiella nova* were present in all the treatments, but in low abundance; 38 and 7 individuals, respectively. Neither any particular pattern of similarity or high association between species and treatments could be detected; the samples seemed to be randomly plotted due to the dominance in oribatid mite communities by two species *Scheloribates* sp. nr. *laevigatus* and *Minuthozetes semirufus*.

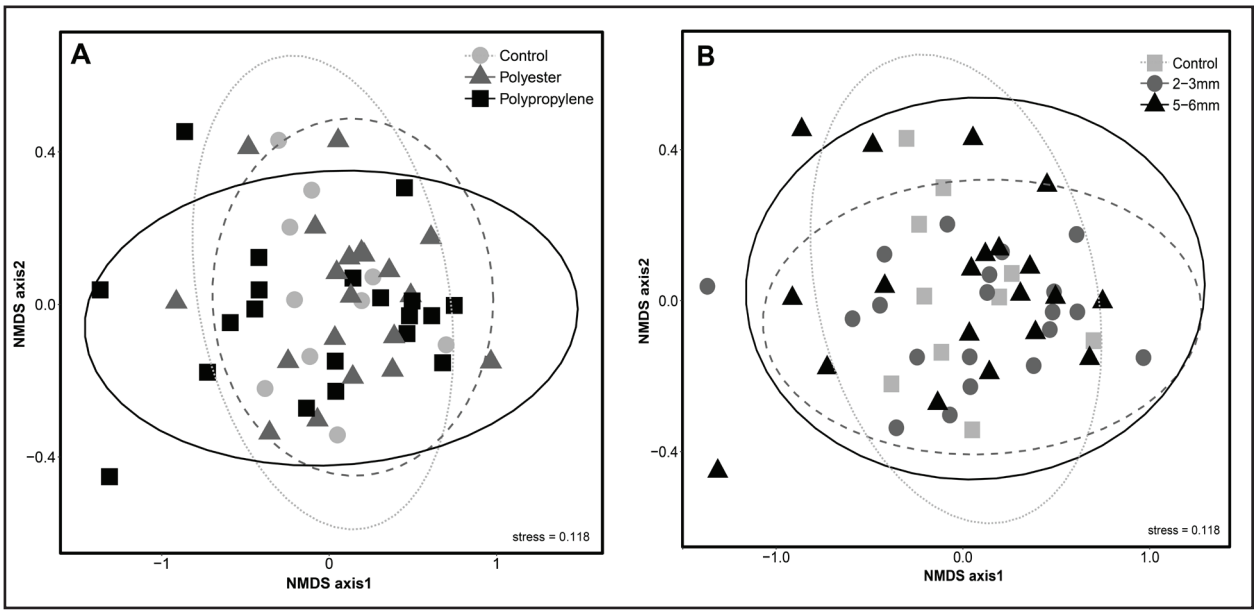

Figure 2. Nonmetric multi-dimensional scaling (NMDS) plot depicting community assembly of oribatid mites in a microcosm experiment with microplastic addition. NMDS is based on Bray-Curtis percent similarity of species standardized abundances (n° individuals-1 dw soil) for each species in 50 samples. Stress=0.118 (**A**) samples are organized by plastic addition treatments. (**B**) samples are organized by microplastic fiber length.

4. Discussion

Effects of microplastics on decomposition

Aboveground and belowground systems are linked by the input of detritus to soils, where it is decomposed by primary decomposers (fungi and bacteria) and secondary decomposers (microarthropods, mostly oribatid mites and collembolans). In addition to the decomposers' activity, abiotic factors such as temperature, moisture, and litter quality (chemical composition) are well known to affect decomposition rates (Bradford et al. 2016). Our study demonstrates that microplastics are potentially another abiotic factor that might affect decomposition rates in soil systems with an increase in decomposition rates seen in litterbags in polyester-addition treatments, compared to polypropylene-addition and control treatments. Although not assessed here, polyester fibers have been shown to decrease soil bulk density and microbial activity and increase water holding capacity (de Souza Machado et al. 2018b), besides reducing soil aggregate stability (Lehmann et al. 2019). In our study, litterbags were placed on the top of soil, thus also in contact with microplastic fibers. The mechanism underlying the increase in litter decomposition remains unknown.

The few studies that have previously addressed the effects of microplastics on decomposition suggest that rates may be affected through changes in microarthropod gut microbiomes. For instance, Zhu et al. (2018b) found that commercial polyvinyl chloride (PVC) particles in soil significantly increased gut microbe alpha-diversity in *F. candida* Willem 1902, whereas Ju et al. (2019) demonstrated that polyethylene beads, instead, decreased gut microbe alpha-diversity in the same species. Changes in gut microbial communities can favour or impair species that are primary decomposers, ultimately affecting decomposition rates.

However, considering that microplastics can be carbon sources to microbial communities in soils (Huerta Lwanga et al. 2018), they may contribute to a 'priming' effect (Chen et al. 2020), and therefore differences in microplastic decomposition rates may be a result of increased microbial activity through microbial growth. That said, as we did not measure the degradation of the microfibers, this would need further study to substantiate this hypothesis. Nonetheless, supporting this hypothesis, Chen et al. (2020) using a soil incubation experiment addressing the effect of biodegradable microplastics on soil functions and microbial communities, concluded that polylactic acid microplastics (a type of polyester) could induce the 'priming' effect as a carbon source, which could potentially alter the nutrient content, for example, inorganic nitrogen and dissolved organic carbon. Polyesters are polymers with the monomer units linked by an ester group (–COO–) (Gooch 2007), which is easier to degrade than polypropylene, a

thermoplastic polymer with a carbon-carbon backbone $(C_3H_5)_n$. Polyesters undergo hydrolysis, a relatively easier chemical reaction compared to the oxidation reactions involved in the degradation of polypropylene. Nonetheless, polypropylene also has been shown to be degraded by isolated soil microbial communities (Cacciari et al. 1993).

Effects of microplastics on microarthropods

In our study, the addition of polyester and polypropylene microfibers did not contribute to differences in abundance of all microarthropods analysed individually (major taxonomic groups) or in totality. To the best of our knowledge and as this was one the first experiments using this type of soil, plastics, and assessing microarthropod community responses, it is uncertain whether our study captured a short, long, or an ideal-duration for obtaining experimental results. Polyester fibers have been found to have weak negative effects on soil invertebrates (isopod, collembolan, enchytraeid and oribatid mite) in a short-term laboratory assay (Selonen et al. 2020). Althogh this study also used polyester fibers, it differs from ours in the soil used (Lufa 2.2 (Lufa Speyer, Germany) compared to our loamy sand soil collected in Berlin), microplastic concentration (0.02, 0.06, 0.17, 0.5 and 1.5 % ww compared to 0.4 % dw in ours), microarthropod communities (four species compared to our natural communities), fiber length (12 mm–2.87 mm 4–24 mm compared to 2–3 mm and 5–6 mm here) and finally the effects investigated (reproduction, mortality, energy reserves, ingestion compared to feeding rates and changes community structure here).

Microplastics have the ability to adsorb toxic substances like heavy metals (Hodson et al. 2017, Horton et al. 2017) on their surface, which may pose a threat to soil biota. Here, we used commercial microplastics that were recently bought and thus we did not expect the particles to carry other substances on their surface. Therefore, any potential direct negative effects of microplastic addition associated with toxins would not have been detected in our study.

The microplastic concentration used here is in line with other studies on soil fauna, although most previous studies have looked at macrofauna (invertebrates >2mm) rather than microarthropods (Rodriguez-Seijo et al. 2017, Rodríguez-Seijo et al. 2018, Selonen et al. 2020). The concentration of 0.4 % dw microplastic addition was previously seen to have direct effects on soil physical properties and microbial activity (de Souza Machado et al. 2018b), both with potential negative consequences to microarthropod communities. Nonetheless, we did not detect significant differences in microarthropod abundance or Oribatida richness when microplastics were added to the microcosms. In a short-term study, Ju et al. (2019) found that significantly more individuals of *F. candida* chose to live in soil without addition of polyethylene beads, and that collembolan reproduction was inhibited in relatively low concentrations of microplastics [0.1 % in dry soil (w/w)]. Regarding ingestion of microplastics in our study, although assessing it was not our goal, 85 % of the oribatid individuals were bigger than 6mm (the longest length treatment), which leaves open the question whether these oribatid mites could ingest microfibers, as seen in Bergami et al. (2020) for smaller particles detected in Collembola.

Microarthropods are essential to ecosystem services in soil systems. For instance, the feeding behaviour of collembolans (and most oribatid mites) promotes decomposition of organic matter and nutrient cycling in soils through feeding on fungi and bacteria (Potapov et al. 2016). Although considered the best method to reflect soil animal and microbial feeding activity (Helling et al. 1998, van Gestel et al. 2003), in our study, bait-lamina strips showed no differences in feeding rates with the addition of polyester or polypropylene. Nonetheless, van Gestel et al. (2003) detected increases in feeding rates with increases in earthworm density, but found no significant differences when exposed to collembolans and mites without earthworms. It is possible we did not detect responses because in our samples most of the fauna were microarthropods (mesofauna), with only a few macrofauna individuals (i.e. 43 earthworms total, most were juvenile). Bait strips could have fed upon steadily, but not enough to affect the entire bait substrate. As such, we consider the results of our bait lamina strips as underestimations of feeding.

The fact that little is known regarding the effects of microplastics in soil microarthropods is concerning because the few results available [e.g., Maaß et al (2017) for *F. candida*, and Zhu et al. (2018a) for *F. candida*, *Hypoaspis aculeifer* (Canestrini) (Mesostigmata) and *Damaeus exspinosus* Wang & Norton, 1989 (Oribatida)] suggest that the movement of microarthropods in soils may influence the exposure of other soil biota to microplastics and change the physical properties of soils (see de Souza Machado et al. 2018b, Lehmann et al. 2019, Wan et al. 2019) with unknown and potentially greater consequences at the ecosystem level. Even though in our study we detected no strong direct effects of microplastics on soil microarthropod communities, the movement of particles can rather impose a greater threat to ecosystem processes like decomposition.

Conclusion

We detected effects of polyester addition in litter decomposition rates, but no direct effects of plastic addition on soil microarthropod communities. Although results are still conflicting in microplastic studies in soil systems, and it is difficult to directly compare our results due to differences in methodology and low number of studies, it is important to consider microplastics as a factor of global change that could affect soil biota and ecosystem process rates (Rillig & Lehmann 2020), since they persist and accumulate in soils (Rillig 2012). For example, Rillig et al. (2019) points to the need of considering potential evolutionary implications of the presence of microplastics in soils, including changes in soil structure, alteration of host availability or function (host microbiome), toxic effects, and plastic particles themselves becoming a carbon resource and providing novel surfaces where heavy metals could adhere. With microplastics potentially being an issue in urban environments (e.g. our site) and due to their wide distribution, this topic may also deserve attention of policy makers and regulatory bodies (Rillig 2012).

5. Acknowledgments

The authors thank Dr. Anika Lehmann, Dr. Eva Leifheit, Dr. India Mansour and Dr. Moisés Sosa Hernández and for helping with experiment setup, and Sabine Buchert for helping with logistics (all above at Freie Universität). We thank Dr. Elizabeth Gillies (Western University) for helping with the chemistry involved in polymers. This research was funded by grants to CB by Mitacs Canada (IT13825 GRA) and Science International Engagement Fund Award by Western University. MCR acknowledges support from an ERC Advanced Grant (694368).

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Supplementary Informations Table S1 and Figure S1

Table S1. List of oribatid mite species (Acari: Oribatida) and their average abundance (# individuals per g dw soil) sampled from mesocosms (species are listed in taxonomic order). Abundance values are averages (± SE) for microplastic addition treatments.

Species	Control	Polypropylene 2–3mm	Polyester 2–3mm	Polypropylene 5–6mm	Polyester 5–6mm
Tectocepheus velatus (Michael, 1880)	0.018 (0.004)	0.017 (0.006)	0.034 (0.005)	0.017 (0.006)	0.030 (0.008)
Oppiella nova (Oudemans, 1902)	0.008 (0.006)	0.002 (0.002)	0.013 (0.009)	0.012 (0.006)	0.010 (0.005)
Moritzoppia unicarinata (Paoli, 1908)	0.002 (0.002)	0.006 (0.004)	0.004 (0.003)	0.006 (0.005)	0.002 (0.002)
Suctobelbella sp.	0	0	0	0.001 (0.001)	0
Scheloribates sp. nr. *laevigatus*	0.151 (0.021)	0.158 (0.025)	0.246 (0.044)	0.140 (0.028)	0.145 (0.026)
Minuthozetes semirufus (C.L.Koch, 1841)	0.064 (0.015)	0.062 (0.015)	0.089 (0.018)	0.077 (0.015)	0.101 (0.026)
Trichoribates cf. *novus*	0	0.002 (0.002)	0.001 (0.001)	0.002 (0.002)	0.001 (0.001)
Eupelops cf. *curtipilus*	0.005 (0.002)	0.005 (0.002)	0.010 (0.003)	0	0.006 (0.002)

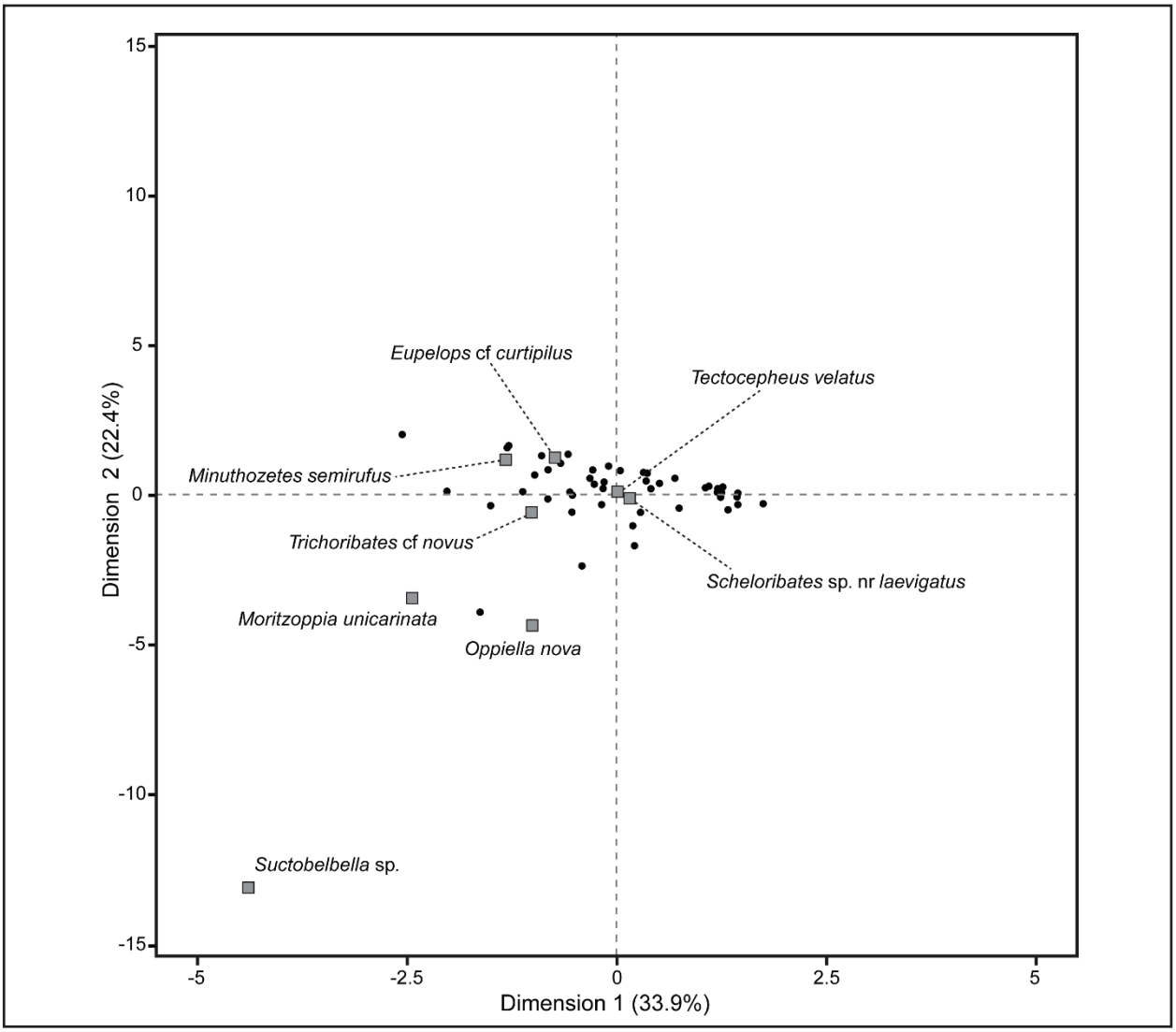

Figure S1. Regular correspondence analysis (CA) of oribatid mite data displaying relative abundances. Black dots represent samples and grey dashed lines represent the actual position of the species. Inertia explained in the two-dimensional map is 56.3%.