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NOTE

The Effects of Lawn Management on Soil Microarthropods[1]

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Lawns are one of the most common habitats in urban landscapes. They support a diversity of arthropods, including pests, predators, and detritivores, many of which reside in the soil and litter (Falk 1976, Potter & Braman 1991). Most research in lawns has focused on managing turfgrass pests and soil nutrients to achieve optimum plant growth and health. A smaller number of experimental studies have investigated the effects of lawn chemical applications on nontarget, beneficial arthropods (e.g., Cockfield & Potter 1985, Potter et al. 1985, Arnold & Potter 1987, Kunkel et al. 1999). However, little is known about arthropod communities in urban ecosystems (McIntyre 2000).

The objective of the present study was to collect field data on soil microarthropod abundances from preexisting lawns and unmowed fields within an urbanized environment. Our secondary goal was to use this observational data to develop hypotheses for future experimental research. We sampled microarthropods (mites and collembolans) from three habitat types—high- and low-maintenance lawns and unmanaged fields—to examine their utility for urban arthropod studies. High-maintenance lawns were managed by a commercial lawn care company with fertilizers and pesticides and were mowed regularly to maintain vegetation heights of 5–7 cm; low-maintenance lawns received no chemical inputs but were mowed (Cockfield & Potter 1985). We identified unmanaged fields near the lawns as reference sites for comparison.

Four locations of each of these three habitat types (12 sites total) were located in State College, Pennsylvania, (40E 47′N, 77E 51′W, elevation 350 m, 975 mm annual precipitation), ensuring that each were of similar environmental conditions (i.e., minimum size of 14 by 7 m, well-drained, no overhanging trees). Homeowners were consulted to confirm that lawns were managed as either high- or low-maintenance for the previous 5 years and to obtain permission to sample soils.

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Microarthropod sampling was conducted on 26–28 June 2001. At each location, 15 soil cores—5 cm in diameter and 5 cm deep—were collected at 0.5-m intervals along a 7-m transect in the middle of the sampling area, at least 3 m from habitat edges. Soil cores, including decaying grass clippings, were immediately transported to the laboratory where arthropods were extracted over the course of 4 d into 70% ethanol using modified Tullgren funnels (Crossley & Blair 1991). Five additional cores were collected randomly along each transect and analyzed for soil variables in the authors' laboratory (texture, pH, gravimetric moisture, bulk density) or at the Penn State Agricultural Analysis Laboratory (carbon and nitrogen). Plant species at each location were counted and identified within 0.5 m on either side of the transect. All data were statistically analyzed using analysis of variance for parametric data and the Kruskall–Wallace test for nonparametric data, a more robust test for nonnormal data (Zar 1999), followed by the Tukey and Nemenyii posthoc tests, respectively, using SPSS for Windows, Release 10.0.1 (SPSS 1999).

Soil pH, bulk density, moisture, texture, and carbon were similar among the three habitat types although soils from lawns tended to contain more carbon than the unmowed fields (Table 1). Three classes of loamy soils were distributed evenly among all 12 sites. Total nitrogen contents differed significantly among the treatments ($P < 0.05$; see Table 1 for statistics information) with greater levels observed in the high-maintenance lawns, an expected result given the fertilizer input at these sites. Plant diversity also differed significantly among the land use categories (Table 1) with more species found in the unmowed fields than the lawns and the least number in the high-maintenance lawns. Kentucky bluegrass (*Poa pratensis*) was the only species present at all locations, and it was the dominant plant in both lawn types. Plant diversity was greater in low-maintenance lawns and unmowed fields due to broad-leaf plants such as *Trifolium repens*, *Plantago* spp., and *Taraxacum officinale*. (Although this difference among the habitat types might influence microarthropods, we ignore it in our discussion below for brevity. Future studies will consider this variable in more detail.) An additional difference observed among the land uses was a greater thickness of thatch—the layer of grass shoots, roots and decomposing organic matter—in high- and low-maintenance lawns as compared with the unmowed sites (Byrne, personal observation).

Soil mite abundances were found to be greatest in high-maintenance lawns and least in unmowed reference sites (Table 1). Other studies have reported greater numbers of mites in high-maintenance lawns as compared with low-maintenance lawns (Arnold & Potter 1987, Potter et al. 1985, 1990, Kunkel et al. 1999), and Southwood & van Emden (1967) observed more mites in cut than uncut agricultural fields. Although our mite data are not statistically significant, when viewed with these other studies the data suggest that mites, as a group, are not reduced in numbers by mowing and lawn chemical applications. Two hypotheses may be proposed about the mechanisms for increased abundances of mites in lawns. Some species (i.e., detritivores, fungivores) may increase as a result of the greater availability of decaying organic matter (grass clippings), which they consume directly or graze fungi from, a bottom-up mechanism of population increase (Arnold & Potter 1987, Halaj & Wise 2002). Also, a reduction of macroarthropod predators in high-maintenance lawns, a top-down mechanism, may allow mites to become more abundant, especially in high-maintenance lawns, (Cockfield & Pot-

Table 1. Mean values of soil properties, number of plant species, and soil microarthropods for three management treatments. N = 4 per treatment for each variable. Units are given next to each variable.

Variable	Mean values ± SE for each treatment[a]			Test statistic[b]	*P* value
	High maintenance	Low maintenance	Unmowed fields		
Soil pH	6.0 ± 0.2	6.2 ± 0.1	6.4 ± 0.2	$F = 0.89$	0.44
Bulk density (g/cm^3)	0.99 ± 0.05	1.01 ± 0.07	1.08 ± 0.06	$F = .61$	0.57
Soil moisture (gravimetric)	22.9 ± 2.3	30.6 ± 2.6	25.1 ± 1.55	$F = 3.38$	0.08
Soil carbon (%)	6.5 ± 1.6	5.5 ± 1.1	3.7 ± 0.1	$H = 5.12$	0.07
Total soil N (%)	0.56 ± 0.14 a	0.46 ± 0.08 ab	0.29 ± 0.009 b	$H = 7.48$	0.02
No. plant species	2.5 ± 0.5 a	10.25 ± 1.3 ab	26.3 ± 6.3 b	$H = 9.4$	0.01
Acari (mites)[c]	19.12 ± 5.39	13.90 ± 3.04	10.72 ± 0.5	$H = 2.19$	0.33
Collembolans[c]					
Poduromorpha	0.98 ± 0.54	1.92 ± 0.83	1.77 ± 1.00	$H = 0.74$	0.69
Entomobryomorpha	0.75 ± 0.44 a	15.17 ± 9.36 b	4.32 ± 1.6 ab	$H = 6.98$	0.03
Sminthuridae	1.08 ± 0.54	0.72 ± 0.26	4.45 ± 2.71	$H = 0.18$	0.91

[a]Means followed by different letters in rows differ significantly at $P \leq 0.05$ using the multiple comparison Nemenyi test for non-parametric data (Zar 1996).
[b]Test statistics are F values from one-way analysis of variance for parametric data or H values from the Kruskall–Wallis test for non-parametric data. Data were considered nonparametric if they were found to be non-normally distributed or had unequal variances at $P < 0.05$ using the Kolmogorov–Smimov test and test of homogeneity of variances in SPSS, respectively. DF = 2, 9 for all analyses.
[c]Microarthropod data are means (±SE) per soil core.

ter 1983, Halaj & Wise 2002). These mechanisms are not mutually exclusive and need to be tested in an experimental setting to examine their relative importance for determining mite abundances in lawns.

We were able to sort collembolans into three subordinal groups: poduromorpha, entomobryomorpha, and symphypleona (Christiansen & Bellinger 1980). These taxonomic groups are roughly parallel to the three ecomorphological life forms of collembolans: euedaphic, hemiedaphic, and epedaphic, respectively (see Fig. 1; Christiansen & Bellinger 1980, Hopkin 1997). Although some species' taxonomic status does not reflect their ecomophological type (Hopkin 1997), sorting specimens into these suborder groups provides more ecological information about collembolan communities than grouping them together as "collembolans" as has been done in some previous studies. Total collembolans have been found to be more abundant in high-maintenance lawns with intermediate levels of N fertilizer applications whereas numbers were sometimes but not always reduced by insecticides (Potter et al. 1985, 1990, Kunkel et al. 1999). We know of no studies that have compared collembolan abundances in lawns to unmowed fields. Thus, our data provide new insights into the effects of lawn management on collembolan communities.

Poduromorpha collembolans mostly inhabit pore spaces within the mineral soil and spend little time aboveground (Hopkin 1997). We found poduromorpha springtail abundances to be similar between low-maintenance lawns and unmowed sites (Table 1), suggesting that this group is not affected by mowing. In Poland and Russia, respectively, Sterzyńska (1982) and Stebaeva & Sergeev (1994) also found similar numbers of euedpahic collembolans among lawns and unmanaged habitats. We hypothesize that this euedpahic lifestyle protects poduromorpha collembolans from the disturbance of mowing. Slightly fewer podurpmorphans in high-maintenance lawns may indicate a negative effect of chemical applications, but this is not clear because of the lack of significant differences among our data.

Symphypleona collembolans (all specimens collected in our study were from the family Sminthuridae) are generally epedaphic and spend most of their time above the soil in the litter and vegetation (Hopkin 1997). Although not statistically significant due to high variation among the data, fewer numbers of sminthurids were collected from the lawns than the unmowed fields, a trend observed in previous studies (Sterzyńska 1982, Stebaeva & Sergeev 1994). We hypothesize that sminthurids are negatively affected by mowing due to changes in aboveground environmental conditions (i.e., temperature and moisture) as influenced by shorter vegetation. The effects of chemical applications on sminthurids are less clear, because their numbers were similar in both lawn types.

Entomobryomorpha collembolans can broadly be considered hemiedaphic, because most live in upper layers of the soil and within litter layers (Hopkin 1997). These collembolans were nearly four times more abundant in low-maintenance lawns than in reference sites suggesting that their numbers are not reduced by mowing. As is the case for mites, they may increase in low-maintenance lawns because of increased food supplies (grass clippings and associated microbes) or reductions in their predators (Arnold & Potter 1987). Our data suggest that although mowing did not reduce entomobryomophan abundances, significantly fewer numbers inhabited high-maintenance lawns. Kunkel et al. (1999) reported

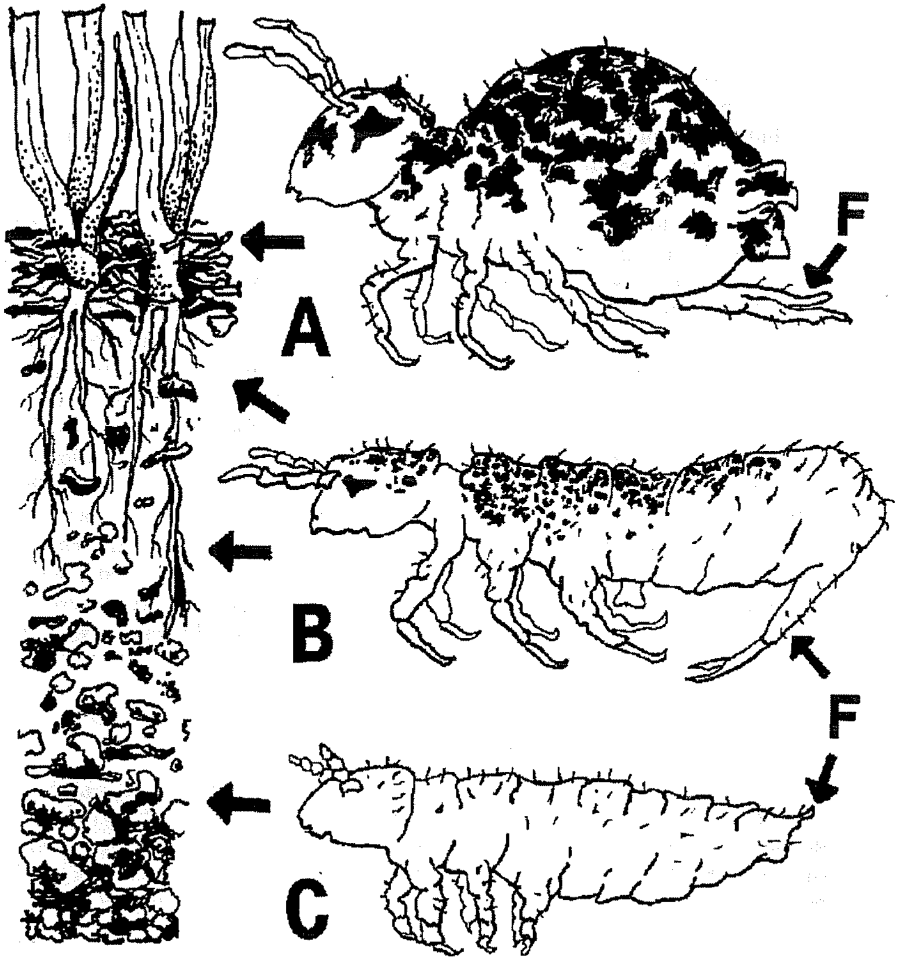

Fig. 1. Three generalized ecomorphological groups of collembolans are depicted, indicating their vertical distributions within the turfgrass-thatch-soil layers of a lawn. The collembolan groups are differentiated by morphological features that reflect adaptations to their preferred habitat within the soil-litter profile. Sizes vary among the groups. (A) Epedaphic collembolans (symphypleonans, the globular springtails, include the families Sminthuridae and Neelidae) dwell mostly above the soil among the litter and vegetation and have well-developed eyes, antennae, furculas and pigmentation. (B) Hemiedaphic collembolans (entomobryomorphans, including the families Isotomidae and Entomobryidae) have intermediate morphologies of the other two groups (most have furculas and antennae, some have eyes and pigmentation) and inhabit upper soil layers and decomposing surface litter. (C) Euedaphic collembolans (poduromorphans, the grub-like springtails, includes the families Onychiuridae and Hypogastruridae) inhabit soil pore spaces as reflected by their reduced or absent eyes, antennae, furculas and pigmentation. Furculas, labeled with an "F," are the springing organs located on collembolans' abdomens. (Modified after Coleman & Crossley 1996.)

a decrease in collembolan population in lawns applied with the insecticide imidacloprid. Although conclusions regarding the effects of specific lawn chemicals on collembolans are outside the scope of this study, it appears that general management practices associated with high-maintenance lawns negatively affect entomobryomorpha collembolans (but see Potter et al. 1985).

In summary, we found that mowing and chemical applications in lawns affects soil mites and the three suborder groups of collembolans in different ways. Because we found no differences among most soil variables within the habitat types, we are confident that the microarthropod data are reflective of the impacts of habitat management on their abundances. Although our study is limited temporally and taxonomically (because we were unable to identify specimens to lower levels of classification), this report is useful for guiding future studies on microarthropods inhabiting lawns. Specifically, our hypotheses should be tested in field experiments with more refined treatments of mowing and chemical applications and more detailed identification of mites and collembolans. Although the effects of specific fertilizer and pesticide applications on arthropods were not part of our objectives, this should also be a primary focus for future work. Such information would benefit lawn managers who wish to conserve beneficial arthropods within urban habitats. In addition, ecological research on arthropods in lawns will contribute needed data about the impacts of urbanization on biodiversity (McIntyre 2000).

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