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Research Note

Grazing Protection Influences Soil Mesofauna in Ungrazed and Grazed Riparian and Upland Pastures

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Abstract

The influence of grazing protection caused by streambank fencing on soil mesofauna density is unknown. Our objective was to determine if grazing protection (ungrazed vs. grazed), location (upland vs. riparian pasture), and seasonal (spring vs. fall) treatment effects associated with streambank fencing had a significant influence on soil mesofauna distribution and density. We collected five intact soil cores (0–5 cm depth) in June and October of 2012 from within four treatments consisting of ungrazed and grazed riparian and upland pastures associated with streambank fencing along an 800-m reach of the Lower Little Bow River in southern Alberta, Canada. Soil mesofauna were extracted and densities of *Acari* (mites) taxa, *Collembola* (springtails) taxa, and other mesofauna were determined. Grazing protection resulted in a significant ($P \leq 0.05$) negative response of *Astigmata* mite densities for the upland pasture, and a positive response for *Oribatida* mites and total *Collembola*, and *Hypogastruridae* and *Onychiuridae* springtails for both pastures. Location and season had a significant influence on *Acari* and *Collembola* taxa, but the effects were dependent on interaction effects. We conclude that grazing protection influenced certain soil mesofauna in pastures associated with streambank fencing, and this may influence decomposition of soil organic matter, nutrient cycling, and soil structure in associated pastures.

Key Words: *Acari*, *Collembola,* grazing, soil invertebrates, streambank fencing

INTRODUCTION

Streambank fencing is used to protect rivers, streams, water quality, and their riparian zones from cattle grazing on adjacent upland grassland pastures. Depending on location of streambank fencing, ungrazed and grazed upland and riparian pastures are created when streambank fencing is installed. Cattle grazing can influence soil mesofauna by the indirect effects on soil properties such as nutrient inputs via feces and urine, soil compaction, and litter removal (Bardgett and Cook 1998; Battigelli et al. 2003). Grazing by cattle causes soil compaction and reduces total pore space, which impedes the movement of soil mesofauna (Hopkin 1997; Battigelli et al. 2004; Schon et al. 2012). Grazing also reduces the litter or surface mulch by trampling, which pulverizes and incorporates the litter into the surface soil, stimulating decomposition (Dormaar et al. 1989); and by removing herbage that cannot then enter litter (Bardgett and Cook 1998).

Most studies have reported a positive response of soil mesofauna to reduced grazing (Bardgett and Cook 1998; Clapperton et al. 2002; Schon et al. 2008, 2010, 2011, 2012). However, some found only minor effects of grazing intensity on soil mesofauna (Leetham and Milchunas 1985) or found a negative response to reduced grazing (Bardgett et al. 1993). Most studies of grazing impacts on soil mesofauna have focused on upland pastures (Behan-Pelltier and Kanishiro 2010), and we are not aware of any studies that have examined soil mesofauna in ungrazed and grazed upland and riparian pastures associated with streambank fencing. The objective of our study was to determine if grazing protection, location, and seasonal treatment effects associated with streambank fencing in southern Alberta had a significant influence on soil mesofauna distribution and density.

MATERIALS AND METHODS

Study Site

The study site is located within the Lower Little Bow (LLB) watershed in Alberta, Canada (Miller et al. 2010). The dominant vegetation is wheat grass (*Pascopyrum* sps.) species [Pascopyrum *dasystachyum* or northern wheatgrass, *Pascopyrum smithii (Rydb.) Á. Löve* or western wheatgrass] as well as needle and thread grass (*Stipa comata*). The soils are medium to moderately coarse-textured dominantly Aridic and Typic Borolls, with significant Entisols.

Streambank Fencing History and Implementation

The streambank fencing with cattle crossing BMP was established in 2001 (Miller et al. 2010). The total potential grazing area is about 184 ha and the area of the fenced riparian pasture is approximately 10 ha. The stocking rate was 0.50 animal unit month (AUM) ha^{-1} from 2001 to 2003, and it was reduced to 0.40 AUM ha^{-1} from 2004 to 2007. Cattle grazed (June–August) the riparian pasture prior to fencing in 2001 and were excluded from the riparian pasture since 2001. Permanent fencing with a

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cattle crossing was installed on both sides of an 800-m reach of the Lower Little Bow River on June 29, 2001. The distance from the edge of the river to the fence ranged from 40 to 80 m.

Treatment Pastures

Three different pastures associated with streambank fencing and one pasture associated with an unfenced reach were used for this study for a total of four treatments (Miller et al. 2010, 2014). The four pastures were (1) grazed upland pasture and (2) ungrazed upland pasture both adjacent to fenced reach; (3) ungrazed riparian pasture within fenced reach; and (4) grazed riparian pasture adjacent to unfenced reach immediately downstream of the fenced reach.

Sampling and Soil Mesofauna Identification

Five intact soil cores (5 cm length × 5.2 inside diam.) were randomly taken with a truck-mounted hydraulic drill within each of the four treatment pastures on June 12 (spring) and October 15 (fall), 2012 for a total of 40 soil cores. The soil cores were shipped to Stantec Consulting (Sydney, British Columbia) for extraction, sorting, and identification using methods as previously described (Battigelli et al. 2004).

Within 48 h of collection, soil cores were placed in a high gradient extractor for 1 wk. Mesofauna were collected into a 0.6% (w/v) picric acid solution and then transferred into vials with 70% ethanol for counting and identification. *Acari* were classified to the suborder level, and *Collembola*, and "other mesofauna" were classified to the family level. Four suborders of *Acari* were identified: *Astigmata*, *Mesostigmata*, *Oribatida*, and *Prostigmata*. Four families of *Collembola* were identified: *Hypogastruridae*, *Isotomidae*, *Onychiuridae*, and *Sminthuridae*. Families of other mesofauna identified included *Coleoptera* (beetle) larvae and adults, *Diptera* (true flies) larvae and adults, *Formicidae* (Ants), *Homoptera*, *Pscoptera* (lice or barkflies), *Thysanoptera* (thrips), *Araneae* (spiders), *Hemiptera* (true bugs), *Staphylinidae* (rove beetles), and non-arthropods *Enchytraeidae* (potworms).

Data Analysis

Density of mesofauna in soil cores were converted to number of individuals per square meter for taxa densities $> 1\%$ of all collected material. Only two taxa in the other mesofauna category (*Pscoptera*, *Araneae*) in the spring had $\leq 1\%$ density and were deleted. A three-way MIXED model analysis in SAS (SAS Institute 2005) was used to examine the main effects of grazing (ungrazed vs. grazed pasture), location (upland vs. riparian pasture), season (spring vs. fall), and their interactions, on soil mesofauna density. All data were used where each taxa was present in at least one soil core. Densities for all taxa were log-transformed prior to analysis. Grazing, location, season, and soil core were used in the CLASS statement. A REPEATED statement with compound symmetry covariance structure was used for season. Treatment differences were considered significant at $P \leq 0.05$.

RESULTS

Relative abundance of the taxa orders in the spring and fall was greatest for total *Acari*, followed by *Collembola*, and then other mesofauna (Figs. 1a and 1b). The exception was for the grazed riparian pasture in the fall, when *Collembola* were most abundant (Fig. 1b). *Prostigmata* were the most abundant among the four suborders of *Acari*, except for the ungrazed riparian pasture where *Oribatida* was most abundant (Figs. 1c and 1d). *Onychiuridae* were generally the most abundant among the four families of *Collembola* (Fig. 1c, d).

Mean Astigmata densities were significantly ($P \leq 0.05$) greater by 2.1-fold for the grazed compared to ungrazed pastures for the upland but values were similar for the riparian pasture (Fig. 2a). *Mesostigmata* mites were significantly greater by 5.4-fold for spring compared to fall (Fig. 2b). *Oribadita* mites were significantly greater by 5.6 to 124-fold for ungrazed than grazed pastures for both upland and riparian locations (Fig. 2c). *Prostigmata* mite densities were significantly greater by 7.8-fold in spring than fall for upland but there was no season effect for the riparian location (Fig. 2d). There was a three-way interaction of all treatment factors on total *Acari* density, but there was no difference between grazed and ungrazed pastures for each location and season (Fig. 2e).

Hypogastruridae, *Onychiuridae*, and total *Collembola* were significantly greater by 2.6 to 12.7-fold for ungrazed than grazed pastures (Fig. 3a). *Isotomidae* springtails and total *Collembola* were significantly greater by 2.3 to-13.4 fold for riparian compared to upland pastures (Fig. 3b). Season by location had a significant influence on *Hypogastruridae* and *Sminthuridae* springtails but the effect differed. *Hypogastruridae* densities were 4.5-fold greater in spring than fall for upland pasture, but were similar for the riparian pasture (Fig. 3c). *Sminthuridae* densities were similar between seasons for the two locations, but mean values were 5.6-fold greater for riparian than upland pasture in fall (Fig. 3d). Densities of other mesofauna was 3.7-fold greater in the spring than fall (Fig. 3e).

DISCUSSION

Our finding that *Astigmata* densities significantly decreased with grazing protection of upland pastures was consistent with previous research (Leetham and Milchunas 1985; Schon et al. 2012). Other researchers reported similar *Astigmata* densities in low- and high-intensity grazed pastures (Schon et al. 2008) or found that grazing pressure reduced *Astigmata* densities in the fall but densities were similar in the winter (Schon et al. 2010). Agricultural practices that cause disturbance to the soil generally increase microarthropods with life cycles less than one year, and decrease densities of those with life cycles longer than 1 yr (Edwards and Lofty 1969). Since *Astigmata* can complete their life cycle in 8 d to 3 wk (Phillips 1990), this may explain why we found greater densities in the grazed than ungrazed upland pasture where there was greater disturbance by cattle. *Astigmata* also responds rapidly to manure addition to soil and increased nutrient availability (Behan-Pelltier and Kanishiro 2010), and this may have contributed to greater densities in the grazed pasture where fecal and urine deposition by grazing cattle may have increased nutrient availability. Astigmata feed on plant material, fungi, and algae, preferably of high-protein content, and also consume the liquefied products of decaying organic material (Behan-Pelltier and Kanishiro 2010). No grazing effect for *Astigmata* densities in

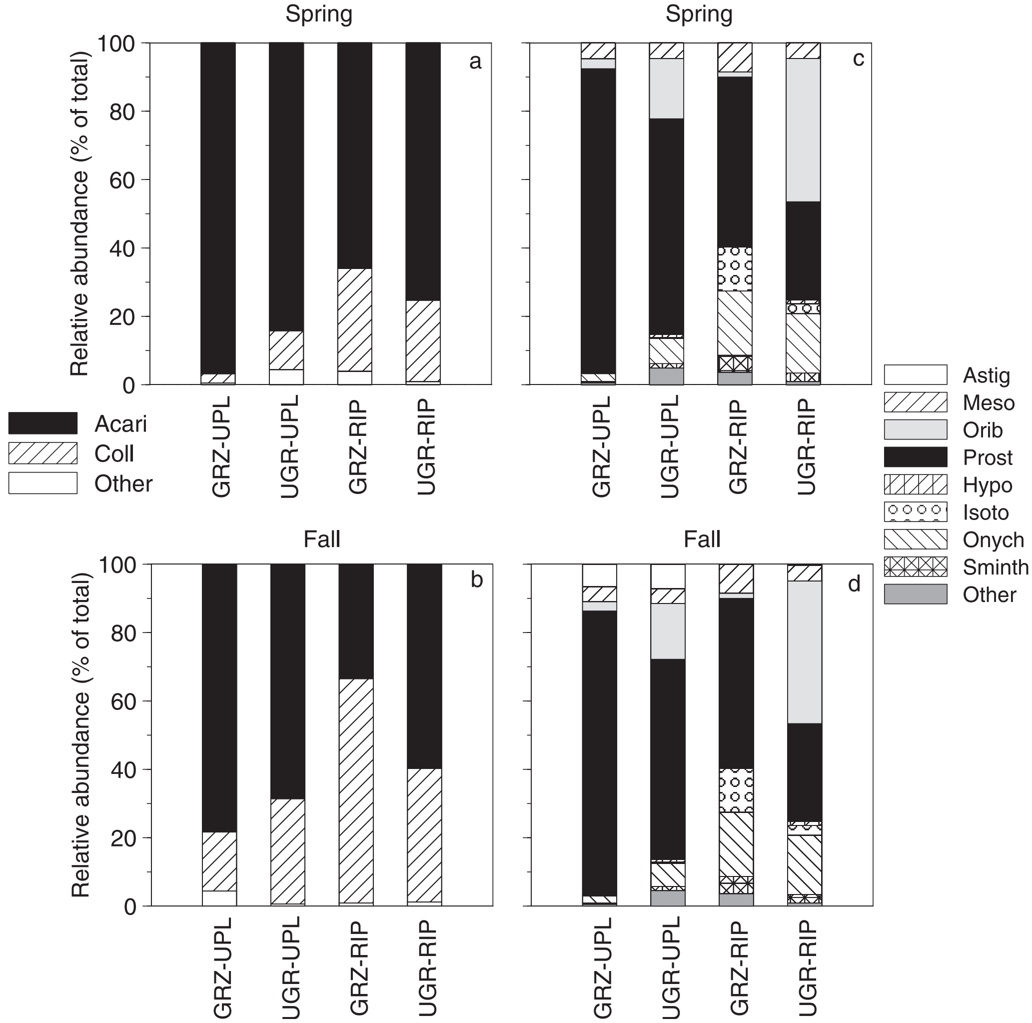

Figure 1. Relative abundance of total *Acari*, *Collembola* (Coll), and other mesofauna (other) in surface soil of four treatments in **a**, spring and **b,** fall and relative abundance of *Acari* and *Collembola* taxa in **c,** the spring and **d,** fall. Taxa abbreviations: *Astigmata* (Astig), *Mesostigmata* (Meso), *Oribatida* (Orib), *Prostigmata* (Prost), *Hypogastruridae* (Hypo), *Isotomidae* (Iso), *Onychiuridae* (Onych), Sminthuridae (Sminth). Treatment abbreviations for four pastures are GRZ (grazed pasture), UGR (ungrazed), UPL (upland pasture), RIP (riparian pasture).

the riparian pasture was likely related to the low absolute densities and prevalence of *Collembola* over *Acari* in the wetter and cooler riparian pasture.

Our finding of significantly greater *Oribatida* mite densities in the ungrazed than grazed upland or riparian pastures was consistent with the relatively low tolerance of this suborder to soil disturbance since many species of *Oribatida* have life cycles longer than one year (Edwards and Lofty 1969). Our findings were consistent with others who reported that reduced grazing generally increased *Oribatida* in surface soils (Schon et al. 2008, 2010, 2012). However, Clapperton et al. (2002) reported that reducing grazing increased *Oribatida* in the spring but not the fall. Oribatida feed on living and dead plant and fungal material, lichens, and carrion (Behan-Pelltier and Kanishiro 2010) and cannot respond rapidly to nutrient pulses because of their low fecundity (Clapperton et al. 2002).

No grazing effect on total *Acari* in the upland or riparian pastures was in contrast to other researchers that generally reported greater densities of total *Acari* with reduced grazing (Leetham and Milchunas 1985; Schon et al. 2010, 2012). Prostigmata was the most dominant Acari in the upland pastures but was unaffected by grazing. This acarine group is generally dominant in most grasslands, and species can be algivores, bacterivores, fungivores, phytophages, predators, parasites, and parasitoids (Behan-Pelltier and Kanishiro 2010). Most studies have reported a positive response of Prostigmata to decreased grazing pressure (Leetham and Milchunas 1985; Battigelli et al. 2003; Schon et al. 2008, 2012), and this was attributed to grazing causing a decline in soil quality (Battigelli et al. 2003). However, some have reported a negative response of Prostigmata to reduced grazing, which was attributed to their high fecundity and ability to respond quickly to nutrient pulses in grazed pastures (Clapperton et al. 2002). Grazing influences on total Acari and Prostigmata in our study may not have been great enough to overcome other sources of variability (e.g., climate, soil moisture) and the net effect of simultaneous positive and negative effects of grazing (Leetham and Milchunas 1985).

Significantly greater densities of total *Collembola*, *Hypogastruridae*, and *Onychiuridae* springtails in the ungrazed than the

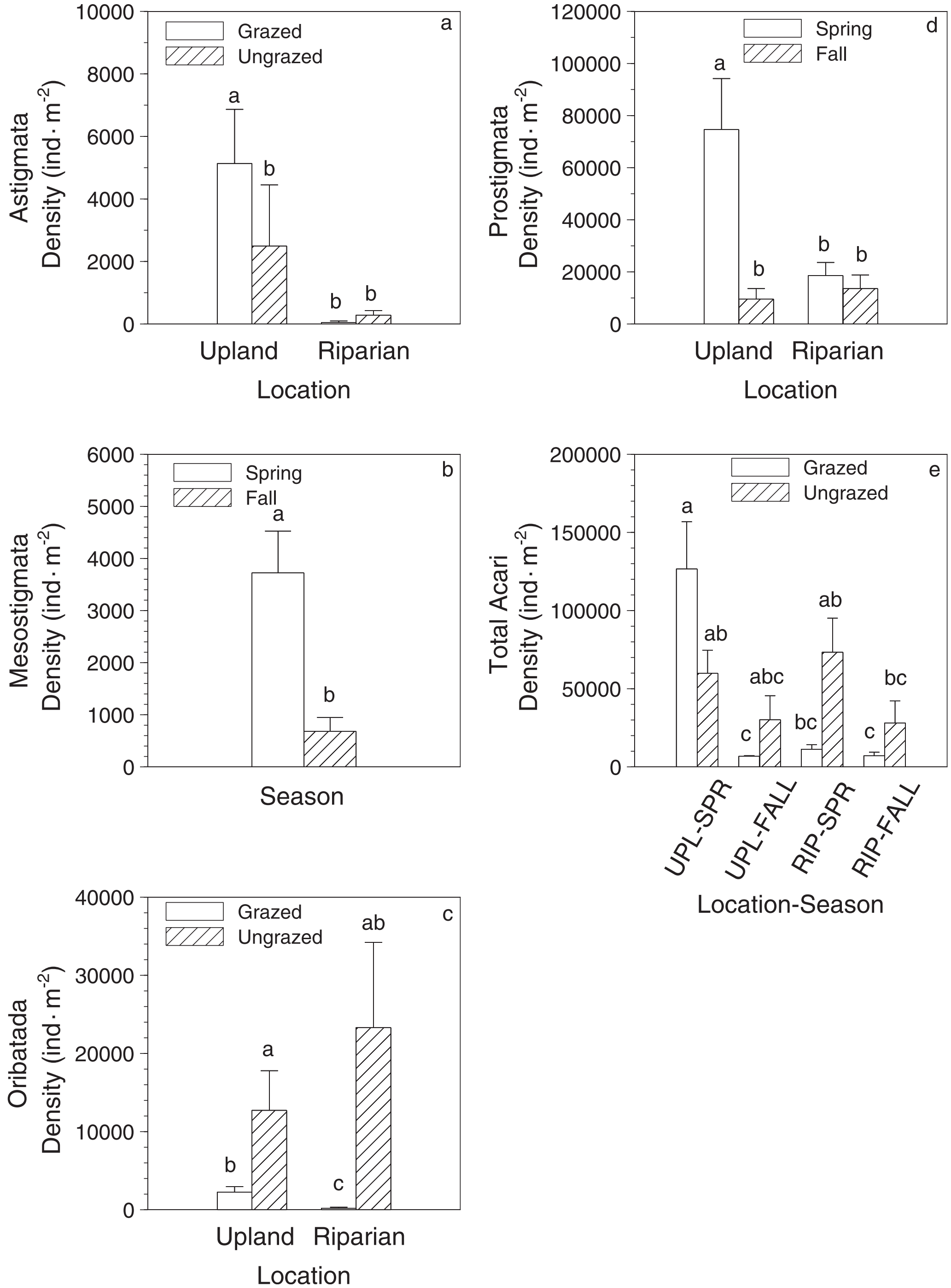

Figure 2. Grazing by location on **a,** *Astigmata* mite densities, seasonal effect on **b,** *Mesotigmata*, grazing by location effect on **c,** *Oribatida*, season by location effect on **d,** *Prostigmata*, and grazing by location by season effect on **e,** total *Acari* densities. Different lowercase letters above vertical bars indicates significant ($P \leq 0.05$) difference among all treatments.

grazed pastures by 3- to 13-fold suggested a positive influence of grazing protection on *Collembola*. This finding was surprising since many *Collembola* have fast reproduction and short lifespans, which allows them to respond quickly to environmental change (Hopkin 1997; Lindo 2014). Previous studies have reported a positive (Clapperton et al. 2002) or negative (Bardgett et al. 1993) response of *Collembola* to decreased grazing, others found no or little response (Leetham and Milchunas 1985; Schon et al. 2008, 2010), or that grazing effects were dependent on site (Schon et al. 2012). The positive response of *Collembola* to decreased grazing pressure has been attributed to increased pore space and surface litter (Bardgett and Cook 1998) and suggests that these factors may influence Collembola abundance more than their fecundity. Soil compaction by trampling generally decreases abundance of Collembola that live in soil (Hopkin 1997). Greater densities of total *Collembola* and certain taxa in the ungrazed than grazed pastures may be related to greater fungal biomass in

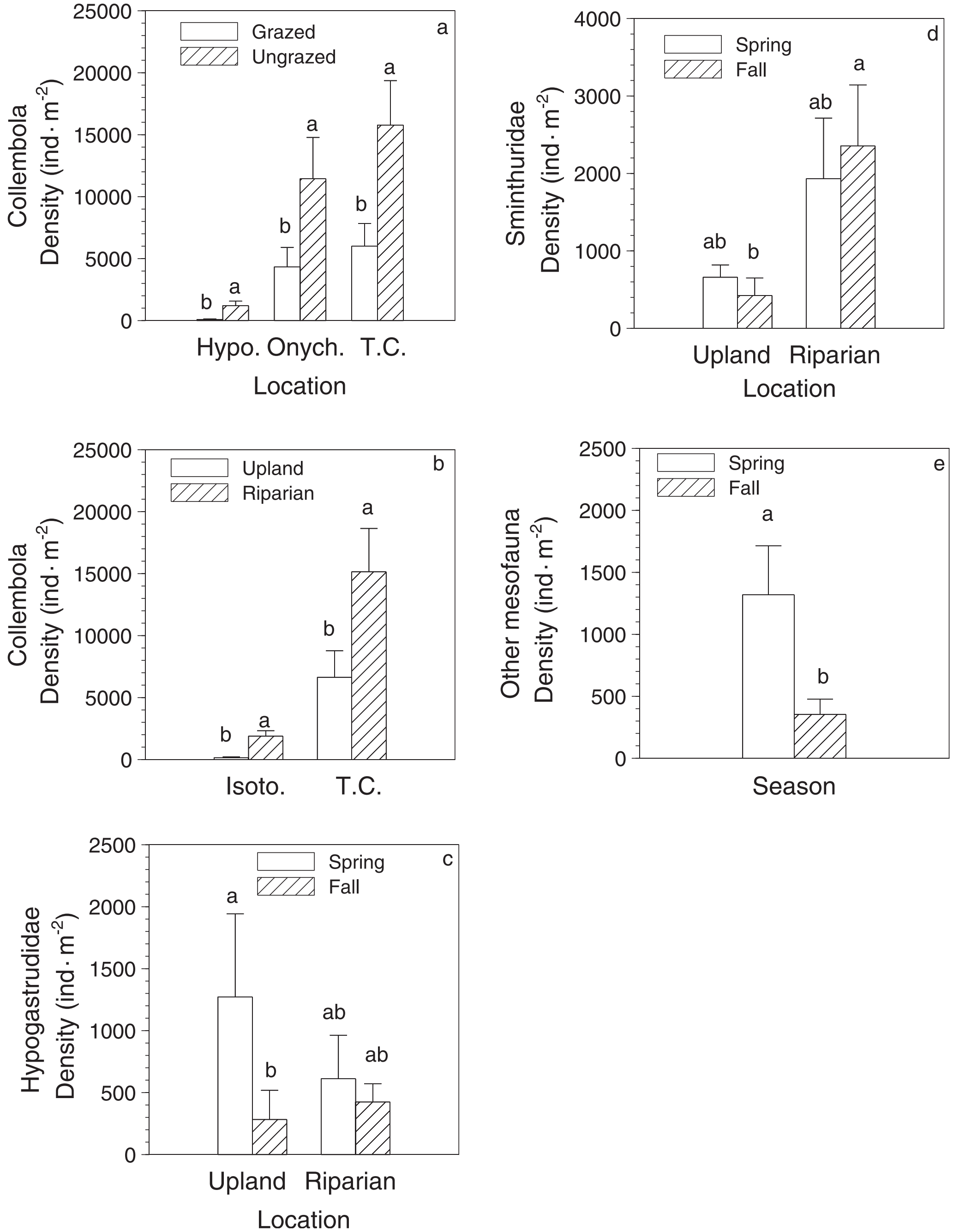

Figure 3. Grazing by location effect on **a,** *Hypogastruridae*, *Onychiuridae*, and total *Collembola*, location effect on **b,** *Isotomidae* and total *Collembola*, season by location effect on **c,** *Hypogastruridae*, season by location effect on **d,** *Sminthuridae*, and season effect on **e,** other mesofauna. Different lowercase letters above vertical bars indicates significant ($P \leq 0.05$) difference among all treatments.

ungrazed pastures (Dormaar et al. 1989). Fungal hyphae are a major constituent of *Collembola's* diet (Hopkin 1997). Livestock grazing promotes faster nutrient cycles because of changes in the quality and quantity of root exudates that favor bacterial over fungal populations (Clapperton et al. 2002), which could inhibit *Collembola* in grazed pastures. Collembola such as Onychiuridae and Isotomidae feed on both mycorrhizal and saprophytic fungi in grassland soils (Jonas et al. 2007).

The greater densities of total *Collembola* and *Isotomidae* springtails in riparian compared to upland pastures, and greater density of *Hypogastruridae* springtails in the spring versus fall for upland pasture, was consistent with the preference of most Collembola for moist and cool environments that encourages greater fungal growth that is their main food source (Hopkin 1997).

IMPLICATIONS

Astigmata mites may be useful as bio-indicators of increased grazing pressure; and *Oribatida* mites, total *Collembola*, *Hypogastruridae* and *Onychiuridae* springtails as bio-indicators of grazing protection. More long-term research is required to study the influence of streambank fencing and associated pastures on soil mesofauna. Installation of streambank fencing closer to the river at transition between riparian and upland pastures could eliminate the ungrazed upland pasture and influence soil mesofauna distribution in the remaining pastures.

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