

## Reductions in foliar Hemiptera in portions of a fescue grassland invaded by Smooth Brome (*Bromus inermis*)

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### Abstract

Fescue grassland in Canadian prairie is characterized by Plains Rough Fescue (*Festuca hallii*), but the introduced exotic grass, Smooth Brome (*Bromus inermis*), is expanding therein. Hemiptera play an important role as herbivores in vegetation. In an invaded fescue grassland in Manitoba, 52 plant species had a combined average cover of 216%. Kentucky Bluegrass (*Poa pratensis*), another exotic grass, was most abundant at 64%, followed by *B. inermis* at 21% and the native grass *F. hallii* at 18%. Across 47 random sample points, *B. inermis* cover ranged from 0% to 180%. At these points, 2445 specimens of Hemiptera were collected by sweep net and divided into 99 morphologically distinct species. *Bromus inermis* cover had negative correlations with Hemiptera species richness and diversity, but not with abundance and biomass of Hemiptera. However, *B. inermis* cover was negatively correlated with abundance of two individual species of Hemipteran leafhoppers in the family Cicadellidae: *Doratura stylata* and *Diplocolenus configuratus*. Total graminoid cover had no significant correlation with any of the above Hemiptera variables. We conclude that feeding requirements deter some phytophagous Hemiptera from entering sections of fescue grassland invaded by *B. inermis*. In this way, invasion by *B. inermis* can be expected to modify ecosystem function by increasing feeding pressure on neighbouring natural vegetation and other introduced species.

Key words: Invasive species; Smooth Brome; *Bromus inermis*; foliage cover; Hemiptera; Cicadellidae; insect diversity; fescue grassland

### Introduction

Smooth Brome (*Bromus inermis* Leysser) is an invasive grass in North America, forming persistent stands in disturbed areas and next to trails, and reducing plant diversity in prairie by 70% (Otfinowski *et al.* 2007). Plant invasion changes the primary base of available food, thereby potentially changing ecosystem function via the activities of arthropods that consume vegetation, carry out pollination, and decompose litter (Litt *et al.* 2014). However, the response of arthropods to invasive plant species is variable. In 87 published articles, 48% of cases reported a decrease in the abundance of herbivorous arthropods after invasion, but 17% reported an increase; corresponding values for arthropod richness were 48% and 13% (Litt *et al.* 2014).

Smooth Brome invasion of natural grasslands has an impact on arthropods (Chu and Knutson 1970; Jonas *et al.* 2002). More specifically, the response of plant-feeding Hemiptera to Smooth Brome in-

roduction was reported as negative at 12 Montana sites (Bess *et al.* 2004). In that study, Smooth Brome was absent from nine sites but varied from 20% to 57% cover at another three locations. Compared with non-infested control locations, the sites with Smooth Brome showed reduced diversity of Hemiptera.

Given the potential for Smooth Brome to modify Hemiptera populations and, thereby, modify prairie function in terms of herbivory, our aim was to evaluate the response of Hemiptera to Smooth Brome invasion of fescue prairie. The approach taken was to collect Hemiptera across a Smooth Brome-invaded fescue grassland in Manitoba, Canada. The grassland studied was expected to exhibit a considerable range in Smooth Brome cover because of the patchiness of local invasion.

### Methods

In 2015, vegetation cover was scored and Hemiptera collected under permit at Grasshopper Valley in Riding Mountain National Park, Manitoba,

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Canada (Figure 1). The northwest corner of the 9780-m<sup>2</sup> trapezoid-shaped study area was at 50.7561°N, 100.2767°W. Spatial variability associated with the invasion of Smooth Brome at Grasshopper Valley presented an opportunity for a natural experiment (Gurevitch *et al.* 2006) to test the impact of this grass on attendant Hemiptera.

Sample points were based on randomly selected latitudes and longitudes. At each point, vegetation scores and arthropod samples were taken across a 2-m by 2-m plot. Sampling was undertaken at all 28 plots that contained Smooth Brome and the first 19 plots that did not contain Smooth Brome, for a total of 47 plots. To focus sampling effort on areas with the invasive grass, 53 additional sets of coordinates without Smooth Brome were omitted. On 15 and 16 June 2015, vegetation cover by species was determined using a pin-frame system and 80 pins for each 2-m by 2-m plot. With one exception, plant identification followed Scoggan (1957), with names as given in Flora of North America Editorial Committee (1993+). Plains Rough Fescue (*Festuca hallii* (Vasey) Piper) was not listed in Scoggan (1957); thus, the description in Flora of North America Editorial Committee (1993+) was used for identification of this taxon.

Following Martin (1977), sweep-nets were used to collect foliar feeders. Plots were sampled weekly for five consecutive weeks between 15 June and 24 July. Samples were not taken when wind speed exceeded 15 km/h. Each sweep-net sample comprised 12 sweeps across each 2-m by 2-m plot. Sweeps were conducted in six horizontal rows, involving one low

sweep followed by one high sweep in the same row. To focus effort on a manageable number of specimens, a single sample date was selected for counting. Based on inspection of all samples for specimen abundance and quality, we selected the fourth round of sweep net samples from 13–17 July. Hemiptera were sorted into morphologically distinct species and counted. No evaluation of cryptic species was attempted.

Biomass estimates for Hemiptera followed Sample *et al.* (1993), using relationships for Auchenorrhyncha, Sternorrhyncha, and Heteroptera. Insect length and width were measured separately by species to the nearest 0.01 mm using an eyepiece micrometer in a dissecting microscope. Based on preliminary measurements to determine SD stabilization as sample size increased, a sample size of ten insects per taxon was used where possible. Biomass per taxon was then combined with abundance data to calculate biomass per sample for all Hemiptera combined.

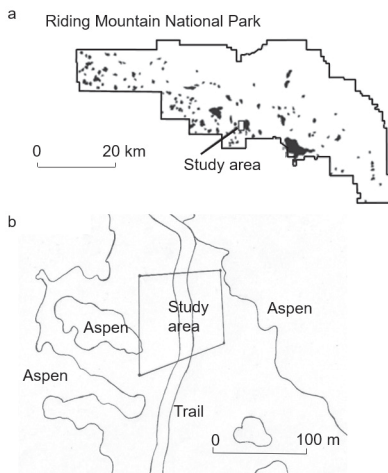
Shannon-Wiener diversity (Gurevitch *et al.* 2006) was calculated as

$$H' = -\sum P_i \ln(P_i)$$

for relative abundance ( $P$ ) of Hemiptera species in each plot. In addition, minimum and maximum theoretical diversity values for a plot were calculated based on the species count and total Hemiptera abundance. The Shannon-Wiener diversity values were re-scaled proportionally across this possible range from a minimum of 0% to a maximum of 100%, enabling comparison among plots.

A linear regression approach was taken, as used previously (Tadey 2016). Linear regression was used to relate percentage cover of Smooth Brome to Hemiptera abundance, biomass, species richness, and species diversity. Similar regression tests were run separately for abundance of common Hemiptera as individual species. All regression tests were also run substituting percentage of total graminoid cover for cover of Smooth Brome. Linear relationships were evaluated by regression analysis of variance using Statistix 8.0 (2003). Given the sample size of  $n = 47$ , each regression analysis of variance calculated the test statistic  $F_{1,45}$  to determine if the relationship was significant at the 0.05 probability level.

Species of Hemiptera with abundance responding significantly to cover of Smooth Brome were determined by K.G. Andrew Hamilton and deposited as voucher specimens at the Manitoba Museum, 190 Rupert Street, Winnipeg, Manitoba R3B 0N2, Canada. Ten *Doratura stylata* Boheman and 15 *Diplocolenus configuratus* Uheler were deposited as voucher specimens MM66800 to MM66809 and MM66810 to MM66824, respectively. There are no common names for these insects.



**FIGURE 1.** a. Location of Grasshopper Valley, the study area, in Riding Mountain National Park, Manitoba. In the map of the study area (b), the width of the access trail is exaggerated, but the trapezoid and stands of Trembling Aspen (*Populus tremuloides*) are drawn to scale.

## Results

Fifty-two plant species, including ten grasses, were recorded from the plots. The most abundant plant was Kentucky Bluegrass (*Poa pratensis* L.), with the percentage cover for Smooth Brome similar to that of the naturally occurring Plains Rough Fescue (Table 1). Across plots, Smooth Brome cover ranged from 0% to 180%, and total graminoid cover (grasses and sedges) ranged from 51% to 189%. Mean cover was 216% for all vegetation across all plots.

For the samples collected 13–17 July, 2445 Hemiptera in 99 species were recovered, with a mean per-plot abundance of  $52.0 \pm 31.6$  (SD) and a corresponding median of 50 for the 47 plots. The Hemiptera collected were 58 species and 1932 individuals of suborder Auchenorrhyncha; 30 species and 433 individuals of suborder Sternorrhyncha; and 11 species and 80 individuals of suborder Heteroptera.

Although numerical reductions in both abundance and biomass of Hemiptera fell short of significance when related to Smooth Brome cover (Table 2), species richness (Figure 2) and species diversity (Table 2) both decreased significantly with increasing Smooth Brome cover. *Doratura stylata* and *D. configuratus*, two common species of suborder Auchenorrhyncha in the family Cicadellidae, had significant negative responses in terms of abundance (Table 2) to increasing cover of Smooth Brome. Cover of all graminoid vegetation combined had no significant relation to any of

the above measures of Hemiptera (Table 2).

## Discussion

Plant-feeding Hemiptera are often specialized consumers (Scudder 2014), and the negative effect of increased Smooth Brome cover on Hemiptera richness and diversity likely follows from a reduction in acceptable foliage for feeding. Vegetation architectural diversity can also influence insect species occurrence (Browne 1982). However, the lack of any discernible response of Hemiptera species to variation in overall graminoid cover across the study site indicates that responses to Smooth Brome invasion were related to feeding preference rather than any change in vegetation type from forb to grass.

The large number of Hemiptera species (99) recorded in our study is a reasonable representation of the marked diversity of this order. For example, of the Heteropteran family Miridae alone, 314 species occur in the Canadian prairies (Kelton 1980).

The leafhopper *D. stylata* prefers grasses in the subfamily Pooideae over other subfamilies (Whitcomb *et al.* 1987), and all ten grass species recorded in our study, including Smooth Brome, are in this subfamily. Thus, the impact of Smooth Brome invasion on *D. stylata* at our study site is not related to a change in grass subfamily available for feeding.

Our results differ from those of Bess *et al.* (2004), who found that both *D. stylata* and *D. configuratus*

**TABLE 1.** Vegetation cover by rank for plant species with average cover exceeding 10% across 47 plots in Grasshopper Valley, Riding Mountain National Park, Manitoba. The remaining 46 plant species found varied in cover from 9.1% to 0.05%.

Rank	Species	Mean cover, %
1	Kentucky Blue Grass ( <i>Poa pratensis</i> L.)	63.6
2	Smooth Brome ( <i>Bromus inermis</i> Leysser)	20.5
3	Plains Rough Fescue ( <i>Festuca hallii</i> (Vasey) Piper)	18.3
4	Western Snowberry ( <i>Symphoricarpos occidentalis</i> Hooker)	17.8
5	Northern Bedstraw ( <i>Galium boreale</i> L.)	12.1
6	Smooth Blue Aster ( <i>Symphotrichum laeve</i> (L.) A. Löve and D. Löve)	11.6

**TABLE 2.** Probabilities of the test statistic  $F_{1,45}$  for analyses of variance for linear regressions with percentage cover of Smooth Brome (*Bromus inermis*) or all graminoids as independent variable, with dependent variable as listed, in 47 plots in Grasshopper Valley, Riding Mountain National Park, Manitoba. Where regressions are significant, the equations relating  $y$  (measure of Hemiptera presence) to  $x$  (Smooth Brome cover) are given.

Measure of Hemiptera presence	Probability of $F_{1,45}$ value for Smooth Brome cover	Equation for Smooth Brome cover	Probability of $F_{1,45}$ value for Graminoid cover
Hemiptera abundance	0.066	Not significant	0.96
Hemiptera biomass	0.190	Not significant	0.63
Hemiptera species richness	<0.001	$y = 14.8 - 0.05x$	0.62
Hemiptera diversity index	0.002	$y = 66.4 - 0.10x$	0.76
<i>Doratura stylata</i> abundance	0.011	$y = 9.7 - 0.06x$	0.24
<i>Diplocolenus configuratus</i> abundance	0.001	$y = 3.3 - 0.03x$	0.87

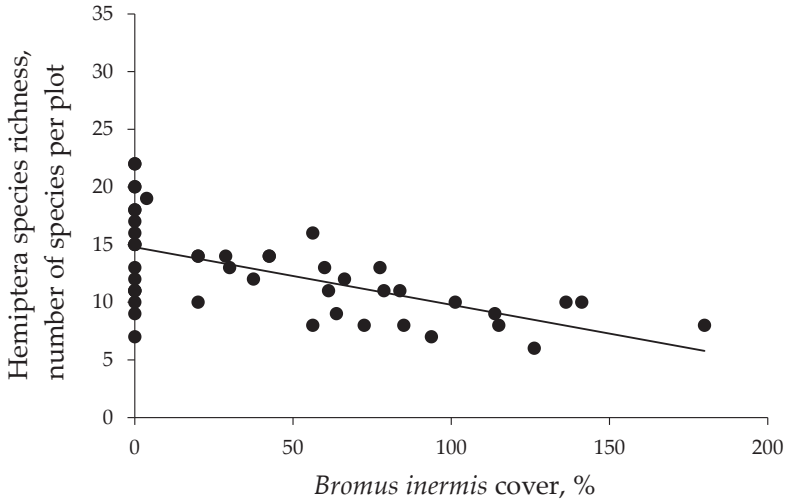


FIGURE 2. Relation between Hemiptera species richness and Smooth Brome (*Bromus inermis*) cover in 47 study plots in Grasshopper Valley, Riding Mountain National Park, Manitoba. The regression line is  $y = 14.8 - 0.05x$ .

were associated positively with Smooth Brome sites, compared with sites with Idaho Fescue (*Festuca idahoensis* Elmer) and without Smooth Brome. However, in that study, the Idaho Fescue sites contained only half the total grass cover seen at Smooth Brome sites, the shortfall being made up by forbs. In contrast, the sites with Smooth Brome also included abundant Kentucky Bluegrass. From our study, both *D. stylata* and *D. configuratus* seem to avoid Smooth Brome at the plot level in a grassland dominated by Kentucky Bluegrass.

The changes in Hemiptera occurrence that we observed in response to Smooth Brome invasion might vary with different environmental conditions in other seasons or years. For example, arthropod abundance at a semi-arid site sown with a native plant mix was greater than in monospecific grass-sown plots when irrigation was provided, but not under ambient rainfall (Wenninger and Inouye 2008). The palatability of foliage relates to its quality, which in turn changes with season. As production among grassland plant species varies through spring and summer, relationships evaluated here for Hemiptera collected in July might be different in other months. Notably, Smooth Brome grows mainly in spring (Dibbern 1947). Seasonal variation in feeding may also occur via direct effects on the insects, not just the foliage (Stiegel *et al.* 2017).

Management of Smooth Brome invasion employs cutting and fire (Otfinowski *et al.* 2014) rather than biological control. Thus, reduced Hemiptera in association with increasing Smooth Brome cover does not affect management of this invasive grass. However, knowledge of the impact of Smooth Brome invasion,

including effects on arthropods, such as Hemiptera, contributes to our understanding of how the functioning of fescue prairie is modified by this persistent introduced plant species. Avoidance of Smooth Brome infestation by Hemiptera presumably increases feeding pressure on neighbouring plants, including not just native species, but also the dominant and introduced Kentucky Bluegrass.

In summary, Hemiptera appear to select regions in a grassland for feeding. Field areas more heavily invaded by Smooth Brome in fescue grassland ecosystems of the Canadian prairies show a reduction in Hemiptera in terms of both species richness and diversity, with corresponding decreases in abundance of two common species, *D. stylata* and *D. configuratus*. Loss of Hemiptera in Smooth Brome invaded grassland seems to relate to the feeding requirements of these phytophagous insects.

### Author Contributions

Writing – Original Draft: V.E.R.; Writing – Reviewing & Editing: T.P.M.; Conceptualization: V.E.R. and T.P.M.; Investigation: V.E.R.; Formal Analysis: V.E.R.; Visualization: V.E.R. and T.P.M.; Supervision: T.P.M.

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