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Forb and Invertebrate Response to Treatments for Greater Sage-grouse in Wyoming Big Sagebrush☆

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ABSTRACT

Treatments in big sagebrush (*Artemisia tridentata* Nutt.) are often implemented to improve habitat conditions for species such as greater sage-grouse (*Centrocercus urophasianus*). These treatments aim to increase the availability of forbs and invertebrates critical to juvenile and adult sage-grouse during the breeding season. However, information regarding the response of forbs in treated sagebrush are often conflicting, dependent on the type of sagebrush community treated and time after treatment. In addition, there is little information on the response of invertebrates to treatments, particularly herbicide treatments in Wyoming big sagebrush (*A.t.* ssp. *wyomingensis* Beetle & Young) communities. We evaluated the response of forbs and invertebrates in Wyoming big sagebrush that had been mowed or aerially treated with tebuthiuron compared with untreated reference areas. We also compared forb and invertebrate dry matter (DM) between treated plots and locations used by brood-rearing females. Forb and invertebrate DM in mowed and tebuthiuron treatments did not differ from untreated plots up to 4 yr after treatment and were equal to or less than locations used by brood-rearing grouse up to 2 yr after treatment. Our findings corroborate best available science that suggest treating Wyoming big sagebrush may not increase food availability for sage-grouse.

Introduction

Rangeland managers and wildlife biologists implement brush treatments to improve habitats for various wildlife species (Beck et al., 2012; Fulbright et al., 2018). Big sagebrush (*Artemisia tridentata* spp.) has been historically treated through chemical application, mechanical treatments, and prescribed burning to increase herbaceous forage species competing with sagebrush overstory (Beck et al., 2012). Treatments typically aim to remove older sagebrush plants to promote growth of younger plants and increase herbaceous production (Perryman et al., 2002; Davies et al., 2009). These techniques have been increasingly applied in attempts to improve habitat for species such as greater sage-grouse (*Centrocercus urophasianus;* hereafter sage-grouse). For example, small (< 200 ha) mechanical and herbicide treatments were associated with increased male sage-grouse lek counts in mountain big sagebrush (*A.t. vaseyana* [Rydb.] Beetle) and basin big sagebrush (*A.t. tridentata*) communities (Dahlgren et al., 2015). In contrast, burning and mowing in Wyoming big sagebrush (*A.t. wyomingensis*) were negatively associated with annual population change; chemical treatments were positively associated with annual population change 11 yr after treatments (Smith and Beck, 2018). In the absence of more fine-scale information, we lack an understanding of potential mechanisms associated with habitat use and demographic responses of sage-grouse to sagebrush treatments (Beck et al., 2012).

Forbs and invertebrates are critical food resources for juvenile and adult sage-grouse (Johnson and Boyce, 1990; Barnett and Crawford, 1994). If herbaceous production is limiting, big sagebrush reduction treatments may be beneficial if they increase the availability of forbs and invertebrates necessary for adults and juveniles. Information regarding the response of forbs and invertebrates to treated sagebrush habitats is often conflicting and depends largely on the sagebrush community and time period of study (Pennington et al., 2016). Furthermore, there is little information available about the response of forbs and invertebrates following chemical treatments in Wyoming big sagebrush communities. We evaluated the response of forb and invertebrate dry matter (DM) in Wyoming big sagebrush treated with mowing and tebuthiuron compared with adjacent untreated reference areas. We also compared forbs and invertebrates at brood-rearing locations of female sage-grouse to mowing and tebuthiuron treatments. Understanding the relative capacity of treated sites to provide forbs and invertebrates equivalent to dietary needs of sage-grouse will provide further information about the potential value of sagebrush treatments for sage-grouse.

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Study Area

Our study was located near Jeffrey City, Wyoming (42.49′N, −107.83′W). Elevation ranged from 1 594 to 2 534 m with yearly precipitation averaging 26 cm (PRISM 2016). The area was primarily managed by the Bureau of Land Management, with smaller inholdings under private and state ownership. Wyoming big sagebrush was the dominant shrub species; mountain big sagebrush, basin big sagebrush, black sagebrush (*A. nova* A. Nelson), yellow rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.), and rubber rabbitbrush (*Ericameria nauseosa* [Pall. ex Pursh] G.L. Nesom & Baird) were common. Mowing and tebuthiuron treatments were implemented in winter and spring 2014, respectively. Treatments were placed in areas that were predicted to have high probability of use during sage-grouse early brood-rearing (i.e., first 2 wk post hatch). Treatment areas were demarcated by developing resource selection functions with radio-tagged female sage-grouse (see Smith, 2016). Mowing treatments were implemented during January and February 2014 and totaled (4.9 km^2) across two areas (Fig. 1). Mowing treatments reduced sagebrush height to approximately 25.4 cm. Tebuthiuron (1.12 kg/ha [0.22 kg/ha active ingredient], anticipating a 50% kill rate) was aerially applied to 6.1 km^2 of sagebrush habitat across two additional areas in early May 2014. Live Wyoming big sagebrush percent canopy cover was reduced by approximately 52.9% in mowed (treated, 8.4% ± 1.0% [SE]; untreated reference,

Figure 1. Example of mowing treatments, treated and untreated reference plots, and sage-grouse brood-rearing locations during 2014–2017, Jeffrey City, Wyoming.

17.9% ± 0.9%) and 46.2% in tebuthiuron (treated, 15.6% ± 2.6%; untreated reference, 29.0% ± 2.8%) treated areas, compared with paired untreated areas during 2017 (K Smith, unpublished data). Mowing and tebuthiuron were applied in a mosaic pattern within larger treatment areas, where no point within treatments was > 60 m from undisturbed sagebrush (*sensu* Dahlgren et al., 2006). Treatments adhered to Wyoming Game and Fish Department protocols for treating sagebrush in Sage-Grouse Core Areas (WGFD, 2011). Please see Smith (2016) for more details about our experimental design.

Methods

In each of the 4 treatment study areas, we randomly sampled 10 treated locations and 10 un-treated reference locations adjacent to each treated plot each yr (2014–2017; see Fig. 1). The average distance of reference locations to a treatment was 122 m (range 42–278 m), ensuring that sampling locations experienced similar climatic conditions. Sampling dates of treated and reference locations corresponded to the brood-rearing period during each year (described later); we began sampling locations within 1 wk after we documented the first successfully hatched nest. To compare the availability of forbs and invertebrates at brood-rearing locations, we captured and radio-tagged female sage-grouse with hoop nets and spotlights (Wakkinen et al., 1992) during spring and summer 2013–2017 (22 g [Model A4060; Advanced Telemetry Systems Incorporated, Isanti, Minnesota, USA] or [PTT-100 Solar Argos/GPS PTT; Microwave Telemetry, Columbia, Maryland, USA]). Sage-grouse were captured and monitored in adherence with approved protocols (Wyoming Game and Fish Department Chapter 33-801 and University of Wyoming Institutional Animal Care and Use Committee protocols 03132011 and 20140128JB0059). We located tagged individuals weekly from late April through mid-August each year to monitor nest and brood success (see Smith et al., 2018). We sampled one location per week for each brood-rearing female sage-grouse during the first 4 wks of the brood-rearing period to identify potential foraging locations (brood use; 2013–2015). If a female lost a brood, we only sampled weekly locations before brood loss. Sampling was conducted no later than 2 wk after broods were located. At each treated, reference, or brood-rearing location, we sampled forbs and invertebrates in plots consisting of two perpendicular 30-m transects oriented in cardinal directions (Smith et al., 2019). Quadrats were randomly placed at either 3, 6, 9, or 12 m without replacement from the center of the intersecting transects. Invertebrate quadrats were fitted with mesh window screening to prevent insect escapement. We used an invertebrate vacuum with a 2-min duration per quadrat (Model 1612, The John W. Hock Company, Gainesville, FL; Schreiber et al., 2015). We clipped annual and perennial food forbs (Table 2 in Kirol et al., 2012) in the adjacent 1-m^2 quadrat. Samples were stored in a freezer before processing. We dried forbs (g) and invertebrates (mg) in a forced-air drying oven at 60°C for 48 h to obtain DM (DM/4 m^2).

We used four linear mixed models (package nlme; Pinheiro et al., 2016) to test the response of forbs and invertebrates to mowing and tebuthiuron treatments, separately. Fixed factors included treatment type (treated or reference) and yr (2014–2017), with a treatment type by year interaction term. Individual plots were treated as a random effect. We used additional linear mixed models to compare forb and invertebrate DM at brood use locations (2013–2015) and treatments (2014–2015). We first determined that forbs and invertebrates differed at brood-rearing locations across weeks during 2014, so we partitioned brood use plots into early (first 2 wk post hatch) and late (wk 3 and 4 post hatch) in all years for comparison. Fixed factors included treatment type (treated [mowing or tebuthiuron], brood use [early or late]) and year, with plot (treatment plot or brood) treated as a random factor. We used least squares means with Tukey adjustments to assess post hoc differences between treatment and year when the main effects were significant (package lsmeans; Length, 2016). All statistical analyses were performed in program R (R version 3.24; R Core Team, 2016), with statistical significance set at $\alpha = 0.05$.

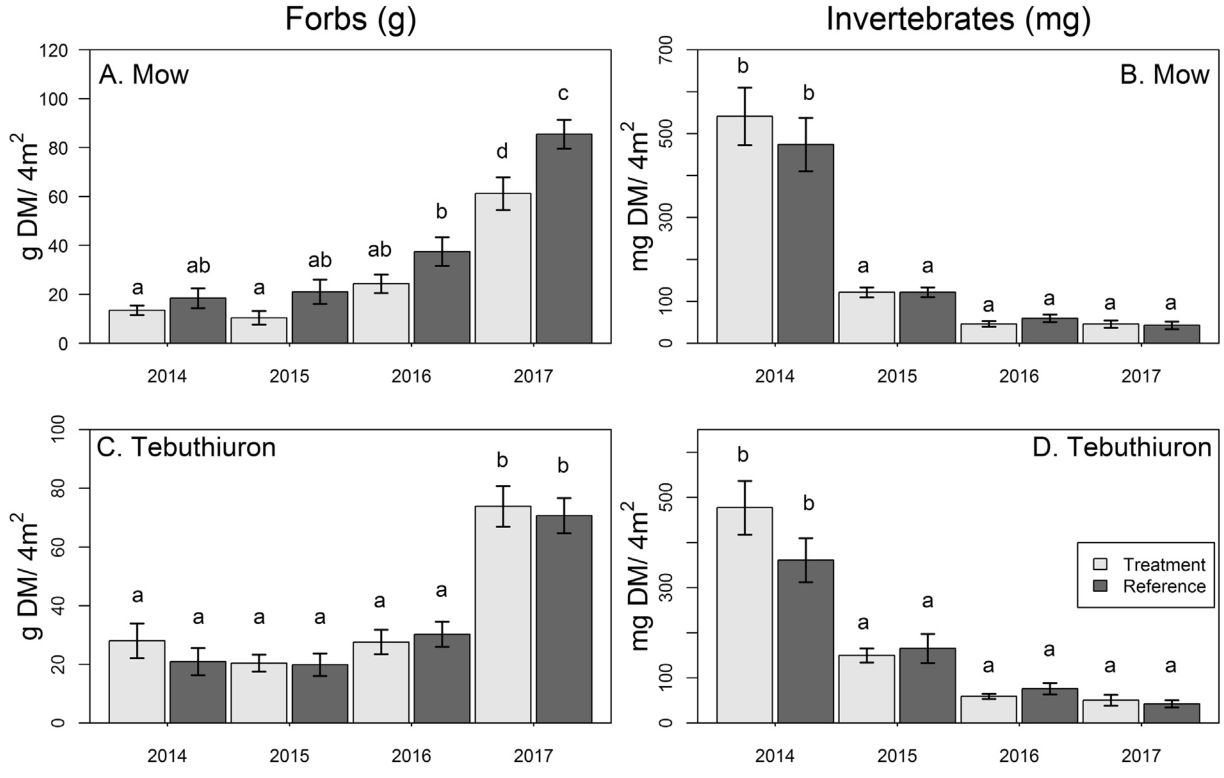

Figure 2. Mean (±SE) forb (g dry matter [DM]/4 m^2) and invertebrate (mg DM/4 m^2) production at mowing (**A** and **B**) and tebuthiuron (**C** and **D**) treatments compared with untreated reference plots sampled during 2014–2017, Jeffrey City, Wyoming. Within each panel, means marked with the same letter do not differ (Tukey's honestly significant difference test, $P >$ 0.05).

Results

We found differences in forb DM between mowed and untreated reference plots ($F_{1,\ 38} = 7.00, P = 0.012$) and year ($F_{3,\ 114} = 108.96, P < 0.001$; Fig. 2A). Forb DM was 1.4× greater during 2017 at reference plots compared with mowed plots. Invertebrate DM did not differ between mowed and reference plots ($F_{1,\ 38} = 0.35, P = 0.558$) but differed across years ($F_{3,\ 112} = 81.44, P < 0.001$), with greatest invertebrate DM during 2014 (see Fig. 2B). At tebuthiuron treatments, forb DM did not differ between treated and reference plots ($F_{1,\ 38} = 0.14, P = 0.714$) but differed across years ($F_{3,\ 114} = 91.07, P < 0.001$; see Fig. 2C). Forb DM was greatest during 2017 at tebuthiuron treatments. There were no differences in invertebrate DM between treated and reference plots at tebuthiuron treatments ($F_{1,\ 38} = 0.990, P = 0.326$). However, there were differences across years ($F_{3,\ 114} = 66.07, P < 0.001$; see Fig. 2D), with greatest invertebrate DM in 2014.

Forb DM differed between brood use locations and treatment plots ($F_{3,\ 264} = 4.51, P = 0.004$) and year ($F_{2,\ 264} = 8.656, P < 0.001$; Fig. 3A). Forb DM at early brood-rearing locations did not differ from mowing or tebuthiuron treatments during 2014 or 2015. Forb DM was 3.8× greater at late brood-rearing locations compared with mowing treatments in 2014 and 2015 but did not differ from forb DM at tebuthiuron treatments during 2014 or 2015. Forb DM at brood-rearing locations during 2013 did not differ from treatments during 2014 and 2015. Invertebrate DM did not differ between plots ($F_{3,\ 264} = 1.886, P = 0.132$) but differed across years ($F_{2,\ 264} = 155.492, P < 0.001$; see Fig. 3B), with 2014 having the highest invertebrate DM compared with 2013 and 2015.

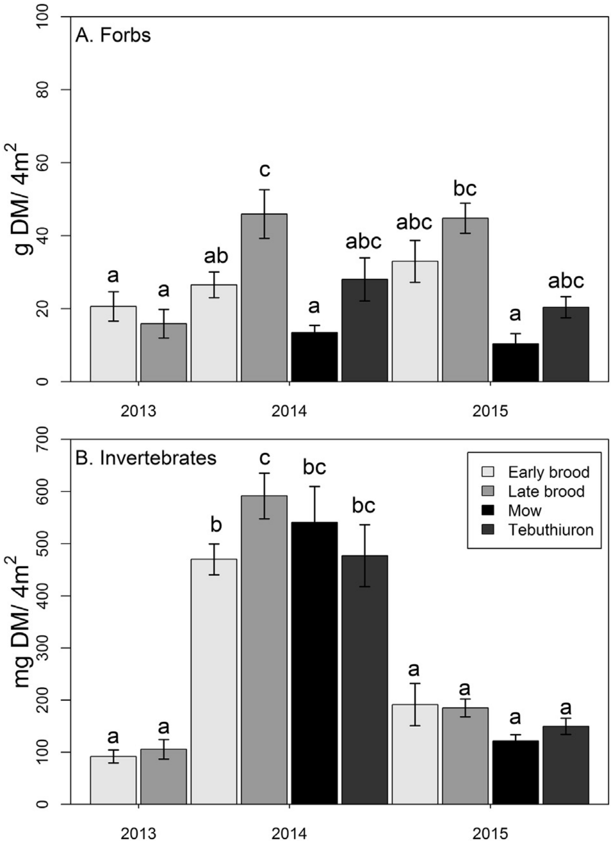

Figure 3. Mean (±SE) forb (g dry matter [DM]/4 m^2) and invertebrate (mg DM/4 m^2) production at locations used by brood-rearing females (2013–2015) and areas treated with mowing and tebuthiuron (2014–2015) in Jeffrey City, Wyoming. Means marked with the same letter do not differ (Tukey's honestly significant difference test $P > 0.05$).

Discussion

We found that both forb and invertebrate production (DM/4 m^2) in treated Wyoming big sagebrush did not differ from untreated reference plots, with the exception that forb DM was greater in reference compared with mowed plots in 2017. Forb and invertebrate DM in mowing and tebuthiuron treatments were equal to or less than locations used by brood-rearing females. Our results are consistent with research that demonstrated a neutral or negative response of forbs after treatments in Wyoming big sagebrush (Fischer et al., 1996; Davies et al., 2007; Rhodes et al., 2010; Davies et al., 2012; Hess and Beck, 2014). In addition, treatments are unlikely to directly increase invertebrate abundance (Harju et al., 2013; Hess and Beck, 2014), because invertebrates are positively associated with herbaceous production (Wenninger and Inouye, 2008). Environmental variation may influence how dietary items for sage-grouse respond after treatment. Annual weather influences total herbaceous production in sagebrush communities (Noy-Meir, 1973); however, the relationship between annual weather and forb production is less understood (Pennington et al., 2016).

Our study did not identify forb and invertebrates to taxa or functional groups. For example, Hess and Beck (2014) found greater grasshopper (Orthoptera) abundance in burned Wyoming big sagebrush relative to reference areas but no change in abundance of ants (Hymenoptera), beetles (Coleoptera), or grasshoppers at mowed compared with reference sites. Brood-rearing site selection and chick survival have also been associated with specific orders of forbs and insects (Gregg and Crawford, 2009; Schreiber et al., 2015). Nonetheless, forbs represent an important food source for sage-grouse during brood rearing (Hagen et al., 2007). Our study was conducted over a relatively short term compared with the long-term recovery rates of big sagebrush after treatments (Watts and Wambolt, 1996). However, in the absence of more long-term studies, our findings do not support treating Wyoming big sagebrush as a tool to enhance sage-grouse populations. Our findings add to the literature base that practitioners may draw from as they determine whether desirable effects of treating Wyoming big sagebrush for wildlife may actually be achieved.

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