BioOne DIGITAL LIBRARY

Grazing of Reed Canarygrass (Phalaris arundinacea) in Restored Wet Meadows

Authors: Norland, Jack, Cleys, Jake, and Sedivec, Kevin

Source: Natural Areas Journal, 42(3) : 185-195

Published By: Natural Areas Association

URL: https://doi.org/10.3375/21-28

The BioOne Digital Library (https://bioone.org/) provides worldwide distribution for more than 580 journals and eBooks from BioOne's community of over 150 nonprofit societies, research institutions, and university presses in the biological, ecological, and environmental sciences. The BioOne Digital Library encompasses the flagship aggregation BioOne Complete (https://bioone.org/subscribe), the BioOne Complete Archive (https://bioone.org/archive), and the BioOne eBooks program offerings ESA eBook Collection (https://bioone.org/esa-ebooks) and CSIRO Publishing BioSelect Collection (https://bioone.org/csiro-ebooks).

Your use of this PDF, the BioOne Digital Library, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/terms-of-use.

Usage of BioOne Digital Library content is strictly limited to personal, educational, and non-commmercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne is an innovative nonprofit that sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Research Article

Grazing of Reed Canarygrass (*Phalaris arundinacea*) in Restored Wet Meadows

Jack Norland,[1,3] Jake Cleys,[2] and Kevin Sedivec[1]

[1]School of Natural Resource Sciences, North Dakota State University, Fargo, ND
[2]Stearns County Soil and Water Conservation District, Waite Park, MN

[3]Corresponding author: jack.norland@ndsu.edu; 701-231-9428
Associate Editor: Noel Pavlovic

ABSTRACT

Reed canarygrass (*Phalaris arundinacea*) is a grass species that can dominate wet meadow plant communities. This study investigated if grazing by cattle on restored wet meadows suppresses reed canarygrass, thereby promoting the restored plant community. This study was conducted at two locations in northwest Minnesota, one managed by The Nature Conservancy (TNC) and the other a Minnesota Board of Water and Soil Resources (BWSR) wetland bank site. Management practices used were a patch-burn grazing treatment on the TNC site and a high-density, short-duration grazing rotation system on the BWSR site. A pretreatment survey of total species canopy coverage was conducted before grazing followed by periodic surveys up to 7 y after grazing started. Both the patch-burn grazing and the grazing rotation system reduced reed canarygrass canopy cover by 49% compared to non-grazed control sites 5–7 y after grazing. With a reduction in reed canary grass canopy coverage due to grazing, the plant community moved toward a community with higher canopy coverage of *Carex pellita* that met restoration goals. Some of the species change was to grasses like Kentucky bluegrass (*Poa pratensis*), which is an exotic, invasive grass in prairies. The changed plant community held steady in native plant species richness or had an increase in native plant species richness. This study demonstrates grazing reduces the cover of reed canarygrass, while meeting restoration goals for wet meadows.

Index terms: Carex pellita; native plant species richness; patch burn grazing; *Poa pratensis*; rotational grazing

INTRODUCTION

Reed canarygrass (*Phalaris arundinacea* L.) is a prolific invader that can easily spread throughout wetlands and create monospecific stands (Lavergne and Molofsky 2004; Adams and Galatowitsch 2005). These stands of pure reed canarygrass are undesirable because they create areas of low plant diversity (Kercher et al. 2004) and undesirable wildlife habitat (Kirsch et al. 2007; Evans-Peters et al. 2012). Reed canarygrass has been used as a forage source for livestock and has been used in environmental plantings to treat wastewater and control erosion. These uses have led to the spread of reed canarygrass across landscapes (Galatowitsch et al. 1999; Green and Galatowitsch 2002; Kercher and Zedler 2004; Adams and Galatowitsch 2005; Kim et al. 2006; Kidd and Yeakley 2015). Reed canarygrass can exist and thrive in a variety of growing conditions: (1) increased nitrate (N) in the soil, (2) high amounts of soil organic matter, (3) flooding conditions, (4) shade, and (5) heavy soil disturbance (Green and Galatowitsch 2002; Kellogg et al. 2003; Kercher and Zedler 2004). Not only is this grass tolerant of flooding but it can withstand fluctuating water levels (Galatowitsch et al. 2000). These characteristics are why reed canarygrass has been classified as an invasive species and a management problem for wetlands.

Several methods have been used to varying degrees of success to control the invasion of reed canarygrass. Herbicide application has been used with total control being elusive (Bahm et al. 2014). Replacement of reed canarygrass using cultivation accompanied with herbicide and planting of desirable vegetation has shown some success in reducing the monospecific stands but again total control was not achieved (Adams and Galatowitsch 2005; Kim et al. 2006). Fertilizing with nitrate was not effective at reducing reed canarygrass canopy cover (Green and Galatowitsch 2002) nor was burning (Adams and Galatowitsch 2006; Kim et al. 2006). The use of grazing as a control method had only been mentioned and prior to 2010 there was no information on the effects grazing has on controlling reed canarygrass.

The goal of this study was to investigate if grazing cattle could be an effective practice for reducing the canopy cover of reed canarygrass in two restored wetland complexes in western Minnesota. Our wetland complexes included northern wet prairie, prairie mixed-cattail marsh, and prairie wet meadow/sedges, while the uplands included northern dry prairie and northern mesic prairie (MNDNR 2019). Because reed canarygrass has been planted as a forage for livestock it is predicted that grazing will be effective at reducing reed canarygrass canopy cover. Reed canarygrass is a palatable grass to cattle, with high crude protein and low content of alkaloids, creating a desirable feed (Vetsch et al. 1999). Grazing by cattle should defoliate the plant, suppress flower development, and reduce or eliminate seed production and spread. When reed canarygrass is grazed the plant does not create monoculture stands (Paine and Ribic 2002; Hillhouse et al. 2010; Kidd and Yeakley 2015).

Two grazing treatments were used at two separate sites. The first treatment used rotational grazing with a high stock density of cattle using a short grazing duration (7 d or less). Cattle were rotated through four paddocks three times (spring, early

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

summer, and fall). This treatment design is similar to previous studies by Oates et al. (2011), Rinella and Bellows (2016), and James et al. (2017). These previous research studies showed a decrease in invasive plant abundance and increase in native species richness from grazing.

The second treatment used patch-burn grazing. This treatment used one large paddock, grazed season-long with cattle, with portions burned periodically. Biondini et al. (1999) showed bison selectively grazed new burned sites over unburned and previously burned. Spiess et al. (2020) showed cattle selectively grazed burn patches when patch-burn grazing in western North Dakota. Others (Cummings et al. 2007; Diamond et al. 2012; Scasta et al. 2016) predicted combining grazing and burning would reduce the abundance of invasive species from the dominant species to a component of the plant community. While this study is not designed to reduce reed canarygrass with burning alone, which Lavergne and Molofsky (2006) showed to be ineffective, it is believed burning paired with grazing will boost reed canarygrass suppression compared to burning alone. We predict that grazing in both approaches will reduce canopy cover of reed canarygrass.

Our second prediction is if reed canarygrass is reduced, the plant communities will change to a more diverse community. While much research has been conducted on reed canarygrass and grazing practices (patch-burn, targeted, rotational), only a few studies address controlling reed canarygrass on restored wet meadows (Green and Galatowitsch 2002; Adams and Galatowitsch 2005, 2006). No studies have looked at both rotational and patch-burn grazing as control methods for reed canarygrass on restored wet meadows.

The two sites selected for the research have as their restoration objectives:

(1) Brantner site objectives are to restore and maintain the soil and water of a restored wet meadow habitat by partnering with a private landowner to implement rotational grazing to lower the abundance of the invasive plant reed canarygrass and promote a restored native plant community.
(2) Williams site objectives are to closely mimic native prairie using adapted native seed to promote native plant communities invaded by reed canarygrass through the use of patch-burn grazing.

The research objectives were:

(1) Determine the effects of rotational and patch-burn grazing on reed canarygrass cover in restored wetland complexes.
(2) Determine the effects of rotational and patch-burn grazing on the wetland and upland plant communities in the restored wetland complexes.
(3) Determine if the reduction of reed canarygrass through rotational and patch-burn grazing will affect native plant richness in the restored wetland complexes.

METHODS

This research was conducted at two study sites, the Brantner and Williams sites, each located near Glyndon, Minnesota, in Clay County. The sites were located in the northeastern region of the Tallgrass Prairie (USDI US Fish and Wildlife Service 2019).

Brantner Site

The Brantner site (46°54′33.70″N, 96°26′08.83″W) was a restored wetland complex that was mowed, burned, then reseeded using the Minnesota Board of Water and Soil Resources (MNBWSR 2019) approved mesic prairie and wetland fringe seed mixes (Lynn Foss, Clay County Soil and Water Conservation District, pers. comm.). The site is managed by a private landowner and part of the BWSR wetland bank (Figure 1). The study site was 36 ha in size. The soils are typically poorly drained loams with low spots where soils are hydric in nature (USDA Natural Resource Conservation Service 2006). The native plant communities in the region are dominated by tallgrasses such as prairie cordgrass (*Spartina pectinate* Bosc ex Link), big bluestem (*Andropogon gerardii* Vitman), tufted hair grass (*Deschampsia cespitosa* (L.) P. Beauv.), slimstem reedgrass (*Calamagrostis stricta* (Timm) Koeler) and prairie dropseed (*Sporobolus heterolepis* (A. Gray) A. Gray) as well as arctic rush (*Juncus arcticus* Willd.) and Buxbaum's sedge (*Carex buxbaumii* Wahlenb.). Canada goldenrod (*Solidago canadensis* L.) and giant sunflower (*Helianthus giganteus* L.) are the most common forbs (MNDNR 2019).

The restoration of the Brantner site began in 2003 with the restoration of a 22 ha wetland complex. It was previously used as pasture, then cropped, and then placed into the Conservation Reserve Program. Ditch plugs were used to reestablish wetland hydrology. The site was sprayed with glyphosate in August 2003 and burned with a prescribed fire to prepare the site for restoration. The site was seeded using a grass drill in October 2003. The BWSR mesic prairie seed mix #3 was used on the 6 ha upland prairie area and the BWSR wetland fringe mix #1 on the 11 ha wet meadow area. Areas with minor erosion were repaired, reseeded, and mowed.

Williams Site

The Williams site (46°48′41.46″N, 96°25′48.87″W) is managed by The Nature Conservancy (TNC) and is part of the Bluestem Prairie Scientific and Natural Area. The site is 534 ha in size (Figure 2). TNC acquired the site in 2005 and began restorations in 2008, completing the first phase of the restoration in 2010. A perimeter fence was established on the site in 2011 and 2012, and a patch-burn grazing program implemented.

Upland soils were highly permeable sands, loamy sands, poor to well drained, moderately permeable to permeable, to fine and medium textured loams. The wetland soils formed in periodically inundated shallow basins and classified as mollisols (USDA Natural Resource Conservation Service 2006; MNDNR 2019). Native plant communities are tallgrasses and sedges with rushes in flooded areas (see plant list for Brantner site) (MNDNR 2019).

TNC used a local restoration contractor, Prairie Restoration Inc., who provided locally sourced seed. The differing parts of the site were sprayed with a glyphosate and clopyralid herbicides mix in July 2008, June 2009, and June 2010. Differing parts of the site were seeded in 2008, July and August 2009, and July 2010. The seed used was harvested directly from several local

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

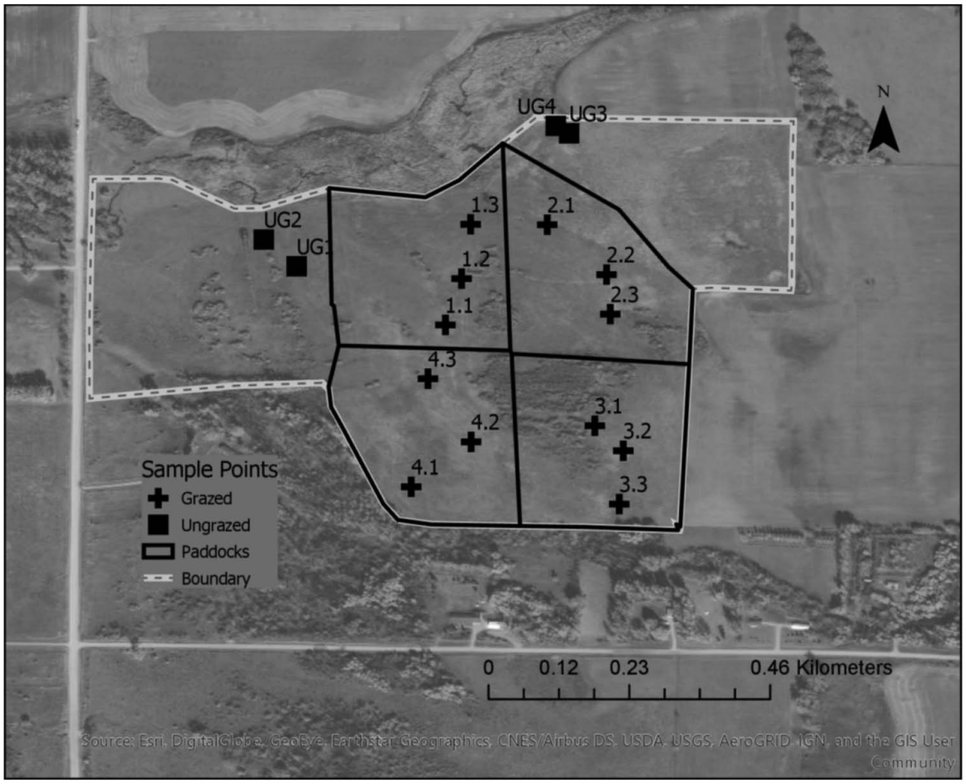

Figure 1.—The Brantner site showing the boundary, paddock fences, and labeled sample points. The UG label represents non-grazed exclosures. The first number of the sample point labels denotes the paddock while the number after the decimal is the point ID.

native prairie sites and broadcasted over the site as a bulk seed mix. The 2008 bulk seed mix was made up of 39% big bluestem and 4.1% Indiangrass (*Sorghastrum nutans* L.(Nash)). Other species seeded included two invasive grasses (*Poa pratensis* L. and *Bromus* spp.) at trace amounts, nine native grasses at 5.8%, and 3% various native forb species. The remaining 48.1% was inert matter. Snow seeding of the bulk seed collected during the fall of 2010 was conducted in March 2011, with big bluestem at 20%, Indiangrass 19%, leadplant (*Amorpha canescens* Pursh) 8.2%, and prairie dropseed (*Sporobolus heterolepis*) 5.4% of the mix; 5% of the seed mixture contained 12 native and one nonnative grasses, and 1% various native forb species. The remaining 42.4% was inert matter.

Areas seeded in 2009 and 2010 were clipped for weed control. Bird's-foot trefoil (*Lotus corniculatus* L.), an invasive legume, was sprayed on the previously seeded areas with aminopyralid in 2010. In September 2011, 21 ha of the site was mowed and the bird's-foot trefoil found on 40 ha was sprayed using aminopyralid. The restoration project restored 476 ha upland prairie and 40 ha of wetlands.

Study treatments

This study used two different grazing practices: (1) rotational grazing (RG) using a high stock density of cattle for short periods (7 d) and (2) patch-burn grazing (PBG). The Brantner site used the RG within a four-paddocks system. The four-paddock rotation was designed to graze each paddock twice starting late May through July when reed canarygrass was vigorously growing, and then a single rotation in the fall starting late August. The cattle were kept in other paddocks on the site when not used in the rotations. Each of the four paddocks was considered a replicate and approximately 6 ha each. A herd of 25–30 cross-bred cattle with calves was used to graze the RG system. The paddocks were considered to be moderately grazed according to regional conditions (Jeff Duchene, regional range specialist, NRCS, pers. comm.).

The RG system was designed to start in the summer of 2012 and end after the summer of 2018. Due to unforeseen watering problems, the cows were not always properly rotated in 2012, 2013, and 2014. Because there was only one watering source the gates to the pastures were left open and the cows were allowed to move freely through all four paddocks. The grazing period from 2012 to 2014 was restricted to May through July and a period from later August into September. This resulted in the cows being allowed to graze for a time similar to what would have happened if the rotational system was going. When the water system was not functioning from 2012 to 2014 grazing by the cows resulted in an uncontrolled application of the grazing treatment since cows could select to spend more time grazing in a certain paddock over the others. In 2015 until the end of the experiment in 2018 the watering system functioned as planned so that the cows were rotated through the four paddocks in a controlled fashion so the grazing treatment was identical for each paddock with stock density, grazing time, and frequency being the same.

Four locations were selected outside the four paddocks and used as non-grazed controls. These sites were fenced creating an exclosure measuring 10 × 10 m. In the areas around the grazing

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

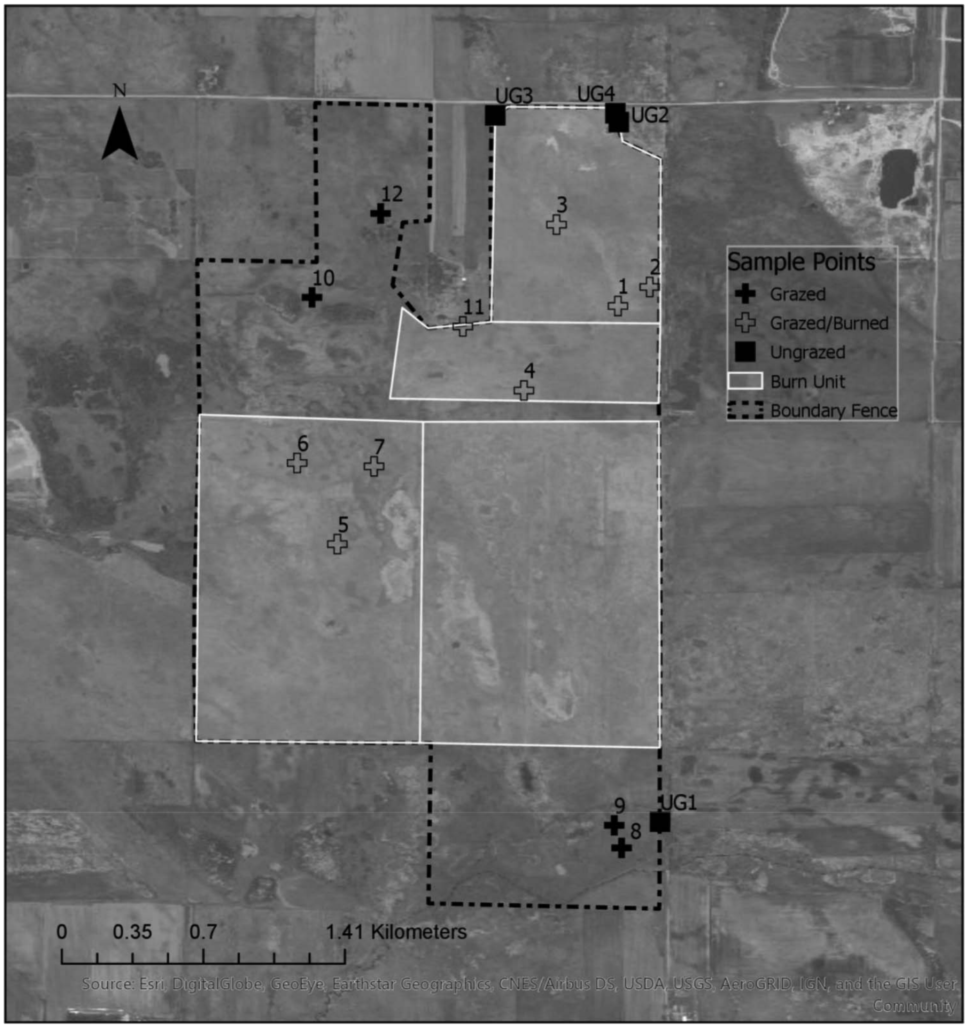

Figure 2.—The Williams site showing the sample points, boundary fence, and the burn units that were burned during the study. The UG label is the non-grazed exclosures.

exclosure cattle were allowed to graze at different times. The non-grazed locations were dispersed over the site to decrease the chance they were subject to conditions that would invalidate them as controls.

The Williams site had the PBG system installed with season-long grazing every year from mid-May to September, and a burn conducted every year with a burn return rate of 6 y (Figure 2). The Williams site was one 485 ha paddock. Not all sampling points had a burn occur at their location by the end of the study in 2017. An average of 578 AUMs was grazed on the site for 4–5 mo per year. This stock density resulted in the site being lightly to moderately grazed according to regional conditions over the time of the study (Jeff Duchene, regional range specialist, NRCS, pers. comm.). Because watering locations were not uniformly distributed, certain areas had less cattle use compared to other areas. The intent of PBG is to attract cattle to sites irrespective of watering locations so they get preferred grazing use for 1–2 y after a burn. Four non-grazed locations were selected on similar soils and plant communities and used as controls. These locations were areas built in 2011 and not included in the grazed paddock. The non-grazed locations were dispersed over the site to decrease the chance they were subject to conditions that would invalidate them as controls. The burning schedule resulted in 66% of points being burned once. Approximately 65% of the study site was burned once.

The Brantner site (RG) had three randomly selected sampling points within each of the four paddocks. This resulted in a total of 12 points assessed for a grazing effect along with four non-grazed control plots. The Williams site (PBG) had 12 points randomly located in the fenced paddock. If a random point did not fall within a reed canarygrass patch, the point was moved to the closest patch. A global navigation satellite system receiver was used to navigate to the sampling points each sampling period. At each sampling point, three 1 m^2 quadrats were arranged in a triangle 1 m from the sample point. In each quadrat the canopy cover of all species was ocularly estimated to the nearest percent (Daubenmire 1959). Bare ground and litter cover were also recorded. Canopy cover estimation was determined by the same observer to maintain consistency over time. Plants not present in the quadrats were recorded if found within a 4 m^2 area around the three quadrats. The additional species within the 4 m^2 area were given a 0.5% canopy cover in

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

the analysis. All sampling occurred in September to capture the effects of grazing over the growing season.

Data Analysis

The experimental design for the Brantner site was a randomized design with the four paddocks treated as replications and the three sample points within each replication treated as subsamples and averaged together within a replication for analysis (total of 12 sites). In the case of the four non-grazed locations they were treated as four replications and the three 1 m^2 quadrats were averaged together. The grazed and non-grazed treatments were analyzed separately. The main factor analyzed was sampling dates where pretreatment was compared to later years. Reed canarygrass canopy cover and native plant richness were analyzed using SAS 9.4 (SAS Institute Inc., Cary, North Carolina, USA) using a mixed model design where replication was the random factor and sampling date was a fixed factor. Least square mean comparison tests used the Tukey procedure at the $P = 0.05$ significance level. The plant community data (species canopy cover) were analyzed as mixed model with replications as the random factor and sampling dates (pretreatment, 6 y after grazing, and 7 y after grazing) as a fixed factor using PERMANOVA (Anderson et al. 2008) as implemented in PRIMER-e (Quest Research Limited). The Bray-Curtis distance measure was used in the analysis. There was no adjustment to the paired comparison *P* values as recommended by Anderson et al. (2008).

The Williams site was treated as a completely randomized design with each sample point being a random sample. Because separate paddocks were not established, the different sample points are not true replications but are samples within a large paddock. The four non-grazed locations were also treated as four random locations. The main factor analyzed was sampling dates where pretreatment was compared to later years. The grazed and non-grazed treatments were analyzed separately. Reed canarygrass cover and native plant richness were analyzed as a completely randomized design where the main factor was sample dates using SAS 9.4. Least square mean comparison tests used the Tukey procedure at $P = 0.05$ significance level. The plant community data (species canopy cover) were analyzed as completely randomized design using PERMANOVA (Anderson et al. 2008) as implemented in PRIMER-e where sampling date was the main factor. The Bray-Curtis distance measure was used in the analysis. There was no adjustment to the paired comparison *P* values as recommended by Anderson et al. (2008).

Plant community data (species canopy cover) was analyzed using nonmetric multidimensional scaling (NMS) ordination as a way to graphically display how the plant communities have changed over time. The NMS analysis was completed using PC-ORD 7 software (Wild Blueberry Media LLC) (McCune and Grace 2002). The Bray-Curtis distance measure was used to assess the dissimilarity in the data, which was the same used in the PERMANOVA analysis. Patterns in the data were found by doing 500 iterations of the data in PC-ORD reducing to one axis from six with an instability criterion of 0.0001. The number of axes (dimensions) and model selection was based on (1) a significant Monte Carlo test ($P < 0.05$), (2) a model with a stress <25, (3) an instability <0.0001, and (4) axes selection was discontinued if the next axis did not reduce stress >5. Successional vectors connected samples over time and were used as an aid to interpreting if there was a pattern over time. Pearson's correlation coefficients $R \geq 0.4$ or $R \leq -0.4$ between species cover and axes scores were used to interpret the ordination and appropriately reflect an interpretable effect size (McCune and Grace 2002).

RESULTS

A total of 102 species were identified at the Brantner site and 98 at the Williams site over the course of the study. Grazing reduced the canopy coverage of reed canarygrass by 50% from pretreatment condition for both the Brantner and Williams sites 7 and 5 y after grazing, respectively (Figure 3). In contrast, the non-grazed locations at both the Brantner and Williams sites did not show any reductions in reed canarygrass canopy coverage over the same time period (Figure 3). Pictures of the fence line contrasts (Figure 4) show the effect of the canopy cover reduction from grazing with a decrease in the height and stems of reed canarygrass. The PERMANOVA analysis found grazed reed canarygrass patch plant communities did differ ($P < 0.05$) compared to the pretreatment communities for both the Brantner and Williams sites 7 and 5 y after grazing, respectively. The non-grazed plant communities did not differ ($P > 0.05$) compared to the pretreatment communities for both Brantner and Williams sites 5 and 7 y after grazing, respectively.

Nonmetric multidimensional scaling ordinations of the reed canarygrass patch plant community data for the Brantner site found three explanatory axes where the stress was 10.8 (Figure 5). The Brantner NMS ordination had 80% of data represented by the first two axes with the third only representing 11%. Because only 11% of the variability was explained by the third axis, this axis was not included in the results. Knowing that the grazed plant communities differed from pretreatment communities the Brantner site directional vectors can be used to show where the plant communities were trending. The trend was that all the grazed samples moved from the positive end of axis 1 where a high cover of reed canarygrass was correlated, to the negative end of axis 1 where a high cover of wooly sedge (*Carex pellita* Muhl. ex Willd.) occurred (see Table 1 for canopy coverage values for species interpreted within the NMS analysis). The major effect of the RG treatment over time was to decrease the cover of reed canarygrass with a subsequent increase in wooly sedge cover. The negative end of axis 1 where the grazed sites were trending over time has two exotic grass species, Kentucky bluegrass and redtop (*Agrostis gigantean* Roth), with correlations of higher cover (Figure 5). Axis 2 has four native forb species correlated with the positive end of the axis. Axis 2 appears to be related to sample differences as opposed to change over time due to RG grazing treatment which axis 1 shows.

The NMS ordination of the Williams site found two explanatory axes with a stress of 18.4 accounting for 81% of the variability in the data (Figure 6). The NMS ordination of the Williams sites shows the same trends as the Brantner site, although the grazing response and axes scores are reversed. The major effect of PBG over time was to decrease the cover of reed canarygrass with a subsequent increase in wooly sedge cover. The

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

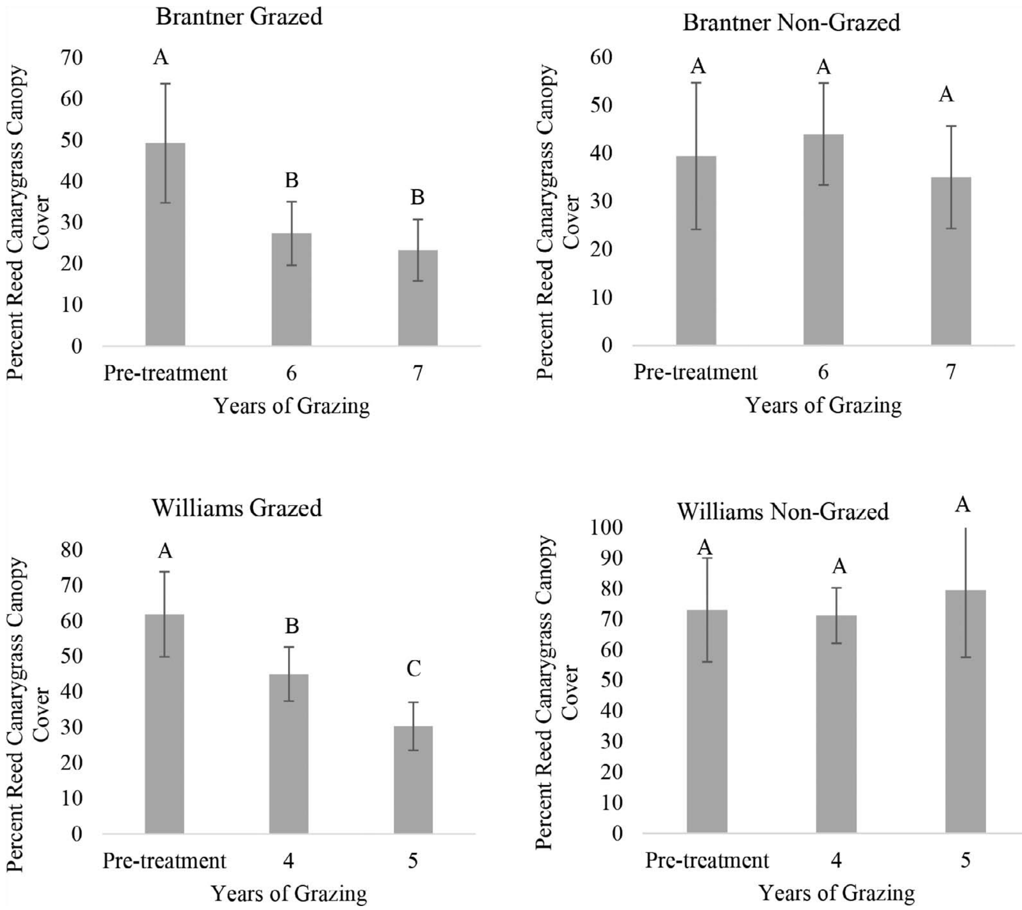

Figure 3.—Percent canopy coverage of reed canarygrass for grazed and non-grazed patches before grazing (pretreatment) and so many years after grazing for the Brantner and the Williams sites. Treatments with the same letters are not significantly different ($P > 0.05$). The error bars show standard deviation.

three native species correlated with axis 2 are different but the patterns are the same. There were no consistent directional changes noted for both the Brantner and Williams non-grazed samples, which matches the analysis that showed the communities did not differ over the study.

Native species richness was compared from pretreatment levels to 7 and 5 y after grazing for the Brantner and Williams sites, respectively. Native species richness did not differ ($P = 0.976$) between pretreatment levels and 7 y after grazing in the reed canarygrass patches at the Brantner site (Table 2). Native species richness in the reed canarygrass grazed patches increased ($P = 0.039$) from the pretreatment level to 4 y after grazing at the Williams site (Table 2). The increase in richness was also found for total and exotic species richness at the Williams site. There were no changes in native, total, or exotic species richness in the non-grazed locations over the course of the study (Table 2).

DISCUSSION

The RG treatment at the Brantner site was not consistently applied in the first 3 y due to watering issues, but was consistently applied as planned in the final 4 y. This inconsistent application meant that replications were not treated the same until later in the study. We maintain that the early inconsistent grazing application did not unduly affect the RG treatment as it was applied later in the study. The early inconsistent grazing application would have introduced variability in how the sites would react to grazing, but the NMS results of the Brantner sites showed a uniform trend across all the grazed sample sites. Therefore, we contend any interpretation of the RG effects from the study should apply to rotational grazing. Concerning the lack of replication in the PBG treatment, we want to make the case that even though the PBG is an un-replicated experiment that given the experiment covered a large area and the results agree with the RG results, we can assert that the interpretation of the results can be applied to the grazing of reed canarygrass.

We found that grazing can reduce reed canarygrass cover resulting in an increase of both native and grazing-resistant species cover. One of the species that increased was a native sedge (*Carex pellita*), which is the type of species desired in restored wet meadow communities. Grazing did not decrease native species richness over time in the reed canarygrass patches using RG while increasing native species richness using PBG. Others (Hillhouse et al. 2010; Guretzky et al. 2018) also found that grazing of reed canarygrass did not result in lower native species richness. Therefore, the reduced cover of reed canarygrass from grazing is moving the plant community toward one with a higher cover of native wet meadow species and does not

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Figure 4.—Pictures showing fence line contrast between grazed and non-grazed areas. The picture on the right is from the Brantner site with the grazed portion on the left. The picture on the left is from the Williams site with the grazed portion on the right. Both pictures show a reduction in the height and old stems of reed canarygrass.

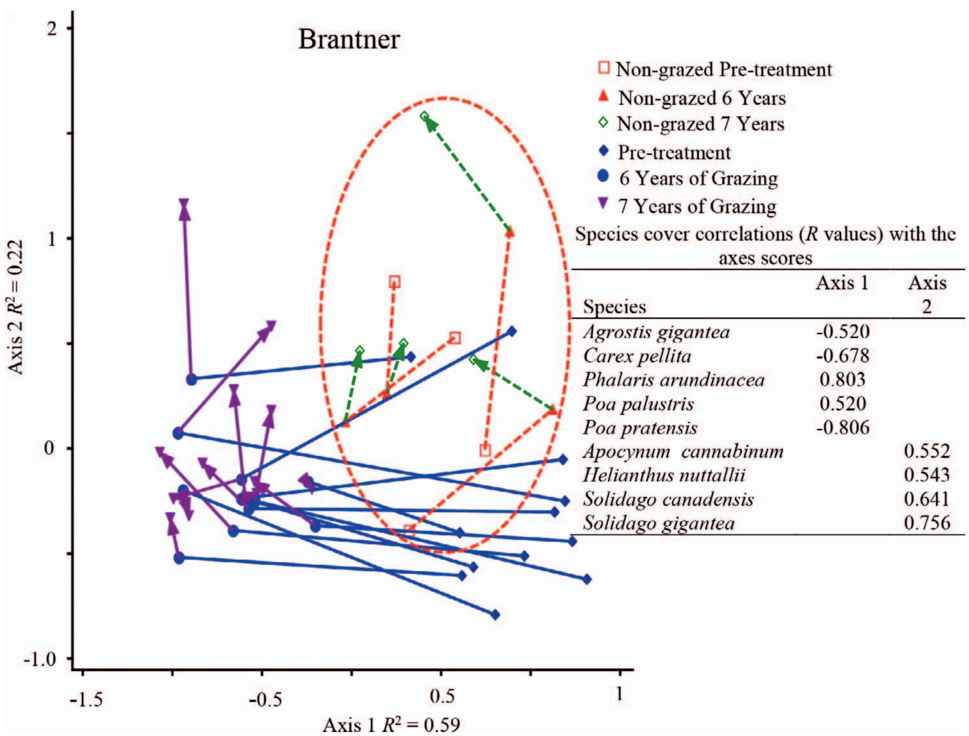

Figure 5.—Ordination NMS graph representing the shift in the plant communities over time for the Brantner site for both grazed reed canarygrass patches and non-grazed patches. The directional successional arrows show the shift in the plant community in the reed canarygrass patches from the start of the experiment to the end of the experiment. The dotted line highlights the non-grazed patches with dotted directional successional arrows showing the shift from the start of the experiment to 7 y after grazing. Species that were highly correlated (*R* values >0.4 or <–0.4) with the axes are represented on the graph. Values after the axis labels show the amount of variability explained by the axis.

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Table 1.—Average cover of plant species that had a Pearson's correlation coefficient of $R \geq 0.4$ or $R \leq -0.4$ with the significant NMS axes for either the Brantner or Williams site. Values for pretreatment and so many years after grazing started are shown.

	Brantner					
	Non-grazed			Grazed		
Species	Pretreatment	6 years	7 years	Pretreatment	6 years	7 years
Agrostis gigantea	6.4	1.7	0.3	3.3	7.8	10.7
Apocynum cannabinum	–	1.0	1.0	–	–	0.2
Carex pellita	7.9	2.9	4.0	1.2	17.3	14.8
Helianthus maximiliani	–	–	–	–	–	–
Helianthus nuttallii	–	2.1	1.8	–	–	–
Poa palustris	11.8	–	–	7.9	–	0.1
Poa pratensis	5.1	12.5	11.3	2.0	27.7	20.7
Solidago canadensis	3.9	4.0	15.4	0.7	1.9	2.9
Solidago gigantea	12.5	21.3	23.8	5.0	2.1	2.4
Zizia aurea	0.1	0.4	0.2	0.1	0.3	0.1
	Williams					
	Non-grazed			Grazed		
	Pretreatment	4 years	5 years	Pretreatment	4 years	5 years
Agrostis gigantea	0.2	–	–	0.1	3.1	4.2
Apocynum cannabinum	–	–	–	–	0.8	1.0
Carex pellita	6.3	3.4	0.8	5.1	18.1	19.4
Helianthus maximiliani	–	–	–	0.1	0.1	0.1
Helianthus nuttalli	–	–	–	–	0.5	0.5
Poa palustris	0.2	–	–	0.1	2.8	–
Poa pratensis	1.7	2.3	5.4	1.3	5.7	12.4
Solidago canadensis	–	2.5	4.2	0.2	0.3	0.7
Solidago gigantea	1.8	–	1.7	0.1	1.1	0.9
Zizia aurea	–	–	–	–	0.3	0.2

lower native species richness. While grazing is an effective way of reducing reed canarygrass canopy cover, grazing did not guarantee eradication but rather is a way to limit reed canarygrass effects on restored wet meadows.

The reduction in height and old stems that is reflected in the reduced canopy coverage of reed canarygrass from grazing is probably conducive to the increase of native sedges and other native species. By reducing the height, old stems, and canopy coverage more of the area is open to sunlight, reducing competition so other species were able to establish and grow such as native sedges (Hillhouse et al. 2010; Marchetto et al. 2021). The result of more sedge species may also be a result of saturated soils and spring flooding, with sedges more tolerant of certain wet conditions.

One of the consequences of grazing in the reed canarygrass patches is that other introduced, invasive grazing-resistant grasses, such as Kentucky bluegrass and redtop, increase in cover within the changed plant community. Both grasses were present on the site prior to restoration and were not eradicated during the restoration process. Kentucky bluegrass can be a more difficult plant to suppress and reduce, creating a new concern (DeKeyser et al. 2013). Kentucky bluegrass can be problematic for restorations and its long-term management is a problem for restorations (DeKeyser et. al. 2015; Larson et al. 2017). Because the grazed wet meadows have other species increasing like the native sedge and the wet meadow habitat not ideal for Kentucky bluegrass, it is unknown if this introduced, invasive grass will be a long-term problem as seen in other restoration studies (Larson et al. 2017). Although redtop is adapted to wet meadows, it is unclear if it is an issue for wet meadow restorations (Cao et al. 2019). This species warrants more research on its effects in wet meadow restoration, since it can increase once reed canarygrass is reduced.

Grazing has mixed results with some studies showing a reduction in exotic plants and others no change (Paine and Ribic 2002; Launchbaugh and Walker 2006; Hillhouse et al. 2010; James et al. 2017; Marchetto et al. 2021). Our study demonstrated a reduction in reed canarygrass from RG without any reduction in native species richness. James et al. (2017) along with Marchetto et al. (2021) reported grazing does not decrease and can increase native species abundance and provide other benefits to conservation. This agrees with our study and shows how RG can control certain invasive species in restorations while providing benefits to conservation.

Patch burn grazing has been advocated as a way to reduce invasive species dominance (Scasta et al. 2016) and the results of this study confirm that PBG can reduce the dominance of reed canarygrass. We speculate some of the conditions that made PBG successful were the burns attracting cattle to reed canarygrass patches making reed canarygrass accessible through removing litter and old stems (Sheaffer et al. 1990; Biondini et al. 1999). Once attracted to the patches, reed canarygrass cover was reduced by grazing and native species like sedges increased. In addition, native species richness increased. This increase in native species richness may be a function of a matured restoration with native richness naturally increasing even

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

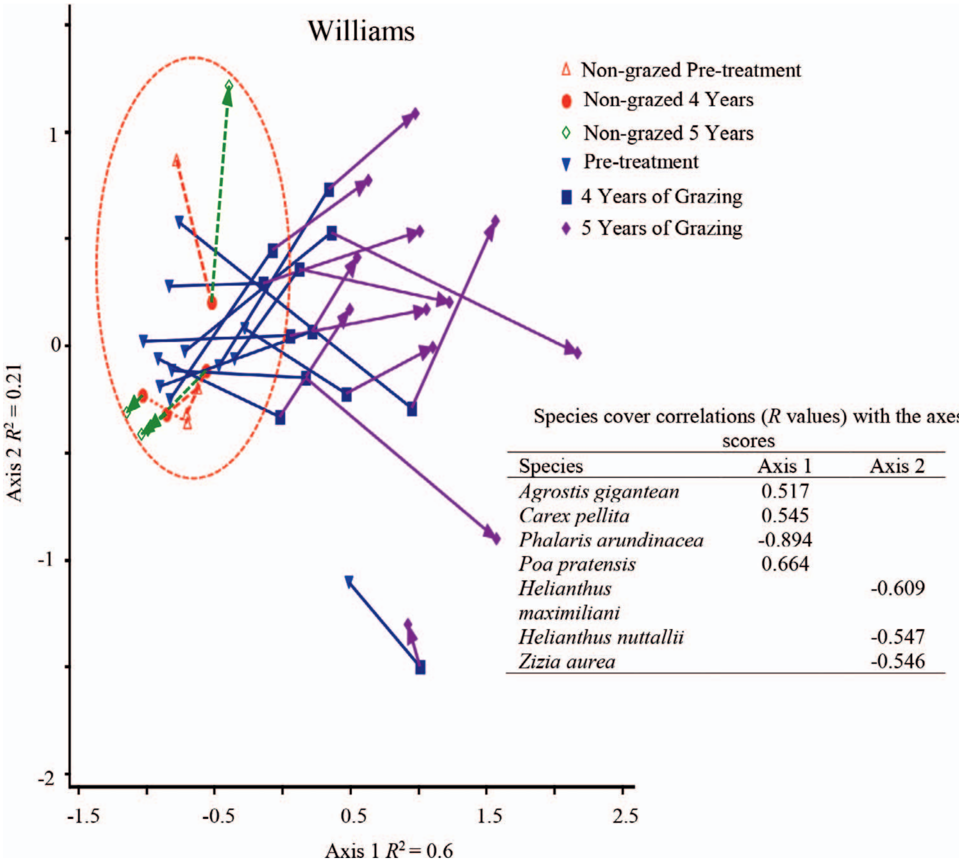

Figure 6.—Ordination NMS graph representing the shift in the plant communities over time for the Williams site for both grazed reed canarygrass patches and non-grazed patches. The directional successional arrows show the shift in the plant community in the reed canarygrass patches from the start of the experiment to the end of the experiment. The dotted line highlights the non-grazed patches with dotted directional successional arrows showing the shift from the start of the experiment to 7 y after grazing. Species that were highly correlated (*R* values >0.4 or <–0.4) with the axes are represented on the graph. Values after the axis labels show the amount of variability explained by the axis.

without grazing. Nonetheless, it appears grazing is not a hindrance to increasing native species richness even though it might not be a factor in promoting native species richness.

One suggestion for managing the reed canarygrass patches is once a reduction in reed canarygrass has been achieved, removing grazing and applying rest to the sites would be beneficial to the plant community and meet restoration goals. Based on the findings of Kidd and Yeakley (2015), we recommend that rest from grazing should be short term if at all. Rest could potentially aid in the invasions of other exotic species

Table 2.—Average species richness for the Brantner or Williams sample points comparing pretreatment values with so many years after grazing. Different letters denote a significant difference ($P < 0.05$) among dates within a richness category row. Categories and rows with no letters were not significantly different ($P > 0.05$).

	Brantner					
	Non-grazed			Grazed		
Richness category	Pretreatment	6 years	7 years	Pretreatment	6 years	7 years
Total species richness	14	10.5	13.7	11.1	12.3	13.2
Exotic species richness	4	2.5	4.2	3.2	4.3	5.4
Native species richness	10	8	9.5	7.9	8	7.8
	Williams					
	Non-grazed			Grazed		
	Pretreatment	4 years	5 years	Pretreatment	4 years	5 years
Total species richness	5.8	6	5.5	6.6 A	10 B	11.9 B
Exotic species richness	3	2.8	2.3	2 A	2.8 A	5.1 B
Native species richness	2.8	3.2	3.2	4.6 A	7.2 B	6.8 B

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

such as Kentucky bluegrass (DeKeyser et al. 2015). The tradeoff between reducing reed canarygrass and increasing exotic species is to be expected, as some plants will fill the niche left after reed canarygrass is reduced.

Because both grazing systems, RG and PBG, resulted in reduced cover of reed canarygrass and movement of the plant community toward restoration goals, we speculate that grazing rather than the grazing system maybe the primary factor in plant community changes. This may mean that any grazing system that managers consider would be effective, and grazing from light to moderate levels will produce the desired results. Further studies on grazing systems and levels of grazing use will need to be conducted to establish if grazing systems are important or, as we speculate, the act of grazing at effective levels is the major cause for change.

CONCLUSION

- Rotational grazing and patch-burn grazing were both effective in reducing the canopy cover of reed canarygrass on restored wet meadows, with up to 50% canopy cover reduction on grazed areas.
- With the reduction in cover of reed canarygrass from grazing, native species like sedges increased in cover leading to a plant community that meets restoration goals.
- There was no change in native species richness in the reed canarygrass patches that met restoration goals due to grazing.
- While grazing lowered the canopy cover of the target species reed canarygrass, other invasive species such as Kentucky bluegrass increased in canopy cover, creating a trade-off between the reduction of one invasive species and the increase of another invasive species.
- We recommend the use of either patch-burn grazing or rotational grazing as effective forms of grazing management for reducing reed canarygrass canopy cover and for changing the plant community to meet restoration goals.

ACKNOWLEDGMENTS

We would like to thank The Nature Conservancy in Minnesota, the Minnesota Board of Soil and Water Resources, and the Clay County Soil and Water Conservation District for collaborating on the study. We specially like to thank Lynn Foss at the Clay County SWCD, Matt Mecklenburg at TNC, Steve Hoffstad at BWSR, and Jeff Mortenson the landowner at the Branter site for helping with the study. We would like to thank Breanna Paradeis-Kobiela for helping with study design.

Jack Norland is an Assistant Professor of Natural Resources at North Dakota State University. His research interests are restoration ecology, invasive plant management, and management of socio-ecological systems.

Jake Cleys (MS North Dakota State University) is a Conservation Planner with the Stearns County Soil and Water Conservation District. His research interests are invasive plant management, conservation land management, and wildlife/habitat management.

Kevin Sedivec is a Professor of Range Science at North Dakota State University. His research interests are restoration ecology, grazing management, integrated livestock/cropping systems, and wildlife/pollinator habitat management.

LITERATURE CITED

Adams, C.R., and S.M. Galatowitsch. 2005. *Phalaris arundinacea* (reed canarygrass): Rapid growth and growth pattern in conditions approximating newly restored wetlands. Ecoscience 12:569–573.

Adams, C.R., and S.M. Galatowitsch. 2006. Increasing the effectiveness of reed canarygrass (*Phalaris arundinacea* L.) control in wet meadow restorations. Restoration Ecology 14:441–451.

Anderson, M.J., R.N. Gorley, and K.R. Clarke. 2008. PERMANOVA+ for PRIMER: Guide to software and statistical methods. PRIMER-E, Plymouth, UK.

Bahm, M.A., T.G. Barnes, and K.C. Jensen. 2014. Evaluation of herbicides for control of reed canarygrass (*Phalaris arundinacea*). Natural Areas Journal 34:459–465.

Biondini, M.E., A.A. Steuter, and R.G. Hamilton. 1999. Bison use of fire-managed remnant prairies. Journal of Range Management 52:454–461.

Cao, L., J. Larson, L. Berent, and A. Fusaro. 2019. *Agrostis gigantea* Roth: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, and NOAA Great Lakes Aquatic Nonindigenous Species Information System, Ann Arbor, MI. Revision date 14 Nov 2018; accessed 5 Jul 2019 from <https://nas.er.usgs.gov/queries/GreatLakes/FactSheet.aspx?SpeciesID=2683>.

Cummings, D.C., S.D. Fuhlendorf, and D.M. Engle. 2007. Is altering grazing selectivity of invasive forage species with patch burning more effective than herbicide treatments? Rangeland Ecology & Management 60:253–260.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43–64.

DeKeyser, E.S., M. Meehan, G. Clambey, and K. Krabbenhoft. 2013. Cool season invasive grasses in Northern Great Plains natural areas. Natural Areas Journal 33:81–90.

DeKeyser, E.S., L.A. Dennhardt, and J. Hendrickson. 2015. Kentucky bluegrass (*Poa pratensis*) invasion in the Northern Great Plains: A story of rapid dominance in an endangered ecosystem. Invasive Plant Science and Management 8:255–261.

Diamond, J.M., C.A. Call, and N. Devoe. 2012. Effects of targeted grazing and prescribed burning on community and seed dynamics of a downy brome (*Bromus tectorum*)–dominated landscape. Invasive Plant Science and Management 5:259–269.

Evans-Peters, G.R., B.D. Dugger, and M.J. Petrie. 2012. Plant community composition and waterfowl food production on Wetland Reserve Program easements compared to those on managed public lands in western Oregon and Washington. Wetlands 32:391–399.

Galatowitsch, S.M., N.O. Anderson, and P.D. Ascher. 1999. Invasiveness in wetland plants in temperate North America. Wetlands 19:733–755.

Galatowitsch, S.M., D.C. Whited, R. Lehtinen, J. Husveth, and K. Schik. 2000. The vegetation of wet meadows in relation to their land-use. Environmental Monitoring and Assessment 60:121–144.

Green, E.K., and S.M. Galatowitsch. 2002. Effects of *Phalaris arundinacea* and nitrate-N addition on the establishment of wetland plant communities. Journal of Applied Ecology 39:134–144.

Guretzky, J.A., C.D. Dunn, and A. Bishop. 2018. Plant community structure and forage nutritive value of reed canarygrass-invaded wetlands. Agronomy Journal 110:200–209.

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use

Hillhouse, H.L., S.J. Tunnell, and J. Stubbendieck. 2010. Spring grazing impacts on the vegetation of reed canarygrass-invaded wetlands. Rangeland Ecology & Management 63:581–587.

James, J.J., J. Davy, M.P. Doran, T. Becchetti, P. Brownsey, and E.A. Laca. 2017. Targeted grazing impacts on invasive and native plant abundance change with grazing duration and stocking density. Rangeland Ecology & Management 70:465–468.

Kellogg, C.H., S.D. Bridgham, and S.A. Leicht. 2003. Effects of water level, shade and time on germination and growth of freshwater marsh plants along a simulated successional gradient. Journal of Ecology 91:274–282.

Kercher, S.M., and J.B. Zedler. 2004. Multiple disturbances accelerate invasion of reed canarygrass (*Phalaris arundinacea* L.) in a mesocosm study. Oecologia 138:455–464.

Kercher, S.M., Q.J. Carpenter, and J.B. Zedler. 2004. Interrelationships of hydrologic disturbance, reed canarygrass (*Phalaris arundinacea* L.), and native plants in Wisconsin wet meadows. Natural Areas Journal 24:316–325.

Kidd, S.A., and J.A. Yeakley. 2015. Riparian wetland plant response to livestock exclusion in the Lower Columbia River Basin. Natural Areas Journal 35:504–514.

Kim, K.D., K. Ewing, and D.E. Giblin. 2006. Controlling *Phalaris arundinacea* (reed canarygrass) with live willow stakes: A density-dependent response. Ecological Engineering 27:219–227.

Kirsch, E.M., B.R. Gray, T.J. Fox, and W.E. Thogmartin. 2007. Breeding bird territory placement in riparian wet meadows in relation to invasive reed canarygrass, *Phalaris arundinacea*. Wetlands 27:644–655.

Larson, D.L., J.B. Bright, P. Drobney, J.L. Larson, and S. Vacek. 2017. Persistence of native and exotic plants 10 years after prairie reconstruction. Restoration Ecology 25:953–961.

Launchbaugh, K., and J.W. Walker. 2006. Targeted grazing—A new paradigm for livestock management. Pp. 2–8 *in* K. Launchbaugh, ed., Targeted grazing: A natural approach to vegetation management and landscape enhancement. American Sheep Industry Association, Centennial, CO.

Lavergne, S., and J. Molofsky. 2004. Reed canarygrass (*Phalaris arundinacea*) as a biological model in the study of plant invasions. Critical Reviews in Plant Sciences 23:415–429.

Lavergne, S., and J. Molofsky. 2006. Control strategies for the invasive reed canarygrass (*Phalaris arundinacea* L.) in North American wetlands: The need for an integrated management plan. Natural Areas Journal 26:208–214.

Marchetto, K.M., T.M. Wolf, and J.D. Larkin. 2021. The effectiveness of using targeted grazing for vegetation management: A meta-analysis. Restoration Ecology 29:e13422.

McCune, B., and J.B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR.

[MNDNR] Minnesota Department of Natural Resources. 2019. Native plant communities: System summaries & NPC factsheets. Accessed 20 Mar 2019 from <https://www.dnr.state.mn.us/npc/index.html>.

[MNBWSR] Minnesota Board of Water and Soil Resources. 2019. Minnesota wetland restoration guide. Accessed 10 Apr 2019 from <http://bwsr.state.mn.us/restoration/>.

Oates, L.G., D.J. Undersander, C. Gratton, M.M. Bell, and R.D. Jackson. 2011. Management-intensive rotational grazing enhances forage production and quality of subhumid cool-season pastures. Crop Science 51:892–901.

Paine, L.K., and C.A. Ribic. 2002. Comparison of riparian plant communities under four land management systems in southwestern Wisconsin. Agriculture, Ecosystems and Environment 92:93–105.

Rinella, M.J., and S.E. Bellows. 2016. Evidence-targeted grazing benefits to invaded rangelands can increase over extended time frames. Rangeland Ecology & Management 69:169–172.

Scasta, J.D., E.T. Thacker, T.J. Hovick, D.M. Engle, B.W. Allred, S.D. Fuhlendorf, and J.R. Weir. 2016. Patch-burn grazing (PBG) as a livestock management alternative for fire-prone ecosystems of North America. Renewable Agriculture and Food Systems 31:550–567.

Sheaffer, C.C., G.C. Marten, D.L. Rabas, N.P. Martin, and D.W. Miller. 1990. Reed canarygrass. Station Bulletin 595-1990 (Item No. AD-SB-5533), Minnesota Agricultural Experiment Station University of Minnesota, St. Paul, MN.

Spiess, J.W., D.A. McGranahan, B. Geaumont, K. Sedivec. M. Lakey, M. Bertie, T.J. Hovick, and R.F. Limb. 2020. Patch-burning buffers forage resources and livestock performance to mitigate drought in the Northern Great Plains. Rangeland Ecology & Management 73:473–481.

The Nature Conservancy. 2019. Restoring your invasive perennial-dominated grassland to conservation prairie. Accessed 10 Apr 2019 from <https://www.nature.org/content/dam/tnc/nature/en/documents/Restoration-Guide-Invasive-Perennial-to-Conservation-Prairie.pdf>.

USDA Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296:152–153.

USDA Natural Resources Conservation Service. 2019. USDA Natural Resources Conservation Service plants database. Accessed 18 Apr 2019 from <https://plants.usda.gov>.

USDI US Fish and Wildlife Service. 2019. Northern tallgrass prairie: Wildlife and habitat. Accessed 21 Mar 2019 from <https://www.fws.gov/refuge/northern_tallgrass_prairie/wildlife_and_habitat/index.html>.

Vetsch, J.A., G.W. Randall, and M.P. Russelle. 1999. Reed canarygrass yield, crude protein, and nitrate N response to fertilizer N. Journal of Production Agriculture 12:465–471.

Downloaded From: https://complete.bioone.org/journals/Natural-Areas-Journal on 08 Jul 2025
Terms of Use: https://complete.bioone.org/terms-of-use