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Patch Burn-Grazing: An Annotated Bibliography

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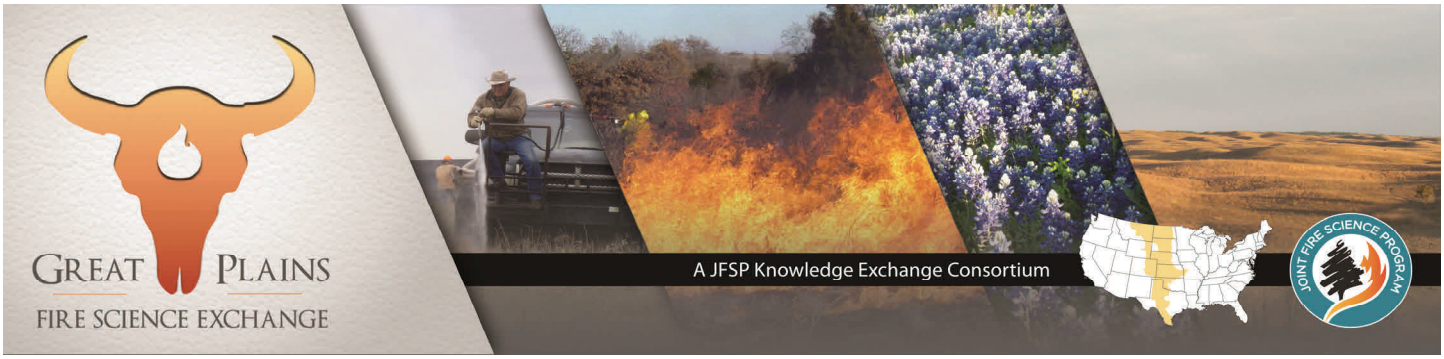

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Patch burn-grazing: an annotated bibliography

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INTRODUCTION

Patch burn-grazing is a rangeland management strategy that exploits the attraction of grazing animals to recently burned areas in order to achieve management objectives. When fire is applied to a landscape in a patchy manner, leaving some patches unburned, the resulting grazing animal activity, forage utilization, and animal impact are patchily distributed within that landscape as well. Areas that have been recently burned tend to be characterized by the highest levels of grazing animal activity while areas that have gone the longest without burning tend to be characterized by the lowest levels of grazing animal activity. This can be advantageous for a multitude of reasons related to wildlife conservation, livestock productivity, herbaceous fuel management, invasive species management, and woody plant control.

The following annotated bibliography lists resources about patch burn-grazing in North America. The bibliography includes all citations known by us of research conducted within the context of patch burn-grazing as an explicit management strategy. Included in the bibliography are papers representing original research, review and synthesis papers, theses (10), and a dissertation. In instances where the research in a thesis or dissertation was subsequently published, we include the citation for the published article(s) but not for the original thesis or dissertation. We did not include reports or extension publications although many valuable publications of this type exist on this topic. For additional resources such as extension publications, look at the Great Plains Fire Science Exchange website or university extension websites in the region.

The majority of citations we present here represent research conducted in the tallgrass prairie (Table 1). Additionally, research on patch-burn grazing has been generated in at least 10 states (Table 2).

Table 1. Ecosystems represented by citations in the patch burn-grazing bibliography.

Ecosystem	Tallgrass prairie	Mixed-grass prairie	Shortgrass steppe	Sand sagebrush prairie	South Texas brushlands
Citations	48	2	1	5	1

Table 2. Geographic location of research represented by citations in the patch burn-grazing bibliography.

State	CO	IA	KS	MO	NE	ND	OK	SD	TN	TX	Multi-state
Citations	1	8	4	4	6	1	31	1	2	2	2

While a vast body of knowledge about the effects of fire and grazing in North American tallgrass prairie has been generated from the Konza Long Term Ecological Research site (http://www.konza.ksu.edu/KNZ/pages/publications/knzpubs.aspx), most is not presented here for two reasons: 1) it's a vast body of knowledge beyond the scope of this bibliography and is best accessed from the link above; and 2) it typically represents research that is conducted within a conceptual framework that treats fire and grazing as independent factors (see Fuhlendorf et al. 2009 for discussion of this topic). Similarly, there is an even greater body of knowledge from around the globe that illuminates the components of the fire-grazing interaction. These components include the effects of fire on fuel load and animal distribution; the effects of grazing on fuel load and subsequent fires; the effects of the fire and grazing interaction on vegetation communities; and the effects of the fire and grazing interaction on higher trophic levels. This global body of knowledge is also beyond the scope of this bibliography.

Patch burn-grazing research has been conducted on a number of species groups. This bibliography includes citations focused on large mammals (n=15 for cattle; 10 for bison; 1 for deer), birds (n=14), plant communities (n=14), vegetation structure (n=10), insects (n=5), small mammals (n=2), soil (n=2), and herpetofauna (n=1).

You can also find these citations referenced in the Fire Research and Management Exchange System (FRAMES) online database, including abstracts where appropriate. Use the keywords *patch burn grazing* to find them. We hope for this to be a living document to be periodically updated with additional published research citations contributed by the Great Plains Fire Community. You can contribute citations at: http://bit.ly/XWxaUm.

THESES AND DISSERTATIONS

Anderson, J. D. 2012. Influence of habitat heterogeneity on small mammals in the Central Platte River Valley, Nebraska. MS Thesis, Fort Hayes State University. Fort Hayes, KS. 58 pp.

The effects of heterogeneity-based management on small mammal communities in the Central Platte River Valley, Nebraska. Small mammal communities in recently burned areas were distinct from those that occurred in areas that were not recently burned. Analyses indicated some of these differences could be attributed to differences in vegetation structure, while some of the differences could not be attributed to any of the environmental variables measured.

Biodrowski, M. C. 2013. The effects of patch burn grazing on breeding grassland birds. M.S. Thesis, University of Nebraska-Omaha. Omaha, NE. 882 pp.

Vegetation and bird response to patch burn-grazing was assessed within grasslands of the Platte River Valley in Nebraska. Patch burn-grazing was found to affect vegetation heterogeneity and grassland birds were found to not be affected by their proximity to patch edges within patch burn grazed pastures.

Cook, T. 2008. A comparison of patch-burn grazing and continuous grazing in the Northern Tallgrass Prairie. M.S. Thesis, South Dakota State University.

Research conducted in South Dakota with cattle representing the grazing animal. Compared to continuously grazed pastures, patch burn-grazing pastures were characterized by patch scale heterogeneity in vegetation structure as indicated by visual obstruction measurements. Recently burned patches in patch burn-grazing pastures had decreased cover of litter and introduced grasses and increased cover of bare ground. Unlike research conducted in the southern Great Plains, this research did not find substantial effects of patch burn-grazing on species composition such as the cover of dominant grasses and forbs.

Huffington, M. P. 2011. Rangeland and pasture improvements for southeastern North Dakota. M.S. Thesis, North Dakota State University. Fargo, ND. 71 pp.

Data was collected in one patch burn-grazing pasture and one pasture managed with no burning. Grazing in both pastures consisted of similar stocking rate and season of use by cattle. The patch burn-grazing pasture consisted of three spring-burn patches and data was collected after two of the burns had been conducted. No statistical differences between the two pastures were found in the density of forb species or the frequency of grass species.

Larson, D. N. 2014. The influence of fire and grazing on tallgrass prairie streams and herptofuana. M.S. Thesis, Kansas State University. Manhattan, KS. 168 pp.

In Kansas tallgrass prairie, this research was conducted in a patch burn grazed pasture grazed by bison, and patch burn grazed pastures grazed by cattle. Within the bison grazed pasture, bison spent negligible time in streams and did not affect water quality. In cattle grazed pastures, cattle spent a greater amount of time in streams and this was associated with increased concentrations of water quality metrics such as total suspended solids, nutrients, and bacteria. In cattle grazed pastures, stream-inhabiting amphibian communities did not differ according to patch type (time since being burned). Terrestrial reptile communities, however, were distinct within distinct patches that differed in time since being burned.

Ramirez Yáñez, L. E. 2011. Impact of alternative range management systems on grasslands in the central Platte River Valley, Nebraska. PhD Dissertation. School of Natural Resources, University of Nebraska-Lincoln. 167 pp.

In this research, a four-patch, spring-burn patch burn-grazing system was compared to two other forms of grazing management: a season-long continuous grazing system without fire; and a four-pasture modified rest rotational system where each pasture was burned once in it's entirety once every four years. There were differences between the treatments in vegetation structure, plant species richness, evenness, and percent composition of native and exotic species. but not in plant diversity or floristic quality.

Rensink, C. B. 2009. Impacts of patch-burn grazing on livestock and vegetation in the tallgrass prairie. MS Thesis, Kansas State University, Manhattan, KS.

Research conducted in Kansas tallgrass prairie that compared patch burn-grazing, utilizing spring burns, with a grazing system in which pastures were burned in their entirety every spring. Yearling cattle were used in all pastures during the study. During three years of study, there was no statistical difference in average daily gain between the treatments. Composition of forbs and woody plants did not differ between treatments, but composition of grasses did. In recently burned patches, percent composition of perennial grasses was less in the patch burn grazed pastures than in the other pastures, but this difference was not found in patches that had not recently burned, indicating recovery of perennial grasses after the first year of being burned and heavily grazed.

Smith, B. W. 2014. Vegetation pattern and response in the context of heterogeneous pasture management in southeastern Nebraska. M.S. Thesis, Oklahoma State University. Stillwater, OK. 68 pp.

A three-patch, spring-burn patch burn-grazing system was compared to a grazing system in which pastures were burned in their entirety during the first year of a three year study. At the treatment level, there were no detectable differences in measures of vegetation structure or diversity between patch burn-grazing pastures and the other pastures. At the patch level, however, patch burn-grazing pastures were characterized by greater heterogeneity in vegetation structure. Plant species composition was likely influenced to a greater degree by pasture ownership, a proxy for management history, and soil properties than it was by treatment. However, it was noted that treatment effects might be apparent after application of treatments for a greater period of time (treatments were applied for only a three-year period). A treatment effect was not apparent when bird abundances were assessed. An effect of some landscape variables on bird abundances, such as perimeter to area ratio, distance to nearest wooded edge, and percent total woodland, was apparent. Study pastures were likely too small to detect any effects of patch burn-grazing on grassland birds such as effects detected in other studies that were conducted in larger pastures.

Stroppel, D. J. 2009. Evaluation of patch-burn grazing on species richness and density of grassland birds. M.S. Thesis, University of Missouri-Columbia. Columbia, MO. 40 pp.

This study assessed bird response to a three-patch, spring-burn patch burn-grazing system in southwest Missouri. Results that were reported included an increase in species richness and density of some species due to patch burn-grazing.

Tunnell, T. R. 2002. Effects of patch burning on livestock performance and wildlife habitat on Oklahoma rangelands. MS Thesis, Oklahoma State University. Stillwater, OK. 49 pp.

This research was conducted at two sites: a tallgrass prairie site in the central part of the state and a mixed-grass prairie site in the southwestern part of the state. The research was conducted in the earliest stages of implementation of patch burn-grazing at both sites, with subsequent research being published by others for both the tallgrass prairie site (Fuhlendorf and Engle 2004; Limb et al 2011) and the mixed-grass prairie site (Limb et al 2011). At both sites, a full rotation of the patch burn-grazing system had not yet been completed when the research was conducted. Cattle performance did not differ between patch burn-grazing pastures and the other pastures at either site. At the tallgrass prairie site, patch-scale heterogeneity of multiple habitat variables was greater in the patch burn-grazing pastures compared to the other pastures. At the mixed-grass prairie site, there were few differences in patch-scale heterogeneity when the patch burn-grazing pastures were compared to the other pastures.

Yancey, S. R. 2013. Grassland bird response to patch burn-grazing in a sand sagebrush-mesquite rangeland. M.S. Thesis, Texas Tech University. Lubbock, TX. 233 pp.

Research conducted in the Rolling Plains of Texas that examined a variety of different treatments: patch burn-grazing, rotational grazing without burning, burning in two seasons without grazing, and areas that were not grazed or burned. Numerous treatment effects were reported for vegetation variables but no positive benefit of patch burn-grazing was noted for grassland birds or northern bobwhite quail. Possible confounding effects included severe drought during the study and the small size of treatment patches.

PUBLISHED PAPERS

Allred, B. W., S. D. Fuhlendorf, D. M. Engle, and R. D. Elmore. 2011. Ungulate preference for burned patches reveals strength of fire-grazing interaction. Ecology and Evolution 1:132–144.

This study compared utilization preferences of two large ungulate species (bison and cattle) for burned areas in two Southern Great Plains grasslands. The study concluded that both ungulate species selected areas which were recently burned and avoided areas with greater time since fire, independent of landscape size or burned area proportion, herbivore population and burned area proportion. Forage quality was negatively related to time since being burned while forage quantity was positively related.

Allred, B. W., S. D. Fuhlendorf, and R. G. Hamilton. 2011. The role of herbivores in Great Plains conservation: comparative ecology of bison and cattle. Ecosphere 2:art26.

Research on the grazing behavior of bison and cattle in southern Great Plains tallgrass prairie and site selection preferences of each species as indicated by various environmental variables. Both species preferred recently burned sites and avoided steeper slopes. Cattle preferred areas near to water while bison had no such preferences; cattle preferred areas characterized by woody vegetation but bison avoided similar areas.

Allred, B. W., J. D. Scasta, T. J. Hovick, S. D. Fuhlendorf, and R. G. Hamilton. 2014. Spatial heterogeneity stabilizes livestock productivity in a changing climate. Agriculture, Ecosystems and Environment 193:37–41.

Cattle production was studied in tallgrass prairie of the southern Great Plains. In pastures managed in a homogeneous manner (i.e., no patch burn-grazing), cattle production declined during years with low precipitation. In patch burn-grazing pastures, there was not a negative effect of low precipitation on cattle productivity.

Anderson, R. H., S. D. Fuhlendorf, and D. M. Engle. 2006. Soil nitrogen availability in tallgrass prairie under the fire-grazing interaction. Rangeland Ecology & Management 59:625–631.

This study was conducted in tallgrass prairie of the southern Great Plains. Nitrogen availability in patch burn-grazing pastures were compared to that in pastures managed in a homogeneous manner. Within patch burn-grazing pastures, recently burned patches that were being heavily grazed were characterized by greater nitrogen availability relative to patches that had not burned recently and were grazed very little. Spatio-temporal patterns of nitrogen availability in patch burn-grazing pastures differed from

those in homogeneously managed pastures, and also differed from what has been documented by previous research involving only fire but no grazing.

Augustine, D. J. and J. D. Derner. 2014. Controls over the strength and timing of fire-grazer interactions in a semiarid rangeland. Journal of Applied Ecology 51:242–250.

A study conducted in shortgrass prairie of Colorado. Across all seasons and years of study, cattle spent a greater proportion of time in recently burned patches than would be expected if cattle were distributed randomly across pastures. However, the selection for recently burned patches was less than what has been documented in more mesic regions of the Great Plains. Selection of burned patches and cattle weight gain in patch burn pastures were greatest during periods following pulses of precipitation.

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.

This study compared the landscape distribution patterns of bison in Sandhills mixed-grass prairies of Nebraska, and tallgrass prairie of Oklahoma. Bison strongly preferred to use recently burned patches at both locations during the growing season. In patches that had not recently burned, bison avoided areas with steeper slopes but they strongly selected for recently burned patches regardless of the degree of slope. Selection for recently burned patches was greater during the fall and winter in the Oklahoma tallgrass prairie site than in the Nebraska Sandhills mixed-grass prairie site. In part, this was likely explained by much greater fall and winter regrowth of forage in recently burned patches at the southern site (Oklahoma) compared to the northern site (Nebraska).

Churchwell, R. T., C. A. Davis, S. D. Fuhlendorf, and D. M. Engle. 2008. Effects of patch-burn management on dickcissel nest success in a tallgrass prairie. Journal of Wildlife Management 72:1596–1604.

Nesting ecology of the dickcissel, a common obligate grassland bird species, was studied in Oklahoma tallgrass prairie. Data were collected in patch burn grazed pastures and pastures managed with annual burning across the entire pasture. Within patch burn-grazing pastures, nest initiation occurred earlier, predation was lower, and nest parasitism was lower. Mean number of eggs laid and young fledged were similar between the two types of management. Overall nest success was highest in patch burn grazed pastures.

Coppedge, B. R., D. M. Engle, C. S. Toepfer, and J. H. Shaw. 1998. Effects of seasonal fire, bison grazing and climatic variation on tallgrass prairie vegetation. Plant Ecology 139: 235-246.

This study focused on identifying the relationship of environmental variables with phytomass and plant functional groups in a seasonally burned and grazed by bison tallgrass prairie site in Oklahoma. Phytomass varied with climate, seasonal burn type and also grazing, although it was greatest during warm seasons. Plant functional groups like tall grasses, little blue stem, annual grasses, forbs and legumes responded differently to individual environmental variables.

Coppedge, B. R., S. D. Fuhlendorf, W. C. Harrell, and D. M. Engle. 2008. Avian community response to vegetation and structural features in grasslands managed with fire and grazing. Biological Conservation 141:1196–1203.

Bird communities in patch burn-grazing pastures were compared to those in pastures managed with annual burning across the entire pasture. The study occurred in Oklahoma and cattle were the grazing animal. Overall bird species diversity and grassland obligate bird species diversity were highest in patch-burn treated pastures compared to pastures managed in a traditional system. Henslow's sparrow, a grassland obligate species of conservation concern, were only found in patch burn grazed pastures.

Coppedge, B. R., D. M. Leslie, and J. H. Shaw. 1998. Botanical composition of bison diets on tallgrass prairie in Oklahoma. Journal of Range Management 51:379–382.

Bison diet within a patch burn-grazing pasture was examined using micro histological fecal analysis. Bison primarily grazed grasses while forbs were rarely consumed. Consumption of sedges increased in the winter and spring, corresponding with seasonal variation in sedge availability.

Coppedge, B. R. and J. H. Shaw. 1998. Bison grazing patterns on seasonally burned tallgrass prairie. Journal of Range Management 51:258–264.

Mixed groups of bison (cows, yearlings, calves and young) preferentially used recently burned areas and avoided areas that had not recently burned. Mature bulls, however, used areas that had not recently burned a greater percent of the time than areas that had recently burned. Regression analysis showed that bison grazing was negatively related to burn age and positively related to size of patch.

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

This study compared the rate of invasion of *Sericea lespedeza,* an exotic legume in rangelands of the southern Great Plains, in pastures managed with patch burn-grazing and pastures managed with tri-annual fires. While *S. lespedeza* cover increased in both traditional and patch burned pastures, the rate of increase was much less in the patch burn grazed pastures. Within patch burn grazed pastures, the rate of increase was greater in spring burned patches than in summer burned patches.

Debinski, D. M., R. A. Moranz, J. T. Delaney, J. R. Miller, D. M. Engle, L. B. Winkler, D. A. McGranahan, R. J. Barney, J. C. Trager, A. L. Stephenson, and M. K. Gillespie. 2011. A cross-taxonomic comparison of insect responses to grassland management and land-use legacies. Ecosphere 2: 131.

In this study, butterflies, ants and leaf beetles were used to test their responses in patch-burn graze, graze-and-burn and burn-only treatments. These three invertebrate groups had more positive responses to patch burn-grazing. Within patch burn grazed pastures, distinct patches were characterized by distinct insect communities. However, insect communities were influenced primarily by land use legacies while current management had minimal effects.

Doxon, E. D., C. A. Davis, S. D. Fuhlendorf, and S. L. Winter. 2011. Aboveground Macroinvertebrate Diversity and Abundance in Sand Sagebrush Prairie Managed With the Use of Pyric Herbivory. Rangeland Ecology & Management 64:394–403.

Patch burn-grazing effects on aboveground invertebrates were studied in sand sagebrush prairie of northwest Oklahoma. Some measures of invertebrate community composition were similar when patch burn grazed pastures were compared to traditionally managed pastures, while other measures differed. Within patch burn grazed pastures, distinct invertebrate communities characterized patches of differing time since burn.

Engle, D. M., S. D. Fuhlendorf, A. Roper, and D. M. Leslie, Jr. 2008. Invertebrate community response to a shifting mosaic of habitat. Rangeland Ecology & Management 61:55–62.

The influence of patch burn-grazing and traditional type management on aboveground invertebrate community was studied in tallgrass prairie of Oklahoma. Different patches within patch burn grazed pastures were characterized by distinct invertebrate communities. Transitional patches (12–24 months since being burned) within patch burned pastures showed 50% greater total invertebrate mass as compared to traditional pastures.

Fuhlendorf, S. D. and D. M. Engle. 2001. Restoring heterogeneity on rangelands: ecosystem management based on evolutionary grazing patterns. BioScience 51:625–632.

A foundational article that details how patch burn-grazing as a rangeland management strategy contrasts with many traditional forms of rangeland management.

Fuhlendorf, S. D. and D. M. Engle. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41:604–614.

One of the earliest, and most-cited, research papers on patch burn-grazing. Patch burn-grazing pastures, consisting of 3 spring burn patches and 3 summer burn patches in each pasture, were compared to traditionally managed pastures where the entire pasture was burned every third year. Vegetation structure and composition in patch burn grazed pastures was distinct from that in traditionally managed pastures, and specific patches within patch burn grazed patches differed from each other based on the time since

being burned. In patch burn grazed pastures cattle preferred to use the most recently burned patches and avoided using patches that had not burned recently. In traditionally managed pastures cattle distributed themselves randomly across the pastures. Cattle weight gain did not differ between patch burn-grazing management and traditional management.

Fuhlendorf, S. D., D. M. Engle, J. Kerby, and R. Hamilton. 2009. Pyric herbivory: rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588–598.

An essay paper that emphasizes the contrast in traditional approaches to the research and management of rangelands with that of an approach that acknowledges the interaction of fire and grazing in shaping rangeland ecosystems and how important that acknowledgement will be in conserving biodiversity.

Fuhlendorf, S. D., W. C. Harrell, D. M. Engle, R. G. Hamilton, C. A. Davis, and D. M. Leslie, Jr. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. Ecological Applications 16:1706–1716.

This research contrasted bird communities in patch burn grazed pastures with traditionally managed pastures in Oklahoma, where the grazing animals were cattle. Patch burn grazed pastures were characterized by greater heterogeneity in vegetation structure and by bird communities that included a greater suite of species compared to traditionally managed pastures. Henslow's sparrows, a grassland obligate bird species of conservation concern, was only found in patch burn grazed pastures.

Fuhlendorf, S. D., D. E. Townsend II, R. D. Elmore, and D. M. Engle. 2010. Pyric-herbivory to promote rangeland heterogeneity: evidence from small mammal communities. Rangeland Ecology & Management 63:670–678.

A study conducted in Oklahoma tallgrass prairie. Within the patch burn-grazing pastures, distinct small mammal communities were found in patches that varied by time since being burned. Patches that had recently burned were characterized by an abundance of granivorous species while patches that had not recently burned were characterized by an abundance of herbivorous species.

Griebel, R. L., S. L. Winter, and A. A. Steuter. 1998. Grassland birds and habitat structure in sandhills prairie managed using cattle or bison plus fire. Great Plains Research 8:255–268.

An early research paper on the effects of patch burn-grazing on wildlife in the Nebraska Sandhills. Vegetation structure and bird communities in a pasture grazed by bison where fire was applied in spatially distinct patches were compared to that of pastures grazed by cattle where fire was not applied. More differences were found from comparisons of the burned and unburned patches within the bison pasture than from comparisons of the bison pasture and the cattle pastures.

Hamilton, R. G. 2007. Restoring heterogeneity on the Tallgrass Prairie Preserve: applying the fire-grazing interaction model. Pages 163–169 *in* R.E. Masters and K. E. M. Galley (eds.). Proceedings of the 23rd Tall Timbers Fire Ecology Conference: Fire in Grassland and Shrubland Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

This paper describes the application of patch burn-grazing management at The Nature Conservancy's Tallgrass Prairie Preserve in northeast Oklahoma. At the Preserve, patch burn-grazing is conducted in a single bison pasture >23,000 acres in size. Patches are burned within the bison pasture in a random manner, based on fuel availability, during all seasons of the year. Additionally, patch burn-grazing is applied to cattle pastures at the Preserve with a variety of patch burn-grazing systems being represented: cattle patch burn-grazing pastures consist of 2–8 patches, some with spring burn patches only and some with both spring and summer burn patches.

Helzer, C. J. and A. A. Steuter. 2005. Preliminary effects of patch-burn grazing on a high-diversity prairie restoration. Ecological Restoration 23:167–171.

Application of patch burn-grazing in high-diversity restoration plantings in the Platte River Valley of Nebraska. The prevalence of cattle grazing on nine species of forbs was tracked through two years in patches that were burned in the first year of the study and patches that had not been burned. Preliminary data indicated some species were preferentially grazed in recently burned patches while other species were not grazed regardless of the patch they were found in.

Holcomb, E. D., C. A. Davis, and S. D. Fuhlendorf. 2014. Patch-burn management: implications for conservation of avian communities in fire-dependent sagebrush ecosystems. Journal of Wildlife Management 78:848–856.

Research conducted in sand sagebrush prairie of northwest Oklahoma. Bird species richness and abundance of lark sparrows were higher in patch burn grazed pastures, while abundances of grasshopper sparrows and brown-headed cowbirds were higher in traditionally managed pastures. Nest survival did not differ between patch burn grazed pastures and traditionally managed pastures.

Hovick, T. J., D. R. D. Elmore, and S. D. Fuhlendorf. 2014. Structural heterogeneity increases diversity of non-breeding grassland birds. Ecosphere 5(5):art62.

Grassland bird communities in Oklahoma tallgrass prairie were studied during the winter in patch burn grazed pastures where cattle were the grazing animal. Distinct patches within the pastures were characterized by distinct bird communities. Patches that had recently burned had higher abundances of Smith's longspurs, while patches that had not burned recently had higher abundances of Le Conte's sparrows. Abundances of savannah sparrows and meadowlarks did not vary across patch types.

Hovick, T. J., J. R. Miller, S. J. Dinsmore, D. M. Engle, D. M. Debinski, and S. D. Fuhlendorf. 2012. Effects of fire and grazing on grasshopper sparrow nest survival. Journal of Wildlife Management 76:19–27.

This study investigated the clutch size and nest survival of grasshopper sparrows in Southern Iowa grasslands managed with patch burn-grazing and grazed pastures that had been burned in their entirety the year before the study. Clutch size did not differ between the pasture types but constant daily nest survival rates were greater in patch burn grazed pastures.

Hovick, T. J., J. R. Miller, R. R. Koford, D. M. Engle, and D. M. Debinski. 2011. Postfledging survival of grasshopper sparrows in grasslands managed with fire and grazing. Condor 113:429–437.

This study monitored the survival, cause of mortality, and movements of grasshopper sparrow chicks after they left the nest in Iowa grassland. Data were collected in patch burn grazed pastures and grazed pastures that were burned in their entirety once before the study began. The type of pasture did not have an effect on survival of grasshopper sparrows after they left their nests.

Leis, S., L. Morrison, and M. Debacker. Spatiotemporal variation in vegetation structure resulting from pyric-herbivory. Prairie Naturalist 45:13–20.

Within a patch burn grazed pasture in Kansas tallgrass prairie, vegetation height and vegetation visual obstruction were measured in patches that differed in time since being burned. Visual obstruction was quantified for three 25-cm strata of the vegetation canopy. Height and visual obstruction measurements were lower in recently burned patches compared to patches that had not recently burned. Within patches, the amount of variability in visual obstruction measurements was greatest in the lowest stratum of vegetation canopy within recently burned patches compared to patches that had not recently burned. In the middle and highest strata, variability in visual obstruction measurements was greatest in the patches that had not recently burned compared to the patches that had recently burned.

Limb, R. F., S. D. Fuhlendorf, D. M. Engle, J. R. Weir, R. D. Elmore, and T. G. Bidwell. 2011. Pyric-herbivory and cattle performance in grassland ecosystems. Rangeland Ecology & Management 64:659–663.

Cattle performance was assessed at two sites in Oklahoma, one characterized by tallgrass prairie and one characterized by mixed-grass prairie. At the tallgrass prairie site, patch burn-grazing pastures consisted of six patches: three that were burned in the spring on a three-year rotation and three that were burned in the summer on a three year rotation. These were compared to pastures in which the entire pasture was burned every three years. Animal performance was measured as gain per steer during the first four-four years of study, while gains per calf and cow body condition score was measured during the final four years of study. During all years of study at the tallgrass prairie site, cattle performance in the patch burn grazed pastures was similar to that in the comparison pastures. At the mixed-grass prairie site, patch burn grazed pastures consisted of four patches burned in the spring while comparison pastures were not burned; cattle performance was measured as gain per steer for 11 years of study. During the first four years of study at the mixed-grass prairie site, cattle performance did not differ between the patch burn

grazed pastures and the comparison pastures. During the subsequent seven years of study, cattle performance in the patch burn grazed pastures was greater than that in the comparison pastures.

McGranahan, D. A., D. M. Engle, S. D. Fuhlendorf, S. J. Winter, J. R. Miller, and D. M. Debinski. 2012. Spatial heterogeneity across five rangelands managed with pyric-herbivory. Journal of Applied Ecology 49: 903-910.

The effect of patch burn-grazing on heterogeneity of vegetation structure and plant functional group composition was assessed in five rangelands of the central United States representing a variety of vegetation communities and a range of precipitation amounts. Patch burn-grazing was found to create heterogeneity in three of the five rangelands assessed. At sites where patch burn-grazing did not create heterogeneity, possible reasons may have been the confounding variables of excessive stocking rate and poor fire spread due to invasive plant species, both of which may have prevented fire from being the primary driver grazer site selection at those locations.

McGranahan, D. A., D. M. Engle, S. D. Fuhlendorf, S. L. Winter, J. R. Miller, and D.M. Debinski. 2013. Inconsistent outcomes of heterogeneity-based management underscore importance of matching evaluation to conservation objectives. Environmental Science and Policy 31: 53-60.

This paper reviews much of the literature on fire-grazing interaction effects on grassland fauna. Additional analyses of data from the sites assessed in McGranahan et al. 2012. The importance of identifying appropriate evaluation metrics when implementing management actions is stressed and context-specific limitations of patch burn-grazing are discussed. Includes a brief review of literature on the influence of fire-grazing interactions on wildlife.

McGranahan, D. A., C. B. Henderson, J. S. Hill, G. M. Raicovich, W. N. Wilson, and C. K. Smith. 2014. Patch burning improves forage quality and creates grassbank in old-field pasture: results of a demonstration trial. Southeastern Naturalist 13:200-207.

Crude protein was greatest post-burn in the burned patch and declined as the growing season progressed in a patch burn-grazing system dominated by tall fescue. Cattle grazed primarily on the burned patch as evidenced by fecal pat frequency and tiller heights. Even though unburn patch usage increased as the season progress, heterogeneity was maintained. The unburned patch served as a grassbank.

McGranahan, D., G. Raicovich, W. Wilson, and C. Smith. 2013. Preliminary evidence that patch burn-grazing creates spatially heterogeneous habitat structure in old-field grassland. Southeastern Naturalist 12:655–660.

This study tested the viability of patch burn-grazing in old field grassland of Tennessee invaded by tall fescue. Results concluded that patch burn-grazing created spatial heterogeneity for grass height, litter cover, bare ground, and canopy cover of native and exotic grasses.

Meek, M. G., S. M. Cooper, M. K. Owens, R. M. Cooper, and A. L. Wappel. 2008. White-tailed deer distribution in response to patch burning on rangeland. Journal of Arid Environments 72:2026–2033.

Research on the application of patch burn-grazing in a semi-arid region of Texas utilizing summer burns. White-tailed deer use of burned areas increased slightly during periods of 1–2 months after the burns. A lack of response in vegetation variables to patch burn-grazing was attributed to drought conditions during the study period.

Monroe, A. P. and T. J. O'Connell. 2014. Winter bird habitat use in a heterogeneous tallgrass prairie. American Midland Naturalist 171:97–115.

Patch use by wintering birds was assessed within an Oklahoma bison pasture managed with patch burn-grazing. Recently burned patches were characterized by bird communities distinct from the bird communities characterizing patches that had not recently burned. Vegetation height was the primary driver of bird species abundances; Smith's longspur responded to the low values of vegetation structure found in recently burned patches while Le Conte's sparrows and sedge wrens responded to the high values of vegetation structure associated with patches that had not recently burned.

Moranz, R. A., D. M. Debinski, D. A. McGranahan, D. M. Engle, J. R. Miller. 2012. Untangling the effects of fire, grazing, and land-use legacies on grassland butterfly communities. Biodiversity and Conservation 21:2719–2746.

A study conducted in southern Iowa and northern Missouri where patch burn-grazing pastures were compared to pastures that were burned in their entirety and grazed, and pastures that were burned in their entirety and not grazed. While treatments had an effect on habitat variables such as vegetation height and bare ground, butterfly responses was primarily due to non-treatment variables such as land-use legacy and native versus exotic plant species composition.

Moranz, R. A., D. M. Debinski, L. Winkler, J. Trager, D. M. McGranahan, D. M. Engle, and J. R. Miller. 2013. Effects of grassland management practices on ant functional groups in central North America. Journal of Insect Conservation 17:699–713.

Research conducted at the same sites as in Moranz et al 2012. The response of ant functional groups (dominants, subdominants, generalists, opportunists) to both fire and grazing was often mediated by the response of, and subsequent competitive interactions with, a single dominant species, *Formica montana*.

Moranz, R. A., S. D. Fuhlendorf, and D. M. Engle. 2014. Making sense of a prairie butterfly paradox: the effects of grazing, time since fire, and sampling period on regal fritillary abundance. Biological Conservation 173:32–41.

In study sites in southwestern Missouri, abundances of regal fritillaries in patch burn-grazing pastures were compared to those in pasture managed with fire only and no grazing. In patch burn-grazing pastures, regal fritillary abundances tended to be reduced in patches that were burned in the year of data collection but not in patches that had been burned in previous years. Abundances of regal fritillaries were correlated with flowering stem densities of preferred nectar sources.

Pillsbury, F. C., J. R. Miller, D. M. Debinski, and D. M. Engle. 2011. Another tool in the toolbox? Using fire and grazing to promote bird diversity in highly fragmented landscapes. Ecosphere 2:art28.

Research conducted in southern Iowa and northern Missouri where patch burn-grazing pastures were compared to pastures that were burned in their entirety and grazed, and pastures that were burned in their entirety and not grazed. Pastures managed with patch burn-grazing were characterized by bird communities that were distinct from those characterizing pastures in the other treatments. Bird communities responded to both vegetation structure variables within pastures as well as landscape variables outside of the study pastures.

Polito, V., K. Baum, M. Payton, S. Little, S. Fuhlendorf, and M. Reichard. 2013. Tick abundance and levels of infestation on cattle in response to patch burning. Rangeland Ecology and Management 66:545–552

In Oklahoma, tick abundance in vegetation and on cattle were compared between patch burn-grazing pastures and grazed pastures that were burned in their entirety. In patch burn-grazing pastures, adult tick abundance within patch burn grazed pastures was less than in the other pastures during one of four years of study, but abundance of all ticks combined (adults, nymphs, larvae) did not differ in any years. During three years of study, abundance of all ticks combined on cows and calves in patch burn-grazing pastures was less than that on cows and calves in the other pastures during four out of the seven months when data were collected.

Scasta, J. D., D. M. Engle, J. T. Talley, J. R. Weir, J. C. Stansberry, S. D. Fuhlendorf, and R. N. Harr. 2012. Pyric-herbivory to manage horn flies (Diptera: Muscidae) on cattle. Southwestern Entomologist 37:325–334.

In Oklahoma, abundance of horn flies on cattle in patch burn-grazing pastures was less than their abundance on cattle in pastures that were managed by burning them in their entirety every third year.

Schuler, K. L., D. M. Leslie, Jr., J. H. Shaw, and E. J. Maichak. 2006. Temporal-spatial distribution of American bison (*Bison bison*) in a tallgrass prairie fire mosaic. Journal of Mammalogy 87:539-544.

In an Oklahoma patch burn-grazing pasture, bison preferentially selected recently burned patches during the first growing season after being burned but avoided patches that had been burned more than one year previously.

Vermeire, L. T., R. B. Mitchell, S. D. Fuhlendorf, and R. L. Gillen. 2004. Patch burning effects on grazing distribution. Journal of Range Management 57:248–252.

In Oklahoma sand sage mixed-grass prairie, patch burn-grazing was compared to grazing without fire. All pastures were characterized by sandy soils and high abundances of the shrub sand sagebrush. In the patch burn-grazing pastures, relatively small patches (4-ha; less than <2% of each pasture) were burned in the autumn or spring. In patch burn-grazing pastures, there was no apparent preference of cattle for autumn or spring burned plots. Within burned plots, grass standing crop was substantially reduced (78%) and decreased in a predictable manner with increasing distance from the burned plot. Conversely, forb standing crop was substantially greater within the burned plots but was not affected by distance from the burned plot.

Vermeire, L. T., D. B. Wester, R. B. Mitchell, and S. D. Fuhlendorf. 2005. Fire and grazing effects on wind erosion, soil water content, and soil temperature. Journal of Environmental Quality 34:1559–1565.

This research was conducted in the same study sites described in Vermeire et al 2004. Wind erosion varied by burn, year, and sampling height. While the amount of wind erosion in burned plots was greater than in unburned plots, no blowouts or drifting of sand was observed. Soil temperatures in burned plots were greater than in unburned plots, but there was no difference in soil water content.

Vinton, M. A., D. C. Hartnett, E. J. Fink, and J. M. Briggs. 1993. Interactive effects of fire, bison (*Bison bison*) grazing and plant community composition in tallgrass prairie. American Midland Naturalist 129:10–18.

At Konza Prairie in the Flint Hills of Kansas, bison preferentially used recently burned watersheds in the spring and summer relative to watersheds that were not recently burned or were unburned. In frequently burned watersheds, bison grazing patches tended to be larger and with vegetation composition more similar to that of the watershed as a whole, whereas grazing patches in infrequently burned watersheds tended to be smaller and more distinct from the vegetation composition of the watershed as a whole.

Winter, S. L., S. D. Fuhlendorf, C. L. Goad, C. A. Davis, and K. R. Hickman. 2011. Topoedaphic variability and patch burning in sand sagebrush shrubland. Rangeland Ecology and Management 64:633–640.

This research was conducted in sand sagebrush mixed-grass prairie of northwest Oklahoma where patch burn-grazing pastures were compared to pastures with grazing but no fire. An effect of patch burn-grazing on vegetation structure was apparent at portions of the landscape characterized by rolling topography and sandy soils but not in areas characterized by flat topography and soils with a higher clay content. An effect of patch burn-grazing on the amount of grazing by cattle on grasses was not apparent but detection of an effect may have been hindered by low replication of study pastures (two patch burn-grazing pastures and two pastures that were grazed but not burned).

Winter, S. L., S. D. Fuhlendorf, C. L. Goad, C. A. Davis, K. R. Hickman, and D. M. Leslie, Jr. 2012. Restoration of the fire-grazing interaction in *Artemisia filifolia* shrubland. Journal of Applied Ecology 49:242–250.

Patch burn-grazing in sand sagebrush mixed-grass prairie was compared to grazing without fire. Patch burn-grazing had an effect on many measures of vegetation structure for 1–3 years after burns were applied, but little to no effect thereafter. In both types of pastures, heterogeneity of vegetation structure tended to decrease as the scale of measurement increased (quarter-point, point, transect, patch, pasture, treatment), but the amount of heterogeneity at the patch-scale was substantially higher in the patch burn -grazing pastures. At the patch-scale, heterogeneity in vegetation composition and structure tended to increase through time in the patch burn-grazing pastures but not in the pastures that were grazed but not burned.

Winter, S. L., S. D. Fuhlendorf, and M. Goes. 2014. Patch-burn grazing effects on cattle performance: research conducted in a working landscape. Rangelands 36:2–7.

In southeast Nebraska, a patch burn-grazing system, utilizing three spring-burn patches, was compared to a grazing system where pastures were burned in their entirety once at the start of the study. No differences were found in various measures of cattle performance between the two systems.

Winter, S., K. Hickman, C. Goad, S. Fuhlendorf, and M. Gregory. 2013. Seasonal fires, bison grazing and the tall-grass prairie forb *Arnoglossum plantagineum* Raf. Natural Areas Journal 33:327–338.

Measures of plant growth and reproductive effort for Indian plantain, a common forb in many tallgrass prairies, was assessed in an Oklahoma bison pasture managed with patch burn-grazing. Many measures of growth and reproduction differed between patches that were recently burned and patches that had not been burned recently. These responses, however, were often dependent on topographic position. Overall, the results indicated that Indian plantain benefitted from greater resource availability in recently burned patches compared to patches that had not recently burned.

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