Pigs and Prairies: Evaluating the Biodiversity Impacts of Prairie Restoration for Biogas Production

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Principal Investigator: Lisa Schulte Moore, PhD[1]

Authors: Jordan Giese, Lisa Schulte Moore

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[1] Contact information: Iowa State University, Natural Resource Ecology and Management, 2301 Pammel Drive, Ames, IA 50010; email: lschulte@iastate.edu; phone: 515-294-7339.

Executive Summary

This project set out to determine the biodiversity impacts of land restoration associated with renewable energy development through biodigestion of hog manure and native plant material. Our objectives were to (1) establish a robust scientific design for experimentation, (2) monitor the biodiversity response (i.e., vegetation, birds, small mammals, herps, and pollinators) to land restoration, and (3) disseminate our study results.

Roeslein Alternative Energy (RAE) seeded 14 experimental prairie fields at Smithfield Foods Ruckman Farm in northern Missouri in February, 2018, based on our experimental design. The study design is a randomized complete block; individual fields were assigned to one of three blocks and treatment type was randomly assigned. We surveyed the plant, breeding bird, small mammal, herp, and pollinator communities in experimental fields as well as six control fields consisting of pre-existing fescue-brome pasture from May through August in 2018-2020. We examined the biodiversity response to field treatment type, plant composition, and time since restoration.

Our results indicated a large increase in native perennial vegetation between years two and three of study. We found more small mammals and snakes in experimental fields than treatment fields, but no discernible differences between low diversity and high diversity experimental treatments. Bird communities did not differ among treatments. This highest pollinator abundance and species richness occurred in high diversity fields in year three. This may signal a more noticeable response in subsequent years and the plant communities in low and high diversity fields diverge. We expect bird, small mammal, and snake communities to remain similar in experimental fields as their response is likely a function of vegetation structure and surrounding habitat instead of plant species composition.

We continue to disseminate this research through a project website, presentations, and social media. We plan to submit findings from this research for journal publication and as a CCAST case study in the coming months. With journal publication, data and metadata will be archived and made public through Iowa State University Library’s DataShare platform. Eight students have received training through this project. The plant and pollinator portion of this research is being extended for two additional field seasons (2021, 2022) with additional funding from Iowa State University USDA National Institute for Food and Agriculture.

Introduction

Agricultural land cover comprises nearly half of the global land base (Ramankutty et al. 2018). With rising global population and changing diets, demand for agricultural products is expected to grow in coming decades (Godfray et al. 2010, Naylor 2011). Increases in production have historically equated to declines in the remaining suites of ecosystem services, including habitat for biodiversity (MEA 2005: Ramankutty et al. 2018). Given this situation, effective means for balancing agricultural production with other needs—or blurring the lines between production and conservation—are sorely needed.

Results from literature review (Asbjornsen et al. 2013) and the STRIPS (Science-based Trials of Row-crops Integrated with Prairie Strips; www.prairiestrips.org) experiment indicate that integrating diverse, native, perennial vegetation, even in small amounts, into agricultural landscapes provides a promising approach for balancing habitat for biodiversity with human production needs. One aspect missing from the STRIPS research, however, was an evaluation of the impact of different levels of plant community diversity on biodiversity. This research seeks to fill this gap and also support land restoration objectives associated with a commercial scale renewable energy development project.

The goal of the project was to determine biodiversity impacts of land restoration associated with renewable energy development; specifically, natural gas production through biodigestion of hog manure and native plant material, as being forwarded by Roeslein Alternative Energy (RAE) and Smithfield Foods. The land restoration occurred at Smithfield Food's Ruckman Farm located near Albany, Missouri, and included a February 2018 conversion of 220 ac in exotic cool-season grasses to diverse, native plant cover. Project objectives were to:

1. Establish a robust scientific design;
2. Monitor of biodiversity response to land restoration; and
3. Disseminate study results.

This report details findings from our initial data compilation and analysis. We expect to continue our analysis and publish additional findings in scientific literature.

Objective 1: Establish a Robust Scientific Design

Roeslein Alternative Energy converted 14 fields from fescue-brome pasture grass to experimental prairie vegetation at Smithfield's Ruckman Farm in northern Missouri in early February 2018 (Figure 1). Each experimental field received either a high diversity (HD, 31 species) or low diversity (LD, 15 species) seed mix. A detailed list of species found in each seed mix can be found in Appendix A. Six additional fields were left in pasture grass to serve as controls. The 20 fields ranged in size from 3.1-19.2 acres. A randomized complete block study design was used to split fields into three blocks of similar spatial proximity and historical management (Figure 2). We split each block into two whole-plots to control for eventual every-other-year harvest. We used seed mix as a random split-plot factor to determine the treatment type for each field (Figure 3). Post-restoration management included strategic mowing and spot spraying of noxious weeds including Canada Thistle (*Cirsium arvense*) and Wild Parsnip (*Pastinaca sativa*). The intent with this study was also to implement biomass harvesting and hog manure application in the third year. Those aspects of the experiment have not yet occurred in order to provide more time for the native plant communities to become well established.

Figure 1. Seeding of experimental fields at Ruckman Farm in February 2018.

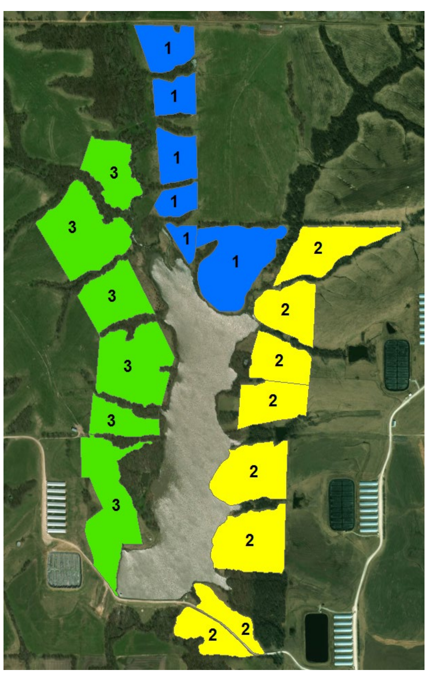


Figure 2 (left). Randomized complete block design used to split 20 fields into three blocks of similar spatial proximity and historical management at Ruckman Farm.

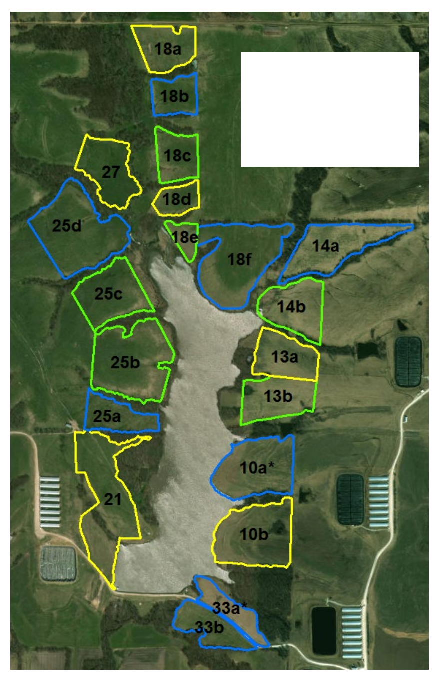


Figure 3 (right). Randomized treatment types of 20 fields at Ruckman Farm.

Objective 2: Monitor Biodiversity Response to Land Restoration

We monitored biodiversity response to prairie restoration May-August, 2018-2020. We surveyed the plant, breeding bird, small mammal, amphibian, reptile, and pollinator communities of each experimental and control field. A complete list of species detected during surveys can be found in Appendix B.

Plant Community

Field data collection to determine the composition of the plant communities developing in each field employed the Daubenmire method (Hirsch et al. 2003). During the first week of August of each year, we generated 12 random points in each field to place Daubenmire quadrats. In each quadrat, we measured vegetation height, species composition and percent coverage, and noted the number of flowering forb and milkweed individuals. In total, we conducted 648 plant surveys.

The plant communities in each treatment type during each year of monitoring are presented in Figures 4 and 5. Vegetation in control fields was relatively stable throughout the three years of study, consisting primarily of the fescue-brome pasture grass that is common on the surrounding landscape. Vegetation in both high and low diversity experimental treatments shifted significantly between years. In general, plant communities transition from exotic annual species in 2018 to native species in 2019 and 2020. In high diversity fields, native grass coverage increased 9% and native forb coverage increased 33% from 2018 to 2020. In low diversity fields, native grasses increased 15% and native forbs increased 20% from 2018 to 2020. We conducted ANOVAs to test for differences in the native plant communities of each treatment (Table 1-2). Differences between control and both experimental treatments were expected. Most notably, native forb/legume composition was higher in high diversity fields than low diversity fields (Table 2).

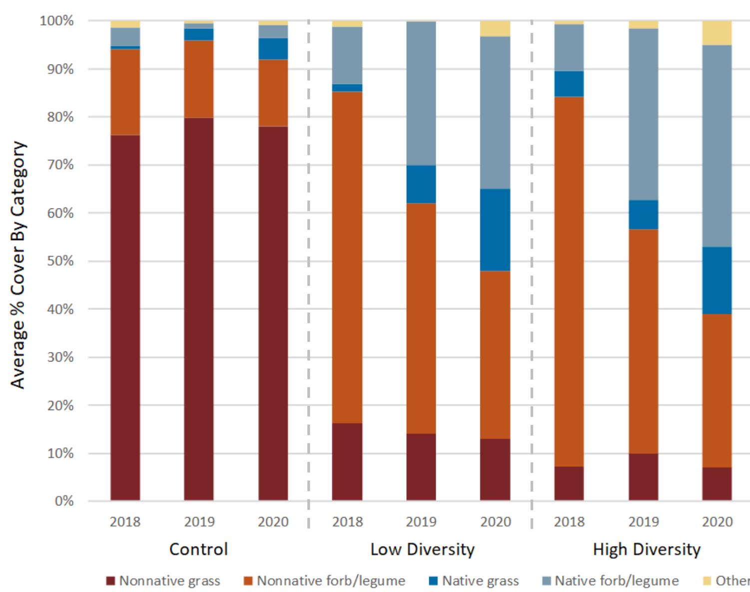


Figure 4. Plant community composition of control, low, diversity, and high diversity fields, 2018-2020.

Table 1. Mean comparisons of native grass composition among treatments. LD = low diversity. HD = high diversity. *Denotes statistically significant difference.

Year	Treatment Comparison	Mean Difference
2018	LD - Control	0.94
	HD - Control	4.39*
	HD - LD	3.73*
2019	LD - Control	6.50
	HD - Control	3.62
	HD - LD	-1.88
2020	LD - Control	12.81*
	HD - Control	9.36*
	HD - LD	-3.45

Table 2. Mean comparisons of native forb/legume composition among treatments. LD = low diversity. HD = high diversity. *Denotes statistically significant difference.

Year	Treatment Comparison	Mean Difference
2018	LD - Control	8.28*
	HD - Control	6.0*
	HD - LD	-2.28
2019	LD - Control	28.13*
	HD - Control	34.03*
	HD - LD	5.87
2020	LD - Control	29.08*
	HD - Control	39.36*
	HD - LD	10.28*

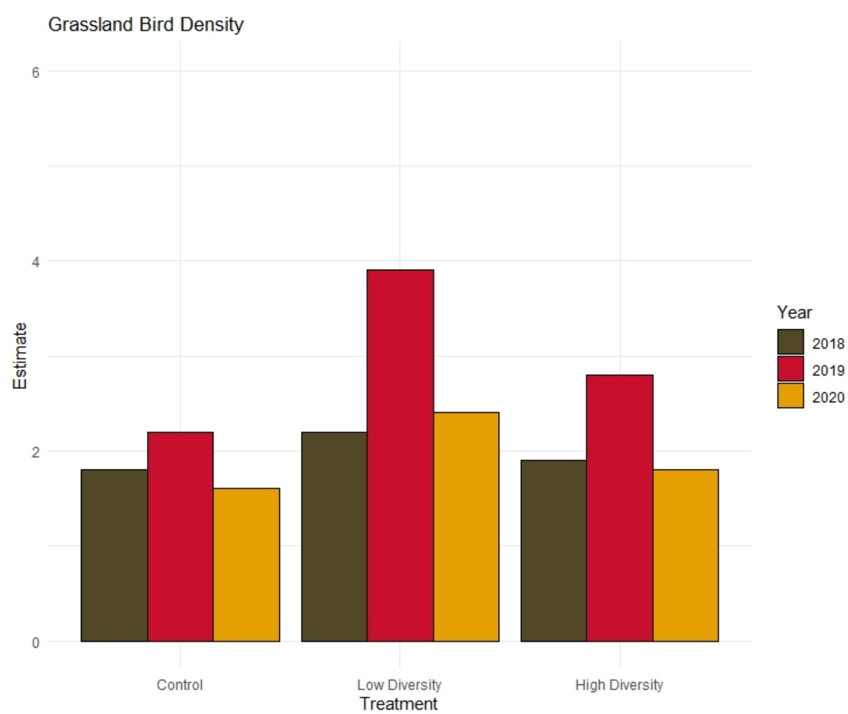
Figure 5. Examples of control, low diversity, and high diversity treatment fields at Ruckman Farm.

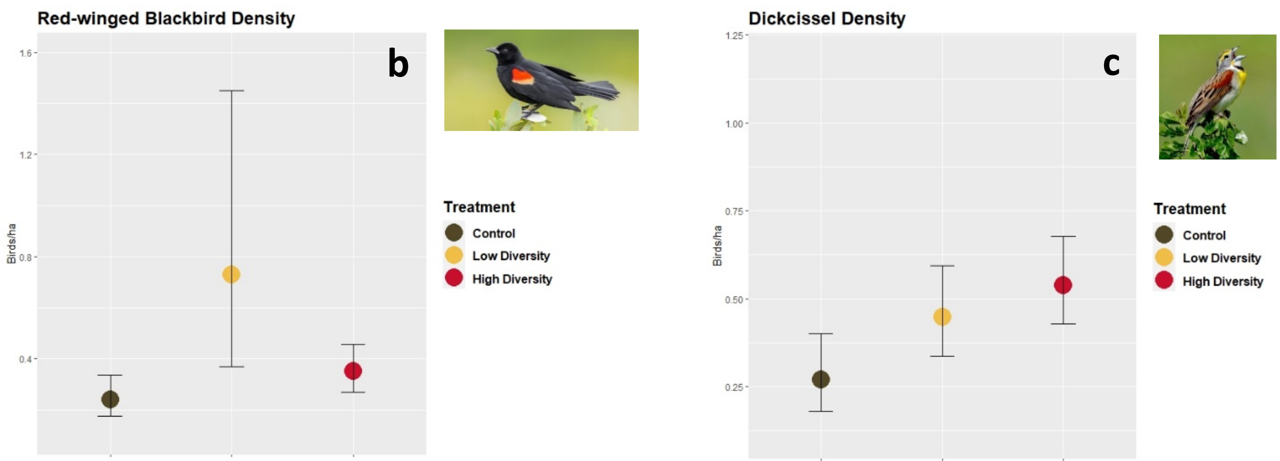
Bird Community

To investigate the bird community response to restoration efforts, we conducted 5-minute bird point count surveys (Ralph et al. 1993) three times each year at random locations in each field. The number of locations varied between one and three dependent on field size. During surveys, an observer used auditory and visual cues to identify species and estimate distance to each detected individual bird. We used detection distances to estimate detection probability and density of the community and individual species (White and Barnham 1999; Thomas et al. 2010).

In total, we made 5,088 bird detections of 67 species of which 14 are considered grassland species. Red-winged Blackbirds (*Agelaius phoeniceus*) and Dickcissels (*Spiza americana*) made up 60.3% of all grassland bird detections. Grassland bird density was similar across treatments (Figure 6a) and years. The mean number of birds detected did not differ among treatments. Red-winged Blackbird (Figure 6b) and Dickcissel (Figure 6c) densities were similar across treatments. Red-winged Blackbird density varied greatly in low diversity fields. We attribute this to tendency of low diversity fields to be close to water; blackbirds frequently associated with surface water and wetlands (Figure 6b). While not statistically significant, there is a trend toward higher dickcissel density with greater plant diversity (Figure 6c).

Figure 6. Grassland bird density across treatments and years (a). Red-winged Blackbird density across treatments in 2020 (b). Dickcissel density across treatments in 2020 (b).





Small Mammal and Snake Communities

To investigate the small mammal and herp community response to prairie restoration, we conducted coverboard surveys (Grant et al. 1992; Joppa et al. 2010). In April of 2018, we randomly placed 201 plywood coverboards across the study fields. From May 2018 – August 2020, we flipped each board twice per month and identified any small mammal or snake species underneath.

In total we conducted 3,961 coverboard surveys, detecting 879 small mammals of 6 species and 699 snakes of 9 species. A complete list of species detected during surveys can be found in Appendix B. Occupancy rates for both small mammals (Figure 7) and snakes (Figure 8) increased significantly from 2018 to 2019 and 2020. This was expected as animals had more time to locate and use coverboards as burrowing sites and thermal refuges. Occupancy of both communities was higher in experimental treatments than in control.

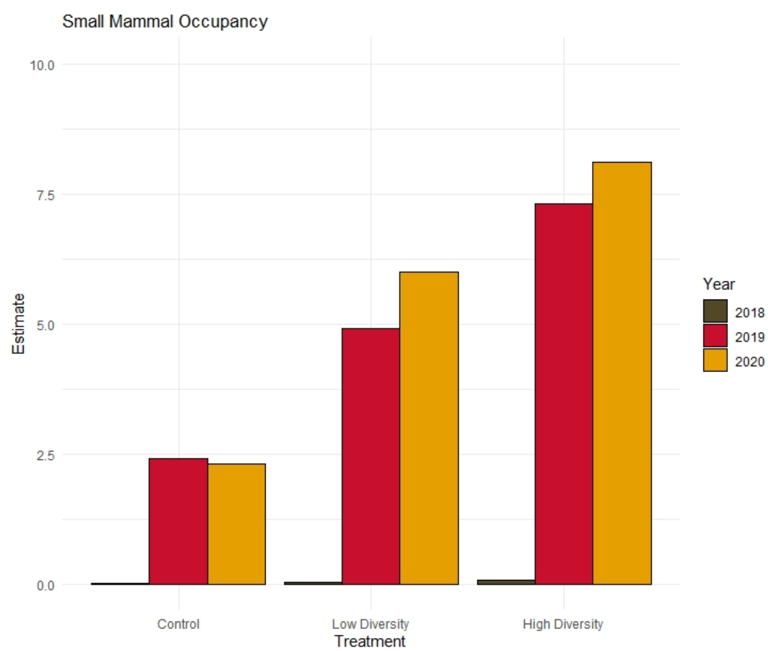


Figure 7. Small mammal occupancy rates across treatment and year.

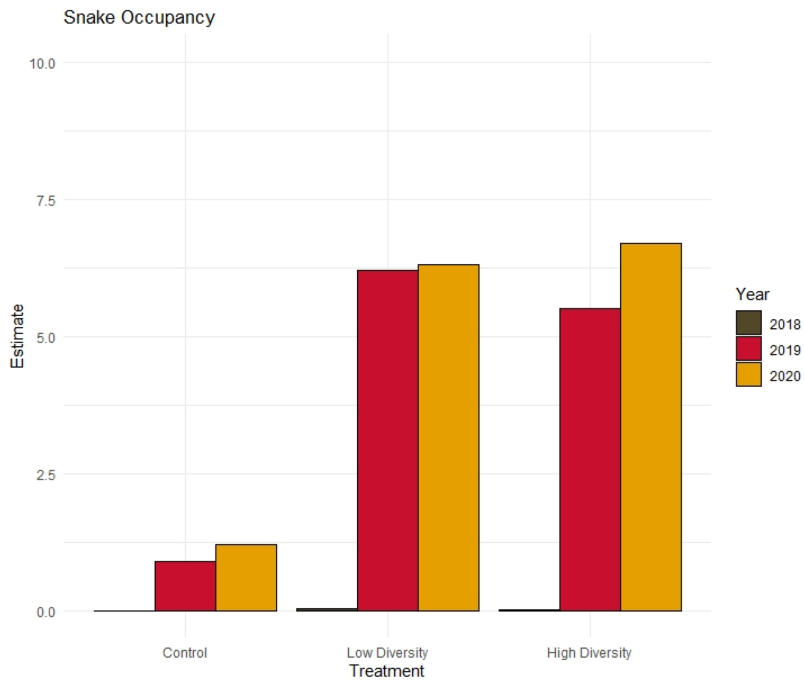


Figure 8. Snake occupancy rates across treatment and year.

Pollinator Community

To investigate the pollinator community response to restoration efforts, we conducted 24-hour bee bowl surveys (Droge 2012; Gill and O'Neal 2015). At five random locations within each field, we deployed fluorescent bee bowls filled with soapy water once per month, June-August of each year. After collecting bowls, we used morphological characteristics to identify all wild bees under a microscope. Bees were identified to the lowest taxonomic unit possible, and stored on ISU campus for later confirmation of identification.

In total we conducted 680 bee bowl station-days and collected 4,728 individual bees of at least 71 species (Table 3). All specimens of the genus *Lasioglossum* could not be identified to the species level using morphological characteristics. There were not statistically significant differences in bee species richness or abundance between treatments in any year. Richness and abundance were higher in high diversity fields in 2020 than in low diversity and control fields (Figure 9). Using linear regression analysis to test whether forb cover influenced the pollinator community, we found native forb cover to be a significant predictor of bee species richness (Figure 10, $p < 0.05$) in 2020.

Table 3. Seven most common wild bee taxa collected during bee bowls surveys.

Bee taxa	Number of individuals (% of total)
Lasioglossum spp.	2,758 (58.3)
Augochlorella aurata	418 (8.8)
Halictus ligatus	386 (8.2)
Agapostemon texanus	237 (5.0)
Agapostemon virescens	218 (4.6)
Melissodes bimaculatus	173 (3.7)
Augochlora pura	124 (2.6)

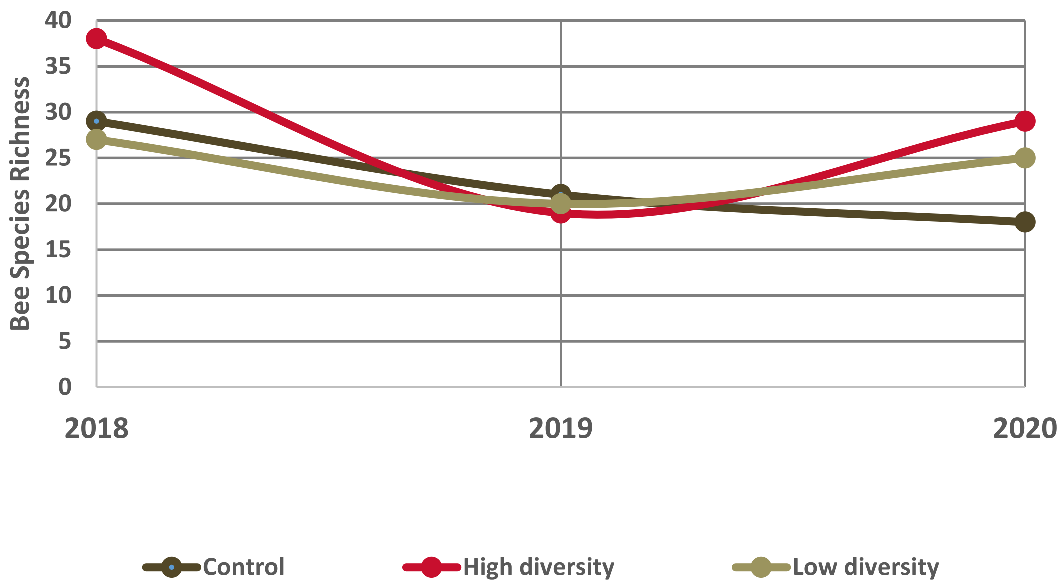


Figure 9. Wild bee taxa richness across treatments and years.

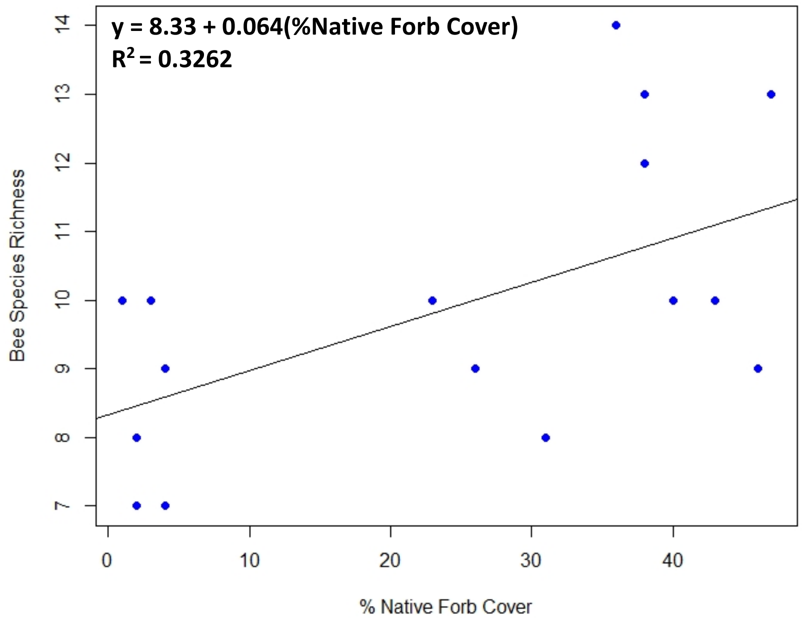


Figure 10. Linear trend comparison between bee taxa richness and native forb cover in treatment fields; data from 2020.

We have disseminated our research through our project website, presentations, and social media platforms, such as Twitter, as shown below. We plan to submit findings from this research for journal publication in the coming months. We are further coordinating to have this study represented by the US Fish and Wildlife Study as a Collaborative Conservation and Adaptation Strategy Toolbox (CCAST) case study.

The project website, where we posted findings and annual progress reports, can be found at https://www.nrem.iastate.edu/landscape/projects/pigs-and-prairies-evaluating-biodiversity-impacts-prairie-restoration-biogas-production. This research has further been presented at the following meetings:

- Giese, J.C., and L.A. Schulte. 2021. Pigs & Prairies: Evaluating the biodiversity response of prairie restoration for biogas production. FW3 Prairie Biology Network Quarterly Meeting [virtual].
- Giese, J.C., and L.A. Schulte. 2020. Pigs & Prairies: Evaluating the biodiversity response of prairie restoration for biogas production. Pigs & Prairies Collaborators Meeting [virtual].
- Giese, J.C., and L.A. Schulte. 2018. An update on biodiversity monitoring of prairie restoration for biogas production. Monarch Bioenergy Grand Opening, Smithfield Foods Missouri Headquarters, Princeton, MO.

Eight student researchers have furthermore received training through this grant (Table 4). Students help disseminate research by sharing their learning and experiences with their relatives and their peers.

Table 4. Student researchers receiving training through this project.

Name	Degree Program	Employment Period
Jordan Giese	Ph.D. Wildlife Ecology	2017-present
Melanie Bogert	M.S. Wildlife Ecology and Sustainable Agriculture	2020-present
Ellen Audia	M.S. Wildlife Ecology	2019-2021
Cody McKune	B.S. Forestry	2018-2019
Drake Fehring	B.S. Animal Ecology	2019-2020
Kate Borchardt	Ph.D. Ecology and Evolutionary Biology	2019-2020
Mary Kate Shaver	B.S. Animal Ecology	2020-2021
Maura Speck	B.S. Animal Ecology	2021-present

Conclusions and Next Steps

Our results indicated a large increase in native perennial vegetation between the second and third year of study, in 2019 and 2020, respectively. We found more small mammals, and snakes in experimental fields than control fields, but no discernible differences between low diversity and high diversity experimental treatments. Bird communities did not differ among treatments. This highest pollinator abundance and species richness occurred in high diversity fields in 2020. This may signal a more noticeable response in subsequent years and the plant communities in low and high diversity fields diverge. We expect bird, small mammal, and snake communities to remain similar in experimental fields as their response is likely a function of vegetation structure and surrounding habitat instead of plant species composition.

This research has been disseminated through a project website, presentations, and social media. We plan to submit findings from this research for journal publication and as a CCAST case study in the coming months. With journal publication, data and metadata will be archived and made public through Iowa State University Library's DataShare platform. Eight students have received training through this project. Eight students have received training through this project and disseminated the research to relatives and peers. The plant and pollinator portion of this research is being extended for two additional field seasons (2021, 2022), supported through grants from Iowa State University (C-CHANGE Presidential Interdisciplinary Research Initiative) and the USDA National Institute for Food and Agriculture (grant ID: 2020-68012-31824). Assessment of plant and pollinator response to manure addition is now being investigated on an Iowa State University Research and Demonstration Farm near Ames, Iowa.

Acknowledgements

We sincerely thank our US Fish and Wildlife Service for funding and our partners for facilitating this work, including Roeslein Alternative Energy, Smithfield Foods, Eastern Tallgrass Prairie and Big Rivers LLC, National Wild Turkey Federation, Pure Air Natives, and Environmental Defense Fund. We thank Dr. Jarad Niemi, Associate Professor of Statistics at Iowa State University, for his assistance with experimental design.

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Appendix A. Composition of high and low diversity prairie seed mixes used in experimental fields at Ruckman Farm.

Table A1. Grass species in experimental prairie seed mixes.

Common Name	Scientific Name	lbs/acre
Big Bluestem	*Andropogon gerardii*	1
Little Bluestem	*Schizachyrium scoparium*	0.75
Indiangrass	*Sorghastrum nutans*	1
Switchgrass	*Panicum virgatum*	0.75
Virginia Wildrye	*Elymus virginicus*	0.5
Canada Wildrye	*Elymus canadensis*	0.5

Table A2. Forb and legume species in experimental prairie seed mixes.

Common Name	Scientific Name
Ashy Sunflower*	*Helianthus mollis*
Black-eyed Susan*	*Rudbeckia hirta*
Butterfly Milkweed	*Asclepias tuberosa*
Common Milkweed	*Asclepias syriaca*
Compassplant*	*Silphium lacinatum*
Cup Plant	*Silphium perfoliatum*
Entire-leaved Rosinweed*	*Siphium integrifolium*
False Sunflower*	*Heliopsis helianthoides*
Foxglove Beardtongue*	*Penstemon digitalis*
Gray-headed Coneflower*	*Ratibida pinnata*
Hoary Vervain*	*Verbena stricta*
Indian Paintbrush*	*Castilleja indivisa*
Leadplant*	*Amorpha canescens*
New England Aster	*Symphyotrichum novae-angliae*
Prairie Blazing Star*	*Liatris pycnostachya*
Purple Coneflower*	*Echinacea purpurea*
Purple Prairie Clover	*Dalea purpurea*
Sawtooth Sunflower*	*Helianthus grosseserratus*
Showy Goldenrod*	*Solidago speciose*
Showy Partridepea	*Chamaecrista fasciculate*
Stiff Goldenrod	*Solidago rigida*
Swamp Milkweed*	*Asclepias incarnate*
Tall Tickseed Coreopsis*	*Coreopsis tripteris*
White Prairie Clover	*Dalea candida*
Wild Bergamot	*Monarda fistulosa*

*Species in high diversity mix only

Appendix B. Species detected during surveys by taxa category.

Birds	Ruby-throated Hummingbird	*Bombus griseocollis*
American Crow	Savannah Sparrows	*Bombus impatiens*
American Goldfinch	Sedge Wren	*Bombus pensylvanicus*
American Robin	Song Sparrow	*Calliopsis andreniformes*
Baltimore Oriole	Tree Swallow	*Ceratina calcarata*
Barn Swallow	Tufted Titmouse	*Ceratina dulpa*
Bell's Vireo	Turkey Vulture	*Ceratina mikmaqi*
Belted Kingfisher	Veery	*Eucera hamata*
Black-capped Chickadee	Warbling Vireo	*Halictini* sp.
Blue Jay	Western Meadowlark	*Halictus confusus*
Bobolink	White-breasted Nuthatch	*Halictus ligatus*
Brown-headed Cowbird	Wild Turkey	*Halictus parallelus*
Brown Thrasher	Wood Duck	*Halictus rubicundus*
Canada Goose	Yellow-billed Cuckoo	*Halictus tripartitus*
Cedar Waxwing	Yellow Warbler	*Hoplitis spoliata*
Chipping Sparrows	***Mammals***	*Hylaeus affinis*
Common Grackle	Deer Mouse	*Hylaeus floridanus*
Common Yellowthroat	White-footed Mouse	*Hylaeus messillae*
Dickcissel	Vole sp.	*Hylaeus modestus*
Downy Woodpecker	Least Shrew	*Lasioglossum* sp.
Eastern Bluebird	Northern Short-tailed Shrew	*Megachile addena*
Eastern Kingbird	***Reptiles***	*Megachile brevis*
Eastern Meadowlark	Brown Snake	*Megachile campanulae*
Eastern Phoebe	Common Garter Snake	*Megachile centucularis*
Eastern Towhee	Eastern Yellow-bellied Racer	*Megachile frugalis*
Eastern Wood-peewee	Great Plains Ratsnake	*Megachile motivaga*
Field Sparrow	Lined Snake	*Megachile paralella*
Grasshopper Sparrows	Plains Garter Snake	*Megachile pugnata*
Gray Catbird	Prairie Kingsnake	*Megachile rotundata*
Great-crested Flycatcher	Prairie Ringneck Snake	*Megachile texana*
Hairy Woodpecker	Western Ribbonsnake	*Melissodes agilis*
Henslow's Sparrow	***Bees***	*Melissodes bimaculatus*
House Sparrow	*Agapostemon sericeus*	*Melissodes boltoniae*
House Wren	*Agapostemon splendens*	*Melissodes communis*
Indigo Bunting	*Agapostemon texanus*	*Melissodes comptoides*
Killdeer	*Agapostemon virescens*	*Mellisodes coreopsis*
Lark Sparrow	*Andrena barbara*	*Melissodes denticulatus*
Least Flycatcher	*Andrena commoda*	*Melissodes druriellus*
Mallard	*Andrena cressonii cressonii*	*Melissodes menuachus*
Mourning Dove	*Andrena evythronii*	*Melissodes niveus*
Northern Bobwhite	*Andrena geranii*	*Melissodes subillatus*
Northern Cardinal	*Andrena nivalis*	*Melissodes trinodis*
Northern Flicker	*Andrena wilmattae*	*Osmia lignaria*
Orchard Oriole	*Apis mellifera*	*Peponapis pruinosa*
Red-bellied Woodpecker	*Augochlora pura*	*Ptilothrix bombiformes*
Red-headed Woodpecker	*Augochlorella aurata*	*Specodes pimpinellae*
Red-tailed Hawk	*Augochlorini* sp.	*Svastra obliqua*
Red-winged Blackbird	*Augochloropsis metallica*	*Triepeolus cressonii*
Ring-necked Pheasant	*Bombus bimaculatus*	*Xylocopa virginica*
Rose-breasted Grosbeak		