Spring 2016

A Comparison Of Small Mammal Communities Among Three Habitats In Western North Dakota

Samantha R. Pounds
Fort Hays State University, srpounds@mail.fhsu.edu

A COMPARISON OF SMALL MAMMAL COMMUNITIES AMONG THREE HABITATS IN WESTERN NORTH DAKOTA

being

A Thesis Presented to the Graduate Faculty

of Fort Hays State University in

Partial Fulfillment of the Requirements for

the Degree of Master of Science

by

Samantha R. Pounds

B.S., Dickinson State University

Date______________________ Approved_________________________

Major Professor

Approved_________________________

Chair, Graduate Council

This thesis for

The Master of Science Degree

By

Samantha R. Pounds

Has been approved

Chair, Supervisory Committee

Supervisory Committee

Supervisory Committee

Supervisory Committee

Chair, Department of Biological Sciences

ABSTRACT

There is recent oil and natural gas development within western North Dakota, which makes it imperative to update outdated and incomplete small mammal records. Small mammals are vital components to many ecosystems, including grasslands. Small mammals contribute to grazing, seed dispersal, and provide food for other animals. I surveyed small mammals in three habitats, grassland, badland, and wet meadow, in the summers of 2014 and 2015 in western North Dakota. In 2014, I surveyed in 8 badland and 10 grassland habitats and in 2015 I surveyed in 1 badland, 13 grassland, and 4 wet meadow habitats, with 1 transect per site. Each transect consisted of museum special snap traps and pitfall arrays with drift fencing. The resulting shape of the array was a 'Y'. Each array had 10 pitfalls and 90 snap traps. Arrays were operated for 5 consecutive nights over 18 sampling periods during 20 May to 26 July 2014 and 19 May to 25 July 2015; 9 in 2014 and 9 in 2015, for a total of 18,000 trap nights. A total of 708 small mammals were collected in 2014 and 397 small mammals were collected in 2015, with an overall total of 1,105 small mammals for both years. These included 978 rodent and 127 insectivore individuals. There was no difference in species diversity across habitats in 2014 and 2015. There were higher captures of small mammals during the new moon phase. There were no distinct small mammal communities across the 3 habitats. Due to the recent oil boom in western North Dakota, it is critical to assess which small mammals inhabit the area before the effects of the oil boom potentially destroy small mammal habitats.

ACKNOWLEDGMENTS

I thank my graduate advisor, Dr. Elmer J. Finck, for his support and jocularity during my time at Fort Hays State University. He has taught me many life lessons that I will take with me in my future endeavors. I also thank my graduate committee, Drs. Brian Maricle, Michael Shaughnessy, and William Stark for their guidance, input, and support while completing this research project.

Many thanks go to the North Dakota Game and Fish for the grant to support this project. I especially thank Patrick Issacson and Kent Luttschwager for their support and willingness to help us throughout the project. I also thank the private land owners of North Dakota who allowed myself and research assistants to conduct research on their land. I thank the Zahn family, Steve Foss, and Bridgett Perry for their hospitality and generosity by allowing myself and research assistants to stay with them during the two summers of research.

I thank Dickinson State University (DSU) for allowing me and research assistants to use their facilities and equipment. I thank Dr. Craig Whippo for his support and guidance during this research project. I thank the DSU secretary, Laurie Heick, for organizing hotel rooms and travel forms.

I thank my field assistants, Kayla Miller and Jacob Ward for their time and effort during the project. I especially thank Morgan Petersen who helped me through the entire project, working long hours, and always willing to laugh and joke, even during the worst times. Watching her grow as a biologist and person was one of my favorite parts about this project. I could not have carried out the research without her hard work and effort, thank you Morgan!

I thank Fort Hays State University, including the Choate Fellowship, Department of Biological Science, Graduate School, and the Sternberg Museum of Natural History. I have taken away a wide array of information from the professors. They have made me a better biologist and for that, I thank them. Thank you Dr. Robert Channell for all of your help, providing me with a listening ear, and always willing to talk about running shoes. I am thankful for all of the amazing opportunities provided by the faculty and staff. To all of my fellow graduate students, past and present, I thank you for all of the fun times and hard times. It has been a wild ride and I am glad that I was able to share it with you all. I am forever grateful for the help in my research from the following students: Elizabeth Bainbridge, Kasandra Brown, Mitchell Meyer, Jeffrey Seim, Angelica Sprague, Taylor Rasmussen, Holly Wilson, and Brian Zinke.

I am grateful to have the love and support from my family and friends. Thank you Jeff Seim for being so patient, kind, and supportive and for going on this adventure with me. Lastly, I thank my parents, Dennis and Julie Pounds, for their encouragement and teaching me to never give up.

TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

LIST OF APPENDICES

APPENDIX

PREFACE

This thesis is written in the style of the Journal of Mammalogy, to which a portion will be submitted for publication. Fort Hays State University IACUC approval number 14-0006.

INTRODUCTION

Ecosystems, such as grasslands and forests, in North America are declining due to modification of natural vegetation (Saunders et al. 1991; Coppedge et al. 2001). These areas of natural vegetation are being converted to agriculture, sites of production for non-renewable and renewable energy sources, or they are being exploited through logging of forests, overgrazing of prairies, or overharvesting of animals, leaving the land fragmented (Saunders et al. 1991; Vitousek et al. 1997; Cane and Tepedino 2001; Coppedge et al. 2001; Copeland et al. 2009). These modifications to North American ecosystems have contributed to habitat loss for many species and soil erosion, which alters the ability of species to survive and produce offspring (Saunders et al. 1991; Welsh and Droege 2001).

Grasslands once covered an area of 4.1 x 10^8 ha, extending south from Canada to Oklahoma and the eastern Rocky Mountains in the west to Ohio (Samson et al. 2003). These grasslands once consisted of native species, but as the human population increased, the demand for more crops increased. Non-native plant species were established with the idea of protecting the soils from water and wind erosion (Samson et al. 2003; Grant et al. 2009). A wide range of organisms depend on grasslands. Non-native grass species threaten the natural ecosystem by altering habitats on which organisms depend. Today, about 99.9 % of the historic Great Plains prairie ecosystem is gone (Samson and Knopf 1994). With that in mind, society should be cautious about non-native species in the grasslands (Coppedge et al. 2001; Crall et al. 2006).

Historically the predominate ecosystems of North Dakota, South Dakota, and Nebraska composed of tallgrass, mixed grass, and short grass prairies in roughly an east to west gradient. Currently, each is considered to be an endangered habitat within each state (Samson and Knopf 1994; Samson et al. 2003). Over half (60%) of the mixed grass prairie in North Dakota has been replaced by cropland (Higgins et al. 2002). The western portion of North Dakota is composed primarily of short and mixed grass prairies, with tall grass prairie in the eastern portion of the state (Seabloom et al. 2011). Aside from the mixed and short grass prairie, 2 other prominent habitats in North Dakota include the wet meadows and badlands.

The Prairie Pothole Region is in northwestern North Dakota, north of the Missouri River and extends southeast into Iowa (Stewart and Kantrud 1973). The wet meadows, within the Prairie Pothole Region, are composed of mixed and tall grass prairie and are characterized by wetland vegetation. Primary vegetation in the wet meadows habitat is composed of little bluestem (*Schizachyrium. scoparium*), prairie junegrass (*Koeleria macrantha*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), rushes, sedges, willows, and cattails (Rudd 1951; Seabloom et al. 2011). The Prairie Pothole Region contains elements of cropland and grassland (Balsbaugh and Aarhus 1990). These shallow wetlands, small lakes, or prairie potholes are the result of receding glaciers scouring the landscape (Seabloom et al. 2011) from the Wisconsin glaciation event (Johnson et al. 2005; Kahara et al. 2009). The Wisconsin glaciation was the most recent glaciation event. South of the Missouri River was not glaciated.

The Badlands region is in west central North Dakota and within the mixed and short grass prairie (Seabloom et al. 2011). The Badlands region is arid (Dix 1958) and is composed of highly eroded topography with more native vegetation present compared to other non-Badland regions (Seabloom et al. 2011). One reason more native vegetation persists in the Badlands region is the extreme topography of the area. Farmers are unable to develop these areas because it is difficult to plow in these areas of highly eroded topography, which allows native plants to thrive (Seabloom et al. 2011). Prominent vegetation in the badland habitat and short grass prairie are blue grama (*Bouteloua gracilis*), needle-and-thread (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), *Carex* spp., and *Artemisia* spp. (Rudd 1951; Johnson and Larson 1999; Kolar et al. 2011). South of the Badlands region, the area is dominated by short grass prairie (Seabloom et al. 2011).

With increasing presence of crops and non-native plant species, animal habitats, especially small mammal habitats, are modified or eliminated. The mixed and short grass prairies have been invaded by cool season grasses such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*), and forbs like yellow sweet clover (*Melilotus officinalis*) (Grant et. al 2009). Aside from the increasing presence of non-native species, there has been an increase in the production of natural resources, more specifically oil and natural gas, within North Dakota that also might be contributing to habitat fragmentation and is comparable to other studies (Gillen and Kiviat 2012; Brittingham et al. 2014; Abrahams et al. 2015). The demand for energy production will continue to contribute to habitat fragmentation because fossil fuels are a main source of energy with natural gas, oil, and coal composing 80% of nonrenewable resources (Copeland et al. 2009). The production of oil and natural gas can have profound effects on wildlife. These production sites fragment habitats, which can interfere with species ability to survive and produce offspring (Cypher et al. 2000; Welsh and Droege 2001; Finer et al. 2008; Bamberger and Oswald 2012

Small mammals play a vital role in the maintenance of the prairie ecosystem (Horncastle et al. 2005). Small mammals can alter plant diversity by caching seeds and grazing vegetation (Sieg 1987). Seed caching can change vegetation composition and abundance in an area. Small mammals store seeds in their cheek pouches and/or consume seeds, these seeds are either dropped during transport to their burrows or through defecation. Small mammal grazing stimulates growth in plants (Sieg 1987). The abundance, and ultimately the presence, of small mammals is correlated with habitat (Geier and Best 1980; Stancampiano and Schnell 2004). As native grasslands continue to decline and the increasing production of natural resources, the current distributions of many small mammal species in North Dakota are poorly known, as most records are 20 to 60 years old (VertNet 2015).

Small mammals are less active during a full moon phase (Caldwell and Connell 1968; Prugh and Brashares 2010). More light is emitted during a full moon, making small mammals more visible to predators (Lockard and Owings 1974; Mohammadi 2010). In response to full moon phase, small mammal abundance or catch rates decrease.

Diversity indices are used to describe how a community or communities are related based on the species or individuals present (Menhinick 1964). These diversity indices include species richness, evenness (J’), and Shannon-Weiner diversity (H’). Species richness is the number of species in a community, evenness is how evenly the individuals are distributed over different species in a community, and diversity is a function of species richness and evenness in a community (Heip et al. 1998; Stirling and Wilsey 2001). Diversity indices can be used to monitor changing landscapes (Nagendra 2002) and assess the overall health of an ecosystem (Rapport 1989).

Non-metric multidimensional scaling (NMDS) analyses are used to assess communities of organisms (Minchin 1987; Fischer et al. 2011). Studies have used the NMDS to assess community structure at various scales and variables (i.e. habitat, altitude, vegetation) (Caceres et al. 2011; Fischer et al. 2011). Based on these community analysis studies, an NMDS was used to assess small mammal communities in western North Dakota.

My objectives were 1) to determine species richness, evenness, and diversity among the grassland, badland, and wet meadow habitats; 2) to compare small mammal abundance during new moon phase and full moon phase; 3) assess new county records of small mammals in western North Dakota; 4) determine the small mammal communities at 36 sites in western North Dakota based on the three habitats (grassland, badland, and wet meadow); and 5) to describe the percent cover of vegetative categories and visual obstruction among the grassland, badland, and wet meadow habitats. I hypothesized that 1) species diversity would be significantly greater in the badland habitat than the grassland and wet meadow habitats; and 2) small mammal abundance would be greater during new moon phase than the full moon phase.

METHODS

Study sites

I surveyed small mammals in 13 counties in western North Dakota from 20 May to 26 July 2014 and from 18 May to 25 July 2015. The number of transects installed in each county was based on the area of the county (Fig. 1). Adams, Billings, Bowman, Burke, Divide, Golden Valley, Hettinger, Slope, and Stark counties all had 2 transects each. Dunn, Mountrail, and Williams counties all had 4 transects each (Fig. 1). McKenzie County, the largest of the 13 counties, had 6 transects (Fig. 1).

I surveyed 3 habitats: grassland, badland, and wet meadow (Fig. 1). The grassland habitat was composed of mixed and short grass prairie. The badland habitat included areas of highly eroded topography and generally contained sagebrush, shrub, and wooded areas (Morris 1992; Morris 1997). The badland habitat is a unique area, generally containing natural vegetation due to the highly eroded topography that makes farming difficult. The wet meadow habitat is similar to the grassland habitat. It is composed of mixed and short grass prairie, however it is different from grassland habitats as there are shallow wetlands, small lakes, or prairie potholes that cover the landscape (Klett et al. 1988).

Twenty-four of the sites were selected randomly by using the random function in Microsoft Excel. The remaining 12 sites were not selected randomly and transects were placed where I had permission to access the land. These 12 sites were either owned by North Dakota Game and Fish or by private land owners and there was no selection of suitable habitat for these sites. Potential sites selected in Microsoft Excel were visually inspected, to determine the most suitable habitat. Suitable habitat in the grasslands and wet meadows were heterogeneous areas with diversity of grasses and forbs. In the badland habitat I looked for sagebrush, shrub, and wooded areas. If the site was not suitable, I went to the next closest site and examined it for suitability. Once a site was selected, a transect was installed, the pitfall array was installed first, then the snap trap array was installed. GPS coordinates were recorded in UTMs with a Delorme Earthmate PN 40 handheld GPS device. The process was repeated at each sample site.

Small mammal trapping

I used pitfall traps and museum special snap traps to sample small mammals. The pitfall and snap traps were laid out in a Y shaped array covering approximately 345 m^2 (Fig. 2, Kirkland and Sheppard 1994). The pitfall portion of the array was composed of ten, 0.946 L pitfall cups. The top of each pitfall cup was flush with the ground and spaced 5 m apart with plastic drift fences separating each pitfall cup. Each 5 m section of drift fence was held vertically by stapling it to 3 wooded garden stakes. Garden stakes were hammered into the ground. The bottom edge of the drift fences were held to the ground by twenty 20 cm wooden blocks that were nailed into the ground. Drift fences were nailed to the ground to ensure that small mammals did not crawl under the drift fence, escaping capture. All pitfall cups were filled 2/3 full of water to drown the individual that fell into the trap. The resulting array was in the shape of a ‘Y’, with 1 pitfall cup in the center of the ‘Y’ and 3 pitfall cups on each arm. Off the end of each arm of the ‘Y’-shaped pitfall array, there were 10 stations of museum special snap traps; 90 snap traps overall. Each station was separated by 10 m and marked with brightly colored flagging tape. There were 3 museum special snap traps at each station, placed 1 m apart, perpendicular to the arm of the pitfall array. The arrays were operated for 5 consecutive nights and checked every morning. Pitfall cups were refilled with water and snap traps were re-baited if necessary.

Yearly precipitation totals were recorded from North Dakota Agricultural Weather Network (NDAWN 2016). These data were used to assess if there was a difference in precipitation between the two years that were sampled for small mammals.

Small mammal preparation

I recorded species and trap station for each individual captured. All individuals caught were placed into a bag that contained yellow corn meal to dry the specimens prior to preparation. For each individual trapped, species, sex, total body length (mm), tail length (mm), hind foot length (mm), ear length (mm), and mass (g) were recorded and assigned an Arabic number. A study skin or skeleton was kept for each individual. Tissue samples of the heart, liver, skeletal muscle, and kidney were removed, when possible. Tissue samples from 261 individuals were preserved in 95% ethanol. Prepared mammals and tissue samples were housed at the Northeastern State University Natural History Collection in Tahlequah, Oklahoma and the Fort Hays State University Sternberg Museum of Natural History in Hays, Kansas.

Vegetative Sampling

Percent vegetative cover was assessed at each of the 36 sites. A 1 m x 0.5 m Daubenmire frame was used to assess the percent cover of the vegetative structure in the 3 habitats (Daubenmire 1959). Ten Daubenmire plots were assessed at each site. The Daubenmire frame was placed 2 m to the right of each arm of the array and each

Daubenmire plot assessment was 35 m apart. On 1 arm of the array the center of the transect was assessed; this arm had a total of 4 Daubenmire plots and the remaining 2 arms had a total of 3 Daubenmire plots. While assessing percent cover, vegetation was identified to species and if the plant was not known it was classified as grass, forb, shrub, sedge, or rush. All of these species and/or vegetative categories were recorded as percent cover in the Daubenmire plot. The percent cover of litter, bare ground, standing dead vegetation, and height of the standing dead and live vegetation also were recorded. Once the 10 plots were completed, all plant species identified were grouped into the following vegetative categories as percent cover: grass, forb, shrub, sedge, rush, litter, bare ground, and standing dead vegetation. After the vegetation was assigned a vegetative category, they were placed into cover classes depending on the percent cover in each vegetative category (Daubenmire 1959). The cover classes were used to calculate the midpoint of each vegetative category (Table 1).

I also used the Robel Pole (2 m) to assess vegetative obstruction at 34 of the 36 sites. The Robel pole had alternating markers of decimeters on a round PVC pipe (2.54 cm diameter) that were color coated (red, black, and white) (Robel et al. 1970; Toledo et al. 2008). Each section of color corresponded to a number between 1 and 20, where 1 was the lowest measurement and 20 the highest measurement. There was a 1 m sight pole attached to the center of the vertical Robel pole by a 4 m string (Toledo et al. 2008). The sight pole was used to make observations of the obstruction of vegetation. The Robel pole was placed vertically at the center station where a museum special snap trap was located. The visual obstruction was measured in 4 cardinal directions (north, east, south, and west) at each of the 30 stations of snap traps.

The Daubenmire plots and Robel pole measurements for sites 1-6 were conducted from 30 June to 3 July in 2014. In 2015 Robel pole measurements were recorded at sites 19-28 from 29 to 30 June. For sites 7-36, Daubenmire plots and Robel measurements were conducted at the same time as small mammal trapping in 2014 and 2015.

Statistical Analysis

Statistical analyses were performed in the program R (Version 3.2.3) with an alpha level of 0.05. Package vegan and MASS were used to perform the Nonmetric multidimensional scaling (NDMS).

Small mammal data analysis- I assessed alpha diversity between 2 habitats, grassland and badland, in 2014 and among 3 habitats, grassland, badland, and wet meadow in 2015. Shannon-Weiner index was used to calculate species diversity. I used a Chi-square test to determine if diversity differed between the grassland and badland habitats, in 2014 and among grassland, badland, and wet meadow habitats in 2015.

I reported small mammal abundance during new moon and full moon phases. Chi-square tests were used to determine if there was a significant difference in the number of individuals captured after both summers of research and for 2014 and 2015 separately.

I used Non-metric Multidimensional Scaling (NMDS) to assess small mammal communities at 36 sites in 3 habitats (Figs. 4-6). NMDS is an ordination technique that works well with determining community structure of organisms (Minchin 1987; Fischer et al. 2011). I used 18 of 19 small mammal species captured. The northern pocket gopher

(*Thomomys talpoides*) was omitted from the dataset because this species is fossorial and traps set were not targeting fossorial individuals.

RESULTS

Small mammal population assessments

A total of 1,105 individuals were collected in the 2014 and 2015 field seasons representing 20 species (Table 2). My trapping effort was 18,000 trap nights and an overall trapping success rate of 6.1% (Table 3). Site 11, in the badland habitat, had the highest trapping success at 19.6%. The most frequently captured species was the meadow vole (*Microtus pennsylvanicus*) represented by 406 individuals (Table 2).

Small mammal community assessments

Species richness was greater in the badland habitats than grassland habitats in 2014 (Table 4), whereas species richness was greater in the grassland habitats than wet meadow habitats (Table 5). Site 18 (Adams/Bucyrus) in the grassland habitat had the highest species diversity (H') of 1.86. Grassland habitat site 19 (Williams/Alamo) had the lowest species diversity (H') of 0.54. When comparing species diversity in 2014 between the grassland and badland habitats and among the badland, grassland, and wet meadow habitats in 2015 there was no significant difference (X^2=0.003, df=1, p=0.951; X^2=0.128, df=2, p=0.937) (Table 6).

Trapping of small mammals took place during both new moon phase and full moon phase. The number of captures of small mammals differed significantly during new moon and full moon phase for the entirety of the research (X^2= 144.4, df= 1, p< 0.0001). The abundance of small mammals was greater during new moon phase than full moon phase (Fig. 3). The same trend was evident in both years: 2014 (X^2= 75.6, df= 1, p<0.0001) and 2015 (X^2=79.8, df= 1, p<0.0001)

Non-metric Multidimensional Scaling (NMDS) was used to assess small mammal community composition based on 36 sites. According to the Shepard plot, 95.1% of the variation is explained and a linear fit of 77.0% (Fig. 4). The stress was adequate at 0.221 (Fig. 5). Stress is a measure of mismatch between distance measures and distance in ordination space. There are no distinct small mammal communities based on the 3 habitats at the 36 sites (Fig. 5); this is confirmed with a Bray-Curtis Cluster Dendrogram (Fig. 6).

Small mammal new county records assessment

There was a total of 21 new county records of small mammals in 2014 and 2015 in 11 of the 13 counties surveyed (Tables 7 and 8). In 2014 there were 13 new county records, where Adams County had the most records (4) (Table 7). In 2015 there were 9 new county records, where McKenzie County had the most new county records (5) (Table 8). See Appendices 5-14 for maps.

Vegetative cover types and visual obstruction

Badland habitat vegetative categories for 2015 are omitted because only 1 badland site was surveyed for 2015. Badland sites surveyed in 2014 had the highest shrub (24.7% ± 10.26%) and bare ground (7.2% ± 9.94%) percent cover, and greater height of standing live vegetation (27.3 cm ± 4.22 cm), compared to the grasslands in 2014 and 2015 and wet meadows in 2015 (Table 9). Grassland sites surveyed in 2014 and 2015 had more grass percent cover (47.4% ± 18.19% and 38.5% ± 23.97%) compared to badland sites in 2014 and wet meadow sites in 2015 (Table 9). Wet meadow sites had more litter (17.7% ± 21.20%) and standing dead vegetation (29.0% ±

26.24%) percent cover, and greater height of standing dead vegetation (20.4 cm ± 5.17 cm) compared to the other habitats (Table 9). Visual obstruction was comparable for grassland (6.6 dm ± 2.0 dm) and badland (6.9 dm ± 1.89 dm) sites in 2014, and grassland (7.8 dm ± 3.35 dm) and wet meadow (7.6 dm ± 2.36 dm) sites in 2015 (Table 9).

DISCUSSION

Small mammal population assessments

In 2014 I captured a total of 708 individuals. In 2015 there was a decrease in the number of captures to 397 individuals. There was an overall trap success of 6.1% for this project, which is comparable to other studies (Patterson et al. 1989; Simonetti et al. 1989; Woodman et al. 1996) while some studies report a trap success greater than 10.0% (Howell 1954; Mills et al. 1998; Banks et al, 2003).

Precipitation might have played a large role in small mammal abundances in this project. More precipitation produces more foliage (Brendenkamp et al. 2002; Letnic et al. 2004; Yarnell et al. 2007)), which would contribute to more food availability for small mammals (Letnic et al. 2011). More available food (resources) would contribute to the potential for larger populations (Parmenter et al. 1999). Precipitation influences the amount of ground water available to plants, which can have an effect on the following year's plant growth (Reynolds et al. 2004). The previous year to trapping small mammals, 2013, was a wet year with 585.4±89.6 mm of precipitation (NDAWN 2016). This might explain the high number of individuals captured in 2014. In 2014 there was less precipitation, 350.7±84.5 mm (NDAWN 2016), which would cause less availability of resources for 2015. Precipitation data at the exact sites would be necessary for determining the decrease in the number of individuals captured, unfortunately these data were unavailable.

Other factors that affect small mammal populations are predators, disease, and competition (Merritt et al. 2001; Banks and Powell 2004; Korpimaki et al. 2004: Meserve et al 2011). An abundance of predators, such as hawks and weasels, will keep small mammal populations low (Merritt et al. 2001; Banks and Powell 2004). During cycles of high small mammal populations, it is more likely that there will be a disease outbreak that could drastically decrease small mammal populations (Korpimaki et al. 2004). Any of these listed factors might explain why there was a decrease in small mammal captures in the 2015 field season.

Small mammal community assessments

Species diversity in the 3 habitat types did not differ significantly, which was not what was hypothesized. I hypothesized species diversity would be significantly greater in the badland habitat. There was no difference in species diversity among 3 habitat types. The 3 habitats defined a priori in this study might be perceived as the same by small mammals or the habitats are too broad of an area to see a difference in species diversity. The difference in species diversity might be seen at a smaller scale (Williams et al. 2002). Species richness was greater in the badland habitats in 2014 but greater in the grassland habitats in 2015. The badland habitat sites could have been better sites in terms of habitat suitability or heterogeneity of plant species compared to the grassland habitat sites (Tews et al. 2004). Species richness might be greater in the grassland habitats in 2015 because there were more grassland habitat sites trapped.

Full moon vs. new moon sampling assessment- Significantly more individuals were captured during new moon phase than full moon phase (Fig. 3). My results are comparable to other studies of small mammal abundance relative to moon phase (Caldwell and Connell 1968; Prugh and Brashares 2010). During a full moon more light is emitted, which makes foraging small mammals more visible to aerial predators

(Lockard and Owings 1974; Mohammadi 2010). My catch rates are consistent with these observations. More individuals were captured during new moon phase, as there were probably fewer small mammals foraging during the full moon phases in 2014 and 2015.

The new moon phase might also be a reason why there were fewer captures in 2015. There were more new moon phases trapped in 2014 (28 days) than 2015 (22 days) (Appendices 3 and 4). As mentioned earlier, trapping during full moon phase significantly affects the number of individuals captured.

Small mammal community assessments

In the NMDS analysis I expected to see small mammal communities based on the 3 different habitats, but I did not find any distinctions (Figs. 5 and 6). There is a dense cluster of grassland and badland sites that are mixed (Fig. 5), which means these sites were similar based on small mammal composition. There could be a dense cluster of these sites because this was also where more common or generalist species were seen on the graph. I had the highest captures of *P. maniculatus*, *P. leucopus*, *M. pennsylvanicus*, *M. ochrogaster*, and *Z. hudsonius*, which are typically generalist species. Generalist species can occur in a wide variety of habitats, especially habitats that are fragmented with agriculture and other human infrastructures (Alder and Wilson 1987; Bellows et al. 2001). With more sampling in these 3 habitats, omitting these generalist species from the dataset, and performing another NMDS, I might see more distinct small mammal communities. However, when I omitted generalist species in the current dataset, there are not enough captures of rare species to perform NDMS. I assume these generalist species already were occurring at those habitats and the more rare species might be defining small mammal communities rather than the generalists.

Other studies have assessed small mammal communities within an area. One study found that small mammals can be used as bio indicators in a boreal forest, however rare species in the study had to be removed because there were not enough captures (Pearce and Venier 2004). Some small mammal species respond differently to variables such as altitude and vegetation (Caceres et al. 2011). Depending on theses variables and habitat type, small mammals will assimilate into communities (Caceres et al. 2011). Another study was unable to determine small mammal communities because there were so many captures of generalist species, which is similar to my results (Bellows et al. 2001). The small mammals in this project might be responding to variables at a finer scale than the variables I measured. The 3 habitats I selected might not be specific enough to determine small mammal communities. These communities might be definable at a much smaller scale (Fischer et al. 2011) or these communities might not even exist.

Moving forward

With North Dakota's landscape continuing to change due to the production of oil and natural gas, it is critical to update outdated records and species distributions. Small mammals are usually a neglected group when devising management plans (Gibbons 1988). Small mammals serve as a food source for other organisms such as weasels, owls, and snakes (Gregory et al. 1980; Merritt et al. 2001). Although their contributions are small in terms of grazing and seed dispersal, they are an integral part of the food web and should be taken under consideration when managing an area.

Moving forward, it is critical to assess how small mammals are being impacted by the production and infrastructure of oil sites. I think the next step is to measure the density of oil and natural gas production sites and determine how the densities of these sites are affecting small mammal distributions. This can be applied and extended to all taxonomic groups. Without understanding complex animal communities (i.e. small mammals, insects, herpetofauna), how can we as a society be sure we are not only destroying the food webs that all animals depend on, but also negatively impacting entire ecosystems? For these reasons, it is critical that we continue to study, monitor, and understand small mammal and other taxonomic group (i.e. herpetofauna, insects) communities.

LITERATURE CITED

ABRAHAMS, L. S., W. M. GRIFFIN, AND S. MATTHEWS. 2015. Assessment of policies to reduce core forest fragmentation from Marcellus shale development in Pennsylvania. Ecological Indicators 52:153-160.

ALDER, G. H., AND M. L. WILSON. 1987. Demography of a habitat generalist, the white-footed mouse, in a heterogeneous environment. Ecology 68:1785-1796.

BALSBAUGH, E. U., AND D. G. AARHUS. 1990. Checklist and new state records of Curculionidae (broad sense) (Coleptera) for North Dakota. Journal of Kansas Entomological Society 2:227-236.

BAMBERGER, M., AND R. E. OSWALD. 2012. Impacts of gas drilling on human and animal health. New Solutions 22:51-77.

BANKS, P. B., K. NELIKA, A. HUGHES, AND T. ROSE. 2003. Do native Australian small mammals avoid faeces of domestic dogs? Responses of *Rattus fuscipes* and *Antechinus stuartii*. Australian Zoologist 32:406-409.

BANKS, P. B., AND F. POWELL. 2004. Does maternal condition or predation risk influence small mammal population dynamics? Oikos 106:176-184.

BELLOWS, A. S., J. F. PAGELS, AND J. C. MITCHELL. 2001. Macrohabitat and microhabitat affinities of small mammals in a fragmented landscape on the upper coastal plain of Virginia. American Midland Naturalist 146:345-360.

BRENDENKAMP, G. J., F. SPADA, AND E. KAZMIERCZAK. 2002. On the origin of northern and southern hemisphere grasslands. Plant Ecology 163:209-229.

BRITTINGHAM, M. C., K. O. MALONEY, A. M. FARAG, D. D. HARPER, AND Z. H. BOWEN. 2014. Ecological risks of shale oil and gas development to wildlife, aquatic resources and their habitats. American Chemical Society 48:11034-11047.

CALDWELL, L. D., AND C. E. CONNELL. 1968. A precis on energetics of the old-field mouse. Ecology 49:542-548.

CANE, J. H., AND V. J. TEPEDINO. 2001. Causes and extent of declines among native North American invertebrate pollinators: Detection, evidence, and consequences. Conservation Ecology 5:1.

CACERES, N. C., M. N. GODOI, W. HANNIBAL, AND V. L. FERREIRA. 2011. Effects of altitude and vegetation on small-mammal distributions in the Urucum Mountains, western Brazil. Journal of Tropical Ecology 27.3:279-287.

COPELAND, H. E. K. E. DOHERTY, D. E. NAUGLE, A. POCEWICZ, AND J. M. KIESECKER. 2009. Mapping oil and gas development potential in the US intermountain west and estimating impacts to species. PLoS One 4:e7400.

COPPEDGE, B. R., D. M. ENGLE, R. E. MASTERS, AND M. S. GREGORY. 2001. Avian response to landscape change in fragmented southern Great Plains grasslands. Ecological Applications 11:47-59.

CRALL, A. W., L .A. MEYERSON, T. J. STOHLGREN, C. S. JARNEVICH, G. T. NEWMAN, AND J. GRAHAM. 2006. Show me the numbers: what data currently exist for non-native species in the USA? Frontiers in Ecology and the Environment 4:414-418.

CYPHER, B. L., G. D. WARRICK, M. R. M. OTTEN, T. P. O'FARRELL, W. H. BERRY, C.E. HARRIS, T. T. KATO, P. M. MCCUE, J. H. SCRIVNER, AND B. W. ZOELLICK. 2000.

Population dynamics of San Joaquin kit foxes at the Naval Petroleum Reserves in California. Wildlife Monographs 145:1-43.

DAUBENMIRE, R. F., 1959. A canopy-cover method of vegetational analysis. Northwest Science, 33:43-46.

DIX, R. L. 1958. Some slope-plant relationships in the grasslands of the Little Missouri Badlands of North Dakota. Journal of Range Management 11:88-92.

FINER, M., C. N. JENKINS, S. L. PIMM, B. KEANE, AND C. ROSS. 2008. Oil and gas projects in the western Amazon: Threats to wilderness, biodiversity, and Indigenous peoples. PLoS One 3:e2932.

FISCHER, C., C. THIES, AND T. TSCHARNTKE. 2011. Small mammals in agricultural lanscapes: opposing responses to farming practices and landscape complexity. Biological Conservation 144:1130-1136.

GEIER, A. J., AND L. B. BEST. 1980. Habitat selection by small mammals of riparian communities: effects of habitat alterations. Journal of Wildlife Management 44:16-24.

GIBBONS, J. W. 1988. The management of amphibians, reptiles, and small mammals in North America: the need for an environmental attitude adjustment. U.S. Forest Service, General Technical Report RM-166.

GILLEN, J. L., AND E. KIVIAT. 2012. Hydraulic fracturing threats to species with limited ranges in the eastern United States. Environmental Practice 14:320-331.

GRANT, T. A., B. FLANDERS-WANNER, T. L. SHAFFER, R. K. MURPHY, AND G. A. KNUTSEN. 2009. An emerging crisis across northern prairie refuges: prevalence if invasive plants and a plan for adaptive management. Ecological Restoration 27:58-65.

GREGORY, P. T., J. M. MACCARTNEY, AND D. H. RIVARD. 1980. Small mammal predation and prey handling behavior by the garter snake *Thamnophis elegans*. Hepetologica 36:87-93.

HEIP, C. H. R., P. M. J. HERMAN, AND K. SOETAERT. 1998. Indices of diversity and evenness. Oceanis 24:61-87.

HIGGINS, K. F., D. E. NAUGLE, AND K. J. FORMAN. 2002. A case study of changing land use in the northern Great Plains, U.S.A: an uncertain future for waterbird conservation. International Journal of Waterbird Biology 25:42-50.

HORNCASTLE, V. J., E. C. HELLGREN, P. M. MAYER, A. C. GANGULI, D. M. ENGLE, AND D. M. LESLIE, JR. 2005. Implications of invasion by *Juniperus virginiana* on small mammals in the southern Great Plains. Journal of Mammalogy 86:1144-1155.

HOWELL, J. C. 1954. Populations and home ranges of small mammals on an overgrown field. Journal of Mammalogy 35:177-186.

JOHNSON, J. R., AND G. E. LARSON. 1999. Grassland plants of South Dakota and the northern Great Plains. South Dakota State University College of Agriculture and Biological Science South Dakota Agricultural Experiment Station.

JOHNSON, W. C., B. V. MILLETT, T. GILMANOV, R. A. VOLSETH, G. R. GUNTENSPERGEN, AND D. E. NAUGLE. 2005. Vulnerability of northern prairie wetlands to climate change. BioScience 55:863-872.

KAHARA, S. N., R. M. MOCKLER, K. F. HIGGINS, S. R. CHIPPS, AND R. R JOHNSON. 2009. Spatiotemporal patterns of wetland occurrence in the prairie pothole region of eastern South Dakota. Wetlands 29:678-689.

KIRKLAND, G. L., AND P. K. SHEPPARD. 1994. Proposed standard protocol for sampling small mammal communities. In: J. F. Merrit, G. L. Kirkland, and R. K. Rose (Eds.) Advances in the biology of shrews. Carnegie Museum of Natural History Special Publication 18:277-283.

KLETT, A. T., T. L. SHAFFER, AND D. H. JOHNSON. 1988. Duck nest success in the prairie pothole region. Journal of Wildlife Management 52:431-440.

KOLAR, J. L., J. J. MILLSPAUGH, AND B. A. STILLINGS. 2011. Migration patterns of pronghorn in southwestern North Dakota. Journal of Wildlife Management 75:198-203.

KORPIMAKI, E., P. R. BROWN, J. JACOB, AND R. P. PECH. 2004. The puzzles of population cycles and outbreaks of small mammals solved? BioScience 54:1071-1079.

LETNIC, M., C. R. DICKMAN, M. K. TISCHLER, B. TAMAYO, AND C. -L. BEH. 2004. The responses of small mammals and lizards to post-fire succession and rainfall in arid Australia. Journal of Arid Environments 59:85-114.

LETNIC, M., P. STORY, G. STORY, J. FIELD, O. BROWN, AND C. R. DICKMAN. 2011. Resource pulses, switching trophic control, and the dynamics of small mammal assemblages in arid Australia. Journal of Mammalogy 96:1210-1222.

LOCKARD, R. B., AND D. H. OWINGS. 1974. Seasonal variation in moonlight avoidance by bannertail kangaroo rats. Journal of Mammalogy 55:189-193.

MENHINICK, E. F. 1964. A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology 45:859-861.

MERRITT, J. F., M. LIMA, AND F. BOZINOVIC. 2001. Seasonal regulation in fluctuating small mammal populations: feedback structure and climate. Oikos 94:505-514.

MESERVE, P. L., D. A. KELT, M. A. PREVITALI, W. B. MILSTEAD, AND J. R. GUTIERREZ. 2011. Global climate change and small mammal populations in north-central Chile. Journal of Mammalogy 92:1223-1235.

MILLS, J. N., J. M. JOHNSON, T. G. KSIAZEK, B. A. ELLIS, P. E. ROLLIN, T. L. YATES, M. O. MANN, M. R. JOHNSON, M. L. CAMPBELL, J. MIYASHIRO, M. PATRICK, M. ZYZAK, D. LAVENDER, M. G. NOVAK, K. SCHMIDT, C. J. PETERS, AND J. E. CHILDS. 1998. A survey of Hantavirus antibody in small-mammal populations in selected United States national parks. American Journal of Tropical Medicine and Hygiene 58:525-532.

MINCHIN, P. R. 1987. An evaluation of the relative robustness of techniques for ecological ordination. Vegetatio 69:89-107.

MOHAMMADI, S. 2010. Microhabitat selection by small mammals. Advances in Biological Research 4:283-287.

MORRIS, D. W. 1992. Scales and costs of habitat selection in heterogeneous landscapes. Evolutionary Ecology 6:412-432.

MORRIS, D. W. 1997. Optimally foraging deer mice in prairie mosaics: a test of habitat theory and absence of landscape effects. Oikos 80:31-42.

NDAWN. 2016. www.ndawn.ndsu.nodak.edu. Accessed February 2016.

NAGENDRA, H. 2002. Opposite trends in response for the Shannon and Simpson indices of landscape diversity. Applied Geography 22:175-186.

PATTERSON, B. D., P. L. MESERVE, AND B. K. LANG. 1989. Distribution and abundance of small mammals along an elevational transect in temperate rainforests of Chile. Journal of Mammalogy 70:67-78.

PARMENTER, R. R., E. P. YADAV, C. A. PARMENTER, P. ETTESTAD, AND K. L. GAGE. 1999. Incidence of plague associated with increased winter-spring precipitation in New Mexico. American Journal of Tropical Medicine and Hygiene 61:814-821.

PEARCE, J., AND L. VENIER. 2004. Small mammals as bio indicators of sustainable boreal forest management. Journal of Forest Ecology and Management 208:153-175.

PRUGH, L., AND J. BRASHARES. 2010. Basking in the moonlight? Effect of illumination on capture success of the endangered giant kangaroo rat. Journal of Mammalogy 91:1205-1212.

RAPPORT, D. J. 1989. What constitutes ecosystem health? Perspectives in Biology and Medicine 33:120-132.

REYNOLDS, J. F., P. R. KEMP, K. OGLE, AND R. J. FERNANDEZ. 2004. Modifying the ‘pulse-reserve’ paradigm for deserts of North America: precipitation pulses, soil water, and plant responses. Oecologia 141:194-210.

ROBEL, R. J., J. N. BRIGGS, A. D. DAYTON, AND L. C. HULBERT. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-298.

RUDD, V. E. 1951. Geographical affinities of the flora of North Dakota. American Midland Naturalist 45:722-739.

SAMSON, F. B., AND F. L. KNOPF. 1994. Prairie conservation in North America. BioScience 44:418-421.

SAMSON, F. B., F. L. KNOPF, C. W. MCCARTHY, B. R. NOON, W. R. OSTLIE, S. M. RINEHART, S. LARSON, G. E. PLUMB, G. L. SCHENBECK, D. N. SVINGEN, AND T. W. BYER. 2003. Planning for population viability on northern Great Plains National Grassland. Wildlife Society Bulletin 31:986-999.

SAUNDERS, D. A., R. J. HOBBS, AND C. R. MARGULES. 1991. Biological consequences of ecosystem fragmentation: A review. Conservation Biology 5:18-32.

SEABLOOM, R. J., J. W. HOGANSON, AND W. F. JENSEN. 2011. Mammals of North Dakota. 2nd ed. North Dakota Institute for Regional Studies 1-491.

SIEG, C. H. 1987. Small mammals: pests or vital components of the ecosystem. Internet Center for Wildlife Damage Management. Great Plains Wildlife Damage Control Workshop Proceedings. University of Nebraska-Lincoln, Lincoln, Nebraska, USA.

SIMONETTI, J. A. 1989. Microhabitat use by small mammals in central Chile. Oikos 56:309-318.

STANCAMPIANO, A. J., AND G. D. SCHNELL. 2004. Microhabitat affinities of small mammals in southwestern Oklahoma. Journal of Mammalogy 85:948-958.

STIRLING, G., AND B. WILSEY. 2001. Empirical relationships between species richness, evenness, and proportional diversity. American Naturalist 158:286-299.

STEWART, R. E., AND H. A. KANTRUD. 1973. Ecological distribution of breeding waterfowl populations in North Dakota. Journal of Wildlife Management 37:39-50.

TEWS, J., U. BROSE, V. GRIMM, K. TIELBORGER, M. C. WICHMANN, M. SCHWAGER, AND F. JELTSCH. 2004. Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. Journal of Biogeography 31:79-92.

TOLEDO, D. P., L. B. ABBOTT, AND J. E. HERRICK. 2008. Cover pole design for easy transport, assembly, and field use. Journal of Wildlife Management 72:564-567.

VERTNET. 2015. Ver. 2015-05-15. www.vertnet.org. Accessed November 2013.

VITOUSEK, P. M., H. A. MOONEY, J. LUBCHENCO, AND J. M. MELILLO. 1997. Human domination of earth's ecosystems. Science 277:494-499.

WELSH JR., H. H., AND S. DROEGE. 2001. A case for using Plethodontid Salamanders for monitoring biodiversity and ecosystems integrity of North American forests. Conservation Biology 15:558-569.

WILLIAMS, S. E., H. MARSH, AND J. WINTER. 2002. Spatial scale, species diversity, and habitat structure: small mammals in Australian tropical rain forest. Ecology 83:1317-1329.

WOODMAN, N., R. M. TIMM, N. A. SLADE, AND T. J. DOONAN. 1996. Comparison of traps and baits for censusing small mammals in neotropical lowlands. Journal of Mammalogy 77:274-281.

YARNELL, R. W., D. M. SCOTT, C. T, CHIMIMBA, AND D. J. METCALFE. 2007. Untangling the roles of fire, grazing, and rainfall on small mammal communities in grassland ecosystems. Oecologia 154:387-402.

Table 1. Cover class, range of coverage, and midpoint range for assessing percent cover of vegetation by using the Daubenmire frame (Daubenmire 1959).

Cover Class	Range of Coverage	Midpoint Range
0	0%	0%
1	1 – 5%	2.5%
2	5 – 25%	15.0%
3	25 – 50%	37.5%
4	50 – 75%	62.5%
5	75 – 95%	85.0%
6	95 – 100%	97.5%

Table 2. Species of small mammals captured in 2014 and 2015 in western North Dakota. The species code is used in another analysis that can be found in figure 5.

Species, common name, (species code)	2014	2015
Microtus pennsylvanicus, meadow vole (MiPe)	339	67
Peromyscus maniculatus, deer mouse (PeMa)	226	141
Sorex cinereus, masked shrew (SoCi)	35	82
Peromyscus leucopus, white-footed mouse (PeLe)	26	17
Zapus hudsonius, meadow jumping mouse (ZaHu)	26	55
Ictidomys tridecemlineatus, thirteen-lined ground squirrel (IcTr)	16	11
Microtus ochrogaster, prairie vole (MiOc)	14	0
Chaetodipus hispidus, hispid pocket mouse (ChHi)	6	0
Myodes gapperi, red-backed vole (MyGa)	5	1
Thomomys talpoides, northern pocket gopher (Ttal)	3	1
Lemmiscus curtatus, sagebrush vole (LeCu)	2	0
Perognathus fasciatus, olive-backed pocket mouse (PeFa)	2	7
Reithrodontomys montanus, plains harvest mouse (ReMo)	2	
Tamias minimus, least chipmunk (TaMi)	2	3
Blarina brevicauda, northern short-tailed shrew (BlBr)	1	2
Mus musculus, house mouse (MuMu)	1	0
Reithrodontomys megalotis, western harvest mouse (ReMe)	1	3
Sorex merriami, Merriam’s shrew (SoMe)	1	0
Sorex arcticus, arctic shrew (SoAr)	0	5
Sorex hoyi, pygmy shrew (SoHo)	0	1

Table 3. Trap success rates for 36 sites (in chronological order) in 2014 and 2015 in western North Dakota. Each site had a total of 500 trap nights; 9,000 trap nights in 2014 and 9,000 trap nights in 2015. Habitat types: G=grassland, B=badland, P=wet meadow.

2014		2015	
Site	Trap Success (%)	Site	Trap Success (%)
1 G	3.4	19 G	0.2
2 G	5.8	20 G	0.4
3 B	7.4	21 P	2.6
4 B	7.4	22 P	0.4
5 G	9.2	23 G	1.6
6 B	14.4	24 G	3.2
7 G	3.2	25 P	2.0
8 G	1.8	26 P	1.8
9 B	12.0	27 G	2.6
10 G	3.4	28 G	2.4
11 B	19.6	29 G	2.6
12 B	15.4	30 G	2.6
13 G	7.6	31 G	12.8
14 G	10.8	32 G	8.0
15 B	5.2	33 G	11.0
16 B	7.2	34 G	7.4
17 G	4.8	35 B	5.2
18 G	3.0	36 G	12.6

Table 4. Species richness, evenness (J'), and diversity (H') in two habitats, G=grassland and B=badland, in 2014 in western North Dakota across 18 sites. Each habitat type is ordered from greatest species richness to least species richness.

Habitat Type	North Dakota County/Nearest City (Site Number)	Species Richness	Evenness (J')	Diversity (H')
G	Adams/Hettinger (17)	8	0.82	1.71
G	Adams/Bucyrus (18)	8	0.89	1.86
G	Hettinger/Regent (7)	5	0.93	1.5
G	Bowman/Scranton (13)	5	0.65	1.05
G	Bowman/Rhame (14)	5	0.69	1.11
G	Stark/Richardton (1)	4	0.66	0.91
G	Stark/Dickinson (2)	4	0.39	0.54
G	Dunn/Marshall (10)	4	0.87	1.21
G	Slope/Amidon (5)	3	0.67	0.74
G	Hettinger/Mott (8)	3	0.89	0.98
B	Golden Valley/Beach (16)	9	0.49	1.08
B	Dunn/Dunn Center (11)	7	0.57	1.11
B	Dunn/Killdeer (12)	7	0.66	1.29
B	Dunn/Manning (9)	6	0.6	1.08
B	Billings/Belfield (3)	5	0.75	1.2
B	Golden Valley/ Sentinel Butte (15)	5	0.62	1.0
B	Billings/Fryburg (4)	4	0.71	0.98
B	Slope/Belfield (6)	4	0.76	1.06

Table 5. Species richness, evenness (J'), and diversity (H') in three habitats, G=grassland, P=wet meadow, and B=badland, in 2015 in western North Dakota across 18 sites. Grassland and wet meadow habitats are ordered from greatest species richness to least species richness. Badland habitat 2015 does not have a standard deviation because only one site was surveyed in this habitat.

Habitat Type	North Dakota County/Nearest City (Site Number)	Species Richness	Evenness (J')	Diversity (H')
G	Mountrail/New Town 2 (32)	7	0.87	1.69
G	McKenzie/Alexander (33)	7	0.7	1.36
G	McKenzie/Watford City (34)	7	0.68	1.32
G	McKenzie/Killdeer (36)	7	0.73	1.42
G	Mountrail/Parshall (31)	6	0.76	1.37
G	Mountrail/New Town (30)	5	0.86	1.38
G	McKenzie/Buford (28)	4	0.95	1.32
G	Mountrail/Tioga (29)	4	0.76	1.06
G	Williams/Williston (23)	3	0.69	0.76
G	Williams/Trenton (24)	3	0.71	0.78
G	McKenzie/Williston (27)	3	0.73	0.8
G	Williams/Grenora (20)	2	0.98	0.68
G	Williams/Alamo (19)	1	0	0
P	Burke/Columbus (25)	3	0.73	0.8
P	Burke/Powers Lake (26)	3	0.87	0.96
P	Divide/Fortuna (21)	2	0.61	0.42
P	Divide/Alamo22)	2	0.98	0.68
B	McKenzie/Grassy Butte (35)	4	0.79	1.1

Table 6. Average of species diversity (H') of small mammals in grassland, badland, and wet meadow habitats in 2014 and 2015 in western North Dakota. Badland habitat 2015 does not have a standard deviation because only one site was surveyed in this habitat.

Species Diversity (H')		
Habitat	2014	2015
Grasslands	1.16±0.419	1.07±0.452
Badlands	1.10±0.102	1.1
Wet meadow	-	0.715±0.227

Table 7. New county records of small mammals for 2014 in western North Dakota counties surveyed. X indicates a new county record.

Species	Adams County	Billings County	Bowman County	Dunn County	Golden Valley County	Slope County	Stark County
Sorex cinereus	X	X	-	-	X	-	-
Peromyscus leucopus	-	-	-	-	X	X	-
Chaetodipus hispidus	-	-	X	-	X	-	-
Blarina brevicauda	X	-	-	-	-	-	-
Lemmiscus curtatus	X	-	-	-	-	-	-
Microtus ochrogaster	-	-	-	X	-	-	X
Reithrodontomys montanus	X	-	-	-	-	-	-

Table 8. New County records of small mammals for 2015 in western North Dakota counties. X indicates a new county record.

Species	Divide County	McKenzie County	Mountrail County	Williams County
Sorex arcticus	X	X	-	X
Reithrodontomys megalotis	-	X	X	-
Peromyscus leucopus	-	X	-	-
Sorex cinereus	-	X	-	-
Reithrodontomys montanus	-	X	-	-
Sorex hoyi	-	-	X	-

Table 9. Percent cover of vegetative structure (mean ± SD) in three habitats in 2014 and 2015 in western North Dakota; grassland 2014 (n=10), badland 2014 (n=8), grassland 2015 (n=13), badland 2015 (n=1), and wet meadow 2015 (n=4).

Habitat	Grass (% cover)	Forb (% cover)	Shrub (% cover)	Sedge (% cover)	Rush (% cover)	Bare ground (% cover)	Litter (% cover)	Standing Dead Vegetation (% cover)	Height of Standing Dead Vegetation (cm)	Height of Live Vegetation (cm)	Robel Pole (dm)
Grassland 2014	47.4 ± 18.19	23.5 ± 17.43	4.3 ± 6.02	1.8 ± 2.99	0.0	2.1 ± 4.49	14.3 ± 5.57	4.4 ± 3.92	8.0 ± 7.29	26.8 ± 5.72	6.6 ± 2.0
Badland 2014	25.8 ± 15.22	14.6 ± 6.28	24.7 ± 10.26	1.3 ± 3.15	0.0	7.2 ± 9.94	15.5 ± 9.17	6.2 ± 3.16	10.3 ±5.90	27.3 ± 4.22	6.9 ± 1.89
Grassland 2015	38.5 ± 23.97	11.9 ± 9.55	5.3 ± 5.80	0.7 ± 1.76	1.3 ± 4.09	3.9 ± 4.41	11.9 ± 10.69	22.8 ± 20.63	19.0 ± 6.41	22.7 ± 10.45	7.8 ± 3.35
Badland 2015	32.3	13.5	15.8	0.0	0.0	0.0	10.5	24.8	18.1	20.7	7.8
Wet meadow 2015	26.0 ± 10.0	6.2 ± 3.34	12.5 ± 6.84	1.0 ± 1.86	0.0	0.0	17.7 ± 21.20	29.0 ± 26.24	20.4 ± 5.17	18.1 ± 3.23	7.6 ± 2.36

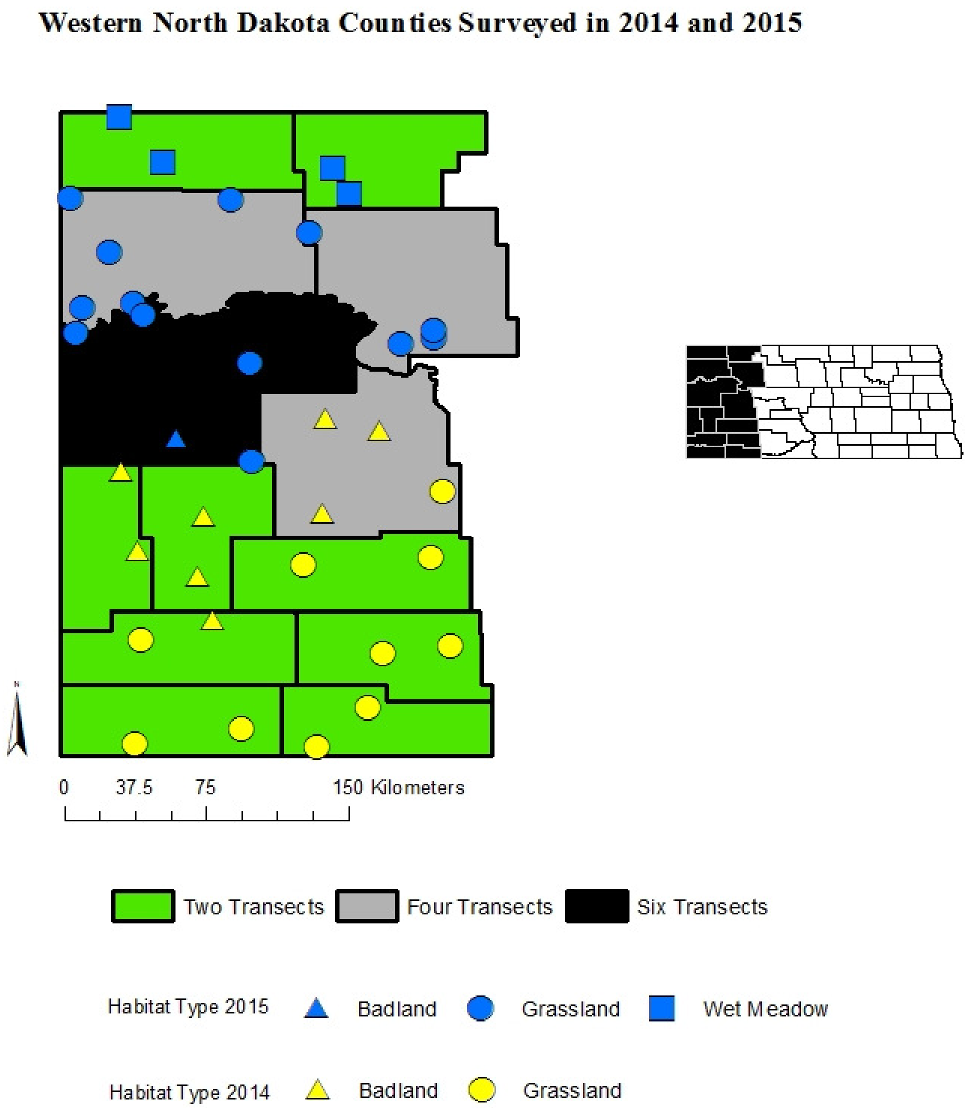


Fig. 1. Western North Dakota counties surveyed in 2014 and 2015. Two transects were installed into 9 counties, 4 transects were installed into 3 counties, and 6 transects were installed into 1 county. Thirty-six total transects; 18 transects in 2014 and 18 transects in 2015. Three habitats were surveyed: badland, grassland, and wet meadow.

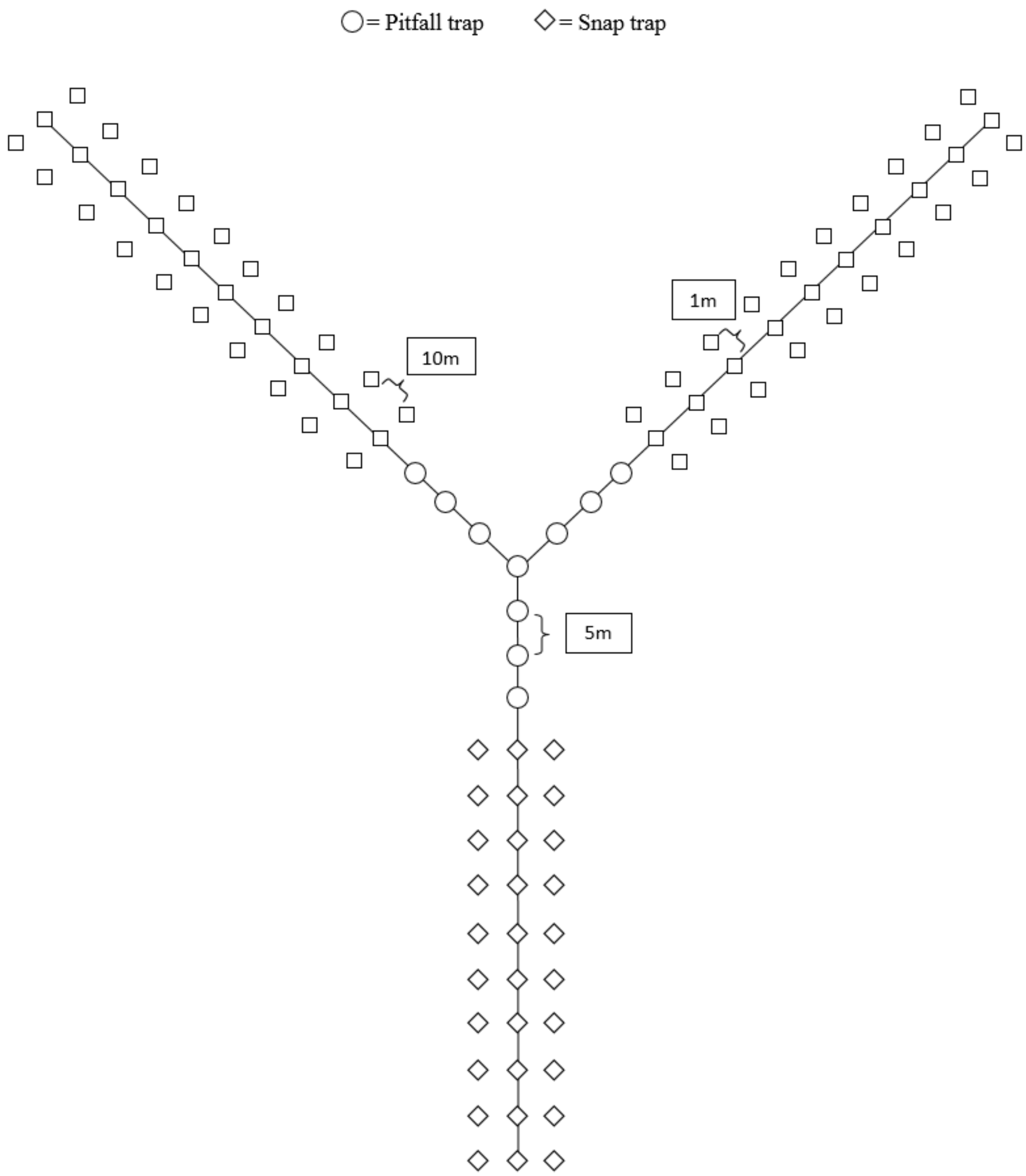


Fig. 2. Transect composed of pitfall traps and museum special snap traps. Pitfall traps are indicated by circles and snap traps are indicated by diamonds. Pitfall traps were separated by 5 m plastic drift fences. There was a total of 10 pitfall traps. At the end of each pitfall trap there were 10 stations of snap traps. Each snap trap station was separated by 10 m. At each snap trap station there were 3 snap traps that were 1 m apart. Snap traps were baited with peanut butter and oats. There was a total of 90 snap traps; 100 traps overall.

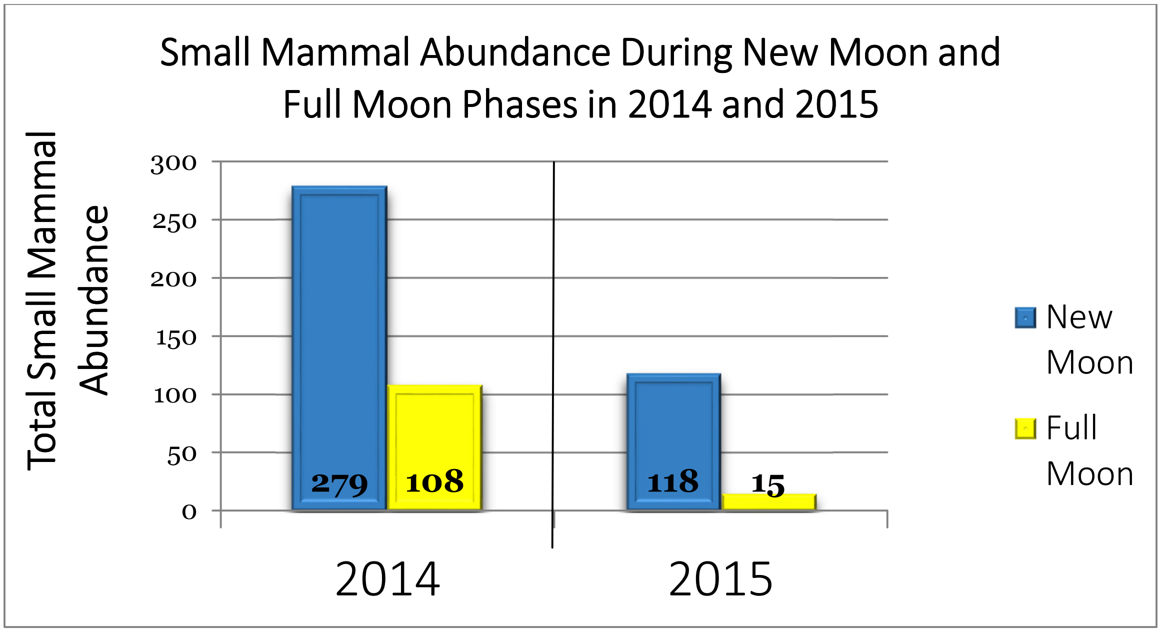


Fig. 3. Number of small mammal captures in 2014 and 2015 during new moon and full moon phases in western North Dakota.

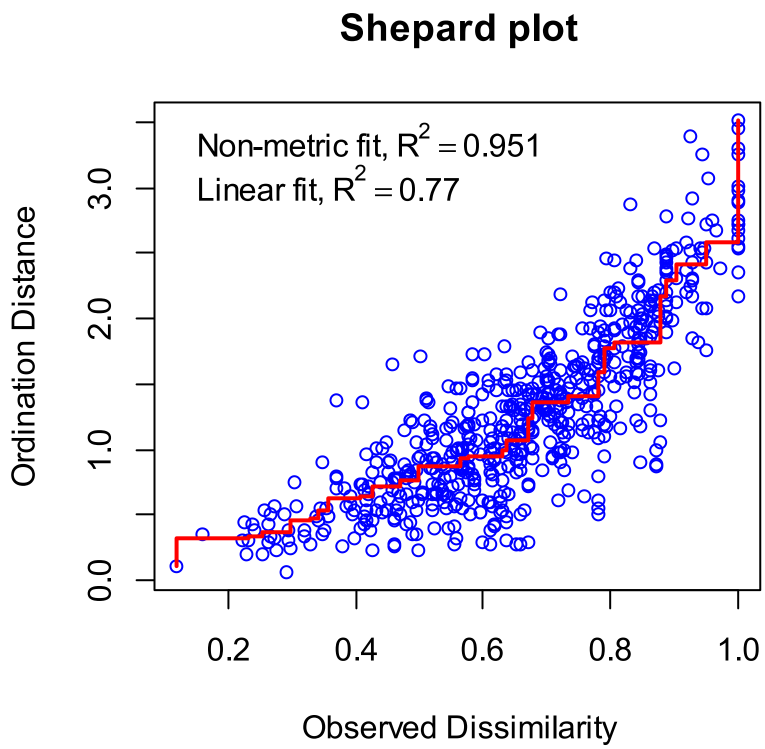


Fig. 4. Non-metric multidimensional scaling (NMDS) Shepard plot. 95.1% of the variation is explained with a linear fit of 77.0%.

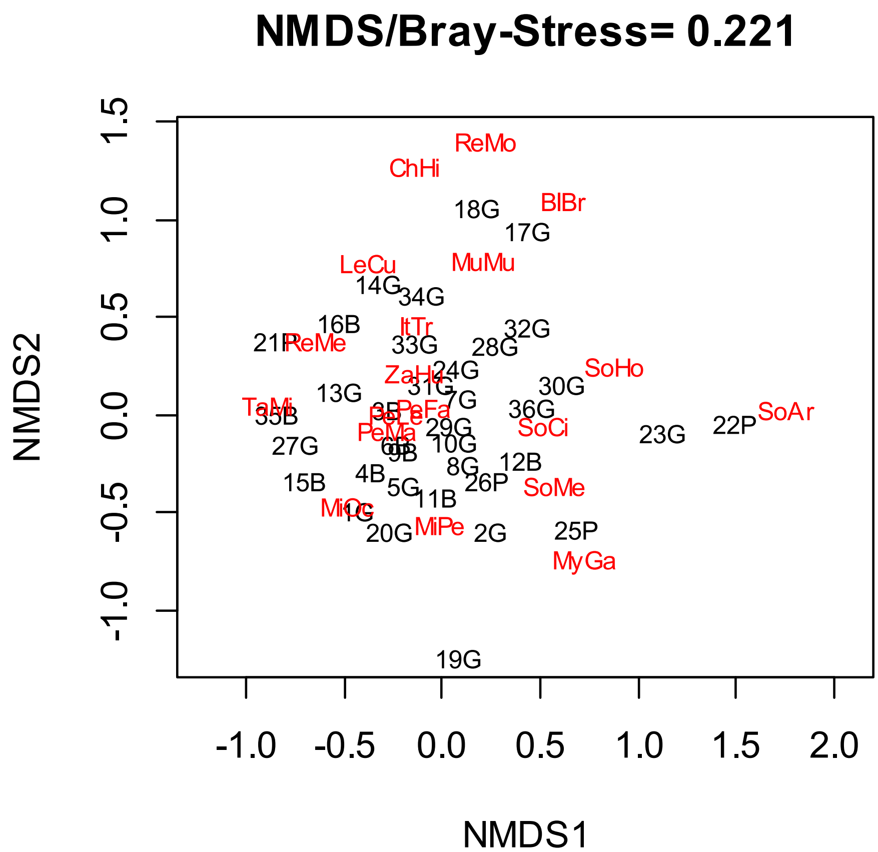


Fig. 5. Multidimensional analysis of small mammal communities in western North Dakota. The NMDS/Bray-stress is indicative of dissimilarity among habitats (G=grassland, B=badland, P=wet meadow) based on small mammals captured at 36 sites. The stress was adequate at 0.221. Stress is a measure of mismatch between distance measures and distance in ordination space. A number (1-36) followed by a letter corresponds to the habitat and site trapped. In red are the species that were captured (Table 2). There are no distinct small mammal communities based on the 3 habitats.

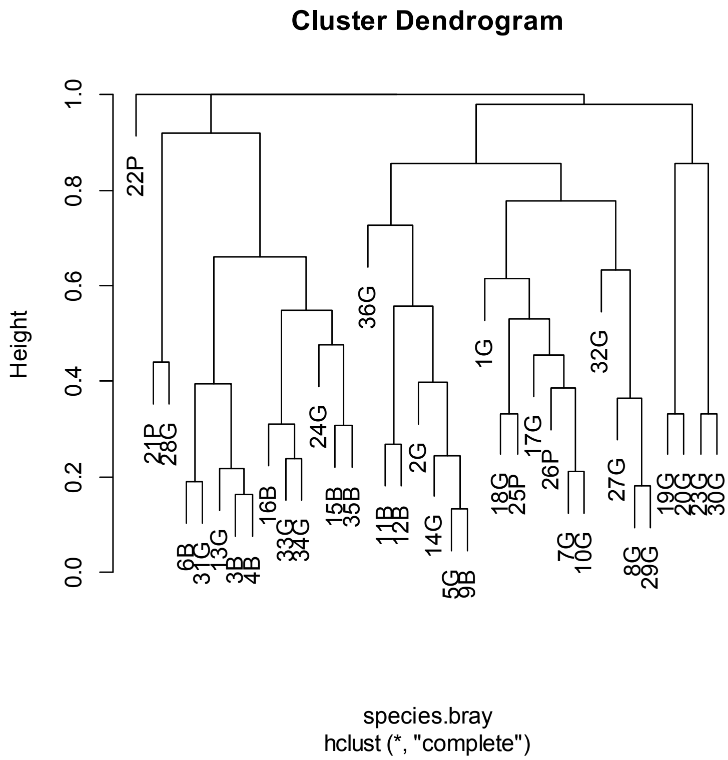


Fig. 6. Bray-Curtis Cluster Dendrogram. Complete link clustering was used to create the dendrogram. Complete-link clustering is a measure of similarity of the most dissimilar sites. This dendrogram groups the sites based on dissimilarity and confirms the NMDS graph in figure 5. There is a mixing of habitats, which explains no distinct small mammal communities based on the three habitats (G=grassland, B=badland, and P=wet meadow).

Appendix 1. Average Daubenmire percent (%) cover for vegetative structure from 18 sites in 2014: grass, forb, shrub, sedge, bare ground, litter, standing dead vegetation, height (cm) of standing dead vegetation, and height (cm) of standing live vegetation. The Robel pole to assess visual obstruction is measured in decimeters. Each site had 10 Daubenmire plots and 30 Robel pole stations.

Site	Grass (% cover)	Forb (% cover)	Shrub (% cover)	Sedge (% cover)	Bare ground (% cover)	Litter (% cover)	Standing Dead Vegetation (% cover)	Height of Standing Dead Vegetation (cm)	Height of Live Vegetation (cm)	Robel Pole (dm)
1	52.0	10.0	18.0	0.0	0.0	18.8	0.5	2.1	28.1	10.1
2	78.7	0.0	0.0	0.0	0.0	15.0	8.0	24.9	31.2	7.7
3	38.8	11.3	27.8	0.0	10.3	6.3	5.3	10.9	26.1	7.5
4	12.8	27.5	32.3	0.0	0.0	11.3	6.5	6.5	32.3	8.2
5	21.5	57.3	9.8	1.5	0.0	7.5	1.8	5.5	35.7	9.1
6	14.3	12.3	28.2	0.0	0.0	27.8	9.0	14.6	26.8	8.3
7	34.7	27.5	0.0	9.7	5.9	18.8	6.9	15.8	19.0	6.4
8	52.3	13.0	0.0	3.0	0.0	15.8	11.5	7.6	23.6	6.4
9	38.8	15.5	7.8	0.0	0.5	19.3	11.8	21.3	26.5	5.9
10	28.5	35.5	3.0	1.5	1.5	21.8	7.5	10.0	25.6	4.8
11	3.3	15.0	33.0	1.5	11.3	28.0	4.5	6.2	25.0	8.6
12	38.0	14.5	12.5	9.0	0.0	18.3	6.5	11.6	29.9	8.3
13	33.3	36.8	1.8	1.8	13.8	5.3	0.5	3.1	17.2	3.0
14	45.0	33.3	8.8	0.0	0.3	8.3	0.5	2.0	26.9	6.4
15	42.3	5.0	36.0	0.0	6.5	6.8	1.5	1.9	32.3	5.0
16	18.3	15.5	19.8	0.0	28.8	6.5	4.0	9.7	19.6	3.5
17	64.0	10.0	1.8	0.0	0.0	18.3	1.8	3.6	31.4	6.5
18	64.3	12.0	0.0	0.0	0.0	13.8	4.5	5.6	29.8	5.6

Appendix 2. Average Daubenmire percent (%) cover for vegetative structure from 18 sites in 2015: grass, forb, shrub, sedge, bare ground, litter, standing dead vegetation, height (cm) of standing dead vegetation, and height (cm) of standing live vegetation. The Robel pole to assess visual obstruction is measured in decimeters. Each site had 10 Daubenmire plots and 30 Robel pole stations.

Site	Grass (% cover)	Forb (% cover)	Shrub (% cover)	Sedge (% cover)	Rush (% cover)	Bare ground (% cover)	Litter (% cover)	Standing Dead Vegetation (% cover)	Height of Standing Dead Vegetation (cm)	Height of Live Vegetation (cm)	Robel Pole (dm)
19	10.8	8.5	6.5	1.5	0.0	0.0	4.0	62.5	17.3	10.9	5.9
20	5.3	9.3	3.3	6.3	14.8	3.5	1.8	48.8	15.4	7.9	3.5
21	20.3	8.3	16.0	0.0	0.0	0.0	1.5	51.0	27.1	18.5	-
22	15.8	9.8	7.5	3.8	0.0	0.0	4.3	52.3	21.4	13.4	-
23	19.5	9.8	6.5	0.0	0.0	0.0	7.5	52.5	17.2	12.5	4.8
24	13.8	5.5	16.8	0.0	0.0	14.5	7.8	41.5	16.0	13.5	5.1
25	38.3	3.8	20.3	0.0	0.0	0.0	17.0	5.0	15.0	20.5	5.9
26	29.5	3.0	6.0	0.3	0.0	0.0	47.8	7.5	18.1	19.9	9.2
27	24.3	32.0	0.0	0.0	0.0	6.8	24.0	11.3	24.0	26.1	8.0
28	63.3	0.0	0.0	0.0	0.0	0.0	10.5	17.8	27.5	43.2	14.0
29	30.3	10.0	0.0	0.3	1.5	5.5	41.8	10.0	26.0	28.6	13.0
30	52.5	7.8	11.0	1.5	0.0	0.0	14.5	4.5	18.4	26.1	7.5
31	73.8	5.5	2.0	0.0	0.0	0.5	13.0	2.5	8.2	36.4	11.7
32	74.8	5.5	0.0	0.0	0.0	0.0	10.3	8.5	28.3	30.6	9.8
33	37.0	23.5	9.0	0.0	0.0	7.3	4.8	14.5	16.8	17.3	6.9
34	57.3	9.3	0.5	0.0	0.0	6.5	10.3	12.0	9.3	22.5	5.8
35	32.3	13.5	15.8	0.0	0.0	0.0	10.5	24.8	18.1	20.7	7.8
36	38.3	27.5	13.8	0.0	0.0	6.0	3.8	10.0	23.1	20.1	5.4

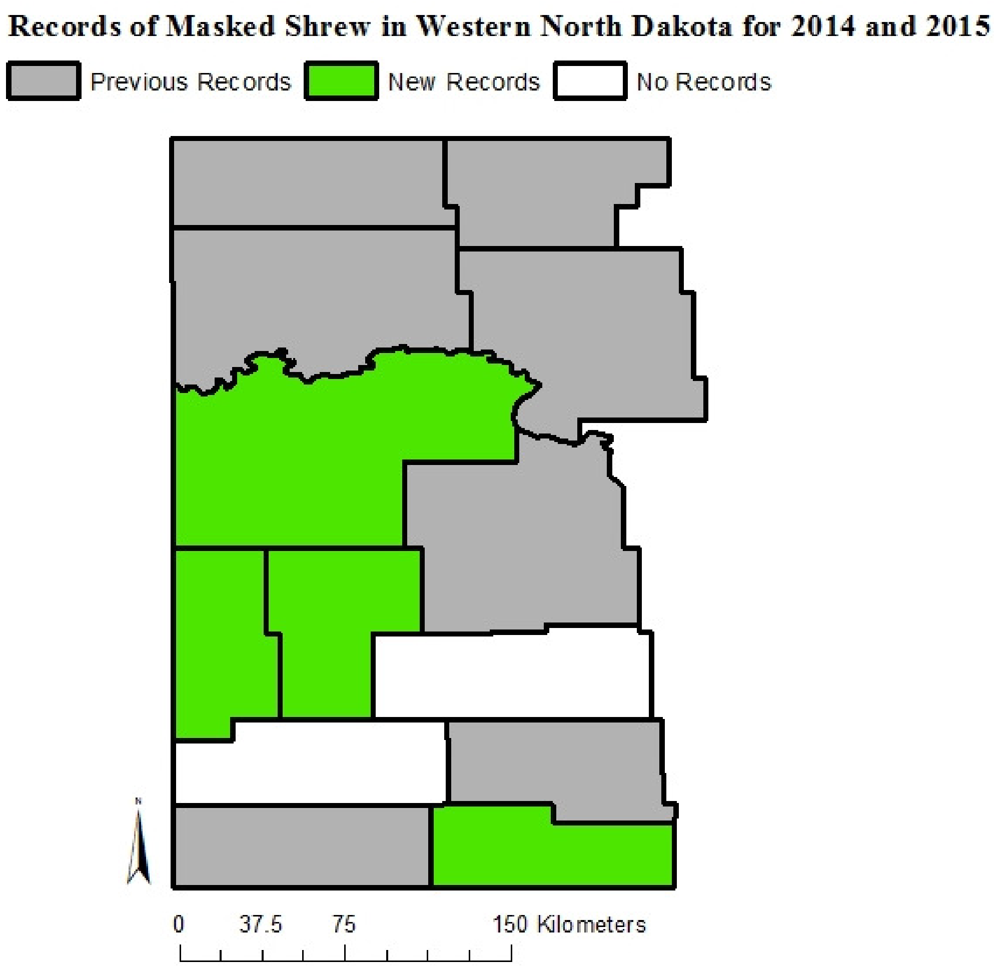
Appendix 3. Sites (in chronological order), county and nearest city, locality (latitude and longitude), habitat type (G= grassland (n=10), B= badland (n=8)), and new moon (28) and full moon (18) days trapped for 18 sites surveyed in western North Dakota in 2014.

Site Number	County/Nearest City	Locality (Latitude Longitude)	Habitat Type	New Moon Days	Full Moon Days
1	Stark/Richardton	N 46.885 W -102.283	G	0	0
2	Stark/Dickinson	N 46.852 W -102.888	G	0	0
3	Billings/Belfield	N 47.084 W -103.363	B	5	0
4	Billings/Fryburg	N 46.794 W -103.387	B	5	0
5	Slope/Amidon	N 46.494 W -103.659	G	0	0
6	Slope/Belfield	N 46.586 W -103.317	B	0	0
7	Hettinger/Regent	N 46.432 W -102.509	G	0	5
8	Hettinger/Mott	N 46.469 W -102.187	G	0	5
9	Dunn/Manning	N 47.093 W -102.794	B	0	0
10	Dunn/Marshall	N 47.200 W -102.223	G	0	0
11	Dunn/Dunn Center	N 47.490 W -102.527	B	5	0
12	Dunn/Killdeer	N 47.547 W -102.783	B	5	0
13	Bowman/Scranton	N 46.077 W -103.184	G	0	4
14	Bowman/Rhame	N 46.002 W -103.690	G	0	4
15	Golden Valley/Sentinel Butte	N 46.913 W -103.670	B	0	0
16	Golden Valley/Beach	N 47.293 W -103.752	B	0	0
17	Adams/Hettinger	N 46.173 W -102.579	G	4	0
18	Adams/Bucyrus	N 45.992 W -102.821	G	4	0

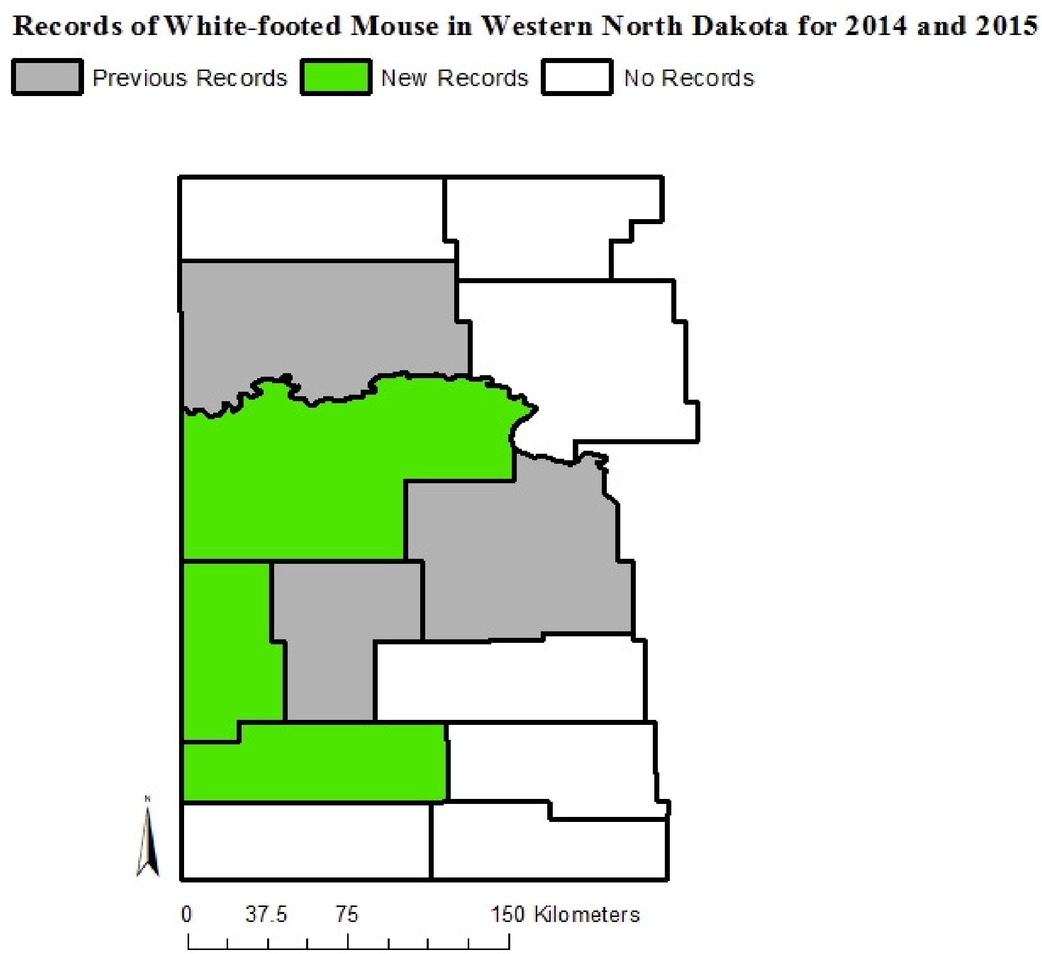
Appendix 4. Sites (in chronological order), county and nearest city, locality (latitude and longitude), habitat type (G= grassland (n=13), B= badland (n=10), P=wet meadow (n=4)), and new moon (22) and full moon (8) days trapped for 18 sites surveyed in western North Dakota in 2015.

Site Number	County/Nearest City	Locality (Latitude Longitude)	Habitat Type	New Moon Days	Full Moon Days
19	Williams/Alamo	N 48.587 W -103.230	G	2	0
20	Williams/Grenora	N 48.597 W -103.996	G	2	0
21	Divide/Fortuna	N 48.983 W -103.756	P	0	0
22	Divide/Alamo	N 48.766 W -103.549	P	0	0
23	Williams/Williston	N 48.340 W -103.807	G	0	4
24	William/Trenton	N 48.071 W -103.941	G	0	4
25	Burke/Columbus	N 48.736 W -102.745	P	0	0
26	Burke/Powers Lake	N 48.614 W -102.668	P	0	0
27	McKenzie/Williston	N 48.094 W -103.695	G	4	0
28	McKenzie/Buford	N 47.952 W -103.968	G	4	0
29	Mountrail/Tioga	N 48.428 W -102.863	G	0	0
30	Mountrail/New Town	N 47.903 W -102.426	G	0	0
31	Mountrail/Parshall	N 47.933 W -102.265	G	0	0
32	Mountrail/New Town 2	N 47.964 W -102.269	G	0	0
33	McKenzie/Alexande r	N 48.037 W -103.648	G	5	0
34	McKenzie/Watford City	N 47.809 W -103.135	G	5	0
35	McKenzie/Grassy Butte	N 47.449 W -103.488	B	0	0
36	McKenzie/Killdeer	N 47.341 W -103.130	G	0	0

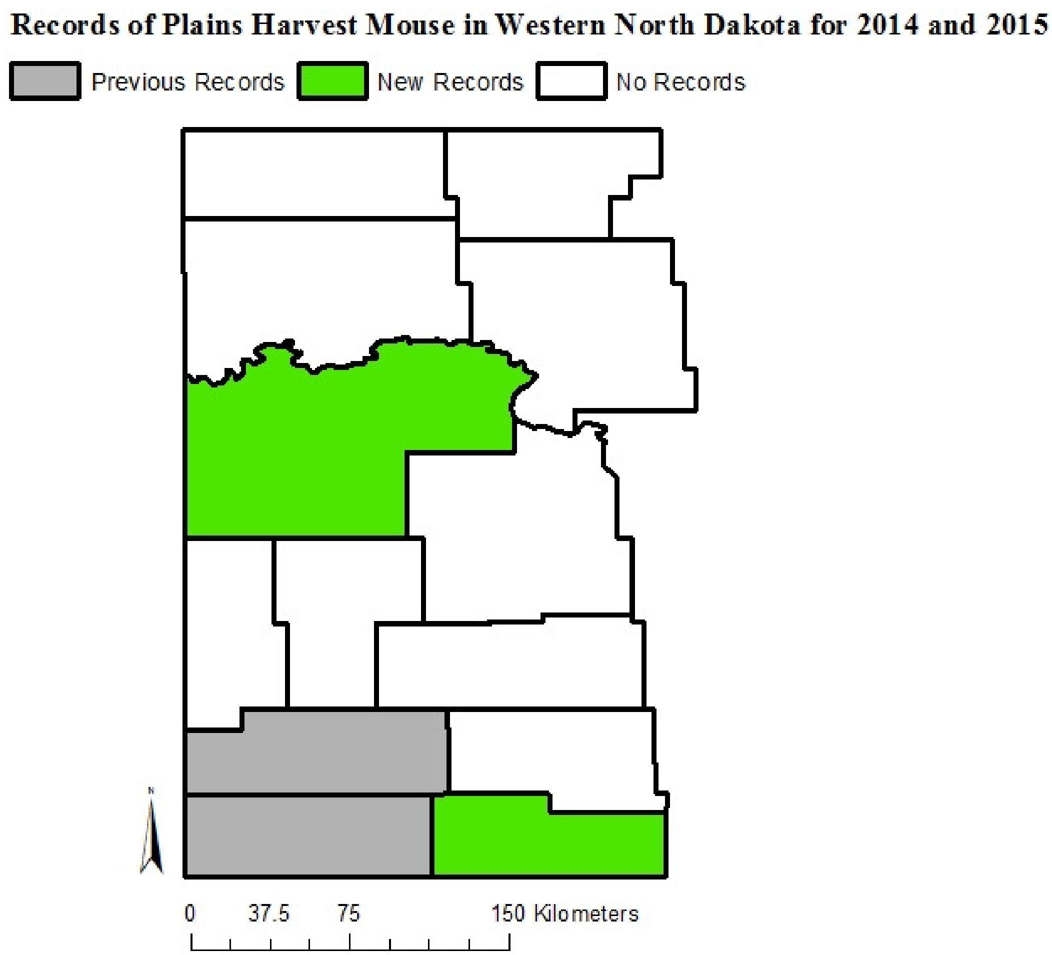
Appendix 5. New county records of masked shrew (*Sorex cinereus*) in western North Dakota for 2014 and 2015. Green indicates a new county record, gray indicates previous records, and white indicates no records of the masked shrew.



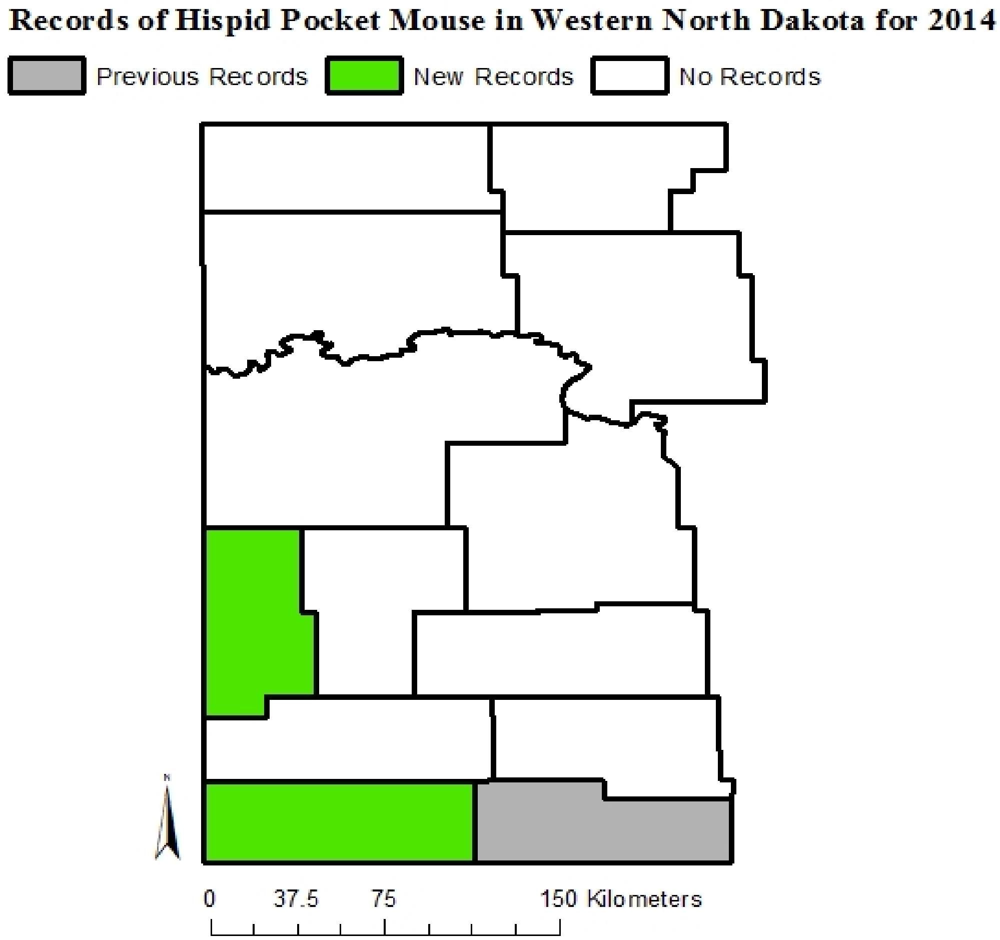
Appendix 6. New county records of white-footed mouse (*Peromyscus leucopus*) in western North Dakota for 2014 and 2015. Green indicates a new county record, gray indicates previous records, and white indicates no records of the white-footed mouse.



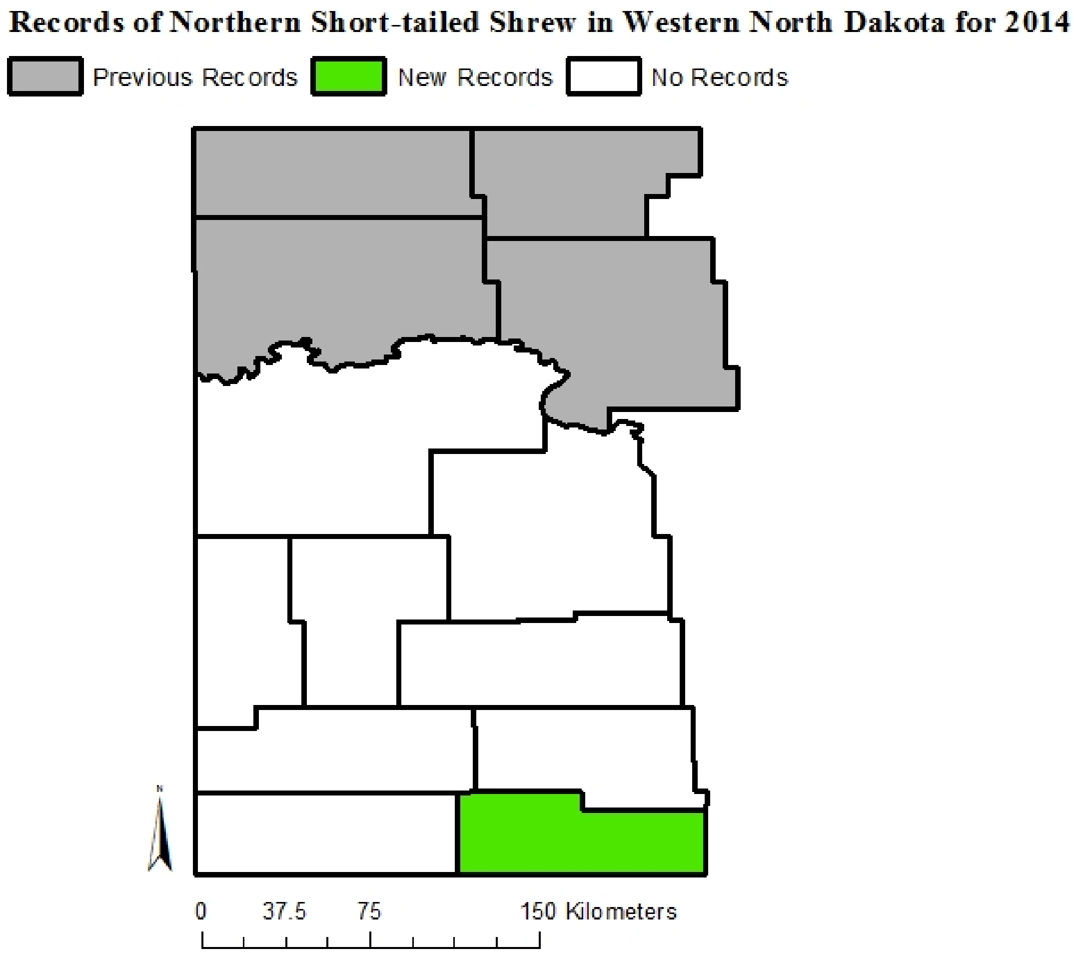
Appendix 7. New county records of plains harvest mouse (*Reithrodontomys montanus*) in western North Dakota for 2014 and 2015. Green indicates a new county record, gray indicates previous records, and white indicates no records of the plains harvest mouse.



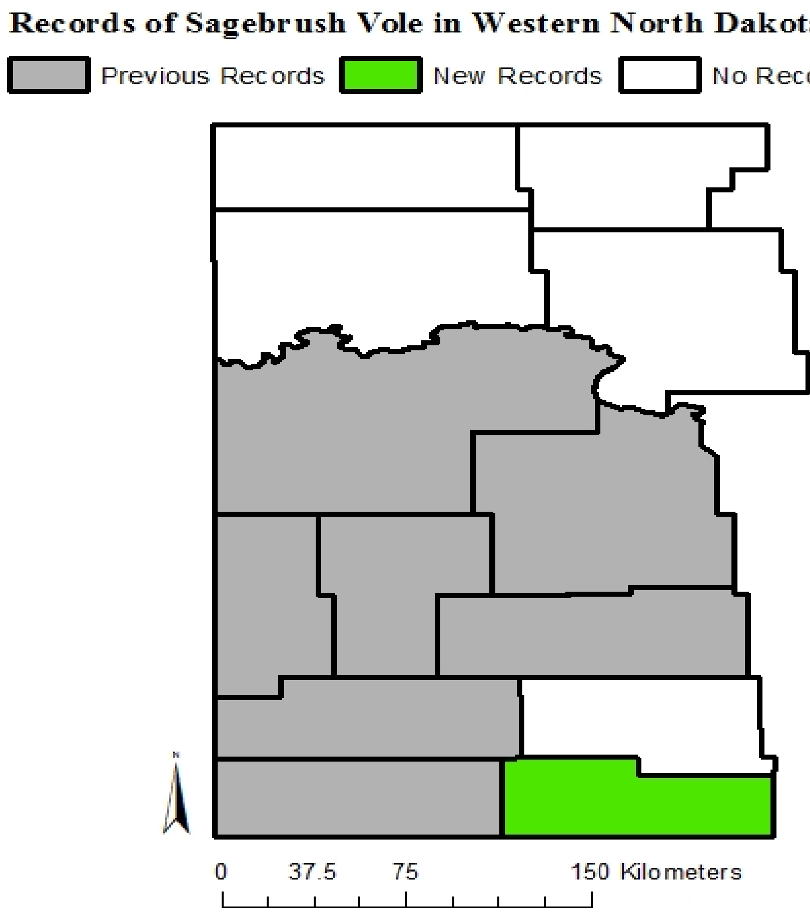
Appendix 8. New county records of hispid pocket mouse (*Chaetodipus hispidus*) in western North Dakota for 2014. Green indicates a new county record, gray indicates previous records, and white indicates no records of the hispid pocket mouse.



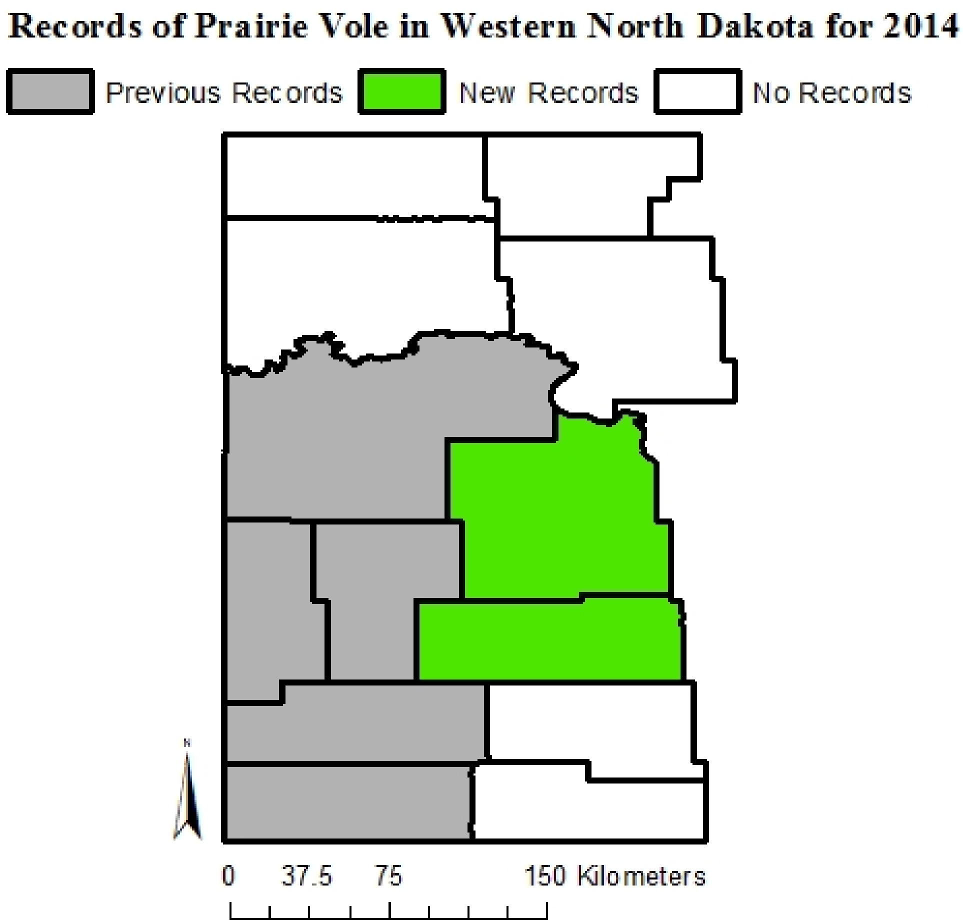
Appendix 9. New county records of northern short-tailed shrew (*Blarina brevicauda*) in western North Dakota for 2014. Green indicates a new county record, gray indicates previous records, and white indicates no records of the northern short-tailed shrew.



Appendix 10. New county records of sagebrush vole (*Lemmiscus curtatus*) in western North Dakota for 2014. Green indicates a new county record, gray indicates previous records, and white indicates no records of the sagebrush vole.

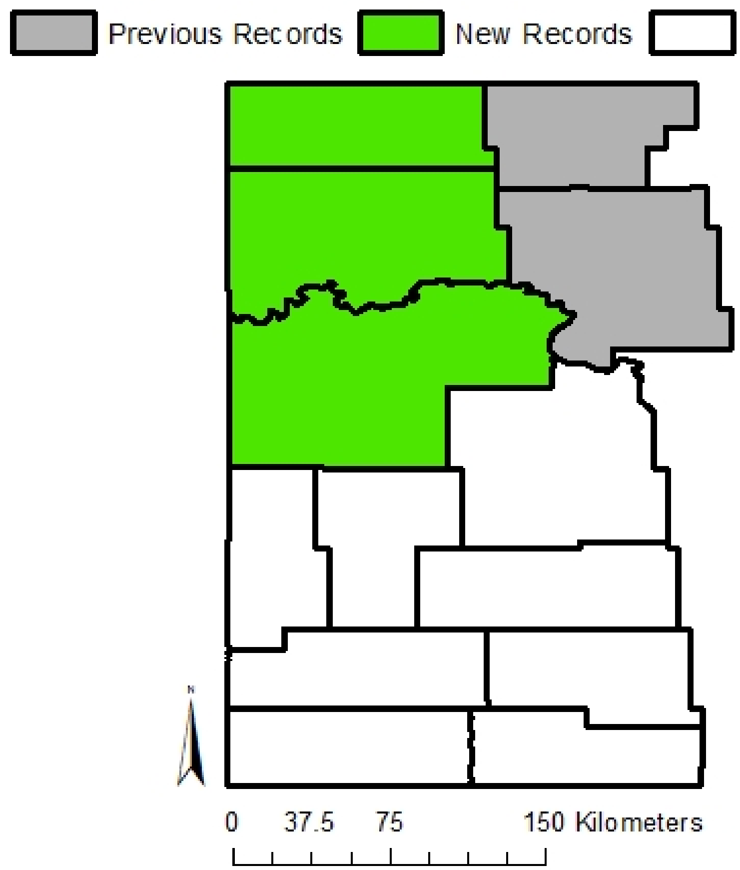


Appendix 11. New county records of prairie vole (*Microtus ochrogaster*) in western North Dakota for 2014. Green indicates a new county record, gray indicates previous records, and white indicates no records of the prairie vole.

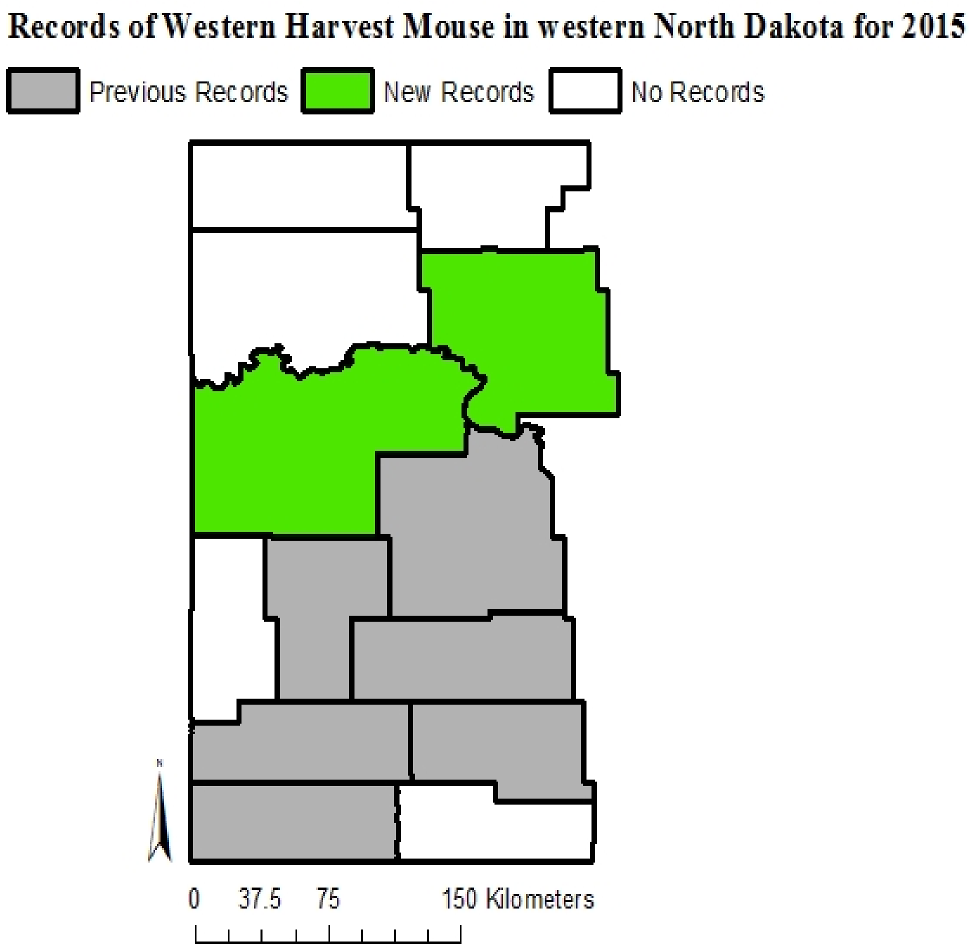


Appendix 12. New county records of arctic shrew (*Sorex arcticus*) in western North Dakota for 2015. Green indicates a new county record, gray indicates previous records, and white indicates no records of the arctic shrew.

Records of Arctic Shrew in Western North Dakota for 2015



Appendix 13. New county records of western harvest mouse (*Reithrodontomys megalotis*) in western North Dakota for 2015. Green indicates a new county record, gray indicates previous records, and white indicates no records of the western harvest mouse.



Appendix 14. New county records of pygmy shrew (*Sorex hoyi*) in western North Dakota for 2015. Green indicates a new county record, gray indicates previous records, and white indicates no records of the pygmy shrew.