NORTH DAKOTA GAME AND FISH DEPARTMENT

Final Report

Survey of 'fringe' mammals in western North Dakota.

T-39-R-1

May 1, 2013 – April 30, 2016

Terry Steinwand

Director

Submitted by Greg Link

Chief, Conservation and Communications Division

Bismarck, ND

July 2016

State Wildlife Grant Proposal – Final Report

Project Title: Survey of 'fringe' mammals in western North Dakota.

Species of Conservation Priority: Arctic shrew (*Sorex arcticus*), Merriam's shrew (*Sorex merriami*), Western small-footed myotis (*Myotis ciliolabrum*), Townsend's big-eared bat (*Corynorhinus townsendii*), Snowshoe hare (*Lepus americanus*), Desert cottontail (*Sylvilagus audubonii*), Nuttall's cottontail (*Sylvilagus nuttallii*), Hispid pocket mouse (*Chaetodipus hispidus*), Sagebrush vole (*Lemmiscus curtatus*), Northern grasshopper mouse (*Onychomys leucogaster*), Plains harvest mouse (*Reithrodontomys montanus*), Richardson's ground squirrel (*Spermophilus richardsonii*), Swift fox (*Vulpes velox*), Red fox (*Vulpes vulpes*), Lynx (*Lynx canadensis*), Bobcat (*Lynx rufus*), River otter (*Lontra canadensis*), Long-tailed weasel (*Mustela frenata*), Black-footed ferret (*Mustela nigripes*), Least weasel (*Mustela nivalis*), Mink (*Mustela vison*), Eastern spotted skunk (*Spilogale putorius*).

Contact Information:

Michael Shaughnessy
Associate Professor of Biology
Department of Natural Sciences
Northeastern State University
Tahlequah, OK 74464
918 444 3823
918 458 9693 (FAX)
shaughnm@nsuok.edu

Activity Period: May 1, 2014 – April 30, 2016

Location: Counties of western North Dakota, including: Divide, Williams, McKenzie, Golden Valley, Billings, Slope, Bowman, Adams, Hettinger, Stark, Dunn, Mountrail and Burke.

Need: Recent work conducted on prairie dog towns in western North Dakota indicates that data for mammal occurrence and distributions are critically lacking (Shaughnessy and Woodman, 2015). The status of 22 western North Dakota mammal species is presently unknown or incomplete (Seabloom, 2011). A search of museum records (MANiS) demonstrates that, among these 22 species, most recent voucher specimens were collected from North Dakota no later than 1970 (*Sylvilagus audubonii*). Nine of 22 species have not been collected in North Dakota since 1950 and ten of the species are represented by three or fewer specimens. We describe these mammals as 'fringe' mammals; mammals which are known or suspected to occur in North Dakota, but for which little information or recent records are available.

The Dickinson State University Natural History Collection presently holds new county voucher specimens for seven species of mammals in western North Dakota. Two new *Sorex merriami* specimens represent the first specimens to be collected since 1913 and only the second and third specimens collected from North Dakota. Still, little is known about *S. merriami*'s status, habitat affinities or associations with other mammals in North Dakota (Seabloom, 2011). This pattern is true for many of the other twenty-one species of North Dakota 'fringe' mammals.

To understand the habitat associations between the 'fringe' mammals of western North Dakota, a more complete study of plant species diversity and distribution is required. Furthermore, the relationship between plant biodiversity and mammal biodiversity in western North Dakota lacks resolution.

A number of North Dakota 'fringe' mammals are thought to be associated with specific plants and plant assemblages (Seabloom, 2011). For example, Townsend's big-eared bat (*Corynorhinus townsendii*) is considered to be affiliated with cottonwood/willow bottomlands (Seabloom, 2011). This affiliation is based upon locality data for only seven specimens, all female, captured in North Dakota during 2009. This habitat description does not completely agree with the general habitat description for *C. townsendii* from Kunz and Martin (1982), which describes the habitat of *C. townsendii* as common in highland areas and evergreen forests. Clarification of these types of associations between plants and mammals in western North Dakota is vital towards understanding the ecology of the region.

Almost half (9 of 22) of the 'fringe mammals' in North Dakota are small mammals. Small mammals are particularly sensitive to environmental change and disturbance (Horncastle et al., 2005; Carey and Wilson, 2001). Consequently, recent energy exploration and extraction in western North Dakota may impose significant disturbance upon the native habitats of North Dakota mammals. The current cycle of energy development in the western third of North Dakota also presents new land management demands and challenges. Complete distribution and occurrence data for western North Dakota mammals are essential for effective habitat management. As the energy industry expands and matures, management of North Dakota's natural history and resources may require new management practices. Without baseline data for non-game species such as small mammals, it will not be possible to predict the effects of energy development on the native communities in the western North Dakota ecosystem or prescribe alternative management strategies.

Objectives:

1. Establish baseline survey data for western North Dakota 'fringe' mammal species that are historically underrepresented in natural history collections.
2. Determine current status and range limits of western North Dakota 'fringe' mammals.
3. Identify the vegetation associations and habitat parameters of North Dakota 'fringe' mammals detected during surveys.
4. Produce updated range distribution maps for North Dakota 'fringe' mammals detected during surveys.

Summary: All field work associated with the project has been completed. Over two field seasons (2014 and 2015), 13 western North Dakota counties were sampled using 36 total Y-shaped pitfall arrays and associated snap traps, 36 carnivore tracking plates and 14 passive acoustic monitoring events (2015 only) (Appendix A, Figure 1). This resulted in a total trapping effort of 18000 total trap nights for small mammals, 180 tracking plate nights and 70 acoustic monitoring nights for bats. This effort resulted in the capture of 1105 small mammal specimens representing 14 genera and 19 species.

We established a single carnivore tracking plate baited with a fatty-acid scent disk at each pitfall array, along with a motion-triggered camera. We recorded multiple visits from white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) at the tracking stations, and a single carnivore species (*Procyon lotor*) in 2014.

Bats were passively monitored at each site during the second field season using a Petterson D500X passive ultrasound recording system. Monitoring resulted in 1697 individual .wav files. When analyzed using the classification software Sonobat 3.2.2, 17 bat detections representing 3 general and 4 species were identified.

Progress to Date: The first field season began on 20 May 2014 in Stark County. Once started, small mammal surveys were conducted continuously from 20 May 2014 through 28 June 2014. During this time, five counties were surveyed (Stark, Billings, Slope, Hettinger and Dunn) with 12 pitfall arrays and 12 established tracking plates. These effort resulted in 600 trap nights and 60 tracking nights which produced 520 small mammal captures and a single carnivore at the tracking plates.

During the week of 30 June to 4 July 2014, intensive vegetation analyses were conducted at the sites previously sampled. From 8 July 2014 until 28 July 2014, vegetation analyses were conducted in conjunction with animal sampling. NDVI, Robel pole, and densitometer measurements were taken at a distance of four meters from each snap trap station in each major cardinal direction. This effort resulted in 2,160 measurements of NDVI, visual obstruction, and overhead cover. Nine randomly located sets of nested quadrats were used per pitfall array to determine plant frequency and species richness. Ten Daubenmire plots per location were used to estimate ground cover and calculate biodiversity indexes. A total of 232 plant voucher specimens were collected during season to better document plant biodiversity at each location and provide evidence of plant identification quality.

Small mammal and carnivore sampling resumed on 8 July 2014 and continued uninterrupted until 28 July 2014. During this period, another three counties were surveyed (Bowman, Golden Valley and Adams) with six pitfall arrays and 6 established tracking plates. These efforts resulted in an additional 300 trap nights, 30 tracking nights and another 191 small mammal captures.

A total of 708 small mammals were collected during the 2014 field season (Table 1). This equates to a trapping success rate (# captures/effort) of 79%. Small mammals captured during the project represented two Orders (Rodentia and Soricomorpha), 7 Families, 14 genera and 17 species. All specimen identifications have been confirmed and they are in the process of being catalogued in the Northeastern State University Museum collection. Two species of soricomorphs were collected during the trapping sessions: *Blarina brevicauda* and *Sorex haydeni*. We also collected three of the five species of rodents from our target list (*Lemmiscus*, *Reithrodontomys montanus* and *Cheatodipus*).

Two specimens of sagebrush vole (*Lemmiscus curtatus*) were collected in Adams Co. and Bowman Co. ND. The specimen from Adams Co. represents a range extension east for this species in North Dakota (Appendix A, Figure 2). An additional 8 new county records were identified from the 2014 sampling session. New county records for *Peromyscus leucopus* were

recorded for Slope Co. (3 specimens) and Golden Valley Co. (2 specimens)(Appendix A, Figure 3). New records for *Sorex haydeni* were recorded for Billings Co. (1 specimen), Hettinger Co. (5 specimens), Golden Valley Co. (1 specimen) and Adams Co. (11 specimens). A new specimen of *Reithrodonotmys montanus* was collected from Adams Co. (Appendix A, Figure 4). Finally, new county records for *Cheatodipus hispidus* were recorded for Bowman Co. (1 specimen) and Golden Valley Co. (1 specimen)(Appendix A, Figure 5).

The second field season began on 19 May 2015 in Williams County. Once started, small mammal surveys were conducted continuously from 19 May 2015 through 27 July 2015. During this time, five counties were surveyed (Williams, Divide, Burke, McKenzie and Mountrail) with 12 pitfall arrays, 12 established tracking plates with motion-triggered cameras. The passive ultrasound recording system was deployed at 10 of these 12 sites, missing only the first pair of sites in Williams County. These effort resulted in 600 trap nights and 60 tracking nights which produced 112 small mammal captures and approximately 90 hours of acoustic monitoring.

During the week of 29 June to 4 July 2015, intensive vegetation analyses were conducted at the sites previously sampled for mammals except for the sites in Divide County. We were unable to regain entry to the state school lands in Divide County. From 7 July 2015 until 28 July 2015, vegetation analyses were conducted in conjunction with animal sampling. NDVI, Robel pole, and densitometer measurements were taken at a distance of four meters from each snap trap in each major cardinal direction. The cumulative effort resulted in 4,084 measurements of NDVI, visual obstruction, and overhead cover. Nine randomly located sets of nested quadrats were used per pitfall array to determine plant frequency and species richness. Ten Daubenmire plots per location were used to estimate ground cover and calculate biodiversity indexes. The voucher specimens are being processed at the Dickinson State University Herbarium, and collection information can be found on the Consortium of Northern Great Plains Herbaria web portal. The plant specimen information from project is available on the Consortium of Northern Great Plains Herbaria web portal. Approximately, 5,500 plant species determinations were made and 270 unique plant species were collectively found at the trapping arrays.

Small mammal and carnivore sampling resumed on 7 July 2015 and continued uninterrupted until 25 July 2015. During this period, McKenzie and Mountrail counties were sampled with six pitfall arrays and 6 established tracking plates. These efforts resulted in an additional 300 trap nights, 30 tracking nights and another 285 small mammal captures. The passive ultrasound recording system was deployed at 4 of these 6 sites resulting in an additional 36 hours of acoustic monitoring.

A total of 397 small mammals were collected over the course of this part of the project (Table 1). This equates to a trapping success rate (# captures/effort) of 44.11%. Small mammals captured during this field season represented two Orders (Rodentia and Soricomorpha), 6 Families, 11 genera and 16 species.

Four species of soricomorphs were collected during the 2015 trapping sessions: *Blarina brevicauda*, *Sorex haydeni*, *S. hoyi* and *S. arcticus*. Five specimens of *S. arcticus* were captured during the 2015 season. *Sorex arcticus* is one of the target species identified by the project and

representative specimens were collected from three of the five counties in the 2015 trapping season. Captures of *Sorex arcticus* in Divide (1 specimen) and Williams Co. (1 specimen) are new county records for North Dakota (Appendix A, Figure 6). A single specimen of *Sorex hoyi* was captured in Mountrail Co. This represents a new county record for the species in North Dakota as well as a significant westward range extension within the state (Appendix A, Figure 7). Additionally, new county records for *Blarina brevicauda* and *Sorex haydeni* were also captured. *B. brevicauda* were captured in Adams Co. (1 specimen) and *S. haydeni* were captured in McKenzie Co. (49 specimens)(Appendix A, Figure 8). New records of *S. haydeni* are not surprising. *Sorex haydeni* is the most common shrew in North Dakota and has the most extensive distribution in North America (Seabloom, 2011). New records of *S. haydeni* collected during this project do not represent range extensions or expansion of the species into new habitats but instead simple reflect a lack of past sampling effort for small mammals in western North Dakota.

Three specimens of western harvest mouse (*Reithrodontomys megalotis*) were captured during the 2015 field season from McKenzie Co and Mountrail Co. These specimens represent new county records (Appendix A, Figure 9). A single specimen of *R. montanus* was collected from McKenzie Co. as well. It also represents a new county record (Appendix A, Figure 4). This specimen extends the known range of *R. montanus* in North Dakota significantly to the north.

Interesting trends are immediately apparent in the small mammal data. First is the lack of grasshopper mice (*Onychomys leucogaster*) captured during the study. Previous sampling of small mammals in western North Dakota in conjunction with black-tailed prairie dog (*Cynomys ludovicianus*) surveys produced specimens of *O. leucogaster* in Billings Co. and Bowman Co. (Shaughnessy, pers. data). These sites were located on active prairie dog colonies. The association between black-tailed prairie dogs and grasshopper mice has been documented (Stapp et al. 2009, Stapp and Salkeld 2009, Salkeld and Stapp 2009, Stapp 2007). In addition, it has been suggested that grasshopper mice are the mammal reservoir for plague (*Y. pestis*) in black-tailed prairie dog colonies, as grasshopper mice are the primary host for the plague carrying flea (*Oropsylla hirsuta*)(Stapp et al. 2009, Salkeld and Stapp 2008). The absence of grasshopper mice away from black-tailed prairie dog colonies over the course of this study supports the connection between the two species. Further examination of this trend could provide greater insight into the dynamics of black-tailed prairie dogs, their rodent associates and the frequency and prevalence of plague outbreaks.

The capture data for the meadow jumping mouse, *Zapus hudsonius*, is also of interest. Meadow jumping mice were the fourth most abundant small mammal captured during the study and the third most abundant rodent (Table 1). The distribution of the meadow jumping mouse was not uniform across western North Dakota. Hierarchical cluster analysis of the small mammals caught suggest that *Z. hudsonius* was the dominant small mammal species at sites where the overall floristic quality is low and smooth brome grass, crested wheat grass, western snowberry and American ash are the dominant plant species. Where it was captured, it was most often captured in abundance (Mountrail Co., Divide Co., McKenzie Co.). Further analyses of the correlations between *Z. hudsonius*, habitat and other captured species are necessary before forming conclusions.

Small mammal biodiversity was found to be weakly but significantly associated with the number of grass species (Appendix B, Figure 1) and the number of captures at a location was also weakly but significantly correlated with the number of plant species present. (Appendix B, Figure 2). Greater plant biodiversity may support more small mammals due to the formation of greater microhabitat variation. Mammal abundance is also highest when the vertical cover is moderately high (Appendix B, Figure 3). As vertical cover increased, grass species also diversity decreased (Appendix B, Figure 4). Low vertical cover may not provide enough protection for small mammals against predators. Whereas high vertical cover may hinder the growth of shade intolerant grass species that contributes to greater mammal populations and diversity.

All captured specimens have been processed as skins and skulls, full skeletons, alcoholics or skulls only. Specimens are in the process of being catalogued in the Northeastern State Vertebrate Museum. The Sternberg Museum of Natural History at Fort Hays State University maintains an extensive collection of alcoholic specimens. Alcoholic specimens from the project are being installed and maintained at SMNH. Tissue samples were collected from many of the specimens as well. These are being maintained in the Sternberg Museum of Natural History tissue collection.

Shannon Diversity Indices were computed for all counties sampled both years of the project. Highest diversity is observed in Adams County and McKenzie County (Table 2). In general, small mammal species diversity appears to peak in the south and far western regions of the state. There are also two counties with particularly low species diversity: Stark Co. and Divide Co. The pattern and distribution of the diversity indices for the counties is interesting and suggests some trends however, further examination of these data are required before conclusions can be made.

The trapping protocol proved to be extremely efficient in harvesting insects again. During the process of closing the traps, each pitfall was drained and filtered. The accumulated insects were preserved in ethanol and labeled according to the location of their capture. Insects will be transported to the Northeastern State University Vertebrate Museum for sorting, counting and identification.

Bats were sampled during the 2015 field season using a Petterson 500DX passive acoustic monitoring system. The monitoring equipment consists of a weather-proof digital recording unit and an ultrasonic microphone sensitive to bat echolocation calls mounted and elevated on a 15 foot pole. The unit was operated overnight on clear nights at 14 of the 18 field sites, from sundown to sunrise. Four of the five counties in the second field season were monitored for bat activity. Only Williams County, at the start of the field season, was missed due to logistic and technical issues related to learning how to operate the monitor.

Ninety hours of bat echolocation monitoring produced 1697 individual .wav files. These files were analyzed using Sonobat 3.2.2 software specific to the bat species assemblages present in the western North Dakota region. Seventeen bat echolocation calls were identified by the Sonobat 3.2.2 software representing 3 genera and 4 species. The most commonly detected bat

was the Hoary bat, *Lasiurus cinereus* (11 detections: Williams Co., Mountrail Co., McKenzie Co.). Also detected were Silver-haired bats (*Lasionycterus noctivagans* – 2 detections; Williams Co., McKenzie Co.), Red bats (*Lasiurus borealis* – 2 detections; Mountrail Co., McKenzie Co.) and Brazilian free-tailed bats (*Tadarida brasiliensis* – 2 detections; McKenzie Co.).

Three of the four bat species detected are considered 'tree' bats, meaning that they roost in the open, hanging on the branches of trees (Seabloom, 2011). Only the Brazilian free-tailed bat is a cave dwelling bat. Western North Dakota habitats are dominated by open spaces and grasslands. Trees do persist along riparian corridors and as occasional, isolated 'islands'. Given the relative frequency in this study of tree bats in our limited sample, the role of these isolated and sometimes widely dispersed tree habitats in the bat communities of western North Dakota may warrant further investigation.

Tasks Completed from May 2014 to April 2016

- Conducted small mammal and predator sampling surveys in 13 western North Dakota counties.
- Operated 36 small mammal pitfall arrays, collecting 1105 total small mammals.
- Established 36 carnivore tracking stations.
- Passively monitored bat echolocation calls at 14 sites in 5 western North Dakota counties.
- Recorded 1697 individual .wav files during bat monitoring activity.
- Analyzed 1697 .wav files collected during bat monitoring activities – identify and classify bat echolocation data.
- Identified 17 individual bats in 4 species.
- Computed diversity indices for small mammals in sampled counties.
- Completed verification of unknown/uncertain specimens
- Collected insects from pitfall arrays sampled for small mammals
- Continued sorting, counting and identifying insect specimens.
- Measured NDVI, visual obstruction, and overhead cover at each snap trap location.
- Inventoried plant species diversity at each pitfall array.
- Clean, catalogue and install mammal specimens in the Northeastern State University Vertebrate Museum.
- Ongoing analyses of small mammal and vegetation data in order to identify trends in diversity and associations with vegetation.
- Produced updated range distribution maps for North Dakota 'fringe' mammals detected during surveys.
- Completed the final project report, June 2016.

Other Activities Associated with this Project

- One graduate student research assistant at Fort Hays State University has been trained and led both summer field projects.
- One graduate student research assistant has successfully defended her thesis at Fort Hays State University.

- Undergraduate poster presentation entitled, "Determination of unknown *Sorex* species from western North Dakota using cranial morphometric analysis." – given at Oklahoma Research Day, 13 March 2016.
- Three undergraduate field assistants have been trained in survey and capture techniques for small mammals and vegetation surveying through this project.
- Three undergraduate field assistants and one graduate assistant have been supported over one summer through this project.
- Three undergraduate museum assistants have been trained in curatorial techniques.
- One undergraduate museum assistant has been supported over the academic year through this project.
- Small mammal holdings of the NSU Vertebrate Museum have been increased by 1105 specimens.
- Insect holdings of the NSU Vertebrate Museum have been increased.
- Small mammal alcohol preserved specimen holdings of the Sternberg Museum at Fort Hays State University have been increased.
- Tissue samples of small mammals collected during the project have been cataloged and stored at the Sternberg Museum at Fort Hays State University.

Table 1 – Total numbers of small mammals collected in 8 western North Dakota counties during the small mammal sampling sessions.

Genus	species	2014	2015	Total
Blarina	*brevicauda*	1	2	**3**
Sorex	*arcticus*	0	5	**5**
Sorex	*haydeni/cinereus*	36	82	**118**
Sorex	*hoyi*	0	1	**1**
Ictidomys	*tridecemlineatus*	16	11	**27**
Tamias	*minimus*	2	3	**5**
Thomomys	*talpoides*	3	1	**4**
Chaetodipus	*hispidus*	6	0	**6**
Perognathus	*fasciatus*	2	7	**9**
Zapus	*hudsonius*	26	55	**81**
Lemmiscus	*curtatus*	2	0	**2**
Microtus	*ochrogaster*	14	0	**14**
Microtus	*pennsylvanicus*	339	67	**406**
Myodes	*gapperi*	5	1	**6**
Peromyscus	*leucopus*	26	17	**43**
Peromyscus	*maniculatus*	226	141	**367**
Reithrodontomys	*megalotis*	1	3	**4**
Reithrodontomys	*montanus*	2	1	**3**
Mus	*musculus*	1	0	**1**
	Total	**708**	**397**	**1105**

Table 2 – Shannon Diversity Indices for small mammals by county in western North Dakota.

County	# sampling arrays	# species captured	SDI
Divide County	2	4	.8572
Williams County	4	5	1.3595
Burke County	2	4	.9904
McKenzie County	6	11	1.7251
Mountrail County	4	8	1.3086
Stark County	2	6	.7923
Billings County	2	6	1.1439
Slope County	2	4	.9739
Hettinger County	2	5	1.4343
Dunn County	4	8	1.0568
Bowman County	2	7	1.1515
Golden Valley County	2	10	1.0897
Adams County	2	11	2.0021
Totals	36	20	

Literature Cited

Salkeld, D.J. and P. Stapp. 2008. Prevalence and abundance of fleas in Black-tailed prairie dog burrows: Implications for the transmission of plague (*Yersinia pestis*). Journal of Parasitology 94:616-621.

Salkeld, D.J. and P. Stapp. 2009. Effects of weather and plague-induced die-offs of prairie dogs on the fleas of Northern Grasshopper mice. Journal of Medical Entomology 46:588-594.

Seabloom, R. 2011. Mammals of North Dakota. North Dakota Institute for Regional Studies, North Dakota State University, Fargo, ND. 461pp.

Shaughnessy, M.J.Jr. and N. Woodman. 2015. New records of Merriam's shrew (*Sorex merriami*) from western North Dakota. Checklist 11(3): 1623.

Stapp, P. 2007. Rodent communities in active and inactive colonies of Black-tailed prairie dogs in shortgrass steppe. Journal of Mammalogy 88:241-249.

Stapp, P. and D.J. Salkeld. 2009. Inferring host-parasite relationships using stable isotopes: implications for disease transmission and host specificity. Ecology 90:3268-3273.

Stapp, P., D.J. Salkeld, H.A. Franklin, J.P. Kraft, D.W. Tripp, M.F. Antolin and K.L. Gage. 2009. Evidence for the involvement of an alternate rodent host in the dynamics of introduced plague in prairie dogs. Journal of Animal Ecology, 78:807-817.

Appendix A

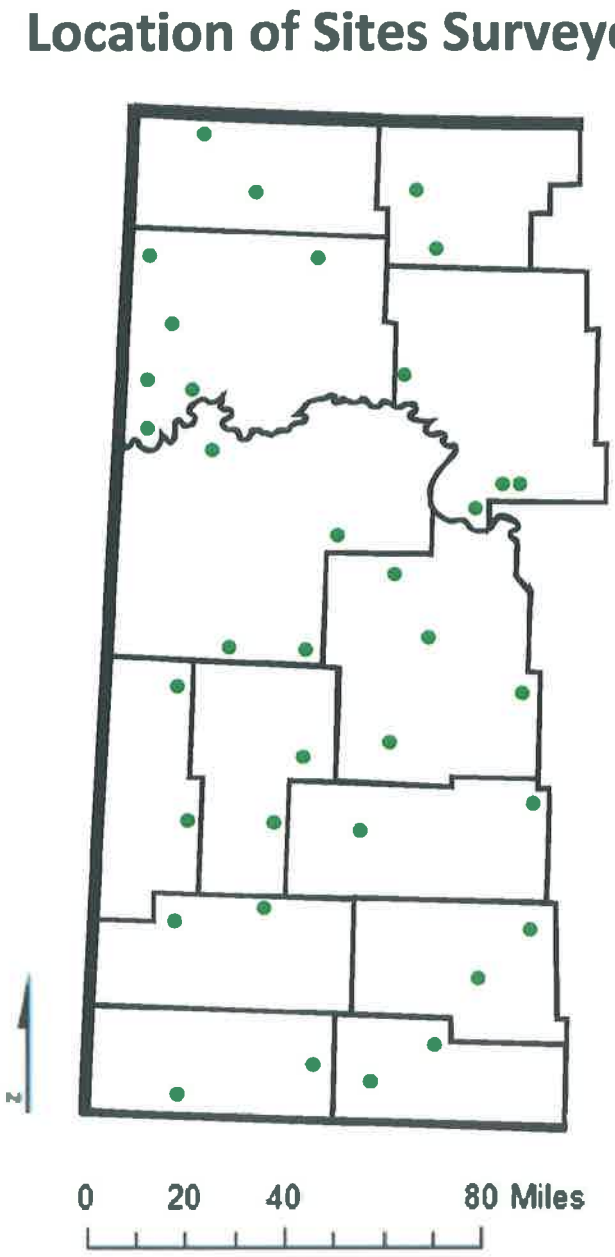

Figure 1: Locations of sites surveyed during the summers of 2014 and 2015.

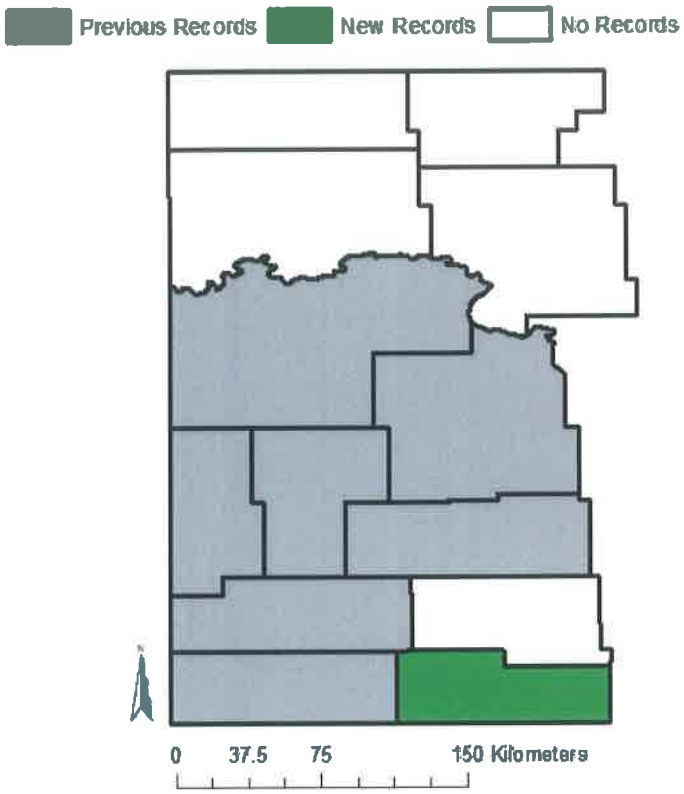

Figure 2: Records of Sagebrush Vole (*Lemmiscus curtatus*) in Western North Dakota.

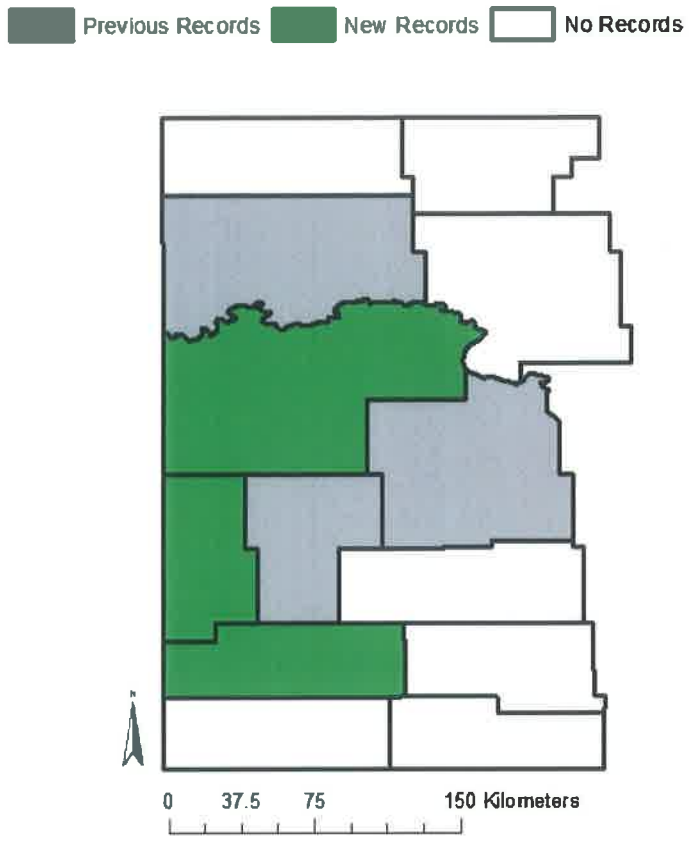

Figure 3: Records of the white-footed mouse (*Peromyscus leucopus*) in Western North Dakota.

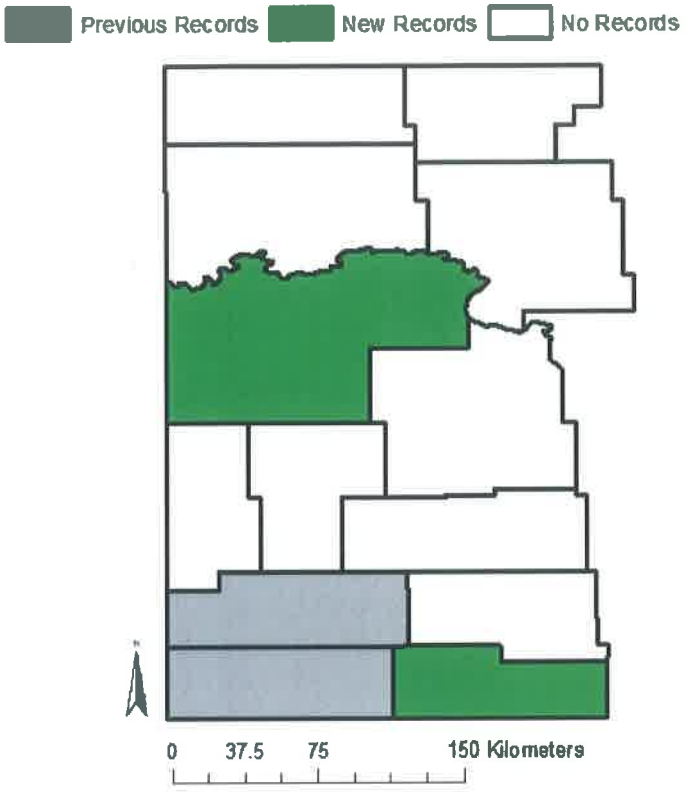

Figure 4: Records of the plains harvest mouse (*Reithrodonotmys montanus*) in Western North Dakota.

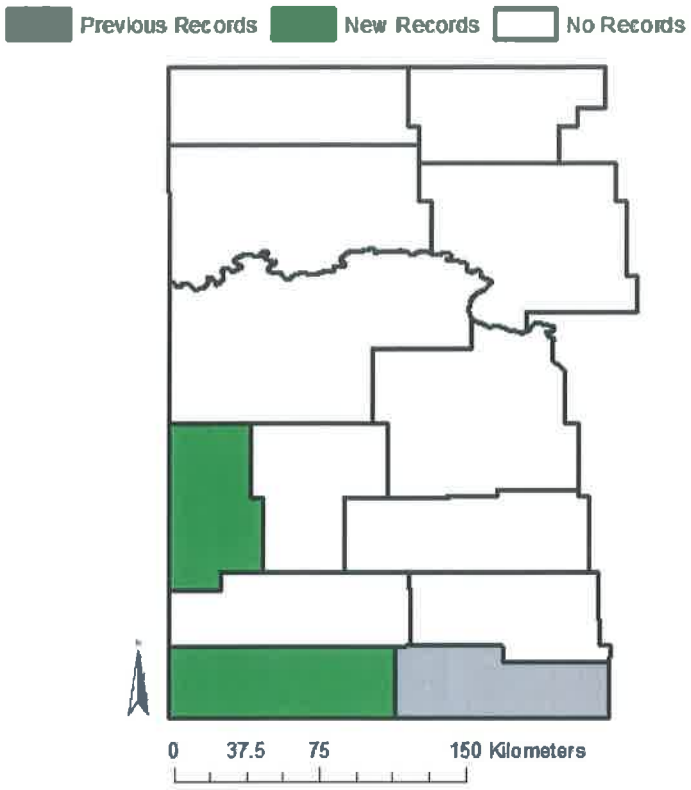

Figure 5: Records of the hispid pocket mouse (*Cheatodipus hispidus*) in Western North Dakota.

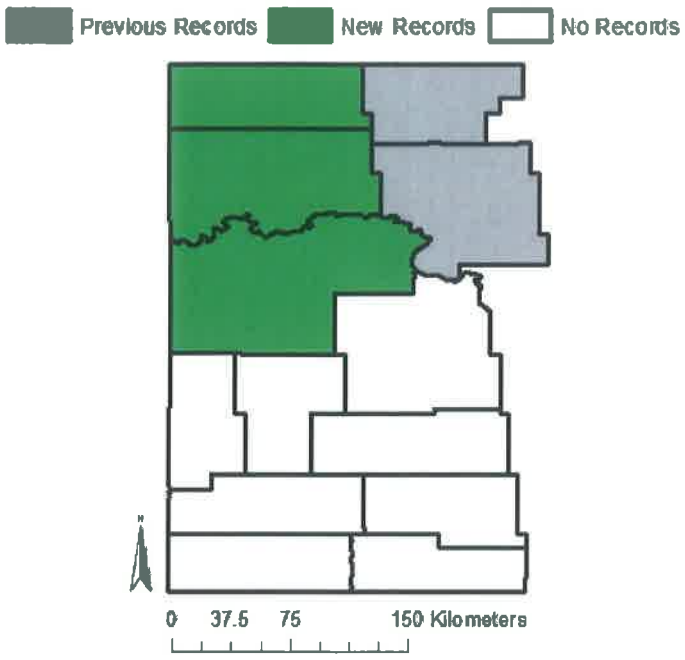

Figure 6: Records of the arctic shrew (*Sorex arcticus*) in Western North Dakota.

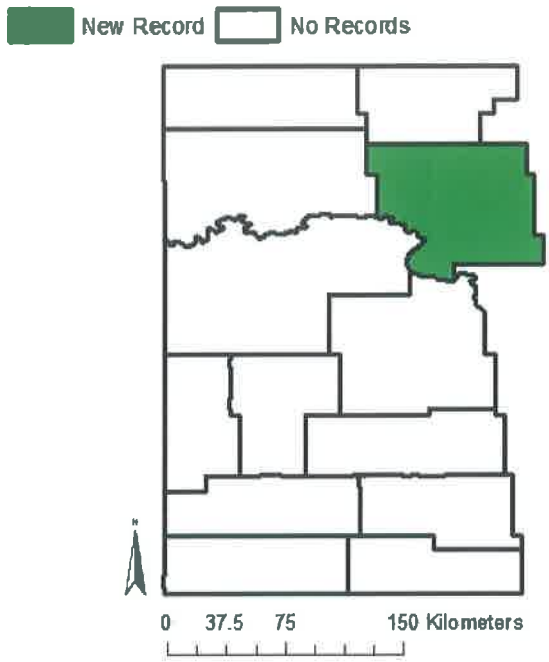

Figure 7: Record of the pygmy shrew (*Sorex hoyi*) in Western North Dakota.

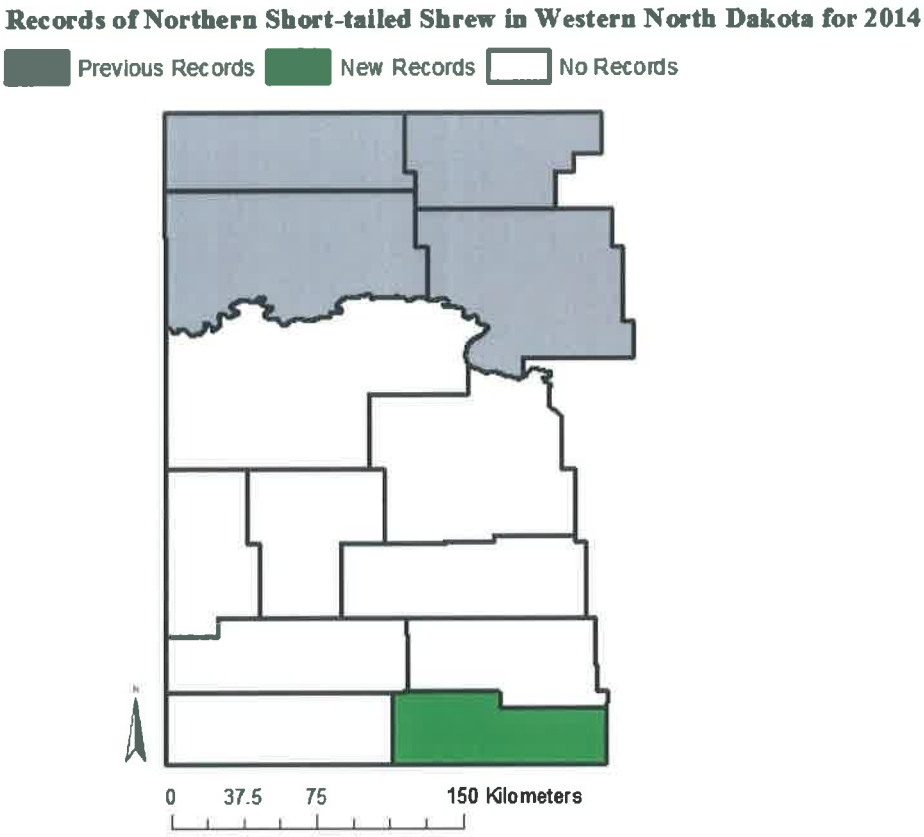

Figure 8: Records of the short-tailed shrew (*Blarina brevicauda*) in Western North Dakota.

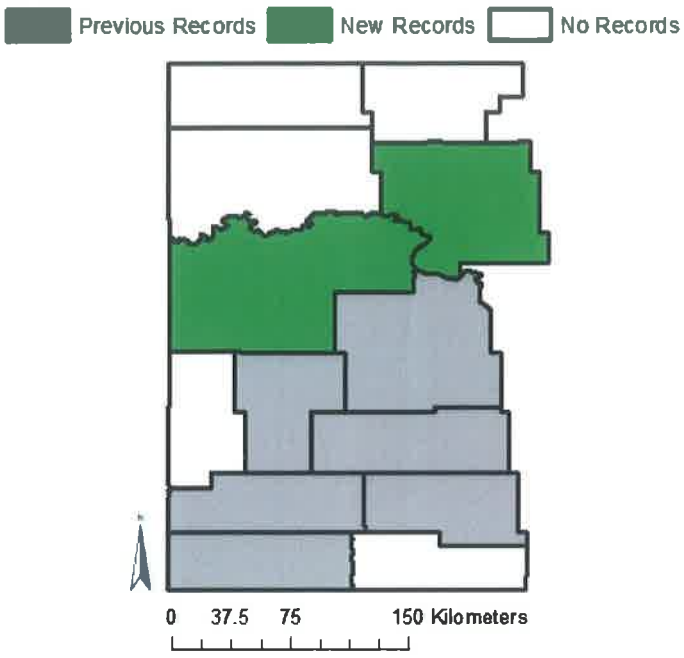

Figure 9: Records of the western harvest mouse (*Reithrodontomys megalotis*) in Western North Dakota.

Appendix B

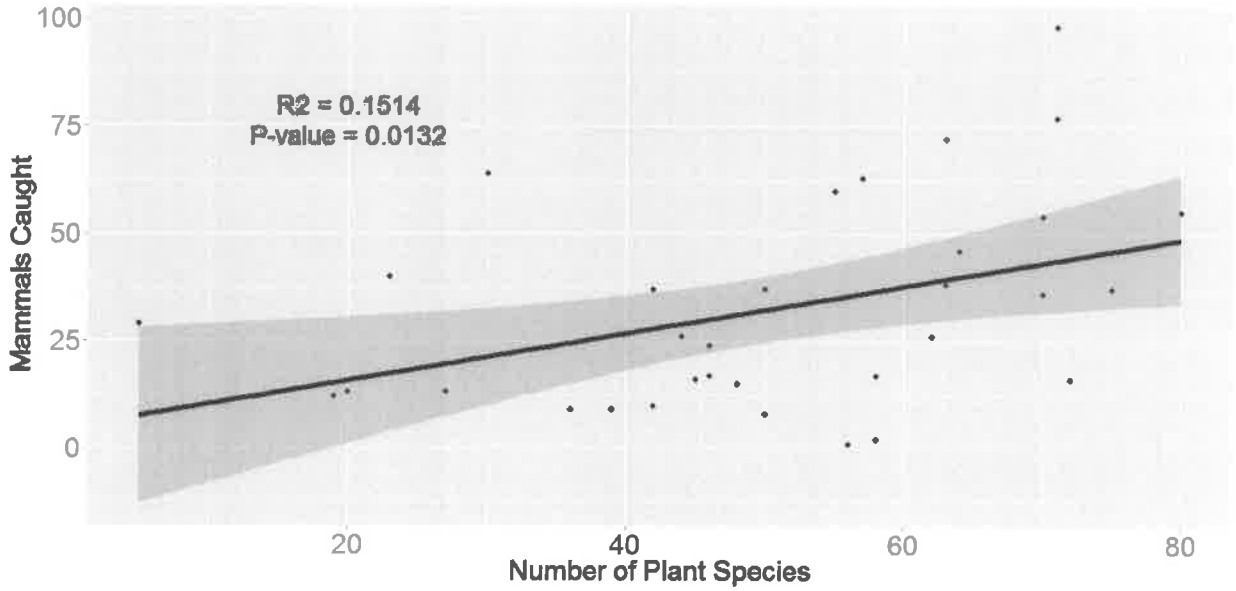

Figure 1: The relationship between plant species diversity and number of small mammal captures. Darker grey areas represent 95% confidence interval.

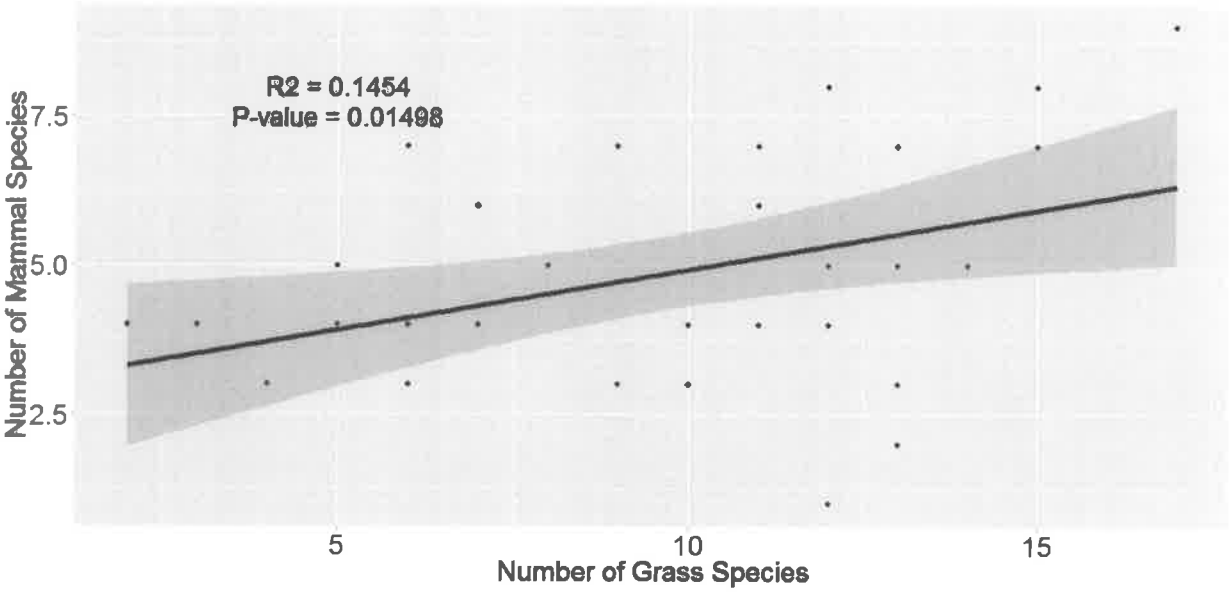

Figure 2: The relationship between grass species diversity and small mammal species diversity. Darker grey areas represent 95% confidence interval.

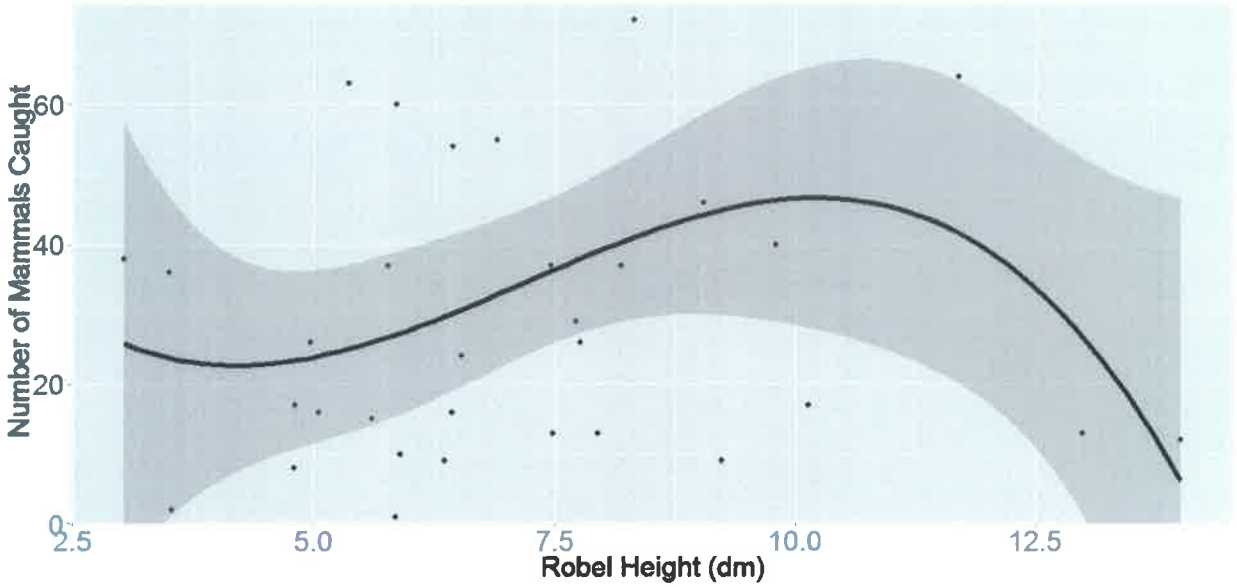

Figure 3: The relationship between vertical plant cover as measured by a Robel Pole and number of small mammal captures. Darker grey areas represent 95% confidence interval.

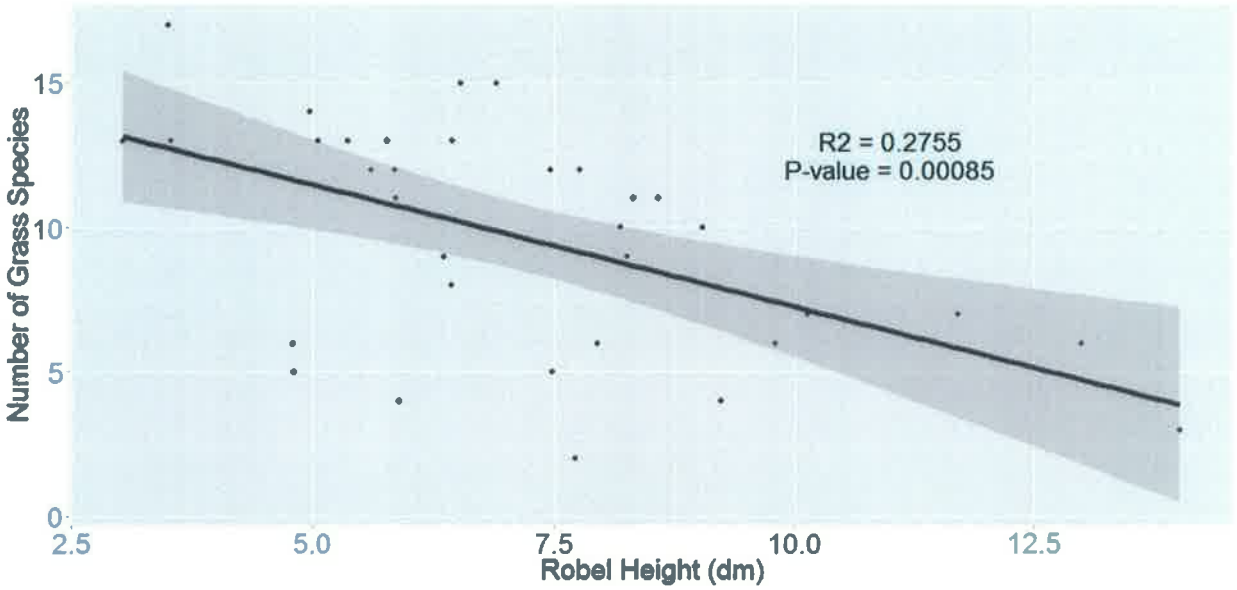

Figure 4: The relationship between vertical plant cover as measured by a Robel Pole and grass species diversity.