THE FLORA AND COMMUNITY ASSEMBLY OF BEAVER COUNTY: VASCULAR PLANTS OF THE WESTERN GREAT PLAINS AND PHYLOGENETIC PATTERNS ALONG A HYDROLOGICAL GRADIENT

By

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Bachelor of Science in Botany

The Evergreen State College

Olympia, Washington

2014

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2019

THE FLORA AND COMMUNITY ASSEMBLY OF BEAVER COUNTY: VASCULAR PLANTS OF THE WESTERN GREAT PLAINS AND PHYLOGENETIC PATTERNS ALONG A HYDROLOGICAL GRADIENT

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ACKNOWLEDGEMENTS

I'd like to offer my profoundest gratitude to Dr. Mark Fishbein, my advisor and mentor throughout graduate school. His floristic knowledge, thesis and teaching guidance, hours of editing, and patience and support throughout my project has been phenomenal. My present and past committee members, Drs. Linda Watson, Henry Adams, and Janette Steets provided me with ample research help and morale, and I'd like to thank them too. My predecessor in the Fishbein lab, Dr. Angela McDonnell, provided me with near limitless support in navigating my thesis research, herbarium work, and graduate student duties.

Many of the residents of Beaver County were instrumental in my completion of field work. Dr. Pauline Hodges is a font of knowledge about the county, as was Dr. Harold Kachel, and they helped guide me to many friendly landowners in the county. Drs. Curtis Bensch and Katy Levings at Panhandle State University were also great help, providing access to the university and properties around the county, as well as sharing their own botanical and historical knowledge. The staff of the Beaver County Extension and Beaver River Wildlife Management Area were also incredibly generous with their time and resources.

Financial aid was integral to the completion of my project, and I'd like to thank the Society of Herbarium Curators, American Society of Plant Taxonomists, and the Plant Biology, Ecology, and Evolution Department at Oklahoma State University for their help funding my floristic study and supporting my personal growth as a botanist.

Many herbaria were utilized for this project, and I'd like to specifically thank the Robert Bebb Herbarium at University of Oklahoma (OKL), and staff members Drs. Abby Moore and

Acknowledgements reflect the views of the author and are not endorsed by committee members or Oklahoma State University.

Amy Buthod, who were incredibly helpful for my many hours spent in the herbarium and over emails. Other herbaria whose staff personally made my research possible were OPSU, OKLA, and BRIT.

Finally, I'd love to sincerely thank my friends and family, in Oklahoma and abroad, whose support helped me through so much. I wouldn't have made it without you all. Specifically, my parents Richard and Claudia Starzak, had limitless confidence in me as a scientist for my entire childhood- I owe you two so much.

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Date of Degree: MAY, 2019

Title of Study: THE FLORA AND COMMUNITY ASSEMBLY OF BEAVER COUNTY: VASCULAR PLANTS OF THE WESTERN GREAT PLAINS AND PHYLOGENETIC PATTERNS ALONG A HYDROLOGICAL GRADIENT

Major Field: BOTANY

Abstract: Beaver County has the lowest plant collections per area of any county in western Oklahoma, and is located in the understudied shortgrass/mixed-grass prairies of the western Great Plains. The region has a history of high disturbance with a low proportion of protected areas and high risk for climate change induced drought. Through field work and herbarium specimen study, I documented a list of the vascular plants of the county, recording 497 vascular plant species. To facilitate the collection effort of a county-level floristic study, I developed methods for identifying knowledge gaps in the known flora. Using soil, geological, and hydrological maps, I identified intersections of unique environments as candidates for sampling in the 4700 km^2 county. By querying data from other shortgrass and mixed-grass prairie floras, I produced a checklist of likely plants in Beaver County. Utilizing these methods, I documented 60 new county records in two field seasons, including one state record, *Gutierrezia sphaerocephala*, roundleaf snakeweed (Asteraceae). Species-rich families were typical for the Great Plains: Asteraceae (19.4% of the flora), Poaceae (16.4%), and Fabaceae (8%). The largest genera were *Oenothera* (Onagraceae, 15 species), *Euphorbia* (Euphorbiaceae, 14 species), and *Eragrostis* (Poaceae, 9 species). The four vegetation types in Beaver County, bottomland, stabilized dune, sandsage grassland, and shortgrass prairie, were also recorded and had their species compositions studied. Special attention was paid to introduced species (63 species, 12.7% of the flora), as exotic species can displace native plants. Beaver County floristic data was used to test community assembly hypotheses, by analyzing the phylogenetic relatedness of four communities on a hydrological gradient from river bottom to upland dune. The relatedness of exotic species in each community was also analyzed to infer how species naturalize along a western Great Plains hydrological gradient and inform management of an economically important and anthropogenically disturbed region. Significant phylogenetic clustering, representative of environmental filtering, was found in the wetter communities of the River Bottom and Terrace, while the dunes showed random assemblage. Inclusion of exotic species increased clustering in the wetter communities. Possible abiotic factors that filter plants are drought and salinity.

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CHAPTER I

INTRODUCTION

The western Great Plains is a floristically understudied ecosystem in North America (Withers 1998), and more complete characterization of its biodiversity is critical due to continued anthropogenic disturbance in an already threatened ecosystem, as some studies estimate that over 99% of the vegetation of the historic Great Plains vegetation has been lost (Sampson and Knopf 1994). Related to plant biodiversity, the phylogenetic relatedness and assembly of wild plant communities have rarely been studied in this region (Foster et al. 2004, O'Connell et al. 2013). Climate change affects native plant populations through climactic variability and land use alterations that require more irrigation and greater area to meet food and energy productivity demands (Guo 2000). This makes the study of biodiversity and the relevant abiotic and biotic interactions in prairie communities in the Great Plains region increasingly important.

Beaver County in the Oklahoma Panhandle is an ideal site to study the floristics and community assembly of the western Great Plains, as both shortgrass and mixed grass prairies occur in the 4707 km^2 area county (Woods et al. 2005). The goals of this research are to identify and voucher specimens for as many vascular plant species as possible in Beaver County, to gain a greater understanding of the diversity of the western Great Plains. Testing hypotheses of community assembly utilizing phylogenetic methods on a hydrological scale in the arid western Great Plains will also fill an important ecological knowledge gap. Analysis of the evolutionary histories of exotic species represented in the flora of Beaver County can also better shape our understanding of how invasion shapes communities and inform future conservation and management decisions.

CHAPTER II

THE FLORA OF BEAVER COUNTY: VASCULAR PLANTS OF THE WESTERN GREAT PLAINS

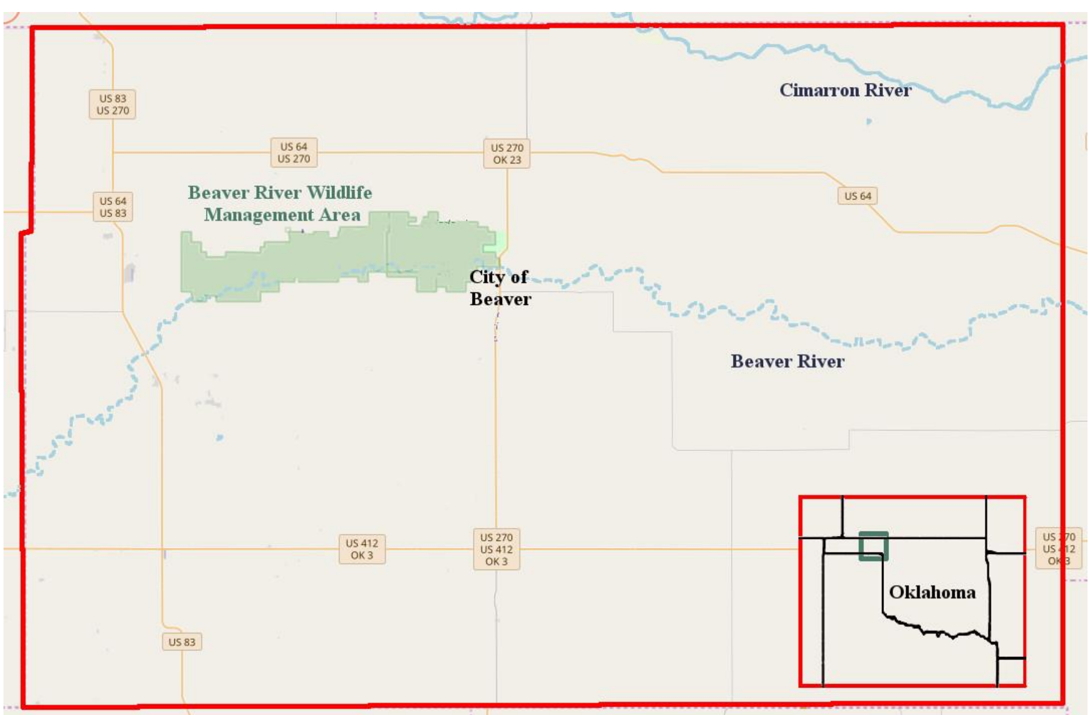
Introduction

Beaver County is the easternmost county on the Oklahoma Panhandle, bordered by Texas County, Oklahoma, to the west, Seward, Meade, and Clarke Counties, Kansas, to the north, Harper and Ellis Counties, Oklahoma, to the east, and Ochiltree and Lipscomb Counties, Texas, to the south (Figure 1. The county seat and largest city is Beaver, with 1,515 of the county's 5,315 population (U.S. Census Bureau, 2017), and other communities include Forgan and Gate. Two rivers flow intermittently through the 4707 km^2 Beaver County. The Beaver River, which is the main branch of the North Canadian River, flows through the center of the county, and the Cimarron briefly snakes into the northeastern corner of the county.

The underlying geology, soils, and climate of Beaver County help explain heterogeneity in vegetation, as they influence water and nutrient availability. Once an inland sea, the Great Plains emerged due to continental uplift 70 million years ago. Like most of the Great Plains (Trimble 1980), the geology of Beaver County consists of stream laid rocks carried down from the Rocky Mountains, and sandier soils where rivers have eroded the rocks. River briefly snakes into the northeastern corner. The most prevalent geological formation mainly consists of the

Neogene Ogalalla Formation, which consists of alluvial sand, silt, clay, and gravel, covered by caliche, and which is found throughout the southern and northeastern part of the county (Allgood et al. 1962). Soils found in this geologic formation are Sherm-Ulysses Mollisols in the south and northeast, flanked by Mansic-Irene Mollisols. The next most common geological surface is Quaternary Cover Sand consisting of windblown sand and minor silt, which is most prevalent in the northwest. Common soils over this geologic formation are Dalhart-Vona Alfisoils and Aridisoils. Windblown Quaternary Dune Sand flanks the north bank of the Beaver River; soils found here are Mobeetie-Veal-Devol-Lincoln-Eda Inceptisols, Alfisols, and Entisols. The riverbeds are classified as Quaternary Alluvium, which consists of sand, silt, clay, and gravel floodplains. At the far eastern side of the county, Quaternary Windblown Silt is prevalent (Allgood et al. 1962). Topographic relief is 300 m, ranging from 600 m elevation in the northeastern corner to a 900 m at the southwestern edge, following the general east-west elevation gradient of the Great Plains (USGS 1970).

Figure 1: Political geography and rivers of Beaver County. Map available under Open Database License from OpenStreetMap contributors ©.



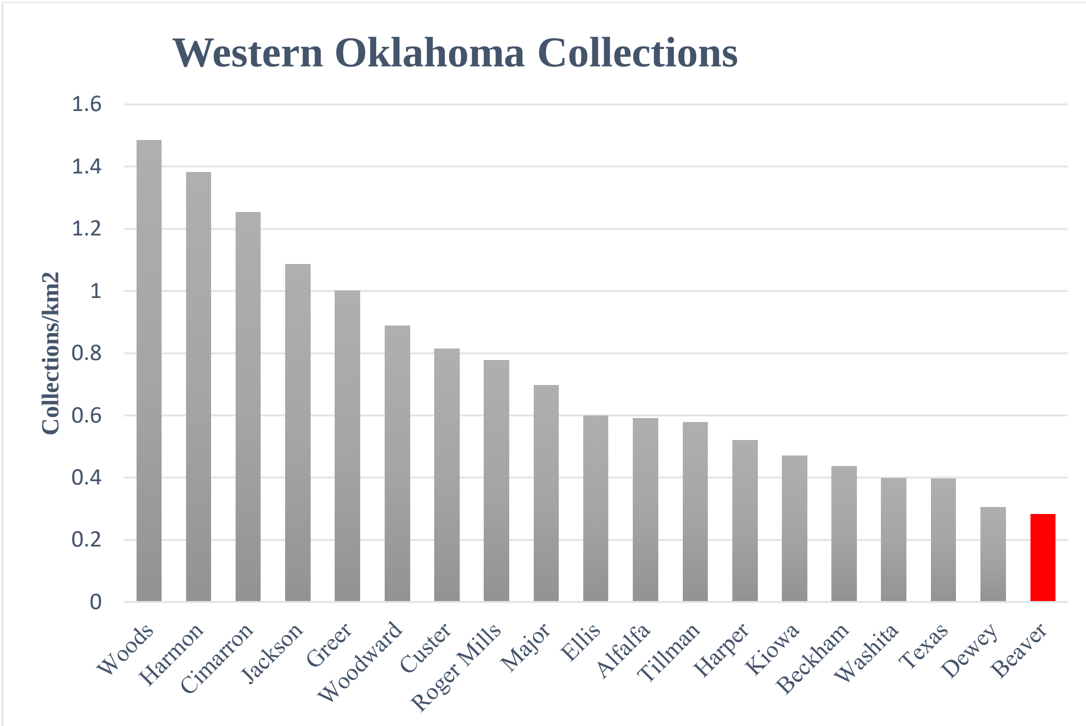
Plant life is also strongly influenced by climate. The Great Plains receives less precipitation in the west, due to the rain shadow of the Rockies and the great distance from large bodies of water. The high winds of the plains increase evaporation and make for a very dry climate (Webb 1931). Beaver County is situated in the coldest, driest part of Oklahoma. The Panhandle receives an average of 50.24 cm of annual precipitation in the form of rain, snow, and hail. The first frost date on average is October 17th and last frost is around April 17th, resulting in a six-month growing season. High winds, thunderstorms, and tornadoes are all common in the county, which limit plant height and creates regular disturbance events (NOAA 2017). Guo (2000) predicted that the region will likely experience drastic climate change, with increasing temperature and less frequent, more intense precipitation events. This will affect the fragmented landscape by shifting dominance to more arid-adapted scrub, grasses, and disturbance-tolerant, high dispersal, "weedy" plants where human impacts increase as they manage the changing landscape.

Human activities have influenced the disturbance regime of the Great Plains, so understanding the history of human colonization is integral to understanding the contemporary flora. The broad area encompassing Beaver County was settled over 6000 years ago by Paleo-Indians (LaBelle et al. 2003). The Comanche, Apache, Cheyenne, and Kiowa peoples called the western Great Plains home. Euro-American settlement began in the mid-19th century, mostly by cattle ranchers. In the Compromise of 1850, the northern border of Texas was drawn at the 36°30' parallel. Between Kansas' southern border at the 37th parallel and the eastern border of New Mexico, there was a thin strip of 'No Man's Land' left over, and this region was added to Oklahoma Territory in 1890. At the ratification of statehood in 1907, the Panhandle was divided into three counties, Beaver, Texas, and Cimarron (Wardell 1957). The Homestead Act, followed by the establishment of railroads, brought droves of potential farmers from a diversity of backgrounds (with potential plant introductions) to the Panhandle, and wheat production became immense. Heavy plowing coupled with drought led to the incredible erosion and disturbance that led the Dust Bowl in the 1930s, which decimated the region economically and environmentally (Hornbeck 2012). Efforts to control erosion through windbreaks were made with both native and non-native trees, such as the native *Maclura pomifera, Populus deltoides,* and *Gleditsia triacanthos*, and the exotic genera *Tamarix* and *Morus* (McDonald 1938).

As of the 2017 census, there were 5315 people in Beaver County, or an average of 1.2 people per km^2 (United States Census Bureau, 2018). This density is sparse compared to the average of 22 people per km^2 across the state. Over 95% of the current land usage is agricultural, and about 2% is publically managed, including Beaver Dunes Park and the Beaver River Wildlife Management Area (Figure 1). Although prairie and sage scrub vegetation types are adapted to regular fire intervals (Winters 2008), human activity has disrupted the regime, resulting in rare, destructive wildfires like that of March 2017, which burned the northeastern corner of the county before the growing season began, causing significant property damage (Manwarren 2017).

Previous to this study, botanical knowledge of Beaver County was known from a total of 1504 herbarium specimens present in the Oklahoma Vascular Plant Database (OVPD), which represents the lowest collection effort per area of any western Oklahoma county (Figure 2). The OVPD documents specimens accessioned in ten Oklahoma herbaria and the Botanical Research Institute of Texas. Eight additional specimens from the county are found in the Kansas State University Herbarium. There is little information about the Oklahoma Panhandle flora prior to western settlement, except a catalogue from Edward James on the Long-Bell expedition to the Rockies (James 1825). No plant collections were recorded in Beaver County before 1913, and only 151 collections (3.4% of all collections) before 1936 (OVPD), the end of the Dust Bowl (Hornbeck 2012).

Figure 2: Collection effort for western Oklahoma counties. Data obtained from the Oklahoma Vascular Plants Database



Over 100 years, five plant collectors made the greatest contributions to the floristic knowledge of Beaver County (Table 1). George Walter Stevens, a biology teacher in Alva and later director of the State Botanical Survey, collected over 4500 specimens in Oklahoma. Stevens' Beaver County collection effort focused around the communities of Beaver and Knowles, mostly in 1913, while working on the Flora of Oklahoma for his doctoral thesis at Harvard (Stevens 1916). Fred Hindman collected mostly around the city of Beaver in 1960 and 1961. Hindman was the work unit conservationist of the Jackson County soil conservation district (Bluestem 1951), so it is unclear if these were personal collections or for soil conservation work. Kurt Schaefer, a professor and Biology Department head at Oklahoma Panhandle State University, collected around Beaver County in the 1960s and 1980s. Bruce Hoagland, professor at the University of Oklahoma and coordinator of the Oklahoma Natural Heritage Inventory, collected for a diversity of studies such as "A classification and analysis of emergent wetland vegetation in western Oklahoma" (Hoagland 2015). Mark Fishbein, professor at Oklahoma State

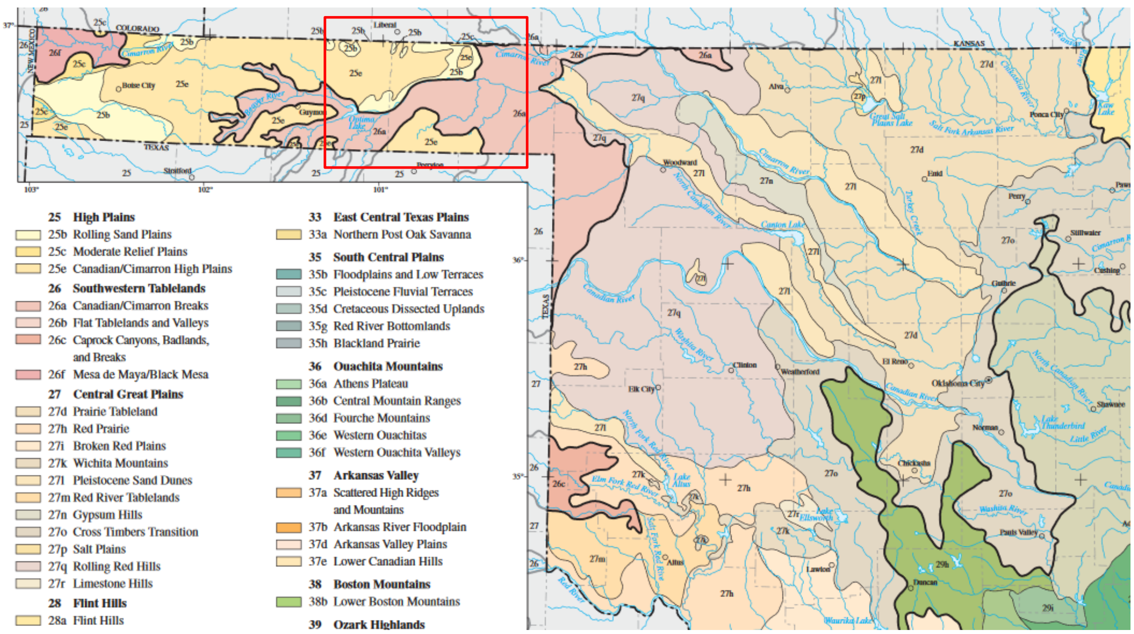
University, director of the Oklahoma State University herbarium, and co-editor of the Flora of Oklahoma, collected specimens in the Beaver River Wildlife Management Area in 2013, in order to characterize communities along a hydrological gradient, as well as general collections to document the flora of the understudied county.

Table 1: Major historic plant collectors in Beaver County.

Botanist	**Beaver Co Collections**	**Years Active in Beaver**
G. W. Stevens	135	1913
F. Hindman	184	1960-1962
K. Schaefer	174	1962-1987
B. Hoagland	180	1992-2001
M. Fishbein	147	2013

The vegetation of the Great Plains is dominated by grasses. These grasslands are often divided longitudinally, due to the response of vegetation to precipitation and evaporation variation, into tallgrass, mixed grass, and shortgrass prairie. Within these major types, differences in soil chemistry, local hydrology, topography, and other factors determine finer scale vegetation types, such as those found on sand dunes and gypsum outcrops (McGregor and Barkley 1986). A good starting point for discussing the vegetation of Beaver County is their place in the Environmental Protection Agency’s classification of ecoregions. Beaver County is in the Level II West Central Semi-Arid Prairies (9.3), region of the Level I Great Plains (9). At the finer Level IV ecoregions, Rolling Sand Plains (sandsage-bluestem prairie, 25b) and Canadian/Cimarron High Plains (shortgrass prairie, 25e) are part of the Level III High Plains ecoregion, and the Canadian/Cimarron Breaks (shortgrass prairie with sandsage-bluestem on stabilized dunes, 26a) with riparian bottomlands are included in the broader Level III Southwestern Tablelands (Woods et al. 2005, Figure 3). A higher resolution classification (Hoagland 2000) placed the vegetation of Oklahoma into alliances based on dominant and/or codominant species and the associations that make up these alliances. For simplicity, the vegetation types recognized in these studies can be generalized into the four following vegetation types: shortgrass prairie, sandsage grassland, stabilized dune, and bottomland.

Figure 3: EPA Level IV ecoregions of Oklahoma, western excerpt (Woods et al. 2005). Map available under Creative Commons Attribution 3.0 License, attributed to US Geological Survey.



Shortgrass Prairie

The most common vegetation type in Beaver County and the rest of the Oklahoma Panhandle is shortgrass prairie, which is found in the western, drier areas of the Great Plains (McGregor and Barkley 1986). *Bouteloua dactyloides*, *B. gracilis*, *B. curtipendula*, and *Schizachyrium scoparium* are the dominant grasses in this prairie type. Common associates depend on the composition of the shallow soils found over caliche or sandstone bedrock, with clay soils being most extensive and home to grass species including *Aristida purpurea, Hopia obtusa, Muhlenbergia torreyi, Sporobolus asper,* and *S. cryptandrus,* and forbs *Ambrosia psilostachya, Machaeranthera tanacetifolia, Melampodium leucanthum,* and *Zinnia grandiflora* (Hoagland and Collins 1997). Better drained soils and rocky slopes support grasses *Bouteloua hirsuta, Andropogon gerardii, Sorghastrum nutans,* and *Sporobolus asper,* and forbs *Opuntia macrorhiza, Yucca glauca, Symphiotrichum ericoides, Helianthus hirsutus,* and *Physaria ovalifolia* (Bruner 1931). Sandier soils support grasses *B. hirsuta, Muhlenbergia torreyi, M. paniculata,* and *Elymus elymoides,* as well as the forbs *Ratibida columnifera* and *Sphaeralcea coccinea* (Bruner 1931).

Because much of the shortgrass prairie was converted to agriculture and pastureland, disturbance is extensive. Dominant plants of recently disturbed shortgrass prairie are native *Amphiachyris dracunculoides, Gutierrezia sarothrae,* and *Hordeum jubatum,* and introduced *Bothriochloa ischaemum* and *Salsola tragus*. Succession in old-fields and degraded grasslands leads to a dominance of the *Aristida purpurea* and *Ambrosia psilostachya* alliance (Hoagland 2000), as well as grasses *Bouteloua gracilis, Eragrostis spectabilis,* and *Chloris verticillata,* and forbs *Conyza canadensis, Coreopsis tinctoria, Grindelia ciliata,* and *Erigeron* species. Similar vegetation is found in prairie dog towns (Kaputska and Moleski, 1976; Osborn and Allan, 1949).

Sandsage Grassland

The sandsage grassland of the western Great Plains is largely defined by its dominant shrub, sand sagebrush or sandsage (*Artemisia filifolia*). Deep sandy deposits blown north of the rivers, streams, and adjacent stabilized dunes make up the sandy substrate for *A. filifolia* (Allgood et al. 1962). Besides sandsage, other dominant shrubs are *Prunus angustifolia* and *Rhus* *aromatica*. Grasses that fill in the scrubland gaps include *Schizachyrium scoparium, Sporobolus cryptandrus, Andropogon gerardii* subsp. *hallii, Bouteloua curtipendula, B. gracilis,* and *Calamovilfa gigantea*. Forbs commonly present are *Oenothera serrulata* and *Eriogonum annuum*, and *Cyperus schweintzii* is a common sedge (Duck and Fletcher 1945, Jones 1963). Disturbance in the form of grazing does not affect *A. filifolia* as much, since it is unpalatable to cattle. Where it is absent or managed, *Prunus angustifolia, Bothriochloa laguroides, Gutierrezia sarothrae,* and *Salsola tragus* increase in cover (Hutchinson 1967).

Stabilized Dunes

Sand dunes made up of Quaternary windblown dune sand (Allgood et al. 1962) are stabilized by deep-rooted plants, and are found on the north sides of the Beaver and Cimarron Rivers. Vegetation includes shrubs such as *Rhus aromatica* and *Prunus angustifolia*. Although they are present in sandsage grassland as well, on dunes they are more dominant than *Artemisia filifolia*. There is also more bare sand without cover on dunes. Graminoids such as *Andropogon gerardii* spp. *hallii*, *Calamovilfa gigantea,* and *Cyperus schweintzii,* and forbs like *Eriogonum annuum* and *Stillingia sylvatica*, are more dominant on dunes than in sandsage grassland (Penfound 1953, Baalman 1965). Trees such as *Populus deltoides* and *Celtis* species find shelter from wind in dune swales, another marked difference from the relatively treeless prairie and sandsage grassland. High levels of disturbance caused by off road vehicles in the Beaver Dunes Park have led to local destabilization, erosion, and devegetation of the dunes (Hoagland 2000).

Bottomlands

Bottomlands are scattered throughout Beaver County as riparian corridors of rivers and ephemeral streams. Bottomland plants must be adapted to varying water depths, drought conditions, and salt tolerance, and the vegetation reflects this. Dominant trees are *Populus deltoides, Sapindus saponaria, Salix amygdaloides, S. nigra, Celtis* species, and the non-native *Tamarix*. Common shrubs are *Salix exigua, Baccharis salicina, Cephalanthus occidentalis,* and the grape vine *Vitis acerifolia* is also common. Herbs include *Distichlis spicata, Panicum virgatum, Symphiotrichum subulatum, Eupatorium serotinum,* and *Pluchea odorata* (Hoagland 1998). In the tributaries feeding into bottomland streams, vegetation density, height, and canopy cover decrease as water availability decreases. These soils, lower in moisture than the more wooded bottomlands, are often gazed and the understory is dominated by *Hopia obtusa, Bouteloua dactyloides, B. gracilis, Pascopyrum smithii, Ratibida tagetes,* and *Muhlenbergia paniculata* (Hoagland 1997). Human disturbances, such as irrigation, damming, and channelization of rivers and streams also decrease water availability, selecting for shorter species in the bottomland woodlands (Dodds et al. 2004). A unique disturbance event to this habitat is exotic *Tamarix* control. Where mowed or removed, loss of canopy is conspicuous and other exotic species such as *Salsola tragus* and *Bromus tectorum* have opportunity to proliferate (Gonzalez 2017).

A distinct wetland vegetation type in Beaver County, rare due to land development, pollution, and water extraction (Smith 2011), is that of playas and seasonal depressions. Dominated by *Pascopyrum smithii, Schoenoplectus americanus*, and *Eleocharis* species (Hoagland 2000), these wetlands provide important ecosystem services such as avian habitat, aquifer recharge, and seed banks (Smith 2011).

The goals of this research are to determine the vascular plant Flora of Beaver County as completely as possible through collection of voucher specimens and identification of species. I will also compare the richness of the flora to other shortgrass/mixed grass prairie floristic studies from western North America with respect to the size of the land area of Beaver County.

Methods

Assessment of Undocumented Species

In order to most completely document the plant life of Beaver County, I surveyed published floristic studies on the Floras of North America Project (Withers et al. 1998) from the western Great Plains to compile a list of taxa to be expected and sought in Beaver County, but were not yet recorded (Appendix 2). The included floristic studies were located within the shortgrass/mixed grass vegetation type outlined in the Flora of the Great Plains (McGregor and Barkley 1986), with an upper limit of Nebraska's northern border (to reduce dissimilarity due to climatic differences). The species richness and areas from these floristic studies were used to generate a species-area curve and evaluate the known species richness of Beaver County at the outset of the study.

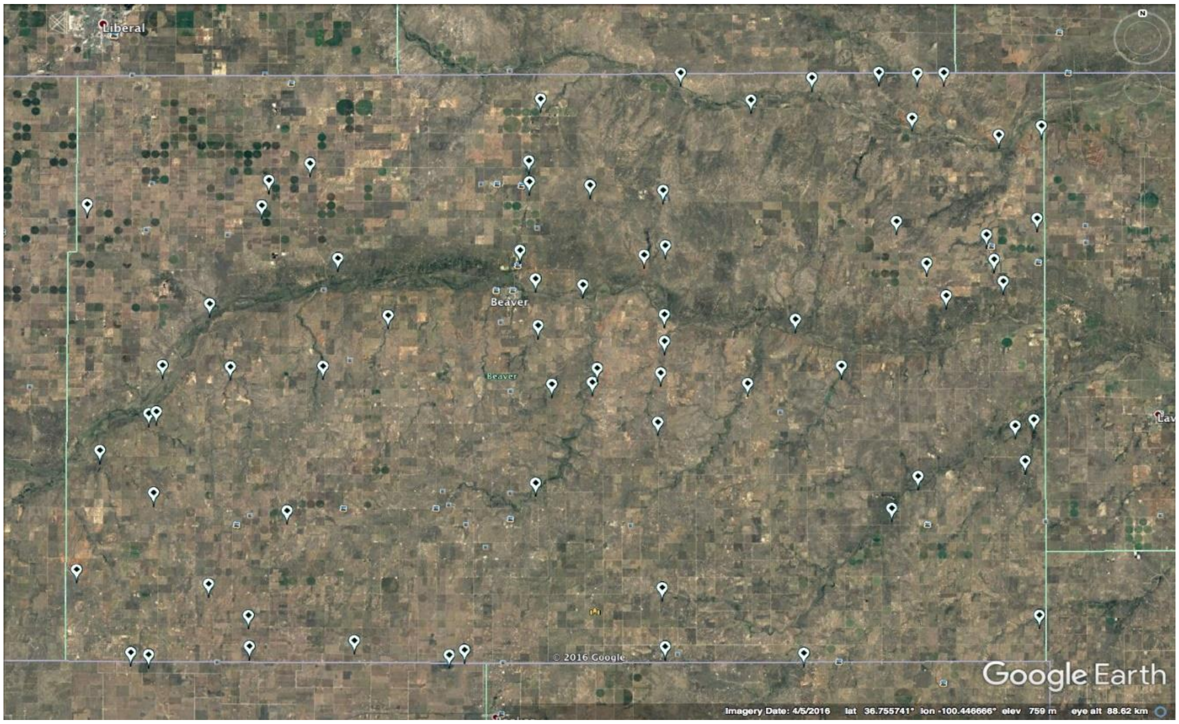
I produced a "target" list of species to seek in Beaver County from the nearest published floristic studies outside the county: Alabaster Caverns State Park, Four Canyons Nature Preserve, an unnamed gypsum-dominated site north of Chester in Major County, Gypsum Hills and Redbed Plains, and Washita Battlefield National Historic Park in Oklahoma, Kiowa County in Kansas, and Kiowa & Rita Blanca National Grasslands in Oklahoma, Kansas, and New Mexico, (Appendix 2). I used the Integrated Taxonomic Information System (ITIS; http://www.itis.gov, consulted in April 2017) to produce a table of nomenclatural synonyms for cross-referencing floristic studies. I constructed the database in Microsoft Access, in which I created queries for finding species that were common to more than two Floras and found 163 species not yet documented from Beaver County, including common species, such as *Achillea millefolium*, *Juniperus virginiana*, and *Elaeagnus angustifolia*.

Sampling Sites

USGS Soil and Geology maps were analyzed to delineate abiotically dissimilar areas, and generate a collection plan. To identify sites that were potentially dissimilar in plant composition based on soils and geology, I used ArcGIS (ESRI 2011) to overlay data layers, a USGS high-resolution soil/hydrology map (Stanley et al. 2002) and a geology map of Beaver County (Allgood et al. 1962), and located centroid points for these overlapping polygons. Where four or more points clustered in <10 km^2 on the map, I placed a central pin, determined land survey coordinates (TRS system), and found 76 unique locations in terms of underlying geology, substrate composition, clay-silt-sand ratios, and porosity (Figure 4). The iPhone app OnX (https://www.onxmaps.com/hunt-app) was used to find landowner names, and Beaver County residents and the county extension office were then contacted to find land owners. Additional sampling sites were identified based on appearance from roadsides, satellite imagery, and information from residents and other knowledgeable people. Location data from existing collections, largely in and near the Beaver River Wildlife Management Area and north of Slapout, were also resampled, yielding the sampling strategy in Figure 4.

I studied specimens collected in Beaver County, including all of those at Oklahoma State University (OKLA) and many at University of Oklahoma (OKL) and Oklahoma Panhandle State University (OPSU). According to the OVPD, collections from Beaver County include 592 specimens at OKL (39% of collections), 523 specimens at OKLA (35%), and 232 specimens at OPSU (19%). Specimen identification, and location were verified.

Figure 4: Planned sampling sites based on intersection of abiotic characteristics. Attribution: Image Landsat / Copernicus ©2018 Google



Specimen Collection and Identification

To further document the flora, I collected herbarium specimens in 2017 and 2018, with weekly excursions from April through October each year. Specimens are deposited in the Oklahoma State University Herbarium with duplicates to be distributed to University of Oklahoma or the Botanical Research Institute of Texas. Metadata recorded for each collection include GPS coordinates, habitat, associated species, descriptive morphology, and abundance (Palmer et al. 1995). Collections were identified using the Flora of Oklahoma (Tyrl et al. 2015), Flora of North America (Flora of North America Editorial Committee, 1993+), Illustrated Flora of North Central Texas (Diggs et al. 1999), Flora of Nebraska (Kaul et al. 2006), and Flora Neomexicana (Allred 2008). Nomenclature and native/introduced status were obtained from ITIS (http://www.itis.gov), or Flora of North America when ITIS did not have data or listed species as simultaneously native & exotic (Flora of North America Editorial Committee, 1993+).

Results

The previous 1504 collections were most recently identified as 561 species. Removing taxonomic synonyms, misidentifications, and database errors reduced this total to 437 species. The 1417 specimens I collected in Beaver County in 2017 and 2018 brought the total species count in the Beaver County Flora to 497 (Appendix 1, Figure 5). The species-area curve for the Floras of the western Great Plains (Withers et al. 1998, Appendix 2) is fitted by the regression line $y = 0.0882x + 2.1858$ (Figure 6). Based on this regression and the area of Beaver County, the predicted richness is 485 species. This is higher than the preliminary Beaver County checklist of 437 species. Through my field work, I collected 424 species, adding 60 species to the known flora and was unable to relocate 73 species. The result of this floristic study of 497 species is greater than the hypothetical species richness, but falls within the 95% confidence interval (431 – 547 species). Of the 60 newly documented plant species in Beaver County, one is a state record (*Gutierrezia sphaerocephala*, Asteraceae, roundleaf snakeweed).

Figure 5: Locations of plant collections in Beaver County. Prior collections in grey, new collections for this study in green. Attribution: Image Landsat / Copernicus ©2018 Google

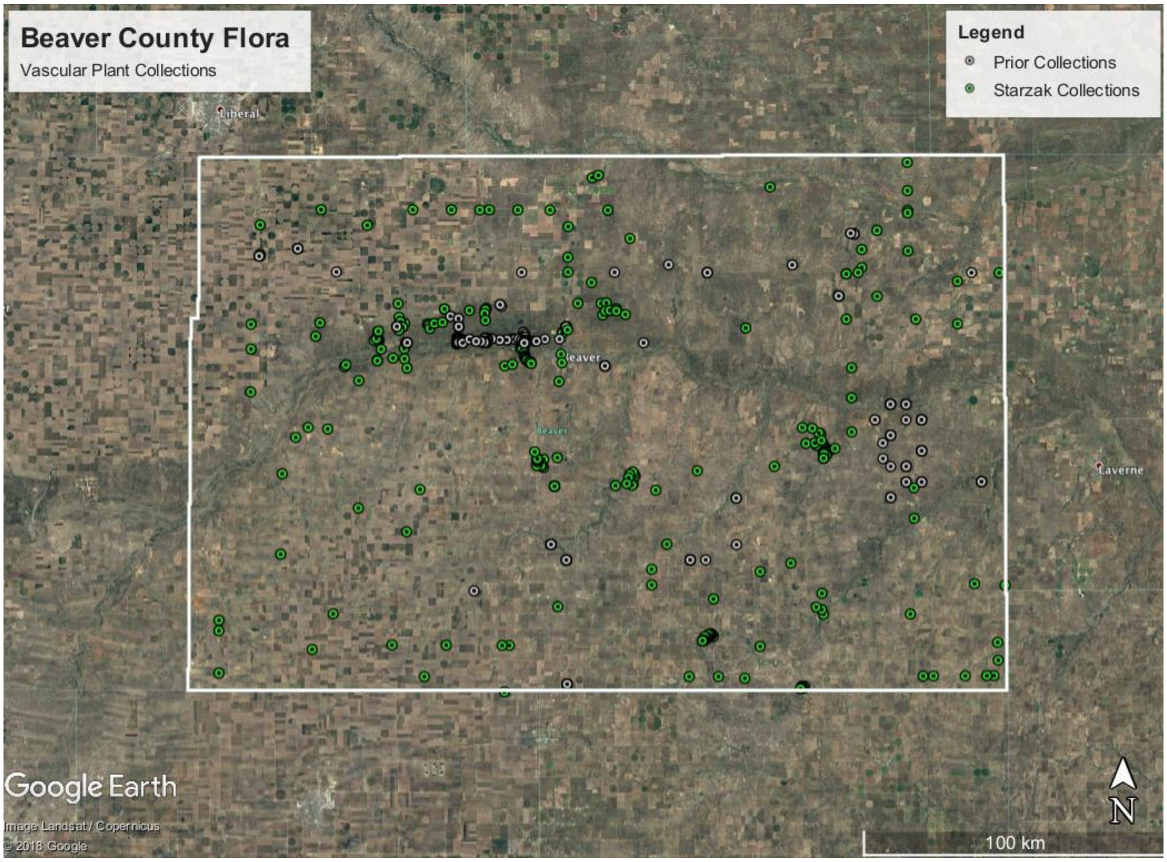
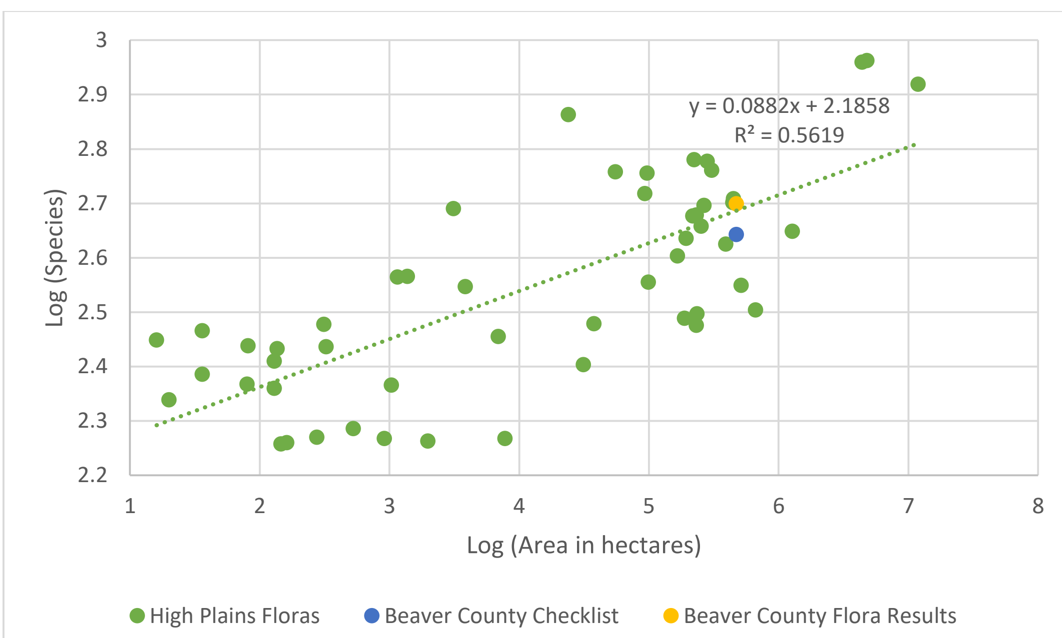


Figure 6: Species-area curve for western Great Plains floras



The Flora of Beaver County consists of 87% native species to the Great Plains, and 12.6% that were introduced (ITIS, consulted on 2/25/2019; Flora of North America Editorial Committee, 1993+). This is consistent with western Great Plains Floras, e.g., 15.3% non-native species for Alabaster Caverns (Caddell 2013), 7.8% for Four Canyon Nature Preserve (Hoagland 2007), 11% for Kiowa and Rita Blanca National Grasslands (Hazlett 2009), 9.6% for the Gypsum Hills and Redbed Plains (Barber 2008), and 7.7% for Kiowa County (Baldock 2014). There were two species for which place of origin is ambiguous. Introduced *Corispermum nitidum* hybridizes with *C. americanum*, and introgression can make identification between these two difficult (Flora of North America Editorial Committee, 1993+). *Phragmites australis* has native and introduced genotypes, which are difficult to differentiate morphologically (Flora of North America Editorial Committee, 1993+).

The three most species-rich families are Asteraceae (97 species, 19.4% of the Flora), Poaceae (82 species, 16.4%), and Fabaceae (40 species, 8%) (Table 2). This is typical for comparative Floras, with Asteraceae ranging 17-20%, Poaceae ranging from 11-19%, and Fabaceae ranging from 8-10% (Caddell 2013, Hoagland 2007, Hazlett 2009, Barber 2008, Baldock 2014). The three most species-rich genera are *Oenothera* (Onagraceae, 15 species), *Euphorbia* (Euphorbiaceae, 14 species), and *Eragrostis* (Poaceae, 9 species) (Table 2).

Vegetation types inhabited by each species were determined by observations made at the time of collection and data recorded on specimen labels (Table 3, Appendix 1). For *Rudbeckia hirta*, the only Beaver County collection had no location information, vegetation type was inferred from a collection made in adjacent Texas County. Bottomland vegetation had the most unique species (108), while the stabilized dune had the fewest (9). Cumulatively, the shortgrass prairie was home to 282 species, while only 113 were found in the stabilized dunes.

Table 2: Species richness of the largest families and genera in Beaver County

Largest Families:	Species	%	**Largest Genera:**	Species
Asteraceae	97	19.5%	*Oenothera*	15
Poaceae	82	16.5%	*Euphorbia*	14
Fabaceae	40	8.0%	*Eragrostis*	9
Amaranthaceae	19	3.8%	*Dalea*	8
Cyperaceae	19	3.8%	*Cyperus*	8
Euphorbiaceae	18	3.6%	*Asclepias*	7
Brassicaceae	17	3.4%	*Erigeron*	6
Onagraceae	17	3.4%	*Astragalus*	6
			Amaranthus	6

Table 3: Vegetation distribution for recorded species. "Unique" refers to species only found in that vegetation type, while "Total" refers to all species represented in that type. "Unique Species" in "All" indicates the number of plant species that occur in every vegetation type.

Vegetation:	Unique Species	Total Species
Sandsage grassland:	53	268
Shortgrass prairie:	80	282
Stabilized dune:	9	113
Bottomland:	107	238
All:	44	497

Cultivated and Excluded Species

Solanum ptycanthum belongs to a species complex that also includes *S. nigrum* and *S. americanum*, names that have been commonly applied to plants in this complex in North America (Särkinen et al. 2018). I followed ITIS (http://www.itis.gov, consulted on 2/25/2019) and the Flora of Missouri (Steyermark et al. 2009) in treating these as synonyms of *S. ptycanthum*, and these names are excluded from the Flora. *Catalpa speciosa* was excluded because the sole specimen (F.B. Erteeb 1647, OKLA) could not be confidently differentiated from *C. bignonioides* without floral or fruit material (Tyrl et al. 2015). Plants that are deliberately planted are often excluded from floristic studies, but this status was difficult to determine in Beaver County for tree species that were introduced as wind breaks after the Dust Bowl (McDonald 1938), such as *Maclura pomifera*. Some ornamental or domesticated species documented by herbarium specimens were included in the Flora if location data reflected naturalization, such as for *Consolida ajacis*, which is commonly escaped from gardens in North America (Flora of North America Editorial Committee, 1993+). A single collection of this species from Beaver County was made in 1962 in an "old ditch" (C. Fisher 60, OPSU). The domesticated sorghum, *Sorghum bicolor*, was collected near a creek on property that was used for intermittent grazing, not *Sorghum* farming (N. Starzak 1324, OKLA). However, two species were excluded from the Flora because of their proximity to old homesteads, *Iris* sp. (N. Starzak 53, OKLA) and *Chilopsis linearis* (N. Starzak 1289, OKLA).

Discussion

The addition of 60 vascular plant species to the Flora of Beaver County, a 14% increase to 497 species, has implications for understanding causes of changes in the composition of the flora, conservation strategies, and future study opportunities. Although a floristic study cannot definitively prove the absence or extirpation of a species, examination of the species that could be recollected can provide insights into the probability of extirpation. Taxonomic and ecological patterns in species that were newly added to the Flora can also provide insights. Conservation implications range from tracking potentially invasive species in their spread through Beaver County and documenting the vegetation types they proliferate in, to following range extensions of native plants, an important endeavor with changing climate. There are, however, no endangered species or candidates present in the Beaver County Flora.

Aquatic plants represent a group of species that may have declined in Beaver County during the time that historical collections have been made. I could not find 17 aquatic and emergent species previously documented in the county, including three out of four species of *Lemna* and three *Sagittaria* species. Several original collection sites were revisited without success in finding these species, e.g., Clear Lake and Gate Playa, and several other sites were dry, e.g., Forgan Playa, or could not be relocated (and thus likely dry), e.g., Red Horse Lake. Two non-aquatic species in Asteraceae that were previously collected, *Silphium laciniatum* (K. Schaefer 1900, OPSU) and *Rudbeckia hirta* (C. Fisher 176B, OPSU), and *Ulmus rubra* (S. Rooker 91, OPSU) in Ulmaceae were not found. I did not expect to find these species in the shortgrass/mixed grass prairie due to their minimal representation in adjacent floristic studies, and they were only collected in Beaver County once before. However, the specimens are identified correctly to species, and I have no basis for claiming that they were not members of the flora.

Of my 60 additions to the Flora, 28% were introduced species, higher than the percentage of introduced species in the flora as a whole. This may be because of the ubiquitous nature of the introduced species and a lack of desire to collect them by previous collectors (e.g., *Carduus, Cirsium*, and *Elaeagnus*) or because of recent arrival (likely for *Scorzonera laciniata*). Although I did not relocate many aquatic plant species, I added new water-associated species to the Flora, like the aquatic *Lemna minor,* emergent aquatic *Justicia americana,* and riparian *Juglans microcarpa*. Three Apiaceae species (*Ammoselinum popei*, *Berula erecta,* and *Conium maculatum*) were added to the Flora, with the latter two being wetland species. This could indicate previous gaps in sampling in mesic areas, or possible shifts in wetland vegetation, although these species are not dominant. Many of the additions to the Flora were expected shortgrass/mixed grass species that were present in my target list, such as *Juniperus virginiana,* *Sapindus saponaria*, *Argemone squarrosa*, and *Mentzelia oligosperma.* Many native and introduced species that colonize disturbed areas were county records, such as the native *Acalypha ostryifolia, Solidago mollis, Amaranthus tuberculatus*, and *A. palmeri.* Introduced, disturbance-tolerant additions included *Bromus inermis, Erodium cicutarium, Sisymbrium altissimum*, and *Verbascum thapsis.*

The Flora of Beaver County also documented several range extensions of native species, utilizing the Flora of North America (Flora of North America Editorial Committee 1993+), Oklahoma Vascular Plants Database (OVPD), and SEInet (SEInet Portal Network, accessed April 8 2019). The northernmost collection of *Gutierrezia sphaerocephala*, with two Texas Panhandle collections previously recorded ~20 kilometers south (Wallis 7886 & 7978, BRIT). Northwestern extensions of the ranges of *Justicia americana*, 160 km NNW of Sayre, OK (J. Engelman, OKLA 114522) and *Erigeron tenuis,* 90 km W of Selman, OK (P. Nighswonger 2323, OKL), were also recorded in Oklahoma (OVPD). These should be tracked as climate change and human disturbance alters the environment of the Great Plains (Guo 2000).

Understanding dynamics of introduced and exotic species is an important part of conservation, and floristic studies can provide useful information about their range and expansion. One species on the state noxious weed list (Oklahoma House of Representatives 1998), *Carduus nutans*, was recorded in multiple locations across the county. *Poa pratensis*, the exotic Kentucky bluegrass, has been implicated in shifting native C_4 dominant grasslands towards C_3 dominant grasslands, with significantly lower native species richness (Miles and Knopps 2009). An introduced species of note is *Scorzonera laciniata*, as only one collection has been recorded in Oklahoma prior to my collections, in Cimarron County at the western end of the Panhandle (A. Buthod and B. Hoagland BM-345, OKL). I collected it at several truck stops, and perhaps this warrants concern for its invasiveness in Oklahoma; the species has been recorded as spreading rapidly in disturbed sites in Colorado, Montana, and New Mexico (Tony et al. 1998).

Documenting which vegetation types are colonized by introduced species is also important in order to track which areas are more susceptible to new invasion, or which areas act as reservoirs (Table 4). Most of the vegetation types maintain similar proportions of introduced plant species (8-15%) as in other Great Plains floristic studies (Caddell 2013, Hoagland 2007, Hazlett 2009, Barber 2008, Baldock 2014). The stabilized dunes, with the lowest species richness, have lower levels of introduced species, perhaps because of the harsh environmental conditions, such as sandy soil and low water availability.

Table 4: Metrics for introduced species by vegetation type.

Introduced Species	Unique Species	%	All Species	%
Sandsage grassland:	9	17.0%	30	11.2%
Shortgrass prairie:	16	20.0%	39	13.8%
Stabilized dune:	1	11.1%	7	6.2%
Bottomland:	11	10.3%	29	12.2%

Occurrence of introduced species within plant families can be of use to conservation efforts and future studies, as plant families sometimes have obvious synapomorphies, like Brassicaceae with its typical four-petal-six-stamen morphology. This can make identification by amateur botanists and weed scientists easier for exotic-rich plant families. Of the three major families in Beaver County and other shortgrass/mixed grass prairie Floras, Asteraceae had 7% introduced species, Poaceae had 25.6%, and Fabaceae had 10% (Table 5). The high number of Poaceae species might be due to the use of nonnative grasses for cattle grazing. Two of the eight most species rich plant families in the Flora had very high percentages of introduced species, Brassicaceae with 41.2% and Amaranthaceae with 21.1%, making these important plant families for land managers to learn and document.

Table 5: Metrics for introduces species by plant family.

Plant Family	Introduced Species	%
Asteraceae	7	7.2%
Poaceae	21	25.6%
Fabaceae	4	10%
Brassicaceae	7	41.2%
Amaranthaceae	4	21.1%

CHAPTER III

COMMUNITY ASEMBLY IN BEAVER COUNTY: PHYLOGENETIC PATTERNS ALONG A HYDROLOGICAL GRADIENT

Introduction

The ecological theory of community assembly provides explanations for the processes that determine the species composition of communities. Community assembly was born out of island biogeography, in an attempt to describe the factors for why certain organisms arrive on islands, such as distance from mainland, and why some are excluded, such as by being outcompeted (MacArthur and Wilson 1967, Diamond 1975). In island biogeography, the pool of species available to disperse into a habitat, the organisms arriving from the mainland, would be randomly assembled if there were no limiting forces, and a null model could be drawn. Study of succession was used to explore community structure on land, and this gave rise to a new structuring force, environmental filtering, which explained exclusion in communities due to limiting abiotic factors (Van der Valk 1981). Abiotic factors such as soil chemistry, water availability, and microclimate play roles in limiting the success of available species in a community (Cornell and Harrison 2014, Carstensen et al. 2013). Biotic factors also structure communities, through processes such as competition. The weight of biotic versus abiotic factors is one approach to understanding community assembly. To test their influences, an approach developed in the early 2000s makes use of the relatedness of species in the community.

An important assumption of this approach is that organisms that have diverged recently exhibit similar characters and ecological attributes, resulting in phylogenetic niche conservatism (Losos 2008).

Opposing predictions for how relatedness structures communities are made depending on the relative importance of abiotic and biotic factors. Under the hypothesis that abiotic limitation is more influential, it is predicted that the environment restricts the persistence of organisms that lack suitable adaptations through a process known as environmental filtering. In arid environments, traits such as dormancy and those that minimize water loss are adaptive, e.g., needles, waxy cuticles, or succulent leaves (Chesson et al. 2004). Alternatively, under the hypothesis that biotic factors are more important to community assembly, it is predicted that when the environment is less challenging, organisms with similar traits compete more strongly, resulting in competitive exclusion. For example, when water is a limiting resource, plant species with similar root depths would be subject to competition and potentially be excluded (Chesson et al. 2004).

To test whether environmental filtering or competitive exclusion has greater influence in community assembly phylogenetic metrics are used to characterize the degree of relatedness in the community. Assuming niche conservatism, if communities are composed of species that are more closely related (i.e., phylogenetically clustered) than a random sample of the species pool, this is interpreted as support for environmental filtering. Alternatively, if the relatedness of species in a community is more overdispersed than a random sample, then it is interpreted as support for competitive exclusion (Webb 2000).

Utilizing phylogenetic metrics for assessing community assembly hypotheses is not without its criticisms, however. There is concern that there is not enough evidence for a correlation between trait similarity and phylogenetic clustering (Pavoine 2013). Gerhold et. al

(2015) identified seven major assumptions that lack evidence in phylogenetic-based community assembly. Phylogenetically conserved traits, on larger scales of area and evolutionary history, can converge or diverge at the smaller-scale community level, due to differences in community structure and evolutionary rate. Traits can serve different functions in different environments, and interplay with each other in unique ways, like plant height used to access more light and crowd out competitors. Trait similarity can increase coexistence or facilitation, like sharing pollinators or better excluding predators. Many communities are successional and not in equilibrium like community assembly assumes. Competitive exclusion and environmental filtering are not necessarily mutually exclusive. Finally, community context is rarely taken into account, and communities may differ in regional pools or ages of niches. However, identifying and analyzing patterns of phylogenetic relatedness of communities still generates valuable data for studying the evolution of organisms, such as how coexistence can lead to macroevolution, e.g., diversification through evolutionary arms races or insect-gut microbe mutualism (Gerhold 2015).

Because of their irrelevance in evolutionary time, non-native species are often omitted from community assembly studies (Gallien and Carboni 2017). However, studying the traits and relatedness of nonnative species is not an unprecedented idea. Darwin (1859) hypothesized that more closely related species should be more likely to compete, now known as Darwin's naturalization hypothesis, which has been explored in different ecosystems to varying successes. Rejmánek's (1996) study of California's Poaceae and Asteraceae, which found support for success of exotic genera compared to naturalized genera, as opposed to Daehler's (2001) study that showed a lack of significant results investigating if invasion in Hawaii was mostly exotic genera or exotic species in native genera. Understanding relatedness of invasive species also helps inform predictions for possible new invaders, and this has practical consequences for management practices. Given the role of disturbance in the Great Plains, it is worth exploring the phylogenetic relatedness of nonnative species.

There is currently a dearth of literature for plant community assembly of the Great Plains utilizing phylogenetic data, making the flora of Beaver County important for filling an ecological knowledge gap. Foster et al. (2004) studied how propagule pools affect prairie community assembly in Kansas and showed that the availability of key species in the propagule pool influenced dominance, and their absence resulted in new dominant species. Studying community assembly in shortgrass prairie playas, O'Connell et al. (2013) found that plowing and sediment accumulation acted as environmental filters, reducing species richness and propagation of perennials. Martin and Wilsey (2012), researching tallgrass prairie community assembly history, demonstrated early colonization by native species could increase beta-diversity. Fargione et al. (2003) found evidence for competitive exclusion in prairie communities in Minnesota, due to increased diversity of resident native plants negatively influencing invasive encroachment. None of these address the interplay of wild plant communities, phylogenetic analyses, and hydrological gradients in the western Great Plains.

The goals of this project are to analyze patterns of phylogenetic relatedness of the Beaver River Wildlife Management Area communities along a hydrological gradient, in order to test hypotheses of environmental filtering and competitive exclusion on community assembly. This study also compares the relatedness of exotic species in each community to see if they followed a similar pattern to non-native species. I hypothesize that the riparian area of Beaver County, with fewer limiting abiotic factors, such as water availability, would have greater competitive exclusion than the upland dunes, which would be dominated by more closely related species and have more open space available. When exotic species are included in the analysis, I predict greater relatedness in the harsher, drier upland dunes than the riparian areas, where novel evolutionary lineages would reduce competition, and increased anthropogenic disturbance due to irrigation and land use would introduce more invasive species.

Methods

Species Pool

The flora of Beaver County (Chapter 2) was utilized as the species pool for analysis of the assembly of communities in the Beaver River WMA, which is located near the center of the county. Utilizing the native/introduced status from ITIS (http://www.itis.gov), or Flora of North America (Flora of North America Editorial Committee, 1993+) when ITIS did not have data or ambiguous nativity, I categorized species as native or exotic. Two species have disputed or unknown origins, and were not included in the species pool. *Corispermum nitidum* hybridizes with *C. americanum*, and introgression can make identification between these two difficult (Flora of North America Editorial Committee, 1993+). *Phragmites australis* has native and introduced genotypes, which are difficult to differentiate morphologically (Flora of North America Editorial Committee, 1993+). Three pools were used for separate analyses, native only, introduced only, and all species.

Community Species Lists

Community species lists were derived from vegetation sampling plots studied by Fishbein (unpublished), who recorded the species present in four 900 m^2 quadrats located along six transects parallel to the elevation gradient, for a total of 24 quadrats. The transects and quadrats were established by K. Maslowski and C. Greenwood (Oklahoma State University) in a study on arthropod communities, with a relief of about 18 meters. Each of the four quadrats along each transect was placed in *a priori* defined communities at increasing elevation and distance from the streambed: 1) River Bottom, 2) River Terrace, 3) Dune Base, and 4) Upland Dune. As with the species pool, native, introduced, and combined species lists for each community were generated. Along the Beaver River, invasive *Tamarix* dominated the river bottom, commonly occurring with other introduced species such as *Bromus tectorum* and *B. japonicus*. Slightly further from the river, terrace vegetation was dominated by *Sporobolus airoides, Pascopyrum smithii,* and *Ambrosia psilostachya.* At the dune base, *Rhus* cover was low and herbs, such as *Erigeron bellidiastrum* and *Calamovilfa gigantea* had greater importance. The upland dunes were dominated by *Rhus aromatica* and *Artemisia filifolia* and were low in exotic species compared to the other communities.

Community Assembly

Phylogenetic diversity in each community was measured using the Net Relatedness Index (NRI) and Nearest Taxon Index (NTI) with Phylocom (Webb et al. 2008, Table 6. The NRI measures the mean phylogenetic distance (MPD) among all pairs of taxa in the community, whereas NTI quantifies the mean nearest taxon distance (MNTD), the distance between each taxon and its closest relative. Significance of the values of these indeces for each community (alpha=0.05) was assessed by comparing NTI and NRI values to a simulated distribution generated by 999 assemblages created by randomly drawing the same number of taxa from the species pool. If the NRI or NTI results were more extreme than 975 of the null runs, it would be considered equivalent to a 0.05 two-tailed p-value (Webb 2000). In practice, NTI is more sensitive to clustering and overdispersion at the tips of the phylogeny, while NRI reflects deeper evolutionary patterns (Freilich 2015). Significant clustering (positive NRI and NTI) is interpreted as indicating environmental filtering as the primary factor in community assembly, meaning that abiotic factors may have played a larger role, whereas overdispersion (negative NRI and NTI) indicate competitive exclusion.

Table 6 Interpretation of NRI and NTI results

INDEX	**NRI > 0**	**NRI < 0**
NTI > 0	Phylogenetic clustering: environmental filtering	More terminal clustering
NTI < 0	More deep-level clustering	Phylogenetic overdispersion: competitive exclusion

Results

Significant phylogenetic clustering of native species was found for the River Bottom (NTI = 1.5216, p = 0.0472) and River Terrace (NTI = 2.2043, p = 0.0071) communities (Table 7, Figure 7). Although NRI was also positive for these communities, the values were not significantly different from 0. These communities were also significantly clustered when native and introduced species were considered together (River Bottom NTI = 2.04, p = 0.0101; River Terrace NTI = 2.4062, p = 0.003). When considered alone, introduced species showed significant phylogenetic clustering at the Dune Base (NTI = 1.7234, p = 0.0406; NRI = 2.0351, p = 0.0428). However, these results should be interpreted with caution because only three introduced species were present in the Dune Base community, and non-random results are likely due to sampling bias. The Upland Dune community had only one introduced species, so community phylogenetic analyses could not be completed.

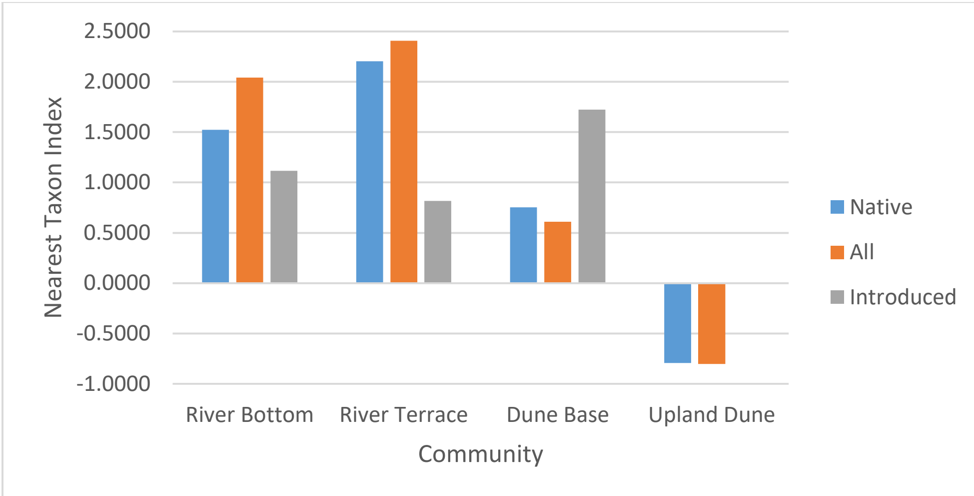
Table 7: Results of community assembly analyses for native, introduced, and all plant species. Significance ($p < 0.05$) is marked by a *. MPD = Mean Phylogenetic Distance, NRI = Net Relatedness Index, MNTD = Mean Nearest Taxon Distance, NTI = Nearest Taxon Index, SD = Standard Deviation.

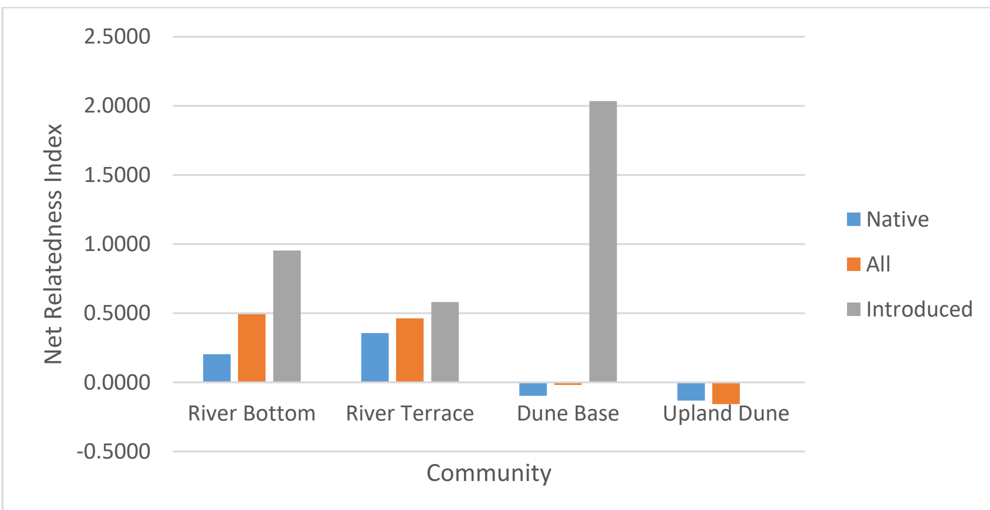
NATIVE	**Species**	**MPD**	**MPD SD**	**NRI**	**p-value**	**MNTD**	**MNTD SD**	**NTI**	**p-value**
River Bottom	42	246.34	13.42	0.2027	0.9286	69.00	11.62	1.5216	0.0472 *
River Terrace	60	245.24	10.96	0.3573	0.7224	58.24	9.20	2.2043	0.0071 *
Dune Base	52	250.23	12.16	-0.0982	0.5609	74.26	10.31	0.7532	0.2874
Upland Dune	39	251.14	14.48	-0.1329	0.4844	98.78	12.76	-0.7931	0.2425

EXOTIC	**Species**	**MPD**	**MPD SD**	**NRI**	**p-value**	**MNTD**	**MNTD SD**	**NTI**	**p-value**
River Bottom	9	227.28	14.82	0.9541	0.1507	76.67	27.04	1.1147	0.1314
River Terrace	11	234.30	12.45	0.5821	0.2646	78.41	22.08	0.8163	0.2703
Dune Base	3	124.67	56.27	2.0351	0.0428 *	81.33	65.75	1.7234	0.0406 *
Upland Dune	1	-	-	-	-	-	-	-	-

ALL	**Species**	**MPD**	**MPD SD**	**NRI**	**p-value**	**MNTD**	**MNTD SD**	**NTI**	**p-value**
River Bottom	51	244.42	11.23	0.4937	0.4713	59.15	10.74	2.04	0.0101*
River Terrace	71	245.36	9.59	0.4622	0.5609	53.51	8.47	2.4062	0.0030*
Dune Base	55	249.71	10.65	-0.0184	0.6377	72.90	10.17	0.6108	0.4051
Upland Dune	40	250.98	12.28	-0.1571	0.5136	95.47	12.14	-0.8002	0.2503

Figure 7: NTI and NRI for Beaver County communities. Statistically significant values are indexed > 1.5 or < -1.5.





Discussion

Contrary to my hypothesis, phylogenetic clustering of native and all species, rather than overdispersion, was supported for River Bottom and River Terrace communities when applying the Nearest Taxon Index. Significant phylogenetic clustering indicates the effect of environmental filtering on community assembly, which I erroneously assumed would be more present in the dunes, given the implicit status of water as a limiting factor in dryland ecology. I had not considered the possibility of other factors increasing the stress of riparian areas, such as drought and salinity. Thus, environmental filtering is inferred to be more important than competitive exclusion in wetter communities. Because the NTI is more sensitive to clustering at the tips of the phylogenetic tree than the NRI (Webb et al. 2002), this suggests that clustering is driven mostly by recently diverged taxa in the communities.

Within the context of phylogenetically-informed community assembly studies, assembly processes are fairly split in the global literature, with 55% support for environmental filtering and 45% for competitive exclusion within non-random assemblages latitudes (Götzenberger 2011). However, many more examples lack support for non-random assemblage, as only 29% of 9658 studies showed significant patterns of relatedness (Götzenberger 2011). When non-random assemblage occurred, the same study found a slight skew towards competitive exclusion at temperate latitudes (Götzenberger 2011). Great Plains and other arid grasslands studies also showed mixed support for assembly processes with some showing random assemblage (MacDougall 2008), but the majority finding competitive exclusion (Chesson 2004, Martin and Wilsey 2012, Fargione et al. 2003) rather than environmental filtering (O'Connell et al. 2013). Highly significant phylogenetic clustering in River Bottom and River Terrace communities and random assemblage of Dune Base and Upland Dune communities in Beaver county is consistent in a global context, with over half of community assembly studies finding random assemblage. The prevalence of support towards competitive exclusion in grassland studies compared to the environmental filtering found in Beaver County riparian communities is slightly surprising.

Several factors could explain the support for environmental filtering in the river bottom and terrace communities, including salinity, drought, and anthropogenic disturbance. Increasing salt concentration due to irrigation and climate-change induced evaporation is a threat to Great Plains hydrology (Covich et al. 1998). Salt detrimentally affects growth and survival of plants lacking appropriate adaptations (Peel 2004), including C_4 grasses like *Andropogon gerardii* and

Sorghastrum nutans (Schmer 2012). Halophilic plants like *Distichlis spicata* (desert saltgrass) and *Tamarix ramosissima* (saltcedar) were collected in river bottoms in Beaver County, supporting this idea.

Although the aridity of the western Great Plains means many plants are adapted for drought conditions (McGregor and Barkley 1986), direct human intervention like irrigation and climate change can exacerbate drought conditions. No-flow days for the Beaver River are increasing, and the average base flow decreased by 14% comparing the periods of 1978-1994 to pre-1971 (Wahl and Tortorelli 1997). Drought stress is present throughout the western Great Plains ecosystems (McGregor and Barkley 1986), but exacerbation in recent times would certainly affect the species present, such as loss of some aquatic species (Chapter 2), although it is not certain if this would drive clustering or overdispersion.

There was a lack of significant phylogenetic clustering or overdispersion for dune communities, in contrast to my prediction that clustering, indicative of environmental filtering, would be apparent in these water-limited communities. This could be because I overestimated the environmental filtering capabilities of sandy soil with low water retention. Communities with low competition increase the power of NTI, and bare ground accounted for a large proportion of vegetation cover in the dune communities (Fishbein unpublished data). Thus, lack of support for phylogenetic clustering in the dune communities cannot be attributed to low power.

Testing of the native vs introduced community phylogenetics in Beaver County met some difficulty. Although I could not directly calculate significance between the different native and exotic pools, there was a general trend for the inclusion of non-natives to increase the signal for clustering in wet areas. Contrary to my hypothesis, increased environmental filtering of introduced species supports the naturalization hypothesis of more success for more closely related organisms, due to their shared adaptations, in this case perhaps salinity tolerance. This is contradictory to many studies on the naturalization hypothesis, which generally find evidence for overdispersion of introduced species (Daehler 2001). Likely, my perception of the relatedness patterns of introduced species was influenced by the dominance of *Tamarix* in wet areas of Beaver County, a tree which has no native familial relatives. In dune communities, small sample size of introduced species affected the results of relatedness. Of the three introduced species in the Dune Base, two were in the family Amaranthaceae *(Kochia scoparia* and *Salsola tragus*), so their phylogenetic proximity would certainly influence results, resulting in the sampling bias that led me to discount the significance of their results. The only introduced species I found exclusively on dunes was *Eragrostis lehmanniana,* although this was not sampled in the community plots (Appendix 2).

My results may illustrate some of the criticisms of the phylogenetic approach to analyzing community assembly, such as abundance, scale, and rate of evolution (Elias 2009, Pavoine 2013, Gerhold 2015). However, both indexes are negatively affected when using occurrence over abundance metrics, like the presence/absence recorded in a flora versus counts of individuals/coverage. The relative size of the species pool can also present issues (Freilich 2015). Systems of low competition, too, increases the power of NTI, and the ample bare ground in Beaver communities could support that (Freilich 2015). Silvertown et al. (2005) found no significant phylogenetic patterns in alpha-niches in British meadows, specifically along hydrological gradients, drawing the conclusion that water availability is an evolutionarily labile filter. Although British meadows are a much more mesic environment, the discrepancy in results here show possible issues with the “phylogenetics as proxy for environmental filtering” model along hydrological gradients.

While the size of the Beaver County species pool compared to its communities falls within the standards of some studies (Swenson et al. 2006, Kraft et al. 2007), other studies state that too large of a pool can negatively affect statistical power, especially of NRI, which had no statistical support in my analysis (Kraft and Ackerly 2010). It has been recommended that community richness should be >30% of the pool (Freilich 2015). Functionally, however, a species pool consists of any organism able to disperse into a community, and different ecosystems would have different variability in ranges, like the many wind dispersed fruit of Asteraceae and Poaceae greatly represented in the plains. The lack of the model to account for dispersal mechanisms seems problematic. Conversely, the scale of communities measured may be too large, and fail to encapsulate direct competitive effects seen at smaller scales. Whether or not the models of community assembly based on phylogenetic pattern are reflective of plant evolution, phylogenetic patterns and characterization of communities in an understudied ecosystem are valuable sets of data (Gerhold et al. 2015).

CHAPTER IV

CONCLUSION

Through two years of field work, 1417 plant collections, 60 additions to the flora, and herbarium specimen study, I have documented much of the flora of Beaver County. A total of 497 species of vascular plants is within the 95% confidence interval of predicted species richness for an area this size in Great Plains floras. Largest families and native to introduced ratios also fall well within patterns documented by other floras. Vegetation types in which plants were found are also better described through this flora. This vascular plant checklist has potential to inform systematic study, biogeography, ecology, conservation, and land management, of an ecosystem under threat from climate change and continued anthropogenic disturbance.

The flora of Beaver County was used as a species pool to inform community assembly hypothesis testing in a hydrological gradient in the western Great Plains. Despite a rejection of the hypothesis that dunes would show habitat filtering through phylogenetic clustering, the wetter communities like the River Bottom and River Terrace communities showed significant support for habitat filtering. Other research shows increasing drought and salinity in Great Plains riparian systems, and the community assembly signal for abiotic stress may be explained by that. Community phylogenetic indexes could not illustrate significant differences between native and introduced members of communities, but there was a trend of increased phylogenetic clustering and habitat filtering when introduced species were included in analyses of wetter communities, supporting the naturalization hypotheses that more closely related invaders are can pass environmental filters of harsher abiotic systems. All of these community assembly conclusions can better inform biogeography, ecology and land management in the changing climates of the western Great Plains.

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APPENDICES

Appendix 1: Flora of Beaver County. Taxa are listed alphabetically by family and common names follow scientific names (ITIS, accessed 2019). Additions to the flora (county records) are in **bold**. Introduced species are indicated by a *. Two species have unknown origins: *Corispermum nitidum* ([1]) and *Phragmites australis* ([2]). Vegetation types where each species was found are reorded as shortgrass prairie (SGP), sandsage grassland (SSG), stabilized dune (SD), and bottomland (BL).

ACANTHACEAE
Justicia americana (L.) Vahl
American water-willow. BL

ADOXACEAE
Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli
Black elderberry. BL

ALISMATACEAE
Echinodorus berteroi (Spreng.) Fassett
Upright burrhead. BL

Sagittaria latifolia Willd.
Wapato. BL

Sagittaria longiloba Engelm. ex J.G. Sm.
Longlobe arrowhead. BL

Sagittaria montevidensis Cham. & Schltdl.
ssp. *calycina* (Engelm.) Bogin
Hooded arrowhead. BL

AMARANTHACEAE
Amaranthus albus L.
White pigweed*. SSG, SGP

Amaranthus arenicola I.M. Johnst.
Sandhill amaranth. SGP, SD, BL

Amaranthus blitoides S. Watson
Prostrate pigweed*. SSG, SGP, BL

Amaranthus palmeri S. Watson
Palmer's amaranth. SSG, SGP

Amaranthus retroflexus L.
Redroot pigweed. SSG, SGP

Amaranthus tuberculatus (Moq.) J.D. Sauer
Roughfruit amaranth. SSG, SGP, BL

Chenopodium album L.
Common lambsquarters. All

Chenopodium berlandieri Moq.
Pit-seed goosefoot. SSG, SGP

Chenopodium incanum (S. Watson) A. Heller
Mealy goosefoot. SSG, SGP, SD

Chenopodium pallescens Standl.
Light goosefoot. SSG, SGP

Chenopodium pratericola Rydb.
Desert goosefoot. All

Corispermum nitidum Kit. ex Schult.
Shiny bugseed[1]. SD

Cycloloma atriplicifolium (Spreng.) J.M. Coult.
Winged pigweed. SSG, SGP, SD

Froelichia floridana (Nutt.) Moq.
Plains snakecotton. SSG, SGP, SD

Gossypianthus lanuginosus (Poir.) Moq.
woolly cottonflower. SSG, SGP, SD

Kochia scoparia (L.) Schrad.
Common kochia*. All

Monolepis nuttalliana (Schult.) Greene
Nuttall's povertyweed. BL

Salsola tragus L.
Prickly Russian thistle*. All

Tidestromia lanuginosa (Nutt.) Standl.
Woolly tidestromia. SSG

AMARYLLIDACEAE
Allium canadense L.
Meadow onion. SSG, SGP

Allium drummondii Regel
Drummond's onion. SSG, SGP

ANACARDIACEAE
Rhus aromatica Aiton
Fragrant sumac. All

Toxicodendron radicans (L.) Kuntze
Poison ivy. BL

APIACEAE
Ammoselinum popei Torr. & A. Gray
Plains sandparsley. BL

Berula erecta (Huds.) Coville
Cutleaf waterparsnip. BL

Conium maculatum L.
Poison hemlock*. BL

Lomatium foeniculaceum (Nutt.) J.M. Coult. & Rose
Desert biscuitroot. SSP

APOCYNACEAE
Apocynum cannabinum L.
Hemp dogbane. SSG, SGP

Asclepias arenaria Torr.
Sand milkweed. SSG, SD, BL

Asclepias asperula (Decne.) Woodson
Antelopehorn milkweed. SSG, SGP

Asclepias engelmanniana Woodson
Engelmann's milkweed. SSG, SGP, BL

Asclepias latifolia (Torr.) Raf.
Broadleaf milkweed. SSG, SGP

Asclepias pumila (A. Gray) Vail
Plains milkweed. SSG, SGP, SD

Asclepias speciosa Torr.
Showy milkweed. SSG, SGP

Asclepias subverticillata (A. Gray) Vail
Whorled milkweed. BL

ARACEAE
Lemna minor L.
Lesser duckweed. BL

Lemna minuta Kunth
Least duckweed. BL

Lemna obscura (Austin) Daubs
Little duckweed. BL

Lemna valdiviana Phil.
Valdivia's duckweed. BL

Spirodela polyrrhiza (L.) Schleid.
Common duckmeat. BL

Wolffia columbiana H. Karst.
Columbian watermeal. BL

ASPARAGACEAE
Yucca glauca Nutt.
Great Plains yucca. SSG, SGP, SD

ASTERACEAE
Achillea millefolium L.
Yarrow. SGP

Ambrosia grayi (A. Nelson) Shinners
Woollyleaf bur ragweed. SGP

Ambrosia psilostachya DC.
Western ragweed. All

Ambrosia trifida L.
giant ragweed. BL

Amphiachyris dracunculoides (DC.) Nutt.
Prairie broomweed. SSG, BL

Artemisia carruthii Alph. Wood ex Carruth.
Carruth's sagebrush. SGP, SSG

Artemisia dracunculus L.
Tarragon. SSG

Artemisia filifolia Torr.
Sand sagebrush. SSG, SGP, SD

Artemisia ludoviciana Nutt.
ssp. *mexicana* (Willd. Ex Spreng.) D.D. Keck
Mexican White sagebrush. SSG

Baccharis salicina Torr. & A. Gray
Great Plains false willow. BL

Baccharis wrightii A. Gray
Wright's baccharis. SGP

Berlandiera lyrata Benth.
Lyreleaf greeneyes. SGP

Berlandiera texana DC.
Texas greeneyes. SSG

Bidens cernua L.
Nodding beggartick. BL

Bidens frondosa L.
Devil's beggartick. BL

Brickellia eupatorioides (L.) Shinners
var. *chlorolepis* (Woot. & Standl.) B.L. Turner
False boneset. SSG

Carduus nutans L.
Musk thistle*. SSG, SGP

Chaetopappa ericoides (Torr.) G.L. Nesom
Rose heath. SGP

Cirsium ochrocentrum A. Gray
Yellowspine thistle. SGP, SSG

Cirsium undulatum (Nutt.) Spreng.
Wavyleaf thistle. All

Cirsium vulgare (Savi) Ten.
Bull thistle*. BL

Conyza canadensis (L.) Cronquist
Canadian horseweed. All

Conyza ramosissima Cronquist
Dwarf horseweed. SSG

Coreopsis tinctoria Nutt.
Golden tickseed. SSG

Croptilon divaricatum (Nutt.) Raf.
Slender scratchdaisy. SSG

Croptilon hookerianum (Torr. & A. Gray) House
Hooker's scratchdaisy. SD

Cyclachaena xanthiifolia Fresen.
Giant sumpweed. BL

Diaperia verna DC.
Spring pygmycudweed. BL

Dyssodia papposa (Vent.) Hitchc.
Fetid marigold. SGP

Echinacea angustifolia DC.
Blacksamson echinacea. SSG, SGP

Engelmannia peristenia (Raf.) Goodman & C.A. Lawson
Engelmann's daisy. SSG, SGP, BL

Erigeron bellidiastrum Nutt.
Western fleabane. SSG, SD, BL

Erigeron divergens Torr. & A. Gray
Spreading fleabane. SSG, SGP

Erigeron flagellaris A. Gray
Trailing fleabane. SGP

Erigeron modestus A. Gray
Plains fleabane. SSG

Erigeron tenuis Torr. & A. Gray
Slenderleaf fleabane. SSG

Erigeron tracyi Greene
Running fleabane. SGP

Eupatorium perfoliatum L.
Common boneset. BL

Euthamia gymnospermoides Greene
Texas goldentop. SSG

Flaveria campestris J.R. Johnst.
Alkali yellowtops. BL

Gaillardia pinnatifida Torr.
Red dome blanketflower. SGP

Gaillardia pulchella Foug.
Indian blanketflower. SSG, SGP, SD

Gaillardia suavis (A. Gray & Engelm.) Britton & Rusby
Perfumeballs. SGP

Grindelia ciliata (Nutt.) Spreng.
Spanish gold. SSG, SGP

Grindelia squarrosa (Pursh) Dunal
Curlycup gumweed. SSG, SGP

Gutierrezia sarothrae (Pursh) Britton & Rusby
Broom snakeweed. SSG, SGP, SD

Gutierrezia sphaerocephala A. Gray
Roundleaf snakeweed. SSG, SD

Helianthus annuus L.
Common sunflower. All

Helianthus ciliaris DC.
Texas blueweed. SGP

Helianthus maximiliani Schrad.
Maximilian sunflower. SSG, BL

Helianthus petiolaris Nutt.
Sand sunflower. All

Heterotheca stenophylla (A. Gray) Shinners var. *stenophylla*
Stiffleaf false goldenaster. SSG, SGP

Heterotheca stenophylla (A. Gray) Shinners var. *angustifolia* (Rydb.) Semple.
Stiffleaf goldenaster. SSG

Heterotheca subaxillaris (Lam.) Britton & Rusby
ssp. *latifolia* (Buckley) Gandhi & R.D. Thomas
Camphorweed. SSG, SD, BL

Heterotheca villosa (Pursh) Shinners
Hairy false goldenaster. SGP

Hymenopappus flavescens A. Gray
Yellow woolywhite. SGP

Hymenopappus tenuifolius Pursh
Chalk Hill woolywhite. SSG

Hymenoxys odorata DC.
Bitter rubberweed. SGP

Iva annua L.
Annual marshelder. BL

Lactuca serriola L.
Prickly lettuce*. SSG

Liatris punctata Hook.
Dotted blazing star. SSG, SGP

Liatris squarrosa (L.) Michx.
Scaly blazing star. SGP

Lorandersonia baileyi (Wooton & Standl.) Urbatsch, R.P. Roberts & Neubig
Bailey's rabbitbrush. SD

Lygodesmia juncea (Pursh) D. Don ex Hook.
Rush skeletonplant. SSG, SGP

Machaeranthera tanacetifolia (Kunth) Nees
Tanseyleaf tansyaster. SSG, SGP

Melampodium leucanthum Torr. & A. Gray
Plains blacksfoot. SSG, SGP, SD

Nothocalais cuspidata (Pursh) Greene
Sharppoint prairie-dandelion. SGP

Palafoxia sphacelata (Nutt. ex Torr.) Cory
Othake. SSG, SD

Palafoxia texana DC.
Texas palafox. SD

Picradeniopsis woodhousei (A. Gray) Rydb.
Woodhouse's bahia. SGP

Pluchea odorata (L.) Cass.
Sweetscent. SD, BL

Psilostrophe villosa Rydb.
Woolly paperflower. SSG, SGP, BL

Pyrrhopappus grandiflorus (Nutt.) Nutt.
Tuberous desert-chicory. SGP, BL

Ratibida columnifera (Nutt.) Woot. & Standl.
Prairie coneflower. SSG, SGP

Ratibida tagetes (James) Barnhart
Green prairie coneflower. SSG, BL

Rudbeckia hirta L.
blackeyed Susan. SGP

Scorzonera laciniata L.
Cutleaf vipergrass*. SGP

Senecio riddellii Torr. & A. Gray
Riddell's groundsel. SGP, BL

Shinnersoseris rostrata (A. Gray) S. Tomb
Beaked skeletonweed. SSG, SD

Silphium laciniatum L.
Compassplant. SGP

Solidago canadensis L.
var. *canadensis*
Canada goldenrod. SSG, BL

Solidago gigantea Aiton
Giant goldenrod. SSG

Solidago missouriensis Nutt.
Missouri goldenrod. All

Solidago mollis Bartlett
Ashy goldenrod. SGP

Sonchus asper (L.) Hill
Prickly sowthistle*. BL

Symphyotrichum subulatum (Michx.) G.L. Nesom
Eastern annual saltmarsh aster. BL

Symphyotrichum ericoides (L.) G.L. Nesom
White heath aster. BL

Taraxacum officinale F.H. Wigg.
Common dandelion*. SGP

Tetraneuris acaulis (Pursh) Greene
Stemless four-nerve daisy. SSG, SGP

Tetraneuris scaposa (DC.) Greene
Stemmy four-nerve daisy. SGP

Thelesperma megapotamicum (Spreng.) Kuntze
Hopi tea greenthread. SSG, SD

Townsendia exscapa (Richardson) Porter
Stemless Townsend daisy. SGP

Tragopogon dubius Scop.
Yellow salsify*. SSG, SGP

Vernonia baldwinii Torr.
Interior ironweed. SSG, BL

Vernonia marginata (Torr.) Raf.
Plains ironweed. SGP, BL

Xanthisma spinulosum (Pursh) D.R. Morgan & R.L. Hartm. var. *spinulosum*
Lacy tansyaster. SSG, SGP

Xanthium strumarium L.
Rough cocklebur. SSG, SGP, BL

Zinnia grandiflora Nutt.
Plains zinnia. SSG, SGP

BIGNONIACEAE
Catalpa bignonioides Walter
Southern catalpa. BL

BORAGINACEAE
Cryptantha cinerea (Greene) Cronquist var. *jamesii* (Torr.) Cronquist
Bownut cryptantha. SSG, SD, BL

Cryptantha minima Rydb.
Little cryptantha. All

Lappula occidentalis (S. Watson) Greene var. *occidentalis*
Flatspine stickseed. SGP, SD, BL

Lappula occidentalis (S. Watson) Greene var. *cuppulata* (A. Gray) Higgins
Flatspine stickseed. SSG

Lithospermum incisum Lehm.
Fringed gromwell. SSG, SGP

BRASSICACEAE
Camelina microcarpa DC.
Littlepod falseflax*. SSG

Capsella bursa-pastoris (L.) Medik.
Shepherdspurse*. SGP, BL

Chorispora tenella (Pall.) DC.
Purple mustard*. SSG

Descurainia pinnata (Walter) Britton
Green tansymustard. All

Descurainia sophia (L.) Webb ex Prantl
Flaxweed tansymustard*. SSG, SGP, BL

Dimorphocarpa candicans (Raf.) Rollins
Palmer's spectaclepod. SD

Draba reptans (Lam.) Fernald
Carolina draba. SSG

Erysimum asperum (Nutt.) DC.
Western wallflower. SGP

Erysimum capitatum (Douglas ex Hook.) Greene
Sand dune wallflower. SGP

Erysimum repandum L.
Spreading wallflower*. SGP

Lepidium densiflorum Schrad.
Miner's pepperweed. SSG, SGP, SD

Lepidium oblongum Small
Veiny pepperweed. SSG, SGP

Nasturtium officinale W.T. Aiton
Watercress*. BL

Physaria gordonii (A. Gray) O'Kane & Al-Shehbaz
Gordon's bladderpod. SSG, SGP

Physaria ovalifolia (Rydb.) O'Kane & Al-Shehbaz
Roundleaf bladderpod. SGP

Rorippa sinuata (Nutt.) Hitchc.
Spreading yellowcress. SSG, SGP, BL

Sisymbrium altissimum L.
Tumblemustard*. SSG

CACTACEAE
Cylindropuntia imbricata (Haw.) F.M. Knuth
Tree cholla. SGP

Escobaria vivipara (Nutt.) Buxb.
Spinystar. SSG, SGP

Opuntia macrorhiza Engelm.
Twistspine pricklypear. All

CAMPANULACEAE
Lobelia cardinalis L.
cardinalflower. BL

Triodanis holzingeri McVaugh
Western Venus' lookingglass. SD

CANNABACEAE
Cannabis sativa L.
Hemp*. SGP

Celtis reticulata Torr.
Netleaf hackberry. All

CARYOPHYLLACEAE
Minuartia michauxii (Fenzl) Farw.
Michaux's stitchwort. SGP

Paronychia jamesii Torr. & A. Gray
James' nailwort. SSG, SGP, SD

Silene antirrhina L.
Sleepy catchfly. SD

CERATOPHYLLACEAE
Ceratophyllum demersum L.
Common hornwort. BL

CLEOMACEAE
Peritoma serrulata (Pursh) DC.
Rocky Mountain beeplant. BL

Polanisia dodecandra (L.) DC.
Redwhisker clammyweed. All

Polanisia jamesii (Torr. & A. Gray) Iltis
James' clammyweed. SD

COMMELINACEAE
Commelina erecta L.
Erect dayflower. All

Tradescantia occidentalis (Britton) Smyth
Prairie spiderwort. SD, BL

CONVOLVULACEAE
Convolvulus arvensis L.
Field bindweed*. SSG, SGP

Convolvulus equitans Benth.
Texas bindweed. SSG

Cuscuta cuspidata Engelm.
Cusp dodder. SSG, SGP

Evolvulus nuttallianus Schult.
shaggy dwarf morningglory. SSG

Ipomoea leptophylla Torr.
Bush morningglory. SSG

CORNACEAE
Cornus drummondii C.A. Mey.
Roughleaf dogwood. BL

CUCURBITACEAE
Cucurbita foetidissima Kunth
Buffalo gourd. SSD, SGP, SD

CUPRESSACEAE
Juniperus virginiana L.
Eastern redcedar. SGP

CYPERACEAE
Bolboschoenus maritimus (L.) Palla
ssp. *paludosus* (A. Nelson) T. Koyama
Cosmopolitan bulrush. BL

Carex gravida L.H. Bailey
Heavy sedge. SGP, BL

Carex pellita Muhl. ex Willd.
Woolly sedge. BL

Cyperus acuminatus Torr. & Hook. ex Torr.
Taperleaf flatsedge. BL

Cyperus bipartitus Torr.
Slender flatsedge. BL

Cyperus lupulinus (Spreng.) Marcks
Great Plains flatsedge. SSG

Cyperus odoratus L.
Fragrant flatsedge. BL

Cyperus rotundus L.
Purple nutsedge*. SGP

Cyperus schweinitzii Torr.
Sand flatsedge. SD, BL

Cyperus squarrosus L.
Bearded flatsedge. SGP

Cyperus strigosus L.
Strawcolored flatsedge. BL

Eleocharis erythropoda Steud.
Bald spikerush. BL

Eleocharis macrostachya Britton
Pale spikerush. SGP, BL

Eleocharis montevidensis Kunth
Sand spikerush. BL

Eleocharis parvula (Roem. & Schult.) Link ex Bluff, Nees & Schauer
Dwarf spikerush. BL

Fuirena simplex Vahl
Western umbrellasedge. BL

Schoenoplectus americanus (Pers.) Volkart ex Schinz & R. Keller
Chairmaker's bulrush. BL

Schoenoplectus pungens (Vahl) Palla
Common threesquare. BL

Schoenoplectus saximontanus (Fernald) J. Raynal
Rocky Mountain bulrush. SGP

ELAEAGNACEAE
Elaeagnus angustifolia L.
Russian olive*. SSG, SGP, BL

ELATINACEAE
Bergia texana (Hook.) Seub. ex Walp.
Texas bergia. SGP

EQUISETACEAE
Equisetum hyemale L.
Horsetail. BL

Equisetum laevigatum A. Br.
Smooth scouringrush. BL

EUPHORBIACEAE
Acalypha ostryifolia Riddell
Hophornbeam copperleaf. BL

Croton texensis (Klotzsch) Mull. Arg.
Texas croton. All

Ditaxis mercurialina (Nutt.) J.M. Coult.
Tall silverbush. SGP, BL

Euphorbia corollata L.
Flowering spurge. SSG

Euphorbia davidii Subils
David's spurge. SSG, SGP, BL

Euphorbia dentata Michx.
Toothed spurge. SSG, BL

Euphorbia fendleri Torr. & A. Gray
Fendler's sandmat. SSG, SGP, BL

Euphorbia geyeri Engelm.
Geyer's sandmat. BL

Euphorbia glyptosperma Engelm.
Ribseed sandmat. All

Euphorbia hexagona Nutt. ex Spreng.
Sixangle spurge. SSG

Euphorbia lata Engelm.
Hoary sandmat. SSG, SGP

Euphorbia maculata L.
Prostrate spurge. SSG

Euphorbia marginata Pursh
Snow-on-the-mountain. SSG, SGP, BL

Euphorbia missurica Raf.
Prairie sandmat. All

Euphorbia nutans Lag.
Eyebane. BL

Euphorbia prostrata Aiton
Prostrate sandmat. SSG, SGP, BL

Euphorbia serpens Kunth
Matted sandmat. SGP, BL

Euphorbia spathulata Lam.
Roughpod spurge. SSG, SGP, BL

Euphorbia stictospora Engelm.
Slimseed sandmat. SGP

Stillingia sylvatica L.
Queen's-delight. SSG, SD

FABACEAE
Amorpha fruticosa L.
Desert false indigo. BL

Astragalus gilviflorus E. Sheld.
Plains milkvetch. SGP

Astragalus gracilis Nutt.
Slender milkvetch. SSG, SGP

Astragalus lotiflorus Hook.
Lotus milkvetch. SSG, SGP

Astragalus missouriensis Nutt.
Missouri milkvetch. SSG, SGP

Astragalus mollissimus Torr.
Woolly milkvetch. SSG, SGP

Astragalus racemosus Pursh
Cream milkvetch. SSG

Chamaecrista fasciculata (Michx.) Greene
Partridge pea. SSG

Dalea aurea Nutt. ex Fraser
Golden prairie clover. SSG, SGP

Dalea candida Michx. ex Willd.
var. *oligophylla* (Torr.) Shinners
White prairie clover. SSG, SGP

Dalea enneandra Nutt. ex Fraser
Nineanther prairie clover. SSG, SGP, SD

Dalea lanata Spreng.
Woolly prairie clover. SSG, SD, BL

Dalea nana Torr. ex A. Gray
Dwarf prairie clover. SSG, SD

Dalea purpurea Vent.
var. *arenicola* (Wemple) Barneby
Purple prairie clover. SSG, SGP

Dalea tenuifolia (A. Gray) Shinners
Slimleaf prairie clover. SGP

Dalea villosa (Nutt.) Spreng.
Silky prairie clover. SSG, SD

Desmanthus illinoensis (Michx.) MacMill. ex B.L. Rob. & Fernald
Illinois bundleflower. SSG

Gleditsia triacanthos L.
Honeylocust. SSG, SGP, BL

Glycyrrhiza lepidota Pursh
American licorice. All

Hoffmannseggia glauca (Ortega) Eifert
Hog potato. SGP

Indigofera miniata Ortega
Coastal indigo. SD, BL

Lathyrus polymorphus Nutt.
Manystem pea. SSG, SGP

Medicago sativa L.
Alfalfa*. BL

Melilotus albus Medik.
White sweet-clover*. SSG, SGP

Melilotus officinalis (L.) Lam.
Yellow sweet-clover*. SGP

Mimosa borealis A. Gray
Fragrant mimosa. SSG, SGP, SD

Oxytropis lambertii Pursh
Purple locoweed. SSG, SGP

Oxytropis sericea Nutt.
White locoweed. SSG, SGP

Pediomelum cuspidatum (Pursh) Rydb.
Largebract Indian breadroot. SSG, SGP
Pediomelum digitatum (Nutt. ex Torr. & A. Gray) Isely
Palmleaf Indian breadroot. SSG

Pediomelum hypogaeum (Nutt.) Rydb.
Subterranean Indian breadroot. SSG

Pediomelum linearifolium (Torr. & A. Gray) J.W. Grimes
Narrowleaf Indian breadroot. SSG, SGP, SD

Pomaria jamesii (Torr. & A. Gray) Walp.
James' holdback. SSG

Psoralidium lanceolatum (Pursh) Rydb.
Lemon scurfpea. SSG, SD

Psoralidium tenuiflorum (Pursh) Rydb.
Slimflower scurfpea. SSG, SGP

Robinia pseudoacacia L.
Black locust. SGP, BL

Sophora nuttalliana B.L. Turner
Silky sophora. SSG, SGP
Strophostyles leiosperma (Torr. & A. Gray) Piper
Slicksleed fuzzybean. BL

Vicia americana Muhl. ex Willd.
American purple vetch. SGP

Vicia villosa Roth
Hairy vetch*. SGP

GENTIANACEAE
Eustoma exaltatum (L.) Salisb. ex G. Don
Showy prairie gentian. BL

GERANIACEAE
Erodium cicutarium (L.) L'Her. ex Aiton
Redstem stork's bill*. SGP

GROSSULARIACEAE
Ribes aureum Pursh
var. *villosum* DC.
Golden currant. All

HELIOTROPIACEAE
Euploca convolvulacea Nutt.
Bindweed heliotrope. SSG, SD, BL

HYDROCHARITACEAE
Najas guadalupensis (Spreng.) Magnus
Southern naiad. BL

HYDROPHYLLACEAE
Ellisia nyctelea (L.) L.
Aunt Lucy. BL

JUGLANDACEAE
Juglans microcarpa Berland.
Little walnut. BL

*Juglans n*igra L.
Black walnut. BL

JUNCACEAE
Juncus scirpoides Lam.
Needlepod rush. BL

Juncus torreyi Coville
Torrey rush. BL

KRAMERIACEAE
Krameria lanceolata Torr.
Trailing ratany. SSG, SGP

LAMIACEAE
Hedeoma hispida Pursh
Rough false pennyroyal. SGP

Lamium amplexicaule L.
Common henbit*. SGP, BL

Lycopus americanus Muhl. ex W.P.C. Bartram
American waterhorehound. SSG, BL

*Marrubium v*ulgare L.
White horehound*. SGP, BL

Monarda citriodora Cerv. ex Lag.
Lemon beebalm. SGP

Monarda pectinata Nutt.
Plains beebalm. SGP

Monarda punctata L.
var. *occidentalis* (Epling) E.J. Palmer & Steyerm. Spotted beebalm. All

*Salvia a*zurea Michx. ex Lam.
Blue sage. SGP

Salvia reflexa Hornem.
lance-leaf sage. SGP, BL

Scutellaria resinosa Torr.
Sticky skullcap. SSG, SGP

LINACEAE
Linum berlandieri Hook.
Berlandier's yellow flax. SSG

Linum lewisii Pursh
Lewis' blue flax. SGP

Linum pratense (Norton) Small
Blue flax. SGP

Linum rigidum Pursh
Stiffstem flax. SSG, SGP, BL

LOASACEAE
*Mentzelia n*uda (Pursh) Torr. & A. Gray
Bractless blazingstar. SSG, SGP, SD

Mentzelia oligosperma Nutt. ex Sims
Chickthief. SGP

LYTHRACEAE
Ammannia coccinea Rottb.
Purple ammannia. BL

Lythrum alatum Pursh
Wing-angle loosestrife. SGP, BL

MALVACEAE
Callirhoe involucrata (Torr. & A. Gray) A. Gray var. *involucrata*
Purple poppymallow. SSG, SGP, BL

Malvastrum hispidum (Pursh) Hochr.
Hispid false mallow. SGP

Sphaeralcea coccinea (Nutt.) Rydb. ssp. *coccinea* Scarlet globemallow. SSG, SGP, BL

MARTYNIACEAE
Proboscidea louisianica (Mill.) Thell.
Devil's claw. SSG, SGP

MOLLUGINACEAE
Mollugo verticillata L.
Carpetweed. SSG, SGP, BL

MORACEAE
Maclura pomifera (Raf.) C.K. Schneid.
Osage orange. BL

Morus alba L.
White mulberry*. SSG, BL

NYCTAGINACEAE
Mirabilis glabra (S. Watson) Standl.
Smooth four-o'clock. SSG, SD

Mirabilis linearis (Pursh) Heimerl var. *linearis*
Narrowleaf four-o'clock. SGP, SSG, SD

Mirabilis nyctaginea (Michx.) MacMill.
Heart-leaved four-o'clock. SGP

ONAGRACEAE
*Ludwigia p*alustris (L.) Elliott
Marsh primrose-willow. BL

Ludwigia repens J.R. Forst.
Creeping primrose-willow. BL

Oenothera albicaulis Pursh
Whitest evening primrose. SGP

Oenothera capillifolia (Spach) Steud. ssp. *berlandieri* (Spach) W.L. Wagner & Hoch comb. nov.
Berlandier's sundrops. SSG, SGP

Oenothera canescens Torr. & Frem.
Spotted evening primrose. SGP

Oenothera cinerea (Wooton & Standl.) W.L. Wagner & Hoch
Woolly beeblossom. All

Oenothera curtiflora W.L. Wagner & Hoch
Velvetleaf gaura. SSG, SGP, BL

Oenothera glaucifolia W.L. Wagner & Hoch
False gaura. SSG, SGP

Oenothera grandis (Britton) Smyth
Showy evening primrose. SSG, SGP

Oenothera hartwegii Benth.
Hartweg's sundrops. SSG, SGP

Oenothera jamesii Torr. & A. Gray
James' evening primrose. BL

Oenothera laciniata Hill
Cutleaf evening primrose. SSG, SGP

Oenothera lavandulifolia Torr. & A. Gray
Lavenderleaf sundrops. SSG, SGP

Oenothera macrocarpa Nutt.
Bigfruit evening primrose. SGP

Oenothera pallida Lindl.
Pale evening primrose. SSG, SD

Oenothera serrulata Nutt.
Yellow sundrops. SSG, SGP

Oenothera suffrutescens (Ser.) W.L. Wagner & Hoch
Scarlet beeblossom. SSG, SGP, SD

OROBANCHACEAE
Agalinis tenuifolia (Vahl) Raf.
Slenderleaf false foxglove. SSG

Castilleja purpurea (Nutt.) G. Don var. *citrina* (Pennell) Shinners
Citron paintbrush. SSG, SGP

Orobanche ludoviciana Nutt.
Louisiana broomrape. SSG, SGP

OXALIDACEAE
Oxalis corniculata L.
Yellow wood sorrel. SSG

PAPAVERACEAE
Argemone polyanthemos (Fedde) G.B. Ownbey
Bluestem prickly poppy. SSG, SGP

Argemone squarrosa Greene
Hedgehog prickly poppy. SGP

Corydalis aurea Willd.
Scrambled eggs. SSG, BL

PHRYMACEAE
Mimulus glabratus Kunth
Roundleaf monkeyflower. BL

PHYTOLACCACEAE
Phytolacca americana L.
Pokeweed. SSG

PLANTAGINACEAE
Nuttallanthus canadensis (L.) D.A. Sutton
Canada toadflax. SSG

Penstemon albidus Nutt.
White penstemon. SSG, SGP

Penstemon buckleyi Pennell
Buckley's penstemon. SSG, SD

Penstemon fendleri Torr. & A. Gray
Fendler's penstemon. SGP

Plantago major L.
Broadleaf plantain*. BL

Plantago patagonica Jacq.
Woolly plantain. All

Plantago rhodosperma Decne.
Redseed plantain. SSG, SGP, BL

Veronica polita Fr.
Gray field speedwell*. BL

Veronica anagallis-aquatica L.
Water speedwell. BL

Veronica peregrina L.
Purslane speedwell. SGP

POACEAE
Aegilops cylindrica Host
Jointed goat grass*. SGP

Andropogon gerardii Vitman ssp. *gerardii*
Big bluestem. All

Andropogon gerardii Vitman ssp. *hallii* (Hack.) Wipff
Sand bluestem. All

Aristida adscensionis L.
Sixweeks threeawn. SGP

Aristida purpurea Nutt. var. *purpurea*
Purple threeawn. All

Aristida purpurea Nutt. var. *longiseta* (Steud.)
Fendler threeawn. SGP

Bothriochloa bladhii (Retz.) S.T. Blake
Caucasian bluestem*. SGP

Bothriochloa ischaemum (L.) Keng
Yellow bluestem*. SSG, SGP

Bothriochloa laguroides (DC.) Herter
var. *torreyana* (Steud.)
Silver beardgrass. SSG, SGP

Bouteloua curtipendula (Michx.) Torr.
Sideoats grama. All

Bouteloua dactyloides (Nutt.) Columbus
Buffalograss. SSG, SGP

Bouteloua gracilis (Kunth) Lag. ex Griffiths
Blue grama. SSG, SGP, SD

Bouteloua hirsuta Lag.
Hairy grama. SSG, SGP, SD

Bromus catharticus Vahl
Rescue grass*. SSG, SGP

Bromus inermis Leyss.
Smooth brome*. SGP

Bromus japonicus Thunb. ex Murray
Japanese brome*. SSG, BL

Bromus tectorum L.
Cheatgrass*. All

Calamovilfa gigantea (Nutt.) Scribn. & Merr.
Giant sandreed. SSG, SD

Cenchrus incertus M.A. Curtis
Field sandbur. All

Cenchrus longispinus (Hack.) Fernald
Longspine sandbur. SGP, SD, BL

Chloris verticillata Nutt.
Tumble windmill grass. All

Chloris virgata Sw.
Feather windmill grass. SGP

Cynodon dactylon (L.) Pers.
Common bermudagrass*. BL

Digitaria cognata (Schult.) Pilg.
Carolina crabgrass. BL

Digitaria pubiflora (Vasey) Wipff
Carolina crabgrass. BL

Digitaria sanguinalis (L.) Scop.
Purple crabgrass. SSG

Distichlis spicata (L.) Greene
Desert saltgrass. BL

Echinochloa crus-galli (L.) P. Beauv.
Barnyardgrass*. SSG, SGP, BL

Echinochloa muricata (P. Beauv.) Fernald
Rough barnyardgrass. SSG, SGP, BL

Eleusine indica (L.) Gaertn.
Crowsfoot grass*. SSG

Elymus canadensis L.
Canada wildrye. SSG, SD, BL

Elymus elymoides (Raf.) Swezey
Bottlebrush squirreltail. SSG

Elymus virginicus L.
Virginia wildrye. SGP

Eragrostis barrelieri Daveau
Mediterranean lovegrass*. SSG

Eragrostis cilianensis (Bellardi) Vignolo ex Janch.
Candy grass*. All

Eragrostis curtipedicellata Buckley
Gummy lovegrass. SSG, SGP, BL

Eragrostis lehmanniana Nees
Lehmann's lovegrass*. SD

Eragrostis pectinacea (Michx.) Nees
Tufted lovegrass. SGP

Eragrostis secundiflora J. Presl
Red lovegrass. SSG, SGP, BL

Eragrostis sessilispica Buckley
Tumble lovegrass. SSG

Eragrostis spectabilis (Pursh) Steud.
Purple lovegrass. SSG

Eragrostis trichodes (Nutt.) Alph. Wood
Sand lovegrass. SSG, SD

Erioneuron pilosum (Buckley) Nash
Hairy woollygrass. SGP, SD

Hesperostipa comata (Trin. & Rupr.) Barkworth
Needle and thread. SSG, SGP, SD

Hopia obtusa (Kunth) Zuloaga & Morrone
Vine mesquite. All

Hordeum jubatum L.
Foxtail barley. SSG, BL

Hordeum pusillum Nutt.
Little barley. SSG

Hordeum vulgare L.
Common barley*. SSG

Leersia oryzoides (L.) Sw.
Rice cutgrass. BL

Muhlenbergia arenicola Buckley
Sand muhly. SGP, BL

Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi
Alkali muhly. BL

Muhlenbergia multiflora Columbus
Blowout grass. SSG

Muhlenbergia paniculata (Nutt.) Columbus
Tumblegrass. SSG, SGP, BL

Muhlenbergia racemosa (Michx.) Britton, Sterns & Poggenb.
Marsh muhly. BL

Munroa squarrosa (Nutt.) Torr.
False buffalograss. SSG, SD

Panicum capillare L.
Annual witchgrass. All

Panicum virgatum L.
Switchgrass. All

Pascopyrum smithii (Rydb.) Barkworth & D.R. Dewey
Western wheatgrass. SSG, SGP, BL

Paspalum setaceum Michx.
Sand paspalum. SSG, SD, BL

Phragmites australis (Cav.) Trin. ex Steud.
Common reed[2]. BL

Poa arachnifera Torr.
Texas bluegrass. BL

Poa arida Vasey
Plains bluegrass. SGP, BL

Poa pratensis L.
Kentucky bluegrass*. BL

Polypogon monspeliensis (L.) Desf.
Rabbitfoot grass*. SGP, BL

Schizachyrium scoparium (Michx.) Nash
Little bluestem. SGP, SSG

Secale cereale L.
Common rye*. SSG

Setaria parviflora (Poir.) Kerguelen
Knotroot bristlegrass. SSG, SGP, BL

Setaria pumila (Poir.) Roem. & Schult.
Yellow bristlegrass*. SSG, SGP, BL

Sorghastrum nutans (L.) Nash
Indiangrass. SSG, SGP

Sorghum bicolor (L.) Moench
Broomcorn*. BL

Sorghum halepense (L.) Pers.
Johnsongrass*. SGP

Spartina pectinata Link
Prairie cordgrass. SSG, SD, BL

Sphenopholis obtusata (Michx.) Scribn.
Prairie wedgegrass. SSG

Sporobolus airoides (Torr.) Torr.
Alkali sacaton. All

Sporobolus compositus (Poir.) Merr.
Composite dropseed. SSG, BL

Sporobolus cryptandrus (Torr.) A. Gray
Sand dropseed. All

Sporobolus giganteus Nash
Giant dropseed. SSG, SD

Sporobolus pyramidatus (Lam.) Hitchc.
Whorled dropseed. SSG

Tridens albescens (Vasey) Wooton & Standl.
White tridens. SSG, SGP, BL

Tridens flavus (L.) Hitchc.
Purpletop tridens. BL

Triplasis purpurea (Walter) Chapm.
Purple sandgrass. SSG, BL

Tripsacum dactyloides (L.) L.
Eastern gamagrass. SSG, SGP, BL

Triticum aestivum L.
Wheat*. SGP

Vulpia octoflora (Walter) Rydb.
Pullout grass. SSG

POLEMONIACEAE
Giliastrum rigidulum (Benth.) Rydb.
Bluebowls. SGP

Ipomopsis longiflora (Torr.) V.E. Grant
White-flower skyrocket. SSG, SD

POLYGALACEAE
Polygala alba Nutt.
White milkwort. SSG, SGP

POLYGONACEAE
Eriogonum annuum Nutt.
Annual buckwheat. All

Eriogonum lachnogynum Torr. ex Benth.
Woollycup buckwheat. SGP

Eriogonum longifolium Nutt.
Longleaf buckwheat. SSG, SGP

Persicaria bicornis (Raf.) Nieuwl.
Pink smartweed. SSG, SGP

Persicaria lapathifolia (L.) Gray
Curlytop knotweed. SGP, BL

Persicaria pensylvanica (L.) M. Gomez
Pennsylvania smartweed. SGP, BL

Polygonum aviculare L.
Prostrate knotweed. SSG, SGP

Polygonum ramosissimum Michx.
Yellow-flower knotweed. SGP

Rumex altissimus Alph. Wood
Smooth dock. SSG, SGP, BL

Rumex patientia L.
Patience dock*. SSG

PONTEDERIACEAE
Heteranthera limosa (Sw.) Willd.
Blue mudplantain. SSG

PORTULACACEAE
Portulaca pilosa L.
Kiss-me-quick. SSG, SGP, BL

Portulaca oleracea L.
Common purslane*. SSG, SGP, BL

POTAMOGETONACEAE
Potamogeton nodosus Poir.
Longleaf pondweed. BL

Potamogeton pusillus L.
Small pondweed. BL

Stuckenia pectinata (L.) Borner
Broadleaf pondweed. BL

Zannichellia palustris L.
Horned pondweed. BL

PRIMULACEAE
Androsace occidentalis Pursh
Western rockjasmine. SGP

Samolus valerandi L.
Seaside brookweed. BL

RANUNCULACEAE
Consolida ajacis (L.) Schur
Rocket larkspur*. SGP

Delphinium carolinianum Walter
ssp. *virescens* (Nutt.) R.E. Brooks
Carolina larkspur. SSG, SGP

Myosurus minimus L.
Tiny mousetail. BL

Ranunculus cymbalaria Pursh
Alkali buttercup. BL

Ranunculus sceleratus L.
Cursed buttercup. BL

ROSACEAE
Potentilla rivalis Nutt.
Brook cinquefoil. BL

Prunus angustifolia Marshall
Sand plum. All

Rosa woodsii Lindl.
Woods' rose. BL

RUBIACEAE
Cephalanthus occidentalis L.
Buttonbush. BL

Stenaria nigricans (Lam.) Terrell
Diamondflowers. SGP

RUPPIACEAE
Ruppia cirrhosa (Petagna) Grande
Spiral ditchgrass. BL

SALICACEAE
Populus deltoides W. Bartram ex Marshall
Plains cottonwood. All

Salix amygdaloides Andersson
Peachleaf willow. BL

Salix exigua Nutt.
Sandbar willow. SD, BL

Salix nigra Marshall
Black willow. BL

SANTALACEAE
Comandra umbellata (L.) Nutt.
Bastard toadflax. SGP

SAPINDACEAE
Acer negundo L.
Boxelder. BL

Sapindus saponaria L.
Soapberry. BL

SCROPHULARIACEAE
Verbascum thapsus L.
Common mullein*. SGP

SOLANACEAE
Chamaesaracha coniodes (Moric. ex Dunal) Britton
Gray five eyes. All

Datura wrightii Regel
Sacred thorn-apple. SGP

Datura stramonium L.
Jimsonweed*. SGP

Physalis hederifolia A. Gray
Ivyleaf groundcherry. SGP

Physalis hispida (Waterf.) Cronquist
Prairie groundcherry. All

Quincula lobata (Torr.) Raf.
Purple groundcherry. SSG, SGP

Solanum elaeagnifolium Cav.
Silverleaf nightshade. All

Solanum ptychanthum Dunal
Black nightshade. SSG, SGP, BL

Solanum rostratum Dunal
Buffalobur nightshade. SSG, SGP, BL

Solanum triflorum Nutt.
Cutleaf nightshade. SSG

TAMARICACEAE
Tamarix gallica L.
Saltcedar*. BL

Tamarix ramosissima Ledeb.
Saltcedar*. SD, BL

TYPHACEAE
Typha domingensis Pers.
Southern cattail. BL

Typha latifolia L.
Common cattail. BL

ULMACEAE
Ulmus americana L.
American elm. BL

Ulmus pumila L.
Siberian elm*. All

Ulmus rubra Muhl.
Slippery elm. BL

VERBENACEAE
Glandularia bipinnatifida (Nutt.) Nutt.
Dakota mock vervain. SSG

Phyla cuneifolia (Torr.) Greene
Wedgeleaf fogfruit. SGP, SSG, BL

Phyla lanceolata (Michx.) Greene
Lanceleaf fogfruit. BL

Verbena bracteata Cav. ex Lag. & Rodr.
Bracted vervain. SSG, SGP, SD

Verbena hastata L.
Blue vervain. BL

Verbena stricta Vent.
Tall vervain. SGP

VIOLACEAE
Viola sororia Willd.
Common blue violet. BL

VITACEAE
Parthenocissus quinquefolia (L.) Planch.
Virginia creeper. SD, BL

Vitis acerifolia Raf.
Mapleleaf grape. SGP, SD, BL

ZYGOPHYLLACEAE
Tribulus terrestris L.
*puncture vine**. SGP, SSG

Appendix 2: Floras included in the species-area curve (Figure 6) and their area and species number. Floras used to produce the target species list are highlighted in green.

Location of Flora	**State**	**Area (hectares)**	**Species**	**Citation**
Alabaster Caverns State Park	OK	81	274	Caddell, G.M. & Rice, K.D. 2013. Vascular Flora of Alabaster Caverns State Park, Cimarron Gypsum Hills, Woodward County, Oklahoma. *Oklahoma Native Plant Record* 12(1):43-62.
Altus Air Force Base	OK	1,036	232	Johnson, F.L., Proctor, MD, McCarty, NA, Benesh, DL. 1996. Biological Survey of Altus AFB, Oklahoma. Part 1. Floral Inventory. *Oklahoma Biological Survey*, Norman
Arapaho Prairie	NE	526	193	Keeler, Kathleen H.; Harrison, A. T.; and Vescio, L.S. 1980. The Flora and Sandhills Prairie Communities of Arapaho Prairie, Arthur County, Nebraska. *Faculty Publications in the Biological Science*s. Paper 282.
Baca County	CO	664,615.38	319	Anderson, Joe McCall Jr., 1950. *The Flora of Baca County, Colorado*. University Libraries Digitized Theses.
Bailey County	TX	217,300	475	Rosson, Tommy Claud. 1971. *Vascular flora of Bailey County, Texas*. Texas Tech University.
Banner County	NE	193,000	432	Hardy, J. P. 1991. The vascular flora of Banner County, Nebraska. *Transactions of the Nebraska Academy of Science* 18:109–126.
Black Mesa	OK	312	300	McPherson, J.K. 2003. Black Mesa Flora Study. *Oklahoma Native Plant Record*: 3, 8-18.
Cannon Air Force Base and Melrose Air Force Base	NM	6,888	285	U.S. Air Force. 2009. *Excerpt from draft Integrated Natural Resource Management Plan for Cannon Air Force Base and Melrose Air Force Range*. 4 p.
Cimarron and Comanche National Grasslands	KS, CO	223,457	603	Kuhn, B., Nelson, B., & Hartman, R. 2011. A FLORISTIC INVENTORY OF THE CIMARRON NATIONAL GRASSLAND (KANSAS) AND THE COMANCHE NATIONAL GRASSLAND (COLORADO). *Journal of the Botanical Research Institute of Texas*, 5(2), 753-772.

Clark County	KS	252,524	455	Miller, Jacob H. 1975. *The vascular flora of Clark County, Kansas*. Emporia State University Theses.
Comanche National Grasslands	CO	443,765	503	Hazlett, D. L. 2004. *Vascular plant species of Comanche National Grassland in southeastern Colorado*. General Technical Report. RMP-GTR-130, United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. 36 pp.
Deaf Smith County	TX	390,311	422	Waller, F.R. 1968. *Vascular flora of Deaf Smith County, Texas*. M.S. Thesis, Texas Technological College, Lubbock.
Eastern Kiowa National Grassland	NM	93,077	522	Hazlett, D.L.; Schiebout, M.H.; & Ford, P.L. 2009. *Vascular plants and a brief history of the Kiowa and Rita Blanca National Grasslands*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Four Canyon Nature Preserve	OK	1,376	368	Hoagland, B.W. & Buthod, A. 2007. Hardy, J. P. 1991. The vascular flora of Banner County, Nebraska. *Transactions of the Nebraska Academy of Science* 18:109–126. Oklahoma Biological Survey
Frederick Lake	OK	911	185	Hoagland, B., Crawford, P., Crawford, P., & Johnson, F. 2004. VASCULAR FLORA OF HACKBERRY FLAT, FREDERICK LAKE, AND SUTTLE CREEK, TILLMAN COUNTY, OKLAHOMA. SIDA, *Contributions to Botany*, 21(1), 429-445.
Greer County	OK	165,700	401	Bull, Rotha Zelma. 1932. *Vascular Plants of Greer County, Oklahoma*. Thesis. University of Oklahoma.
Gypsum dominated site	OK	80	233	Hoagland, B. W. and A. K. Buthod. 2005a. Vascular flora of a gypsum-dominated site in Major County, Oklahoma. *Proceedings of the Oklahoma Academy of Science* 85:1–8.
Gypsum Hills and Redbed Plains	OK	514,892	354	Barber, Susan C. 2008. A floristic study of the vascular plants of the gypsum hills and redbed plains area of southwestern Oklahoma. *Oklahoma Native Plant Record* 8.1.
Hackberry Flat	OK	2,770	121	Hoagland, B., Crawford, P., Crawford, P., & Johnson, F. 2004. VASCULAR FLORA OF

				HACKBERRY FLAT, FREDERICK LAKE, AND SUTTLE CREEK, TILLMAN COUNTY, OKLAHOMA. SIDA, *Contributions to Botany*, 21(1), 429-445.
Keith County	NE	281,020	599	Sutherland, David M. and Rolfsmeier, Steven B. 1989. An Annotated List of the Vascular Plants of Keith County, Nebraska. *Transactions of the Nebraska Academy of Sciences and Affiliated Societies.* Paper 175.
Kiowa County	OK	265,475	497	Baldock, L. O. 2014. Flora of Kiowa County, Oklahoma. *Oklahoma Native Plant Record* 14: 4-37
Lillian Annette Rowe Sanctuary (LARS)	NE	324	273	Nagel, Harold G. and Kolstad, Ole A. 1987. Comparison of Plant Species Composition of Mormon Island Crane Meadows and Lillian Annette Rowe Sanctuary in Central Nebraska. *Transactions of the Nebraska Academy of Sciences and Affiliated Societies.* Paper 201.
Little Sahara State Park	OK	146	181	Sherwood, R.T.B.; Risser, P.G. 1980. Annotated checklist of the vascular plants of Little Sahara State Park, Oklahoma. *Southwest. Nat.* 25, 323-338.
Melrose Air Force Range	NM	31,210	253	U.S. Air Force. 2009. *Excerpt from draft Integrated Natural Resource Management Plan for Cannon Air Force Base and Melrose Air Force Range.* 4 p.
Mesa de Maya Region	CO	305,253	577	Rogers, C.M. 1953. *The vegetation of the Mesa de Maya Region of Colorado, New Mexico, and Oklahoma*. Lloydia:257-290.
Mesa de Maya Region	CO	96,841	570	Clark, D.A. 1996. A floristic survey of the Mesa de Maya region, Las Animas County, Colorado. *Natural History Inventory of Colorado* 17. Universty of Colorado Museum, Boulder
Mormon Island Crane Meadows and Lillian Annette Rowe Sanctuary	NE	1,151	367	Nagel, Harold G. and Kolstad, Ole A. 1987. Comparison of Plant Species Composition of Mormon Island Crane Meadows and Lillian Annette Rowe Sanctuary in Central Nebraska. *Transactions of the Nebraska* Academy of Sciences and Affiliated Societies. Paper 201.

Morton County	KS	187,775	308	Richards, E. 1968. Vascular Plants of Morton County, Kansas. *Transactions of the Kansas Academy of Science* (1903-), 71(2), 154-165.
NW Oklahoma Study Area	OK	1,274,020	445	Erteeb, F.B. 1988. *TAXONOMIC INVESTIGATIONS OF THE FLORA OF OKLAHOMA.* Thesis. Oklahoma State University.
Ochiltree County	TX	234,910	314	Headlee, Roy L. 1973. *A Flora of Ochiltree County, Texas, U.S.A.* Thesis. West Texas State University.
Osborne County	KS	231,600	299	Neher, S. 1934. The Flora of Osborne County, Kansas. *Transactions of the Kansas Academy of Science* (1903-), 37, 77-82.
Parts of NE New Mexico	NM	4,386,660	911	Schiebout, M.H., D. Hazlett and N. Snow. 2008. A floristic survey of vascular plants over parts of northeastern New Mexico. *Botanical Research Institute of Texas* 2: 1407–1447.
Pawnee National Grassland	CO	447,566	511	Hazlett, D. L. 1998. *Vascular plant species of the Pawnee National Grassland*. General Tech. Rep. RMRS-GTR-17. Fort Collins, Colo: U.S. Dept. of Agr, Forest Serv., Rocky Mountain Res. Sta. 26 pp.
Rita Blanca National Grassland	TX	37,636	301	Hazlett, D.L.; Schiebout, M.H.; & Ford, P.L. 2009. *Vascular plants and a brief history of the Kiowa and Rita Blanca National* Grasslands. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Sandsage Prairie Site	KS	1,970	183	Hulett, G.K., J.R. Tomelleri, and C.O. Hampton. 1988. Vegetation and flora of a Sandsage prairie site in Finney County, southwestern Kansas, USA. *Transactions of the Kansas Academy of Science* 91:83-95.
Selman Living Laboratory	OK	129.5	229	Buckallew RR, Caddell GM. 2003. Vascular flora of the University of Central Oklahoma Selman Living Laboratory, Woodward County, Oklahoma. *Oklahoma Academy of Science* 83:31-45
Sheridan County	KS	232,200	477	Weber, C. 1932. The Flora of Sheridan County, Kansas. *Transactions of the Kansas Academy of Science* (1903-), 35, 161-178.

Suttle Creek	OK	161	182	Hoagland, B., Crawford, P., Crawford, P., & Johnson, F. 2004. VASCULAR FLORA OF HACKBERRY FLAT, FREDERICK LAKE, AND SUTTLE CREEK, TILLMAN COUNTY, OKLAHOMA. SIDA, *Contributions to Botany*, 21(1), 429-445.
Texas Panhandle	TX	11,862,200	830	Rowell, Chester Morrison, Jr. 1967. *Vascular Plants of the Texas Panhandle and South Plains*. Thesis. Oklahoma State University.
Thomsen meadow	NE	16	281	Veloso SL and Rothenberger SJ. 2008. *Thomsen meadow: a quantitative study and floristic quality analysis of a botanically diverse lowland*. Pages 113-126 In Springer, JT (ed). Proceedings of the 20th North American Prairie Conference, University of Nebraska Kearney, USA.
Three sites in Tillman County	OK	3,842	352	Hoagland, B., Crawford, P., Crawford, P., & Johnson, F. 2004. VASCULAR FLORA OF HACKBERRY FLAT, FREDERICK LAKE, AND SUTTLE CREEK, TILLMAN COUNTY, OKLAHOMA. SIDA, *Contributions to Botany*, 21(1), 429-445.
Two wet meadows of the Loup River Valley	NE	36	292	Rothenberger SJ, Veloso SL, and McGee JJ. 2010. A floristic analysis and comparison of two wet meadows in the middle and south Loup River Valleys of Nebraska. *Proceedings of the 21st North American Prairie Conference* 21:69-81
Washita Battlefield National Historic Park	OK	136	271	Hoagland, Bruce W., Amy Buthod, and Wayne Elisens. 2004. Vascular flora of Washita Battlefield National Historic Site, Roger Mills County, Oklahoma. *SIDA, Contributions to Botany*: 1187-1197.
Western Kiowa National Grassland	NM	55,206	573	Hazlett, D.L.; Schiebout, M.H.; & Ford, P.L. 2009. *Vascular plants and a brief history of the Kiowa and Rita Blanca National Grasslands*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
Wichita Mountain Wildlife Refuge	OK	23,885.2	730	Carter, K. A., P. Rodriguez, and M. T. Dunn. 2008. An updated flora of the Wichita Mountains Wildlife Refuge. *Oklahoma Native Plant Record* 8:45–46.

Appendix 3: Species lists for Beaver WMA communities (Fishbein, unpublished). Introduced species are signified by a *.

River Bottom

AMARANTHACEAE

Amaranthus arenicola

*Amaranthus blitoides**

Chenopodium album

Chenopodium pratericola

*Kochia scoparia**

*Salsola tragus**

ANACARDIACEAE

Rhus aromatica

APOCYNACEAE

Asclepias arenaria

ASTERACEAE

Ambrosia psilostachya

Baccharis salicina

Cirsium undulatum

Conyza canadensis

Erigeron bellidiastrum

Helianthus petiolaris

Heterotheca subaxillaris

BORAGINACEAE

Cryptantha minima

Lappula occidentalis occidentalis

BRASSICACEAE

Descurainia pinnata

*Descurainia sophia**

CACTACEAE

Opuntia macrorhiza

COMMELINACEAE

Commelina erecta

CYPERACEAE

Cyperus schweinitzii

EUPHORBIACEAE

Croton texensis

Euphorbia glyptosperma

FABACEAE

Dalea lanata

Glycyrrhiza lepidota

HELIOTROPIACEAE

Euploca convolvulacea

MOLLUGINACEAE

Mollugo verticillata

PLANTAGINACEAE

Plantago patagonica

POACEAE

*Bromus tectorum**

Cenchrus incertus

*Cynodon dactylon**

Distichlis spicata

Elymus canadensis

*Eragrostis cilianensis**

Hordeum jubatum

Panicum capillare

Panicum obtusum

Panicum virgatum

Pascopyrum smithii

Poa arachnifera

Sporobolus airoides

Sporobolus cryptandrus

POLYGONACEAE

Eriogonum annuum

PORTULACEAE

*Portulaca oleracea**

Portulaca pilosa

ROSACEAE

Prunus angustifolia

SOLANACEAE

Physalis hispida

Solanum elaeagnifolium

Solanum rostratum

TAMARICACEAE

*Tamarix ramosissima**

River Terrace

AMARANTHACEAE

Amaranthus arenicola

*Amaranthus blitoides**

Chenopodium album

Chenopodium pratericola

*Kochia scoparia**

*Salsola tragus**

Tidestromia lanuginosa

APOCYNACEAE

Apocynum cannabinum

Asclepias arenaria

ASPARAGACEAE

Yucca glauca

ASTERACEAE

Ambrosia psilostachya

Artemisia filifolia

Baccharis salicina

Cirsium undulatum

Conyza canadensis

Erigeron bellidiastrum

Gaillardia pulchella

Grindelia squarrosa

Helianthus annuus

Helianthus petiolaris

Heterotheca subaxillaris

Thelesperma megapotamicum

BORAGINACEAE

Cryptantha cinerea

Cryptantha minima

Lappula occidentalis occidentalis

BRASSICACEAE

*Descurainia sophia**

Lepidium oblongum

CACTACEAE

Opuntia macrorhiza

CARYOPHYLLACEAE

Silene antirrhina

COMMELINACEAE

Commelina erecta

EUPHORBIACEAE

Croton texensis

Euphorbia glyptosperma

Euphorbia marginata

Euphorbia missurica

Stillingia sylvatica

FABACEAE

Dalea enneandra

Dalea lanata

Dalea purpurea purpurea

Dalea villosa

*Medicago sativa**

LOASACEAE

Mentzelia nuda

MALVACEAE

Callirhoe involucrata

MARTYNIACEAE

Proboscidea louisianica

MOLLUGINACEAE

Mollugo verticillata

NYCTAGINACEAE

Mirabilis glabra

ONAGRACEAE

Oenothera cinerea

Oenothera curtiflora

PLANTAGINACEAE

Plantago patagonica

POACEAE

Bothriochloa laguroides

Bouteloua dactyloides

*Bromus catharticus**

*Bromus tectorum**

Calamovilfa gigantea

Cenchrus incertus

*Cynodon dactylon**

Distichlis spicata

*Eragrostis cilianensis**

Munroa squarrosa

Panicum capillare

Panicum obtusum

Panicum virgatum

Pascopyrum smithii

Poa arachnifera

Sporobolus airoides

Sporobolus cryptandrus

POLYGONACEAE

Eriogonum annuum

PORTULACACEAE

*Portulaca oleracea**

SOLANACEAE

Physalis hispida

Solanum elaeagnifolium

Solanum rostratum

TAMARICACEAE

*Tamarix ramosissima**

Dune Base

AMARANTHACEAE

Chenopodium album

Chenopodium incanum

Chenopodium pratericola

*Kochia scoparia**

*Salsola tragus**

ANACARDIACEAE

Rhus aromatica

APOCYNACEAE

Asclepias arenaria

Asclepias pumila

ASPARAGACEAE

Yucca glauca

ASTERACEAE

Ambrosia psilostachya

Artemisia filifolia

Cirsium undulatum

Conyza canadensis

Erigeron bellidiastrum

Gaillardia pulchella

Gutierrezia sarothrae

Helianthus petiolaris

Heterotheca subaxillaris

BORAGINACEAE

Cryptantha cinerea

Cryptantha minima

Lappula occidentalis occidentalis

BRASSICACEAE

Descurainia pinnata

Lepidium densiflorum

CACTACEAE

Opuntia macrorhiza

CAMPANULACEAE

Triodanis holzingeri

CANNABACEAE

Celtis reticulata

COMMELINACEAE

Commelina erecta

Tradescantia occidentalis

CUCURBITACEAE

Cucurbita foetidissima

CYPERACEAE

Cyperus schweinitzii

EUPHORBIACEAE

Croton texensis

Euphorbia glyptosperma

Euphorbia missurica

Stillingia sylvatica

FABACEAE

Pediomelum linearifolium

LAMIACEAE

Monarda punctata

LOASACEAE

Mentzelia nuda

NYCTAGINACEAE

Mirabilis glabra

PLANTAGINACEAE

Plantago patagonica

POACEAE

Bouteloua curtipendula

Calamovilfa gigantea

Cenchrus incertus

Elymus canadensis

Hesperostipa comata

Munroa squarrosa

Panicum capillare

Panicum obtusum

Panicum virgatum

Sporobolus airoides

Sporobolus cryptandrus

POLYGONACEAE

Eriogonum annuum

ROSACEAE

Prunus angustifolia

SOLANACEAE

Physalis hispida

Solanum elaeagnifolium

TAMARICACEAE

*Tamarix ramosissima**

Upland Dune

AMARANTHACEAE

Chenopodium pratericola

*Salsola tragus**

ANACARDIACEAE

Rhus aromatica

ASPARAGACEAE

Yucca glauca

APOCYNACEAE

Asclepias arenaria

ASTERACEAE

Ambrosia psilostachya

Artemisia filifolia

Cirsium undulatum

Conyza canadensis

Erigeron bellidiastrum

Helianthus petiolaris

Heterotheca subaxillaris

Thelesperma megapotamicum

BORAGINACEAE

Cryptantha minima

Lappula occidentalis occidentalis

BRASSICACEAE

Lepidium densiflorum

CACTACEAE

Opuntia macrorhiza

CANNABACEAE

Celtis reticulata

COMMELINACEAE

Commelina erecta

CUCURBITACEAE

Cucurbita foetidissima

CYPERACEAE

Cyperus schweinitzii

EUPHORBIACEAE

Croton texensis

Euphorbia glyptosperma

Euphorbia missurica

Stillingia sylvatica

FABACEAE

Pediomelum linearifolium

LOASACEAE

Mentzelia nuda

NYCTAGINACEAE

Mirabilis glabra

POACEAE

Andropogon gerardii hallii

Calamovilfa gigantea

Hesperostipa comata

Munroa squarrosa

Panicum capillare

Panicum obtusum

Sporobolus cryptandrus

POLYGONACEAE

Eriogonum annuum

ROSACEAE

Prunus angustifolia

TAMARICACEAE

*Tamarix ramosissima**

SOLANACEAE

Physalis hispida

Solanum elaeagnifolium

VITACEAE

Vitis acerifolia

VITA

Nikolai Starzak

Candidate for the Degree of

Master of Science

Thesis: THE FLORA AND COMMUNITY ASSEMBLY OF BEAVER COUNTY: VASCULAR PLANTS OF THE WESTERN GREAT PLAINS AND PHYLOGENETIC PATTERNS ALONG A HYDROLOGICAL GRADIENT

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Biographical:

Education:

Completed the requirements for the Master of Science in Botany at Oklahoma State University, Stillwater, Oklahoma in May, 2019.

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