GARVIN HEIGHTS RESTORATION PROJECT

A THESIS PRESENTED TO THE FACULTY OF
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Thesis Table of Contents

Chapter 1: Introduction

Currently Garvin Heights is facing an over-abundance of European buckthorn *Rhamnus cathartica*, that it is altering the natural bur oak savannah and dry bluff prairie habitats that have existed there for thousands of years. In past years, occasional efforts attempted to remove buckthorn from prairies, but the invasives quickly returned when control activities lagged. The purpose of the current project and the focus of this thesis is to use disturbances such as cutting, chemical treatment, prescribed grazing, and burning to reduce buckthorn abundance and allow native species to recover. Both the habitats and species within are extremely rare, adding to the importance of this research and the restoration efforts.

For this project, there were two hypotheses. First, goats are facultative eaters that will start by browsing on buckthorn yearlings and as those populations decrease will move on to taller(adolescent) and shorter(seedlings) buckthorn plants. Second, goats will selectively browse on buckthorn with intermediate stem diameters, while avoiding those that are too large or too small for them to browse on. These hypotheses will be explored further in later chapters. In addition to these hypotheses, this project will also cover habitat delineation of the Garvin Heights area, an educational workshop on invasive species, and recommendations for future management activities.

Chapter 2: Background

Dry Bluff Prairie and Bur Oak Savannah

Dry bluff prairies or dry-mesic prairies are unique to the Midwestern United States, specifically the Driftless area, and are uncommon because of the conditions needed for them to occur (Wisconsin DNR, 2018), although they once occupied large portions of the tallgrass region (Ladd, 1995). Dry-mesic prairies usually grow in steep, bedrock-cored bluffs created from glacial till along river valleys and, because of space limitations, grow in patches rather than large running prairies like one might see with traditional lowland prairies (Fred Harris and Robert Dana , 2014). To have a dry bluff prairie, generally a south- or west-facing slope is required to provide ample sunlight for evaporation. A slope with a north- or east-facing slope will usually have forest or savannah, due to higher moisture levels present in these habitats. Traditionally, dry bluff prairies are found on top of bedrock with steeper slopes where water is excessively drained, within areas that experience extreme moisture deficits throughout the growing season (Fred Harris and Robert Dana , 2014). The amount of canopy coverage is generally very low, with around 10% being the cut-off. Conversely the amount of ground coverage is usually very high, reaching around 100% with very few sparsely populated plots (Fred Harris and Robert Dana , 2014). The soil content can range from loams to loess and residuum, the latter being found on steeper slopes (Fred Harris and Robert Dana , 2014). These xeric conditions favor plants that are adapted to surviving with little moisture and poor soil fertility, like medium

grasses and forbs with trichomes, little biomass above ground, and smaller leaves (Fred Harris and Robert Dana , 2014).

The following grasses are all found on the dry bluff prairie: little bluestem (*Schizachyrium scoparium*), side-oats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), and prairie dropseed (*Sporobolus heterolepis*) (Wisconsin DNR, 2018). The following are all common shrubs found on dry bluff prairies: Lead plant (*Amorpha canescens*), silky aster (*Symphyotrichum sericeum*), flowering spurge (*Euphorbia corollata*), purple prairie-clover (*Dalea purpureum*), cylindrical blazing-star (*Liatris cylindracea*), and gray goldenrod (*Solidago nemoralis*) (Wisconsin DNR, 2018). A majority of the plant species found in a dry bluff prairie are grasses and forbs, with only a few shrubs (Fred Harris and Robert Dana , 2014). The exact composition of a dry bluff prairie varies greatly, but usually is dominated by little bluestem. Regular wildfires are required to maintain dry-mesic prairies, but the required frequency is much lower than mesic or wet prairies due to its xeric nature (Fred Harris and Robert Dana , 2014). If fire does not occur on a regular basis, these prairies will start to transition to savannah or woodland, although the dry conditions and poor soil make this very difficult. Before large populations of humans were present, these biomes also saw heavy grazing from large ungulates. Since then, most of these species have been hunted to extinction or are endangered. This lack of herbivory has also had a strong impact on the makeup of these natural area.

There a several classes of dry bluff prairie, including dry barrens prairie, dry sand/gravel prairie, dry hill prairie, and dry bedrock prairie. Garvin Heights is the latter of these classes. These classes are created by landscape present, but also by the flora that exists within the ecosystem. In this case, species present will include false boneset, beardless birdfoot violet,

cylindric blazing star, and gray-headed coneflower, all of which are uncommon in the other three classes (Fred Harris and Robert Dana , 2014). Due to the unique plant species present in these areas, there also is a unique set of animals that exist in these areas, including rare species like timber rattlesnakes, skinks, loggerhead shrikes, prairie voles and prairie pocket mice.

The other area of interest to this project is the bur oak savannah or oak opening. A savannah is defined by its lack of coverage, specifically its ability to allow grasses to be the dominant species in the area, and generally has one tree species at higher concentration than any other (Curtis 1959). Additionally, canopy coverage in a savannah typically ranges from 10% to 50% (Curtis 1959). The coverage is kept low or open via regular fire and/or grazing by herbivores (USDA, 2003). Without disturbances to keep the coverage low, the amount of trees increases in the understory and we see a transition to a woodland or forest. This fact is abundantly clear for the savannahs found at Garvin Heights, which have a canopy coverage >75% (N. Mundahl, unpublished data).

Savannahs in the Midwest typically exist in what are called border zones between prairies and woodlands. Bur oak savannahs typically develop on well-drained, south- or southwest-facing slopes (Curtis 1959). The soil typically is deep with a high level of calcium carbonate or calcareous in nature (Curtis 1959). The dominant tree species in Garvin Heights is the bur oak. This species does particularly well in the savannah due to its thick bark, which allows it to survive fire and create seedbeds (Abrams, 1992). Deep roots and xeromorphic leaves also give it an advantage in the dry conditions typically seen on the savannah (Abrams, 1992). Unfortunately, one of the weak points of the bur oak is its lack of shade tolerance

(Abrams, 1992). This is a major issue for this project, as one of the negative aspects of buckthorn is its creation of shade and ability to outcompete young oaks (Abrams, 1992).

Part of how a savannah is defined is by how the dominant trees grow on it. Because canopy coverage is low, savannah trees display an open growth pattern, with branches growing horizontally rather than vertically as traditionally seen in woodlands and forests. When walking a savannah area you will typically see what are known as street trees. This have low horizonal branches that spread out.

Much like the dry bluff prairies, the bur oak savannah has a characteristic makeup of grasses and forbs that includes little bluestem (*Schizachyrium scoparium*), white wild indigo (*Baptisia leucantha*), lead plant (*Amorpha canescens*), purple coneflower (*Echinacea purpurea*), round-headed bush clover (*Lespedeza capitata*), and blue aster (*Aster anomalis*) (USDA, 2003). Shrubs typical to this ecosystem include New Jersey tea (*Ceonothus americanus*), hazelnut (*Corylus americana*), and pasture rose (*Rosa carolina*) (USDA, 2003). The bur oak savannah at Garvin Heights can be defined by its increased canopy coverage (>75%) predominantly of fire-tolerant bur oak trees, with grasses and forbs scattered throughout. Bur oak savannahs are one of the most threatened ecosystems in the Midwest and are among the most threatened in the world, with less than 0.01% of the original savannah community remaining. This only increases the need for restoration research on these areas (USDA, 2003).

This project took place within the boundaries of Garvin Heights Park. Part of the project focused on the two dry bluff prairies (different strategies for each one). The upper and lower dry bluff prairies at Garvin Heights both have high diversities of grasses and forbs, with

buckthorn growing along prairie edges and in isolated patches. The upper prairie shown in figure 3 has been subjected to several prescribed fires and two buckthorn cut-and-treat activities during the past 15 years. The lower prairie shown in figure 4 has only experienced prescribed fire during the same time period. Larger buckthorn were removed (cut and treated) within the savannah by the Conservation Corps of Minnesota starting in February 2016 and continuing through 2019. The other ecosystem of interest is bur oak savannah at Garvin Heights shown in figures 1 and 2, which currently is defined by its high canopy coverage (>75%) predominantly of fire-tolerant bur oak trees, with grasses and forbs scattered throughout. Until recently this area has not seen as many treatments as the prairies have, and consequently had a much larger population of buckthorn with a greater size range. Unlike the prairies where the buckthorn was mostly restricted to the fringes, the savannah had large numbers of buckthorn throughout the habitat. This can be attributed to the greater amounts of shade found on the savannah due to lack of disturbances. As mentioned previously, disturbances help maintain the preferred level of canopy coverage for a savannah and the loss of disturbance leads to greater amounts of shade and niches for plants like buckthorn.

Habitat Restoration

When planning a restoration, it is important to have a strategy in mind. This strategy is based on several factors, including the type of ecosystem, level of degradation, intended use, and target community, to help guide actions taken (Kline 1997). For example, ecosystems like prairie tend to repair themselves over a relatively short period when compared with a boreal forest that, due to poor soil quality and a short growing season, do not rebound well after damage has occurred.

There are two general strategies to use when performing a habitat restoration, passive and active, with the level of degradation being the most important factor determining which approach to use (Muller et al. 1998). There are many factors to examine when assessing land degradation and many ways to do it. Of these factors there are six essential ones that we focus on in reference to degradation: biomass, social, economic, biodiversity, water, and soil (SOLAW: Land Degradation report 3, 2011). Biomass includes all living matter, ignoring all abiotic factors (SOLAW: Land Degradation report 3, 2011). Social factor is how the land is being used by humans for non-economic reasons; camping, picnicking and fishing are all good examples of social aspects land useEconomic is focused on what kind of financial benefits an area of land provides. This might include things likes lumber, agriculture, or natural resources. This factor focuses more on overuse and deforestation. Biodiversity is the diversity of life that is present in a given area. In degradation terms, we are looking at things like loss of species and formation of monocultures. Water is the loss of usable water for organisms. This can refer to things like desertification, pollution, or eutrophication (Eswaran, 2001). The final factor is soil health, which refers to the ability of the soil to sustain life (SOLAW: Land Degradation report 3, 2011). Many different things can affect soil health, ranging from leaching, salinization, acidification, loss of nutrients, and erosion. These factors combined can all be used to help judge degradation, but a given area does not require us to look at all of them. For Garvin Heights, the focus is on social, biodiversity, and soil health, which all are negatively impacted by buckthorn and will be discussed in detail within the buckthorn section below.

If the level of degradation is minor and the environment appears that it will return to normal after removal of the stresses causing the change, then taking a passive approach is

preferred (Muller et al. 1998). The passive approach allows the environment to fix itself. For example, if humans picking flowers were causing an issue, one might simply implement rules against picking flowers, removing the stress and letting the seed bank repair the damage. If the habitat has been degraded to such an extent that the environment cannot fix itself, a more active approach may be considered. Active restoration is when heavy intervention is used to restore the habitat. When this route is chosen, there are several tools available in our toolkit, including thinning, burning, invasive species control, planting, and seeding (DellaSala et al. 2003).

Prescribed burns are the intentional burning of lands to simulate the natural fires that occurred there historically. The restoration objective of a prescribed burn includes reducing overstory tree density and basal area to levels historically reported, selecting for native tree species, eliminating/suppressing understory as well as creating a healthy herbaceous layer with grasses as the dominant species (Peterson, 2001). Once a “healthy” savannah has been established the long-term goal of prescribed burning should be the maintenance of said area. Reduction in fire frequency leads to structural changes in the prairie and savannah including increased tree density, basal area, and canopy cover (Peterson 2001; Abrams 1990).This effectively improves the habitat and native plant communities while reducing chances of the far more dangerous wild fires (Kurtz, 2013; Peterson, 2001). In fact, seedling density of bur oak is increased by prescribed burns, not damaged by it (Peterson, 2001). Bur oak is classified by Rowe (1983) as a resistor, which means it is very effective at coping with fire. They are described as shade-intolerant with the ability to survive low-severity fires with little or no damage due to their thick bark (Rowe, 1983; Peterson, 2001). Conversely buckthorn is an

avoider or a shade-tolerant and fire-sensitive species that slowly reinvades following a disturbance (Peterson, 2001). They require a long, fire-free period to become established and the juveniles are easily killed by fire (Peterson, 2001). Avoiders also have the tendency to alter the habitat to make fire less likely. This is indeed true of buckthorn, as its rapidly decaying litter and increased shading make fires less likely (Peterson, 2001). Coupling these facts with the history of fire suppression in the area makes Garvin Heights an ideal area for prescribed burns, and for that reason fire was added to the restoration plan. For the Garvin Heights restoration, prescribed burns will serve to eliminate buckthorn and reduce the amount of shade. It also will serve the purpose of pushing back the understory and reducing the overstory, bringing the canopy coverage back to a more natural state in the savannah while stopping any transitions in the prairie. For the long term it should reduce some of the future canopy coverage as well.

Grazing is the intentional release of herbivores onto a piece of land allowing them to eat the plant species present. A prescribed grazing seeks to suppress invasive plants by altering the timing, intensity, and frequency of grazing and by stocking animals based on their dietary preferences (Rinella, 2009). Well managed prescribed grazing seeks to cause significant damage to the target plant, limit damage to surrounding vegetation (especially native species), and can be integrated with other disturbances as part of a larger restoration plan (Frost, 2003).

Much preparation goes into performing a prescribed grazing. The first step in the process is to decide which animals to use, e.g., cattle, goats, sheep, geese, and horses all can be used (Tu et al., 2001). Each organism specializes on different types of plant material. Cattle and horses feed heavily on invasive grasses and roughage, although horses are more selective (Tu et al., 2001; Frost, 2003). Sheep are very effective at taking care of herbaceous flowering plants,

so they are excellent for handling invasive forbs (Frost, 2003). Goats have narrow, strong mouths which are very effective for removal of individual leaves from woody stems and for chewing branches (Frost, 2003). Additionally, they are able to push over larger wood shrubs and trees in order to girdle and damage upper parts of the plant (Tu et al., 2001). They also handle allelochemical metabolism with a greater efficiency than other organisms traditionally used in prescribed grazing (Frost, 2003). Goats have a tendency to eat large amounts of browse even when other kinds of forage are available (Nelle, 2001). Consequently, they will not focus on one type of plant and ignore all others. Goats are the best choice when the trying to remove invasive woody species from an area.

On top of choosing a type of organism, a particular species, age group(s), and sex need to be chosen (Frost, 2003). All these factors influence how an organism feeds and should be considered when making decisions on what organism to use. After deciding on an organism the next thing to consider is when to have the grazing event. The time period of the grazing should be planned to inflict the most damage on the invasive species, while limiting the impact on the native species (Tu et al., 2001). Early in the growing season is generally not a good idea, as many plants are tolerant of herbivory when competition for soil nutrients and moisture is low (Frost, 2003). As the seasons progress and plants shift to seed production, they become less tolerant of herbivores. This is the ideal time to have a prescribed grazing event as it can be extremely detrimental to the plants (Frost, 2003). Too late in the season and the risk of the herbivores becoming transporters for the seed increases (Tu, M., Hurd, C., and Randall, J., 2001).

The final step in the process is deciding how long to leave the animals on the site. Too long will lead to overgrazing and damage to the native species, while inviting new invasive species in(Tu et al., 2001). Too short and they won't have the desired impact on the area. Good management of the area requires monitoring the area to make sure the proper amount of control is achieved without damage to the desirable species(Tu et al., 2001).

There are both positives and negatives to grazing. Positives include allowing native species to make a comeback, pushing back encroaching forest, and improving both nutrient recycling and plant growth. Additionally, herbivores are very good in areas that are sometimes untreatable by other methods (e.g., too steep, too expensive for herbicides, or mechanically difficult). Another positive is that they can eat, fertilize, and spread some of the native species. There also are some negatives that come along with prescribed grazing. When not properly controlled, it can lead to overgrazing which in turn damages the system (Tu et al., 2001). Additionally, it can reduce native plant cover, disturb soil, and spread invasive species from one cut to another (Tu, M., Hurd, C., and Randall, J., 2001). The goal of using prescribed grazing at Garvin Heights is to allow goats to graze on the property, effectively eliminating many of the buckthorn saplings and adolescent trees while limiting the damage to the native species. We also hope to reduce the transitioning of prairie to savannah while reducing the understory and canopy coverage in the existing savannah.

Prescribed thinning is another tool that is used by restoration biologists to help remove invasive species, decrease basal area, and, in the long-term, decrease canopy coverage (Dey, 2017). The objective is to increase desirable plants by selectively removing plants and increasing the amount of available light (Dey, 2017). There is much debate over how to

proceed, but many believe in more holistic approach which removes both mid-story and overstory portions, creating more of an open stand and allowing ground species to flourish (Dey, 2017). The overall goal should be to reduce unnatural shade created by lack of disturbances and invasive species. The actual process starts with evaluating historical surveys and identifying pest species (Dey, 2017). Once these species are identified, healthy amounts of coverage and basal area per acre should be determined. One should keep in mind that just because a tree or plant is native does not mean that it should not be cut during a prescribed thinning, as the purpose of the thinning is not just to remove invasives, but also to make the overall area healthier. The plants and shrubs that will be cut are then identified with an emphasis on certain species. At this point, the stands can be cut and the stumps sprayed.

One of the positives to prescribed thinning is that the trees cut from the stand can then be used to fund other disturbances within the restoration area (Dey, 2017). Another positive that comes with thinning is the amount of control. Thinning allows those performing the restoration to be very specific about what species of plants they want removed and which ones they want to keep (Dey, 2017). The other disturbances discussed in this paper do not allow for this much control. The negatives to the process stem mostly from cost. If the wood that is being harvested is not being sold and the labor provided is not on a volunteer basis, then this process can be very expensive. This expense is even higher when a cut-and-spray approach is taken. As extra costs will be incurred for herbicides. Additionally it can create issues by creating space for opportunistic invasive species to move in (Kinkead, 2013). The process of thinning at its base removes shade and this creates opportunities for species that have a high tolerance for light. For Garvin Heights, the purpose of this process is to eliminate the larger individual buckthorn

that have thicker basal area and higher tolerance to fire. These also are the size buckthorn that we believe to be most resistant to prescribed grazing. The other purpose of the prescribed cutting is to “thin” the area. The savannah and prairie at Garvin Heights were very dense at the beginning of this project, so through thinning the hope is they will return to a more natural state.

To bring back the native species to the area, a system of interseeding and overseeding will be implemented. Instead of plowing and starting with turned soil, interseeding is simply seeding the existing soil as is. That provides several benefits over plowing in that it does not damage the native species that already are present, and it does not lead to unnecessary erosion (Packard 1997).

The process is started by evaluating the area and determining the seed mix. When designing the seed mix, several things should be taken into consideration, such as grass-to-forb ratio (usually 50/50 mix), seed quality, seeding rates/size, germination rates, ecological behavior, efficiency of seeding technique, season of planting, and budget (Diboll 1997). Seed quality and germination rates go hand in hand as the pure live seed (PLS) value is estimated from germination rate and purity (Diboll 1997). This will help to determine the amount of seed needed for interseeding. Ecological behavior of the different plants should also be a major concern; too many slow-to-establish or fast-to-establish plants can lead to problems, as well as plants that can exclude others from the area (Diboll 1997).

Before interseeding can occur, shading and plant density should be accounted for. A major issue with interseeding as opposed to traditional plow-in seeding is light as a limited

resource (Packard 1997). In prairies and savannahs with large numbers of densely packed grasses and forbs, it can be difficult for light to reach new seeds. To decrease this problem, interseeding can occur in early spring or immediately after burn/mowing (Packard 1997). If amount of moisture in the soil and aggressiveness of current plants can be accounted for, this can be helpful in making separate mixes for these different areas. For small areas such as Garvin Heights, hand sowing the seeds was more than adequate.We used a ratio of roughly one cup of seed to every 100 square feet. Similar strategy were used for both the savannah and prairie areas. However the seed mixes were specific to each area.

European Buckthorn

The major issue that threatens the habitats at Garvin Heights is invasive species, particularly European buckthorn (*Rhamnus cathartica*). Invasive species are those that have not faced selection pressure in that area, but can establish and grow in many areas. (USDA 1999). They grow very quickly and spread from their native habitat to other areas, much like a cancer (USDA 1999). Typically, they are introduced as ornamentals or decorative plants. Usually these plants are aesthetically pleasing or serve another purpose such as hedging for cattle. Invasive species are particularly problematic because they have not existed in that area, which means they do not have many of the natural selection pressures that other native species face, which means that they can survive and procreate without population controls keeping them in check.

Buckthorn is a flowering plant or angiosperm. It is deciduous in nature, meaning it drops its leaves and fruit annually via abscission. It grows to about 25 feet in height, but smaller plants are much more common (Hanson 2018). It produces offspring at 9-20 years of age depending

on the location and available resources. The bark is brown with oval-shaped leaves that have a pointed tip at the end, glossy coating, finely toothed, and are arranged opposite to alternate. It has a wide tolerance for both wet and dry conditions, again making it troublesome as an invasive species (Knight et al. 2007). Its light and moisture tolerances allow it to survive in a wide variety of ecosystems. It is an extremely resilient plant that is able to survive in a multitude of areas and conditions.

European buckthorn is classified as an invasive species. It was brought to Minnesota in the mid-1800s and sold as a hedging plant by many nurseries until the 1930s (Hanson 2018). Buckthorn is extremely troublsome for several reasons, chief among them being it out-competes native plants for resources, allowing it to drive these native species out (Hanson 2018). There are several different characteristics that make this possible. Like many plants that grow in the shade of savannah, buckthorn is shade tolerant. It exhibits low mortality at low light levels and higher mortality in deep shade, but many of its seedlings are still able to survive in these conditions (Knight, 2007). Conversely, it exhibits greater growth and abundance in areas with more light, but requires much more moisture (Knight, 2007).

Another feature that allows it to out-compete native plants is the length of time it retains its foliage. Buckthorn buds earlier in the year and sheds its leaves later in the year in comparison to the native species living around it (Knight, 2007). This allows it to gather resources for much longer period of time than the species it is competing against. This also is the reason for its high carbon gains along with carbon efficiency (Knight, 2007).

Buckthorn is extremely prolific and the male plants on average can fertilize 6-7 female plants, this high rate of prolifcation can be problematic when try to control the organism (Knight, 2007). The drupes have a very high germination rate even without scarification or stratification, although both appear to positively influence germination rates (Knight, 2007).

Secondary compounds are chemicals found within a plant that can be both positive and negative for the plant. In the case of buckthorn, it produces a chemical called emodin which causes invertebrates to actively avoid it as well as having an allelopathic aspect (Knight, 2007). This is a huge benefit, as it allows buckthorn to avoid some of the native insect species that feed on other plants as well as facilitating growth of its offspring in the area surrounding it (Knight, 2007).

The formation of thickets by buckthorn alter the community by creating significant amounts of shade in the mid- and understory. These alterations lead to changes in the makeup of the community. Species that survive better on or in buckthorn are selected for, which opens the door for more shade tolerant species to move in, alter the base of the food chain, and change the amount and availability of certain nutrients (Knight, 2007). In essence buckthorn moves in and takes the place of a cornerstone species.

The ability of buckthorn to spread is on of the reasons that it is such a pervasive species to deal withIt produces small berries that are consumed by birds, the seeds pass through bird digestive tracts undamaged, and are dropped far from their parent plants (Bell et al. 2003). Digestive tract juices cause seed scarification, which has a positive impact on germination rates

(Knight, 2007). Using birds as a vector to spread their seeds has allowed buckthorn to cover wide swaths of the United States and Canada.

When combining buckthorns abilities to survive, procreate and spread it start to become very clear why this tenacious plant is so hard to deal with. It is alround tough plant to deal with and eliminate. Through the process of completeling my research project I have developed a very healthy respect for buckthorns adaptability to harsh circumstances.

Chapter 3: Habitat Delineation

Introduction

Degradation of ecosystems has become more and more prevalent over the past decades, leading to drastic alterations in disturbance regimes, exotic species expansion, and loss of native species (Hansen et al. 2011). Most times, an ecosystem or habitat spans a much larger area than what falls within a specific, protected area. Consequently, it has become much more common to delineate entire ecosystems. Usually these delineations are determined by the presence of a specific organism within the ecosystem that is used to define it, for example, the home range of grizzly bears were used to define the greater Yellowstone ecosystem (Hansen et al. 2011). Habitat delineation is a process in which an outline or perimeter of a given ecosystem is made. Within a restoration project, this serves a very important purpose. Each area is unique and should be treated as such. The prairies and savannahs at Garvin Heights each received different treatments, so it was very important that the borders of each area were defined.

Within Garvin Heights, three distinct habitats exist: dry bluff prairie, bur oak savannah, and oak-maple-basswood forest. The dry bluff prairie is defined by the presence of grasses and the lack of large deciduous trees. The lack of canopy coverage is the characteristic that helps identify the borders of the dry bluff prairie. The bur oak savannah is characterized by bur oak that exhibit a growth pattern indicative of “savannah conditions”, with major branches positioned more horizontally than vertically. These types of bur oak werused to define the

areas between the oak-maple-basswood forest and the bur oak savannah. The oak-maple-basswood forest is defined by its high levels of coverage from fire-tolerant oaks, maples, and basswoods, characterized by their relatively few, low branches (Kline 1997). The oak-maple-basswood forest was defined by exclusion; essentially everything that does not fall into one of the other two groups fell within the oak-maple-basswood forest.

Methods

The process of delineating the area occurred in several steps, the first of which was gathering background information on the characteristics of each of the habitats that exist at Garvin Heights. The process involved research into each of habitats and finding a focus for how to define them. In the case of the dry bluff prairie, it was a lack of canopy coverage that was used as the defining factor. Normally the canopy coverage for the prairie ranges between 0-10%, with ground coverage ranging from 50%-100% (Fred Harris and Robert Dana , 2014). The bur oak savannah has anywhere from 10-50% canopy coverage, with slightly less ground coverage (Curtis 1959). Additionally, the presences of bur oaks with lower branches growing in a horizontal manner was used as a defining factor (Curtis 1959).

After the characterizations of each area were settled upon, the next step was to identify the borders of each habitat. The first step in this process involved walking the area to get a feel for what was present. The next step used a dichotomous key called “Minnesota Trees” by David Rathke to identify basswoods and bur oaks that make up the borders between the different habitats at Garvin Heights. After identifying the borders, they were then outlined using fluorescent flagging tape to ease the process of GPS mapping. A phone application called Gaia

was used to delineate each of the habitats. The borders of the habitats were walked again, but this time using the Gaia application to track the borders and mark landmarks to better identify the edges between the areas. This information was then saved as a GPX file and transferred to Google Earth for imaging. Through Google Earth, the habitats were delineated and the images recorded for future use.

Delineated Areas

Several different stands were mapped during the course of this project, each within the confines of Garvin Heights Park. The first area was the non-cleared bur oak savannah on the west side of, and parallel to, the entrance road. This area can be seen in figure 2 and borders private property to the south and west and the second, cleared savannah to the north. This is the area that had seen no restoration efforts previous to the current project, and still has the highest level of mid- and upper-story coverage. The second savannah seen in figure 1 lies to the west of the parking lot and pedestrian walkway to the overlook. Like the other savannah, it is a bur oak-dominated savannah. Part of its southern border abuts private property, with the oak-basswood forest along its western edge. It extends to just north of the downhill walking path, with a narrow section to the northwest that splits the upper and lower prairies. This savannah runs along the southern edge of both the upper and lower prairies. This area has experienced a wide spectrum of disturbances over the last few years, transitioning from a closed stand to an open stand. The upper prairie seen in figure 4 runs along the western edge of the walking path to the overlook. It runs along the cliff edge on the northern end of Garvin Heights, with the second savannah to the south and west. This area had an abundance of buckthorn in its southwestern corner that, through disturbances, has been significantly reduced. The lower

prairie seen in figure 3 is further west than the upper prairie. It can be reached by taking a dirt walking path along the northern cliff edge below the savannah. Its northern border is the cliff edge, its eastern and southern borders abut the savannah, and the western border adjoins oak-basswood forest. This area had the lowest levels of degradation of any area within Garvin Heights, and because of its steep slope, received only prescribed thinning.

Data

Figure 1: Bur oak savannah parallel to the parking lot on the western side. Divides the upper and lower prairie at map points 7-9.

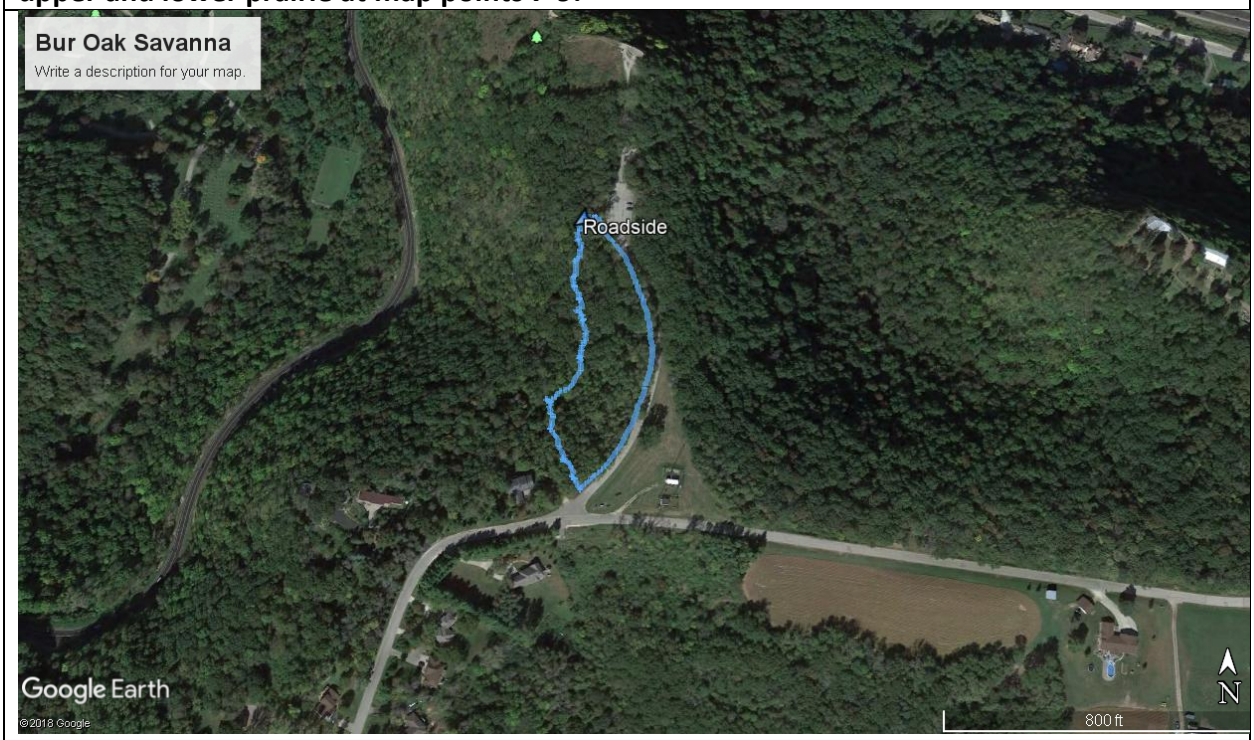

Figure 2: Roadside bur oak savannah which borders the roads, edges of the property and the second savannah on the north side.

Figure 3: Lower dry bluff prairie with the northern border being the cliff side and the other borders being the savannah and forest.

Figure 4: Upper dry bluff prairie runs next to the lookout and the path leading up to it.

Chapter 4: Grazing Surveys

Introduction

In any restoration project, multiple tools are used to decrease the level of degradation. There is no "magic bullet" that will fix all of the problems at a site by itself; rather, a mix of different disturbances is required to bring an area back to its natural state. This portion of the project focused on prescribed grazing and how to improve the outcomes so that future restoration efforts benefit. In particular, we focused on the effect of prescribed grazing on buckthorn densities on the savannah, the mindset being that absolute density of the buckthorn should decrease if the goats are being effective on the savannah. Goats are efficient eaters and so choose plants sizes that reflect that. If given a choice on the savannah, the goats will choose plants at eye level and move up and down from there (Lovreglio, 2014). Based on this, the expectation would be that they would start with yearling and seedling plants, then from there eat larger buckthorn plants. If this is correct then we should see larger amounts of grazing on yearlings initially with increased grazing of larger and smaller plants the following years.

Goats are facultative eaters, having a tendency to change their behavior depending on their environment. When allowed to roam free, they will feed very selectively on whatever they find to be most appetizing, but when penned they have a tendency to feed on what is available within the fenced-in area (Lovreglio, 2014). They become less selective and more efficient. As the seasons change and food availability changes, this also will affect their feeding habits as they have a tendency to move up and down their height range, something many other grazers

will not do (Plessis, 2004). Seasonal changes can be compared to resource availability in a penned-in area; as the feed becomes more scarce in the penned-in area, they move up and down their feed height range.

Methods

To test the first hypothesis, during year 2 we used random quadrant surveys to examine the density of buckthorn and how it changed over the course of the project. To take surveys accurately, a folding, 1-m^2 quadrant was used to define the perimeter of each plot site. Sample sites were assigned randomly using a line and compass to determine direction. Walking from east to west, every 15 paces a plot was taken with the placement rotating to a different compass heading at each plot site. At each site, the number of buckthorn was recorded and categorized into ranges based on their height. Seedlings were classified as 12" or less, yearling as 12"- 54" and adults as greater then 54". After traveling to the edge of the section, the surveyor moved 10 paces north and repeated the process going west to east. Upon reaching the northern boundary of the section the survey was completed. These data were transferred to a spreadsheet for data analysis and interpretation. Counts were made prior to and shortly after goat browsing.

Additional density data were collected by an undergraduate student during year 1 using a smaller quadrant (0.1 m^2). For her collections, the area was divided up into the uncut area (Fig 2) and the cut areas (Fig 1), the difference being that one area (cut) received a prescribed thinning whereas the other did not. Within both cut and uncut areas, plant counts were made by placing a quadrant every 10 paces along a weaving transect, with plants <12" in height

categorized as seedling and plants >12” categorized as yearlings. Buckthorn >36” in height were not tallied. Again, counts were made prior to and shortly after goat browsing.

Goats were provided by Diversity Landworks for a fee. They were penned into each habitat at Garvin Heights for approximately five days, then moved to the next paddock where the procedure was repeated. They were not provided with any supplementary food, only water, so as to force them to feed on the woody browse within the area. They did have regular human interaction, as Garvin Heights sees many guests who frequent the grounds.

Study Site

The savannah next to the parking lot at Garvin Heights was used for this portion of the project. This savannah is west of the parking lot and walking path that leads out to the overlook. It shares a border with the roadside savannah and private property to the south and runs along the oak-basswood forest on its western boundary. It extends over the steps and divides the upper and lower prairies running all the way to the bluff edge. It can be found above in figure 1. This section was historically dominated by bur oaks, but has seen a lot of change over the past several decades as buckthorn moved in and took over. Recently it has seen controlled burns, prescribed thinning, and prescribed grazing. The thinning in particular removed a lot of the adult buckthorn from the area and eliminated much of the mid-story coverage. The second area used in this experiment can be found in figure 2 and is the bur oak savannah found alongside the entry road on the west side of it. It runs along the border of the property on the south and west sides with the northern siding butting up against the other savannah used. This savannah had not received any treatment prior to this grazing.

Table 1: Buckthorn surveys pre- and post-grazing for year 1. Also includes browsing percentages and browsing by paddock.

	Pre-Goat					Post-Goat											
	Cut		Uncut area			Cut area						Uncut area					
	seedlings	yearlings	seedlings	yearlings		eaten seedlings	not eaten seedlings	eaten yearlings	not eaten yearlings	Totals	%browsed	eaten seedlings	not eaten seedlings	eaten yearlings	not eaten yearlings	Totals	%browsed
	49	0	2	0		0	4	1	1	6	16.66666667	1	0	0	0	1	100
	60	1	0	0		0	7	3	0	10	30	0	1	0	0	1	0
	36	0	3	0		0	5	4	0	9	44.44444444	0	5	0	0	5	0
	10	2	0	0		1	2	3	1	7	57.14285714	0	0	3	0	3	100
	29	5	0	0		1	4	0	2	7	14.28571429	0	1	1	0	2	50
	24	2	4	0		0	8	0	0	8	0	0	3	3	0	6	50
	8	3	9	1		1	3	2	0	6	50	1	1	1	0	3	66.66666667
	9	1	12	0		0	6	0	3	9	0	0	4	0	0	4	0
	25	1	20	1		0	2	3	0	5	60	0	4	2	0	6	33.33333333
	8	4	29	1		0	0	2	1	3	66.66666667	0	3	2	0	5	40
	36	2	15	0		2	6	2	1	11	36.36363636	2	2	0	0	4	50
	26	2	29	0		1	23	1	0	25	8	2	0	3	0	5	100
	11	0	29	2		0	0	1	2	3	33.33333333	0	0	2	0	2	100
	55	1	35	3		0	2	0	0	2	0	0	6	0	0	6	0
	71	0	19	0		0	3	0	0	3	0	0	13	3	1	17	17.64705882
	49	0	16	0		0	0	1	0	1	100	0	10	0	1	11	0
	6	1	17	1		0	0	0	0	0	0	2	10	0	0	12	16.66666667
	12	2	6	1		0	2	3	0	5	60	0	6	0	0	6	0
	17	1	18	1		0	0	0	0	0		0	6	0	0	6	0
	9	0	6	0		3	6	0	0	9	33.33333333	0	2	0	0	2	0
	10	3	3	0		5	5	0	0	10	50	0	4	0	0	4	0
	4	0	8	1		3	5	0	0	8	37.5	0	0	4	0	4	100
	4	1	21	1		1	39	1	0	41	4.87804878	1	0	2	0	3	100
	6	0	16	3		1	17	0	0	18	5.555555556	2	1	3	0	6	83.33333333
	4	2	9	0		0	2	0	2	4	0	1	0	5	0	6	100
	5	0	3	2		0	0	2	0	2	100	0	0	2	0	2	100
	15	0	38	1		0	0	0	0	0		0	0	0	0	0	0
	3	4	5	0		0	1	0	0	1	0	1	0	0	0	1	100
	10	2	46	0		0	2	0	0	2	0	1	0	0	0	1	100
	2	1	17	1		0	0	1	0	1	100	0	1	0	0	1	0
	1	0	8	0		0	0	2	1	3	66.66666667	0	0	3	0	3	100
	13	0	6	0		0	0	1	0	1	100	0	2	4	0	6	66.66666667
	55	1	18	2		4	5	2	0	11	54.54545455	0	2	4	0	6	66.66666667
	18	4	7	1		0	1	3	0	4	75	1	13	1	0	15	13.33333333
	3	1	5	0		0	0	2	1	3	66.66666667	0	2	1	0	3	33.33333333
	6	0	11	1		0	0	3	0	3	100	1	0	7	0	8	100
	4	2	2	0		0	0	2	0	2	100	1	4	0	0	5	20
	5	5	5	0		1	5	1	1	8	25	0	4	3	0	7	42.85714286
	24	0	9	0		0	6	1	1	8	12.5	5	7	0	0	12	41.66666667
	24	0	0	1		2	3		0	5	40	0	6	0	2	8	0
Sum	766	54	506	25	Sum	26	174	47	17	Mean	6.6 40.75129064	Sum	22	123	59	4	Mean 5.2 47.30427171
Mean	19.15	1.35	12.65	0.625	Mean	0.65	4.35	1.205128205	0.425	SD	7.475773 34.91353713	Mean	0.55	3.075	1.475	0.1	SD 3.831047 41.39616456
SD	18.5314	1.477177	11.31269	0.837808	SD	1.21000106	7.248518858	1.196034834	0.747217059			SD	0.985796567	3.583348241	1.768492042	0.378932373	
							Sum total seedlings		200 Sum total yearlings	64				Sum total seedlings		145 Sum total yearlings	63

Table 2: T/P values for the densities before and after goat grazing for year 1. Also included is the uncut vs. cut (not directly compared)

T value	Seedling	Yearling
Cut	21.75294846	2.168924929
Uncut	18.40445794	-0.688382979
P value	Seedling	Yearling
Cut	1.22925E-35	0.01652899
Uncut	8.69539E-31	0.246721

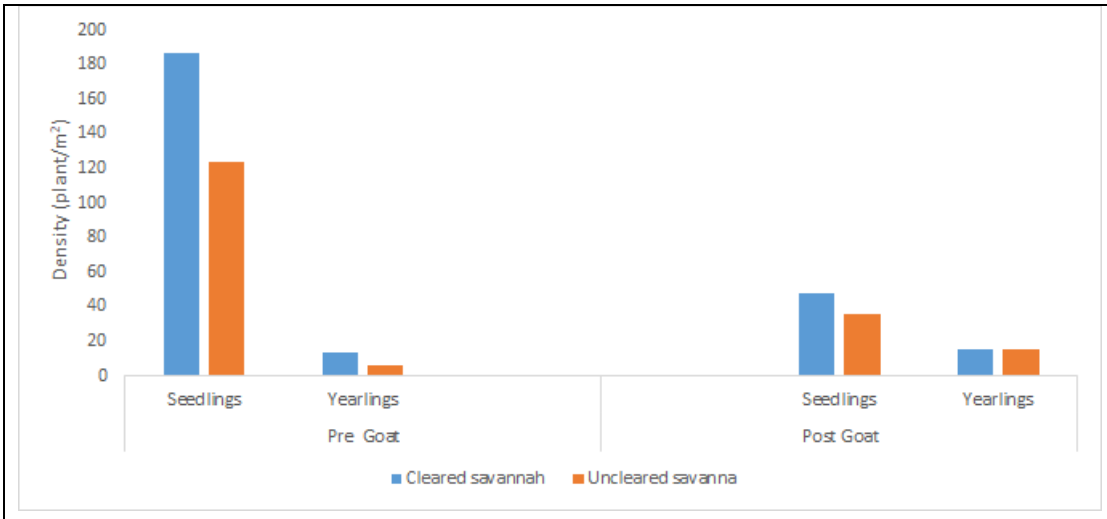

Figure 5: Densities for year one for pre- and post-goat grazing by cut/uncut areas.

Table 3: Buckthorn Surveys pre- and post-grazing on the savannah for year 2.

	Pre Goat Savannah			Post Goat Savannah	
	Seedlings (<12")	Yearlings (12"-54")		Seedlings (<12")	Yearlings (12"-54")
	6	3		18	0
	16	1		0	6
	64	0		2	0
	24	6		0	0
	8	3		22	0
	20	2		1	0
	34	1		4	3
	13	0		1	0
	6	0		6	0
	12	10		0	0
	44	11		6	4
	27	2		0	1
	21	2		0	3
	96	1		0	0
	36	1		0	0
	23	5		13	5
	58	0		0	0
	68	2		7	8
	31	0		10	0
	0	0		0	4
	44	3		2	0
	61	8		0	0
	8	5		0	0
	32	8		0	0
	0	1		6	0
	78	7		3	5
	7	1		4	0
	47	0		1	2
	6	2		16	0
	14	10		11	2
Total	904	95		17	0
Mean	30.13333333	3.166666667		2	2
SD	24.98790512	3.404695878		9	1
Density	30.13333333	3.166666667		12	0
				10	1
				3	0
				86	5
				69	1
				31	0
				37	0
				30	0
			Total	439	53
			Mean	10.70731707	1.292682927
			SD	18.01144623	2.076582558
			Density	10.70731707	1.292682927

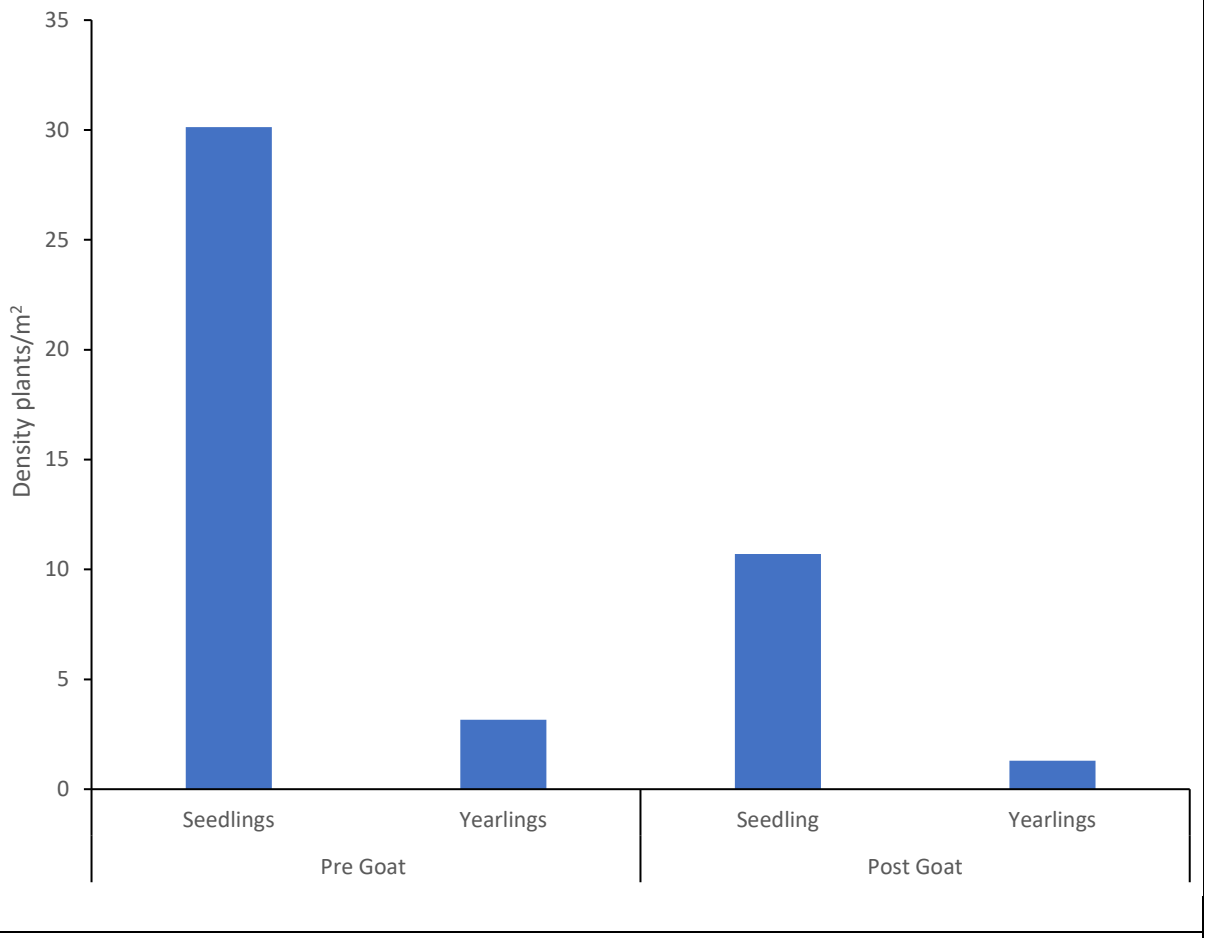

Figure 6: Mean densities for plots on the savannah pre- and post-goat grazing, year 2.

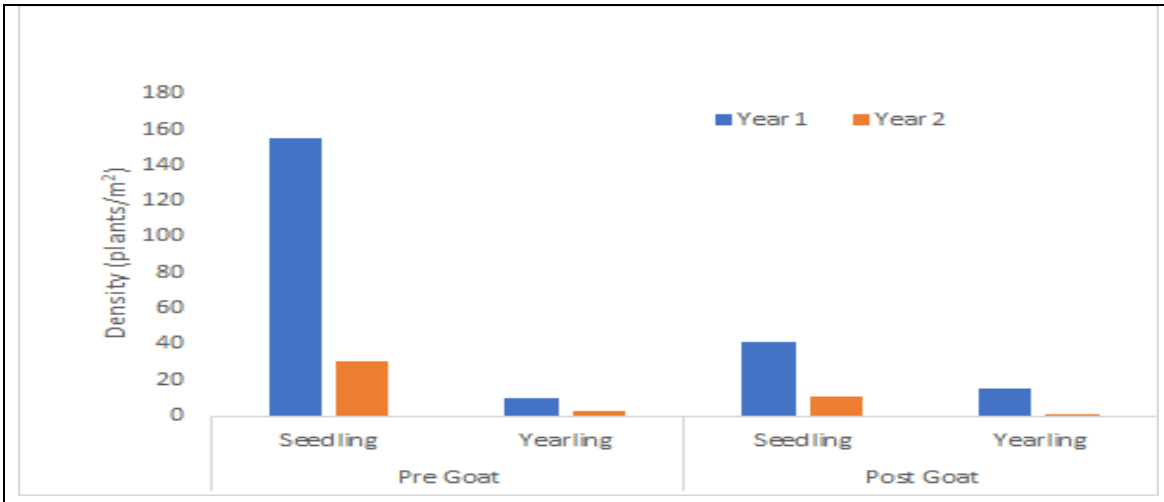

Figure 7: Mean densities from year 1 and year 2 combined.

Table 4: T and P values comparing densities before and after goat grazing for seedlings and yearlings year 2.

	Seedlings	Yearlings
T value	3.624505	2.67283
P value	0.000275	0.004689

Data Analysis

The data was collected and analyzed to determine if there was a significant difference between the densities of buckthorn before and after prescribed grazing occurred. Means and standard deviation/error were calculated using Excel. Densities pre- and post-browsing were compared using simple, two-sample t tests.

Results

Table 1 contains year 1 data collected by Bonnie Hammack. The general trend shows a decrease in average amounts of buckthorn, both seedling and yearling, the one exception being yearlings in the uncut area (Figure 5). Although not the focus of this paper, results did not show a significant difference between the cut and uncut areas for browsing.

Table 2 focuses on the P and t values comparing the densities from year 1. Seedling buckthorn densities were significantly lower after goat bowsing than before, in both cut and uncut portions of the savannah. Yearling densities in the cut area also were significantly lower after browsing, but yearling densities in the uncut area were slightly (but not significantly) higher after browsing than before.

Table 3 and Fig 6 contain buckthorn density data from year 2. Both seedling and yearling densities declined after browsing to levels approximately one-third of their pre-browsing levels. These post-browsing declines in density were statistically significant for both age groups (Table 4). Overall, goat browsing produced significant declines in densities of both seedling and yearling buckthorn during both years. Densities of both seedling and yearling buckthorn also were much lower during year 2 than during year 1, both pre- and post-browsing (Figure 7), suggesting a year-to-year decline in buckthorn densities following repeated browsing events.

Discussion

Browsing data support the use of goats within the savannah habitat, as they show a significant decrease in the number of buckthorn yearlings and seedlings from the beginning of the project to the completion of grazing. Goats had a significant impact on the buckthorn population. This agrees with the concept of goats as facultative eaters, as suggested by the trend seen across the 2-year period. It seems the goats start with plants at eye level and move upward and downward from there, which explains the high browsing observed in yearlings the first year, but as these plants became less available, the focus changed to the shorter seedlings. These results support the experiments hypothesis as well asthe hypothesis created by Plessis in South Africa (Rinella, 2009).

The results of this experiment support the use of goats to reduce the number of seedlings and yearlings during a restoration. However, there are some additional confounding variables that have to be considered. First was the use of multiple disturbances (browsing, cutting, fire) within each of the areas. These different disturbances cannot be accounted for, so it may be hard to tell what, if any impact, they had on the experiment. Second is the natural mortality of the seedling buckthorn. Again, it is difficult to tell if reduction of mean density is due to goats or natural mortality. An obvious experiment to solve this issue would be a control using two areas that did not see grazing and measuring density over a period of time.

Chapter 5: Girdling Survey

Introduction

In addition to browsing on young buckthorn, goats also strip bark from older buckthorn, with some plants being completely girdled. Girdling kills the aboveground portion of the plant, but the plant resprouts from its base. These resprouts are then consumed by goats during their next grazing period. For this portion of the project, the hypothesis was that goats would selectively browse on buckthorn with intermediate stem diameters, while avoiding those that are too large and less palatable. The purpose of this study was to improve how goats are used during restoration efforts. When doing prescribed thinning, girdling is a method that is sometimes implemented, but goats are much more efficient at it then we are. It is extremely effective at eliminating mid-size to larger plants that due to the thickness of their bark, do not always respond well to prescribed burning.

When a generalist is allowed onto a piece of land so it can graze on all plant species that are present it is known as prescribed grazing. The hope is that they will only damage the plants species invasive to the area therefore not tolerant of herbivory, while leaving the native species alone (Rinella, 2009). Prescribed grazing can take the form of eating leaves, whole plants or girdling plants as is the case in this portion of the project. Grazing can be used to treat both the symptoms and the overall problem(s) leading to them. At Garvin Heights, the buckthorn is the symptom of too much coverage in the savannah and prairie leading to transitioning to different habitats. Prescribed grazing can be used to eliminate the buckthorn as well as reducing the amount of coverage and opening up the areas so shade tolerant plants cannot take root.

Goats have very interesting feeding habits. They have very strong jaws with nimble lips and tongues that allow them to graze on short grasses and other foliage not normally eaten by domestic livestock (Lovreglio, 2014). They are very efficient eaters choosing to go after foods that can be found at eye level(Lovreglio, 2014). They tend to move around a lot a browse from plant to plant. Goats do not focus on any specific plant, but it is thought that they have an easier time handling shrubs rather than grasses and forbs (Nelle, 2001; Frost, 2003). They will often feed on shrubs and herbaceous weeds that other domestic herbivores avoid, and their preference for leaves as well as terminal twigs makes them an excellent alternative for handling invasive shrub species (Lovreglio, 2014). In addition to these abnormal feeding behaviors, they also will eat plants such as poison ivy and oak that are poisonous to other grazers (Kauakou, 1992; Duarte, 2012). It is believed this is due to their ability to dilute the poisonous compounds by browsing on other plants, as well as passing some of it into their milk (Lovreglio, 2014). Their ability to reach high into trees also is a factor in goat feeding. Despite their height, they are able to control plants until they reach a height of 1.5 meters (Plessis, 2004). The range of browsing heights appears at least in part to be controlled by season and availability of food. It should also be noted that goats traditionally graze over a large area, allowing them to be more selective when confined and tending to feed more on woody plants and trees (Lovreglio, 2014).

The use of goats was an good choice for Garvin Heights for many reasons. Goats body design makes them perfect for handling buckthorn, as they have no issues with leaves, woody stems, or branches (Frost, 2003). They also are large and strong enough to push over larger buckthorn to reach the branches higher up on the plant (Tu, M., Hurd, C., and Randall, J., 2001). As mentioned previously in the buckthorn section, there are some allelochemicals produced by

buckthorn that can be detrimental to other plants and herbivores, but goats are able to metabolizing these chemicals (Frost, 2003). Combining these factors made goats the obvious choice for prescribed grazing.

Study Site

Two areas within Garvin Heights were surveyed. The first area was the non-cleared bur oak savannah on the west side of, and parallel to, the entrance road as seen in Figure 2 in the habitat delineation section. This area borders private property to the south and west and the second, cleared savannah to the north. This area had seen no restoration efforts previous to the current project, and still has the highest level of mid- and upper-story coverage. The second area was a portion of the second savannah that runs between the upper and lower prairies as seen in Figure 1 (points 5-2). During the prescribed grazing, this area was grazed at the same time as the upper prairie so as not to cause problems with the trail system. Its southern side runs along the stairs, with the northern side ending at the bluff. The western and eastern borders of this area are the upper and lower prairies.

Methods

To collect data on the amount of girdling that occurred, a belt transect girdling survey was performed. The tape was laid down at random intervals within the roadside savannah. A 10-meter length was used for the survey, with buckthorn within a meter of the transect being recorded. Buckthorn were recorded as browsed or not browsed in the context of girdling (if part of the bark was removed it was browsed). Additionally, the size of the buckthorn plants

were recorded by diameter and put within ranges. The percent of the girdling also was recorded (0-100%).

Goats were provided by Diversity Landworks for a fee. They were penned into each habitat at Garvin Heights for approximately 5 days, then moved to the next paddock where the procedure was repeated. They were not provided with any supplementary food, only water, to force them to feed on the food within the area. They did have regular human interaction, as many guests frequent Garvin Heights.

Data

Table 5: Diameter of buckthorn girdled/not girdled. Percent of buckthorn browsed or not browsed by the goats within paddock 1 and 3. Selection is shown to the far right. Chi square analysis was performed and showed significant results.

Paddock 1

Diameter	Browsed	%	Not Browsed	%	Selection
<10	0	0	8	3.2	-3.2
10 to 19	18	7.758621	87	34.8	-27.0414
20 to 29	79	34.05172	64	25.6	8.451724
30 to 39	81	34.91379	42	16.8	18.11379
40 to 49	35	15.08621	20	8	7.086207
50 to 59	15	6.465517	15	6	0.465517
60 to 69	4	1.724138	9	3.6	-1.87586
70 to 79	0	0	3	1.2	-1.2
80 to 89	0	0	2	0.8	-0.8
Totals	232		250		

chi-square = 77.7
degrees of freedom = 8
P (Chi square) = 0.000

Paddock 3

Diameter	Browsed	%	Not Browsed	%	Selection
<10	0	0	19	12.92517	-12.9252
10 to 19	91	51.41243	122	82.9932	-31.5808
20 to 29	81	45.76271	6	4.081633	41.68108
30 to 39	5	2.824859	0	0	2.824859
40 to 49					
50 to 59					
60 to 69					
70 to 79					
80 to 89					
Totals	177		147		

chi-square = 91.2
degrees of freedom = 3
P (Chi Square) = 0.000

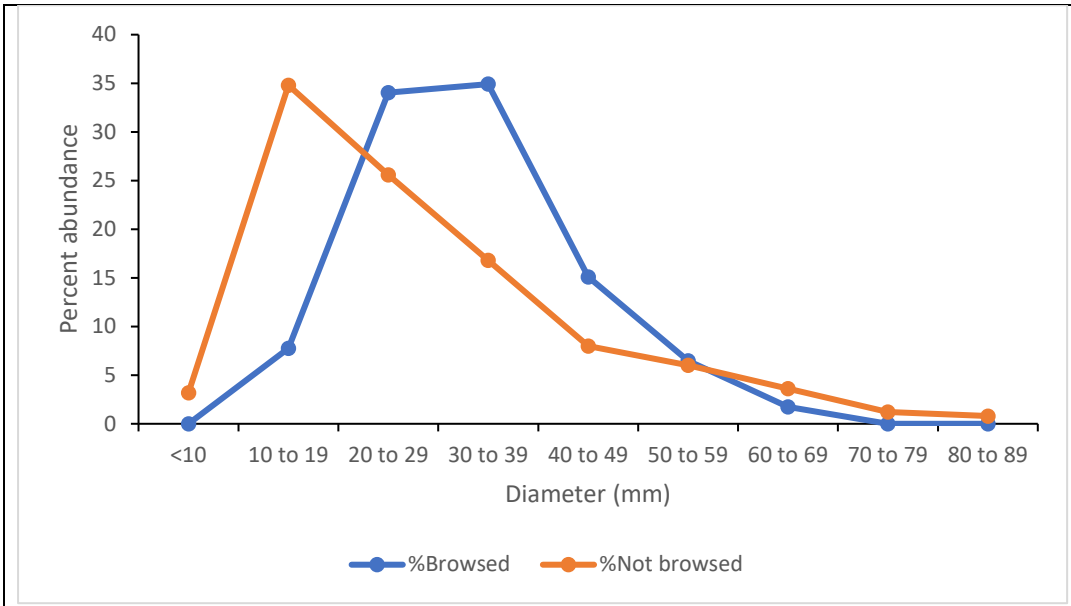

Figure 8: Diameter vs. percent grazed by goats/not grazed by goats. Graph depicts the trend in browsing behavior by the goats in paddock 1.

Table 6: Range of girdling on individual plants within each paddock. The amount that the individuals plants were girdled was measured and a percent of the total calculated.

Paddock 1			Paddock 2		
Range girdled	Number	%	Range girdled	Number	%
1 to 25%	8	3.162055	1 to 25%	10	4.291845
26 to 50%	19	7.509881	26 to 50%	20	8.583691
51 to 75%	24	9.486166	51 to 75%	23	9.871245
76 to 99%	34	13.43874	76 to 99%	30	12.87554
100%	168	66.40316	100%	150	64.37768
Total	253		Total	233	

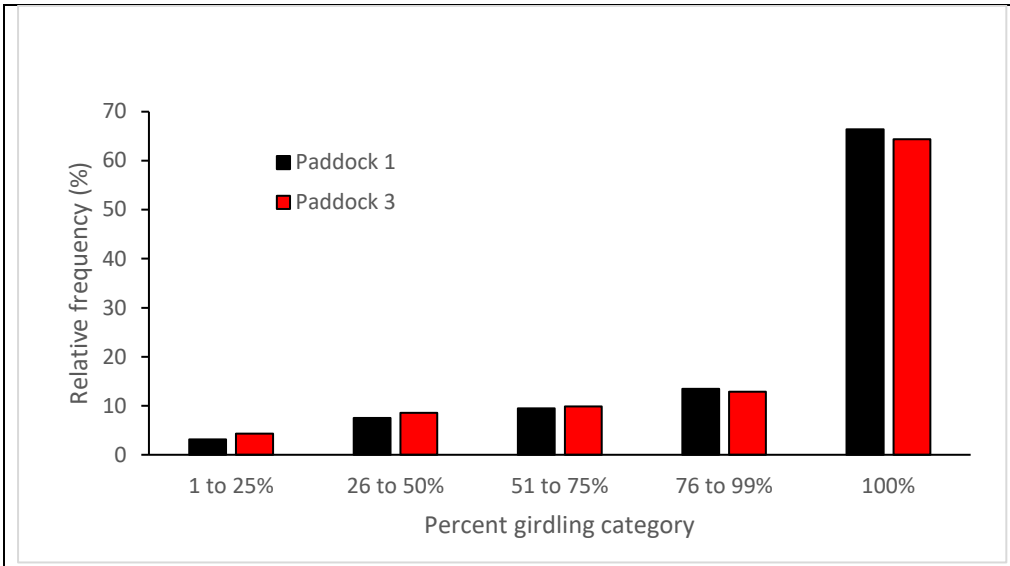

Figure 9: Range of girdling vs relative frequency.

Data analysis

Girdling data were analyzed to see if there was a relationship between girdling and plant diameter and, if so, what diameters goats preferred. Chi-square contingency table analyses were performed to assess whether the distributions of diameters of browsed and unbrowsed buckthorn differed from one another in each of two different parts of the savannah, indicative of possible size-selective browsing by goats. Positive or negative selection by goats was also calculated for each 10-mm diameter size category in each of the two different parts of the savannah by using the following equation:

$$percent_{browsed} - percent_{not\ browsed} = \text{Positive or Negative selection}$$

Data also were gathered to determine how completely goats girdled buckthorn stems, i.e., if goats were completely girdling the plant (100%) or only a certain percentage of the plant stem circumference was stripped of bark. To make this easier, the amount of girdling on a given plant was estimated to be in one of five categories: 1-25% of the plant circumference girdled, 26-50%, 51-75%, 76-99%, or 100%. Chi-square analyses were performed to determine whether each girdling category was represented by equal numbers of plants (separate analysis for each area of the savannah). A chi-square contingency table analysis was used to compare the distribution of plants among girdling categories between the two different parts of the savannah.

Results

In both paddock 1 and 2, buckthorn that goats girdled or partially girdled had larger stem diameters than buckthorn that had no stripped bark (Table 5, Figure 8), and the stem size distributions of buckthorn girdled or partially girdled versus not stripped differed significantly both in paddock 1 ($X^2 = 77.7$, df = 8, $P < 0.0001$) and paddock 3 ($X^2 = 91.2$, df = 3, $P < 0.0001$). Goats displayed positive selection for buckthorn with stem diameters from 20 to 59 mm in paddock 1 and from 20 to 39 mm in paddock 3 (Table 4), selecting against plants with stem diameters <20 mm. Due to the more limited stem size distribution of buckthorn in paddock 3 (5 to 39 mm) compared to paddock 1 (5 to 89 mm; Table 5), the stem size distribution of buckthorn girdled in paddock 3 was significantly skewed ($X^2 = 166$, df = 3, $P < 0.0001$) toward smaller plants than in paddock 1.

Goats stripped bark off 48-55% of the buckthorn stems 5 to 89 mm in diameter within the two paddocks. Of the buckthorn stems that experienced bark stripping by goats, >60% were completely girdled in both of the paddocks examined (Table 6, Figure 9), with complete girdling significantly more common (paddock 1: $X^2 = 347$, df = 4, $P < 0.0001$; paddock 2: $X^2 = 291$, df = 4, $P < 0.0001$) than lesser degrees of bark browsing. The pattern of partial to complete girdling did not differ significantly ($X^2 = 0.72$, df = 4, $P = 0.949$) between the two paddocks.

Discussion

Several different conclusions can be drawn based on the data gathered on girdling behaviors. First, there is a preference towards stem diameters of 20-59 mm. This would suggest that goats prefer to feed on plants within this range of diameters while avoiding those outside of this range. Because the data suggest that goats girdle primarily in the 20-59 mm range, I would suggest altering a restoration for prescribed thinning so that those individuals who are mechanically removing plants should aim for any plants greater than 59 mm while leaving plants below that diameter to be handled by a mix of prescribed grazing and burning. This, in turn, will allow the prescribed thinning to be more focused and efficient. It should also be noted that this supports the hypothesis that goats will selectively browse on buckthorn with intermediate stem diameters, while avoiding those that are too large or too small for them to browse on.

The second conclusion that can be drawn is that goats have a tendency to fully girdle buckthorn when they start browsing on a plant. This supports the use of goats as a restoration tool, as plants can survive if not completely girdled. The fact that the goats girdle all the way

around the plant suggests that those plants they choose to girdle will more than likely die. This should alter restoration strategies slightly, as those performing other types of disturbances can avoid girdled plants with the expectation that they have been girdled to extent that they will not survive. It should also be noted that fully girdled plants can still resprout and it should not be assumed that just because a plant is fully girdled, it is done causing problems. In such cases, additional disturbances such as additional goat browsing on resprouts or prescribed burning are advised.

Goats are effective at dealing with plants below 60 mm in diameter, and when they browse on them, they will likely do so to such an extent that the plant will die. This should alter how a restorationist approach uses goats so that they get the most out of their prescribed grazing. Again, the issue of resprouts should be noted and dealt with accordingly.

Chapter 6: Workshops

Introduction

Based on information that was gathered during this project, it became abundantly clear that the problems facing Garvin Heights cannot be corrected without buy-in from the stakeholders living in the nearby area. With this in mind, the Garvin Heights restoration project also included an outreach portion, to provide the general public with information about invasive plant management and specific information about the Garvin Heights project. This was part of the grant provided for the project by Minnesota's Environmental and Natural Resources Trust Fund. The project has completed one of the two required workshops, with the second one to occur in summer 2019.

Planning

To prepare for the first program, a 4- to 5-hour workshop proposed to connect citizens with experts in invasive plant control and management, a meeting was initiated with a third-party contractor to organize and plan the workshop. However, it was determined that the contractor's fees were beyond the budget for the project, so in-house resources were used instead. Blandine Berthelot with WSU Camps and Conference Services was contacted to help plan the event. Blandine's role was to schedule the venue, set up an online RSVP registration form, order box lunches for attendees, and contract bus transportation for attendees to visit Garvin Heights. The workshop agenda was discussed and included a speaking/booth session in the morning and on-site demonstrations at the Garvin Heights project site in the afternoon. As part of the planning process, many public and private institutions were contacted to see if they

wanted to participate in the symposium and at what level. Several private companies agreed to particiapte and present information, including Diversity Landworks, Prairie Restorations Inc., Landspirit Design, Acer Forest LLC, and Prairie Moon Nursery, and others. From the government sector, the Department of Natural Resources, Conservation Corps of MN and IA, and the City of Winona Office of Sustainability all participated in the workshop.

Several approaches were used to advertise the planned workshop. Fliers and a postcard campaign were started to garner interest, with many of the local buisnesses and landholders receiving information. Postcards were designed by the WSU graphics art department and went through a couple of iterations before they were acceptable. Additionally, a public service announcement was placed into the local newspaper to help gather participants. A website awas designed and connected to the project's website. In an effort to gather some of the school faculty to participate, an email announcement was sent out to let them know about the workshop. Finally, a radio interview on KWNO radio station was used to inform the public and to gather more attendees.

In the weeks leading up to the workshop some of the finer detail were determined. Blandine scheduled food and transportation for 50 partipants. After some discussion, Haake Hall was decided as the location for the indoor portion of the workshop. Three individuals agreed to speaking engagments: Dustin Looman from DNR/Conservation Corps, Kaitlyn O'Conner from Prairie Moon Nursery, and Zach Reusch from Acer LLC. After discussions with each one, it was decided that Dustin would speak about his experiences doing restorations with the Conservation Corps, Kaitlyn would speak about the process of creating a prairie, and Zach would talk about the restoration process itself.

Agenda

The following is the full agenda for the workshop

- 9 am - Table set-up for open forum
    - Arrive at Haake Hall and set up your booth
        - This included Gabe, Kyle, Dustin, Kaitlyn, Eric, and John
- 10am - 10:15 am - Welcoming and intro statements
    - Neal and I will get everyone organized for the speaking portion of the symposium and provide opening remarks.
    - Dustin, Zach, and Kaitlyn will speak in that order
        - Dustin Intro: I graduated from Winona State University in 2004 with a Recreation and Tourism degree. While doing my internship at Frontenac State Park I was informed about the Minnesota Conservation Corps. Once done with the internship I started with MCC in the fall of 2004. I worked as a crew member for 6 months and a crew leader for another 2 years. In 2006 I took the Assistant Manager position with the Corps "now CCM" and have not looked back. During the last 12-ish years I have lead and managed many projects for different Federal, State, County and City organizations. Some of the projects include Rx fire, exotics species removal, hazard tree removal, wildfire details, trail construction/restoration just to name a few. I have also had to opportunity to train over 200 crew members in chainsaw and fire related trainings with many folks moving on to DNR, Federal, or County positions.
        - Zach Intro: After graduating from Michigan Technological University in 2007 with a Bachelor of Science in Forestry, Zach started his forestry career in Western Montana. He has spent the past 10 years working in the forests of Minnesota, Wisconsin, Iowa, and Illinois. Since starting his own forestry business in 2011, he's been able to focus on maintaining and enhancing forested and other wild lands while balancing landowner's interests. Acer Forest and Tree is a family owned natural resource consulting business specializing in forest management planning and implementation, ecological surveys, restoration and also urban tree care. An effort to help a few friends on a few acres in 2011 quickly developed into professional services that currently manage more than 8500 acres of forestland in southeast Minnesota. Every good tree produces fine fruit; strive to keep the good trees.
        - Kaitlyn intro: Kaitlyn O'Connor was born and raised in the Southeast Minnesota Driftless Region, a place she still calls home. Along with being the Education and Outreach Specialist at Prairie Moon Nursery, she also acts as a consultant to the Winona State University Arboretum. Before working in the private sector, Kaitlyn worked with the Minnesota DNR as a park naturalist and local non-profit organization Land Stewardship Project as a political organizer. Her educational background includes

Environmental Science, Geoscience, and Sustainability. She now homesteads in rural Winona County at Wiscoy Valley land co-op where she spends her free time foraging, gardening, cooking, playing frisbee with her dog Indigo, and tending to a small flock of backyard chickens.

- 10:15 - 11:45 Speakers will give 10-20 min presentations (questions will be saved for table session)
    - Each speaker will present information
- 11:45am – 12:30 pm Lunch
    - Lunch will be provided but feel free to talk and interact with the participants
- 12:30 – 1:00 Open forum/table session
- 1:00 – 1:15 Travel to Garvin Heights
- 1:15 – 3:00 Station Exercise (30 mins per station + 10 mins for rotation)
    - Neal and I will break the bigger group up into three groups and send one to each of you. The demo will last 30 mins with a 10-minute transition period in between. Expect about 10 per group.
    - Goat talk/anatomy demo (from goats groups will go to the tour)
        - Goat guys will focus on prescribed grazing, set up, care etc.
            - Tell them about what it is you do and how you go about doing it
        - definitely use the goats during your presentation; if you are comfortable let them touch the goats (completely up to your discretion)
    - Tour of the grounds (from the Tour to the Conservation Corp/eliminating buckthorn)
        - Walk the grounds show participants different invasive species and how to ID them. Try to stick more to the prairie. Neal and I will help out with this one as much as possible. Essentially I want them to be able to ID things like Buckthorn and Honeysuckle but we can also focus on some other interesting plants.
    - Identifying and eliminating buckthorn (From the CC to the goats)
        - Demonstrate cutting, spraying techniques for eliminating buckthorn, honeysuckle etc. Talk a little about the prescribe burning process but emphasize that it not something a land owner should undertake without professional help.
        - Run through the process start to finish of ID, assessing, and eliminating invasive species from an area. Talk about previous project and let them know that it is ongoing, not something that is done once. Compare treated sections to untreated sections.
        - Don't be afraid to let them get a little dirty.
- 3:00 – 4:00 Regroup and answer any lingering questions/sign up for more comprehensive workshop
    - At the end please send your groups back to the parking lot. We will wrap up and head back.

Workshop

The workshop occurred on Saturday June 9, 2018, with 26 attendees and approximately 20 presenters and their assistants. The process was facilitated by Neal Mundahl and Ryan Walsh, with the latter keeping track of the schedule. The speakers presented their information in the morning, and then time was given so that the attendees could eat lunch and talk to the presenters. In the afternoon a chartered bus was taken up to Garvin Heights, where demonstrations occurred. The demonstrations started with how to identify some of the more prevalent invasive species (Garlic Mustard and Buckthorn), which was done by the Conservation Corps and Acer LLC. The Conservation Corps went on to demonstrate each of the tools they used on a daily basis, including weed torchs, hand saws, chainsaws, and herbicides. Also included was a demonstration of the invasive species management app, which is being used currently to track the movements of invasive species across the state. The final demonstration was of the goats and some Q/A on their care. The particpants were bussed back to campus, where the workshop ended.

The second outreach program will be a day-long, hands-on opportunity for a smaller number of attendees to learn about invasive plant control efforts. The set-up for invitation will be much the same as the previous workshop, but with more of an emphasis on using the mailing list to garner particpants. Blandine will be asked to help set up lunches for the event, as well as advertising. The instructors will consist of private contractors and the Conservation Corps. Attendees will have a more interactive experience focusing on hands-on activities. These will include learning to cut and spray invasive species, using a dichotomous key to identify different species, and working on action plans for their own properties.

The goal of the second workshop will be for the participants to be able to go home with an actionable plan for their own property, and to act as ambassadors for a healthier ecosystem in their community. The purpose is to improve the overall health of plant community within the Garvin Heights area.

Chapter 7: Maintenance, Recommendations and Future experiments

Before going into the issue of maintenance, it is important to establish that the actual issue at Garvin Heights is not the presence of buckthorn, but the lack of disturbances. The lack of natural wild fire and grazing created an ideal environment for buckthorn to move into. With this in mind, buckthorn will be treated as a symptom of a larger problem rather than the problem itself. This segues into the issue of how to maintain the three habitats at Garvin Heights Park. Maintaining the current environment will require a long-term, adaptive pest management plan coupled with multiple types of disturbances, including prescribed grazing, prescribed burning, and prescribed thinning. Having a plan in place and these disturbances are key to keeping the habitats at the appropriate coverage levels and buckthorn densities low.

Before trying to perform future disturbances it is important to have a plan in place to determine at what point these disturbances should occur. The adaptive approach focuses on flexible decision-making when it is not certain what impact disturbances will have on the environment. It focuses more on the causal relationship and monitoring the effects to adjust management policies (Williams, B.k., R.C. Szaro and C.D. Shapiro, 2009). In more simple terms, it is learning how to solve the problem by trying to solve it (doing). The basis for this approach was establish in the early part of the 20th century and combined ideas from business, experimental science, systems theory and industrial ecology (Williams, B.k., R.C. Szaro and C.D. Shapiro, 2009). The adaptive management system moves in a cycle and starts by assessing the problem. The next phase is design; in this phase a solution to the problem is created. Implementation is where the plan is set in motion. After the plan is put in motion, it is then monitored via regular assessment and then evaluated. After being evaluated, the plan is then

adjusted and the problem reassessed (Williams, B.k., R.C. Szaro and C.D. Shapiro, 2009). The only real drawback to an adaptive plan is that they are hard to implement for a long period of time, as they require continual work.

Although it was not strictly stated, adaptive management is essentially what has occurred at Garvin Heights. The problem was assessed and it was determined that changes were necessary. A plan was created by Dr. Neal Mundahl, which included hiring a graduate student, habitat delineation, multiple disturbances, and stakeholder education. Ryan Walsh was assigned as the graduate assistant on the project and the plan was implemented, starting with delineation and moving into disturbances as well as education. The monitoring/evaluation was performed in the form of buckthorn densities and data analysis, determining that the disturbances are effective for reducing coverage and lowering density of buckthorn. At this point in the project the management plan needs to be adjusted and reassessed. For an adaptive management plan to work into the future, it will have to be maintained continuously for a long period of time. Otherwise the Garvin Heights area will simply return to the state it was in prior to the disturbances. For this to work, regular monitoring will have to occur at the site with an action threshold for buckthorn density. What this means is that after the site is stabilized, someone will have to go out on a yearly basis and perform surveys. The surveys will be used to assess the problem. Once a certain threshold for buckthorn or coverage is reached, a disturbance should be implemented. This will allow Garvin Heights to be maintained using a system rather than guess work.

Beyond having an adaptive plan in place, a regular set of disturbances should occur on a normal basis. As mentioned above, it is important to keep the coverage at the correct level to

maintain the savannah and prairie. These disturbances will help maintain a healthy community of native plants and keep the invasives from invading. Prescribed burns should occur at a minimum of once every 2.5 years to keep densities and coverage at an acceptable level. This will prevent the development of canopy ingrowth and sapling thickets (Peterson, 2001). When burned at this rate, there is a 6-8% density decline with a 4-7% decline in basal coverage (Peterson, 2001). This also significantly reduces the overstory density, while having a very low impact on the native bur oaks (Peterson, 2001). There should not necessarily be an action threshold for prescribed burning; it should simply occur at regular intervals regardless of the absolute density and coverage. This will decrease the reliance on other disturbances, while keeping the chances of naturally occurring wild fires down.

Prescribed grazing and thinning should be done in tandem on a regular basis to keep the densities of buckthorn seedlings/yearlings at around 10 plants/m^2 and 1 plants/m^2 respectively. An increase above 15 plants/m^2 for seedlings and/or 5 plants/m^2 for yearlings should signal the use of prescribed grazing and thinning. Coverage should be kept around 20-35% for the savannah. If the coverage rises above this range, action should be taken so it does not exceed 75%. The prairie should be kept below 10% coverage, but any buckthorn thickets should signal a need for disturbances. As mentioned, above regular surveys should occur to make sure the levels are staying around these ranges. This recommendation calls for an adaptive plan; if these ranges do no work, then the action threshold should be altered. It should also be noted that the generalists should be expected to handle plants below 59 mm in diameter and for efficiency sake the workers should handle plants larger than that. Again, if this does not appear to work in the future, the plan should be altered.

There are several experiments that should be considered for the Garvin Heights area in the future. Most are related to soil content and buckthorn's impact on it. Based on how buckthorn spreads, it would be interesting to study the impact of buckthorn on nutrient levels, specifically nitrogen, as buckthorn adds a lot to the soil over a very short period of time. This may act as facilitation, but more research would be needed to really know. Additionally, work on allochemicals produced by buckthorn and left in the soil might produce some interesting results. Another set of experiments relates to scarification and buckthorn. This could examine the movement of buckthorn seeds through the digestive tract of goats and birds. There previously have been bird studies in this area, but it might be interesting to look at the native species to see if they impact the seeds in a different way. it would be very novel to study the impact on buckthorn seeds from moving through the digestive track of goats as there does not currently appear to be any studies done in this area. Another avenue of study would be seed choice and birds. This study would be used to see if birds would choose buckthorn fruit when given other choices, and if so, what kinds of birds. Off of this experiment one might study the impact of buckthorn on the diversity of bird species in the Garvin Heights area to see if there is a correlation between species diversity and buckthorn moving in. Finally, a study examining buckthorn's impact on the community might improve our understanding of the plant. In this study, one would look bottom up and seeing what kind of impact buckthorn is having on the community as a whole.

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