Effects of Aboveground Removal of Buckthorn on the Surrounding Plant Community

Christine Karlovitz
May 2008

Abstract

The numbers of invasive plants are increasing in forests of the Midwestern United States. These invasions are causing economic and ecological problems. Buckthorn is a nonnative invasive shrub, which grows rapidly and shades out surrounding native plants. It is important to better understand why buckthorn is invasive and methods of prevention and control. There are many different options to control buckthorn. I chose two mechanical methods that removed the above ground portion of the plant (cut and cut plus girdle) in order to see how buckthorn affects the surrounding plant community. Using transect lines, the surrounding plant community was monitored for four months after one year of treatment. At the end of the study, the regrowth of buckthorn was assessed. It was found that species richness did not differ between the treated plots and the control plots. However the cut plus girdle stumps contained on average 40%-50% fewer new buckthorn sprouts than just the cut stumps, suggesting that cutting and girdling is more effective than cutting along.

Introduction

Many plants that are introduced to a new area have the capability of out competing the native plant species, resulting in changes in habitat structure, and alterations in ecosystem function (Meloche and Murphy 2006). These invasive, non-indigenous plants have the ability to grow rapidly and adapt to many different conditions, and therefore can quickly widen their range north and south from where they originate. Though these plants generally have the ability to tolerate many different conditions, they are especially destructive in areas of similar climate to their native region (Czarapara 2005).

One such invasive plant is buckthorn (*Rhamnus cathartica*). Buckthorn is a non-native invasive shrub that was introduced to the United States from Eurasia during the 1850s. This invasive shrub is increasingly impacting the temperate deciduous forests of Wisconsin. Wisconsin ecosystems are perfectly suited for buckthorn to thrive because of the similar native climate to its native origin, Eurasia. Because buckthorn has the ability to grow into thick dense patches, and maintain its leaves considerably longer than most natives, it is thought to be an effective invader which shades out many of the understory plants below (Czarapata 2005). If understory plants are being affected due to the lack of sunlight, and not because of changes in soil chemistry, or competition of space, then the removal of the aboveground portion of buckthorn should have a positive effect on the surrounding plant community in which increases species diversity.

Here, I present research and findings of a manipulative experiment that was started in the summer of 2006 in southeast Wisconsin. During this time buckthorn sprouts were removed using two mechanical methods. The surrounding plant community as well as regrowth of the buckthorn was monitored in 2007. This research aims to better understand the reason buckthorn is so invasive and to provide better methods for prevention and control of this invasive plant.

Literature Review

I. Invasive Species

According to The Invasive Plant Association of Wisconsin (Czarapata 2005) an invasive plant is a "non-indigenous species or strain that becomes established in natural plant communities and wild areas that replaces native vegetation." Though most invasive plants occur outside their native range (and thus are referred to interchangeably as non-indigenous, alien, or exotic plants species), not all invasive plants are non-native plants; native plants may be considered invasive as well. These non-indigenous plants are plants that did not occur in the area before the European settlement (Czarapata 2005). As the number of invasive plants increases, the native plants are in danger of being out-competed and lost. It has been 10,000 years since the last glacier; it has taken that much time for native herbaceous plants, shrubs, and trees to establish and flourish (Czarapata, 2005). Over the past five hundred years, biogeographic invasions have occurred. In many parts of the world, the flora and fauna consist of many introduced plant species. In the United States, 2000-3000 exotic plant species grow in the country; these invasive plants can equal 10%-25% of all plants (MacDonald 2003). Within the past one hundred years, the United States has seen an increase in the number of invasive plants. Before the colonization of America, Eurasia and North America were isolated from each other. Introducing species started with the spread of the European exploration during the late fifteenth century (MacDonald 2003). This is most likely due to the increase in transportation ability and occurrence (Frappier et al. 2003).

Because alien species compete with non-invasives they often cause harm to the native plants (Lockwood, et al. 2007). And yet now, within only decades, exotic plants are taking over native areas and threatening native species. The consequences of allowing non-indigenous plants to invade our native forests may be one day having a monoculture forested area without the native plants that once blossomed.

Humans and other animals have greatly increased the ranges of certain plants, by accidentally or purposely introducing them to new areas (MacDonald 2003). Some reasons that plants might be introduced intentionally include plants that are introduced as agricultural crops and garden plants (MacDonald 2003). Many introduced plant species that become biological invaders are sold as ornamental plants or as hedgerows, by those who do not realize they will become invasive. Alien species can also be introduced unintentionally, such as seeds of plants that are dispersed through foot traffic. Seeds of plants can get stuck to the bottom of hiker's boots or shoes and then dropped off in another area (Czarapata 2005).

II. Costs of Invasives

Invasive plants are a problem economically and ecologically. In the United States alone, they destroy three million acres a year, costing the society and tax payers $35 billion a year for management and eradication of these plants (Czarapata 2005). Many trees that are needed for fiber and food have declined due to the invasion of invasive trees and shrubs. Many forests are being over run by invasives and therefore they are turning into thickets of undesired wood. Although this can be a gradual change, researchers are predicting it to be a major problem in the future forest production (Czarapata 2005). Every year resource managers are losing 148 million dollars in revenue due to the invasion of these non-indigenous plants (Fagan and Peart 2003).

Exotic plants can also cause problems ecologically. Second to habitat loss, invasive species are now known to cause loss in biodiversity (Heneghan et al. 2004). Biodiversity of plants, animals, and microbes has the potential to decrease in any area with invasive plants. Native plants can be crowded or shaded out due to the large canopies of non-indigenous trees and shrubs. Some invasives even produce chemicals that restrict growth of other plants. Potential long term results may include the extinction of some species locally or widespread. Endangered or threatened species may experience a rapid decline because of their habitat is being severely invaded. Almost all wildlife relies on specific native plants to survive. If these native plants are out competed and do not survive, the wildlife will be affected and may decrease.

Recreation is also being affected by exotic plants, including hiking, birding, and photography. Many non-indigenous plants are often thorny, scratchy, poisonous, or utterly too dense to get through. Property value can also be greatly reduced when invasive plants are present on one's property. Some invasive plants can even cause health harm to humans and livestock, such as skin burns by wild parsnip. Potentially future products may go un-discovered or un-developed due to the possible loss of plants with undiscovered usefulness (Czarapata 2005).

III. Why are Invasive Plants Invasive?

Invasive plants have many advantages over native plants which often times allow them to survive better. Exotic plants usually have a lack of predators, which can include diseases, insects, and herbivores (Czarapata 2005). Introducing non-indigenous plants can cause momentous damage to natural ecosystems. Invasions of alien plants can cause damage and difficultly to people in departments such as forestry and agriculture. In part because they lack predators in the new area, these non-indigenous plants can survive in a variety of conditions.

Invasive plants can be difficult to detect because they can initially be spread very slowly. However, once they establish themselves, they can reproduce and grow quickly. This can make it challenging to detect before the population grows out of control and it is too late to stop the spread of the species (Lockwood et al. 2007). An additional difficulty with detection is that crossbreeding between native plants and invasive plants also may occur, making it difficult sometimes to distinguish between the native and invasive species. As a result of this crossbreeding, native genes are lost as they become intermixed with the new species. Overtime, species and genetic biodiversity can be greatly reduced and in some cases be eliminated due to its ability to take over an entire area (Encyclopedia Britannica 2007). Change in biodiversity often translates to a loss of the ground layer plants, which increases run off and erosion, and decreases soil stability. Because of this increases in sediment transport, water quality in the surrounding area may decrease (Steffey 2006).

Research has increased on invasive plants that have become successful in high densities. Because invasive plants cause ecological and economic problems it is important to understand how they become invasive and how they can be prevented and/or managed. Studies on exotic plant species and their habitat have become increasingly popular (Fagan and Peart 2003) as well as studies on how to manage them in order to protect the non-invasive plants that are being affected by the exotics. For example, Melochie and Murphy (2006) studied four management options for the exotic plant Tree of-Heaven (*Ailanthus altissima*). This plant species is a slow spreading plant that is manageable if detected early. In this study, a cut stump with the application of a glyphosate solution worked the best out of their management treatments. This was measured by counting the number of shoots per square meter. Most importantly, just like many non-indigenous plants, if management is done immediately it can help stop the spread of the particular species (Melochie and Murphy 2006). In other cases, such as a study done on the invasive shrub *Lonicera tatarica* L., it was found it was just a light limiting factor on the under story plants. This study also found that woodlands exceeding thirty percent of *Lonicera tatarica* L., herb species richness was reduced as well as tree seedling growth was eliminated. Once these dense exotic plants are removed from an area, sunlight is able to penetrate down to the once shaded herbaceous plants. Once these understory plants can receive sunlight that can gain back their competitiveness (Henegham et al. 2004).

IV. Buckthorn

Buckthorn is a nonnative invasive shrub to the mid-west of the United States. Buckthorn was introduced from Eurasia to the mid-west during the 1850s. There are two different invasive species of buckthorn, Common Buckthorn (*Rhamnus cathartica*) and Glossy Buckthorn (*Rhamnus fragula,* syn. *Frangula alnus*). Common buckthorn is more wide spread than glossy buckthorn (Czarapata 2005). Therefore, for this study, I will be focusing on *Rhamnus cathartica*. Buckthorn is also known as European buckthorn, Hart's thorn, European waythorn, and Rhineberry. It is most commonly found along wooded edges, such as trails. The plant thrives in well drained soil but also can survive in wet soil as well. Buckthorn can be identified by its simple, opposite, dark-green leaves which are ovate with up-curled veins. This exotic plant has dark round berries that are approximately one quarter inch in cross section. The dark bark roughly textured and is marked with lenticels. Terminal buds are in pairs with a thorn protruding between. This can resemble a buck's hoof hence the name "buckthorn." Buckthorn can grow up to twenty five feet and the trunk can get up to ten inches wide (Czarapata 2005). Buckthorn is spread by the parent plant or by birds (Czarapata 2005). The bulk of the seeds that fall from the parent plants land on the surrounding ground floor, between five and fifteen meters. The density of these fallen seeds are forty times greater five meters from the trunk of the mature buckthorn plants than areas fifteen meters away (Knight and Reich 2005) and so they form dense patches that spread wider each year.

In fact, buckthorn is preferred for its dense foliage and rapid growth. But, for this reason it is also an invasive plant that is of major concern (Czarapata 2005). According to a study involving eleven European woody species, buckthorn was one of the faster growing species. Knight et al. 2007). Buckthorn is commonly planted as visual screening between areas where space is limited for bigger trees, but it has spread and flourished in many forested areas of the Midwest. Buckthorn is considered invasive because it eliminates the native community of seedlings, saplings, and ground layer plants. It also has the ability to grow in a variety of conditions, including soil with few nutrients, full sun, dense shade, and wet soil (Czarapata 2005), a characteristic that few native species have.

As buckthorn multiplies in an area, the ability of other surrounding plants to grow and remain healthy can be limited. This exotic plant usually takes over an area; therefore it would be a moncultured area. Buckthorn has a longer growing season than most other plants. One study by Robin Harrington (1989) found that buckthorn has a high carbon storage capacity. This gives the plant the ability to store energy. This is because buckthorn leafs out early and senescence late. The problem for native plants with a larger plant leafing out early is that the early presence shades out the up coming surrounding plants. The problem with a plant senesensing late is that the plant has more time for photosynthesis and to build up resources that help them establish themselves. This allows the plant to have up to fifty-eight days more photosynthesis than native plants (Harrington 1989). According to a study in southern Wisconsin, it was found that 38% of buckthorn's yearly carbon gain happened within four weeks when native shrubs are leafless (Knight et al. 2007).

Because buckthorn is a nonnative plant that out competes native plants because of its rapid growth and dense foliage, the plant has sparked an increase in research interest (Heneghan at al. 2004). Another study on buckthorn's cousin, *Rhamnus frangula* (glossy buckthorn) found that species of buckthorn reduced the growth and survival of all sapling species. This research also found that *Rhamnus frangula* changed the relative abundance of seedlings in the surrounding area. This study found that less than ten percent of tree saplings can survive due to the dense upper story of buckthorn (Fagan and Peart 2003). In contrast to this study, a two year study done the same species found that after removing *Rhamnus frangula*, percent herb cover nor species richness were not significantly affected. This research suggested that this species of buckthorn hinder the establishment of lower story tree seedlings since it was found that in areas were *Rhamnus frangula* was present had significant fewer native tree seedlings than areas where the shrub was removed (Frappier et al. 2004). Some studies on this particular species of buckthorn suggest that species richness increases once buckthorn is removed (Frappier, at al. 2004) and others found that plant species richness is highest where *Rhamnus frangula* is found (Frappier, et al. 2004). Clearly, different ecosystems respond differently to the invasion of different invasive plants, including the *Rhamnus frangula* (Frappier, et al. 2004).

Due to the fact buckthorn is not native to this area; there is a lack of predators. Birds are the only known species that feeds on buckthorn even though it may not be preferred (Knight et al. 2007). However, the seeds can act as a laxative for birds which causes dehydration and a loss of energy. Also buckthorn plants are not ideal for birds to establish habitat because birds prefer a large number of tree species as well as a variation horizontal and vertical canopies (Czarapata 2005). Because buckthorn is so invasive, states including Illinois and Minnesota have laws preventing buckthorn to be sold (Czarapata 2005). However, it is quite feasible for people who live in these states to drive to another state without restrictions to purchase the invasive plant.

V. Management

Options to control buckthorn include biological, chemical, and mechanical controls, and each of these have varying levels of feasibility and effectiveness. Biological control is introducing a species to feed on the desired species to reduce its fitness (Mooney, et al. 2005). One example of biological control is the weevil (*Hylobius transversovittatus*) that has been introduced to feed on the invasive plant purple loosestrife. To date, this weevil has been successful in decreasing the numbers of purple loosestrife (Bossey 2003). However there are no currently known biological organisms at this time that control buckthorn and there can be problems with biological controls because it introduces the idea of introducing a species not knowing if this species will become invasive or not.

Chemical controls are also an option for controlling the invasive shrub buckthorn. The two recommended chemical treatments for buckthorn include Glyphosate (Round-up) and Triclopyr (Brush-B-Gon). These chemicals can be sprayed on the plant to eventually kill it (Czarapata 2005). Round-up is a glycophospate solution which quickly biodegrades. It can usually be successful on trees or cut stumps (Meloche and Murphy 2006). Chemicals also influence both the above and below ground portions of the plant. Additionally, there are concerns with using chemicals because it is possible it can also negatively affect the surrounding native plants if the chemicals get into the soil or accidentally applied to these non-targeted plants (Mooney et al. 2005). This may be a problem if one is studying the surrounding plant community. Another major draw back of using this control method includes the high cost of the chemicals as well as the need for reapplication (Mooney, et al. 2005). Also, many times the use of herbicides increases the longer invasive plants are left to grow.

The last option for managing buckthorn is mechanical controls. Controlled burning is the number one recommended treatment for buckthorn, which works best if done in the fall or early spring. Controlled burns used on buckthorn may need to be repeated several times in order to completely deplete the seed bank. However, any time fire is used repeatedly in an area; it can negatively affect the native plant community (Czarapata 2005). Also, only trained and experienced people are able take part in controlled burning due to health and safety risks. Controlled burning may also not be appropriate for thick stands, such as buckthorn stands. Overall, there might be too much understory "fuel" to burn. Shrub removal is another mechanical method which pulls the plant out by the roots via machines, tools, or by using ones hands. This method can be effective but very labor intensive. This control method may not always be feasible depending on the size of the shrub. Shrub removal can also cause significant soil disturbance. Another mechanical control includes cutting back the plant using hand tools. This method can be effective if recognized early and removed before the plant begins to fruit such as early spring or late fall. Girdling is another mechanical method. Girdling is removing a two inch strip of bark all the way around the plant, exposing the phloem. This stops the movement of sugars up and down the plant, which will eventually kill the plant (Czarapata 2005). The main downside of using mechanical methods includes to disturbance of humans as well as disturbance of the soil and vegetation by tools or machines. Additionally, manual work can be very labor intensive. Because labor can be costly, mechanical methods seem to be most popular with volunteer groups. Most importantly, managing an invasive species is not the goal; the long term higher goal is to restore habitat, preserve the ecosystem, and re-establish the natural ecosystem process (Mooney et al. 2005).

Many studies and experiments have been done on invasive species, including buckthorn. Using random sampling along transect lines in four sites, Frappier et al. (2003) researched how glossy buckthorn alters the native plant community, concluding that in areas where buckthorn was abundant, the growth of native plant species declined. They also concluded that plant species richness, herb cover, and seedling densities were higher in areas were buckthorn had been removed prior to the experiment (Frappier et al. 2003). Other studies also include researching buckthorns ability to change the surrounding of where buckthorn is dominate compared to where it is not.

In my study, the above ground portion of buckthorn was removed using two mechanical methods in two southeastern Wisconsin forests. The surrounding plant community along with the regrowth of buckthorn was monitored for four months. This is in order to see what effects the dense above ground portion of buckthorn has on the surrounding plant community. Mechanical methods are expected to be viable management methods to control buckthorn, which removes the above ground portion of the plant. If re-growth is minimal, then there will be an increase in the number and species richness of surrounding native plant community in the treated plots due to the now increase of sun light.

Methods

Two local nature preserves were used as study sites for this experiment. One site was Hawthorn Hollow in Kenosha, Wisconsin, and the other was Pringle Nature Center in Bristol, Wisconsin. Hawthorn Hollow is a nature preserve and arboretum. The land at this nature center was purchased in 1935. There are over forty acres at Hawthorn Hollow including two miles of nature trails for the public to use. The area contains an original prairie, annual and perennial gardens, butterfly garden, dwarf conifer collection, as well as a mix deciduous forest (Figure 1a).

Pringle Nature Center, also known as Bristol Woods, is a mixed deciduous forest, dominated by red oak. In the 1970s, the county bought the land from a local resident, Bob Pringle. At Pringle, there are two-hundred acres of woods, marshes, and prairies, including several wood chipped trails. Today the Pringle Nature Center is mainly operated by the Hoy Chapter of the Audubon Society in Racine (Villaire) (Figure 1b). Both of these sites were chosen because they both have been (successfully) invaded by buckthorn. In addition, these nature centers also gave me permission to conduct research and experiments which include the removal of buckthorn on their land.

Figure 1a and 1b: *Maps of Study Sites (Hawthorn Hollow and Pringle Nature Center).*

Figure 1a.

Figure 1b.

At each site, three blocks were measured out and flagged with stakes. In this study, a block is a group of three ten meter by ten meter square plots with five meter buffer zones in between (Figure 1). Therefore, one block is forty meters by ten meters with five meters between the plots. This results in each site having nine plots. All blocks were located off of the trails as much as possible to avoid plant disturbance from foot traffic. Every two meters in each plot, twine was put down to act as transect lines. This produced four transect lines per plot (2m, 4m, 6m, and 8m). Transect lines are often used to survey alterations in plant vegetation along different habitats or gradients (Bullock 1996).

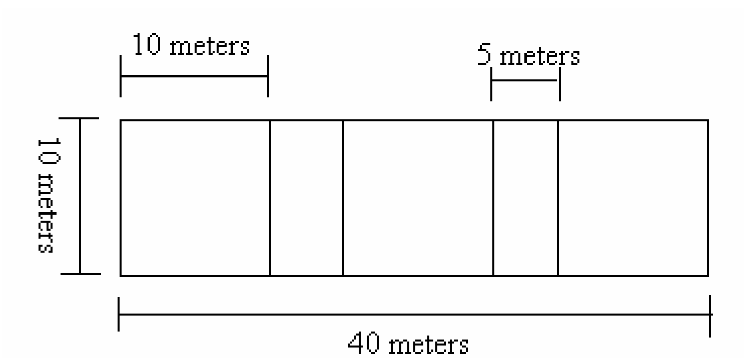


Figure 1. Block method. Block is 40m by 10m. Plots are 10m by 10m with a 5m buffer zone.

the aboveground portion of

' only remove the aboveground portion. Other treatments such as fire or chemicals would disturb the soil and roots in addition to the shoots. Therefore it would not be known if surrounding plant diversity is affected because of aboveground or belowground reasons. Therefore I had two mechanical methods and a control. The control plots received no treatment throughout the entire experiment. One of the treatments was cut, where buckthorn in the plot was cut as low to the ground as possible using pruning sheers and hedge clippers. The other treatment was cut plus girdle, where buckthorn was cut low then girdled. Girdling requires a 1-2 inch wide strip of bark to be cut and pealed all the way around the trunk, which stops the movement of sugars up and down the plant.

It was decided to cut the girdle plants in order to see a response more quickly. By just girdling a plant, it can take one or two years for the shrub to die (Czarapata 2005). Which plot received which treatment was determined by a random roll of a dice. Each block contained a control plot, a cut plot, and a cut plus girdle plot. Treatment of the plots occurred two weeks after the Month 1 data was collected.

To assess the surrounding plant community, transect lines that were laid down were considered the middle of my belt transect of thirty centimeters. Belt transects are mainly framed quadrats that lay continuously along the length of the transect line (Bullock 1996). Every four weeks for four months (June-September), I identified all of the plants that laid rooted within the belt transect using standard plant identification books. This data was tallied and recorded for four months for each site, Hawthorn Hollow and Pringle Nature Center.

At the end of the study, canopy width of the buckthorn plants was measured in the north-south direction as well as the east-west direction using a digital compass. This was done so canopy width could be analyzed. Also, in order to measure the usefulness of the mechanical methods and to assess regrowth, the number of new buckthorn sprouts was counted on all of the buckthorn stumps in the managed plots (cut and cut plus girdle).

Results

Effectiveness of Mechanical Removal

Regrowth of buckthorn was present at both Hawthorn and Pringle. The number of new sprouts was marginally lower at Pringle than at Hawthorn ($p=0.089$) (Figure 4). However, at Pringle the buckthorn shrubs/stumps seemed to have a wider canopy width which was marginally significant to than Hawthorn ($p=0.055$) (Figure 3). The cut and girdle stumps had significantly 40%-50% fewer new buckthorn sprouts than just the cut stumps ($p=0.007$) (Figure

3). There was not a significant difference in the average regrowth width between the two treatments (p=1.000) (Figure 4).

Effectiveness of Buckthorn Removal on Species Richness

At these two sites, more species were present early in the season (p=0.001 June greater to September). At the end of the experiment (September) only the treated plots at Pringle contained 1-2 more plant species than the control plot, but this is not a significant difference (p=0.419). Hawthorn had significantly more species overall (p=0.001) but treatment of buckthorn had no significant effect (p=0.419) (Figure 5 and 6).

New species were present in the managed plots at the end of the study at both sites. At Hawthorn Hollow, poison ivy, basswood, box elder, elm, and white oak were found in the managed plots (cut and cut plus girdle) but not in the control sites. There were also plants such as nightshade and queen anne's lace, that were found in one of the managed plots and not the control. At Pringle, plants that were only found in the treated plots and not the control included, may apple and tick-tree foil. Green dragon, unknown #3, and poplar were found in one of the managed plots and not the control (Appendix 1).

What Happens When Buckthorn is Removed?

At the end of the study (September), in both sites the percent of buckthorn and other invasives have reached over fifty percent of the control plots, which is much greater than in the treated plots. There was not a significant difference between the two treated plots at each site (p=1.000). However there is a significantly higher percent of invasive plants species at Hawthorn than at Pringle (p=0.003). In the control plots at both sites, if the percent of buckthorn and the percent of other invasives were added together, this would reach about 60%. This is significantly greater than the sum of percent buckthorn and percent other invasives in the treated plots, which equals about 20% (p=0.006) (Figure 7).

Figure 3: *Average Number of New Buckthorn Sprouts at Hawthorn Hollow and Pringle Nature Center.*

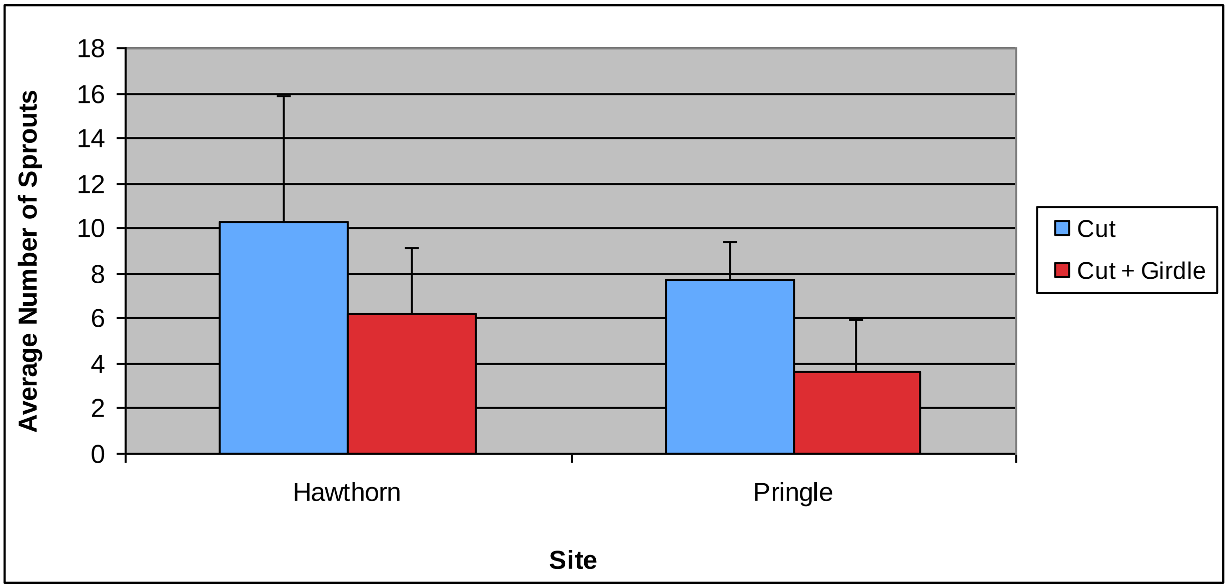


Figure 4: *Average Canopy Width of Buckthorn at Each Site*.

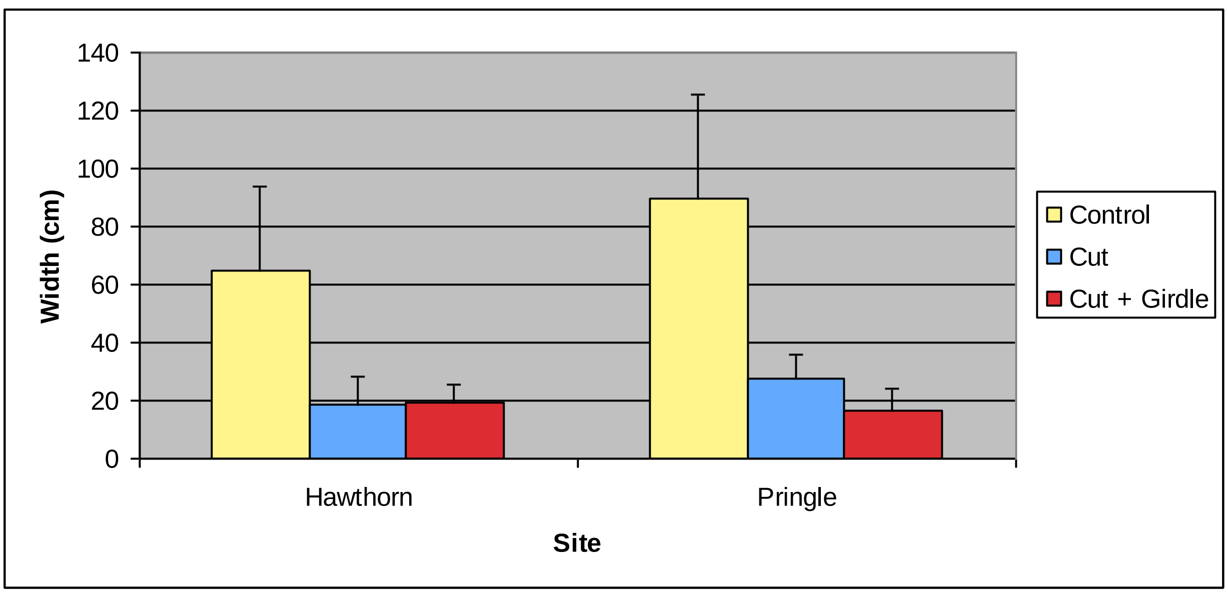


Figure 5: *Average Number of Plant Species at Hawthorn Hollow.*

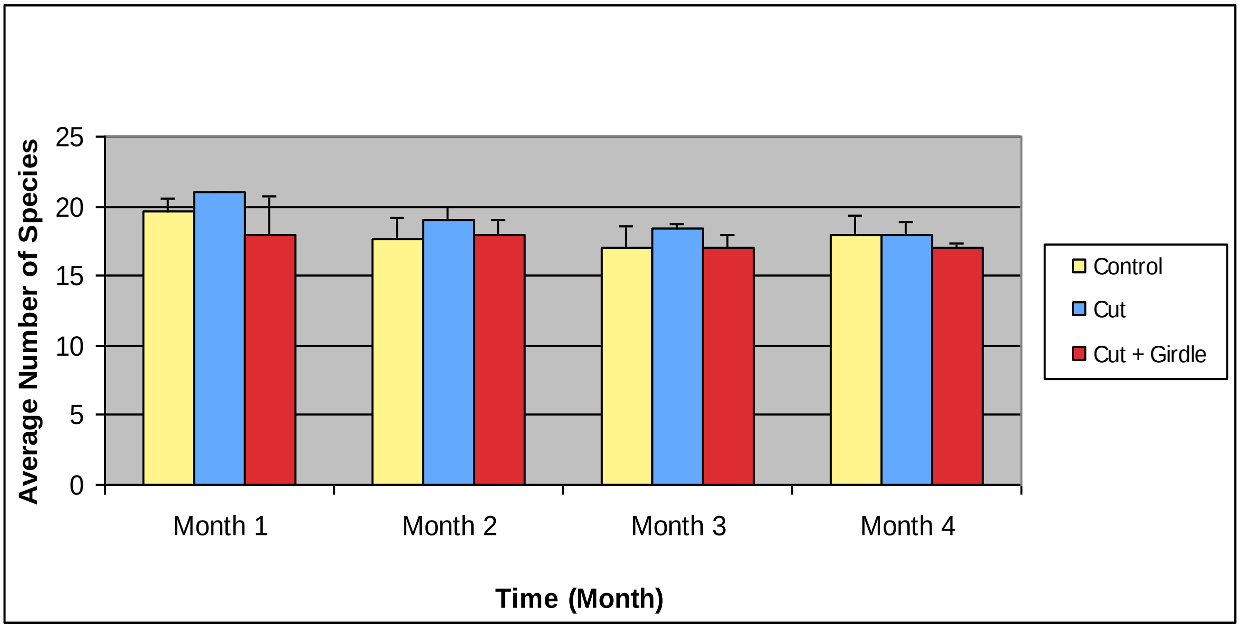


Figure 6: *Average Number of Plant Species at Pringle Nature Center.*

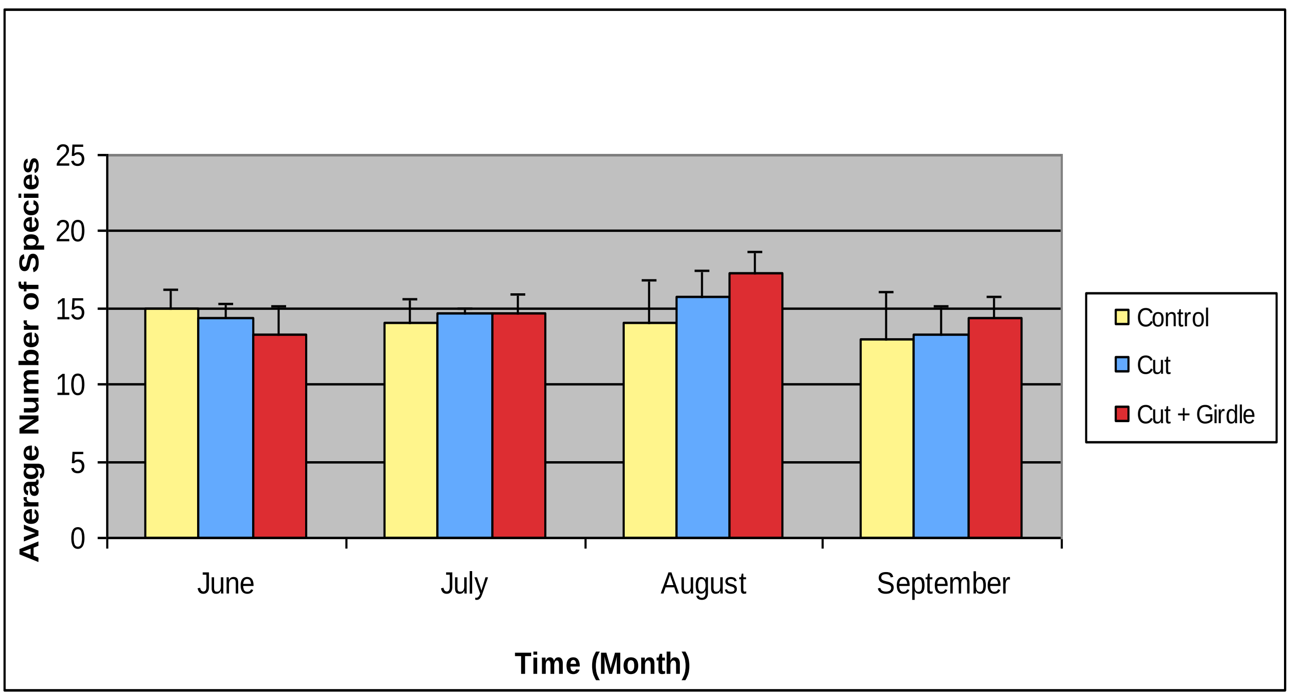
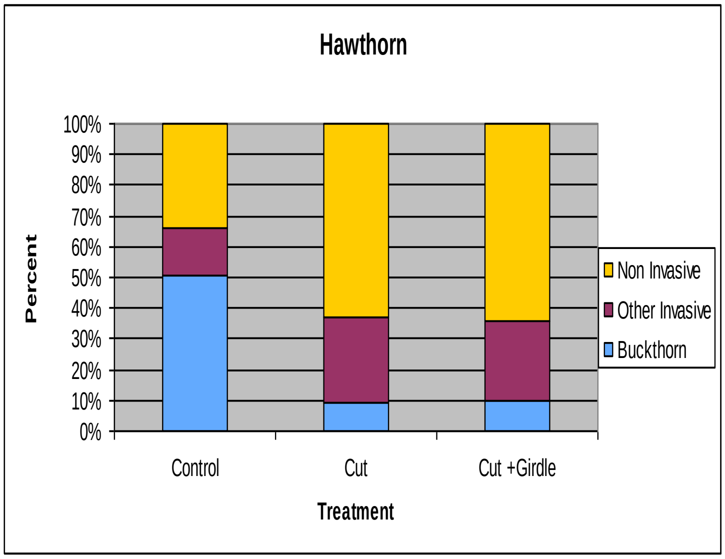
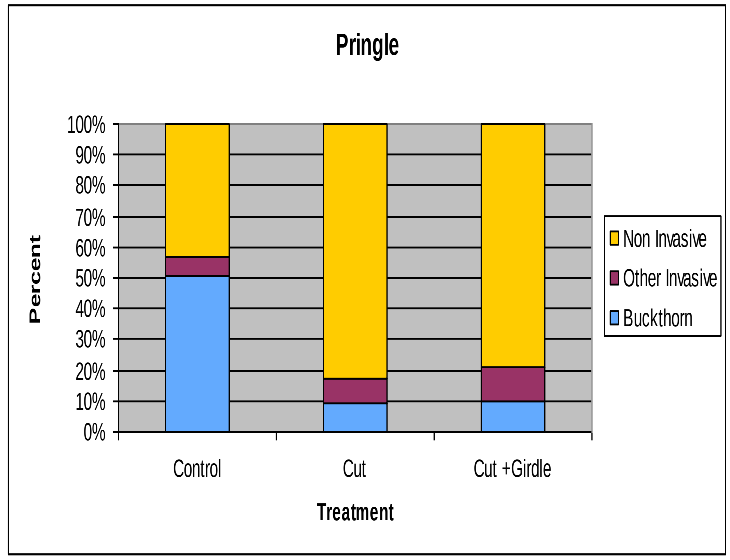


Figure 7: *End of study (September) average Percent of Buckthorn, Other Invasives, and Non Invasive Species at each site.*





Discussion

Effectiveness of Mechanical Removal

It was found that 100% of all new sprouts occurred below the girdle. If the girdle was right at the baseline of the plant and ground, some buckthorn stumps contained zero new sprouts. This may be why the cut plus girdled stumps on average had significantly 40%-50% fewer numbers of new sprouts than the cut method. Some concerns with the girdling method include that girdling is essentially cutting if the girdle was not at the baseline. Girdling is just "cutting" the stump low. Also, because of the hand tools that were feasible, cutting occurred at different heights, depending on the diameter of the buckthorn. Depending on how much stump was left and how high the girdle was depended on how many new sprouts sprouted. If a thick stump was left high, it contained a higher number of new buckthorn sprouts than a much smaller stump that was cut very low to the ground. Also, Pringle might have had more buckthorn stumps that were treated lower to the ground because of the size of the stump, than at Hawthorn. This may also be the reason why the number of new sprouts was marginally lower at Pringle than at Hawthorn. Or perhaps the age of the buckthorn played a role. The buckthorn shrubs at Hawthorn were much younger than at Pringle and because seedlings tend to grow more rapid than when they are adolescent plants, this may also be a reason why the number of new sprouts at Hawthorn was marginally higher than at Pringle.

Because there were fewer numbers of plant species at Pringle, this may explain why the buckthorn shrubs/stumps at Pringle seem to have a wider canopy width than at Hawthorn. Because there were fewer species, buckthorn can grow outward as well as upward. As previously mentioned, because girdling is essentially cutting lower, this may be why there does not seem to be a significant difference in the average regrowth width between the two treatments.

Effectiveness of Buckthorn Removal on Species Richness

It was found that more plant species were present early in the season than at the end of the season. There are many possible reasons why this is, one including seasonality. The spring ephemerals were blooming during the early season and at the end of the study (September) many plants were dying off because of the season changing to fall. However, data was not collected during the month of May, the prime time for spring ephemerals. Hawthorn Hollow and Pringle Nature Center are two different sites and have different histories. This may explain the reason why overall, Hawthorn had significantly more plant species than at Pringle. Because data was only collected for four months after one year of treatment, this may be why there was not a significant difference in the number of plant species in the control plots compared to the treated plots. It may just take a longer time to see a larger response in the plant community in these managed plots. According to Frappier et al. (2004), it may take up to two years to see a response in the plant community. This study found that after two years of the removal of buckthorn, the treated plots contained significantly higher amounts of first-year native tree seedlings (Frappier et al, 2004). Or perhaps there may be a lack of space for other plant species to establish themselves because the buckthorn roots are still present. Also the seed back within these plots may just not be there. Finally, when the management was performed, some disturbance/trampling occurred in the treated plots during the summer of 2006, which may have delayed the recovery of the surrounding plant community.

It was expected that by removing buckthorn, light can now shine down to the ground floor, so that plants would no longer be shaded out and could survive. This may be why some plant species were found in the treated plots and not in the control plots. However, it was also not noted whether the plants rooted in the belt transects were full trees or saplings. Therefore it is unknown for sure whether or not these plant species that are found in the managed plots are trees or new saplings. Also the plants found in the treated plots and not in the controls at Hawthorn were not the same plants found at Pringle. If new saplings were found, this would match Frappier et al. 2004 study. During this research, it was found that buckthorn hinders other understory trees. Because buckthorn is removed these sun-loving understory trees can now flourish.

What Happens When Buckthorn is Removed?

Because of buckthorn's ability to grow rapidly and its ability to shade out the surrounding plant community, this may be why the control plots at both sites the percent of buckthorn along with the percent of other invasives species reached more than fifty percent. Hawthorn Hollow contained a large amount of prickly ash and garlic mustard; this is believed to be the reason why Pringle contained fewer amounts of other invasives than Hawthorn. The increase of the number of invasive plants taking over our forests is likely the reason why the percent of buckthorn plus percent of other invasives are so high (50%-60%). The consequence of this is having an invasive monoculture forested area, without high biodiversity (Czarapata 2005).

Conclusions and Future Studies

If invasive species like buckthorn are not controlled, forests have the possibility of containing over fifty percent invasive plants if management is not performed. Of the two treatments I tested (cut and cut plus girdle) I would suggest using the cut plus girdle method over the cut. This is because it was found that on average the cut plus girdle treatment produced significantly 40%-50% fewer number of new sprouts than the cut method. It was also found that no new buckthorn sprouts sprouted above the girdle and on some of the buckthorn stumps where it was girdled at the baseline of the ground, there were no new sprouts. If all girdles are performed at the base of the stump, it is believed this can be a very effective method to control the invasive plant buckthorn.

In the future, I would like to go back into all of the plots and re-girdle at the baseline. This would make all of the girdled stumps uniform. For the cut method, I would go back and cut all of the stumps at the baseline as well. I believe these methods would be more consistent. Also, I would like to record data on this experiment over a longer period of time, such as two years, since it may take up to two years to see a response in the surrounding plant community (Frappier et al. 2004).

Buckthorn is an introduced invasive shrub that is causing ecological and economic problems, particularly on the surrounding plant community. There are many different options to control buckthorn. As this data shows, it may take time to see a response in the surrounding plant community after the treatments are applied. Clearly long term studies are important and necessary when dealing with such an abundant species.

Appendix 1

Appendix 1: Hawthorn Presence and Absence Data			
Plot	**Control-H 2007**	**Cut-H 2007**	**Cut and G-H 2007**
Herbaceous			
Aster (white flower)	x	x	x
Clinquefoil	x	x	x
Cone Flower	x		
Creeping Charlie	**x**		
Dandelion	x	x	
Grass	x	x	x
Garlic Mustard	**x**	**x**	**x**
Goldenrod	x	x	x
Green Dragon	x	x	x
Jack in the Pulpit	x	x	x
May Apple			
Nightshade		x	
Onion	x	x	x
Poison Ivy		x	x
Queen Anne's Lace		x	
Ribes 1	x	x	x
Salomon's Seal	x	x	x
Tick Treefoil	x	x	x
Trillium	x	x	
Virginia Creeper	x	x	x
White Avens	x	x	
Whorled			x
Unknown # 2	x	x	x
Unknown # 3	x	x	
Unknown # 4 (olives)	x		
Shrub			
Grape Vine	**x**	**x**	**x**
Raspberry	x		x
Red Maple Vine			
Rose			
Star Vine	**x**	**x**	**x**
Viburnum	x	x	x
Tree			
Ash	x	x	x
Ash (Prickly)	**x**	**x**	**x**
Basswood		x	x
Box Elder		x	x
Buckthorn	**x**	**x**	**x**
Cherry	x	x	x

Cherry (Black)	x	x	x
Chestnut	x	x	x
Dogwood	x	x	x
Elm		x	x
Hawthorne	x	x	
Hickory	x	x	
Hickory (Shagbark)	x		x
Ironwood	x	x	x
Maple (Norway)	x	x	x
Maple (Red)	x	x	x
Maple (Sugar)	x	x	x
Poplar	x		x
Oak (Red)	x	x	x
Oak (White)		x	x

*** Plants bolded are listed as invasive.**

Appendix 2: Pringle Presence and Absence Data			
Plot	**Control-P 2007**	**Cut-P 2007**	**Cut and G-P 2007**
Herbaceous			
Aster (white flower)	x	x	x
Clinquefoil	x	x	
Cone Flower			
Creeping Charlie			
Dandelion	x	x	x
Grass	x	x	
Garlic Mustard	**x**	**x**	**x**
Goldenrod			
Green Dragon		x	
Jack in the Pulpit	x	x	x
May Apple		x	x
Nightshade	x		
Onion			
Poison Ivy	x		
Queen Anne's Lace			
Ribes 1	x	x	x
Salomon's Seal	x	x	x
Tick Treefoil		x	x
Trillium	x	x	
Virginia Creeper	x	x	x
White Avens	x		
Whorled	x	x	
Unknown # 2	x		x

Unknown # 3			x
Unknown # 4 (olives)			
Shrub			
Grape Vine	x	x	x
Raspberry	x	x	x
Red Maple Vine	x	x	
Rose	**x**	**x**	**x**
Star Vine		**x**	
Viburnum	x	x	x
Tree			
Ash	x	x	x
Ash (Prickly)			
Basswood			
Box Elder	x	x	x
Buckthorn	**x**	**x**	**x**
Cherry	x	x	x
Cherry (Black)	x	x	x
Chestnut	x	x	x
Dogwood	x	x	x
Elm			
Hawthorne	x	x	x
Hickory	x	x	x
Hickory (Shagbark)	x		x
Ironwood	x	x	x
Maple (Norway)			
Maple (Red)	x	x	x
Maple (Sugar)			x
Poplar			
Oak (Red)	x	x	x
Oak (White)	x	x	x

*** Plants bolded are listed as invasive.**

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