INVASIVE PLANT SPECIES MANAGEMENT AT GWYNEDD WILDLIFE PRESERVE, AMBLER, PA

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Acknowledgements:

When choosing a project for school, it is important to find a topic that forces you to really learn. If you are already something of an expert, you may create a better work, but you will get less out of it. There is a balance, however, in trying not to choose something too far over your own head. Trial by fire leads to many a burned person. Fortunately, to keep from getting overly scorched, there were several people without whom I never would have managed to complete this project. First and foremost is my academic advisor, Dr. Sarah Willig who met with me at Gwynedd Wildlife Preserve on multiple occasions and on campus at the University of Pennsylvania on several other occasions. She also responded to more emails than I can count, assisting in planning, species identification, and edits. Next is Dan Barringer, without whom the project literally never would have existed. Aside from introducing me to the subject and preserve itself, his expertise was especially helpful when literature tried to take me astray. Janet Novak was also an extremely important resource. There are many plant species to know and she volunteered to assist me in identifying samples that had me stumped. Peers of mine at the University of Pennsylvania include Michael McGraw and Michelle Mancini, neither of whom are experts at invasive species or botany, but took the time to help me survey the preserve. Our knowledge supplemented each other, making for better surveying and learning all around. Even when the combined knowledge was lacking, they kept my spirits high and the internal workhorse working.

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I. Introduction to Invasive Species

Introduction

One of the most serious threats to ecosystems worldwide is from the pressure exerted by non-native species entering new habitats that are not part of their native ranges. While the movement of species is a regular occurrence, the unprecedented rate at which humans are introducing organisms to new areas represents a new era. Non-indigenous organisms can alter ecosystem functions and negatively impact native species. Spread by humans in the increasingly connected world, non-indigenous organisms' global presence does not appear to be declining any time soon.

Until relatively recently in human history, distances around the globe were vast, as one could only travel as far as he or she could walk or run. Animals such as horses were domesticated and turned to transportation; ships were built to carry people and goods from place to place. Distances metaphorically shrank as one could get further faster and with more ease. Today people can get from any part of the globe to any other part within hours or days. Experts from a variety of fields have been discussing this dwindling of distances. For a biologist, this is comparable to the creation of a new supercontinent where organisms that had been separated by oceans were now within reach, but rather than a land bridge connecting everything, it is a human bridge of ships and airplanes. Terms such as "New Pangea," "Anthropocene," and "Homogocene" have been created to reflect this concept (Crutzen 2002; McKinney 2005). Surprisingly, this is not a strictly modern concept. In the 1800s, terms such as "Anthropozoic," "Psychozoic," and "Noosphere" had also been developed to indicate the departure from the Holocene. Of course, the changes in ecosystem dynamics today are likely far bigger than the original authors imagined over a century ago. And with the rapid spread of invasive organisms, some see the future Earth as little more than a "planet of weeds" (Zalasiewicz et al. 2010).

Definitions

Aside from physiological descriptions of plants and animals, a native habitat is an important descriptor. This tells people where they came from and to which ecosystems they are adapted. Terms such as "indigenous" and "native" reflect where an organism's native habitat is located. Definitions include "originating naturally in a particular country or region" and "applied to a species that occurs naturally in an area, and therefore one that has not been introduced either accidentally or intentionally" (Schwartz 1997). Therefore, when an organism is moved to a new area, perhaps by natural processes or by another animal such as humans, it becomes "non-indigenous" or "non-native" which are the terms that will be used interchangeably in this paper. Sometimes sources refer to them as "exotic" or "alien" referring to their distant origins.

The next important definition is regarding how damaging an organism is to its new environment. When an organism spreads rapidly in a new habitat, altering the ecology, it is termed "invasive." Only a fraction of non-native organisms act in this manner, and so are not considered invasive (Baskin 2002). Although some native species can be aggressive, in this paper, unless specifically stated otherwise, species labeled invasive are also non-native.

Many researchers have created methods to predict which species are invasive or not. None are perfect, though many have high degrees of accuracy. There have been many traits determined to increase a plant's likelihood of turning invasive. Studies have suggested mean seed mass, minimum juvenile period, growth rates, photosynthetic rates, nitrogen concentration, and specific leaf area are

key indicators. Another indicator is if a species has invaded another region of the world (Reuben and Drake 2009).

History of Non-Native Distribution

There is no one way in which humans have introduced organisms around the world and it is not, in fact, a new development since Western Imperialism. The human transport of non-native species has a rich and ancient history. As agriculture developed around 10,000 years ago, these newly domesticated, or even just semi-domesticated, plants were transported across great distances to be farmed. Today the farming of non-native species alone is worth over 8 billion US dollars (Baskin 2002). But the early introductions of alien species were not limited to just agriculture. About 4,000 years ago, an Egyptian queen sent ships down the coast of Africa to find incense trees for her gardens. Greeks and Romans used ships to sail far in search of fragrances, medicinal plants, and flowers. Even remote islands of Polynesia had fruits and spices brought in from Malaysia centuries ago. As European exploration, and then imperialism, grew, so did the spread of non-native species. In many cases, the explorers saw themselves as helpful, leaving pigs, goats, and even planting crops in places they visited, so the next people to come by would have a food source. By the 1800s, when Darwin made his famous trip in the Beagle, he observed so much damage to the Pampas by European invasives he doubted, "whether any case is on record, of an invasion so grand a scale of one plant over the aborigines" (Baskin 2002). Sometimes it is easy to figure out which species are native and which are non-native. However, historical records are not always clear and such classifications are difficult.

In North America, native species are often considered to be what was there before European colonialism. However, this gets confusing as the first documented colonization by Europeans was actually in the 10th century when Scandinavians settled Greenland and Newfoundland. To Greenland they brought Blue grass (*Poa annua*), common chickweed (*Stellaria media*), knotweed (*Polygonum aviculare*), sheep-sorrel (*Rumex acetosella*), shepherd's purse (*Capsella bursa-pastoris*), and Common yarrow (*Achillea millefolium*), though no pollen records indicate anything was brought to Newfoundland (Jackson 2000). The Spanish then arrived in the Caribbean in the late 15th century, drastically changing the ecology there. However, Europeans were not the only contributors to alien plant dispersal. It is apparent that Native Americans also moved plants around for agriculture and fiber, and likely by accident as well. While the species may have been native to the Americas, they were not always regionally native (Jackson 2000).

The introduction and spread of non-natives was long considered only in a positive light. Plants and animals, since the invention of agriculture, have been understood as great commodities. A species from one region brought to another would help that new place with the benefits it possessed. In the mid 1800s, a movement known as "acclimatization" developed in France, Britain, Spain, the United States, and elsewhere. People formed societies with the purposes of exchanging exotic species for the common benefit. There was a serious effort to bring yaks (*Boss spp.*) to France, believing that they would revolutionize French peasant life for the better. As one society member asked, "We have given the sheep to Australia; why have we not taken in exchange the kangaroo—a most edible and productive creature?" (Baskin 2002).

The Founding Fathers of the United States played a role in plant introductions. In 1790, Thomas Jefferson wrote, "The greatest service which can be rendered any country is to add a useful plant to its

culture." When Benjamin Franklin went abroad, he sought out new seeds to send back to the United States. By 1827, this had become common practice and President John Quincy Adams officially requested that all government officials seek out new and rare seeds. The first time the Federal government used funds to experiment with new crops was in 1847. With the creation of the United States Department of Agriculture in 1862, and especially the Section of Seed and Plant Introduction in 1898, the search for-and importation of-new exotic plants grew at an enormous rate (Hyland 1977).

In more recent history, exotic species exchanges have only increased as the world communities have become more interconnected. Organisms have value to them, whether as food, ornamentals, or another method of resource utilization (Pimentel et al. 2005).

Methods of Non-Native Distribution:

The methods of alien spread across the world today are numerous and diverse. There is, of course, a natural history to this proliferation. Wind and waves may transport organisms across long distance. Plants from the Caribbean naturally made it to the British Isles using the Gulf Stream (Mack 2003). Birds and grazers that migrate may also move themselves and anything they carry. Tectonic activity may introduce entirely separate continents to one another. These introductions are, however, uncommon. Humans are spreading non-native species far more often and on a global scale.

Some of the most common reasons for non-native introductions are as ornamentals, crops, or for erosion control and landscape restoration. Many other organisms are brought in for sport (hunting and fishing). Others come in as a complete accident. For instance, soils arriving with ornamental plants may also have seeds, worms, fungi, or even diseases. When importing seeds for one plant, such as rice, one may accidentally bring in a heterogeneous mixture of seeds, rice as well as another alien. Even the simple process of transportation may spread organisms as they may live in ships (Pimentel et al. 2005). It has been suggested that about 82% of 235 woody invasive species in the United States were brought first for landscaping, 14% for agriculture, 3% for ornamentals (though used mostly as erosion control), and 1% were accidental (Culley and Hardiman 2007). Currently, at least 10,000 species are accidentally being transported around the world in ship ballast water (De Poorter 2009). The sheer number of species, as well as the variety of genera and their human-dispersal mechanisms, is causing rapid changes around the world.

Nonnative organisms can take so many different pathways that they are often difficult to track, making simple logical steps misleading. For instance, the Chinese mitten crab (*Eriocheir sinensis*) is obviously an East Asian crab. Its distribution on the west coast of the United States seems to indicate a logical path as shipping directly between the two areas is common. However, the crab was actually introduced to Europe first and made its way from Europe to the United States. Thus, it was a multiple-step, indirect process that brought about its invasion (Cox 2004).

Once brought to a new area, invasive plants generally find natural means to disperse, often using native herbivores. A study in 1991 demonstrated that 33% of seeds consumed and dispersed by birds in central New Jersey forests were non-indigenous (Schiffman 1997). Even worse, a single cow can disperse 300,000 viable seeds per day. Epizoochory is when seeds have hooks or sticky stuff on surfaces to attach to animal skin, fur, or feathers and disperse. Furthermore, an animal that transports a seed may also cause the disturbance in the soil that allows the seed to germinate and take root (Schiffman 1997).

Habitats are never static systems, and they have been changing dramatically in recent history. The anthropogenic changes to Earth's ecosystems are constantly occurring and can make conditions more favorable for invasions. Global increases in carbon dioxide, nitrogen, ultraviolet radiation, deforestation, desertification, chemical pollution, habitat disturbance and fragmentation, and loss of biodiversity can help invasives. This is because invasives, species who are very opportunistic, make use of the increasingly available resources resulting from these man-made changes. Added to that are their high dispersal rates and rapid population growth, and the future is bright for non-native invasions (Cox 2002).

Sometimes a species arrives in a new region and immediately invades. The main reason for this is that the species has all of its natural survivor adaptations, but lacks its natural predation of pests and diseases. Thus, the lack of predators, or at least decrease of them, in the new habitat may have a significant impact allowing a species to invade. This is known as the "Predator Release Theory." For example, when studying herbivory on Norway maple (*Acer platanoides*) in both its native Europe and its introduced habitats of North America, it was discovered that the tree suffered three times greater herbivory in its native habitat. Thus, for Norway maple at least, moving to North America significantly improved its situation. Furthermore, there was more variation in how much herbivory Norway maple suffered in Europe. While in some places there was less than 1%, in others, there was more than 50%. Only in one place studied in North America was there significant herbivory, which was the result of a European fungus that also crossed the Atlantic (Fang et al. 2009).

It is important to understand that a leaf is not simply a leaf, but a complex of molecules, some of which were designed to make the leaf inedible. Often times, only insects that have evolved to withstand these chemicals may consume that leaf, survive, and complete its life-cycle. Leaves from distant locations are likely to have chemicals that native herbivores are not suited to consuming (Tallamy 2009).

How significant the herbivory is, can be an important question. A plant may suffer 10% loss and still perform just fine, growing and reproducing. However, relative to a plant without this loss, it will be weaker. Examining Sycamore maple (*Acer pseudoplatanus*), it was found that natural herbivory leaf loss of 6-10% reduced overall growth by 35% compared to trees with artificially reduced herbivory of only 1-1.6% (Adams et al. 2009). In a study on oak trees, oak trees suffering from 12% leaf area loss in artificial herbivory produced 50% fewer acorns than undamaged trees. Herbivory on roots may have different, and as yet unknown, results (Adams et al. 2009).

Aside from the escape from predation and disease, there may be physical characteristics that help a species become invasive. However, no complete theory has been developed. Different studies such as those compiled by Keller and Drake (2009) have looked at different types of species, whether pine trees, flowering plants, fish, birds, and others. Unfortunately, many species are not known well enough to even examine in a multi-species comparison. Many studies of plants have examined a variety of aspects, sometimes focusing on similar things, and sometimes very different ones. Some aspects studied, such as flowering early or late, which pollinators they have, and if they are taller than natives, help to determine how the invasives work outside the regular ecosystem by using resources when and where natives are not. Other features, such as mean seed mass and mean interval between large seed crops, are used to figure out how fertile the exotics are. Some facets are used to examine how fast the invasives grow and how well they use their resources. These include: minimum juvenile period, specific

leaf area, nitrogen content, phosphorus concentration, and nitrogen use efficiency (Keller and Drake 2009).

Naturally problems arise in these assessments. One problem with looking at a variety of aspects is that some are more important than others. In one study of invasive fish, 25 criteria were initially used, but using only 4, researchers could correctly determine the invasiveness of 42 of 45 non-native fish in the Great Lakes (Keller and Drake 2009). Another problem is that even when one set of features is perfect for all species studied, they may miss something that a not-yet-invaded fish has. Furthermore, even when 90% of species invasiveness fits a pattern, the other 10% that fall through the cracks can be catastrophic for ecosystems and their related economies.

Invasiveness is not always clear even when the non-native has spread to a new habitat. Rather than immediately invading, sometimes organisms may effectively disappear into the background largely unnoticed, then later suddenly become rampantly invasive quickly. There are likely three reasons for this. First of all, it may take a certain amount of time for the population of the non-native to hit a critical mass that enables it to suddenly spread fast. Second, the local environment may change. For instance, another invasive may appear that alters the habitat and allows it to spread (Baskin 2002). The alien sunfish helps the alien bullfrog (*Rana catesbeiana*) by killing the dragonfly (*Odonata spp.*) that attacks small bullfrog tadpoles. If it was not for the invasion of the sunfish, the bullfrog population would not have become as invasive, or even not invasive at all (Cox 2004). A third cause is that the organism may simply evolve its invasiveness over time (Baskin 2002). This third method, especially through hybridization, has turned out to be a major player in the spread of invasives worldwide.

Plant Adaptations: Invader Adaptations

As all life evolves, so too do alien species in their new surroundings. The adaptations of alien species to their new homes take a variety of paths, and the counter-adaptations by native plants and animals to alien invasives undergo a variety of others.

When an organism first establishes itself in a new geographic region, its population is likely a small number of individuals. Thus, it is expected to have little genetic diversity even as the population grows. This genetically homogenous population expansion is referred to as the Founder Effect, because the founding population's gene pool plays an enormous role in the population's future. Rare traits that may be abnormal in the home population, if present among the founders, become normal in the new one. It would seem logical that this would limit the ability of a species to adapt to new situations, as the genetic diversity is lacking for quick adaptation. However, it is important to note that many invaders with a limited gene pool have been quite successful. One of the best-known examples in North America is the European Starling, which began with the introduction of 100 individuals in New York and is now a population that inhabits much of the continent. The population lacks genetic diversity, but it has been one of the most successful invaders (Cox 2004).

As it turns out, the Founder Effect may actually benefit an invader. The Argentinan ant's (*Linepithema humile*) invasion of North America is a great case-in-point. These ants have created dense communities where ants, workers and queens from neighboring colonies are free to move from one to another. In their native habitats, however, ant colonies differ greatly genetically and so they are often fiercely competitive with each other. As neighboring colonies in North America are closely related, they

cooperate instead. Thus, Argentinan ants in Argentina help regulate themselves while in the United States, they work together resulting in a major ecological problem (Cox 2004).

Another situation where a homogenous gene pool is beneficial is in quick evolution. A large, genetically diverse population may mitigate genetic drift because any changes are constantly being suppressed when they are sexually crossed with the larger population that lacks those alterations. This relates to the changes in reproduction that some communities experience. Some introduced plants that generally favor sexual reproduction move to self-fertilization as cross-breeding with a genetically homogenous population gives little to no benefit. On the other hand, some self-fertilizing species became more sexual, finding the added diversity gives it a competitive edge (Cox 2004).

While there are other examples like the starling and Argentinan ant, many genetic studies have shown invasive species actually have greater genetic diversity than the native populations. The common assumption that a single introduction brought in an alien species is often wrong. Rather than having come from a single invasion event, many invasives appear to have been the result of multiple introductions of a species. When these introductions came from disparate native populations, perhaps crossing continents, the hybrid offspring create genetically diverse and resilient invasives able to easily adapt to new habitats. Thus, while the total number of introduced aliens may still have been small, the fact that they came from very different geographic regions gave a higher genetic diversity to the resulting invaders than the home populations had. Kudzu (*Pueraria montana*) has high genetic diversity because it was repeatedly introduced to the southeastern United States as an ornamental, as forage, and as a method to control erosion (Cox 2004).

Adaptations by non-natives can be incredibly simple, yet lead to huge changes. Ragwort (*Senecio inaequidens*) had naturalized non-invasively, but at some point developed an earlier flowering regime, which meant it had less competition for pollination, and has since become invasive (Cox 2004). Simple adaptations giving an extra small advantage to an exotic with no predators may be all that stands between being a quietly naturalized plant and becoming aggressively invading (Cox 2004).

Whether beginning with a genetically diverse or restricted population, alien species, like their native counterparts, have found many ways to evolve to local conditions. One of the biggest and fastest methods is through hybridization between different species. Many organisms have trouble interbreeding because they have different numbers of chromosomes and so they cannot produce viable offspring. However, sometimes a mutation occurs in which hybrids become polyploidal, obtaining multiple sets of chromosomes which allows them to be reproductively successful. For instance, in England, there is the native cordgrass (*Spartina maritima*) and an introduced American species (*Spartina alterniflora*). After a while, people noticed a new species, eventually named *Spartina townsendii*,a sterile hybrid of the English and American species. While not likely a helpful addition to the ecosystem, *S. townsendii* at least would never be aggressively invasive as it could not reproduce. Unfortunately, after enough hybridizations occurred, a mutation event happened and *Spartina anglica* came to be. This polyploidal hybrid is reproductively isolated from *S. alterniflora* and *S. maritima*, and invasive to boot. Thus, the introduction of one alien resulted in the introduction of three (Cox 2004).

Polyploids may have double the number of chromosomes, but they may also have many more. Hybrids may also hybridize. Thus, a hybrid could be the result of more than two species coming together into one. Because hybrids may result from a single lucky crossbreeding, they may lack genetic diversity and be susceptible to health problems like fungal infections, as is the case of *Spartina anglica*.

However, some reproductively isolated hybrids are the results of more than one mutation allowing for polyploidy, giving the new species' population more diversity and more geographic range. Hybridization is so common that out of 1350 species of the genus Centaurea, there are 232 hybrids, totaling over 17% of the genus (Cox 2004). There is no rule regarding the success or limitations of genetic diversity in an invading population; there is more than one route to success. This is similar to the situation of genetic diversity from self-fertilization or cross-breeding.

If there is a method for a species to evolve a way to invade, it is likely a species will be found doing that sooner or later. One of the most creative types of evolution is mimicry where an animal or plant evolves to look like another, often in an attempt to avoid predation or herbivory (Rettenmeyer 1970). A type of mimicry that has widespread success in invasions by plants is known as agroecotypes. These plants mimic crops, causing humans to accidentally plant them world-wide. The most common are grains like barnyard grass (*Echinochloa crus-galli*). This imitates the phenology, appearance, and even seed morphology of cultivated rice, enabling it to grow in rice fields without people realizing it. They then distribute it elsewhere along with the crop. Other agroecotypes include vetch which is a mimic for lentils and false flax which mimics flax (Cox 2004).

It should be noted that reproductively isolated populations will eventually speciate over time. For plants, insects, and very short-lived, highly reproductive species, this may be relatively fast. Animals that reproduce slower may take a few thousand years. This would replace some of the lost biodiversity that occurred during the original invasion (Cox 2004).

Recently there have been attempts to stem the tide of human-introduced invasions of ornamentals by working on their genetics, specifically, breeding less-fertile cultivars. If successful, the cultivars will provide the shade and beauty of the original ornamentals, but lack one of the major factors of invasion. Evidence suggests, however, that this is not feasible for three reasons. First of all, large changes in fertility do not create large changes in population growth for long-lived species. Second, a less-fertile cultivar can still cross with a more fertile one, producing a more invasive species. Last of all, when crossing with itself, the cultivar may produce offspring that are highly fertile. Thus, it may be that only sterile plants are appropriate for producing ornamentals that lack invasive qualities (Knight et al. 2011).

When creating various seedless fruits for sale, like seedless bananas, watermelons, and grapes, infertile varieties are created in order to prevent the seeds from being created. This is because while the normal plant may be a fertile diploid with two sets of chromosomes, it is manipulated, usually by hybridizing with a tetraploid, a fertile plant with four sets of chromosomes, in order to create a triploid, an infertile variety with three sets of chromosomes. Sometimes triploids do manage to reproduce, but it is rare and their offspring do not tend to do well. Other methods include creating a mutation in a plant that makes it infertile, and another involves modifying its genetics by inserting new genes. A lot of work has already been started on these methods, but it may take some time, especially for long-lived woody plants, to show results (Ranney 2004).

Plant Adaptations: Counter-Adaptations

When invaded, an ecosystem often goes through a dynamic change. The invader will reproduce heavily, spread quickly, push out native organisms, and alter almost any aspect of the ecology from water availability to fire regimes. However, just as non-natives evolve, so too, can natives. Counter-

adaptations refer to evolutionary changes by natives to the invaders. Given enough time, they will fully integrate the new species into the ecosystem. When this happens, it can actually be detrimental to an ecosystem to remove the non-native. Many species will at that point heavily rely on it for food, shelter, and other resources made available through its presence (Cox 2004).

When a new invader appears, it will damage the ecosystem, however, it also creates resources available for another organism able to adapt to use them, for instance, food from the body of the exotic plant or animal. This is similar to the opening of a forest after a fire or the flooding of a stream's banks due to a beaver dam. There is, of course, a lag as species evolve to make use of these resources. While there is genetic variability in most herbivorous insects to adapt to new hosts, it takes time for them to do so. Genetic adaptation to a new host has been shown to happen in as few as 10 generations. Sometimes the new host is preferable as the species does not have to compete with others for the resources and there may even be no predation. Furthermore, the non-native may not have any evolved defenses for this new native herbivore (Cox 2004).

Zebra mussels (*Dreissena polymorpha)* have become a problematic invader in North America as they grow rampantly, both to ecosystems in habitat alteration, and economic, by causing damage to infrastructure they cling to. However, many species have discovered that the zebra mussels are good to eat. Ducks and many native fish have been enjoying the bounty of food and freshwater sponges have been found colonizing zebra mussels which negatively impacts the mussels. There are even some native nematodes that have been infecting the mussels. There still are fewer parasites than in the mussels' home range, but change is happening. There may actually be a boom and bust cycle of invasions (Cox 2004).

The preference of native organisms for non-indigenous hosts may be so strong as to evolve away from the native. Edith's checkerspot butterfly (*Euphydryas editha*) in California has adapted to preferring the non-native ribwort plantain (*Plantago lanceolata*) as a host though it had adapted to native plants for centuries. In fact, in California, more than 1/3 of native butterflies have been reported to oviposit or feed on non-native plants (Cox 2004).

Of course, when the invaders are vastly different than natives, it may take a lot longer for native herbivores to find them palatable. When herbivores make the switch, it is usually to a closely related species. For instance, no native insects in Australia or South Africa have been found to eat prickly pear cactus (*Opuntia spp.*), yet it has been in Australia and South Africa for 150-250 years. It has also been shown that invading insects from North America to Europe have a more difficult time because Europe has less diversity and lacks many genera that exist in North America. Thus, the herbivores cannot find plants related closely enough to what they are used to eating and consequently starve (Cox 2004).

In general, herbivores that are generalists, meaning they eat a wide-range of plants, are the first to use new species. The diversity of generalists consuming non-natives appears to plateau in as little as 100 years. Specialists, those who are adapted to only one species, or a narrow range of them, may not plateau for 10,000 years (Cox 2004).

Natives being attacked by non-natives may also show adaptations in a relatively short time. This could be compared to how many insects and weeds have developed resistance to chemical herbicides and pesticides. Many oaks (*Quercus spp.*) are developing resistance to the invasive gypsy moth (*Lymantria dispar dispar*), which has been defoliating large populations of oak in North America.

Grasses are likely to adapt fast and woody plants more slowly due to the difference in lifespans and speed of reproduction (Cox 2004).

Invasions or not, organisms will continue to evolve through co-evolution and adaptation to climate change. In fact, fossil records show that climate has changed a lot in the Holocene, accounting for most of the changes in plants' ranges (Jackson 1997). So as anthropogenic climate change occurs, many species ranges and habitats have been changing and will continue to change. These changes are not necessarily counter to conservation and must be differentiated from unhealthy non-indigenous invasions.

Invasive Species' Impacts: Ecological Impacts

This spread of humans, and the consequent spread of other organisms, has a massive impact on native wildlife. First of all, the sheer scale of alien organisms is massive. The worldwide total in 2001 was estimated to be about half a million species introduced to new geographic regions (Cox 2004). Alien organisms introduced to a new habitat sometimes have detrimental impacts on the native species, whether it is predation, disease, or simply outcompeting natives. On a global scale, 30% of threatened birds, 11% of threatened amphibians, and 8% of threatened animals are being impacted by invasives. Birds are the most effected as they have done a better job colonizing oceanic islands, which, due to limited space, are the most impacted by invasives (Baillie et al. 2004). About half the plant life on islands like Hawaii, the Galapagos, and Mauritius are non-indigenous (Baskin 2002). While many invasions do little damage, a 1993 assessment estimated that 15% of non-indigenous species in the US cause severe harm (Office of Technology Assessment 1993). It may be only 15%, but that 15% does significant damage. A 1998 study found that, in the US, 49% of imperiled species were either preyed upon, or directly competed with alien invaders, which includes 2/3 of birds, 1/2 of fish and plants, and 1/3 of butterflies and reptiles (Baskin 2002).

The majority of extinctions due to invasives were the result of predation. Introduced predators are a problem for many native species as they do not have any adapted defenses or behaviors to protect themselves. In the Great Smoky Mountains National Park in North Carolina and Tennessee, Fraser firs (*Abies fraseri*) are being eaten to death by European aphids. Pigs in Hawaii kill tree-ferns because they find the insides are tasty. South American nutria (*Myocastor coypus*) destroy wetlands in the Southern United States and elsewhere in the world with their vigorous appetites. And where predators push out a native species, another alien may take its place (Baskin 2002).

In a more subtle way of harming native life, invasives can change the available nutrients. In the ground, the salinity, water, pH, nitrogen, and other nutrients can be altered, making it more difficult for natives to compete. Fire regimes may change, altering the frequency and severity to which natives have adapted. Also, the community dynamics, the interactions between organisms, can be transformed. Some of these may be slight changes that merely stress natives and give an edge to invasives (Walker and Smith 1997). On the other hand, non-natives can change the habitat so much that it is essentially unrecognizable. Sea turtles cannot scoop nests out of the sand when Australian casuarinas trees' dense roots take over the Florida beaches. Western snowy plovers cannot find open stretches of sand for nesting on the West Coast when the beaches are covered in European grasses (Baskin 2002).

The harm from invasions should not be understood as simply of invasive vines, rats, snakes or similar creatures, but of all living organisms and viruses. Diseases are impacting 5% of threatened birds,

3% of threatened mammals, and 17% of threatened amphibians. Examples include the African lion (*Panthera leo*), which was sickened by canine distemper in 1994 and the Ethiopian wolf (*Canis simensis*) which lost 80% of its population in Web Valley due to rabies in 2003 (Baillie et al. 2004). Even in the remote Antarctic, seals are suffering from cattle diseases while penguins are stricken with poultry viruses (Baskin 2002).

In a situation more specific to Pennsylvania, the American chestnut (*Castanea dentata*) had been one of the most common trees in North American forests. The Chestnut Blight is a fungal disease that was brought to New York City sometime before 1904 and has nearly wiped the species out. Within 20 years of introduction it had killed almost all mature chestnut trees in the northeast. By the time another 20 had passed, it had invaded the entire range of chestnuts from Georgia and Alabama in the south to Maine in the north and west to the Mississippi River. Interestingly, the trees' roots are resistant to the disease, so while the aboveground parts die, the roots produce saplings that later get killed and then the cycle repeats (Cox 2004).

An invasive plant is often removed from the ecosystem, not contributing to its structures and functions. For example, insect populations, which are vitally important to the health of the system, may suffer. When the secondary chemicals produced by a non-indigenous plant prevent native insects from consuming it, then it might as well be made of stone. When hungry animals need food, especially during migration, an area covered by a monoculture of invasives may cause the animal to die from starvation. This is especially problematic during spring bird migrations when there are no fruit available, and, because insects are not eating invasive plants, no insects for the birds to eat (Tallamy 2009).

Non-native organisms in a new habitat can be said to increase biodiversity. Sometimes this is true, however, as they fill up niches, there is less room for natives. Sometimes space is limited enough that only a certain number of species are able to survive. In Hawaii, it was found that the introduction and establishment of new coastal birds would lead to the extirpation of another bird that existed in the same niche (Cox 2004).

Invasive Species' Impacts: Economic Impacts

Most estimates of the costs of invasive species in the United States are astronomical. This cost may be damage to croplands or ranchlands, the price of hospital visits from animal attacks, and the cost of control or eradication. When a single invasive like Purple Loosestrife (*Lythrum salicaria*) may cause 45 million dollars per year, one can see how the combined costs of invasives may be staggering. In an often cited study, Pimentel et al. (2005) attempted to examine and total the costs of invasive species in the United States. Using the estimate of 50,000 alien species in the US, the study determined that the total damages per year are nearly 120 billion dollars (Pimentel et al. 2005).

However, because market values generally reflect real costs like hospital visits, they may miss the value of a good that was never actually in the market, for example, the value of a scenic view. Willingness to Pay (WTP) is an analysis often done on environmental issues to determine the economic value of something that is not reflected in a normal market analysis. People are asked how much of their income they would be willing to give up in order to retain something, perhaps the existence of a wetland or rare species. In terms of invasives, the WTP is cost reflected in controlling the species to retain the environmental services (McIntosh et al. 2009).

In 2009, McIntosh et al. published a study where they used WTP to find some surprisingly strong support of efforts to control invasive species. First of all, their survey determined that people were willing to fight a losing battle, to delay the impacts of invasives. This is not normally politically feasible because many do not wish to fight a losing battle and be seen to waste money on it. However, the survey suggested that people were willing to spend their own money on it, thus there is an impetus. Second, people understood that long-term investments were important. They were willing to pay continuously for 10 years, not just 1. Not surprisingly, people were concerned with invasives that have more direct impacts on them personally. Thus, fishermen are more interested in preserving the species they fish than a tree they do not feel dependent on. Last of all, people with higher incomes were willing to pay more (McIntosh et al. 2009).

Aside from the cost of invasions due to damage and control, or the cost in a willingness to pay scenario, the loss of biodiversity due to invasions has a cost, too. A forest floor taken over by garlic mustard no longer has the same benefits. The key is to find a value for each function of a species in an ecosystem, its value as a marketable product, or its value to people simply for existing, and place a value on that. Many problems develop when trying to implement this as there are often unclear relationships and a lack of knowledge (Fromm 2000).

Two papers, Fromm (2000) and Nijikamp et al. (2008), examining a synthesis of valuation methods for ecosystems or individual species were reviewed. They often used the same terminology, but sometimes used them differently. Furthermore, within each paper there were issues of re-explaining a valuation method, but in a contradictory way. Nijikamp et al. (2008) came across as the most clear and thus will be used for examining methods of value. Fromm (2000) is still important in understanding the uses of biodiversity.

The first method for differentiating types of value for biodiversity separates them into *use values* and *non-use values*. Use value is the value derived from the present or future use of an ecosystem and can be subdivided into *direct use values*, which would be timber, food, recreation, etc., and *indirect use values*, which would be for things like water filtration and carbon sequestration. On the other hand, non-use value is the value in having the ecosystem or species, perhaps in some distant location, without using it. That is, many people may place value on knowing that a certain coral reef exists, but have never made use of it and do not plan on ever doing so. This is sometimes also considered part of *psychological value*, the perception that there is value in nature (Nijikamp et al. 2008).

A type of value that blurs the lines of use and non-use is *existence values*. Existence values are the value of an organism whether or not it is going to be used in the present or future. Examples of existence values are *bequest values* and *altruistic values*. They are both directly described as non-use values, however, use-values are also described as the “present or *future* use” (emphasis added) (Nijikamp et al. 2008). Therefore, they fit into both categories depending on how one wishes to describe them.

The use and non-use values are part of what is described as the total economic value (TEV) since it attempts to consider all methods of valuing natural systems. However, it is all purely from an anthropocentric point of view, and there may be value without taking humans into consideration. Thus, methods of *contributory value* and *inherent value* came to be (Nijikamp et al. 2008). Inherent values are those that support the ecosystem itself. Without these values, the whole thing might collapse.

Contributory values are those that promote the biodiversity. The variety of niches and conditions in a complex ecosystem promote genetic diversity (Nijikamp et al. 2008). This description is not dissimilar to that of a use value.

Sometimes these methods can over-value biodiversity. Pharmaceutical industries are often interested in searching a diverse gene pool for new drugs. In fact, Merck and Co., a large drug company, signed a contract with Instituto National de Biodiversidad in Costa Rica, whereby Merck paid, for the use of the gene pool discovered, about 1 million dollars up front in 1991 with the obligation to pay royalties whenever a new commercial product was explored. Since then, many other companies and even non-profits have made similar deals (Nijikamp et al. 2008). However, as the same valuable genes may be in multiple species, and as more species increase the costs of bio-prospecting, out of a million species, the production value may be as low as 0.1 cents per species. Thus, the marginal production value of biodiversity is negligible (Fromm 2000). It is important to note that many consider bio-prospecting to be little more than biopiracy (Nijikamp et al. 2008). Another problem is that more "charismatic" creatures and ecosystems are more highly valued in non-use valuations (Fromm 2000).

Invasive Species' Impacts: Positive Impacts

It has long been thought that non-natives brought benefits. The acclimatization movement and modern agriculture are strong proponents of this thinking. However, even when the concept of invasives was better understood, many still saw more benefits. For instance, in a 1945 article by C. O. Handley, the author acknowledges the "pest" nature of Japanese Honeysuckle (*Lonicera japonica*), but also refers to the benefits it provides as an emergency supply of food for birds during snows (Handley 1945).

In his 1997 article "Potential Valuable Ecological Functions of Nonindigenous Plants," Charles E. Williams identifies a series of characters that can be used to determine if an alien plant may in fact benefit the ecosystem. As natives are extirpated or become extinct and as aliens become incorporated into an ecosystem, it is important to analyze the aliens in terms of value they may provide rather than simply as a destructive force (Williams 1997). This relates to the distinction between invasive species and simply exotic species.

The first question is whether or not the existence of the alien hurts management goals of the land and if it is invasive or just an alien. Obviously if an alien invades an area, creating a monoculture, then it is not helpful to the ecosystem (Williams 1997).

Second, does this alien function in the same role as a species that has already been removed from the area? Considering the Japanese honeysuckle example from before, if there are no other berry-producing plants, than it would be an important resource for the area. Relating to that, one must consider if the species's presence may facilitate or prevent the growth of another species. If it facilitates a species of high value, than that is good, similarly if it inhibits a harmful species, then it has value. For example, the European mosqueta rose (*Rosa rubiginosa*) has been used as a barrier against cattle grazing in Argentina. Indigenous trees can grow from inside the rose, protected from cattle in a favorable microclimate. Thus, the rose has been used to regenerate forested areas. Also, some plants change fire or other disturbance regimes, so if this species actually stabilizes the system, then that can be a benefit. In the United States, prairies can be reestablished by using alien grasses. Quack grass (*Agropyron repens*) and Curly dock (*Rumex crispus*) can stabilize soil and provide cover while the native

prairie grasses take root and begin to grow. As the natives mature, they eventually out-compete Quack grass and Curly dock, which disappear from the system (Williams 1997).

Last of all, one must look to the future. The ecological value of the species may change over time. Relating to the example of the Mosqueta rose, if the forests have been reestablished and its cover is no longer needed as protection from cattle, is it then reclassified as a harmful invasive (Williams 1997)?

Interestingly, Charles Williams determines that the ecological values of non-indigenous plants increase as the ecosystem becomes more invaded, but decrease the more native it is. This is because the fewer indigenous plants there are, the more the ecosystem needs the nonindigenous ones to fill the roles left open (Williams 1997).

Policy: International Systems

As the spread of exotic species is happening on a global scale, there are many global organizations and treaties that are attempting to remedy the problem. The International Union for Conservation of Nature (IUCN) is the world's oldest and largest global environmental network. It is made up of over 1,200 organizations (government and non-government) and over 10,000 scientists in over 160 countries. It has official observer status at the United Nations and is centered in Switzerland. Using its wide membership of scientists and organizations, the IUCN pressures governments to change policy in order to help natural ecosystems. Invasive species policies are one of main areas of focus. (IUCN).

Specific to invasive species management and part of the IUCN is the Invasive Species Specialist Group (ISSG). This organization's focus is to help make the knowledge of invasive species, and the control of them, publicly and easily available. After all, if both recognition and management are not understood, the invasions will continue.

Another international organization seeking to help remedy the problem is focused around one of the groups most responsible for invasive species spreads. The International Maritime Organization (IMO), established in 1948 by the United Nations to promote maritime safety, has recently been acutely aware of the impacts of shipping on accidental invasions. In February 2004, in London, the IMO's International Conference on Ballast Water Management for Ships adopted a set of guidelines to help, among other things, prevent the spread of organisms through ship ballast. The Convention noted that shipping has increased in recent decades and new technology and techniques, such as using water ballast rather than dry ballast, have significantly increased the accidental spread of organisms around the world (IMO).

One of the most significant international environmental events was the Rio Earth Summit in 1992. It was the first to really address invasive species, asking all "to prevent the introduction of, or control or eradicate, those alien species which threaten ecosystems, habitats, or species" (Baskin 2002; De Poorter 2009). Subsequent conferences have reaffirmed this goal, taking new information into account and attempting to fix inconsistencies (De Poorter 2009). There are many other conventions and summit and international organizations such as the 1971 Ramsar Convention (De Poorter 2009) or the 1996 Norway/United Nations Conference on Alien Species and the Global Invasive Species Programme (GISP) (Baskin 2002). The number is constantly increasing and there are too many to list in a non-policy paper, but the ones mentioned are some of the most significant.

Policy: United States

Similar to the complex of treaties and conventions at the international level, the United States policy on non-native organisms is multifarious, but with a much longer history. Also like the international system regulating invasive species, the US policy is much too large to go into full detail. For instance, while the first Quarantine Act came into effect in 1905, it had changes in 1912, 1917, 1926, and 1957 (Hyland 1977). Furthermore, no place lists all the laws. Even the USDA's National Invasive Species Information Center list of "laws and regulations" is grossly incomplete. Thus, such detail will not always be included.

The structure of the US government has made it difficult to control the flood of invasives. Part of the problem is that the executive branch has many different departments and agencies that often overlap. No single agency could handle an invasive species management system. Also, the laws regarding invasives are scattered and patchwork, rather than comprehensive. Furthermore, the main concern for a long time had been regarding invasives' impacts on agriculture. In fact, there was no law restricting the movement and importation of zebra mussels for 2 years, allowing them sufficient time to establish a strong presence before any governmental concern developed (Office of Technology Assessment 1993).

The United States has a history dating back well over a century to combat invasive species. Unfortunately, this lengthy history helps contribute to the fragmentary and hodgepodge nature of laws, regulations, policies, and programs (Office of Technical Assessment 1993). It should be noted that this early history is also the same time as the acceleration of importing exotic seeds through the Section of Seed and Plant Introduction (Hyland 1977). So, just as the focus of importing seeds was for agriculture, regulating them was also for agriculture, but for the prevention of weeds, pests, and diseases. There is one notable exception, however. The Lacey Act of 1900 prohibited the "…import, export, transport, sell, receive, acquire, or purchase any fish or wildlife or plant taken, possessed, transported, or sold in violation of any law, treaty, or regulation of the United States or in violation of any Indian tribal law…." Thus, this law was encompassing, protecting wildlife as well as agricultural life (Legal Information Institute).

Other early laws regarding the importation of exotic species are the Quarantine Act of 1905 (Hyland 1977) and the Plant Quarantine Act of 1912, which focused on regulating trade and importation of plants in case they held pests and diseases harmful to agriculture (NISIC 2014). Next came the 1931 Animal Damage and Control Act which gave the government the authority to control wildlife that damaged Federal, state, and private lands and protected crops and rangeland. The 1939 Federal Seed Act dealt with increasing standards in seed purity, which would help control accidental introductions of weeds in crops. The Organic Act 1944 gave authority to conduct tests on pests of plants. Although likely still focusing on agriculture, the Federal Plant Pest Act of 1957 prohibited the movement of pests from a foreign country unless authorized by the Department of Agriculture (NISIC 2014).

1973 and 1974 saw significant changes in the environmental movement and invasive species control. With the Endangered Species Act passed in 1973, the government received broad authority to remove or control invasives when they threaten endangered species. 1974 was another important year as the government defined noxious weeds in the Federal Noxious Weed Act. It defined the weeds as "any living stage (including, but not limited to, seeds and reproductive parts) of any parasitic or other

plant of a kind, or subdivision of a kind, which is of foreign origin, is new to or not widely prevalent in the United States, and can directly or indirectly injure crops, other useful plants, livestock, or poultry or other interests of agriculture, including… the fish and wildlife resources of the United States or the public health" (NISIC 2014). By defining noxious weeds, this act allowed broader powers in invasive controls. It also gave the US Secretary of Agriculture the authority to declare plants as noxious weeds and then to inspect and even destroy plants and quarantine areas to prevent the spread of the noxious weeds (NISIC 2014).

Just as ballast is of concern on a global scale for the United Nations, the US has made its own efforts in controlling its damage. In 1990, Congress passed the Non-Indigenous Aquatic Nuisance Prevention and Control Act which established the Aquatic Nuisance Species Task Force that focused on ship ballast water and how to control the spread of aquatic invasives (NISIC 2014).

Over much of this first century of laws, the rate of laws appears to be fairly stable, with new ones scattered in the decades. However, the trend in new laws recently began to increase. Realization of the impacts by invasives was widespread enough and had finally reached a tipping point. The National Invasive Species Act passed in 1996. Amending the Non-Indigenous Aquatic Nuisance Prevention and Control Act, it was created to help prevent ballast water from importing invasive species into the Great Lakes. Unfortunately, it expired in 2002. In 2000 Congress passed the Plant Protection Act, which was broad legislation focusing on many types of invasive plants and many ways they are introduced. It consolidated and updated several laws and regulations including the Plant Quarantine Act, the Federal Plant Pest Act, and the Federal Noxious Weed Act of 1974 (NISIC 2014).

In the 21st century, first came the Farm Security and Rural Investment Act of 2002 and Public Health Security and Bioterrorism Preparedness and Response Act of 2002, which focused on the spread of livestock diseases and pests. The years 2003, 2004, 2006, 2007, 2008, and 2010 saw bills passed (or sections of bills not wholly devoted to invasives issues) focusing on specific eradication of nutria, the brown tree snake (two separate laws), the disease causing Sudden Oak Death, salt cedar, Russian olive, sea lamprey, and Asian carp (also two separate laws). In 2004, there was also a much broader program created under the Noxious Weed Control and Eradication Act. In 2005, there was the Safe, Accountable, Flexible, Efficient Transportation Equity Act which provided more funding to control noxious weeds as well as the Public Lands Corps Healthy Forests Restoration Act which dealt with the Public Lands Corps, a youth-oriented education and work program in the National Parks Service. The Clean Boating Act of 2008 focused on helping to prevent the spread of aquatic invasives by boats (NISIC 2014).

One recent change in the midst of all these new bills is to amend a very old one, the Lacey Act. Since the law prevented the importation of certain species, amendments could include invasives, preventing their importation and even local trade. Examples of amendments occurred in 1992, 1998, and 2010 (NISIC 2014).

Despite all these laws, there still was no overarching plan on invasives and controlling their introductions to the United States. A couple of presidents have tried, but neither did enough. This is especially prominent in how ineffective President Jimmy Carter's attempt turned out to be. In 1977, with Executive Order 11987, he tried to stem the flow of invasives. However this was largely ignored by most Federal agencies. This would have had no impact on non-natives that were not believed to be invasive, but would have restricted the federal government from importing exotic species as well as encouraging other levels of government and private citizens from it as well (US Congress 1993).

More than two decades later, President Bill Clinton created his own executive order. Focused on cooperation between Federal agencies, the Executive Order asked for them to "prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause" (NISC 2005). Rather than set up a new agency department, the plan called for the Secretaries of State, Treasury, Defense, Interior, Agriculture, Commerce, Transportation, and the administrator of the EPA to sit on a new Invasive Species Council. The Secretaries of Health and Human Services, US AID, and Homeland Security, the US Trade Representative, and the administrator of NASA have been added as well. Working independently in their respective departments and agencies, or together through the council and its committees, progress has happened. In the broad sense, they created the National Invasive Species Management Plan of 2001. While in a more targeted manner, they created a fund for rapid responses to target invasives before they spread and caused more damage (NICS 2005). So far the Council has been doing a lot to help fix the patchwork system in place in the United States, but more work has to be done, especially from the preventative standpoint.

Even if the US had the strongest policy, enforcement is always an issue. In 1993, 456 million exotic plants were imported to the US through 16 plant introduction facilities-80% through Miami. Inspectors are overwhelmed and inspect less than their goal, which is only 2%. Thus the odds of missing banned organisms and pathogens are rather high (DeLoach 1997).

Policy: Pennsylvania and Regional

The United States Federal government is certainly not the only government to play a role in invasive species control. Many states regulate invasive weeds on their own, likewise primarily to protect agriculture. Pennsylvania is no exception, though its list is rather small. Interestingly, marijuana (*Cannabis sativa*) is first on the list, suggesting the list had less input by wildlife or farm managers than one might think. The other 12 species are: Purple loosestrife (*Lythrum salicaria* and any other non-native *Lythrum*), Canada thistle (*Cirsium arvense*), multiflora rose (*Rosa multiflora*), Johnson grass (*Sorghum halepense*), musk thistle (*Carduus nutans*), bull thistle (*Cirsium vulgare*), jimson weed (*Datura stramonium*), mile-a-minute (*Polygonum perfoliatum*), kudzu (*Puerria lobata*), shattercane (*Sorghum bicolor* cv. *drummondii*), Giant Hogweed (*Heracleum mantegazzianum*), and Goatsrue (*Galega officinalis*) (3 P.S. § § 255.1—255.11).

In 2004, Pennsylvania Governor Edward Rendell issued Executive Order 2004-1. In this order, he established the Pennsylvania Invasive Species Council. In 2009, the Council published "Invaders in the Commonwealth: Pennsylvania Invasive Species Management Plan." In this, it outlines a lot of the issues that are significant with invasive species. It also looks to take a proactive approach, making sure the government does things like preventing invasions with risk-assessments on different species, performing early detection and rapid response when invasions do happen, improving communication and coordination, and keeping funding available (PISC 2009). However, invasive species management plans are only as good as their implementation, so it remains to be seen if the needed long-term commitment from the government and voting public will last.

Policy: Examples From Other Countries

Creating a national policy that eliminates the threats of invasive species is both simple and complex. The simplest idea is, of course, to prohibit the spread of all alien species, as any may be invasive. This, however, is not feasible. As Keller and Drake (2009) argue, a policy should reduce invasions balanced with the acceptance of some aliens to create a net economic benefit. Prohibiting all aliens would be incredibly costly especially given the high number of non-invasive aliens. For instance, while Australia deals with many problems due to invasive species, only 5% of the aliens are invasive, a rather low number world-wide (Keller and Drake 2009). Thus, to ban all aliens would be to ban the 95% that do little harm while providing economic benefits.

Thus, there is a balance to maintain between restricting non-natives and supporting the trade industry. Governments do not wish to create a system with too many false-positives, nor do they want to invite disaster, bringing in invasive and damaging pests and plants. Australia and New Zealand have the strongest systems in place, using a risk-assessment system that looks at alien plant characteristics. The Australian Weed Risk Assessment, based on studying over 200 introduced plants, is a series of 49 questions that rate a plant before it may be introduced to Australia. If it scores a 7, it is banned, if it scores less than 0, it is allowed entry, and anything in between requires further study. Not all questions must be answered, but there is a minimum that must be. New Zealand's policy is similar to Australia's, and together they are the only two countries with risk-based assessments. Their "guilty-until-proven-innocent" approaches are strict, but likely more effective than others. Aside from preventing invasions, these systems are advantageous in that they work at market speeds. If an individual wishes to import a plant, it may take only a couple days to find out if it is allowed or not. An advantage that Australia and New Zealand have is that they own their entire landmasses. That is, Australia does not have to handle another country on its continent with a weak system in place, importing invasives (Keller and Drake 2009). Effective policies to protect the Great Lakes, for instance, would require a treaty encompassing two national governments and ten state/provincial governments.

One problem with risk assessment is that it assumes static ecosystems and species, both of which are dynamic and evolving. Both invaders and native species may adapt, which influences the invasiveness of a species. Furthermore, not all taxonomic groups have been studied well enough to create a risk assessment. For instance, animals and birds are best known, mollusks, not well at all. For example, Australia and New Zealand use risk assessments for plants (Keller and Drake 2009).
Some studies, however, have determined that some of these criteria are not conducive to invasiveness. Some of these aspects of invasiveness like "specific leaf area" are difficult for most to determine as they require specialized equipment (Baskin 2002).

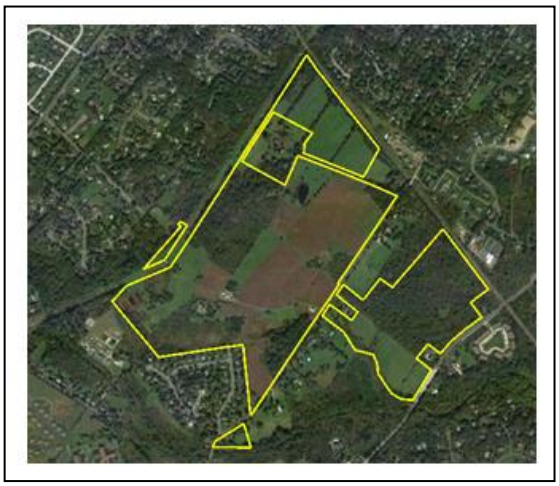
Furthermore, as noted above, invasive species may be self-fertilizing or cross-fertilizing (or both) and genetically diverse or genetically alike. Thus, for many traits, sometimes one is beneficial and sometimes the other is. Sometimes invasives act differently than they did in their native habitats. For instance, house sparrows in North America may produce 24 fledglings per year, breeding continuously, which is something that is not observed in Europe (Baskin 2002). Other times, a specific event causes changes opening a hole in an ecosystem for an invasive. A predator may push one native species to the side allowing for an invasive to take over (Cox 2004). A unique chemistry that goes unnoticed may increase invasiveness. Garlic mustard is not invasive in its native home because, while it produces and spreads allelochemicals, toxic to many plants, the plants of its native ecosystem are adapted to this

chemical (McCarthy 1997). Thus, it may seem harmless in an assessment, but a chemical that may be unnoticed in an invasiveness evaluation program may cause it to spread and cause damage. Most importantly, however, is the fact that a species may evolve from something non-invasive into something highly invasive, and thus, even a known non-invasive is potentially a risk (Cox 2004). Thus, while one can find trends, there are no hard and fast rules except perhaps that no invasive species happens to reproduce and grow extraordinarily slowly. Creating rules based on mechanisms that may not be fully understood can lead to disaster.

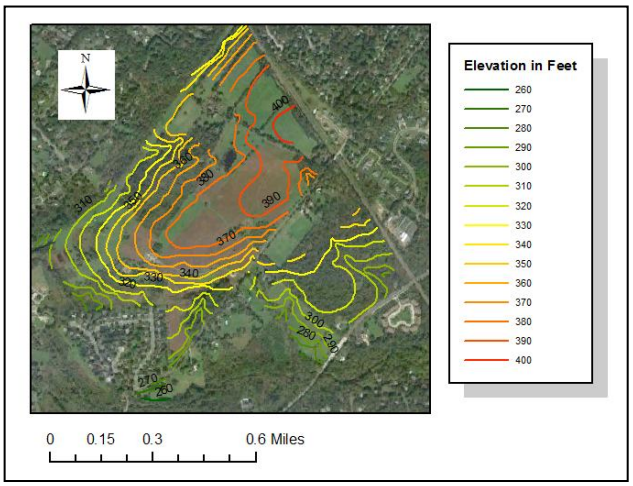
Despite the problems, a policy that is strongly inhibitive towards the possibility of importing invasives is a lot better than none. However, it is difficult to implement one as there are lobbies to keep risk-assessments from appearing in more countries. Some people would dislike such a system because they make a profit importing alien species either on purpose or by accident. On the other side, there is not much of a lobby supporting risk-assessments (Keller and Drake 2009).

II. Gwynedd Wildlife Preserve

Introduction



Gwynedd Wildlife Preserve (Google Earth 2013*)



Gwynedd Elevation (Contours from USGS, The National Map)

Gwynedd Wildlife Preserve is a 279-acre preserve in southeastern Pennsylvania owned by the Natural Lands Trust. It consists of forested areas, open meadows and scrub-shrub habitat as well as a man-made pond and wetlands. It is open to the public and has 6 miles of trails for walking. Surrounding the preserve is developed land, mostly large suburban homes (Natural Lands Trust 2013).

Geology and Climate

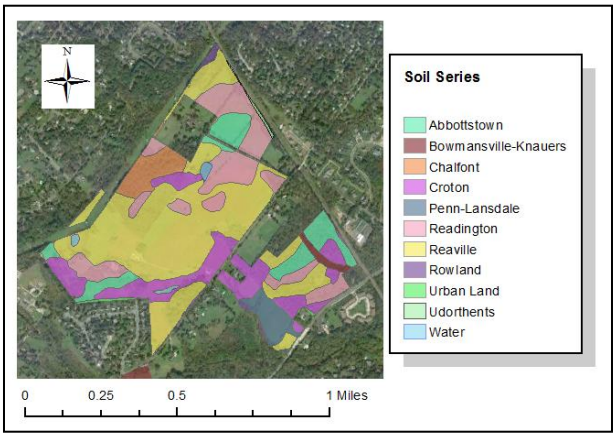
Understanding the physical characteristics of a property is important for managing a wildlife preserve for native habitat. Although conditions may change from year to year depending on precipitation, temperature, and other variables, in the long-term, due to constant physical properties, it has very predictable conditions, such as water table depth, soil porosity, and acidity. As native species evolved to specific conditions including soil types, they perform best in the soils they are accustomed to (NRCS 2013).

Gwynedd Wildlife Preserve sits on the Lockatong geological formation (DCNR). This sedimentary rock was formed in the late Triassic stage known as the Carnian (Tanner 2010). The Lockatong is 1150 meters at its thickest area, around Lockatong Creek, but thins out considerably at its edges (Olsen 1980). The rock was created in the bed of a large, shallow alkaline lake, roughly 2,700 square miles in area, about 300 feet deep at the most. This lake went through periodic cycles of wet and dry periods, drastically changing the sedimentation (Senior and Sloto 2007).

Cycles from wet periods averaged 17.1 feet thick and consisted of laminated, medium dark-gray to black, calcareous, pyritic siltstone and shale in the lower part of the cycle overlain by platy to massive, disrupted (mudcracked and burrowed), dark-gray, calcareous siltstone, ripple-bedded siltstone, and fine-grained sandstone. As the lake was shallow, dry periods sometimes saw the lake completely dry. Layers from dry periods averaged 10.5 feet thick and were more influenced by chemical precipitation

*Google Earth image is used for all subsequent maps

than detritus and consist of platy, medium dark-gray to black, dolomitic siltstone and marlstone with shrinkage cracks and lenses of pyritic limestone in the lower part overlain by massive, gray or red, analcime- and carbonate-rich, disrupted siltstone (Senior and Sloto 2007).



Gwynedd Wildlife Preserve Soils Series (GIS Data, USGS Soil Survey Staff 2013).

Although consisting of a variety of different soil series, the soils at Gwynedd Wildlife Preserve have a lot of general trends. First of all, though many of them are mostly cleared in their current ranges, their native, historical vegetation is mostly hardwoods, especially oaks. Where un-limed, some of the soil series may be extremely acidic, though others may be slightly acidic or even neutral (NRCS 2013).

The Reaville soil series is the most common series found at the Gwynedd Wildlife Preserve. In fact, it makes up nearly 45 percent of the preserve. This series is made of Fine-loamy, mixed, active, mesic Aquic Hapludalfs. It is moderately deep and moderately to poorly drained. Observations during vegetative surveys have shown that much of the preserve is often quite wet and mucky. This soil is formed from red Triassic, interbedded shale, siltstone, and fine-grained sandstone. It has slopes from 0 to 15 percent. The depth to bedrock is 20 to 40 inches. This series is generally found in a cleared and cultivated area for grains and pasture, however, the native vegetation is mixed hardwoods, mostly oak (NRCS 2008e).

The next most common soil series is the Readington series and is about 18 percent of the land. This series is made of Fine-loamy, mixed, active, mesic Oxyaquic Fragiudalfs. Readington soils are deep to very deep and are moderately well-drained. They are formed from noncalcareous shale, siltstone, and fine-grained sandstone. Depth to the fragipan is 20 to 36 inches and to the bedrock depth ranges from 40 to 90 inches. Today, these soils are about 85% is cropland, but native wooded areas are oak-hickory mixed hardwoods (NRCS 2008d).

At just over 15 percent, the third most common soil series at Gwynedd Wildlife Preserve is the Croton series. This series is made of fine-silty, mixed, active, mesic Typic Fragiaqualfs. It is deep, poorly-drained soils with nearly negligible runoff on uplands. They come from medium-textured materials on sandstone, siltstone, or shale. Depth to the fragipan is 15 to 25 inches, but to the bedrock, it is 2.5 to 5 feet. Slopes range from 0 to 8 percent. Cleared areas are mostly pasture, but some corn is grown. Native vegetation is forested with pin oak, white oak, ash, beech, and red maple (NRCS 2008c).

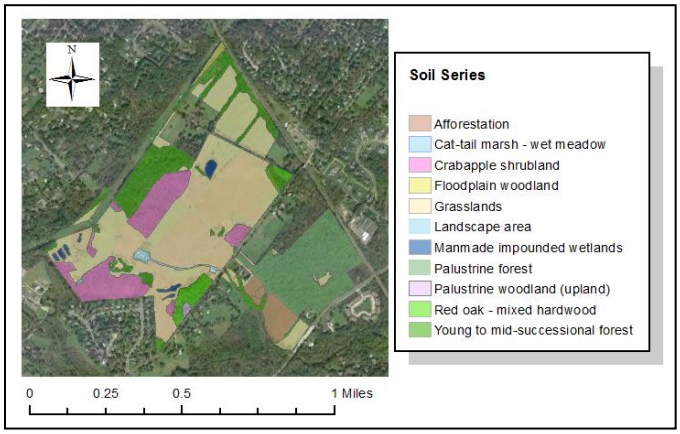
The fourth most common soil series is the Abbottstown series. These are fine-loamy, mixed, active, mesic Aeric Fragiaqualfs. They are deep to very deep and somewhat poorly drained soils. They

are formed from acid red shale, siltstone, and sandstone. Depth to the fragipan is 15 to 30 inches and to the bedrock, depth ranges from 30 to 60 inches. The soils are concave upland slopes of 0 to 15 percent. About 85 percent of this series's range is cropland and pasture, but native areas are forested mostly with hardwoods especially hickory and oak (NRCS 2008a).

The fifth most common soil series is the Chalfont series. These are fine-silty, mixed, active, mesic Aquic Fragiudalfs. This series is deep to very deep soils that are somewhat poorly drained. They are formed in a loess mantle with an underlying residuum of shale and sandstone. Depth to the fragipan ranges from 15 to 30 inches and the depth to the bedrock is 3.5 to 8 feet or more. They can be quite steep, ranging from 0 to 25 percent slope. Most of the series's range has been cleared and is now cropland, hay, and pasture, but native wooded areas are mixed hardwoods, mostly oaks and yellow poplar (NRCS 2008b).

The Koppen-Geiger system was the first quantitative classification developed to describe world climates and today it is the most commonly used. It was developed by Wladimir Koppen in 1900 and updated in 1954 and 1961 by Rudolf Geiger. According to this model, the greater Philadelphia area is in the Dfa zone, meaning it has snow, is humid, and has a hot summer (Kottek et al. 2006). From 1961-1990, the average precipitation for the region was 42.5 inches per year (The National Atlas).

Current Vegetation



Gwynedd Vegetation Communities (GIS Data: Megan Boatright, NLT)

The vegetative communities at Gwynedd Wildlife Preserve are in constant flux as grasslands are managed through burning, successional habitats are either allowed to mature or cut down, and mature forests see new trees reach the canopies. The earlier management style of the Natural Lands Trust involved having as many diverse habitats as possible, but has since moved into more large blocks of habitat. Thus, there is some evidence of the old style as well as the new one.

Land Use History

Gwynedd Wildlife Preserve was created in 1986 when Jack and Claire Betz donated 110 acres and a tenant house to the Natural Lands Trust. Another 67 acres were added by the Betzes in 1989 and then Claire Betz donated 35 more in 1991 in memory of her husband. In 1993, Claire provided money for the purchase of another 22.5 acres across Swedesford road. In 1996, 10 more acres were added. In 2009, large property owners adjacent to the preserve's land across Swedesford road donated another

45 acres (NLT 2007). Aside from these donors, the area that is now Gwynedd Wildlife Preserve has a long history of human land-use.

The Native Americans who had long inhabited the region were the Lenni Lenape, which means "Common People." The name given to them by Europeans was the Delaware, as they lived in the Delaware Bay, which was named for Lord de la Warr, who never even saw the bay, much less a Delaware Native American (Weslager 1972). The Native American agricultural lifestyle was often described as supplementary to their hunting, fishing, and foraging. They lived along rivers for transportation and fertile soils as well as access to fish. Each family grew crops on 1-1.5 acres, often corn, beans, and peas, and field labor was mostly done by women. There were no domesticated animals except for dogs, which were sometimes eaten. In 1654, Peter Lunderstrom, a European surveyor along the lower Schuylkill said there were large fields of corn raised there by Native Americans. The process of clearing land was generally by girdling trees with a hatchet and letting them die, then piling brush up and burning them a few years later (Fletcher 1950).

In 1616, in Massachusetts, the first recorded case of Smallpox hit the colonies north of Mexico. Nearly 90% of the Algonquin tribe in the area died. Smallpox was the great killer, but it was not the only disease brought by the Europeans that killed Native Americans. As explorers and traders sought new routes, more and more Native Americans died (Patterson and Runge 2002). As Native American populations decreased and European settlement increased, land-use changed and increased in intensity.

European settlers to Pennsylvania were a diverse group as William Penn advertised in many languages. Main European settlers in Pennsylvania were English, Germans, Scotch-Irish with minor groups of Dutch, Swedes, Finns, Welsh, French, Irish, and Scotch. It was a melting pot, but still somewhat divided along lines of nationality, religion, and culture. The area of Philadelphia and Montgomery County was mostly English (Fletcher 1950).

Although Native Americans had cleared land, more had to be cleared for the booming European populations. The early Swedes in the mid 17th century would clear the land by burning it, while the English and Scotch-Irish would use the Native American method of girdling. Germans would use the method employed in New England and chop down everything and even remove all but the biggest stumps. Neighbors often worked together, assisting when one family was undertaking a major endeavor of clearing trees. Europeans often grew rye, wheat, or oats, but most supplemented their income as fur trappers. It is believed that the abundance of fur was what enabled Pennsylvania to be settled as quickly and successfully as it was (Fletcher 1950).

Since Europeans arrived, Southeast Pennsylvania has seen a lot more intense use. The first European surveyors of the Wissahickon arrived in 1681 and divided the land up into 12 parcels for purchase and settlement. The mouth of the Wissahickon had a natural dam, preventing its use for transportation and somewhat secluding the settlers who did arrive. Despite this, Germantown was founded alongside the banks in 1683. Roads had to be used to get to Philadelphia until the dam was removed in 1826 (Daly 1922). As industry picked up, the first paper mill of North America was founded in 1690 in Germantown, and is still an important landmark in the area (Jones et al. 1896).

As more humans settled in the region, more land had to be put into agricultural use, though also sometimes more as country retreats than true farms. Gwynedd Wildlife Preserve is part of what was once Normandy Farm, a place recorded by the USDA as part of the National Register of Historic Places due to its history and cultural resources. Normandy Farm was named for Normandy France, where

Ralph Strassburger and May Bourne honeymooned. The land (though not part of the preserve) still hosts what was once the country's largest barn. The farm has since been broken up into smaller parcels and sold separately (Normandy Farm).

Aerial surveys document the agricultural use of most of the 20th century

1942 **1971** **1995**

(Source: USGS Earth Observer)

Surrounding Land:

The major landowners that border Gwynedd Wildlife Preserve are SEPTA, who's regional rail borders the northeastern edge of the preserve, the Wissahickon Valley Watershed Association (WVWA), which has land on the southeastern edge near Gwynedd's afforestation project, and Gwynedd Upper Township's Open Space, which owns a lot of land on the southwest and western side of Gwynedd as well as a little on the northern tip.

The WVWA and NLT have a long history together where the WVWA owns some of the easements on the preserve. With similar goals to the NLT, there could be some coordination between the two. The bordering WVWA land is heavily infested with Callery pears and would be a seed source at Gwynedd (if they are removed from the preserve). Thus, it would be in NLT's best interest to work on some cooperative agreements. The preserve has some good equipment that is closer to and perhaps better than what the WVWA would be using.

Upper Gwynedd Township owns a lot of fragmented land totaling a few hundred acres. Areas that are forested are to be kept forested and areas that are grass are to be kept as grass. There is little in the way of coordinated invasive species management in these areas because of how fragmented the land is and the high costs of management. There had been an effort to time mowing of grassy areas so that some growth was allowed to promote habitat, but many local residents concerned about ticks, deer, and other things, got upset with this (Len Perrone, *personal communication*). On the bright side, mowed areas prevent many serious invasive plants.

The Upper Gwynedd Township's adjacent lands are mostly the result of a sewage treatment plant which is situated near the preserve's southwest corner. It also has land along the Wissahickon creek where sewage pipelines exist to transport the waste to the plant. In an agreement with the WVWA, the land is cared for as the township requires (mowing) and as a result, the WVWA gets control

over it for their trails (Len Perrone, *personal communication*). Thus, there may be room for NLT to have some access to bordering land as part of invasive species management.

Threats:

A wildlife preserve that doubles as a recreation area for humans will have many threats to its value as a habitat. These threats are compounded by the fact that Gwynedd Wildlife Preserve is surrounded by human habitation, an island of wildlife among civilization. The first and foremost threat in terms of invasive species is from transportation by wind, water, and animals from nearby sources. One of the biggest sources is garden ornamentals. A short walk down the road from the preserve is a large nursery for upscale ornamental plantings. Furthermore, building alongside the preserve continues. One of the homes inset within the boundaries of the preserve has been undergoing massive renovations in 2013 to 2014.

Gale Nurseries, Ambler, PA (Photo: Nathan Hartshorne)

Thus, human activities near the preserve can have a significant impact on the invasive species populations within it. Furthermore, human use of the preserve can significantly damage it. Appropriate use can even be a problem. Humans and dogs are the most common visitors, disturbing ground and opening up space for invasive species to germinate. Horses, though less frequent, cause even more damage. Furthermore, horse manure may transport many invasive seeds. According to preserve manager Tom Kershner, areas previously used as horse pasture are now riddled with orchard grass from their feces (Tom Kershner, *personal communication*). Another major weed of the preserve, Canada thistle (Cirsium arvense) has been documented as dispersed along trails by horses (Zouhar 2001). Obviously there is a conflict in management goals and neither can completely beat out the other.

There is also inappropriate use of the preserve. Dogs are generally kept off leash, despite the common signage to end this practice. Furthermore, sometimes neighbors see the preserve as a site for their yard waste, perhaps not understanding the problems. Surprisingly common is the presence of piles of trash.

Trail damage done by horse hooves at Gwynedd Wildlife Preserve, April 14th (Photo: Nathan Hartshorne)

(Left) Yard waste dumped on the preserve; common enough that a trail exists, May 7th, 2014. (Right) Trash and bottles in a forested area of the preserve, April 6th, 2014 (Photos: Nathan Hartshorne)

III. Methods of Management

Introduction

Controlling for invasive plants, animals, fish, and insects all have different strategies while retaining some basic similarities. Plant eradication may be more difficult due to the fact that even if all the plants are killed, seeds may survive in the soil for decades, which can then produce large numbers of new plants. Declaring victory too soon may eliminate control efforts and/or funding and lead to an eventual re-invasion. On the other hand, continuous monitoring may be costly as well. Compared to animals, however, controlling plants has some benefit. Individual plants will not demonstrate intelligence like animals, nor will they fear something new and avoid it. Furthermore, it is easier to poison a plant than animals that eat only living prey. Larger areas of land may be difficult because more niches will be found and more space will be available. Thus it is easier for a species to hide away safely. Some plants can reproduce before they are even seen, like the composite bitterweed (*Helenium amarum*). Another problem comes when using government funding which often comes with set time-tables, but eradication may take longer than this time table allows, or it may require a different time period due to the individual species's biology (Parkes and Panetta 2009). As usual, while occasionally referencing invasive animals, this project will focus on invasive plant species.

There are four overarching objectives when attempting to keep invasions at bay. The first is cultural control, or prevention. Pimentel et al. (2005) states that 80% of the cost of invasives can be prevented with a formal approach to risk assessment (Pimentel et al. 2005). After all, any invasion that is prevented is an invasion that never happened (Grice 2009).While cultural control includes government policy such as noxious weed lists, which is the realm of governments, there are aspects that land managers can utilize. First of all, they can prevent the establishment of invasive species by not planting them or by not causing too much disturbance when conducting activities. Also, by promoting strong communities of native species, invasive species generally have more difficulty establishing themselves (Stohlgren and Jarnevich 2009).

The second objective is eradication. This occurs after the invasion. If a species is eradicated, then it no longer negatively impacts the native ecosystem (Grice 2009). This is, of course, unlikely and difficult. It is actually counterproductive if it is not feasible because of the high cost. For a while, eradication was not really considered but due to recent successes and improvement of methods, it is now, especially in island systems as well as small colonial populations or limited and patchy populations. As of 2007, there have been 348 successful rodent eradications, but 34 failures (Parkes and Panetta 2009). While the rate of success has not decreased, the sizes of the islands with success have increased. Other eradications include goats, cats, pigs, rabbits, brushtail possums, foxes, mink, mongoose, and coypu. There are different issues that must be addressed when attempting eradication. For instance, there may be harm done to non-target species. Sometimes some of them can be removed until the danger (often poison) has passed. There can be no immigration of breeding individuals, or eradication meets re-invasion very soon. Next, removal of one species may allow another species to take over. For instance, a removal of goats may increase the growth of invasive plants, which may then change fire regimes, allowing for more invasive animals to come in. Landowners and animal rights groups sometimes prevent successful eradication (Parkes and Panetta 2009).

Next is the goal of containment. In containment, a species that has invaded is kept to an isolated area and not allowed to invade others. This is, of course, very difficult and probably a fight land

managers will not win. It often does not take much for a species to get past human barriers. For instance, a fence thousands of kilometers long failed to keep rabbits from spreading out in Australia (Grice 2009). Plants can, of course, be distributed down streams and rivers or on the wind.

Last of all is the goal of control. Most non-native species are going to stay in their new habitats and so this goal is to keep them from doing severe damage. Controlling them limits their numbers and therefore their impacts. This contrasts with containment in that it is for larger populations that have spread further. Both, however, require indefinite effort. Control is more likely to be effective as it is difficult to set up barriers to neighboring habitat (Grice 2009).

Related to all these methods is the utilization of watch lists and rapid response. Watch-lists help early detection and therefore, help prevent massive outbreaks. That way there is already people looking for the weed and ready to eradicate it. For example, Caulerpa seaweed (*Caulerpa taxifolia*) has invaded Mediterranean areas and therefore was a known invader. Due to the similarities in climate, California put it on a watch list so when it was discovered off the coast, it was removed 17 days after discovery. Wisconsin has an early detection program for purple loosestrife (*Lythrum salicaria*). Public service announcements ask viewers to call in locations to a hotline. Systems like this need to be used with care, however. There are many invasive species and people can get overwhelmed. There may need to be a narrow focus on specific plants for the general public (Holcome and Stohlgren 2009).

Early detection is great, however, if it is not used properly, then it is no help. Thus, having a rapid response is helpful. In Kakadu National Park in Australia, a stand of mimosa trees was found in 1983. Managers immediately killed them and searched the park for any others. Continual surveillance costs $2 a hectare per year. But in Oenpelli, a nearby area, a stand 200 hectares big was found. No one responded soon enough. The stand eventually covered 8200 hectares and cost 220 dollars per hectare per year to eradicate when they finally did respond. After 5 years of that it is now 2 dollars per hectare (Holcome and Stohlgren 2009).

One of the keys is to make sure that information is both freely available and in the proper quantities for the numerous wildlife managers to be able to access it. They need data on specific invasives' distribution, habitat, and biology as well as strategies to properly manage it. A large number of databases and invasive watch systems have been created. Some of these include the Global Invasive Species Database (GISDF), the Global Register of Invasive Species (GRIS), the Global Invasive Species Information System (GISIN), the Global Organism Detection and Monitoring system (GODM) within the US National Institute of Invasive Species Science (NISS), and the International Non-indigenous Species Database Network (NISbase) are just a few (Holcome and Stohlgren 2009).

There are of course, state and regional networks that help manage invasive species through watch lists and mapping. The Pennsylvania Invasive Species Council promotes early detection systems and cooperation among different organizations (PISC 2009).

Regional associations include the Delaware River Invasive Plant Partnership and the Mid-Atlantic Invasive Plant Council. The Council is made of people from the states of Virginia, West Virginia, Maryland, Delaware, Pennsylvania, New York, New Jersey, and the District of Columbia. Representatives include government officials (federal, state, and local), academics, and people from NGOs and industry. It provides leadership, guidance, and training to people in the region working on invasive plant management. It also promotes cooperation and coordination in mapping and distribution of species (MAIPC 2012).

Beginning an Invasive Management Plan

Focusing on control is the main focus of invasive species management, especially for a preserve manager. There are a wide variety of methods to deal with invasive species. Some methods are more effective with one species, but ineffective against another. All invasive species are naturally difficult to deal with as they tend to have high fertility and growth rates. Methods to remove them range from hand-pulling to chemical applications, to herbivore introductions. As this project is focused on invasive plants, the only methods dealing with invasive animals are in reference to their impacts on invasive plants.

The first step in deciding what to do about an invasive species is to determine its impact (or potential impact) to the area it is invading. Data may need to be extrapolated from elsewhere as well as using local observations. Without evidence of damage, it may be difficult to build the support required to control the species. Furthermore, managers have to consider the impacts of the invasive species compared to the cost of control. After all, something with little impact would not be as important to control and thus not worth the cost (Grice 2009).

Next, all the biological characteristics of the species need to be determined. That is, what is its habitat, how does it grow, and how does it reproduce. For instance, knowing how long seeds stay in the seed bank helps managers know how long monitoring has to happen. Knowing how long it takes for a seedling to mature and reproduce lets managers know how quickly new generations can reproduce. Furthermore, one must know how management methods impact the species. If it reproduces vegetatively, then controlling just the seeds will not stop its spread. If it sprouts after being cut, then chopping it down will not control it (Grice 2009).

There is a burgeoning field at the intersection of weed control and populations dynamics. Many weeds exhibit density-dependent population structures, which alter aspects such as their fecundity. Thus, removing some individuals, thus changing the population density, may induce effects counter to the goals of eradication. Thus, along with the life cycle of a plant, it may be necessary to understand the extent of eradication required to keep an invasion at bay, if not eradicated. Anything short of this would be a waste of time and money (Pardini et al. 2009).

Natural barriers can be used to help curtail an invasion (Grice 2009). If a plant does not like wet soils, then a wetlands may provide a barrier on one side of its range. The same may go for rivers, mountains, or even a different type of soil (pH, minerals, etc).

The best times to attack a species are when its populations are low. Control methods prior to reproduction can also reduce the rates of spread. If seed banks are a problem, then killing plants before they reproduce will slowly erode the seed bank. Seasonal and climatic events can be useful, too (Grice 2009).

Setting up a continuing commitment in both effort and funding is an easy to overlook step. If funding is an issue and is cut after one year, then there will be no control over the species. This is where public support and participation are very helpful. Without those, management plans are less likely to succeed (Grice 2009).

Related to continuing commitment is being sure of cooperation among partners. Cooperation can be achieved through effective public outreach. First of all, the public has to be made to understand that there is a problem. This helps create the public will to eradicate or control (Green and O'Dowd

2009). Intergroup cooperation is one of the keys to successful invasive management. Rarely is any single group in charge of the entire area that one invasive has entered. Also, top-down approaches rarely create the same energy among workers needed to put in the hard hours. Thus, cooperation between groups and individuals is key (Green and O'Dowd 2009). Taking Japanese honeysuckle (*Lonicera japonica*) as an example, it exists in at least 42 US states and Puerto Rico (Schierenbeck 2004). Thus, any wide-scale success would require a lot of cooperation between many partners. At the same time, however, having a clear authority that can take responsibility is very important (Green and O'Dowd 2009).

Last of all, one has to be sure to keep monitoring the situation (Grice 2009). Seed banks may produce new seedlings or new invasions may occur from outside. If a species is thought to be eradicated, but is not, the survivors can completely repopulate the area.

Mapping the extent of an invasive species is the next step (Grice 2009). This is especially important in hard-to-reach habitats that require careful and expensive planning to access. If an eradication or management plan is in effect, not knowing all the population locations will likely allow some populations to continue unhindered (Green and O'Dowd 2009).

Next, one should coordinate the management of similar species. If two species are in the same area and can be controlled in the same method, then coordinating the management is more efficient than doing them one at a time (Meloche and Murphy 2006).

All the data of distribution, life cycle, impacts, and ease of control can be examined together between different species to determine which to target, where to target, and when to target. The methodology has been used in the past by the Natural Lands Trust, taken from the Virginia Department of Conservation and Recreation as well as The Nature Conservancy. They look at the potential impact, the current distribution, the value of the habitat, and the difficulty of control. By examining each one, they create a priority score based on the species' cost-benefit ratio (Heffernan et al. 2001; Dan Barringer, *personal communication*).

Enacting Invasive Species Control Methods

When actually performing control methods, the main types for a land manager are physical, chemical, biological, and integrated management. Physical methods, also known as mechanical, involve physical and/or machine labor to remove, kill, or damage a plant. Chemical methods require chemical herbicides to be used. Biological control uses one species (generally an insect or browsing mammal like a goat) to kill or damage another (the invasive weed) which provides control. Lastly, integrated management incorporates multiple control methods together for a more effective, overarching plan.

Cultural control can also be used. Land managers can promote healthy communities of native species. Competition will be fierce and therefore it will be more difficult for invasive species to establish themselves (Stohlgren and Jarnevich 2009).

Enacting Invasive Species Control Methods: Physical/Mechanical Methods:

Physical methods involve cutting, uprooting, burying, and burning vegetation. First of all is hand-pulling, hoeing, or digging which are often effective and cheap methods. Machines can also be used in a variety of ways. Mowing is a method that may decrease an invasive plant's ability to spread and out-compete others. By mowing, part of the plant is removed and it must compensate for the lack

of energy from the sun by using its own stores of carbon. Depleting the plant's carbon stores will make it weaker and easier to eliminate or be out-competed by natives. This method must be done before seeds are created, otherwise mowing will likely spread seeds. In a similar method, chains can be attached to a couple of tractors and dragged, tearing up anything in between and above a certain height. Fire also works as a control method for many invasives as it literally destroys plants not adapted to survive it. However, all these methods are problematic in that they may create a disturbed area sufficient to introduce a new invasive (Holt 2009).

Another physical method involves using mulch. This can be an effective two-pronged control of invasive weeds. First of all, mulch is used to cover plants, preventing sunlight from reaching them. Furthermore, as many invasives occur where land use has changed the chemistry of the soil, native plants have more difficulty competing. Higher than normal nitrogen rates are one of the main culprits, providing aggressive invaders with a nutrient source. By adding non-decomposed mulch to an area, it can decrease the nitrogen supply as the soil organisms breakdown the mulch and use up the nitrogen. As a result, nitrophilous exotics no longer have access to a high supply of nitrogen and native plants can begin to win the fight (Holt 2009). However, one has to be careful what type of mulch is used as it may be material with a non-native ratio of chemicals. For instance, Russian olive (*Elaeagnus angustifolia*) has higher nitrogen content, so woodchips made from it can increase the nitrogen content of the soil. Allelochemicals in plants can also suppress native regeneration (Katz and Shafroth 2003).

Solarization is an interesting technique involving covering tilled soil with plastic rather than mulch. This heats up the ground as the sun hits the plastic, hopefully destroying the seeds (Holt 2009). As many invasives are shameless in the number of seeds they produce, this can help prevent future growth and invasions by the aliens.

Enacting Invasive Species Control Methods: Chemical Methods:

Chemical control is when chemicals are added to poison a plant in order to kill it. Different plants have different responses to chemicals. This can make it more difficult to apply the correct ones. Also, it can be difficult to apply chemicals to one plant and not damage surrounding plants. Chemical residues may also persist in the soils (Holt 2009). Naturally, when using chemicals, the larger the area, the higher the cost, sometimes making them more impractical for large invasions (DeLoach 1997). A lesson learned from fire ants was that chemical controls may cause more harm than good—if any good even occurs. Chemicals applied by airplanes were used to kill fire ants. The chemicals, however, caused severe ecological harm, killing both predators and competitors of the ants, consequently opening up areas for fire ants to colonize (US Congress 1993). Chemicals also have limited applicability as organisms adapt fast to survive their effects. More than 100 plant species and over 500 species of insects have evolved resistance to some chemical controls (Cox 2004).

Since World War II, the use of chemical herbicides has been increasingly popular at controlling unwanted pest species (Duke and Powles 2008). Often developed for agriculture, the herbicides can be effectively used for invasive species management as well. Herbicides, when used properly, generally have low environmental impacts and toxicity (Pennsylvania State University 2013c). The most commonly used herbicide today is glyphosate and it is featured prominently in invasive species control efforts (Duke and Powles 2008). Thus, a short review of the chemical appears below.

Glyphosate is one of the major herbicides used in weed management. It was first tested and patented as an herbicide by Monsanto in 1970. Becoming commercially available in 1974, it has since become the world's most important herbicide (Duke and Powles 2008). As an herbicide, it is broad-spectrum, meaning it will kill most plants, it is easy to use, and it is not likely to cause any health problems. For instance, glyphosate can be used in a variety of settings, from rural to urban, because it is one of the least toxic herbicides for animals. Furthermore, it does not do lasting harm to the environment, being broken down quickly by microbes. It also binds to soil and is not likely to reach groundwater. As an added bonus, since becoming generic, it is now both effective and inexpensive (Duke and Powles 2008).

The fact that glyphosate provides very good weed control with little effort has created a problem in that users often rely on it too heavily, forgoing other methods of treatment. In crop systems, glyphosate was originally used as a burndown, destroying weeds before planting crops. Weeds that resisted the poison's effects were likely eradicated soon through tillage. As these were early-season weeds only, the later growing populations were not impacted and there was little pressure on the populations as a whole to develop glyphosate resistance. However, since 1996, glyphosate-resistant crops have become available, allowing users to spray it throughout the season. This puts more pressure on the weeds to evolve resistance. Furthermore, as glyphosate became heavily relied upon, other herbicides were skipped and tillage was reduced, making it easier for weeds to survive only one treatment method and then propagate. When glyphosate was merely for burndown, there were no reported cases of resistance, but since its heavy usage and lack of other methods of control, many resistant species have appeared (Powles 2008).

The impacts are not just on crop weeds, but can be seen in many roadside weeds as well. Glyphosate is often used multiple times through the year on roadsides, pressuring weed populations to develop resistance. In one recent study in Israel, 50% of 60 samples of one roadside weed were glyphosate-resistant (Powles 2008). Not surprisingly, the weeds which have been evolving glyphosate-resistance the fastest tend to be those with high genetic diversity and the ability to hybridize (Powles 2008).

Lessons from the development of resistance are clear. Relying simply on one method of control can lead to complete failure when resistance appears. Integrated management of weeds will prevent the evolution of resistance to weed control methods as well as provide more effective control (Powles 2008).

As the number of species with populations resistant to glyphosate increases, so too does the likelihood of them becoming problematic for conservationists. According to the International Survey of Herbicide Resistant Weeds, there are three invasive species found at Gwynedd Wildlife Preserve that have populations that are herbicide-resistant. These species are: Nodding thistle (*Carduus nutans*), Queen Anne's lace (*Daucus carota*), Giant foxtail (*Setaria faberi*), and perhaps other Setaria species. Carduus nutans (only in New Zealand) and Daucus carota are only resistant to 2,4-D, while the Setaria genus has resistance to several herbicides, though none are glyphosate (Heap 2014). So the current impact of herbicide resistance in Gwynedd is low, but it may develop into a problem.

When using chemical herbicides, there are some general guidelines to follow and trends for treatment from one type of plant to another. First of all, herbicides come with a label explaining how they are to be used. That is the most important information for use and the instructions are law (The

Nature Conservancy). The chemicals are generally low in toxicity, especially if applied according to the directions (Pennsylvania State University 2011c). The main methods of control that utilize chemical herbicides are cut stump, hack and squirt, basal bark, and foliar spray.

According to The Nature Conservancy, cut stump works best when plants are cut to 4 inches from ground level and then the stump is wiped with an herbicide. Application is more efficient if the herbicide has dye mixed in to help distinguish it from untreated stumps (The Nature Conservancy). Glyphosate, 2,4-D, triclopyr, imazapyr, dicamba, fosamine, and a picloram and 2,4-d mixture are all herbicides recommended for a cut-stump treatment (Pennsylvania State University 2014a). The literature review conducted on individual species found at Gwynedd mostly focused on glyphosate.

The Hack and Squirt method, also known as frill girdle and sometimes also stem injection (Pennsylvania State University 2014c), is similar to the cut stump, but not as labor intensive. At a downward angle, a hatchet or similar device makes a cut into a plant where herbicide is applied. A lance-type tree injector can also be used to inject herbicides. This is best done on larger trees with greater than 5 inch diameters (Pennsylvania State University 2011c). Glyphosate, triclopyr, imazapyr, 2,4-D, clopyralid, dicamba, hexazinone, and a picloram/2,4-D mixture have been recommended for this method (Pennsylvania State University 2014c).

Basal bark herbicide uses ester triclopyr rather than glyphosate or other herbicides. In this method, the 12 to 18 inches of the trunk are sprayed with the herbicide. It should not be used in wetlands and dripping chemicals should be avoided (The Nature Conservancy). Since the chemicals must penetrate the bark, it is best done on thin-barked trees with less than 6 inch diameters (Pennsylvania State University 2011). The Nature Conservancy Chemical Factsheet states that only triplocyr can be used in this method, however, the Pennsylvania State University states that 2,4-D and imazapyr may also be used (The Nature Conservancy and Pennsylvania State University 2014d).

Foliar spray is effective on the leaves of plants. It can be most effective when plants are dense and when in fruit or flower. It is best on herbaceous or woody plants. Also, waiting until there is no wind is necessary so that non-target plants are not affected (The Nature Conservancy).

Enacting Invasive Species Control Methods: Integrated Management

One has to be careful when using physical and chemical methods to control invasives because they may harm native plants. Native plants are, naturally, often good at preventing invasions through competition. Using native plants to compete with aliens can help stress the invasives and prevent them from taking over. The stronger the presence of natives, the less likely it is that aliens will invade and those that try may be outcompeted. Natives can be planted or seeds added to an area to increase their populations (Holt 2009).

Integrated Pest Management or Integrated Weed Management is when a variety of methods are used. For instance, one might use mulch to cover an invasive and then plant natives where the weeds had been, to help prevent any re-growth or seed germination of the aliens (Holt 2009). As stated before, the simple herbicide method in farm fields has rendered glyphosate useless because an integrated plan was not in effect. This, of course, can include the cut stump method that uses both physical and chemical methods of control (Pennsylvania State University 2014c).

Enacting Invasive Species Control Methods: Biological Methods

Although native species eventually adapt to non-natives, finding ways to consume them, may be a slow process, may not actually slow down the invader, and, if the invader is very different from the local flora, may take an exceptional amount of time. Thus, in order to help prevent the spread of an alien and make it more manageable, many governments have been looking at using herbivores that already consume an invasive to control it. This method, termed biological control has been in use for over a century and has had many successes and failures. The "classical approach" to biological control is when an insect from an invasive alien's natural habitat is introduced to where it has invaded in order to control the invasive.

Native to the Americas, the prickly pear cactus became an aggressively invasive weed in much of the world. When it was discovered that a scale insect, *Dactylopius ceylonicus*, could control the plant, it was introduced to Sri Lanka in 1865 as one of the first deliberate attempts at biological control of a weed. *D. ceylonicus* demonstrated a lot of success for this new method (DeLoach 1997). Since then, the twenty-two species of insects introduced to Australia have provided significant control of the 11 cacti that have invaded. The "augmentation" approach is when there already is an insect herbivore where the alien is invading that eats the invasive. Its population is then increased, for instance, by being grown in a lab, and then released (DeLoach 1997). The classical approach is for governments, as they are the only ones with the ability to take responsibility for these actions. Also, importing a new species should not be done without government approval anyways. Augmentation, however, is something commonly in practice and can be on the preserve management level.

Since 1945, the United States government has been conducting research on biological control of invasives through the USDA. The first biological control was for St. John's wort, or Klamath weed (*Hypericum perforatum*). St. John's wort is poisonous to many animals, hurting livestock that unwittingly eat it, causing significant economic damages. Thus, the leaf beetle *Chrysolina quadrigemina* was released in California, providing almost complete control of the weed. Since 1945, the USDA has maintained offices around the world to study species' interactions before bringing them to the US. As of 1992, insects have been introduced to the US to control 32 species in the conterminous US as well as 21 in Hawaii (DeLoach 1997).

Interestingly, the wisdom of biological control is not always understood. As the prickly pear cactus was a serious pest of the past, today some people want to save it, preferring to focus on the positive benefits provided by the plant. Keren Kayemet Leyisrael, also known as the Jewish National Fund, is introducing insects to feed on *Dactylopius* that infect the cactus (The Jerusalem Post 2014).

Just because an insect consumes an invasive does not provide control over the invasive. The insect needs to either feed voraciously or cause significant damage in another way that harms the invasive to the point where it does not function properly. For instance, in an early survey to determine herbivory on the invasive mile-a-minute (*Persicaria_perfoliata*) weed in the eastern United States, 34 species were found developing on the plant and 12 more that fed on it only as adults, yet none caused significant damage (Wu et al. 2002). Thus herbivory does not necessarily constitute control. On the other hand, it can do a lot of control despite not appearing to. As stated earlier, increasing Sycamore maple (*Acer pseudoplatanus*) herbivory from 1-1.6% to 6-10% reduced growth by 35% and oak trees suffering from 12% leaf area loss produced 50% fewer acorns than undamaged trees (Adams et al. 2009).

The use of biological control is high-risk high-reward. The reward for a successfully controlled invasive is great, as biological control is relatively inexpensive to implement as it is self-perpetuating. However, the risk can be great, as once released, an agent cannot be recalled. Many introductions have not only failed to control the target invasive, but caused severe damage to natives instead. For instance, the gypsy moth (*Lymantria dispar)*, a prolific defoliator of North American forests, was introduced from France in 1868 or 1869 (Liebhold et al. 1992). In order to control this serious invader, multiple introductions of a tachinid fly *Compsilura concinnata* occurred from 1906 to 1986. The fly does attack Gypsy moths, but it is also a predator to many other species and is responsible for extirpating multiple native species from northeastern states (Louda et al. 2003).

If an insect is introduced to control one invasive plant, but there are natives closely related, it is more likely that the insect will also consume the native. In an analysis by Pemberton in 2000 of 117 introductions of biological control, only 1 resulted in a species using an unrelated host. Of the 41 species used for biological control that did use natives as hosts, 36 of the new hosts were in the same genus and 4 were in closely related genera. Of the 61 biological control agents with closely related host species, 14, or 23%, used natives (Pemberton 2000). As landscaping plants are often alien ornamentals, biological control agents are likely to damage them if they are nearby (DeLoach 1997).

Biological control can also be difficult beyond the research needed to determine host-specificity of the agents. First of all, most cases need more than one agent to give full control over a weed. Secondly, there are situations where a biological control agent is introduced and then disappeared, presumably extirpated, only to be found 5-15 years later when it begins to control the invasive (DeLoach 1997).

Biological control has to be examined carefully. Aside from the possibility that agents may switch hosts, they may also bring in other invasions. When a nematode, *Deladenus siricidicola*, was brought in to control wood wasp (*Sirex noctilio*) in Australia, South Africa, and South America it arrived with White Rot fungus (*Amylostereum areolatum*), which subsequently began to damage native pine trees (Cox 2004).

It should also be noted that biological control has neither eliminated plants from an ecosystem, nor made rare plants more rare (DeLoach 1997). It is apparent, however, that as biological control agents naturally evolve, they will almost inevitably change hosts. Generalists may do it faster, but the rest also have the ability, regardless of their current host-specificity (Cox 2004).

The record of complete control using biological control methods is 10-15% for invasive insects and 30-39% for invasive plants. Not surprisingly, countries that do more research have higher success. Although sometimes multiple agents are released, most successes are from one or two agents. Host-specificity was not mentioned in risk-assessment of older biological control texts and was rarely, if ever, tested (Murphy and Evans 2009).

A major advantage of biological control is that it skirts one of the main issues of land management, specifically control over the land. One of the biggest difficulties with controlling invasives is when they have established populations near the land being managed. For instance, according to Daniel Barringer of the Natural Lands Trust in Pennsylvania, plants such as the Norway Maple (*Acer platanoides*) and Japanese silvergrass (*Miscanthus sinensis*) are never fully eliminated despite his best efforts because people who live nearby like to grow them as ornamentals (Dan Barringer, *personal communication*). In a system-wide approach like biological control, this does not have an impact, but for

physical and chemical methods of control, having a nearby population makes efforts less fruitful. Information like this helps managers determine how to go about controlling invasives knowing that populations thrive nearby.

Predator-prey interactions (also biological control) can be very complex and require detailed knowledge of feeding habits. If invasive goats are removed from an area, the sudden lack of herbivory may allow for invasive plants to run rampant while before they had been controlled by the goat. Similarly if there is an invasive predator of invasive pigs and the predator is removed, the pigs may run amok destroying native vegetation in the process. So just as consideration of removing herbivores must be taken into account, so too must the consequences of removing carnivores be considered. This relates to when invasive plants are removed and their former locations are taken over by another invasive plant (Bull and Courchamp 2009).

A simple, yet effective biological control method for many invasive weeds is the use of chickens. As seeds are designed to go through many animal guts without being harmed, and sometimes even induced to germinate, species that do not allow this can be used to control invasive propagation. In articles on Common mullein (*Verbascum thapsus*) and Japanese honeysuckle (*Lonicera japonica*), it has been noted that chickens can be used to reduce the seed bank production (Handley 1945 and ISSG 2005).

Invasive Issues Specific to Gwynedd Wildlife Preserve: Introduction

While invasive plant management may seem to be an issue of plants, there are many interactions outside of the plant community that play an important role. The interactions of all the species in an ecosystem are what define the ecosystem. So just as invasive plants may harm native plants, exuding allelochemicals or hosting diseases, fauna, native or exotic, may also play an important role. The snapshot of Gwynedd Wildlife Preserve provided by vegetation surveys will change due to these faunal influences and thus need to be briefly addressed.

Invasive Issues Specific to Gwynedd Wildlife Preserve: Deer Management:

Perch for deer hunter, Gwynedd Wildlife Preserve, April 6, 2014 (Photo: Nathan Hartshorne)

One of the most noticeable management issues of Gwynedd Wildlife Preserve is that of the local deer population and consequent herbivory. The impact of deer on a forest understory can be significant. They may propagate seeds through their feces, they may consume native species and ignore

invasive species, and they may eat invasive species as they do natives. Gwynedd Wildlife Preserve has a significant number of deer that frequent it. Due to the close proximity of many homes, only bow-hunting is allowed, but deer management practices are actively encouraged. It is estimated that 45 deer need to be killed each year, but only about 15 are, thus there is a major problem with too many deer (Tom Kershner, *personal communication*).

In the last 50 years, the population of white-tailed deer has quadrupled in the eastern United States (Knight et al. 2009). This boom has been causing significant impacts to local ecosystems. For example, increases in deer population have resulted in decreases of herb and shrub species by 48-81 percent in old-growth forest stands. Populations of Eastern hemlock (*Tsuga canadensis*) and Northern white cedar (*Thuja occidentalis*) have been having difficulty as deer herbivory prevents seedlings from maturing (Rooney 2001). Thus, too many deer reduce plant species populations, something that may make the areas ripe for invasion.

Many invasive plants are unpalatable to deer. Thus, they will consume local, native flora that they have evolved with, but let the invasive vegetation grow freely. An example of this is Japanese stiltgrass (*Microstegium vimineum*) which deer do not like to eat (DCNR). Garlic mustard (*Alliaria petiolata*) is another example which, with around 15,000 seeds per individual, is also blessed by having the deer trample through it, helping to spread the seeds mechanically (Kleinstein 2001).

In one study using deer-exclusion plots, the forest understory was dramatically different after 5 years, with a native plant dominating areas deer were kept out of, and Japanese stiltgrass and Garlic mustard dominating the rest (Knight et al. 2009). This is supported by my field survey observations at Gwynedd Wildlife Preserve in 2014 where one forested area has significant deer feces present and is dominated by Japanese stiltgrass, while another forested area a short distance away has little to none of either.

While many invasives are not consumed by deer, those that are may find it beneficial. Many seeds are adapted to surviving in the guts of animals, improving their innate dispersal abilities as the deer may drop them significant distances from their parents. In studies on invasive species, many rely heavily on deer, though others, while not relying on it, still make use of it (Myers et al. 2004). A study germinating seeds from deer feces in Connecticut yielded 57 species of plants, 32 of which were exotics (Williams and Ward 2006).

It should be noted that birds are also significant dispersers of seeds (native and exotic), so deer are not solely to blame. Fruit-bearing plants are especially attractive to birds that will then eat the fruit and spread the seeds out their guts (Gosper et al. 2005). Thus, species of honeysuckles, pears, crabapples, and the like will be spread by birds.

While deer are to blame for many problems associated with invasives, it should be noted that they may sometimes consume invasive plants at a rate that helps suppress their growth, so in heavily invaded areas (especially if there is little to no seed sources of natives), removal of deer may possibly encourage invasives to grow. For example, in a study published in 2007, deer herbivory did diminish the amount of Oriental bittersweet (*Celastrus orbiculatus*) (Knight et al. 2009). This could be compared to the issue of goats being removed from islands discussed earlier under invasive eradications.

It is interesting to note that invasive plant species that provide more food for deer consequently sustain a larger deer population can have impacts on human health. Increased deer populations result

in increased deer tick populations, which are, in-turn, hosts for Lyme disease (Carroll 2007). Thus, there may be a possibility of developing public interest in the eradication of some non-indigenous species.

Thus, deer herbivory can work changes on a forest community from any direction and only a case-by-case basis can determine what the impacts will be. However, the overall trend is that unmanaged deer populations facilitate the decline of a forest, especially in terms of native species abundance and exotic infestations. Thus, deer management will continue to be an issue in the preserve's future.

Invasive Issues Specific to Gwynedd Wildlife Preserve: Invasive Worms

In 1881, Charles Darwin was the first to note and explain how earthworm processes facilitated terrestrial ecosystems (Hendrix and Bohlen 2002). Since then they have been used for a lot of different activities, creating quite an economic niche. Unfortunately, worms, like any other species, can be a non-native invasive. Many introductions are by accident, the results of agricultural and horticultural imports or ship ballast. Others are due to using the worms directly as fish bait, waste management, or bioremediation (Hendrix and Bohlen 2002).

Earthworms (phylum Annelida, class Clitellata, subclass Oligochaeta, order Opisthophora) are a diverse group with many species from around the world. There are about 70 species of native earth worms in the Eastern US. However, due to climate change, glaciers and permafrost pushed earthworms south-well beyond the distance that even the glaciers went. Some slowly migrated north following the retreat of the glaciers, but not many were found in northern North America by the time early European settlers arrived. Since then, about 45 non-native species have made their ways to invade the continent north of Mexico (Hendrix and Bohlen 2002).

Earthworms do many things that significantly alter ecosystems by changing the soil composition. Worms actively remove and bury litter, which increases soil erosion, they produce fresh casts that increase soil erosion and surface sealing, they increase compaction of surface soils, they disperse weed seeds, they transmit plant or animal pathogens, they increase soil nitrogen loss through leaching and denitrification, they alter the natural horizons of soil, sometimes erasing them completely, and they increase soil carbon loss by increasing microbial respiration. The impacts can be quite strong depending on how robust the population and species is and where they live in the soil layers (Hendrix and Bohlen 2002).

There are three general types of earthworms and they alter the soil in different ways. Based on their food and where they live, they may not even directly interact with other worms in the same area. Epigeic, epi-endogeic and epi-anacic species feed and live on littler and surface layers of soil while poly-, meso-, and oligohumic and endo-anacic endogeic species inhabit the mineral soil within the rhizosphere and anacic species feed on the surface, but live in the mineral soil (Hendrix and Bohlen 2002).

The biggest impacts of non-native worms are in areas that did not have worms until they invaded. Thus the ecosystems are not adapted to their presence. Lumbricidae from Europe are the most common non-natives north of the glacial margins (Hendrix and Bohlen 2002). One of the biggest impacts is the decomposition of leaf litter (Migge-Kleian et al 2006).

Both the physical changes caused by earthworms as well as direct actions done by earthworms can have effects on flora and fauna-especially those in the forest soil. It is not always certain the impacts of worms on microflora and microfauna due to the lack of studies, however some have been

done and conclusions can be drawn. As earthworms change and mix the soil horizons and nutrient levels, organisms like fungal and bacterial communities will be immediately impacted as they adapted to specific levels. Though often increasing nutrient availability, the earthworms may also be a competitor for nutrients. Furthermore, as earthworms move through the soil, they may ingest microfauna, altering their communities (Migge-Kleian et al 2006).

Immediate introductions of earthworms can actually positively influence the ecosystem by adding habitat complexity or increase nutrient availability. These, unfortunately, are generally short term impacts, often weather-dependent or possibly due to a negative impact on dominant species. In an experiment, microarthropod-inhabited soil and with worms in cages within, the soil in the cages had lower densities of microarthropods than outside. This indicated that either the worms destroyed the microarthropods or they migrated away. Long-term studies in previously worm-free soils from German mining areas have reflected this. Studies in Europe have shown similar impacts on enchytraeid, which play a role in breaking down organic matter fragmentation and humification in soils. Also, while earthworms may increase nutrient availability, promoting the population expansion of protozoa and nematodes, they may also digest the creatures in the soil. Studies have shown that worm-populated soils show a decrease in nematode populations and an alteration in its structure. Protozoan decreases, though not fully studied, could be especially important as they significantly improve plant growth. This changes the microhabitats of the area, depriving salamanders of food (Migge-Kleian et al 2006).

Obviously the earthworms' impacts on microflora and microfauna have an impact on the species that feed on these and depend on the habitat structure to remain intact. In a paper published in 2001, the Minnesota Breeding Bird Survey noted a decline of almost 50% in ovenbird nesting success that was the result of decreases in forest floor litter due to invasive worms. In the same area, the Chippewa National Forest, red-backed vole and shrew populations declined. In a study of 10 sites in New York and Pennsylvania, salamander populations have been in decline as the result of leaf litter removal by invasive worms. Interestingly, worms provide a large source of food for some adult salamanders. However, this is limited to cool and wet times of the year, making it less predictable than the traditional earthworm-free diets of meso- and macro-invertebrates. Furthermore, juvenile salamanders cannot eat worms, and the worms compete with salamanders for food, so earthworms may hinder salamander maturation. Also, the lack of forest litter may increase the likelihoods that salamanders' moist skin dries out (Migge-Kleian et al 2006).

The lack of forest litter has been shown to increase the invasion of non-native shrubs. Compounding this, if the invasive shrubs have a different chemistry than the natives, such as a low C:N ratio, their leaf litter and other decaying parts can impact the soils even more. Then, changes to the soil may impact the micro- and meso-fauna populations (Migge-Kleian et al 2006).

The impact of non-native earthworms on areas with native earthworms is not always clear. It appears that many non-native worms have difficulty in areas already dominated by native worms. However, if the area has been disturbed, then non-natives can take over. Whether or not non-native worms displace native worms is still uncertain, as is what happens when one invasive worm encounters another. In some places where invasions have occurred, native worms still dominate the sites (Hendrix and Bohlen 2002).

The study of the interactions of invasive worms and invasive plant species is just beginning, however, some conclusions have already been drawn. Just as native worms are more adapted to native

plants, so, too, will exotic worms be more adapted to exotic and thus be better suited to utilize the changes in the soil chemistry. In one study, removing Common buckthorn (*Rhamnus cathartica*) from one plot and Japanese honeysuckle (*Lonicera japonica*) from another, the invasive worm populations dropped by half for the next three years (Madritch and Lindroth 2009).

The future of northeastern ecosystems is uncertain as non-native worms continue to spread through population growth as well as importation by humans. The altering of the forest floors may have an impact, or may pave the way for larger changes, such as the colonization of other invasive species.

Invasive Issues Specific to Gwynedd Wildlife Preserve: Emerald Ash borer

The Emerald Ash borer's impact on Gwynedd Wildlife Preserve will be significant due to the high number of Ash (*Fraxinus*) trees currently present. The Emerald Ash borer (*Agrilus planipennis*) is an invasive insect from Asia. As a larva it consumes the phloem of the Ash trees the eggs are laid into, while as an adult, it defoliates the Ash (Poland and McCullough 2006). According to one study, in 2007, Ash mortality was 80-100 percent in areas within 30 kilometers of the assumed epicenter of the Emerald Ash Borer (Pugh et al. 2011). It was first noticed in Detroit in 2002 and is rapidly killing Ash trees in North America (Poland and McCullough 2006). However, studies suggest that it may have been present in the 1990s, though in smaller populations not yet noticeably invasive (Pugh et al. 2011). Sometimes infected ash are then colonized by native borers that increase the damage. It was likely introduced either through the horticultural industry or solid wood packing material. By 2004, an estimated 15 million ash trees were dead or dying in Michigan alone (Poland and McCullough 2006). The Emerald Ash Borer is now in Pennsylvania and continuing to spread rapidly (Pugh et al. 2011). Although not yet confirmed, it is believed that as of May, 2014, the borer has been found in Upper Gwynedd Township's Open Space lands (Len Perrone, *Personal Communication*)

Invasive Issues Specific to Gwynedd Wildlife Preserve: Beech Bark Disease

Beech Bark Disease is an important issue in the future of Gwynedd Wildlife Preserve because the preserve is home to some large American Beech (*Fagus grandifolia*). Beech Bark Disease is not a traditional disease, but the interactions of an insect and fungus that result in the deaths or damage of American Beech. The insect, a beech scale (*Cryptococcus fagisuga*), feeds on the bark of the American beech. The canker fungi *Neonectria coccinea* (exotic) and *Neonectria galligena* (native) are then able to invade the inner bark and cambium of the tree. The insect (and presumably the exotic fungus) were introduced to Novia Scotia around 1890, however separate introductions appear to have been made in the Boston/New York area, North Carolina/Tennessee area, and in Michigan (Morin et al. 2007).

Beech Bark Disease spreads radially and has recently entered southeast Pennsylvania. Infected trees may live for decades, with the largest being the most heavily impacted. Interestingly, in most places invaded by Beech Bark Disease, the amount of American beech has actually increased, however, less so than the increase in associated species. Also, invaded Pennsylvania forests are one of the few areas where American beech has declined overall. There may, of course, be outside factors influencing this (Morin et al. 2007).

IV. Controlling Non-Native Plants at Gwynedd

Introduction

Controlling invasives after they have invaded is expensive, sometimes prohibitively so. As Frederick the Great stated, "He who defends everything, defends nothing" (Mack 2003). So in many cases, invasions have to be accepted. In other cases, the government is able to control and even eradicate the invader. One important aspect to note is that as invasions can spread exponentially, it is often considered worthless to clear the invader at a slower rate than it spreads (Turpie and Heydenrych 2000).

A rubric must be created in order to determine which species should be eliminated, as well as how, and in what order. For instance, plants that are highly invasive often need to be dealt with immediately and receive a high priority. However, if the invasive is spread so thoroughly that it cannot be eliminated or controlled, then it is no longer a high priority. The expense is too prohibitive to try to deal with it as long as is not damaging to the entire ecosystem. Next, the value of the habitat it is invading is considered. If the habitat is important to an endangered or threatened species, then it is of extra high value and given higher priority. The rubric used in the past by the Natural Lands Trust comes from the Virginia Department of Conservation and Recreation (Natural Lands Trust 2005). This was used again for this project both because it is a good system, and in order to keep some standardization for NLT documents. An example of a rubric is below:

Scientific Name	**Common Name**	**Potential Impact**	**Current Distribution at preserve**	**Value of Habitat**	**Difficulty of Control**	**Priority Score**
Acer platanoides	Norway maple					

(Heffernan et al. 2001; Natural Lands Trust 2005)

Subrank	**High**	**Medium**	**Low**	**Insignificant**
Impact	4	3	2	0
Current Distribution	0	1	2	3
Value of Habitat	3	2	1	0
Difficulty of Control	2	1	0	0

(Heffernan et al. 2001; Natural Lands Trust 2005)

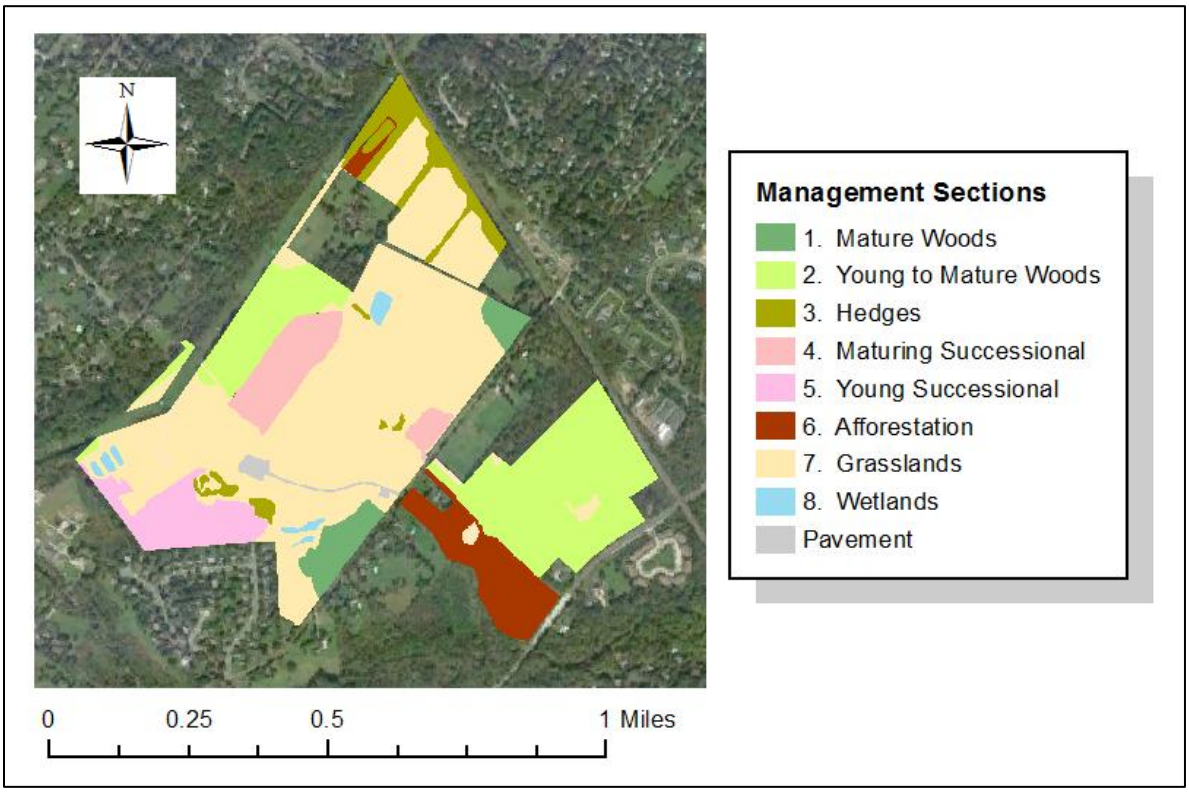
In order to properly determine these characteristics, a detailed map of invasive species at Gwynedd Wildlife Preserve was created. The location and density of communities and what habitats they are in will help provide information to decide which invasive species receive priority (NLT 2005). With unlimited resources, all invasives could be dealt with. Resources are not, however, unlimited.

Invasive Priorities at Gwynedd Wildlife Preserve

Scientific Name	**Common Name**	**Potential Impact**	**Current Distribution at preserve**	**Value of Habitat**	**Difficulty of Control**	**Priority Score**
Acer ginala	Amur maple	med	low	med	low	7
Acer platanoides	Norway maple	high	med	high	med	9
Achillea millefolium	Common yarrow	low	low	low	high	7
Ailanthus altissima	tree-of-heaven	high	low	low	med	8
Alliaria petiolata	garlic mustard	high	med	med	high	9
Barbarea vulgaris	Bittercress	med	med	med	high	8
Berberis thunbergii	Japanese barberry	high	low	high	med	10
Cardamine hirsute	Hairy bittercress	med	med	med	high	8
Cardamine impatiens	Narrow-leaf bittercress	med	med	med	med	7
Carduus nutans	Nodding thistle	high	low	med	high	10
Celastrus orbiculatus	Oriental bittersweet	high	high	high	high	9
Cerastium fontanum	Mouse-eared chickweed	low	low	low	high	7
Cirsium arvense	Canada thistle	high	high	med	high	8
Coronilla varia	Crown vetch	med	high	med	high	7
Dactylis glomerata	Orchard grass	med	high	med	high	7
Duchesnea indica	Indian strawberry	med	low	med	med	8
Elaeagnus umbellata	autumn olive	high	med	med	high	9
Euonymus alatus	winged euonymous	med	low	high	med	9
Forsythia spp.	Forsythia	low	low	low	low	5
Glechoma hederacea	Ground ivy	med	med	med	high	8
Helesia carolina	Carolina silverbell	low	low	low	low	5
Hedera helix	English ivy	med	insig.	med	med	9
Hemerocallis fulva	Day lily	low	low	med	low	6
Hesperis matronalis	dame's rocket	low	low	med	low	6
Iris pseudacorus	Yellow iris	med	low	med	med	8
Lamium purpureum	Purple dead-nettle	med	low	med	med	8
Larix kaempferi	Japanese larch	low	low	med	low	6

Scientific Name	Common Name	Potential Impact	Current Distribution at preserve	Value of Habitat	Difficulty of Control	Priority Score
Ligustrum obtusifolium	European privet	high	high	med	low	6
Lonicera japonica	Japanese honeysuckle	high	high	high	high	9
Lysimachia nummularia	Moneywort	med	low	high	high	10
Microstegium vimineum	Japanese stiltgrass	high	high	med	high	8
Quercus acutissima	Sawtooth oak	low	low	low	low	5
Ornithogalum umbellatum	Star-of-Bethlehem	low	low	med	low	6
Phellodendron amurense	Corktree	med	low	high	low	8
Picea abies	Norway spruce	low	med	med	low	5
Picea glauca	White spruce	low	med	med	low	5
Platanus x acerifolia	London planetree	low	low	med	low	6
Polygonum perfoliatum	mile-a-minute	high	low	low	high	10
Prunus avium	Sweet cherry	high	med	med	med	9
Pyrus calleryana	Callery pear	high	high	med	med	7
Ranunculus bulbosus	Bulbous buttercup	med	med	low	high	7
Ranunculus ficaria	Lesser celandine	high	med	med	med	8
Rhamnus cathartica	Common buckthorn	high	med	high	med	9
Rhodotypos scandens	Jetbead	med	low	med	med	8
Rosa multiflora	multiflora rose	med	med	med	med	7
Rubus phoenicolasius	wineberry	low	med	med	med	6
Rumex obtusifolius	Bitter dock	med	low	low	high	8
Salix fragilis	Crack willow	low	low	high	low	7
Setaria spp.	foxtail	med	high	med	high	7
Trifolium repens	White clover	low	med	low	high	6
Veronica serpyllifolia	Thyme-leaf speedwell	low	low	low	high	7
Vicia tetrasperma	Slender vetch	med	med	high	high	9
Vinca minor	Common Periwinkle	med	low	low	med	7

Management Plans for Specific Units Within the Preserve



(GIS Data: Megan Boatright, NLT)

Section 1: Mature Woods

Status

These two areas are very mature woods (the southern one even more so) with less of an invasive species problem than the rest of the preserve. The main invasive threat to both is Norway maple. The northern section has more problems with garlic mustard, Japanese stiltgrass, and European privet due to its smaller size and more light penetration. There are scatted Japanese barberry, Burning bush, Garlic mustard, and others, but it these are the healthiest of the ecosystems present.

Recommendations

The reason for these areas' healthy status is their maturity. Light does not easily penetrate, which would promote invasive species. However, shade-tolerant Norway maple is a significant problem and threatens to become the main over-story species. Furthermore, as deer prevent the growth of many trees, it may be difficult for the forest to regenerate itself. Steps have already been taken to plant seedlings in tree tubes in the southern section. There should probably be more of them. Given the relative lack of invasives, a single push could eradicate most in a single season with monitoring after. The northern section should be expanded, creating a greater contiguous habitat.

Section 2: Young to Mature Woods

Status

These two sections are far apart, but both are mostly young, with sections that are more mature. In the northwestern woods, the northern 1/3 is the most mature. In the eastern forest (Tunnel Woods), there are various older patches. The mature areas are very similar to Section 1, but with significant problems of fallen trees opening up space in the canopy. The younger areas have significant non-native species problems. There are large amounts of Japanese stiltgrass, wild garlic, lesser celandine, and European privet along with several other invasive species.

Recommendations

The recommendations for the northwestern section follow those for Site 1 with tree tube plantings at sites of fallen trees and forest openings. Not only do they promote invasives, but open spaces in forests create more wind, which cause more fallen trees. For the southern part, the open spaces are one of the main causes for the poor understory and mid-story. Deer herbivory is a powerful force and only tree tubes will allow for proper growth of beneficial over-story trees. Many of the invasive species problems will be eliminated with more shading. However, already established species will sometimes manage after shade is created, so an effort will have to be made to eliminate them, especially privet and buckthorn.

Section 3: Hedgerows

Status

The hedgerows at Gwynedd appear to be more invasive species than native, from flowering trees to vines to shrubs to herbs. This makes sense as species that like sun and shade will find refuge. Also, some of the hedgerows are made largely of non-native trees that were planted.

Recommendations

Hedgerows can be valuable habitat, but difficult to maintain. Right now it appears that they are a seed source for invasives. If they are desirable, then sections should be removed and planted with native plants. Some hedgerows could be removed completely, letting the grasslands take over. Some hedgerows are being converted into forest in the afforrestation areas and do not need to be as actively managed.

Section 4: Maturing Successional

Status

There are three early to mid successional sites at Gwynedd. These two are not being maintained as young and are being allowed to mature. They are heavily crabapple, with privet, buckthorn, stiltgrass, and some garlic mustard.

Recommendations

These areas are very difficult to access and therefore not much management is likely to happen until they mature. Fortunately, many of the problems with this habitat will be solved as the area matures and taller trees create more shade. However, in order to ensure that they develop properly,

tree tubes should be planted as well as native forest shrubs, which appear to be currently lacking. The northern young successional area is next to a privet-dominated forest, so heavy invasions brought in by deer and bird feces will be likely without management.

Section 5: Young Successional

Status

This area is a younger crabapple habitat than Section 5. It is to be kept as a young to mid-successional habitat. Thus, it has the highest density of invasives that prefer these habitats, such as Autumn olive, Callery pear, and Common buckthorn.

Recommendations

As sections are managed to become younger-successional (chained or chopped), they should be carefully monitored for invasive species (except crabapple). This way, as they mature, they will not be seed sources when the next section gets managed. There are many native early successional plants that may be seeded in the area, for example native crabapple and various native *Rubus* species.

Section 6: Aforrestation:

Status

There are two areas included in this section. The eastern area by Tunnel Woods is currently being pushed into afforestation. It has many seedlings and saplings and is actively mowed to encourage their growth. The northern area is a grasslands that is not very rich in species and has a chokecherry grove in the middle. There are many invasive herbs, shrubs, and crabapples, but they are very short due to the constant mowing. Thus, there is not really an invasive species problem at the moment.

Recommendations

For the eastern section, although producing a canopy layer of native species, this does not produce a native shrub or herbaceous layer. Soon, the more mature areas will be producing more shade, removing the full-sun species, but still allowing invasives to rapidly appear. Native forest shrubs like spicebush, dogwood, and viburnum should be planted. Grass should be preemptively killed with glyphosate and then replaced with native forest floor herbs. For the northern section, it should be promoted as afforestation due to the current lack of benefits to wildlife. Research has shown that forested buffers along streams help promote a healthy stream ecosystem by removing nitrogen and suspended solids (Sweeney and Blaine 2007). Due to the previous agricultural use and many invasives that increase nitrogen content in the soils of the preserve's fields, this would probably be very beneficial.

Section 7: Grasslands

Status

The grasslands are expansive, but are heavily infested with non-native woody plants, grasses and herbaceous plants such as orchard grass, Oriental bittersweet, autumn olive, and slender vetch. Fortunately, most of the vines are actually native, probably *Rubus allegheniensis* and occasionally *Rubus hispidus*.

Recommendations

These should be properly burned as they are. However, burning does not eliminate many herbaceous invasives. Many of these need to be hand-pulled. Also, many woody species sometimes survive the fires. While most Oriental bittersweet dies after burns, many members of the community survive burns and create dense thickets until the next burn years later. Thus, soon after a burn, when these woody species begin to leaf out, they should be cut and painted with glyphosate.

Section 8: Wetlands

Status

The wetlands only have small patches of invasive species, perhaps due to the fact that they have a small size. The main problem appears to be the eagerness of certain species to turn it into a successional area. Thus, Callery pear, Autumn olive, and crabapple are the main problems.

Recommendations

When the boundaries are mowed each year, care should be taken to make sure invasive successional species (and any other undesirable woody plants) are also removed. There are local wetland invasives that do not appear to have made it to the managed wetlands, for instance, Moneywort. They should be monitored and have a system in place to drown invasive species (lower and raise the water level for management). This would also be beneficial for removing overly aggressive cattail from time to time.

Gwynedd Wildlife Preserve as a Whole:

Just as each particular area may have its own specific issues and recommendations for invasive species control, the preserve can also work as a whole. There is a conflict between management for wildlife and management for humans and the limitations of funding. Thus, many recommendations are either not feasible, or only partly so. The first thing that can happen (and has already happened) is to prevent invasive species from arriving. Previous management of Gwynedd has not taken this into consideration. Non-native species such as Norway spruce, Carolina silverbell, Amur maple, daffodil, and Sawtooth oak were planted after Gwynedd become a wildlife preserve. The understanding of invasive species impacts were not as well understood and fortunately none of these species have proven to be particularly invasive so far.

Many non-native species perform well at the edge of grassy trails. These include Ground ivy and Common yarrow. Neither has had much success moving into the middle of grasslands, but do well at the edges. Likewise, many species do well at the edge of forest habitats, such as Japanese stiltgrass, Autumn olive, Tree-of-heaven, Sweet cherries, and many more. It is important that Gwynedd Wildlife Preserve not have too few trails, as having trails encourages visitors to use them rather than walk through (and on) the wildlife. However, sometimes trails seem redundant. For example, there are mowed trails in Tunnel Woods that do not appear on the map. Some forested trails are wide enough that they will never be shaded. To reduce the impact, some not used for management vehicles could be narrowed with tree tubes or even removed completely (also with tree tubes and native shrubs).

The Betz memorial garden has a significant number of non-native plants. Fortunately, except for the daffodils, they do not appear to be a problem in spreading and invading other areas. This garden, however, may be expanded upon using native ornamentals. Signage can be used to explain to visitors the benefits of planting these natives in their own yards. This will help with prevention of invasions from the local community. Some funding may even be available from local native-specific nurseries that want to promote their products.

Proper deer management is integral to preventing invasive species spreads. That has already been covered in the section on deer management, so it will not be re-explained in detail.

Gwynedd Wildlife Preserve is not surrounded only by suburban homes, but actually has forested lands owned by the Wissahickon Valley Watershed Association (WVWA) as well as Upper Gwynedd Township. Management within Gwynedd can be supplemented with Memorandums of Understanding with the other sites. Furthermore, efforts can be coordinated. For instance, most Callery pear trees at Gwynedd have been flagged for removal. However, the WVWA has many Callery pears on its site, despite it being significantly smaller. Removal of the trees at Gwynedd will help, but the birds will transport seeds right back into Gwynedd. Thus discussion and cooperation will help. This was also discussed in more detail in a previous section.

V. Controlling Non-Native Plants at Gwynedd

Introduction

Invasive species issues are well-known and there are many organizations that work to help mitigate the problem by producing information on each species including their life cycles, impacts, and control methods. However, no list is exhaustive. Thus, in order to do research on each species, these "fact sheets" promoted by organizations such as the US Forest Service, the National Parks Service, Morris Arboretum of the University of Pennsylvania, and others were searched for, and even international websites such as the Global Invasive Species Database were consulted. While these fact sheets were informative, they often referred to each other rather than outside scientific sources. For instance, in a fact sheet on Dame's rocket (*Hesperis matronalis*), a US Forest Service fact sheet had four other fact sheets in its citations (US Forest Service). Thus, they were a bit lacking in definitively scholarly work. To look more in-depth, searches were also done on scholarly articles which proved fruitful, sometimes noting biological control or more specific methods that were missing from the giant lists of species.

One more problem is that while many invasive species are well-known, some are not heavily studied. A literature review of Norway maple (Acer platanoides) brings up an extensive list of scientific articles regarding its biology, invasions, and management. Other species have little to no literature produced. Thus, sometimes there is a difference in how much data is produced for this report between different species.

Furthermore, different sources often gave slightly different descriptions of species life cycles or morphologies. Most were minor, but some were not. For instance, Uva et al. (1997) states that Ailanthus altissima gets to be 18 meters tall while Schall and Davis 2009 state that it grows to be 27 meters (Uva et al. 1997; Schall and Davis 2009). Therefore, regarding physical descriptions, the authoritative *Plants of Pennsylvania* by Ann Rhoads and Timothy Block was cited for each. As a result, the height of 25 meters for Ailanthus altissima from Plants of Pennsylvania is the one being used. Also, as flowering times often differed from one source to another, Plants of Pennsylvania was also used for this. Hopefully if there is a bias in this source, the bias is towards the sizes and flowering times of Pennsylvania flora. Also, it provides consistency in the terminology describing the morphology of each species. The citation for this source is once below rather than being repeated for each plant.

During a literature review of these invasives, some were found to have a history of being promoted and planted. In fact, sometimes invasives are still found to be promoted by the government. For instance, a USDA Natural Resources Conservation Service pamphlet explains how to cultivate Amur maples (*Acer ginnala*) (USDA NRCS).

Regarding control methods, sometimes no information was found regarding physical or chemical control. However, despite this it was assumed herbicides are still effective at controlling the species. When information was found, it was cited, but often without any real specifics. However, some species have species-specific issues or methods that will be discussed in individual sections. When control methods were provided, those that were provided were cited, though many times other methods would also work. For instance, if one plant has a reference to it regarding cut stump, but not hack and squirt, the hack and squirt will likely still work.

Trees

Acer ginnala/Amur Maple:

Amur maple foliage (Photo: Wikipedia)

> "Shrub or small tree; leaves 3-lobed, the middle lobe much longer than the lateral ones; flowers yellowish-white; inflorescence a long-peduncled panicle; samaras 2-3 cm long, the wings nearly parallel; cultivated and occasionally escaped; flr. Late May-Jun; native to Asia" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Amur maple (*Acer Ginnala*) is a small ornamental tree with fragrant flowers that is native to Central and East Asia (ISSG 2005).

The tree can grow from 4.5 to 6 meters in height. It prefers moist, but well-drained soils. However, it is drought tolerant as well as salt tolerant, cold tolerant, and will grow in a variety of soil types (Acer ginnala 2005). The Amur maple flowers in late May to June (Rhoads and Block 2007).

Impact:

Amur maple is a problematic invasive because it effectively pushes out native species. It tolerates partial shade, so it can grow under native trees that cannot withstand the shade it produces. Furthermore, it produces allelochemicals that inhibit the growth of other plants. Although an ornamental, it is now found in agricultural areas, natural forests, disturbed areas, and urban areas (ISSG 2005).

Management Options:

Physical

When controlling Amur maple through mechanical methods, it is important to keep in mind that it tolerates heavy pruning, so it must be cut low to the ground. Prescribed burning will not eradicate it.

Chemical

For chemical control, cut stump has been recommended (ISSG 2005).

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Acer ginnala (tree)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=1134&fr=1&sts=sss&lang=EN

Wikipedia. "Acer Ginala." Retrieved from http://en.wikipedia.org/wiki/Acer_ginnala

Acer platanoides/Norway Maple:

Norway maple foliage (Photo: Wikipedia)

> "Large tree with broadly spreading crown; leaves with 5-7 acuminate lobes and a few large teeth; flowers yellow, petals present; inflorescence a many-flowered, erect, glabrous corymb; samaras 3.5-4.5 cm long, spreading at nearly 180 degrees; cultivated and frequently escaped throughout; flr. Apr-early May; native to Europe; UPL." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Norway Maple (*Acer platanoides*) is the most widely distributed native maple in Europe. It first came to North America when John Bartram ordered seeds from an Englishman in about 1762. A second introduction occurred in about 1784 when William Hamilton brought seeds in. By 1792, popularity had risen enough to catch the eye of George Washington who bought two Norway maples from Bartram. Other early introductions appear to have come from France, Belgium, and Germany with conflicting reports about introductions from southern Europe. Thus, there is likely high genetic diversity in Norway maples in North America. As the Norway maple grows fast and has an attractive form, it became a popular street tree, especially after the demise of the American elm after the Dutch Elm disease came through. As of 1990, there were 89 cultivars (Nowak and Rowan 1990). The Norway maple flowers April to early May (Rhoads and Block 2007).

The Norway maple is a broad tree up to 28 meters tall and produces a dense shade. The leaves produce a distinctive white sap that comes out when the petioles are broken. The tree can handle a variety of soil types, including slightly alkaline (ISSG 2005).

Impact:

Compared to native species of maple, the Norway maple has a distinct competitive advantage. As they are shade-tolerant, but produce heavy shade, they do well as seedlings under native sugar maples (*Acer saccharum*), but sugar maples do not fare well underneath Norway maples. Diversity beneath Norway maples is less than under sugar maples because many species cannot handle the heavier shade (Martin 1999). The canopies may block out 95% of the photosynthetically active radiation. The consequent lack of vegetation beneath their canopies decreases ground cover and thus

increases erosion. On the other hand, some invasives that handle deep shade do quite well in these conditions (ISSG 2005).

In general, it has been found that in-tact forests may decrease the rate of invasion by Norway maples, but they are still highly susceptible and will eventually be overtaken. Along with a lack of disturbance, acidic soil may also slow down the invader, but neither stop it (Martin and Marks 2006).

For example, in the Drew University Forest Preserve, the native dominant species were American Beech, Oak, and Sugar Maple. Norway maple arrived by 1915 and by 1993, was the second most dominant canopy tree and also had the most density in seedlings and saplings (Webb and Kalafus 1993).

Control:

Physical

Mechanical methods of control include removing the overstory, which prevents new seeds (ISSG 2005). Girdling the tree by cutting through the bark and the growing layer all around the trunk can be effective when done in the spring (US Forest Service 2004). Care must be taken as many times, removal of Norway maple involves removing large amounts of biomass, which may open up space for new invasives. Also, there will likely be many seedlings already and more to come, so they must be removed as well (ISSG 2005).

Chemical

Chemical methods of control will likely be effective and are recommended (US Forest Service 2004).

Biological

Rhytisma acerinum, a European fungus that consumes Norway maple has found its way into North America. It is the only significant defoliator of the tree and so far occurs mostly in Canada and Upstate New York (Adams et al. 2009). It is related to a native fungus that causes tar spots on Red and Silver Maples, but differs greatly (Hudler et al. 1987).

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Acer platanoides (tree)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=979&fr=1&sts=sss&lang=EN

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United States Forest Service Northeast Region. (2004). "Norway Maple." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/norway-maple.pdf

Webb, S. L., & Kaunzinger, C. K. (1993). Biological invasion of the Drew University (New Jersey) forest preserve by Norway maple (Acer platanoides L.). *Bulletin of the Torrey Botanical Club*, 343-349.

Wikipedia. "Acer platanoides." Retrieved from http://en.wikipedia.org/wiki/Acer_platanoides

Ailanthus altissima/Tree of Heaven:

Tree-of-heaven in leaf (Photo: Wikipedia)

> "Tree to 25 m tall with coarse twigs and odd-pinnate leaves to 1 m long; leaflets 11-41, with one or more glandular teeth near the base; dioecious; inflorescences terminal, 1-2 dm; flowers 5 mm wide, greenish, malodorous; samaras winged at both ends, produced in large, conspicuous, reddish clusters; widely naturalized in disturbed woods, roadsides, fencerows, vacant lots, and railroad rights-of-way; flr. Jun-early Jul, frt. Aug-winter; native to Asia" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The invasive Tree-of-heaven (*Ailanthus altissima*) is native to China, but has existed in the United States for hundreds of years. First introduced from China into England by a missionary who thought it was a Japanese varnish tree, the Tree-of-heaven was then was soon introduced to the U.S. either in the late 18th century (Burch and Zedaker 2003), or as early as 1751 (Uva et al. 1997). It arrived first to the east coast of the U.S. as an ornamental and was later brought to the West coast by Chinese immigrants who likely desired its traditional medicinal uses (Burch and Zedaker 2003).

Interesting because of its heavy use as an ornamental, the Tree-of-heaven is a particularly obnoxious-smelling tree (Schall and Davis 2009a), which some describe as popcorn- or peanut butter-like (Uva et al. 1997). Almost every part of the tree, including the flowers, leaves, and wood, smell bad (Schall and Davis 2009a).

The Tree-of-heaven grows up to a height of 25 meters (Rhoads and Block 2007), at a rate of 1-1.5 meters per year. It flowers in June and July and fruits from August to the winter (Rhoads and Block 2007). A single plant may produce over 300,000 seeds when only 12 years old (Schall and Davis 2009a). Seeds have a survivorship of almost 2% and seedlings may reach 1-2 meters their first growing season (Meloche and Murphy 2006). Aside from seed dispersal, Tree-of-heaven roots may sprout (Schall and Davis 2009a). This can be a problem when cutting it down, as suckers may grow as far away as 3.5 meters from the stem (Uva et al. 1997).

Impact:

The Tree-of-Heaven is an invasive species in North America that inhabits disturbed areas as a successional species. It can survive in a variety of areas with different temperatures, humidity, light, moisture, and soil compaction and is resistant to ice damage, herbivory, seed predation, and pollution (Meloche and Murphy 2006). The plant is hardy and can withstand harsh urban conditions like growing in the cracks of cement and rubble (Uva et al. 1997). It is, however, shade intolerant (Miller 1990). With shallow roots that spread wide, this helps it invade locally as the seeds help it invade broadly. It can tolerate a wide range of sites, including those with poor soil and stony conditions. Once established, the plant will continue to produce a pure stand, pushing out other species (Burch and Zedaker 2003). Thus, it is often found naturalized in disturbed woods, roadsides, fencerows, vacant lots, and railroad rights-of-way (Rhoads and Block 2007) as well as fields, roadsides, fencerows, woodland edges and forest openings (Swearingen and Pannill 2009). It is so invasive that a survey of interstate highways in southwestern Virginia found Ailanthus present in 30% of the mileage (Burch and Zedaker 2003).

Furthermore, compared to a native successional species which enrich the soil, tree-of-heaven makes the soil relatively toxic, preventing succession from progressing (Call and Nilsen 2005). Tree-of-heaven produces several quassinoids which have phytotoxic allelopathic properties that are toxic to over 35 broadleaved and 34 coniferous species. This also helps it outcompete native plants as an early successional (Schall and Davis 2009). Its roots are also aggressive, able to penetrate the roots of other species and steal resources (Call and Nilsen 2005).

Management:

Physical

Management options include pulling or digging up young seedlings, preferably when the soil is moist. However, one must be careful to remove the entire plant, including the roots. Cutting in early summer can be especially good as that is when its root reserves are lowest (Swearingen and Pannill 2009).

Chemical

The most effective control of Tree-of-heaven is through herbicides, which can be foliar, basal bark, applied to cut stumps, or even hack-and-squirt. Basal bark works well during early spring, summer, and late winter (Swearingen and Pannill 2009).

When attempting to manage Tree-of-heaven in Rondeau Provincial Park in Ontario, Canada, Meloche and Murphy (2006) used a variety of methods to test for the most appropriate management system. They compared hand-pulling and mulching, cut stump, and glyphosate applications. It was found that cut stump and glyphosate application combined was the most effective. Cut stumps alone actually made the situation worse, but adding the glyphosate improved the situation. Using the EZJect Capsule Injection System with glyphosate was effective as well, however it is more expensive in capital costs (Meloche and Murphy 2006).

Biological

There may be potential for a new biological control of Ailanthus. After observing over 8,000 canopy tree-of-heaven trees die in south-central Pennsylvania from 2002 to 2008, Schall and Davis

(2009a) set out to determine the cause. Fungi *Verticillium albo-atrum* and *Verticillium dahlia* were both isolated from diseased tree-of-heaven. After studying the effects of each one, it was determined that while *V. dahlia* did infect the plants and cause damage, it was *V. albo-atrum* that was causing the most damage by far. Tree-of-heaven seedlings infected with *V. albo-atrum* died within 3 months, but those infected with V. dahlia had an 84% survivorship after 1 year (Schall and Davis 2009a).

When studying the impacts of *V. albo-atrum*, Schall and Davis further found that it had little impact in associated trees in Pennsylvania. Innoculation with V. albo-atrum had no impacts on chestnut oak (*Quercus montana*), northern red oak (*Quercus rubra*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and yellow-poplar (*Liriodendron tulipifera*) seedlings or canopy trees. Other species growing next to infected tree-of-heaven plants showed no effects. The only impacts found on other species were in understory striped maple (*Acer pensylvanicum*) saplings. When inoculated, they, like the tree-of-heaven seedlings and canopy trees, had 100% mortality. However, in infected stands, only 1% of striped maple saplings showed any associated wilt. Thus, there may be a lot of potential to use *V. albo-atrum* as a biological control agent, but more research needs to be done. There have been reports of wilt in yellow-poplar seedlings and the fungus can last for years in the soil (Schall and Davis 2009b).

Another study published in 2011 found that inoculation could impact a variety of other trees, but in naturally occurring stands, only devil's walkingstick (22% mortality) and striped maple (less than 4% mortality) were impacted. Six species had greater than 10% mortality when inoculated: tree-of-heaven, blackberry, poison-ivy, redbud, striped maple, and sumac (Kasson and Davis 2011).

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Schall, M. J., & Davis, D. D. (2009b). Verticillium Wilt of Ailanthus Altissima: Susceptibility of Associated Tree Species. *Plant Disease*. Vol. 93, No. 11, pp. 1158-1162.

Swearingen, Jil M. and Pannill, Phillip D. (2009). "Tree-of-Heaven." Plant Working Group of the Plant Conservation Alliance. Retrieved from http://www.nps.gov/plants/alien/fact/aial1.htm

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Halesia carolina/Silverbell-tree/Carolina Silverbell:

Carolina silverbell tree and flowers at Gwynedd Wildlife Preserve, May 11, 2014 (Photos: Nathan Hartshorne)

> "Tree to 15 m tall; leaves 10-15 cm, oblong or elliptic, acuminate, serrulate; flowers in small clusters on slender pedicels; corolla white, bell-shaped, 2-2.5 cm broad; fruit 2.5-3.5 cm, with 4 wings; cultivated and occasionally naturalized in disturbed woods or edges; flr. May; native from WV south." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Silverbell tree (*Halesia carolina*) is actually native to North America in the southeast US, but is a non-native to Pennsylvania (Rhoads and Block 2007). It is actually a complex with poorly defined taxonomy where intergradations are so broad that there may be no reason for taxonomic differentiation beyond "Halesia carolina" (Fritsch and Lucas 2000). It is a tree, but may have a multi-stemmed trunk as a low shrub. It generally reaches 20-40 feet high and 15-30 feet diameter, but some have been known to be 100 feet tall. It is shade-tolerant. It prefers moist, well-drained soils that are slightly acidic and organically rich. It blooms March to May, depending on the local climate (Sluder 1990).

Carolina silverbell can easily grow from roots and stumps are known to sprout repeatedly. It is shade-tolerant. It prefers gaps made by fallen trees. It competes well with other species. It lacks serious pests (Sluder 1990).

Impact:

It is found in disturbed woods or wood edges (Rhoads and Block 2007). It is shade-tolerant, but an understory tree (Sluder 1990). Therefore, it is less likely to have a large impact on the overstory like Norway maple (*Acer platanoides*), but can still shade-out seedlings.

Carolina silverbell has a strong arsenal of reproduction. It produces large numbers of seeds, but fortunately many of them are sterile. However, aside from seeds and root propagation, it can air-layer whereby branches root into new trees (Sluder 1990).

Control:

Physical

Growth from the roots and cut branches must be watched when removing mechanically.

Chemical

Chemical herbicides will likely provide control over the species.

Biological

Biological control is not likely to be effective. Despite being nearly native, there are no serious pests or diseases for this species (Sluder 1990).

Fritsch, Peter W. and Lucas, Shannon D. (2000). Clinal Variation in the Halesia Carolina Complex (Styracaceae). *Systemtiatic Botany*. American Society of Plant Taxonomists. Vol. 25, No. 2, pp. 197-210.

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Wikipedia. "Halesia Carolina." Retrieved from http://en.wikipedia.org/wiki/Halesia_carolina

Larix kaempferi/Japanese larch:

Japanese larch leaves (Photo: Wikipedia)

> "Tree to 20 m tall with narrowly conic crown when young; needles light yellow-green to blue-green, keeled beneath with faint white stomatal bands; cones 2-3 cm; cone scales reflexed at the margin; forest plantations; scattered; native to Japan" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Japanese larch (*Larix kaempferi*) is an invasive needle deciduous conifer native to Japan. It generally grows reaching 20 meters tall (Rhoads and Block 2007), but it may reach as high as 45 meters. It prefers the full sun as well as moist, acidic, and well-drained soils. It cannot handle full-shade, dry soil, and city pollution ("Laerix Kaempferi").

Impact:

It is found in forest plantations (Rhoads and Block 2007)

Management:

Physical

Mechanical removal will likely manage this species.

Chemical

Chemical methods of control will likely be effective for this species.

Biological

Japanese larch is not free from pests, which may explain why it is not especially invasive. Potential insect pests include larch case-bearer, larch sawfly, larch looper, tussock moth, Japanese beetle and woolly aphids. Potential disease problems include needle cast, needle rust, and canker ("Laerix Kaempferi").

"Laerix Kaempferi." Retrieved from the Missouri Botanical Garden Plant Finder. Accessed 04/01/2014. Retrieved from: http://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=d882

Wikipedia. "Larix Kaempferi." Retrieved from http://en.wikipedia.org/wiki/Larix_kaempferi

Malus spp./Crabapple:

Crabapples at Gwynedd Wildlife Preserve, May 5th, 2014 (Photo: Nathan Hartshorne)

> "Deciduous trees to 10-15 m tall; leaves alternate, simple or somewhat lobed, serrate; flowers in umbel-like clusters on short, lateral branch spurs that sometimes end in thorns; hypanthium well-developed; sepals and petals 5; stamens numerous; ovary inferior, 3-5 locular; fruit a pome. Hybridization and the presence of numerous horticultural cultivars can make identification difficult." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Most crabapple (*Malus*) species encountered are ornamentals from China, rather than native from North America (Tallamy 2009). It is very difficult to tell one species from another as there are many cultivars and they hybridize very easily (Rhoads and Block 2007).

Impact:

According to Douglas Tallamy, a professor of entomology at the University of Delaware, and author of books on native plants, the leaf chemistry of the non-native crabapples are so similar to the natives, that, at least for *Lepidoptera*, there is no difference. Furthermore, the one indigenous (to the northeast) and the various non-native crabapples hybridize very easily. In the northeastern US, there are 311 species of *Lepidoptera* that feed on crabapples (Tallamy 2009).

At Gwynedd Wildlife Preserve, crabapples infest fields and are one of the most common woody plants at the preserve. They push out native grasses and require extra management to rid them.

Management:

Physical

Hand-pulling seedlings will likely be effective. Cutting, however, is not likely to be very effective. Mowed areas of Gwynedd have high numbers of crabapple that survives easily. Though a literature search proved fruitless, they also appear to sprout from the roots.

Chemical

Chemical herbicides, especially cut stump applications, will likely provide effective control over this genus.

Tallamy, Douglas. (2009). Bringing Nature Home: How You Can Sustain Wildlife With Native Plants. Timber Press.

Picea abies/Norway spruce:

Row of Norway spruce at Gwynedd Wildlife Preserve, April 27th, 2014 (Photo: Nathan Hartshorne)

> "Evergreen tree to 30 m tall with narrow, conical crown; secondary branches drooping in mature specimens; needles dark green; cones 12-16 cm long, cylindrical; cone scales widest near the middle, margins toothed; forest plantations and other cultivated sites throughout; native to Europe." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Norway spruce (*Picea abies*) is native to northern Europe and is now found in many places throughout the US and Canada (Nebraska Forest Service). It generally reaches 30 meters (Rhoads and Block 2007) and is fast-growing. The tallest in the US is 108 feet, though it can grow much taller in its native range. It is tolerant of a variety of soil types as well, but prefers moist, cool areas. However, many die from too much water (Nebraska Forest Service). It is also shade-tolerant, sometimes staying dwarfed until a forest opening appears (Sullivan 1994).

Norway spruce does not reproduce sexually until 30-40 years old. Cones will open in May to June and seeds ripen in late fall. It does not reproduce vegetatively through roots, however it can reproduce through layering (Sullivan 1994).

Impact:

It is found in forest plantations and other cultivated sites throughout (Rhoads and Block 2007)

Management:

Physical

Mechanical methods of control will likely be effective on Norway spruce. However, as it may reproduce by layering, care must be given to broken branches and stems (Sullivan 1994).

Chemical

Chemical herbicides should provide control over this species.

Biological

Only a spider mite, Western spruce budworm, and Mountain pine beetle feed on Norway spruce, so there is no current biological control (Nebraska Forest Service and Sullivan 1994).

Nebraska Forest Service. "Norway Spruce (Picea abies)." University of Nebraska, Lincoln. Retrieved from http://nfs.unl.edu/CommunityForestry/Trees/NorwaySpruce.pdf

Sullivan, Janet. 1994. Picea abies. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/plants/tree/picabi/all.html

Picea glauca/White spruce:

White Spruce (Photo: Wikipedia)

> "Evergreen tree to 30 m tall with broadly conic crown; needles blue-green; cones 2.5-6 cm; cone scales fan-shaped, margin entire; forest plantations; scattered; native farther north, FACU." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

White spruce (Picea glauca) is a native plant of North America, though its natural southern range only barely reaches New York. Thus, it is a non-native to Pennsylvania. It can grow in a variety of conditions and soils, especially extreme places due to its far northern habitats. Vegetative reproduction is common, perhaps as an adaptation to climates not suited to sexual reproduction. It has an intermediate tolerance to shade. Rodents, birds, and insects feed on the seeds. There is a lot of variation within the entire range and trees on the southern limit grows the fastest (Nienstaedt and Zasada 1990). White spruce is often used to rehabilitate sites, such as those suffering from coal mines (Uchytil 1991).

Impact:

No impact of note has been found in a literature review.

Management:

Physical

Mechanical methods of control have to be careful of the species's ability to reproduce vegetatively.

Chemical

Chemical herbicides will likely provide effective control.

Biological

There are many diseases and insects that infect the tree (Nienstaedt and Zasada 1990). Many birds and mammals consume the seeds (Uchytil 1991). Since this is a native plant with many pests, it is not an invasive free of predation. It is also a contributing member of the ecosystem.

Nienstaedt, Hans and Zasada, John C. (1990). " Picea Glauca." Burns, Russell M. and Honkala, Barbara H. Silvics of North America. Vol. 1: Conifers. Agriculture handbook 654, USDA, Forest Service. http://www.na.fs.fed.us/pubs/silvics_manual/Volume_1/picea/glauca.htm

Uchytil, Ronald J. 1991. Picea glauca. In: Fire Effects Information System.
U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/

Wikipedia. "Picea Glauca." Retrieved from http://en.wikipedia.org/wiki/Picea_glauca

Plantanus x Acerifolia/London Planetree:

London planetree trunk, leaf, and fruiting head (Photos: Wikipedia)

> "Very similar to the native sycamore but with blotchy, yellowish-gray, exfoliating bark, and multiple fruiting heads per peduncle; frequently planted in urban areas and occasionally escaped." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The London planetree is actually a hybrid tree. It is a cross between the American sycamore (*Platanus occidentalis*) and the Oriental planetree (*Platanus orientalis*). The hybrid was developed as early as the 1640s in Europe and became a very popular urban tree. The popularity soon spread to the US where it is still common (Missouri Botanical Garden). Although there are descriptions of how to distinguish the American sycamore and the London planetree, they are so similar and hybridize so easily, that the only real way to tell is to see how many fruiting heads are on each peduncle. Two for the non-native and one for the native (Timothy Block, *personal communication*).

Impact:

No impact was found in a literature survey. It is not a particularly invasive non-native. However, some conclusions can be drawn. There is a variety of resistance to certain fungal diseases depending on the level of hybridization (Missouri Botanical Garden). Thus, a plant's contribution to the ecosystem may vary the same way.

Management:

Physical

Physical methods such as cutting the tree or pulling seedling should be effective.

Chemical

Herbicides with cut stump, hack and squirt, or basal bark methods should be effective.

Biological

The fungal disease sycamore anthracnose affects London planetrees to varying extents, depending on the hybride. Some cultivars may be resistant. There is also the cankerstain, which sometimes kills entire plants. Other fungal issues are canker, leaf spot, and powdery mildew. Borders,

scale insects, Japanese beetles, caterpillars, and mites all feed on London planetrees (Missouri Botanical Garden).

Missouri Botanical Garden. "Platanus x Acerifolia." Plant Finder. Retrieved from http://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=a892

Wikipedia. "Platanus x Acerifolia." Retrieved from http://en.wikipedia.org/wiki/Platanus_%C3%97_acerifolia

Prunus avium/Sweet cherry:

Sweet cherry in bloom (Photo: Wikipedia)

> "Tree to 20 m tall with spreading, ashy-gray branches; leaves to 1.5 dm long, abruptly acuminate, pubescent on the nerves beneath, coarsely and double-serrate; flowers white, 2.5-3.5 cm broad; fruit dark reddish-purple, 2-2.5 cm in diameter, sweet; common in forests, wooded edges, and fencerows; Flowers May with the leaves, fruits late June to July. Native to Eurasia." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Sweet cherry (*Prunus avium*), native to Eurasia, has been present in North America since early settlers arrived from Europe. By 1671, it was commonly grown in colonial America(Mack and Erneberg 2002). Sweet cherry prefers soils that are not acid rich. It can grow in part shade and full sun. They will reproduce vegetatively as well as by seeds (Missouri Botanical Garden). Dispersal is generally performed by birds and squirrels that consume the fruit. This is apparent enough that the name "avium" is Latin for "bird" (Missouri Botanical Garden)

Impact:

Sweet cherries are often found in hedgerows and woods. They will easily shade-out smaller plants, suppressing the ecosystem (Missouri Botanical Garden). Fortunately, based on surveys in 1938 and 1999, although increasing in the number of forests it is found in, this species does not appear to be particularly invasive in forest systems (Hunter and Mattice 2002).

Management:

Physical

Manual control includes pulling out of the ground. However, larger trees need to have the roots removed as well (Missouri Botanical Garden).

Chemical

Chemical control can be effective on this invasive (Missouri Botanical Garden).

Biological

There are a lot of pests to the Sweet cherry, perhaps due to its close native relatives. Diseases include bacterial canker, rots, scab, crown gall and powdery mildew, while insects such as aphids, caterpillars, scale and flies also feed on it (Missouri Botanical Garden).

Hunter, J. C., & Mattice, J. A. (2002). The spread of woody exotics into the forests of a northeastern landscape, 1938-1999. *Journal of the Torrey Botanical Society*, 220-227.

Mack, R. N., & Erneberg, M. (2002). The United States naturalized flora: largely the product of deliberate introductions. *Annals of the Missouri Botanical Garden*, 176-189.

Missouri Botanical Garden. "Prunus Avium." Plant Finder. Retrieved from http://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=l860

Wikipedia. "Prunus Avium." Retrieved from http://en.wikipedia.org/wiki/Prunus_avium

Pyrus calleryana/Callery Pear:

Callery pear at Gwynedd (left), field of Callery pears bordering Gwynedd (right), April 25, 2014 (Photos: Nathan Hartshorne)

> "Leaves ovate, glossy, and somewhat leathery, glabrous; margins crenate; flowers about 2 cm wide, petals white, frequently cultivated, especially as a street tree, and escaped to roadsides, old fields, and disturbed woods; flr. late Mar-Apr, before the leaves; native to China." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Callery pear (*Pyrus calleryana*) is an invasive species from East Asia. It was first brought to the US by the USDA in the early 1900s with the hopes that it could be used as a rootstock to help the suffering American pear industry that had 86% losses due to a bacterial pathogen, the Fire Blight. The very common and popular cultivar, "Bradford," was brought from China in 1919. Although initially used for the pear industry, Callery pears were first tested as ornamentals in 1952 and were available for sale in 1962. By 1964, the pear had escaped and naturalized. Since then it has become a major invader of North America (Culley and Hardiman 2007).

Callery pears can grow rapidly and start flowering by age 3. Fruit develops slowly and matures in August to October. Fruits are commonly eaten by birds and dispersed by them. Seeds can become dormant and generate a seed bank. This species is one of first woody species to leaf out in spring and one of the last to retain leaves in the fall (Culley and Hardiman 2007).

As the ornamentals are clonal cultivars, and callery pears are unable to self-fertilize, there would be prevention from invasion built into their genes. However, they are such popular ornamentals that they are planted commonly enough that crossing is common. Furthermore, as they came from different areas in China, they can have a large gene pool (Culley and Hardiman 2007).

Impact:

Callery pears prefer full-sun, but create dense thickets, helping to prevent successional stages of growth. Although they provide food for birds, the invasive European starling is one the main consumer of it (Culley and Hardiman 2007).

Management:

Physical

Mechanical methods include complete removal of the tree and this is the most effective. Mowing seedlings does not work because they will resprout. Seedlings can be easily pulled if the soil is moist, though care must be taken as they may resprout from roots. The same goes for cut trees, so mowing seedlings also does not work. Trees can also be girdled 15 cm above the ground during spring and summer (Culley and Hardiman 2007).

Chemical

Glyphosate or other herbicides must be added to cut stumps to prevent regrowth (Culley and Hardiman 2007).

Biological

Biological control is not currently available. After all, the plant was brought to the US as a result of its hardiness and resistance to pests and disease (Culley and Hardiman 2007).

Culley, T. M. and Hardiman, N. A. (2007). The beginning of a new invasive plant: a history of the ornamental Callery pear in the United States. *BioScience*. Vol. 57, No. 11, pp. 956-964.

Quercus acutissima/Sawtooth oak:

(Left) Sawtooth oak (Photo: Wikipedia). (Right) Sawtooth oak leaf and acorn at Gwynedd Wildlife Preserve, April 27, 2014 (Photo: Nathan Hartshorne)

> "Tree to 20 m tall; mature twigs finely pubescent to glabrate; buds slender, sharp-pointed, hairy; leaves lanceolate, with coarse sharp teeth bearing long bristles; acorn cup heavily fringed; occasionally escaped from cultivation to fallow fields, also planted by the Pennsylvania Game Commission; native to Asia." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Native to East Asia, the Sawtooth oak (*Quercus acutissima*) was brought to the US in 1862. It traditionally has been used in landscaping for areas like parking lots, roadsides, and highway medians because it is tolerant of compacted soil with poor drainage as well as air pollution. However, it is becoming more common as it is being planted more for restoration projects. It also has some aesthetic appeal. Because of its widespread planting, it is considered "a potential or emerging threat to the mid-Atlantic region" (Stokes 2012). It has invaded several states in the eastern US as far north as Pennsylvania. It is often found in edge habitats as well as open meadows (Stokes 2012).

Flowers are produced in mid spring and acorns are produced in summer and fall every other year (Stokes 2012).

Impact:

The impacts of Sawtooth oak are not clear. It does produce acorns after only 5 years and produces them earlier than native oaks, so these features may enable the plant to outcompete native oaks. Furthermore, because the acorns it produces are less nutritious than native oaks, it does not help the wildlife that consumes acorns. Production of copious amounts of acorns can help it reproduce quickly (Stokes 2012).

Management:

Physical

Sawtooth oak is fairly easy to control. Seedlings can be mowed or hand-pulled. Larger trees can be girdled (Stokes 2012).

Chemical

Seedlings can also be treated with foliar glyphosate. Large trees can be treated cut-stump and hack and squirt methods (Stokes 2012).

Stokes, Hannah. (2012). "Sawtooth Oak." Ed. Frey, Mark. Weed Alert. Exotic Plant Management Team. National Capitol Region. National Park Service. US Department of the Interior. Retrieved from http://www.nps.gov/cue/epmt/products/Quercus%20acutissima%202012%20NCREPMT.pdf

Wikipedia. "Quercus Acutissima." Retrieved from http://en.wikipedia.org/wiki/Quercus_acutissima

Salix fragilis/Crack willow:

Crack willow (Photo: Wikipedia)

> "Tree to 20 m tall with yellow-brown, hairy to glabrescent branchlets; stipules leaf-like or rudimentary; petioles glandular-dotted or lobed; leaf blade lanceolate to very narrowly elliptic, lower surface very sparsely silky to glabrescent, upper surface shiny or highly glossy, base obtuse to rounded, margin coarsely serrate, tip acuminate to caudate; catkins on short, leafy branchlets; floral bracts tawny, the pistillate ones deciduous after flowering; overies glabrous; infrequently cultivated and rarely escaping to roadsides and woods edges; native to Europe; FAC+" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Crack willow (*Salix fragilis*) is an invasive that has spread to nearly all US states north of Oklahoma. It flowers in early spring and fruits in the late spring. Seeds will germinate upon dispersal. It is shade intolerant, preferring wet areas and is found along streams, marshes, fens, and in wet woods as well as disturbed areas with wet soils. It is tolerant of inundation. It prefers soils that are acidic or neutral and can grow in sandy, loamy, and clay-rich conditions. It can also grow vegetatively through roots or even broken twigs that may be transported long distances.

Impact:

The crack willow can form monocultures lacking in other vegetation. Called, the crack willow due to its breaking under strong winds or ice, it reproduces vegetatively from breaking, thus it can expand easily as twigs may root (US Forest Service 2006).

Roots can enter a stream and alter the structure of the bed, altering hydrology, aeration, and the direction of flow (Department of the Environment 2003).

In a study in Western Australia, riparian areas invaded by Crack willow had fewer arthropod and bird species than those with native trees. Habitat structure was also less complex (Holland-Clift et al. 2011).

A similar study in New Zealand showed macroinvertebrate populations had significantly less density and biomass in areas invaded by Salix fragilis. It was suggested that a decrease in substrate surface as well as light (which decreased primary productivity) were contributing factors (Lester et al. 1994).

Crack willow can hybridize with both White willow (Salix alba) and Black willow (*Salix nigra*) (US Forest Service 2006). No White willow currently exists in the Gwynedd preserve, but it may in the future. Black willow does currently exist and that could be cause for concern. Aside from changing the ecology of the area, Salix hybrids, like many others, may have high genetic diversity, helping them to adapt to different conditions. The hybrid of Crack willows and White willows are tetraploidal. Crack willow itself is normally tetraploidal, but may also be diploid or even hexaploid (Barcaccia et al. 2003).

Management:

Physical

Mechanical methods may work for management, however, one has to be very careful not to leave behind large roots or even broken twigs as they may sprout. Thus, this method is not recommended (Department of the Environment 2003).

Chemical

Due to the resprouting, chemical methods are best. However, cut stump is not recommended due to the difficulty of removing the trees without breaking off twigs. Thus it is best to drill a hole in the tree and apply chemicals. It is recommended to drill holes below the branches, around the trunk, 20-30 mm into the trunk with 130 mm intervals. Holes should be drilled angled downwards in order to help prevent the herbicide from flowing out. It is also recommended to wait 12 months before removing the dead tree to ensure that it was, in fact, killed. Foliar spray is best only for small trees less than 2 m tall (Department of the Environment 2003).

Australian Government Department of the Environment. (2003). "Willow (Salix spp.)" Weed Management Guide. Retrieved from http://www.environment.gov.au/biodiversity/invasive/weeds/publications/guidelines/wons/pubs/salix.pdf

Barcaccia, G., Meneghetti, S., Albertini, E., Triest, L., & Lucchin, M. (2003). Linkage mapping in tetraploid willows: segregation of molecular markers and estimation of linkage phases support an allotetraploid structure for Salix alba× Salix fragilis interspecific hybrids. *Heredity*. Vol. 90, No. 2.

Holland-Clift, Sarah, O'Dowd, D. J., and Mac Nally, R. (2011). Impacts of an Invasive Willow (Salix× Rubens) on Riparian Bird Assemblages in South-Eastern Australia. *Austral Ecology*. Vol. 36, No. 5, pp. 511-520.

Lester, P. J., Mitchell, S. F., & Scott, D. (1994). Effects of Riparian Willow Trees (Salix Fragilis) on Macroinvertebrate Densities in Two Small Central Otago, New Zealand, Streams. *New Zealand Journal of Marine and Freshwater Research*. Vol. 28, No. 3, pp. 267-276.

United States Forest Service, Northeast Region. (2006). "Crack Willow." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/crack-willow.pdf

Wikipedia. "Salix Fragilis." http://en.wikipedia.org/wiki/Salix_fragilis

Shrubs

Berberis thunbergii/Japanese barberry:

Japanese barberry at Gwynedd Wildlife Preserve, April 20th, 2014 (Photos: Nathan Hartshorne)

> "Densely branched shrub to 2 m tall with simple spines; leaves 1-2 cm, obovate to spatulate with entire margins; flowers solitary or in small umbel-like clusters of 2-4 fruit to 1 cm, often persisting through the winter; cultivated and frequently naturalized in woods, old fields, roadsides, and hedgerows throughout; flr. Apr, frt. Aug-winter; native to Japan." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Japanese barberry (*Berberis thunbergii*) is a spiny shrub native to Japan. Russian botanist Carl Maximowicz discovered it in the mountains of Japan and sent seeds to St. Petersburg Botanical Gardens in 1864. From there it was introduced to the New York Botanical Garden in 1896 (ISSG 2005).

Japanese barberry is a small shrub, growing .6-.9 meters in height. It prefers wet lowlands, rocky dry roadsides, and waste areas. It is often found in forests, disturbed sites, and scrub-shrub habitats. It will grow in sandy, clay, or loamy soils with pH 3.7-6.2. Thus, it has a wide-range of areas it can grow in. However, it does not do as well in oak-dominated forests (ISSG 2005).

This invasive shrub turns green and leafs early in the spring before most other plants (ISSG 2005). It flowers in April and fruits from August to the winter (Rhoads and Block 2007).

Impact:

Japanese barberry is often found in woods, old fields, roadsides, and hedgerows (Rhoads and Block 2007) as well as wet lowlands, rocky dry roadsides, waste areas, disturbed sites, and scrub-shrub habitats (ISSG 2005).

Aside from growing earlier in the spring, the fact that deer do not like to eat Japanese barberry makes it more invasive. Also, branches will root when they touch the ground. Although it grows much better in full light, it can grow in less than 1% full sun and even fruit in 4% full sun. It also increases growth in areas with extra nitrogen (ISSG 2005).

Management:

Physical

Hoes or other mechanical methods as well as hand-pulling are effective at controlling it. Mowing can control it, but not eradicate it (ISSG 2005).

Chemical

Chemical control using herbicides such as glyphosate or triclopyr have been shown to be effective when sprayed on leaves. This is best done in early spring. Also, cutting stumps and applying the chemicals works (ISSG 2005).

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Berberis thunbergii (shrub)* Retrieved from the Global Invasive Species Database. Retrieved from http://www.issg.org/database/species/ecology.asp?si=592&fr=1&sts=sss&lang=EN

Elaeagnus umbellata/Autumn Olive:

Autumn olive invading Gwynedd Wildlife Preserve, May 4th, 2014 (left), May 20th, 2014 (right) (Photos: Nathan Hartshorne)

> "Deciduous shrub to 5 m tall, leaves becoming green and glabrescent above, silver-scaly beneath; flowers about 1.2 cm long, yellowish-white, scaly on the outside, fragrant; fruit subglobose to ovoid, 6-8 mm, red with scales; extensively naturalized in old fields, abandoned pastures, and other open ground; mostly S, a serious weed in some parts of the state; flr. Late May, frt. Sep—Nov; native to Asia."—*Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Autumn olive (*Elaeagnus umbellata*), a native to Asia, was introduced to the United States in the 1830s (Rhoads and Block 2011). It is highly invasive, but has long been promoted as a roadside and bank stabilizer, as wildlife food and cover, as a hedgerow and windbreak, as strip mine land reclamation, and as an ornamental. All this planting combined with its natural invasiveness has made it widespread in North America (Kessler 1990). It is very easy to confuse with Russian olive (*Elaeagnus angustifolia*) and literature reviews may run into problems as a result.

Autumn olive can produce fruit starting at 3-5 years. A mature plant can produce about 30 pounds of fruit per year, containing 3 pounds of seeds (about 66,000). The fruit are commonly eaten by animals, mostly birds, and dispersed (Munger 2003).

Autumn olive is tolerant of poor soils and a wide variety of pH and moisture. However, it prefers coarse-textured soils that are moderately-well to well-drained (Munger 2003).

Black walnut (*Juglans nigra*) are popular for their wood. In tests of different nursery trees, Autumn olive performed very well in promoting the growth of Black walnut. The two have been planted together for years (Schlesinger 1984).

Interestingly, Autumn olive may find new proponents in the food industry. As a health food, Autumn olive may find proponents as its fruit may have 18 times the lycopene as tomatoes and thus be a good cancer-fighter (Swain 2002). Furthermore, bee keepers find the plant particularly useful in part due to the early production of nectar for the bees (WVDA Apiary Program).

Impact:

It is often found in fields, gravel pits, early-successional forests, forest edges, rights-of-way, disturbed areas, and planted forests. It often displaces native plants and forms dense thickets (Munger 2003). It is also a shade-tolerant species that allows it to dominate an understory (Kessler 1990). However, some research suggests that it does poorly in full shade and prefers more open areas in a forest (Munger 2003).

Autumn olive impacts the soils of an ecosystem. First of all, it is nitrogen-fixing. Therefore, the soils will become more nitrogen rich than they were before (Kessler 1990). This is actually one reason why it is promoted as a nursery crop for Black walnut (Munger 203). However, the same property can also promote invasions by other nitrogen-loving species.

Management:

Physical

Mechanical methods of control are largely ineffective. Autumn olive is a difficult plant to kill that generally re-sprouts quickly when burned, mowed, or cut. Seedlings can be pulled out by their roots, but larger ones cannot (Munger 2003).

Chemical

In order to provide effective control, herbicides are required. Cut stump methods and basal bark have been shown to provide effective control. Foliar spray works as well, but 100% of cover is recommended, so it is best only on smaller plants. It may take several treatments of herbicides to kill plants. In one study where an area cleared of autumn olive showed new stems 3-4 years later, 11% were believed to have come from previously “killed” plants (Munger 2003).

Biological

Recently a disease has been found that have effects Autumn olive. A canker Tubercularia vulgaris has been found infecting many Autumn olives. It needs breakage to infect the plants, so is more common in those older than 3 years which sometimes suffer from breaking due to their heavy loads of fruit. Cankers are sometimes subsequently colonized by decay fungi. Entire stems often die as a result (Kessler 1990).

There are also diseases that have been infecting the closely-related Russian olive and may, as a result, also begin to impact Autumn olive. For Russian olive, *Phomposis eleagni*, a canker-causing fungus that appears to have been accidentally imported from Europe in the late 1960s to Canada. There have been reports of this being responsible for die-backs of Autumn olive (Arnold and Carter 1974). It will also kill stems and seedings (Stannard et al. 2002). Tubercularia ulmea is a disease that infects Siberian elm (*Ulmus pumila*), Russian-olive (*Elaeagnus angustifolia*), and honeylocust (*Gleditsia triacanthos*). It is believed to enter the plant through physical injury to the bark, lenticels, and leaf buds (Jackson and Stack 2002). This disease can girdle and kill stems and even deform or kill trees over time (Stannard et al. 2002). Due to the fact that it infects the native honeylocust, it may not be good for control of autumn olive. Testing would have to be done on both to determine the appropriateness of their use as biological control agents.

Arnold, R. H., & Carter, J. C. (1974). Fusicoccum Elaeagni, the Cause of a Canker and Dieback of Russian Olive Redescribed and Redisposed to the Genus Phomopsis. *Mycologia*. Vol. 66, No. 1, pp. 191-197.

Jackson, M. B., & Stack, R. W. (2002). Effects of Dicamba Herbicide on Tubercularia Ulmea Canker Development. *Journal of Arboriculture*. Vol. 28, No. 2, pp. 94-98.

Katz, G. L., & Shafroth, P. B. (2003). Biology, Ecology and Management of Elaeagnus Angustifolia L.(Russian olive) in Western North America. *Wetlands*. Vol. 23, No. 4, pp. 763-777.

Kessler, J. J. (1990). A Canker Disease of Autumn Olive caused by Tubercularia Vulgaris. *European Journal Of Forest Pathology*. Vol. 20, No. 3, pp. 148-153.

Munger, Gregory T. 2003. Elaeagnus umbellata. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Available: http://www.fs.fed.us/database/feis/

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Euonymus Alatus/Burning Bush:

(Top Right) Burning bush at Gwynedd Wildlife Preserve May 21st, 2014 and (Top Left) April 20, 2014 (Photo: Nathan Hartshorne).
(Bottom) Burning Bush in fall colors (Photo: Wikipedia)

"Deciduous shrub to 2.5 m tall with conspicuous corky wings on the twigs; leaves sessile or with very short petioles, elliptic to obovate, finely serrate, usually turning bright red in the autumn; flowers 4-merous, green; fruit purplish; aril orange; cultivated and frequently naturalized in woods and along stream banks, fencerows, and edges; mostly SE and SW; flowers Apr-June, fruit Sept-Oct; native to china and Japan." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Burning bush or Winged euonymus (*Euonymus alatus)* is shrub native to Asia introduced to the United States in about 1860 as an ornamental. It grows to about 4.6-6.1 meters in height (ISSG 2005).

While birds love the fruit (which it produces in quantity), deer do not eat the plant, helping it to both spread and not get killed. It is tolerant to full shade and survives in a variety of soils and pH levels (ISSG 2005).

Impact:

It impacts the local ecosystem by shading herbs and crowding out other shrubs. It is commonly found in agricultural areas, natural forests, planted forests, range/grasslands, scrub/shrublands, and urban areas (ISSG 2005).

Management:

Physical

For mechanical control, seedlings 2 feet tall can be hand-pulled, but larger plants have to be dug out.

Chemical

Chemical methods of control include cut stump and foliar spray. Early summer is recommended as best for foliar spray (ISSG 2005).

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Euonymus alata (shrub)* Retrieved from the Global Invasive Species Database. Retrieved from http://www.issg.org/database/species/ecology.asp?si=574& fr=1&sts=sss&lang=EN

Wikipedia. "Euonymous Alatus." Retrieved from http://en.wikipedia.org/wiki/Euonymus_alatus

Forsythia sp./Forsythia:

Forsythia (Photo: Wikipedia)

> Spreading deciduous shrubs with arching branches and numerous yellow, bell-shaped flowers appearing before the leaves; leaves simple, entire or toothed; petals united, corolla deeply 4-lobed; stamens 2, inserted on the corolla tube; fruit a 2-locular, many seeded capsule. Many forms are in cultivation based on the species below and their hybrid F. x intermedia Zabel." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Forsythia (*Forsythia spp.*) are native to China and are used as an ornamental (Rhoads and Block 2007). Little information exists except on how nice they are for gardens.

Impact:

No impact was noted in a literature review. Given the hedgerow of forsythia at Gwynedd has not become invasive, the impact is likely very small.

Management:

Physical

Hand-pulling seedlings or cutting down bushes will likely provide control.

Chemical

Chemical herbicides will likely be effective against this species.

Wikipedia. "Forsythia." Retrieved from http://en.wikipedia.org/wiki/Forsythia

Ligustrum obtusifolium/European privet:

European privet at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Deciduous shrub to 3 m tall with pubescent twigs; leaves elliptic to oblong-ovate, 2.5-5 cm, acute or obtuse, glabrous or pubescent only on the midrib beneath; panicle to 3.5 cm; calyx pubescent; corolla tube 2-3 times longer than the lobes, anthers reaching the middle of the corolla lobes; cultivated and frequently naturalized in disturbed woods, thickets, hedgerows, and old fields, mostly S; flowers June, fruits Sept-winter; native to Japan." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Privets are native to much of the world outside of the Americas. Since the 1700s, nine privet species (out of a total of about 40) from Europe, North Africa, East Asia, and Australia have been introduced to the US. They were brought in as ornamentals and retained their popularity as such (Maddox et al. 2010). Today, European privets are found scattered around the US (US Forest Service).

Privets generally produce a lot of seeds which are consumed and spread by birds and other animals. They are tolerant of a wide variety of conditions (Maddox et al. 2010).

Impact:

Privets in general are serious invaders, forming dense thickets, which made them popular in Europe as hedgerows in the 16th century. They often invade old fields, ditch banks, forest margins, open canopies, and along fencerows, rights-of-way, and ditch banks. Different species of privets often grow together, confounding identification (Maddox et al. 2010).

Management:

Physical

Mechanical methods of control include pulling seedlings. Annual mowing can be an effective method of control, though it will not eradicate the weed (Maddox et al. 2010).

Chemical

For chemical controls, cut-stump remains effective (Maddox et al. 2010). Foliar spray can also be effective (US Forest Service).

Biological

There is no official biological control, however, there is a leaf-eating European insect, *Macrophya punctumalbum*, that will consume privet as well as *Pseudocercospora ligustri*, a fungal leaf spot, and *Agrobacterium tume-faciens*, a root crown bacteria (US Forest Service).

United States Forest Service, Northeast Region. "Privets." Weed of the Week. Retrieved from http://www.na.fs.fed.us/fhp/ invasive_plants/weeds/privets.pdf

Maddox, V., Byrd Jr, J., & Serviss, B. (2010). Identification and Control of Invasive Privets (Ligustrum spp.) in the Middle Southern United States. *Invasive Plant Science and Management*. Vol. 3, No. 3, pp. 482-488.

Lonicera spp./Honeysuckle Shrub:

Honeysuckle bush at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Shrubs or twining vines withi opposite, simple, mostly entire leaves; flower in pairs on axillary peduncles, often witih fused ovaries, or in terminal whorls subtended by one or more pairs of fused, disk-like leaves that surround the stem; corolla tubular, 5-lobed, often bilabiate, and/or bulging at the base; stamens 5, fruit a few-seeded berry." – Plants of Pennsylvania (Rhoads and Block 2007) (For all *lonicera*)

General:

Honeysuckle shrubs (*Lonicera* spp.) are native to East Asia and Europe and were introduced to North America as ornamentals as well as erosion control and wildlife benefits. Unfortunately, they have now invaded much of the eastern of the US (DCNR).

Honeysuckle shrubs are shade-intolerant and tend to inhabit disturbed areas with abundant sunlight (DCNR).

The two species identified at Gwynedd Wildlife Preserve are *L. morroii* and *L. maackii*, though there may be more.

Impact:

Honeysuckle shrubs can compete for nutrients and push out native species. Also, while providing food for birds, it is not very nutritious and therefore may do harm to migratory species. Honeysuckle shrubs are often found in disturbed wods, forest edges, roadsides, and fields (DCNR).

Management:

Physical

Small seedlings canbe hand-pulled, but large bushes should be cut to the base at least once a year. Fire can be effective, but should be done before the shrubs produce seeds (DCNR).

Chemical

Chemical herbicides, both foliar and cut stump applications, are effective at managing this invasive species (DCNR).

Pennsylvania Department of Conservation and Natural Resources (DCNR). "Shrub Honeysuckles (Amur, Morrow's, Bells, Standish, and Tartarian)." Invasive Plants in Pennsylvania. Retrieved from http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_010229.pdf

Rhamnus cathartica/Common Buckthorn:


Common buckthorn taking over a forest floor at Gwynedd Wildlife Preserve, May 7th, 2014 (Photos: Nathan Hartshorne)

> "Shrub or small tree to 6 m tall; leaves opposite, margins crenulate-serrate, 3-7 cm, ovate to elliptic; some branches ending in spines; usually dioecious; flowers 4-merous, 10-15 per inflorescence; fruit glassy-black, 4-seeded, 5 mm diameter; open woods, pastures, fencerows, and roadside banks; flowers May-June; native to Europe." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Common buckthorn (*Rhamnus cathartica*) is a native to Africa, Asia, and Europe that has been used in North America as an ornamental as well as for hedgerows and wildlife habitat (ISSG 2005). Currently, it has invaded most of the northern US and Canada. It is a shrub or small tree that can grow 20 feet tall and 10 feet wide. It often forms dense thickets that prevent growth of natives (US Forest Service). Common buckthorn will generally flower May through June and fruit ripens in August through September. The seeds are a strong laxative, which helps them to be distributed (ISSG 2005). It prefers light shade and is tolerant of many different soil types from well-drained sandy to clay to poorly-drained calcareous. It handles neutral or alkaline conditions as well as wet or dry soil (US Forest Service). The plant will leaf early in the spring and hold onto the leaves later (an average of 58 days) into the fall than most others (ISSG 2005).

Impact:

Because of its ability to crowd out other species, it changes the fire regimes, even eliminating them (US Forest Service). It is often found in natural forests, planted forests, range/grasslands, scrub/shrublands, wetlands, open oak woods, deadfall openings in woodlands, and woods edges (ISSG 2005).

Management:

Physical

Cut buckthorn can resprout and grow vigorously, thus mechanical methods of control must be done with care. Hand-pulling can be effective on small infestations, but will need to be done for multiple years and the roots have to be removed. Repeated mowing can also be effective. In fire

adapted areas, fire can be an effective control. However, resprouting may occur, so there will likely need to be subsequent burnings for 5-6 years (ISSG 2005).

Chemical

Chemical applications such as glyphosate on cut stumps can be effective means of control as well. It has been suggested that herbicide applications in the fall or early winter are the most effective, but other good times are warm winter days, or just after the plants leaf out in the spring (ISSG 2005).

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Rhamnus cathartica (tree)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=809&fr=1&sts=&lang=EN

United States Forest Service, Northeast Region. "Common Buckthorn." Weed of the Week. Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/common_buckthorn.pdf

Wikipedia. "Rhamnus Cathartica." Retrieved from http://en.wikipedia.org/wiki/Rhamnus_cathartica

Rhodotypos scandens/Jetbead:

Jetbead (Photo: Wikipedia)

> "Deciduous shrub to 2 m tall with opposite, simple, doubly serrate leaves; flowers 2-3 cm across with 4 white petals and 4 large, toothed sepals; ovaries distinct, superior; fruit a cluster of black, 1-seeded dry drupelets; cultivated and occasionally escaped to roadsides and disturbed woods; flowers April-May; native to Japan." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Jetbead (*Rhodotypos scandens*) is an invasive shrub native to East Asia that was first brought to the United States in 1866 as an ornamental. It has currently invaded at least 18 states in the eastern US, though fewer in the South. Although preferring full sun, it can still grow in full shade. It is also tolerant of compacted soils, poor soils, and varying pH, but prefers moist soils. It is also tolerant of pollution and salt (US Forest Service).

Impact:

Jetbead can produce thick shrub layers that push out natives. Also, due to its shade tolerance, it can shade native plants on the forest floor and prevent their growth (US Forest Service).

Management:

Physical

Jetbead is tolerant of heavy pruning, so cutting is not effective. When manually removing, the entire root system needs to be removed as well (US Forest Service).

Chemical

Herbicides can be effective, especially cut-stump (Rhoads and Block 2011).

Rhoads, Ann F and Block, Timothy. (2011). "Jetbead." The Pennsylvania Flora Project of Morris Arboretum. Morris Arboretum. Retrieved from http://www.paflora.org/pdf/INV-Fact%20Sheets/Rhodotypos %20scandens.pdf

United States Forest Service, Northeast Region. "Black Jetbead." Weed of the Week. Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/black-jetbead.pdf

Wikipedia. "Rhodotypos Scandens." Retrieved from http://en.wikipedia.org/wiki/Rhodotypos_scandens

Rosa Multiflora/Multiflora Rose:

Multiflora rose (Photo: Wikipedia)

> "Vigorous shrub with arching-ascending branches to 3 m long; stipules conspicuously fringed; leaflets 5-11; flowers in many-flowered terminal panicles; petals white or slightly pinkish; hips 5 mm in diameter; frequently naturalized in disturbed woods, pastures, old fields, roadsides, and thickets; flowers late May-June. Native to Asia." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Native to East Asia (Japan, Korea, and eastern China), Multiflora rose (*Rosa multiflora*) was introduced to North America in the late 1700s as part of the ornamental trade (Amrine 2002). By the 1930s, it became popular to use as a living fence in pasture and as a crash barrier on roadsides. It has since invaded the entirety of the U.S. except for the Rocky Mountains, the southeastern Coastal Plain, and the deserts of California and Nevada (Bergmann and Swearingen 2009).

Multiflora rose is tolerant of a variety of conditions of moisture, light, and soil types. Multiflora rose produces many fruits that are consumed and then spread by birds (which helps germination of the seeds). It can also reproduce vegetatively when roots grow from the tips of canes that touch the ground (Bergmann and Swearingen 2009).

Impact:

Multiflora rose can grow and reproduce rapidly, forming dense thickets that push out and prevent growth of native plants. It is often found in open woodlands, forest edges, successional fields, savannas, prairies,steam banks, roadsides, dense woods, and disturbed areas (Bergmann and Swearingen 2009).

Today it is listed as a noxious weed in 10 states, lllinois, Iowa, Kansas, Maryland, Missouri, Ohio, Pennsylvania, Virginia, Wisconsin, and West Virginia. Besides North America, Multiflora rose is invasive to Europe. In the 1940s to 1960s, many states planted it for erosion control and as a living fence. Kentucky chose not to and today remains relatively free of the weed. 1996 estimates put 45 million acres infested. These infestations have significant impact on agriculture, especially on grazing. From 1981 to 1982, West Virginian farmers spent an estimated 40 million dollars trying to control it (Amrine 2002).

Conflicting USDA sources claim a mature plant may produce half a million or even up to a million seeds per year (Amrine 2002; Bergmann and Swearingen 2009). As seeds may stay in the soil for 20 years before germinating, the plants may persist as weeds for a very long time even with active human prevention (U.S. Dept. of Agriculture 2002). Seeds may be spread through songbird and deer feces after they consume the berries (Amrine 2002).

Management:

Physical

Mowing is effective, though it needs to be done 6 times per growing season for 2-4 years. Controlled burns have also been shown to help eradicate multiflora rose (ISSG 2005). However, observations are that the fire only burns it back, but does not eliminate the weed (Dan Barringer, *personal communication*).

Chemical

Foliar spray is effective as long as it is done when the leaves are fully formed. Basal bark applications can be done in the lower 6-46 cm of the plant (ISSG 2005). Cut stump herbicide applications are likely the best chemical control (Swearingen and Pannill 2009).

Biological

Without human intervention, biological control systems have developed that are rapidly controlling the weed. Many believe that soon Multiflora rose will become a non-native that sits in the background rather than invading and damaging the ecosystems it comes into contact with. The controls are, rose rosette disease and the mite that is its vector, the rose seed chalcid, and the rose stem girdler. First found in California, Wyoming, and Manitoba, Canada in 1941, rose rosette disease has recently been devastating Multiflora rose stands across North America. The disease severely damages the growth of roses. Infected Multiflora roses have a change in pigmentation of both veins and foliage. Veins may turn red, purple, or dark green, while leaves become yellowish. Leaves are also dense and dwarfed. Lateral buds produce many branches that create “witches’ brooms.” The plants also become extra cold-sensitive, dying at -10 degrees Celsius. This disease is transmitted naturally by the eriophyid mite *Phyllocoptes fructiphilus*, but may also be introduced to a plant through grafting. As many mites may live on the plants without carrying the virus, this can contaminate a whole stand. As of 1998, no plants have been found to be resistant to the virus. In a test site in Indiana with both healthy and infected plants, nearly all Rosa multiflora died within 5 years. The lifespan of an infected plant ranged from 3 to 48 months, averaging at 22.4 (Amrine 2002).

There have been attempts to augment the natural spread of rose rosette disease, much to the dismay of rosarians and those in the rose industry. Although the disease does not harm any native mid-Atlantic roses, it can be very harmful to the ornamental industry (Amrine 2002).

The rose seed chalcid, *Megastigmus aculeatus*, also has begun destroying populations of multiflora rose. The chalcid is a light yellowish-brown wasp about 2-3mm long that lays its eggs in the rose hips. The larvae then feed on the seeds, preventing new roses from growing (Amrine 2002).

Despite the use as a biological control, the chalcid is native to Japan where it feasts on the weed and was not purposefully brought to North America. The chalcid was first reported in the United States

in New Jersey in 1917, imported in rose seed from Japan. Interestingly, just as the seeds can be passed through certain animal guts and distributed far, the chalcid inside the seeds may also pass through the gut unharmed. The chalcid is not particularly good at finding new stands of Rosa multiflora on its own, so this dispersal by birds has greatly helped it find new populations. The chalcid is expected to eventually infest at the same rate as plants in Korea and Japan, at 90-95%. An improvement from rose rosette disease, the chalcid lives only in multiflora rose. Human-augmented population distributions have pushed infestation from 3.2 to 77.5% in West Virginia (Amrine 2002).

Sadly, as multiflora dies off, if it is not manually replaced with native species, it is likely to be replaced by other invasives. In Clifty Falls State Park, Japanese honeysuckle covered nearly all dead Multiflora rose, while in Virginia, the Japanese honeysuckle competes for the new real-estate with Tartarian honeysuckle, autumn olive, and Japanese knotweed (Amrine 2002).

The last of the main controls for multiflora rose is the stem girdler, *Agrilus aurichalceus aurichalceus* (Amrine 2002).

Amrine, J. W. (2002). "Multiflora Rose." Van Driesche, R., Lyron, Suzanne, Blossey, Bernd, Hoddle, Mark, and Reardon, Richard. Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Publication.

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Rosa multiflora (shrub)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=215 &fr=1&sts=sss&lang=EN

Bergmann, Carole and Swearingen, Jill M. (2009). *Multiflora rose*. Retrieved from the Plant Working Group of the Plant Conservation Alliance. http://en.wikipedia.org/wiki/Rosa_multiflora

Wikipedia. "Rosa Multiflora." Retrieved from http://en.wikipedia.org/wiki/Rosa_multiflora

Vines

Celastrus orbiculatus/Oriental Bittersweet:

Oriental bittersweet at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Leaves nearly as wide as they are long; flowers in axillary clusters; widely naturalized in disturbed woods, fields, fencerows, and edges; flowers May-June; Fruit Sept-Nov; native to Japan and China; UPL" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

A popular ornamental, Oriental bittersweet (*Celastrus orbiculatus*) arrived in the US in the 1860s. Today it has invaded 21 states in much of the northeast US. It reproduces through the copious amount of seeds it produces in berries that are consumed and spread by birds and other animals. It also reproduces vegetatively through root suckering (Swearingen 2009).

According to Ellsworth et al. (2004), Oriental bittersweet produces little in the way of a seed bank. A 2 year study in a greenhouse found no seeds after 1 year. This may be due to the fact that the seeds are larger than most and lack the protective coating necessary for larger seeds. It performs better when forest litter is fragmented, but only really dense litter can actually stop it from germinating. When clumped, seedlings may push litter up, helping them to get out from under the dense forest litter (Ellsworth et al. 2004). However, despite this data, observations at Crow's Nest Preserve of the Natural Lands Trust suggest that there is indeed, a long-term seed bank (Daniel Barringer, *personal communication*). Mammal predation on seeds may control them well.

Oriental bittersweet plants will grow rapidly with sunlight. However, even with dense shade, they will still survive (Ellsworth et al. 2004).

Impact:

Oriental bittersweet is often found in roadsides, fence-rows, agricultural areas, coastlines, forests, rangelands, riparian areas, scrub-shrub habitats, disturbed areas, and urban land (ISSG 2005).

It can grow 3 meters per year, allowing it to climb over and girdle native woody plants, choking them in a very short time. It can also prevent the natural succession of forests (ISSG 2005).

Native bittersweet, known as American bittersweet (*Celastrus scandens*), has been declining and both competition and hybridization with Oriental bittersweet may be two of the causes. The two species can easily cross. Fertility in a study was a little lower when hybridizing compared to American bittersweet reproducing intraspecifically, but it was not statistically significant. Seeds resulting from hybridization had less seed dormancy and grew faster and larger than the others (Pooler et al. 2002).

There are several aspects that make Oriental bittersweet a better competitor in comparison to the native bittersweet. First of all, Oriental bittersweet matures faster, has a higher photosynthetic rate, and has increased seed viability and reproductive potential. Furthermore, it can produce fruit after 2 years, while the native requires 4 years. It also produces more fruit than the native bittersweet (Pooler et al. 2002). The invasive also performs much better in heavy shade, making it not just an edge habitat species, but something that can perform in forested areas (Leicht-Young et al. 2007).

Management:

Physical

Management control includes hand-pulling of entire vines. This is best done before fruiting. If they have fruited, care must be taken to prevent the fruit from spreading and should be bagged and put in a landfill or baked in the sun. The roots need to be removed as well (Swearingen 2009). Continual mowing can also provide good control, but needs to be done 2-3 times a year at minimum. Fire can also provide control, but since it does not kill the roots, it will not eliminate the plant (ISSG 2005).

Chemical

Cut-stem, basal bark applications, and foliar spray are all effective methods of chemical control. However, as it is a vine that generally uses a plant to grow on, one has to be careful not to hurt the host (Swearingen 2009).

Ellsworth, J. W., Harrington, R. A., & Fownes, J. H. (2004). Seedling Emergence, Growth, and Allocation of Oriental Bittersweet: Effects of Seed Input, Seed Bank, and Forest Floor Litter. *Forest Ecology and Management*. Vol. 190, No. 2, pp. 255-264.

Invasive Species Specialist Group (ISSG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Celastrus orbiculatus (vine, climber)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=1811&fr=1&sts=sss&lang=EN

Leicht-Young, S. A., Silander Jr, J. A., & Latimer, A. M. (2007). Comparative Performance of Invasive and Native Celastrus Species Across Environmental Gradients. *Oecologia*. Vol. 154, No. 2, pp. 273-282.

Pooler, M. R., Dix, R. L., & Feely, J. (2002). Interspecific Hybridizations Between the Native Bittersweet, Celastrus Scandens, and the Introduced Invasive Species, C. orbiculatus. *Southeastern Naturalist*. No. 1, Nol. 1, pp. 69-76.

Swearingen, J., B. Slattery, K. Reshetiloff, and S. Zwicker. (2010). "Oriental Bittersweet." Plant Invaders of Mid-Atlantic Natural Areas, 4th ed. National Park Service and U.S. Fish and Wildlife Service. Washington, DC. Accessed 4/16/2014. Retrieved from: http://www.nps.gov/plants/alien/fact/ceor1.htm

Hedera sp./English Ivy:

English ivy choking a tree near Gwynedd Wildlife Preserve, April 27, 2014 (Photo: Nathan Hartshorne)

> "Evergreen vine climbing by means of aerial rootlets; flowering branches extending horizontally from the climbing stems and lacking rootlets; leaves alternate, simple, suborbicular-cordate, and somewhat palmately 3-5 lobed on vegetative stems, narrowly ovate and unlobed on flowering stems, dark green with lighter veins; inflorescence a raceme of umbels; flowers small, green; fruit black, 2-3 seeded; widely cultivated and occasionally naturalized in disturbed woods; mostly SE; flowers Aug-Sept; native to Eurasia." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

English ivy is a complex of different species of evergreen woody vines native to Europe, Asia, and North Africa (Green et al. 2011). The first type of English ivy brought by early colonists appears to have been Hedera hibernica, a tetraploid cross of Hedera helix and another diploid ancestor (Clarke et al. 2006). English ivy is currently a common ornamental (Yang et al. 2013). There are 13 species and over 400 cultivars, though not all are aggressive invaders (Clarke et al. 2006). Every year over 8 million potted plants are sold (Green et al. 2011). There is, however, a debate about the number of species and cultivars of Hedera, as some believe there has been "excessive taxonomic splitting" (Green et al. 2011). This may be due to the significant horticultural interests. Thus, the taxonomy of the entire complex is generally poorly defined and controversial. It becomes especially significant in management when one species is banned by a government, yet the dominant invader of Hedera in the region may be a different one, as is the case in Oregon. The chromosome structure varies a lot, from diploid to tetraploid. For instance, Hedera helix is diploid, while Hedera hibernica is a tetraploid hybrid of H. helix and another ancestor still up for debate (Green et al. 2011).

Impact:

English ivy can grow in full sun or deep shade, giving it a range of habitats and is now in at least 31 states of the US and is invading many forested regions. It can compete with many native plants and hurt the local ecosystems. The vines may climb into the forest canopies and choke the trees to death (Yang et al. 2013).

While many invasives decrease the seed bank richness, English ivy does not. Regardless, it does reduce species diversity in places it takes over by inhibiting germination (Biggerstaff and Beck 2007b).

Management:

Physical:

Mechanical methods of control include cutting vines that are climbing trees or other structures as well as pulling up and bagging vines in the ground (US Forest Service 2006).

Chemical

Simply applying chemical herbicides has been shown to fail at providing enough consistent control of English ivy. Mixtures of 2, 4-D and glyphosate were the most effective than either individually (Yang et al. 2013).

Cutting the leaves and then applying 25% glyphosphate has been shown to have a nearly 100% removal of ivy. This can be more efficient in time and do a better job at eradication than hand-pulling. There is potential that large areas cleared of ivy may be more prone to erosion, however research has suggested that the soil changes little. Furthermore, by not pulling the ivy out completely, it hinders seedling growth, which is one of the main purposes of removing the ivy in the first place. Nondiscriminatory herbicide may also be problematic in hurting beneficial plants and persist in the soil. Studies generally suggest adding seeds to the seed bank to help supplement seedling growth of native plants after ivy removal. This also helps to prevent another invasive takeover as they will generally return to the pulled plots faster than natives (Biggerstaff and Beck 2007a).

Biggerstaff, M. S., & Beck, C. W. (2007)a. Effects of Method of English Ivy Removal and Seed Addition on Regeneration of Vegetation in a Southeastern Piedmont Forest. *The American midland naturalist*. Vol. 158, No. 1, pp. 206-220.

Biggerstaff, M. S., & Beck, C. W. (2007)b. Effects of English Ivy (Hedera helix) on Seed Bank Formation and Germination. *The American Midland Naturalist*. Vol. 157, No. 2, pp. 250-257.

Clarke, M. M., Reichard, S. H., & Hamilton, C. W. (2006). Prevalence of Different Horticultural Taxa of Ivy (Hederaspp., Araliaceae) in Invading Populations. *Biological Invasions*. Vol. 8, No. 2, pp. 149-157.

Green, A. F., Ramsey, T. S., & Ramsey, J. (2011). Phylogeny and **B**iogeography of Ivies (Hedera spp., Araliaceae), a Polyploid Complex of Woody Vines. *Systematic Botany*. Vol. 36, No. 4, pp. 1114-1127.

United States Forest Service, Northeastern Area. (2006). "English Ivy." Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/english-ivy.pdf

Yang, Q., Wehtje, G., Gilliam, C. H., McElroy, J. S., & Sibley, J. (2013). English Ivy (Hedera helix) Control with Postemergence-Applied Herbicides. *Invasive Plant Science and Management*. Vol. 6, No. 3, pp. 411-415.

Lonicera japonica/Japanese Honeysuckle:

Japanese honeysuckle at Gwynedd Wildlife Preserve, April 8, 2014 (Photo: Nathan Hartshorne)

> "Semievergreen trailing or twining vine; leaves ovate to oblong, 4-8 cm, occasionally toothed or lobed; flowers in pairs on axillary peduncles; corolla 3-5 cm, strongly bilabiate, white to occasionally pinkish turning yellow with age; fruit black; commonly established as an invasive weed of disturbed woods, thickets, old fields, banks, and roadsides; flowers June, fruits Sept-Oct; native to Asia; FAC-" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Native to East Asia, Japanese honeysuckle (*Lonicera japonica*) is currently invasive in 42 states and Puerto Rico as well as all continents except Antarctica. It was first brought outside its habitat by William Kerr to Kew Gardens in London in 1806. The first record in a North American herbarium is from a specimen collected in Kentucky in 1842. A very attractive and fragrant plant, it became popular quickly (Schierenbeck 2004).

Japanese honeysuckle is often brought to an area by humans as either an ornamental or roadside stabilizer. However, it is spread by wildlife. Many birds and mammals consume the berries and spread the seeds through their feces. In some areas, it can be 49.5% of the year-round food-supply of white-tailed deer. Thus, many wildlife managers, especially game managers have planted it as forage for the animals (Schierenbeck 2004).

Japanese honeysuckle is a deciduous to evergreen perennial depending on temperature and drought. It is a high-twining or trailing plant that likes to climb on other plants, wrapping around them and climbing high. When there are no plants to attach to, it is a low-lying plant that can cover an entire area 1.5 m deep. Stems will grow when soil temperatures range from 3 to 8 degrees Celsius (Schierenbeck 2004).

This invasive vine can spread by runners that grow roots at nodes. This can happen rapidly as runner growth can exceed 9m a year (Uva et al. 1997).

Japanese honeysuckle can flower within a year of germination and a mature stem will produce an average of 27 flowers, 57% of which produce berries. The berries are purple-black and 6-7 mm in diameter with an average of 5.9 seeds per fruit. Fresh seeds need 5-8 degrees Celsius for 60 days and

germinate at about 10 degrees Celsius. After three years, seeds have a viability of 1 to 3 percent. Plants can grow 30 cm within 5 months of germination. Aside from seed dispersal, it can sprout from the roots (Schierenbeck 2004).

Japanese honeysuckle prefers well-drained soils, but occurs often at the edges of wetlands as long as they are not permanently saturated. It prefers moderate pH from 6.1-7.9, but can be found in soils with pH 4.0 to 8.0. It is tolerant to heavy metals and SO_2, low soil organic matter, and low mineral levels. It prefers an average winter temperature of -1 degree Celsius, and -10 or less will kill the above ground portions, though it will likely re-sprout (Schierenbeck 2004).

As of 1994, there were 12 horticultural varieties available on the internet. With these and multiple introductions that are constantly being crossed with each other, it has a lot of genetic diversity, though it is unknown how this compares to its native ranges (Schierenbeck 2004).

Impact:

Japanese honeysuckle has some adaptations that make it compete well against native plants, reducing biodiversity. For instance, it is able to maintain a higher specific leaf area than native species in different light environments which helps it adapt better to changes in the environment. It can grow in full sun or shade and anything in between. It can hurt plants it uses as a host to climb or use its roots to compete with other plants (Schierenbeck 2004). Japanese honeysuckle has also been found to produce allelopathic chemicals that are toxic to other plants, inhibiting their growth (Skulman et al. 2004). It can cover 6 percent of areas in young stands and 100 percent of mid-successional areas (Schierenbeck 2004).

Management:

Physical

The best control methods for Japanese honeysuckle are when it is actively growing. Application of herbicides following any control method is best. Hand-pulling can work, but only on smaller plants as older ones can have thick woody stems.

Fire control can be effective, but if used improperly, can increase the invasion. Fires that are not high-intensity, are unlikely to control the plant as it will just encourage it to re-sprout. In fact, Japanese honeysuckle is responsible for changing the fire regime of areas it invades. It survives most fires, which allows it, as a quick-growing invader to disturbed areas, to increase its takeover of an area. In an experiment in which an area was burned then left for 11 years, Japanese honeysuckle cover was 4 times greater than in pre-burn levels. In another experiment of 23 years, when burned every two years, effective control occurred. When burned in winter, it had 0% cover, 1.2% cover for spring burn, 0% cover for summer burn, but 16.05% cover for no burn. It has been suggested that burning every 5 years will provide control without eliminating it (Schierenbeck 2004).

Chemical

Applications of chemical herbicides are best in the fall when there are leaves on the plants. Fall is best as many non-target plants are going dormant and will be less likely to be hurt (US Forest Service 2005).

Biological

Although some fungi and herbivores have been found on Japanese honeysuckle, none do it much harm. Part of this may be due to the fact that its peak leaf expansion is in the late fall, late winter, and early spring counter to when insects generally want it. Compared to the native Coral honeysuckle, Japanese honeysuckle performs much better under herbivory from both mammals and insects by compensating to increase biomass allocation to its leaves (Schierenbeck 2004). Attempts to find a biological control agent for Japanese honeysuckle in America have failed as native agents examined preferred native Lonicera over the invasive (Froude 2002).

Goats can be effectively used to control Japanese honeysuckle (Japanese Honeysuckle 2005).

Froude, V. (2002). *Biological control options for invasive weeds of New Zealand protected areas*. Department of Conservation.

Schierenbeck, K. A. (2004). Japanese Honeysuckle (Lonicera japonica) as an Invasive Species; History, Ecology, and Context. *Critical Reviews in Plant Sciences*. Vol. 23, No. 5, pp. 391-400.

Skulman, B. W., Mattice, J. D., Cain, M. D., & Gbur, E. E. (2004). Evidence for Allelopathic Interference of Japanese Honeysuckle (Lonicera Japonica) to Loblolly and Shortleaf Pine Regeneration. *Weed Science*. Vol. 52, No. 3, pp. 433-439.

USDA Forest Service Northeast Region. (2005). "Japanese Honeysuckle." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/japanese_honeysuckle.pdf

Rubus phoenicolasius/Wineberry:

Wineberry at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Stems arching, to 2 m long, densely covered with purple, glandular hairs and bristles; leaflets 3, densely white tomentose beneath; flowers in a panicle; petals white; fruit an orange-red raspberry, enclosed by the long-acuminate, glandular-hairy sepals until ripe, common on roadsides, banks, woods, and thickets; flowers June, fruits July-Aug; native to Asia." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Wineberry (*Rubus phoenicolasius*) is native to East Asia, but has spread throughout the eastern half of the United States: From Massachusetts to Florida and west to Missouri. It is believed that wineberry was introduced in 1890 by John Lewis Childs who had a mail order seed company based in New York (Innis et al. 2011). It was likely introduced to cross with raspberry and blackberries to form new cultivars (ISSG 2005).

Wineberry produces one aboveground shoot per year unless the area is well-lit. In the first year, the shoots are called primocanes and are unbranched. In the second year, they are woody and branched "floricanes," and may flower and fruit. Initially shoots are upright, but as they age, they arch back towards the ground. They will root where they touch the ground. Stems last for 2 years (Gorchov et al. 2011).

Wineberry appears to have low genetic diversity, at least compared to the native sawtooth blackberry (*Rubus argutus*). This is probably due to few introductions. However, this study was examining one area rather than several from its large North American range (Innis et al. 2011).

Wineberry is heavily dependent on gaps in forest cover for seed germination. In larger, older forests, bigger gaps were needed, though in young stands, gaps were not always needed. Once established, wineberry could last in an undisturbed site. This is likely due to the need for light to germinate. Light, however, may not be as important as exposed soil with no leaf litter covering it. Exposure to more light was also found to be important in sexual reproduction (Gorchov 2011).

Impact:

It can form dense thickets that crowd out native species. It can be found in forests, fields, streams and wetlands, edge habitats, and open woods. Many species of birds and mammals use the brambles for nesting and shelter (US Forest Service 2005).

Management:

It is likely that removing Wineberry once every three years is sufficient to prevent invasion due to the fact that it grows slowly and is slow to fruit. Also, as it needs disturbance to establish, it can be easier to manage (Gorchov 2011).

Physical

Management in terms of mechanical control include removal of plants by hand or using a 4-prong spading fork, best when the soil is moist. Mowing or burning for several years in a row can be effective. Mowing several times in one year will reduce its vigor (US Forest Service 2005).

Chemical

Herbicides have been shown to be effective. Cut stump applications are good at control (US Forest Service 2005).

Gorchov, D. L., Thompson, E., O'NEILL, J. A. Y., Whigham, D., & Noe, D. A. (2011). Treefall Gaps Required for Establishment, but not Survival, of Invasive Rubus Phoenicolasius in Deciduous Forest, Maryland, USA. *Plant Species Biology*. Vol. 26, No. 3, pp. 221-234.

Innis, A. F., Forseth, I. N., Whigham, D. F., & McCormick, M. K. (2011). Genetic Diversity in the Invasive Rubus Phoenicolasius as Compared to theNative Rubus Argutus Using Inter-simple Sequence Repeat (ISSGR) Markers. *Biological Invasions*. Vol. 13, No. 8, pp. 1735-1738.

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Rubus phoenicolasius (shrub)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=1811&fr=1&sts=sss&lang=EN

US Forest Service, Northeast Region. (2005). "Wineberry." Weed of the Week. Retrieved from http://na.fs.fed.us/fhp/invasive_plants/weeds/wineberry.pdf

Herbs

Achillea millefolium/Common Yarrow:

Common yarrow at Gwynedd Wildlife Preserve, April 20, 2014 (Photo: Nathan Hartshorne)

> "Stems simple, leafy, 3-9 dm tall; leaves sessile, lanceolate in outline, fern-like, once to twice pinnately parted into linear, toothed segments, about 15 cm long, pubescent or nearly glabrous; heads about 6 mm wide, rays 4-5, white or pink, surrounding smaller central disk florets; common in fields, roadsides, and waste places; flr. Jun-Sep; native to Europe; FACU" – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Common yarrow (*Achillea millefolium*) is a long-lived perennial native to Eurasia that was spread by early settlers who used it as a medicinal herb (Queensland Government 2011).

It is very easy for Common yarrow, *Achillea millefolium*, to be confused with Western yarrow, *Achillea millefolium* L. var. *occidentalis* DC. which is native to North America and which easily hybridizes with it (Lowry et al. 2011). In fact, the Natural Resources Conservation Service Plant Guide appears to confuse the two (Hurteau 2001). Thus it is important to note that they are, in fact, the same species and may not be considered a management problem. The Common yarrow is often found in turfgrass, roadsides, waste areas, public parks, dry hillsides, overgrazed rangeland, open woodland, grasslands, and fields (Lowry et al. 2011; Rhoads et al. 2009).

Common Yarrow forms a mat along with a dense network of stems and rhizomes. From these, upright stems are produced each year. Yarrow reproduces both through seeds and vegetatively. Western yarrow, at least, does not tend to spread much vegetatively, as new shoots stay attached and close to the original plant (Queensland Government 2011).

Impact:

Compared to Western yarrow, Common yarrow is taller, more vigorous, and more weedy. It also flowers later and seeds ripen later. The fact that it is more weedy than Western yarrow is of note, because Western yarrow is known for being very adaptable to different conditions, being one of the most abundant flowers of the Western US, and is a pioneer species (Winslow 2006).

In Australia, Common yarrow is described as a major environmental problem in some areas. The root system allows it to survive areas where conditions above the surface are harsh. There it is generally found in industrial areas, roadsides, open fields, marshy sites, coasts, and cultivated areas (Queensland Government 2011).

Management:

Physical

For mechanical methods of control, due to the rhizomatous nature of the plant, if hand-pulling, roots need to be removed as well.

Chemical

Herbicides should be effective at controlling this weed.

Biological

There are many insects that consume this plant, at least in the Western US, since it is native there (Winslow 2006).

Queensland Government. (2011). "Yarrow. Achillea Millefoium." Weeds of Australia. Retrieved from http://keyserver.lucidcentral.org/weeds/data/03030800-0b07-490a-8d04-0605030c0f01/media/Html/Achillea_millefolium.htm

Matthew D. Hurteau. 2001. Common Yarrow. Plant Guide. Natural Resources Conservation Service. http://plants.usda.gov/plantguide/pdf/cs_acmi2.pdf

Lowry, Brenda Jarvis, Whitesides, Ralph E., Dewey, Steven A., Ransom, Corey V., and Banner, Roger E. (2011). Common Weeds of the Yard and Garden. Utah State University Extension. http://extension.usu.edu/files/publications/publication/Horticulture_Weeds_2011-01pr.pdf

Winslow, Susan. (2006). Western Yarrow. United States Department of Agriculture, Natural Resources and Conservation Service. https://plants.usda.gov/plantguide/pdf/pg_acmio.pdf

Alliaria petiolata/Garlic Mustard:

Garlic Mustard at Gwynedd Wildlife Preserve, May 4, 2014 (Photos: Nathan Hartshorne)

> "Biennial with simple or branched stem to 1 m tall, smelling strongly of garlic; basal leaves long-petioled; blade palmately veined, ovate-cordate; upper leaves similar but with progressively shorter petioles and venation becoming palmately-pinnate; sepals erect, not saccate; petals white; fruiting pedicels nearly as thick as th divaricately ascending, 2-4 cm long, terete fruits; an invasive weed of shady, moist areas including woods, floodplains, and waste ground throughout; flr. Late Apr-June; native to Europe; FACU-" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Garlic Mustard *Alliaria petiolata*, has its first known introduction on Long Island, New York in 1868. Its native range is in Europe and Asia, from England to Sri Lanka (Blossey et al. 2002). Having been used as a spice and a medicinal plant in Europe, it was likely introduced several times to North America. Genetic analysis confirms this as the aggregate of North American Garlic mustard has more diversity than any single native populations. It appears that most of the introductions came from the British Isles (Durka et al 2005).

It is now a pest in North America and New Zealand. Garlic mustard is a cool-season shade-tolerant species, meaning it invades the forest floor, an uncommon occurrence for invaders. The invasive range in North America extends from the northeast to the Midwest, from Ontario to Georgia and Kansas. However, there are some introductions to Utah, Colorado, and the Pacific Northwest (Blossey et al. 2002).

Garlic mustard is a biennial that smells like garlic. The flowering parts may grow 2.5-3 feet high. Rosettes remain green through the winter, however in May the seeds are produced and by June, the flowering part dies. It generally prefers moist, shaded areas and prefers calcareous soils with low acidity. It is often found in river floodplains, forests, roadsides, trail edges, forest openings, and disturbed areas (US Forest Service).

Part of what makes Garlic mustard so successful is that plants may produce as many as 7,900 seeds. Fortunately the seed bank is short-lived, though as dense as 20,000 per square meter, it can be quite dense (Blossey et al. 2002).

Impact:

Garlic mustard has a big impact in areas it invades. It can out-compete native vegetation for light, moisture, and nutrients, pushing them out of the area (US Forest Service). Furthermore, this weed produces allelopathic chemicals that interfere with other species, perhaps inhibiting mycorrhizal activity (Durka et al. 2005).

Management:

According to one study, high numbers of Garlic mustard must be removed in order to achieve control. The stated figures are over 95 percent of rosettes and over 85 percent of adults need to be eradicated each year. Less than this does not achieve control due to the fecundity of the plant and the newly opened space (Pardini et al. 2009).

Physical

Mechanical methods of control include fire, pulling, and cutting. Cutting is most effective when the plants are in full bloom. If done earlier, the plants may produce new flowers. Fire does not always work as a control method because a low-intensity burn may not kill the roots well enough and encourages Garlic mustard growth (Pardini et al. 2009). It may also promote the germination of the seed bank (US Forest Service). Hand-removal of the plant may work, but it must include its root system (ISSG 2006; US Forest Service 2005).

Chemical

Herbicides can be used effectively to control the weed (ISSG 2006; US Forest Service 2005).

Biological

There is no biological control at the moment. However, there are two weevils, two flies, a scale insect, two fungi, and unknown aphids have been found attacking Garlic mustard, but not vigorously enough to harm the plant (Blossey et al. 2002). However, the US Forest Service states that there are 5 weevils and 1 flea beetle that feed on it (US Forest Service 2005). However, none of this is biological control. In field studies in Europe, 69 insect herbivores and 7 fungi use garlic mustard as a host. Weevils were the biggest group of insects. However, most of these species are not host-specific and would be bad to introduce to North America. Host ranges and tests are being studied for biocontrol agents that may be introduced in the near future (Blossey et al. 2002).

Blossey, Bernd, Nuzzo, Victoria A., Hinz, Hariet L., and Gerber, Esther. (2002). "Garlic Mustard." Van Driesche, R., Lyron, Suzanne, Blossey, Bernd, Hoddle, Mark, and Reardon, Richard . Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Publication.

Durka, W., Bossdorf, O., Prati, D., & Auge, H. (2005). Molecular Evidence for Multiple Introductions of Garlic Mustard (Alliaria Petiolata, Brassicaceae) to North America. *Molecular Ecology*. Vol. 15, No. 6, pp. 1697-1706.

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2006). *Alliaria petiolata (herb)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=406&fr=1&sts=sss&lang=EN

Pardini, E. A., Drake, J. M., Chase, J. M., & Knight, T. M. (2009). Complex Population Dynamics and Control of the Invasive Biennial Alliaria Petiolata (Garlic Mustard). *Ecological Applications*. Vol. 19, No. 2, pp. 387-397.

United States Forest Service, Northeast Region. (2005). "Garlic Mustard." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/garlic_mustard.pdf

Allium vineale/Wild Garlic:

Wild garlic at Gwynedd Wildlife Preserve April 13, 2014 (Photo: Nathan Hartshorne)

> "Herb to 1 m tall; bulb coat membranous; leaves cauline, terete, 2-5 mm wide; umbel erect; perianth white, pink, or purple, 3-5 mm long; flowers often replaced by bulblets; common in disturbed ground and open woods; mostly S; flr. Jun-Jul; native to Europe; FACU-." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Wild garlic (*Allium vineale*) is a native to Eurasia and North Africa that has spread throughout most of the contiguous 48 states except the mountain West. It has a noticeable garlic or onion smell, especially when crushed (US Forest Service 2006). It is a perennial that reproduces through seed-producing flowers, aerial bulbs that form just below the flowers, and underground bulbs. However, there are two types of Wild garlic, one of which produces seeds and one which does not. Bulbs can persist underground for up to 6 years (Altland).

Impact:

Wild garlic often displaces native vegetation by forming dense mats. It is commonly found in waste areas, open fields, thickets, roadsides, right-of-ways, along stream banks, and disturbed areas (US Forest Service 2006).

Management:

It is best to kill the plants in the fall to early spring so new bulbs cannot be formed ("Wild Garlic" 2006 and Altland).

Physical

When doing manual methods of control, the entire root system and bulb need to be removed (US Forest Service 2006). Hoeing can also be effective in the winter to prevent new underground bulbs (Altland).

Chemical

Herbicides can be effective at controlling Wild garlic. 2,4-D is commonly recommended (US Forest Service 2006 and Altland).

Altland, James. "Wild Garlic Control in Nursery Crops." Weed Management in Nursery Crops. Oregon State University. North Willamette Research & Extension Center. Access 4/7/2014. http://oregonstate.edu/dept/nursery-weeds/feature_articles/wild_garlic_email/wild_garlic.html

United States Forest Service, Northeast Region. (2006). "Wild Garlic." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/wild-garlic.pdf

Arctium minus/Common Burdock:

Common burdock rosette (left), May 21st, 2014, and mature/deceased (right), April 6th, 2014 at Gwynedd Wildlife Preserve (Photos: Nathan Hartshorne)

> "Stems to 1.5 m tall; lower leaves with hollow petioles; blade narrowly to broadly ovate with a cordate base; inflorescence racemiform, heads short-pedunculate or subsessile; involucres 1.5-2.5 cm thick, slightly shorter than the florets; widely naturalized along fields, woods, railroad tracks, and waste ground; throughout; fl. Jul-Sep; native to Eurasia; FACU-." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Common burdock (*Arctium minus*) is a biennial that has invaded the entire contiguous 48 states except Florida (US Forest Service). A native to Eurasia, Common burdock was probably introduced to North America in the early 1600s (Hawthorn 1978). Each plant tends to produce 15,000 seeds (US Forest Service).

Impact:

Common burdock is often found alongside roads and ditches, in fields, and in waste and neglected areas (US Forest Service).

Common burdock has some significant economic impacts. First of all, it is a host for certain fungi that also harm valuable plants. Next, it decreases the value of sheep wool that it gets tangled in. Lastly, if dairy cows consume sufficient quantities, their milk can become tainted (US Forest Service).

Control:

Physical

Mechanical methods of control including hand-pulling and mowing can be effective at controlling this invasive (US Forest Service).

Chemical

Herbicides should provide effective control (US Forest Service).

Biological

Though the USDA Forest Service factsheet cites there is no biological control, it does mention the fungi that Common burdock hosts (US Forest Service). Furthermore, there is an introduced microlepideptera, *Metzneria lappella*, that is native to Eurasia. It is a seed predator that consumes several seeds per larvae. The weed was a serious problem that reduced significantly after the insect's arrival (Hawthorn 1978). Likewise, the tortoise beetle *Cassida rubiginosa*, was accidentally brought to North America and feeds on burdock as well as other invasives such as Canada thistle (McClay 2002).

Hawthorn, W. R., & Hayne, P. D. (1978). Seed Production and Predispersal Seed Predation in the Biennial Composite Species, Arctium Minus (Hill) Bernh. and A. Lappa L. *Oecologia*. Vol. 34, No. 3, pp. 283-295.

McClay, A. S. (2002). "Canada Thistle." Van Driesche, R., Lyron, Suzanne, Blossey, Bernd, Hoddle, Mark, and Reardon, Richard. Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Publication.

United States Forest Service, Northeast Region. "Common Burdock." Weed of the Week. Retrieved from: www.na.fs.fed.us/fhp/invasive%5Fplants/weeds/common_burdock.pdf

Barbarea vulgaris/Bittercress:

Bittercress at Gwnedd Wildlife Preserve, May 3rd, 2014 (Photo: Nathan Hartshorne)

> "Erect, mostly glabrous biennial; stem 2-8 dm tall, branched above; basal leaves petiolate, lyrate-pinnatifid with 1-4 pairs of lateral lobes; upper cauline leaves sessile, entire to dentate; petals bright yellow, 6-8 mm long; pedicels slender, 3-5 mm long; fruits 1-3 cm tipped by a 2-3 mm style; common in moist fields and roadsides; throughout; flr. Apr-Jun; native to Eurasia; FACU." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Bittercress (*Barbarea vulgaris*) is native to Eurasia (Rhoads and Block 2007). It came to the US around 1800 (Clements et al. 2004). It is a perennial plant from the mustard family and reproduces both with seeds and vegetatively through its roots (Schreiber 1962). The roots have adventitious buds that sprout (Martinkova and Mihulka 2008).

Bittercress is edible, leaves and stems can be cooked as a vegetable (Iverson et al. 2009).

Impact:

Bittercress is an economically harmful invader as it tends to invade crop fields of alfalfa and cereals (Hastings and Kust 1970; Clements et al. 2004). Furthermore, it appears to have allelopathic properties (Roshchina et al. 2009).

Bittercress is often found in meadows, roadsides, railroads, and waste places (Iverson et al. 2009).

Management:

Physical

Simply pulling or mowing this weed will not be effective. Bittercress is a powerful survivor, adapted to conditions of disturbance. In one experiment, 100% of plants survived a complete removal of aboveground biomass. Furthermore, seed production did not differ between injured and uninjured

plants (Martinkova and Mihulka 2008). Also, do to vegetative reproduction, all parts of roots need to be removed as well.

Chemical

Chemical herbicides will likely provide control over this invasive (Hastings and Kust 1970).

Clements, D. R., DiTommaso, A., Jordan, N., Booth, B. D., Cardina, J., Doohan, D., Mohler, Charles L., Murphy, Stephen D., and Swanton, C. J. (2004). Adaptability of Plants Invading North American Cropland. *Agriculture, Ecosystems & Environment.* Vol. 104, No. 3, pp. 379-398.

Hastings, R. E. and Kust, Cyril A. (1970). Control of Yellow Rocket and White Cockle in Established Alfalfa. *Weed Science*. Vol. 18, No. 3, pp. 329-333

Iverson, Louis, Ketzner, David, and Karnes, Jeanne. (2009). Illinois Natural History Survey. Illinois Plant Information Network. Retrieved from http://www.nrs.fs.fed.us/data/il/ilpin/spp/?spp=359

Martinkova, J. and Mihulka, S. (2008). Compensation of Seed Production After Severe Injury in the Short-Lived Herb Barbarea Vulgaris. *Basic and Applied Ecology*. Vol. 9, No. 1, pp. 44-54.

Roshchina, V. V., Yashina, A. V., Yashin, V. A., & Prizova, N. K. (2009). Models to Study Pollen Allelopathy. *Allelopathy Journal*. Vol. 23, No. 1.

Schreiber, Marvin. (1962). Growth, Development and Perennial Nature of Yellow RocketAuthor(s): Marvin M. Schreiber. *Weeds*. Vol. 10, No. 2, pp. 91-95

Cardamine Hirsute/Hairy bittercress:

Hairy bittercress (Photo: Wikipedia.org)

"Annual with ascending stems 0.5-3 dm tall; leaves mostly basal, pinnate with orbicular to ovate, short-petioled leaflets, leaflets of cauline leaves narrower; stems, petioles, and upper surface of cauline leaves sparsely hairy; petals white, 1.5-2 mm; stamens 4; siliques erect, their valves coiling tightly from the bottom when shed and forcibly expelling the seeds; a common weed of lawns, gardens, and stream margins in moist soil; mostly S, but spreading rapidly; flr. Mar-Apr; native to Europe; FACU." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Hairy bittercress (*Cardamine hirsute*) is an annual herb native to Eurasia that has invaded much of North America and is found throughout the east coast of the United States (Giblin). It is important to note that this species has an earlier flowering time than *C. impatiens*, which helps distinguish the two (Rhoads and Block 2007).

Impact:

No information on the impact of this non-native species was found in a literature search.

Management:

Physical

Hand-pulling is likely effective at controlling this invasive.

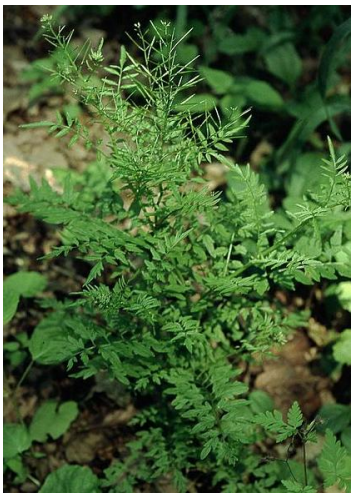
Chemical

Chemical herbicides will likely provide good control this invasive.

Giblin, David. "Cardamine Hirsuta." Burke Museum of Natural History and Culture. University of Washington. Retrieved from http://biology.burke.washington.edu/herbarium/imagecollection.php ?Genus=Cardamine&Species=hirsuta

Wikipedia. "Cardamine Hirsuta." Retrieved from http://en.wikipedia.org/wiki/Cardamine_hirsuta

Cardamine impatiens/Narrow-leaf Bittercress:



Narrow-leaf bittercress at Gwynedd Wildlife Preserve, May 21, 2014 (Photo: Nathan Hartshorne)

> "Annual or biennial; stems erect, glabrous, 2.5-8 dm tall; leaves very numerous, not much reduced upward, pinnate with 13-19 narrow, sharply-toothed, sparsely ciliate leaflets; leaf bases sagittate-auriculate; petals white, 2-3 mm or lacking; fruits 1.5-2 cm long and 1 mm wide, ascending; ocaisional in moist woods and slopes; scattered and spreading rapidly; flr. May; native to Europe." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Part of the mustard family, Narrow-leaf bittercress (*Cardamine impatiens*) was first found in the US in New Hampshire in 1916, but it is unknown how it arrived. It has currently invaded the northeastern US from Maine to North Carolina to Michigan (DCNR).

Each flower contains 10-24 seeds which can shoot. They are easily spread by water or by sticking to passing animals (DCNR).

Impact:

Narrowleaf bittercress is often found in woods with open parts in the canopy, along forest edges, stream banks, roadsides, vacant lots, and gardens. It can form dense monocultures that push out native species (DCNR).

Management:

Physical

Small infestations may be removed by hand-pulling. However, care must be taken not to cause too much disturbance or to spread seeds (DCNR).

Chemical

Chemical herbicides are likely to be effective against this invasive (DCNR).

Pennsylvania Department of Conservation and Natural Resources (DCNR). "Narrowleaf Bittercress." Invasive Plants in Pennsylvania. Retrieved from http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_010243.pdf

Carduus nutans/Nodding Thistle/Musk Thistle:

Nodding thistle at Gwynedd Wildlife Preserve, May 7th, 2014 (Photo: Nathan Hartshorne)

> "Plant to 2 m tall; leaves deeply lobed, glabrous or villous along the midvein beneath; heads solitary and nodding on naked peduncles; common in pastures, roadsides, waste ground, and ballast; mostly SE; flr. May-Aug; native to Europe; designated as a noxious weed in Pennsylvania." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Nodding thistle (*Carduus nutans*) is an invasive weed from Eurasia that was first reported in the United States in Harrisburg, PA, Nodding thistle is now widespread throughout the country. It has been declared a noxious weed in 20 states as of 1999. It prefers moist, well-drained alluvial soils, causing the most economic damage in fertile areas with limestone, but will grow in eroded uplands without difficulty (Gassman and Kok 2002).

Nodding thistle is an herbaceous biennial, but sometimes a winter annual that grows from 20 to 200 centimeters in height (Gassman and Kok 2002). It flowers in May to August (Rhoads et al. 2007). Seeds are generally dispersed by wind within about 50 meters from the parent. Each flower head may produce 1,500 seeds with 11,000 achenes per individual. The seeds may last for 10 years (Gassman and Kok 2002) though it is suggested that the depth of the seed affects how long it may last, from 3 years for shallow seeds to beyond 15 for deep burial. Self-pollination can result in a quick expansion of a minor invasion. Since so many seedlings are produced, mortality is high in the dense areas and seedling survival may be 0-46% (Zouhar 2002).

Impact:

This invasive has caused massive economic damage to rangelands where it has spread to (Gassman and Kok 2002).

Management:

Physical

Mechanical means can be effective at controlling Musk thistle, but special care has to be taken in order to not spread the seeds during implementation (ISSG 2006).

Hand-pulling or using another means to sever the plant's roots 2-4 cm beneath the base will kill it. However, flowers can still produce seeds, so they must be removed (Zouhar 2002).

Mowing can also be effective, but it must be done late, as they may still grow flowers. Thus, the best time is just before the flowers grow. As a community of Musk thistle will have variable age, mowing or cutting once will not be effective (Zouhar 2002).

Burning may be ineffective at control. If there is little competition, fire will simply open up space for Musk thistle seeds to germinate. However, frequent burning in some areas has been shown to decrease Musk thistle, depending on the severity of the fire and the ecosystem where it occurs (Zouhar 2002).

Chemical

Chemical herbicides can also be used for control (Zouhar 2002 and ISSG 2006). Foliar spray is best when the weed is in its rosette stage or just before flowering (ISSG 2006).

Biological

The first biological control agent released to control the Nodding thistle was the seed-feeding weevil *Rhinocyllus conicus*. It has a high egg potential and dispersion. *Rhinocyllus conicus* is a seed-feeding weevil that was introduced as a control agent by Canada in 1968 and by the United States in 1969. Eggs are laid on bud bracts. After hatching, larvae eat their way into the bracts and receptacles, feeding on the receptacles and florets. It overwinters in litter, but may have two generations in a year. It was not well-understood, however, and has been found to feed on many native species (Gassman and Kok 2002).

In 1974, a rosette weevil, *Trichosirocalus horridus*, was released in Virginia (and many other states since). Eggs are laid on the lower side of leaves. In 13 days, larvae hatch and feed on the plant until they are mature (Gassman and Kok 2002).

In the 1980s, attempts were made to also introduce two rosette beetles *Ceutorhynchus trimaculatus* and *Psylliodes chalcomera*, but due to concerns of non-target impacts, they were both denied. However, in 1997, *P. chalcomera* was released after studies showed it had no impact on native species. *Puccinia carduorum*, a rust fungus, had been studied as a biological control agent, but was actually introduced to North America by accident, but subsequently released as a control agent. Attempts to maintain it on native species failed as it appeared to be host-specific to Nodding Thistle (Gassman and Kok 2002).

Released only in Montana in 1996, *Urophora solstitialis*, is a seed-feeding tephritid fly. However, it sometimes consumes native plants and so has not been released elsewhere (Gassman and Kok 2002).

A root-crown fly, *Cheilosia corydon*, has also been released in a few states. Eggs are laid on young leaves in the center of the thistle rosette and young shoots. Larvae then mine into the young shoots. There are three larval instars, all of which mine (Gassman and Kok 2002).

As of 2002, establishment of *Rhinocyllus conicus*, *Trichosiroalus horridus*, and *Puccinia carduorum* have been confirmed. They also spread from the original release sites. However, the other agents had not been confirmed as established. *R. conicus* has shown more than 75 percent reductions of nodding thistle in some test sites while some sites showed up to 96 percent reduction as a result of *T. horridus*. However, *T. horridus* infestations brought about changes in the plants. While shoots were infested, many plants adapted to create more shoots, larger stems, and larger capitula. A major factor in high reductions was when there was heavy competition by native grasses reestablishing themselves when the thistle was attacked by the agents (Gassman and Kok 2002).

Gassman, A. and Kok, L. T. (2002). "Musk Thistle (Nodding Thistle)." Van Driesche, R., Lyron, Suzanne, Blossey, Bernd, Hoddle, Mark, and Reardon, Richard. Biological Control of Invasive Plants in the Eastern United States, USDA Forest Service Publication

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2006). *Carduus Nutans (herb)* Retrieved from the Global Invasive Species Database. Retrieved from http://www.issg.org/database/species/ecology.asp?si=519&fr=1&sts=sss&lang=EN

Zouhar, Kris. (2002). Carduus nutans. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/

Cerastium Fontanum/Common Mouse-ear Chickweed:

Mouse-ear chickweed (Photo: Wikipedia)

> Short-lived perennial, viscid-puberulent; leaves ovate or obovate, rounded to acute, 1-2 cm long; inflorescence crowded or becoming more open with age; bracts of the inflorescence scarious-margined; hairs of the sepals not extendeing beyond the sepal tips; petals equaling or slightly shorter than the sepals, notched to 1 mm or more; a common weed of cultivated ground; throughout; flr. Apr-Oct; native to Eurasia; FACU-. Ours is car. Trivial" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Mouse-ear chickweed (*Cerastium fontanum*) has an unclear native range, but has been recorded throughout Europe, Western Asia, and North Africa. It is currently found throughout the US and Canada as well (ISSG 2009).

Dispersal is often when seeds cling to animals or are consumed by herbivores that drop them elsewhere in their feces (ISSG 2009).

Impact:

No impact has been noted in a literature survey.

Management:

Physical

Hand-pulling is likely effective at controlling this non-native.

Mowingis not likely to be effective as it is a low-growing plant (Jantunen et al. 2007).

Chemical

Chemical herbicides will likely prove effective against this non-native.

Invasive Species Specialist Group (ISSG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Cerastium fontanum (herb)*. Retrieved from the Global Invasive Species Database.
http://www.issg.org/database/species/ecology.asp?si=1422&fr=1&sts=&lang=EN

Jantunen, Juha, Saarinen, Kimmo, Valtonen, Anu, and Saarnio, Sanna. (2007). Flowering and Seed Production Success Along Roads with Different Mowing Regimes. *Applied Vegetation Science*. Vol. 10, No. 2, pp. 285-292.

Wikipedia. "Cerastium Fontanum." Retrieved from http://en.wikipedia.org/wiki/Cerastium_fontanum

Coronilla Varia/Crown Vetch:

"Sprawling to ascending perennial 3-10 dm tall; leaves sessil, with 11-25 leaflets; flowers inkish (or white) in long-peduncled, axillary umbels; fruits linear, 4-angled; plants extensively along highways; throughout; flr. Jun-Nov; native to S. Europe." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

A member of the pea family, Crown vetch (*Coronilla varia*), is a perennial creeping herb (ISSG 2005).

Crown vetch reproduces both through its heavy seed production as well as vegetatively through rhizomes. Each plant will produce 11-1000 seeds and develop a new plant through rhizomes once a year. The seed bank has been known to last at least 10 years (ISSG 2005).

It is tolerant of both drought and heavy precipitation. It lives on a wide variety of soils. However, it is not tolerant of shade (ISSG 2005).

Crown vetch has been used widely in the United States for erosion control as well as to reclaim land and acid mine waste (ISSG 2005).

Impact:

It is often found in grasslands, disturbed areas, and urban areas. It increases the nitrogen in the soil so it can alter the soil, creating ripe conditions for other invasives (ISSG 2005).

Management:

Physical

Hand-pulling can be effective, but all parts of the roots must be removed to prevent regrowth.

Mowing can be effective, but if done only once a year, it does little except to help prevent the spread. Mowing around an invaded area can also help prevent the spread (ISSG 2005).

Chemical

Many chemical herbicides will be effective at controlling this invasive. However, Crown vetch has been shown to be tolerant to imazethapyr, imazapic as well as other herbicides (ISSG 2005).

Invasive Species Specialist Group (ISSG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Coronilla varia (herb)*. Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=276

Cirsium Arvense/Canada Thistle:

Canada thistle at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> Colonial perennial; leaves glabrous or more or less white tomentose beneath; heads numerous in an open, branched inflorescence, unisexual or nearly so; the plants polygamo-dioecious; involucres 1-2 cm high; corollas pink-purple, longer than the pappus in staminate heads, shorter than the pappus in pistillate heads; common in fields, pastures, roadsides, and waste ground; throughout; flr. Jun-Sep; native to Eurasia; designated as a noxious weed in Pennsylvania; FACU." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Canada thistle (*Cirsium arvense*) is native to Europe, North Africa, and across much of Asia. It has invaded much of the eastern United States, except some of the south. It was probably brought to North America in the 1600s when it contaminated seeds or ship ballast. It spread so much that by 1795, a Vermont law was enacted to help prevent its spread (Zouhar 2001).

Canada thistle prefers full sun and grows in all soils except the waterlogged. Thus, it is tolerant of a lot of conditions, but reports vary. For example, some sources suggest that the thistle is not tolerant of saline soils, but others state that it is (Zouhar 2001).

Canada thistle produces a large number of seeds that are dispersed by wind. It also has a creeping root system that reproduces vegetatively (McClay 2002). Estimates of seed production is 0-40,000 seeds per stem. This may be the result of a variety of poor conditions that may reduce seed numbers. Seeds have been shown to disperse hundreds of meters and even kilometers from their source. Seeds are generally dispersed by wind which have been shown to disperse hundreds of meters and even kilometers. Horses that have consumed seeds are common dispersers of this weed along trails. The seed bank is not strong, usually lasting less than 5 years, with most lost in the first year due to germination. When buried 8 inches, the seed bank has been shown to last up to 22 years (Zouhar 2001).

Despite all the seed reproduction, most of the species's efforts go into vegetative reproduction. The weed can reproduce through the roots, root fragments, and underground stem tissue. Any point on the roots is a viable location for sprouting. There can be 13-22 feet of horizontal root growth in a single season. After only 18 weeks, a single plant may produce 26 adventitious shoots, 154 adventitious root buds, and 364 feet of roots (Zouhar 2001).

Canada thistle does have some beneficial uses. For instance, it attracts honeybees. Thistles are edible and have been considered medicinal. The roots and shoots are supposed to be tasty when harvested in the early spring, though the roots may be an emetic. Medicinal uses have included as a mouthwash, a treatment for tuberculosis, as tonic for gastrointestinal problems, and as a cure for swollen veins ("cirsos" is greek for "swollen vein") (Zouhar 2001).

Impact:

Canada thistle's vegetative reproduction allows it to form dense mats, pushing out all other vegetation (Zouhar 2001). It also has some allelopathic effects, inhibiting growth in some plants (Stachon and Zimdahl 1980).

Canada thistle is a very economically damaging weed, lowering the value of rangeland and cropland across the country. Rangeland damage is the result of the weed not being consumed by grazers. For cropland, it prevents the growth of crops. When densities may reach 173 shoots per square meter, merely 20 shoots per square meter have been shown to cause 34% yield losses in barley, 26% in canola, 36% in winter wheat, and 48% in alfalfa seed (McClay 2002).

It is often found in grasslands and disturbed areas.
Canada thistle can be an invasive species in some natural communities, including prairie potholes and wet or wet-mesic grasslands in the Great Plains and sedge meadows in the upper Midwest (Nuzzo, 1997). It usually is a problem in disturbed areas and

Management:

Physical

Care has to be taken in how and when physical methods of control are done. Seedlings are more susceptible to physical methods, but by 19 days, they can regenerate top-growth after clipping. Therefore, it is recommended that seedlings be pulled within 2.5 weeks or they will become perennial. A more mature 40-day old plant may produce 2-3 shoots. Root fragments between 6 weeks and 2 years of age and only 0.2 inches long can regenerate into an entire plant. It has been shown that an 18-week-old plant could produce 930 shoots when the roots were cut into 10-cm long segments.

Repeated mowing can reduce carbohydrate stores in roots, eventually damaging the plants enough to kill them. Mowing has to be done every 7-28 days for up to 4 years. One site was mowed for several years and then stopped. Native prairie was then able to take over.

If the primary stem is removed to control seed production, new shoots may grow to compensate. Therefore, 8 inches of stem must be remaining. However, in humid areas, there will be new shoots regardless.

As Canada thistle reproduces quickly and strongly from its root system, burning is not likely to control it. Some studies have suggested that certain fire regimes may be more beneficial, such as 5 burns in 7 years, or late spring burns every 4 years.

Chemical

Chemical herbicides have had limited success on Canada thistle. Foliar applications are best, but need to be done repeatedly.

Biological:

There is a lot of potential for biological control of Canada thistle. However, there are many related North American species that are cause for concern. Furthermore, this is a common agriculture weed in its native ranges. Therefore, a plethora of herbivores has not prevented it from being a pest. So far, several non-native species have been accidentally released that feed on this weed. The leaf-feeding tortoise beetle *Cassida rubiginosa* is currently in the eastern US, the seed-feeding weevil *Larinus planus* is in PA, MD, OH, and NY, the seed-head fly *Terellia ruficauda* is widespread across the eastern US, and the root-feeding weevil *Cleonis pigra* is in NY, PA, MI, and IN. The fungus *Puccinia punctiformis* is widespread across the continent. There is also a phytopathogenic bacterium in Maryland, *Pseudomonas syringae*, that has been shown to result in 57% mortality rates in Canada thistle. Lastly, the seed-head weevil *Rhinocyllus conicus* was released on purpose to control Nodding thistle (*Carduus nutans*) and has been found feeding on Canada thistle.

Aside from biological augmentation of *C. rubiginosa* and *C. pigra*, there have been releases made of other biological control agents. A stem-and petiole-galling fly *Urophora cardui*, the weevil *Ceutorhynchus litura*, and the leaf-feeding beetle *Altica carduorum* have all been released.

McClay, A. S. (2002). "Canada Thistle." Van Driesche, R., Lyron, Suzanne, Blossey, Bernd, Hoddle, Mark, and Reardon, Richard. Biological Control of Invasive Plants in the Eastern United States. USDA Forest Service Publication.

Stachon, W. J. and Zimdahl, R. L. (1980). Allelopathic activity of Canada thistle (Cirsium arvense) in Colorado. *Weed Science*, 83-86.

Zouhar, Kris. (2001). "Cirsium Arvense." Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/

Daucus carota/Wild Carrot/Queen Anne's Lace:

Queen Anne's lace (Photo: Wikipedia)

> "Biennial, 4-10 dm tall, glabrous to roughly hairy; leaves finely divided; flowers white (the central flower of each umbellet often purple); umbels 4-12 cm across usually with 20 or more rays; roadsides, gardens, old fields, and waste ground; throughout; flowers Jun-Sept; native to Eurasia." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The wild carrot (*Daucus carota*) is an invasive that is currently found in all of the US contiguous states. Native to Asia and Europe, it is a biennial with a basal rosette of leaves first year and erect flowering stalk in second year and reaches 3-4 feet (US Forest Service 2006). It was brought to the US in the 1700s. Daucus carota mostly outcrosses, so populations have more genetic diversity than if they self-crossed or cloned (Clements et al. 2004). It blooms from May to October. It has a taproot that smells a bit like a carrot as it is the ancestor to the cultivated one. One plant can produce 1,000 to 40,000 seeds. Seeds stay viable in the soil for 1-2 years (US Forest Service 2006).

Impact:

It is often found in dry prairies, abandoned fields, waste sites, and roadsides (Minnesota DNR). Wild carrot is especially a problem in no-tillage crop production (Stachler et al. 2009). It prefers well-drained, fine soil in the full sun (US Forest Service 2006). While it can invade disturbed areas, outcompeting native grasses by maturing faster, when native grasses become established, they do well in pushing it out (US Forest Service 2006).

Management:

Physical

Hand-pulling or mowing in mid or late summer before the seeds set can be an effective control (US Forest Service 2006).

Burning is not an effective method of control as it may actually induce seeds to germinate (US Forest Service 2006)

Chemical

One emerging problem is that populations have been found to be resistant to the herbicide 2, 4-D in the upper Midwest as well as sites in Canada (Stachler et al. 2009). Aside from 2, 4-D, triclophyr is also recommended as an herbicide ("Queen Anne's Lace" 2006).

Clements, D. R., DiTommaso, A., Jordan, N., Booth, B. D., Cardina, J., Doohan, D., Mohler, Charles L., Murphy, Stephen D., and Swanton, C. J. (2004). Adaptability of Plants Invading North American Cropland. *Agriculture, Ecosystems & Environment.* Vol. 104, No. 3, pp. 379-398.

Stachler, J. M., Kells, J. J., & Penner, D. (2009). Resistance of Wild Carrot (Daucus carota) to 2, 4-D in Michigan1.

United States Forest Service, Northeast Region. (2006). "Queen Anne's Lace." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/queen-annes-lace.pdf

Wikipedia. "Daucus Carota." Retrieved from http://en.wikipedia.org/wiki/Daucus_carota

Duchesnea indica/Indian Strawberry:

(Left) Indian strawberry at Gwynedd Wildlife Preserve, May 20, 2014. (Right) Native Wild strawberry at Gwynedd Wildife Preserve, May 3rd, 2014 (Photos: Nathan Hartshorne)

> "Low-growing, spreading, perennial herb; leaves trifoliate; flowers solitary from the nodes of the decumbent spreading stems or stolons, with 5 yellow petals and 5 sepals alternating with 5 larger, 3-toothed bracts; receptacle enlarging and turning red in fruit (but not becoming sweet and edible), nearly covered with numerous achenes; extensively naturalized in woods, lawns, and waste ground; SE; flowers Mar-Sept; native to Asia; FACU-." – Plants of Pennsylvania

General:

The Indian Strawberry (*Duchesnea indica*) is native to East Asia and has invaded 31 US states and 2 Canadian provinces (USDA Natural Resources Conservation Service Plants Database). It is a perennial creeping plant that reproduces both sexually as well as vegetatively (ISSG 2008).

Impact:

It is found in a variety of areas including agricultural areas, natural forests, planted forests, riparian zones, rural/disturbed, and wetlands (ISSG 2008).

Control:

No methods of control have been found in a literature survey, however hand-pulling is likely effective, though since it reproduces vegetatively, one must be careful. Given its preference for wet soils such as wetlands, it may be easy to pull.

Herbicides will likely be effective at controlling this invasive.

United States Department of Agriculture. Natural Resources and Conservation Service. *Duchesnea Indica*. Retrieved from http://plants.usda.gov/core/profile?symbol=DUIN

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2008). *Duchesnea Indica (herb)* Retrieved from the Global Invasive Species Database. Retrievedd from http://www.issg.org/database/species/ecology.asp?si=1286&fr= 1&sts=sss&lang=EN

Dipsacus fullonum/Common Teasel (also Dipsacus sylvestris):


Common teasel at Gwynedd Wildlife Preserve, April 18, 2014 (Photos: Nathan Hartshorne)

> "Tall biennials to 2 m tall; prickly on the angles of the stem and leaf midribs; leaves opposite, sessile or even fused at the base; inflorescence ovoid to sub-cylindric, 3-10 cm long, surrounded by narrow, spreading, or up-curved involucral bracts the longest of which exceed the head; flowers pale lavender to white; 4-merous; flr. Jul-Aug; native to Europe, brought by the earliest settlers for use in the preparation of wool for spinning." (for all *Dipsacus*)
> "Bracts on the receptacle straight, awn-tipped; roadsides, fields, and waste ground; common throughout; FACU-." – *Plants of Pennsylvania* (Rhoads and Block 2007) (for *Dipsacus sylvestris*)

General:

Common teasel (*Dipsacus fullonum*) is a native of Eurasia that was introduced to North America as early as the 1700s (Gucker 2009). Common teasel and another invasive, cutleaf teasel (*Dipsacus laciniatus*), likely arrived in conjunction with the cultivated variety, *Dipsacus sativus*. Cultivated teasel was an important crop in the process of making wool thread during the carding, or "teasing" stage (Rector et al. 2006).

Teasel is a rosette in its first year, sprouting a bolt and seeds in the second or subsequent years and then soon dies. Teasel prefers open sun habitats. Individual plants may produce 3,000 seeds, though the seed bank is short-lived. In one study, less than 1% of seeds laying in soil for 5 years could be germinated (Gucker 2009).

Impact:

Teasel may form large monocultures where native vegetation is suppressed. There may be allelopathic properties of teasel as its seeds appear to prevent the germination of other species. Teasel is often found in riparian areas, open fields, forest openings, and disturbed sites (Gucker 2009).

Control:

Physical

For mechanical methods of control, cutting teasel may not be effective as it may still resprout and flower. However, when timed correctly, for instance, just as they flower, cutting should be effective (Gucker 2009).

Fire is not likely a good method for controlling teasel. Unless it is of high intensity, the seeds will likely survive and germinate (Gucker 2009).

Chemical

Using chemical herbicides can provide effective control, however when used in early spring or late fall, damaging associated vegetation can be more easily avoided (Gucker 2009).

Biological

Currently there is no biological control for any teasel in North America. In the entire Dipsacaceae family, there are no members native to the Americas. Therefore, options of importing species-specific biocontrol agents may be found. Surveys have found 102 species of insects, 27 fungi, 3 mites, 2 viruses, and 1 nematode that prey on teasel in Europe. Studies are being conducted to determine if any will be appropriate for release in North America (Rector et al. 2006). Large herbivores generally do not like it, but those that do can provide control through grazing (Gucker 2009).

Gucker, Corey L. 2009. Dipsacus fullonum, D. laciniatus. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/plants/forb/dipspp/all.html

Rector, B. G., Harizanova, V., Sforza, R., Widmer, T., and Wiedenmann, R. N. (2006). Prospects for biological control of teasels, Dipsacus spp., a new target in the United States. *Biological Control*. Vol. 36, No. 1, pp. 1-14.

Glechoma hederacea/Ground-Ivy:

Ground ivy at Gwynedd Wildlife Preserve, April 27th, 2014 (Photos: Nathan Hartshorne)

> "Stems creeping, to 1 m long; leaves rotund to reniform, 1.5-3 cm wide, crenate calyx 5.5-9 mm long; braclets subulate, shorter than calyx; flowers purple; common in fields, disturbed woods, roadsides, gardens, and waste ground; throughout; flr. Apr-Jun; native to Eurasia; FACU" – *Plants of Pennsylvania* (Rhoads and Block 2007).

General:

Native to Eurasia, Ground ivy (*Glechoma hederacea*) is a perennial mat-forming herb. It is currently found in all continental US states except New Mexico and Nevada as well as across southern Canada. The earliest record of this weed in the US is from 1814. Pennsylvania, Maryland, and Virginia were cited in the 1814 document, so it has a long history in the area (Scholler and Bölmann 2004).

Ground ivy can reproduce through nodes on trailing stems that may reach 2 meters in a year. It can also reproduce through nutlets produced by hermaphroditic flowers (it also has sterile-male flowers). Each flower produces up to 4 seeds, which many believe are dispersed by ants. It is believed that vegetative fragments distributed by humans are the reason for the rapid dispersal by a rather slow-spreading plant (Scholler and Bölmann 2004).

It does not like strongly acidic or saline soils. It prefers decent amounts of phosphate, nitrogen, and Ca^{2+}. Although it likes wet soils, it is not likely to be found in a wetland area (Hutchings and Price 1999).

Impact:

As Ground ivy produces dense mats, it can displace other plant species (Scholler and Bölmann 2004). However, it often simply infiltrates the other vegetation. It is generally found in shaded habitats such as woodlands and hedgerows, however it is often in grasslands with full sunlight. It can even dominate areas at the edges of arable fields (Hutchings and Price 1999). Locations are often disturbed or waste areas, open woods, forest edges, lawns, and right-of-ways (US Forest Service 2006).

Ground ivy can also produce allelochemicals, reducing competition from other plants (Hutchings and Price 1999).

Control:

Physical

Plants can be pulled or raked, especially when the soil is moist (US Forest Service 2006). However, as the weed is often spread through vegetation fragments (Scholler and Bölmann 2004), care must be taken that all parts are removed. Ground ivy is known for having high plasticity in response to shade and light (Slade and Hutchings 1987). Observations at Gwynedd Wildlife Preserve confirm this ability, but in response to mowing. Areas mowed close to the ground have low-ground ground ivy, with very low flowers, while un-mowed areas have taller plants. Thus, mowing is not an effective control method.

Chemical

Applications of chemical herbicides should be effective at removing infestations (US Forest Service 2006).

Biological

A rust fungus, *Puccinia glechomatis*, has recently been discovered infecting Ground ivy (US Forest Service 2006; Böllmann and Scholler 2006). The first published references were in 2000, but the distribution is already wide-spread. While Scholler and Böllmann (2004) suggest that early spread of Ground ivy was 30 km/year and is currently 50 km/year, the rust fungus is spreading at an estimated 120 km/year (Scholler and Böllmann 2004; Böllmann and Scholler 2006). The disease may cause severe damage or even death of plants (US Forest Service 2006; Böllmann and Scholler 2006). Monocultures, as often formed by ground ivy, may be especially susceptible if not resistant to the fungus (Böllmann and Scholler 2006).

Böllmann, J. and Scholler, M. (2006). Life cycle and life strategy features of Puccinia glechomatis (Uredinales) favorable for extending the natural range of distribution. *Mycoscience*. Vol. 47, No. 3, pp. 152-158.

Hutchings, M. J. and Price, E. A. (1999). Glechoma hederacea L.(Nepeta glechoma Benth., N. hederacea (L.) Trev.). *Journal of Ecolog.* Vol. 87, No. 2, pp. 347-364.

Scholler, M. and Böllmann, J. (2004). Glechoma hederacea (Lamiaceae) in North America: invasion history and current distribution. *Feddes Repertorium*, Vol. 115, No. 1-2, pp. 178-188.

Slade, A. J. and Hutchings, M. J. (1987). Clonal integration and plasticity in foraging behaviour in Glechoma hederacea. *The Journal of Ecology*, 1023-1036.

United States Forest Service, Northeastern Area. (2006). "Ground Ivy." USDA. Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/ground-ivy.pdf

Hemerocallus fulva/Day-lily:

Day lily (Photo: Wikipedia)

> "Herb to 1 m tall; leaves to 3 cm wide; flowers not fragrant; perianth orange, 6 cm or more long; fruit not developing; common in woods borders, clearings, roadsides, and disturbed ground; throughout; flowers June-early August; native to Asia; UPL. A double-flowered form occurs in some areas." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Daylily (*Hemerocallus* fulva) is a native to Asia that was brought to the United States in the 19th century as an ornamental. The plant has become so popular that there are over 40,000 registered cultivars. Interestingly, buds and flowers are edible and are described as "sweet-spicy or peppery" (Swearingen et al. 2010). They are commonly used in Asian cooking (Rhoads and Block 2011). Plant Invaders of the Mid-Atlantic Areas states that the Daylily reproduces both through underground tubers as well as seeds, however, paflora.org states that the flowers are actually sterile and produce no seeds (Swearingen et al. 2010; Rhoads and Block 2011). Plant dispersal is, then, only through the growth and distribution of the tubers which can be spread by human impacts (road work) or through flooding events (Rhoads and Block 2011).

Impact:

Daylilies can spread through a site, creating a dense population, pushing out native vegetation. They are most often found near old homes where they have escaped. They are often found in open fields, floodplains, moist woods, and forest edges (Swearingen et al. 2010).

Control:

Physical

Manual methods of control have to take into consideration the vegetative growth of the Daylily (Swearingen et al. 2010; Rhoads and Block 2011). Thus the plant may persist for years with only the above-surface vegetation removed (Rhoads and Block 2011).

Chemical

Chemical herbicides will likely have effective control (Swearingen et al. 2010; Rhoads and Block 2011).

Rhoads, Ann F. and Block, Timothy. "Orange daylily (*Hemerocallis fulva*) Day-lily Family (Hemerocallidaceae)." Invasive Species Fact Sheet. Morris Arboretum. Accessed 04/14/2014 http://www.paflora.org/pdf/INV-Fact%20Sheets/Hemerocallis%20fulva.pdf

Swearingen, J., B. Slattery, K. Reshetiloff, and S. Zwicker. 2010. "Common Daylily." Plant Invaders of Mid-Atlantic Natural Areas, 4th ed. National Park Service and U.S. Fish and Wildlife Service. Washington, DC. Accessed 4/16/2014. Retrieved from http://www.nps.gov/plants/alien/pubs/ midatlantic/hefu.htm

Wikipedia. "Hemerocallis Fulva." Retrieved from http://en.wikipedia.org/wiki/Day_lily

Hesperis matronalis/Dame's-rocket:

Dame's rocket at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Erect biennial, 5-13 dm tall, with leafy stems and showy purple to white flowers; both simple and branched hairs present; leaves pubescent, simple, lanceolate to ovate-lanceolate, 5-20 cm long, the lower long-petioled, the upper sessile; flowers fragrant; sepals pubescent, the inner pair strongly saccate at the base; petals 1.8-2.5 cm; fruits terete, 4-15 cm; seeds in 1 row per locule, wingless; common in low woods, floodplains, wet meadows, and roadside ditches; throughout; flr. May-Jun; native to Europe; FACU-." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Dame's rocket (*Hesperis matronalis*) has invaded nearly all of the United States except some of the South. It was originally an ornamental brought from Europe in the early 1600s that has escaped gardens. It is also quite edible and the leaves are rich in vitamin C. It is even cultivated in order to extract its seed oil for perfume. Each plant may produce thousands of seeds and the seed bank is long-lasting (US Forest Service). Dame's rocket can self-seed easily (Missouri Botanical Garden). It prefers partial sun (though will tolerate full sun) with semi-moist to dry soil that is fertile and loamy. It does poorly in acidic soil (US Forest Service).

Impact:

Dame's rocket is often mixed in with commercial "wildflower" seed packages and is spread with them. It is often found on roadsides, forest edges and interiors, moist meadows, thickets, fence rows, and ditches. It can prevent germination of other seeds by using up resources (US Forest Service).

Control:

Physical

Mechanical methods can be utilized at any time before the seeds are produced. However, care must be given not to disturb a site too much and encourage seed germination. Controlled burns may also be effective (US Forest Service).

Chemical

Herbicides should provide control over this invasive (US Forest Service).

Biological

Dame's rocket has no insect or disease problems in North America and even tolerates deer herbivory quite well (Missouri Botanical Garden).

Missouri Botanical Garden Plant Finder. "Hesperus Matronalis." Retrieved from: http://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=d200

United States Forest Service. "Dame's Rocket." Forest Invasive Plants Resource Center . Retrieved from: http://na.fs.fed.us/spfo/invasiveplants/factsheets/pdf/dames-rocket.pdf

Iris Pseudacorus /Yellow Iris:

Yellow iris at Gwynedd Wildlife Preserve, May 20th, 2014 (Photo: Nathan Hartshorne)

> "Clump forming, stems to 1 m tall from short, thick rhizomes; leaves erect, 8-20 mm wide; flowers bright yellow; capsules 5-8 cm long, 6-angled; frequent in marshes, shallow water, or moist shores; flr. Late May-Jul; native to Europe; OBL." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Yellow iris (*Iris pseudacorus*) is a native to Europe, Asia, and North Africa that now occurs in most of US except some of Midwest and southwest. It was originally brought to North America as an ornamental, but has since escaped. The first documentation of the plant in the United States was in 1771 (Stone 2009).

This non-native is often used for bioremediation as it can absorb heavy metals and reduce the bacterial loads in water. As it prefers wet areas that are prone to flooding, it is also good for erosion control. It has also been used as a diuretic, to prevent gas, to treat eczema, and as a coffee substitute (Stone 2009).

Yellow iris prefers wet areas, and moving water often helps it spread to new locations. It has a strong root system that helps it manage fluctuations in water level. It also reproduces both through seeds and vegetatively through roots. Rhizomes that break off the roots in storms may grow into new plants. Even after being dry for 3 months, a rhizome may still establish itself once wet. Rhizomes in plants 10 years old will independently break apart and form new plants (Stone 2009).

This plant will grow on a variety of surfaces as long as it is wet. It prefers full sun to partial shade, but will tolerate heavy shade. Seedlings may not be as tolerant (Stone 2009).

Impact:

Yellow iris can form dense vegetation that pushes out natives and alters successional systems. The changes it causes to habitats are not good for waterfowl or fish. It can also clog streams, irrigation channels, and pipes (Stone 2009).

Management:

Physical

As Yellow iris reproduces vegetatively, removal of all rhizomes must be done when digging up the plant. Repeated mowing can also reduce vigor and kill the plant (Stone 2009).

Chemical

Chemical herbicides should provide effective control over this invasive (Stone 2009).

Biological

There are many species that currently attack this plant. Borers, rot slugs, and black vine weevils feed on it and many fungi attack it (Stone 2009).

Stone, Katharine R. (2009). "Iris pseudacorus." Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/plants/forb/iripse/all.html

Lamium Purpureum/Purple Dead-Nettle:

Purple dead-nettle at Gwynedd Wildlife Preserve, May 11, 2014 (Photo: Nathan Hartshorne)

> "Annual, similar to *L. amplexicaule* in habit and size; calyx 5-7 mm long, the lobes about as long as the tube; common in wooded slopes, fields, and roadsides throughout; flr. Apr-Oct; native to Eurasia." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Purple dead-nettle (*Lamium purpureum*) is native to Europe, Asia, and North Africa. A member of the mint family, it has a faint minty smell (Lowry et al. 2011).

Each plant can produce 30,000 seeds and once mature, seeds may germinate immediately. It prefers moist soil, but is tolerant of dry conditions. Purple dead-nettle has been used for medicinal reasons and the leaves are edible raw or cooked (Lowry et al. 2011).

Impact:

Soybean cyst nematode is the cause of major damage to the soybean industry, and Purple dead-nettle is an alternate host. Thus, this invasive weed helps promote the soybean cyst nematode and causes economic losses (Harrison et al. 2008). Similarly, it is an alternate host of alfalfa weevil (Lowry et al. 2011).

Purple dead-nettle has been shown to have allelopathic properties (Jones et al. 2012). Thus, it will inhibit the growth of native plant species.

Management:

Physical

Physical methods such as hand-pulling, hoeing, and tilling will likely provide control over this species. Also, seeds can be killed with solarization (Lowry et al. 2011).

Chemical

Chemical herbicides will likely provide control over this invasive.

Harrison, S. Kent, Venkatesh, Ramarao, and Riedel, Richard M. Purple Deadnettle (Lamium purpureum) Emergence and Removal Time Effects on Soybean Cyst Nematode (Heterodera glycines). *Weed Science*. Vol. 56, No. 2, pp. 327-335.

Jones, C. D., Woods, K. E., and Setzer, W. N. (2012). A chemical ecological investigation of the allelopathic potential of Lamium amplexicaule and Lamium purpureum. *Open Journal of Ecology*. Vol, 2, No. 4.

Lowry, Brenda Jarvis, Whitesides, Ralph E., Dewey, Steven A., Ransom, Corey V., and Banner, Roger E. (2011). Common Weeds of the Yard and Garden. Utah State University Extension. http://extension.usu.edu/files/publications/publication/Horticulture_Weeds_2011-01pr.pdf

Lysimachia nummularia/Moneywort:

Moneywort at Gwynedd Wildlife Preserve, May 4th, 2014 (Photo: Nathan Hartshorne)

> Creeping, mat-forming perennial; leaves opposite, short-petioled, oval to nearly round; flowers 2-3 cm wide, solitary in the leaf axils; corolla yellow dotted with dark red; a common weed of lawns, meadows, wet woods, and floodplains throughout; flr. Late May-Oct; native to Europe; FACW-." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Moneywort (*Lysimachia nummularia*) is native to Eurasia and was introduced to North America as an ornamental groundcover. It is sometimes called "creeping Charlie" but should not be confused with *Glechoma hederacea* which is also sometimes called "creeping Charlie." It is widespread in the US, covering the entire Eastern United States with the exception of Florida, the west coast, and some central states (US Forest Service 2005).

Moneywort reproduces both through seeds and vegetatively through rooting nodes. It is believed that some animals aid in dispersal, but the process is not yet known (US Forest Service 2005).

Impact:

Moneywort is an aggressive invader. It prefers very moist areas and tends to invade wet meadows, swamps, floodplain forests, and along bodies of water (US Forest Service 2005).

Control:

Physical

Hand-pulling moneywort is an effective control measure. However, as it will easily reproduce vegetatively, all parts must be removed and transported away. High water levels as well as tall plants and shade will kill it. Mowing is ineffective as it grows close to the ground (US Forest Service 2005).

Chemical

Chemical herbicides can be effective at controlling this invasive. However, as it is often occurring in wetlands, regular herbicides should not used. Wetland-specific herbicides such as Rodeo are appropriate (US Forest Service 2005).

United States Forest Service, Northeastern Area. (2005). "Moneywort." USDA. Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/monewart.pdf

Narcissus pseudonarcissus/Daffodil:

Daffodils at Gwynedd Wildlife Preserve. (Left) Cultivated and (right) escaped. April 20th, 2014 (Photo: Nathan Hartshorne)

> "Herb to 4 dm tall; leaves to 1.2 cm wide; perianth yellow, the segments to 2.5 cm long, equaling or shorter than the often fluted or frilled corona; cultivated and occasionally escaped; native to Europe." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Daffodil (*Narcissus pseudonarcissus*) is a long-lived plant native to Europe. A single individual might be a reproducing adult, an adult, a sub-adult, or a juvenile and individuals may move from one stage to another in either direction. It reproduces through seed, adventitious roots, and bulbs. Seed production is not strong and seedlings do not often survive very well. Seed distribution is not far; they generally fall near the parent. There is often more seed production and vegetative offspring in open areas than closed canopies (Barkham 1980).

Impact:

Daffodils form clumps, producing more when there is disturbance, so they have the potential to push out native vegetation. They do not, however, reproduce very quickly (Barkham 1980).

Management:

Physical

Hand-pulling may be effective as long as bulbs and roots are removed.

Chemical

Chemical herbicides are likely to be effective.

Barkham, J. P. (1980). Population Dynamics of the Wild Daffodil (Narcissus Pseudonarcissus): I. Clonal Growth, Seed Reproduction, Mortality and the Effects of Density. *Journal of Ecology*. Vol. 68, No. 2, pp. 607-633.

Ornithogalum Umbellatum/Star-of-Bethlehem:

Star-of-Bethlehem and leaf with its distinctive stripe down the middle at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Herb to 3 dm tall; leaves 2-6 mm wide; lower pedicels >1 cm long, longer than the bracts; perianth white with green stripes on the back, 1-2 cm long; frequent in lawns and moist disturbed ground; mostly S; flr. Apr-Jun; native to Europe; FACU." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Star-of-Bethlehem (*Ornithogalum umbellatum*) is native to western Asia, North Africa, and Europe. Originally brought to the US as an ornamental, it has since escaped and become invasive. Star-of-Bethlehem reproduces both vegetatively through underground bulb production, but reproduces through seeds as well (Breeden and Brosnan).

Impact:

A poisonous plant, it has been known to harm people who consumed it. It is often found on riverbanks, early successional forests, forest edges, floodplains, wet meadows, yards, and gardens (Breeden and Brosnan).

Management:

Physical

Hand-pulling can remove the plant, however the bulbs are often deep and need to be removed as well (Breeden and Brosnan).

Chemical

Chemical herbicides are often ineffective at controlling this species. Even for those that do work, repeated applications are often necessary. Herbicides recommended are: Buctril, Dismiss, QuickSilver, and Surge (Breeden and Brosnan).

Breeden, Greg and Brosnan, James T. "Star-of-Bethlehem, Ornithogalum Umbellatum." Turfgrass Science at the University of Tennessee. University of Tennessee Extension. Retrieved from http://www.tennesseeturfgrassweeds.org/admin/Lists/Fact%20Sheets/Attachments/6/w216%20star-of-bethlehem.pdf

Polygonum perfoliata/Mile-a-Minute Weed/Devil's Tear-thumb:

Mile-a-minute weed (Photo: Wikipedia)

> "Slender, annual vine with reflexed prickles and barbs; leaves roughly triangular with barbed midribs; ocreae conspicuous, shallow, saucer-like collars at the nodes; inflorescences axillary or terminal panicles with discoid ocreolae similar to the ocreae; flowers creamy-white; perianth wingless, enlarging and becoming fleshy in fruit; fruit a small, juicy blue berry; climbing or sprawling in thickets, open woodlands, meadows, fields, and roadsides; S; native to Asia, has become invasive in Pennsylvania; FAC." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Mile-a-Minute Weed (*Polygonum perfoliatum*) also known as Devil's tear-thumb, is a native of East Asia that has invaded seven states and Washington, DC. It is known for its numerous little thorns. It has been introduced to the United States three times in over 120 years. The first introduction in 1890 in Portland, Oregon was eradicated, as was the second in Beltsville, Maryland in 1937. The third, however, in 1938 in Stewartstown, Pennsylvania was not. It was imported in the pots of a nursery owner's Asian rhododendron. He transplanted it to see if anything of value would appear in a mature plant. Nothing did, and he killed it, but the damage was done as the seeds had already been distributed by birds. Interestingly, the population stayed small and local for 40 years, however it recently began to spread at incredible rates around the country, likely due to the concurrent explosion in deer population (Tallamy 2009).

Mile-a-minute weed has been described as both an annual and perennial, but behaves like an annual in North America. It produces blueberry-like fruits about 5 mm in diameter that are consumed by animals that spread the seeds in their feces. Besides through seeds, new plants can form when new roots grow from nodes on climbing stems, developing into new plants. New plants have green stems, older ones red, and mature, woody. Old plants' main stems may be 1 cm in diameter and supported by a taproot. Where frost does not occur, the plant has been found to grow all year long, but frost will kill the weed (Wu et al. 2002).

Mature plants can produce more than 2200 seeds (Lake et al. 2011). Wu et al. (2002) states that the seed bank lasts 4 years, while Lake et al. (2011) says it is 6 years (Wu et al. 2002; Lake et al. 2011). Either way, the longer the seed bank, the more difficult it is to control an invasive as it requires monitoring.

Impact:

Mile-a-minute weed can be quite damaging, as it may cover every other plant in an area, forming a dense, thorny covering. Although often low-lying, it may climb has high as 8 meters. Costs range from 60 to 500 dollars a hectare for weed management (Wu et al. 2002).

Mile-a-minute weed is very opportunistic, taking over places where other invasives have been eradicated. For example, kudzu eradication areas in Washington, DC, have seen subsequent mile-a-minute weed infestations (Wu et al. 2002).

The weed is often found in disturbed areas, right-of-ways, edge habitats, riparian areas, alongside roads, and places with wet soils. It does not handle full-shade well (US Forest Service 2005).

Control:

Physical

Mechanical methods of control such as hand-pulling can be effective, but preferably done before the stems and leaves produce barbs. This can be done throughout the summer. Repeated mowing is another viable option which will prevent the plants from flowering and seeding (US Forest Service 2005).

Chemical

Applications of chemical herbicides are also effective (US Forest Service 2005).

Biological

When searching for biological control agents, surveys in the United States have uncovered many insects that feed on mile-a-minute weed. A survey from 1981 through 1983 found 34 species that developed on the plant and 12 species that consumed it as adults, but none did significant damage. A survey done in 1998 found a Japanese beetle doing significant defoliation to the plant, but none others (Wu et al. 2002). The USDA commissioned surveys in Asia for host-specific herbivores of Mile-a-minute weed from 1996 to 2001. 111 insects were identified in this survey. Due to its population density and distribution as well as its host range and damage it caused to mile-a-minute, the weevil *Rhinoncomimus latipes* was chosen for further study as a biological control agent in the United States. After proving itself as extremely host-specific, R. latipes was released for biological control in 2004. As of 2009, it has been released in 10 states. One chosen site was in Chester county, PA, which is near Gwynedd Wildlife Preserve. Field studies of the release have shown that the weevil is effective at finding remote populations of Mile-a-minute weed. In fact, dispersion was quick enough that control plots were overtaken by the weevil 4 months after release and abandoned after little more than a year. Thus, data are a bit skewed, but it appears that the weevil has done significant damage to the weed (Lake et al. 2011).

Lake, E. C., Hough-Goldstein, J., Shropshire, K. J., & D'Amico, V. (2011). Establishment and dispersal of the biological control weevil Rhinoncomimus latipes on mile-a-minute weed, Persicaria perfoliata. *Biological Control*. Vol. 48, No. 3, pp. 294-301.

Tallamy, Douglas. (2009). Bringing Nature Home: How You Can Sustain Wildlife With Native Plants. Timber Press.

United States Forest Service, Northeast Region. (2005). "Mile-a-minute Weed." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/mile-a-minute_weed.pdf

Wikipedia. "Polygonum Perfoliatum." Retrieved from http://en.wikipedia.org/wiki/Polygonum_perfoliatum

Wu, Yun, Reardon, C., and Jian-qing, Ding. (2002). "Mile-a-Minute Weed." Van Driesche, R., Lyron, Suzanne, Blossey, Bernd, Hoddle, Mark, and Reardon, Richard . Biological Control of Invasive Plants in the Eastern United States, USDA Forest Service Publication.

Ranunculus Bulbosus/Bulbous buttercup:

Bulbous buttercup at Gwynedd Wildlife Preserve, May 17th, 2014 (Photo: Nathan Hartshorne)

> "Perennial, stems 3-7 dm tall from a cormose base to 1.5 cm thick; basal leaves pinnately compound, 1-5 cm wide; leaflets 3, the divisions variously lobed and toothed; cauline leaves alternate, similar to the basal, greatly reduced and less divided upward; inflorescences paniculate, racemose, or rarely 1-flowered; sepals usually tightly reflexed, about 7 mm long; petals 5, bright yellow, 10-14 mm long; styles stigmatose laterally; achenes obliquely obovoid, 2-3 mm broad, smooth, glabrous, margins sharply keeled, beaks stout, about 1.5 mm long, recurved; fruiting receptacles ovoid, 4 mm long, pubescent; common in lawns; fields, roadsides, and pastures; mostly SE, less frequent elsewhere; flr. Late Apr-early Sep; native to Europe; UPL" – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Bulbous buttercup (*Ranunculus bulbosus*) is a native of Europe that has invaded North America (Rhoads and Block 2007). It reproduces solely through seeds and not vegetatively. Tests have shown that when under heavy competition, it may produce as few as 69 seeds, but without competition, as many as 687 (Sarukhan and Harper 1973). Seeds are dispersed by sticking to animals or by birds that consume them (Matter et al. 2014).

Impact:

Little impact has been noted from this invasive, but tests have shown it to produce allelopathic chemicals that would inhibit the growth of other plants (Foy 2001).

Management:

Physical

Bulbous buttercup may not reproduce vegetatively, but it does have a bulb. The bulb, like the aboveground biomass, is renewed each year, so when flowering in mid-May, it has usually disappeared completely (Sarukhan and Harper 1973). This is probably the best time to remove, mow, or otherwise damage the plant.

Chemical

Chemical herbicides will likely be effective at controlling this invasive.

Foy, C. L. (2001). Understanding the Role of Allelopathy in Weed Interference and Declining Plant Diversity 1. *Weed Technology*. Vol. 15, No. 4, pp. 873-878.

Sarukhan, Jose and Harper, John L. (1973). Studies on Plant Demography: Ranunculus Repens, L., R. Bulbosus L., and R. Acris L.: II. Population Flux and Survivorship. *Journal of Ecology*. Vol. 61, No. 3, pp. 675-716.

Matter, P., Kettle, C. J., Frei, E. R., Ghazoul, J., and Pluess, A. R. (2014). Geographic Distance is More Relevant Than Elevation to Patterns of Outbreeding in Ranunculus Bulbosus. *Journal Of Ecology*. Vol. 102, No. 2, pp. 518-530.

Ranunculus ficaria/Lesser celandine/Fig buttercup


Lesser celandine at Gwynedd Wildlife Preserve, April 13, 2014 (Photos: Nathan Hartshorne)

> "Erect to reclining perennial form a cluster of tuberous roots; stems 1-3 dm tall, branching, producing small aerial tubers at the nodes; basal leaves simple, broadly cordate, 1-5 cm long and 1-4.5 cm wide, entire or sinuate to broadly crenately toothed; inflorescences; sepals 5-10 mm long, petals 7-12, yellow 8-15 mm long; achenes obovoid, ca. 2.5 mm long, but rarely maturing; fruiting receptacles pear-shaped to globose, 1-2 mm long, glabrous; an invasive weed of low, open woods, floodplains, meadows, and waste places; SE, scattered elsewhere; flowering Mar-May; native to Eurasia; FAC. A form with double flowers and silvery blotches on the leaves occurs in some areas." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Lesser celandine (*Ranunculus ficaria*) is a perennial invasive currently found in 19 US states, mostly in the northeast. It is a spring ephemeral that has invaded much of the northeastern United States (US Forest Service). It was first recorded in Pennsylvania in 1867 in the Wissahickon Valley (Khan and Rhoads 2011). Lesser celandine reproduces through seeds, although not often. Mostly it reproduces through bulbs and tubers that can spread locally or get carried away, often by water (Khan and Rhoads 2011).

Impact:

Lesser celandine is often found in moist forest floodplains, but also some dry uplands and it prefers sandy soil. It forms dense mats on the forest floor that prevents growth of natives, especially other spring flowering plants (US Forest Service).

Control:

Physical

Lesser celandine is very difficult to manage. Manual control is only really good for small infestations and the weed can be pulled or dug. However, it has a bulb and tubers that need to be removed, too (US Forest Service and Khan and Rhoads 2011. It is recommended to plant stakes where mechanical removal happened for follow-up monitoring because the site may be difficult to find (US Forest Service).

Chemical

Herbicides can be used to minimize disturbance and are best applied in late winter to early spring (US Forest Service and Khan and Rhoads 2011). Extra care must be used during herbicide application due to the fact that it is often found in wetlands areas.

Khan, Nancy and Rhoads, Ann F. (2011). "Lesser Celandine Ranunculus ficaria L. Buttercup Family (Ranunculaceae)." Invasive Species Fact Sheet. Morris Arboretum. Accessed 04/04/2014 http://www.paflora.org/pdf/INV-Fact%20Sheets/Lesser%20Celandine.pdf

United States Forest Service, Northeast Region. "Lesser Celandine." Weed of the Week. Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/lesser_celandine.pdf

Rumex Obtusifolius/Bitterdock:

Bitter dock at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Leathery perennial from tough rootstock; main stem erect-ascending to 1.2 m tall, subtended by a rosette, but also bearing large oblong to lanceolate leaves upward; leaves dark gree, infused with red along the veins, the upper ones crisped; flowers born in fascicles in relatively compact panicles near the plant apex; fruiting calyx with golden to dark red-brown valves, at least one of which bears a plump basal grain; valve margins with well-developed teeth and small spines; common in fields, woods, and roadsides; native to Europe; FACU-." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Bitter dock (*Rumex obtusifolius*) is a perennial herb native to Europe where it is a major crop weed. It may produce from hundreds of seeds to 80,000. The seed bank easily lasts 20 years, with some even remaining viable after 80. It is tolerant of a wide variety of soils as well as drought (ISSG 2010).

Bitter dock has long been used as medicine for nettle, sores, blisters, burns, and cancer (ISSG 2010).

Impact:

Bitter dock has significant allelopathic properties that alter the community around it (Zaller 2006). It can also host many pathogens and pests to neighboring plants (ISSG 2010).

As a major weed of farms and rangeland, Bitter dock can be extra problematic as it may be toxic to animals (DiTomaso et al. 2013).

Bitterdock is often found in riparian areas, roadsides, wetlands, meadows, alfalfa fields, pasture, orchards, and disturbed areas (DiTomaso et al. 2013).

Management:

Physical

Hand-pulling small infestations can be effective. The roots need to be removed as deep as 20 centimeters. A motorized machine has been created that can mechanically pull 600 Rumex plants per

hour. Mowing or other aboveground biomass removals have to be done repeatedly for years to destroy plants (ISSG 2010).

Chemical

Numerous chemical herbicides can help control this invasive (ISSG 2010).

Biological

Numerous studies have been looking into the possibilities of biological control, but none have been implemented. This is likely due to the fact that as a major weed in its native range, it will be difficult to find an insect or pathogen that will control it in non-native ranges. Though not good for many farm animals, goats can be used to graze and control this species (ISSG 2010).

DiTomaso, J. M. and, Kyser, G. B. et al. (2013). "Rumex Crispus L.; Curly Dock. Rumex Obtusifolius L.; Broadleaf Dock." Weed Control in Natural Areas in the Western United States. Weed Research and Information Center, University of California. Page 544. Retrieved from http://wric.ucdavis.edu/information/natural%20areas/wr_R/Rumex_crispus-obtusifolius.pdf

Invasive Species Specialist Group (ISSG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2010). *Rumex Obtusifolius (herb)*. Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=695 &fr=1&sts=sss&lang=EN

Zaller, J. G. (2006). Allelopathic Effects of Rumex Obtusifolius Leaf Extracts Against Native Grassland Species. *Journal of Plant Diseases and Protection.* Special Issue 20, pp. 463-470.

Trifolium Repens/White Clover:

White clover at Gwynedd Wildlife Preserve, May 20th, 2014 (Photo: Nathan Hartshorne)

> "Creeping, glabrous perennial with stems prostrate and rooting at the nodes; leaflets often notched at the tip; flowers 7-11 mm, distinctly stalked; corolla white or pink-tinged; common in lawns, fields, and roadsides; throughout; flr. May-Oct; native to Europe; FACU-." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

White clover (*Trifolium repens*) is a cool-season forb native to Europe and has been introduced and naturalized all over North America. White clover is a valuable plant, often used as a companion crop with grasses and in reclamation in corridors and acid mine waste. The plant provides a lot of nutrition for many species of wildlife as well as livestock (Coladonato 1993).

White clover reproduces both with seeds and vegetatively through nodes on stolons. The seed bank can be very long-lasting (Coladonato 1993).

The non-native plant prefers moderation in sites. It does not tolerate drought or flooding, high or low pH, or salinity. It prefers full sun and does not perform well when taller plants crowd around (Coladonato 1993).

Impact:

As white clover is nitrogen fixing, it may alter the soils of the sites it invades, making them more suitable for subsequent invasions (Coladonato 1993).

Management:

Physical

Mowing early in spring will likely have a negative effect in management as it hurts grasses more. However, mowing in the summer will increase grass vigor, which hurts the clover (Coladonato 1993).

Chemical

Chemical herbicides will likely provide control of this invasive (Coladonato 1993).

Biological

Many species already consume the plant and its seeds (Coladonato 1993).

Coladonato, Milo. (1993). Trifolium repens. Fire Effects Information System.
U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/plants/forb/trirep/all.html

Verbascum blattaria/Moth mullein:

Moth mullein (Photo: Wikipedia)

> "Biennial to 1.2 m tall, glandular pubescent in the inflorescence, leaves and lower stem glabrous; corolla yellow or white, filament hairs purple or purple and white; common in fields, roadsides, railroad embankments, and waste ground; throughout; flr. May-Jul; native to Eurasia; UPL." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Moth mullein (*Verbascum blattaria*) is a biennial native to Eurasia that has been in Pennsylvania since at least 1818 and has spread throughout the US and southern Canada (Ohio Perennial and Biennial Weed Guide). It is a very difficult weed to get information on as most sources refer to only a closely related species, Common mullein (*Verbascum thapsus*).

Moth mullein is a prolific seed distributor. Each plant may produce 1000 capsules with an undetermined (though described as "many") number of seeds per capsule. The seed bank may last 90 years (Ohio Perennial and Biennial Weed Guide).

Impact:

Moth mullein is commonly found in fields, openings in woods and prefers rich soils, but is tolerant of sandy or gravelly soils as well as dry soils (Ohio Perennial and Biennial Weed Guide)

Control:

Physical

Sources citing control methods for Moth mullein tend to group it with Common mullein. For example, separate websites run by Weld County Colorado and the University of California-Davis, both group the two species together. For methods of control, acting before seeds are formed is recommended. For mechanical methods of control, hand-pulling, repeated mowing, and tillage are effective, though one has to be careful when creating disturbances, as those will promote seed

germination. Cutting the deep tap roots is also important (DiTomaso et al. 2013; Weld County Colorado).

Chemical

Both sources cite herbicide use as a method of control (DiTomaso et al. 2013; Weld County Colorado), however it is not easily effective against Common mullein due to its hairiness (ISSG 2005), so it is unclear if they also would have the same problems with Moth mullein.

DiTomaso, J.M., G.B. Kyser et al. (2013). "Common and Moth Mullein." Weed Control in Natural Areas in the Western United States. Weed Research and Information Center, University of California. http://wric.ucdavis.edu/information/natural%20areas/wr_V/Verbascum_blattaria-thapsus.pdf

Invasive Species Specialist Group (ISSG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Verbascum Thapsus (herb)*. Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=695 &fr=1&sts=sss&lang=EN

Ohio Perennial and Biennial Weed Guide. "Moth Mullein." http://www.oardc.ohio-state.edu/weedguide/singlerecord.asp?id=760

Weld County Colorado. Weld County Public Works Department, Weed Division. Rangeland-Pasture Recommendations: Common Mullein and Moth Mullein Identification and Management.

Wikipedia. "Verbascum Blattaria." Retrieved from http://en.wikipedia.org/wiki/Moth_Mullein

Verbascum thapsus/Common mullein:

Common mullein at Gwynedd Wildlife Preserve, May 7, 2014 (left) and May 11, 2014 (right) (Photos by Nathan Hartshorne)

> "Densely yellowish-gray-tomentose biennial to 2 m tall; leaves decurrent forming broad wings on the stem; inflorescence dense, usually unbranched; corolla yellow, white hairs present on the upper filaments; common in fields, roadsides, shale barrens, railroad embankments, and dry waste ground; throughout; flowers June-August; native to Europe." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Common mullein (*Verbascum thapsus*) is biennial native to Eurasia and was brought to the United States in the mid 1700s as a fish poison. It has since also been used as a medicine for coughs and diarrhea and then as an insect repellant. In its first year it is a 20-60 cm rosette and does not flower until its second year when it produces a large un-branched stem. The plant is very hairy. It flowers from June through September and seeds germinate in late summer, early autumn, or early spring (Verbascum Thapsus 2005).

Impact:

Common mullein is a problematic invasive because it grows more vigorously than similar natives. Furthermore, each plant can produce 100,000 to 180,000 seeds that may remain viable for 100 years. It is common in landscapes, perennial crops, and roadsides. It prefers dry, gravelly, stony soil and needs bare ground. It is widespread through the United States and southern Canada (Uva et al. 1997). Cattle and sheep dislike it, making land it invades less suitable for grazing, causing economic damage (Verbascum Thapsus 2005).

It is effective at pushing out native grasses and herbs with a dense cover, especially when following a fire. It is often found in meadows, forest openings, alongside roads and fences, and in industrial areas (Common Mullein 2006).

Control:

Physical

As Common mullein needs bare ground, management of it should work to prevent any bare ground from being created, especially due to its long-lasting and large seed bank. It can, however, be hand-dug or hoed, preferably before it produces seeds (Verbascum Thapsus 2005).

Chemical

Chemicals can be used to control this invasive. However, the dense hairs may make aqueous solutions less likely to penetrate into the plant. A2,4-D/2,4,5-T mixture at 16oz per acre in the first year can control it. An application of Tebuthiuron at 4-6 pounds per acre and follow-up treatments have also proven effective (Verbascum Thapsus 2005).

Biological

There is potential for natural control of Common mullein. First of all, a species-specific curculionid weevil (*Gymnaetron tetrum*) has been introduced from Europe. Its larvae can destroy 50% of the mullein's seeds. Also, powdery mildew (*Erysiphe cichoracearum*) and root rot (*Phymatotricum omnivorum*) are two species of fungi that affect mullein. However, they are also common in crop species as well. Other fungi found on mullein include *Cercospora verbasciola*, *Mycosphaerella verbasciola, Oidium pyrinum, Septoria verbasciola, Ramularia veriabilis*, *Phoma thapsi*, and *Phyllosticta verbaciola*. Parasitic nematodes in mullein include *Heterodera maroni* and *Meloidogyne* sp. (Verbascum Thapsus 2005).

Other biological control includes using goats that will eat it and chickens have even been recommended as a control for the seeds (Verbascum Thapsus 2005).

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN - International Union for Conservation of Nature. (2005). *Verbascum Thapsus (herb)*. Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=695 &fr=1&sts=sss&lang=EN

USDA Forest Service Northeast Region. (2006). "Common Mullein." Weed of the Week. http://www.na.fs.fed.us/fhp/invasive_plants/weeds/common-mullein.pdf

Veronica serpyllifolia/Thyme-leaved speedwell:

"Low-growing, spreading perennial rooting at the nodes; stems and pedicels densely short-hairy; leaf blades mostly glabrous except on the margins; flowers white with purple veins, 5 mm wide; fruit glandular-hairy, flattened, somewhat cordate with long style; common in lawns, fields, meadows, and open woods; throughout; flr. May-Aug; native to Europe; FAC+." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Thyme-leave speedwell (*Vernoica serpyllifolia*) is actually both native and invasive in the United States. Although only listed as an invasive in Plants of Pennsylvaniva (Rhoads and Block 2007), there are actually two subspecies *ssp. humifusa* and *ssp. serpyllifolia* (Flagstad 2012). *V. serpyllifolia ssp. humifusa* is native, although the USDA Plants database does not list it as occurring in Pennsylvania, but does in New York and Maryland. *V. serpyllifolia ssp. serpyllifolia*, on the other hand, is a non-native European introduction in much of the US (USDA Plants Database).

Thyme-leaved speedwell reproduces through seeds, through rhizomes in the roots, and through creeping stems that root at nodes. The seed bank can be quite long-lasting, persisting for decades. Seeds have no dispersal method, so they are likely accidentally spread by humans (Flagstad 2012).

Impact:

Thyme-leaved speedwell can be mat-forming, which pushes out native species. Its major impacts, however, appear to be in disturbed areas and so do not affect natural ecosystems much. It is most commonly found in waste places, roadsides, and ditches (Flagstad 2012). This is reflected in surveys of Gwynedd Wildlife Preserve, where it was only found on a mowed and trampled path.

Management:

Physical

Hand-pulling this weed will likely be effective, but every part of the stem and root has to be removed as it can reproduce vegetatively through both.

Chemical

Herbicides have not shown to be particularly effective at controlling this weed.

Flagstad, Lindsey. (2012). "Thymeleaf Speedwell." Alaska Natural Heritage Program. University of Alaska, Anchorage. Retrieved from http://aknhp.uaa.alaska.edu/wp-content/uploads/2013/01/Veronica_serpyllifolia_ssp_ serpyllifolia_BIO_VESES.pdf

USDA Plants Database. "Veronica serpyllifolia L. ssp. humifusa (Dicks.) Syme Brightblue speedwell." Retrieved from http://plants.usda.gov/core/profile?symbol=veseh2

USDA Plants Database. "Veronica serpyllifolia *L.* ssp. serpyllifolia Thymeleaf speedwell." Retrieved from https://plants.usda.gov/core/profile?symbol=VESES

Vicia Tetrasperma/Slender Vetch:

Slender vetch at Gwynedd Wildlife Preserve, May 21st, 2014 (Photo: Nathan Hartshorne)

> "Slender annual with climbing stems to 5 dm; leaflets 4-10; peduncles 1-3cm long bearing 1-6, pale purple to whitish flowers; calyx lobes unequal; fruits flat, glabrous, 4-seeded; naturalized in moist meadows, roadsides, and moist areas on serpentine barrens; E; flr. May—Aug; native to Eurasia." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Sleder vetch (*Vicia tetrasperma*) is an annual, climbing or decumbent herbaceous plant native to Europe, Asia, and North Africa. It has invaded most of the contiguous US except for the great plains and southwest (Santanna et al.).

Although self-fertilizing, populations have been shown to have high genetic diversity. Each plant may produce 70-150 seeds (Santanna et al.). Seeds have been found to be distributed in deer feces (Myers et al. 2004).

Impact:

Slender vetch has an association with nitrogen-fixing bacteria and so alters the soil that it grows in, possibly promoting new invasives (Santanna et al.).

Management:

Physical

Hand-pulling this weed should be effective.

Chemical

Chemical herbicides will likely provide control over this species.

Myers, Jonathan A., Vellend, Mark, Gardescu, Sana, and Marks, P. L. (2004). Seed Dispersal by White-Tailed Deer: Implications for Long-Distance Dispersal, Invasion, and Migration of Plants in Eastern North America. *Oecologia*. Vol. 139, No. 1, pp. 35-44

Santanna, Cristine, Dorey, Jenna, and Burnham, Robyn J. "Vicia Tetrasperma." Plant Diversity Website. University of Michigan. Retrieved from http://climbers.lsa.umich.edu/wp-content/uploads/2013/07/VicitetrFABAFINAL.pdf

Vinca minor/Common periwinkle/Creeping Myrtle:

Common periwinkle (Photo: Wikipedia)

> "Evergreen plant with creeping stems rooting at the nodes and erect flowering stems; leaves opposite, entire, petiolate; flowers solitary in the axils; corolla blue (rarely white), salverform; cultivated and occasionally naturalized in woods, fields, or roadsides; throughout; flowers April-June; native to Europe." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

The Common periwinkle (*Vinca minor*) is a European native ornamental turned invasive and is now found in most of the US including everything bordering and east of the Mississippi River. It is a creeping evergreen perennial vine. Common periwinkle reproduces both through seeds as well as root growth and rooting where nodes touch the ground (US Forest Service 2006).

Impact:

Its shallow root system can help the Common periwinkle to out-compete natives for nutrients and water. It is often found in forests, woodland edges, roadsides, moist rich soils and fields (US Forest Service 2006).

Control:

Physical

Common periwinkle can be managed through hand-pulling or raking (US Forest Service 2006).

Chemical

Several chemical herbicides can be used to provide control (US Forest Service 2006).

United States Forest Service, Northeast Region. (2006). "Periwinkle." Weed of the Week. Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/periwinkle.pdf

Wikipedia. "Vinca Minor." Retrieved from http://en.wikipedia.org/wiki/Vinca_minor

Grasses:

Dactylis glomerata/Orchard Grass:

Orchard grass (Photo: Wikipedia)

> "Perennial; culms 6-12 dm tall, usually in large tussocks; blades 2-8 mm wide; sheaths scaberulous; ligules 5-7 mm long; panicle 5-20 cm long, few branched, the branches stiff, as much as 10 cm long; spikelets 3-6 flowered; lemmas 5-8 mm long, usually ciliate on the keel, fields, meadows, and roadsides; common throughout; May-July; C3; native to Europe; FACU." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Orchard grass (*Dactylis glomerata*) was introduced to the United States from Europe in 1760 and has now invaded most of the country. It is a cool-season grass that reproduces through seeds and tillering. The seeds do not go dormant and may germinate in light or dark, so it does not build up a seed bank. Orchard grass is shade-tolerant and some cultivars are drought-tolerant as well. It has commonly been planted to help rehabilitate a site after a fire, mostly to prevent erosion (Sullivan 1992).

Impact:

As Orchard grass is fire-tolerant, it can promote fires that burn away other local vegetation, but it stays alive (Sullivan 1992).

Control:

Physical

Hand-pulling the grass may be effective at control because the rootstalks do not spread. Mowing is unlikely to provide control as much of it has adapted under cultivation and even grows in peoples' lawns. In fact, repeated mowing may induce tillering (NPS).

Fire is not an effective method of control for this invasive (Sullivan 1992).

Chemical

Herbicides should provide effective control (NPS).

Biological

There is no biological control, though many animals such as cattle and deer do find Orchard grass tasty, if less nutritious (NPS).

National Parks Service (NPS), United States Department of the Interior. "Orchard Grass." Alaska Exotic Plant Management. Retrieved from: http://www.nps.gov/akso/NatRes/EPMT/Species_bios/Dactylis%20glomerata.pdf

Sullivan, Janet. 1992. Dactylis glomerata. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. Retrieved from http://www.fs.fed.us/database/feis/

Wikipedia. "Dactlylis Glomerata." Retrieved from http://en.wikipedia.org/wiki/Dactylis_glomerata

Microstegium vimineum/Japanese Stiltgrass:

Japanese stiltgrass at Gwynedd Wildlife Preserve, April 6, 2014 (Photo: Nathan Hartshorne)

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Forest floor invasion of new Japanese stiltgrass at Gwynedd Wildlife Preserve, May 17th, 2014 (Photo: Nathan Hartshorne)

> "Annual or short-lived perennial; culms 6-10 dm long, decumbent and spreading; blades lanceolate, 5-10 mm wide by 3-8 cm long; panicle with 1-6 racemes; racemes 2-5 cm long; glumes about 5 mm long; moist ground of open woods, thickets, paths, clearings, fields, and gardens; mostly SE, but spreading rapidly and probably elsewhere; Sept-early Nov; C4; native to tropical Asia; FAC." – Plants of Pennsylvania (Rhoads and Block 2007)

General:

Japanese stiltgrass (*Microstegium vimineum*) is native to East and South Asia. It was first noted in Tennessee in 1919, perhaps having escaped after being used as packing material for porcelain shipped in from China (DCNR).

Japanese stiltgrass is an annual grass that looks a bit like bamboo. It is a shade tolerant grass that reproduces both by clonal means at nodes as well as fruiting. Each plant may produce 100-1000 seeds per year. Seeds may float on the water, helping it to spread (DCNR and ISSG 2005).

Impact:

Japanese stiltgrass will easily crowd out native vegetation in areas that it invades, though it may be slow where there is less disturbance (ISSG 2005). It often is found in moist woodlands, wetlands, roadside ditches, right-of-ways, as well as lawns, gardens, and agricultural land (ISSG 2005).

Furthermore, it changes the soil chemistry of invaded areas. First of all, there is less litter and thinner organic horizons. Futhermore, the pH is raised and nitrogen is immobilized. Invasive worms have been found in higher abundance in areas also invaded by Japanese stiltgrass (ISSG 2005).

Invasions by Japanese stiltgrass have shown to reduce native plant diversity by 38% and biomass by 64% (Kleczewski and Flory 2010).

Deer avoid eating this weed. This will likely encourage feeding on native plants, which helps Japanese stiltgrass invade more (DCNR).

Control:

Physical

Hand-pulling has been found to be best at controlling Japanese stiltgrass. Mowing can also be effective. However, both methods need to be done around the end of summer when the grass is about to flower. If it is done earlier, it encourages flowering and early seed dispersal. Follow-up treatments will be required (DCNR).

Controlled burns have not been shown to be effective at controlling this invasive (ISSG).

Chemical

The use of herbicides can control this weed, however, care must be done in wet areas that the herbicide does not contaminate and destroy wetlands. Using grass-selective herbicides are preferable for a Japanese stiltgrass invasion because they allow the other species to remain (DCNR and Peskin et al. 2005). Other species will help prevent reoccurring invasions (Peskin et al. 2005).

Biological

In West Virginia, in 2009, a fungus was spotted infecting Japanese stiltgrass. A population would show 80-100% infection. Many plants, or parts of plants including seeds, would be killed by the disease. Seed head production was reduced significantly as a result. The fungus, *Bipolaris spp.*, may actually be an evolved form of *Bipolaris zeicola*, a native to North America and a disease of corn world-wide. However, *Bipolaris* is a diverse group with a wide range of hybridizations, so it is unclear how this stiltgrass infection came to be. Testing on native plants will have to be done before this can be purposefully introduced as a biological control (Kleczewski and Flory 2010).

Just as deer do not like to eat this non-native, it is often stated that cows and goats will not graze on it, either. A quick search on google will show many such statements, for example, by Columbia's Introduced Species Summary Project (Simpson 2004). However, goats and cows are already

used to control stiltgrass. The cows at Crow's Nest Preserve eat it regularly (Dan Barringer *Personal Communication*)

Invasive Species Specialist Group (ISSGG) of the SSC- Species Survival Commission of the IUCN -International Union for Conservation of Nature. (2005). *Acer ginnala (tree)* Retrieved from the Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=686&fr=1&sts=sss&lang=EN

Kleczewski, N. M. and Flory, S. L. (2010). Leaf Blight Disease on the Invasive Grass Microstegium vimineum Caused by a Bipolaris sp. *Plant disease*. Vol. 94, No. 7, pp. 807-811.

Pennsylvania Department of Conservation and Natural Resources (DCNR). Invasive Plants in Pennsylvania: Japanese Stilt Grass Microstegium Vimineum. http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_010258.pdf

Peskin, N., Mortensen, D. A., Jones, B. P., & Booher, M. R. (2005). Grass Selective Herbicides Improve Diversity of Sites Infested with Japanese Stiltgrass (Pennsylvania). *Ecological Restoration*. Vol. 23, pp. 64-65.

Simpson, Joshua. (2004). "Japanese Stilt Grass." Introduced Species Summary Project. Retrieved from http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Microstegium_vimineum.html

Setaria faberi/Giant foxtail/Japanese Bristlegrass

Foxtail that has fallen over, Gwynedd Wildlife Preserve, May 7, 2014 (Photo: Nathan Hartshorne)

> "Annual; similar to S. viridis in habitat; panicle nodding; spikelets about 3 mm long; cultivated fields, roadsides, and waste ground; mostly S; July-Oct; native to eastern Asia; UPL." – *Plants of Pennsylvania* (Rhoads and Block 2007)

General:

Giant foxtail (*Setaria faberi*) is an annual monocot native to Asia that has now invaded every state of the United States except parts of the West (US Forest Service 2006). It was brought to the US in the 1930s when it contaminated millet seed (Clements et al. 2004). It prefers fertile, sandy soils. It is often spread in manure or straw (US Forest Service 2006).

Impact:

It is often found in crops, waste areas, along roadsides and woods, and open fields. It competes well with other vegetation, causing economic problems, especially in corn fields. It can form monoculture areas in burned prairies (US Forest Service 2006).

Control:

Physical

Manual methods of control of Giant foxtail include hand-pulling (US Forest Service 2006). Burning is not a method of control as fire promotes its spread (US Forest Service 2006).

Chemical

Herbicides should provide good control of this weed (US Forest Service 2006).

Clements, D. R., DiTommaso, A., Jordan, N., Booth, B. D., Cardina, J., Doohan, D., Mohler, Charles L., Murphy, Stephen D., and Swanton, C. J. (2004). Adaptability of Plants Invading North American Cropland. *Agriculture, Ecosystems & Environment.* Vol. 104, No. 3, pp. 379-398.

United States Forest Service, Northeast Region. (2006). “Japanese Bristlegrass.” Retrieved from http://www.na.fs.fed.us/fhp/invasive_plants/weeds/japanese-bristlegrass.pdf

VI. Maps of Invasive Species

Introduction

The 2014 mapping of invasive species at Gwynedd Wildlife Preserve started on April 1st, and ran through May 21st. It was relatively late in the year for plants to leaf out and bloom, thus the initial surveying was difficult in that many plants were still in their winter conditions. Many invasive herbaceous plants did not appear until late in the surveying and thus could not be properly mapped, though their presence was noted.

As this was done as a learning exercise as well as to create a useable document, the 2008 survey done of Gwynedd Wildlife Preserve done by Botanical Inventory was used as a guide, helping me to know what species to look for and some of their distribution. However, it was mostly an inventory and had little to say about distribution. Also, there have been changes to the preserve's vegetation and it is possible that mistakes were made, as they always are.

Background to Surveying

Vegetative and wildlife surveys are a murky science at best, often relying on information that is not totally clear. Sometimes there appears to be as many survey methods as there are people to perform them. However, information can still be derived from them relaying data on species and abundances. Vegetative surveys generally involve using sample areas that should be indicative of the whole. Sampling may be as little as 1% of the entire area (Barbour et al 1987).

Furthermore, terminology gets confusing as many terms sometimes mean the same thing. For example, the Releve method is also called SIGMA, Braun-Blanquet, or Zurich-Montpellier (A-M) school (Barbour et al. 1987). In terms of spacial distribution of sample plots, uniform, regular, even, negative contagion, and underdispersed are terms used to refer to the same concept while aggregated, contagious, clustered, clumped, patchy, positive contagion, and overdispersed are likewise all synomyms (Krebs 1989). Also, the only way to truly be certain if something is statistically significant is to do more work than is required and check the data (Barbour et al. 1987). Another problem is that methods sometimes have to be adapted to suit the conditions of the site, making them less standardized and scientific.

When conducting a vegetation survey, there are important considerations no matter the method used. Perhaps most important of all, ecologists need to make sure that methods do not harm the environment. Some long-term monitoring has essentially been nothing but monitoring the impacts of monitoring (Tucker et al 2005).

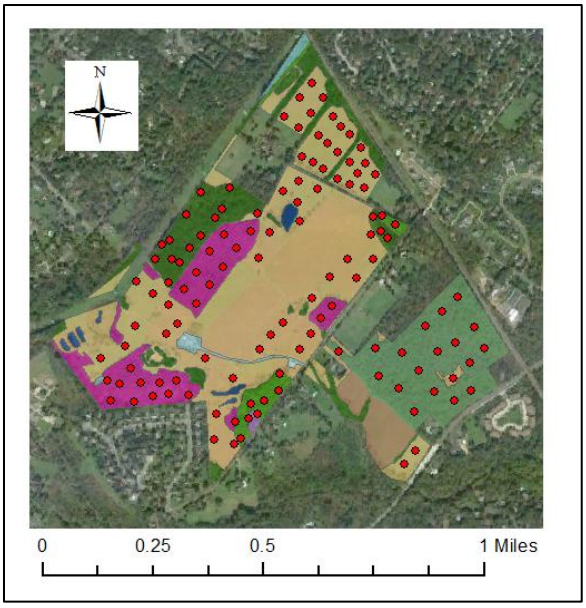
There are a couple methods to find the proper size of a quadrat. Using existing literature and what methods were used in similar surveys is a recommended method (Krebs 1989). A more statistical way is to start small and slowly increase the size of the quadrat. As the area gets bigger, the number of species in the quadrat increases. However, at a certain point, the number of species added per additional area of quadrat decreases. A graph of this would show a line approaching an asymptote. At this point where the line begins to hook to the side, it begins to be pointless to make the quadrat any bigger. Where precisely this point is, is debated. This kind of a quadrat is called a relevé, relating to the relevé method of surveying (Barbour 1987).

The line transect methods are another popular type of surveying method. There are a variety based on this process. The original is the Line Intercept method developed by H. L. Bauer in 1943. Any plants that cross that line (tree canopies, bushes, herbs, etc.), are recorded (Barbour et al. 1987). Others suggest that only species actually touching the line are recorded, which changes based on the elevation of the line (Rich et al 2005). This can be adapted to finding species's distances to the line, examining only at certain points along the line, or others (Fasham and Mustoe 2005; Rich et al. 2005). Obviously transects and quadrats can be combined whereas quadrats are placed on the transect, perhaps at the ends, or at certain distances along it, such as the Belt Transect, the Strip Transect, or the Line Strip method (Barbour 1987).

Placement of quadrats and transects can vary based on what the researcher wishes. Sometimes it is better to go across environmental gradients. Transects can go down a slope just as long, rectangular quadrats can. Other times, the researcher wishes to place them in places he/she thinks are most appropriate, which is known as part of the releve method (Barbour et al. 1987). A systematic method creates a grid and places survey points along that grid while a random method uses completely random points (Tucker et al. 2005). A stratified method separates an area into regions to ensure that all get properly surveyed, then creates random points in each one (Barbour et al. 1987). Each of these methods naturally has its own pros and cons and can be combined with others into something new.

Methodologies Used

Surveys were done with stratified quadrats in all contiguous habitats. As finding non-native species was more important than a statistical density, this was believed to be more accurate. Forested areas had 8 meter diameter circular quadrats, while grasslands and early to mid successional areas had quadrats with 6 meter diameters. Ideally the forested areas would have much larger quadrats, enabling trees and vines to be better recorded, but as a first-time surveyor working mostly alone and without good equipment, 8 meters was about as good as it was going to get. As a result, certain trees are mapped differently and are discussed in their own specific sections. When species appeared in habitats that used different sized quadrats, the numbers were multiplied or divided so that they stayed proportional and did not simply reflect a change in quadrat size. Over all, there were 124 quadrats used to survey Gwynedd.



123 quadrats were used to survey

A middle section is missing in these quadrats. There are two reasons for this. The northeastern rectangle was burned as part of its management. Though new growth occurred soon, it would take a while for it to be truly comparable to the other sections. Southwest of that is an area missing because some ground-nesting meadowlarks were discovered in the area. In hopes that they would nest, it was decided that surveying (and trampling that occurs as a result) would not be proper. Across Swedesford road is an area being afforested, so it was also skipped in surveys because it is actively mowed while trees grow.

After all the quadrats were completed, a walkthrough was performed to examine hedgerows and along wetlands to see the growth in those areas. Specific numbers were not recorded like in the quadrats. Maps were made to reflect the common or significant presence of invasives. However, due to the more haphazard nature, they will be less accurate.

Few of these maps are truly accurate. On a small scale, it is difficult to perform analyses with quadrats to note specific distribution (as opposed to density). Thus, in some cases, simply noting the presence or absence matters more. Missing large sections was likely to miss the presence/absence more. However, due to the stratified nature, sometimes the quadrat was supposed to be placed in a stream or on a path or in some impenetrable thicket. Thus, they were moved slightly with an attempt to still reflect the lay of the land, but not falsely show no invasives due to things like open water. Using a GPS is more difficult than anticipated. There was an obvious learning curve, which is reflected in how well the pre-made stratified maps were used. Note in the very first set of quadrats, they do not appear very stratified, but in the last set they do. The last set was actually more difficult as the GPS unit had trouble with the canopy coverage.

The first area surveyed is to the left, while the last area is to the right. Both are similarly-aged forests. The learning curve is apparent.

Maps include one to three methods. The first is simple points of distribution. Every Callery pear found is mapped with an individual point. Other species, like multiflora rose, are mapped in a distribution pattern based off counts in each quadrat. Some quadrats had many, and some had very few. The data is put into GIS, creating a map that shows locations adjacent to quadrats with lots of multiflora rose having higher numbers as well. The same method was employed for species that were not counted, but given a percent cover, such as garlic mustard. The third method of mapping shows regions in which a species has high or low occurances. For instance, no distribution of Japanese honeysuckle within a hedgerow was mapped, but if the hedgerow was known to have a high number, then the entire area is marked as such.

Due to the late appearance of some invasives, they did not get mapped. A few herbaceous species discovered in Tunnel Woods were not noticed on the other half of Swedesford, but almost certainly exist there. However, it was too late to go back and check all the previous quadrats to get a thourough examination of the preserve. These species are: Narrow-leaved bittercress (*Cardamine impatiens*), Mouse-ear chickweed (*Cerastium fontanum*), Bittercress (*Barbarea vulgaris*), Bulbous buttercup (*Ranunculus bulbosus*), Thyme-leaf speedwell (*Veronica serpyllifolia*), and Dandelion (*Taraxacum officinale*). Each species will be described in the section it would be, but just not mapped.

Improvements and Further Study

As a learning experience, it is important to reflect back upon what could have been done better and what one might do in the future when repeating a similar project. First and foremost, doing more to be familiar with the possible non-native plants of the area would have helped. Using the previous survey in 2008 was a good guide, but it lacked some invasive species found. A print-out of pictures of expected plants was sometimes used, but it was difficult to use and overwhelming. This relates to the time of year. The 2008 survey was done in March and this project was done April-May. Both ran into difficulties regarding the early dates before the growing season really got underway. There is no perfect time for a survey. To do a complete one needs to take late-season herbaceous plants into account and have later surveys as well as early ones. For someone who has difficulty IDing most plants, starting before they had leaves added to the problems, but time was limited.

Having better equipment would have helped as well. A rigged plant press helped a lot, but it was smaller than professional ones from the store, which made it more difficult to make good samples.

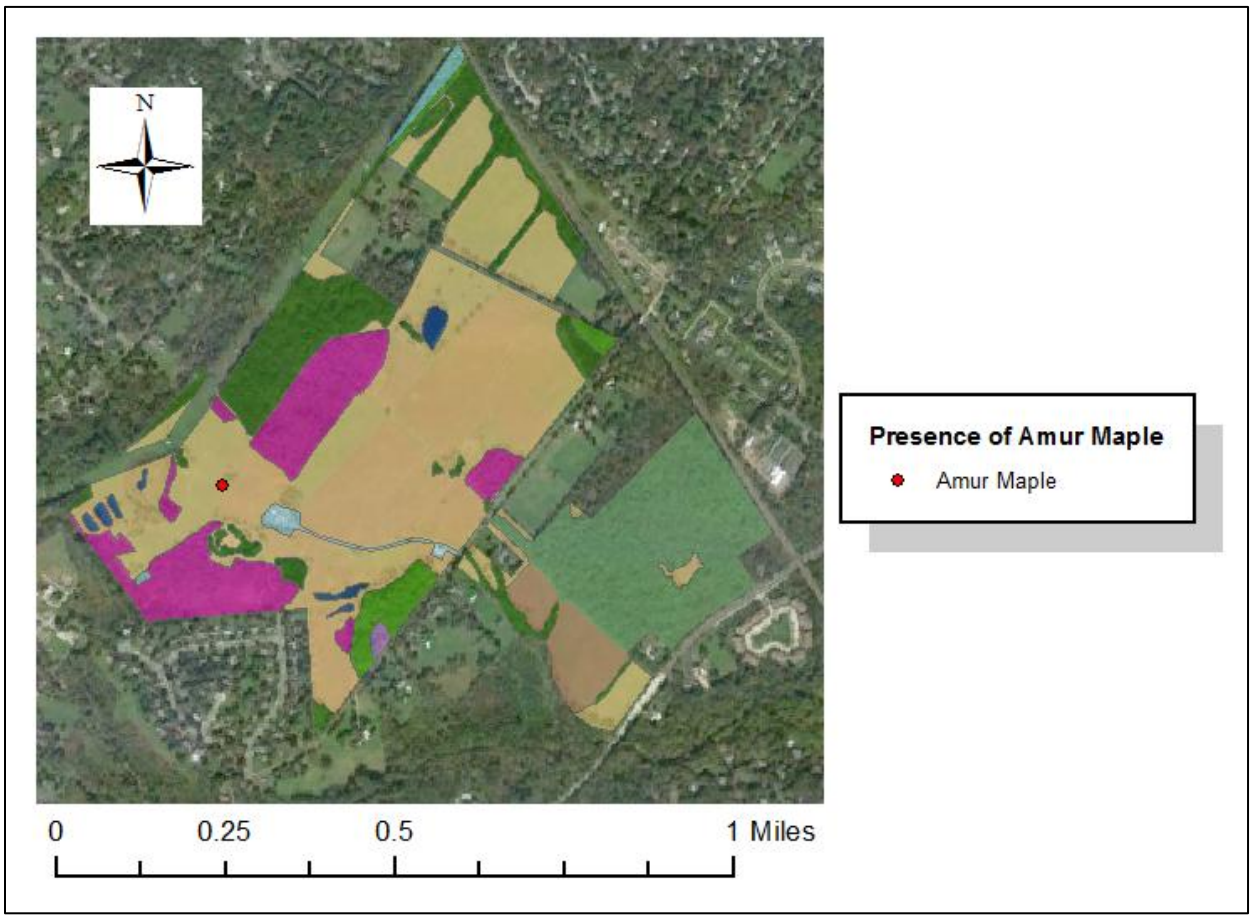
Early-season samples were simply put into a bag and pressed at home. The GPS unit was decent, but more modern ones have more features.

The baseline map used in this project was a GIS map provided by the Natural Lands Trust. This map, while very good, was outdated, referring to vegetation communities that no longer existed or having boundaries that have since changed. Examinations of the distribution of pear and autumn olive do not always make sense based on the map, but that is the result of rapidly changing successional habitats. Furthermore, there are many extensive trails throughout the preserve. As some are several feet wide, they play significant roles in the vegetation communities and should probably be reflected in the maps. Any future project should attempt to update these maps first. It is a big project just to do that, however, which is why it was not done for this project.

Trees

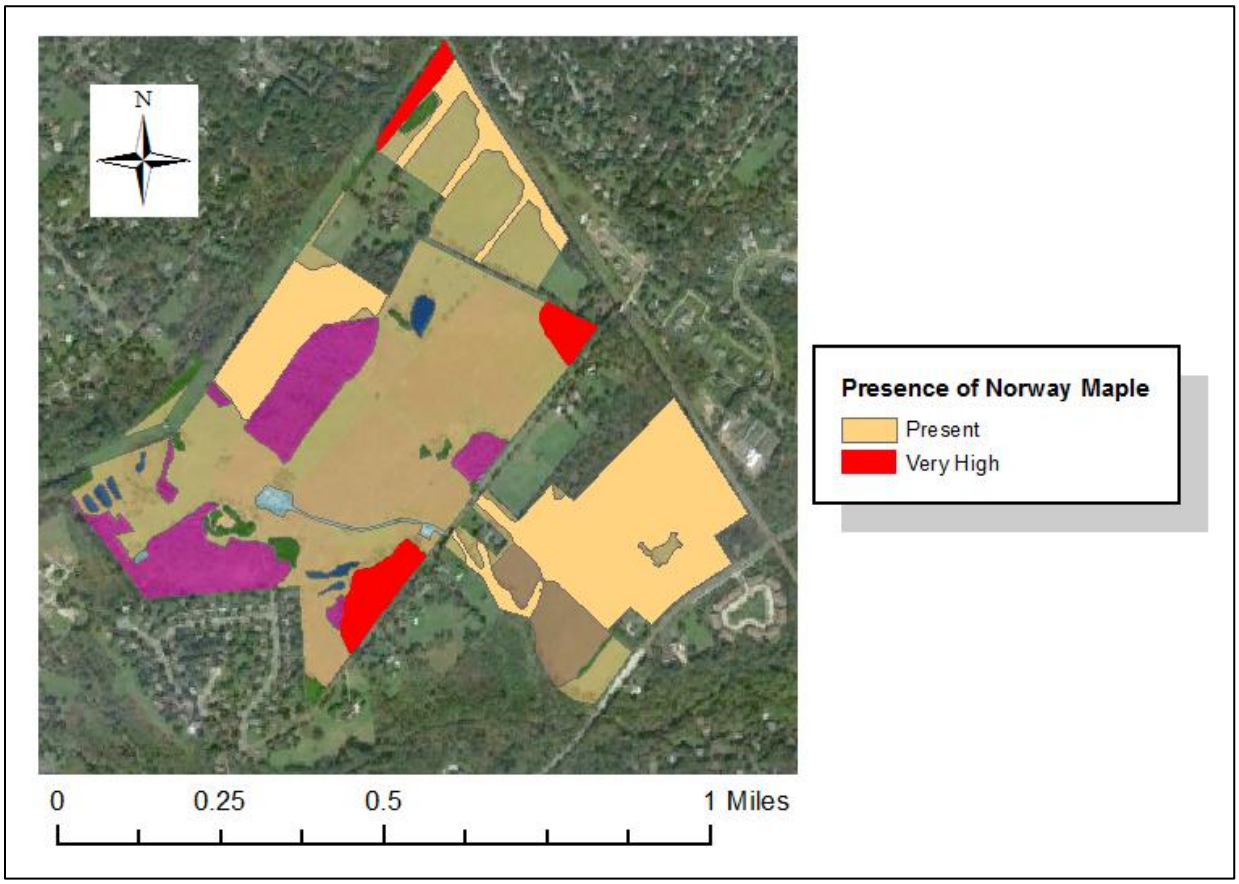
Acer Ginala/Amur Maple:

Amur maple was planted at the Betz Memorial Garden.



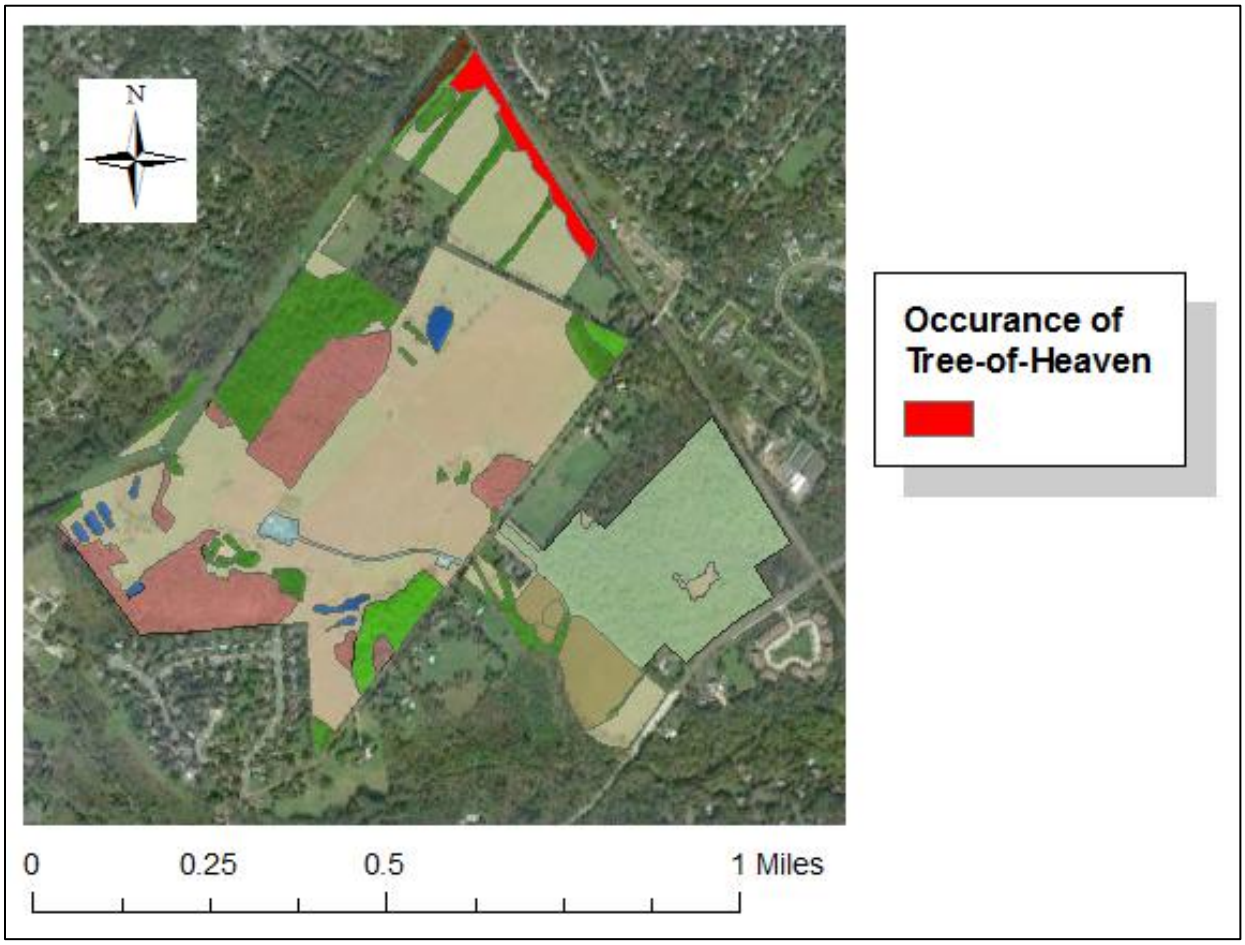
Acer Platanoides/Norway Maple:

It is difficult to determine where Norway maples are without pulling a leaf off and testing it. This was done many times to determine where they were most common. Surprisingly, the two oldest forested sections had the most Norway maple. Of many maples tested, only two in the Tunnel Woods area were found to be Norway maples.



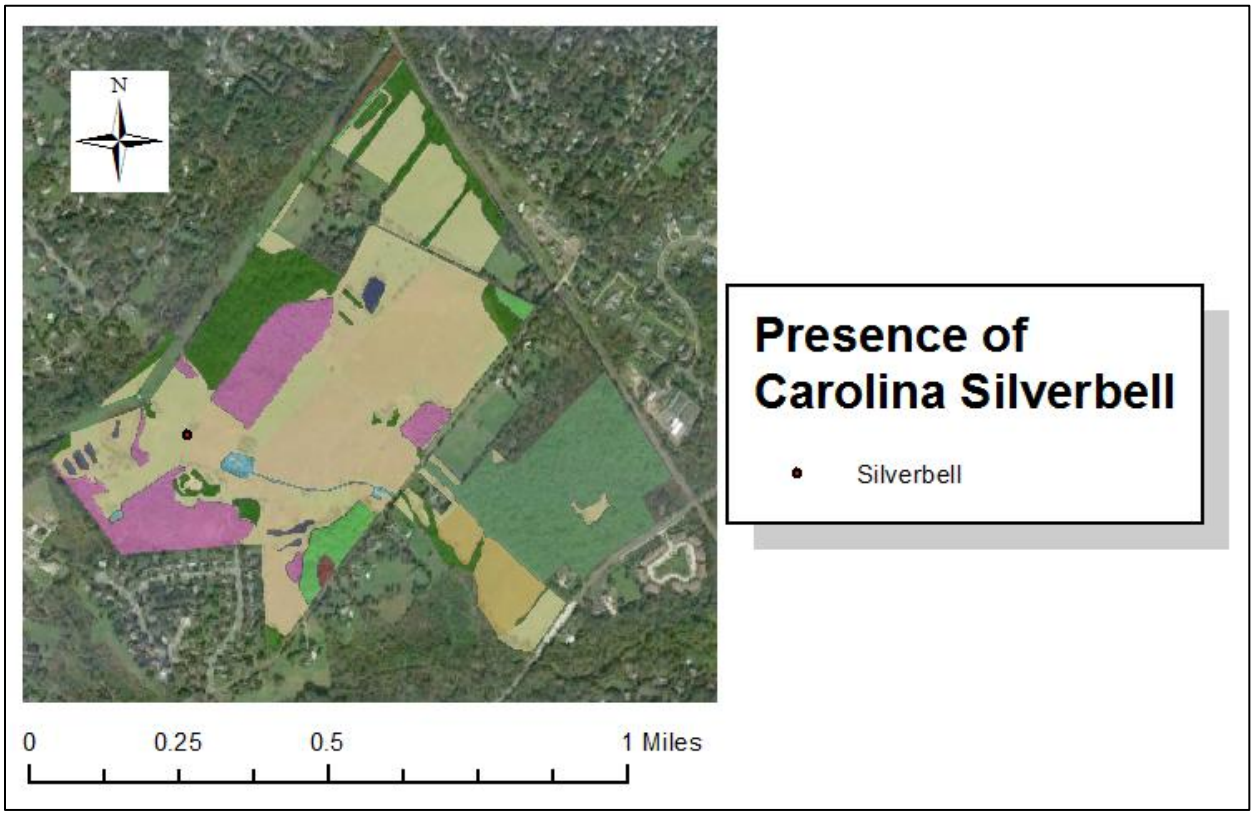
Ailanthus Altissima/Tree-of-Heaven:

No Tree-of-heaven was found, but the 2008 survey listed it as along the railway.



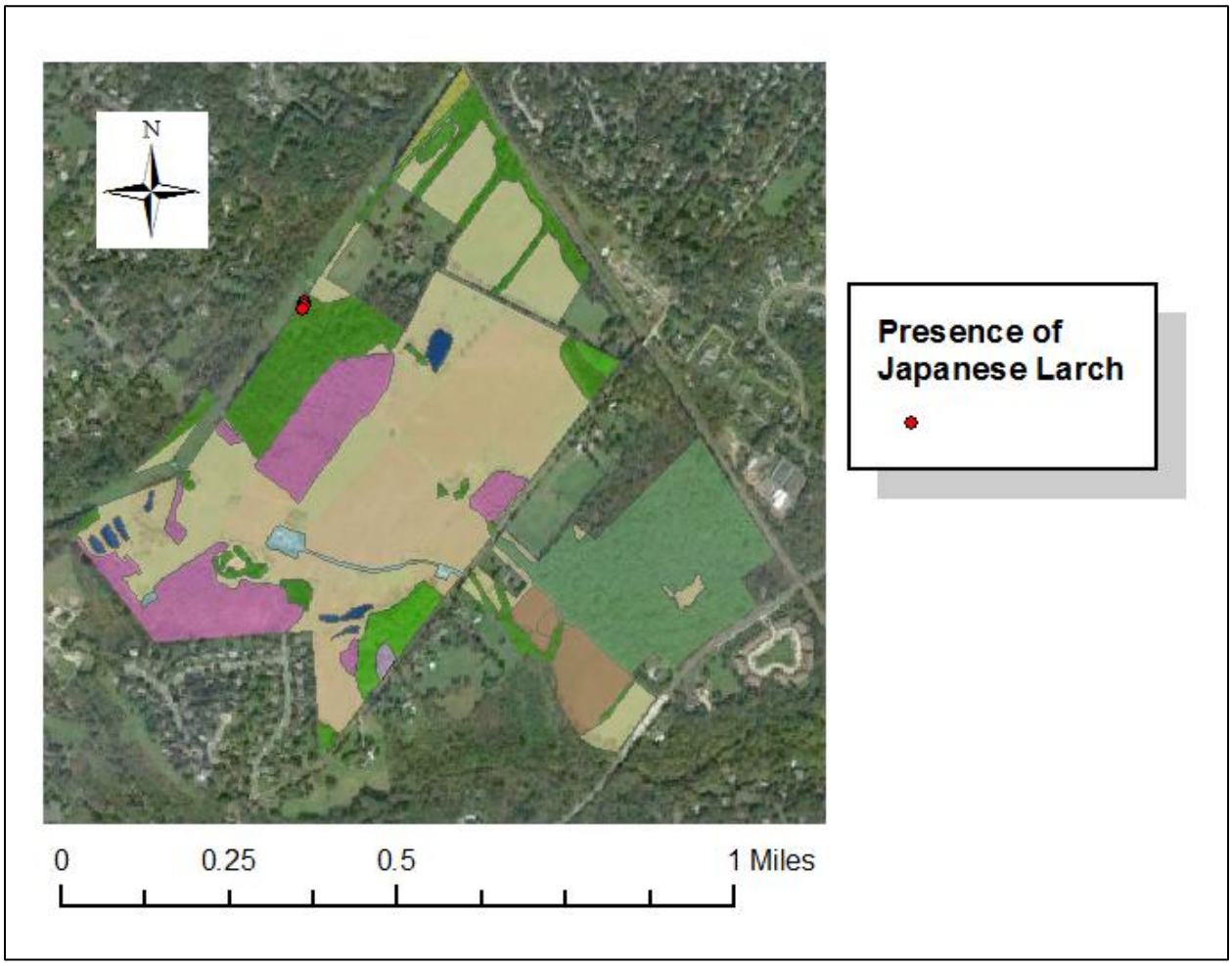
Halesia Carolina/Carolina Silverbell:

One Carolina silverbell was planted at the Betz Memorial Garden.



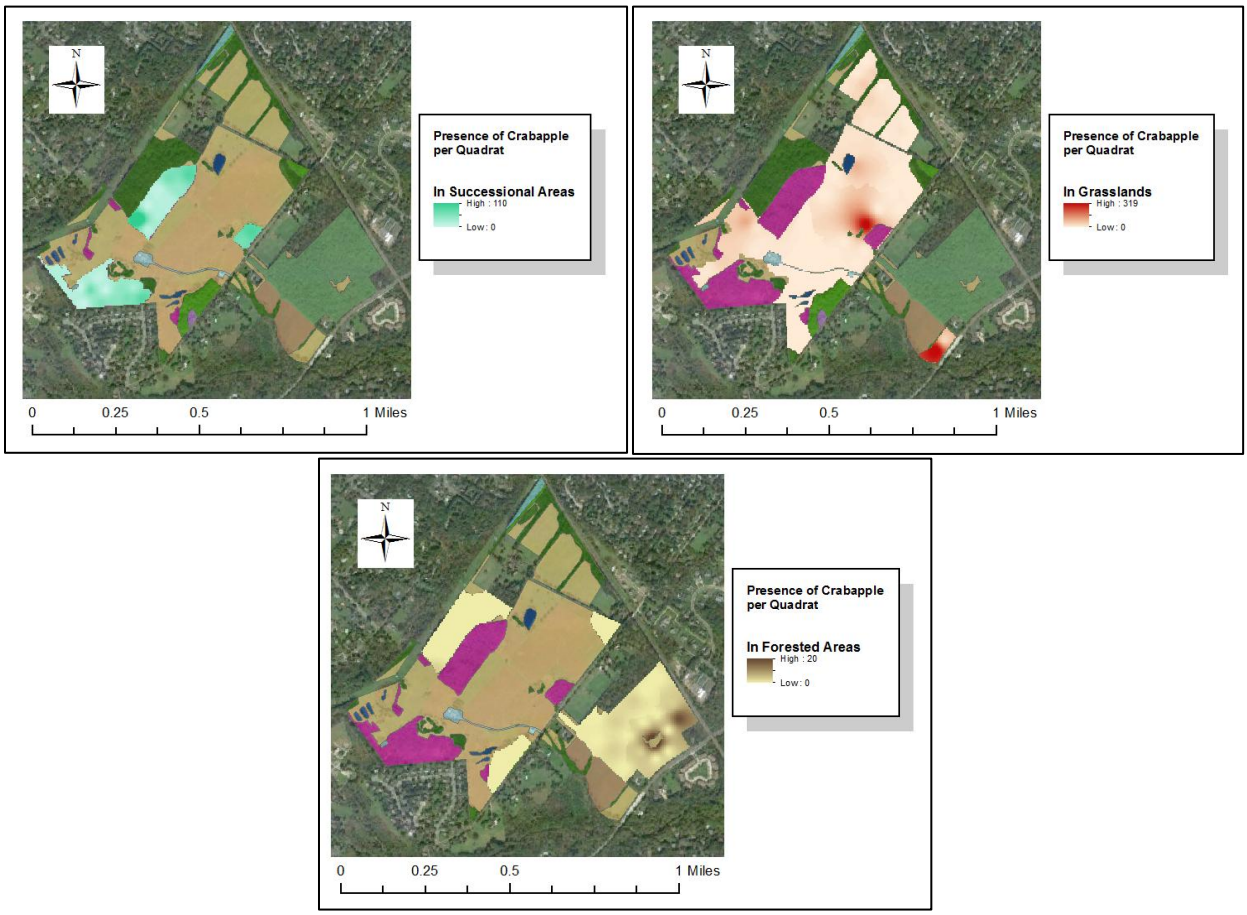
Larix Kaempferi/Japanese Larch:

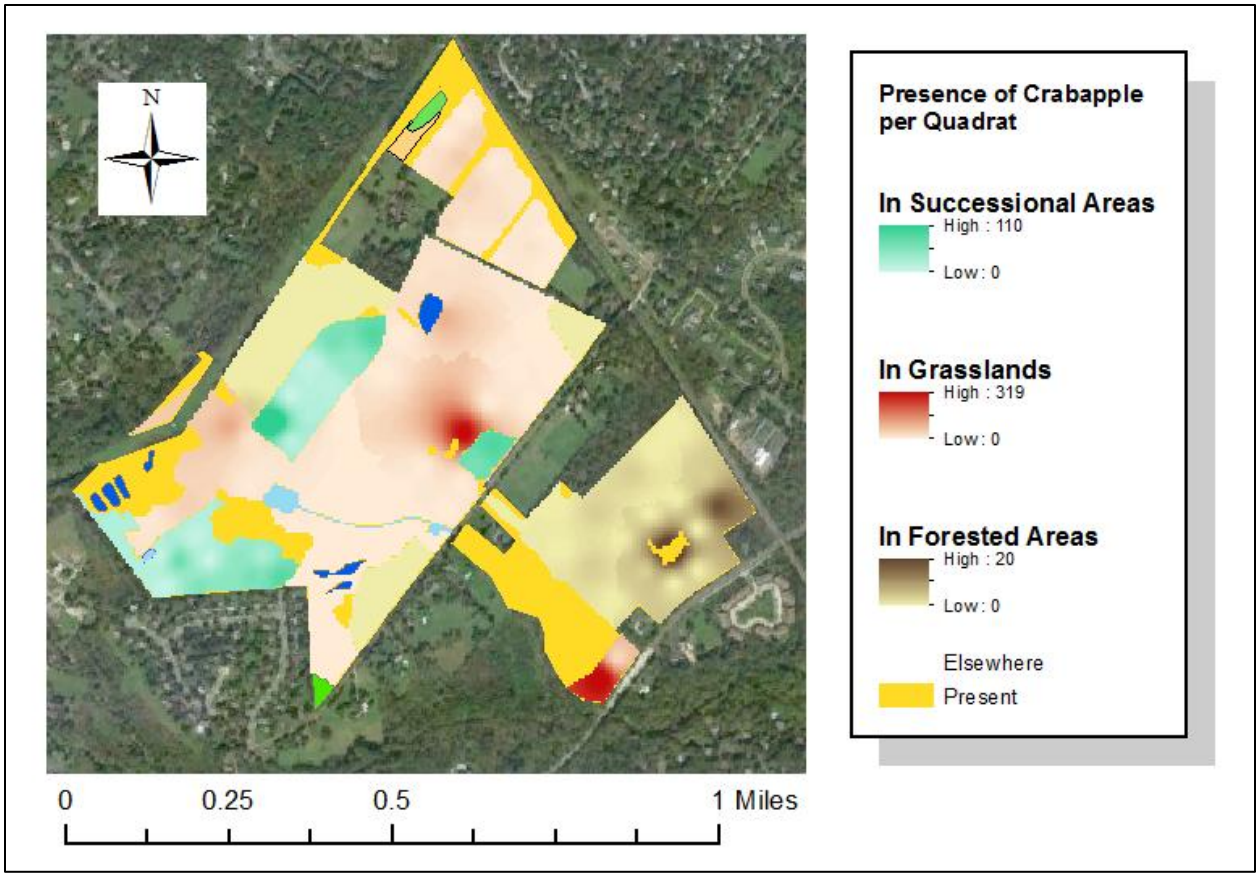
A plantation was listed in the 2008 survey, but could not be found for sure. The survey stated that it was in the forested area east of the power line right-of-way. There were a few trees in the same general area that were examined with binoculars. They are on the map for Norway spruce as well, but are more likely the Japanese larch. Inexperience sometimes matters.



Malus/Crabapple:

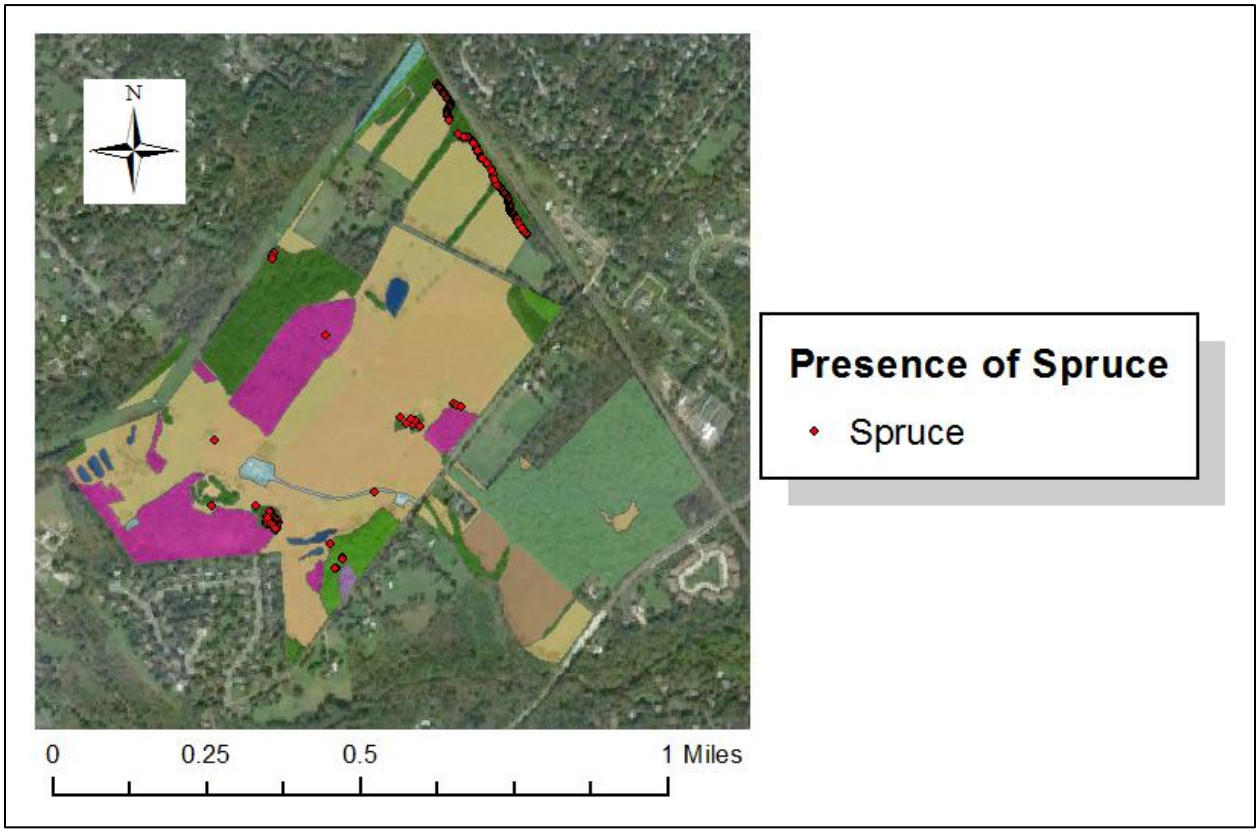
Crabapples are one of the most common plants at the preserve. A mixture of non-native cultivars and hybrids, there do not appear to be any native crabapples. As *Plants of Pennsylvania* states, "hybridization and the presence of numerous horticultural cultivars can make identification difficult" (Rhoads and Block 2007). Four maps were created to help understand the density. One for forested areas, one for early to mid successional areas, and one for grasslands. A combined map also includes the fact that everywhere else has some presence of these plants.




N
Presence of Crabapple per Quadrat
In Successional Areas
High : 110
Low : 0
In Grasslands
High : 319
Low : 0
In Forested Areas
High : 20
Low : 0
Elsewhere
Present
0
0.25
0.5
1 Miles

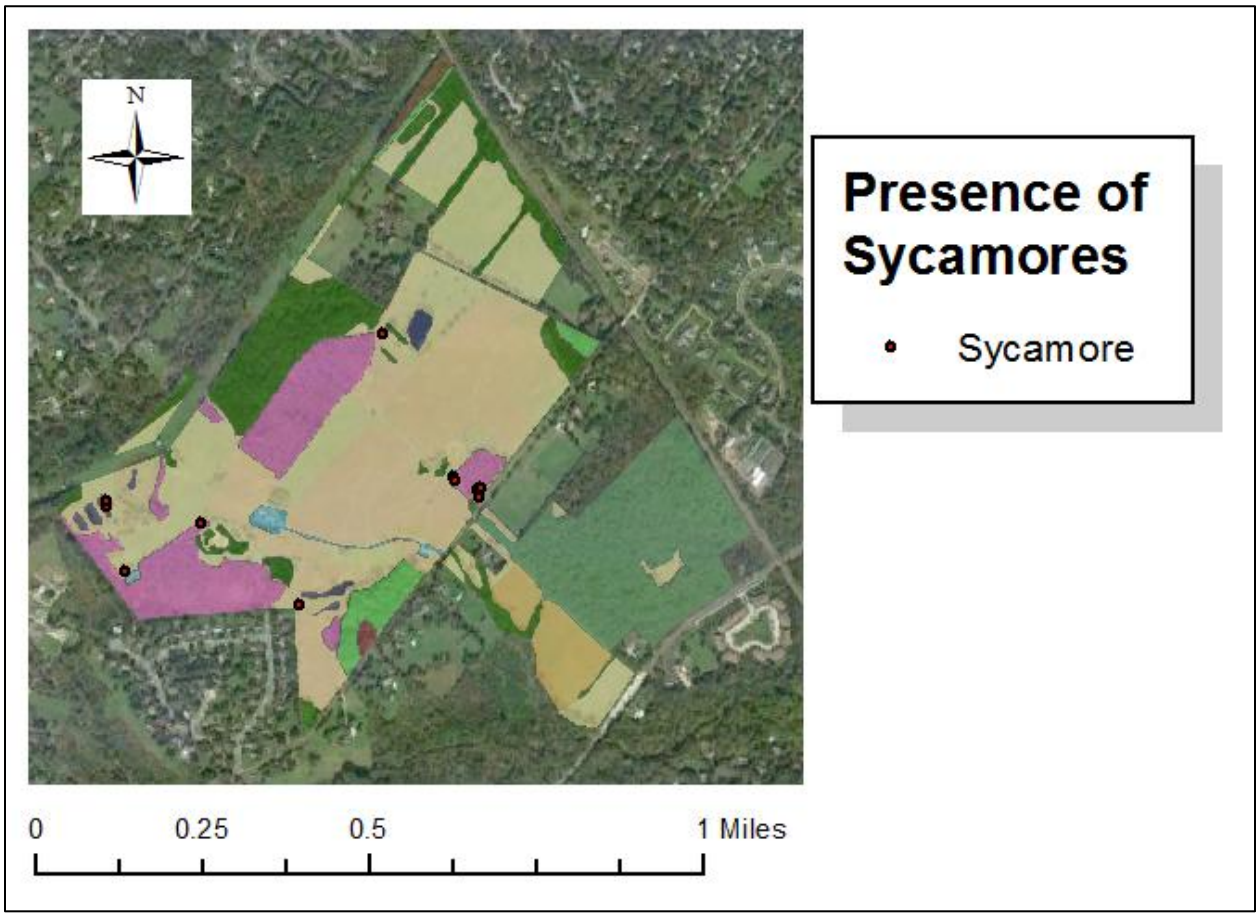
Picea Abies/Norway Spruce and Picea Glauca/White Spruce:

As management of these two species is similar, and the fact that they look very similar, these two species were mapped together to save time. There are likely some individuals that were missed as one or both appear to have begun escaping from where they were planted.



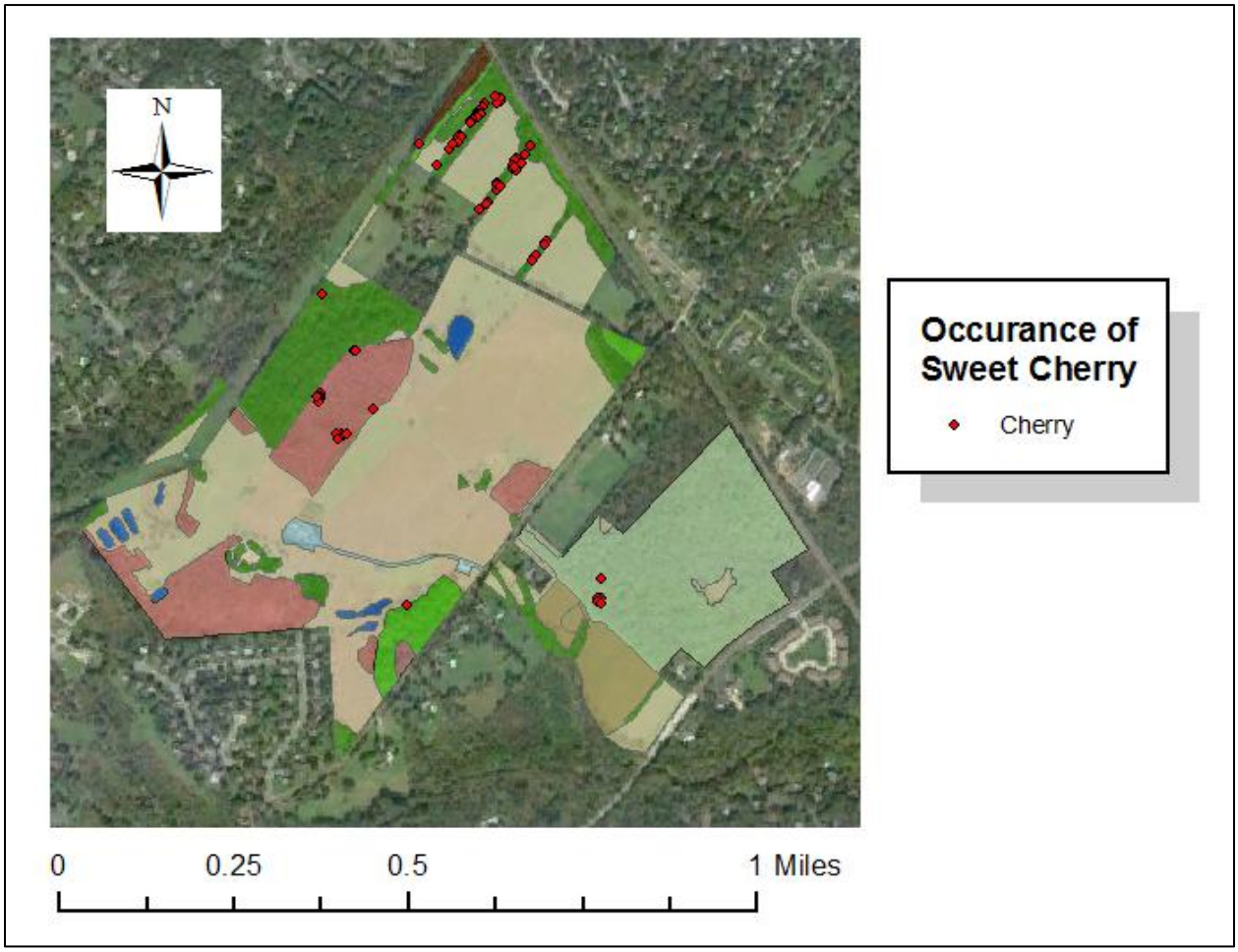
Platanus x Acerifolia/London Planetree and Platanus Occidentalis/Sycamore:

These two species hybridize in a long continuum and so the only way to truly distinguish them is to see how many fruiting heads are on each peduncle. Two for the non-native, and one for the native (Timothy Block, *personal communication*). As native sycamore is FACW-, it is likely that at least the ones found in the wetlands are native, but the rest will have to wait until later in the season.



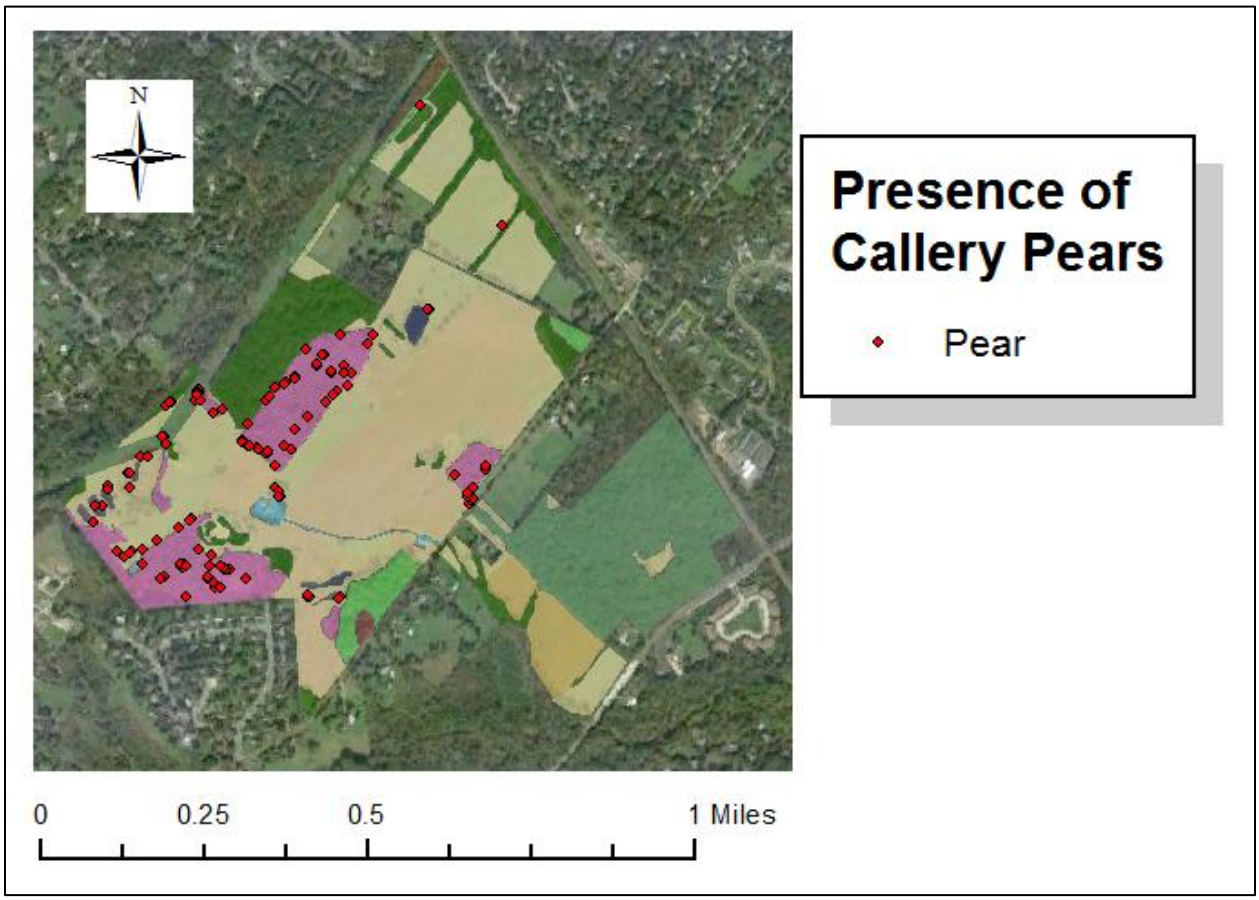
Prunus Avium/Sweet Cherry:

Prunus avium often grows in clumps, with many appearing next to each other. It is certain that many were not mapped, but as mapping of the preserve took place, when these trees were found, they were recorded. The most appear to be in the hedgerows in the north.



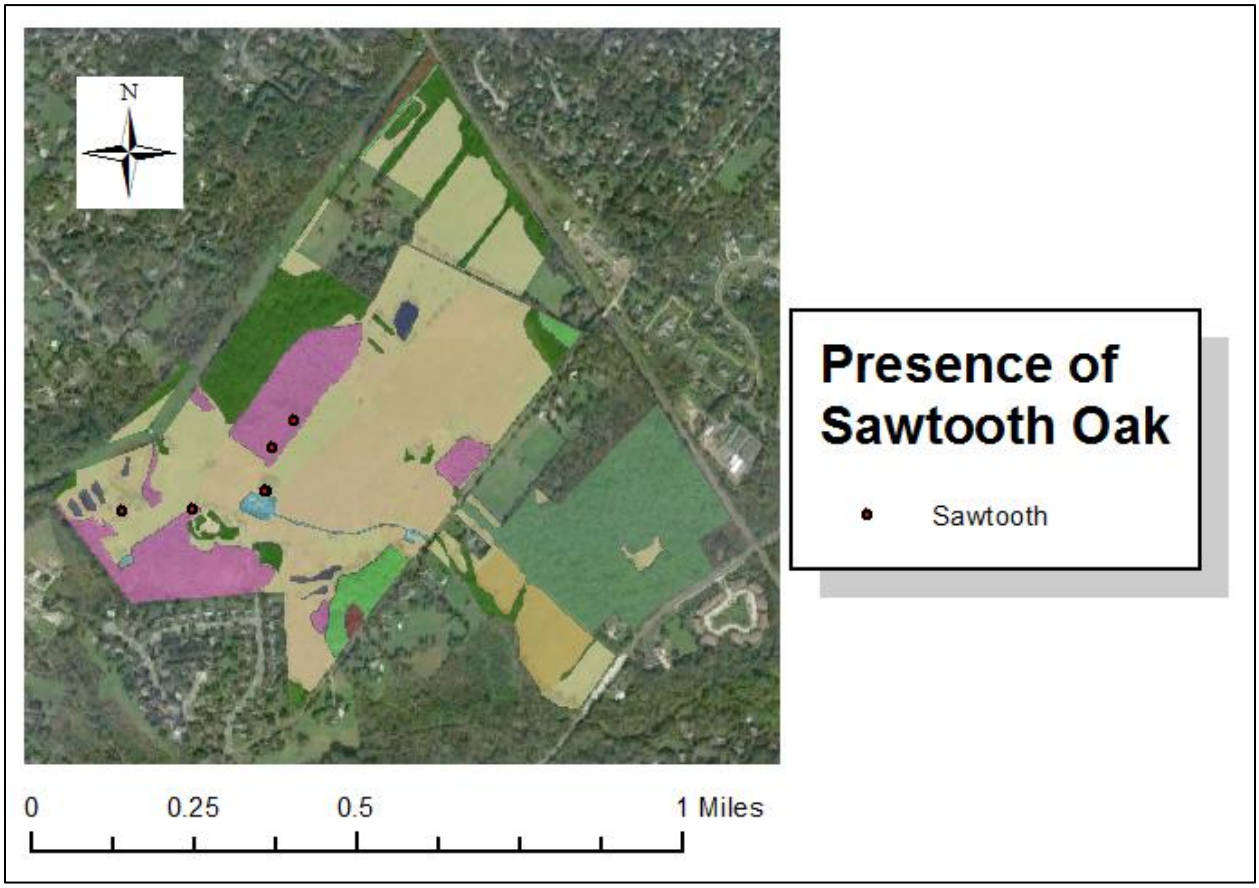
Pyrus Calleryana/Callery Pear:

An attempt was made to record all Callery pears when they flowered because the only other flowering species at the time was Sweet cherry. Otherwise, it is difficult to always be certain that the plant is a callery pear and not another pear or a crabapple. However, there was not enough time, so while the northwestern half of the preserve is very accurate, the southeastern half is less so. The areas east of Swedesford road did not appear to have any, but may have had a few as the Wissahickon Valley Watershed Association land that borders Gwynedd has a major invasion.



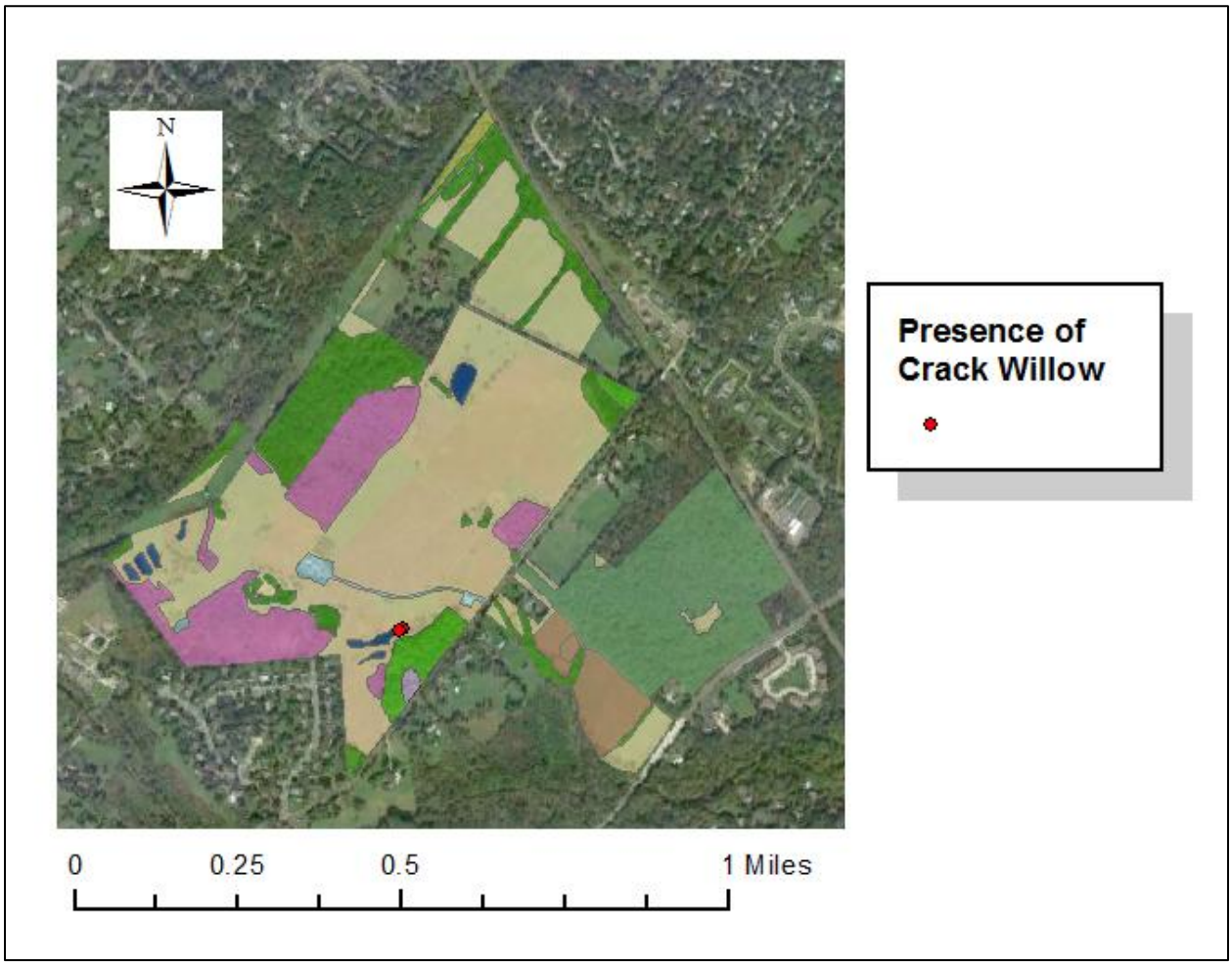
Quercus Acutissima/Sawtooth Oak:

Many of these have been planted by previous management and appear to have become slightly invasive. It is not certain that all were recorded. The 2008 survey suggests that there may be some more that were missed in the lower crabapple areas.



Salix Fragilis/Crack Willow:

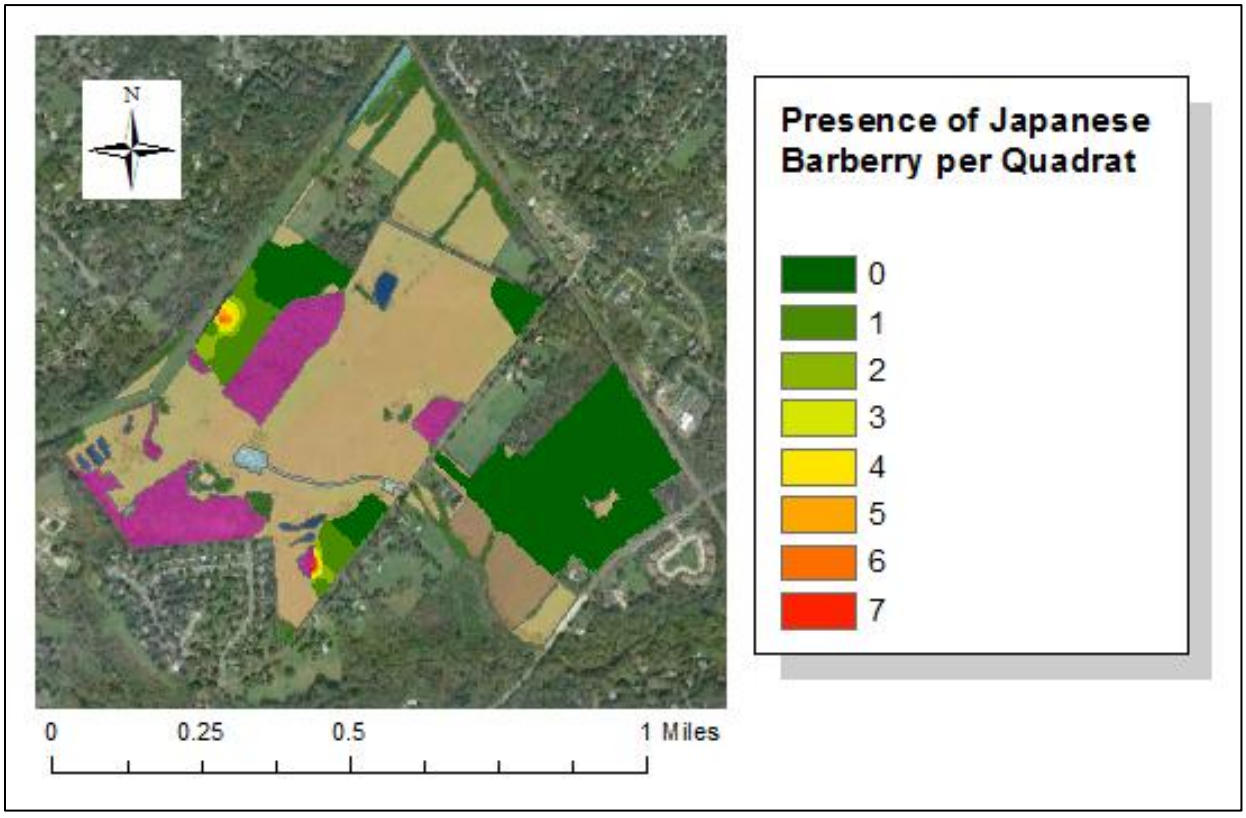
Identifying willows is very difficult. The 2008 survey even sometimes listed genus and not species. Using this survey as a guide, it is believed that the crack willows are in the southern wetlands. This is because the survey mentioned that Black willow (Salix nigra) occurs in most of the wetlands and there appeared to be 2-3 individuals in this location that were different.



Shrubs

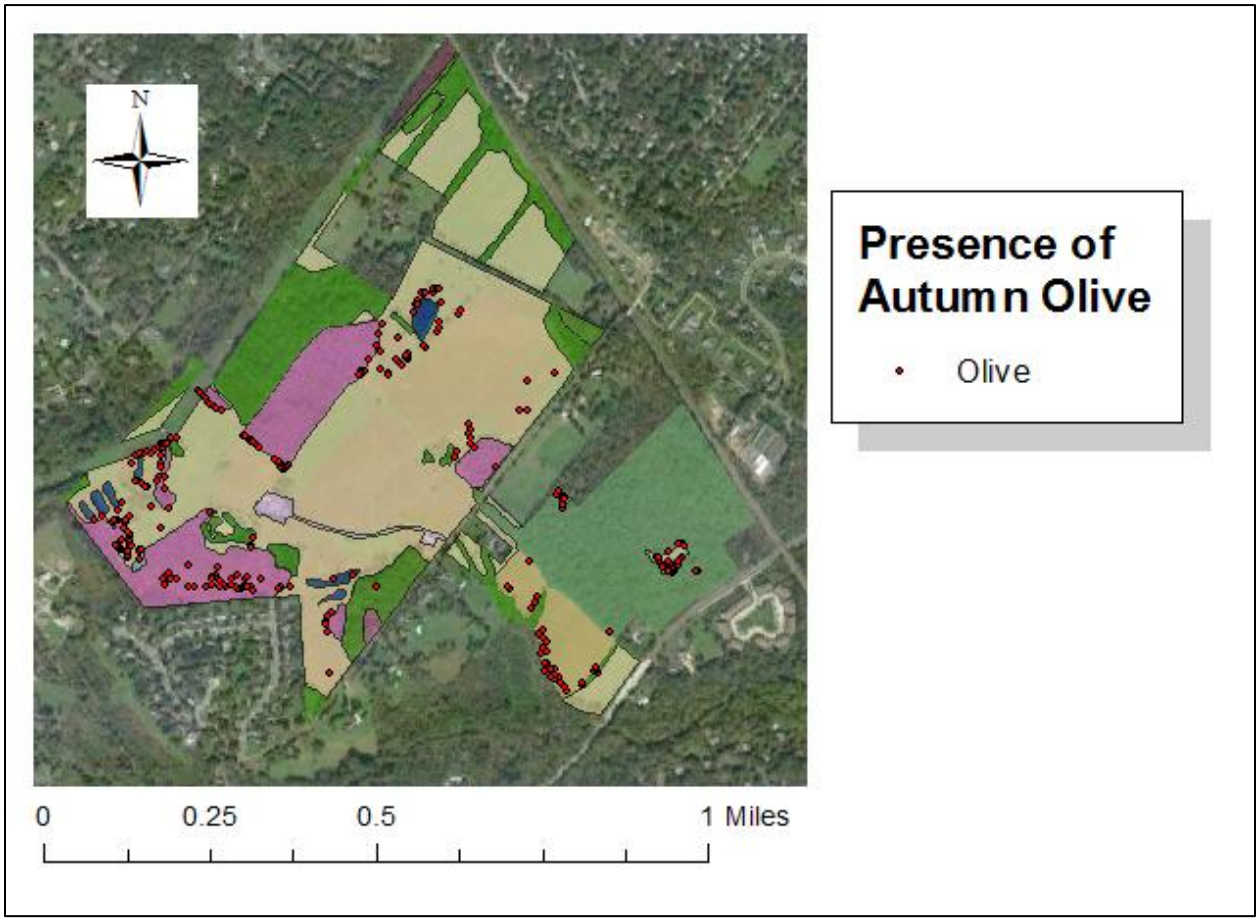
Berberis thunbergii/Japanese barberry:

Not very common at Gwynedd, Japanese barberry was found most often in the southern forest along Swedesford with one rather large individual present.



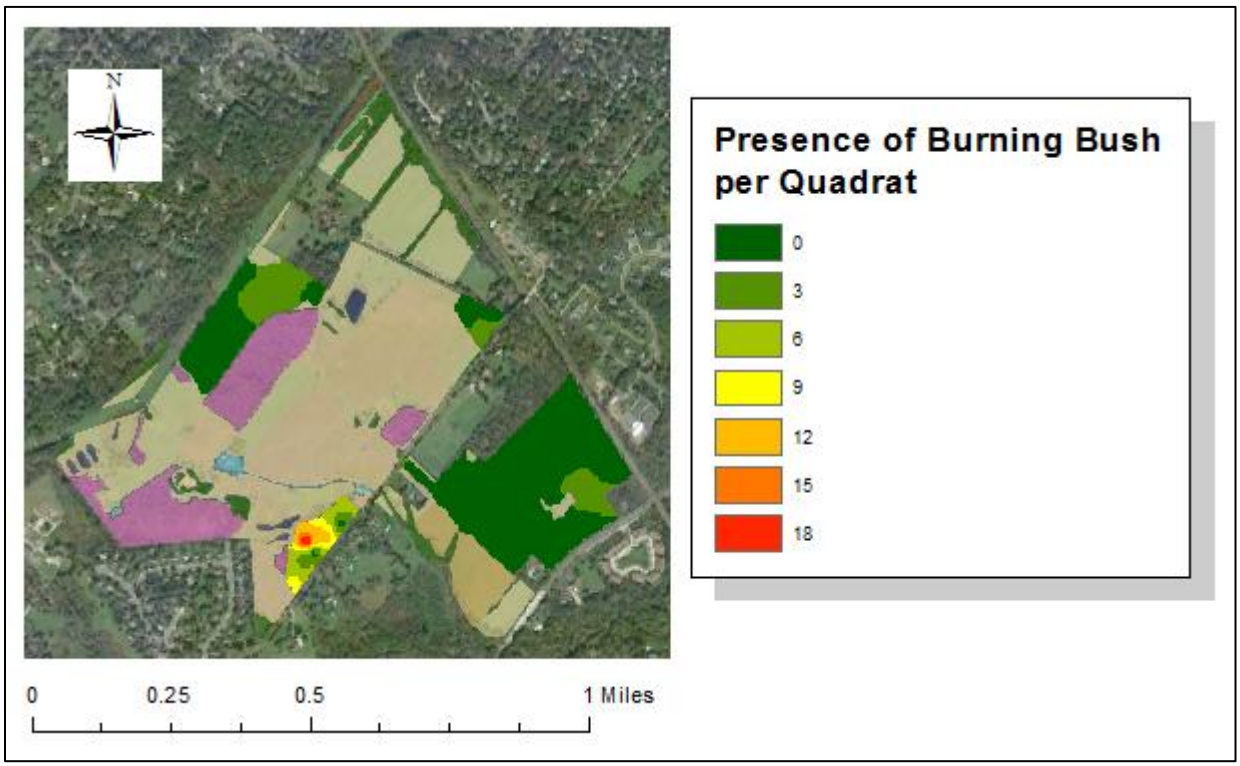
Elaeagnus Umbellata/Autumn Olive:

This is probably the most accurately mapped species as its distinctive coloring is easy to spot. There are many individuals in mowed grassland areas that are not easy to pick out and were missed by surveying.



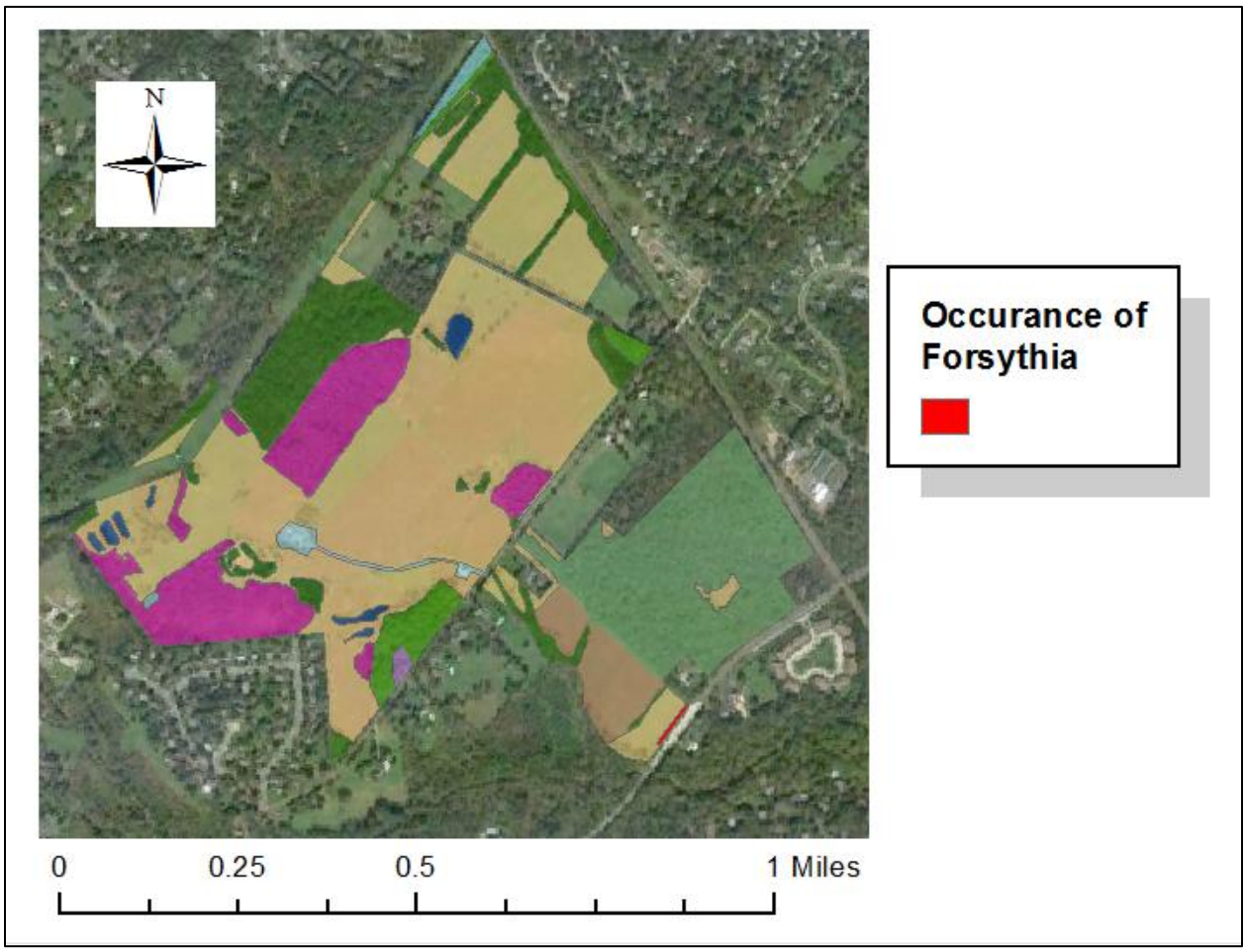
Euonymus Alatus/Burning Bush/Winged Euonymus:

Not very common, Burning bush was found only in forested areas. Most individuals were short from deer herbivory, but some very large ones were present.



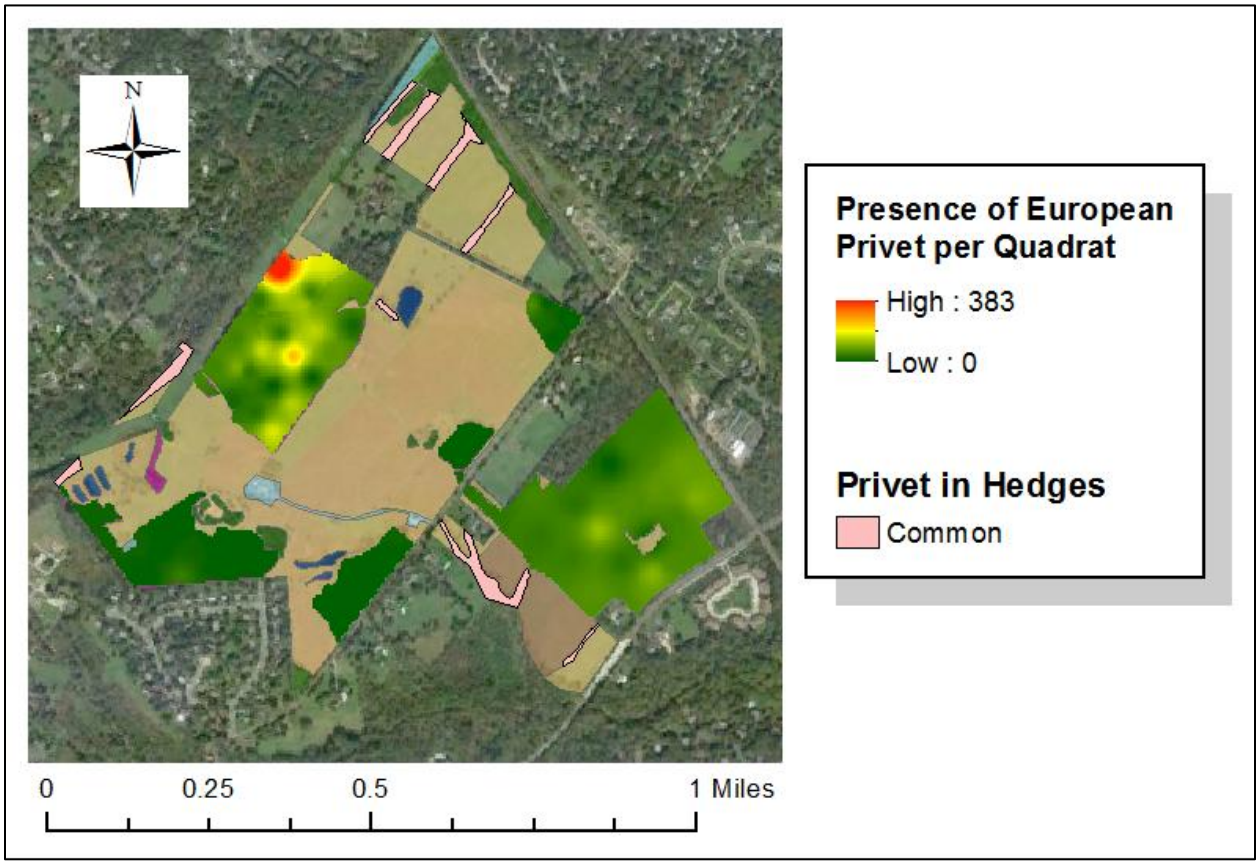
Forsythia sp./Forsythia:

No Forsythia were noted, but the 2008 survey mentioned a number of them in a hedgerow at the far southeastern edge of the preserve.



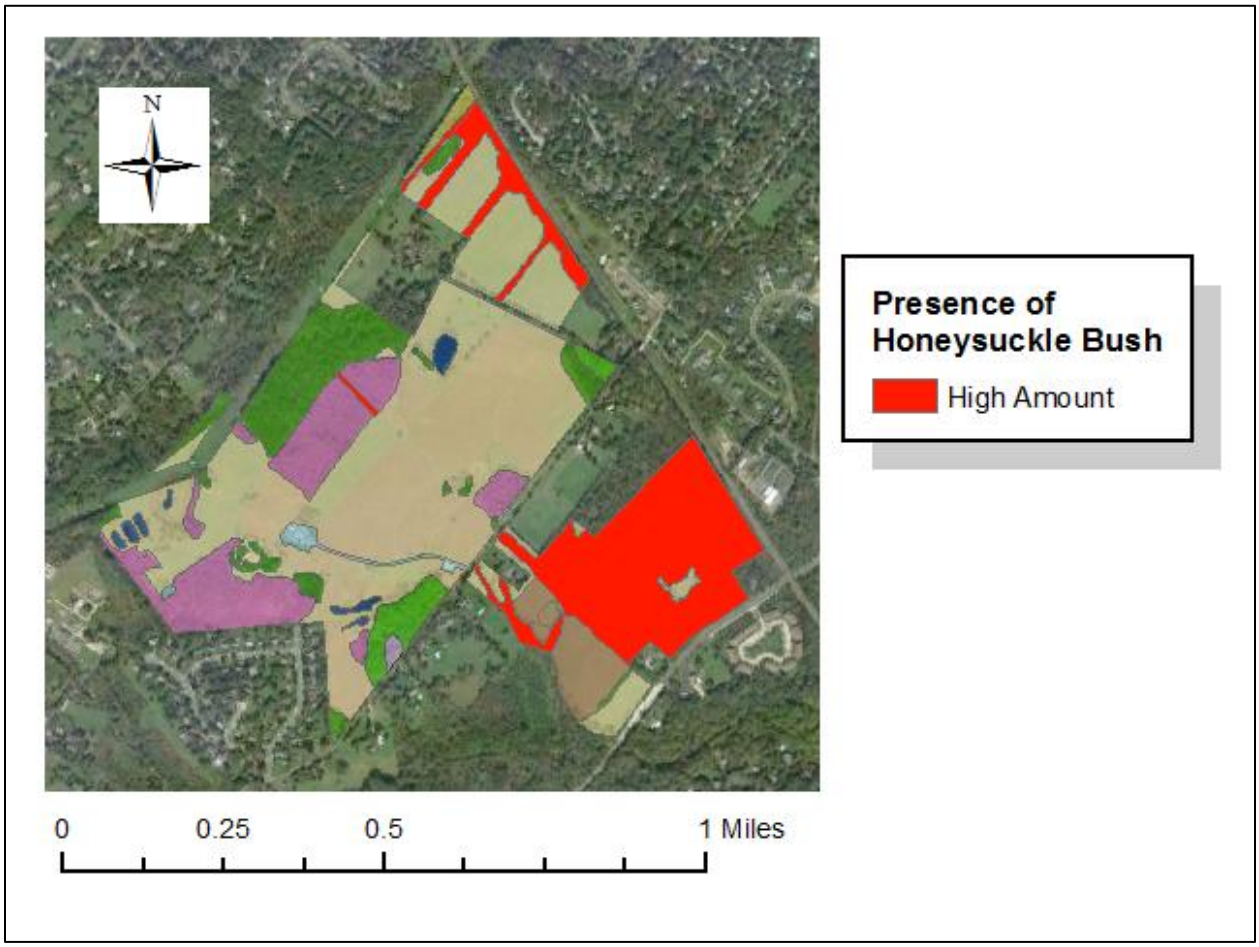
Ligustrum Obtusifolium/European Privet:

European privet is a very common invasive at Gwynedd. It is heaviest in the northern hedgerows, the large northwestern forested area, and Tunnel Woods. An attempt was made to do a stem count of privet, except when the stems obviously came from the same plant. This did a disservice to large privets where the stems were more apparently of the same plant than smaller ones (the stems on large privets were joined together above the ground).



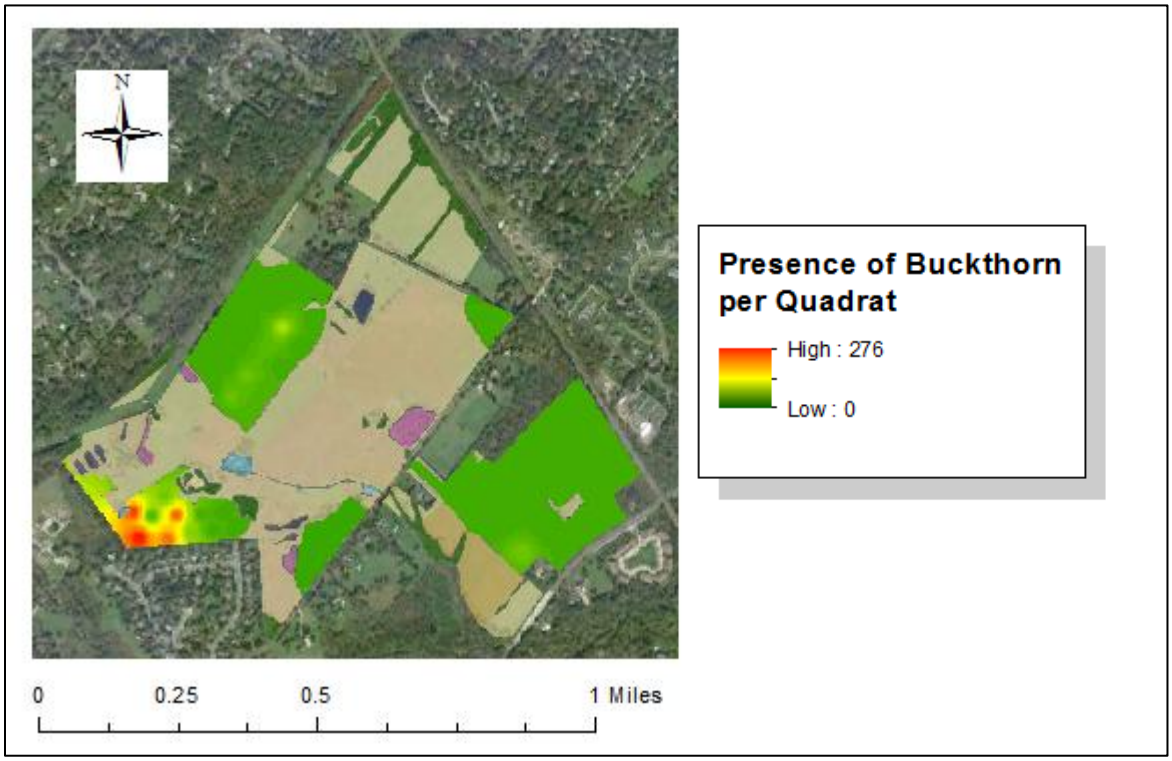
Lonicera sp./Honeysuckle Shrub:

Honeysuckle bushes are fairly common at Gwynedd. There are likely more than one species, but time considerations prevented checking them out in detail. Morrow's honeysuckle (*Lonicera morroii*) was the only one keyed with a high degree of confidence. Due to the high number of wide forested trails and open canopies, Tunnel Woods was recorded as having a high presence, similar to some of the hedgerows, but there may be bias in that Tunnel Woods was surveyed mostly when these bushes were flowering. More time would have been helpful to be more precise as this plant was rarely recorded in quadrats. Another day spent doing a walkthrough probably would have been useful for these particular species.



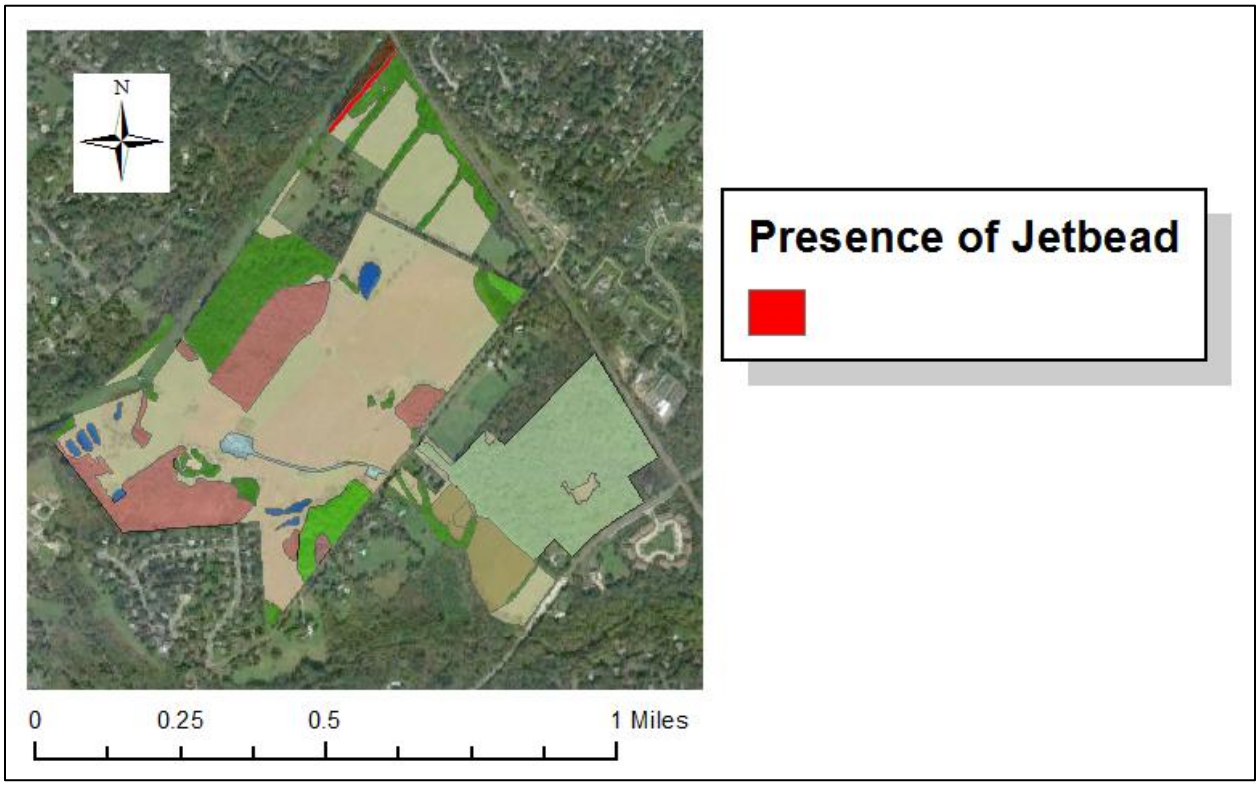
Rhamnus Cathartica/Common Buckthorn:

Common buckthorn is a problem and becoming worse as it spreads from its main centers. None was recorded at the beginning in the large northwestern forest. This may be that when recording many, many privets, buckthorns, with no leaves, are similar and may have gotten confused. Their sub-opposite branching is different, but similar enough. However, later less-extensive walkthroughs did not notice any populations of note in the forest.



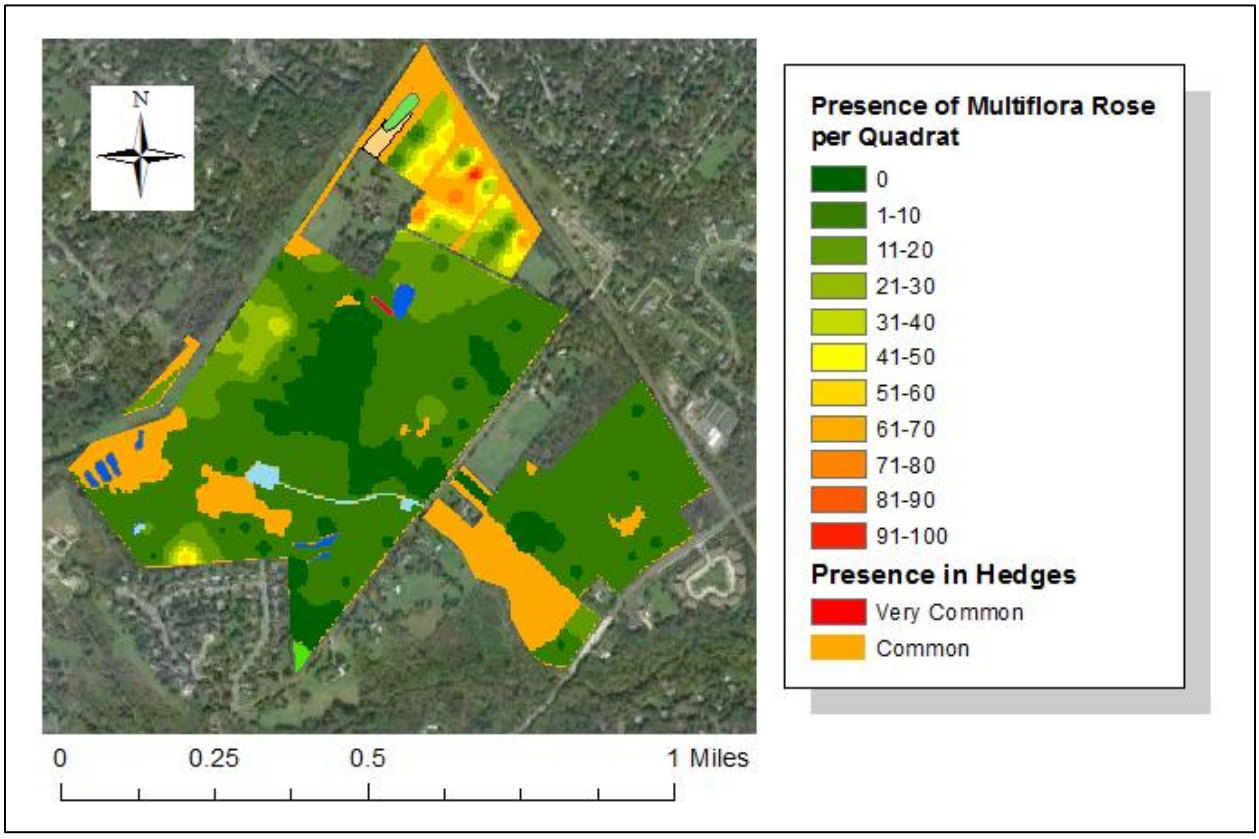
Rhodotypos Scandens/Jetbead:

No Jetbead was noted, but the 2008 survey put them in the far north forest along Haines run.



Rosa Multiflora/Multiflora Rose:

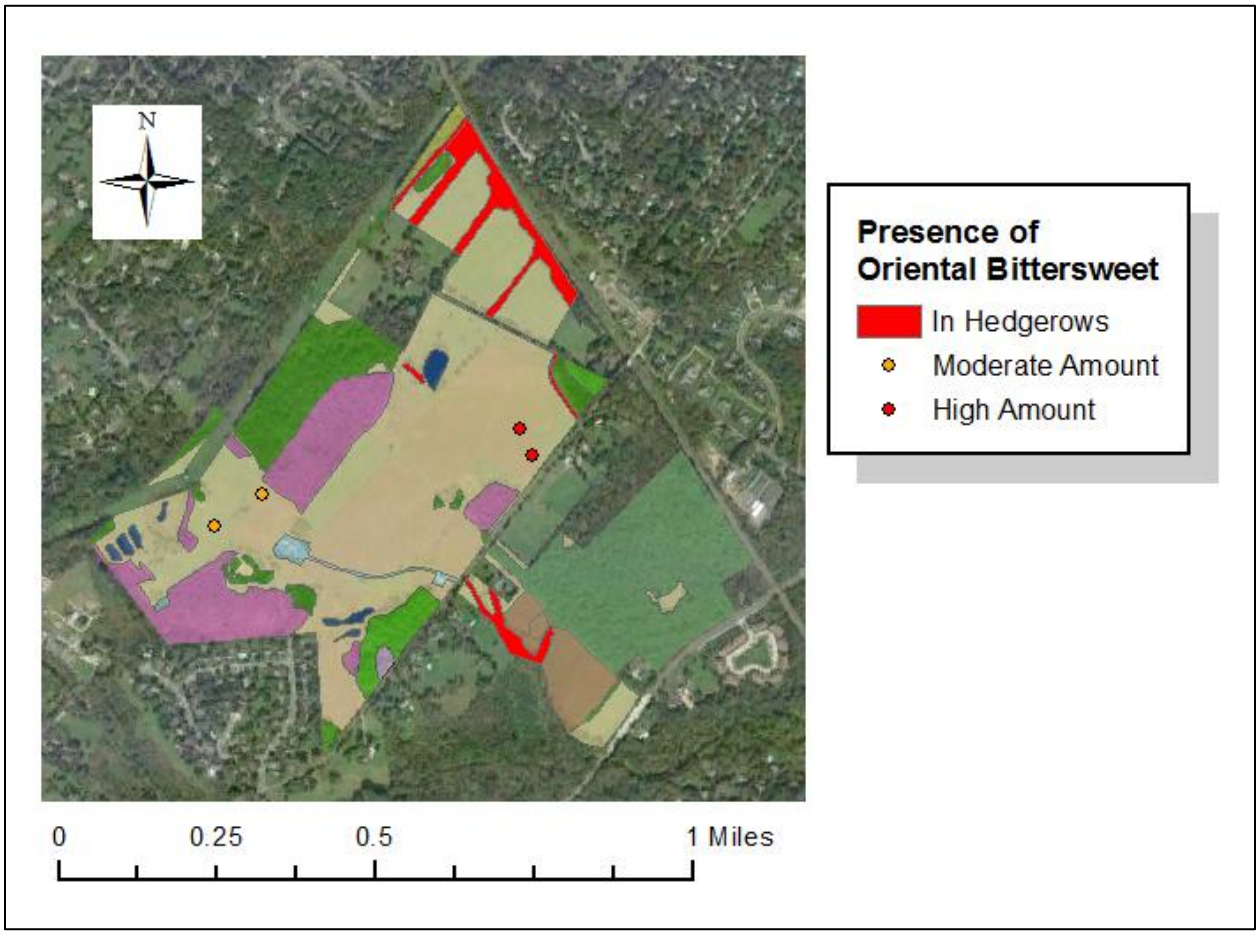
This invasive species appears to be on the decline. The crabapple habitats were formerly called crabapple AND multiflora rose, but virtually no roses are found any more. Rose rosette disease is likely taking a toll. There are still some large individuals, with the largest found in Tunnel Woods. Individual roses were counted, rather than stems. There may have been some error due to this method (as with all methods that don't involve extracting the plant by the roots).



Vines

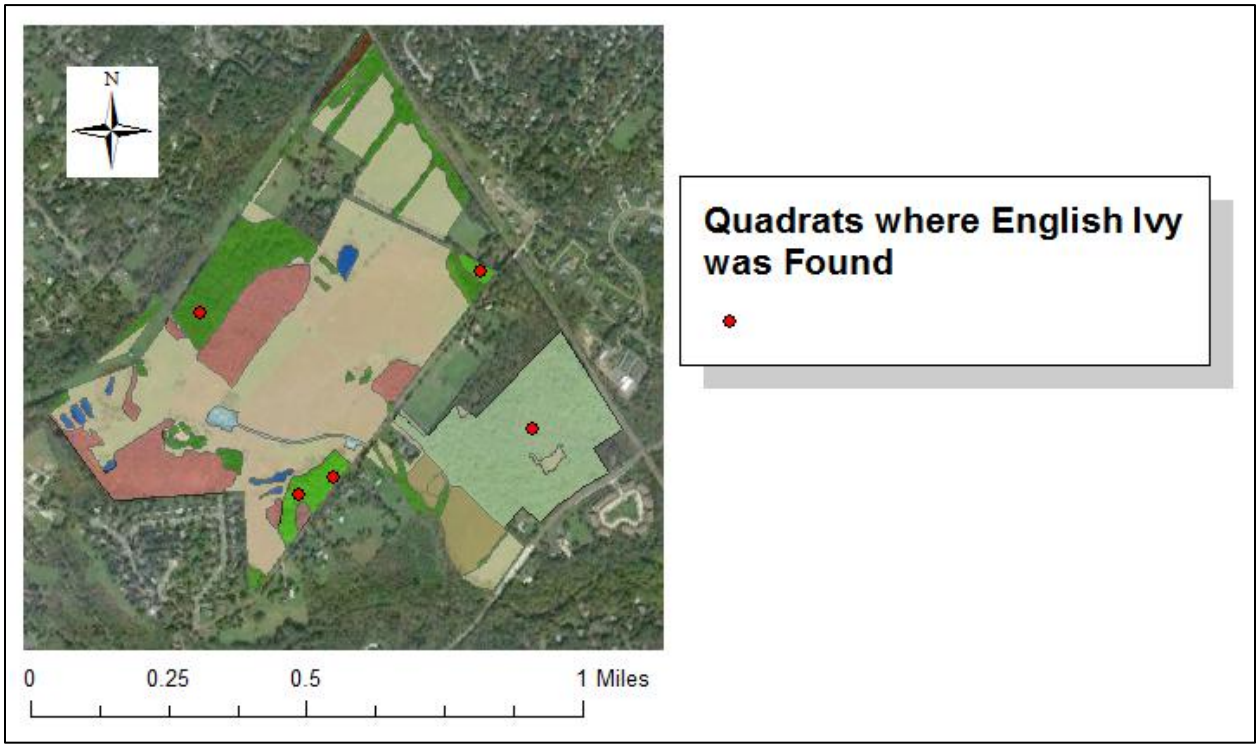
Celastrus Orbiculatus/Oriental Bittersweet:

As a vine, Oriental bittersweet is very difficult to map. It is very common in hedgerows and forest edges. It is also common in some the fields where many individuals have been found to survive burns. The points where it is recorded in the fields in high amounts are surrounded by many other invasions of this weed. The burned area just to the northwest is also heavily infested. Much of the preserve has invasions in the mentioned habitats, but in lesser amounts. Forested trails in Tunnel Woods are common occurrences.



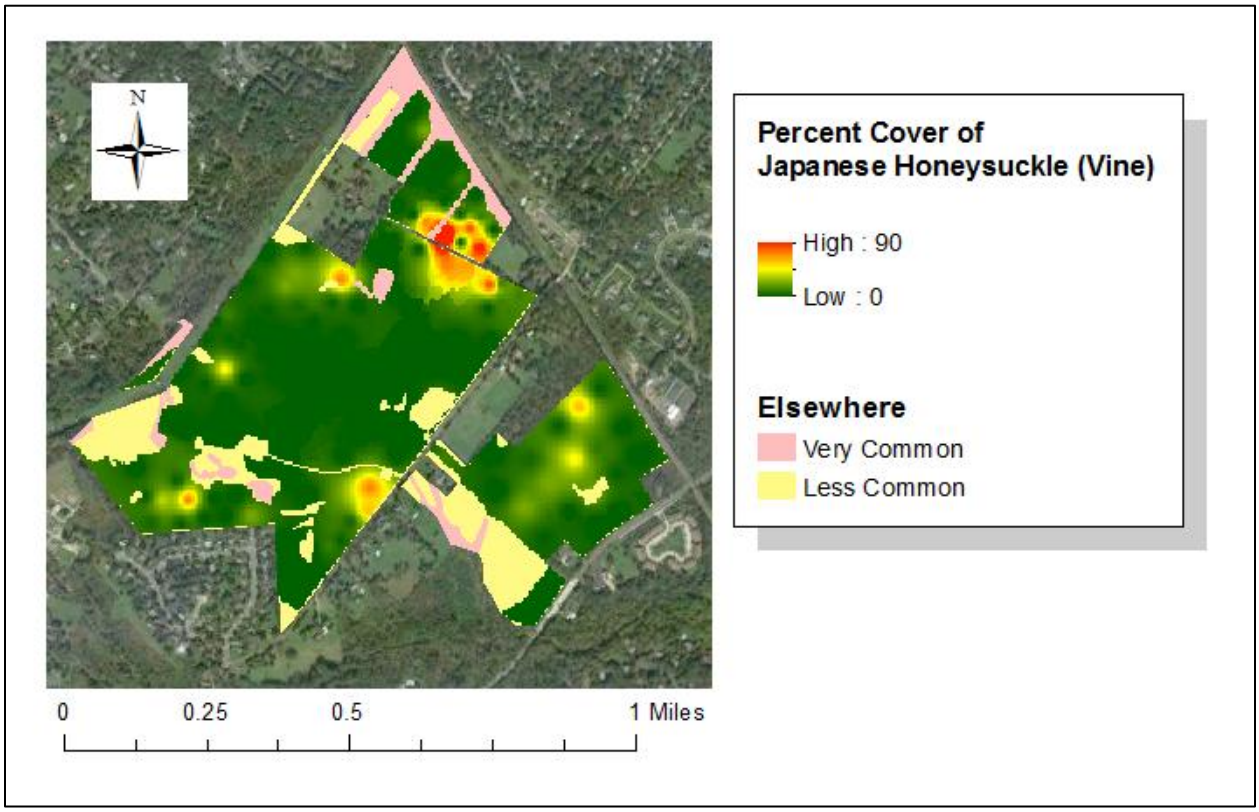
Hedera Helix/English Ivy:

English ivy is very rare. Only one example in Tunnel Woods was actually discovered climbing a tree and the rest were seedlings. The one climbing individual is also competing with poison ivy and Oriental bittersweet for the same doomed tree.



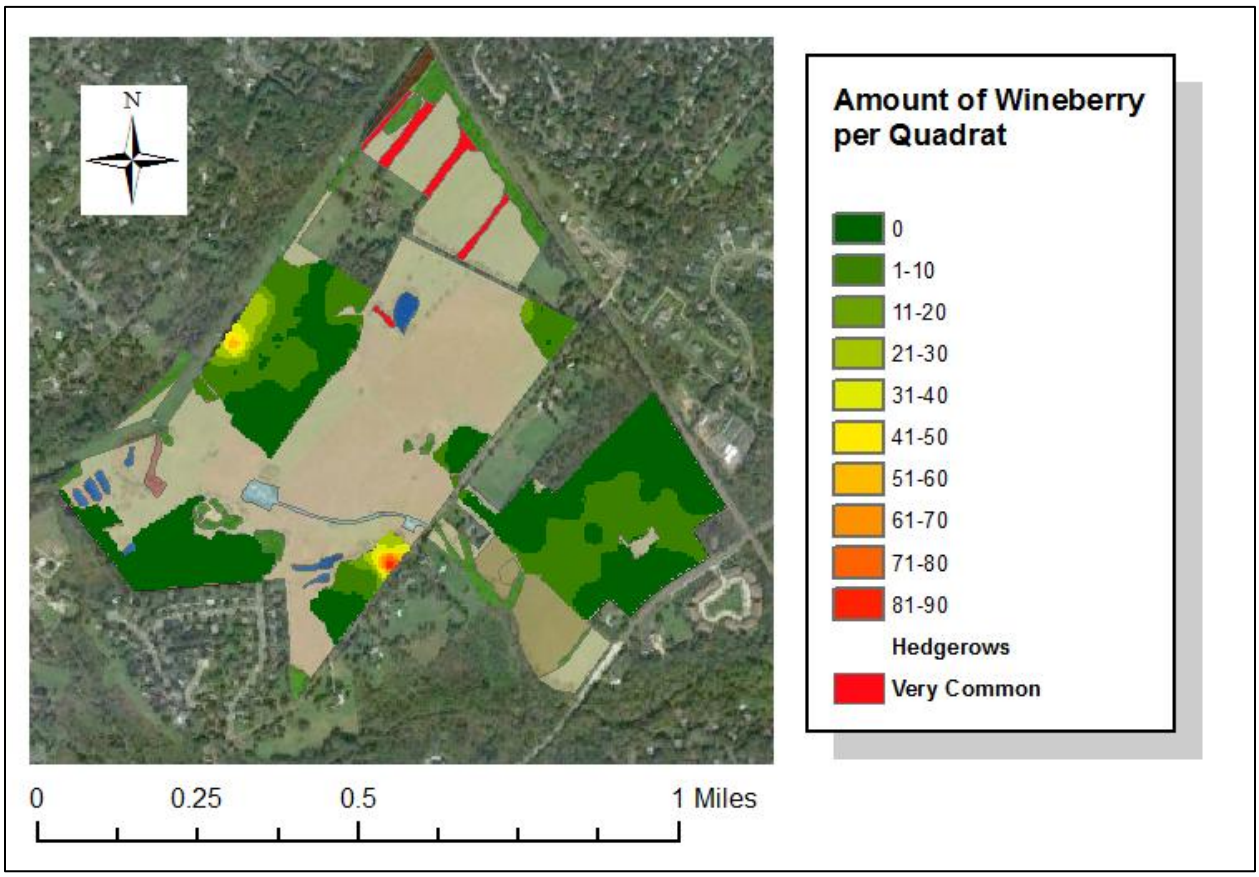
Lonicera Japonica/Japanese Honeysuckle:

Japanese honeysuckle probably has the most area covered of any plant in Gwynedd.



Rubus Phoenicolasius/Wineberry:

Wineberry is common in the shaded forested areas, especially near streams, and in some hedgerows, but is not found much elsewhere.



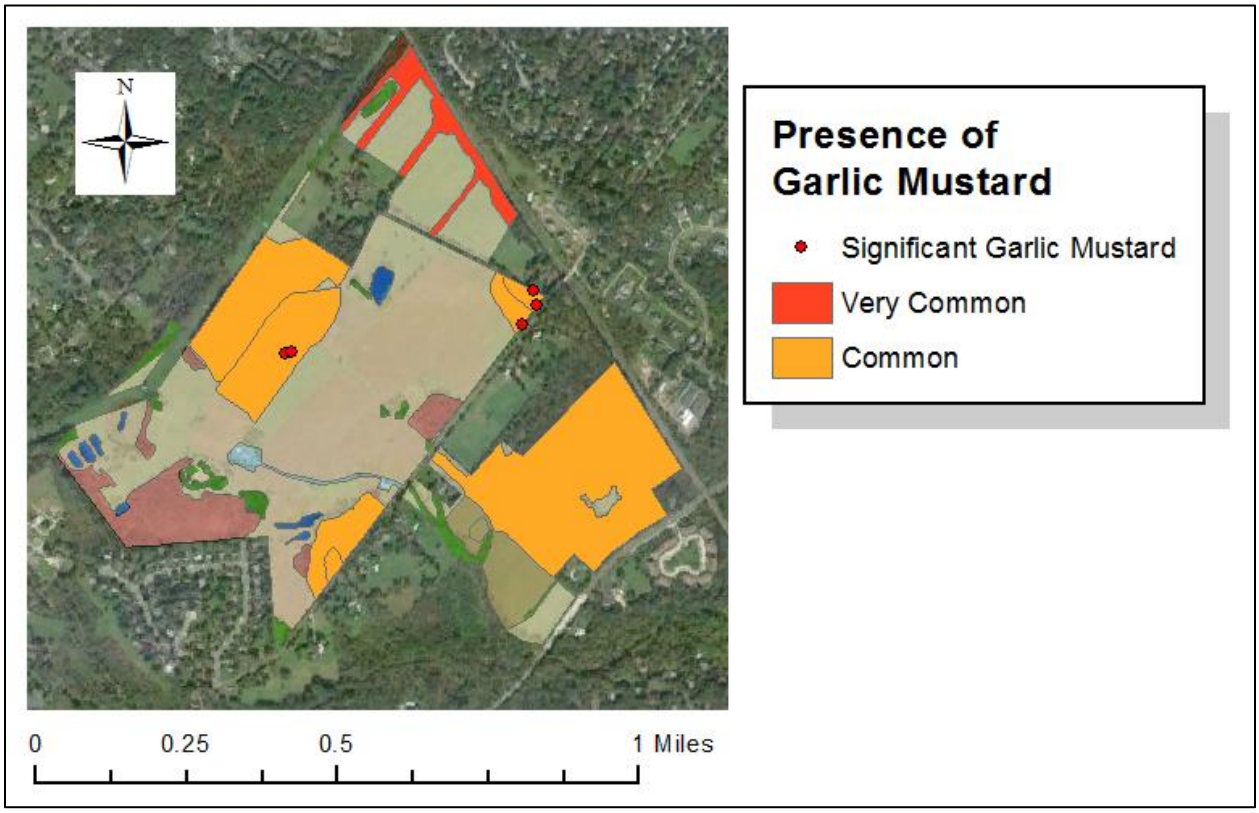
Herbs

Achillea Millefolium/Common Yarrow:

Although yarrow was recorded at quadrats and made note of elsewhere, it was very uncommon and so it was decided that a map would not be useful data and actually be misleading. Yarrow is most heavily distributed at the edges of fields, near the mowed trails.

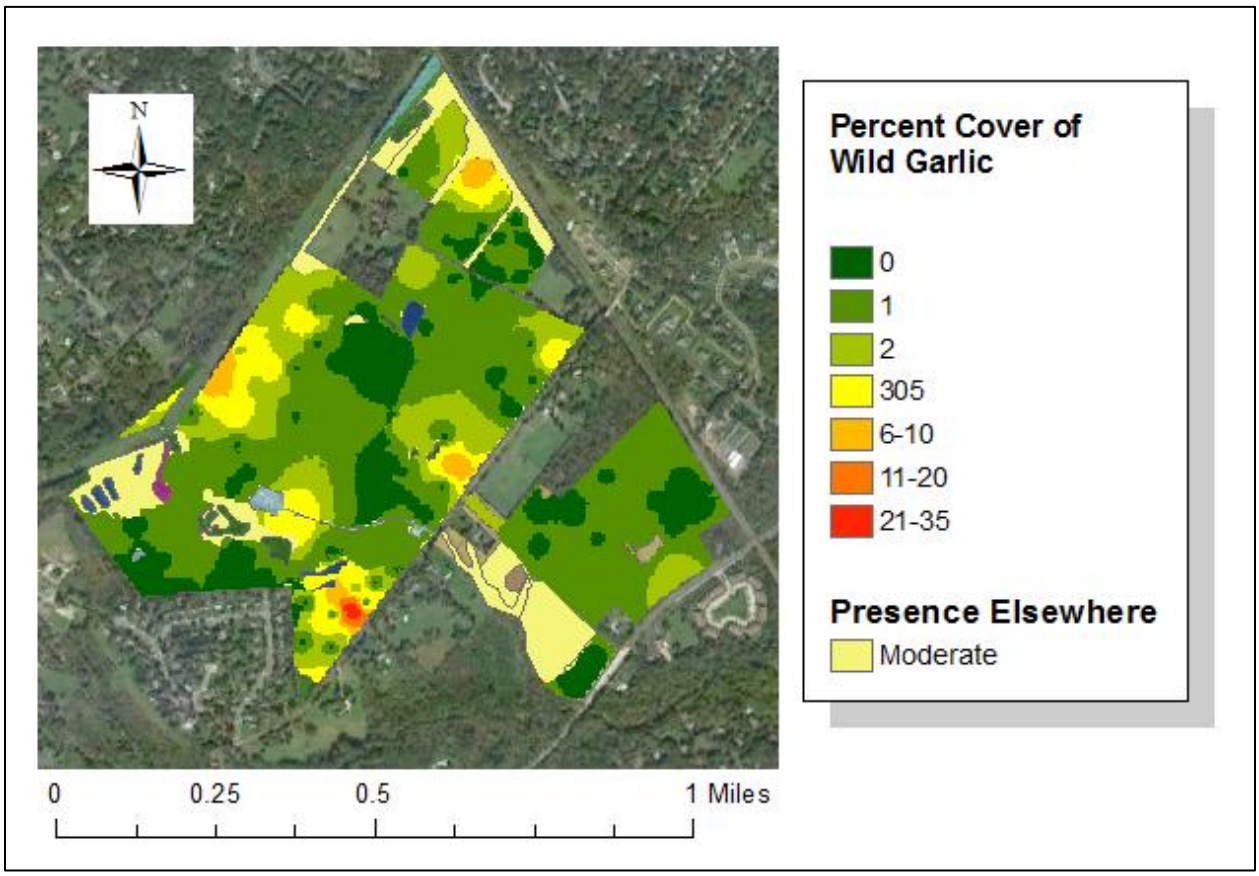
Alliaria Petiolata/Garlic Mustard:

Garlic mustard is not a problem at the preserve, but may be turning into one. It is in small numbers throughout, but there are two areas with significant patches. None was recorded in the large forested area in the northwest. This is likely due to the early season in which this area was surveyed, however in subsequent trips, only small amounts of garlic mustard was found.



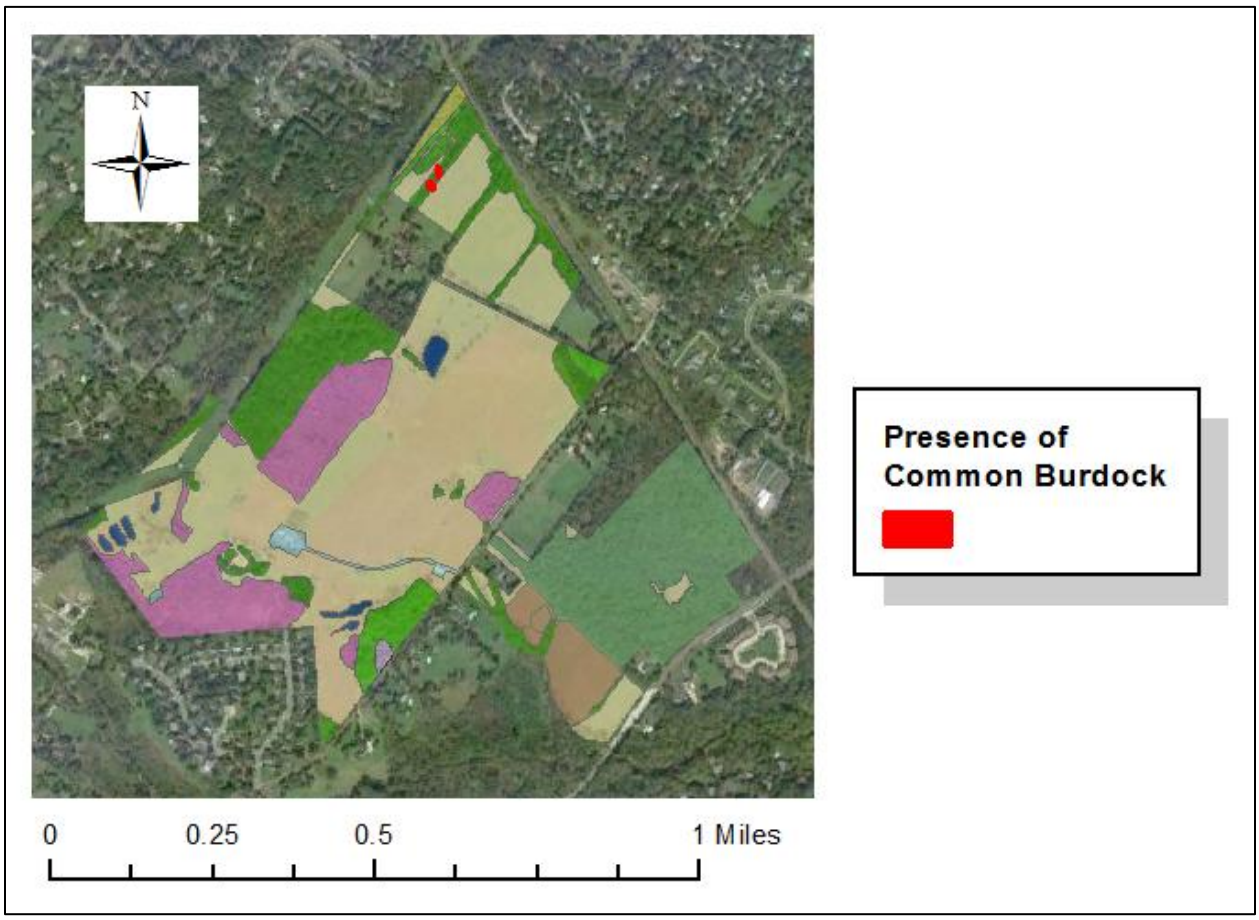
Allium Vineale/Wild Garlic:

Wild garlic is very common at Gwynedd, but usually in low numbers. Later surveys may have noted it less due to the presence of other green herbaceous plants camouflaging it.



Arctium minus/Common Burdock

Common burdock was not noted in the 2008 survey and may not have been present as it appears to only be in two areas.

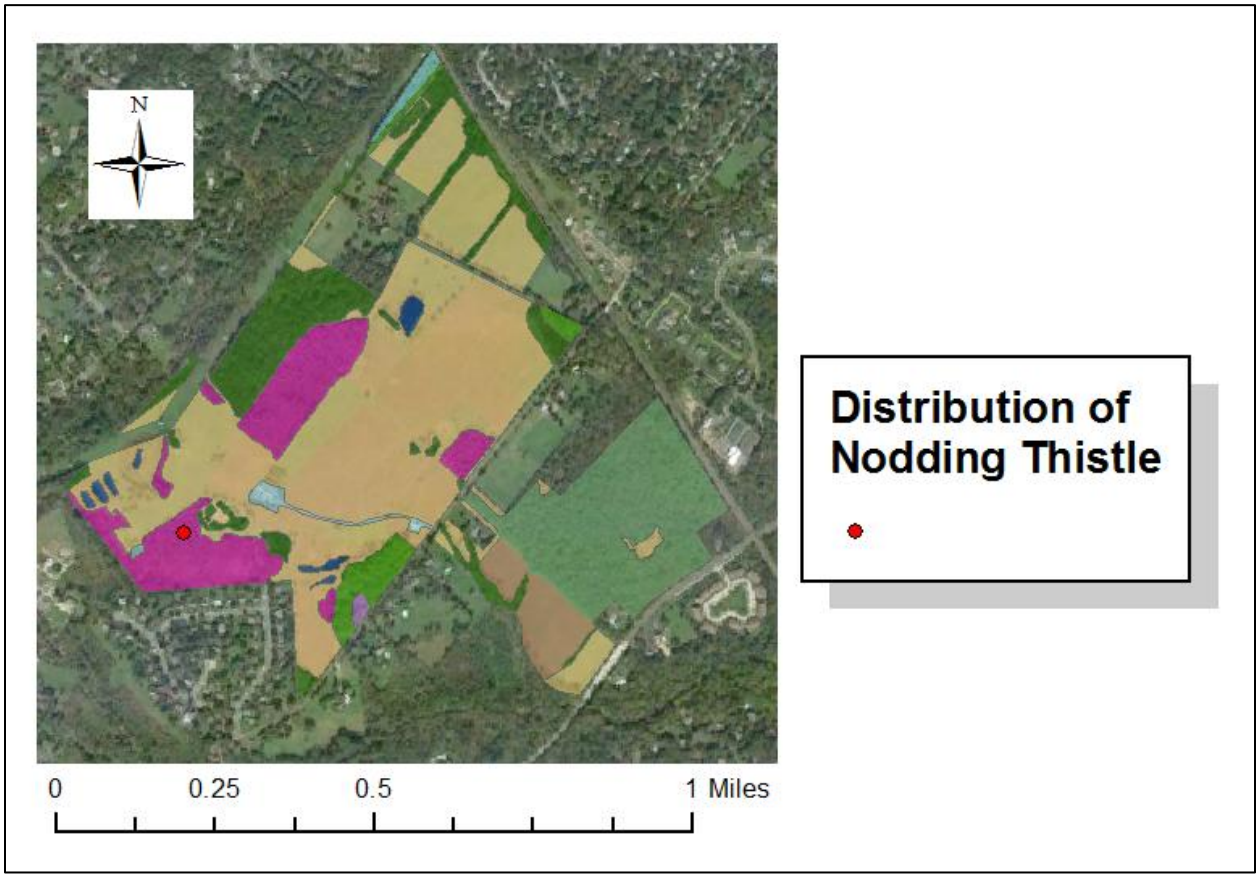


Cardamine Impatiens/Narrow-Leaved Bittercress:

This species was found common in all open fields. There were no dense monocultures, but it was easy to find in most locations.

Carduus Nutans/Nodding Thistle:

Although listed in the 2008 survey, only one area with Nodding thistle was found. In fact, as it was just a rosette, it is uncertain that it is Nodding thistle, but the 2008 survey was used as a guide. There were 5 rosettes in the one location (likely a single plant). The other thistles found were Canada thistle.

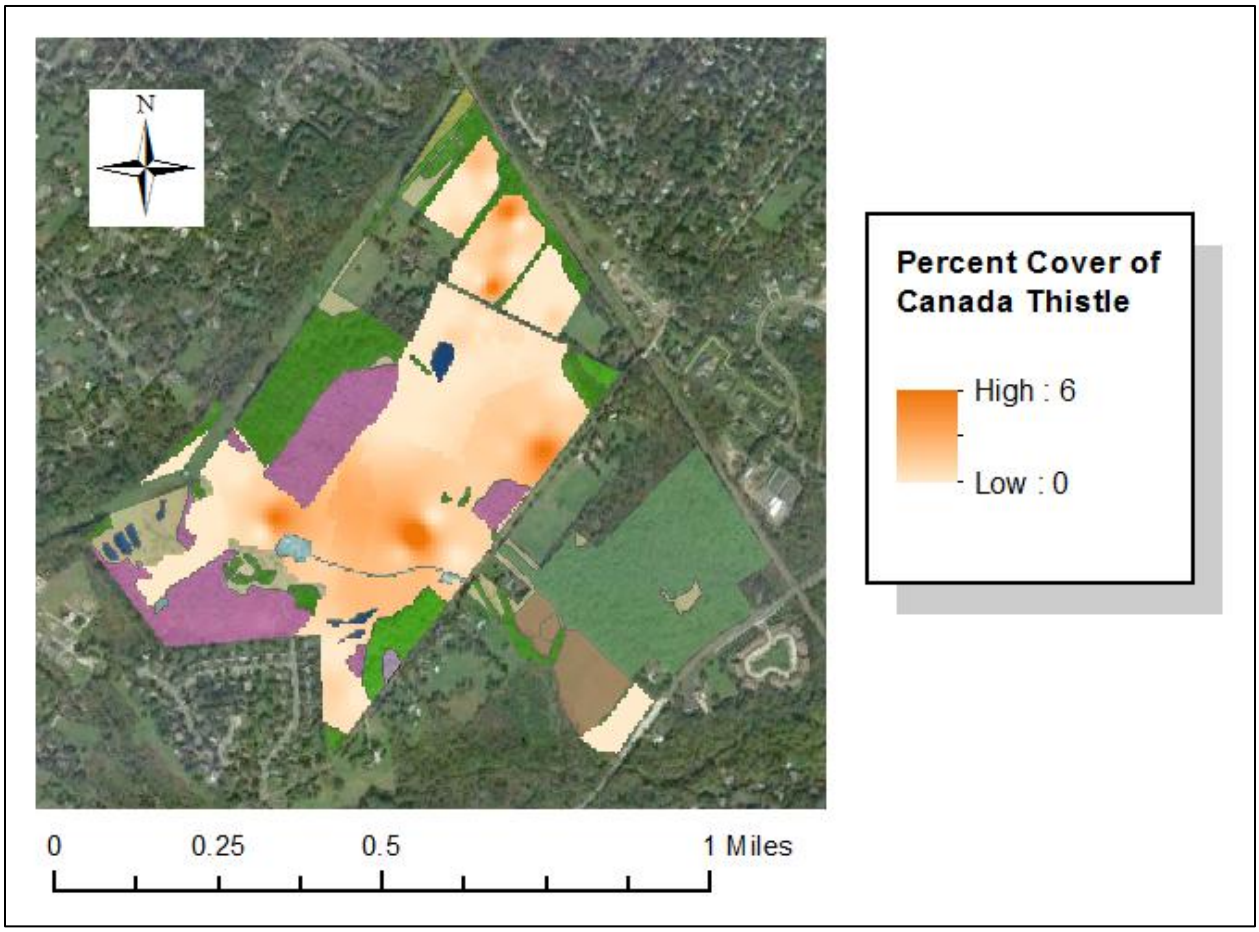


Cerastium Fontanum/Mouse-ear Chickweed:

This species was very rare and only discovered in the large meadow in Tunnel Woods near the bench. It may be elsewhere, however, but was not noticed due to it being found late in the survey.

Cirsium Arvense/Canada Thistle:

Canada thistle is widespread in the grasslands of the preserve. Rosette counts probably would have been more appropriate than a percent cover, especially given that the rosettes grow and spread during the season.

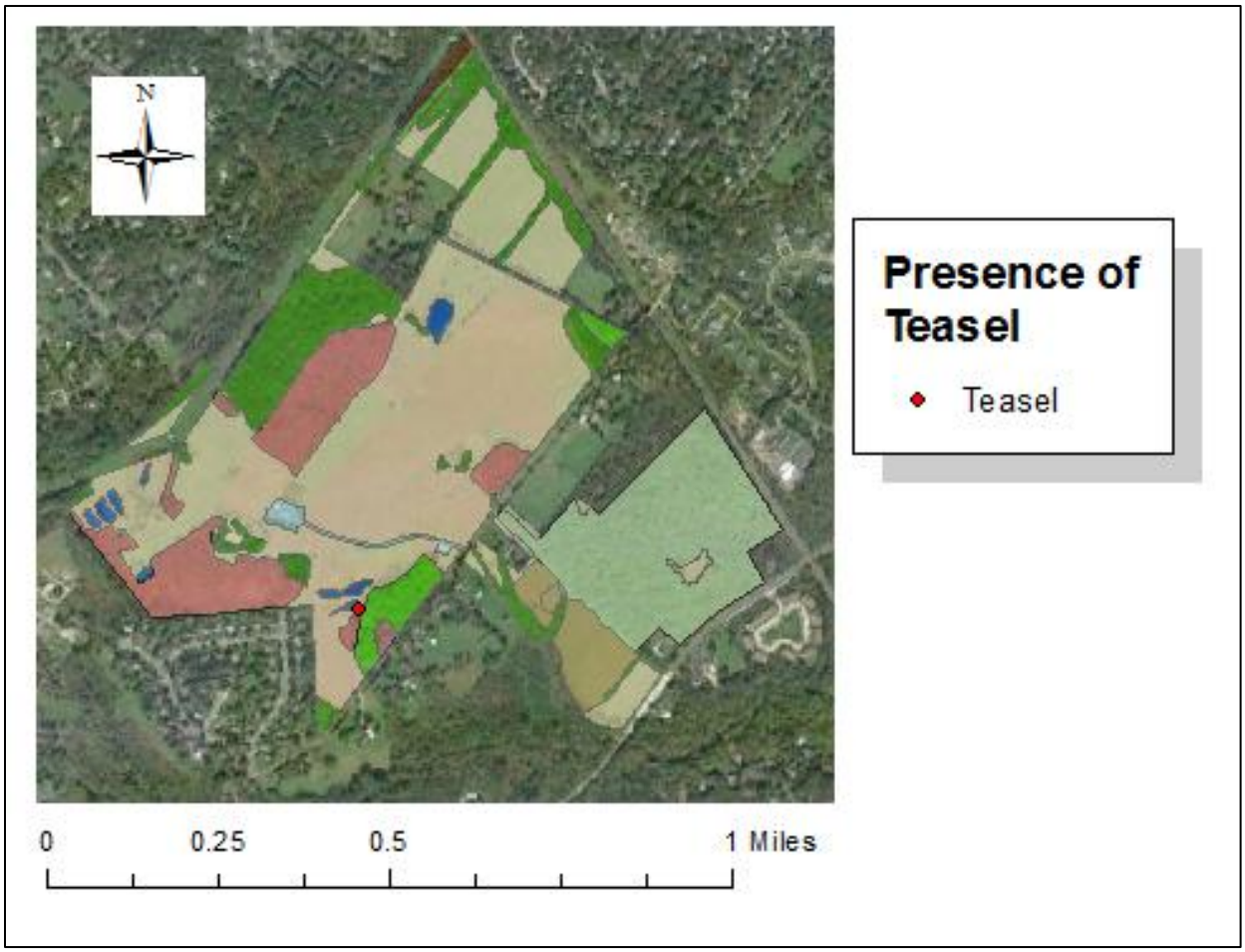


Daucus Carota/Queen-Anne's Lace:

Queen-Anne's lace was not noted during these surveys of Gwynedd. The 2008 survey does not state where it was found.

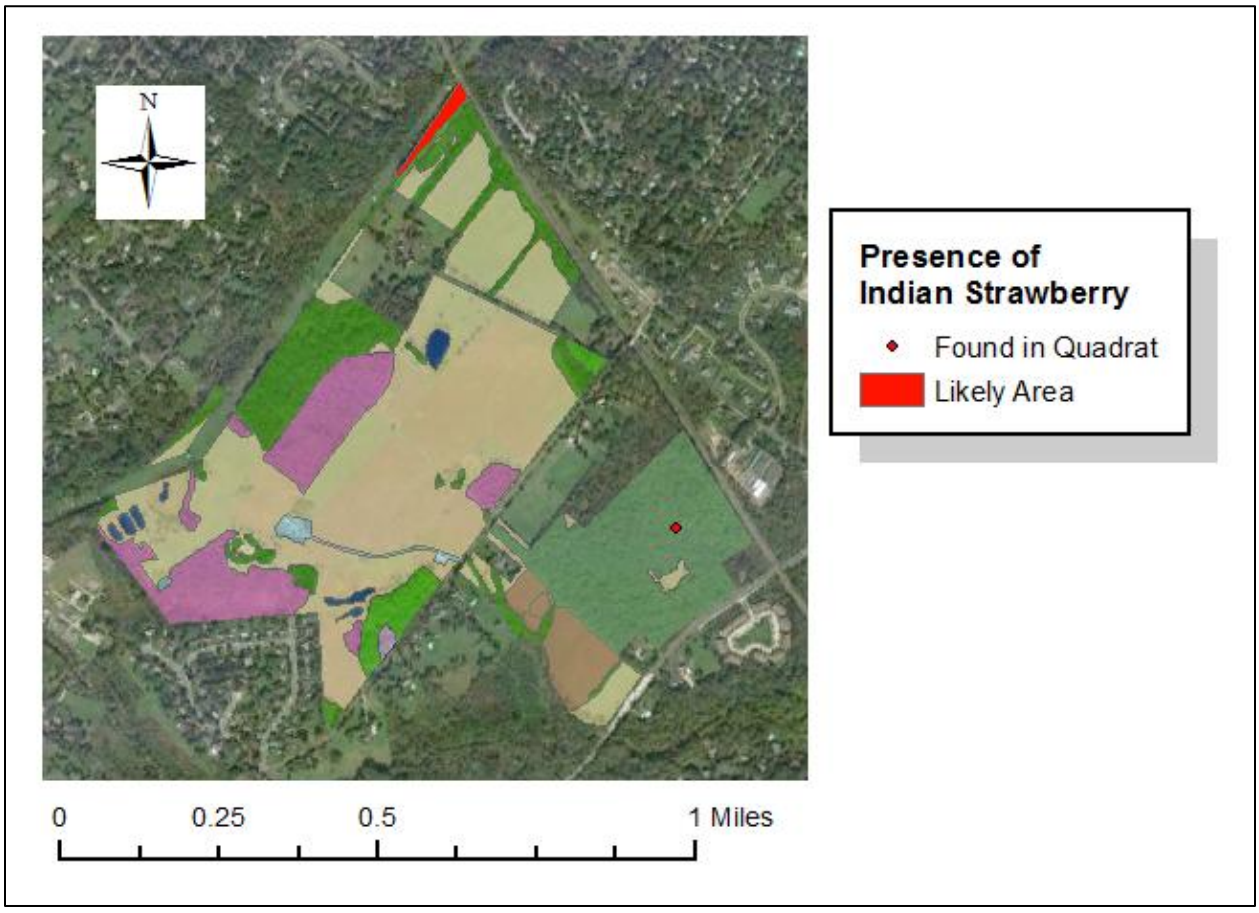
Dipsacus Fullonum/Common Teasel:

Only one area was discovered to have Common teasel. It was in a single clump about 4 square meters.



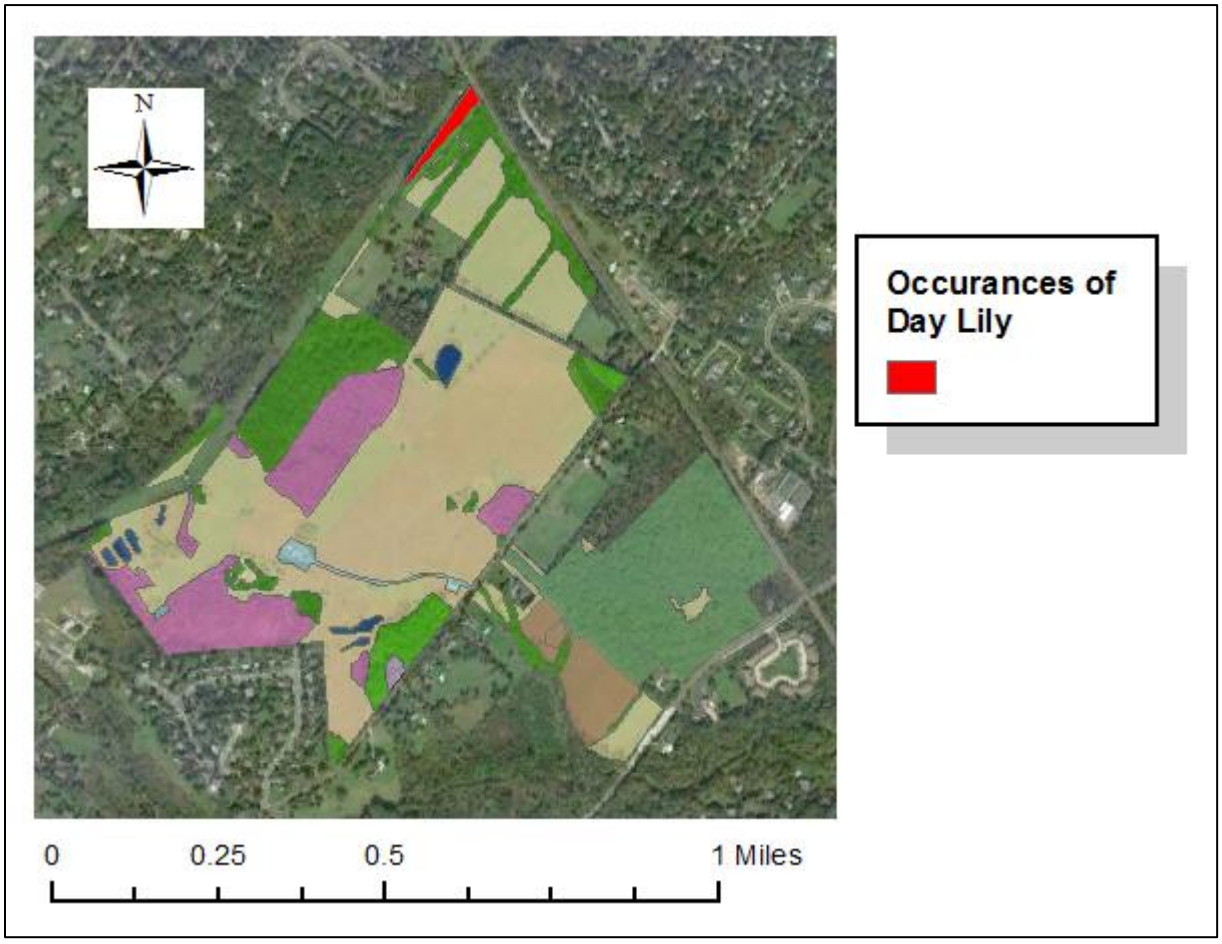
Duchesnea Indica/Indian Strawberry:

A lot of effort was spent to find Indian strawberry due to the very widespread distribution of Wild strawberry (*Fragaria virginiana*). However, though listed in the 2008 survey, it was only discovered in one area (about 5 individuals) along a stream in Tunnel Woods. It is likely in the floodplain area in the far north of the preserve, which is where the 2008 survey put it.



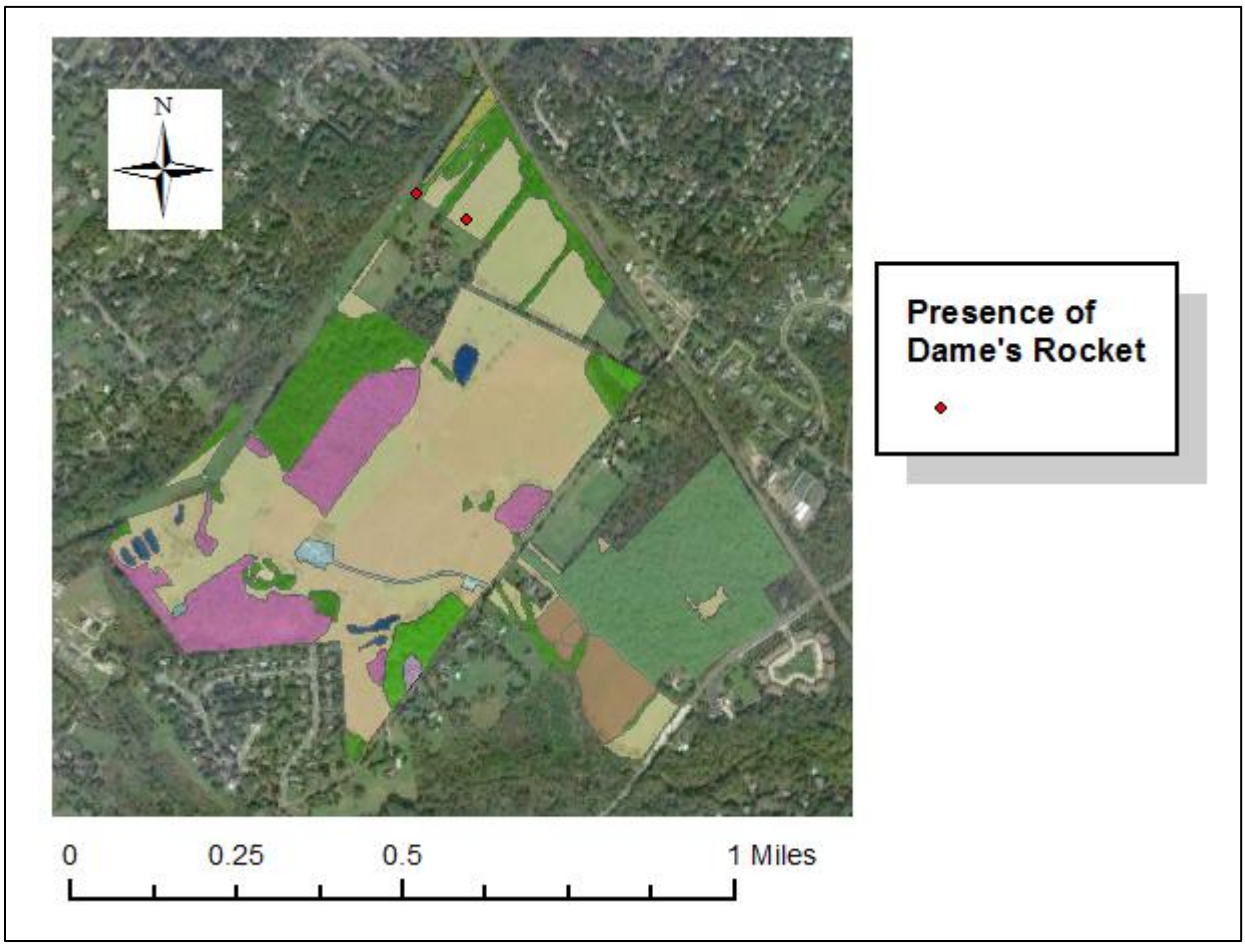
Hemerocallus fulva/Day-lily:

Day lily was mentioned in the 2008 survey, but not found during this survey. It may have been missed when the flowers were blooming and surveying was elsewhere. Based on the survey, it is in the far northern area.



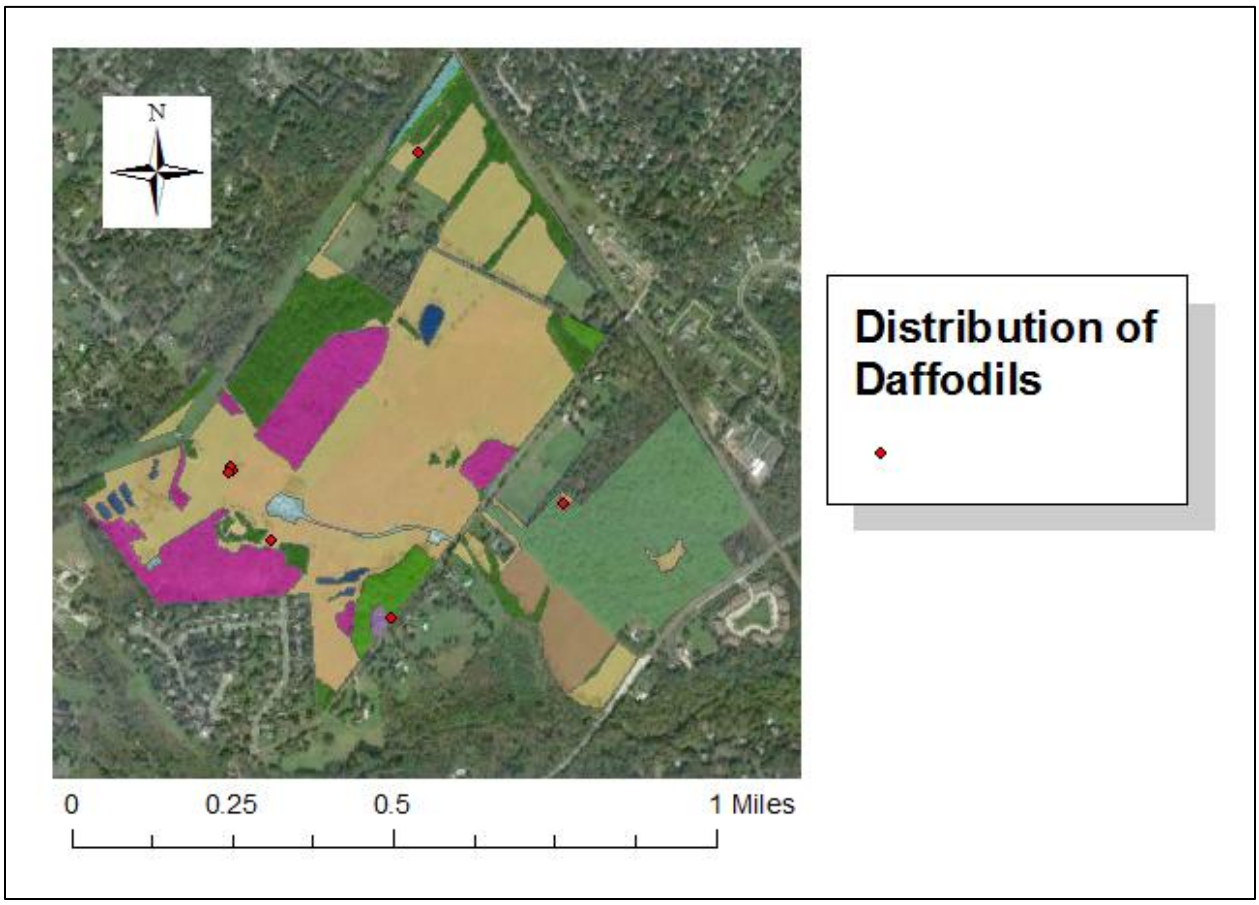
Hesperis matronalis/Dame's-rocket:

Two patches of Dame's rocket was found at the preserve. However, it appears that the power line corridor has a significant presence.



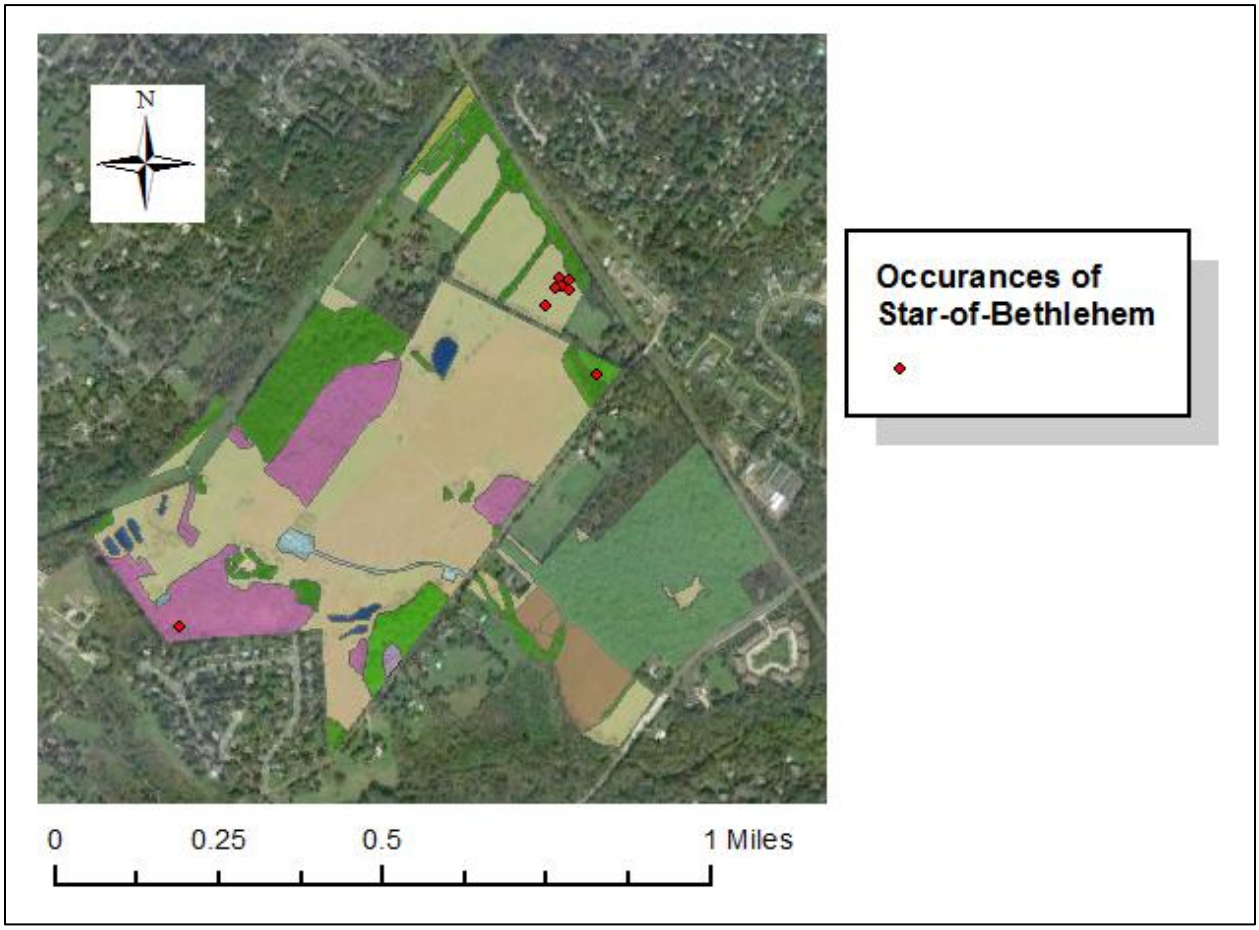
Narcissus sp./Daffodil:

Daffodils at Gwynedd are planted in the Betz Memorial Garden and at the Tunnel Woods dedication monument. There are also several escapees that naturalized.



Ornithogalum Umbellatum/Star-of-Bethlehem:

Originally thought as very rare, in the last walkthrough of the preserve, several were found in one of the northern fields due to the fact that they had finally flowered. The map reflects where it was found in quadrats as well as a few extra points added to represent those found on the last day.



Persicaria Perfoliata/Mile-a-Minute Weed:

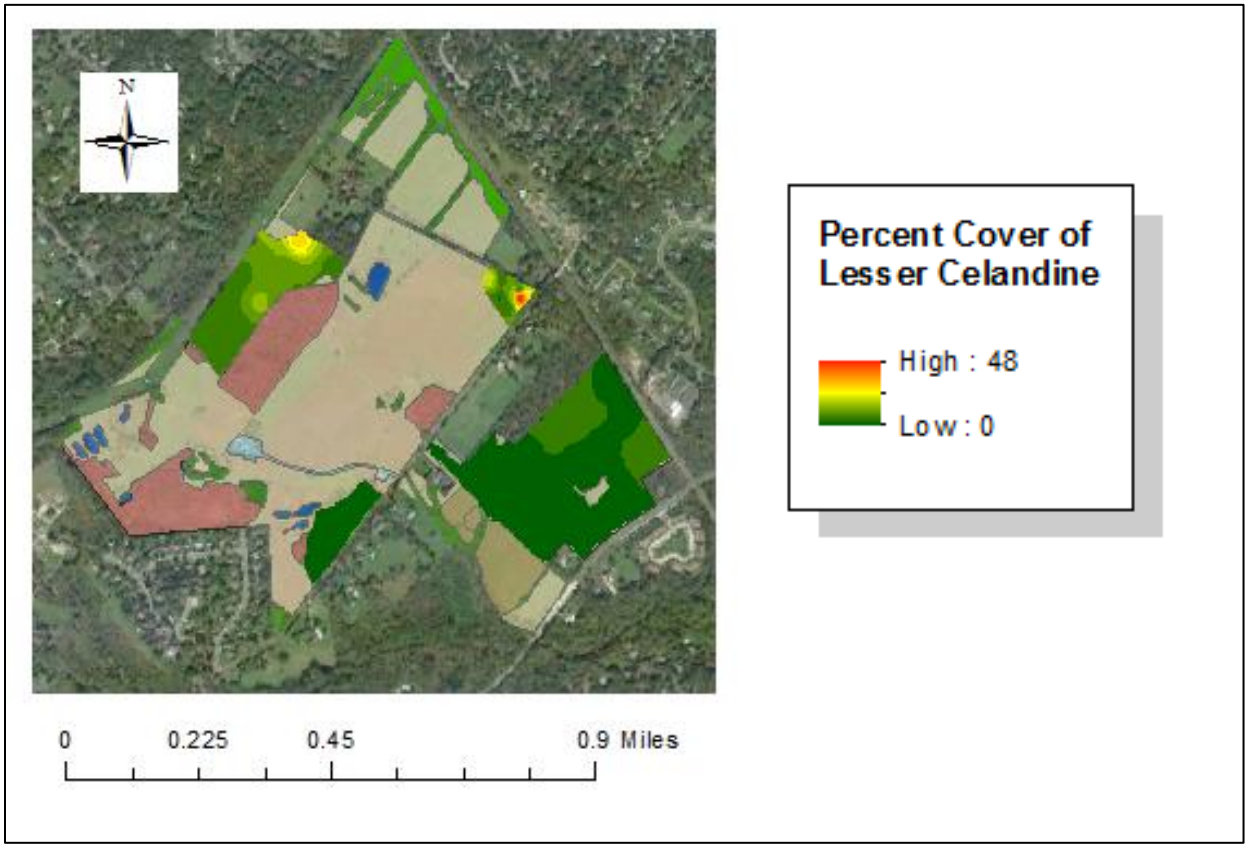
No Mile-a-minute weed was found at Gwynedd, however there is a lot of potential invasives coming from the train tracks where there is an infestation. They can (and have in the past) then easily travel down Haines run.

Ranunculus Bulbosus/Bulbous Buttercup:

This species was a late arrival in the survey and so was not mapped. However, it appeared to be common in open fields throughout the preserve, however it did not appear to be creating any monocultures or causing problems.

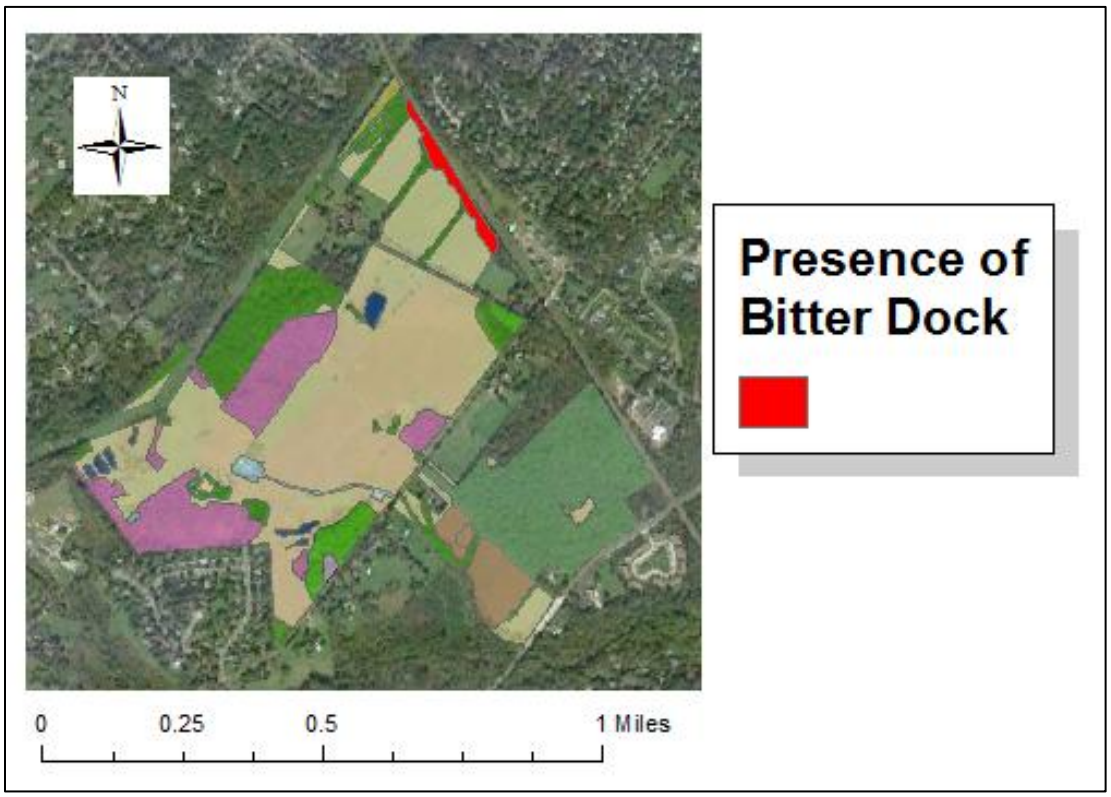
Ranunculus Ficaria/Lesser Celandine:

Lesser celandine is fairly common as Gwynedd's forested areas are also generally rather wet.



Rumex Obtusifolium/Bitter Dock:

Bitter dock was only noted behind the Norway spruce hedgerow. It was scattered and not in any large clumps



Taraxacum Officinale/Dandelion:

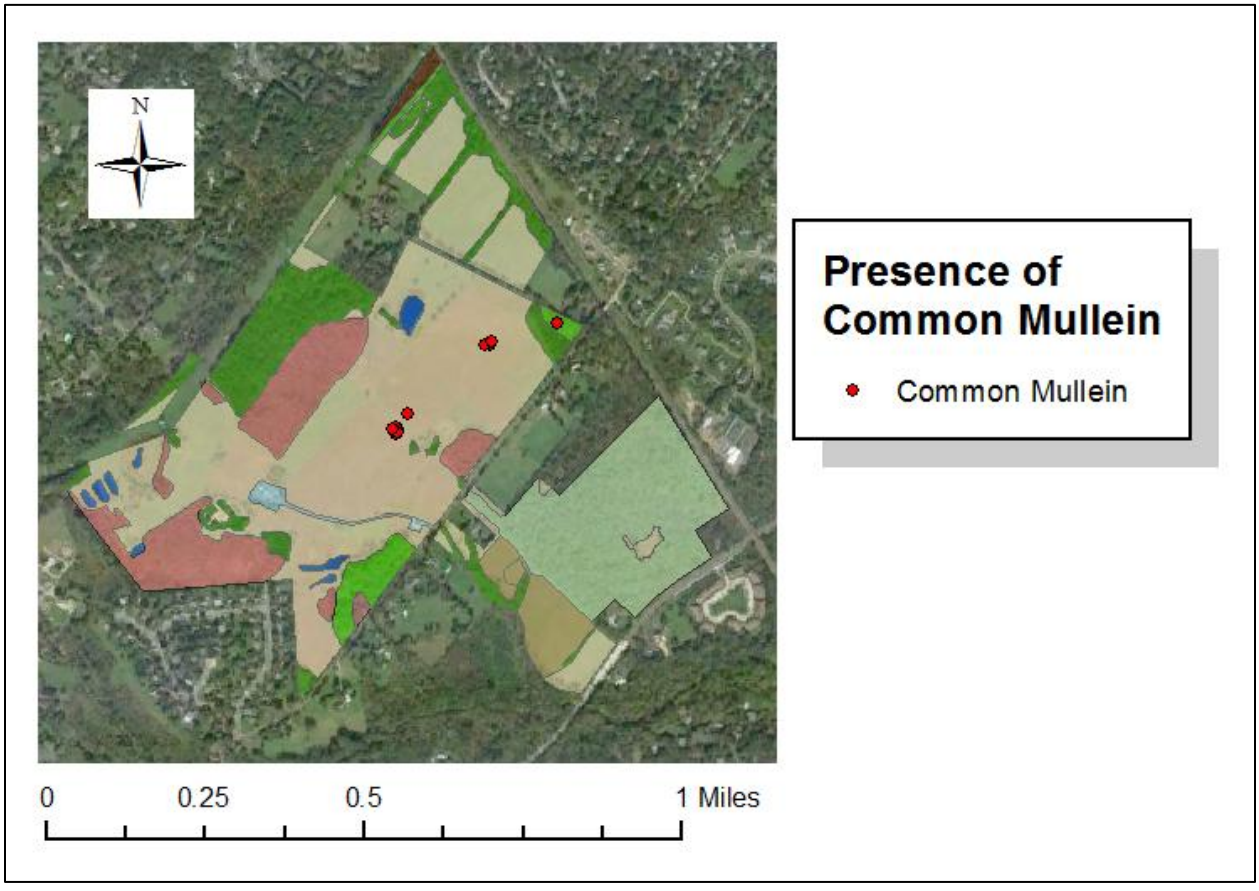
This species occurred rarely within habitats and was mostly found along mowed paths or edges. It was never found in any dense monoculture.

Verbascum Blattaria/Moth Mullein:

Though listed in the 2008 survey, its specific locations were not mentioned and no Moth mullein could be found.

Verbascum Thapsis/Common Mullein:

Common mullein is found mostly in the central part of the preserve. There are not many instances of it. One was found next to the office, but got removed. One was surprisingly in a well-shaded forest floor.

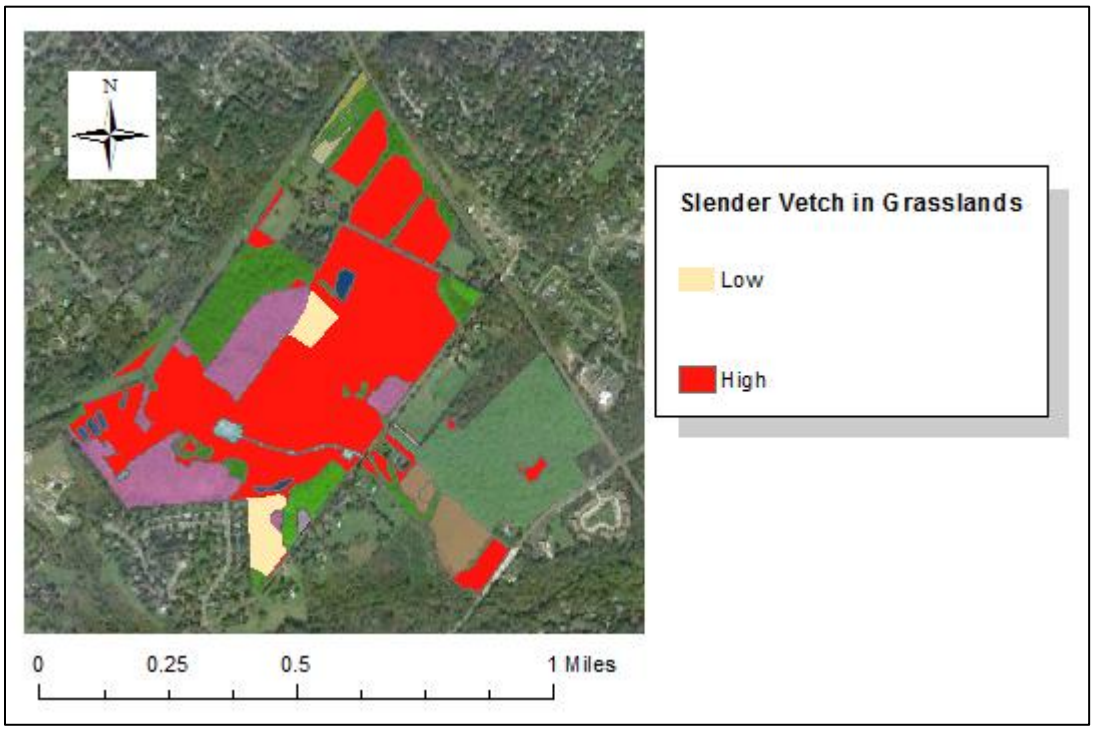


Veronica Serpyllifolia/Thyme-leaf speedwell:

A late arrival in the survey, this species was not mapped. It is small and difficult to see and was only noted in the large Tunnel Woods field near the bench. No dense monoculture was noticed.

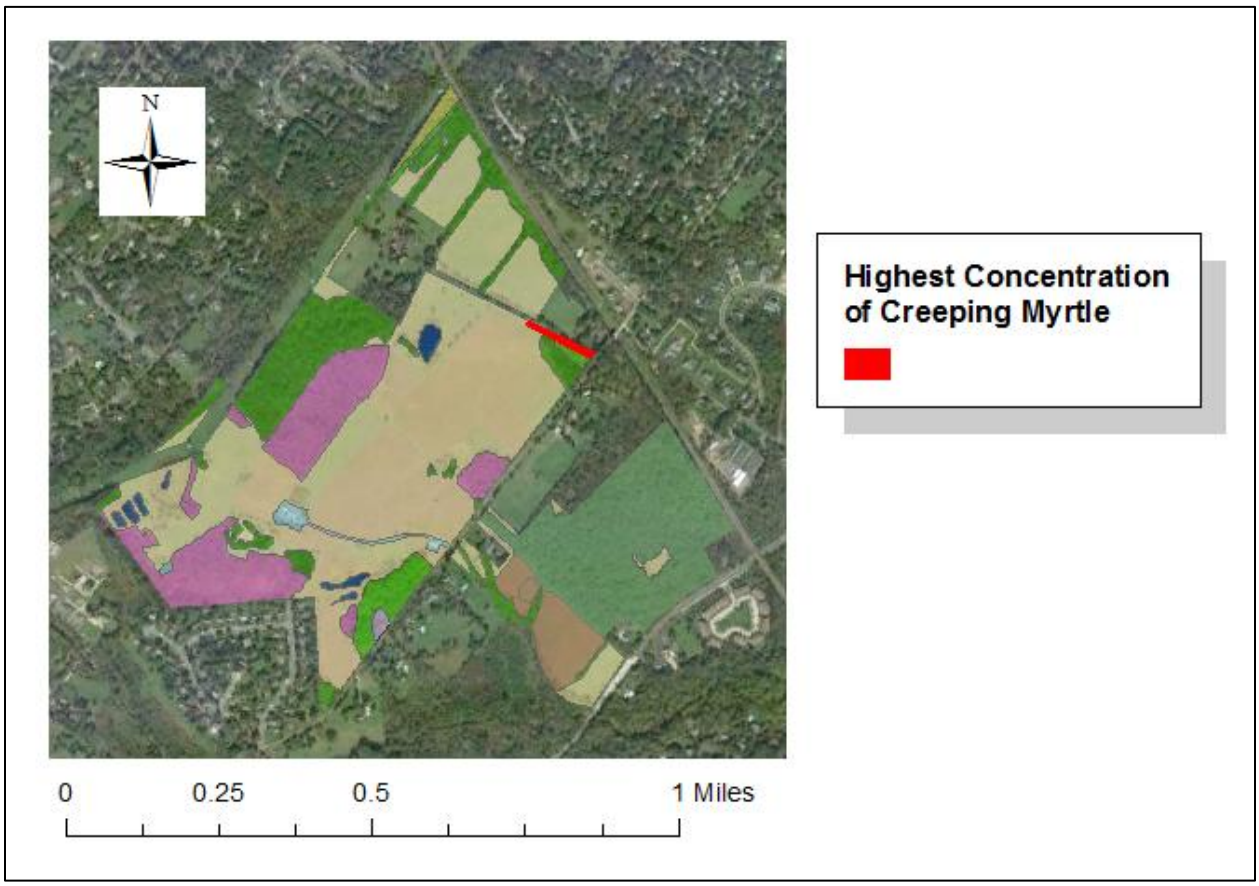
Vicia Tetrasperma/Slender Vetch:

This species was difficult to map as it grew over the course of the surveying. Also, it was confused with Cardamine hirsuta. The two can be more easily distinguished by the different flowering times and different colored flowers. However, as neither were mentioned in the 2008 survey, neither was expected and they were confused with each other. Late surveys noted a very heavy invasion by slender vetch in all open fields and meadows within the preserve. Also, since early surveys put it at 1% cover of a quadrat, and later surveys noticed growth up to 30%, it felt inappropriate to use that data in a distribution map. There were, however, a couple areas with little to no representation of this species, the far southern tip and the area just southwest of the Betz pond.



Vinca Minor/Common Periwinkle:

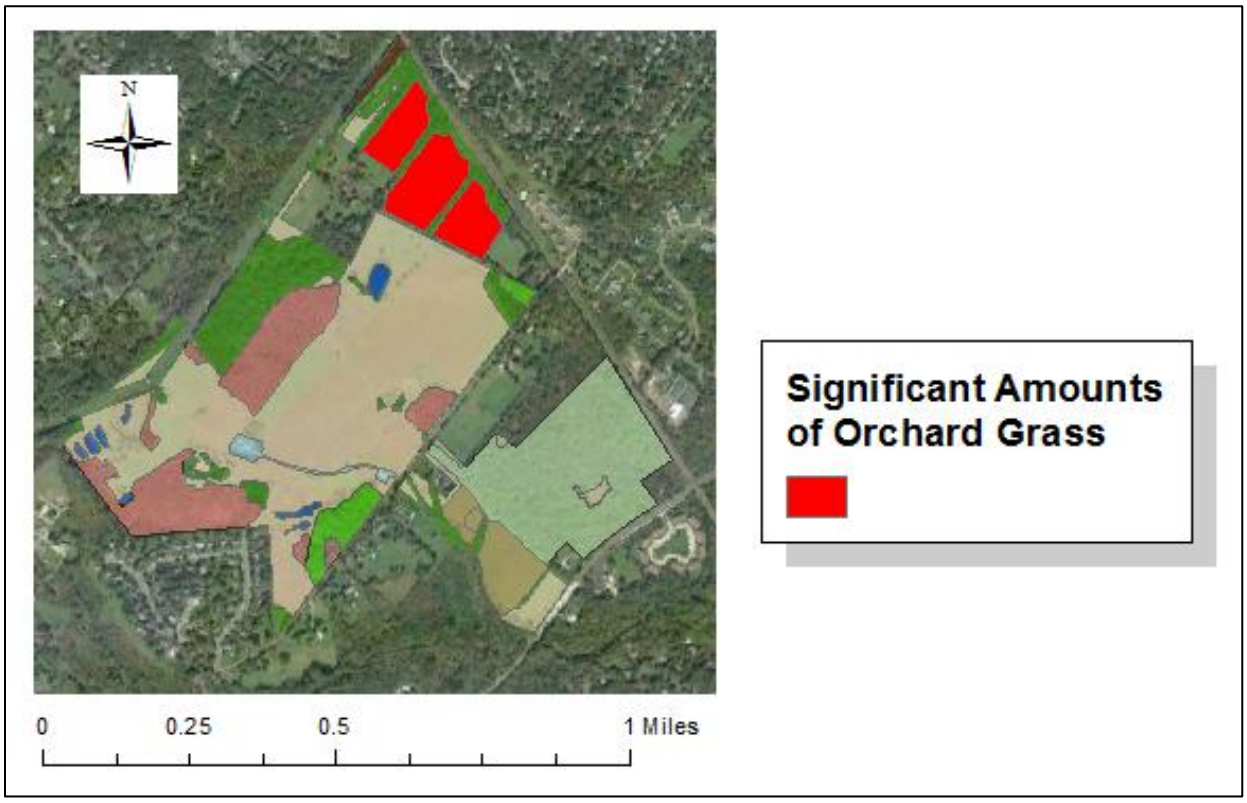
This was a difficult species to map. It is in very low amounts, but in many parts of the preserve. The largest numbers appeared to be along the driveway to the Betz estate.



Grasses

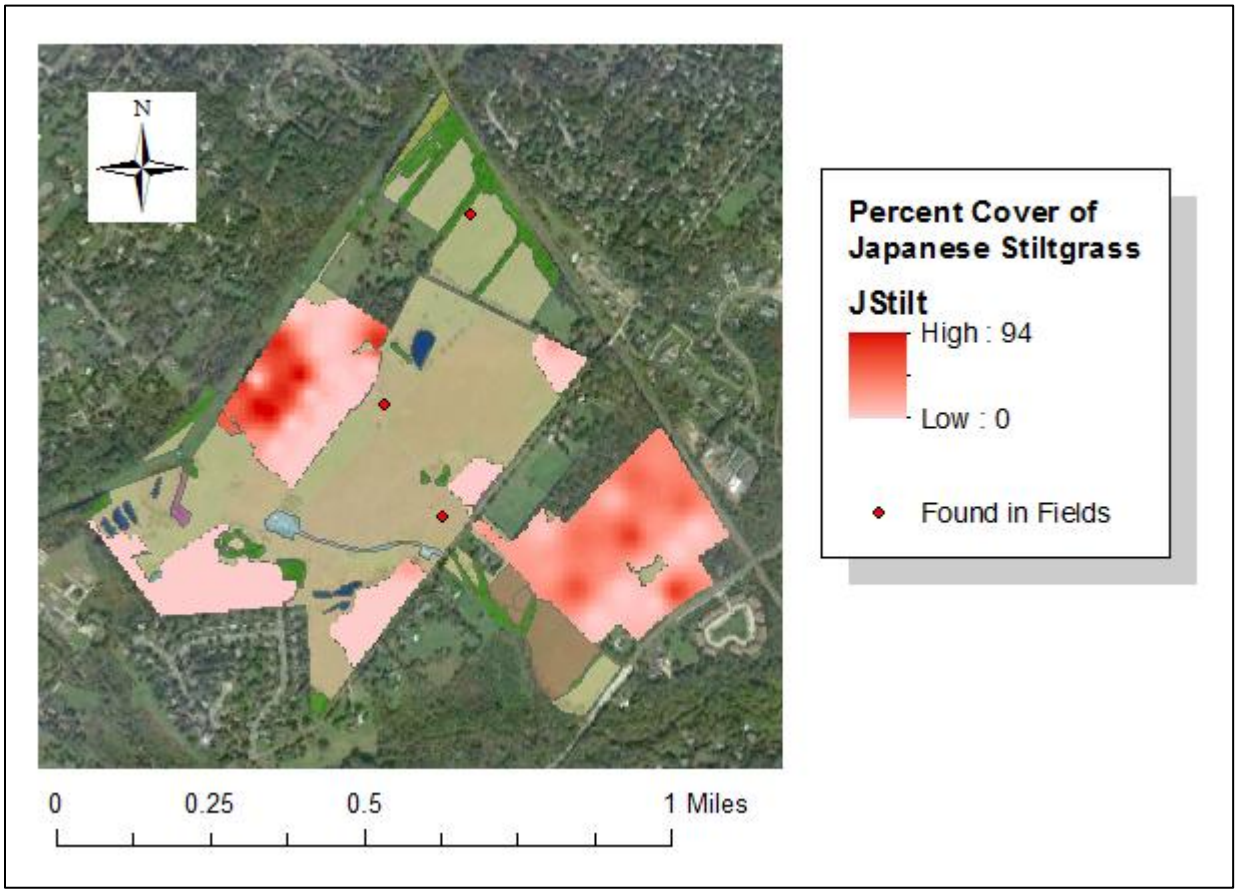
Dactylis Glomerata/Orchard Grass:

Orchard grass was difficult to map due to the season. However, it is known to be in very high concentrations in the three large fields at the north end of the preserve. This is due to the previous horse-grazing and manure-dumping of the previous owners.



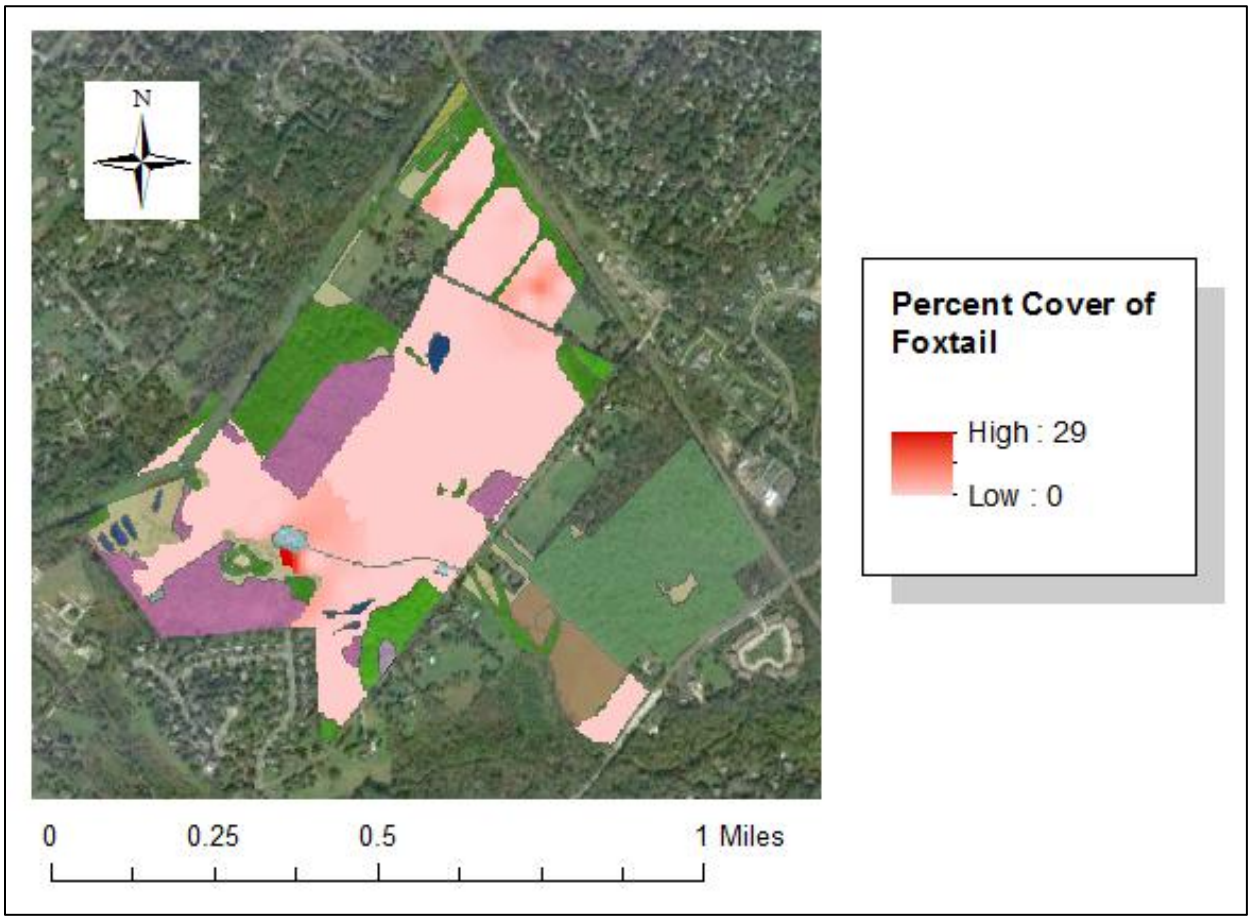
Microstegium Vimineum/Japanese Stiltgrass:

Japanese stiltgrass is very common in forested areas. As spring developed, it became even more common. Due to its clumping nature and very widespread distribution, maps of spread out quadrats are less helpful and do more to state presence or absence. Although less common fields, there was some spotted southwest of the Betz pond, east of the office, and near a northern hedgerow. There is likely more, but it was more difficult to spot amongst the other grasses when all were dead. These points were included to reflect the fact that it can be found anywhere.



Setaria Spp./Foxtail:

Foxtail species were all mapped together rather than attempting to distinguish separate species, something not likely to prove fruitful. It is not a very common invasive at Gwynedd, though as it is encouraged by fire, it may become worse. When walking by, an area just south of the office was noted to have the highest amount of foxtail seen, so it was included.



Appendix A

Tunnel Woods Inventory

While doing the survey for invasives in Tunnel Woods, a botanical inventory was also conducted. This was completed through quadrats as well as the inclusions of timed meanders from each quadrat where various species were examined and written down. The time was supposed to be 5 minutes, but some leeway was given due to the fact that many species were completely new and took more time to collect. Also, when traveling from one quadrat to another, a new species was not going to be ignored.

Tunnel Woods is largely a mature forest with two meadows and some places with very open canopies. Judging from the aerials, there were pockets in 1941 that were in the early stages of becoming forested, but most was herbaceous. Currently, the overstory is dominated by ash (*Fraxinus spp.*) and maple (*Acer spp.*), but there are a fair number of oaks (*Quercus spp.*), black cherry (*Prunus serotina*), and some other scattered species. The midstory is largely dogwood (*Cornus spp.*), viburnum (*Viburnum spp.*), and crabapple (*Malus spp.*). The understory is dominated by European privet (*Ligustrum vulgare*) and Common buckthorn (*Rhamnus cathartica*). The groundcover does not appear to be dominated by any particular species.

Trees:

Acer platanoides	Norway maple (I)
Acer rubrum	Red maple
Acer saccharinum	Silver maple
Acer saccharum	Sugar maple
Carya ovate	Shagbark hickory
Cornus florida	Flowering dogwood
Fraxinus americana	White ash
Fraxinus pennsylvania	Red ash
Juglans nigra	Black walnut
Juniperus virginiana	Eastern red cedar
Liquidambar styraciflua	Sweet gum
Malus spp.	Crabapple (I)
Prunus avium	Sweet cherry (I)
Prunus serotina	Black cherry
Quercus alba	White oak
Quercus palustris	Pin oak
Quercus rubra	Red oak
Ulmas americana	American elm

Shrubs:

Elaeagnus umbellata	Autumn olive (I)
Euonymus alatus	Burning bush (I)
Ligustrum obtusifolium	European privet (I)
Lindera benzoin	Spicebush

Lonicera morrowii	Morrow's honeysuckle (I)
Lonicera maackii	Amur honeysuckle (I)
Lonicera spp.	Honeysuckle shrub
Rhamnus cathartica	Common buckthorn (I)
Viburnum dentatum	Southern arrow-wood
Viburnum prunifolium	Blackhaw

Vines

Celastrus orbiculatus	Oriental bittersweet (I)
Hedera helix	English ivy (I)
Lonicera japonica	Japanese honeysuckle (I)
Parthenocissus quinquefolia	Virginia creeper
Rosa multiflora	Multiflora rose (I)
Rubus spp.	Raspberry
Rubus phoenicolasius	Wineberry (I)
Toxicodendron radicans	Poison ivy
Vitis sp.	Grape

Herbs:

Achillea millefolium	Common yarrow (I)
Ageratina altissima	White-snakeroot (Eupatorium rugosum)
Alliaria petiolata	Garlic mustard (I)
Allium vineale	Wild garlic (I)
Antennaria spp.	Pussytoe
Apocynum cannabinum	Dogbane
Arissima trifilum	Jack-in-the-pulpit
Barbarea vulgaris	Bittercress (I)
Cardamine impatiens	Narrow-leaved bittercress (I)
Cerastium fontanum	Mouse-ear chickweed (I)
Duchesnea indica	Indian strawberry (I)
Erigeron philadelphicus	Philadelphia fleabane
Fragaria virginiana	Wild strawberry
Geum virginianum	Cream avens
Impatiens capensis	Jewelweed
Iris pseudacorus	Yellow flag/Yellow iris (I)
Juncus effuses	Soft rush
Lysimachia nummularia	Moneywort (I)
Narcissus spp.	Daffodil (I)
Packera aurea	Golden ragwort
Podophyllum peltatum	Mayapple

Potentilla Canadensis	Dwarf cinquefoil
Ranunculus ficaria	Lesser celandine (I)
Ranunculus bulbosus	Bulbous buttercup (I)
Solidago spp.	Goldenrod
Taraxacum officinale	Common dandelion (I)
Trifolium repens	White clover (I)
Veronica serpyllifolia	Thymeleaf speedwell (I)
Vicia tetrasperma	Slender vetch (I)
Viola spp.	Violet

Grasses:

Microstegium vimineum	Japanese stiltgrass (I)
Phalaris arundinacea	Reed canary grass
Poaceae spp.	Grass

Sedges:

Andropogon virginicus	Broom sedge
Carex spp.	Sedge

Ferns:

Onoclea sensibilis	Sensitive fern
Polystichum acrostichoides	Christmas fern

Fungi:

Morchella spp.	Morel mushroom

Appendix B

Plants in Other Parts of Gwynedd

During surveys, some plants were found that were not listed in the 2008 survey or the correct species was discovered for plants listed as "spp." These plants are ones not found in Tunnel Woods, but were found elsewhere

Trees:

Prunus virginiana	Chokecherry

Vines:

Rubus allegheniensis	Common blackberry
Rubus hispidus	Swamp dewberry
Rubus occidentalis	Black raspberry

Herbaceous:

Agrimonia spp.	Agrimony
Barbarea vulgaris	Bittercress (I)
Cirsium arvense	Canada thistle (I)
Fragaria virginiana	Wild strawberry
Glechoma hederacea	Ground ivy (I)
Iris veriscolor	Northern blue flag
Lamium perpureum	Purple dead-nettle (I)
Ornithogalum Umbellatum	Star-of-Bethlehem (I)
Rumex obtusifolius	Bitter dock
Symplocarpus foetidus	Skunk cabbage

Appendix C

Pictures of Fauna

As a wildlife preserve, the concern is not just plants, but the fauna as well. It is important to note that the preserve is working as intended.

A curious deer, May 15th, 2014 (Photo: Nathan Hartshorne)

Bullfrog (*Lithobates catesbeianus*), May 14th, 2014 (Photo: Nathan Hartshorne)

Northern green frog (*Lithopates clamitams melanota*), May 17th, 2014 (Photo: Nathan Hartshorne)

Eastern forktail damselfly (*Ischnura verticalis*), May 14th, 2014 (Photo: Nathan Hartshorne)

Great horned owl, April 18th, 2014 (Photo: Nathan Hartshorne)

Eastern box turtle near the Betz entrance, May 11, 2014 (Photo: Nathan Hartshorne)

Eastern box turtle in Tunnel Woods, May 17th, 2014 (Photo: Nathan Hartshorne)

Snails on a Skunk cabbage (the only one in Gwynedd), May 8th, 2014 (Photo: Nathan Hartshorne)

Eggs, perhaps salamander, April 25th, 2014 (Photo: Nathan Hartshorne)

Possibly a red fox (Vulpes vulpes), May 3rd, 2014 (Photo: Nathan Hartshorne)

Butterfly in Tunnel Woods, May 17th, 2014 (Photo: Nathan Hartshorne)

Tent caterpillars (*Malacosoma spp.*), May 7th, 2014 (Photo: Nathan Hartshorne)

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