2016 CURRENT ISSUE

Invasive Species: A Challenge to the Environment, Economy and Society

Invasive species pose a serious threat to the stability of many North American ecosystems. Invasive species have been known to disrupt food webs, damage or destroy habitat and contribute to the decline of indigenous species at risk. In addition to their environmental impact, invasive species can have a significant impact on local economies; in the United States alone it is estimated that invading alien species cause major environmental damage and loss adding up to almost $120 billion per year (Pimentel, Zuniga, Morrison – 2005).

The 19th and 20th centuries have seen an exponential increase in the number of invasive species being intentionally and unintentionally introduced to North America and around the world through a variety of methods. The vast majority of invasive species that have established themselves in North America did so through unnatural or "human-assisted" means, including being introduced by early settlers for agricultural purposes. However, many others have been inadvertently transported to North America through trade and travel, as stowaways on ships or in packaging materials, and through horticulture. With the expected increases in exports and trade in the future, we can likely expect greater challenges and introductions of new species not yet known to occur in North America.

Students will learn about invasive species prevention, introduction, impact and management.

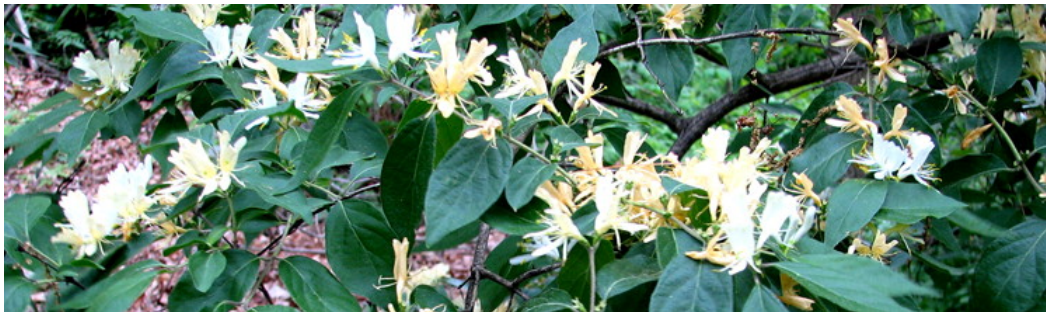
Key Topics

1. Invasive Species and Their impacts
2. Pathways of Introduction and Spread
3. The Invasive Species Management cycle (Prevent, Detect, Respond, Control)
4. Roles and Responsibilities (Government, Non-Government, the Individual)
5. Tools in the Toolbox (Models, Detection Tools, Monitoring Tools, Communications)

Learning Objectives

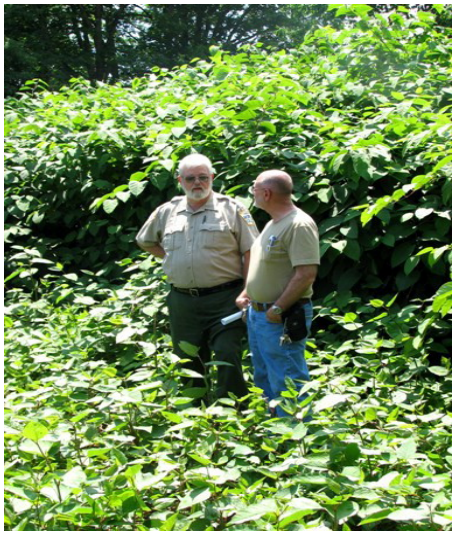
1. Explain what an invasive species is.
2. Describe the economic, social, and environmental impacts of invasive species.
3. Comprehend the effects/impacts of invasive species on aquatic, forest, wildlife and soil ecosystems with specific reference to biodiversity.
4. Explain how ecological impacts may vary by species.
5. Compare theories about the characteristics that assist invasive species in successfully establishing new populations. What makes a good invader?
6. Describe the pathways through which invasive species are introduced.
7. Discuss the stages of the invasive species management cycle and components of an invasive species management plan.
8. Assess the costs associated with controlling an invasive species on a state/province-wide basis.
9. Outline methods of controlling an invasive species.

10. Understand how various levels of government and other organizations are involved in the management of invasive species.
11. Are all invasive species created equal? Describe how risk is assessed.
12. Discuss the means by which invasive species are detected and monitored and have a basic knowledge of models and tools used to monitor invasive species.
13. Demonstrate knowledge of the policies/legislation involved in preventing, detecting, monitoring, and controlling invasive species.
14. Describe the role for non-government and the average citizen in managing invasive species.
15. Investigate ways to reduce the arrival of new invasive species by setting the foundations for environmentally ethical behaviors and sound environmental decision making.
16. Demonstrate knowledge of the various forms of outreach and education being used and assess their effectiveness.



What is an Invasive Species?

People have been moving plants around the world for centuries. Most countries now rely on plants from other regions of the world for food, construction materials, ornamental plants and fibers. Organisms that have been moved from their native habitat to a new location are referred to as "non-native," "non-indigenous," "exotic," or "alien" to the new environment. Most U.S. food crops are non-native species and their beneficial value is obvious. A small percentage of non-natives, however, cause serious problems in their new environments and are collectively known as "invasive species."



How Did They Get Here?
Non-native species have been introduced into the U.S. in a variety of ways. Some non-native species, intentionally introduced for beneficial purposes, later turn out to be invasive. Examples include purple loosestrife, which was sold as an ornamental plant, as well as Japanese knotweed, which was introduced for erosion control. Yet many of the non-native species that later become invasive were unintentionally introduced; they move as unknown stowaways and hitchhikers when people and their products are transported by air, water, rail or road. Examples of invasive plant species unintentionally introduced into the U.S. include mile-a-minute vine and Japanese stiltgrass.

Why Are They a Problem?
The most important aspect of how a non-native plant does or does not become invasive is how it responds to a new environment. An **invasive** plant displays rapid growth and spread, allowing it to establish over large areas. Free from the vast and complex array of natural controls present in their native lands, including herbivores, parasites and diseases, invasive plants may experience rapid and unrestricted growth in new environments. Their phenomenal growth allows them to overwhelm and displace existing vegetation and form dense monocultures.

What Makes a Non-Native Plant Become Invasive?

- Ability to grow in many conditions
- Rapid growth
- Ability to exploit and colonize disturbed ground
- Ability to thrive in high nutrient conditions (i.e. excess fertilizers)
- Reproduce rapidly by roots and shoots. If spread by seed, produce numerous seeds that disperse and sprout easily
- Having roots and rhizomes with large food reserves
- Ability to survive and reproduce under adverse conditions
- Having high photosynthetic rates - "greening up" earlier in the spring than natives gives these plants an competitive advantage
- Lack of natural predators, pathogens and parasites

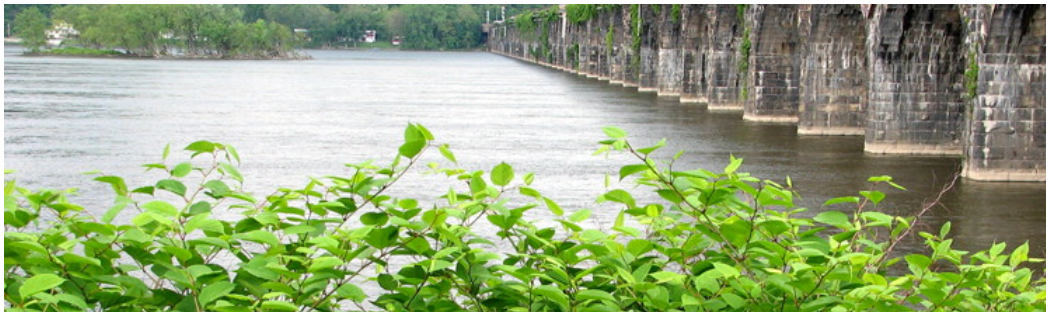
Impacts of Invasive Plants

Invasive plant species are a considerable threat to biodiversity. Once these species are well established it is sometimes impossible to remove them. When removal is possible, it comes at a high cost financially and ecologically. For instance, researchers at Cornell University estimate that invasive species are costing Americans more than $130 billion every year. Even controlling a single unwanted invader can carry a price tag in the millions.

In some cases, invasive plants are driving our rarest species closer to extinction. According to the U.S. Fish and Wildlife Service, an estimated 42 percent of the nation's endangered and threatened species have declined as a result of encroaching invasive plants and animals. Recent research has shown that some invasive species can cause the populations of even common species to collapse.

Ecological impacts

- Changes in the availability or quantity of water or nutrients
- Changes in light availability to plants in the ground layer and shrub layer or to plants and animals in lower depths of lakes and streams
- Toxicity
- Allelopathy (when one plant produces chemicals that are toxic to other plants)
- Reduction or elimination of localized or specialized native plant communities
- Disruption of insect-plant associations necessary for seed dispersal of native plants
- Disruption of native plant-pollinator relationships
- Reduction and elimination of host plants for native insects and other wildlife
- Serving as host reservoirs for plant pathogens and other organisms that can infect and damage desirable native and ornamental plants
- Replacing nutritious native plant foods with lower quality sources
- Killing trees and shrubs through girdling
- Preventing seedling establishment of native trees and shrubs
- Changes in the rate of soil erosion
- Changes in the frequency of wildfire
- Changes to natural ecological processes, such as plant community succession
- Genetic dilution - incidence of cross-breeding with native species, alters the natives' genetic make-up



Prevention and Early Detection

The most effective, economical and ecologically-sound approach to managing invasive plants is to prevent their invasion in the first place. Often limited resources are directed to fight firmly established infestations, but by that stage management is expensive and eradication is probably impossible. Certainly it is necessary to manage infestations to limit the spread of invasive plants into non-infested areas. However, limited resources might be spent more efficiently on proactive invasive plant management that controls existing infestations but also focuses strongly on prevention or early detection of new ones.

Prevention and Early Detection Guidelines

Plant invasions often follow a typical pattern. Seeds or plant fragments arrive by various mechanisms and become established; however, the persistence of these new individuals is tenuous because of unsuitable habitat or low population levels. If the plant invaders persist, it takes some time (the lag phase) for the population to increase in size. Only after a time specific to species and habitat has elapsed does the population suddenly expand. Control efforts are most cost-effective and likely to succeed during this lag phase. Thus the early detection of newly arriving exotic plant species is an important component of a control program. Unfortunately, these newly establishing populations are rare and consequently difficult to detect.

Prevention and early detection activities can be focused at different scales. A land manager of a 2,000-acre state park may be limited to focusing prevention efforts on that specific landscape. Invasive species may be well established in other parts of the region or state, but may be new to the 2,000-acre state park. On the other hand, land managers may have the ability to work beyond the borders of their state forest or state park. Having this larger focus will result in greater success in keeping unwanted species off protected natural lands.

Prevention techniques may include:

- Checking soil, mulch, or other materials that may be brought to a new site for invasive plant presence.
- Cleaning equipment, gear and clothing when moving between sites where invasive plants may be present.
- Moving your activities from the least infested site to the most infested site to avoid bringing in invasive plant propagules to a new area.
- Use certified seed for restoration, landscaping, and lawns to decrease bringing in unwanted invasive plant seed.

Watch List Species

Another focus for prevention and early detection activities is on species that are not yet well-established in Pennsylvania or a region of Pennsylvania (e.g., eastern PA or western PA). In addition to known species, there are a number of species that experts believe may be future problems for Pennsylvania's natural areas. These species have been observed acting invasively in natural settings in other parts of the Mid-Atlantic region. Of greatest concern are invasions in bordering states with similar habitats. These species are included on the DCNR Watch List and should be a major focus of any EDRR

efforts in the state. Recording the presence of these species on shared networks like EDDMapS allows other concerned land managers to view the introduction of a new invasive plant.

Getting Started on EDRR
Early detection of non-native species should be based on a system of regular surveys to find newly established species. However, not all species will become established, and only a small percentage of those that do will become invasive, presenting threats to biodiversity and the economy. Thus, some surveys will need to focus on specific target species known to be invasive under similar conditions or species that have been successfully eradicated before.

In addition, site-specific surveys looking for non-native species in general can be carried out. They should be targeted at key sites, e.g. areas of high conservation value, within the range of highly endangered species, and at high-risk entry points such as airports and harbors (logging roads, trail heads, parking lots). The drawback of these general surveys is that only well-trained staff will be able to identify non-native species in many taxonomic groups.
A crucial part of early detection is a contingency plan, which determines the action to be taken when a non-native species is been found. Given the diversity of potential new incursions, an initial plan will be rather general. It should summarize the stakeholders and experts who need to be contacted for a more detailed action plan. Contingency plans targeted at specific high-risk species can be very efficient, with an exact schedule for what to do.

Please refer to the Monitoring and Evaluation Section for important information on monitoring for potential new invasive species.

Resources

1. The National Invasive Species Council has developed general guidelines for the establishment of invasive species EDRR systems, which can be downloaded here.
2. The National Park Service has developed an *Early Detection of Invasive Species: Surveillance, Monitoring and Rapid Response* document that can be downloaded here.
3. Factsheets on avoiding transporting invasive plant hitchhikers during your recreational activities can be viewed here under "Characteristics and Impacts".

Contract and Bid Language
For all projects, general prevention measures can have a great effect on keeping invasive plants out. The following activities will help with preventing the introduction or spread of invasive plants and you can build them into your contract as requirements by the operator:

- Inventory the site for presence of invasive species prior to disturbance. If invasive plants are present, pre-treat with appropriate control methods to ensure they won't spread during project activities.
- Wash all equipment prior to bringing it on site to be sure it is free of any soil or plant parts from previous work areas. Equipment may be inspected before entering a site to be sure it is clean and ready for use. Truck powerwash stations may be used to clean equipment; provide addresses or locations of the facilities in your area.
- Be sure to require only weed-free soil, mulch, gravel and other materials used in the project. Often, invasive plants can be introduced through the materials brought onto the site. You can inspect source materials for presence of invasive species or use reliable sources. Mulching with straw rather than hay can reduce the chance of unintended invasive species introductions.
- Seed all disturbed areas and exposed soil with suitable mixes that do not contain invasive species and are suitable for soil and erosion control. Depending on what the long-term use of the site may be, you can incorporate native grasses and herbaceous plants to occupy the site and provide wildlife habitat. Keep in mind that invasive species contamination can occur during seeding activities and be sure the equipment being used to spread seed is clean and free of any previously-used seed "hitch-hikers".
- Monitor the site while it is being revegetated to ensure desired species are growing and invasive species have not come in. If invasive plants are present, treat with early detection methods.

Depending on your project, you may be able to require the contractor or operator to do long-term inspections of the site to be sure desired vegetation is growing and invasive species are not introduced. This can be done where the contractor may have benefits gained on the site even after construction is complete, such as oil or gas development projects or rights-of way. Requiring the contractor to monitor the site for invasive plants and treat any invasive plants that may appear for a length of time after construction, say five years, may help in keeping these unwanted plants from establishing. This can be as detailed as requiring annual formal monitoring with reporting to simply requiring treatments when you notice invasive plants on the site.

Management Tools

After you assess which invasive plant species to target for management, the next step is to evaluate options for control. There are a number of tools available. They include everything from manually or mechanically removing plants to using biocontrol methods or chemicals. Understanding the biology of the targeted plant, as well as its population size, degree of threat and tools that have proven successful by other practitioners should all play in to your decision of what tools to use. In most cases, more than one tool will be necessary to control your target.

Mowing Pulling Prescribed Fire Soil Covers Chemical Biocontrol Grazing Aquatic Plants

Mowing and Cutting

Mowing and cutting can reduce seed production and restrict weed growth, especially in annuals cut before they flower and set seed. However, some species re-sprout vigorously when cut, so be sure to consider the biology of the plant before cutting.

How To
Mowing and cutting are often used as primary treatments to remove aboveground biomass, in combination with prescribed burning or herbicide treatments. It is important to collect the cut plant fragments to prevent roots and seeds from washing or blowing into uninfested areas when they can re-sprout. The timing of this control is key – be sure to remove the plant before they set seed, otherwise you will have to start over again next year.

Girdling
Girdling is one form of cutting that is often used to control trees or shrubs that have a single trunk. It involves cutting away a strip of bark several centimeters wide all the way around the trunk. The removed strip must be cut deep enough into the trunk to remove the vascular cambium, or inner bark, which is the thin layer of living tissue that moves sugars and other carbohydrates between areas of production (leaves), storage (roots), and growing points. This inner cambium layer also produces all new wood and bark.

How To
To girdle a tree, cut parallel lines approximately three inches or more apart around the circumference of the tree. The cuts can be made using a knife, ax or saw, and should be slightly deeper than the cambium. Strike the trunk sharply between the cuts using the back of an ax or other blunt object. The bark should come off in large pieces and prevent the tree from any further growth. It is important not to cut too deeply into the trunk because this could cause the tree to snap and fall in high winds. To determine the depth of the cambium, make two short test cuts and strike the bark between the cuts. After several strikes the bark should come off intact, exposing the cambium and wood (xylem) below.

Girdling is typically less labor intensive than cutting and removal of a tree, is inexpensive and kills only the targeted plant. It also leaves no residue except the standing trunks. In addition, a dead standing tree (snag) can provide valuable wildlife habitat, and if left to decay, allows the nutrients of the tree to be returned to the system, rather than being removed and deposited elsewhere. A few species, notably tree of heaven (*Ailanthus altissima*), should not be girdled because they respond by producing many fast growing root and stem sprouts. Therefore, before girdling, find out if the target species responds by re-sprouting. If so, use another control technique, such as cut stump or hack and squirt herbicide applications.

Proper Disposal

All plant material should be bagged and properly disposed of. Composting is not recommended for most invasive plants because the seeds may still be able to germinate. You may want to place the plant material in a heavy-grade plastic bag and leave in the sun for several weeks. This will help kill the seeds. Then composting that material becomes a viable option.

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Pulling

Pulling can be effective against some shrubs, tree saplings and herbaceous plants but it is not as effective against many perennial invasive plants with deep underground stems and roots that are often left behind to re-sprout.

How To
Minimize soil disturbance by pulling out plants slowly and carefully, and replace soil to disturbed areas where possible. Pull low to the ground to remove as much root material as possible. It helps to pull when soil is moist. Trampled and disturbed areas can provide optimal germination sites for many invasive plants. Minimize trampling by limiting the number of people in the site and the amount of time spent there. Whenever pulling is used, it is wise to wear gloves, a long-sleeved shirt and long pants because some plants can cause moderate to severe skin irritation, especially when their stems and leaves are crushed and broken.

The advantages of pulling include its small ecological impact, minimal damage to neighboring plants and low (or no) cost for equipment or supplies. Pulling is extremely labor intensive, however, and is effective only for relatively small areas, even when abundant volunteer labor is available.

Tools
A garden spade can be used to remove shallow rooted plants. For those with deeper roots, several tools are available including the Root Talonand the Weed Wrench™. The Root Talon is low-cost and lightweight tool shaped like a pick-ax with a plastic handle and metal head. It has a specialized claw and gripping device that allow the user to grab the plant stem and provide leverage to pull-up and remove the plants. The Root Talon is not effective against deep-rooted plants because it does not provide enough leverage.

The Weed Wrench™ provides more leverage than the Root Talon. Its all-steel frame is capable of withstanding more strain than the plastic handle of the Root Talon. It comes in four sizes. Larger Weed Wrenches provide more leverage and pulling power, but it is best to choose the smallest size needed because larger Weed Wrenches are heavy and can be difficult to carry and use in remote sites.

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Prescribed Burning

Fire has been used since ancient times by humans to manage vegetation. In modern times, prescribed burns, or controlled fires set by humans, are used to reduce hazardous fuel loads, restore historical disturbance regimes, improve forage habitat for game and livestock species, and promote biodiversity. This last point includes the use of prescribed fires in invasive species management.

Planning and Implementing Prescribed Burns

In planning a prescribed burn, there must be an Agency Administrator, who has the final responsibility of prescribed burns on their land. Examples include: District Forester, Park Superintendent, Regional Land Manager, and the landowner if the burn is on private lands. The Agency Administrator is responsible for:

- Appointing a plan writer who develops and obtains approval for the burn plan.
- Reviewing and approving a specific prescribed burn plan for each site, which includes considerations of the availability of resources, training and qualifications of personnel, safety, budget limitations, and project review.
- Appointing a qualified Burn Boss to implement the burn plan. Duties of the Burn Boss include ensuring that resources are available, determining that fuel and weather conditions are within acceptable parameters according to the plan, managing the activity and resources during the burn, and conducting the burn effectively and safely.
- Ensuring that proper notifications are made as outlined in the PA Prescribed Fire Standards

Under the Pennsylvania's Prescribed Burning Practices Act (Act 17 of 2009), the Department of Conservation and Natural Resources developed standards for planning and conducting prescribed fires in the Commonwealth, which include minimum qualifications and training requirements, as well as required content for prescribed burn plans. Pennsylvania's Prescribed Fire Standards, which cover in detail the essential planning and implementation procedures for prescribed fires, can be found at here.

Education of the public is also important in successful implementation of prescribed burn plans. Opposition to a prescribed burning from the public can be strong, even if the project is potentially beneficial, so the responsible party (lead agency) should do their best to provide information to the cooperators, neighbors and community. This can be best achieved by encouraging participation in the planning process and accepting feedback from interested individuals. Concerns need to be addressed and, as necessary, mitigated.

Control of Invasive Plants with Prescribed Fire
Prescribed burns can be used to control some, but not all, invasive species. The life history of the species will determine when and how to treat.

Prescribed Fire and Integrated Management Strategies

Repeated burnings that completely manage an invasive species population are rare. Therefore, other management strategies can and should be used with prescribed fire in an integrated approach.

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Soil Covers

Because invasive plants are some of the first species to appear in exposed or disturbed soil, the use of a soil covering, like mulch or plastic, can suppress the growth of some invasive plants while minimizing the risk to non-target native species.

Mulching
Mulching can be used on relatively small areas to control invasive plants, but the technique will often stunt or stop growth of desirable native species too. Mulching cannot control some perennial weeds because their extensive food reserves allow them to continue to grow up through the mulch.

How To
Cover the ground seedlings with several inches of mulch (straw, grass clippings, wood chips, etc.) or other type of ground cover (newspaper). This prevents some weed seeds and seedlings from receiving sunlight necessary to survive and grow. While it may not eliminate the invasive plant entirely, it has been shown to suppress flowering rates in plants like Canada thistle.

Soil solarization
This technique involves placing a plastic cover over the soil surface to trap solar radiation and cause an increase in soil temperatures to levels that kill plants, seeds plant pathogens and insects. However, this technique can cause significant biological, physical and chemical changes in the soil that can last up to two years, and deter the growth of desirable native species.
This method has not been used extensively for invasive plant control in natural settings. The effectiveness of soil solarization depends, in part, on how susceptible invasive seeds are to temperature increases. It is most effective against winter annual weeds that germinate under cool conditions. Summer annuals and other species adapted to higher temperatures, which germinate during warmer parts of the year, are less susceptible.

Soil solarization is most effective during the summer months, and may be less effective in cooler climates. The higher the temperature, the more quickly a kill is achieved. Solarization is effective only if done in wet soil. Where soils are typically dry, they must first be irrigated.

How To
Polyethylene plastic film is the most useful for soil solarization. Clear and black films both trap infrared radiation that is re-radiated from the soil surface, therefore keeping the soil hot. Transparent film allows more radiation to reach the soil than black films, as it lets visible light in, causing even greater temperature increases. Because black films exclude visible light however, they stop photosynthesis, which can be enough to kill some young annuals and perennials given sufficient time. Double layers of film have been found to increase soil temperatures by three to 10 degrees over single layers.

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Chemical Control

These guidelines are designed to ensure that you carefully consider the overall impacts of herbicide use on the invasive plant, native species and the ecological system. Base all decisions whether to treat invasive plants with herbicides instead of other methods on the management goals for the site. Herbicides should only be used when one is confident the treatments will meet management and conservation goals, while ensuring protection of the applicators, water sources, wildlife and other values.

Determining the right course of action in invasive species management can be difficult. For many land managers, whether to apply herbicides is a decision that is not taken lightly. Herbicides should be used as a last resort, when other attempts have failed, and action is imperative. However, for the control of some tenacious species like tree of heaven, herbicide use is required for effective control.

How to Know When to Use Herbicide or Another Control Option

- Determine whether invasive plants threaten conservation targets or management goals on the site. Use herbicides (versus other control methods) only if confidant they can be used safely and will do more conservation good than harm.
- Develop safety protocols for storing, mixing, transporting, handling spills and disposing of unused herbicides and containers before obtaining herbicides.
- Follow all federal, state and local regulations regarding herbicide use. You MUST read and follow product labels. It is a violation of federal law to use an herbicide in a manner inconsistent with its label.
- Contact your state Department of Agriculture for information about state and local regulations regarding applicator permits and posting requirements.
- Check with the legal staff for your program (State or Regional Office) before obtaining herbicides if you have any questions about regulations or liability issues.
- Applicators MUST wear all protective gear required on the label of the herbicide they are using. Provide all safety and protective gear requested by the employee applying the herbicide.

Herbicide Properties to Consider

- Effectiveness against the target species (not all herbicides will control invasive plant species the same)
- Mechanisms of dissipation (persistence, degradation and likelihood of movement via air or water to non-target organisms)
- Behavior in the environment (in soils, water and vegetation)
- Toxicity to non-target organisms (including soil organisms)
- Application considerations

- Safety
- Human toxicology

In general for work in natural areas, it is best to select compounds that are:

- Effective against the invasive
- Not likely to drift, leach to groundwater or wash into streams
- Nontoxic to people and other organisms
- Not persistent in the environment
- Easy to apply.

In some circumstances, a single application of a more toxic or persistent chemical is effective in killing the invasive plant, and may be preferable over a less persistent, less toxic compound that must be applied repeatedly. Strive to do the job with the smallest total negative impact to the environment.

Application Methods
Herbicides can be applied in a variety of ways. The most appropriate application method is determined by the invasive being treated, the herbicide being applied, the skills of the applicator and the application site.

Safe Use
Herbicides can be dangerous if not handled properly. Learn about safety gear, proper handling methods and what to do in an emergency.

Safe Storage and Disposal
Herbicides must be stored and disposed of in certain ways to protect both human health and the environment.

Different Formulations
An herbicide formulation is the total marketed product. It includes the active ingredient and any additives that enhance herbicide effectiveness, stability or ease of application. Learn about the technical components of herbicides.

Management Tools

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Mowing Pulling Prescribed Fire Soil Covers Chemical **Biocontrol** Grazing Aquatic Plants

Biocontrol

Biological control is the use of animals, fungi or other microbes to feed upon, parasitize or otherwise interfere with a targeted invasive species. Successful biocontrol programs usually significantly reduce the abundance of the invasive, but in some cases, they simply prevent the damage caused by the species without reducing overall abundance. Biocontrol is often viewed as a progressive and environmentally friendly way to control pest organisms because it leaves behind no chemical residues that might have harmful impacts on humans or other organisms, and when successful, it can provide essentially permanent, widespread control with a very favorable cost-benefit ratio.

Successful biocontrol projects reduce the abundance or impacts of the targeted species to acceptable levels across large areas. Use of biocontrol agents should be approached with caution, however, due to concerns that biocontrol agents may attack and damage populations of non-target native species. If a biocontrol agent does in fact attack any native non-target species, its persistence and ability to spread to areas far from release sites become serious liabilities. While biocontrol offers great promise, it will provide long-term benefits to natural areas and biodiversity preservation only if it is practiced carefully and its potential risks are fully recognized and addressed.

There is also concern about releases of biocontrol agents among some conservationists precisely because the agents are themselves non-native introductions. In some cases the agents may carry additional non-native parasite and commensal species. There has been at least one case in the past decade in which a biocontrol release unintentionally included a second non-native look-alike species that has now become established. Intentional introductions of non-native biological control agents may, however, contribute to global biodiversity by significantly reducing large populations of targeted non-native organisms that would otherwise reduce or threaten populations of native species.

Of course, it must be recognized that all courses of action against invasive organisms, including that of taking no action, carry some risk to valued, non-targeted organisms. If no action is taken, the invasive may continue to spread and reduce or eliminate valued native species, and in the worst cases, drastically alter community and ecosystem functioning.

Species with Existing Biocontrols

Cirsium arvense	Canada thistle
Cirsium vulgare	bull thistle
Conium maculatum	poison hemlock

Eichhornia crassipes	water hyacinth
Hydrilla verticillata	hydrilla
Lythrum salicaria	purple loosestrife
Pistia stratiotes	water lettuce
Polygonum perfoliatum	mile-a-minute

Species with Biocontrols Being Researched

Acroptilon repens	Russian knapweed
Alliaria petiolata	garlic mustard
Ligustrum spp.	privets
Phragmites australis	common reed
Pueraria montana var. lobata	kudzu
Rhamnus cathartica	common buckthorn
Frangula alnus	glossy buckthorn

Obtaining and Releasing Biocontrol Agents
It is best to obtain biocontrol agents locally, if possible, as this will minimize losses in storage and transport and increase the likelihood that the agents can survive in the local environment. It is also wise to start lining up a supply of agents several months before you will need them. The USDA's Animal and Plant Health Inspection Service (APHIS) issues permits that relate to the importation and testing of biocontrol agents. To learn more about their program and find contact information for staff within the program, visit their Biological Control Program.

Biocontrols on State Park and State Forest Lands
To control mile a minute (*Polygonum perfoliatum*), the weevil, *Rhinoncomimus latipes Korotyaev*, has been released at many parks over several years, including Boyd Big Tree and Ibberson conservation areas, and Bald Eagle, Caledonia, Codorus, French Creek, Kings Gap, Memorial Lake, Nockamixon, Sam Lewis, Sinnemahoning, Susquehannock, Swatara, and Tyler state parks.

For purple loosestrife (*Lythrum salicaria*) control, *Galerucella* beetles (either *G. calmariensis or G. pusilla)* were released at Codorus. These beetles can be found at many other state parks, as well on some of the islands on the Susquehanna River that are managed by the Bureau of Forestry.

Hemlock wooly adelgid (*Adelges tsugae*) is being controlled with *Sasajiscymnus tsugae* and *Laricobius nigrinus* beetles. They were released at many parks over the past several years, showing various degrees of success. A couple of the sites are Blue Knob and Jacobsburg. A fungus is also being researched as potential biocontrol.

Emerald Ash Borer parasitoids will be released at Greenwood Furnace and Shawnee state parks in 2012-13.

Weevils for Eurasian water milfoil were released at Gifford Pinchot State Park. They were unsuccessful in establishing, possibly due to the turbidity of the lake. Due to the cost they have not been trialed in any other body of water.

To control mile a minute (*Polygonum perfoliatum*), the weevil, *Rhinoncomimus latipes Korotyaev*, has been released at many forests over several years, including Michaux, Buchanan, Tuscarora, Rothrock, Gallitzin and Susquehannock state forests.

Management Tools

After you assess which invasive plant species to target for management, the next step is to evaluate options for control. There are a number of tools available. They include everything from manually or mechanically removing plants to using biocontrol methods or chemicals. Understanding the biology of the targeted plant, as well as its population size, degree of threat and tools that have proven successful by other practitioners should all play in to your decision of what tools to use. In most cases, more than one tool will be necessary to control your target.

Grazing

Grazing can either promote or reduce invasive plant abundance at a particular site. By itself, grazing will rarely, if ever, completely eradicate invasive plants. However, when grazing treatments are combined with other control techniques, such as herbicides or biocontrol methods, severe infestations can be reduced and small infestations may be eliminated. Grazing animals may be particularly useful in areas where herbicides cannot be applied or are prohibitively expensive. Animals can also be used as part of a restoration program by breaking up the soil and incorporating in seeds of desirable native plants

When not properly controlled, however, grazing or other actions of grazing animals (wallowing, pawing up soil) can cause significant damage to an ecosystem and promote the spread and survival of invasive plants. Overgrazing can reduce native plant cover, disturb soils, weaken native communities and allow invasive plants to invade. In addition, animals that are moved from pasture to pasture can spread invasive plant seeds.

In general, the specific invasive and desirable native plants will determine the number and species of animal grazers and the duration and frequency of grazing. A grazing plan should be developed in situations where prescribed grazing is desirable, and this plan must be tailored to fit the specifics of the site.

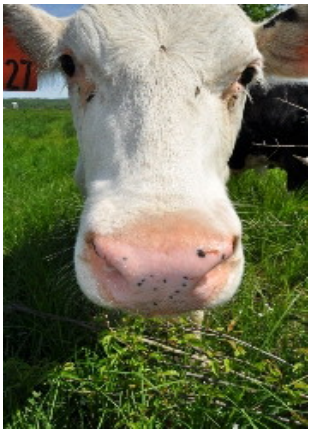
Species to Use for Grazing
Cattle, goats, sheep and even geese may be used to control invasive plants. Cattle will graze invasive grasses, can trample inedible weed species, and can incorporate native seeds into soil. Horses can also be used to control invasive grasses, but horses tend to be more selective than cattle. Geese are also useful for the control of invasive grasses, but are more subject to predation than other animals.

Sheep and goats prefer broadleaf herbs and have been used to control plants like Russian knapweed (*Acroptilon repens*). These animals appear to be able to neutralize the phytochemicals toxic to other animals that are present in these and other forbs. Goats can control woody species because they can climb and stand on their hind legs, and will browse on vegetation other animals cannot reach. Goats additionally, tend to eat a greater variety of plants than sheep.
Plant availability, hunger and previous experience can determine a grazer's selection of food plants. Differences in vegetation quality may cause an animal to eat one species in one situation and to ignore the same species in another. A period of adjustment is generally required to get a grazing animal to eat a new type of forage. It is therefore helpful to find animals previously experienced with the target invasive.

Finding grazing animals to use for invasive control can be a problem. Land managers are sometimes forced to make use of the animals available in the immediate area, especially since transportation costs can be excessive.

Timing and Duration of Grazing
Animals should be brought into an infested area at a time when they will be most likely to damage the invasive species without significantly impacting the desirable native species. Grazing during seed or flower production can be especially useful. On the other hand, some weeds are palatable only during part of the growing season. For example, cheatgrass (*Bromus tectorum*) is preferred in spring before seed heads develop, but avoided by cattle once it has begun to set seed because the seed heads have stiff awns that can puncture the mouth and throat tissue of livestock. Grazing will often result initially in an increase in stem density and root buds, but repeated grazing should lead to reduced stem densities in the longer term.
Grazing should be closely monitored and the animals promptly removed when the proper amount of control has been achieved and before desirable native species are impacted. Consequently, land managers must be flexible and have control over herd movements. Lack of control can result in overgrazing of desirable species, which can enhance infestations or allow new invasive species to become established. The necessary flexibility is not always possible with commercial herds. In most cases, several years of intensive grazing followed by annual brief periods of grazing by the same grazing species is required to gain and maintain control of an infestation.

Animal Fencing and Movement
The containment and movement of grazers within and between infested areas is necessary for the successful implementation of an appropriate grazing plan. Temporary fencing, including electric net fences, erected to contain animals in a particular area may be suitable for goats and sheep, but is often inadequate for larger animals like cows and horses. More stable and expensive barbed wire fencing may be required to contain these larger animals. Salt licks have been used successfully to concentrate animal impact in a particular area.



A herder is usually required to move goats and sheep between pastures or infestations and to ensure that the animals concentrate grazing on the appropriate species. Cattle must be moved periodically, but generally do not require a herder. Goats have been tied to stakes within infested areas to concentrate their activity and eliminate the need for full-time herders. "Open" herding is usually more beneficial than "close" herding, where animals are kept close together causing much of the forage to be trampled.

Controlling Seed Dispersal
Seeds of spotted knapweed (*Centaurea maculosa*) and other species can pass through the digestive tract of animals and remain viable. Animals that are removed from an infested area should not be transported to weed-free areas until all seeds have passed through their digestive tracts (five to nine days). Invasive seeds can also be transported to new areas in animal hair. Care and precaution should be taken when moving animals from infested areas.

Pennsylvania Example of Controlled Grazing
Kings Gap Environmental Education Center
500 Kings Gap Road, Carlisle, PA 17015
Scott Hackenburg, Center Manager, (717) 486-5031, shackenbur@pa.gov
Kim Mihalek, Environmental Education Specialist, (717) 486-5031, kmihalek@pa.gov

The Pine Plantation Day-Use Management Area is a 70-acre unit located in the northern part of Kings Gap Environmental Education Center. As the trees in the Pine Plantation age and die, the forest floor is no longer completely shaded by the dense canopy of the pines. These openings in the canopy allow plants to grow in the understory. The management goal is to maintain the Pine Plantation Day-Use Area in a manner that will provide a forest habitat that will offer wildlife cover for a variety of woodland species as well as serve as an area for environmental education programs and low impact recreational pursuits such as hiking and cross country skiing.

As the canopy opens in the Pine Plantation, invasive plants are thriving. Recently the populations of these non-native invasive plants have become very dense and are out-competing the native plants, disrupting the natural succession of the forest. The non-native invasive plants include multiflora rose, oriental bittersweet, honeysuckle vine, shrub honeysuckle, tree of heaven, privet, garlic mustard, Japanese stiltgrass and mile-a-minute weed.

To sustain a viable and healthy forest ecosystem, Kings Gap is implementing a systematic approach called Integrated *Vegetation* Management. As part of the integrated strategy, Kings Gap will use a combination of different control methods, including chemical, biological, and mechanical practices, to control the invasive species and encourage growth of desirable native plants.

Goals
Control the spread of mile-a-minute weed by removing seedlings inside the treatment area before they produce seeds
Decrease vegetative growth of multiflora rose, blackberry and bittersweet in order to make treatment area more accessible for follow-up treatments
Increase multiflora rose susceptibility to rose rosette disease by stressing plants through defoliation

Pre-Treatment
To establish baseline data, a series of photographs were taken before the goat grazing begins. These pictures reflect the quantity and density of the invasive plants in the treatment area, as well as the current state of the desirable plant species.

Fencing

The goats were contained using electric netting, which is designed to keep goats in and predators out. This fence is 42 inches high and comes in rolls 164 feet each. They ordered four rolls for a total of 656 linear feet, which enclosed one area of 25,000 to 32,000 square feet (approximately 0.6 - 0.7 acre). In order to use an electric fence, existing vegetation must be cleared to the ground. They cleared an eight-foot swath around the perimeter of the treatment area, two feet for the fence (one foot on either side) plus a six-foot wide access route for the Gator, allowing the fence to be monitored and maintained daily by driving the Gator around the perimeter. The vegetation removal was done by hand using loppers and chain saws, and with a Fecon brush clearing machine.

Goats

For most effective control of mile-a-minute, they placed the goats inside the treatment area beginning June 1, 2011. They used six goats, leased from local farmers: Sandy Miller, whose farm is located in Newburg, Pa. and Bill Yocum, in Carlisle, Pa. Goats from both of these farms have experience grazing in forested areas. Because the forest provides adequate shade, a shelter for the goats was not needed. They provided fresh water and monitored the goats daily. The goats grazed for approximately 30 days. The amount of time is dependent on grazing rate, which varies with individual goats and the amount and type of vegetation available. Kings Gap staff monitored the grazing rate and removed the goats from the treatment area when the targeted vegetation was eaten and the goats had begun to feed on the twigs and bark of woody plants. When the grazing period ended, the goats were returned to their owners.

Post Treatment

Immediately after removing the goats from the treatment area, they evaluated the results and took a second series of photographs, showing the impact that the goats had on both invasive plants and desirable vegetation. Following this, the fence was removed and stored for future use. The eight-foot wide fence perimeter will be maintained and herbicides applied as needed to prevent vegetation regrowth so that the fence can be used again the following season, if needed.

Cost

The total cost of renting the goats, and purchasing fencing, battery, charger, fence tester, water trough and shipping charges was $968.79.

Management Tools

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Aquatic Plant Control

Freshwater aquatic plants are plants (not algae) that can only grow in freshwater or permanently saturated soils. Typical freshwater habitats where aquatic plants are found include lakes, ponds, marshes, bogs, wetlands, rivers, streams and ephemeral pools, which exist seasonally. There are three forms of aquatic plants: emergent plants, submersed plants and floating-leaf plants. Emergent plants are rooted underwater and have stems that grow above the waterline. A well-known example is the cattail. Floating-leaf plants have roots and stems underwater, but produce leaves and flowers on or slightly raised above the waterline. Water-lilies are a classic example. Submersed plants live entirely beneath the waterline and are the only one of the three forms of aquatic plants that can be considered truly aquatic.

Pennsylvania is home to many native aquatic plants but this section is dedicated to those non-native invasive plants that are causing economic and ecologic harm to the state's freshwater areas.

Why Control Aquatic Plants?
Aquatic invasive plants can negatively affect recreational activities, businesses that rely on boats, the dissolved oxygen content needed for aquatic life, and human health via disease vectors like mosquitoes. When aquatic invasive plants infest waters that are used commercially or recreationally by boaters, they get entangled in propeller blades and stress the engine, leading to costly repairs. Thick aquatic invasive plant infestations in recreational swimming areas can make the area look unsightly and potentially dangerous for swimming. They can change completely the character of the habitat, making it unsuitable for native wildlife and vegetation.

Manual Control
Mechanical control of aquatic invasive plants typically involved large power-driven equipment, although it can also include hand-pulling or using a rake to dredge up rooted, submerged vegetation and drawing down the water to expose submerged vegetation. The type of equipment and method you use will depend on the type of invasive plant to be controlled and the habitat in which it can be found. Mechanical harvesters include cutter boats, shredding boats, rotovators, dredgers and harvesters (the most commonly used aquatic plant control machine).
Emergent plants like *Phragmites* and purple loosestrife can be mowed during dry seasons, although significant environmental damage and harm to non-target species could result. Pulling these species by hand is not recommended, however, as their root structure is difficult to remove fully and the population size of these species is usually so large as to make hand-pulling too onerous.

Most mechanical control for aquatic invasive plants occurs in water greater than two feet deep. Floating plants tend to have a very large biomass, which can make gathering and disposing of all the plant material time consuming and difficult. Submerged plants like *Hydrilla* tend to have a much smaller biomass and can therefore be harvested more easily.

Water drawdowns require a combined permit from the Department of Environmental Protection and the Fish and Boat Commission, which can be downloaded at here. If your project involves dredging and any other control effort that may impact wetlands or streams, be sure to contact the nearest DEP regional office to ensure that you are meeting all regulations. A list of DEP regional office contacts can be found here.

Biological Control

Biological control, also known as biocontrol, involves the intentional use of an organism, like an insect or fungus, to suppress the growth of another organism, such as an invasive plant. Like all control methods, biological approaches to aquatic invasive plant control can have positive and negative effects on aquatic ecosystems. Biocontrols are typically brought over from the invasive plant's country of origin, then rigorously tested in laboratory and field settings to ensure that they will not cause damage to native plant species. Only if successful and not harmful to non-target species, can biocontrols be released into the wild. The USDA Animal and Plant Health Inspection Service (APHIS) is responsible for approving all biocontrol agent releases in the U.S. Biocontrol agents for *Hydrilla*, purple loosestrife, mile-a-minute and Eurasian watermilfoil are now available.

Chemical Control

Hundreds of herbicides are registered in the U.S. but only a dozen or so are registered for use in aquatic habitats. Anyone wishing to apply an herbicide in an aquatic setting is required to obtain a permit from the Pennsylvania Fish and Boat Commission, who will then obtain approval from the Department of Environmental Protection's Bureau of Water Supply Management. This process ensures that the proper chemical is selected and applied in the correct manner, to minimize impacts to non-target species. The permit form can be downloaded here.

Herbicides for aquatic invasive plant control will either be applied to emergent or floating foliage through a spray or wipe method or to submerged vegetation using concentrated liquids, granules or pellets. Two types of herbicides can be used: contact and systemic. Contact herbicides are those that do not travel through the plant's tissues; they injure the plant tissue with which the herbicide comes in contact. These include Copper, Endothall, Diquat, and Carfentrazone. Systemic herbicides, on the other hand, move through the plant's tissues, affecting roots, stems and leaves. Aquatic-approved systemic herbicides include 2,4-D, Triclopyr, Glyphosate, Imazapyr, and Fluridone (for in-water use only).

No matter which chemical control you decide to use, be sure to follow all instructions on the label and abide by all state and federal herbicide regulations.

And for more detailed information about the biology, impacts and control of aquatic invasive plants, download a copy of the "Best Management Practices Handbook" from the *Aquatic Ecosystem Restoration Foundation* here. Most of the information included above came from that comprehensive document.

Management Planning

Land managers who have been successful at tackling invasive plants typically take the time to develop an invasive species management plan. To be successful, plans should be well thought out and designed to meet the goals of the project. In cases time, money and staff resources are limited, management planning will help land managers best use these resources. The management plan is the guiding document for any invasive plant management program and should be designed for long-term goals for treating and monitoring invasive plants.

The management of natural, biological systems is inherently difficult because predicting the way an ecosystem will behave is highly unpredictable. The outcome of invasive species management and control is based on a relatively short history and understanding of invasive plant management. Taking an adaptive approach to invasive plant management will provide the most successful results.

Adaptive Management Invasive Species Management Plans Inventory and Mapping Monitoring and Evaluation

The Adaptive Management Approach

Many approaches can be taken to address invasive plant problems. The obvious considerations include money, time and available resources (tools, staff, etc.). Most often, all are limited. Fortunately, a great many land managers who have faced these challenges over the years and have developed guidelines, plans and approaches that can assist you.

Overview of the Adaptive Management Approach (AMA)
Adaptive management differs from traditional management approaches because it allows management activities to proceed despite uncertainty regarding how best to achieve desired outcomes, and adjust practices when inevitable changes or surprises arise. In fact, it specifically targets such uncertainty: it compels ecosystem managers to be open and explicit regarding what is not known about how best to achieve conservation and management objectives.

Steps in the AMA

(1) Establish conservation goals and objectives for the site. These may be identified in a broader management plan for the site or may need to be identified for purposes of the invasive plant management plan for the site.

(2) Conduct an assessment to determine is invasive plants exist that could impede achieving desired management goals and objectives. If invasive plants are found to be an issue, mapping and ranking these plants becomes important. If no invasive plants are found during the assessment, then regular follow-up assessments should be performed to detect early introductions.

(3) Determine which methods are available to control the invasive plants.

(4) Develop and implement a management plan designed to move conditions toward management goals and objectives. Evaluate which control methods will work best given your site conditions and resource constraints.

(5) Monitor and evaluate the effectiveness of management actions in moving conditions toward these goals and objectives. If the evaluation reveals that management goals and objectives have not been met, then begin the cycle again and determine whether or not you need to modify your goals and objectives. If you reach success, then it is important to use preventative measures for reintroduction and regularly monitor and evaluate the site.

Control activities are not started until the first three steps have been taken. Invasive plant control programs should be part of an overall restoration program, so focus on what species or conditions are desired to replace the invasive plant, rather than simply eliminating the plant. When selecting control methods, keep in mind that the ultimate purpose of the work is to preserve native species, communities or functioning ecosystems.

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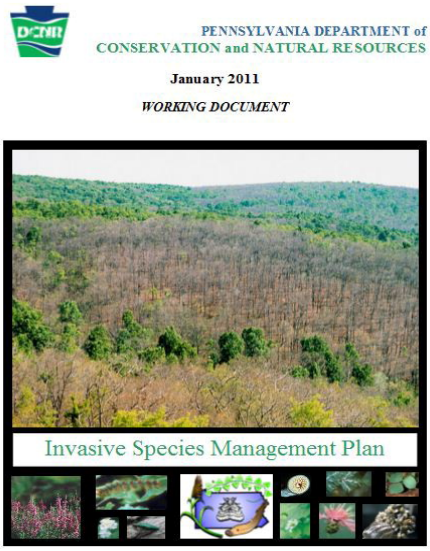
Invasive Species Management Plans

The most effective invasive species management programs have taken the time to develop management plans that were well thought out and designed to meet the goals of the project. In cases where resources (time, money and staff) are limited, management planning will ensure that those resources are used wisely. The management plan is the guiding document for any invasive plant management program and should be designed for the long-term.

Before developing a management plan under the Adaptive Management Approach, several steps need to occur first. Those include goal setting, assessment and prioritization and evaluating what methods or tools will be used to control the invasive plants that you have targeted.



Management Plan Templates

1. PA Invasive Species Management Plan is a framework for response that will aid in minimizing the harmful ecological, economic and human health impacts of nonnative invasive species through the prevention and management of their introduction, expansion and dispersal into, within and from Pennsylvania. Developed by the Pennsylvania Invasive Species Council, this document outlines risk assessment, prevention, early detection, control and restoration.

2. The Nature Conservancy's Invasive Species Initiative has developed a Weed Management Plan Template that is widely used. The strength of this template is that it is self-explanatory. Measures have been taken to thoroughly explain what the user should be considering in addressing each component of the plan.

3. The 2008 to 2012 National Invasive Species Management Plan directs federal efforts to prevent, control and minimize invasive species and their impacts. The 2008 Plan is focused upon five "Strategic Goals": Prevention; Early Detection and Rapid Response; Control and Management; Restoration; and Organizational Collaboration.

4. A Cooperative Weed Management Area (CWMA) is a distinguishable zone based on similar geography, weed problems, climate or human-use patterns. These management areas cross jurisdictional boundaries between

agencies and municipalities and are recognized by a natural boundary as opposed to a legal boundary. The concept is popular in the western U.S. Click here to learn more about CWMAs.

5. An Annual Operating Plan (AOP) addresses how, on an annual basis, the objectives of the over-all Management Plan are implemented. Due to manpower, funding or other limitations, it may not be possible for the AOP to address all the objectives of the Management Plan in a given year. The Management Plan must address long term objectives and priorities. The Annual Operating Plan guides implementation of the Management Plan in yearly increments. Budgets and circumstances may change from year to year and these changes are best addressed in making new Annual Operating Plans rather than rewriting the Management Plan annually.

6. The Center for Invasive Plant Management provides a good overview of initiating a CWMA, writing managment plans, and developing AOPs.

7. For species-specific or state/region-specific management plans, visit the National Invasive Species Information Center and search for "management plan".

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Adaptive Management Invasive Species Management Plans Inventory and Mapping Monitoring and Evaluation

Inventory and Mapping

Identification and prioritization of species or infestations that threaten conservation targets or goals is the second step in the Adaptive Management Approach. To be cost-effective and efficient in using resources, it is critical to know which plants exist and the extent of their occurrences. For the majority of public lands in Pennsylvania this information is limited. Therefore, it will be necessary to take this step for the site under consideration. Not only will this information benefit management planning efforts for this site, but it will assist in filling in information gaps for the state's biodiversity.

Inventory can be described as a point-in-time measurement of the resource to determine location or condition. Without location and distribution information, park resource managers lack the critical tools required to develop a focused strategy for addressing invasive plant management issues.

What can Invasive Plant Inventory and Mapping Information do?

- Increase the ability of resource managers to analyze and prioritize invasive plant management needs and to appropriately direct work efforts and resources, enhancing the time and cost-effectiveness of invasive plant management actions.
- Serve as a baseline for long-term monitoring, and assist with the evaluation of changes in invasive plant populations over time or the detection of new exotic plant infestations.
- Combine with other layers of information (e.g. soil types, depth to water table, elevations) that can assist in identifying appropriate treatment or control options as well as adding to the knowledge of ecological relationships associated with alien plant invasions (predictive modeling).
- Serve as a critical tool for increasing public and political awareness and education on invasive plant issues.

Inventory and mapping of invasive plants should be integrated with general vegetation surveys and surveys being conducted by other agencies and organizations. Data organized into maps and databases provide valuable information towards the development of a network-monitoring scheme. Ancillary uses of maps and data are for public education, development of predictive models and estimations of risk from various plant species. Goals and objectives for inventory and mapping should ensure products can serve the above purposes

Mapping
Mapping is an important way to communicate inventory information. This tool provides a visual picture of how abundant a species is and how it is distributed across the landscape. When overlaid on a map of priority habitats or natural communities, one may be able to quickly evaluate the species that are priorities for control or eradication. Mapping can take many forms, everything from recording written information on a paper map to using GPS (global positioning system) and recording in a mapping program such as GIS (global information system).

The Early Detection and Distribution Mapping System (EDDMapS) is a useful resource for mapping new invasive species sightings. The EDDMapS database shows species occurrences at a national, state and county level. Species are listed by plant type and are connected to the Bugwood Network, which includes many photos and species descriptions that are useful for identification purposes. You can even download a free smart phone app for iPhone or Android that will help you keep track of invasive sightings in the field.

Prioritization
Managing and controlling invasive plants is difficult, expensive and requires a long-term commitment. Land managers have limited resources and so prioritizing efforts is critical. High priority should be given to those species that have substantial impacts on natural resources or on attainment of management goals and are believed to be easy to manage. High priority should also be given to those species that are not yet established or causing major impacts, but have the potential to do so. Low priority should be given to species that cause little impact, are virtually impossible to control, or both.

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Monitoring and Evaluation

Monitoring refers to repeated observations and evaluation as well as relating that information to the objectives of a management plan (changes in condition and progress towards meeting management objectives). Monitoring and evaluation provide the documentation of site conditions for managed areas and provide a means for reporting changes in vegetation trends. Through the process of monitoring and evaluation, we can also measure progress towards or success at meeting a management objective. This is the fifth step in the Adaptive Management Approach. If an objective is met, the management activities have been effective. If not, monitoring provides the needed evidence for changes to the management plan.

Monitoring
Monitoring begins with pooling all available information to establish baseline data. The purpose of a Monitoring System is as follows:

- Collect baseline field data on existing infestations and control practices.
- Compile data on which to base invasive control decisions.
- Evaluate the effectiveness of treatments, including modifications to the design or maintenance of the system and the education and training program.
- Prevent re-invasion by returning to eradicated stands to determine if new plants have established.

Monitoring Resources
The National Park Service provides a good overview of designing an integrated monitoring program, which you can download here.

The Early Detection and Distribution Mapping System (EDDMapS) is another useful resource for reporting new invasive species sighting, as well as tracking and monitoring invasive species control programs. The site is free to use and endorsed by a variety of well-known organizations.

Evaluation

Evaluation is relating information obtained from monitoring to the objective of the management plan.

Use evaluation to determine:

- If the weed management program accomplishes the objectives of the management plan.
- If the management plan is still desirable and realistic. Evaluation requires analyzing information gained through monitoring, including benefits versus costs, comparing it with the cost/benefit of other alternatives, comparison with untreated areas, and projected costs of no action.

Evaluation should answer the following questions:

- Was the weed population adequately suppressed?
- Was the planned procedure used? If not, what was different and was it documented?
- Was the cost of weed suppression equal to or less than the potential loss?
- What was the effect on target organisms?
- Were natural enemies affected by the treatment?
- Were there any other side effects from the treatment?
- Were the side effects included in the cost-benefit analysis?
- Should the treatment be repeated or modified?
- Should another kind of treatment be considered?
- Was funding and manpower available at the appropriate time?
- Was training adequate?
- Were changes in the weed regime due to external factors?
- Make changes to the management based on your evaluation.

Laws and Regulations

There are a number of laws and regulations that address the control, eradication or prevention of invasive plant species. New legislation or changes to current legislation have an important impact on how we are able to deal with invasive plant problems. For the benefit of those using this site, we will discuss only a few of the most pertinent pieces of legislation. For a full review of national and state laws and regulations, see the National Invasive Species Center website: www.invasivespeciesinfo.gov.

PA Noxious Weed Law

The Pennsylvania Noxious Weed Law, updated in 2012, states that it is illegal to propagate, sell or transport the following noxious weeds in Pennsylvania:

Canada thistle (*Cirsium arvense*)
Multiflora rose (*Rosa multiflora*)
Johnson grass (*Sorghum halepense*)
Mile-a-minute weed (*Polygonum perfoliatum*)
Kudzu (*Pueraria lobata*)
Bull or spear thistle (*Cirsium vulgare*)
Musk or Nodding thistle (*Carduus nutans*)
Shattercane (*Sorghum bicolor*)
Purple loosestrife (*Lythrum salicaria*), including all cultivars
Giant hogweed (*Heracleum mantegazzianum*)
Goatsrue (*Galega officinalis*) (Amended November 18, 2000)

This list was initially developed to identify agricultural weeds and more recently has included weeds of natural areas. Any changes or expansions of this list require an act of the Pennsylvania Legislature.
For additional information on the PA Noxious Weed Law or noxious weeds, go to the Pennsylvania Department of Agriculture website, http://www.agriculture.state.pa.us/ and search under "noxious weed."

Restoration

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability. Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed or entirely destroyed as the direct or indirect result of human activities, such as the intentional or unintentional introduction of invasive species. In some cases, impacts to ecosystems have been caused or aggravated by natural agents such as wildfire, floods or storms, to the point at which the ecosystem cannot recover to its pre-disturbance state.

Restoration consists of removing or modifying a specific disturbance, thereby allowing ecological processes to recover. Restoration also may require the deliberate reintroduction of native species that have been lost, along with the elimination or control or harmful, invasive species.

When the desired outcome is realized, the ecosystem under manipulation may no longer require external assistance to ensure its future health and integrity, in which case restoration can be considered complete. Nevertheless, the restored ecosystem often requires continuing management to counteract the invasion of opportunist species and the impacts of various human activities, climate change and other unforeseeable events. In this respect, a restored ecosystem is no different from an undamaged ecosystem of the same kind, and both are likely to require some level of ecosystem management.

Native Plant and Seed Sources
Depending on the site conditions, goals for restoration and resources available, native plant material in the form of a seed mix or nursery stock can be used to restore a site once the invasive plants have been removed.

It is an ideal situation if the expertise, equipment and staff are available to produce propagated native plant material or native seed on site for the restoration project. However, this is usually not feasible. Native plant material is available from retail or wholesale nurseries or specialized growers. Native seed is available from commercial seed suppliers. Choosing a supplier who specializes in native plants and seeds is desirable, but is not always an option.

Select nurseries or plant growers that have experience working in your ecoregion and carry plant materials or can collect plant materials from the area in which you are doing the project (within the same ecoregion). The supplier should have staff knowledgeable about local native flora. If specific plants are to be grown for the restoration project, interview the grower about their knowledge of propagating all planned species.

Find out where and how the plants they are selling have been grown. Plants may have been grown in a very different part of the country and would thus not be well-suited for the restoration site. Make sure plant material has never been dug in the wild and removed from its natural habitat. Nursery owners and growers should assure the customer that all plants have been "nursery propagated." This means that staff have collected only seeds or cuttings from the wild, and have not removed whole plants from the wild. You should also ask the supplier for information about the original location of the parent plant material so you can determine how locally adapted the plants might be. Good native plant nurseries will have this type of information on record. If plants have been salvaged, ask the staff person where and how they were salvaged. Ethical salvage occurs when plants are removed before some type of construction or destruction takes place and always with the landowners' permission.

To learn more about native plants resources, visit DCNR's native plant website.

Landscaping with Native Plants

A native plant is one which occurred within this region before settlement by Europeans. Native plants include ferns and clubmosses; grasses, sedges and rushes; perennial and annual wildflowers; and the woody trees, shrubs, and vines which covered "Penn's Woods" when the first settlers arrived. There are 2,100 native plant species known in Pennsylvania.

An introduced or non-native plant is one that has been brought into the state and escaped cultivation to become established in the wild. At the turn of the 21st century, about 1,300 species of nonnative plants existed in Pennsylvania outside of gardens, parks and agricultural lands. That is 37 percent of Pennsylvania's total wild plant flora. More introduced plants are identified every year.

Native Plants for Your Garden

Choose the best native plants for your garden conditions using DCNR's interactive plant selection resources.

Native Plant Publications

Access lists of wildflowers and trees for different conditions: shady-dry; shady-moist; sunny-dry; sunny-moist. Download the Landscaping with Native Plants brochure.

Buy Native Plants

Find nurseries throughout the state that specialize in native species.

Six Basics of Plant Conservation

1. Protect native plant communities and minimize habitat destruction

The most important guideline is to conserve already existing areas of native vegetation as a whole, functioning unit. The easiest, least expensive, and best way to conserve Pennsylvania's plant heritage is to protect existing native plant communities from further disturbance. If disturbance is necessary, strive for minimum habitat destruction. In some cases ecological restoration may be necessary, which can include planting native species, removing invasive introduced species, controlling erosion and loosening soil compaction.

2. Landscape with native plants

Native plant communities have been destroyed in many areas. Intelligent landscaping in parks, yards and campuses can help redress this loss. Well-chosen native plants can flourish in these landscapes. The Department of Conservation and Natural Resources (DCNR)-Bureau of Forestry (BOF) recommends avoiding rare, endangered, and threatened plants and instead choosing native plant species which grow commonly throughout the state. If you do not want all natives, plant adapted introduced plants suited for the site, colorful annuals, or flowering plants that will not escape and become environmental weeds.

3. Learn more about native plants

Learn what plants are native in your area. There are many field guides to wildflowers that can get you started.

4. Buy nursery-propagated native plants

Most retail nurseries and mail-order catalogs now offer native plants. The more consumers request native plants, the more this supply will grow. If you want guaranteed ornamental characteristics, cultivars (named varieties) are available in some cases; for instance, A cultivar of New England Aster named 'Purple Dome', was selected for shorter height and showier flowers. Cultivars should be predictable in attributes like height, color, blooming period, or absence of seed pods/thorns--qualities many gardeners want. If your goal is genetic diversity, however, ask for straight species, not cultivars, grown from local seed sources. Plants grown from seed have much more variety than cloned cultivars.

5. Do not remove native plants from the wild

Taking native plants from the wild depletes native populations. Also, many wild-collected plants do not survive transplanting. Prevent wild-collecting of plants by making sure that plants you buy are propagated at a nursery, or

by starting plants yourself from a local seed supply. Before you collect seed always obtain the property owner's permission.

6. Practice responsible landscaping techniques

The first rule of responsible landscaping is to plant the right plants in the right environment: never introduce invasive plants to your landscape that will aggressively spread off your property and invade native plant communities. They can drastically alter ecosystems and give you and your neighbors maintenance headaches for years to come.

When landscaping with native plants it is important to choose plants that will grow well at the site: wet or dry, shade or sun, acid or neutral soil. A good trick is to notice which native plants are thriving nearby, and to use those clues to guide plant selection. Other information can be found from plant nurseries, catalogs, books, or the Internet.

For soil fertility, compost and mulch of leaves or grass clippings provide slow release nutrients. Chemical fertilizers often provide too many nutrients too quickly for native plants, and this flush of nutrients gives weeds a competitive edge. Proper site preparation begins with a soil test before applying fertilizer. Try organic pest control. Keep the soil covered to prevent weeds. Remove invasive plants nearby. Take out severely diseased plants, or ones with insect infestations. Many native plants attract beneficial insects which help control pests, so try creating habitat for "good bugs."

Invasive Plants

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A small number of native plants can become "weedy" meaning they become aggressive after the landscape is altered. But the fundamental condition here is the disturbance of the habitat that upsets the balance. This is not true "invasiveness".

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What Can I Do? | Characteristics & Impacts | Trees | Shrubs | Vines | Grasses | Herbs | Aquatic Plants

What Can I Do About Invasive Plants?

The best insurance against future problems is to avoid the use of known invasive plants and educate others about the problems of invasive species. This website lists many of the plants that are considered invasive in Pennsylvania. Plants on this list should not be used around your home or community because they can escape cultivation and aggressively move into surrounding ecosystems. Avoid invasives by choosing plants that are native to your area. Natives often are adapted to a specific environmental niche, and have natural controls that keep them in balance.

Download DCNR's brochure **Invasive Plants in Pennsylvania**. This document summarizes features of many of Pennsylvania's worst plant invaders, discusses the issues involved, and provides a list of resources.

Minimize landscape disturbance. Invasive plants thrive on bare soil and disturbed ground where the native plant community has been displaced. The key to controlling invasives is to protect healthy native plant communities.

Use fertilizers wisely. Proper site preparation begins with a soil test before applying fertilizer. High nitrogen levels sometimes give an advantage to invasive species that are better adapted to using plentiful nutrients for explosive growth. For soil fertility, try using organic, slow-decomposing compost and mulches

Have a land management plan for maintenance over time. It makes sense when designing a property to plan for future maintenance. Lawns are maintained by weekly mowing, while gardens are often hand-weeded. Meadows in Pennsylvania may need to be mowed every year. Woodlands are probably the lowest-maintenance landscape, but they too will need to be monitored and invasive plants removed.

Scout your property annually for invasives or other problems. The best way to control invasives is prevention, and prevention can only happen through vigilance. Listed on this web site are resources to help property owners.

Remove invasives before they are a problem. Effective scouting or monitoring means that problems are found while they are still small and easily controllable. For instance, do not let invasive plants go to seed. Mechanical removal through digging or cutting is preferred. Large populations of invasives may need to be stopped chemically with spot applications of herbicide by trained individuals or by homeowners carefully following label instructions.

Replace invasive plants with native or noninvasive species. Invasives are good at exploiting bare soil and empty niches. When you remove an invasive plant, unless there is another plant substituted, the invasive will tend to come right back. What grows in the future depends largely on what is there now; so it is important to fill that niche with a desirable plant that will provide seed for the future.

Remove invasives as they appear while their densities are low. This gives the most immediate success because invasive plant control works best where there is a functioning native plant community still in place which can move right into the empty niche.

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Characteristics of Invasive Plants

Invasive plants are noted for their ability to grow and spread aggressively. Invasive plants can be trees, shrubs, vines, grasses, or flowers, and they can reproduce rapidly by roots, seeds, shoots, or all three. Invasive plants tend to: not be native to North America; spread rapidly, reproducing by roots or shoots; mature quickly; and if spread by seed, produce numerous seeds that disperse and sprout easily. Invasives are typically generalists that can grow in many different conditions and are exploiters and colonizers of disturbed ground.

Impact of Invasive Plants

Invasive species should not be used in our landscape because they are degrading our native plant communities and ecosystems. In fact, second only to habitat loss, invasives are a major factor in the decline of native plants. Plants like kudzu, purple loosestrife, and garlic mustard are displacing native plants and degrading habitat for native insects, birds, and animals. Endangered, rare, and threatened native species of plant and animals are

especially at risk because they often occur in such small populations that make them particularly vulnerable.
A very practical reason to avoid using invasive plants in your landscape is that they escape, spread and require regular weeding to manage even when grown in a cultivated yard. In urban and suburban areas the worst weeds are escaped ornamentals like Japanese honeysuckle, multiflora rose, Japanese knotweed, tree-of-heaven and oriental bittersweet. In yards, gardens, fields, and parks these plants are very expensive to control.

Invasive Hitchhikers

People can accidentally spread invasive species when they go for a hike, take their boat out on an infested lake or go hunting. Seeds from some invasive plants can stick to clothing or get lodged in the tread of boots and shoes. Some aquatic invasives have tiny larvae that can spread on fishing tackle, waders and boats. Preventing the spread of these invasive species is much easier than trying to control them once they have become established, so it is essential that when people spend time outdoors they are cautious about where they travel. The factsheets listed below give simple tips to lower the chance that you will spread invasive species.

ATV Riders	Bikers	Bird Watchers
Boaters	Campers	Equestrians
Fishers	Hikers	Hunters and Trappers
Leased Campsite Owners	Trail Maintainers	Wildlife Watchers

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What Can I Do? | Characteristics & Impacts | **Trees** | Shrubs | Vines | Grasses | Herbs | Aquatic Plants

Amur maple, *Acer ginnala*, is a small ornamental tree that spreads by numerous winged seeds.

Norway maple, *Acer platanoides*, a common street and lawn tree that frequently escapes cultivation.

Sycamore maple, *Acer pseudoplatanus*, a tall Eurasian tree invading urban and suburban woods in southern PA.

European black alder, *Alnus glutinosa*, is often found along streams and other wet areas.

Tree-of-heaven, *Ailanthus altissima*, grows throughout PA. Another immigrant from China introduced as an ornamental.

Mimosa, *Albizia julibrissin*, has escaped cultivation to invade roadsides and woodland edges in eastern PA.

Japanese angelica tree, *Aralia elata*, has sharp spines on the trunk and resembles our native devil's waking stick.

Paper mulberry, *Broussonetia papyfera*, is a common, small ornamental tree from Asia.

White mulberry, *Morus alba*, is a fast-growing species that will hybridize with our native red mulberry, *Morus rubra*.

Princess-tree, Empress-tree, *Paulownia tomentosa*, imported from China this purple-flowered tree has spread across southern PA by winged seeds.

Corktrees, *Phellodendron amurense, P. japonicum, P. lavallei*, these Asian trees are problematic in urban and natural areas in southeastern PA.

Callery pear, *Pyrus calleryana*, has established populations in fields and hedgerows in southeastern PA.

Bee-bee tree, *Tetradium daniellii*, is an uncommon landscape tree that is slowly spreading in south-central and southeastern PA.

Siberian elm, *Ulmus pumila,* a fast growing tree reaching 50-70 feet high.

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European and Japanese barberries, *Berberis vulgaris* and *B. thunbergii*, form dense thickets in woodlands, wetlands and meadows.

Butterfly bush, *Buddleja davidii*, has numerous cone-shaped bunches of purple flowers that attract butterflies.

Russian olive & Autumn olive, *Elaeagnus angustifolia* and *E. umbellata*, imported from Asia, have become serious weeds in southern PA pastures and other open ground.

Winged euonymus or Burning-bush, *Euonymus alatus*, a shrub from China and Japan imported for its bright purple-red fall color and frequently found along streams and in woods mostly in southern PA.

Chinese and Shrubby bushclovers, *Lespedeza cuneata* and *L. bicolor*, are semi-woody shrubs that readily invade open and disturbed habitats.

Privets, *Ligustrum* species imported from Europe and Asia are aggressive, thicket forming shrubs.

Shrub honeysuckles, five *Lonicera* species that rapidly invade and dominate field edges and pastures.

Common buckthorn and Glossy buckthorn, *Rhamnus cathartica* and *R. frangula (*syn. *Frangula alnus).* Small trees or shrubs to 20' high with yellow sapwood and pink to orange heartwood.

Jetbead, *Rhodotypos scandens*, is a deciduous shrub with clusters of small black fruits and white four-petaled flowers.

Multiflora rose, *Rosa multiflora*, this import from Asia has become a noxious weed in PA field, pastures and woodlands.

Wineberry, *Rubus phoenicolasius*, imported from Asia for its raspberry-like fruit and now common on roadsides and in woods and thickets.

Japanese spiraea, *Spiraea japonica*, was imported from Japan for its pink flowers. It escapes from cultivation to forest openings and meadows.

Doublefile viburnum, *Viburnum plicatum*, Linden viburnum, *V. dilataum*, and Siebold viburnum, *V. sieboldii*, are Asian shrubs with abundant fruits that are spread by birds.

Guelder rose, *Viburnum opulus*, a tall shrub with maple-like leaves imported from Eurasia and escaped to woods fields and roadsides.

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Five-leaf akebia, *Akebia quinata*, a woody twining vine from Asia that has escaped cultivation to disturbed woods in southeastern PA.

Porcelain-berry, *Ampelopsis brevipedunculata*, a deciduous, woody, perennial vine in the grape family imported from Asia.

Oriental bittersweet, *Celastrus orbiculatus*, a twining woody vine imported from Asia and rapidly replacing the native bittersweet in woods and fencerows.

Wintercreeper, *Euonymus fortunei*, is an evergreen woody vine that aggressively invades forest edges and openings.

English ivy, *Hedera helix*, is a common evergreen climbing vine in the landscape that can smother native vegetation.

Japanese hops, *Humulus japonicus*, is a prickly vine that invades moist, sunny areas.

Japanese honeysuckle, *Lonicera japonica*, a common ornamental vine from Asia now an abundant weed in roadside thickets, woods and fields across southern PA.

Mile-a-minute weed, *Persicaria perfoliata*, a slender annual vine with reflexed prickles was accidentally introduced from Asia with nursery stock and now a noxious weed in PA.

Kudzu, *Pueraria lobata*, a vigorous half-woody vine introduced from Asia for ornament, forage and erosion control and now an uncommon but officially noxious weed in southeastern PA.

Common and Bigleaf periwinkle, *Vinca minor* and *V. major*, are evergreen, ornamental groundcovers that can form thick mats, even under dense tree canopy.

Black and Pale swallow-wort, *Vincetoxicum nigrum* and *V. rossicum*, are twining vines that can dominate old fields and poison livestock.

Chinese and Japanese wisteria, *Wisteria sinensis* and *W. floribunda*, are long-lived woody vines with bright purple flowers that can out-compete and smother native vegetation.

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Goutweed, *Aegopodium podagraria*, imported from Eurasia and frequently found in fields, thickets, woods and roadsides throughout PA.

Garlic-mustard, *Alliaria petiolata*, a weed of shady moist spots in suburban gardens, woods and floodplains throughout PA; introduced from Europe.

Wild chervil, *Anthriscus sylvestris*, is a member of the carrot family that competes with native plants and carries a virus that can infect some vegetable crops.

Narrowleaf bittercress, *Cardamine impatiens*, is a member of the mustard family native to Europe.

Musk thistle, *Carduus nutans*, is also known as nodding thistle from the way the flowers droop once mature.

Black, Brown and Spotted knapweeds, *Centaurea nigra, C. jacea, C. stoebe micranthos*, have pink to purple flowers that resemble small pineapples.

Greater celandine, *Chelidonium majus*, is a four-petaled yellow flower from Europe that is poisonous.

Canada thistle, *Cirsium arvense*, imported from Eurasia (not Canada) now common and noxious weed in fields pastures and roadsides throughout PA.

Bull thistle, *Cirsium vulgare*, is a large-flowered thistle with long spines and abundant seeds.

Poison hemlock, *Conium maculatum*, was brought to U.S. gardens from Europe in the 1800s it now invades native plant communities in riparian woodlands, open floodplains and stream banks.

Crown-vetch, *Coronilla varia*, a sprawling perennial native to southern Europe planted extensively along highways. It spreads into open, grassland and prairie habitats.

Jimsonweed, *Datura stramonium*, is a state noxious weed that is highly toxic and frequently found in cultivated fields and other disturbed sites.

Smallflower and hairy willow herb, *Epilobium parviflorum* and *E. hirsutum* are ornamental perennials with showy, rose-colored flowers that can quickly form dense stands.

Goats rue, *Galega officinalis*, is a state and federal noxious weed that is very poisonous to livestock.

Orange day-lily, *Hemorocallis fulva*, is a very hard perennial that grows in abundance along roadsides and old home sites.

Giant hogweed, *Heracleum mantegazzianum*, 15 feet tall member of the carrot family introduced from Eurasia. Its sap can cause blisters so it is listed as a federal and PA noxious weed.

Dame's-rocket, *Hesperis matronalis*, introduced from Europe to American gardens, now common in low woods floodplains and roadside ditches throughout PA.

Yellow flag iris, *Iris pseudacorus*, is a showy ornamental plant commonly found in wetlands, along pond edges, and other wet areas where it can dominate.

Moneywort, *Lysimachia nummularia*, goes by many common names and was introduced into the U.S. from Europe as an ornamental groundcover.

Purple loosestrife, *Lythrum salicaria*, a European perennial with a woody base that has escaped gardens and destroyed large areas of waterfowl habitat by dominating wetlands and excluding all other plant life.

Star-of-Bethlehem, *Ornithogalum nutans* and *O. umbellatum*, garden bulbs from Europe that escape to infest lawns and roadsides.

Japanese pachysandra, *Pachysandra terminalis*, is an evergreen perennial groundcover that can spread from cultivation into natural areas if left uncontrolled.

Wild parsnip, *Pastinaca sativa*, a European import now a widespread and abundant weed of roadsides throughout PA.

Beefsteak plant, *Perilla frutescens*, a member of the mint family introduced from India now occasionally found in moist shaded roadsides and woods.

Bristled knotweed, Persicaria longiseta, is an annual plant from Asia that can dominate wet, disturbed habitats.

Japanese and Giant knotweed, *Fallopia japonica* and *F. sachalinensis*, are extremely difficult weeds to control. Imported from Japan they dominate stream and river banks throughout PA.

Lesser celandine, *Ranunculus ficaria*, an aggressive weed in wetlands imported from Eurasia.

Invasive Plants

Invasive plants are plants which grow quickly and aggressively, spreading and displacing other plants. Invasive plants are usually introduced by people either accidentally or on purpose, into a region far from their native habitat. Invasive plants are often referred to as "exotic," "alien," introduced" or "non-native" species. In their natural range, these species are limited by environmental, pest or disease conditions, keeping these species in balance within their ecosystem. When introduced into an area where these limitations are absent, some species have the ability to become invasive. These are the species we are concerned about in conservation.

Invasive Plant Management Tutorial

Find information to identify, prevent and control invasive plants.

Invasive Plant Database Search

Use this tool to identify invasive plants on your property based on their physical characteritics.

Download a list of invasive plant species threatening Pennsylvania natural lands here.

Recognition of the problem of invasive plants is growing, at the same time as damage to native ecosystems is mounting. Identifying invasive plants and understanding the potential damage they can cause is essential to stopping their spread and protecting native vegetation. Invasive plants tend to appear on disturbed ground. The most aggressive can actually invade existing ecosystems. Invasive plants are generally undesirable because they are difficult to control, can escape from cultivation, and can dominate large areas. In short, invasive plant infestations can be extremely expensive to control, as well as environmentally destructive.

A small number of native plants can become "weedy" meaning they become aggressive after the landscape is altered. But the fundamental condition here is the disturbance of the habitat that upsets the balance. This is not true "invasiveness".

Fact Sheets

The tabs below provide a library of information about troublesome trees, shrubs, vines, herbs and aquatic plants that have impacted the state's natural lands and suggest actions you can take to protect your property from invasive plants. This list is non-regulatory in nature. The species listed here are considered invasive by DCNR staff and are managed for accordingly.

What Can I Do? | Characteristics & Impacts | Trees | Shrubs | Vines | **Grasses** | Herbs | Aquatic Plants

Small carpetgrass, *Anthraxon hispidus*, is native to Asia. It is currently found in a few counties in southern PA, usually alongside invasive stiltgrass.

Cheatgrass and Poverty brome, *Bromus tectorum and B. sterilis*, accidentally introduced from Europe in ballast soil or impure wheat seed shipments. A serious agricultural weed in the Midwest and western states.

Common velvet grass, *Holcus lanatus*, introduced as early as the 17th Century in imported pasture seed.

Japanese stiltgrass, *Microstegium vimineum*, introduced from tropical Asia in packing material and spreading through moist areas open woods and clearings across southeastern PA and probably elsewhere.

Chinese silvergrass, *Miscanthus sinensis*, is a tall bunched grass that spreads through vigorous roots and rhizomes.

Wavyleaf basketgrass, *Oplismenus undulatifolius*, is a fast-growing, creeping grass not yet in PA but found across the border in Maryland.

Reed canary grass, *Phalaris arundinacea*, forms dense monocultures in wet habitats that disrupt waterways and degrade habitat for native wildlife.

Common reed, *Phragmites australis*, a very large perennial grass, forms extensive colonies in wetlands. The scattered native American populations are being replaced by the vigorous European subspecies.

Golden bamboo, *Phyllostachys aurea*, is a very tall grass with round, hollow stems that spreads rapidly via its underground rhizomes.

Rough bluegrass, *Poa trivialis*, is a non-descript grass that out-competes native grasses.

Ravenna grass, *Saccharum ravennae*, is also known as hardy pampas grass. It grows up to ten feet tall and quickly colonizes wet habitats.

Tall fescue, *Schedonorus arundinaceus*, is a very common cool season perennial grass that adapts to a variety of conditions and crowds out native vegetation.

Shattercane, *Sorghum bicolor* was imported from Africa as a forage crop but is now a noxious weed in Pennsylvania.

Johnsongrass, *Sorghum halepense*, is native to the Mediterranean region. It is designated as a noxious weed in Pennsylvania.

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What Can I Do? | Characteristics & Impacts | Trees | Shrubs | Vines | Grasses | Herbs | **Aquatic Plants**

Carolina fanwort, *Cabomba caroliniana*, is a submerged, rooted plant native to the southeastern U.S. and sold for aquariums.

Didymo, *Didymoshenia geminate*, is a microscopic alga called a diatom. It can form dense mats that smother stream beds and native vegetation.

Brazilian water-weed, *Egeria densa*, is a popular aquarium plant that can grow vigorously and choke out native vegetation once it reaches ponds, lakes and other waterbodies.

Hydrilla, *Hydrilla verticillata*, is a submerged aquatic plant that resembles several other aquatic plants, making ID difficult.

Floating Primrose-willow, *Ludwigia peploides* ssp. *glabrescens* is indigenous to slow-moving waters of the southeastern U.S. now found in across southern PA.

Parrot feather watermilfoil, *Myriophyllum aquaticum*, is an aquarium plant native to South America that can form dense mats in PA lakes and ponds.

Eurasian Water-milfoil, *Myriophyllum spicatum*, a common an abundant Eurasian invader of lakes and rivers throughout PA.

Curly pondweed, *Potamogeton crispus*, an aggressive European weed common in lakes, ponds and streams.

Water-chestnut, *Trapa natans*, a locally abundant Eurasian invader of ponds and lakes.

Narrow-leaved cattail, *Typha angustifolia*, is from Europe and difficult to visually distinguish from our native cattail.

Hybrid cattail, *Typha* x *glauca*, a cross between narrow-leaved cattail and native common cattail.