Terrestrial Invasive Plants

Problem Statement and Management Strategy for Properties under the Care and Control of the DCR Division of Water Supply Protection

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Massachusetts Department of Conservation and Recreation
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Abstract

Terrestrial Invasive Plants Problem Statement and Management Strategy for Properties under the Care and Control of the DCR Division of Water Supply Protection explains the threat of terrestrial invasive species, describes the current status of these species on the Department of Conservation and Recreation/Massachusetts Water Resources Authority (DCR/MWRA) reservoir system, and describes the potential strategies available to control existing infestations and prevent new introductions.

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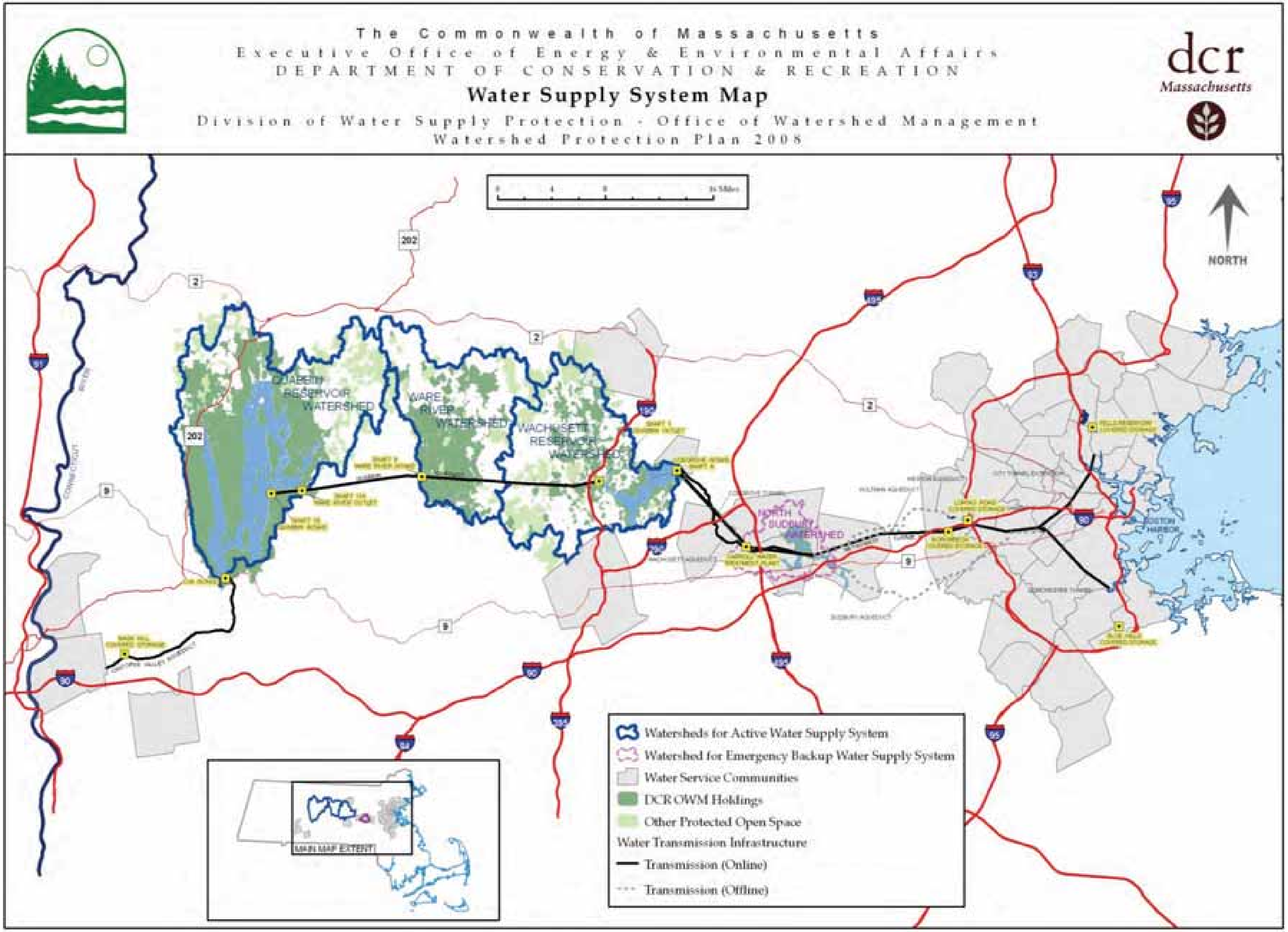


Figure 2: DCR/MWRA Water Supply System

1 Introduction

The Massachusetts Department of Conservation and Recreation, Division of Water Supply Protection, Office of Watershed Management (DWSP, or the Division) manages and protects the drinking water supply watersheds that provide water for approximately 2.2 million Massachusetts residents (see **Figure 2**). The mission of the Division is to utilize and conserve water and other natural resources to protect, preserve and enhance the environment of the Commonwealth and to assure the availability of pure water for future generations. This report explains the threat of terrestrial invasive species, describes the current status of these species on the Department of Conservation and Recreation/Massachusetts Water Resources Authority (DCR/MWRA) reservoir system, and describes the potential strategies available to control existing infestations and prevent new introductions.

A significant percentage of the plants in natural landscapes in Massachusetts are introduced, non-indigenous, exotic or alien species. Some have common names that indicate their origin, like Queen Anne's lace, Bermuda grass, French rocket, or Japanese mazus. Other less blatantly introduced exotics include the familiar butter-and-eggs or the common mullein. However, none of these is considered a problem species, because each shares its habitat with other native and common plants. Some clearly native species, such as hay-scented fern, can dominate an area when the conditions are right and may be considered locally "invasive" in this way. However, the term "invasive plant" is generally saved for those species that are both non-indigenous and aggressive habitat monopolizers at scales ranging from a small patch to hundreds of contiguous acres.

The problem of invasive plants has been widely articulated. The plants of greatest concern have been transported out of their native environment and consequently are free of the evolved biological controls that manage population expansions and maintain biological diversity. Without these constraints, invasives have monopolized communities, out-competing a wide range of pre-existing natives. This monopolization can have economic consequences, impact rare and endangered native species, dramatically alter long-established balances of both species composition and habitat qualities, and may result in losses of both human uses and the ecological integrity of the affected environment. The changes accompanying invasions are often subtle, even attractive, so that the "problem" is not always immediately obvious. The following, however, are just a few examples of the undesirable effects of invasive plants:

1. Purple loosestrife has expanded to cover an estimated 500,000 acres in northern US and southern Canada and is now present in most of the wetlands used by breeding waterfowl along the Atlantic and Mississippi flyways (www.npwrc.usgs.gov/resource/plants/loosstrf/contain.htm, Blossey et al., 2001). Its density in some shallow wetlands has

rendered them inhospitable not just for ducks, but also muskrats, turtles, and even spawning northern pike (www.carlislehoney.com/purpleloosestrife.htm).

2. While the West Virginia white butterfly – diminishing throughout its range – has long utilized native mustards, larvae that emerge from eggs laid on the invasive garlic mustard (*Alliaria petiolata)* fail to develop (www.gbbr.ca/list-of-species-at-risk/insects/west-virginia-white-butterfly.html)

3. Invasive plants can cause long-term indirect changes to habitats. *Melaleuca*, an Australian tree species introduced in south Florida, has escaped plantations and converted nearly half a million acres of marsh into swamp forest that is hydrologically altered and devoid of native herbaceous species. (http://pesticide.ifas.ufl.edu/courses/pdfs/melaleuca/Melaleuca.pdf) There is evidence that the invasive Chinese tallow tree (*Sapium sebiferum)* is altering nutrient cycling and introducing toxic allelopathic chemicals in the soil where it invades, causing a decline in the native soil invertebrates as a consequence (www.pepps.fsu.edu/FACT/sec_D/upland.html).

4. The Nature Conservancy has estimated that 40-50% of imperiled species have been impacted to some extent by invasive plants and that "all of the lands and waters that TNC and its partners have protected in our entire history are at risk from the invasive species threat" (TNC Invasive Species Business Plan, March 2001 draft). Invasive species are considered to be the second most important threat to biological diversity worldwide, following habitat destruction.

5. The Massachusetts Executive Office of (Energy and) Environmental Affairs report "The State of Our Environment" (April, 2000) states that "the two biggest threats to biodiversity in Massachusetts are the destruction and fragmentation of wildlife habitats and the introduction of invasive non-native species." In the Connecticut River valley, *Phragmites* is becoming the dominant species in wetlands of international importance as exemplary communities (The Connecticut River Watershed/Long Island Sound Invasive Plant Control Initiative: Strategic Plan, March 1999).

6. In 1993, the Congressional Office of Technology Assessment concluded that just 79 non-indigenous species in the US caused documented losses in agriculture, industry, and human health of $97 billion during the period from 1906 to 1991. (OTA, *Harmful Non-Indigenous Species in the United States*).

2 Definitions of "Invasive"

2.1 General Definitions

"Invasive" plants fall into at least two categories – native or non-native species. Most of the difficulties associated with invasive plants involve plants that are non-native. This is true in part because these non-native "aliens" have been transported out of the ecosystem in which they evolved and may have escaped specific population-controlling insects and diseases in the process. It is important to point out that not all non-native plants are invasive. Most have been intentionally introduced into agricultural or horticultural environments, and many are unable to reproduce outside of these intensively managed environments. There are, unfortunately, hundreds of others that were introduced either deliberately or accidentally to natural settings and have managed to aggressively force out native plants, raising serious biodiversity issues and potential threats to water quality protection.

It has taken time for these issues to become apparent. Some of the invasive plant problems on DWSP properties are the result of deliberate plantings of species that effectively addressed other concerns (for instance, planting autumn olive to improve wildlife habitat), but then became invasive. Other invasive species are escapees from landscaping that predates DWSP's acquisition of reservoir properties, including Japanese barberry, common barberry, Japanese knotweed, the buckthorns, Asiatic privets, honeysuckles, and purple loosestrife. In all cases, a plant's "invasiveness" is composed of several defining qualities:

- The plant grows and matures rapidly in abundantly available habitats.
- The plant is capable of producing vast quantities of seed that is easily dispersed by animals; often it can also reproduce vegetatively.
- There are no diseases or pests effectively controlling its reproduction and spread (which generally means there are no close relatives in the habitats it invades).
- The plant does not require intensive management to thrive.

2.2 Federal and Massachusetts Definitions

The Federal definition of invasive species appears in President Clinton's Executive Order 13112, which simply refers to invasive species as **"an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health**." In the Executive Summary of the National Invasive Species Management Plan (NISMP) the term *invasive species* is further clarified and defined as **"a species that is non-native to the ecosystem**

under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health."

The Massachusetts Invasive Plants Advisory Group (MIPAG) has produced a methodically developed list of invasive and potentially invasive plants in the Commonwealth, through cooperation and objective, scientific review among biologists, government staff, non-profits, nurseries, and landscape organizations (see: www.massnrc.org/MIPAG/index.htm). MIPAG first generated the following definitions of invasiveness: *"Non-native species that have spread into native or minimally managed plant systems in Massachusetts. These plants cause economic or environmental harm by developing self-sustaining populations and becoming dominant and/or disruptive to those systems."* As defined here, "species" includes all synonyms, subspecies, varieties, forms, and cultivars of that species unless proven otherwise by a process of scientific evaluation.

MIPAG further developed detailed criteria to objectively evaluate and categorize plant species suspected of being, or with the potential to become, invasive in Massachusetts. These criteria enable the separation of plants into the following categories:

- *Invasive Plants* in Massachusetts
- *Likely Invasive Plants* in Massachusetts
- *Potentially Invasive Plants* in Massachusetts (species not currently known to be naturalized in Massachusetts, but that can be expected to become invasive within minimally managed habitats within the Commonwealth)**.**

For details of these definitions and a current list of plant species that have been ranked, refer to the MIPAG website at: www.massnrc.org/MIPAG/index.htm

3 Federal Invasive Species Programs and Mandates

In February of 1999, President Clinton signed Executive Order 13112, to "prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause." EO 13112 further requires federal agencies to pursue the duties set forth in consultation with the National Invasive Species Council (NISC), consistent with the National Invasive Species Management Plan and in cooperation with stakeholders, as appropriate, and, as approved by the Department of State, when working with international organizations and foreign nations. Rather than establish a separate agency to cover the problem, EO 13112 assembled the NISC as an upper-level, inter-departmental organization to coordinate the invasive species management efforts of the 13 departments and agencies of the Federal government, the Secretaries and Administrators of which serve as members of the NISC. The Council is co-chaired by the Secretaries of the Interior, Agriculture, and Commerce. The Invasive Species Advisory Council is comprised of non-federal representatives who collectively advise the NISC.

NISC was created to "recommend plans and actions at local, tribal, state, regional, and ecosystem-based levels" to address prevention and control of invasives. The first edition of a National Invasive Species Management Plan (NISMP) from this Council was produced in January of 2001, serving as a blueprint for invasive species actions. This plan provided both additional mandates and an overview of the costs and agency responsibilities to begin to gain control over invasives. The 2001 NISMP was revised with the 2008-2015 NISMP, which details the objectives for meeting goals to:

1. Prevent the introduction of invasive species
2. Find and stop new invasive species
3. Stop the spread and minimize impacts
4. Restore native species and habitats; rehabilitate high-value ecosystems and processes
5. Maximize effectiveness and collaboration on invasive species issues.

(See Factsheet from The National Invasive Species Council (NISC): www.anstaskforce.gov/Meetings/2008_October/NISC_Plan_09_29_08%20fact%20sheet.pdf)

4 Massachusetts Programs and Mandates

Since 1995, the Massachusetts Invasive Plants Advisory Group (MIPAG), in addition to methodically developing a list of invasive and potentially invasive plants in the Commonwealth, has developed strategic recommendations for managing invasive plants in Massachusetts, outlined below and posted at: www.massnrc.org/MIPAG/publications.htm .

4.1 MIPAG Strategic Recommendations

The 2005 MIPAG *Strategic Recommendations for Managing Invasive Plants in Massachusetts* were intended to provide guidance to public and private landowners seeking to address the issue of invasive plants in an effective and efficient manner. The document includes the following nine principle recommendations:

1. Massachusetts should develop and implement a strategic management plan based on the recommendations of the MIPAG and integrated with the existing Massachusetts Aquatic Invasive Species Management Plan to address introduced invasive plant species.

2. A strategic management plan for managing invasive plants in Massachusetts should include a scientifically objective assessment process; a system for early detection and rapid response; criteria for setting research, management and education priorities; and develop broad public and private partnerships integrating efforts from the local to national scales.

3. Massachusetts should adopt the MIPAG criteria for invasive plant assessment and recognize the list of plant species determined by this process to be Invasive, Likely Invasive or Potentially Invasive within the Commonwealth. It should maintain an ongoing, transparent assessment process using the MIPAG criteria and with the participation of both public and private interest groups. This assessment should inform invasive species management strategies. Prevention strategies should predominantly focus on species assessed as Potentially Invasive and controlling the spread of Invasive species into priority conservation areas. Candidate species for eradication strategies should be selected from among those assessed as Likely Invasive.

4. Massachusetts should establish and support a centralized means within state government for inter-agency coordination on invasive species management, in partnership with public and private sector interests. This mechanism should facilitate the production of a strategic management plan for invasive plant species in the Commonwealth based on MIPAG's recommendations. It should help coordinate invasive species management efforts within the Commonwealth and integrate efforts with regional and national partners.

5. Massachusetts should establish and support an effective early detection and rapid response system for invasive species that is well integrated with regional and national efforts.

6. Massachusetts should assign to a responsible entity the task of assessing invasive species research needs and priorities for Massachusetts. It should integrate the work of public and private research partners, actively develop sources of funding for this research, and maintain a centralized database of this research in easily accessible form and linked to regional or national databases of this type. Funding sources for needed research should be developed and promoted.

7. A strategic management plan for invasive species in Massachusetts should set priorities for prevention, control, eradication and restoration efforts. Prevention should emphasize an early detection and rapid response system for new invasions and education about best management and prevention practices directed at the primary vectors for spreading invasive plant material. Except where eradication is feasible, control efforts should always manage toward a desired status or outcome for conservation resources compromised by invasive plant species, rather than the invasive species itself. Priority areas for management should be determined by identifying at all scales the natural and cultural resources at risk from invasive species and conducting baseline assessments of invasive species at those sites.

8. Massachusetts should adopt a policy of targeted outreach and education to raise awareness of the extent of the invasive plant problem and of the importance of each of our roles in preventing and controlling invasive species. Public education should focus on those vectors of spread most likely to introduce invasive plants into priority areas. The Commonwealth should endorse and adopt the voluntary protocols established under the Saint Louis Declaration for all government agencies, and promote their adoption by nursery professionals, landscape architects, the gardening public, and botanic gardens and arboreta in Massachusetts. Specifically, the Commonwealth should prohibit state agencies from purchasing or intentionally introducing species determined to be Invasive, Likely Invasive, or Potentially Invasive through the scientifically objective assessment process of the MIPAG. Commercial industries should adopt a carefully constructed phase-out of these species in the trade while accommodating the economics of current inventories and existing contracts. Education and outreach described herein should be sufficiently funded and implemented assertively in order to steadily reduce the consumer demand for these species.

9. Public and private partnerships should be endorsed and strengthened as part of a strategic management plan for invasive plants in Massachusetts. The transparent, collaborative work of the MIPAG should be encouraged and supported as the means of assessing invasive species for the Commonwealth. Regional and national Partnerships and sources of funding for invasive plant management should be promoted and integrated into invasives management efforts in Massachusetts.

4.2 State Terrestrial Invasive Plant Legislation

Following the creation of the list of invasive and potentially invasive plants in Massachusetts, the Massachusetts Department of Agricultural Resources, Division of Regulatory and Consumer Services filed legislation to phase these species out of commercial production and use. This legislation passed and became effective on January 1, 2006, effectively phasing out the sale and importation of 140 plant species over a three-year period (see: www.mass.gov/agr/farmproducts/Prohibited_Plant_Index2.htm).

5 The Problem of Terrestrial Invasive Plants on Drinking Water Supply Watersheds

Terrestrial invasive plants may not categorically threaten the short-term protection of a drinking water supply. In fact, they aggressively reoccupy disturbed ground, stabilize soils, assimilate nutrients, and mitigate the erosive power of precipitation. But they also can monopolize the species composition and simplify the structural complexity of the watershed cover, which conflicts with watershed objectives for a diverse, resistant and resilient forest cover.

With a few exceptions (e.g., Norway maple, Tree-of-heaven), the non-native invasive plants that occur on DWSP watersheds are herbs, grasses, shrubs, or vines, so that they do not provide the water supply protection benefits of trees (deeper root systems, greater control of temperature and therefore control over decomposition rates, and the simple depth or thickness of a tree-dominated versus a shrub-dominated biological filter, which lengthens the path of precipitation to the ground and increases the opportunities to remove precipitation-borne pollutants), putting them further in conflict with objectives for water supply protection. Many of these invasive plants compete directly with tree regeneration, and the invasive vines (e.g., bittersweet, mile-a-minute) are capable of infesting individual trees sufficiently to shade their leaves and eventually kill them. Finally, their displacement of native plants puts non-native invasive plants categorically in conflict with biological diversity objectives that favor wide and varied distribution of plant communities composed of diverse, native species.

Beyond issues of biodiversity conservation, resilient plant communities are important to watershed management for long-term control of the erosion of soil and nutrients following the range of natural disturbances (e.g., droughts, insect outbreaks, fire, wind, heavy snow and ice). Resilience is dependent upon species and size diversity in the plant community, because disturbances are frequently species and/or size specific. When plants become aggressively invasive, replacing the diverse native flora with monocultures of non-native plants, there is concern that this reduction in diversity will reduce the capacity of the watershed forest to recover following other disturbances. The prevention of forest regeneration by certain aggressive invasive plants has become a problem on some areas of the watersheds, displacing what would have returned as a diverse forest cover of maturing trees with low-diversity cover of shrubs (e.g., *Berberis thunbergii*) or vines (e.g., *Celastrus orbiculatus*). This pattern is common elsewhere; in Australian watersheds, for instance, native forest seedlings decrease exponentially in abundance and richness as invasive biomass increases (Standish, et al., 2001).

Around the Quabbin Reservoir, barberry that was planted on historic home sites took advantage of high deer populations to colonize and monopolize the understories of significant areas of the watershed forest and severely limits tree regeneration when the overstory is subsequently lost to disturbance or deliberately removed. On limited areas within the Ware River watershed, non-native buckthorns (*Rhamnus cathartica, Rhamnus frangula*) are replacing native understory vegetation. At the Wachusett Reservoir, autumn olive (*Elaeagnus umbellate*) has aggressively occupied open fields, delaying or precluding their return to forest cover. These are just examples of the growing encroachment by non-native invasive plant species on DWSP watersheds. As seed sources continue to rise on or adjacent to these watersheds, non-native invasive plants may be more effective than natives in colonizing disturbed areas and may overrun young trees even after these trees have become initially established.

There is a limited but growing literature reporting research findings on the direct effects of invasive plants versus native plants on drinking water supplies, although the impact of non-natives on related ecosystem processes has been studied for several decades (e.g., Vitousek and Walker, 1989). The effects of invasive plants on water quality are variable and may be direct or indirect. Some invasive plants, including *Phragmites*, are used as part of water treatment facilities due to their nutrient capture and growth characteristics (Moshiri, ed., 1993; Williams, et al., 1995) or in remedial treatment of nutrient-impoverished landscapes, such as the use of nitrogen-fixing, non-native olives to rapidly revegetate strip mines (Wade et al., 1985). Some invasive plants are known to alter soil nitrogen cycles and pH with potentially negative consequences for associated water quality. Japanese barberry and microstegium grass both produce increased pH and increased nitrification in eastern forests (Ehrenfeld et al., 2001). Litter from invasive species in mesic hardwood forests in New York generally decomposes and releases nitrogen more rapidly than adjacent forests dominated by native species (Ashton, et al., 2005), which may result in changes in soil water chemistry. Japanese barberry will not thrive unless existing available nitrogen levels are above minimum thresholds (Cassidy et al., 2004), and barberry litter is higher in N concentration than the litter of native species, decomposes more rapidly, and immobilizes N less effectively (Ehrenfeld et al., 2001). Church, et al., (2004) reported significantly greater nitrate leaching during the dormant season under autumn olive, a non-native invasive that is also a nitrogen fixer, than in un-invaded open fields of native early successional species. Goldstein, et al., (2009) found that in first order ephemeral streams draining watersheds with mixed forest cover and a range of 0-35% autumn olive cover that the percent of autumn olive cover was positively correlated with mean stream nitrate-nitrogen concentrations. How these observations of changes to soil chemistry or stream nutrient levels might translate into the degradation of a water supply reservoir has yet to be modeled.

In general, wetland macrophytes (large plants) have evolved characteristics that allow them to capture nutrients in flooded conditions and thereby populate these habitats by also taking advantage of the abundant available sun and water. Macrophytes contribute significantly to the importance of wetlands in cleaning water supplies. Invasive macrophytes that occupy wetlands are no exception to this rule. Some are in fact better adapted to grow and take advantage of these conditions than native plants, which is why they aggressively out-compete the natives.

Throughout the northeast *Phragmites*, for example, has gained competitive advantage over cattails, which it gradually replaces as the dominant macrophyte in wetlands and roadside ditches

(Bellavance and Brisson, 2010). While this represents a setback in native plant diversity, it may result in an improvement in the quality of the water flowing from these wetlands. *Phragmites* is routinely a component of bioremediation in engineered sewage treatment plants around the world because of its effectiveness in reducing water-borne nutrients, through more effective uptake (Hoffman, 1990; Cooper and Green, 1995; Williams, et al., 1995).

The indirect effects of invasive plants on water supplies include the changes they bring about in watershed hydrology. These effects are often scale dependent. For instance, while stomatal conductance through the leaves among alien invasive species has been shown to be higher than for native species, the significance of this difference is dependent on the number of leaves per plant and plants per unit area for native versus non-native plants (Cavaleri and Sack, 2010). Calder and Dye (2001) report on water use by native tree and short crops versus alien species in Scotland, South Africa, and India. There are hydrological shifts associated with the replacement of shorter native shrubs with non-native trees species. Because trees generally intercept and transpire more water than shorter vegetation, water yields, especially during the dry seasons or from water-limited portions of the watershed may be altered by this replacement.

In Massachusetts watersheds, the most prevalent invasive trend is the replacement of forest cover by non-native and invasive shrubs, vines, and other low vegetation, which, according to the Calder and Dye paper should increase water yields. While this may be desirable during low water years, increased water yield also carries the risk of increased nutrient and sediment transport. Deliberate conversion from native to non-native watershed vegetation can affect water yield in less obvious ways. In China, planted non-native rubber trees increase root water uptake during the dry season, while the native vegetation has evolved to coordinate high water demand with the arrival of monsoon rainfall, so that planting with the non-native significantly depletes deep soil moisture, a type of effect that is not simulated in traditional hydrologic models (Guardiola-Claramonte et al., 2008).

Success as an invader relies on variable characteristics in these plants that may or may not affect water resources. Some are successful by simple tolerance of low light conditions in combination with their own ability to outshade native competitors (Feng, et al., 2007(a)). Others are more adept than competing natives in their capture or allocation of nutrients (Feng et al., 2007(b)) and their ability to accumulate above or below ground biomass. Some invasive plants reduce the native mycorrhizal densities on which some native plants, including trees, depend for vigorous growth and survival (Vogelsang and Bever, 2009). While some characteristics of invasive plants may relate directly to the quality and quantity of the water leaving sites that they dominate, the general trend in Massachusetts toward large monocultures of primarily non-tree, non-native invasive plants clearly runs contrary to the resiliency sought through the diversification of the watershed forest cover and may prove to be the most significant water supply threat posed by non-native terrestrial invaders.

6 The Relationship Between Ecosystem Disturbance and Invasions

The susceptibility of an area to invasion by non-native invasive plants depends on propagule pressure (a *propagule* is any structure with the capacity to give rise to a new plant, e.g., a seed, a spore, or a part of the vegetative body capable of independent growth if detached from the parent; *propagule pressure* is a function of the number of propagules in a release event, the number of release events, and the health/vigor of the propagules) and the availability of resources necessary for establishment and growth. While potentially invasive plants may rain seed on an area fully occupied by native plants, the ability of the invasive species to populate that area depends on its ability to compete for water, nutrients, or sunlight. A stable and vigorous assemblage of native plants may be relatively resistant to invasion until something alters the availability of resources. For instance, a strong wind disturbance might fell and/or kill overstory trees, reducing both the number of established natives and their combined consumption of available resources. Immediately following that disturbance, invasive seeds are competing with native seeds to reoccupy the site and seize the available resources, rather than trying to compete against well-established native plants. It is characteristic of invasive species to be very rapid growers and very successful competitors when a disturbance levels the playing field and restarts the game.

Historical land use plays a critical role in determining the presence and abundance of invasive species, due both to direct manipulation of the land (e.g., for agriculture or the development of the property for other human uses) and the deliberate introduction of non-native species for economic or aesthetic purposes, which then become invasive in the landscape into which they were introduced. Recent research on the Quabbin watershed showed that the presence of Japanese barberry within a currently forested area was strongly correlated to the past agricultural use (followed by abandonment and return to forest) and that modern forest harvesting activities within areas that had been continuously forested did not affect the abundance or presence of barberry (DeGasperis and Motzkin, 2007). The basic occurrence of this invasive species varies with site fertility (favoring lower than average acidity and higher than average nutrient levels; in particular, N availability is strongly correlated to barberry success (Cassidy, et al., 2004)) while abundance of the plant was strongly correlated with agricultural clearing that had occurred after the initial introduction of the species on the landscape (generally around house sites). High deer populations, which avoid Japanese barberry when browsing, have also played a significant role in its expansion at Quabbin.

Another factor that may influence the dynamics of plant invasions is the presence and abundance of non-native (European) earthworms. Non-native earthworms have been shown to cause remarkable changes in soil structure, nutrient cycling and availability, soil biotic communities, and aboveground plant communities. Many of the negative effects of earthworm invasion result from the destruction of the litter layer. The combination of the loss of surface litter and increased soil bulk density is likely to lead to increased overland flow during precipitation events, and related erosion of nutrients and sediments, in earthworm-invaded forest (Shuster, 2000).

Non-native earthworms and non-native plants have been observed to occupy the same habitats, leading some to suggest potential facilitation between the two groups of invaders. Belote and Jones (2008) wrote that "some ecologists have suggested that non-native plants may change soil characteristics, which allows for non-native earthworms to invade. Others suggest that earthworms facilitate plant invasions, or that both non-native earthworms and non-native plants respond similarly to co-varying factors such as disturbance or proximity to agricultural land use." The results of Belote and Jones' experiments with forest floor mesocosms in a greenhouse suggest that invasion by a non-native tree (Ailanthus) and the litter layer it produces, coupled with invasion by non-native earthworms might directly facilitate further understory plant invasions. Nuzzo, et al., (2009) studied native vegetation, non-native earthworm biomass, and leaf litter volume in 15 northeast forests. Their results suggest that earthworm invasion, rather than non-native plant invasion, is the driving force behind changes in forest plant communities including declines in native plant species, and that earthworm invasions appear to facilitate plant invasions in those forests.

Madrich and Lindroth (2008) posit that fast-growing shrubs such as honeysuckle and buckthorn with high quality leaf litter are likely to increase earthworm populations. Correspondingly, large earthworm populations are likely to favor fast-growing invasive shrubs by increasing nutrient cycling rates and availability, thus forming a positive feedback loop or mutual facilitation that can result in a so-called "invasion meltdown" – accelerated invasion rates and accelerated replacement of the native community. If so, interrupting the positive feedback loop could benefit ecosystem function and integrity. Exploring the potential management implications, Madrich and Lindroth found that removal of invasive shrubs (buckthorn and honeysuckle) reduced exotic earthworm abundance by roughly 50% for the following 3 years, though earthworm biomass was reduced to a lesser extent.

Disturbance is a relentless component of ecosystem development. Even without deliberate human disturbance, the typical average pace of mortality in the temperate forests of the Northeast is in the range of 0.5% to 2.0% annually (Attiwill, 1994). Even though some individuals might live several centuries, it is uncommon in this region for a large area of maturing forest to persist for more than 100 years without stand-initiating disturbances. Consequently, where invasive plant propagule pressure is strong, it is just a matter of time before opportunity presents itself for the species to become established. Deliberate human disturbance, through development or timber harvesting or agriculture can potentially accelerate the spread of invasive species, but does not by itself "cause" the invasion.

Some invaders create their own disturbance by overtaking native plant populations. Vines, in particular, compete this way. An invasive vine (e.g., Oriental bittersweet) can capitalize on both the sun at the edge of the forest and the scaffolding provided by well-branched trees. Once a vine has grown to the top of the forest by way of the forest edge, it can continue its way across the abundantly well-lit treetops, stealing the light away from the trees and eventually killing its hosts, thus prolonging the availability of light for its own growth. Though more protracted than a catastrophic ice storm or a silvicultural patch cut, this self-perpetuating disturbance is ultimately equally effective in shifting resources to the invasive plant.

7 Principles for Managing Invasive Plants

The list of examples of invasive plants is long and neither defining the problem with invasive plants nor presenting a viable solution is a simple task. Many of these invaders have become so well established across our landscape that eradication of any given species is at least impractical, if not impossible. But this does not mean that nothing is possible. On the contrary, there are clear choices about what our landscape will look like in the future and how its ecosystems will function. Several principles of invasive management need to be acknowledged before developing a strategic plan to address them:

1. Developing a meaningful strategy of control requires first defining what is to be conserved and protected from invasion. Conserving native biological diversity requires first defining minimum levels of ecological function to preserve, then describing priority habitats and species to protect.

2. It is possible to exert some control over invasives, but collectively and individually they are not a problem with a short-term solution. Successfully managing invasive species requires a commitment to vigilance and action in perpetuity.

3. Resources devoted to control of invasives will never be sufficient to fund and staff all desirable management approaches. Therefore, it is critical to find ways to identify priority species, populations, and control methods so that available resources are allocated wisely.

4. Regardless of the extent of the area of concern, the least expensive method of control is to prevent new invasions at every entry port and to move quickly to control recently discovered populations. Eradication of established invasives may be impossible, but committing to prevention of new invasions is possible, logical, efficient, and imperative.

5. Effective watershed or landscape level control requires effective communication among public and private landowners, government agencies, and NGOs. Carefully designed and targeted education is the foundation of effective communication. Propagule pressure from invasives is not deterred by property boundaries or differences of opinion.

6. Effective specific management techniques for invasives will require better information, acquired through ongoing research on the growth and reproduction of individual species and the effect of these species on both habitats and the associated native community.

7.1 Determining Control Objectives

Following the recognition of the potential negative effects of invasive plants on other resources, a common response is to declare all-out war, to request or initiate the process of obliterating these species from the landscape of concern. Yet, for all the reasons that these species are successful at invading a habitat, the desire to eliminate them is often met with frustration. Without careful consideration of reasonable objectives that can be accomplished with the available resources, expensive control efforts may produce very short-lived results. The plant may be set back by the initial charge, but then its ability to reproduce rapidly via propagule pressure from nearby uncontrolled populations refills the area, sometimes more aggressively than before the effort to eliminate it, because the disturbance during the elimination effort provided more suitable habitat and removed competing vegetation. A more rational and more effective program begins with assessing the distribution and abundance of invasive plant populations, determining available control resources and then setting priorities for species and areas to treat and objectives for control. While detailed objectives need to be specific to the site and need to adapt to changing conditions, in general, these objectives range from prevention to eradication to management. And where eradication is not possible, control efforts should always manage toward a desired status or outcome for the resources compromised by invasive plant species, rather than the invasive species itself.

A Method for Intensive Invasive Species Surveys on Large Properties

Mass Audubon's Ecological Extension Service has developed an invasive plant survey method for use on large properties such as the 2,200-acre Assabet River National Wildlife Refuge and the 2,400-acre Westover Air Reserve Base. Desktop GIS software is used to create a grid of contiguous 50-meter square cells over the study area. The grid is then loaded into an ArcPad project on a handheld gps/palmtop computer. In the field, the investigator uses the palmtop's built-in GPS unit, the grid, and aerial photos to navigate to and then explore each cell. A customized data entry form on the palmtop allows the investigator to use drop-downs to enter species encountered, percent cover, and other data for each cell. Data is regularly backed up to a desktop computer and later analyzed with desktop GIS.

Mass Audubon states that this intensive method allows for rapid and accurate navigation, inventory, and data capture over wide areas. One person can map as much as 50 acres/day in forested settings. Mass Audubon estimates their cost in the field at roughly \$10/acre but says that efficiencies of scale could lower the cost by half on a very large property.

At these rates, an inventory of approximately 100,000 acres of DWSP holdings would take one person anywhere from 4 to 8 years and cost \$500,000 - \$1,000,000. The result would be a complete and fine-resolution picture of the invasive plant populations on DWSP watershed lands. The method could be adapted by enlarging the size of the grid cells, thereby lowering the time and cost involved, but with concomitant loss of detail.

7.1.1 Survey/Inventory

Conducting an inventory (catalogue of species in an entire area) or survey (sample of a representative portion of an area) of invasive plants in the watersheds is required in order to determine what species are present, their general distribution and relative abundance in relation to other resources of interest or concern. This in turn allows the development of priorities for management action based upon an assessment of the risks presented by the alien plant populations, and also establishes a record of baseline conditions for future monitoring of new arrivals (early detection), effects of control efforts, invasion spread rate, and impacts on native plants.

There are three general inventory/survey approaches- remote sensing, direct observation from aircraft, and ground-based methods. It is extremely difficult to inventory invasive plants remotely because they are commonly understory plants. Some pilot research has taken advantage of the early leaf-out of some invasive species to pick out these plants on early season aerial photos, but this technology is still under development and not widely published. Direct observation from aircraft can be practical in some situations. For example, populations of purple loosestrife and common reed were successfully identified and mapped from the air at Quabbin. C.D. Huebner (2007) reported on a test of common ground-based methods used to inventory invasive plants, including systematic plot, stratified-random plot, the modified Whitaker method (which uses nested plots of a range of sizes), and the timed-meander method (in which species present are recorded as the observer walks throughout the site for a specific amount of time until no new species are encountered in 10 minutes of meandering). Each of these is designed for, and captures a different component of inventory goals. The timed-meander appears to be the best method for simply establishing species richness. Systematic plots allow a quantification of the abundance or frequency of occurrence of a species, but can be expensive to implement. As a

IPANE

The Invasive Plant Atlas of New England project (IPANE; www.eddmaps.org/ipane/) developed an invasive plant inventory method designed to determine presence or absence of invasive species in specific habitats, rather than providing a detailed mapping of the areal extent of these species. Starting in 2004, the IPANE approach was applied for several years on Division watersheds, both by Natural Resources staff and IPANE volunteers.

This simple presence/absence data was a useful and much less costly starting point for surveying invasive plants on the watersheds, and provided a complimentary component to the Division's regular forest inventory activities. The information is available in a searchable database at www.eddmaps.org/ipane/distribution/.

result of testing these methods, Huebner recommends combining a timed-meander and stratified-random sampling method to initially inventory invasive plants, followed by long-term monitoring using just the stratified-random method.

Ideally, the Division would have sufficient staff and resources to conduct a complete and thorough census of each watershed. That not being the case, ongoing inventory work will consist of surveys and sampling regimes tailored to support each of the management goals and objectives outlined in Chapters 10 and 11. The level of survey detail must be in balance with the resources available for control effort. The more one spends on inventory, the clearer the scope and nature of the problems, but the less there is available to manage them.

7.1.2 Prevention

By far, the cheapest and most effective approach to controlling any threatening invasive species is to detect its approach to the site of interest and prevent its establishment at that site, either by reducing the adjacent propagule pressure or by avoiding changes in the site that invite the spread of the plant. Site changes are not always predictable. Even in the absence of deliberate disturbances, such as timber harvesting or land use conversions, natural disturbances such as wind or disease or ice damage can open a site to invasion if the seed sources are nearby. So sometimes the most important component of prevention is keeping track of the arrival of invasive species on adjacent properties, and when possible, controlling them there.

The Massachusetts Invasive Plants Advisory Group (MIPAG) has been developing an Early Detection/Rapid Response system as part of its overall strategic plan for managing invasive plants in Massachusetts. This approach will be posted on the MIPAG website when completed (www.massnrc.org/MIPAG/). Predicting the pace and direction of spread for any invasive species is a complicated modeling exercise. Researchers are working on models to attempt to at least generally predict spread at the regional, landscape, and local scales, using what is known about the each plant's behavior in its native environment and working to translate this information to the invaded area (e.g., Ibanez et al., 2009). In time, these models will help managers develop more refined priorities for treatment based on the greatest threat of spread.

Prevention in the context of an actively managed watershed forest also requires attention to transport sources that may bring in seeds or viable pieces of invasive plants from distant areas into the DWSP holdings. For instance, private logging equipment that has been working in an area with invasive plants can transport these plants to DWSP properties in the mud left on the tires or the organic debris that accumulates on the surface of the machine. When that equipment is being brought from an area known to have invasives onto a DWSP property on which invasives are not yet present, requiring steam cleaning, pressure washing or other methods of thorough cleaning may significantly reduce the risk of invasive transport. Similarly, the movement of gravel or organic material during road maintenance carries the potential to transport propagules of invasives from one area to the next. Mowing of roadsides or fields infested with plants such as Japanese knotweed, which readily reproduce vegetatively, or when invasive seeds are mature can result in moving these plants to other areas. Ideally, mowing should occur before seeds mature (for instance, when the plants are still in flower) and mowing machines should be regularly pressure washed to reduce the likelihood of transport of propagules.

7.1.3 Eradication

When truly isolated populations are detected, the imperative to literally 'nip them in the bud' should not be underestimated. The costs to control a population rise dramatically, if not exponentially, as it spreads beyond its point of origin. Local eradication in the early stages of establishment is much more feasible, especially when staffing and budget are limited, which they almost always are. Like so many natural resource issues, it is uncommon for the problem to raise concern until it becomes more widespread, at which point it is much more difficult to successfully control. Smaller populations make the likelihood of success with simple methods, like mowing or hand-pulling or covering, more feasible.

The challenge in setting the priority for eradication is more a challenge of inventory and policy. To be eligible for eradication, an invasive population needs first to be detected; making invasive plant inventory a component of any regular survey of the property is critical. Field managers also need to understand and have the resources to enact control policies that call for immediate eradication when a relatively new population is below maximum thresholds for extent and density. For instance, a species that is known to spread very rapidly (e.g., Mile-a-minute vine, *Polygonum perfoliatum*), may only be a candidate for eradication while it is quite limited, while slower growing species might be possible to eradicate some time after their initial detection.

7.1.4 Management and Control

A very common starting point for the decision to "do something about all these invasive plants" is well after they have become firmly established on the landscape of concern. They often go undetected or unchallenged until they begin to push out something familiar, for instance when common reed (*Phragmites australis*) replaces common cat-tail (*Typha latifolia*) in a wetland or when purple loosestrife (*Lythrum salicaria*) fills in the low heathland at the top of a large pond or when a population of Asiatic bittersweet (*Celastrus orbiculatus*) emerges at the tops of large trees after quietly climbing its way up their trunks and lower branches, killing them by strangling and then shading and eventually toppling them to the ground. What begins as a silent 'invasion' becomes a full on assault, but unfortunately goes unnoticed until the invading army is well entrenched.

While eradication eventually becomes economically and perhaps even ecologically impossible after population establishment (at least without severe collateral damage), it may still be possible to find ways to live with the invasive population's presence while modifying its impact enough to accommodate other objectives. On the DWSP watersheds, maintaining a diverse species composition of vigorous tree regeneration in the understory of the forest is considered by the agency to be of paramount importance for the long-term protection of the water supply, especially in areas considered to be of greatest hydrological sensitivity. Furthermore, there are statutory obligations to protect plants considered to be rare enough to be threatened, a condition that is exacerbated by the arrival of aggressive invasive plants.

Within the realm of "control", there are essentially three approaches – mechanical, chemical, or biological – as well as at least one variant of mechanical control, the use of prescribed fire.

7.2 Principles of Manual and Mechanical Control

The manual removal or killing of invasive plants generally represents the most direct and specific method for control. The range of mechanical or manual methods for removal includes cutting, pulling (by hand or with tools such as a "weed wrench"), girdling, mowing, grazing (with controlled herds of goats or sheep), smothering (with mulch, plastic sheeting, plywood, etc.), and burning (either prescribed fire or spot application with torches). In each of these, the concept is to either remove the plant altogether or injure it sufficiently to kill it in place.

While seemingly more benign than either chemical or perhaps biological methods of control, there are exceptions to this premise. For instance, sometimes the simple matter of pulling many plants from the ground can cause a soil disturbance that welcomes the return of the target species or other undesirable plants, thus exacerbating rather than solving the problem. Mowing, if not done carefully, can spread the plant's seed or vegetative structures capable of reproducing the plant. Similar to pulling, fire can create an ideal substrate for the return of the plant or of other invasive species. Cutting can stimulate plants like the olives to produce abundant root suckers that develop into mature plants.

In most cases, manual methods of control require persistent monitoring and more than a single treatment to be successful; single treatments without follow-up are generally a significant waste of effort. Nonetheless, for small populations of easily removed plants and in situations requiring extreme caution with chemical or biological controls, manual methods may well be the best choice.

7.3 Principles of Chemical Control

The way that herbicides kill plants is referred to as the "mode of action," and is either a biochemical or physical mechanism. Some modes of action disrupt metabolic processes; others disrupt cellular membranes, causing contents of the cells to leak out. Specific mode-of-action categories include auxin mimics, mitosis inhibitors, photosynthesis inhibitors, amino acid synthesis inhibitors, and lipid biosynthesis inhibitors. Modern herbicides principally affect processes exclusive to plants like photosynthesis or the production of aliphatic amino acids. Some herbicides selectively kill certain types of plants, e.g., monocots but not dicots, because of their particular mode of action.

Since most modes of action influence plant growth, the choice of which chemical to use and when to use it is tied strongly to the physiology of the target plant and the season or time of year. For example, in the Northeast, some herbicides are optimally applied in autumn, 3 to 6 weeks before the target plant goes dormant. This is because many plants transfer sugars and nutrients from their stems and leaves to below ground storage organs at this time and will carry herbicides along to these areas as well.

Herbicides are less effective if applied when plants are already stressed and have reduced their metabolic activity, such as during a drought, because most herbicides work by attacking growing tissue and active metabolic processes. Herbicides that work by inhibiting amino acid or lipid synthesis may show a long time lag between the time of application and the appearance of symptomatic effects while the plants are relying on stored supplies to continue growing.

In addition to the range of modes of action, there are many methods of herbicide application. The most common methods of chemical control for invasive upland plants include mist-blown and wick foliar applications, basal bark treatments, frill or direct injection, and cut stump applications. A variety of herbicides can be applied to the surface of leaves via mist blowing from a low-pressure sprayer. This method is used on large, dense invasive plant populations that are not beyond the reach of a low pressure backpack sprayer. Foliar spray is commonly done during the growing season when plants are in flower or fruit. Herbicide can also be applied to leaf surfaces via long-handled sponge or wick, generally in solution with a surfactant that dilutes the chemical and increases its absorption. Basal bark treatments involve the direct application of the herbicide to the thin bark near the bottom of younger trees. Enough chemical is applied to girdle the tree by killing the inner bark. Herbicide may also be applied into a gap behind a girdling frill made by ax or machete, or injected through the bark. This technique is used on individual trees greater than 5" in diameter or those with thicker bark. Injection can also be used on herbaceous stems (e.g., Japanese knotweed). For plants that are capable of sprouting or root suckering after being cut, herbicide can be applied via sponge or brush directly to the cut surface immediately after cutting, so that the chemical is absorbed into the stem and roots and kills reproductive tissue. This method is used for shrubs, trees, vines, and knotweed.

The sponge/wick, basal bark, frill, injection and cut stump methods of applying herbicides are labor intensive, but provide a high level of control and specificity in the delivery of the chemical and therefore minimize contact with non-target plants or other organisms. Adjuvants, surfactants, carriers, dyes or other ingredients are usually included in or added to herbicide formulations to improve their effectiveness or make them safer to handle or easier to apply. For example, dyes mixed with herbicides enable applicators to easily see which plants have been treated.

Many terrestrial invasive plants are very successful at reproducing vegetatively, so that some mechanical control methods (mowing, cutting) alone may do little to eradicate the plant and can increase dispersal. Thus, chemical (herbicide) control of invasive terrestrial plant species is often the most cost-efficient and effective way to eradicate or reduce the number of invasive plants in an area. Using chemical methods in conjunction with mechanical methods also has advantages. In order to reduce the amount of herbicide used in foliar applications, an invasive plant infestation with lots of small diameter but relatively tall stems might be cut or mown first, then sprayed later when the cut stems have re-sprouted with a significantly diminished leaf area needing to be sprayed. In situations where there are fewer but larger stems, a low-volume of concentrated herbicide may be immediately applied to the cut stem, which draws the herbicide into the roots and kills the plant. This method may not result in a lower total amount of the active ingredient of an herbicide applied per acre compared to mist-blowing, because the solution applied directly to the cut stem is more concentrated than that used in spray applications. But because it is applied directly to each target plant, the danger of unintended damage to adjacent, non-targeted species, or general environmental contamination, can be substantially reduced.

In addition to choosing an herbicide that is effective against an invasive plant, it is imperative that the combination of the properties of the chemical formulation and the method of application will avoid drift and/or contact with non-target vegetation or organisms, leaching to groundwater, runoff into streams or water bodies, and persistence in the environment.

The Massachusetts Department of Agriculture (MDAR) maintains a website on rights-of-way vegetation management that includes a detailed list of materials MDAR has approved for use in “sensitive” areas (water supplies, wetlands, state-listed species habitats, and inhabited or agricultural areas): www.mass.gov/agr/pesticides/rightofway/Sensitive_Area_Materials.htm. Each pesticide listed is linked to a detailed fact sheet that covers uses and toxicity.

7.4 Principles of Biological Control

The absence of native insects or diseases capable of controlling alien invasive plants is among the major factors that allow invasives to monopolize resources and dominate native plant species. The basic principle of biological control is to discover and then introduce insects or other biological agents capable of injuring or killing the invasive plant. Generally this involves surveying the origin of these plants for their pests (for instance, searching Japan for insects that thrive on Japanese barberry) and then importing these pests into areas where the plant has become invasive.

There are unfortunately too many examples in which this kind of approach led to unanticipated collateral damage to non-target native species. Successful biological control requires extensive preliminary testing for potential damage to natives and also testing for the ability of the imported control to survive and reproduce in the importing environment, followed by rearing of sufficient numbers of the control agent in the lab to provide sufficient distribution at the sites of interest. Despite these challenges, biological control provides the best possible chance for long-term, low-cost management of potentially invasive species.

7.5 Principles of Control Using Prescribed Fire

Intense wildfire is generally problematic on water supply watersheds, because it releases nutrients that can leach into the water supply, reduces the organic layers that protect the mineral soil from erosion, and causes long-chained hydrophobic substances (e.g., resins) to move downward into the soils, condense, and produce a water-repellent layer that can lead to overland flow of water and associated sediments and nutrients (DeBano, 2000). Hot fires that remove organic layers and expose mineral soils can result in the sealing of soil pores by ashes and may also result in the compaction of that soil by subsequent rains, thus further reducing infiltration rates (Ralston and Hatchell, 1971).

In contrast to wildfire, prescribed fire is deliberately controlled in both extent and intensity in order to limit its deleterious effects while taking advantage of its positive value as a management tool. Prescribed fire has long been employed to control "weeds" and has a role in the management of invasive plants. Successful use of prescribed fire for invasive plant control requires coordinating detailed knowledge of both the phenology of the plants of interest and the effects of fire across the spectrum from least to most intense. For example, prescribed fires are traditionally scheduled for the dormant season, when fuels make them more likely to catch and after most wildlife is beyond its nesting season. However, this timing also means that plant resources have been stored below ground, so that most fires will burn off the dead or dying plant residues above ground, but leave below ground structures capable of vigorous recovery the following spring. For effective invasive plant control, this timing needs to be adjusted.

Fire used in invasive plant control may range from direct heating of stems with a propane torch to relatively intense area fires. A few basic principles apply in this management approach:

1. To successfully reduce or eliminate invasive plants with fire, the fire must kill all reproductive structures, including roots, stems, and seeds. Fire sufficiently hot to kill underground structures may need to be localized (e.g., via torch heating) to avoid unintended destruction of adjacent soil organic matter.

2. Timing of fire used to control invasives is critical and problematic. By the time plants are mature and dry enough to burn, they may well have thrown their seed for that year, requiring fire that is sufficiently hot and extensive to consume dispersed seed. Late flowering plants may be susceptible to dry season burns prior to seed formation. Prescribed burns may also be successful if used during the best burn period to reduce the plant mass, but followed with other control methods to respond to germinating seedlings or vegetative sprouting that succeeds the fire.

3. Invasive plants that do not reproduce vegetatively are good candidates for fire control, but are uncommon. For the majority of woody invasive plants, which reproduce by sprouting, an alternative to fires intense enough to burn their roots may be repeat burns within one or several growing seasons, causing the plants eventually to exhaust stored resources in repeated regenerations following burns. Where the treatment area or the number of plants to be treated is relatively small, direct applications of heat via torches may kill the rootstock without intensively burning the surrounding understory.

Fire has been tested as a control method for many invasive plant species, with variable results. Plants with a preference for hydric soils or wetlands (e.g., purple loosestrife) are clearly more difficult to burn, although dried common reed burns easily and is considered a fire hazard in some areas. Fire can be used to retard the growth of common reed and other invasives such as Japanese barberry temporarily, but without follow-up treatment, e.g., with herbicides or torch heating, the surviving roots will restore the population aggressively. Invasive trees such as black locust can be controlled with crowning fires, but these are difficult to control, so burning black locust while it is still relatively short is preferable. For some species, such as the buckthorns, burning can be effective if it is repeated for three to five years, and/or repeated 2-3 times within the same growing season. While planning that includes detailed understandings of both plant reproduction and fire dynamics is critical, the use of fire can provide cost-effective, rapid invasive plant management under ideal conditions and presents minimal threat to drinking water if properly scheduled and controlled. Research on using fire to control invasive plants has intensified as agencies and NGOs look for efficient solutions to this daunting problem.

Brooks and Lusk (2008) developed an assessment of the general impacts of fire on invasive plants, adapted in the following table:

Table 1: General effects of fire on invasive plants

Life form	Regenerative tissues	Damage by fire	Examples
Annual or biennial plants	Seeds that reside on or under the soil surface, or on dead plants	Depends on whether seeds are located above ground on the parent plant, or at or below the soil surface after they have been dispersed.	Garlic mustard
Rhizomatous plants	Living tissue just above or below soil surface	Depends on the percentage of litter burned and amount of smoldering combustion	Japanese barberry
Shrubs	Living tissue just above the soil surface	Non fire-adapted shrubs can be killed by fire due to their positioning directly in the flame zone of surface fires	Multi-flora rose
Trees	Living tissue well above soil surface	Can be killed by crown fire or by surface fire that girdles the tree	Black locust

Figure 3: Treating invasive plants with fire

7.6 Relative Costs of Control Methods

The cost to achieve a particular control objective regarding an invasive plant population depends on many factors, including the species involved, its growth habit, life cycle stages present, the magnitude and character of the infestation (density, extent, and distribution), size of the plants, and size of the seed bank, access, topography, and the type of control method. Each situation is unique.

In general, manual/mechanical methods are more expensive and less effective than chemical methods. Biological control methods, if available, can be more or less costly on a per acre basis than other alternatives. Regardless of the control methods employed, a multi-year commitment is generally required to reach the desired level of control, and resources will need to be devoted in perpetuity to maintain the level of control that has been achieved.

Control expense data were gathered from several organizations working at different scales and with a variety of methods that illustrate the range of control costs. The USDA Natural Resource Conservation Service offers cost share assistance to landowners to undertake invasive plant control projects through the Wildlife Habitat Incentives Program. The 2010 NRCS cost share rates were based on the following per acre estimated costs for "Conservation Practice MA-595, Pest Management, Invasive Plant Control."

Table 2: NRCS Conservation Practices MA-595, Invasive Plant Control

Type of Control	Description	Cost per acre
Mechanical/chemical	Use of herbicide or by mechanical pulling. Cost includes all labor. Multiple treatments allowed as necessary.	$450
Intensive mechanical/chemical	Treatment entails cutting by chainsaws etc. immediately prior to an herbicide application. Cost includes all labor, equipment and materials. Only one intensive treatment is allowed per area. Additional treatments of non-intensive control may be scheduled.	$850
Biological control of purple loosestrife	Entails the release of a minimum of 10,000 *Galerucella* beetles per acre of infestation. Multiple treatments allowed as necessary.	$1,500
Chemical control of *Phragmites*	Treatment of *Phragmites* using chemical control. Includes labor and materials for one treatment. Multiple treatments allowed as necessary.	$3,000

Two contractors working in New England (A and B) and one in Tennessee (C) gave the estimates in **Table 3** as per acre costs for several treatment methods.

Table 3: Contractor Estimates of Treatment Costs/Acre

Treatment Method	Contractor	Infestation level	Hours/ acre	Rate/ hour	Cost/acre
Foliar spray	A	Moderate	1-2	$50	$50-100
Foliar spray	B	Light-heavy	-	-	$125-400
Foliar spray	C	Low/Med/High	4/8/16	$75	$300/$600/$1,200
Cut/stump herbicide	A	Moderate	2-4	$50	$100-200
Cut/stump herbicide, stem injection	B	Moderate-heavy	-	-	$1,000-2,000
Cut/stump herbicide	C	Low/Med/High	13/33/67	$75	$1,000/$2,500/$5,000
Basal bark	C	Low/Med/High	8/16/32	$75	$600/$1,200/$2,400
Mow	B	-	-	-	$300-400
Hand pull	C	Low/Med/High	27/53/106	$75	$2,000/$4,000/$8,000

The Connecticut Agricultural Experiment Station Research Foundation reduced barberry cover by an average of 85% and barberry frequency of occurrence by 42% using handheld propane torches as an initial treatment on stands less than 3 ft. tall. For every 1 percent barberry cover, the treatment required 0.52 gallons/acre of propane and 0.6 hours/acre of labor (Ward 2008). Thus, a stand with 50% cover would require 26 gallons of propane and 30 hours of labor per acre. They estimate that to initially treat the same stand with a brush saw would take 6 hours/acre of labor. For follow up treatment, labor required when using the propane torch falls to 22 hours/acre. Follow-up with herbicides would take 6 hours/acre plus the cost of the herbicide.

Effective control of Japanese barberry can be achieved in a single growing season by integrating an early-season initial treatment (prescribed fire or mechanical) that kills the aboveground tissues with a midseason follow-up treatment such as directed heating or targeted herbicide application (Ward et al., 2010).

The Wilds, a conservation organization located on 3,700 hectares of reclaimed surface mine land in southeastern Ohio, experimented with chemical control of autumn olive (*Elaeagnus umbellata)*, which had been planted as part of the surface mine reclamation process. They achieved 98% mortality after one growing season using foliar application, and 71% mortality using dormant season stem herbicide applications at a contracted cost of $750/ha ($304/ac) (Byrd and Cavender 2010).

In the United Kingdom, the estimated costs of using herbicides to control Japanese knotweed are about $1.60 per square meter, which is about $6,500 per acre (Hathaway 1999). This does not include the costs of revegetation after herbicide treatment.

Contractor costs to treat the invasive tree Melaleuca (*Melaleuca quinquenervia*) at a site in south Florida, using frill/injection or cut stump with herbicides, cost $1,823/acre (Laroche and McKim 2004). The tree density on the site was 9,152 small diameter stems per acre.

A pilot program was conducted at Quabbin in the summer of 2007 using a variety of manual and mechanical control techniques on four species of invasive plants (see section 10.2). The seasonal staff conducting the pilot arrived at per acre figures for thorough mechanical control of at least $3,515, depending on site conditions and species.

The final set of cost figures comes from the Marin Municipal Watershed District, Marin County, California (MMWD). MMWD has estimated that over 900 acres of its 22,000 acre watershed is infested with French broom, an exotic invasive shrub (Klein, 2007). **Table 4** shows the estimated per acre costs for a variety of control methods used by the MMWD over the years. The cumulative 10-year cost reflects the efficacy of the treatment methods over a time frame more likely to realistically achieve the stated objective, which in this case is a reduction of broom density to below 5,000 stems per acre. At this density, MMWD can prevent French broom seed production by devoting fewer than 16 person hours per acre to maintenance control work, and also allows the MMWD to consider reintroduction of native perennial species to particularly species-poor sites. In addition to biodiversity concerns, one of MMWD's primary goals is to remove broom (or keep it from infesting) 960 acres of fire breaks on the watershed. The broom requires annual mowing in the fire breaks whereas native vegetation requires mowing only every 3-5 years.

Table 4: Estimated per-acre costs for French broom treatments, MMWD, 2001-2006

Methods	Labor Source	Person Hrs/ Acre	Cost/Acre (1 Treatment)	Cost/Acre (10 Yrs.)
Excavator/Tiger Mower	MMWD	5	$350	$3,500
Power Brushcutting	Contractor or MMWD	20	$500	$4,875
Prescription Burning	MMWD	Insufficient data	$1,500	$8,850
Mulching*	MMWD	16	$475	$1,825
Propane Flaming	Contractor or MMWD	75	$1,975	$6,025
Hand pulling	Contractor or AOWP** or Volunteer	300	$2,400	$9,850
Terra Torch***	Contractor w/MMWD	7	$725	$2,775
Grazing (goats)***	Contractor w/ MMWD	10	$975	$5,300
Waipuna Hot Foam***	MMWD	110	$3,550	$6,800
Cut Stump/ Herbicide	Contractor or MMWD	30	$750	$2,850

* Requires removal of adult plants prior to application.
* * AOWP Adult Offenders Work Program.
*** These methods were tried on an experimental basis and deemed either impractical or ineffective.

In 2009, synthesizing data from the MMWD as well as from experienced private contractors and other public agencies, a consulting firm hired by MMWD estimated the overall average annual cost for an integrated pest management program (IPM) over a 10-year treatment period that included the use of herbicides as well as non-chemical means at $650 per acre. The average annual cost of hand and mechanical treatments without herbicides was projected at $3,750 per acre, or 5.8 times as much. These are estimates for the watershed as a whole and take into account conditions ranging from extensive stands of broom to areas where the broom stands are smaller and/or less dense (www.marinwater.org/documents/vmp_alternatives_report.pdf, p 9.).

8 Current Status of Terrestrial Invasives on DWSP Lands

8.1 Invasive Plant Presence on Continuous Forest Inventory Plots

The Continuous Forest Inventory (CFI) system on DWSP land consists of permanent 1/5 acre circular plots established on a ½ mile grid across two of the four watersheds, so that each plot represents 160 acres. There are 361 plots representing 57,760 acres at Quabbin, and 124 plots representing 19,840 acres at Ware River. In addition to taking measurements on the mature trees in the plots (species, height, diameter, etc.) and regeneration (seedlings and saplings), the plots are checked for presence and abundance of invasive plants. If invasive plants are present, abundance is classified in terms of percent cover.

8.1.1 Quabbin

The 2010 Quabbin CFI measured tree and understory data on 361 one-fifth acre plots. Of these, one or more invasive plant species were found to be present on 63 plots (17.5%). Of these 63 plots, 49 had just one invasive species present, eight had two species, and six had three species. In 15 plots (4.2% of all plots, 23.8% of those with invasive presence), the percent cover was greater than 25%. Of the 299 plots where no harvesting had occurred in the previous decade, 48 plots (16%) had at least one invasive plant present. Thirteen of those plots (4.3%) had greater than 25% invasive cover. Of the 62 plots that had seen a harvest in the last ten years, just two plots (3.2%) had an invasive species present with greater than 25% cover. The percent cover of invasive plants on harvested plots prior to the harvest is unknown. Eighty-four percent of the 299 plots where no harvest had taken place in the previous decade are free of non-native invasive plants.

On the 63 plots with at least one invasive plant species, the most frequently occurring species is Japanese barberry (45), followed by bush honeysuckle (13), buckthorn (13), oriental bittersweet (6), multi-flora rose (3), Japanese knotweed (2), and autumn or Russian olive (2). Tree-of-heaven and burning bush occurred on one plot each. (See **Figure 4** for a graphic display of the distribution of barberry and buckthorn on Quabbin CFI.)

Factors interfering with tree regeneration are also included in the CFI dataset. Forty-one percent of the plots had no regeneration interference, while 59% of the plots had one or more interfering factors. The most common interference factors are browsing (120) and native ferns (80), followed by witch hazel (61) and mountain laurel (47), with invasive plants (18) and striped maple (8) the least frequent regeneration interference factors.

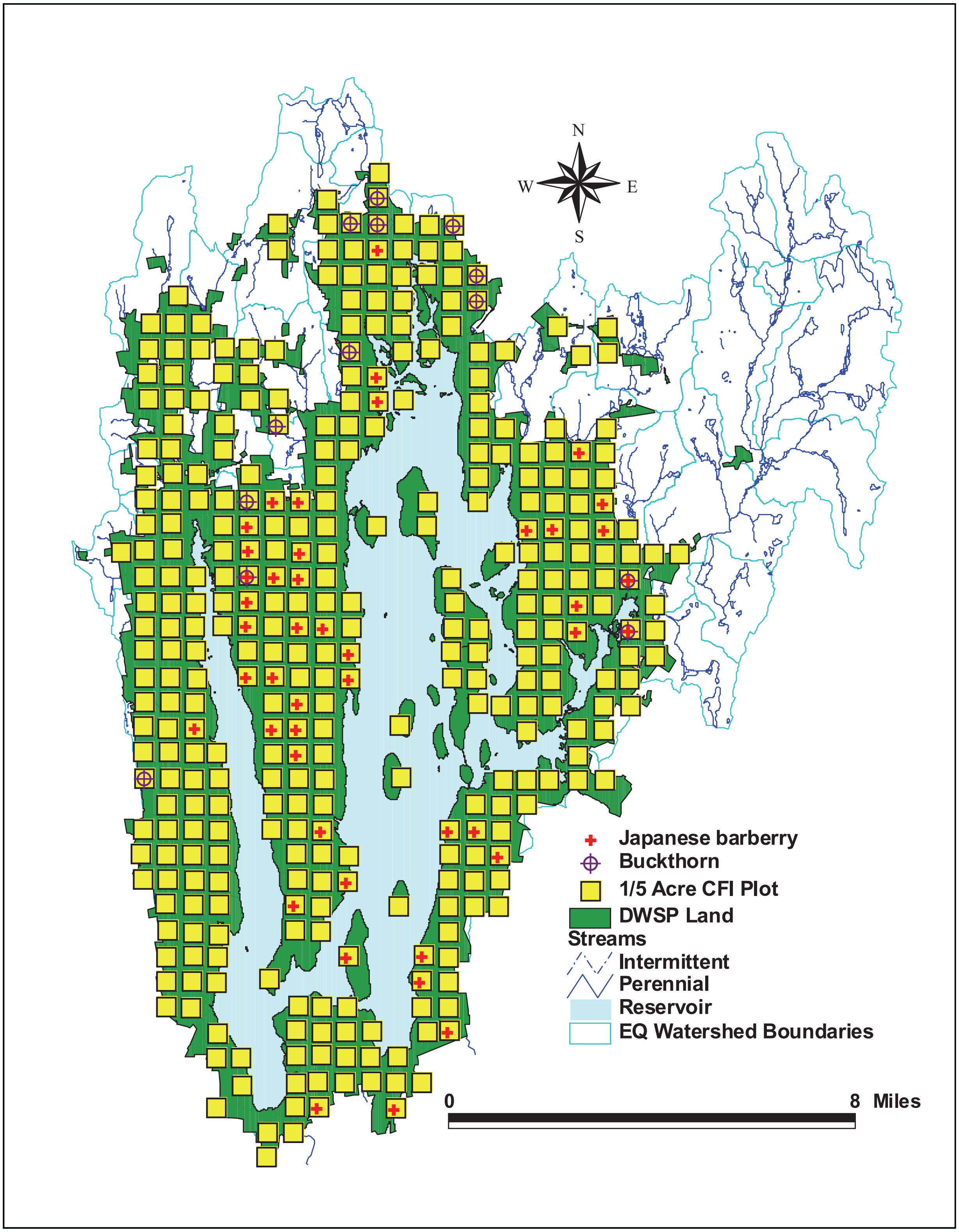


Figure 4: Quabbin watershed CFI plots containing barberry or buckthorn

(Note that the yellow squares in Fig. 3 are symbolic of the 160 acres represented by each CFI plot (NOT the 1/5 ac of the plot), and are not scaled exactly.)

8.1.2 Ware River

CFI plots on the Ware River watershed were revisited in 2009. One or more species of invasive plants were found on 34 of 124 plots (27.4%). One species was found on 28 of the plots; two species were found on six plots. On the 15 plots where harvesting had occurred, seven plots had one or more invasive plant species present and three plots (20%) had greater than 10% cover. Eight of the 15 plots (53%) were invasive free. Invasives were present on 27 of the 109 plots where no harvest had occurred in the previous decade. On 10 of these plots (37%), invasive cover was at least 20%. Seventy percent of plots where no harvest had occurred in the previous decade were free of invasives. The presence or percent cover of invasives on the harvested plots prior to harvest is unknown.

Buckthorns were the most common species (30 occurrences) at the Ware River. Barberry was found on seven plots, and oriental bittersweet, honeysuckle, and purple loosestrife on one each.

Forty-three of the plots (34.7%) were judged to have regeneration interference. Invasive plants accounted for only two of those cases or 1.6% (both buckthorn and barberry were found on both plots). The most common cause of regeneration interference was native ferns (14 plots) followed by wildlife (11 plots), witch hazel (8 plots), and mountain laurel (6 plots).

8.2 Other Inventory and Assessment Efforts

8.2.1 Regeneration Success Versus Invasive Presence at Wachusett and Sudbury

In the spring of 2011, the success of forest regeneration silviculture versus the percent cover by invasive plant species was estimated and recorded on Wachusett and Sudbury harvesting sites to verify general perceptions of these relationships and to begin to quantify thresholds of invasion that can prevent regeneration success. Wachusett Foresters walked transects 200 feet apart and recorded information at plots spaced 100 feet apart along these transects. Within approximately 1/100th acre plots, the cumulative percent cover by all invasive plant species was categorized as none, trace, 5-25%, 26-50%, 51-75%, or 76-100%. Plots were also categorized as either within the silvicultural opening or within adjacent, untreated forest. In addition, the forester recorded an expert opinion of the likely success or failure of attempts to establish or release tree regeneration as: likely to succeed, uncertain, or likely to fail. From these observations, the study created an invasives incidence level (percent of plots containing invasives) by opening versus forest cover and by general invasive cover category, and a species detection ratio for each species, again by cover category.

Sites were deliberately chosen to represent the extreme ends of the spectrum, ranging from areas considered very likely to fail to areas where regeneration efforts were either already successful or considered very likely to succeed. Sites were also sampled where the foresters had already successfully established or released advance tree regeneration, or where site conditions appear very likely to support such regeneration (i.e., where invasive plants do not appear likely to impede it).

8.2.1.1 Wachusett/Sudbury Stony Brook Ash Lot

The first site is a 12 acre area at the Sudbury Reservoir which has not been managed since 1914-1916, when there was a failed attempt to convert the area to a white pine plantation. In 1988, this site was noteworthy for the white ash overstory and the honeysuckle understory. As the ash has slowly succumbed to ash yellows, bittersweet has taken advantage of the increased light. The Overall Incidence Level is 92% meaning that 92% of the 25 plots had invasives present. Twenty-four percent of the plots had more than 75% invasive cover and 56% (32 + 24) had more than 50% invasive cover. Bittersweet occurred in 84% of the plots with honeysuckle occurring in 60% of the plots. In all, six species were detected in the plots with a seventh, Ailanthus (Tree-of-heaven), seen at the site but not picked up in the plots. The expert opinion from the foresters that forest regeneration is unlikely to succeed on this site is fully supported by these numbers.

	RESULTS	Area/Sale/Working Unit:	Stony Brook Ash					
		Overall Invasives Incidence Level	92%	Date: 5/3/11			Regen Class: 3	
			Incidence by Density of Invasive Cover					
	Plots Taken Inside/Outside Openings	Incidence ratio inside/outside	Ratio of plots with None	Ratio of plots with Trace	Ratio of plots with 5-25%	Ratio of plots with 26-50%	Ratio of plots with 51-75%	Ratio of plots with 76-100%
Openings	0	N/A (Openings)	N/A	N/A	N/A	N/A	N/A	N/A
Forest	25	92% (Forest)	8	0	16	20	32	24
Combined	25	92% (Combined)	8	0	16	20	32	24
	Overall Species Detection Ratio (%)	Any Species Green is present in area	None	Trace	5 - 25%	26 - 50%	51 - 75%	76 - 100%
	84	Bittersweet		4	24	36	16	4
	8	Euonymus		4	4			
	60	Honeysuckle		8	20	16	12	4
	24	Jap. Barberry		12	12			
		Norway maple						
	28	Multiflora Rose		16	4		4	4
	4	Garlic Mustard		4				
		Buckthorn						
		Ailanthus						
		Jap. Knotweed						
		Autumn olive						
		Swallow-wort						
		Cork tree						
		Locust						

8.2.1.2 Wachusett/Sudbury Lot 5233

The second site, Lot 5233, removed narrow strips of white pine along Rt. 140 in West Boylston in 2009. White pines that were planted following the 1938 hurricane were removed primarily for public safety reasons as this un-thinned plantation began to deteriorate. The site also had an excellent understory of hardwood saplings, including sugar maple. While bittersweet was present prior to the cut, it was not initially an impediment to the sapling understory. However, as the sampling shows, bittersweet has exploded in growth and coverage. The Overall Incidence Level is 92% in the 52 plots taken with bittersweet occurring in 88% of the plots with 42% of the plots having more than 50% coverage of bittersweet. Eight different invasive species were detected at this site.

	RESULTS	**Area/Sale/Working Unit:**	**Lot 5233**					
		Overall Invasives Incidence Level	92%	**Date:** 5/9/11			**Regen Class:**	3
			Incidence by Density of Invasive Cover					
	Plots Taken Inside/Outside Openings	Incidence ratio inside/outside	Ratio of plots with None	Ratio of plots with Trace	Ratio of plots with 5-25%	Ratio of plots with 26-50%	Ratio of plots with 51-75%	Ratio of plots with 76-100%
Openings	52	92% (Openings)	7	0	32	13	25	21
Forest	0	N/A (Forest)	N/A	N/A	N/A	N/A	N/A	N/A
Combined	52	92% (Combined)	7	0	32	13	25	21
	Overall Species Detection Ratio (%)	Any Species Green is present in area	None	Trace	5 - 25%	26 - 50%	51 - 75%	76 - 100%
	88	Bittersweet			32	13	21	21
		Euonymus						
	3	Honeysuckle			3			
	1	Jap. Barberry			1			
	1	Norway maple		1				
	1	Multiflora Rose			1			
		Garlic Mustard						
	19	Buckthorn		7	11			
		Ailanthus						
		Jap. Knotweed						
	3	Autumn olive		3				
		Swallow-wort						
		Cork tree						
	1	Locust		1				
		Crabapple						

8.2.1.3 Wachusett/Sudbury Lot 5210A

The first successful site is Lot 5210A, an 89 acre timber sale cut in 2006-07 in Sterling. At the time that this lot was proposed, invasive plants were not known to be present in this area. The sampling results support this with an Overall Incidence Level of 0%. None were found in any of the 71 plots (22 plots in openings and 49 in the uncut forest).

	RESULTS	Area/Sale/Working Unit: Lot 5210A							
		Overall Invasives Incidence Level	0%	Date: 5/6/11			Regen Class: 1		
			Incidence by Density of Invasive Cover						
	Plots Taken Inside/Outside Openings	Incidence ratio inside/outside	Ratio of plots with None	Ratio of plots with Trace	Ratio of plots with 5-25%	Ratio of plots with 26-50%	Ratio of plots with 51-75%	Ratio of plots with 76-100%
Openings	22	0% (Openings)	100	0	0	0	0	0
Forest	49	0% (Forest)	100	0	0	0	0	0
Combined	71	0% (Combined)	100	0	0	0	0	0
	Overall Species Detection Ratio (%)	Any Species Green is present in area	None	Trace	5 - 25%	26 - 50%	51 - 75%	76 - 100%
		Bittersweet						
		Euonymus						
		Honeysuckle						
		Jap. Barberry						
		Norway maple						
		Multiflora Rose						
		Garlic Mustard						
		Buckthorn						
		Ailanthus						
		Jap. Knotweed						
		Autumn olive						
		Swallow-wort						
		Cork tree						
		Locust						
		Crabapple						

8.2.1.4 Wachusett/Sudbury Sterling Fairgrounds Lot

Not all successfully regenerated sites have 0% detection of invasives. The lot from the Sterling Fairgrounds area to the north of West Waushacum was a 20 acre red and white pine plantation that was first cut in 1983 with the goal of establishing regeneration. Advance regeneration that was established by the first treatment was then released in 2003. The operator successfully protected the dense white pine and hardwood understory. However, invasive species were detected on 62% of the 36 plots (57% in openings and 66% in the unreleased forest). Forty-five percent of the plots had less than 26% coverage by invasives. Buckthorn (*Rhamnus frangula*) is the primary invasive and it was detected in 62% of the plots.

	RESULTS	**Area/Sale/Working Unit:**	**Sterling Fairgrounds**					
		Overall Invasives Incidence Level	62%	**Date:** 5/6/11			**Regen Class:** 1	
			Incidence by Density of Invasive Cover					
	Plots Taken Inside/Outside Openings	Incidence ratio inside/outside	Ratio of plots with None	Ratio of plots with Trace	Ratio of plots with 5-25%	Ratio of plots with 26-50%	Ratio of plots with 51-75%	Ratio of plots with 76-100%
Openings	19	57% (Openings)	42	15	15	21	5	0
Forest	18	66% (Forest)	33	22	38	5	0	0
Combined	37	62% (Combined)	37	18	27	13	2	0
	Overall Species Detection Ratio (%)	Any Species Green is present in area	None	Trace	5 - 25%	26 - 50%	51 - 75%	76 - 100%
	5	Bittersweet			5			
		Euonymus						
	2	Honeysuckle			2			
	13	Jap. Barberry		2	8	2		
		Norway maple						
		Multiflora Rose						
		Garlic Mustard						
	62	Buckthorn		27	21	10	2	
		Ailanthus						
		Jap. Knotweed						
		Autumn olive						
		Swallow-wort						
		Cork tree						
		Locust						
		Crabapple						

8.2.1.5 Wachusett/Sudbury Conclusions

Using the sampling methods described above, the Wachusett Foresters surveyed 13 different locations and arrived at the following general conclusions:

1. Bittersweet is the most problematic invasive plant in these watershed forests. Having a high incidence of bittersweet even with very low coverage is likely to prevent tree regeneration from successfully establishing when the overstory is removed or significantly opened.

2. Soils play a significant role in the presence and especially the behavior of invasive plants. Small depressions, with greater soil moisture, often result in significant increases in the presence of and coverage by invasive plants. Bittersweet, in particular, seems to be far more aggressive on the more mesic sites. Conversely, the best chances for successfully regenerating the forest even in the presence of invasives is on the driest soils.

3. Successful regeneration efforts in the presence of invasives can sometimes be misleading. There are DWSP sites that were cut nearly 20 years ago that were exceptionally successful in regenerating the forest. Invasives, including bittersweet, are present but not interfering aside from the occasional inch+ diameter stem climbing a hardwood. However, the age of the bittersweet suggests it was not present at the time of the overstory removal but moved in within a few years. While advance hardwood regeneration was able to quickly and fully occupy the site before the bittersweet got a strong foothold, now that bittersweet is present, it may respond aggressively to further opening of these sites.

8.2.2 Monitoring of Post-harvest Conditions on Wachusett

In 2010, a study was conducted of the tree regeneration levels, mature tree retention levels, and competition potential from native and invasive species presence in a sample of forest openings created by silvicultural operations from 2001 through 2009 in the Wachusett Reservoir watershed, coinciding with the time frame of the *2001 – 2010 Wachusett Reservoir Land Management Plan*.

Eight hundred and nine plots were measured to sample 71 of the 642 silvicultural openings that were created from 2001-2009. The openings ranged from one-half acre to two acres, and averaged just less than one acre. At each plot four different samples occurred:

1. Basal area of residual mature trees in the opening using a 10 BAF prism from the plot center.
2. Numbers by species of tree seedlings and saplings >1 foot in height up to 5.5 inches dbh (in three groupings) rooted inside a 1/1000th acre (milacre) plot.
3. Heavy or light presence of native interfering species – laurel, witch hazel, and hay-scented fern in the milacre.
4. Degree of infestation of non-native invasive species in a one-hundredth acre plot around the same center.

Nine species of invasives were encountered during this survey. **Table 5** below lists them in decreasing order of frequency of encounter.

Table 5: Encounter frequency for invasives on plots and harvest openings, Wachusett

Common Name	Frequency By Plot (%)	Frequency by Opening (%)
European buckthorn, glossy buckthorn	8.7	21.1
Oriental bittersweet	5.2	15.5
Tartarian or Morrow's honeysuckle	0.9	2.8
Norway maple	0.4	2.8
Japanese barberry	0.4	2.8
Ailanthus altissima (Tree-of-heaven)	0.1	1.4
Multiflora rose	0.1	1.4
Black locust	0.1	1.4
Autumn olive	0.1	1.4

Forty-six of the seventy-one openings sampled (65%) had no invasive plants on any sample plots. In twenty-five openings (35%), invasive plants were present on at least one plot; seventeen of those openings (24%) had a trace or light presence (only one or two plots had any invasives, and typically only one plant per plot), and eight openings (11%) had a significant presence (invasives were present on a majority or all of the plots).

Foliar coverage of individual invasive species and all invasive species combined was estimated in five categories: None; 1 to 25%; 26 to 50%; 51 to 75 %; and 76 to 100%. No plots had >75% coverage. Only ten plots in four openings had >50% coverage; two of those openings were older, and buckthorn and honeysuckle were the species encountered, while in the two young openings bittersweet was predominant.

Heavy presence of invasive plants does not appear to be crowding out all native tree regeneration, but there clearly is a reduction in the average number of tree stems counted per plot with increasing density of invasives (**see Figure 5**).

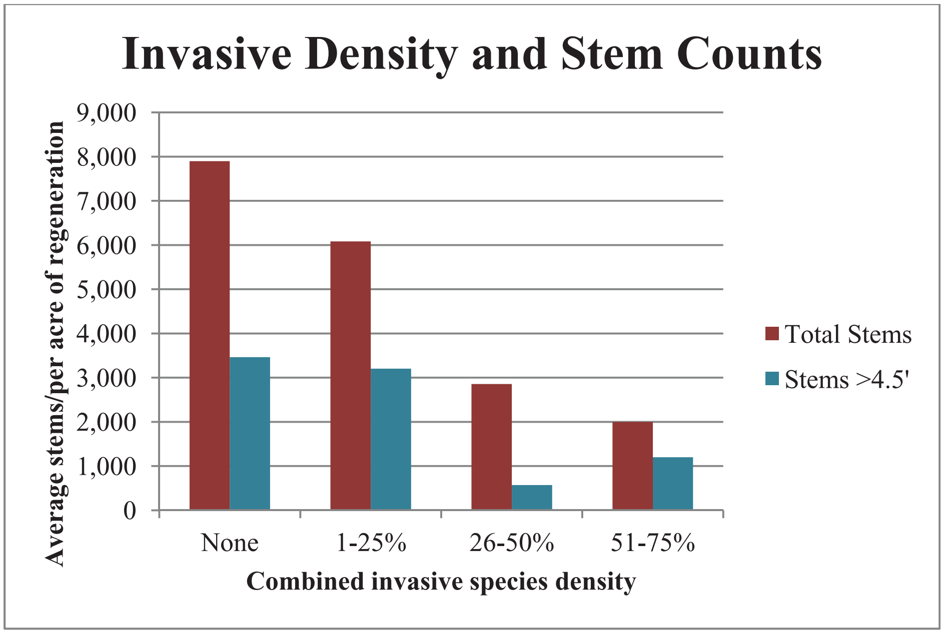


Figure 5: Regeneration by invasive plant density in Wachusett harvest openings

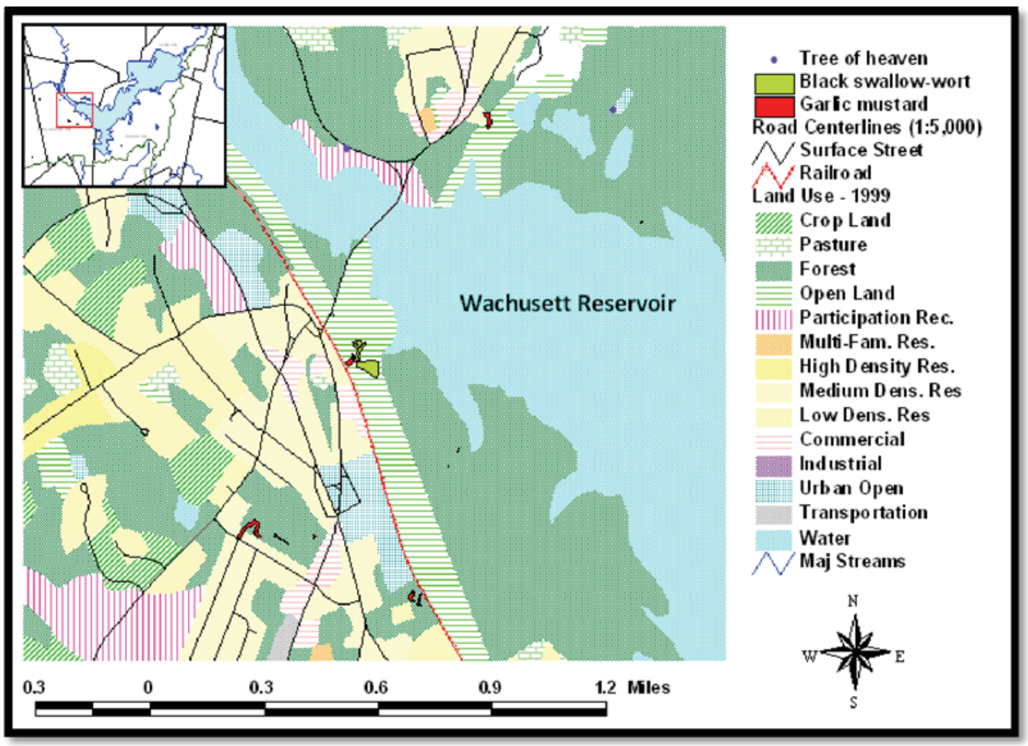


Figure 6: Sample mapping of invasive plant populations at Wachusett

8.2.3 2008 Quabbin Survey and Mapping

In the summer of 2008, a seasonal crew of three traveled every road inside the gates on the Quabbin watershed, recording with GPS the roadside occurrence of ten species of terrestrial invasive plants: Japanese barberry (*Berberis thunbergii*), Oriental bittersweet (*Celastrus orbiculatus*), Japanese knotweed (*Polyganum cuspidatum*), autumn olive (*Eleaganus umbellata*), common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), glossy buckthorn (*Frangula alnus* P. Mill.), honeysuckle (*Lonicera* spp.), multiflora rose (*Rosa multiflora*), and Norway maple (*Acer platanoides*). Occurrences were recorded as circles around points (most of 10 ft. radius but some ranging up to 100 ft. radius), or polygons (ranging in size from 87 sq. ft. to 244 acres). Cover density estimates for the circles and polygons were recorded as trace, low, low-medium, medium, medium-high, and high. Shoreline populations of *Phragmites* and *Lythrum* were located and mapped by boat and from the air. Areas between roads in several portions of the watershed were also reconnoitered on foot and the invasives encountered were recorded and mapped. All together across the watershed, 3,937 points and circles representing 45 acres, and 187 polygons representing 808 acres were tallied and mapped. The largest polygon, 244 acres at Webster Road in the Park, is being re-surveyed since it was subsequently determined that at least 49 acres and perhaps more of the polygon were actually invasive free. Some summary comments and maps follow:

Table 6: Results of 2008 Quabbin invasive plant survey

Invasive Species	Number of polygon acres*	Number of points (total=3,937)*
Japanese barberry	290**	2,676
Glossy buckthorn	49	28
Bush honeysuckle	120	631
Common reed	174	126
Oriental bittersweet	116**	507
Autumn olive	15	44
Multiflora rose	42	117
Japanese knotweed	49	258
Norway maple	17	0
Purple loosestrife	34	134

**Two or more species were recorded at many of the points and polygons.*
***Does not include the Webster Road polygon*

Japanese barberry: Barberry was by far the most prevalent and widely distributed invasive plant species within the Quabbin watershed (2,676 out of 3,937 points of occurrence on the road system). Infestations covering large areas were mapped in Quabbin Park, Dana Common, and in parts of the Prescott Peninsula. Japanese barberry was encountered least frequently in the Pelham Block.

Glossy buckthorn: 28 "points" 10 ft. radius, classified "L" (low density), were found in the vicinity of Pottapaug Pond and the north end of Prescott Peninsula. Eight patches (from .05 ac. to 16.6 ac.) were mapped at the mouth of the east branch of the Swift River and south of Rt. 202 where it crosses the middle branch of the Swift River near gate 30 in New Salem.

Bush honeysuckle: 631 points, the majority around the north side of Pottapaug Pond, central Prescott and the Observatory, Dana Commons, gate 38 Road, Quabbin Park.

Common reed: *Phragmites* was found mostly in the northern half of the main reservoir on the eastern shore, and at the mouth of Pottapaug, but not in the main body of the pond. It was also mapped in ponds or wetlands on islands. Only one population was found in the western arm of the reservoir.

Oriental bittersweet: Heavy infestations were concentrated in areas around the Administration Building, the stand of white pines and other areas below the dam, along Webster Road between gates 53 and 54 in Quabbin Park, Enfield lookout, and around Dana Common. Relatively few occurrences were noted elsewhere, although anecdotally Quabbin foresters have suggested it is common on Prescott Peninsula.

Autumn olive: 44 points, mostly "low density" in pockets at Goodnough Dike.

Multiflora rose: 117 points, mostly on the Prescott peninsula, around Pottapaug Pond, and New Salem area near gates.

Japanese knotweed: 258 points. There is a heavy infestation near the Gate 39 road and the first junction after the power line, and north of Dana Center. Also, populations were recorded on Doubleday Road on Prescott south of 20-7, and also at the Observatory, 17-9B and Gate 8-5.

Norway maple: None were noted in the vicinity of the road system.

Purple loosestrife: 134 points, mostly "trace" or "low density". The majority was found in Pottapaug Pond. Some was found in north Prescott at 20-3 to 20-4.

This effort provided a good starting point for further inventory work. A number of areas of heavy infestation were located, and the nature, scope and extent of the problems are better understood. The road system inside the gates was thoroughly traveled and documented. The scouting that was accomplished away from the roads covered some areas but was far from complete. Most of the territory away from the roads has not been mapped. Even the roadside inventory probably underestimates the frequency, since the foresters know of infestations that were not identified by the summer survey crew.

The figures on the following pages illustrate the locations of the occurrences of several invasive species based on the data collected in the 2008 survey.

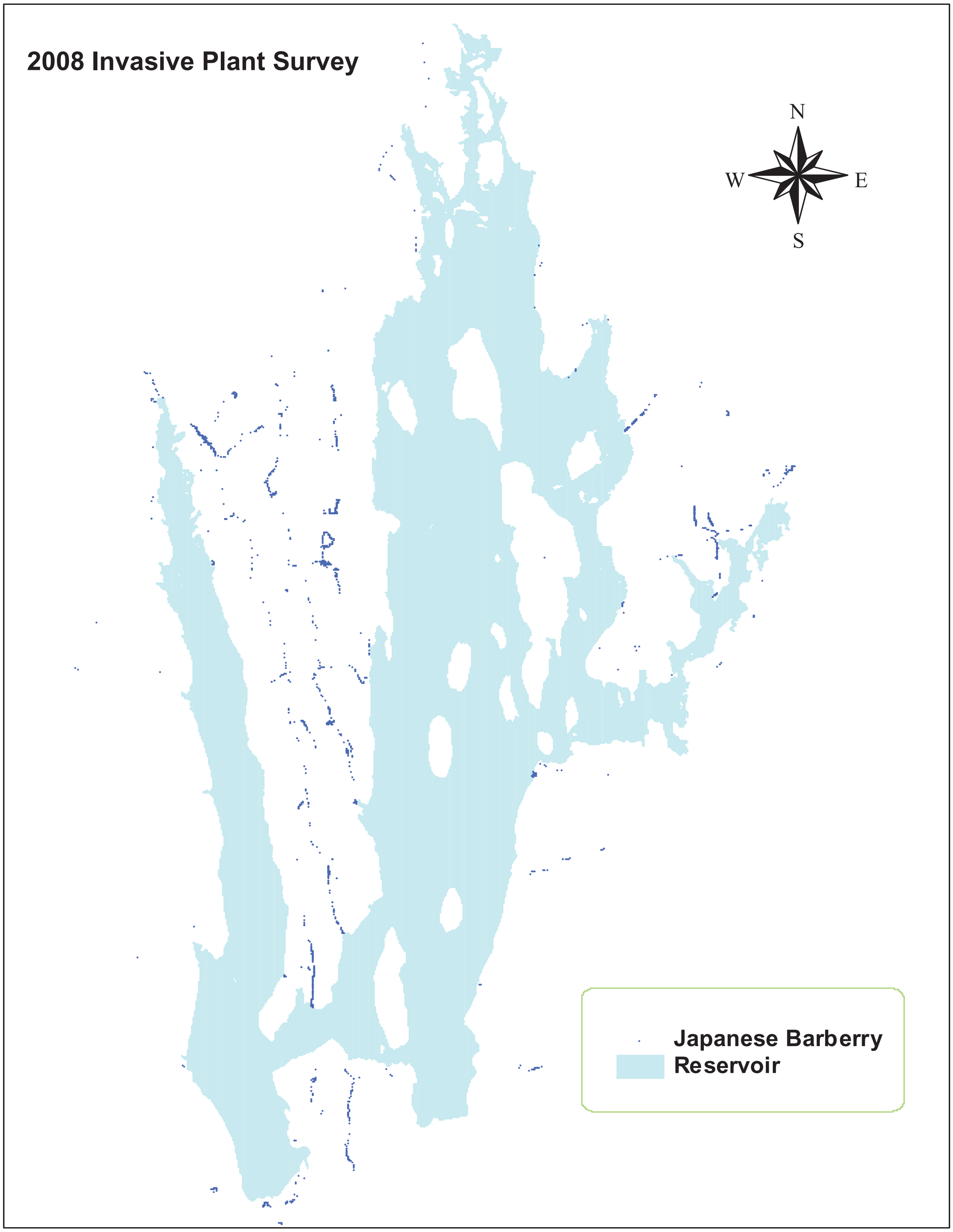


Figure 7: Point occurrences of Japanese barberry along Quabbin roads

(NOTE: Japanese barberry is by far the most widely distributed terrestrial invasive plant at Quabbin. Dots show location of plants within ~10 ft of the roads, but not actual population size. At this scale (1:150,000), a dot representing a 20 ft. diameter population would be 16 ten-thousandths of an inch in diameter.)

Figure 8: Point occurrences of Oriental bittersweet along Quabbin roads
(NOTE: Dots show location of Oriental bittersweet found within ~10 feet of Quabbin roads, but not actual population size. At this scale (1:150,000), a dot representing a 20 ft. diameter population would be 16 ten-thousandths of an inch in diameter.)

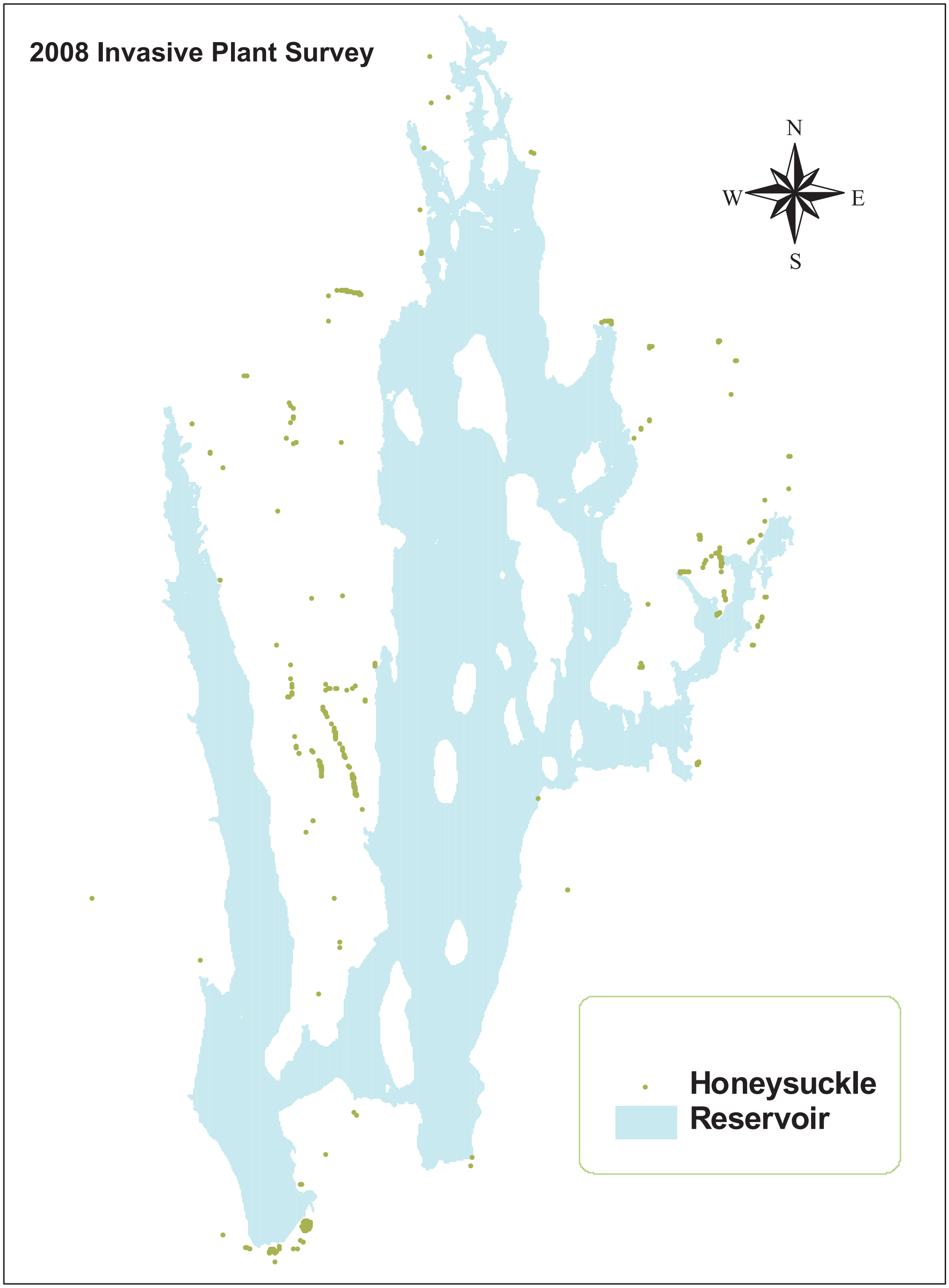


Figure 9: Point occurrences of bush honeysuckle found along Quabbin roads
(NOTE: Dots show location of non-native honeysuckle within ~10 of the roads, but not actual population size. At this scale (1:150,000), a dot representing a 20 ft. diameter population would be 16 ten-thousandths of an inch in diameter.)

Figure 10: Point and polygon occurrences of glossy buckthorn at Quabbin
(NOTE: Polygons of mapped populations range in size from 0.05 to 16.6 acres. Dots show plant locations within ~ 10 feet of Quabbin roads, but not actual population size. At this scale (1:150,000), a dot representing a 20 ft. diameter population would be 16 ten-thousandths of an inch in diameter.)

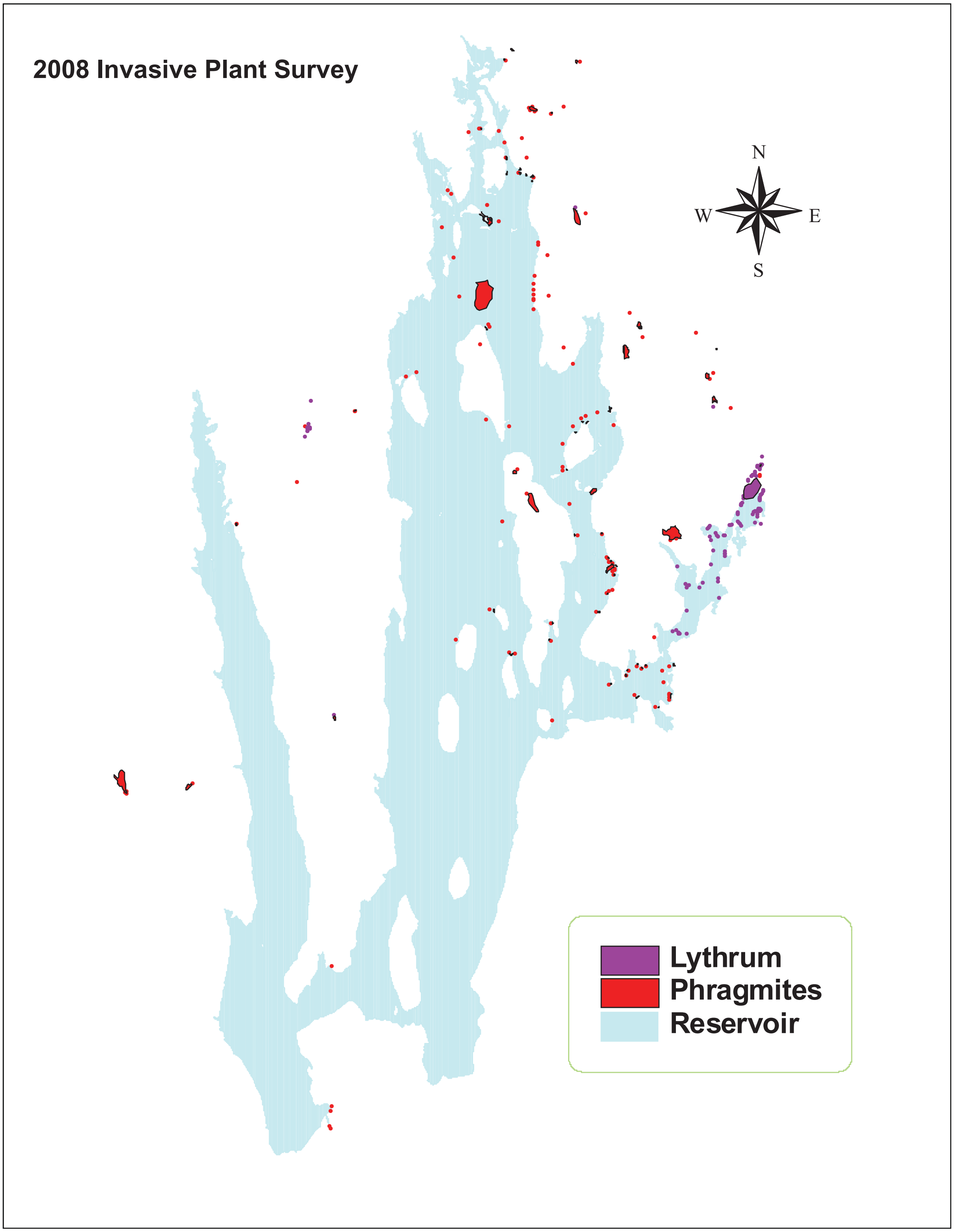


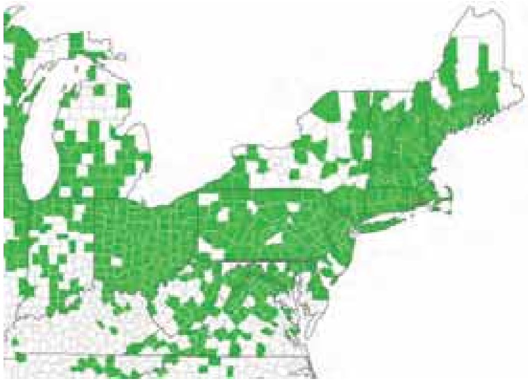
Figure 11: Phragmites (common reed) and Lythrum (purple loosestrife) populations at Quabbin
(NOTE: Common reed (*Phragmites*) was found mostly in the northern half of the main reservoir on the eastern shore. Purple loosestrife (*Lythrum*) was found principally in Pottapaug Pond.)

Table 7: Terrestrial invasive plant species present on DWSP watersheds as of 2008

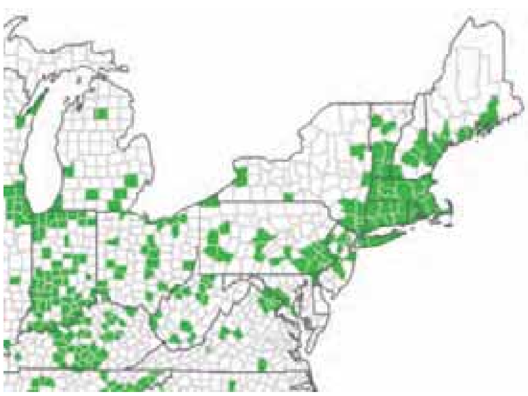
Common name	*Latin name*	Habitat	Status[1]	Qu	WR	Wa	Su
Norway maple	*Acer plantanoides*	Forest edges, mesic woodlands	I	X	X	X	X
Goutweed	*Aegopodium podagraria*	Flood plains, riparian areas	I	X	X	X	X
Tree-of-heaven	*Ailanthus altissima*	Open areas, disturbed areas	I	X		X	X
Garlic mustard	*Alliaria petiolata*	Flood plains, moist edges, roadsides	I	X	X	X	X
Japanese barberry	*Berberis thunbergii*	Forest, mesic to moist soils, open areas	I	X	X	X	X
Common barberry	*Berberis vulgaris*	Forest, calcareous outcrops, thin canopy woods	LI	X			
Oriental bittersweet	*Celastrus orbiculata*	Forest edges, woodlands, fields	I	X	X	X	X
Black swallow-wort	*Cynanchum louiseae*	Open areas and edges, roadsides	I			X	X
Russian olive	*Elaeagnus augustifolia*	Open areas	DNL	X	X	X	X
Autumn olive	*Elaeagnus umbellata*	Open areas, tolerates poor soils, roadsides	I	X	X	X	X
Winged euonymus	*Euonymus alata*	Open woods, fields, edges, well-drained soils	I	X		X	X
Glossy buckthorn	*Frangula alnus*	Forest or open, most dense in wet areas	I	X	X	X	X
Honeysuckles	*Lonicera sp.*	Woods, edges, floodplains, wetlands, roadside	Varies	X	X	X	X
Purple loosestrife	*Lythrum salicaria*	Wetlands and moist, disturbed sites	I	X	X	X	X
Japanese stiltgrass	*Microstegium vimineum*	Open areas, wet areas, riverbanks, fields	LI			X	
Amur cork-tree	*Phellodendron amurense*	Upland forest, wide range of shade and soils	LI				X
Common reed	*Phragmites australis*	Wetlands	I	X	X	X	X
Japanese knotweed	*Polygonum cuspidatum*	Riverbanks, wet edges, roadsides	I	X	X	X	X
Common buckthorn	*Rhamnus cathartica*	Open forests, well-drained calcareous sites	I	X	X	X	X
Black locust	*Robinia pseudoacacia*	Edge of forest/field, sandy soils, woodlands	I	X	X	X	X
Multiflora rose	*Rosa multiflora*	Open, fertile, moist areas and edges	I	X	X	X	X
Coltsfoot	*Tussilago farfara*	Open areas, wet edges, riverbanks, roadsides	LI	X			

[1]MIPAG Status: I=Invasive; LI = Likely Invasive; DNL = Do Not List at this time

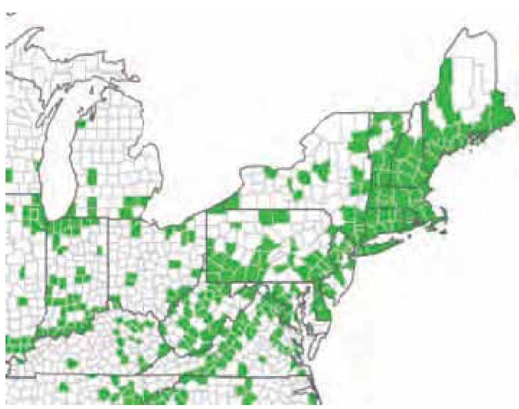
8.3 Invasion History and Current Regional Distribution of Three Terrestrial Invasive Plant Species



Japanese barberry



Oriental bittersweet



Burning bush

Figure 12: Regional distribution (presence/absence by county) of three invasive plant species. EDDMapS, 2011

To provide additional context to present day invasive plant management concerns, it is instructive to trace the invasion history of several non-native plant species-- their “escape” from cultivation, and spread over the regional landscape.

Japanese barberry (*Berberis thunbergii*) was introduced in the U.S. in 1875 at Boston’s Arnold Arboretum (Silander and Klepeis, 1999). Eastern Massachusetts nurseries were selling it as a hedge plant and ornamental by the late 1800s. There is little evidence that it had naturalized in the region prior to 1920, but by the 1930s Japanese barberry had spread in concentric circles around Boston and New York. Based on herbarium records and other sources, Japanese barberry was recorded in fewer than 10 counties in 1920. By 1940 it was reported in 25 counties, and in another 20 years, it was recorded in nearly 50 counties. By the 1960s and 1970s it had become recognized as a serious invader of many natural communities in the landscape (e.g., closed forests, woodlands, wetlands, meadows, pastures, fence rows, waste places, etc.) It had spread to 100 counties by the late 1980s.

Today Japanese barberry is widespread, often forming dense continuous stands, especially in the Middle Atlantic States, and southern and central New England (see **Figure 12)**.

Oriental bittersweet (*Celastrus orbiculatus* Thunb.), native to Japan, Korea, and northern China, was introduced into the U.S. in 1860 as an ornamental and for erosion control. Naturalized plants were first collected in Connecticut in 1916. It spread to Massachusetts by 1919, and New

Hampshire by 1938. By 1974, Oriental bittersweet had spread to 33 states and was considered invasive in 21. Present distribution is throughout the northeastern and southeastern U.S. extending to the southeastern Great Plains (www.fs.fed.us/database/feis/plants/vine/celorb/all.html#Introductory).

Winged euonymus, also known as burning bush (*Euonymus alata*), was also first introduced in the United States in the 1860s as an ornamental. Gleason and Cronquist's 1991 *Manual of vascular plants of northeastern United States and adjacent Canada* described it as widely cultivated but only "locally escaped from cultivation" in the Northeast. By the turn of the 21st century, burning bush was considered locally invasive in many northeastern states (www.fs.fed.us/database/feis/plants/shrub/euoala/all.html#INTRODUCTORY).

Humans were responsible for the initial introduction and spread of these invasive plants. But even today this process continues in many states where there are no regulations or prohibitions on the sale of invasive plants through the nursery trade. Here in Massachusetts and in New Hampshire, the sale of all three of these invasive plant species is prohibited. But in Connecticut and Vermont only one of these three species, Oriental bittersweet, is banned. Maine and New York do not restrict the sale of any of them.

Table 8: Site preferences and effects of common terrestrial invasive plants on DWSP watersheds

	Light Preferences			*Site Preferences*				*Effects On*			*Frequency of Occurrence*
Species	***Full sun***	***Partial shade***	***Full shade***	***Dry to moist***	***Moist to hydric***	***Wetlands***	***Riparian areas***	***Overstory***	***Understory***	***Soil***	***(all watersheds)***
Autumn olive	X			X				None	Uncommon in forest	Nitrogen fixer	Uncommon except planted
Japanese barberry	X	X	X		X	X	X	None	Competes	Alters soil biota, chemistry (pH), structure, and function	Common on moist to wet sites
Black locust	X	X		X				Competes	Competes	Nitrogen fixer	Variable by watershed
Black swallow-wort	X	X		X				None	Competes via smothering		
Asiatic bittersweet	X	X		X	X			Strangles and smothers	Competes for light		Common; prefers disturbed sites, calcareous soils
Common and glossy buckthorn	X	X	X	X	X	X	X	None	Compete		Infrequently common
Common reed	X				X	X	X	None	Competes in wetlands	Alters soil hydrology; bioremediator	Increasingly common in wetlands with cattails

	Light Preferences			Site Preferences				Effects On			Frequency of Occurrence
Species	*Full sun*	*Partial shade*	*Full shade*	*Dry to moist*	*Moist to hydric*	*Wetlands*	*Riparian areas*	*Overstory*	*Understory*	*Soil*	*(all watersheds)*
Garlic mustard	X	X	X	X	X	X	X	None	Competes		Common except not currently present @ Quabbin
Goutweed		X	X	X	X			None	Competes		Uncommon (?)
Non-native honeysuckle	X	X		X	X			None	Early leafing; competes		Infrequently common
Japanese knotweed	X	X			X	X	X	None	Roadside, not interior		Common along roadsides
Multiflora rose	X	X			X		X	None	Competes		Increasingly common
Norway maple	X	X	X		X			Competes	Seedlings are shade tolerant		Common as roadside planting
Purple loosestrife	X	X				X		None	Competes in wetlands		Increasingly common in wetlands
Tree-of-heaven	X	X		X				Competes; rapid growth	Competes	Allelopathic	Spotty
Winged euonymous; burning bush	X	X		X				None	Competes but needs sun		Expansion from landscape plantings

NOTE: Detailed descriptions of each of the most common species are included in the Appendices of this document.

9 Past Management of Invasive Terrestrial Plants on DWSP Watersheds

Over the past decade or so, as the problem with invasive plants began to receive more attention, a variety of efforts to control these plants has taken place across the watershed system:

- Roadside mowing of Japanese knotweed has occurred as part of the regular maintenance program, but largely resulted in the continuation, and sometimes in the spread, of these populations.
- Some of the wildlife plantings of species like autumn olive or winged euonymus that were dutifully installed in the 1980s were systematically removed in the late 1990s, although some of these had spread well beyond the initial plantings.
- For several years, purple loosestrife has been pulled along the banks of Pottapaug Pond in the Quabbin Reservoir watershed and in other areas, but without much landscape level effect.
- Reductions of common reed have mostly been associated with flooding activities by beaver, although expansions have outpaced reductions.
- Several large and smaller Norway maples were removed from roadsides in Dana Common at Quabbin.
- Quabbin Park maintenance crews have battled with limited effectiveness against the continuous expansion of oriental bittersweet. A population of bittersweet that was infringing on a small population of the watch-listed maple-leaved goosefoot in the Pottapaug Natural Area has been repeatedly cut and pulled by hand.
- Small sections of Japanese barberry have been brush-sawed, mowed, pulled by hand and by grapple, and burned with limited long-term reduction.
- Garlic mustard has been pulled and repeatedly mowed at the Ware River and Wachusett watersheds.
- Glossy and common buckthorns have been mowed on disturbed sites and pulled with a ‘weed wrench’ a few plants at a time from sites within the woods at the Quabbin and Ware River watersheds.
- Multiflora rose frequently occurs near roadsides or on the edges of fields, where it has been either deliberately or routinely mowed back, resulting in at least temporary reductions.

Until 2007, none of these efforts were carefully monitored.

9.1 Terrestrial Invasive Plant Management at Wachusett and Sudbury Reservoir Watersheds, 2005-2010

Beginning in 2005, DWSP Foresters on the Wachusett and Sudbury watersheds began deliberate efforts to control invasive plants, focusing on garlic mustard, black swallowwort, and Japanese stiltgrass.

9.1.1 Garlic Mustard

The forestry staff began noticing patches of garlic mustard in May and June of 2005. Two extensive patches were found: one in West Boylston off the end of Malden Street, and one in Southborough around the shaft building and landfill off of Route 30 just west of the Dam. Smaller patches were found that year at the detention basin outflow on the entrance road into the Sudbury Dam. In June of 2005, weed trimmers were used to cut all plants.

In May of 2006, those same areas were again cut with trimmers. In addition, several more areas were found and cut. In May of 2007, all the same areas were cut again, in addition to many new sites, including a site over an acre in size on Wachusett Street in Holden opposite the north end of Unionville Pond. A hiatus occurred in 2008, but treatments were resumed in 2009, when staff started hand-pulling and bagging plants from the scattered small populations. The existing larger populations were not treated in 2009. In 2010, extensive control efforts resumed and attempts are being made to pull or cut every known population at Wachusett and most at Sudbury.

Where populations occur along DWSP property lines, efforts have been made to educate abutters about the issue. In some cases staff has been given permission by an abutter to cut garlic mustard outside the DWSP boundary where the population is contiguous and can be efficiently treated. Wachusett Greenways has agreed to work at controlling an infestation found in 2009 at the Rail Trail in West Boylston. Control work began there in 2010.

To date, nine separate populations of garlic mustard at the Sudbury Reservoir have been mapped and documented on DCR land (several others have been identified on adjacent, non-DWSP land), some small and some quite extensive. At Wachusett, the count is up to 41 locations. There is only one treatment site where mustard may have been eliminated. The location is a small population that was newly discovered in 2009 near one of the gates. Only robust mature plants were seen then, and were hand-pulled and bagged. The following year no plants were seen at that site. Otherwise, the infestations persist at every other site. Treatment will continue until seed banks can be exhausted at each location.

Labor effort was not tracked in prior years, but in 2010 approximately 65 person-hours were spent hand-pulling and 13 person-hours weed-trimming garlic mustard.

9.1.2 Black Swallowwort

Forestry staff have documented three separate patches of swallowwort at Wachusett. The first was found in 2004 at the entrance to the Paddock acquisition on Griffin Road in Sterling. This population began on an abutter's yard waste pile near a DWSP gate, and has since spread extensively. The second location is on the DCR North Dike in Clinton. In 2005 it was seen growing on the fence line inside Gate 38. Since then, it has invaded grassy open areas, shoreline, rip-rapped areas, and forest from Gate 38 all the way to the Spillway. The third location, discovered in 2005, is located at the intersection of the power lines and West Boylston Brook inside Gate 25 in West Boylston.

The only attempt at control was made in the summer of 2006. Weed trimmers were used on a portion of the colony inside Gate 38, along the shoreline and rip rap. Only a few hours were spent doing this, but the foresters quickly concluded that it was not going to have much of a long-term impact on the population. The plants are tough, and the ability of the machines to reach all the areas was limited.

9.1.3 Japanese Stiltgrass

Japanese stiltgrass is beginning to appear on the Wachusett Reservoir watershed in small but expanding patches. In 2010, Forestry and Natural Resources staff spent parts of three days pulling stiltgrass from an area along Muddy Brook, just before it enters the reservoir. An area estimated at just under an acre and situated along either side of approximately 1,200 feet of the brook was cleaned of readily visible plants. Sixty person-hours were used to clean this area, from the delta at the mouth of Muddy Brook to a railroad track above, filling ten 30-gallon trash bags with plants. While this effort should slow the spread of the plant to the reservoir, where seed could move further along the shore, there is an additional half acre of dense stiltgrass above the railroad track that is not on DWSP property, so follow-up is definitely required to gain full control over this population.

9.2 Pilot Quabbin Watershed Forest Invasive Plant Management Program

In the summer of 2007, the Division hired a crew consisting of an Assistant Forester (crew leader) and two seasonal park laborers to implement a pilot program to deliberately reduce invasive plants in specific locations and to document the effort, its cost, and its short- and long-term effectiveness. This crew did not use herbicides but instead used a variety of mechanical removal techniques to address pre-selected representative invasions. The initial objectives are described below.

9.2.1 Summer 2007 Objectives

The pilot program was designed to test manual treatment control method techniques on five invasive species at specified areas (see **Table 9**). The Division will monitor the effects of these treatments to inform future, larger-scale efforts to control these species.

Table 9: Quabbin invasive plant control efforts, summer 2007

Species	Areas	Method of Control	Method of Disposal
Japanese knotweed	1. Gate 8	Pull carefully to remove most of plant. Cover pulled area with black plastic or thick cardboard or other light-excluding material. Alternatively, cut and remove plants. Repeat every 1-2 weeks through August.	Bag and remove to burn site. Treat as toxic; fragments as small as ½ inch can restart a colony.
Oriental bittersweet	2. Pine south of Windsor dam 3. Administration building 4. Rotary by power plant	Cut larger diameter stems that have climbed; ground stems should be pulled. Repeat cutting as re-growth occurs	Bag all removed plants and compost or burn. Large stems cut and leave in trees to die.
Japanese barberry	5. Roadside uphill from Enfield Lookout	Cut with brush saw or mow (skid steer with lift able rotary mower); then torch or pull stumps. Repeat treatment as re-growth occurs	On site. Cut and leave or chip or pile to burn.
Purple loosestrife	6. Pottapaug Pond	Timing is critical. Mechanically pull and bag plants after flowering but before seed is set (note: one plant can throw 500,000 seeds)	Bag and remove to compost or burn site

9.2.2 Summer 2007 Program Results; 2008, 2010 Updates

The purpose of the Quabbin Invasive Management Program the pilot project was to test the use of different types of mechanical treatments for the removal and elimination of various invasive plant species. The species that were chosen for removal were the invasive plants that are most abundant on the Quabbin watershed. The six sites that were chosen represent a broad selection of soil types and topography. Future treatments of invasive plants will be informed by the results of this pilot project.

9.2.2.1 Area I

Location: Gate #8, Pelham (see **Figure 13**).

Species targeted: Japanese knotweed *Polygonum cuspidatum.*

Treatment: Pulling, cutting and covering.

Overview: In this location the invasive treatment was by hand pulling and cutting of all larger stems. The material was removed from the site and was composted in an area that would minimize the chance of spreading the plant to non-infected areas. Knotweed is very easily spread. Even small pieces of the plant stem or root will start a new colony if the material comes into contact with moist soil. One section of the treatment area was covered in 6 mil black plastic to remove light and water from the residual root systems of the plant. All areas were monitored and any re-growth was cut on a weekly basis.

Observations: The plant is being spread by road maintenance. The cutting of roadside plants spreads them further along the road. Many small plants were discovered in areas where road spoils were dumped. Also sediment traps and drainage areas were prime sites for new colonies to start. These areas collected fair amounts of cut plant material from roadside mowing. Also notable was the existence of colonies in gravel banks and parking areas where sites would be assumed to be hostile to its growth. After first treatment, re-growth occurred at a rate of one to two feet per week. Follow up treatment commenced immediately. Mechanical treatment eventually reduced plant growth to around 3 inches per week as season progressed. Treatment was very labor intensive. Total treatment area was less than 300 square feet and consumed over 140 labor hours over the course of the project. As of last field inspection no re-growth has occurred under plastic covered areas.

2008 Follow up: The black plastic was still in place, but had degraded and been punctured in a few places by wildlife. Knotweed stems were growing through these breaks in the plastic. The plastic was left in place, and the surrounding area that had been treated in 2007 was cleared to bare soil with brush saw, weed whacker and backpack blower, and then reseeded with bank mix grasses.

2009, 2010: There was no additional treatment in 2009. Inspected in May of 2010, the black plastic is still in place, with knotweed stems growing through the scattered holes noted in 2008. The surrounding area that had been mechanically cleared and seeded in 2008 has been re-colonized by knotweed.

9.2.2.2 Area II

Location: Pine stand south of Windsor Dam.

Species targeted: Oriental bittersweet *Celastrus orbiculata.*

Treatment: Cutting

Overview: This area was heavily infested with bittersweet. Most of the pine trees had large colonies of vines growing into the trees in excess of thirty feet. Many trees had their crowns completely covered. The forest floor was also covered with the vine as well as privet, barberry, and other invasive species. All vegetation (except for the trees) was cut in the treatment area. The vines that grew into the trees were cut into sections to kill the vines and prevent strangulation of the trees.

Observations: Some of the vines were over 6 inches in diameter and could only be cut with a chain saw. Upon cutting all plants died quickly. Re-growth occurred within two weeks and the plants began to climb back over existing brush. Larger cut stems began to sprout and climb once again up the trunks of the trees. Due to the density of the trees, treatments could only be done with powered hands tools as tractor access was impossible.

Follow up: One follow up treatment was performed to attack the plant in its vegetative state before it became woody. Total labor expended was 175 hours and treatment area was less that 3\4 acre.

9.2.2.3 Area III

Location: Administration building.

Species targeted: Oriental bittersweet *Celastrus orbiculata.*

Treatment: Cutting and removal.

Overview: This was an area of 900 square feet where invasive bittersweet had over taken the original plantings. All plant material was cut and removed and the area later reseeded to return to lawn. No further treatments were performed. The area of rip rap around the water's edge was also treated as was the roadsides where invasives were present.

6/19/07 – Untreated

6/19/07 – After cutting and hand pulling.

6/19/07 – 6 mil black plastic placed over part of 300 sq. ft. treatment area.

Treatment area not covered by plastic was re-cut weekly through the growing season

6/4/08 – One year later. Knotweed not covered by black plastic continues to thrive.

5/20/10 – Three years post treatment. Knotweed growing through holes in plastic and robust elsewhere.

Figure 13: Area 1 - Gate 8 road knotweed test treatment

Observations: Fifty labor hours were used in this treatment area that was reseeded. The area will be repeatedly mowed so invasive control should be successful. This treatment would not be practical in most of the Quabbin landscape as seeding and regular (bi-weekly) mowing would not be practical or desirable. The sides of the road and the rip-rap area adjacent to the reservoir will need, at a minimum, yearly cutting to maintain the reduction of the invasive. Initial treatment in this area consumed 150 hours of labor. Yearly cutting may take as long due to the difficult terrain.

9.2.2.4 Area IV

Location: Rotary by Winsor Dam power plant (see **Figure 14**).

Species targeted: Oriental bittersweet *Celastrus orbiculata.*

Treatment: Cutting and removal and covering.

Overview: A 400 square foot area of bank was treated by cutting and hand pulling all plants. The bank was raked and all material was removed for composting. The entire area was covered with 6 mil black plastic to prevent water and sunlight from reaching the treated area. No other treatment was performed. The plastic will remain until well after frost or later.

Observations: No re-growth occurred under the plastic. Small sprouts began and succumbed to lack of sunlight. Forty hours of labor were used on this treatment. It is unknown how long the site will remain free from invasives once plastic is removed. Mowing or over-seeding may be an option on sites treated this way. This may be a viable treatment of small sensitive areas, as long as follow up treatments are continued.

2008 Follow up: The plastic tarp had partially slid down the 45 degree slope over winter. Few plants had survived under the portion of the treatment area that had remained covered. A slope mix of perennial grasses was sown in mid June.

2009, 2010: No additional treatment in 2009. In July of 2010, the treatment area had become completely overgrown with approximately 50% bittersweet and 50% *Rubus* where the grass had been sown.


6/19/07 - Prior to any treatment. 6/19/07 - After cutting, hand pulling and raking.


9/12/07 - After almost 3 months with black plastic covering 400 sq.


8/20/08 - Grass had been sown in mid June. 7/30/10 - *Rubus* and bittersweet have out-competed the grass.

Figure 14: Area IV, bittersweet test treatment at rotary by Winsor Dam power plant

9.2.2.5 Area V

Location: Roadside below Enfield lookout.

Species targeted: Japanese barberry *Berberis thunbergii.*

Treatment: Cutting and removal.

Overview: The treatment area was a roadside patch of very heavy Japanese barberry. A treatment area of 600 square feet was selected and all of the invasive plants were cut with a brush saw and removed. The purpose was to remove the seed source but also to gain access to the stumps of the cut plant. A group of 10 of these plants was selected to be burned with a propane torch. A high flame was applied to each stump for three to five minutes to ensure total desiccation. Another group of five stumps was selected for pulling or digging for total removal. The rest of the treatment area was left as a control area. The total area was treated as needed to control any re-growth.

Observations: Re-growth was significant after four weeks on the site. The burned stumps did not re-sprout from the stumps themselves, but did from the intact root mass. The root mass was unaffected by the heat treatment. The soil around dug stumps did not sprout as quickly. New plants began from the roots left in the soil showing that total removal was not accomplished. The control plants started to re-sprout from the cut stems and put on rapid growth once started. The entire site was re-cut to set back the re-growth further. Total labor hours were over 100 and continued presence of the invasive is certain.

9.2.2.6 Area VI

Location: Pottapaug Pond.

Species targeted: Purple loosestrife *Lythrum salicara.*

Treatment: Hand pulling.

Overview: The target area was the bank of the pond heading northeast away from the fishing area and the main body of the reservoir. A survey of the reservoir itself found no evidence of the invasive. The goal was to prevent the spread of the plant into unaffected areas. The banks of the pond showed scattered infestation starting at the boat launching area and proceeding along both banks. Using access by both foot and by boat, the banks were searched and any plants found were removed by hand pulling. In the areas where boat access was impossible, a foot survey was done. This ensured complete coverage. Plants were bagged and removed off site for composting.

Observations: Identification was difficult until the plants were in full bloom. The same areas needed to be examined multiple times to ensure that plants were not missed as younger plants matured. It was common to find new plants in areas that were assumed to be free from the invasive. Pulling was almost impossible where the loosestrife grew interspersed with blueberries. The loosestrife roots would become tangled with native woody species making it impossible to remove before they snapped. In this case, as much of the stalk and flowers were removed as was practical. Including pre-treatment screening, over 160 labor hours was involved in the treatment. At most, no more than 30% of the total bank area was treated. Massive populations of plants in the northern end where deemed not practically treatable in this fashion.

9.2.3 Costs for Summer 2007 Pilot Program

In an effort to understand the costs associated with using a strictly manual approach to reducing these plant populations, the labor and acreage figures above were summarized as follows:

Knotweed
300 sq ft = (300/43,560) = 0.007 ac
140 hours* @ $15/hr = $2,100 for 300 sq ft
* note that this area was revisited and retreated weekly and included the spreading of black plastic to test its effectiveness in killing the remaining plant material

Bittersweet
Area I
0.75 acres treated; 175 hours @ $15/hr = $2,625
Area II
900 sq ft = (900/43,560) = 0.02 ac treated; 50 hours @ $15/hr = $750
Area III
400 sq ft = (400/43,560) = 0.009 ac; 40 hours @ $15/hr = $600

Japanese Barberry
600 sq ft = (600/43,560) = 0.014 ac; 100 hours @ $15/hr = $1,500

This crew also pulled purple loosestrife from the banks of Pottapaug Pond when it was in bloom. The area covered is unclear, but they devoted 160 hours @ $15 per hour = $2,400.

Total crew time recorded above was 665 hours, or $9,975, with which they treated approximately 3 acres total, including the loosestrife. Total average cost is therefore about $3,000 per acre for initial treatment. Some of the area treated received multiple follow-up treatments during the same summer; all of the area treated will need follow-up treatment in subsequent years to remain invasive-free, but as control is gained, follow-up treatment should decline in cost.

9.3 *Other Control Efforts at Quabbin and Ware River Watersheds*

9.3.1 Asiatic Bittersweet Threatening a Rare Plant

In August 2003, a single small population of Maple-leaved goosefoot (*Chenipodium gigantospermum)*, a MA Watch List species, was identified on the east-facing cliff and talus slopes within the Pottapaug Pond Natural Area. At the same time, an approximately 20m x 20m patch of Asiatic bittersweet was noted in the immediate vicinity. During the fall of 2003 and again in the spring of 2004, this isolated occurrence of bittersweet was hand-pulled and removed in an effort to protect the rare plant from encroachment. Unfortunately, a porcupine took up residence in the talus and used a path that included the goosefoot during 2004, so that the rare plant was heavily impacted. Repeated observations since that time have confirmed that the rare plant is gone from this site. The bittersweet was successfully under control at the 2004 observation of this site.

Figure 15: Pulling bittersweet in Pottapaug Pond Natural Area

9.3.2 Garlic Mustard at Ware River

A small roadside infestation of garlic mustard was discovered on the north side of Old Turnpike Road in the vicinity and mostly east of gate OT-3 in May 2007. Each spring for four years several small patches (the largest being approximately 600 square feet and 1,000+ plants) have been treated by manually pulling the stems and roots of the second year plants (prior to flowering) and as many of the first year seedlings as possible. Plants are bagged and removed from the site. In 2010, pulling occurred four times over a six week period starting in early April, with 6 hours time spent.

A couple of the colonies have shown partial reduction in numbers in 2010. One colony, the largest, extends under a concentration of downed branches, making access difficult. Knowing that the seed bank takes 5 to 7 years to become exhausted, manual control efforts will most likely be necessary for another couple of seasons.

10 DWSP Goals for Terrestrial Invasive Plant Management

The following sections outline the broad goals for a program of terrestrial invasive plant management on DWSP watersheds going forward. Details for meeting these goals are summarized in Section 11 as objectives for future management.

10.1 Goals for Education of Staff and Public

Successful management and control of terrestrial invasive plants requires a broad general awareness of the problem. DWSP field staff should have a basic orientation to the issues associated with these plants and, to the extent possible, the ability to identify the problem species so that their management can be addressed during the course of regular land management practices. For Natural Resources and Forestry staffs, as well as Environmental Quality, Ranger, and Watershed Maintenance staffs, the ability to accurately identify both known invasives and those migrating onto Division watersheds is critical to a successful early detection and eradication program. The public that spends time visiting these watersheds can also be an important ally in the invasive plant control process, by providing information on populations seen and by understanding the ways in which their activities can exacerbate the problem (e.g., by inappropriate disposal of vegetative waste that includes invasive plant propagules). Therefore, it is the goal of the Division to provide both staff training and public education in the issues of invasive plants and in identification and notification procedures.

10.2 Goals for Early Detection/Rapid Response (ED/RR)

It is likely that new non-native plants with invasive properties will regularly arrive on the watersheds over the course of time. The simplest invasive plant population to control is one that is detected early, when it is present on a small enough area to make eradication relatively simple. Therefore, early detection (ED) is a primary goal for control of invasive plants, which relies in turn on the successful education of both internal staff and the general public in the recognition and reporting of these populations. Understanding the threats posed by these species is critical to prioritizing their identification and control in a timely manner. Early detection must be followed by a rapid response (RR) that thoroughly eradicates a new invasion before it can become established and spread.

10.3 Broad Goals for Terrestrial Invasive Plant Control

For invasive species that have become established, the broadest goals for control are to understand which of these pose the most direct threat to the primary objective of producing clean drinking water in perpetuity as well as to native species populations (flora and fauna) and in particular those that are protected by endangered species regulations.

10.3.1 Goals for Water Supply Protection

The Land Management Plans for each of the DWSP watersheds have built the case that a vigorous, diverse, and actively regenerating forest provides superior protection for an unfiltered drinking water supply. Therefore, to the extent that invasive species threaten the maintenance of this forest cover and its ability to regenerate following natural or deliberate disturbances, these invasive populations threaten the best protection of the drinking water supply. A broad Division-wide goal is to understand where and under what conditions each invasive plant species may have an impact on the maintenance or regeneration of the forest, then to reduce that impact.

While the Division owns significant percentages of its watersheds, invasive plants do not respect boundaries. The efficient, effective control of invasive intrusions depends on the reduction of the species not just on Division property but on adjacent private or other public lands as well. It is therefore a broad goal of the Division to promote awareness of the relationship between invasive species and water supply protection among abutting landowners.

10.3.2 Goals for the Protection of Biological Diversity

10.3.2.1 Goals for Protecting Rare Populations

DWSP is required by law to provide protection for both state and federally listed rare or endangered species. Invasive plants have the potential to disrupt the best designed plans for protecting populations of listed plant species, either by directly overwhelming the plants or by altering critical conditions of the habitats in which they are growing. Therefore, it is a Division goal to identify both the location of these rare species and the proximal presence of invasive plant populations, and to prevent the invasives from negatively impacting the rare species.

10.3.2.2 Goals for Habitat Protection

In addition to rare species, there are habitats or communities within the watersheds that are considered rare or uncommon (e.g., shallow-soiled outcrops or talus slopes supporting such plants as *Adlumia fungosa* or *Clematis occidentalis*, or a pitch pine-oak forest type) or otherwise critical habitats supporting overall biological diversity (e.g., wetlands). Within rare upland communities, the specific goal regarding invasive plants is to prevent changes to the habitat that might result from monopolization by an intruding invasive plant. Within wetlands, invasive terrestrial plants such as *Phragmites australis* or *Lythrum salicaria* have been documented to dramatically alter hydrology, nutrient cycling, and/or species composition. It is a Division goal for both habitat and water quality protection to reduce the impact these species have on the functioning of wetlands.

11 DWSP Invasive Plant Management Objectives and Methods

Addressing the goals summarized in Section 10 will be an incremental process, implemented as time and budget allow, within a dynamic set of priorities that respond to changes in the regional and local populations of terrestrial invasive plant species and to an increasing understanding of the ways in which these species are in conflict with Division management priorities and ways in which they are best controlled.

11.1 Education of DWSP Staff and the General Public

The terrestrial invasive plant problem is only dramatic to those who are aware of the difference between a predominately native flora and one that is being invaded. This fact contributes to the insidious nature of an invasive plant's spread. However, once staff or members of the general public learn to identify the most common invasives and their monopolizing growth habits, they begin to "see them everywhere", and at that point become more interested in objectives for control and management. The will to manage and control is therefore dependent upon successful education.

DWSP Natural Resources and Forestry staff are professionally responsible for plant identification, including terrestrial invasives, and are acutely aware of the problem, confronting it regularly in planning and implementation of land management. Other staff are variably aware of these plants, even though some activities (e.g., mowing, moving brush, scraping organic material from roads) can significantly exacerbate the problem by spreading seed and vegetative propagules.

> ***Objective for education of DWSP staff***: NR section will work with staff whose job responsibilities intersect with terrestrial invasive plants and provide them with training opportunities for understanding the issue, learning to identify the plants of concern, and understanding the concepts of early detection, prevention, and control.

Invasive plant awareness in the general public is also widely variable. There are significant volunteer efforts undertaken regularly by state and federal agencies (e.g., DAR, DCR, DFG, USFWS Silvio O. Conte National Fish and Wildlife Refuge) and NGOs (e.g., The Nature Conservancy, New England Wild Flower Society, Massachusetts Audubon Society, the Invasive Plant Atlas of New England project) in Massachusetts to provide education and to work on identification and/or control, but there remains significant need for education of the general public regarding the problems and the potential role of individuals in preventing them.

In May and June of 1997, through a small grant from the Massachusetts Forest Stewardship Program, DWSP staff and trainers from outside the agency put on two day-long workshops on protecting rare native plants and discouraging exotic invasives through identification and management. These workshops drew 44 participants to sites at Quabbin and in the Blue Hills for intensive classroom and field training. In September, 2008, NR staff hosted a one-day workshop at Quabbin for the general public specifically on the problem of terrestrial invasive plants on DWSP watersheds. In addition to both class discussions and field training in identification, this workshop initiated an effort to directly encourage the public to fill out field forms to identify invasive plant populations they encountered, with a “reward” (a copy of a publication) for turning in 10 or more forms.

DWSP interpretive staff has assisted this effort on an ongoing basis, providing literature that becomes available, support for workshops, and displays at the Quabbin Visitor Center. The summer control and mapping efforts of seasonal staff during 2007-2009 were summarized in a large poster displayed at the Visitor Center during the spring and summer. It is difficult to gauge the success of these displays in reaching and informing the general public, but the Quabbin Visitor Center is visited by thousands of members of the public in a typical year, so there is lots of exposure.

Objective for public education: NR staff will continue to work with Quabbin Interpretive staff to provide displays and reports on DWSP terrestrial invasive plant management efforts for general distribution as well as opportunities for teachers, school groups, or other organizations to become better informed on the problem and its solutions through presentations and workshops. Similar efforts will be organized by NR working with the interpretive staff in the Wachusett section.

11.2 Terrestrial Invasive Plant Control

Given the current extent of terrestrial invasive plant populations within and adjacent to DWSP properties on the Quabbin, Ware River, Wachusett, and Sudbury watersheds, and the limited availability of staff and budget to address this problem, DWSP has set current priorities for the allocation of these resources.

11.2.1 Priority 1: Buffering Rare Plant Populations

Existing and newly discovered rare plant populations are protected by endangered species laws and regulations and by priorities for biological diversity on DWSP properties. Invasive plants encroaching on these populations present a clear danger to their survival and addressing these threats is a direct responsibility of the agency. Therefore, these populations will be visited annually by NR staff and assessed for the threat of invasive plants within a 300 foot buffer area surrounding the population. Invasive plants discovered within this buffer will be eliminated, in part to meet the requirements of 321 CMR 10:00 Massachusetts Endangered Species Act Regulations, which states that *"Unless specifically required otherwise by statute, localities on state owned lands that provide habitat for state listed species shall be managed for the benefit of such listed species. Said agencies shall give management priority to the protection, conservation, and restoration of Endangered, Threatened, and Special Concern species occurring on state owned lands."*

> ***Objective for invasive control near rare species populations****:* Remove terrestrial invasive plants discovered within 300 feet of known rare plant populations. Removals or other treatment of invasive plants within these areas will be done in consultation with professional botanists and/or the Natural Heritage and Endangered Species Program to assure there will be no collateral damage to the protected species.

11.2.2 Priority 2: Early Detection/Rapid Response (ED/RR)

Early detection and rapid response are ongoing activities and are the second priority of Division invasive plant management. "Early Detection" refers to the accurate identification of an invasive terrestrial plant species that has not been previously recorded on or near DWSP properties, or has not yet expanded beyond localized, small populations. "Rapid Response" implies the immediate eradication of the species while its population is small and sufficiently contained to allow complete control (kill or remove) and the prevention of re-growth.

> ***Objective for Early Detection/Rapid Response****:* In support of the goal to protect the watersheds against the establishment of new invasive terrestrial plant populations, the Division will implement an Early Detection/Rapid Response (ED/RR) system.

11.2.2.1 Early Detection

1. Preliminary risk assessment for high priority species: The Massachusetts Invasive Plant Advisory Group (MIPAG) maintains a list (see #4) of "Early Detection" species (www.massnrc.org/mipag/invasive.htm). This list will be reviewed regularly by NR staff to determine which of the listed species would pose the greatest threat to the DWSP watersheds or a direct threat to human health if they were to become established here, and where they are most likely to occur, and to publish updated lists periodically (at least annually).
2. Formal detection activities: Quantitative and qualitative measures of invasive plant presence and abundance are now formally included in existing surveys, including annual regeneration surveys, forest stand analyses, annual silvicultural lot reviews, and the decadal Continuous Forest Inventory. Specific invasive plant surveys that occur in support of the other priority objectives described in this section will also monitor for new invaders. NR staff will summarize the results of these formal surveys periodically.
3. Informal detection activities: DWSP staff will be trained in the identification of high priority potential new invaders so that they can extend the reach of the early detection network to areas of the watershed that they traverse in the course of their regular field work. For example, Rangers traverse widely within the watersheds, Environmental Quality staff routinely survey major tributaries and annually visit every island, and the Watershed Maintenance staff have a strong presence on the road network and at disturbed areas and open fields, areas that are likely habitats for some new invaders. NR will develop invasive plant report forms for these staffs to carry with them in the field. In addition, NR staff will coordinate with Interpretive Services staff in developing a program of workshops, posters at the Quabbin Visitor Center, and reporting sheets for the visiting public.
4. Research: DWSP is represented on the MIPAG (www.massnrc.org/mipag/index.htm) and thus has regular access to the latest research and developments regarding new and potentially invasive plant species. MIPAG publishes a list of species that have been evaluated and classified as either invasive, likely invasive, or potentially invasive and either have not yet been found in Massachusetts or occur in small enough populations that eradication is still a realistic possibility. These lists are updated with alerts, via email and web postings, on the discoveries in the state of populations of new species.
5. Training: NR staff will take the lead in arranging training for DWSP staff in Early Detection species identification and reporting.
6. Voucher specimen collection: A voucher specimen of any new invasive species will be collected by NR following protocols provided by the UMass Herbarium.
7. Authoritative verification: If necessary, species identification will be verified by a professional botanist before the eradication response is started.

11.2.2.2 Rapid Response

1. Standing response team: There will be a core response team comprised of a staff member from NR, Forestry, and Watershed Maintenance at each watershed.
2. Training in control methods: Experience in control methods likely to be used against an Early Detection species will be gained through ongoing efforts to control existing invasive plant populations.
3. Response contingency budget: The core response team will develop a contingency budget. The funds in such a budget line item may go unused in some years, but when the need does arise, "a stitch in time" will indeed "save nine."
4. Prior understanding of potential legal constraints: The core response team will consult with NHESP whenever an Early Detection species is discovered, to ensure that any control actions will not negatively impact a listed rare or endangered species.

11.2.3 Priority 3: Forest Regeneration Near Intakes

The riparian zones adjacent to tributaries and the reservoirs that are also close to intakes are considered to be critical zones of hydrologic sensitivity for the protection of the quality of the water entering the distribution system. This zone is defined generally as the area of land within one-half mile radius of any intake and also within the watershed of that intake. The ability of the forest within this intake protection zone to regenerate to a diverse forest following natural or deliberate disturbances is considered by DWSP to be critical to maintaining the biological filtration that protects the water supply. The estimated area of land within these zones at each watershed is: 20 acres around the Chicopee Valley Aqueduct at the Quabbin Reservoir (most of the zone around the CVA is either water or off-watershed land); 180 acres around the Shaft 12 intake to the Quabbin aqueduct; 250 acres around the Ware River intake to the Quabbin aqueduct; and 70 acres around the Cosgrove aqueduct intake at Wachusett Reservoir, for an overall total of 520 acres.

Objective for maintaining regeneration near intakes*:* Survey intake areas for invasive plants and maintain terrestrial invasive plant populations at levels that allow native tree regeneration to become established and persist to maturity.

11.2.4 Priority 4: Inventory and Control of Terrestrial Invasive Plants within Proposed Regeneration Harvests

DWSP Land Management Plans call for active forest management to regenerate small portions of the watershed forest each year, in an effort to diversify age structure and species composition of these forests. As deliberate disturbances, these regeneration harvests have the potential to stimulate the expansion of invasive plant populations that may be present or nearby. These proposed harvest areas are reviewed internally each year, at least one year prior to their implementation. The Forestry staff will conduct standardized surveys for invasive plants designed to both detect every invasive species present and provide quantitative measures of density and distribution of the invasive plant population. The results of these surveys as well as maps will be included in the pre-harvesting review report. Before the harvest proceeds, the populations within the harvest area will be assessed and controlled to levels believed to allow native forest regeneration to become established and survive to maturity. Forestry and Natural Resources staff will select methods for controlling these populations from among those agreed upon by DWSP.

***Objectives for invasive control within harvest areas**:* Inventory TIPs during internal review process for proposed harvests and prior to harvest, control discovered populations to levels that will allow the establishment and growth of regeneration.

11.2.5 Priority 5: Protection of Biological Diversity in Wetlands

Similar to the riparian zones within the intake protection zones, wetlands are generally critical water resource areas for a variety of reasons. They provide short-term storage that attenuates flooding and the associated movement of sediments and nutrients, and they provide for uptake of nutrients prior to release of these waters to surface flow. Wetlands are also critical habitats for many plants and animals, and as such are important components supporting biological diversity. The most common wetland invasives within Division properties are common reed (*Phragmites australis* ssp. *Australis)* and purple loosestrife (*Lythrum salicaria).* The literature does not indicate direct water quality threats associated with these or other wetland invasive plants versus native wetland plants, so the concern of the Division is the impacts on biological diversity in these wetlands. NR staff will continue to survey permanent wetlands for the presence of invasive species and, as time and budgets allow, will work to first remove recently-established small populations and then to control the expansion of larger, well-established populations of these invasive species.

***Objectives for control of biological diversity in wetlands**:* Survey permanent wetlands for presence of invasive plant species, and as time and budgets allow, remove recently established populations and work to control the expansion of well-established populations.

11.3 Modifications to Existing Management Practices

11.3.1 Silvicultural Adjustments to Reduce Invasions

In areas of the watersheds in which propagule pressure (the presence and abundance of seeds and other sources of plant reproduction) is high, the relationship between the range of invasive plant habits and the range of habitats produced by silvicultural treatments may be critical to adjusting silviculture to reduce invasions. While these areas will likely eventually be invaded as natural disturbances take place, careful limitations in silviculture: a) can reduce the suitability of the habitat for the invasives that are present, and b) may reduce susceptibility to invasives overall, by increasing native plant diversity (Hughes et al., 2007; Waring and O'Hara, 2005).

For instance, as *Celastrus orbiculatus* is primarily an edge species, silviculture proposed within an area subject to *Celastrus* invasion should reduce the ratio of edge to opening rather than increase it. This would mean focusing on fewer, larger openings rather than on more, smaller openings. As evidence of this issue on DWSP properties, the *Celastrus* that now occupies Webster Road plantations in Quabbin Park was unintentionally exacerbated by heavy thinning, which provided ideal habitat for the expansion of the vine (lots of edges with tall "ladders" to climb in the form of widely scattered mature residuals). On the other hand, if a shade intolerant invasive plant (e.g., *Ailanthus altissima*) is the species of concern, then limiting large openings and focusing on single tree or small group selection silviculture might discourage the expansion of the invasive.

> ***Objective for silvicultural modifications***: Within the annual internal review of proposed timber harvesting operations, DWSP will specifically survey the proposed lot and adjacent areas for invasive plants and will initiate invasive plant control measures and/or tailor the proposed silviculture accordingly.

11.3.2 Logging Equipment Inspection

Logging equipment routinely picks up soil and vegetative debris during the course of operating a timber harvest. When this equipment moves from one area to the next, it is potentially a vector for transporting invasive plant propagules. While absolute prevention is not practical, there is an ongoing need for education of the operators about the issue and for basic rules to limit this form of invasive transplantation.

Objective for logging equipment inspection: In order to limit the spread of terrestrial invasives via logging equipment, Division foresters will work to educate loggers about the issue. In addition, DWSP will implement logging equipment cleaning policies designed to minimize the likelihood that seeds or rhizome fragments of invasive plants are brought on to watershed lands, especially to areas that currently do not have invasive plant infestations. These policies are currently under development by DCR and will apply to both DWSP properties and those managed by the Division of State Parks and Recreation, Bureau of Forestry.

11.3.3 Field Mowing Practices

Watershed maintenance crews routinely mow fields and administrative or recreational areas. Mowing chops the vegetation in the mowers path and frequently carries debris along the route. When mowing passes through existing invasive plant populations that are capable of reproducing vegetatively, the risk of spreading these populations throughout the mowed area and/or the travel path of the mower can be substantial. A combination of education, routine mower cleaning, and avoidance of established invasive plants (unless the intent is to mow these species) will reduce inadvertent spreading of invasives during mowing. Timing mowing around invasive plants to occur prior to seed maturation may also reduce spreading.

Objective for modifying mowing practices**:** To reduce the spreading of invasive plant populations through mowing, maintenance crews will receive training from NR staff in identifying invasive plant species and the timing of seed production. When mowing in areas containing invasive species, mowers will be cleaned before moving to uninfected areas. Infected areas will be avoided unless mowing is part of a treatment plan.

11.3.4 Road Maintenance Activities

Routine road maintenance includes the collection and transportation of soils and gravels that may contain invasive plant propagules. In order to assist with preventing this transportation, maintenance crews need to be aware of the plants considered to be invasive that grow on woods roads or roadsides.

When loam or gravel is taken off site from an area that contains invasive plants, contamination of the destination site may be prevented by watching piled material for evidence of these plants and eradicating new growth via mulching or otherwise killing these plants before the material is spread again. Routine road work also includes mowing, which may result in the transportation and spread of invasives if seed or vegetative material is captured on the mowing machine and released at other locations. To prevent this, operators must either avoid mowing when seed from the invasive plants in the area is viable, and/or pressure wash the mowing machine periodically to prevent the spread of propagules.

> ***Objective for road maintenance modification:*** To limit the spread of invasive material during routine road maintenance activities, NR staff will educate operators about the need to adjust the timing of these activities according to seed maturation dates, and the need to perform routine cleaning of mowing or other road maintenance equipment to reduce the spread of seed or vegetative material.

11.4 Invasive Plant Control Methods on DWSP Watershed Lands

DWSP intends to continue to use non-chemical control methods for the management of terrestrial invasive plants and will monitor and evaluate the results of these efforts for their safety, effectiveness and cost. However, there may also be situations where the judicious use of herbicides is the preferred approach. An example might be a rare plant population, sensitive to the disturbance associated with mechanical control methods, where professional botanists specifically recommend herbicide treatments, such as cut stump application, as the most protective and least threatening approach to removing the threat to the rare plant population. In these situations, a detailed site-specific management approach will be written that will include the justification for herbicides, the specific protocol that will be followed, and the precautionary measures that will be taken to ensure all resources are protected. These site specific documents will be written as needed and will be presented to the appropriate advisory committees and the public for review and comment.

11.5 Specific Projects Currently Designed or Underway

11.5.1 Protection of Listed (Special Concern) Purple Clematis (*Clematis occidentalis*) Population – Quabbin Reservoir

11.5.1.1 Background

While the location will not be specified here in order to protect the plant, there are two known populations of purple clematis, a Special Concern species in Massachusetts, within Division watershed properties. The long-term management of these populations includes efforts to eliminate populations of invasive plants from within a 300 foot buffer as part of the protection of rare and endangered species (Priority 1). While these populations are within unmanaged reserves on the watersheds, away from popular recreational areas, the NHESP status sheet on the species suggests that “invasive exotic plant species may over-shade or out-compete purple clematis at some sites”. In an effort to prevent this, the Division will survey for and control invasives within this buffer.

11.5.1.2 Extent of Problem

In the summer of 2011, a transect method designed to thoroughly observe the roughly 6.5 acre area contained within the 300 foot buffer surrounding both of these populations was surveyed by two NR staff. At one population, no invasive species were found. At the other, one large non-native honeysuckle and approximately 10 small Japanese barberry plants were discovered.

11.5.1.3 Control Approach

Due to the small numbers of invasive plants within these buffers, control will simply be eradication through mechanical pulling.

11.5.1.4 Resources Needed

This effort can be conducted by Division staff using Division equipment. Specifically the following will be needed:

1. 1-2 staff in late summer to pull these 11 plants.
2. Possibly a weed wrench or spade to ensure complete root removal.
3. 1 NR staff to evaluate the effectiveness of the removal on subsequent annual visits to the site.

11.5.2 Japanese Stiltgrass – Wachusett Watershed

11.5.2.1 Background

Japanese Stiltgrass (*Microstegium vimineum*) is an annual grass native to Japan, China, India, Malaysia, and Korea. Individual plants can produce up to 1,000 seeds per year that fall close to the parent plant, but may be easily moved by heavy rains, foot traffic, or vehicles. Seeds can remain viable in the soil for at least five years. Stiltgrass can form dense, extensive patches that displace native plants. The Invasive Plant Atlas of New England has documented stiltgrass in relatively few locations in Massachusetts, making it a strong candidate for an early detection and eradicationprogram (priority 2) when it is found.

11.5.2.2 Extent of Problem

Japanese Stiltgrass was first noticed in 2009 by a federal botanist as he travelled along Route 140 in West Boylston. Upon investigation, he documented that the grass along the shoreline of Wachusett Reservoir could be traced to a small tributary (see **Figure 16**). This population seems to have originated along the railroad tracks and has made its way along the drainage ditch associated with the tracks and entered a small stream that flows downhill towards the reservoir. The highest concentration covers approximately one acre on either side of the track. About 2.5 acres further down the tracks have fewer plants, and the remaining three acres on either side of the stream and the cove of the reservoir contain pockets of dense grass or scattered individuals.

11.5.2.3 Control Approach

In the late summer of 2010, Division staff attempted to control the further spread of the grass by hand-pulling and bagging the grass before is set seed. Starting at the reservoir, small teams spent 3 days hand-pulling, working their way upstream towards the railroad tracks. This effort was extremely labor intensive and did not address the source population. Future plans would rely on mechanical control. Specifically, the plan is:

1. Starting at the core population along the railroad track, the Stiltgrass will be mowed in late summer (August or September) when the plants are flowering, but have not produced seed. Mowing will be done by hand using weed trimmers.
2. Mowing will be conducted along the length of the affected railroad and along the stream to the reservoir. Because the Stiltgrass is often mixed in with other vegetation and can occur in small pockets, all vegetation within 10 feet of either side of the stream or railroad will be mowed.

3. Monitoring will be done annually to assess the extent of the population.
4. Mowing will continue as needed annually to exhaust the seed bed in this location.

11.5.2.4 Resources Needed

This effort can be conducted by Division staff using Division equipment. Specifically the following will be needed:

1. 3-5 Labor staff for 2-3 days during late summer to mow the entire population of Stiltgrass.
2. 3-5 gas powered weed trimmers
3. 1 NR staff to evaluate the effectiveness of the annual mowing and make recommendations for future mowing.

Figure 16: Japanese stiltgrass removal area near Route 140

11.5.3 Japanese Barberry – Quabbin Park

11.5.3.1 Background

Japanese barberry, historically planted around home sites, has become problematic for the regeneration of diverse native tree species as it is able to compete aggressively in areas with high deer populations, mesic to hydric soils, and partially to fully shaded light conditions. Barberry also may alter soil chemistry and nutrient loads in undesirable ways and supports high population densities of *Ixodes scapularis*, the black-legged or deer tick, which carries and transmits the spirochete bacterium (*Borrelia burgdorferi*) that causes Lyme disease in humans. Thus, barberry is among the species of highest concern on the Division's watershed lands. Ward et al. (2010), reported reasonably successful control of Japanese barberry using a combination of mowing and direct heating (propane torch). The purpose of this project is to see if this new technique can be applied cost effectively while achieving the desired control results on DWSP watersheds.

Figure 17: Webster Road barberry treatment area locus map

11.5.3.2 Extent of Problem

The Webster Road area within Quabbin Park contains foundations, old dump sites, and a small quarry, all of which draw the public a short distance into the generally open woods, where barberry cover ranges up to 100% and tick populations are high. Treatment will focus on areas in which barberry plants are generally less than four feet tall and occurring at densities not greater than approximately 30%, where it is believed control of these populations can be accomplished using the methods described below. There are several sites along Webster Road where barberry is cover is nearly 100%, but the initial strategy is to control the shorter, less dense expansion beyond these sites, where control is more likely.

Figure 17 shows the general area for proposed treatment at Webster Road. The pale yellow polygon is an area of approximately five acres of low to moderate barberry infestation around foundations and stonework that attract visitors. This will be the main focus area for initial treatment. The smaller, red and orange polygons are heavier concentrations of barberry. Barberry in these areas will not be treated (too tall, too dense for the Ward methods to succeed), but, if time allows, the less-dense populations surrounding these more concentrated sites will be treated to limit the expansion of barberry along Webster Road (see **Figure 18**).

11.5.3.3 Control Approach

Applying the methods developed by Ward, et al., 2010, a crew of three spent three half days mowing barberry plants in the study area with brush saws in mid-June, 2011. The cut plants were allowed to resprout during the subsequent eight weeks. A crew of three then returned in mid-August, one to torch and two to rake on a day when the ground was sufficiently moist to prevent unintended burning beyond the immediate treatment. About half of the sprout clumps were heated to glowing with the propane torch in about an hour and a half before the tank chilled and lost pressure due to the rapid flow rate of the gas. A second torching session (3.5 person hours) was conducted in early October, torching the remaining sprout clumps and re-torching those that had been burned in August and that were again developing sprouts. A third session (3 person hours) was spent torching overlooked clumps that had been previously cut but not burned, plus some clumps that had been previously burned and were resprouting. So far, compared to Ward's findings, it took the crews relatively more time at the mowing task and less time in the torching component. The treatment area will be monitored in the spring of 2012 to determine the percent mortality of the treated barberry clumps as compared to the 60-80% mortality reported by Ward.

11.5.3.4 Resources Needed

1. **Equipment**: Using portable brush saws is the most practical way to mow in this rough terrain. NR purchased two propane torches for the heating component of the study. Fire rakes worked well for prying small clumps from the ground or scraping duff from around the base of the clumps and exposing the root crown in advance of the torching.

2. **Staffing**: Ward, et.al., monitored time requirements for these treatments and reported that the initial mowing required 0.12 hours per percent cover and the propane torch treatment required 0.44 hours per percent cover, per treatment. Using these figures, and assuming 10% cover, we would expect that treating four acres will require a total of approximately five hours for mowing and 18 hours each for two torch treatments, or a total of 41 hours.

Table 10: Staffing estimates for Japanese barberry control in Quabbin Park pilot program

Webster Road: four acres of treatment	hrs/ac/%	acres	% cover	hours required
Initial brush sawing	0.12	4	10	5
Follow-up torch 1	0.44	4	10	18
Follow-up torch 2	0.44	4	10	18
TOTAL				**41**

Figure 18: Webster Road barberry treatment areas photographs

12 Estimating the Costs for Invasive Terrestrial Plant Management on DWSP Watersheds

There are significant sources of variability in each invasive plant control situation, making budgeting for the control of invasive plants on large ownerships such as the DWSP watersheds challenging. **Table 11** and its many footnotes are an effort to merge the somewhat limited cost data available with the current conditions of terrestrial invasive plants and their habitats on DWSP watersheds, to make a first-order estimate of the range of costs that might be expected in order to implement the primary objectives identified in this plan.

There are high and low cost estimates and copious footnotes to explain the origin of these calculations. The reader should also recognize that these are estimates for the initial treatment of areas included in each priority. It is uncommon for an established invasive plant population to be completely eradicated by the initial treatment, especially if seed or vegetative sources of regeneration remain within or proximal to the treatment area. However, once initial treatment has been achieved, the cost of follow-up maintenance, if vigilantly maintained, should remain significantly lower on a per acre basis than the initial treatment.

Note that where information is still lacking but eventually critical to setting budgets, the table below includes blank placeholder cells as reminders. Further monitoring efforts over time will enable these cells to be filled.

Table 11: Estimating costs of implementing DWSP terrestrial invasive plant management objectives

Priority Objectives	Watershed	Inventory Acres	Inventory Cost	Treatment Acres	Treatment Costs, Mechanical	Treatment Costs, Chemical	Treatment Costs, Biological
Buffer rare plant populations	Quabbin	130[1]	$2,400-$4,800[2]	6.5[3]	$1,599-$12,188[4]	$1,040-$2,113[5]	
	Ware River	19.5[6]	$360-$720[7]	1[8]	$246-$1,875[9]	$160-$325[10]	
	Wachusett	32.5[11]	$600-$1,200[12]	1.6[13]	$394-$3,000[14]	$256-$520[15]	
Early detection and rapid response (ED/RR)	All watersheds	All watersheds	See note[16]	2[17]	$790-$7,500[18]	$470-$1,300[19]	
Promote forest regeneration success in riparian areas near intakes	Quabbin	200[20]	$735-$1,470[21]	13.2[22]	$5,214-$49,500[23]	$3,102-$8,580[24]	
	Ware River	250	$900-$1,800[25]	16.5[26]	$6,518-$61,875[27]	$3,878-$10,725[28]	
	Wachusett	70	$270-$540[29]	4.6[30]	$1,817-$17,250[31]	$1,081-$2,990[32]	
Promote regeneration success on lots to be harvested.	Quabbin	400[33]	$1,200[34]	26[35]	$10,270-$97,500[36]	$6,110-$16,900[37]	
	Ware River	175[38]	$525[39]	12[40]	$4,740-$45,000[41]	$2,820-$7,800[42]	
	Wachusett	133[43]	$400[44]	9[45]	$3,555-$33,750[46]	$2,115-$5,850[47]	
Protecting biodiversity in wetlands.	Quabbin	Partially complete		34[48]	?	N.A.	$51,000[49]
	Ware River	T.B.D.					
	Wachusett	T.B.D.					

Footnotes for Table 11

1. Survey for invasive plants within a 300 ft. radius buffer zone around 20 rare plant sites. 6.5 acres/site x 20 sites = 130 acres.
2. 8 hrs/site x 20 sites @ $15-30 per hour depending on survey team composition. Time includes travel, survey, data entry, mapping, and report writing.
3. Assumes 5% of the acres surveyed have some presence of invasives, based on preliminary CFI data drawn from plots on unmanaged areas at Quabbin (see Section 8). Most rare plant sites are located in areas that are not managed. Also assumes all acres will be treated no matter how low the density of invasive plants present in the buffer area, and that the average percent cover on these invaded acres is 16% (see next note).
4. The lower figure is derived from Ward (2008) for a preliminary treatment of barberry (assuming 16% cover) with brush saws (2 hrs/ac @$25/hr) followed by midseason directed heating (propane torch) 7 hrs/ac @25/hr. + 6 gal. propane @$3.40/gal): $246/ac. Ward's figures apply to barberry under 3 ft. tall, which is not the case with older denser stands. The higher figure is derived from the Marin Municipal Water District (MMWD) estimate of the average annual cost of $3,750 per acre over a ten year period using hand and mechanical techniques on lands that average approximately 30% cover of the invasive shrub French broom. For the purposes of this set of calculations, it will be assumed that treating areas that have approximately half the percent cover as the MMWD lands (16% vs. 30%) will cost half as much ($1,875/ac. vs. $3,750/ac.). The data on density of invasives on the Quabbin CFI plots was recorded as: 1-25%, 26-50%, 51-75%, and 76-100%. The percent cover on Ware River CFI plots was estimated in 10% increments. The CFI data from both watersheds were combined (after assigning median values of 13%, 38%, 64% and 88% to the four categories of cover in the Quabbin data) giving an overall average value of 16% cover on invaded acres. Another source of uncertainty (among many) in applying cost figures from these two sources is that they are based on treating one species, whereas on DWSP watersheds there is a range of species and growth habits (tree, shrub, vine, herb etc.).
5. The lower figure is derived from Ward (2008): 2hrs/ac @$25/hr of initial brush saw clearing followed by a mid-season foliar spray (2hrs/ac @$50/hr) plus $10/ac for the herbicide for a total of $160/ac. The upper figure uses the MMWD estimate of $650/acre/2= $325 for IPM methods that include herbicide (also assuming, as in note 4, that the cost of treating an area with half the density would cost half as much).
6. 3 sites x 6.5 acres/site = 19.5 ac.
7. 8 hrs/site x 3 sites x $15-30/hr.
8. Uses the same assumptions as note 3. 5% of 19.5 = 1.

9. Same assumptions as note 4.
10. Same assumptions as note 5.
11. 5 sites x 6.5 acres/site = 32.5 acres.
12. 8 hrs/site x 5 sites x $15-30/hr = $600-$1,200.
13. Same assumption as note 3.
14. Same assumptions as note 4.
15. Same assumptions as note 5.
16. DWSP staff will be trained to recognize plants on the Massachusetts Invasive Plant Advisory Group's Early Detection Rapid Response Species List and will monitor for these plants whenever working in the field.
17. If a pioneer population of an invasive species new to the DWSP watersheds is discovered, it is presumed that it will be 2 acres or less if it has been detected early enough.
18. The lower figure is derived from Ward (2008) for a preliminary treatment of barberry (assuming 25% cover) with brush saws (3 hrs/ac @$25/hr) followed by midseason directed heating (propane torch) 11 hrs/ac @25/hr. + 9.5 gal. propane @$3.40/gal): $395/ac. The higher figure is derived from the MMWD estimate of the average annual cost of $3,750 per acre over a ten year period using hand and mechanical techniques on lands that average approximately 30% cover of the invasive shrub French broom.
19. The lower figure is derived from Ward (2008) for treating Japanese barberry at 25% cover: 3hrs/ac @$25/hr of initial brush saw clearing followed by a mid-season foliar spray (3hrs/ac @$50/hr) plus $10/ac for the herbicide for a total of $235/ac. The upper figure uses the MMWD estimate of $650/acre for IPM methods that include herbicide.
20. The area of land within a one-half mile radius of any intake that is also within the watershed of that intake.
21. 49 hours @ $15-30 per hour depending on survey team composition. (Time = 200 acres/ 5 acres/hr (Huebner, C.D. 2007), plus 9 hours for travel, data entry, mapping, and report writing).
22. For purposes of illustration, if areas with greater than 20-25% invasive cover are targeted for treatment, the preliminary CFI data (combined from both Quabbin and Ware River) suggest that one would find 6 or 7% of the acres surveyed at or above this density threshold. 200 x 0.066 = 13.2 ac.
23. Same as note 18.
24. Same as note 19.

25. 60 hrs. @ $15-30/hr.
26. 169 x 0.066 = 16.5 ac. See note 22.
27. See note 18.
28. See note 19.
29. 18 hrs @ $15-30/hr.
30. See note 22. 70 x .066 = 4.6
31. See note 18.
32. See note 19.
33. The 400 acres of planned regeneration openings at Quabbin each year will be surveyed as part of the annual lot proposal review process. See Quabbin Land Management Plan 2007-2017, p. 165 (www.mass.gov/dcr/watersupply/watershed/quablmp.htm).
34. 400 ac/5 ac/hr = 80hr @$15/hr = $1,200. Cost of survey effort required to supplement existing pre-harvest lot proposal field review protocol.
35. Uses same assumptions as note 22.
36. See note 18.
37. See note 19.
38. The 175 acres of planned regeneration openings at Ware River each year will be surveyed as part of the annual lot proposal review process. See Ware River Watershed Land Management Plan 2003-2012, p. 85. www.mass.gov/dcr/watersupply/watershed/warelmp.htm
39. See note 34.
40. 175 x 0.066 = 12. See note 22.
41. See note 18.
42. See note 19.
43. The 133 acres of planned regeneration openings at Wachusett each year will be surveyed as part of the annual lot proposal review process. See Wachusett Reservoir Watershed Land Management Plan 2001-2010, p. 98. www.mass.gov/dcr/watersupply/watershed/wachlmp.htm
44. See note 34.
45. 133 x .066 = 9. See note 22.
46. See note 18
47. See note 19.

48. DWSP staff will be trained to recognize plants on the Massachusetts Invasive Plant Advisory Group's Early Detection Rapid Response Species List and will monitor for these plants whenever working in the field.
49. Treat purple loosestrife in Pottapaug Pond.
50. Cost of $1,500/acre derived from NRCS cost share rate for the release of a minimum of 10,000 Galerucella beetles per acre of infestation.

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14 Appendices

14.1 Images and Descriptions of the Most Common Invasive Terrestrial Plant Species on DWSP Watersheds

NOTE: The descriptions that follow are summaries of what is known about these invasive plant species, based on a literature review and local/regional experiences/observations. ***These are NOT specific recommendations for invasive plant control on DWSP properties.***

Control methods ultimately chosen for reducing specific invasive plant populations on DWSP properties will be selected first from amongst the options that are possible within prevailing DCR/DWSP and MWRA policies at the time, and then based on their relative cost effectiveness or control efficiency.

The constraints of an unfiltered public drinking water supply and a limited state budget may preclude large-scale treatment of some populations of terrestrial invasive plant species on DWSP watershed properties, or at least delay their control until viable options that satisfy these constraints are developed.

14.1.1 Autumn olive (*Elaeagnus umbellata*)

Native origin: Korea, China, and Japan. Species was imported to the US in 1830 from Japan.

Preferred habitat: Full sun, drought tolerant; various soil types, but NOT wetlands; non-leguminous nitrogen fixer; deliberately planted in the past for wildlife food and cover, and land reclamation.

Habit: deciduous shrub 12-20'.

Invasive habits: Spreads gradually but vigorously across open woodlands, fields, grasslands and disturbed habitats. Resprouts vigorously if cut. Abundant fruit (up to 80 lbs per bush) and seed.

Frequency of occurrence on DWSP watersheds: Most common in fields in which or near which it was historically planted for wildlife. *Examples: Planted in open areas in Petersham block of Quabbin watershed, between the East Branch of Fever Brook and Rattlesnake Hill.*

<u>Recommended Controls</u>

Mechanical: Hand or machine-assisted pulling can be effective, but time-consuming. Mowing alone *DOES NOT WORK* due to vigorous resprouting, but can work in conjunction with stump applications of 20% glyphosate.

Biological: Goats and sheep are known to browse autumn olive, otherwise no known biological control.

Chemical: Treatments known to be effective include: foliar applications of 1-2% triclopyr or 1-2% glyphosate; cut stump treatment with 20% glyphosate; basal bark treatment with 2% triclopyr mixed in oil.

Fire: Prescribed burning has *not* been effective in controlling established population; abundant resprouting follows.

14.1.2 Barberry, Japanese (*Berberis thunbergii DC*)

Japanese barberry

Common barberry

Barberry in mesic woodland

Native origin: Japan. Species was introduced to the U.S. as an ornamental plant in 1875 in the form of seeds sent from Russia to the Arnold Arboretum in Boston. In 1896, shrubs grown from these seeds were planted at the New York Botanic Garden.

Preferred habitat: Full sun to [partial] full shade; mesic to moist soils; fields, thickets, wetland edges, swamps, closed-canopy forests and woodlands, forest edge and interior. Drought tolerant.

Habit: Dense deciduous shrub 2-8 ft. tall

Invasive habits: Forms dense thickets that exclude most other species. This species reproduces by seed or vegetatively (90% germination rate for seeds). Barberry is avoided by deer, which gives it a competitive advantage in areas with high deer populations.

Frequency of occurrence on DWSP watersheds: Common at Quabbin; especially well-developed in areas with historically high deer levels. *Examples: along Gate 17 road on Prescott; in mesic plantations; in mesic plantations near Dana Common.*

Recommended Controls

Mechanical: Barberry shrubs up to about 3 ft in height can be pulled, preferably when the soil is moist. Root fragments can regrow, so must be pulled thoroughly. Repeated mowing can also work, as resprouting is slow.

Biological: None known in North America although tests are being conducted in Europe that suggest control by the tephritid fly may be possible.

Chemical: For larger populations, applications of a 2% solution of glyphosate mixed with water and a surfactant early in the growing season can be effective. Triclopyr or glyphosate may control if applied on cut stumps or as a basal bark application in a 25% solution with water, covering the outer 20% of the stump.

Fire: Barberry can be controlled with spring burns to initially kill the mature plants followed in late summer to fall by heating of new sprouts with a propane torch (Ward, 2010).

14.1.3 Bittersweet, oriental or Asiatic (*Celastrus orbiculatus*)



Native origin: Asia. This species was introduced into the U.S. in the 1860s as an ornamental plant.

Preferred habitat: Full sun to partial full shade, wide variety of soils, favors calcareous soils; prefers edges, roadsides, open forests, recently thinned plantation forests, hedgerows.

Habit: Upright branching shrub to 10' and trailing vine.

Invasive habits: Climbing vine that strangles and smothers the trees and shrubs on which it climbs. This species establishes under closed canopy forest conditions and persists indefinitely until it is released by a disturbance that creates conditions optimal for rapid growth. It invades forested land but has also been known to persist on coasts. Can overtop and girdle native trees and shrubs along roads, in clearings and in forest gaps. Bittersweet reproduces prolifically by seed (dispersed by birds) and vegetatively through root suckering.

Frequency of occurrence on DWSP watersheds: Common in favorable habitats, especially in park-like settings. *Examples: Quabbin Park; areas near Wachusett Dam; 300 ft northeast of Old Stone Church, Wachusett Reservoir; between Elm St and Intervale Rd at the Ware River.*

Recommended Controls

Identifying and eradicating populations before they are released by an opening in the canopy is the easiest method of control. Correct identification is important because Oriental bittersweet can be confused with the less common native American bittersweet (*Celastrus scandens*).

Mechanical: Manual, mechanical and chemical control methods can all be effective; combinations may be best. Regular mowing of edges and open areas will exclude expansion of bittersweet into these areas.

Biological: None known to date.

Chemical: Whenever possible and especially for vines climbing up trees or buildings, a combination of cutting followed immediately by cut-surface application of concentrated systemic herbicide like triclopyr and glyphosate is known to be most effective. For large infestations spanning extensive areas of ground, a foliar herbicide may be required for effective treatment.

Fire: No studies found to document fire's effects on bittersweet.

14.1.4 Black locust (*Robinia pseudoacacia L.*)


Native origin: Southeastern US. Planted in the north to produce rot-resistant fence posts.

Preferred habitat: Sandy, well-drained soils; full sun to partial shade; immature forests, roadsides, grasslands.

Habit: Fast-growing tree up to 100'

Invasive habits: Height growth up to two feet annually; reproduces and spreads by seed, root suckering, and stump sprouting. Nectar competes with natives for pollinators.

Frequency of occurrence on DWSP watersheds: Varies. *Examples: Just outside Gate 20 at Quabbin. Significant component of numerous stands on the north side of the Wachusett Reservoir between Gates 28-35.*

<u>Recommended Controls</u>

Mechanical: Small seedlings/saplings can be pulled. Because black locust reproduces through root suckering so readily, cutting will only temporarily treat the population. It may be possible to eliminate the population with repeated cuttings for several years.

Biological: The locust borer, *Megacylline robinin*e, can cause serious injury and/or disfigurement of black locust. No information is available, however, on the use of the borer as a control method.

Chemical: For saplings/seedlings smaller than about 6 inches dbh, basal bark applications of 2% triclopyr that thoroughly soak the stem to a height of about 20 inches above the ground have been successful. Once black locust has become established beyond the small sapling stage, the most effective method for control is to cut the trees down and immediately soak the stumps with a 20% solution of glyphosate.

Fire: Black locust is usually top-killed by fire when young. Shrub-size black locust can be killed by a low-severity, prescribed spring fire.

14.1.5 Black swallow-wort (*Cynanchum louiseae*)



Native origin: Native to France, Italy, Portugal, and Spain. Black swallow-wort is believed to have arrived in North America as a horticultural plant.

Preferred habitat: Occurs in a wide range of habitats from dry and sunny to shady and moist, from shallow soils on limestone bedrock to deep, well-drained silt-loam soils. Tolerates alkaline soils with a possible preference for calcareous soils. Responds to disturbance.

Habit: Herbaceous perennial twining vine, 3-6 feet in height, depending on support.

Invasive habits: Reproduces from windborne, tufted seed released from fruit pods in late summer through the fall, so downwind areas are susceptible to infestation. Also spreads clonally from deep, dense rhizomes. Aggressively smothers and competes with natives for water and nutrients. May confuse ovipositing monarch butterflies looking for native milkweeds; hatching caterpillars cannot develop on swallow-wort.

Frequency of occurrence on DWSP watersheds: Uncommon. *Examples: Several areas around Wachusett Reservoir, including a band along the north shore above the Cosgrove intake.*

<u>**Recommended Controls**</u>

Mechanical: Mowing or hand-pulling of seed pods as they appear reduces seed production. Isolated plants should be pulled, dug and bagged for proper disposal. Roots must be thoroughly removed as reproduction from remaining rhizomes will reestablish the population.

Biological: None tested for North American release although several pests from black swallow-wort's native habitat in Europe are being considered.

Chemical: Controlled best using glyphosate in late summer or early fall, either applied to foliage with a surfactant (most effective) or via cut-stem treatment.

Fire: Fire alone is *NOT* effective in reducing mature populations of black swallow-wort because the rhizome is protected from the heat and will aggressively resprout. However, the less-established seedling layer may be controlled by flame burners after the mature plants are removed or killed by herbicide.

14.1.6 Buckthorns, common (*Rhamnus cathartica L.*) and glossy (*Frangula alnus P. Mill.*)


Common buckthorn


Glossy buckthorn

Native origin: *Frangula alnus* North Africa, Asia, Europe; intro. US 1800s for horticultural purposes. *Rhamnus cathartica:* most of Europe; north & west Asia. Hampe and Bairlein (2000) state, "Pollen records show that the alder buckthorn F. alnus (Miller) was one of the first bird-dispersed woody plants that recovered much of temperate Europe from Mediterranean refugia in the early Holocene (Moe 1984)."

Preferred habitat: Generalist. Full sun, partial shade, full shade, disturbed sites, urban sites, edges, agricultural sites, old fields, forest gaps, early successional, forest interior, plantations, riparian zones, wetlands, rocky soils, calcareous soils, acid soils preferred.

Habit: *Frangula alnus* - upright shrub/small tree 6-21'. *Rhamnus cathartica* - upright shrub/small tree 6-18'

Invasive habits: Dense wetland stands threaten native spp. Seeds dispersed by birds, animals, water currents.

Frequency of occurrence on DWSP watersheds: Spotty occurrences; *Examples: dense stands of buckthorn in some disturbed areas in the Ware River forest*

Recommended Controls (Combination approaches over multiple years may be effective.)

Mechanical: 1) maintaining mowed areas prevents establishment; 2) Pulling/grubbing small populations increases the risk of recolonization; 3) Manual cutting 2x/season for 2-3 yrs yields "fewer/shorter" stems. 4) Girdled stems do not resprout; this may be done all winter w/ no negative soils/wetlands impact. 5) Underplanting disturbed woods with native spp is potentially effective to prevent primary invasion or re-invasion of *Rhamnus* spp.

Biological: Results unknown of experiments (Malicky et al. 1970) w/ *Scotosia vetulata* and *Triphos dubiata* (insects) on *R. cathartica*, and *Tricothecum roseum* (fungus) on *R. frangula*

Chemical: Freshly cut stumps should be treated with a 50% solution of glyphosate to prevent resprouting. As buckthorns enter dormancy later than most species, treatments should be applied mid to late autumn to reduce risk to non-target species.

Fire: Fire may reduce resprouting vigor but enhance density of sprouts & new seedlings; 5-6 years of annual burn may be needed.

*14.1.7 Common reed (**Phragmites australis ssp.**)*

Native origin: *Phragmites australis* is found on every continent in the world except for Antarctica, and in every state in the US except Alaska and Hawaii. It is known to have been present in the US for 40,000 years and present in New England for at least 4,000 years. Non-native strains have been introduced in the last two centuries and most New England populations are non-native.

Preferred habitat: Tidal and nontidal brackish and freshwater marshes, river edges, shores of lakes and ponds, wet meadows, roadsides, disturbed areas.

Habit: Tall perennial grass.

Invasive habits: This grass forms huge monocultures that spread for acres, excluding native species, altering hydrology and wildlife habitat, and increasing fire risk. A dense network of roots and rhizomes can be several feet in depth, with horizontal runners growing 10 or more feet in a single season. The plant spreads both by seed dispersal and by vegetative spread via fragments of rhizomes that break off and are transported elsewhere.

Frequency of occurrence on DWSP watersheds: Increasingly common in wetlands that support cattails. *Example: Large wetland west of Dana Common in the Quabbin watershed.*

Recommended Controls

Mechanical: Repeated mowing may be effective at slowing the spread of established stands but is unlikely to kill the plant. Excavation of sediments may also be effective at control but small fragments of root left in the soil may lead to reestablishment.

Biological: 140 herbivorous insects feed on common reed in Europe and 21 have been accidentally introduced in North America, but no deliberate controlled releases have been made.

Chemical: Glyphosate-based herbicides control established populations. If a population can be controlled soon after it has established chances of success are much higher because the below-ground rhizome network will not be as extensive. Herbicides are best applied in late summer/early fall after the plant has flowered, either as a cut stump treatment or as a foliar spray. Retreatment for several years is required to prevent any surviving rhizomes from resprouting.

Fire: Plants should not be burned in the spring or summer before flowering as this may stimulate growth. Prescribed burning after the plant has flowered, either alone or in combination with herbicide treatment, may be effective and reduces standing dead stem and litter.

14.1.8 Garlic mustard (*Alliaria petiolata*)

Native origin: Europe. May have been brought to North America by settlers for cooking. First recorded on Long Island, NY in 1868.

Preferred habitat: Generalist. Drought-tolerant. Full sun, partial shade, full shade (preferred), disturbed sites, urban sites, edges, forest interior, plantations, riparian zones, wetlands, rocky soils, calcareous soils preferred

Habit: 1-3'; biennial herb

Invasive habits: 600 seeds per stalk, up to 12 stalks per plant on average; seeds dispersed on people, animals; by water currents; seed bank viable 5 yrs

Frequency of occurrence on DWSP watersheds: Scattered, but occasionally dense and expanding. No current known population on DWSP lands at Quabbin, but present at Ware River and Wachusett. *Examples: several populations identified at Wachusett, including two populations east of Thomas Basin and within 500 feet of the shore of the reservoir.*

Recommended Controls

Mechanical: Small areas can be treated by repeated hand-pulling, including root crowns, and removal of pulled plants, especially if flowers present. New plants can sprout from root fragments. Seed ripening can continue even after the plant is pulled, so all parts must be removed from site and destroyed. Seed remains viable in the soil for up to five years, so repeated pullings are required. Larger areas require multiple cuts throughout season, repeated annually.

Biological: Research on biological controls has been underway since 1998. Several species are being tested for host specificity, but no North American releases yet.

Chemical: Recommended treatment is fall application of 1-2% glyphosate.

Fire: Carefully-timed spring fires may be effective in very large infestations, but these encourage germination of banked seed, so must be repeated for 3-5 years to gain control.

14.1.9 Goutweed (*Aegopodium podagraria L.*)



Native origin: Most of Europe and northern Asia, to eastern Siberia. Brought to North America as an ornamental during the early stages of European settlement; well established in the U.S. by 1863.

Preferred habitat: Partial sun to shade, although seedlings do not do well in shade; tolerant of varied soil conditions.

Habit: Creeping, herbaceous perennial up to 1 m tall.

Invasive habits: Spreads aggressively through stolons. Patches of goutweed typically form a dense canopy and can exclude most other herbaceous vegetation and inhibit the establishment of conifers and other native tree species.

Frequency of occurrence on DWSP watersheds: Not common; *Example: Dana Common.*

Recommended Controls

Mechanical: Small patches of goutweed can be eliminated by careful and persistent hand-pulling or digging up of entire plants along with underground stems (rhizomes). Digging must be thorough; fragmentation of the root system stimulates reproduction. Frequent short mowing may control a population or slow its spread. Smothering is effective for small populations.

Biological: None known.

Chemical: Systemic herbicides such as glyphosate are most effective but can damage or kill non-target species. Contact herbicides are usually ineffective.

Fire: Not known.

14.1.10 Japanese honeysuckle (*Lonicera japonica Thunb.*)

Native origin: Bush honeysuckles were introduced to North America between 1752 and the late 1800s.

Preferred habitat: Full sun to full shade, forest edge.

Habit: Upright shrubs 6-20'.

Invasive habits: The early leafing of these species is particularly threatening to native spring ephemerals, which have evolved to bloom before trees and shrubs have leafed out.

Frequency of occurrence on DWSP watersheds: Broadly present but spotty. *Examples: Gate 49, near Richard's Ledges, at Quabbin.*

<u>Recommended Controls</u> Both mechanical and chemical control methods must be repeated for at least three to five years in order to stop new plants emerging from the seed bank. Prevention of re-invasion by bush honeysuckles may be aided by "underplanting" disturbed areas with tolerant native species.

Mechanical: Hand removal of seedlings with minimal soil disturbance is effective for light infestations of shrubs that are less than three years old. In shaded forest habitats, where exotic bush honeysuckles tend to be less resilient, repeated clippings to ground level during the growing season may result in high mortality. Clipping must be repeated at least once yearly to prevent dense regrowth

Biological: None known

Chemical: 1) Systemic herbicide like glyphosate at a 1 % solution sprayed onto the foliage or applied by sponge. Established stands: cut stems to ground and paint or spray stumps with higher rate of glyphosate (2-3%); 2) Cut stems at the base and treat immediately with a 20% active ingredient glyphosate solution. If not followed by herbicide treatment, cuts made in winter will encourage vigorous resprouting. Spraying after the plant blooms may kill mature and seedling plants. Spraying prior to the emergence of native shrubs and ground flora is the safest time to spray without impacting native species.

Fire: Prescribed burning has shown some promise for exotic bush honeysuckles growing in open habitats. In fire-adapted communities, spring prescribed burning may kill seedlings and top-kill larger plants; results have been mixed. Resprouts may occur, so repeated prescribed burning annually or biennially for several years may be necessary.

14.1.11 Japanese knotweed (*Polygonum cuspidatum*)

Native origin: East Asia. Introduced from Japan to UK as horticultural before 1855; by 1894 introduced plants had naturalized in US.

Preferred habitat: Full sun preferred, partial shade, full shade, disturbed sites, urban sites, edges, agricultural sites, old fields, forest gaps, early successional, riparian zones, wetlands.

Habit: Upright perennial herb, 10-15'.

Invasive habits: Dense wetland/riparian thickets; threat to native spp. Species can survive severe flooding and is heat and salinity tolerant. Very effective vegetative reproduction; rhizomes spread to 65' and sprout from fragments. Little viable seed. Eradication difficult.

Frequency of occurrence on DWSP watersheds: Mostly limited to roadsides or fields; does not penetrate woods. *Examples: Quabbin – Mount Pleasant, by old field ; Gate 17, first field in from gate.*

Recommended Controls

Mechanical: Grubbing must remove entire plant to prevent vigorous regrowth. Cutting close to the ground twice a month or more between April and August, and then once a month or more until the first frost for 2-3 growing seasons may successfully control small but well established patches.

Biological: Fungal and herbivorous insect pests have been identified, but no specificity testing or natural releases in North America to date.

Chemical: Difficult to eradicate established populations, but repeated applications of glyphosate following cutting will weaken plants. Small infestations: Cut or mow stalks in late June; allow knotweed to regrow. Cut again after August 1, and drip an 18-25% glyphosate solution into the stems, or use an injector gun. Larger infestations: Cut in June, then in late summer when other populations are flowering, use a low volume foliar spray of 3-8% glyphosate. Spot treat the following year..

Fire: Effects uncertain.

14.1.12 Multiflora rose (*Rosa multiflora*)



Native origin: East Asia (Japan, Korea, eastern China). Species was introduced in 1700s as rootstock for cultivated roses. From 1930 to 1960 planting of multiflora rose was advocated in the US for living fences, erosion control, wildlife food, and cover.

Preferred habitat: Full sun, partial shade, full shade, disturbed sites, edges, agricultural sites, old fields, forest gaps, forest interior, plantations, and riparian zones.

Habit: Shrub to small tree (20').

Invasive habits: Forms dense, impenetrable thorny thickets. Grows most vigorously in full sun, but can persist for many years beneath canopy. Plants produce up to 500,000 seeds annually.

Frequency of occurrence on DWSP watersheds: Variable, often near cellar holes. *Example: Gate 47 at Quabbin, by cellar hole, and by cellar hole near Richard's Ledges*

Recommended Controls

Mechanical: Light infestations can be successfully eliminated with at least six cuts per year near the ground for two or more years. Mowing can control, but not eliminate, larger infestations. Seedlings can be pulled by hand. Small plants can be dug out; larger ones pulled using a chain or cable and a tractor, but care needs to be taken to remove roots also. Dense thickets may require a bulldozer. Repeated mowing for 2–4 years can be effective.

Biological: Rose rosette disease (RRD), transmitted by the eriophyid mite *Phyllocoptes fructiphilus* has the potential to eliminate R. multiflora in areas of dense stands. Rose seed chalcid (*Megastigmus aculeatus*), a Japanese wasp that has become established in the eastern United States, may provide control. Periodic browsing of foliage by livestock may effectively control R. multiflora. Domestic sheep and goats will feed on leaves, new buds, and new shoots.

Chemical: Where mowing is not practical, cutting followed by stump treatment with glyphosate to prevent resprouting is effective in many areas. Regardless, follow-up monitoring and retreatment during the subsequent growing season may be required to ensure effectiveness.

Fire: Prescribed burning is effective for eradication and may be preferred over introducing rose rosette disease, which will affect native and other ornamental roses as well as multiflora rose.

14.1.13 Norway maple (*Acer platanoides*)

Native origin: Europe and Western Asia; introduced to North America in 1756.

Preferred habitat: Full sun, partial shade, full shade, forest gaps, early/late successional. Seedlings are shade-tolerant.

Habit: Tree 40-100’, branch spread to 70'.

Invasive habits: Seedlings are shade-tolerant, so the species can spread beyond roadside plantings deep into the woods.

Frequency of occurrence on DWSP watersheds: Variable. *Examples: Recently removed from Dana Common; in town center, Barre, on Ware River watershed; most likely occurrences are near street plantings, common near Wachusett Reservoir, including area southeast of South Bay.*

Recommended Controls

Mechanical: Weed wrench (saplings); girdling. Soil disturbance from seedling removal or uprooting of overstory trees may enhance germination of Norway maple seeds in the seed bank. Drastic changes in site conditions and species composition may facilitate invasion by other non-native plant species because removal of Norway maple from a site may entail removing a large proportion of existing plant biomass. Removal of overstory Norway maple trees in a New Jersey forest dominated by Norway maple and sugar maple resulted in invasion by tree-of-heaven (*Ailanthus altissima*), Japanese barberry (*Berberis thunbergii*), winged burning bush (*Euonymus alatus*), Japanese honeysuckle (*Lonicera japonica*), and garlic mustard (*Alliaria petiolata*) [www.fs.fed.us/database/feis/plants/tree/acepla/all.html]

Biological: Not known.

Chemical: Treat cut stems with triclopyr.

Fire: Not known but not practical given that most occurrences are near residences.

14.1.14 Purple loosestrife (*Lythrum salicaria*)

Native origin: Eurasia; throughout Great Britain, and across central and southern Europe to central Russia, Japan, Manchuria China, southeast Asia and northern India. Species was introduced to the northeastern U.S. and Canada in the 1800s.

Preferred habitat: Freshwater wet meadows, pond edges, reservoirs, river and stream banks, ditches, tidal and non-tidal marshes.

Habit: Herbaceous wetland perennial up to 5' tall.

Invasive habits: Herbaceous wetland perennial; reproduces vegetatively and through prolific (2-3 million seeds per plant) seed dispersal via water and waterfowl. Forms vast, monotypic stands replacing native wetland plants, clogging waterways, and altering availability of wildlife food and cover. Can hybridize with a native loosestrife, *L. alatum*, considered rare in Connecticut, threatening the *L. alatum* gene pool.

Frequency of occurrence on DWSP watersheds: Increasingly common in wetlands. *Example: Upper reaches of Pottapaug Pond at Quabbin; Flagg Cove, South Bay, Wachusett Reservoir.*

<u>**Recommended Controls**</u>

Mechanical: Small infestations (<100 plants) may be pulled by hand, preferably before seed set. To be effective, the entire rootstock must be removed and all plant parts must be removed from the site and destroyed. Hand cutting of flower heads before seed maturation helps suppress seed production.

Biological: Three insect species from Europe have been approved for biological control: a root-mining weevil (*Hylobius transversovittatus*), and two leaf-feeding beetles (*Galerucella calmariensis* and *Galerucella pusilla*). *Galerucella* and *Hylobius* have been released experimentally in natural areas in 16 northern states, from Oregon to New York. In many release sites *Galerucella calmariensis* has controlled purple loosestrife in as little as three years. Although these beetles have been observed occasionally feeding on native plant species, their potential impact to non-target species is considered to be low.

Chemical: For older plants, cut stem or glove treatment of upper stems (below inflorescence) with glyphosate is recommended, applied late in the season when plants are preparing for dormancy and/or mid-summer to reduce the amount of seed produced.

Fire: Not practical for this wetland plant.

14.1.15 Tree-of-heaven (*Ailanthus altissima*)



Native origin: central China. Introduced to England in 1751, to the US in 1784. Used extensively for urban plantings since 1840.

Preferred habitat: Full sun, partial shade, disturbed sites, urban sites, edges, agricultural sites, old fields, forest gaps, rocky soils.

Habit: Rapid growth up to 100'.

Invasive habits: Prolific sprouter, fast-growing, allelopathic.

Frequency of occurrence on DWSP watersheds: Becoming more common. *Examples: Isolated but expanding population on Mount Pleasant on Prescott Peninsula at Quabbin. Several populations on Wachusett watershed, including a Clinton site 1,000 feet east of Cosgrove intake.*

Recommended Controls

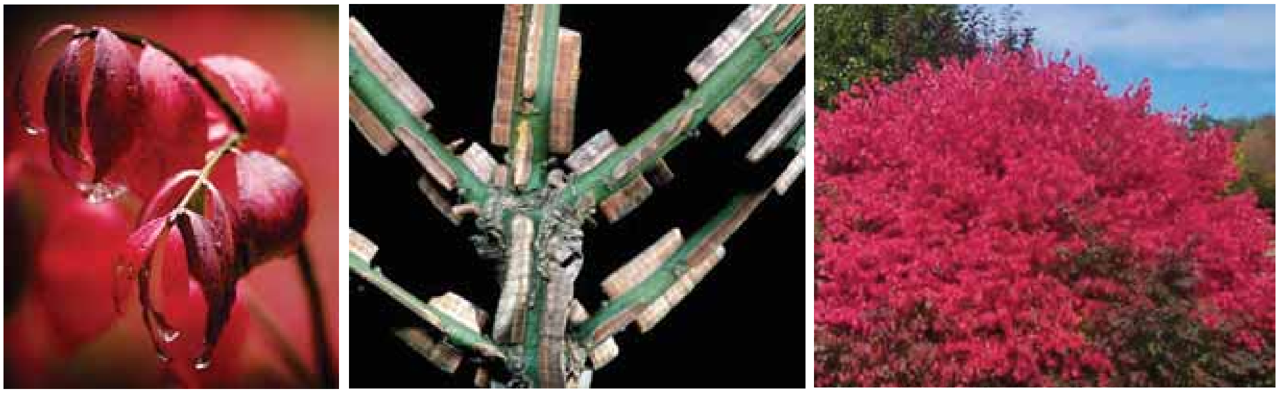
Mechanical: Weekly cutting/mowing throughout entire growing season for 2-3 years, in shaded areas with competitors, may eliminate tree-of-heaven. Simply cutting once results in prolific resprout and root suckering.

Biological: Two weevils, *Eucryptorrhynchus brandti* and *E. chinensis*, are major pests of the plant in China and are reportedly restricted to tree-of-heaven, showing promise as potential biological control agents (Ding, et al., 2006). Heavy grazing pressure (deer, sheep, goats, cattle) may control growth of population.

Chemical: Glyphosate, triclopyr, or imazapyr applications have been effective and may be foliar, basal bark spray, stump, or injection.

Fire: Careful use of fire may be somewhat effective.

14.1.16 Winged euonymus, burning bush (*Euonymus alatus*)



Native origin: Northeastern Asia, Japan, central China. Introduced as an ornamental shrub around 1860, extensively used in landscaping and roadways.

Preferred habitat: Full sun to nearly full shade. Abandoned fields, early successional forest, edge, pasture, plantations, roadsides and rights of way.

Habit: Deciduous shrub 8-12'.

Invasive habits: May form dense thickets, replacing native plants. Abundant seed is bird-dispersed. Also reproduces by sprouting from root crown.

Frequency of occurrence on DWSP watersheds: Gradual expansion from plantings; not common. *Example: along Gate 40 road, northwest of Pottapaug Hill, by former field; above field 750 feet from South Bay, Wachusett Reservoir.*

Recommended Controls

Mechanical: Seedlings up to 60 cm (2 feet) tall can be easily hand-pulled, especially when the soil is moist. Larger plants and their root systems can be dug out with a spading fork or pulled with a weed wrench. The stump must be ground out or the re-growth clipped.

Biological: The euonymus scale, *Unaspis euonymi*, is known by landscapers to be a very common and serious pest of not only euonymus but bittersweet and pachysandra and may have applications for the control of invasive populations of winged euonymous.

Chemical: Cut stumps can be painted with glyphosate immediately after cutting. Where populations are so large that cutting is impractical, herbicide (glyphosate) may be applied during the early summer months as a foliar spray.

Fire: None known.

14.2 IPANE and MIPAG Lists of MA Early Detection/Rapid Response Species

INVASIVE PLANT ATLAS OF NEW ENGLAND

www.eddmaps.org/ipane/

"This ED/RR list is based on the biological potential of the species for widespread invasions into areas where it is not currently known. The list has been generated from a variety of different sources including herbarium specimens, published lists, literature, federal and state early detection efforts and the observations of numerous botanists and naturalists."

EARLY DETECTION [TERRESTRIAL] INVASIVE SPECIES, BY STATE

http://nbii-nin.ciesin.columbia.edu/ipane/earlydetection/early.htm

SPECIES	ME	NH	VT	MA	RI	CT
TREE						
Paulownia tomentosa; Princess tree	0	0	0	?	?	+
SHRUBS						
Lonicera maackii; Amur honeysuckle	0	0	0	+	0	+
Rubus phoenicolasias; Wineberry	0	0	0	+	+	+
HERBACEOUS PLANTS						
Butomus umbellatus; Flowering-rush	1	0	+	0	0	1
Cardamine impatiens; Narrowleaf bittercrest	1	2	0	1	0	+
Cirsium palustre; Marsh thistle	0	H	0	H	0	0
Cynanchum rossicum; Pale swallow-wort	1	1	0	+	2	+
Froelichia gracilis; Slender snake-cotton	0	1	3	+	0	+
Glaucium flavum; Yellow hornpoppy	0	0	0	+	+	H
Heracleum mantagazzianum; Giant hogweed	3	+	0	+	?	+
Impatiens gladulifera; Ornamental jewelweed	+	0	?	+	0	H
Lepidium latifolium; Tall pepperweed	0	0	0	+	0	+
Polygonum perfoliatum; Mile-a-minute	0	0	0	0	1	2
Ranunuculus ficaria; Fig buttercup	1	1	0	+	1	+
Senecio jacobaea; Tansy ragwort or Stinking Willie	1	0	0	3	0	0
WOODY VINES						
Lonicera japonica; Japanese honeysuckle	1	?	?	+	+	+
Pueraria montana subsp. Lobata; Kudzu	0	0	0	2	0	2
GRAMINOID PLANTS						
Arthraxon hispidus; Hairy jointgrass	0	0	0	H	0	1
Carex kobomugi; Japanese sedge	0	0	0	H	1	0
Glyceria maxima; Reed mannagrass	0	0	0	1	0	?
Microstegium vimineum; Japanese stilt grass	0	0	0	3	0	+

0 = No known occurrences, 1 = 1 occurrence, 2 = 2 occurrences, 3 = 3 occurrences, + = 4 or more occurrences, H = historic occurrences about which the current status is unclear and the reports are more than 25 years old, ? = number of occurrences unclear or unsubstantiated

Link to March 2011 MIPAG ED/RR Species in Massachusetts:
www.massnrc.org/MIPAG/docs/EarlyDetectionMIPAG.pdf

14.3 Invasive Terrestrial Plants Websites

Organization / Program	Web link	Contents
MA Invasive Plant Advisory Group (MIPAG)	www.massnrc.org/MIPAG	Plant ranking by invasiveness. Strategic recommendations for MA.
Invasive Plant Atlas of New England (IPANE)	www.eddmaps.org/ipane/	Data and maps for field and herbarium records of NE invasive plants.
Cornell University Biocontrol Program	www.invasiveplants.net	Species fact sheets, biocontrol research.
MA Department of Agriculture	www.mass.gov/agr	List of plants prohibited from importation or sale.
The Nature Conservancy, Global Invasive Species Team	http://tncinvasives.ucdavis.edu/	Methods for controlling invasive species.
USDA National Invasive Species Information Center	www.invasivespeciesinfo.gov/	Wide variety of current news, legislation, and species information.
USDA APHIS Program (Plant Health Services)	www.aphis.usda.gov/plant_health/plant_pest_info/weeds/index.shtml	Policy, alerts, legal lists, controls, for federal noxious weeds.
USDA, Forest Service, Northeastern Area	www.na.fs.fed.us/fhp/invasive_plants/	Invasive plants of the Northeast, identification, control.
USDA Forest Service Regional Invasive Plant Environmental Impact Statement	www.fs.fed.us/r6/invasiveplant-eis/	Detailed assessments of known and predicted impacts of invasive plant control on federal properties.