Fairfax County Hemlock Woolly Adelgid Management Plan

A Fairfax County, Va., publication

Urban Forest Management Division

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1. Purpose

This plan was developed for the purpose of managing hemlock woolly adelgid at high-value sites and achieving long-term conservation of eastern hemlocks. The components are adapted from best management practices and guidance in integrated pest management that have been successfully implemented throughout the eastern United States.

The scope of this management plan is currently limited to Fairfax County Park Authority and NOVA Parks properties along the Occoquan and Potomac rivers. These areas have the highest concentration of remnant hemlock forests, as shown by earlier surveys conducted by the Department of Conservation and Recreation (DCR) and based on years of field experience and institutional knowledge within Fairfax County.

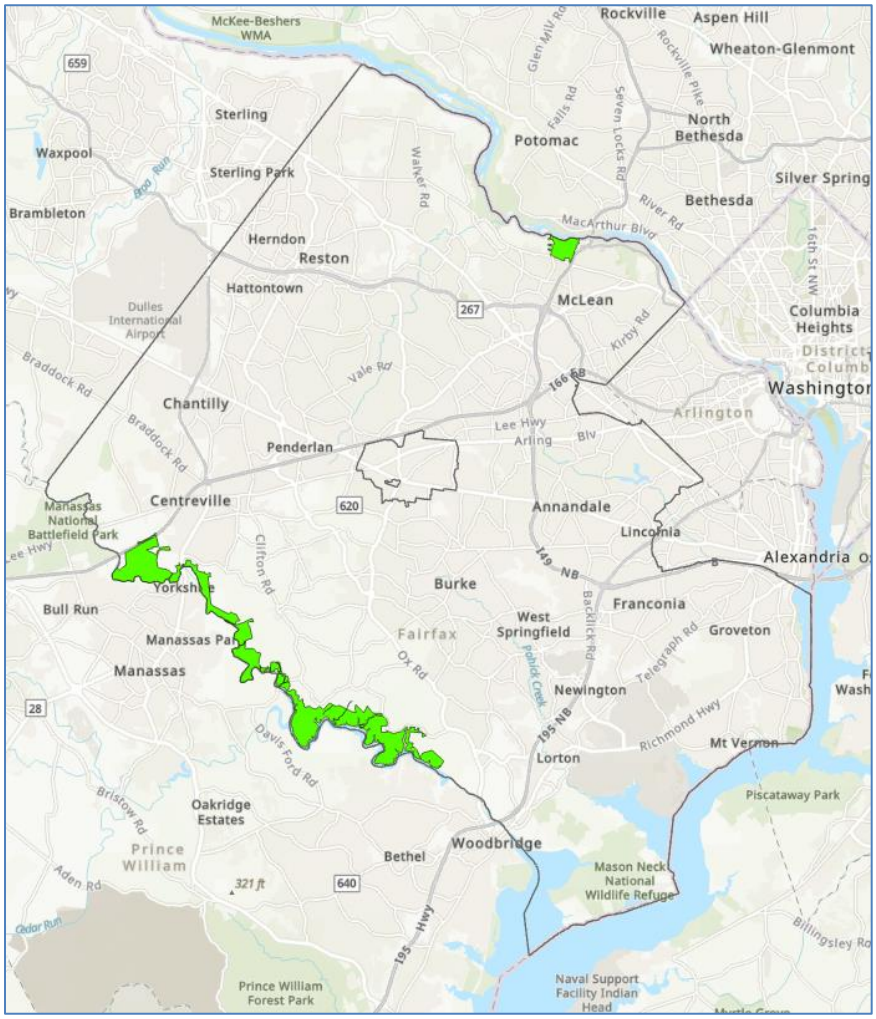

Figure 1. Map of parks in Fairfax County with natural hemlock forests.

2. Background

Eastern hemlocks (*Tsuga canadensis*) are slow growing, shade tolerant evergreen trees found from Nova Scotia to north Alabama and west to northeast Minnesota and eastern Kentucky. Hemlocks are typically found in moist forests or on steep slopes along riparian areas. This conifer can take 250 to 300 years to reach maturity and can exceed 800 years of age. Hemlocks are considered a keystone species because they have a significant influence on plants and animals. The year-round shade they provide cools the understory and soil microclimate. Hemlocks along streams shade and cool the water which is especially beneficial to cold-water fish species like the brook trout. Wildlife such as deer, turkey, and rabbits also utilize hemlocks for cover. There are species of birds that rely on hemlock forests as a source of food and habitat. Hemlocks are a rare component of hardwood forests in Fairfax County, mostly found along the Potomac and Occoquan rivers.

Figure 2. Old-growth hemlock trees along the Occoquan River.

Hemlock woolly adelgid (*Adelges tsugae*), or HWA, was first introduced into the eastern United States in the 1950s through nursery stock in Richmond, Virginia. Native to Japan, the woolly adelgid has spread throughout the eastern hemlock range. HWA attaches to the base of hemlock needles and feeds on the sap, depleting the hemlock's stored energy reserves and its ability to put out new foliage in the spring. By 2007, HWA was found in every county in Virginia, causing dieback and mortality to historical populations of hemlocks. HWA continues to spread throughout the eastern U.S. and has become established from Maine to Georgia, west to Michigan, and as far north as Nova Scotia.

In its native range HWA rarely causes harm to hemlock due to a combination of native predators and evolved resistance. However, in the eastern U.S. it has caused extensive decline and mortality of hemlocks of all ages and sizes. Infested hemlocks can die within 4 to 10 years. Hemlocks weakened by HWA are also susceptible to damage from other pests such as elongate hemlock scale, borers, and spider mites. Since HWA was first found in Fairfax County in the early 1990s it has caused significant mortality to the County's hemlock forests.

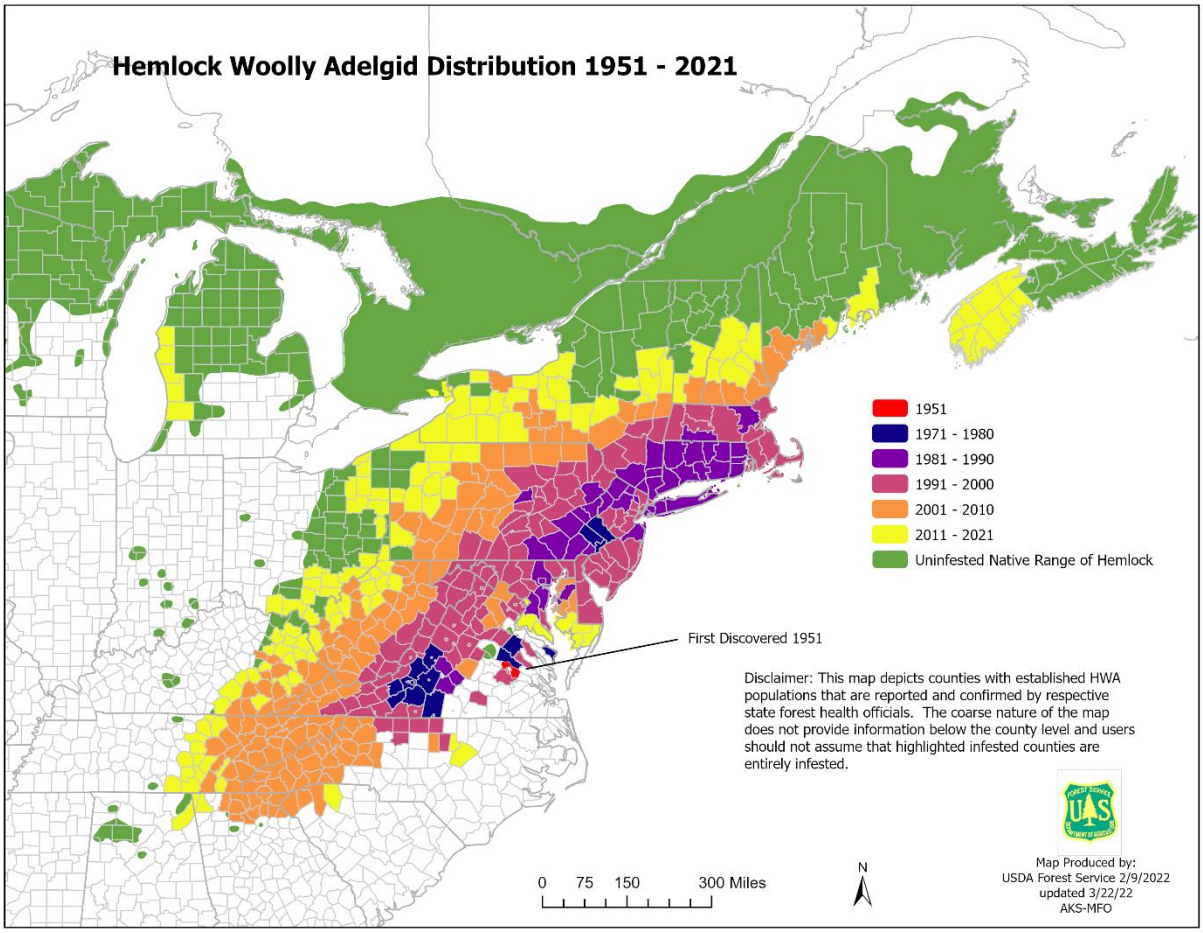

Figure 3. Progression of HWA infestations from 1951 to 2021. Produced by USDA Forest Service.

2.1.Conservation Status

The Virginia Department of Conservation and Recreation (DCR) has classified the hemlock communities in Fairfax County as Piedmont/Coastal Plain Hemlock-Hardwood Forests (https://www.dcr.virginia.gov/natural-heritage/natural-communities/nctb5). This forest type is dominated by eastern hemlock, American beech, chestnut oak, and white oak. Due to its rarity and the outbreak of HWA, this forest type has a national conservation status of Critically Imperiled (S1). A Critically Imperiled community type is at high risk of local extinction because of the few places it grows naturally, few and small populations, and severe threats to its existence.

2.2.Biology

HWA's life cycle consists of two generations per year: the sistens generation in the summer through winter and the shorter progrediens generation in the early spring through early summer. The sistens go into aestivation (summer dormancy) as soon as they hatch and insert their mouth parts into the base of a hemlock needle in June through July. Once they break aestivation in late fall, they enter their feeding and development cycle. The addition of the recognizable white cotton-like ovisac on the underside of hemlock needles occurs during this active period. These woolly masses act as a protective barrier for the HWA eggs. HWA are solely females, and do not need a mate to reproduce.

Hemlock woolly adelgids are stationary during much of their life cycles, with two notable exceptions. The first instar (developmental stage) is considered a "crawler" that is mobile on an individual tree, and can be moved by wildlife, hikers, and wind. The progrediens generation also includes a winged female that can travel up to ten miles. These winged females cannot reproduce in North America.

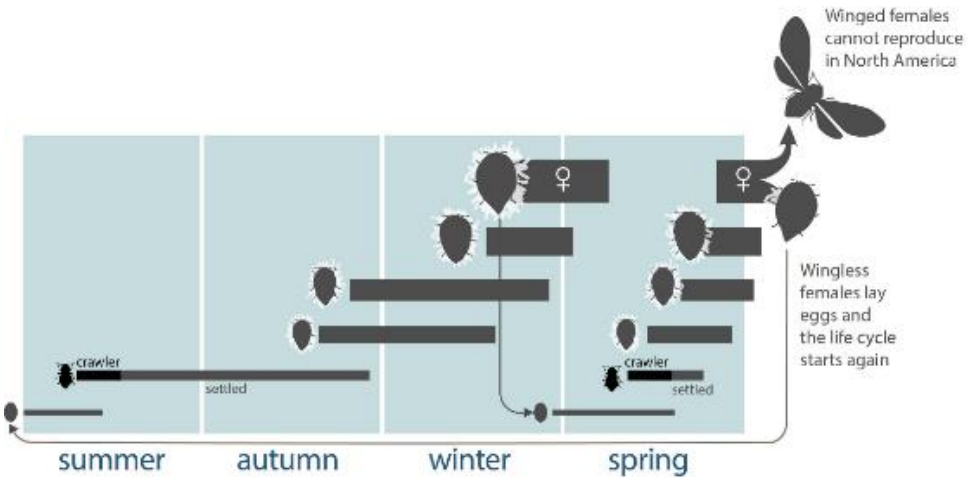

Figure 4. Simplified life cycle of hemlock woolly adelgid. (https://blogs.cornell.edu/nyshemlockinitiative/hemlock-woolly-adelgid/hwa-phenology/), Illustration by N. P. Havill and V. D'Amico

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The photos below show some of the HWA life stages that are too difficult to see without the aid of a microscope. These were taken from infested hemlock trees prior to treatment.

Figure 5. HWA eggs laid inside a woolly ovisac.

Figure 6. HWA crawlers among cottony ovisacs.

Figure 7. HWA adult among its eggs.

Figure 8. A hemlock twig infested with HWA.

2.3.Signs and Symptoms

The feeding of HWA on hemlock trees will result in obvious symptoms of decline. Healthy hemlocks have a classic conical canopy that extends along all or most of their trunks. In contrast, a hemlock tree that is infested with HWA may present symptoms including loss of lower branches, twig dieback, branch desiccation, thinning canopy, premature needle drop, chlorosis (yellowing) of needles, and stunted year-to-year growth.

Figure 9. Thinning and branch dieback on hemlock to the right, accompanied by a fallen defoliated hemlock to the left in Fountainhead Regional Park.

Figure 10. Ailing hemlock forest along the Occoquan. Healthy, uninfected hemlock trees maintain their lower and mid canopy branches.

2.4.Other Pests

Elongate hemlock scale (EHS) is another primary pest of hemlocks that contributes to stress of the trees. It is believed that this armored scale insect was unintentionally introduced into the United States from Japan. EHS is an armored scale insect that presents a challenge because it is resistant to one of the main chemical controls for HWA. Where possible, control measures that target HWA and simultaneously control EHS are being considered.

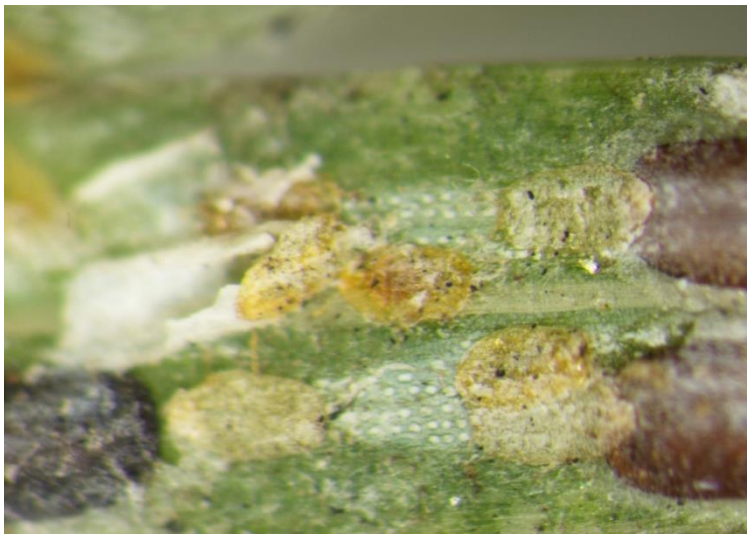

Figure 11. Elongate hemlock scale on a hemlock needle.

3. Integrated Pest Management of HWA

Fairfax County follows the management strategies described in USDA's publication, Integrating Chemical and Biological Control of the Hemlock Woolly Adelgid: A Resource Manager's Guide (http://hiro.ento.vt.edu/hwa/) which follows the principles of integrated pest management (IPM) for the control of HWA. IPM promotes the use of all appropriate tools and tactics to prevent damage from pests with minimal disruption to the environment.

3.1.Management Strategy

The IPM strategy developed for the control of HWA has a strategic approach to pesticide use that facilitates the establishment of biological controls, such as predatory beetles. This approach provides temporary pesticide protection to certain hemlock trees while simultaneously establishing predators on untreated hemlocks. As predator populations increase on untreated hemlock trees, they will eventually disperse to treated hemlock trees as their protection wears off. A healthy and growing population of predators will hopefully reduce HWA populations to a level that maintains the health of hemlock trees without the use of pesticides.

Fairfax has begun implementing the IPM strategy by identifying hemlock stands that will serve as "core" areas for the establishment of HWA predators. These hemlock stands will receive no pesticide treatment. The surrounding hemlock stands will receive pesticide treatments that range from 1-2 years of protection, 5-7 years of protection, or perpetual protection for hemlocks with the highest ecological or cultural importance.

3.2.Hemlock Inventory

An inventory of hemlock resources is a necessary first step to lay the groundwork for analysis and planning of management strategies. The inventory component of this plan consists of a stand level inventory of the size, extent, and location of hemlock trees. The two methods described below are currently used to inventory hemlock stands on Fairfax County Park Authority (FCPA) and NOVA Parks owned properties along the Occoquan and Potomac rivers. A countywide inventory is currently outside the scope of the management plan.

3.2.1. Aerial Photo Interpretation

Aerial photography is used as a preliminary resource for identifying potential hemlock stands. An analysis of aerial photography may include leaf-off color imagery, color-infrared imagery, and oblique imagery. This method is ideal for covering large tracts of land that would be time-consuming or difficult to access in the field. Aerial interpretations of potential hemlocks stands must be field checked for accuracy.

The search of potential hemlock trees was aided by a new type of analysis using deep learning tools, which was utilized to detect evergreen trees from aerial photography with much greater speed and detail than human eyes. The resulting tree location data are used by field survey teams to guide their search for hemlock trees.

3.2.2. Field Survey

In a field survey, a team of foresters collect data on the ground. All potential hemlock stands identified from aerial interpretations are surveyed for the presence of hemlocks. The general extent of stand boundaries is delineated, and data are collected including the hemlock size range, abundance, health, infestation levels, and potential for treatment. Field surveys are also critical to identifying steep slopes, pollinator habitat, streams and wetlands, and other factors that could alter how a hemlock stand is managed.

Figure 12. Field survey for hemlock trees using high-accuracy GPS.

3.3.Assessment and Ranking Process

Conservation of hemlocks is vital to the protection of riparian habitats and the unique ecosystem in which they reside. The loss of hemlock canopy would alter soil and water conditions, plant and animal communities, and could take many years to recover, if it is possible to recover at all. Despite their importance, it is impossible to conserve all hemlock trees. Decisions must be made about which hemlock trees are prioritized for conservation and the have greatest chance of success.

HWA management has been primarily focused on old-growth hemlocks along the steep slopes adjacent to Bull Run in Hemlock Overlook Regional Park (HORP). Protecting these hemlocks has been a top priority because of their age, some are over 200 years old, and out of concern for the public who enjoy using Bull Run-Occoquan Trail. The importance of old-growth hemlocks at HORP has even been recognized by the Old-Growth Forest Network (https://www.oldgrowthforest.net/), a non-profit organization that identifies and promotes preservation of old-growth, native forests across the U.S. While old-growth hemlock forests are the obvious priority for HWA management, most hemlock forests in Fairfax County are not considered old-growth and must be prioritized based on stand traits that provide the most benefit to hemlock conservation in the long-term.

The Regional Hemlock Prioritization Toolkit (https://blogs.cornell.edu/nyshemlockinitiative/), published by the New York State Hemlock Initiative of Cornell University serves as the framework to

guide hemlock prioritization for this management plan. Table 1 shows a list of some of the stand traits from the toolkit that could be used for the purpose of ranking hemlock stands. Each hemlock stand is given a score of 0-3 for a wide range of stand traits, which are weighted differently to match our management goals. The final score is determined from the sum of weighted traits for that stand. The most important stands will have the highest values, while the least important will have the lowest. If the scores agree with the management goals, then the highest scoring stands first are designated as a priority for management.

Table 1. Hemlock Prioritization Factors

Stand Trait	Suggested Weight
Physical Characteristics Category	
Current stand health	3
Environmental stressors	2
Stand size	2
Hemlock density	2
Proximity to water body	1
Aquatic Ecosystem Services Category	
At-risk water quality	2
Stream flashiness	1
Drinking water	1
Terrestrial Ecological Value Category	
Primary forest	4
Rarity of ecosystem	3
Proximity to related rare species	3
High-quality habitat	2
Presence of hemlock-dependent species	2
Steep slopes	1
Cultural Value Category	
Hazard trees	3
Natural/cultural resources	2
Use/outreach potential	1
Sustainability Category	
Protection/investment risk	3
Feasibility of treatment/type of treatment	3
Climate resilience	1
Deer pressure	1

3.4.Monitoring

Monitoring provides crucial information that allows foresters to make informed management decisions. The purpose of monitoring for this plan is to track changes in HWA populations and hemlock health over time. By understanding the severity of an infestation, foresters can implement appropriate and targeted interventions, such as using specific pesticides or employing biological control methods.

Different types of monitoring are used depending on the information needed to inform management decisions. These include HWA and hemlock health evaluations, treatment efficacy surveys, and biological control sampling, as described below.

Figure 13. Field survey of hemlock health and HWA density.

3.4.1. HWA Density and Hemlock Health

Heavy infestations of HWA will result in the decline of tree health and eventually lead to mortality. Monitoring the density of HWA populations allows foresters to determine the type of control needed, or if control is needed at all. This reduces the possibility that pesticides will be used when they really are not needed or that the wrong kind of pesticide will be used. The methodology for assessing the density of HWA and evaluating hemlock health has been adopted from the Maryland Hemlock Woolly Adelgid Management Plan (https://mda.maryland.gov/plants-pests/). Table 2 shows the four categories used to classify HWA densities. Hemlock health is placed in one of the four categories in Table 3.

Table 2 HWA Density Classes

Class	Description
None	no adelgids observed.
Light	less than 25% of the trees are infested and most often individual trees have less than 25% of the branches infested.
Moderate	26-50% of the trees appear to be infested and most often individual trees have less than 50% of the branches infested.
Heavy	More than 50% of the trees appear to be infested and most often the majority of the branches on individual trees are infested.

Table 3 Hemlock Health Classes

Class	Description
Healthy	Less than 10% of the tree showing signs of stress such as defoliation, needle discoloration, and/or branch tip dieback.
Light Decline	Branch mortality, twig dieback, foliage discoloration, or dwarfed leaves on 10-25% of crown.
Moderate Decline	Branch mortality, twig dieback, foliage discoloration, or dwarfed leaves on 26-50% of crown.
Severe Decline	More than half of the crown with branch mortality, twig dieback, foliage discoloration, or dwarfed leaves but foliage is still present indicating the tree is still alive.

3.4.2. Treatment Efficacy

Surveys are conducted to determine the pre and post levels of HWA on treated hemlocks each year. A small sample of hemlocks are selected to have the number of HWA on a length of twig counted. The HWA count prior to treatment and one year after treatment are compared to determine the effectiveness of a control method.

3.4.3. Biocontrol Establishment

Hemlock stands targeted for predatory beetle releases should be monitored for beetle establishment 1-2 years after initial release. Standardized sampling methods for beetle - establishment include beat sheet sampling and larval sampling. Virginia Department of Forestry (VDOF) recommended that Fairfax use the beat sheet method because adult beetles are easier to collect and identify compared to beetle larvae. Regular monitoring of the predator population will help determine whether augmented beetle releases are warranted.

3.5.Chemical Control

Chemical insecticides are highly effective against HWA and have been widely used in large-scale treatment programs to protect hundreds of thousands of hemlocks on state and national parks and forests. Insecticides are crucial to reducing hemlock mortality, but they must be applied on an individual tree basis and are therefore cost and labor intensive. Application of insecticides in Fairfax County are intended to quickly suppress HWA and conserve our native hemlock forests in the short term. Long-term control strategies will focus on biological control with less reliance on insecticides.

Figure 14. Loading pesticide into injection equipment.

3.5.1. Insecticides

The insecticides used for HWA management have systemic properties, which means they are absorbed and transported throughout the plant. This also means insects are killed when they feed on plant tissues anywhere on the tree. Imidacloprid and dinotefuran are two systemic insecticides commonly used against HWA. Imidacloprid can be applied to the soil, injected directly into the trunk, or buried in the soil in the form of a tablet. It takes 3-12 months for imidacloprid to move up tree and reach all the canopy. Protection from HWA lasts for 5-7 years. Dinotefuran can be applied to the soil or to the trunk as a bark spray. Dinotefuran can suppress HWA in as little as one month after treatment but is only effective for 1-2 years. Secondary infestations of EHS are also controlled by dinotefuran.

Insecticide applications are performed by or under direct supervision of a Virginia certified pesticide applicator in strict accordance with the product label, and then only under specific conditions. Treatment data is collected and recorded in a GIS database.

3.5.2. Protection of Pollinators

Imidacloprid and dinotefuran must be used judiciously in HWA management as they are highly toxic to native bees and other insect pollinators. The risk of exposure to pollinators can be reduced if precautions are taken while applying these pesticides. According to the label

requirements for the use of imidacloprid and dinotefuran, applications must be performed in a manner that minimizes pesticide drift away from an application site and must avoid pollinator habitat, such as flowering plants. Pesticide applicators have multiple application methods at their disposal that can be selected to best protect pollinators and their habitat.

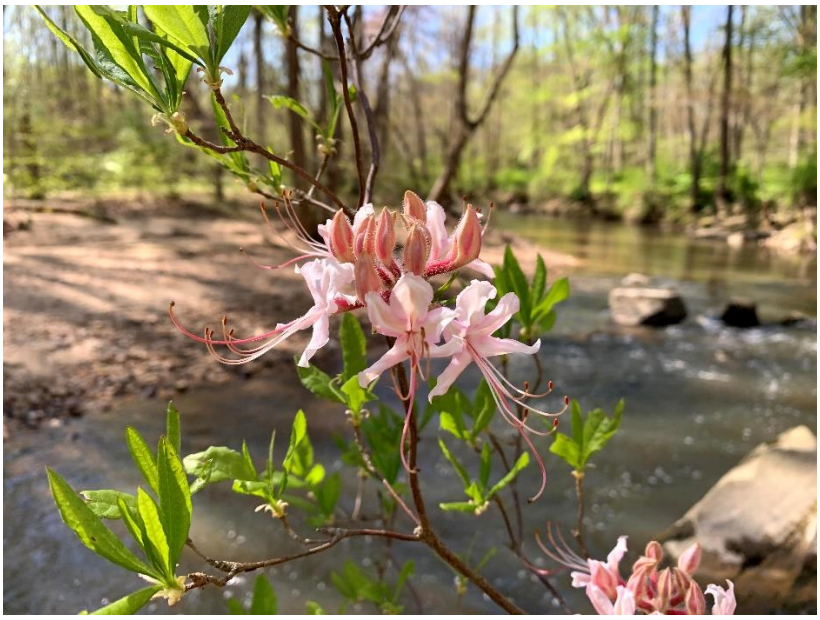

Figure 15. Pinxter bloom azaleas and rhododendrons are commonly found adjacent to streams.

Table 4 shows a list of insecticide and application methods currently employed by Fairfax County. An application method is selected only after field surveys are performed to identify situations that could potentially expose non-target insects and other beneficial organisms either directly or indirectly to insecticide. This includes hemlocks located near pollinator habitat, flowering plants, streams, or saturated soils.

Table 4 Chemical Treatment Options

Insecticide	Target Pest	Mode of Action	Re-application Interval	Application Method
Imidacloprid	HWA	Systemic	5-7 years	Soil Injection
				Soil Drench
				Trunk Injection
				Soil Tablets
Dinotefuran	HWA / EHS	Systemic	1-2 years	Bark Spray
				Stem Injection
				Soil Injection
				Soil Drench
Horticultural Oil	HWA	Contact	6 months	Foliar Spray

3.5.3. Soil Injection

Soil injection is a form of treatment that uses soil injection equipment to deliver pesticide below the soil surface where it can be absorbed by roots and spread to the tree canopy. A water-soluble powder formulation of dinotefuran or a liquid formulation of imidacloprid is typically used for soil injections. This method can evenly distribute the pesticide around the base of the hemlocks and can be used on any size tree. Soil injections are good for treating a large stand of hemlocks. Soil injections must be at least 10 feet away from streams.

3.5.4. Soil Drench

Soil drench applications consist of uniformly pouring pesticide directly on top of the ground around the base of a tree. A water-soluble powder formulation of dinotefuran or liquid formulation of imidacloprid may be applied using this method. The pesticide is absorbed into the roots and spread throughout the tree. This method requires clearing vegetation and dead leaves from around the base of the tree but requires only basic equipment. Soil drench methods can be applied to hemlocks of any size and are good for treating a large stand of hemlocks. Applications must be at least 10 feet away from streams.

3.5.5. Soil Tablets

Tablets contain imidacloprid and can be inserted in the soil just below the surface around the base of hemlock trees at a rate of two tablets per inch of diameter at breast height (dbh). The tablets dissolve when moistened by rain or irrigation. Imidacloprid is released and absorbed by the tree roots similar to a soil drench or soil injection. An advantage of using tablets is their portability and simplicity when treating hemlock trees in remote areas.

3.5.6. Horticultural Oil

Horticultural oil is a non-toxic alternative to pesticides for controlling soft-bodied insects like HWA. The oil acts by dissolving the waxy outer coating of HWA that protects it from desiccation. The oil is applied as a spray on the infested branches and shoots. The adelgids must be thoroughly covered by the oil to be effective. Since coverage is difficult on larger trees this method is better suited to smaller hemlock trees with branches that can be reached from the ground. Protection is temporary and does not persist after the oil breaks down. Horticultural oils are an option on hemlock samplings that could potentially be used for predator releases at some point in the future.

Figure 16. Soil injection at the base of a large hemlock.

Figure 17. Soil drench application.

3.5.7. Trunk Spray

Dinotefuran may be applied directly to the trunk of a hemlock using a backpack sprayer. The sprayer can be adjusted to control the flow and droplet size for a uniform application around the trunk. A water-soluble powder formulation of dinotefuran is used with a penetrant additive to ensure proper absorption through the bark. Dinotefuran is good for a quick knock down effect on HWA, and against scale insects. Opportunistic pests such as elongate hemlock scale (EHS) can infest hemlocks in the absence of HWA. Trunk sprays are good for treating a large stand of hemlocks of any size but require equipment that can be both heavy and bulky. Trunk sprays must be performed with caution around understory vegetation and at a greater distance from pollinator habitat due to the potential for spray drift. Applications must be at least 10 feet away from streams and require calm weather conditions to minimize drift.

3.5.8. Trunk Injection

Tree trunk injections are the preferred treatment for individual trees that are less than 10 feet from water or adjacent to pollinator habitat. This method is also the best choice on steep slopes where soil applications and bark sprays are neither safe nor practical. Treatments utilize a liquid injectable formulation of imidacloprid or dinotefuran in conjunction with specialized equipment designed solely for tree injection. This method injects pesticides directly into the tree's vascular system where it quickly spreads throughout the tree. Although trunk injection is safe near water and pollinators, it is also the slowest to perform and requires drilling multiple holes into the tree. For this reason, trunk injections are reserved for sensitive areas with high value hemlocks.

Figure 18. Bark spray application.

Figure 19. Holes drilled into a hemlock in preparation for trunk injection.

3.5.9. Biological Control

Biological control uses existing natural enemies to control pests, which reduces pesticide use and is self-sustaining. Fairfax started working with VDOF in 2022 to release 700 predaceous beetles (*Laricobius nigrinus*) on hemlock trees in Scotts Run Nature Preserve. The beetles are voracious feeders and enjoy HWA as a primary food source. Once established, the beetles will help suppress HWA and protect hemlock trees. Sources of predator beetles are limited and therefore not available every year. However, an established population of beetles in Fairfax could be used as a source for spreading beetles to other hemlock stands within the county. Fairfax will continue to work with VDOF to obtain and release beetles as they become available.

Fairfax will continue researching options for biological control including new predators of HWA. Prior to the release of any new HWA predator the United States Department of Agriculture (USDA) Animal Plant Health Inspection Service (APHIS) must assess the risks and benefits of releasing it into the United States.

Figure 20. Releasing predator beetles onto infested hemlocks

3.6.Hemlock Restoration

Opportunities for restoration of forest stands that have declined or died are being researched as part of the long-term goals of this plan. For restoration, suitable forest habitats could be enhanced with hemlock plantings or existing regeneration could be supported. Restoration planting may utilize HWA resistance breeding to reduce the need for intervention. HWA resistant hemlocks could potentially be identified from the Fairfax populations to preserve local hemlock genes.

3.7.Minimizing Plant and Soil Disturbance

The plant communities found among hemlock forests often include small native plants such as partridgeberry, wintergreen, rattlesnake plantain, hemlock seedlings, and various ferns and mosses. These plants and the soils they grow in are sensitive to disturbance and compaction from foot traffic, especially on steep slopes where hemlocks typically grow. Although there are usually ways to maneuver around sensitive plants in most areas, there are fewer options when working on steep slopes. Repeated foot traffic on steep slopes can eventually lead to soil erosion and bare soil.

In order to protect workers and minimize disturbance to steep slopes, Fairfax has implemented a fall arrest program. Workers who access hemlock trees on steep slopes are required to descend and ascend with the aid of a harness and rope system. Trained workers can safely move across a steep slope and select routes to avoid sensitive plants and soils. Additionally, with workers' weight supported by the fall arrest system, the foot pressure applied to the ground, and therefore soil disturbance, is greatly reduced.

Figure 21. Fall arrest system utilized on a steep slope.

Figure 22. Virginia saxifrage clinging to a steep rocky slope.

4. Outreach and Education

Outreach and education are important tools for spreading awareness of HWA and the importance of conserving our hemlock forests. Urban Forest Pest Management makes many efforts to provide accurate, current information about HWA and the county's management practices and policies to county residents and businesses through various types of media.

- Publications
- Podcasts
- Public service announcement videos
- SlideShare postings
- County web content
- Newspaper articles and radio interviews
- School programs
- Public webinars made available on YouTube
- Social media

Urban Forest Pest Management utilizes these media resources to reach the many audiences and demographics of the county so that residents and business owners can be informed about:

1. The history, biology, and activity of HWA
2. Homeowner management options
3. How we can all help to slow the spread of HWA
4. Answers to frequently asked questions

5. Regulatory

There are currently no quarantines in Virginia for HWA,however, permits are required for the release of biocontrol agents. These permits are generally provided by the biocontrol agent provider.

6. Conclusion

Hemlock trees are an asset to the natural areas of Fairfax County where they remain. Their attributes of extreme shade tolerance, a long lifespan, and existence on steep slopes and stream banks are some of the reasons they continue to be a vital species. Many of the hemlock trees that were alive before the onset of HWA in the region have died. The remaining trees may have some level of resistance to HWA but will likely die without intervention. Some of them have been treated in the past ten years, but most have not and are threatened by HWA.

UFMD continues to implement the latest scientifically accepted management strategies into its IPM program. The role of biocontrol and chemical programs has expanded greatly to preserve as many of the remaining hemlocks as possible. Other options that may be investigated include planting hemlocks in select locations and participating in breeding trees for resistance. This plan was developed in support of the County's goal to preserve and grow a healthy forest canopy for its environmental and social benefits for the residents of Fairfax County.

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