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Integrated Pest Management for Eastern Hardwood Forests

The rich biodiversity of eastern hardwood forests is threatened by invasive pests such as hemlock woolly adelgid, emerald ash borer, and spongy moth. These threats can be managed with chemical insecticides and biological control, but these control methods can have non-target impacts on the very biodiversity that managers seek to protect. This factsheet **summarizes strategies to mitigate non-target effects of insecticides** used in the control of invasive species and **gives recommendations for biocontrol and integrated approaches.**

Basal bark application of insecticide.

Invasive forest pests

The emerald ash borer (*Agrilus planipennus*), also known as EAB, was introduced from Asia and has been present in Maryland since 2003. Hemlock woolly adelgid (*Adelges tsugae*), also known as HWA, was first detected in the US in 1950 and is now present in every county in Maryland. Spongy moth (*Lymantria dispar*) is an invasive European moth that can defoliate over 300 different species of trees and shrubs. These three pests are managed primarily by insecticides such as imidacloprid and dinotefuran.

Invasive forest pests: emerald ash borer (EAB), hemlock woolly adelgid (HWA), and spongy moth.

Unintended impact of insecticides

While insecticides are effective in treating these invaders, they can leach into soils and waters surrounding treatment sites. Although presence of imidacloprid in streams near HWA treatment was below EPA benchmarks (Benton et al. 2016), insecticides can still have impacts on species of concern, including spiders (Hakeem et al. 2018), ground-nesting bees (Fortuin et al. 2021), salamanders (Crayton et al. 2020) and larval frogs (Sweeney et al. 2021). Even low levels of insecticide can have sub-lethal effects on these organisms, limiting their chances of survival without killing them outright.

Optimizing insecticide application

Despite their non-target impacts, insecticides are still a powerful tool in the fight against invasive forest pests. Insecticides can be applied in ways that minimize non-target impacts, including:

Timing and environmental factors at application.
Annual timing: systemic insecticides will move through the tree's tissues more efficiently when the tree is growing or moving sap and water in spring and fall.

Soil moisture: managers should apply according to directions when soil moisture is low. Insecticides should not be applied through soil drench or injection before or after major rain events or it will leach rapidly into waterways.

Distance to stream: Avoid soil drench and soil injection near waterways wherever possible. Trees near streams should be treated with trunk injection instead. Research has found no significant difference in effectiveness between soil and trunk injections for imidacloprid treatment (Eisenbeck et al. 2014). By choosing trunk injections wherever possible, managers can avoid insecticide leaching into surrounding soils and waterways.

Lower volume insecticide coupled with biocontrol. Dosage recommended by manufacturers is often overestimated. Research has found that using only 25% of the bottle-suggested imidacloprid dose for soil injection allowed for healthier hemlocks that were less susceptible to death and better supported *Laricobius nigrinus,* an introduced natural enemy of HWA, because some prey remained available for them (Mayfield et al. 2015). The same study also found that insecticide residue was not lost from tree tissues until after 7 years, indicating that a lower-than-manufacturer -recommended dosage of imidacloprid may be somewhat effective, even when not coupled with biocontrol.

Optimum dosage calculations. To calculate optimum dosage of imidacloprid, trunk diameter at breast height (DBH) can be used with the following formula:

$$\log(\text{dosage}) = 0.0153 * \text{DBH} - 1.074$$

where the dosage is grams of imidacloprid per 2.5 centimeters of trunk DBH. This equation can be used to calculate the lowest possible dosage that can result in an up to 90% reduction in HWA infestation (Cowles 2009). Even lower optimized doses of imidacloprid or olefin can be calculated using the following model (Benton et al. 2015):

$$\text{dosage} = 0.3 * \log(\text{DBH})^{1.745}$$

For more information on optimal dosage see the 2017 fact sheet published by the University of Georgia.

Biocontrol

Biocontrol is a viable alternative to complement insecticide application or as a primary control method for HWA and EAB in hardwood forest ecosystems. However, biocontrol requires additional management beyond initial release of a natural enemy to provide successful control.

Pros and cons of biocontrol. While the release of natural enemies does help to control invasive populations, biocontrol is not a one and done solution. Careful monitoring of released predators is needed to ensure that populations are stable and monitor impacts such as hybridization between introduced HWA predator *Laricobius nigrinus* and the native *Laricobius rubidus.* The U.S. Forest Service published a guide on a simple and inexpensive technique that can be used for larval *Laricobius* monitoring (Havill et al. 2010).

Several species that prey upon HWA have been released for biocontrol. *L. nigrinus* is most widespread.

Elizabeth Benton, University of Georgia

USDA Biocontrol Partnership

The USDA is actively releasing parasitoid wasps in the control of EAB. There is a program for landowners and managers to become biocontrol partners by submitting the following information to **EAB.Biocontrol.Program@USDA.gov**:

- Property owner/manager name and email address
- MapBio number (see www.mapbiocontrol.org)
- County, latitude and longitude of the property

Using this biocontrol method has the benefit of using previously-tested methods in partnership with federal support.

Natural enemies and their establishment. Biocontrol experiments have been conducted, mostly by federal agencies, throughout eastern hardwood forests. Below are some of the successes and failures in establishing natural enemies in northern hardwood forests. These cases provide guidance to expand upon successes and avoid previous pitfalls.

- *L. nigrinus was* successfully established and reproduced in the Chattahoochee National Forest from 2011 to 2013 to complement low-rate chemical control (Mayfield et al. 2015).
- After the release of two HWA predatory species, *L. nigrinus* established successfully but *Scymnus sinunodulus* was never recovered in post-release monitoring (Jones et al. 2014). *L. nigrinus* is a viable candidate for further releases.
- EAB larvae were reduced by up to 76% over a five-year period by released EAB parasites *Spathius galinae* and *Tetrastichus planipennisi,* along with moderate predation from native natural enemies (Duan et al. 2021). This indicates that EAB could reach sustainable suppression levels with the introduction of parasitoids, allowing for ash tree conservation. This option could be explored via the USDA program (see above), allowing for local agencies to potentially tap into federal funding and support for management.

Proposed ecosystem-based approach

In some areas where extensive die-off of hemlocks and other hardwoods has already occurred, ecosystem-based restoration of ecosystem function may be necessary to ensure the long-term health and survival of other organisms of concern and the ecosystem as a whole (Vose et al. 2013, Abella 2014). Due to the non-target impacts of hardwood pest management, threats from other invasives, and limited resources, managers need to consider how implemented actions will affect overall ecosystem health and success, avoiding an exclusive focus on species-level conservation.

Targeted Prioritization. Areas of particular ecological concern may need to be targeted for conservation due to limited resources and the inability to save all threatened trees. Target areas may include riparian buffer zones or areas where rare species are found that could be more sensitive to ecosystem change.

Restoration of ecosystem function. In some cases, other high-shade producing trees may be suitable to replace some of the ecosystem function of decreased northern hardwoods. Some species that could be considered are Asian hemlock species that resist HWA.

Preservation of genetic resistance. There is some early research on genetic resistance in some hemlock trees to the pest effects of HWA. Hybrids between the Carolina hemlock and several Asian species have shown some promise, but hybrids of eastern hemlock have not yet been produced. While there are not yet genetically resistant trees ready for planting, they may be an option in the future. Conserving trees that show genetic resistance may provide increased ability for the forest to persevere and recover, but may not be a viable option for some time, and likely will not be a suitable way to combat all hardwood pests (Vose et al. 2013, Abella 2014).

Next steps

Managers face the difficult task of developing long-term, ecosystem-based plans to preserve threatened trees with limited resources, but they also have a variety of tools at their disposal to move toward integrated pest management.

Managers should employ the minimum possible pesticide dosage during treatments in order to minimize non-target impacts of pesticide use. By applying for USDA assistance with biocontrol, eligible land managers can move toward a future with decreased need for pesticides and more effective control of invasive forest pests.

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