

Lingering Hemlock Monitoring Project Summary Report

June 30, 2023

Project Overview

Eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*) are threatened by several non-native pests and pathogens. The Nature Conservancy (TNC) is undertaking a three-year "Trees in Peril" project with public agencies, research institutions, and nonprofit partners to advance tree breeding programs and genetic research for five of the most imperiled tree species in the Northeast including eastern and Carolina hemlock.

Identifying hemlock trees that remain relatively healthy despite long-term exposure to hemlock woolly adelgid (*Adelges tsugae*) (HWA) and elongate hemlock scale (*Fiorinia externa*) (EHS) is a necessary step for advancing hemlock breeding programs. TNC and the New York State Hemlock Initiative at Cornell University (NYSHI) convened a working group in late 2022 to develop protocols for identifying and reporting lingering hemlock trees. (Working group members listed on page 23.)

The working group issued draft protocols for peer feedback in April 2023. Peer feedback was incorporated into the final protocols in June 2023. The protocols were then provided to University of Tennessee, which will use them to refine the TreeSnap app for lingering hemlock trees by Fall 2023 and to develop a new app for long-term hemlock health monitoring plot data by early 2025.

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Project Objective

The working group was tasked with developing protocols to identify lingering^{*} hemlock trees in areas infested with hemlock woolly adelgid and/or elongate hemlock scale that can be deployed as follows:

- Across the eastern U.S. and eastern Canada
- For both hemlock species (Tsuga canadensis and Tsuga caroliniana)
- In a variety of habitat conditions
- By trained individuals (both professionals and trained lay people)
- In a way that is suitable for long-term monitoring
- With data entered into a common reporting system that can be accessed by tree researchers

*Lingering is defined as trees that persist in a range of moderately healthy conditions (compared to surrounding same-species trees) in the wake of pest pressure.

Lingering Hemlock Search Protocol Framework Summary

The working group developed two protocols: one to record lingering hemlock tree candidates in areas that have experienced high hemlock mortality (Lingering Hemlock Tree Search Protocol); and one to monitor conditions in areas where there is not yet significant HWA- or EHS-induced mortality (Hemlock Health Monitoring Plot Protocol). The two protocols are summarized below.

Lingering Hemlock Tree Search

Purpose

• To identify individual (or groups of) lingering hemlock tree candidates, in areas that are infested with HWA and/or EHS, where there is already high hemlock mortality due to pests and pathogens.

Data Collection

- Data to be collected via the TreeSnap app. (App to be ready Fall 2023.)
- The app will also be able to record "no lingering trees found" data to guide future searches.

Users

- The public-facing TreeSnap app is intended to be used by public agency and nonprofit field personnel, professional land managers, and trained volunteers who are formally or casually searching for lingering hemlock in high-hemlock mortality areas.
- Researchers working on hemlock resistance can access TreeSnap to view lingering tree data, and can sort on specific data fields.

Hemlock Health Monitoring Plot

Purpose

- To assess hemlock tree health and mortality in hemlock stands where hemlock mortality has not yet reached 80% (dead and dying trees). Once the 80% threshold has been reached, any lingering hemlock tree candidates can be recorded in TreeSnap via the Lingering Hemlock Tree Search Protocol, and searches for lingering hemlock trees can begin in the surrounding forest.
- To record data about individual hemlock trees so that rates of mortality and levels of infestation can be measured over time, providing future researchers with data about specific trees that persist after others have died.

Data Collection

• Data will be collected via a new app that will be available by early 2025, which records information about each hemlock tree in a plot. Plots are to be revisited approximately biennially.

Users

• The plot protocol is intended for use by trained nonprofit personnel, professional land managers, and public agencies that are establishing new plots. (Entities with existing plots may be able to integrate data into the common data-collection app in the future.)

Lingering Hemlock Tree Candidate Definition

[Note: This definition of a potential lingering hemlock tree is designed to be used when training individuals to conduct searches. It is intended to flag potential candidate trees in the field, for which detailed data will then be recorded. Once a candidate tree is identified, the searcher will gather specific data about the tree and the surrounding trees in the TreeSnap app and flag the tree as a potential lingering tree. As more is learned about hemlock resistance, this definition may be refined.]

A lingering hemlock is a tree that persists in a moderately healthy condition when the vast majority of surrounding trees have died or are dying due to pest pressure. A lingering hemlock is/has all of the following characteristics:

- At least 4" (10cm) in diameter
- Growing in a forest, not in a lawn or landscaped setting
- In an area where more than 80% of surrounding hemlocks are dead and/or are dying due to pests and pathogens
- Deep green needles—compared to surrounding hemlock trees
- Thick, full branches—compared to surrounding hemlock trees
- Less sky visible when looking up through tree canopy—compared to surrounding hemlock trees
- Not been treated with pesticides or horticultural oils for at least 10 years (to your knowledge)

Lingering Hemlock Tree Search Protocol

[NOTE: The developers of TreeSnap may adjust the format or questions slightly when refining the app.]

Protocol Purpose

• To identify individual (or groups of) lingering hemlock tree candidates, in areas that are infested with HWA and/or EHS, where there is already high hemlock mortality due to pests and pathogens.



Images. Lingering tree candidates. Left photo is of two small groups of trees remaining after the rest of the trees have died. Right photo is of scattered, very healthy, surviving hemlocks on a hillside where the majority of hemlocks have died. Photos by Ian Kinahan.



Image: Dead and dying hemlock. Photo by David Orwig.

Step 1: Lingering Tree Search Record

- What are you reporting?
 - A single lingering hemlock tree, surrounded by dying or dead hemlocks.
 [Please complete the "Candidate Tree" and "Surrounding Tree Assessment."]
 - A small, localized group of lingering hemlocks, surrounded by dying or dead hemlocks. [Please complete the "Candidate Tree" and "Surrounding Tree Assessment."]
 - Multiple living hemlocks throughout the area, and no-obviously lingering trees in comparison to nearby trees (>20% of hemlocks in the area are alive). [Thank you, your data is complete.]
 - No hemlocks in area because:
 - Area logged
 - All hemlocks found were dead and/or dying
 - No hemlocks here, either alive or dead
 - Time spent searching: ___ (record time in minutes)
 - Comment Field [Please describe the area you searched.]

 IThank you your data is complete 1

[Thank you, your data is complete.]

Step 2: Candidate Tree Record

- Number of Lingering Trees
 - o One
 - o **2-10**
 - o More than 10
 - Comment Field [If you are reporting a group of more than 10 trees, about how many? How different are they from the surrounding forest?]



- Species
 - Eastern hemlock (Tsuga canadensis)
 - o Carolina hemlock (Tsuga caroliniana)
 - o Other hemlock species
 - o l'm not sure

• Tree Diameter

Please enter the diameter of this tree. Measure trunk diameter about 4.5' above the ground. Choose the largest stem if the tree has multiple stems or if you are reporting a group of trees.

- o _____ [inches/centimeter checkbox]
- o _____ [compute from circumference checkbox]

Is this an estimate or a precise measurement?

- Measured checkbox
- o Estimated checkbox
- Hemlock Woolly Adelgid (HWA)

Do you see HWA on this tree?

- Yes, H = Heavily infested
- Yes, M = Moderately infested
- Yes, L = Lightly infested
- No = 0% infested
- o I'm not sure (e.g., cannot see the branches from the ground)

Photo: Hemlock Woolly Adelgid



Images: HWA infestation levels. Left and right photos by Cornell University NYS Hemlock Initiative staff; middle photo by TNC Adirondack PRISM.

Additional Instructional Photos of HWA



Image: HWA in summer as wool is starting to form. Photo by New York State Department of Environmental Conservation Forest Health Lab.



Image: HWA wool in the winter/spring. Photo by Margot Wallston.

Additional Instructional Photos of Elongate Hemlock Scale



Images: Elongate hemlock scale. Left photo by PA Dept. of Conservation and Natural Resources – Forestry; Right photo by Eric R. Day. Both via Bugwood.org.

- <u>Elongate Hemlock Scale</u> (EHS) Do you see EHS on this tree?
 - Yes, H = Heavily infested
 - Yes, M = Moderately infested
 - Yes, L = Lightly infested
 - No = 0% infested
 - o I'm not sure (e.g., cannot see the branches from the ground)

Photo: Elongate Hemlock Scale



Images: EHS infestation levels. Left photo by Joshua Harkness, center photo by Lindsay Dombroski, right photo by Nicole Campbell.

• Other Stressors

Do you see signs of other potential stressors on this tree (e.g., spongy moth damage, hemlock borer, sapsucker feeding, beaver damage, physical damage)? • Yes

Comment Field

Photo: Other Stressors

- o No
- Cones

Does this tree have cones present?

o Yes

Photo: Cones

- o No
- o l'm not sure



Image: Hemlock cones, before and after seed release. Closed cone image by Richard Webb, via Bugwood.org. Open cone by Cornell University NYS Hemlock Initiative staff.

Canopy Health

How healthy is the canopy of the candidate tree (or the largest tree if reporting a group of trees)? Your best estimate of this is fine.

- H = Healthy (>80% healthy canopy; deep green, dense foliage; skylight is mostly blocked when you look at the tree)
- I = In Decline (<80% >20% healthy canopy; foliage beginning to thin; foliage green-to-greyish; some skylight visible when looking at the tree)
- S = Severe Decline (<20% canopy; many limbs dead, foliage sparse; skylight very visible when looking at the tree) [Note: This option would not generally be chosen for a lingering hemlock tree, unless this tree/group of trees are the only ones alive after all others have died.]
- o l'm not sure
- o Comment Field

Hemlock Canopy Health Rating Guide

Health Class	Distance view	Looking up under tree view
Healthy		
n Decline		

Health Class	Distance view	Looking up under tree view
Health Class Severe Decline /Dying	Distance view	Looking up under tree view

Images: Healthy hemlock: photos by Cornell University NYS Hemlock Initiative (NYSHI) staff. Declining hemlock: distance photo by Margot Wallson, upward photo by Cornell University NYSHI staff. Severe decline: distance view photo by Shenandoah National Park staff.

• Treatment Status

Has the tree (or group of trees) been treated with pesticides?

- o Yes
- o No
- o l'm not sure
- Comment Field (e.g., treated five years ago, treated with imidacloprid soil application in year X)
- Canopy Position

What is the canopy position for the candidate tree (or the largest tree if reporting a group of trees)?

- o Dominant, this tree's crown extends above other nearby trees
- Codominant, this tree's crown is level with or slightly below other nearby trees
- o Overtopped, this tree's crown is entirely below other nearby trees
- Not applicable (e.g., tree is isolated, tree is on the forest edge)
- o l'm not sure
- o Comment Field

• Canopy Closure

How "closed" would the total (hemlock and non-hemlock) forest canopy around the tree/group of trees you are reporting be in the summer? [The degree of closure helps assess how much sunlight is available to the hemlock trees.]

- Very closed (>70% canopy closure, very little light would reach the lingering tree's foliage in the summer)
- Medium (>30% < 70% canopy closure, patches of light would reach the lingering tree's foliage in the summer)
- Open (<30% canopy closure, abundant sunlight would reach the lingering tree's foliage in the summer)
- o l'm not sure
- o Comment Field
- Recent Growth

Is the tree (or the largest tree if reporting a group of trees) putting on new growth?

- Branch tips are healthy, with green new growth present
- Some branch tips are discolored or are missing new growth
- No new growth present
- No branches low enough to assess
- o l'm not sure



Image: Branch tips healthy and green. Photo by Mark Whitmore of Cornell University's NYS Hemlock Initiative.



Image: Branch tips dead. Photo by Nick Dietschler of Cornell University's NYS Hemlock Initiative.

- Tree Markings
 - Is the tree marked, tagged, or flagged in any way?
 - o Yes
 - Photo: Tree Marking
 - o No
 - o l'm not sure
- Habitat

Click all that apply.

- o Forest
- o Wetland
- o Field
- Roadside, urban, suburban, or park
- o Riparian area
- o Steep slope
- Comment Field [Describe the habitat in the area (e.g., wet seep, dry ridge top, moderate slope, flat).]
- Have you completed a lingering hemlock search training?
 - o Yes
 - o No

Step 3: Surrounding Trees Record (This section is optional but encouraged.)

- Nearby Hemlock Assessment Assess the health of each nearby hemlock tree (at least ten hemlock trees if they can be found nearby and up to forty hemlocks for a fuller mortality assessment).
 - o Three category "clicker" for each tree assessed
 - Dead, downed hemlock log
 - Dead/dying hemlock tree, still standing (*e.g.*, <20% of the tree canopy remains)
 - Living hemlock tree (*e.g.*, >20% of the tree canopy remains)
- Canopy Health

Assess the average canopy health of the nearby trees.

- H = Healthy (>80% healthy canopy; deep green, dense foliage; skylight is mostly blocked when you look at the tree)
- I = In Decline (<80% >20% healthy canopy; foliage beginning to thin; foliage green-to-greyish; some skylight visible when looking at the tree)
- S = Severe Decline (<20% canopy; many limbs dead, foliage sparse; skylight very visible when looking at the tree)
- o l'm not sure
- o Comment Field

Hemlock Canopy Health Rating Guide

Health Class	Distance view	Looking up under tree view
Healthy		
In Decline		

Health Class	Distance view	Looking up under tree view
Severe Decline /Dying		

Images: Healthy hemlock: photos by Cornell University NYS Hemlock Initiative (NYSHI) staff. Declining hemlock: distance photo by Margot Wallson, upward photo by Cornell University NYSHI staff. Severe decline: distance view photo by Shenandoah National Park staff.

• Forest Management

Do you see signs of active forest management (e.g., recently cut stumps, flagging, disturbance, active road/track)?

o Yes

Photo: Management

- o No
- o l'm not sure
- o Comment Field
- Nearby HWA

What percentage of the hemlock trees nearby the lingering tree(s) have HWA?

- o 0%
- o **1-25**%
- 0 25-50%
- o 50-75%
- 0 75-100%
- o l'm not sure
- Comment Field [Please include information if stressors other than HWA are present.]

• Nearby EHS

What percentage of the hemlock trees nearby the lingering tree(s) have EHS?

- o **0**%
- o **1-25**%
- o 25-50%
- o **50-75**%
- 75-100%
- o l'm not sure
- Comment Field [Please include information if stressors other than EHS are present.]

Hemlock Health Monitoring Plot Protocol

Protocol Purpose

- To assess hemlock tree health and mortality in hemlock stands where hemlock mortality has not yet reached 80% (dead and dying trees). Once the 80% threshold has been reached, any lingering hemlock tree candidates can be recorded in TreeSnap via the Lingering Hemlock Tree Search Protocol, and searches for lingering hemlock trees can begin in the surrounding forest.
- To record data about individual hemlock trees so that rates of mortality and levels of infestation can be measured over time, providing future researchers with data about specific trees that persist after others have died.

Step 1: Establishing the Plot

Choosing a Site

- Plots should be spread across the landscape, in different environments when possible. If creating a cluster of plots, there should be no more than three plots to a cluster and the plots should be separated by at least 50 meters/150 feet.
- Include approximately 20-40 hemlock trees that are close in proximity to each other in the plot. [How the plot is established is flexible: it can be determined with a fixed-radius, along a transect or trail, or as a square or other shape. When establishing the plot, aim for trees that are representative of the forest condition in the area without biasing selection based on tree health or tree size.]
- Each standing hemlock tree >4" DBH (alive or dead) in the plot should be identified with a numbered tree tag. [Only trees tagged when the plot is established are measured in the future. Trees too small to tag when the plot is established, that grow to larger than 4", can be noted in comment fields later.]
- Establish plots in stands that are not likely to be chemically treated for pests and pathogens in the next 15 years (to the best of your knowledge) and, ideally, have not been treated in the last 15 years.
- Depending on the method used for establishing the plot, the plot center, plot corners, or other plot boundary information should also be marked and/or have reference GPS coordinates, as needed, to guide monitors back to the plot in the future.

Plot Data Collection

- Date of Monitoring Visit
- Name of Recorder

This data will autofill after the plot is established. Landowner information can be updated if needed.

- Date Plot Established
- Name of Plot (if plots are named by your organization)
- Land Ownership
 - o Public
 - o Nonprofit
 - Private (other than nonprofit)
 - o Other
- Permission
 - Is permission required to access the property?
 - o Yes
 - Provide landowner contact name and contact information
 - o No
- Plot Location: GPS point for approximate plot center or corner
 - Comment Field [Add notes about location of plot center, corner that can be found again, general plot shape/size description, and/or directions to the plot.]

Step 2: Individual Tree Records

[Note: This data will be gathered for each tree (generally 20-40 trees).]

- Tag number [This will pull up in the app.]
- Tree location: GPS latitude, longitude [This will refresh with your current position.]
- Species* [Autofills after the plot is established.]
 - o Eastern hemlock (Tsuga canadensis)
 - o Carolina hemlock (*Tsuga caroliniana*)
 - o Other hemlock species
- Tree diameter breast height
 - o _____ [inches/centimeter checkbox]
 - o _____ [compute from circumference checkbox]
- <u>Hemlock Woolly Adelgid</u> (HWA)* Do you see HWA on this tree?
 - Yes, H = Heavily infested
 - Yes, M = Moderately infested
 - Yes, L = Lightly infested

- No = 0% infested
- o I'm not sure (e.g., cannot see the branches from the ground)



Images: HWA infestation levels. Left and right photos by Cornell University NYS Hemlock Initiative staff; middle photo by TNC Adirondack PRISM.

- <u>Elongate Hemlock Scale</u> (EHS)* Do you see EHS on this tree?
 - Yes, H = Heavily infested
 - Yes, M = Moderately infested
 - Yes, L = Lightly infested
 - No = 0% infested
 - o I'm not sure (e.g., cannot see the branches from the ground)



Images: EHS infestation levels. Left photo by Joshua Harkness, center photo by Lindsay Dombroski, right photo by Nicole Campbell. • Canopy Health*

How healthy is the canopy of the tree?

- H = Healthy (>80% healthy canopy; deep green, dense foliage; skylight is mostly blocked when you look at the tree)
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- S = Severe Decline (<20% canopy; many limbs dead, foliage sparse; skylight very visible when looking at the tree)
- o l'm not sure
- o Comment Field

Hemlock Canopy Health Rating Guide

Health Class	Distance view	Looking up under tree view
Healthy		<image/>

Health Class	Distance view	Looking up under tree view
In Decline		
Severe Decline /Dying		

Images: Healthy hemlock: photos by Cornell University NYS Hemlock Initiative (NYSHI) staff. Declining hemlock: distance photo by Margot Wallson, upward photo by Cornell University NYSHI staff. Severe decline: distance view photo by Shenandoah National Park staff.

- Canopy Position*
 - o Dominant, this tree's crown extends above other nearby trees
 - Codominant, this tree's crown is level with or slightly below other nearby trees
 - o Overtopped, this tree's crown is entirely below other nearby trees
 - Not applicable (e.g., tree is isolated, tree is on the forest edge)
 - o l'm not sure
 - o Comment Field

• Treatment Status*

Has the tree been treated with pesticides since the last monitoring visit? (Or, for the first year that data is collected, in the last 15 years.)

- o Yes
- o No
- o l'm not sure
- Comment Field (e.g., treated five years ago, treated with imidacloprid soil application in year X)
- Notes

[Use this optional space to record any unique things about this tree (e.g., growing by a big boulder), other stressors that may be present (e.g., spongy moth defoliation), or other information helpful to future monitors.]

Step 3: Site Characteristics

Optional Data to Record Each Visit

- Regeneration
 - Are there hemlock seedlings and/or saplings?
 - Yes
 - No
 - Are there seedlings/saplings of non-hemlock species?
 - Yes
 - No
 - Comment Field (e.g., abundant hemlock seedlings/saplings, abundant beech seedings/saplings, some maple seedings; some of the hemlock saplings that were less than 4"DBH when the plot was established have since exceeded 4" and are still alive)
- Composition of trees in the remainder of the plot What are the three most common, non-hemlock tree species in the plot?
 - _____ Most common, non-hemlock species
 - o ______ Second most common, non-hemlock species
 - o _____ Third most common, non-hemlock species
- Composition of shrubs/understory in the plot What is the composition of the shrub/understory layer of the plot? [Include any notable native and invasive species.]
 - o _____ Composition description (e.g., invasive stiltgrass, hay-scented fern, buckthorn, native mountain laurel)
- Other Hemlock Stressors Comment Field [Note if you see evidence of other stressors that may be impacting hemlock health.]

Hemlock Pest Biocontrols

Do you see signs of and/or know of any biocontrols being present on the trees in the plot?

o Yes

Comment Field

- o No
- o l'm not sure
- Forest management

Do you see signs of active forest management (e.g., recently cut stumps, flagging, disturbance, active road/track)?

o Yes

Comment Field

- o No
- o l'm not sure
- Site changes

Have there been any significant natural or cultural changes to the area since the last monitoring visit (e.g., area has been flooded by beavers; land has been subdivided)?

- o Yes
 - Comment Field
- o No
- o l'm not sure

Data to Record Once at Time of Plot Establishment

- Habitat*
 - Click all that apply.
 - o Forest
 - o Wetland
 - o Field
 - Roadside, urban, suburban, or park
 - o Riparian area
 - Steep slope
 - Comment Field [Describe the habitat in the area (e.g., wet seep, dry ridge top, moderate slope, flat).]
- Soil
 - Hydric (wet, soil drains slowly, water is at or above ground surface all year)
 - Mesic (balanced moisture, moisture level varies depending on rainfall but generally moist)
 - Xeric (dry, moisture deficient during summer growing season)
 - o l'm not sure

- Approximate Elevation
 - o _____ [feet/meter checkbox]
- Slope
 - Flat to gentle slope: 0-8% slope
 - Moderate slope: 9-15% slope
 - Steep slope: 16-35% slope
 - Extremely steep slope: >35% slope
 - o l'm not sure
 - o Comment Field
- Downed Hemlocks

Are there clearly identifiable hemlock trees that have already died and fallen down that are within the plot boundaries?

- o Yes
 - Approximately how many _____
 - Cause of death if known [check all that apply]
 - HWA
 - EHS
 - Natural causes
 - Other: Comment Field
 - I'm not sure
- o No
- o l'm not sure
- Forest Management

Is forest management allowed?

- o Yes
- o No
- o l'm not sure
- o Comment Field
- HWA Establishment When was HWA first identified in the area?
 - o _____ approximate year
 - o l'm not sure
 - o Comment Field
- EHS Establishment When was EHS first identified in the area?
 - o _____ approximate year
 - o l'm not sure
 - o Comment Field

*These fields are the same as the fields in the TreeSnap Lingering Hemlock Tree Search Protocol. Photos and instructional materials from the Lingering Hemlock Tree Search Protocol will be carried over to the plot protocol.

Future Research Needs

The working group recognizes that the Lingering Hemlock Tree Search Protocol and Hemlock Health Monitoring Plot Protocol are only a first step in designing a system to find candidate trees to assist future tree breeders and geneticists in developing resistant hemlocks. There are many information gaps to fill over time.

One information gap identified by the working group is the lack of readilyaccessible data about hemlock mortality. Regional hemlock mortality data would be extremely helpful for identifying when an area should be searched for lingering trees. For now, searchers will need to rely on local knowledge, data released by individual states, and/or, where available, county-level USFS Forest Inventory and Analysis data. Data from the monitoring plots could help bridge this gap over time.

The working group also notes that information about the characteristics of lingering trees will evolve over time as researchers learn more about pest/host interactions and resistance mechanisms. As the science is refined, these protocols can be updated to reflect the best available information.

Working Group Members

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