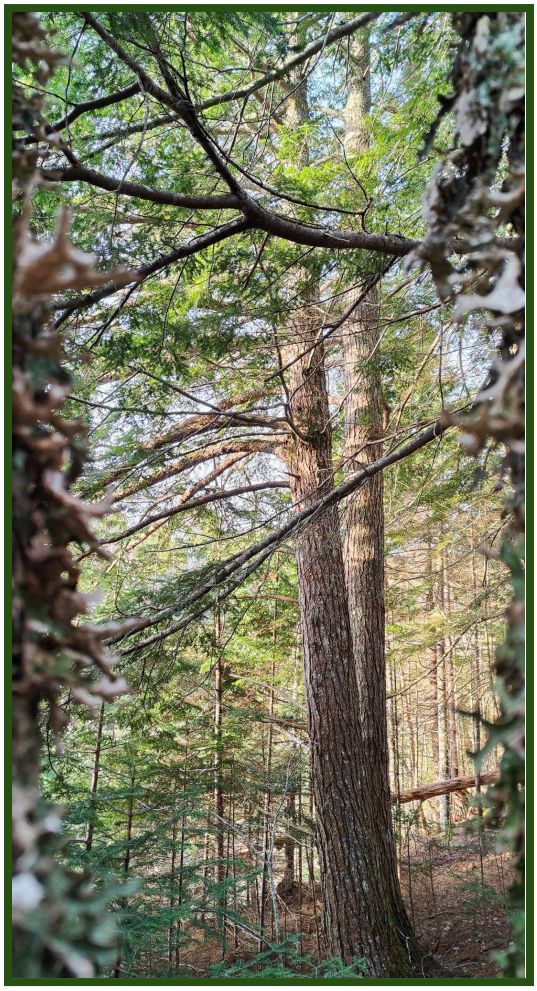
PEIISC SURVEY & MONITORING PROTOCOL FOR HEMLOCK WOOLLY ADELGID



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PEI invasive species council

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Dust of Snow
BY ROBERT FROST

The way a crow
Shook down on me
The dust of snow
From a hemlock tree

Has given my heart
A change of mood
And saved some part
Of a day I had rued.

Introduction

This survey protocol was designed by the Prince Edward Island Invasive Species Council (PEIISC) based on preexisting protocols created by the Canadian Food Inspection Agency (CFIA) combined with useful information from a variety of sources from Canada and the Eastern United States. It contains the most up-to-date information that the PEIISC has available as of February 2024. This protocol strives to break down informational barriers and unify existing information about surveying for hemlock woolly adelgid (HWA) from a PEI perspective to help Islanders contribute to island-wide monitoring efforts.

This survey protocol is a main component of our broader Early Detection, Rapid Response framework. The establishment of such a framework is crucial to the success of a future management effort for HWA when it arrives on PEI. This is because early detection of an infestation makes control efforts much more effective. Increased efficacy is due to the limited distribution of HWA during the early stages of the infestation. By monitoring Eastern hemlocks for HWA, you increase the chance of early detection and thus increase the chance of a successful response.

The PEIISC would like to acknowledge the ongoing collaborative effort of both government and non-government agencies towards the creation of this framework. Over 70 years of preceding research will guide our efforts.

The PEIISC would also like to thank our funders, Environment and Climate Change Canada and the Province of Prince Edward Island's Prince Edward Island Forested Landscape Priority Place for Species at Risk and the Prince Edward Island Wildlife Conservation Fund, for making this work a possibility.

Finally, we would like to thank you, the reader, for taking the time to review our survey protocol and implement its recommendations in hemlock stands you own, manage, or visit. Together we can work to create the best possible future for PEI's Eastern hemlock populations.

The advice provided in this document is by no means an exhaustive list of all possible considerations and does not provide guidance for all situations. Advice should be followed at your own risk, and the PEIISC accepts no liability for any harm incurred during the execution of advised procedures.

This is a living document, and is subject to future changes as Canadian populations of HWA continue to expand and new information becomes available. Visit www.peiinvasives.ca to ensure you have the most up-to-date version of this document.

Objectives and goals

The PEIISC's broad goals for our early detection, rapid response plan for hemlock woolly adelgid are as follows.

1. Prevent the future establishment of hemlock woolly adelgid on PEI.
2. Encourage interagency communication to improve regulatory measures centred around preparedness and prevention.
3. Create a distribution map of all known Eastern hemlock presence on PEI to assist in a response effort to infestation.
4. Promote general awareness of both Eastern hemlock's benefits and the ravages felt by Eastern hemlock populations affected by hemlock woolly adelgid.
5. Assemble a hemlock woolly adelgid stakeholder network for the province that includes all organizations with a vested interest in the preservation of Eastern hemlock populations on PEI.
6. Act as a source of the best, most up-to-date information on hemlock woolly adelgid control in Eastern Canada, and make this information accessible to all interested parties.
7. Create an emergency response plan to facilitate action in the event of a future infestation.
8. In the event of an infestation of hemlock woolly adelgid on PEI, promote an effective and rapid response by assisting both affected landowners and regulatory agencies through careful planning and data collection.

History of hemlock woolly adelgid in North America

Hemlock woolly adelgid is an aphid-like insect. It has a complex life cycle with many stages, all of which depend on the hemlock tree as a host in some capacity.

Hemlock woolly adelgid (HWA) was first introduced to Eastern North America in the American state of Virginia in 1951. The insect is believed to have been introduced by imported nursery stock from Japan, as the adelgid is thought to be native to Japan and China. A distinct, potentially native variety of the hemlock woolly adelgid exists in British Columbia, but this population is believed to have existed there for thousands of years on Western hemlock and does not cause significant damage to those trees. This is likely due to host resistance and the presence of limiting factors like pests and predators of the hemlock woolly adelgid in Western Canada. British Columbia is still considered a regulated area for the spread of HWA, as this Western HWA variety may also cause heavy damage in Eastern hemlocks just like the introduced Asian variety. HWA has been historically limited by extreme cold and thus benefits from the advance of global warming.

Since its initial introduction, the insect has spread to 25 U.S. states, Nova Scotia, and Ontario.

The Eastern hemlock is known as **gsu'sgw, gastog, or kastik** in the Mi'kmaq language. Traditional uses of hemlock among the Mi'kmaw nation are many and varied. These include use of the inner bark as a food, a beverage, and a medicinal tea to treat diarrhea, scurvy, and

chapped skin. A bark and stem tea was used as a treatment for cold and flu. Roots and stems were used to treat kidney ailments. The bark was used in the creation of dyes. as a medicinal treatment (stems, needles, bark, and roots), as a source of vitamin C. Needles have reportedly been used in sweat lodges. Thank you to Helena Perry, Indigenous Chartered Herbalist, for her consultation here.

The Eastern hemlock has been valued for building materials, as a medicinal plant, for poetic inspiration, and more. Its branches were used as brooms by early settlers, and the tree was a significant source of tannins for leather processing. The boughs of hemlock are reported to ward away rodents and were used to line cellars and storerooms.

Hosts affected

The only native species affected by HWA on PEI is the Eastern hemlock. Eastern hemlock is the hemlock species most drastically affected by HWA globally. Other exotic hemlock ornamental plantings may harbour HWA and where possible should not be planted. In the list below, **bolded** species are native, and <u>underlined</u> species are regulated but non-native.

- **Eastern hemlock, *Tsuga canadensis***
- <u>Yeddo spruce, *Picea jezoensis hondoensis*</u>
- <u>Tiger-tail spruce, *Picea polita*</u>
- Carolina hemlock, *Tsuga caroliniana*
- Chinese hemlock, *Tsuga chinensis*
- Japanese hemlock Tsuga diversifolia
- Western hemlock, *Tsuga heterophylla*
- Mountain hemlock, *Tsuga mertensiana*
- Southern Japanese hemlock, *Tsuga sieboldii*
- Himalayan hemlock, *Tsuga dumosa*

What it does to the environment

Hemlock woolly adelgid is a particularly destructive invasive species, causing over 90% mortality in infested Eastern hemlocks. The loss of Eastern hemlock not only affects the species that rely on Eastern hemlock, but the entire ecosystem, the economy, and human wellbeing. Eastern hemlock trees are an important tree species in Northeastern North American forests for a wide variety of reasons.

- Changes in water use and availability, water temperature, and nutrient & energy cycling caused by the loss of hemlocks will result in major shifts in ecosystem structure after hemlock is removed.
- Loss of hemlock in an area can change the way water moves through that area (the hydrology). Hemlock species use less water during the growing season than hardwoods, meaning that more moisture is available for other members of the ecosystem. Hemlock may also help prevent flooding where it grows by taking up excess water during times of peak flow.

- The loss of hemlock results in a shift of ecosystem character towards a hardwood-dominant ecosystem.
- Loss of Eastern hemlock results in an increased likelihood of invasive species establishment.
    - Glossy buckthorn and garlic mustard have been found to be limited by the dark shade created in areas of hemlock growth, and are known to benefit from hemlock mortality related to HWA.
- Loss of Eastern hemlock will result in the loss of shade for interior forest places that rely on the maintenance of a cool, moist environment for proper ecosystem function.
        - Dark, interior forest spaces promote the long-term, slower growth of other trees, increasing their quality and structure.
- Loss of Eastern hemlock will reduce local biodiversity and natural beauty.
- Infested stands see a reduced ability to sequester carbon in the soil and higher soil pH.
- HWA attacks hemlock trees of all ages and sizes, from the seedling to the old-growth tree.
- Loss of Eastern hemlocks will result in the loss of habitat for wildlife that depend on hemlock trees for shelter and nutrition.
    - Species affected include hemlock-associated migratory bird species listed in the “pathways of spread” section.
    - Higher water temperatures caused by the loss of hemlock canopy cover may reduce the fitness of native freshwater fish species and other aquatic organisms that rely on cold water temperatures to grow and reproduce.
    - Eastern hemlocks are often found growing at the edge of wetlands or watercourses. When they die, dead material will end up in the water, potentially causing blockages for water movement and fish passage.
    - Potential impacts include those on registered species at risk. (bolded = studied impact, non-bolded = potential impact)
        - Atlantic salmon, *Salmo salar*
            - Atlantic salmon (Salmo salar): COSEWIC assessment and status report - Canada.ca
        - Northern myotis, *Myotis septentrionalis*
            - Little Brown Myotis (Myotis lucifugus), the Northern Myotis (Myotis septentrionalis), and the Tri-colored Bat (Perimyotis subflavus): recovery strategy 2018 - Canada.ca
        - Little brown myotis, *Myotis lucifugus*
            - Little Brown Myotis (Myotis lucifugus), the Northern Myotis (Myotis septentrionalis), and the Tri-colored Bat (Perimyotis subflavus): recovery strategy 2018 - Canada.ca
        - **Canada warbler, *Cardellina canadensis***
            - Canada Warbler (Cardellina canadensis): COSEWIC assessment and status report 2020 - Canada.ca
            - Insects | Free Full-Text | The Past, Present, and Future of the Hemlock Woolly Adelgid (Adelges tsugae) and Its Ecological

Interactions with Eastern Hemlock (Tsuga canadensis) Forests (mdpi.com)

- Rusty blackbird, *Euphagus carolinus*
  - Rusty blackbird (Euphagus carolinus): COSEWIC assessment and status report 2017 - Canada.ca
- Evening grosbeak, *Coccothraustes vespertinus*
  - Evening grosbeak (Coccothraustes vespertinus): COSEWIC assessment and status report 2016 - Canada.ca
  - Glen Blouin, An Eclectic Guide to Trees East of the Rockies.
- Blue felt lichen, *Degelia plumbea*
  - Blue felt lichen (Degelia plumbea): COSEWIC assessment and status report 2010 - Canada.ca
- Little brown bat, *Myotis lucifugus*
  - COSEWIC assessment and status report on the Little Brown Myotis, Myotis lucifugus, Northern Myotis, Myotis septentrionalis, Tri-colored Bat, Perimyotis subflavus, in Canada .: CW69-14/688-2014E-PDF - Government of Canada Publications - Canada.ca
- Northern myotis, *Myotis septentrionalis*
  - COSEWIC assessment and status report on the Little Brown Myotis, Myotis lucifugus, Northern Myotis, Myotis septentrionalis, Tri-colored Bat, Perimyotis subflavus, in Canada .: CW69-14/688-2014E-PDF - Government of Canada Publications - Canada.ca

- Loss of habitat for rare lichen communities.
- Loss of habitat for amphibians, especially when areas of hemlock growth are salvage cut.
- Loss of Eastern hemlock is likely to negatively impact small mammal populations.
  - For example, the Northern flying squirrel, *Glaucomys sabrinus,* Northern myotis, *Myotis septentrionalis,* and little brown bat, *Myotis lucifugus.*
- Changes in insect diversity may follow the loss of Eastern hemlock. Ground-dwelling ant species increase in number, while the diversity of spiders, mites, and springtails may diminish.
- As the loss of hemlock removes habitat, the surrounding habitats may feel increased pressure from displaced species.

- Risks to human wellbeing:
  - Dead hemlock trees present a risk of falling on people moving nearby.
  - Dead hemlock trees present a fire risk.
  - Loss of hemlock as an economic resource.

Identification, biology & lifecycle

In Northeastern North America, all hemlock woolly adelgids are female, and reproduce asexually.

- Two generations of hemlock woolly adelgid occur each year, the spring generation (progrediens, early spring to midsummer) and the overwintering generation (sistens, early summer through mid-spring).
    - These two generations overlap in their occurrence.
- The most visible portion of HWA is the white woolly ovisac, which is ~1mm across in fall and grows to ~3-5mm by spring.

The life cycle begins when the overwintering adult (sistens) lays its **eggs**.

- Eggs are small reddish orbs coated in a white waxy wool-like substance (ovisac).
- In Maine, egg masses are known to be found most prominently from early March to mid-June. Due to latitude differences, it can be expected that this period may occur somewhat later than this on PEI.
- The egg stage is one of two stages that can be relocated without the transfer of live hemlock trees.
- A single adult in the overwintering (sistens) generation can produce up to 300 eggs.
- Eggs hatch in spring and become mobile crawlers (1st stage larvae).

Crawlers are the only mobile life stage of HWA that survives to reproduce in North America.

- This life stage is extremely small and difficult to see with the naked eye. 100s of crawlers could fit on one side of a dime.
- In Maine, crawlers are usually present from spring until the end of July. Due to latitude differences, it can be expected that this period may occur somewhat later than this on PEI.
- Once these crawlers find a suitable place on a twig at the base of a needle, they insert their mouthparts to begin feeding and do not move for the rest of their lives except to molt.
- Hatching in the spring, progrediens larvae rapidly mature to become adults. These adults lay eggs, which give rise to the following year's sistens generation.
    - A single adult in the spring generation (progrediens) can produce up to 125 eggs.
- Sistens crawlers behave exactly like progrediens crawlers initially, however, after settling in to feed, they enter a period of dormancy before maturing.

From late summer until early fall the sistens nymphs/larvae settle and remain dormant.

- This is called aestivation, essentially the summer version of hibernation.

The second through fourth larval instars are completely immobile.

- These are much easier to spot than crawlers and dormant larvae thanks to a thick woolly coating the adelgids secrete from early fall through the wintertime.
    - This coating is used to protect the adelgid and its eggs from predators or the elements.

- In late summer/early fall, the larvae exit dormancy and, along with the production of their woolly coat, begin feeding.
- Feeding is conducted by inserting the mouthparts into the twig/branch at the base of a needle and sucking out nutritious juices from within.

Wingless adults have a similar appearance to later-stage instars to the naked eye.

- They vary in size depending on their generation.
- The spring generation is less than 1mm in length, while the overwintering generation is ~1.5 mm long.
- Wingless adults can reproduce in North America.

Winged adults do not survive in North America.

- Also known as sexuparae.
- Some eggs laid by sistens will mature into these winged adults in spring and early summer.
- Winged adults do not have a waxy coating, but are dark brown with large compound eyes and four wings, somewhat similar in appearance to a fruit fly.
- Winged adults do not have a suitable host in North America and cannot complete their life cycle. They die looking for a suitable host and do not reproduce. If a suitable host was found, this would allow significant range expansion of the adelgid by flight.
- The spruce species winged adults require as hosts are
    - Yeddo spruce*, Picea jezoensis hondoensis*
    - Tiger-tail spruce*, Picea polita*

The cold and climate change affect HWA fitness.

- Climate change is expected to exacerbate the damage caused by HWA on Eastern hemlock populations not only due to future loss of cold limiting effects on HWA populations but also because of the Eastern hemlock's low expected fitness under future climate conditions.
- Hemlock woolly adelgid is currently found in plant hardiness zones 5-6. Mortality appears to be dependent on temperature and individual health.
    - In warmer areas, hemlocks are usually killed within 3-4 years, but in more northerly regions cold slows the activity of HWA significantly, meaning mortality can take over 10 years.
- Currently, the Northernmost reaches of the range of Eastern hemlock are believed to be out of the reach of hemlock woolly adelgid due to its limited cold tolerance.
- Hemlock woolly adelgid is somewhat limited by extreme cold events, but it is suspected that the adelgid may be able to adapt itself to become more cold tolerant over time.
- As our climate warms each year due to the effects of global warming, this cold limiting will affect the adelgid less and less, potentially allowing for broader expansion of its distribution.
- According to the Nova Scotia Hemlock Woolly Adelgid Management Plan: "Adelgid survival is adversely affected by extremes in winter temperature but adaptation to colder winter temperatures has been observed in some populations (Butin et al. 2005;

Lombardo & Elkinton 2017). Paradis et al. (2008) found that 91% mortality is required to stabilize HWA populations in specific conditions. However, overwintering mortality of HWA in NS in 2019 and 2020 ranged from only 30–60% (Ogden & Boone 2020), suggesting the HWA populations will continue to increase and spread throughout most of NS." (Hemlock Woolly Adelgid Working Group – Maritimes)

Pathways of spread

The various potential pathways of spread for hemlock woolly adelgid.

Like any invasive species, HWA is introduced via some pathway of spread. Most introductions of invasive species are mediated by humans, but due to HWA's small size and activity during periods of bird migration, natural dispersal methods are significant contributors to spread. In any case, **HWA requires some external support to spread,** as the adelgids cannot fly or travel long distances on their own in North America. Pathways of spread include:

- Natural Dispersal (eggs & crawlers only)
    - Wind.

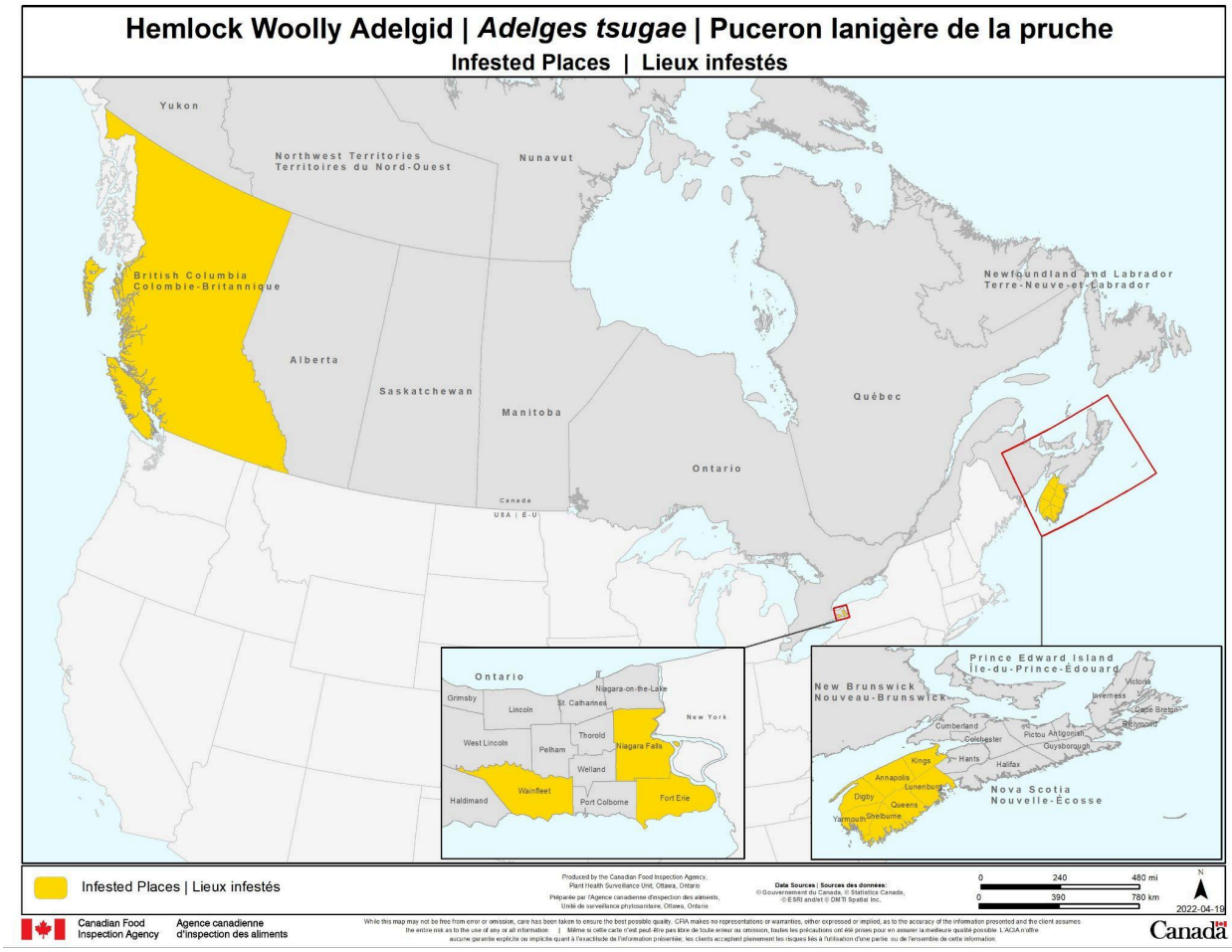
    - Tides.
    - Animals (esp. migratory birds).
        - Of the natural dispersal mechanisms possible, this is most likely, as animals take directed action to visit hemlocks. Long-distance dispersal by migratory birds has yet to be confirmed as the source of any specific infestation, but studies have shown that birds do collect HWA crawlers in their plumage and can transfer them to other uninfested trees.
        - Spring migration, when birds move from southerly infested areas to the North, is when transmission can be expected to occur.
        - Spring migration occurs from mid-April to June, peaking in mid-late-May for arrivals on PEI. Migration coincides with the emergence of mobile crawlers, allowing for coincidental dispersal of HWA.
        - Migratory birds with strong associations with Eastern hemlock in Nova Scotia inlcude:
            - Blackburnian warbler, *Setophaga fusca*
            - Black-throated green warbler, *Setophaga virens*
            - Ovenbird, *Seiurus aurocapilla*
            - Northern parula, *Setophaga americana*
            - Blue-headed vireo, *Vireo solitarius*
            - Red-eyed vireo, *Vireo olivaceus*
            - Yellow-rumped warbler, *Setophaga coronata*
            - Swainson's thrush, *Catharus ustulatus*
            - Hermit thrush, *Catharus guttatus*
            - Least flycatcher, *Empidonax minimus*
            - Eastern wood pewee, *Contopus virens*
            - American robin, *Turdus migratorius*
            - Bay-breasted warbler, *Setophaga castanea*
            - Black-throated blue warbler, *Setophaga caerulescens*
        - Other migratory birds found on PEI with a strong demonstrated carrying capacity for HWA:
            - Rose-breasted grosbeak, *Pheucticus ludovicianus*
            - Veery, *Catharus fuscescens*
            - Gray catbird, *Dumetella caroliniana*
            - Black-and-white warbler, *Mniotilta varia*
            - Song sparrow, *Melospiza melodia*
            - American goldfinch, *Spinus tristis*
- Artificial/human dispersal
    - Nursery Stock/Live Plants: Allows for the movement of any life stage.
    - Wood products, such as unprocessed hemlock wood, wood of other species harvested from within an infested area, and firewood of all species (eggs and crawlers only).
    - Vehicles, humans (clothing, hair), and outdoor equipment (eggs and crawlers only).

- Observed to move ≤30km per year.
- Wind, & hitchhiking allow for long-distance natural dispersal. (Eggs & crawlers only)

Regulated areas and associated federally mandated prohibitions

The CFIA has designated several HWA-infested areas of the country as regulated areas with prohibitions for the movement of certain goods identified as prime sources of spread for HWA. In the event of confirmed HWA establishment on PEI, the Island will likely also become a regulated area for HWA movement.

Infested areas are shown below:



Goods whose movement out of designated HWA-infested places into non-infested places is prohibited include:

- Firewood of all species
- Propagative and non-propagative commodities of *Tsuga spp*., *Picea jezoensis,* and *Picea polita* as follows:

    - Propagative material: Plants for planting
    - Non-propagative material: Christmas trees; fresh decorative wreaths, foliage and branches; forest products with bark attached such as logs and lumber with bark; bark chips; wood mulch with bark; and dried branches
- Specific processing requirements must be met and certification must be provided by the CFIA to legally move the above materials from an infested area to a non-infested area.

Additional information:

- Kejimijuik National Park has a preventative order in place prohibiting the movement of firewood into or out of the park.
- Given that large-scale harvesting operations are not currently restricted in forests with HWA, the movement of HWA on material harvested from nearby trees is still a potential dispersal pathway of concern.
- Infested place order, including details about prohibited products and restricted areas: Amended Hemlock Woolly Adelgid [Adelges tsugae (Annand)] Infested Place Order - Canadian Food Inspection Agency (canada.ca)
- Before moving any of the above materials from an infested place, review and follow the regulations described in the phytosanitary requirements for movement of hemlock from infested places to non-infested places: D-07-05: Phytosanitary Requirements to prevent the introduction and spread of the Hemlock Woolly Adelgid (Adelges tsugae Annand) from the United States and within Canada - Canadian Food Inspection Agency

Detection and monitoring

Monitoring for HWA will allow for early detection of the establishment of this pest. The earlier we detect the pest, the less costly and more effective our response to it will be. This makes early detection crucial to a successful response.

General monitoring notes

- Familiarize yourself with the area.
    - The survey areas should be reviewed using satellite imaging (i.e. Google Maps) or site familiarity.
    - If you would like, print a map of the area and affix it to a hard surface like a clipboard for quick reference in the field. You can mark on your map as you survey if desired but ensure that this data is maintained and recorded in a central place with the other data.
- Datasheets were created by PEIISC staff specifically for monitoring HWA.
    - For those using datasheets, print out a set of datasheets for each site. You will need at least one per site and may want to have extra on hand.
- Data can be recorded digitally using the Survey123 form at the following link: https://arcg.is/0OHGDf0
    - Alternatively, scan this QR code with your smartphone to access the Survey123 form.

    - NOTE: Install the app on your smartphone before clicking the link.
- Safety is always the top priority when conducting fieldwork. No survey data is worth sustaining an injury, illness, or worse.
    - Always survey with a buddy, or at the very least let someone know where you are going and how long you plan to be there.
    - Make sure to monitor weather conditions and dress accordingly. Frostbite, heat exhaustion, dehydration, and sunburns are hazards associated with fieldwork.
    - Be wary of handling unfamiliar plants and animals. You may stress the organism and cause it to defend itself, or encounter unknown irritants, toxins, or poisons.
    - If you are in an area with heavy vehicular traffic, hunting, or construction, you may want to wear a high-visibility vest or coat.
    - Always know where you are and how to get back to where you started.
    - After storms and heavy winds such as hurricanes, be very aware of potential hazards in your survey area. Look up and listen! Windfall trees hanging on other trees can be dislodged unexpectedly. These trees often make a telltale creaking noise.
    - Watch your step! Uneven terrain and debris-covered holes can cause injury. Sinkholes can happen on PEI too, especially in wet or boggy sites. Old wells, especially found on old homestead sites, may be well-covered and you may fall in.
    - PEI's coastline is unstable and constantly changing. Cliffs and erosion may present a significant risk when surveying or monitoring for invasive species. Be mindful of these dangers, and do not put yourself in a position to be injured.

        - As waves and tides wear away the bottom of the cliff, the bank may become very unstable and subject to slumping (when a bank falls down suddenly after the elements have gradually weakened the cliff's footing). Extra weight on this delicate part of the bank may cause the bank to destabilize and fall, causing potential injury to anyone nearby and furthering the effects of erosion.
        - Stay away from the cliff edge.
    - CHECK FOR TICKS! No walk in the woods is worth contracting Lyme.
        - If any ticks are found on your person, carefully remove the tick using a tick-removal kit and place the tick in a container.
        - Removal must be done with care, as you do not want to stress the tick or break any parts off that could be left behind inside the bite area. Follow the instructions on your tick removal kit strictly.
        - Depending on the circumstances, medical attention may be required, especially if you experience any of the following symptoms after being bitten: fever, fatigue, muscle aches, headaches, and/or a rash (particularly a bullseye-shaped rash, but may take other forms).
        - It is a good idea to keep the tick that bit you in case of complications. Removing the tick within 24 hours of attachment will usually prevent infection, but it is always best to air on the side of caution and see a doctor.
        - You can submit your tick and a report of your tick electronically on www.etick.ca or using the eTick application on your smartphone. This will give you an accurate ID of your tick within 48 hours and provide you with any relevant information and suggested actions to take.
        - The PEIISC is currently seeking reports of the black-legged deer tick, *Ixodes scapularis,* an invasive species, and the vector of Lyme disease spread.
        - Common habitats for ticks include temperate humid forested areas with a thick layer of underbrush. Ticks are also commonly found on dead or injured animals, in tall grass, and in leaf piles.
- Trespassing
    - The PEIISC recommends that you survey only those properties that you have been given permission to survey.
    - On PEI, people can access forested places for any reason provided there is no posted signage indicating that the land is private property, no fence, and you have not been given verbal notice to stay away. This access is yours to enjoy provided that you do not engage in disorderly conduct, disturb the property owner's privacy, or operate a motor vehicle unreasonably while on the unmarked property.
    - While legally you may be able to access a forested area, you may not be welcomed there. It is important to be aware of provincial trespassing laws while surveying. Even if you are within your rights, it is always a good idea to ask for permission to survey where possible.

    - You should also note that in some areas, municipal bylaws may have different regulations from provincial laws. Municipal bylaws may outline a stricter set of rules for property access.
    - Respecting privacy and asking first before entering a privately owned area is the best course of action.
    - If you know that you are on private property it is your responsibility to limit any disturbance caused by your presence. Never undertake management here without the express permission of the landowner.
    - Review applicable provincial legislation here: Trespass To Property Act (princeedwardisland.ca)
- Focus on these broad goals for your first survey:
    - Identify Eastern hemlock trees as suitable targets for monitoring.
    - Maximize potential detection of HWA (see site selection below).
    - Minimize ecological impact from survey activity.
        - Be mindful of nesting birds from May to August.
        - Be mindful of fish spawning times and shellfish spatfall times and spend as little time as possible within watercourses or wetlands.
        - Tread lightly and keep to the trails as much as possible.
        - Create as little disturbance as possible and leave no trash or materials behind.

Monitoring data recording and submission

- Data recorded for an HWA monitoring report should include:
    - Location data (GPS coordinates ideal, address also useful).
    - The surveyor's name and affiliation.
    - The survey date.
    - Contact information such as phone number or email address.
    - Number of trees inspected, number of positive & negative results.
    - Survey results.
    - Total area surveyed in hectares.
- **Monitoring data for negative results (when you don't see HWA) should also be recorded.**
    - Data can be recorded digitally using the Survey123 form at the following link: https://arcg.is/0OHGDf0
    - Alternatively, scan this QR code with your smartphone to access the Survey123 form.

        - NOTE: Install the app on your smartphone before clicking the link.
    - Data can also be submitted in an Excel spreadsheet format:
        - From the CFIA:
        - “Survey activities conducted for a regulated pest in accordance with the established CFIA survey protocol should be captured so that all collaborative efforts can be captured. An Excel spreadsheet containing latitude and longitude coordinates and address for the site surveyed, percent hemlock, organization details, and coordinates for any suspect trees can be submitted to the CFIA Surveillance@inspection.gc.ca by no later than September 1st each year so that all efforts can be mapped and reported Nationally. Possible suspects should always be reported in real-time.”
            - Data being submitted to the PEIISC directly would be greatly appreciated, and the PEIISC can provide the data to CFIA subsequently.
        - CFIAsurveyprotocol.pdf (invasiveinsects.ca)
- For those who prefer to record data using pen & paper, we have created PEIISC HWA Monitoring Datasheets, which are appended to this document.
    - When starting a new datasheet, fill in:
        - Your name and contact information (Phone number and/or email address).
        - The date (DD/MM/YYYY).

        - Where you are surveying (Coordinates or address) including survey start point.
        - A short description of the area, goals, and survey crew.
        - The section number and the total area of the section, in ha.
        - The GPS, tablet, or smartphone model used to track data (GPS ID).
        - Weather data.
            - Precipitation and cloud cover can be recorded by using the numeric code found on the datasheet. The wind is measured on the Beaufort scale, shown below, or by simply recording the actual wind speed in km/hr.
        - Survey method (visual sampling/ball sampling/interception traps/eDNA traps).
        - Form ID is an optional field that can be used to keep your sheets in order. Fill this field in with something like A-001 for your first page, A-002 for the second page, etc.
    - Although we encourage surveyors to record all available data on the datasheet, we recognize that this data will not be available in all cases. Essential data to record in any case include
        - Tree ID/waypoint number or coordinates.
        - Direct evidence of HWA presence?
        - Number of samples collected.
    - Ideal data includes:
        - Diameter at breast height.
        - General signs of stress or decline.
        - Flagging the tree and marking the tape with the tree ID/waypoint number.
            - This will help future surveyors easily replicate the survey or expand the survey to trees not previously surveyed.
        - Photos, including photographer's initials and number of photos taken for each tree surveyed.
    - Any notable deviations from standard protocol, difficulties surveying, and other comments can be recorded in the "Additional Comments:" section on the back side of the datasheet.

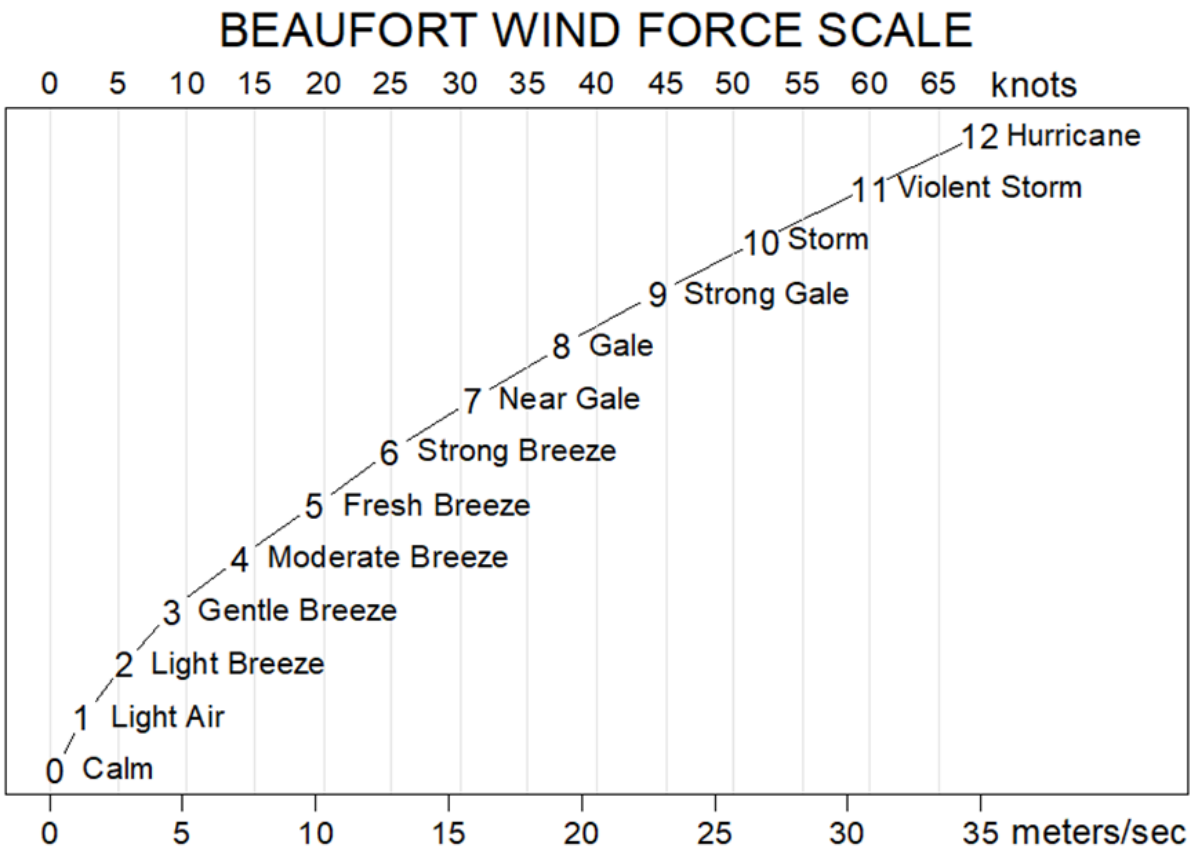


Figure 3: Beaufort Wind Force Scale. [Credit to user Ldecola on Wikimedia Commons, used under Creative Commons Attribution-Share Alike 4.0 International license.]

General symptoms of HWA presence

The following is a list of the most common symptoms of HWA infestation in Eastern hemlock:

- White woolly masses (ovisacs) fixed to twigs near the base of needles. These are either eggs, late-stage instars, or wingless adults. In fall these measure ~1mm across, growing to ~3-5mm by spring.
- Needles of affected trees develop a grayish tint.
- Discoloration of needles (chlorosis)
- Crown or branch dieback.
- Loss of needles.
- Aborted buds, lack of new growth.
- Crown thinning.
- Death of hemlock trees.
- Symptoms may be less apparent after a harsh winter, as many adelgids may be killed.

Site selection

The following considerations should be made when selecting a site for HWA monitoring:

- Stands of at least 4 hectares and a strong hemlock component are desired, although any site with any level of hemlock presence will do.
- Consider wind patterns and routes of migratory birds in site selection, as these are primary pathways of HWA dispersal.
    - Birds that favour hemlocks tend to choose larger, hemlock-dominant stands over smaller stands.
    - Due to these pathways of introduction, taller trees are most likely to harbour early infestations of HWA and should be prioritized for monitoring and treatment over smaller trees where applicable.
- Natural areas, wooded parks, green belts, and riparian zones are sites suggested by CFIA for surveying.
- Early populations are often first detected along roadways or other travel corridors, in the upper canopy of tall trees.
    - Hemlocks along watercourses are also important candidates for monitoring.
- During the initial infestation, infested hemlocks tend to occur in clumps. Once one infested tree is detected, its neighbours will likely be infested as well.
- Survey both edge and interior individuals to elicit a complete picture of HWA presence throughout an area.
- Sites within 100km of known HWA-infested areas are prioritized over other sites.
- If possible, draw a sketch or use a coordinated GPS route to help plan your survey approach.
- Estimate and record the approximate size of the survey area.
- Record notes on the overall health of the stand, prioritizing declining trees near the edge for examination.
- Stands with cultural significance should be prioritized for treatment and monitoring.
    - I.e. those used traditionally by the Mi'kmaq people.

Potential lookalikes

- Commonly reported look-a-likes of HWA include
    - spider eggs.
    - other insects.
        - Balsam woolly adelgid, *Adelges piceae*
        - Pine bark adelgid, *Pineus strobi*
        - Spittlebugs (family Cercopidae)
        - Oak skeletonizer, *Buccalatrix ainsliella*
        - Mealybugs (family Pseudococcidae)
    - fungus.
    - lichen.
    - spider mite injury.
    - drops of pine sap.
    - fake spider webs for Halloween, etc.
    - Lookalikes aside, any report is a good report. Reporting is important in any case, so if you are unsure, send detailed photos of your specimen to the PEIISC as soon as possible. We would rather receive a false negative report than have

something we would have liked to hear about go unreported. Quick action may be key in preventing further spread.

- Before going into the field to monitor, it is important to refresh one's familiarity with the signs of HWA infestation before beginning a survey. Review photos and descriptions of HWA symptoms before heading out. Reach out to the PEIISC for support here.

Other sources of Eastern hemlock stress

Hemlock woolly adelgid, as you can imagine, is not the only species that feeds on Eastern hemlock. Signs of stress may be attributed to other insects, fungi, human activity, or environmental conditions.

- Desiccation and drought are prime sources of stress for Eastern hemlock, a tree that relies on moist conditions to thrive.
- Wind damage is frequently seen in Eastern hemlock, especially in exposed areas.
- Damping-off and root rot fungi of several species are highly damaging to young trees.
- Several species of rust fungi may cause distortion and damage to shoots and needles.
- Sapsuckers frequent Eastern hemlocks, which are quite resilient to their damages compared to some other species of trees.
- Mammals such as snowshoe hares and other rodents will feed on young trees.

Some key insect pests of Eastern hemlock (information sourced from Natual Resources Canada, United States Forest Service)

- Hemlock lopper, *Lambdina fiscellaria*
    - Moth species.
    - Damage visible from late July to early August, caused by larvae feeding
    - Needles turn a reddish colour and drop off in the fall
    - Larvae only eat part of the needle, leaving the rest behind
- Pale winged grey, *Iridopsis ephyraria*
    - Not known to occur on PEI, but common in Nova Scotia.
    - Infestations begin in the understory in the first year, moving up to the crowns of mature trees thereafter.
    - May completely defoliate and kill a tree within 2 years
    - Missing or red needles are characteristic damage types.
    - Damage begins to appear in June when larvae hatch.
- Pine measuringworm moth
    - Little information is available, but the damage appears to resemble other moth infestations.
- Spongy moth
    - Eastern hemlock would not be a primary feeding target but may be defoliated when growing within heavily infested areas.
    - Tan spong-like egg masses seen on the surfaces of trees.
    - Severe defoliation may be seen.
    - Often, understory hemlocks will be killed.
- Spruce budworm

    - Although Eastern hemlock is not the primary food source of spruce budworm, defoliation will occur after primary food sources like balsam fir are exhausted.
- Pine spittlebug
    - Causes flagging and branch mortality when feeding damage prevents nutrient flow to areas of the tree.
    - Can cause death after several years of heavy infestation
    - Spittle is formed at feeding sites.
    - Damage is seen throughout the summertime.
- Spruce spider mite
    - First sign is a dusty substance on the needles.
    - Needles turn brown and drop off.
    - Silk threads on twigs are another sign of infestation
    - Shake a branch over a white piece of paper and see if tiny spider-like creatures fall. They are fast-moving.
    - Multiple generations per year can cause waves of damage.
    - Damage begins in the lower crown and moves upwards.

Some key fungal diseases of Eastern hemlock

- Hemlock-blueberry rust, *Naohidemyces vaccinii*
    - Damage usually does not lead to significant stress.
    - Damage appears when needles become yellowed and gain raised bumps.
        - Yellowing proceeds from the twig to the tip of the needles.
- Pinicola brown crumbly rot, *Fomitopsis pinicola*
    - Causes heartwood rot of living trees.
    - Usually occurs from an existing wound.
    - Discolouration of the wood with a pale yellow or brownish hue is the initial symptom. This is followed by the formation of red fruiting bodies in strips around the infected area. These turn grey and wrinkled with age.
- Brown Cubical sap rot
    - Causes sapwood and some heartwood rot.
    - Yellow or yellowish-brown pockets of discolouration will appear in the sapwood and outer heartwood.
    - Usually occurs from an existing wound.

Sources:

- eastern hemlock (nrcan.gc.ca)
- Tsuga canadensis (L (usda.gov)

Reporting

- **Healthy hemlock stands** can be reported directly to the PEIISC at peiinvasives@gmail.com. This data will help the PEIISC monitor PEI's hemlocks for HWA and inform a response effort should HWA arrive on PEI. Include as much data on the stand as is available. Data may include:

    - Locations of Eastern hemlock trees and stands (as specific as possible, digital data preferred).
    - Sizes of Eastern hemlock trees. (DBH)
    - Percent Eastern hemlock coverage in an area.
    - Economic valuation of Eastern hemlock in an area.
    - Information on the data's source and how the data was collected.
    - Not all of this data is required, any available data will be helpful!
    - Reports of healthy hemlock stands or individuals can also be reported to this iNaturalist project: Healthy Hemlock Forests of the Maritimes · iNaturalist Canada
        - OR to this Google form: https://forms.gle/Jr1Fx6KEsTHVGd2w7
- **If you believe you have seen HWA or symptoms of its establishment on PEI, quick reporting is crucial.**
    - Report findings to the PEIISC at peiinvasives@gmail.com as soon as possible.
        - Include a description of your findings including the number of trees affected, detailed photos, the location of the find, your contact information, and the date of the find.
        - Where possible, include:
            - A description of the host tree(s).
            - The surrounding area.
            - Any other relevant information.
    - DO NOT move HWA out of the infested area or collect any specimens, and allow a CFIA representative to visit the site to confirm the observation.
- If you suspect that you have been in an HWA-infested area, it is important not to inadvertently spread HWA from that area to an uninfested place. **Practice proper biosecurity measures to reduce the chance of spread when moving into and out of an infested place.**
    - When moving into and out of any natural area, it is important to ensure that you are not facilitating the transfer of organisms. This includes insects, arachnids, seeds, root pieces, fungi, nematodes, and other soil-borne organisms. By cleaning your boots and clothing of all organic material before entering and leaving the area, you can prevent the spread of HWA and other invasive species.
    - When leaving an area of known HWA infestation, especially during the period throughout which crawlers are mobile, all clothing should be gone over with a lint roller before leaving the premises. Additionally, preparation and use of a bleach bath for boots is recommended. This practice can protect against pest and disease spread. Alternatively, a general disinfectant product may be used.
    - Wipe down other equipment with alcohol wipes and dry it before leaving.
    - Watch this video for detailed information on HWA biosecurity
        - Hemlock Woolly Adelgid Phytosanitary Protocols - YouTube
- **If requested, and only if requested,** collect a specimen. Specimens can be stored below freezing until dropoff or pickup can be conducted.
    - Specimens can be submitted to the PEIISC for later submission to CFIA or to CFIA directly. Contact sarah.macinnis@inspection.gc.ca for instructions regarding specimen submission in PEI.

- From the CFIA:
  - A digital photograph of the egg sac or symptom should be taken. This should be emailed to your local CFIA office or the Area Survey Biologist: Surveillance@inspection.gc.ca.
  - Suspect twigs or branches are to be clipped at least 15 cm below the egg sac using pruning shears and placed in a plastic bag containing a piece of dry paper towel.
  - Record the GPS coordinates in Latitude and Longitude in decimal degrees (NAD 83 datum) for the tree sampled, your name, comments about the site (estimated diameter of tree, health, etc.), the date, and other location information on a piece of paper and place this into the bag.
  - A piece of flagging tape should be placed on the tree sampled as you will likely need to revisit the tree if the sample is positive.
  - CFIAsurveyprotocol.pdf (invasiveinsects.ca)
- A suspect site survey form may be filled out in association with a suspect or specimen:

Appendix 1: Suspect Site Form

HEMLOCK WOOLLY ADELGID SURVEY SITE FORM

Date of Survey	Y	Y	Y	Y	M	M	D	D	Surveyor(s):
Datum				N	A	D	8	3	Site Type: □ Nursery □ Urban Park or Green Space □ Urban Residential □ Forest Stand
Latitude			.						
Longitude	–			.					
Site Name	ATS-								Size of site (Ha.):
Site Address: _____ Number _____ Street Name _____ City _____ Province _____ Postal Code									
Notes:									Contact name:
									Contact number:
									E-mail (if applicable):
SUSPECT TREE DETAILS									
Datum				N	A	D	8	3	Signs & Symptoms Present: □ Woolly masses □ Crawlers □ Twig Dieback □ Thinning crowns Infestation Rating □ Light □ Moderate □ Heavy
Latitude			.						
Longitude	–			.					
Samples collected? □ Yes □ No									Pictures Taken? □ Yes □ No
LSTS System ID #:									
Notes: Stand Info (dead, declining trees, dbh, age, overall health, etc…):									

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CFIAsurveyprotocol.pdf (invasiveinsects.ca)

Sample submission

- Samples of initial infestations should only be taken by CFIA personnel. Members of the public should only remove HWA suspects from the area where they are found at the

direct request of CFIA personnel. Movement by untrained individuals may facilitate the spread of HWA.

- The CFIA sampling procedure:
    - In the event that HWA signs are encountered during the survey, samples should be taken and prepared for submission to the CFIA lab in collaboration with CFIA inspection staff.
    - A digital photograph of the egg sac or symptom should be taken. This should be emailed to your local CFIA office or the Area Survey Biologist: Surveillance@inspection.gc.ca.
    - Suspect twigs or branches are clipped at least 15 cm below the egg sac using pruning shears and placed in a plastic bag containing a piece of dry paper towel.
    - Record the GPS coordinates in Latitude and Longitude in decimal degrees (NAD 83 datum) for the tree sampled, your name, comments about the site (estimated diameter of tree, health, etc.), the date, and other location information on a piece of paper and place this into the bag.
    - A piece of flagging tape should be placed on the tree sampled as you will likely need to revisit the tree if the sample is positive.
- CFIAsurveyprotocol.pdf (invasiveinsects.ca)

Delivery of completed PEIISC HWA survey datasheets to the PEIISC

- After completing datasheets, send this data to the PEIISC to be included in our central database. When datasheets are complete:
    - Scan all datasheets.
    - Upload all photos and GPS files. This includes both waypoints and track data.
    - Send this data to the PEIISC at peiinvasives@gmail.com. Use the subject line “HWA Survey Datasheet: (insert location, date)”, and include any additional useful information in the body of the email. A link to a Dropbox or Google Drive data location is a suitable alternative.
    - **Alternatively**, data can be sent by mail to the following address: Voluntary Resource Center c/o PEI Invasive Species Council at **81 Prince Street Charlottetown, PE C1A 4R3.**
    - If you are in the Charlottetown area, PEIISC staff may be able to accept an in-person delivery as well.

Survey methods:

Surveyors may benefit from improved accuracy by incorporating multiple monitoring methods simultaneously.

Visual survey, branch examination

- The simplest method.
- This technique involves the examination of fallen branches or branches in the outer canopy of hemlock trees using a hand lens and the naked eye for the presence of HWA signs & symptoms.

- A benefit of this technique is that it can be done by anyone with the ability to identify with essentially no expense.
- *Materials required:*
    - Bleach bath (if within or nearby an infested area)
    - Lint roller (if within or nearby an infested area)
    - Smartphone or GPS and logbook
    - Hand lens
        - HWA can sometimes be seen with the naked eye, but a hand lens helps especially for observing earlier stages of the life cycle.
    - Additional useful gear:
        - PEIISC datasheets
        - Zip-lock bags and sealable dishes for specimen collection.
        - Pruning shears
        - Pole pruners
        - Knife
        - Digital camera
        - Tree identification guide
        - HB pencils
        - Permanent markers
        - Paper labels
        - GPS unit & Compass
        - Maps (including forest cover or municipal forest inventory)
        - Field book with waterproof paper
        - Flagging tape
        - Measuring tape
        - Protective footwear (Safety boots)
        - Reflective vest
        - Sunglasses
        - Hat
        - Sunscreen
- *Target life stages:*
    - **Eggs**, adults, late-stage nymphs/larvae coated in woolly masses (ovisacs).
    - Ovisacs are the most obvious symptom.
- *Timing:*
    - General: November-June
    - Optimal: March-May (ovisac is most visible)
    - Nymphs/larvae: November-February
    - Eggs & adults: March-May (crawlers also present during this period)
    - If monitoring outside the optimal monitoring period, a hand lens should be used to view aestivating HWA.
    - Avoid surveying when snow may be on the branches.
    - Ideally visual surveying should be done twice per year, around the beginning and end of daylight savings time.
- *Procedure:*

- Select a site with branches that can be easily reached.
    - A cane can be used to pull down branches just out of reach.
- Focus on trees with signs of stress or noted symptoms of HWA presence. Focus on the outer 1m of branches for your search. Focus on the bases of the needles along the twig/branch. Focus on branches with green foliage.
- If no branches are within reach at your site, look around on the ground for fallen branches or twigs, or use a pole pruner.
    - Collect branches from the ground as available and examine their undersides for woolly masses at the base of twigs.
- **Pruning:** If you have permission to do so, collect branches from the upper canopy of taller hemlocks using a pole pruner.
    - Prune a portion of the outer 1m of a branch. Select a and prune only branches with green foliage.
    - Pruning should not be used for all sampling, as it can cause damage to the trees and ultimately takes longer meaning fewer overall samples.
    - Ensure that you prune using proper technique to avoid injuring the tree.
    - Pruning in the fall or winter months can reduce the chances of a pruning wound attracting insects, as insects are largely inactive during this period.
    - As HWA often infests the upper canopy first, this practice can increase the chances of early detection compared with sampling from lower parts of the canopy.
- Examine the undersides of branches with a hand lens for woolly masses associated with later-stage nymphs, eggs, and adults. Examine trees for other symptoms of HWA infestation as described above.
- Examine the bole and bark for woolly masses or other signs of HWA.
- When surveying in areas >3ha
    - Ensure that the trees examined are well distributed throughout the survey area.
    - Where hemlock populations follow a watercourse or waterbody edge, prioritize these edge populations for surveying.
    - Survey both interior and edge trees where possible.
    - Survey branches from either side of the tree. At least two branches should be examined per tree until a suspect is found or 100 trees have been surveyed.
    - Record the survey starting point GPS coordinates.
    - After examining the first tree, take 25 paces (2 steps per pace) in the planned survey direction, and examine the nearest suitable tree.
    - Continue this process in a zig-zagging pattern until ~100 trees have been surveyed. Try to maximize coverage of the area during surveys.
    - Contact the PEIISC or CFIA immediately with any suspect information.
- When surveying in areas <3ha
    - Inspect all hemlock to a maximum of 40 trees or two hours per site. If there are many trees on site, distribute your search throughout the area.

        - Address findings as needed. Contact the PEIISC or the CFIA immediately with suspect information.
        - Survey branches from either side of the tree. At least two branches should be examined per tree.
- *Efficacy:*
    - Low-Moderate
        - Visual sampling is generally considered to be affordable and widely applicable, but is not always suitable for early detection.
            - Visual surveys without pruning are not as likely to provide early detection of HWA. This is because early infestations often begin high in the canopy of tall hemlocks.
            - Visual surveys with pruning cause damage to the tree which can result in stress or attracting pests to the area.
        - A benefit of visual surveys is that they can be done throughout the year, although summer surveying (June-October) is not recommended.
        - If no HWA woolly masses are found after sampling 100 hemlock trees, one can state with 75% reliability that less than 2% of the hemlock trees are infested in that area.
- *Biosecurity:*
    - If you suspect that you have been in an HWA-infested area, it is important not to inadvertently spread HWA from that area to an uninfested place. **Practice proper biosecurity measures to reduce the chance of HWA spread when moving into and out of an infested place.**
        - When moving into and out of any natural area, it is important to ensure that you are not facilitating the transfer of organisms. This includes insects, arachnids, seeds, root pieces, fungi, nematodes, and other soil-borne organisms. By cleaning your boots and clothing of all organic material before entering and leaving the area, you can prevent the spread of HWA and other invasive species.
        - When leaving an area of known HWA infestation, especially during the period throughout which crawlers are mobile, all clothing should be gone over with a lint roller before leaving the premises. Additionally, preparation and use of a bleach bath for boots is recommended. This practice can protect against pest and disease spread. Alternatively, a general disinfectant product may be used.
        - Wipe down other equipment with alcohol wipes and dry it before leaving.
        - Watch this video for detailed information on HWA biosecurity
            - Hemlock Woolly Adelgid Phytosanitary Protocols - YouTube
- Information provided here is based on the Canadian Food Inspection Agency's Hemlock Woolly Adelgid Survey Protocol, Revision 2022-12-29: Hemlock Woolly Adelgid (invasivespeciescentre.ca)

Interception traps

- This technique uses sticky traps to catch mobile crawlers that fall out of infested Eastern hemlock trees.
- *Materials required:*
    - Corrugated plastic or sticky traps cut into 20cm x 20cm squares.
    - 1”x1” wooden stakes cut into 2m lengths
    - Adhesive spray: Tangle-trap sticky coating (if using plain corrugated plastic)
    - Hammer and nails
    - Permanent marker to write information on the trap or signs indicating trap function.
        - Mark with some warning not to disturb the trap, and your contact info in case the trap is found to be damaged.
    - Dissection microscope
        - If you do not have one, samples can be submitted to the PEIISC for review.
    - Bleach bath (if within or nearby an infested area)
    - Lint roller (if within or nearby an infested area)
    - Smartphone or GPS and logbook
    - Hand lens
        - HWA can sometimes be seen with the naked eye, but a hand lens helps especially for earlier stages of the life cycle.
    - Additional useful gear:
        - Clothes you don’t care about getting dirty
        - PEIISC datasheets
        - Knife
        - Digital camera
        - Tree identification guide
        - HB pencils
        - Pruning shears
        - Zip-lock bags and sealable dishes for specimen collection.
        - Paper labels
        - GPS unit & Compass
        - Maps (including forest cover or municipal forest inventory)
        - Field book with waterproof paper
        - Flagging tape
        - Measuring tape
        - Protective footwear (Safety boots)
        - Reflective vest
        - Sunglasses
        - Hat
        - Sunscreen
- *Target life stages:*
    - Crawlers (1st stage nymphs/larval instars) that appear after the hatching of eggs.
- *Timing:*

    - Sampling can be conducted from April-July
    - May is the ideal time for sampling
- *Procedure:*
    - When crawlers are active, (most frequently during the month of May in Canada), prepare sticky traps by cutting 20 x 20cm pieces of corrugated plastic and coating one side with a strong, weather-resistant adhesive.
        - Alternatively, you can purchase prepared sticky traps such as those for emerald ash borer, and cut them to size.
    - Select a suitably tall or suspicious tree or group of trees near the edge or centre of a hemlock stand as a sampling site.
    - Select a place beneath the tree's outer canopy.
    - For larger survey areas, place one trap for every 4ha of the survey area.
    - For smaller areas, one trap every 15m may be used as applicable.
        - With an array of 4 traps 15m apart in a smaller area, the likelihood of a positive identification of hemlock woolly adelgid is reported to be 90%:
            - Sticky traps as an early detection tool for crawlers of Adelges tsugae (Hemiptera: Adelgidae) | Journal of Economic Entomology | Oxford Academic (oup.com)
    - Drive one of the 2m stakes 50cm or 25% into the ground, leaving 1.5m aboveground.
    - Wearing gloves, centre a piece of corrugated plastic over the stake, sticky side up.
    - **NOTE**: The trapping adhesive is incredibly difficult to get off of many surfaces and often impossible to get out of clothing. Wear gloves and clothing that you don't mind getting dirty if using this method.
    - Drive a nail through the centre of the trap into the stake below. The sticky surface should be as level as possible to collect anything that falls down from above.
    - Traps should be replaced every 5-7 days and examined.
        - Remove and replace the corrugated plastic at this point.
    - Examine the trees nearby for other signs and symptoms of HWA presence as described above under visual sampling.
    - Place the used piece of corrugated plastic in a medium-sized zip lock bag and store in a freezer until it can be examined.
    - Using a microscope, carefully examine the surface of the plastic for evidence of hemlock woolly adelgid.
        - You may need to cut the plastic into smaller pieces to fit it under the microscope lens.
    - If you are unable to identify hemlock woolly adelgid or do not have access to a microscope, submit samples to the PEIISC. Contact us at peiinvasives@gmail.com
    - If you are concerned about waste, or are short on materials, corrugated plastic traps can be scraped clean using a scraper or putty knife and recoated or simply flipped upside down and recoated.
- *Efficacy:*

    - Moderate-high
        - Effective only during periods of crawler mobility.
        - Requires a microscope and identification training.
        - Effective in most areas.
        - A lot of bycatch may be observed.
- *Biosecurity:*
    - If you suspect that you have been in an HWA-infested area, it is important not to inadvertently spread HWA from that area to an uninfested place. **Practice proper biosecurity measures to reduce the chance of spread when moving into and out of an infested place.**
        - When moving into and out of any natural area, it is important to ensure that you are not facilitating the transfer of organisms. This includes insects, arachnids, seeds, root pieces, fungi, nematodes, and other soil-borne organisms. By cleaning your boots and clothing of all organic material before entering and leaving the area, you can prevent the spread of HWA and other invasive species.
        - When leaving an area of known HWA infestation, especially during the period throughout which crawlers are mobile, all clothing should be gone over with a lint roller before leaving the premises. Additionally, preparation and use of a bleach bath for boots is recommended. This practice can protect against pest and disease spread. Alternatively, a general disinfectant product may be used.
        - Wipe down other equipment with alcohol wipes and dry it before leaving.
        - Watch this video for detailed information on HWA biosecurity
            - Hemlock Woolly Adelgid Phytosanitary Protocols - YouTube
- HOW TO: Sticky Trap Sampling for Hemlock Woolly Adelgid - YouTube

Ball sampling

- This technique uses velcro-coated racquetballs shot using a dog ball launcher to collect HWA woolly masses from the upper canopy of tall trees.
- *Materials required:*
    - **Slingshot/launcher**: Hyper Pet™ Hyperdog Ball Launcher | Cabela's Canada (cabelas.ca)
        - **The PEIISC has these launchers available to loan out to interested surveyors.** Reach out to the PEIISC at peiinvasives@gmail.com to inquire about availability. We have four launchers available and recommend working in pairs.
            - Launchers can be rented for one week, after which they must be returned. If there is nobody else waiting to use a launcher, you may renew your rental.
            - **Rental is free.** PEIISC staff will supply details for picking up the launcher from us once the rental is confirmed (pickup in Charlottetown).

        - In the event of damage to the launcher that renders it unusable, the renter will be responsible for replacing the launcher. A broken sling/cord is considered normal wear and tear, and users are not responsible for providing replacement slings.
    - Alternatively: Notch Big Shot Throw Weight Launcher | Sherrilltree
- **Racquetballs** of a highly noticeable colour (red preferred by CFS).
    - Cut a slit along the seam of the racquetball, and fill it with **wooden beads**.
        - Wooden beads add weight to help the ball push through the canopy and reduce bouncing, making the ball easier to retrieve.
    - Glue the bead-filled racquetballs back together with **super glue.**
    - Surround the ball's seam with **velcro strips** (1cm wide) with adhesive backing. Do the same along the ball's opposite axis. Add additional velcro strips, one per each of the four empty spaces between the circumferential velcro strips. The resulting pattern looks like a basketball's seams.
    - Reinforce the edges of the velcro with **super glue** to keep them from peeling up.
- **Hard hat** and **eye protection** is required to keep surveyors safe.
- Wear **gloves**. Gloves should be fibre-free, rubberized, leather, or at least made with a dark material. This is to prevent fibers from light-coloured gloves from being caught on the velcro balls and confused with actual HWA wool.
- **Extra slings** pending breakage: Hyper Pet™ Replacement Band/Pouch | Cabela's Canada (cabelas.ca)
- **Toothbrush** to clean debris from the velcro between samples.
- Bleach bath (if within or nearby an infested area)
- Lint roller (if within or nearby an infested area)
- Smartphone or GPS and logbook
- Hand lens
    - HWA can sometimes be seen with the naked eye, but a hand lens helps especially for earlier stages of the life cycle.
- Additional useful gear:
    - Zip-lock bags and sealable dishes for specimen collection.
    - Pruning shears
    - Knife
    - Digital camera
    - Tree identification guide
    - HB pencils
    - Permanent markers
    - Paper labels
    - GPS unit & Compass
    - Maps (including forest cover or municipal forest inventory)
    - Field book with waterproof paper
    - Flagging tape
    - Measuring tape
    - Protective footwear (Safety boots)

        - Reflective vest
        - Sunglasses
        - Hat
        - Sunscreen
- *Target life stages:*
    - Eggs, adults, late-stage nymphs/larvae coated in woolly masses (ovisacs).
    - Ovisacs are the most obvious form.
    - Wool from the ovisac will be caught in the velcro.
- *Timing:*
    - April-July, when wool is most abundant. May is ideal.
        - If sampling before this time, ovisacs will be smaller and less likely to be collected, and after this period wool will become brittle and less likely to stick to the ball or be weathered away.
    - When sampling during late may, June, and July, be aware of the possibility of moving crawlers (the mobile life stage of HWA) around the survey area and away from the site. See biosecurity below for instructions on how to prevent this movement.
- *Procedure:*
    - Similar to archery.
    - Only recommended for trees greater than 15m tall, as the ball passes through the crown too quickly in smaller trees.
    - **NOTE:** be aware of your surroundings. Do not sling balls where there is a possibility that the ball will enter traffic, hit a bystander, or damage property.
    - Working in pairs, shoot balls from opposite sides of the trees and collect the ball from your partner's shot.
    - After loading your slingshot with a ball, "cock" the slingshot by pulling the ball back towards your chest
        - **NOTE:** Avoid pulling the ball towards your face initially. This is to avoid punching yourself in the face if the sling breaks.
        - After fully "cocking" the slingshot, bring it up to your face and aim it like you would a bow and arrow.
    - Aim for the outer 1m of the branches, as HWA congregates on branch tips most often.
    - Try to hit at least three branches in each shot to ensure the accuracy of sampling.
    - Collect the ball and examine it for wool from HWA.
    - Clear any debris from the velcro using a toothbrush between samples.
    - Collect at least 10 samples per tree for a complete survey. Experienced crews can conduct 4 samples per minute.
        - With each shot, try to hit a new part of the crown.
    - If wool is found, collect a specimen in a glass vial filled with 95% ethanol for later inspection by a trained professional. Mark the tree the sample originated from. Contact the PEIISC for information on specimen submission. Specimens can be stored below freezing to prevent decay or escape.

- *Sampling issues*:
    - Wool may become clarified and difficult to see after becoming wet, impeding detection. Be careful not to launch balls into the water where possible.
    - Wool may also be picked up from the forest floor after the ball falls, complicating the specific association of a particular tree with ball sampling results.
    - If a sample falls in water or becomes heavily embedded in dirt and debris, consider scrapping and repeating the sample.
- *Efficacy:*
    - Moderate
        - This method allows one to detect early infestations by accessing the upper canopy.
        - The user must create materials themself, or rent them from the PEIISC.
        - Materials are fairly affordable and easily accessible.
        - This method cannot provide accurate information on population density, although the number of positive samples may give some idea.
        - Can be difficult in rough terrain, deep leaf litter, and along waterways.
        - Only effective during certain times of year (spring and summer).

Table 1. Recommended number of ball samples to detect a small infestation of HWA in an individual tree, for a range of detection probabilities. Note: probabilities will be higher than listed if the incidence of HWA in the tree exceeds the level for a small HWA infestation that is defined as one where approximately 2% or more of the twigs have HWA or 2% or more of the hemlock trees in a stand are infested with HWA.

To detect an HWA infestation in a tree with a probability of at least:	Number of ball samples required:
35%	5
50%	10
60%	15
70%	20
75%	25
80%	30

Table 2. Recommended number of trees to sample to detect a small HWA infestation in a hemlock stand, for a range of detection probabilities. For a stand-level survey, the recommendation is to take 10 samples per tree. Method assumes a stocking of 2,000 hemlock trees in a four-hectare hemlock stand.

To detect an HWA infestation in a stand with a probability of:	Number of trees to sample:
75%	130
85%	180
95%	270

Frontline Technical Note, Number 118 (invasivespeciescentre.ca)

- *Biosecurity:*
    - If you suspect that you have been in an HWA-infested area, it is important not to inadvertently spread HWA from that area to an uninfested place. **Practice proper biosecurity measures to reduce the chance of spread when moving into and out of an infested place.**
        - When moving into and out of any natural area, it is important to ensure that you are not facilitating the transfer of organisms. This includes insects, arachnids, seeds, root pieces, fungi, nematodes, and other soil-borne organisms. By cleaning your boots and clothing of all organic material before entering and leaving the area, you can prevent the spread of HWA and other invasive species.
        - When leaving an area of known HWA infestation, especially during the period throughout which crawlers are mobile, all clothing should be gone

over with a lint roller before leaving the premises. Additionally, preparation and use of a bleach bath for boots is recommended. This practice can protect against pest and disease spread. Alternatively, a general disinfectant product may be used.
        - Wipe down other equipment with alcohol wipes and dry it before leaving.
        - Watch this video for detailed information on HWA biosecurity
            - Hemlock Woolly Adelgid Phytosanitary Protocols - YouTube
- HOW TO: Ball Sampling for Hemlock Woolly Adelgid - YouTube

eDNA Sampling

- This technique involves the deployment of specialized environmental DNA collection traps.
- Environmental DNA or eDNA sampling is a technique implemented by professionals to detect trace amounts of genetic material present in the environment.
- Because of the low amount of genetic material required to get a positive ID, this method allows for detection at the earliest stages of infestation.
- The traps may catch the HWA themselves, like crawlers, wool, or eggs. For this reason, a visual inspection under a microscope precedes eDNA analysis.
- *Materials required*
    - See the eDNA sampling protocol document for a complete list of materials.
    - Materials will be picked up by or delivered to participants.
        - The PEIISC greatly appreciates pick-up, as this helps save on shipping costs!
    - If repeating the survey the following year, send back the microscope slides and clean and store the remaining materials. If you do not plan to continue the survey, return all trapping materials to the PEIISC.
- *Target life stages*
    - HWA DNA from activity of all life stages.
    - Visual evidence of HWA of all life stages (especially crawlers and wool fragments)
- *Timing*
    - Traps should be set in place for a minimum of two months, ideally from April 24th-June 24th
- *Registration*
    - If you have a stand of Eastern hemlock on your property and are interested in participating, register for the eDNA trapping program at the following link: **https://arcg.is/1uXqWS**
    - Alternatively, you can scan the QR code below to access the registration form.

- The PEIISC will have 25 traps to distribute in 2024.
- Requirements of registration:
  - Signing a volunteer participation waiver
  - A minimum of two site visits (setup & teardown) although weekly checks for damage are recommended.
  - Concurrent visual sampling is recommended.
  - Submitting sampling data to the PEIISC via the Survey123 app.
    - Data can be recorded digitally using the Survey123 form at the following link: https://arcg.is/0OHGDf0
    - Alternatively, scan this QR code with your smartphone to access the Survey123 form.

        - Although single-year surveys are possible, we would prefer to survey at the same location for multiple years consecutively.
        - In the event of a positive detection, you must agree to allow CFIA and PEIISC staff to access the location to confirm the find.
- *Procedure*
    - Procedural instructions will be included in the protocol document sent to selected registrants.
    - This method can easily be combined with other monitoring techniques during trap visits.
- *Efficacy*
    - High
    - Despite the high chance of detecting an early infestation when compared to other monitoring techniques, this technique cannot tell which specific trees are infested, only that there is HWA in the area. Follow-up monitoring will have to be conducted by other means.
    - Abundance is also impossible to accurately quantify as yet using this method.
- *Biosecurity*
    - *Biosecurity:*
        - If you suspect that you have been in an HWA-infested area, it is important not to inadvertently spread HWA from that area to an uninfested place. **Practice proper biosecurity measures to reduce the chance of spread when moving into and out of an infested place.**
            - When moving into and out of any natural area, it is important to ensure that you are not facilitating the transfer of organisms. This includes insects, arachnids, seeds, root pieces, fungi, nematodes,

and other soil-borne organisms. By cleaning your boots and clothing of all organic material before entering and leaving the area, you can prevent the spread of HWA and other invasive species.
- When leaving an area of known HWA infestation, especially during the period throughout which crawlers are mobile, all clothing should be gone over with a lint roller before leaving the premises. Additionally, preparation and use of a bleach bath for boots is recommended. This practice can protect against pest and disease spread. Alternatively, a general disinfectant product may be used.
- Wipe down other equipment with alcohol wipes and dry it before leaving.
- Watch this video for detailed information on HWA biosecurity
    - Hemlock Woolly Adelgid Phytosanitary Protocols - YouTube

Future monitoring techniques

- Remote sensing is being investigated as a monitoring technique for hemlock woolly adelgid presence in the Maritime provinces.
- This project is still in its infancy but presents a promising opportunity to monitor large areas of Eastern hemlock growth with ease.

Cone collection

- During monitoring activities, be on the lookout for healthy trees in seed. Seed collection from populations of Eastern hemlock for preservation may prove essential to the future survival of local genotypes of Eastern hemlock.
- The National Tree Seed Centre (NTSC) in Fredericton is hoping to ramp up the collection of Eastern hemlock seed on PEI in response to HWA's advance.
- So far, seed collection has only been conducted in the Belfast area, so seed from diverse areas of PEI is sought.
    - In particular, large individuals or individuals from unique habitats such as windswept areas, coastal areas, and those growing in poor soil conditions may have unique genetics that could lend to increased tolerance or resistance to HWA.
- **If you predict your hemlocks will be in heavy cone this year, reach out to the PEIISC and let us know.** Depending on site conditions, the health of the trees, and accessibility, the PEIISC and NTSC may be interested in visiting the site to collect seed.
- Seed collected will be stored at the National Tree Seed Centre in the Atlantic Forestry Centre, Fredericton.
    - Here the seeds will be stored to serve as a source of genetic material for replanting in a future PEI, after HWA's potential future decimation of our Eastern hemlock stock.

    - Seed collected may also be used in the future identification and propagation of resistant hemlock varieties.
- For more information on Hemlock seed collection, contact the PEIISC.
- From the MacPhail Woods Ecological Forestry Project's Publication "Native Trees and Shrubs" https://macphailwoods.org/resources/publications:
    - Propagation: cones can be collected from the tree when ripe in late September and treated the same as red spruce (see below). An easier method is to find a 4-10 year old forest road that has been bulldozed through a stand containing good hemlocks. You will usually find healthy seedlings growing on the roadway. These transplant easily and can go into a shaded nursery bed, at six to 12 inch (15-30 cm) spacings depending on the size of the seedlings. In a few years you can use these transplants for your forest, streamside or home plantings. Placing rotted wood in the hole when planting out will make sure the seedling does not dry out and provide nutrients for future growth. Seedlings should also be mulched well.
    - Red spruce: given the height of most of the red spruce we collect seed from, wait until the red squirrels have knocked down a bunch of cones. This means that you may have to visit the site every few days during October, but it is a lovely excuse to get out into the woods. Each cone will contain many seeds, although some may not be viable. Place the cones in a paper bag or cardboard box with some ventilation, and keep in a warm place. As the cones dry out and open, the seeds will drop out. These can be fall planted or stored in a dry place until spring. Plant seeds every inch (2.5 cm), in rows 4 in. (10 cm) apart, at a depth of 1/4 in. (6 mm). Mulch the area over the winter removing most in the spring. Beds should have some shade and not be allowed to dry out.
- U.S. Cone collection advice (North Carolina):
    - Cone Collection for the NC Forest Service – Hemlock Restoration Initiative (savehemlocksnc.org)

Control methods

IMPORTANT: Note that direct, independent control of hemlock woolly adelgid should not be attempted by any means by members of the public on Prince Edward Island at this time (March 2024). Report your suspected infestation to the PEIISC (peiinvasives@gmail.com) or directly to CFIA (902-566-7290) for information on how to proceed. Once HWA has been confirmed on PEI or nearby in Nova Scotia or New Brunswick, this directive will change.

Indirect controls, such as preventative silvicultural controls may be implemented at any time without CFIA oversight. Chemical control measures can be applied preventatively, but the PEIISC does not recommend widespread chemical treatment at this point as there are no known infestations of HWA within 100km of PEI. Reach out to the PEIISC for advice about these measures.

Control methods are most effective when used in combination through an integrated pest management program rather than singly.

Mechanical eradication in response to initial threat

- For infestations limited to a small area, physical removal has proven successful in eradicating two populations of HWA in Ontario: in Etobicoke and Niagara George.
- In these cases, infested trees were removed and incinerated by professionals under the guidance of the CFIA.
- Surveys of all hemlocks from the same nursery source (trace forward), of the nursery itself (trace back), and a delimination survey of any hemlocks within a minimum 500m radius would be conducted.
- Although these eradications have been considered successful based on negative detection of HWA, small populations of HWA may remain undetected in the area.
- Detection and eradication of Hemlock Woolly Adelgid (Adelges tsugae Annand) in Etobicoke, Ontario (pestalerts.org)

Silvicultural controls, preventative and during infestation

Do you own or manage a woodlot with a large component of Eastern hemlock? Evidence suggests that certain silvicultural management strategies applied to at-risk stands of Eastern hemlock can improve Eastern hemlock fitness and resistance to HWA, and reduce HWA fitness. While extensive study of these techniques has yet to be completed in Canada, early evidence of their use is promising.

Silvicultural control is not enough to prevent infestation alone. Incorporate other methods of control simultaneously when under direct threat of invasion.

Preventative controls, pre-infestation and in lightly infested areas:

- **General promotion of hemlock health** and tolerance can help reduce or slow the effects of infestations.
- **Do not fertilize hemlocks with nitrogen**. This increases HWA densities and reduces the likelihood of hemlock survival.
- **Make hemlocks unattractive to visiting wildlife** such as birds (remove feeders near hemlocks, etc.).
- **Increasing the level of direct sunlight hitting hemlock branches** by 30-50% can decrease the fitness of HWA, slowing hemlock mortality. This will, however, affect light levels and temperatures in the area (affecting other organisms that rely on normal conditions), and is not enough to stop the infestation's progress.
- **Thinning hemlock stands** can promote individual health and increase light levels, increasing the health of individual hemlocks and reducing the fitness of future HWA that may become established in the stand.
    - Removal of weak individuals, especially those with lower than 30% live crown ratio, can benefit remaining trees.
    - Thinning has heretofore implemented a reduction of 20-40% of the less vigorous trees in an area. (Nova Scotia Hemlock Woolly Adelgid Management Plan, 2021)

    - This practice may accelerate hemlock loss when applied to heavily infested stands. (Nova Scotia Hemlock Woolly Adelgid Management Plan, 2021)
- **Salvage cutting in the face of an HWA infestation is not recommended**. The jarring shift in ecosystem character caused by the immediate loss of hemlock through harvesting will be much more harmful on local wildlife than the more gradual shift that would be experienced through HWA infestation. Salvage cutting may also remove resistant trees, stifling the future development of an HWA-resistant Eastern hemlock variety.
- **Improving species diversity** can increase the resilience of forested areas to disturbances such as that caused by invasive species.
    - “Overall, our findings suggest that mixed forests are more resistant to natural disturbances that are relatively small-scale and selective in their effect. However, benefits provided by mixtures are less evident for larger-scale disturbances. Higher tree diversity translates into increased resistance to disturbances as a result of ecological trait complementarity among species, reduction of fuel and food resources for herbivores, enhancement of diversion or disruption processes, and multi-trophic interactions such as predation or symbiosis.” (Jactel et. al, 2017)

Within heavily infested areas:

- Prune hemlocks only from August to February to avoid contact with and movement of crawlers.
- Prune branches that are likely to come in contact with sources of spread like hikers, vehicles, etc.

<u>Chemical controls, preventative and during infestation</u>

- Although chemical controls are costly, they can be less costly than the physical removal of an infested tree.
- For trees at a high risk of infestation, insecticidal treatment can provide protection against HWA.
- Foliar and branch spraying is often ineffective in controlling HWA due to its protective woolly coating. Trunk injection and basal bark spray are the principal methods of application.
- **Insecticide treatments require provincial certification to apply. It is crucial that all local legislation and manufacturer’s instructions be followed during the application of insecticides.**
- **Trees selected for insecticidal treatment**:
    - Should be under direct threat of infestation or in the early stages of infestation.
    - Should have a minimum of 65% canopy density remaining.
    - Taller, old-growth trees should be prioritized for treatment, as these are often initial infestation sites and have a greater ecological value.
        - Old growth should be treated BEFORE HWA arrives.
    - Must have new growth visible.
        - New growth is indicated by lighter green foliage near branch tips.

        - If new growth is present, but more than 30% of new growth shows signs of infestation (HWA directly on new growth), the tree may not respond to treatment.
- Chemical controls approved for use against HWA in Canada include these systemic insecticides:
    - **Trunk injected** (applied using specialized trunk injection tools):
        - TreeAzin (azadirachtin)
            - Naturally derived from the neem tree, lower toxicity, fast acting, low persistence.
            - Provides control for 1-2 years, not practical for long-term treatment, expensive especially for taller trees.
            - Becomes effective one month after initial treatment.
            - Cost/cm diameter at breast height = 0.75$
        - IMA-jet (imidacloprid)
            - Available in 5% and 10% formulations.
            - Synthetic, high toxicity, slower acting, persists for a longer period of time.
            - Provides control for 4-7 years.
            - Takes 6-9 months after treatment to become effective.
            - Cost/cm diameter at breast height = 1-2$
    - **Basal bark spray** (applied by backpack sprayer to the lower 1.4m of the tree's trunk)
        - Often easier to apply and cheaper than trunk injection.
        - Xytect 2F (imidacloprid)
            - Synthetic, high toxicity, slower acting, persists for a longer period of time.
            - Provides control for 4-7 years.
            - Takes 6-9 months after treatment to become effective.
            - Cost/cm diameter at breast height = 1-2$
        - Starkle 20SG (dinotefuran)
            - Synthetic, high toxicity, low persistence, fast acting
            - Provides control for 1-2 years.
            - Becomes effective one month after initial treatment.
            - Cost/cm diameter at breast height = 0.75$
- **Other control products** include the use of horticultural oils or insecticidal soaps. The following product is registered for HWA management in Canada:
    - Landscape oil spray emulsifiable insecticide by Plant Products Inc.
        - Works by suffocating HWA.
        - HWA must be fully drenched to be effective.
        - Requires a large amount of product to treat entire trees, meaning there is a significant opportunity to affect non-target insects.
        - Despite lower toxicity, the greater amount of product needed may negate this benefit.

- **Chemical controls are not considered to be a long-term, final solution**, but can be effective in the interim while a biological control program is established or for the protection of certain high-value trees or stands.
- **Chemical controls are not compatible with biological controls.** Chemical controls will cause mortality in biological controls as well either due to toxicity or lack of prey.
- **Non-target effects of chemical controls are possible**, but due to the limited area and method of application these effects should be low or negligible, especially when compared to the loss of hemlock entirely.

Biological controls, during infestation

- Hemlock woolly adelgid has few natural predators or diseases in Eastern North America to keep its population under control. Natural enemies that do exist tend to be generalist feeders, and do not seek out HWA specifically as prey. This allows HWA to proliferate unchecked by natural controls. To address this problem, extensive research has been done on biological control agents that specifically target and feed on hemlock woolly adelgid.
- Biological control involves the introduction of a suitable predator for HWA. Biological controls are heavily scrutinized before release, and only predators with high prey specificity for the target pest will be used.
- Releases of biological control agents will be overseen and directed by regulatory agencies, usually the CFIA in concert with local agencies.
- A biological control rearing program and facility at Acadia University for *Laricobius* and *Leucopsis spp.* for use in the maritimes has been proposed to reduce cost and increase biological control agent availability locally.
- Biocontrols are not intended to eradicate the pest. If eradication is your goal, biocontrol is not right for your plan. Biocontrols are long-term solutions intended to reduce pest numbers and their effects on host species and the environment.
- The establishment of a large wild population of biocontrol species will take time, up to 20 years or more.
- Multiple biocontrol species will need to be established to have a sufficient effect on HWA.
- Potentially effective biocontrols for use against HWA include:
    - Tiny ladybird beetle: *Pseudoscymnus tsugae/Sasajiscymnus tsugae*
    - *Laricobius nigrinus* and *Laricobius osakensis,* species of tooth-necked fungus beetles.
    - Silverflies: *Leucopis argenticollis* and *Leucopis piniperda*
- In 2023, 3600 *Laricobius nigrinus* beetles were released in Nova Scotia to attempt to establish a population. This is the first Canadian release of a biocontrol agent for HWA.
    - The cost was 40$ per *Laricobius nigrinus* beetle.
    - This particular agent has shown the most promise among suitable agents in past trials in the U.S.
    - There are concerns over releases of another biocontrol agent or the same group, *Laricobius osakaensis,* being contaminated with *Laricobius naganoensis*.
    - There are concerns over the species' potential hybridization with the native *Laricobius rubidus*.

- These concerns are justified, but may be minimized alongside the concern caused by the overall loss of Eastern hemlock populations.

Table 1 Summary of HWA biological control agents explored in the US to date.

Biological Control Agent	Type	Origin	First Release in US	Quantity released as of 2014	Issues
Laricobius nigrinus	beetle	Western North America	2003	~200 000 over 200 sites	Inadequate numbers for release, hybridization with native *L. rubidus*
Laricobius osakensis	beetle	Japan	2012	Limited release	Good recovery rates not yet achieved
Sasajiscymnus tsugae	beetle	Japan	1995 (Discontinued 2014)	>2 000 000 over 400 sites	Inconsistent success results
Scymnus sinuanodulus	beetle	China	2004	Limited release	No recoveries and difficulties in mass rearing
Scymnus ningshanensis	beetle	China	2004	Limited release	No recoveries and difficulties in mass rearing
Scymnus camptodromus	beetle	China	Being prepared for release	N/A	Difficulties rearing
Leucopis spp.	fly	Western North America	2017	1800	Little known about biology
Beauveria bassiana, Lecanicillium lecanii, Metarhizium anisopliae	Entomopathogenic fungi	Eastern USA & China	Tested in a lab setting only (Reid et al. 2010)	N/A	Greater concern for non-target impacts

This figure is taken from the Hemlock Woolly Adelgid Management Plan for Canada

Reference materials

Brantley, S.T., et al. (2020). “Elevated Light Levels Reduce Hemlock Woolly Adelgid Infestation and Improve Carbon Balance of Infested Eastern Hemlock Seedlings.” Forest Ecology and Management, vol. 385, 1 Feb. 2017, pp. 150–160, https://doi.org/10.1016/j.foreco.2016.11.028.

Canadian Food Inspection Agency (2020). “D-07-05: Phytosanitary Requirements to prevent the introduction and spread of the Hemlock Woolly Adelgid (Adelges tsugae Annand) from the United States and within Canada”, 5th revision, 2020-05-28. https://inspection.canada.ca/plant-health/invasive-species/directives/forest-products/d-07-05/eng/1323754212918/1323754664992

Canadian Food Inspection Agency (2021). “Adelges tsugae (Hemlock Woolly Adelgid) - Fact Sheet”, last modified 2021-10-05. https://inspection.canada.ca/plant-health/invasive-species/insects/hemlock-woolly-adelgid/fact-sheet/eng/1325616708296/1325618964954

Canadian Food Inspecition Agency (2022). “Detection Survey Protocol: *Hemlock Woolly Adelgid”*, Revision 2022-12-19, RDIMS 10300082

Canadian Food Inspection Agency (2023). “Amended Hemlock Woolly Adelgid [Adelges tsugae (Annand)] Infested Place Order” https://inspection.canada.ca/plant-health/invasive-species/insects/hemlock-woolly-adelgid/infested-place-order/eng/1591829961468/1591829961828

Ellison, A.; Orwig, D.; Fitzpatrick, M.; Preisser, E. (2018). “The Past, Present, and Future of the Hemlock Woolly Adelgid (Adelges tsugae) and Its Ecological Interactions with Eastern Hemlock (Tsuga canadensis) Forests.” Insects. 9(4):172. doi:https://doi.org/10.3390/insects9040172.

Emilson, C.; Bullas-Appleton, E.; Mcphee, D.; Ryan, K.; Stastny, M.; Whitmore, M.; Macquarrie, C. (2018). “Hemlock Woolly Adelgid Management Plan for Canada”.

Emilson, C. & Stastny, M. (2019). “A decision framework for hemlock woolly adelgid management: Review of the most suitable strategies and tactics for eastern Canada”. Forest Ecology and Management. 444. 327-343. 10.1016/j.foreco.2019.04.056.

Fajvan, M.A. & Hille, A. (2023). “Integrating Silviculture with Hemlock Woolly Adelgid Mitigation: Crown Dynamics of Tsuga Canadensis (L.) Carrière 10 Years after Thinning.” Canadian Journal of Forest Research, vol. 53, no. 11, 1 March 2023, pp. 922–930, https://doi.org/10.1139/cjfr-2022-0251. Accessed 21 Dec. 2023.

Fidgen, J.G.; Turgeon, J.J.; Allison, J.D.; Humble, L.M (2014). “Alien, invasive hemlock woolly adelgid found in Ontario”. Natural Resources Canada. Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario Frontline Technical Note 114, 6 p.

Fidgen, J.G., et al. (2018). “Factors Affecting Velcro-Covered Balls When Used as a Sampling Device for Wool of Adelges Tsugae (Hemiptera: Adelgidae).” Canadian Entomologist, vol. 151, no. 1, 1 Nov. 2018, pp. 101–114, https://doi.org/10.4039/tce.2018.50.

Fidgen, J.G, et al. (2020). “Sticky Traps as an Early Detection Tool for Crawlers of Adelges Tsugae (Hemiptera: Adelgidae).” Journal of Economic Entomology, vol. 113, no. 1, 7 Oct. 2019, https://doi.org/10.1093/jee/toz257.

Fidgen, J.G.; MacQuarrie, C.J.K.; Turgeon, J.J. (2021). “Sampling techniques to detect canopy infestations of the hemlock woolly adelgid”. Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Frontline Technical Note 118. 4p.

Godman, R.M. & Lancaster, K.. “Tsuga Canadensis (L.) Carr.” Srs.fs.usda.gov, United States Department of Agriculture Forest Service, 2019, www.srs.fs.usda.gov/pubs/misc/ag_654/volume_1/tsuga/canadensis.htm.

Hemlock Restoration Initiative. “Hemlock Restoration Initiative – Returning NC’s Hemlocks to Long-Term Health.” www.savehemlocksnc.org/.

Invasive Species Centre, National Resouces Canada, Canadian Food Inspecition Agency, (2022). “Hemlock Woolly Adelgid Monitoring Network 2022 Sampling Protocol and Instruction Manual”.

Jactel, Hervé, et al. (2017). “Tree Diversity Drives Forest Stand Resistance to Natural Disturbances.” Current Forestry Reports, vol. 3, no. 3, 4 July 2017, pp. 223–243, https://doi.org/10.1007/s40725-017-0064-1.

Kendrick, Joseph A., et al. (2015) “Changes in Canopy Structure and Ant Assemblages Affect Soil Ecosystem Variables as a Foundation Species Declines.” Ecosphere, vol. 6, no. 5, 12 May 2015, p. art77, https://doi.org/10.1890/es14-00447.1.

Leppanen, Christy, et al. (2018). “Media Representation of Hemlock Woolly Adelgid Management Risks: A Case Study of Science Communication and Invasive Species Control.” Biological Invasions, vol. 21, no. 2, 18 Sept. 2018, pp. 615–624, https://doi.org/10.1007/s10530-018-1850-9.

Mayfield, Albert E, et al. (2023). “Silvicultural Canopy Gaps Improve Health and Growth of Eastern Hemlocks Infested with Adelges Tsugae in the Southern Appalachian Mountains.” Forest Ecology and Management, vol. 546, 15 Oct. 2023, pp. 121374–121374, https://doi.org/10.1016/j.foreco.2023.121374.

Natural Resources Canada. 2015 Aug 4. “Eastern Hemlock.” Trees, insects, and diseases of Canada’s forests. https://tidcf.nrcan.gc.ca/en/trees/factsheet/75.

New York State Department of Environmental Conservation, Division of Lands and Forest. “Hemlock Woolly Adelgid - NYDEC.”, www.dec.ny.gov/nature/animals-fish-plants/insects-and-other-species/hemlock-woolly-adelgid.

Nova Scotia Hemlock Initiative. “Welcome | Nova Scotia Hemlock Initiative.” www.nshemlock.ca/.

Nova Scotia Hemlock Initiative (2021). “Nova Scotia Hemlock Woolly Adelgid Management Plan (DRAFT).” 3 Aug. 2021, Nova scotia Hemlock Woolly Adelgid Management Plan (nshemlock.ca)

Ontario Ministry of Natural Resources and Forestry. “Hemlock Woolly Adelgid | Ontario.ca.”, 20 Apr. 2023, www.ontario.ca/page/hemlock-woolly-adelgid.
Parker, William C, et al. (2023). “Applying Three Decades of Research to Mitigate the Impacts of Hemlock Woolly Adelgid on Ontario’s Forests.” Forestry Chronicle, vol. 99, no. 2, 24 Aug. 2023, pp. 205–225, https://doi.org/10.5558/tfc2023-024. Accessed 23 Oct. 2023.

Piatek, Kathryn B., et al. (2017). “Thinning Effects on Foliar Elements in Eastern Hemlock: Implications for Managing the Spread of the Hemlock Woolly Adelgid.” Canadian Journal of Forest Research, vol. 47, no. 1, Jan. 2017, pp. 81–88, https://doi.org/10.1139/cjfr-2016-0260.

Russo, Nicholas J., et al. (2019). “Spring Bird Migration as a Dispersal Mechanism for the Hemlock Woolly Adelgid.” Biological Invasions, vol. 21, no. 5, 23 Jan. 2019, pp. 1585–1599, https://doi.org/10.1007/s10530-019-01918-w.

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VERSION HISTORY

- First draft: complete 02-Jan-2024
- Second draft: complete 10-Jan-2024
- Third draft: complete 23-Jan-2024
- Fourth draft: complete 11-March-2024

Appendix

DATE (DD/MM/YYYY): _____

HEMLOCK MONITORING DATASHEET

RECORDER NAME & CONTACT INFO: _____

ADDRESS:_____ GPS ID: _____

STARTING COORDINATES (NAD83):

SITE DESCRIPTION, LIST OF CREW MEMBERS, & SURVEY GOALS:

_____

_____

_____

SURVEY METHOD: _____

SITE TOTAL AREA (ha): _____

WEATHER INFORMATION (SEE RIGHT):

- **WIND:** Measured on the Beaufort Scale, 1-12.
- **PRECIPITATION**: 0 = None, 1 = Drizzle, 2 = Rain, 3 = Snow/Sleet/Hail.
- **CLOUD COVER**: 1 = Clear, 2 = Overcast (>50%), 3 = Partial Cloud (<50%).

ID/Waypoint # or coordinates (NAD83)	Diameter at breast height (DBH) (1.3m)	Direct evidence of HWA presence?	Signs of general stress or decline?	Tree flagged and marked w/ ID?	No. of samples collected or branches surveyed	No. of photos taken and photographer initials
E.g. EH001 or 46.123456, -62.123456	E.g. 40cm	Yes/No, If yes complete suspect form	E.g. grayish foliage, crown/ branch dieback	Check or X	E.g. 2	E.g. 4, JS

FORM ID: _____

ID/Waypoint # or coordinates	Diameter at breast height (DBH) (1.3m)	Direct evidence of HWA presence?	Signs of general stress or decline?	Tree flagged and marked w/ ID?	No. of samples collected or branches surveyed	No. of photos taken and photographer initials
E.g. EH001 or 46.123456, -62.123456	E.g. 40cm	Yes/No, If yes complete suspect form	E.g. grayish foliage, crown/ branch dieback	Check or X	E.g. 2	E.g. 4, CC

ADDITIONAL COMMENTS:

_____

_____

_____

_____

_____

_____

_____

FORM ID: _____