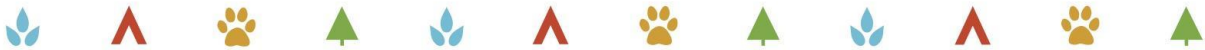


Potential Options for a Comprehensive Chemical Treatment Program to Conserve Eastern Hemlock in Nova Scotia from Hemlock Woolly Adelgid and lessons learned from other jurisdictions



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This report was submitted to Nova Scotia Department of Environment and Climate Change by the **Medway Community Forest Coop (MCFC)** under contract to broadly examine best options and elements of a full chemical treatment program to conserve a small percentage of the formerly dominant conifer tree, eastern hemlock from hemlock woolly adelgid (HWA) as this invasive insect rapidly spreads and decimates some of the most magnificent hemlock forests in Nova Scotia and Canada. Lessons learned by other jurisdictions already conducting HWA management were summarized to inform best strategies for NS.

“Large groves of hemlock growing on woodland slopes present a noble appearance; their tall columns never bend before the gale. There is a general absence of undergrowth, thus affording long vistas through the shady grove of giants; and the softened light invests the interior of these vast forest cathedrals with an air of solemn mystery, whilst the even spread of their mossy carpet affords appreciable relief to the footsore hunter.”

Excerpt from Campbell Hardy (1869) *Forest Life in Acadie*, writing of his early natural history observations on exploring the ‘New World’ in Nova Scotia.



Vision Statement

Nova Scotia will foster conservation of healthy, high value eastern hemlock in a network across the province that showcases the beauty and ecological importance of Nova Scotia's largest and most graceful evergreen conifer. Vast hemlock forests that once dominated Wabana'ki (Acadian) Forest will have incurred massive mortality from invasive hemlock woolly adelgid (HWA) infestations that swept across NS from west to east.

Remnant hemlock forests will have been conserved through careful selection of high value stands to receive chemical protection using a variety of new chemical tools and aided thereafter by tiny insect predators from Canada's west coast to control HWA, devouring the pest so hemlocks may thrive once again in balance with HWA, sustaining hemlock forests in perpetuity. This network of conserved hemlock will carry the genetic stock and biodiversity legacy to gradually restore hemlock to a broader landscape.

Hemlocks will continue to thrive on land and along watercourses as a result of leadership by the province as well as cooperative efforts by federal government, municipalities, private landowners, the public, and caring volunteers. This will enable hemlock trees to continue to buffer streams, protecting homes and infrastructure from floods, absorb excess carbon to help mitigate climate change, and to provide many important ecological and cultural benefits. **Nova Scotians and tourists will continue to admire shady hemlock forests, benefiting from the visionary actions that began in year 2022 to conserve some of Nova Scotia's most highly valued hemlock forest legacies.**



Executive Summary

Eastern hemlock (*Tsuga canadensis*) is the largest and most attractive evergreen conifer in Nova Scotia. Termed 'redwood of the east', massive trunks rise like noble and craggy pillars that are capable of living more than 500 years. Hemlocks are adorned with intense dark green needle foliage that forms dense canopies tipped in delicate lacey splays. Hemlock forms the bulk of rare, old growth forests and is a foundation species with the power to regulate stand temperature, retain high humidity levels that rival the tropics, and influence unique species associations under its intensely shaded, and often moss-covered understory.

Nova Scotia features among the best and last eastern hemlock forests that once extended over vast, shaded expanses. Mature hemlock stands now comprise less than ~ 8 % of the productive forest area in the province. This attractive tree graces many of our most cherished woodlands, and some stands attract global, nature-based tourism attention.

Hemlock woolly adelgid (HWA) (*Adelges tsugae*) is a tiny, invasive, sap-sucking insect from southern Japan that has no natural predators in NS to control its exploding populations. HWA is permanently destroying eastern hemlock forests at an alarming pace, now extending across seven southwestern counties that support the largest remaining amounts of hemlock. This unique forest type that has exceptional capacity to mitigate climate change and protect ecological integrity of both forest lands and waters is now on the edge of catastrophic collapse; its sudden fall causing ripple effects, from losses of plant and animal biodiversity, important shelter to wildlife, and loss of ecosystem services that extend to the health of streams and fish populations.

This report describes program delivery and elements required to successfully conserve a network of healthy hemlock forests against permanent destruction by HWA as it spreads across Nova Scotia. Treatments using targeted small amounts of chemical conducted inside the tree is the only existing mechanism for keeping trees alive in the short-term; to be implemented in a comprehensive HWA chemical control program.

Multiple strategies and tools are outlined in a modern *Integrated Pest Management* (IPM) approach that incorporates the best available tools and closely aligns with successful USA approaches to hemlock treatments. Direct consultations with 10 USA scientists and practitioners who have been researching and implementing HWA management strategies for more than 50 years greatly hastened strategic planning of selected strategies for NS.¹ A great body of scientific research provides a strong scientific basis for the approaches that are further vetted by experts of the *HWA Working Group- Maritimes*. With *immediate* and precision execution, the recommendations in this report will foster achievement of the enclosed 'Vision Statement' for hemlock conservation.

Maintaining a hemlock conservation network across Nova Scotia forms the backbone of the strategy, consisting of treating hemlock in high value, protected and old growth stands, riparian forests that are lined with hemlocks, private conserved lands, including stands most likely to persist with climate change, and supplementing with the finest hemlock stands elsewhere on crown and private/private conserved lands to complete the network. An immediate goal is set for conserving a minimum of 2000 ha annually. The network approach best ensures against local catastrophic disturbances such as fire or hurricanes that could wipe out the last remaining

¹ An informative summary of USA expert advice to Nova Scotia on HWA management strategies is available in Appendix 1.

hemlocks and destroy conservation efforts if only a few high-quality forests were conserved. Maintenance of healthy hemlock stands through a precision-managed chemical treatment program over approximately 10 years is required so they are available to receive the benefits from HWA-consuming insect predators- the 'biocontrols' that will keep HWA populations in check unaided by chemicals in future.

HWA management strategies are outlined in a regionally- specific approach through dividing the province into four main zones based on infestation status, each with a unique program delivery focus. All land tenures are implicated to varying degrees, depending on hemlock distributions.

Most of Nova Scotia's hemlock forests will succumb to HWA, apart from those stands saved in the hemlock conservation network and some stands preserved by landowners who are able to hire private arborist services. This report suggests other strategies to fund and facilitate treatments on private lands. Only a fraction of the remaining legacy forests will be conserved for future generations to experience and admire.

Emergency early action is required to control HWA, acknowledging that opportunities to save hemlock forests are fleeting, particularly in the southwest where earliest HWA infestations began, and where mild winters accelerate population increases and consequent hemlock decline. More than 17, 000 ha of southwestern hemlock forest were already HWA-infested and declining by 2019, and many of those stands are now dead. More lush green hemlocks rapidly turn to brittle grey pillars devoid of needles each day, emitting carbon at a time when maintaining large living trees in continuous forest cover plays an essential role to sequester and store excess greenhouse gas and maintain forest resilience. This tree has superior carbon sequestering capacity owing to a long-life span, large dimensions, slow decay rates and a longer growing season than deciduous trees. Mass hemlock mortality will exacerbate the climate crisis through enormous releases of carbon stores- to be mitigated by early chemical treatments.

Immediate government action to implement a Hemlock Conservation Network Program that comprises comprehensive chemical treatments to control HWA is required to arrest the damage and impede total collapse of Nova Scotia's most treasured, rare, finest and last majestic eastern hemlock forests, many of which occur in parks and protected areas and under the province's updated Old Growth Forest Policy. The largest area affected thus far is located within the Southwest Nova Biosphere Reserve. From the time HWA arrives and is detected (typically 1-3 years after its arrival), there may be only 1-2 short years suitable to conduct viable chemical treatments. Once the canopy thins beyond critical thresholds, and new growth is no longer produced, treatments are no longer effective.

Of equal urgency is the initiation of a government-led biocontrol program that complements and takes over from the interim chemical treatments. Early biocontrol releases of predator insects will reduce the time and amount of chemicals required. USA leading experts warn that a biocontrol program must be initiated *early* to provide adequate time to build sufficient populations of the insect predators to control HWA over the long-term and to address needs that will stretch across the province. The earlier that biocontrols are implemented, the sooner expenditure on chemical treatments is reduced and eventually ceased.

Tools Recommended for Conserving Hemlock. Details outlining risks, benefits, and cost advantages of the most appropriate chemical products to conserve hemlock are thoroughly outlined in this report. The main chemical tool that is used to effectively control HWA is imidacloprid (the active ingredient in both IMA-jet® and Xytect 2F® products) that operates 'systemically'; i.e., inside the tree vascular system, and endures 4 to 7 years. Both products are

recommended to address the range of situations required, but an 'emergency registration' request is required to gain access to Xytect 2F in Canada and pends a decision by the Pest Management Regulation Agency (PMRA). Presently only the more costly IMA-jet product is registered for use in Canada and is limited to more labour-intensive trunk injection methods.

Two faster-acting products with other active ingredients, namely dinotefuran (Safari®) and azadirachtin (TreeAzin®) are needed in the southwest where the HWA populations are extremely heavy and hemlock declines are severe and beyond effective treatment thresholds for imidacloprid. Initiatives are underway to obtain a range of chemical tools that are safe and appropriate. While both imidacloprid and dinotefuran belong to the neonicotinoid family of chemicals that have damaged pollinators in agricultural situations, there is little or no environmental risk in hemlock forests where the chemical use pattern is enclosed inside the tree, and hemlock is wind-pollinated with few flowering plants in the area to attract pollinators.

The suite of chemical tools proposed for use are to address an ecological crisis and are temporary, forecasted to be needed for only 10-15 years, and requiring only 2 to 3 applications. While it is a huge step to embark upon a chemical treatment program, there is no other option to conserve small amounts of hemlock in NS. The hemlock conservation network will be a worthy investment and will benefit all Nova Scotians for future generations.

Biocontrol agents are the final 'tools' required to conserve healthy hemlocks for the long-term. Biocontrol agents consist of at least two insect predators, one to control each of the two HWA generations produced each year. Both predators naturally occur in British Columbia where they feed exclusively on HWA found on western hemlock (*T. heterophylla*). These same insect predators have been released successfully in eastern USA. One small beetle, *Laricobius nigrinus*, is well-established with populations expanding across several states. These predator insect populations must build and disperse through a hemlock network that sustains adequate food (i.e., HWA populations). In NS, this would be assisted by the connectivity of riparian-conserved hemlocks as HWA populations naturally fluctuate. Consumption of HWA by biocontrols will negate the need for chemical treatments once their populations are sufficiently high. Canada has stringent oversites on biocontrol use that are being followed by the Canadian Forest Service. Facilities and a program to monitor biocontrol insects in NS require support. The first releases of *L. nigrinus* are being discussed for fall 2022.

Deployment of strike teams is recommended as the most effective operational approach to rapid execution of chemical treatments, and can capitalize on a tremendous volunteer base; many of whom have clearly voiced desires to play an active role in the race to save old growth hemlocks. The coordination of several strike teams is required to catch up with widely dispersed and unchecked population explosions of HWA. At least one strike team should focus on providing a quick knockdown on the leading edge of the HWA distribution front using an aggressive early intervention containment approach. Other strike teams comb the most highly infested areas in the southwest to salvage what is still viable in high value stands and along waterways. A treatment minimum of 30 healthy, surviving trees in degraded stands is considered to still be a worthy contribution to the network and can protect distinct genetic stock.

Riparian strike teams are a separate focus required to address watershed health and help prevent collapse of fragile aquatic components, e.g., salmon and trout stocks, and to protect Mi'kmaq cultural resources along ancient travel routes that may otherwise be altered and exposed as dead hemlock fall and disrupt soil held in place for centuries.

Mi'kmaq consultation and engagement has been ongoing and collaborative partnerships are expected as treatment operations begin. Some Mi'kmaq Earth Keepers have been trained in HWA chemical treatments.

Riparian strike teams are also expected to avert costly repairs to infrastructure such as roads and homes by saving hemlocks that buffer the watercourses and prevent flooding.

Dedicated funding allocations to support a hemlock conservation program is paramount. The largest costs are for chemical products. Funding for some new employee positions and purchase of application gear is essential. While the new investment may seem high, the costs of doing nothing will also be high as dead hemlocks block rivers and cause flooding and washouts, costing in emergency response and replacement/repairs of infrastructure. At least several years of increased storm flashiness will ensue as rivers once protected by hemlock are exposed to unimpeded runoff and eroding banks. It is impossible to place a value on old growth forests that, once lost, will never return.

New staff positions to accompany the rollout of a comprehensive chemical treatment program include:

- **Hemlock Conservation Program Manager** (government) to oversee the chemical treatment program, assure meeting annual treatment targets, complete geo-spatial planning and coordination to finalize the hemlock conservation network across various land tenures, maintain a provincial treatment database, supervise/oversee education and outreach, and administer funds.
- **HWA Education and Outreach- Volunteer Coordinator(s)** (possibly two positions, one each focused on terrestrial and riparian systems, either government or NGO, and located within the infested area. Tasks: Recruit and train strike team members and volunteers, oversee/lead chemical treatments and tree-marking, coordinate public training and educational events, coordinate volunteers, participate as much as possible on strike team operations.
- **Strike team leads and team members.** Each team staffed with a strike team leader and at least one operational team member and maximizing work with volunteers to lower labour costs to meet tight, emergency timelines for treatments.

Private landowner support is outlined in this report using a range of elements that can facilitate hemlock treatments. A program may include creation of a limited-use pesticide operator certification for hemlock treatments only, a cost-sharing program that may ensure long-term hemlock protection on private lands through land trust agreements, or a loan of tree injection devices to negate costs of purchase.

Public support for chemical protection of eastern hemlock is high. Approximately 64 % of respondents who attended a video seminar on HWA control options voted for treating their trees with a combination of chemicals and biocontrols. Stronger support (75 % of participants) was voiced for chemical control but there were concerns regarding costs. There are mounting cries from the public wanting to learn how they can save hemlock trees on cottage lots and private woodlands, and where to find professional pesticide operators. Greater than 85 % of respondents in a follow-up survey were seeking treatment options but they faced financial barriers or were uncertain of costs for treatment. They were willing to commit to long-term conservation of their hemlocks. The Sporting Lake Nature Reserve hemlock treatments performed in October 2021 by a dedicated group of volunteers clearly demonstrated strong support toward conserving old growth hemlock through high sponsorship and droves of volunteers undaunted by its remote location. The treatments were equated to vaccinations used to save human lives. Nature Nova

Scotia, a federation of more than 10, 000 members, formally requested government intervention against HWA using chemical treatments, and has written Nature Canada to advise against blanket lobbying against neonicotinoid use, citing its need in hemlock conservation. **A government-led hemlock conservation network program with a comprehensive chemical treatment strategy would receive strong public support and is essential for ensuring hemlock conservation.**

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1. Introduction

Land managers of two Nova Scotia government departments, Environment and Climate Change (ECC) and Natural Resources and Renewables (NRR) are exploring the best strategies to address the threat of a tiny insect invader. Hemlock woolly adelgid (HWA) (*Adelges tsugae Annand*) is rapidly causing decline and mortality of eastern hemlock (*Tsuga canadensis*) in Nova Scotia (NS). HWA is infesting hemlock stands and moving across the province from the southwest to the east, killing trees in as little as 3 to 4 years from the time of detection. Rapid hemlock mortality has clearly become a critical environmental emergency not unlike a wildfire that creeps with destructive force through the forest, with intense flareups in some stands and suddenly jumping and spreading to distant new locations. Given the rapid decline observed, interventions to control HWA must be mobilized with a degree of urgency to prevent the loss of high value hemlocks. Hemlock mortality has already reached high levels in Digby, Yarmouth, and Shelburne Counties (Figure 1). Many forests are now moderately to heavily infested in Annapolis and Queens Counties, with mortality already apparent at some locations.

This report addresses elements that should be considered as part of a comprehensive plan to control HWA damage in some of our highest priority hemlock stands. The goal was to research the best strategies that could be used if the province were to conserve approximately 2000 ha annually over the next five years. We have outlined some of the most valid approaches that may be undertaken. Strategies balance what we've learned from consulting US experts who have been battling HWA for more than 50 years, as well as our own experiences with using chemical treatments to control HWA in NS.



Figure 1: Dead hemlock at Pearl Island, Tusket River Wilderness Area, standing as 'grey ghosts' in 2022 (Photo: ECC)

As essential as the use of *water* for controlling wildfires, *chemical treatments* are used to control HWA and keep hemlock forests alive and healthy. While some members of the NS public have expressed strong opposition to the use of chemical herbicides for controlling natural deciduous growth (i.e., glyphosate spray), the use of 'systemic' chemical treatments to protect old growth forest ecosystems is viewed positively by the majority of those who participated in a poll survey early in 2022 (Appendix 2). In the case of HWA, the majority of poll participants accepted that chemical treatment is the only tool that is currently available to safeguard rare

hemlock forests and old growth stands from this destructive invader.

Chemical treatments to protect eastern hemlocks from HWA have long been conducted in the eastern United States (US). They are the only existing mechanism for keeping trees alive in the short-term. Chemical treatments control HWA populations for a period of 4-7 years (depending on product used), and it is worth noting the benefit of chemical treatment to hemlocks and the species they support is far greater than the potential negative effects from the treatment (McCarty 2020). Potential negative impacts are greatly reduced by following all label application standards and best environmental practices. Studies on the impact of imidacloprid use on non-target species like birds, aquatic insects, canopy invertebrates, terrestrial invertebrates, reptiles and fish found only very low concentrations with no or only short-term impacts. (This is further elaborated in Section 5.4.) Use of chemical treatments is temporary, extending for only a brief period until permanent control measures using biocontrol agents come on board to provide longer-term protection to hemlock forests.

Without adopting a strategic approach similar to USA chemical control methods, Nova Scotia will rapidly lose hemlock forests, particularly in western NS. At present, 40% of all forest stands with hemlock occur in the five counties in western NS where HWA is already well established. More than 17,000 ha of damage caused by HWA was identified in Digby, Yarmouth, and Shelburne Counties in 2019. In these same counties and in the neighbouring counties of Queens and Annapolis there are now areas with dead hemlock or hemlock that has declined beyond saving. With speedy action, however, some high value hemlock forests can still be chemically treated and saved. Based on our recent poll and conversations with Nova Scotians who are aware of the HWA threat, people want to see actions taken to protect and conserve as much hemlock as possible before its legacy becomes highly degraded and permanently lost.



Heavily infested hemlock regeneration in Queens County with visible white woolly HWA egg sacs (Photo: M.J. Rodger).

Goal for Hemlock Conservation

The goal is to ensure long-term conservation of high priority hemlock forests through chemical control operations during 2022-2032 so that these areas and other healthy hemlock forests can foster the conditions for successful dispersal of biocontrol agents and thereby conserve healthy hemlock forests in perpetuity in Nova Scotia.

Project Objectives

The objectives of this project were to identify what supports and resources are needed for a large-scale HWA treatment program to conserve hemlock through:

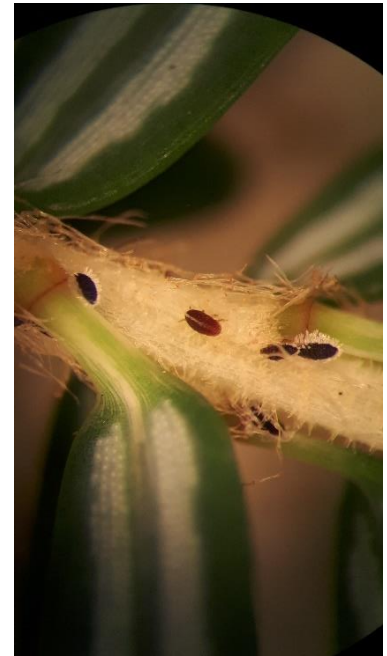
- Examining and developing options for program components on:
 - protected lands (Provincial and private),
 - Crown lands, and
 - private lands.
- Identifying desirable program strategies that can address the significant challenges of building a chemical treatment program to attain: 1) sufficient labor capacity to treat hemlock stands in a timely manner so that resources are not lost waiting for treatment; 2) strategic and tactical planning for treatments; 3) adequate funding and logistical support for treatments and monitoring.
- Identifying safeguards that may ensure the investment in treating hemlock will be protected from future harvests or other destructive activities; managed for long-term conservation values.
- Ensuring/incentivizing optimal use of financial resources and using a full arsenal of people to carry out the large-scale treatment program across all land tenures including but not limited to government and nongovernment staff, commercial agencies and small business operators, and volunteers.
- Outlining an efficient program execution and operation for sufficient numbers of dedicated, highly competent practitioners, volunteer crews and willing landowners to treat at least 2000 ha per year.
- Developing program options to treat stands under various levels of infestation and decline based on scientific evidence of the applicability of fast-acting versus longer-acting treatments.
- Carefully evaluating the science of non-target effects of chemical treatment to determine the limits of treatments per year, giving due consideration to the ecologically profound impacts of stand loss arising from delays or failures to treat.
- Developing options for further research, including the possibility of field trials for biological agents.

2. Hemlock Woolly Adelgid in Nova Scotia

2.1 The Biology of Hemlock Woolly Adelgid (HWA)

Hemlock woolly adelgid (HWA) is a tiny, invasive insect that is closely related to aphids and originates from Southern Japan. During summer until mid-October, HWA exists mainly as an inactive, sessile insect that is difficult to detect without the aid of a hand lens. During this time, they are found on the underside of growing tips at the base of needles as flat, black, oval specs, ringed by a small white waxy fringe.

HWA has remarkable reproductive potential that can rapidly overwhelm a tree. It produces two generations a year, and all individuals are females that reproduce without mating. Many factors affect population numbers but just one over-wintering adelgid female can produce upwards of 200 eggs in early April that produce new fertile females. The highly visible white woolly masses found toward the end of winter-early spring contain a mature female and eventually include her eggs. Each egg produces a nymph which settles down generally on the same twig with its mother (often becoming densely crowded with both generations of egg sacs). There they rapidly mature, forming new white woolly egg sacs to produce 200 eggs or more that hatch into a second generation of young crawlers in time to settle down on the newly expanded hemlock growth tips in late May-June, thus attaining 40,000-50,000 new HWA in just one year.



HWA nymphs and one HWA crawler (center). Photo: J. Ogden

Staff from Forest Protection Branch, NRR have been monitoring the seasonal timing of HWA life stages in NS. In mid-October, the tiny adelgids resume feeding by using their piercing-sucking mouthparts to extract hemlock sap, robbing the tree of carbohydrate reserves and water. While they feed through the winter, they develop into adults and produce egg-masses, as previously explained. Through late spring-early summer many life stages can be present at one time and much feeding and injury to the tree can occur.

High densities of HWA impede the tree from conducting sap to the outer ends of its twigs to make new growth and the trees attempts to cut off the nutrient supply to the adelgid in a defense mechanism. As the sap flow is cut off to the needles, they begin to drop. As hemlocks are starved of nutrients, the canopy thins (Young *et al.*, 1995; Havill *et al.*, 2016). A thinning canopy causes steady decline of tree health until no new growth occurs from the branch tips and photosynthesis slows. Mortality can occur within as little as four years (Orwig 2002; Emilson *et al.*, 2018).



HWA white woolly egg sac masses at the needle bases on the underside of hemlock branch tips. Photo: D. Crossland

2.2 HWA Introduction, Distribution and Spread

HWA was discovered in 2017 in Yarmouth County where it is believed to have been thriving and spreading for up to 10 years (Whitmore Pers Comm.). The introduction of HWA into Nova Scotia is suspected to have occurred through bird migration, but another possibility may have been through boat and ferry transportation that occurs directly from Maine to the Yarmouth port.

By the time HWA was reported, this tiny invasive pest had already spread to 5 southwestern counties (Yarmouth, Shelburne, Digby, Annapolis, and Queens). Distributions were patchy at first, but it is now widespread with high populations throughout most hemlock forests of those counties. Despite the regulatory order placed by the Canadian Food Inspection Agency (CFIA) on movement of hemlock out of these counties, HWA has expanded into Lunenburg and Kings Counties to include a total of seven counties in 2022 that are part of an expanded regulated zone.

There are some smaller occurrences of HWA recently found in southern Ontario in the town of Fort Erie, Wainfleet, and the city of Niagara Falls. NS is no longer the sole place in Canada that is addressing destructive established populations of HWA. Scientists from both infested provinces are in close communication on the issue. As well, HWA is found in British Columbia, but it is a different strain and has co-evolved with insect predators that keep populations from damaging western hemlock (*T. heterophylla*).

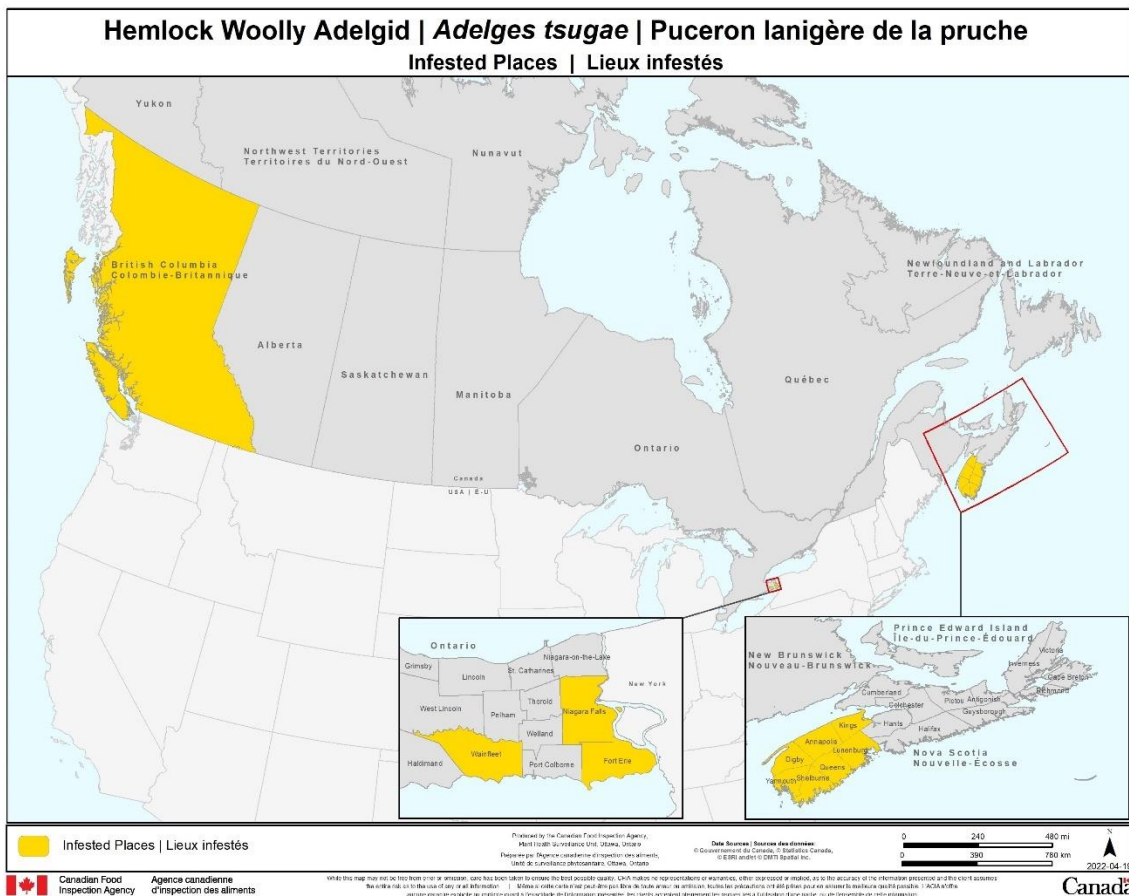


Figure 2. HWA distribution across Canada, including seven counties in Nova Scotia.

HWA populations are expected to continue to increase and spread throughout most of NS over the next decade, since there is little natural mechanism to keep numbers in check. Native insect predators are not having notable impacts, and the generally mild winters will accelerate the pest impacts.

The CFIA restricts movement of all hemlock material leaving a regulated area that presently covers all seven infested southwestern counties (Yarmouth, Shelburne, Digby, Annapolis, and Queens, with Kings and Lunenburg counties added to the regulated area in June 2022).

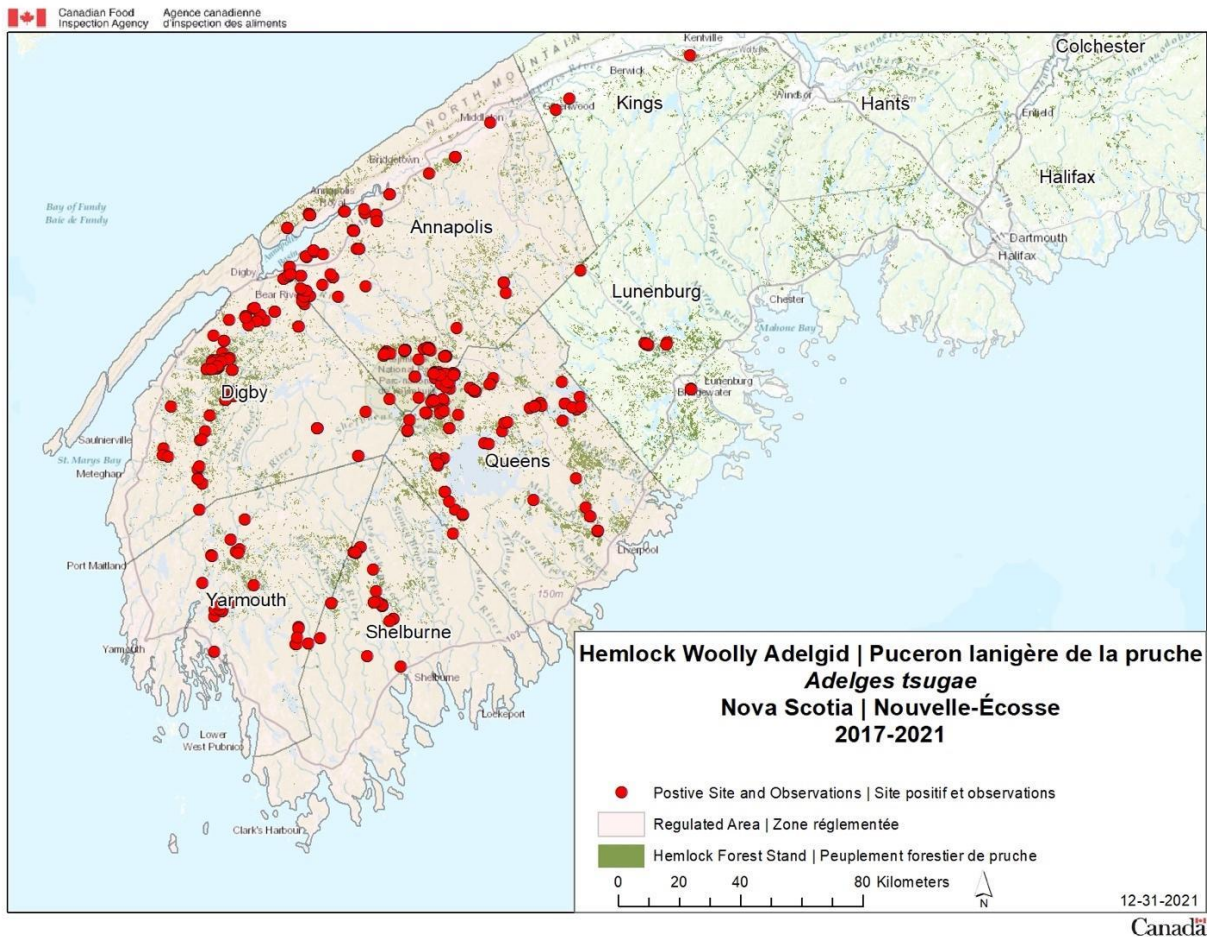


Figure 3: HWA detection map tracked by the Canadian Food Inspection Agency

The more measures that are taken against human-aided spread of HWA to central and eastern forests, the longer those forests will remain healthy, delaying and lowering treatment costs while scientists race to develop and implement longer-lasting control measures.

Education and awareness are needed to help alter human behaviours that can help to slow the spread of HWA. Large jumps in spread of HWA to new areas can be expected from human activities. Minute HWA crawlers and eggs can stick to clothing, gear, and pets. Vehicles, ATVs, forestry machinery, and campers can move HWA. While human dispersal can be curtailed, the natural dispersal of HWA will continue. Wind can disperse crawlers' short distances, and birds

foraging in hemlock trees infested with egg masses and crawlers can transfer HWA on their feathers as they visit new foraging sites.

2.3 The Value of Eastern Hemlock

Eastern hemlock is the longest-lived and largest conifer tree in the Wabana'ki (Acadian) Forest. It sometimes exceeds 1 m diameter at breast height and can form tall, closed-canopy protective networks overhead that instills a sense of awe and for some, a spiritual connection, or cathedral-like experience. Hemlock is extremely tolerant of shade, which allows its seedlings to establish in the understory and perpetuate on the same sites for thousands of years. It is adapted to small gap disturbances and windthrow events that expose bare mineral soil for ideal seedling establishment. A visit to an old growth hemlock-dominated forest may foster a vision of the original forests during the early European settlement period when many settlers lamented about toiling under intense shade of dark evergreens.

There was a time when hemlock forests, along with associate species of red spruce and white pine dominated vast expanses in NS (Loucks 1951). Presently there are only remnant hemlock forests consisting mainly of stands that escaped rampant and repeated European-caused wildfires. Some of the best intact stands are on islands in the middle of lakes or on lakeshores sheltered in the lee of historic fire tracts.

Hemlock has the capacity to modify its forest environment, which earns its recognition as a '*foundation species*'. Tree branches weave a protective web of dense canopy that shuts out the light and creates its own microclimate of high humidity. In cold winter storms, it holds the warmth of the earth, and intercepts snow and freezing rains, a valuable shelter to white-tailed deer, moose, and other wildlife species. In summer, the densely shaded understory can foster a microclimate up to 10 C cooler than temperatures above the canopy. The unique ecological role and function of hemlock cannot be replaced by any other tree. The loss of hemlock extends far beyond the trees to great losses of associated and hemlock-dependent species.

The dense needle hemlock canopy furnishes preferred foraging and nesting sites for many resident and tropical migrant birds, while enormous hemlock trunks form old growth cavities important for barred owls and flying squirrels. Large root flares offer denning habitat for fisher and other wildlife species. Hemlock commonly line streams and lake shores, providing scenic beauty with feathery branches and craggy structures. It's growth on steep banks stabilize erosion and buffers stream flow from storms and rapid winter melts. Tall trunks with heavy, spreading branches shade and cool water temperatures. As the hemlock canopy thins, the increased light levels on forest floor heat soil and water, impacting habitat for cold water fish, such as salmon and trout (Jenkins and Burkhead 1993; Snyder et al. 2002).

Hemlock's value to fish and wildlife and its ecosystem service contribution to stabilizing important riparian habitats generally exceeds its timber value. In the past it provided large dimension timber that were relatively rot resistant for barn boards, bridge construction and wharf pilings. The wood properties are subject to shake and splintering which generally kept it from being used for finer products. Presently it is meeting new demand for decks and flooring.

Aesthetically, hemlocks are highly valued and are iconic natural features of many Nova Scotia parks and tourist destinations. Tourism industry in Nova Scotia continues to grow, outstripping forestry revenues according to 'Finance and Treasury Board' statistics

(<https://novascotia.ca/finance/statistics/news.asp?id=16293>), which may indicate that keeping hemlock alive generates more revenue than allowing them to die and harvesting them. Many of the most prized tourist attractions will soon feature gray pillars of dead trees. Nova Scotia can expect the loss of hemlock in riparian areas to contribute to greater storm flashiness and flooding, placing a new strain on costs and maintenance of bridges, roads, and highway infrastructure.

Mi'kmaq people fished, hunted, sought shelter, and traveled under the shade of the hemlock (Ksu'sk in Mi'kmaq) for millennia. Hemlock bark has been used to make dyes and traditional medicine to treat a variety of ailments (Arnason et al. 1981; AMEC Environment & Infrastructure 2013). Hemlock trees line many of the traditional canoe and portage routes on which the Mi'kmaq traveled. Today, hemlocks are present on some First Nation Reserve lands and in some of the proposed Indigenous Protected Conservation Areas (IPCA), as well as form part of the forest resource on lands managed by the Mi'kmaq Forestry Initiative. Etuaptmuk, or 'two-eyed seeing' (the Mi'kmaq word for integrating perspectives of Indigenous knowledge with western science), will help to incorporate the indigenous perspective in managing hemlock decline throughout their unceded lands.

3. Chemical Tools Required to Control HWA

A minimum of four commercial chemical products are identified to meet the full range of needs for an effective HWA chemical control program in Nova Scotia, listed here by trade name:

1. IMA-jet
2. Xytect 2F
3. Safari
4. TreeAzin

Only IMA-jet is currently registered and available in Canada. These products are described in brief to acquaint the reader with their characteristics and major advantages and disadvantages.

All four of these products are designed to act '*systemically*', i.e., using the tree's vascular system to transport the product inside the tree from the base to the canopy where it kills the feeding HWA. Systemic products are used in much smaller amounts in the intact forest environment than direct spray foliar applications and seed coat treatments in agricultural situations, where chemicals are exposed to the environment, as well as nontarget and beneficial insects, and where they can more easily leach into waterways through exposed/ploughed soil.

The first three products listed contain neonicotinoid compounds as the active ingredient (a.i.), either imidacloprid (IMA-jet and Xytect 2F) or dinotefuran (Safari). Neonicotinoids act as neurotoxins in insects. They are nonlethal to other organisms, including humans, birds, and amphibians, and do not bioaccumulate. (See Section 5.4 for more details.) Of importance is that they must be *ingested* by feeding insects to be lethal and are not effective as 'contact pesticides'.

Traditional pyrethroids and other contact pesticides are less effective than systemic insecticides in hemlock treatments because of the difficulty in achieving adequate coverage in dense hemlock needle canopies and due to the high volumes required for spray applications. Canopy sprays can also result in chemical drift and greatly increase exposure to other organisms in the environment (McCarty, 2020).

The first three products selected are proven to work and are in wide usage to conserve hemlock throughout eastern USA.

1. **IMA-jet®**, (a.i. 5 % imidacloprid) manufactured by ArborJet, the *only* registered product currently available for HWA control in Canada, is injected inside the hemlock tree where it is translocated to the canopy. It is particularly useful for treating hemlocks along watercourses. The Label allows it to be legally used up to the water's edge, so it is a tool that is highly suited for protecting riparian forest ecosystems, and thereby indirectly protecting salmon and trout populations.

Advantages of this product are that it controls HWA for 4 years, and there are no annual area treatment limits associated with IMA-jet, so entire stands can be treated in a single operation.

The disadvantage of imidacloprid-based chemicals (both Ima-jet and Xytect 2F- described next) is that they act too slowly to prevent mortality of hemlocks with significant dieback (i.e., trees with less than ~65 % canopy density and/or reduced new growth). It is particularly slow to translocate in old growth trees where tree vascular system may be damaged or compromised, requiring 6 months up to one year to reach the canopy.

Another disadvantage is that tree injection sometimes does not uniformly disperse to the canopy due to anomalies in the tree vascular system, sometimes called 'candy-striping', resulting in branches that go untreated to support thriving populations of HWA.

The retail price of IMA-jet remains high. A lower price was negotiated for federal and provincial protected areas, dropping from an original price point of ~ \$ 600.00/L to \$ 179.00/L for a drum (holding 192 L of product). The price for private landowner use is likely higher. Some savings are met with a recent a *reduction* in the prescribed dosage of IMA-jet for hemlock treatments (the outcome of research by Benton *et al.* (2016a)), approved on the Canadian Label in 2021. All hemlock trees > 30 cm DBH can receive an effective dose at just 1.6 mL/cm (reduced from 2.4 mL/cm) and smaller trees less than 30 cm DBH can be effectively treated at 0.8mL/cm (reduced from 1.6 mL/cm).

Some considerations for using IMA-jet:

- A provincial negotiation on price directly with ArborJet may greatly lower costs.
 - Consider placing bulk orders of IMA-jet to lower cost per unit.
 - Negotiate a similar cost savings for trees treated in non-protected areas (private lands and public forests).
 - A chemical competitor may assist with lowering price. USA uses Imicide, manufactured by Mauguet. Prices of Imicide and IMA-jet are similar in the US, but Mauguet readily lowered its product price for hemlock treatments in places such as Michigan. This company would have to apply to register its product in Canada, which is costly.
2. **Xytect 2F®**, (a.i. 20% imidacloprid) manufactured by Rainbow Ecoscience, is applied through basal bark spray. It is in wide usage in USA to control HWA, applied both as a basal bark spray and as a soil drench (i.e., applied by pouring the product directly in mineral soil in the tree rooting zone, though not a proposed method in Canada at this time).

Basal bark treatments involve using a back tank equipped with a continual flow, low volume spray wand to treat the bark around the entire circumference of the tree base up to ~ 1.3 m high and without incurring runoff to the soil.

Basal bark treatment of Xytect 2F is likely to be available for use in NS in fall, 2022 pending an emergency use authorization by the PMRA that will span 12 months. Following that time, an extension would be required. Xytect 2F may also be undergoing the registration process needed for use in Canada on HWA soon. Costs associated with full registration in Canada by the manufacturer (Rainbow Ecoscience) are prohibitive, but early provincial use of the product may improve the financial viability outlook for the company. It was used in HWA research trials by Canadian Forest Service and Parks Canada in 2021.

Advantages for acquiring Xytect 2F are:

1. The product is very cheap. (The patent for imidacloprid has expired.)
2. The effects are longer-lasting than IMA-jet. The active ingredient, imidacloprid appears to alter its chemistry more readily into a long-lasting metabolite, olefin, and this aids the chemical effects to last 5-7 years.
3. Reduces labour costs because basal bark treatments are more rapid to apply because they do not require the added step of drilling the tree and placing plugs, or nozzles and canisters.
4. Reduces equipment applicator costs. Back tanks are cheaper compared to most commercial injection devices.
5. There are no tree wounds caused from drill holes.
6. Basal bark treatments increase the likelihood of a more uniform treatment being transferred to the canopy because all of the tree vascular system

A major impediment to using Xytect 2F in NS may arise should the PMRA impose limits on the amount of active ingredient authorized for use per area each year. In the USA, the EPA limits the total amount of imidacloprid applied per ha per year to 0.45 kg active ingredient, an equivalent of 1.89 litres/ha/yr. This necessitates returning to the stand over three or more successive years to complete a full stand treatment. Obvious disadvantages are associated with increased costs for travel to the site and labour incurred by walking the full stand several times and marking each treatment separately. But far more concerning are the risks of hemlock mortality and general stand health decline in the awaiting, untreated trees.

The mild climate of southwestern NS, coupled with climate warming, is resulting in exceedingly rapid mortality of HWA-infested hemlocks, occurring in as little as 3-4 years. Forests do not benefit from winter-related HWA mortality experienced in much of USA. (The exceedingly thin, nutrient poor soils of southwestern NS may also hasten hemlocks mortality.) A treatment that takes 3 or more years for completion will be of little utility, as untreated residual trees would likely be dead or too far in decline to treat in years '2' and '3' using imidacloprid-based products. Consequently, it is likely that a combination of Xytect and IMA-jet would have to be used to complete full stand protection in a single operation.

Some recommendations for using Xytect 2F:

- Consider meeting with the PMRA to request avoiding annual treatment area limits, based upon, 1) scientific evidence that points to only minor environmental risks associated with use of Xytect 2F in intact forested environments with presence of low pollinator

populations (as researched in NS), 2) Highlighting the urgency of Nova Scotia's unique situation where hemlocks are experiencing an accelerated rate of HWA-related mortality, requiring trees to be treated in just one year, and, 3) Climate change considerations, as hemlocks are superior trees for mitigating climate change.

3. **Safari®**, a.i. dinotefuran, is manufactured by Mitsui, Japan, and registered by Nufarm (as well as other companies in USA). This neonicotinoid product it is widely applied as a basal bark spray in USA (*or as soil drench or soil injection though not relevant to Canada*) and is particularly useful on hemlock trees with advanced canopy decline where fast action is needed.

Safari is a fast-acting product that can suppress heavy populations of HWA in just one month after treatment (Joseph et al 2011). Its rapid action is owing to the dinotefuran molecule being highly soluble in water. It can be absorbed through the bark. Using a back tank sprayer enables rapid treatment, thereby reducing labour costs over tree injection methods.

In the USA, it is commonly applied as a basal bark application in a tank mix with imidacloprid, allowing the user to obtain the best of both products: quick uptake of dinotefuran with longer-lasting efficacy of imidacloprid (Whitmore 2014; Mayfield et al. 2020). It is highly effective for treating heavily impacted trees with thin canopies and little or no new growth.

Disadvantages are that dinotefuran remains effective for only a short period of months, is more expensive than imidacloprid, and it incurs a greater threat to the environment due to higher water solubility.

The largest disadvantage is the very low receptivity for authorizing dinotefuran for use in Canada due to environmental concerns. It is currently registered only for tick/flea and structural indoor use. Authorizing use of this product requires a re-think about how the benefits of using this product for hemlock conservation outweigh environmental risks, which can be mitigated. Steps required to potentially obtain it for HWA control under an emergency application in Canada are challenging. The process begins with, 1) approaching the manufacturer to request they make application to the PMRA to have their product approved for emergency use in Canada; finding a registrant who will apply to the PMRA, 2) having a sponsor, such as CFS or a provincial government department pay the registration application fee, and 3) complete a strong rationale for use of dinotefuran including safety information and why its emergency use is necessary in Canada. An additional 'restricted use' clause may aid with concerns that once dinotefuran would become available in Canada, it could be used off-label for other purposes and incur greater environmental risks.

4. **TreeAzin®**, a.i. azadirachtin, was developed as an *organic* pesticide in collaboration with the Canadian Forest Service and a Canadian Company BioForest (now Lallemond). The chemical is a systemic pesticide that is derived from seed extracts of the neem tree (*Azadiracta indica*). Its organic nature caused it to be classified as exempt from Ontario's Cosmetic Pesticide Ban Act and may be relevant regarding the Halifax pesticide ban.

TreeAzin has been researched in NS for its ability to control HWA in comparison with IMA-jet. Results by CFS indicated that it reaches the canopy relatively quickly where it controls HWA very effectively for a short period. It's ability to transfer to the canopy quickly means that it has potential to be a rapid HWA knock down chemical, similar to dinotefuran, but without the controversies associated with using a neonicotinoid.

The TreeAzin Label does not currently include treatment of HWA, but Lallemond intends to apply for label expansion registration for HWA control. It is registered in Canada to control Emerald Ash Borer (*Agrilus planipennis*), so expanding the label to include hemlock for HWA control should be straightforward under the minor use program. Alternatively, Government may apply for *emergency registration* of TreeAzin that is processed in approximately 1 month by the PMRA. Research applications may be processed in about 3 months, which may also be fitting as there are outstanding research questions to be answered. For example, what are the canopy health thresholds for when TreeAzin still be effective for controlling HWA.

Advantages of TreeAzin:

1. It is the ONLY product that can used on riparian hemlocks in advanced decline (where IMA-jet would no longer be effective). Essentially, it may be the only option for preventing mortality of degraded riparian hemlocks.
2. Acts quicker than imidacloprid so it is useful for degraded trees with thin canopies.
3. Has very low toxicity to vertebrates and generally less environmental risk.
4. Does not persist in the environment.

Disadvantages of TreeAzin are: 1) Cost (~\$600.00/L or higher). This will likely limit its use to priority sites of high ecological and cultural value; 2) Thresholds unknown (e.g., canopy density or dieback levels) for when TreeAzin is no longer effective; and 3) Incomplete treatments/ ‘candy-stripping’ that are sometimes associated with tree injection applications.

Some recommendations for using TreeAzin:

- Use TreeAzin in 2022 (assuming PMRA authorization) to conserve some of the oldest and largest hemlocks growing next to rivers and lakes in NS that have declined too far for effective IMA-jet treatments and are on the brink of mortality.
- Government-led negotiations with the manufacturer for lower chemical pricing of this product may be worthwhile, as this is a Canadian-made product that has the capacity to save valuable riparian and old growth trees that are most compromised and otherwise untreatable. This is a potentially positive Canadian research-based news story and an invaluable contribution to the chemical arsenal against HWA using an organic product.

Table 2: Summary of key commercial products recommended for controlling HWA in NS.

Product	Cost Estimate (cost per L)	Application Method	Need or Usage	Chemical transfer HWA Control	Duration
IMA-jet	Expensive (~\$189.00*)	injection	Riparian forests, hemlocks growing on high water table	6- 12 mos	4 yrs
Xytect 2F	Cheap (~\$ 66.00)	Basal Bark	Large stands away from water	6- 12 mos	5-7 yrs
Safari	Expensive (~ \$ 600.00)	Basal Bark	Severely declined stands away from water	Fast knockdown 1 mo	Up to 0.5 yr
TreeAzin	Expensive (~ 600.00+)	Injection	Severely declined trees next to water & possibly elsewhere	Fast knockdown 1 mo	0.5 yr

* Prices quoted on bulk order, June 30, 2021, from ArborJet include shipping, shipping container, 5 % border tax.

Other Potential Chemical Products for HWA Control

There are other highly effective chemicals and alternate brands that have been used in USA for HWA control. Table 3 lists other products used for HWA treatments (McCarty and Adesso 2019). Experts who research and manage HWA advise us to petition for the chemical products we need. We may also gain some guidance from groups like the Christmas tree growers and other agricultural contacts who are extremely experienced in petitioning to obtain new chemical products as new pest situations arise.

CoreTect tablets. While all other product choices that could be requested as a program moves forward were not examined at this time, CoreTect tablets came highly recommended as easy to apply, especially if water sources are not located nearby to facilitate Xytect 2F or other applications. They are light and easy to carry. Practitioners use a bulb planter to reach mineral soil near the tree rooting zone, placing the CoreTect tablet in the ground, and covering it. The tablets have a time release formulation, taking ~3 years to get the full amount into the tree.



Chemical application methods commonly used in USA: a. Soil drench, b. Soil injection, C. CoreTect tablets. Photos from Mayfield et al. (2020).

Other imidacloprid products may eventually be available and cheaper to purchase than IMA-jet or TreeAzin. Exploring the possibility of a label expansion to include hemlock for Merit 75WP or WSP product (*wettable powder Imidacloprid product*) may be useful since these products are already sold in Canada. Explore treatment and chemical options with Maugey for competitive prices and potential use of Imicide as an alternative to IMA-jet.

Contact insecticidal soaps and horticultural oils have been used instead of systemic insecticides to control HWA. They have a lower toxicity and can be effective when properly

applied. Horticultural oils function by suffocating the adelgid. However, infested needles and well-protected waxy ovisacs must be completely drenched. Frequent re-applications are necessary to maintain thorough coverage, which would be impractical on a large hemlock tree.

Domestic pesticide products. Having some domestic products available to cottage owners and other landowners who own low numbers of hemlock trees would greatly assist those who cannot afford a certified applicator and do not want to pursue a pesticide operator certificate. Imidacloprid and dinotefuran domestic products are available at USA garden supply stores, enabling landowners to apply effective products themselves. Products are packaged under various trade names in liquid or granular form and are generally applied to the soil close to the tree trunk, where they are absorbed through the root system. There are obvious environmental concerns with users accessing these powerful products who are unaware of potential environmental harm and have no training, but perhaps there is some room to reconsider the differences in regulatory approaches. Domestic products are often less effective and more expensive than commercial products.

Table 3: Chemical products available for HWA control in USA (McCarty and Adesso 2019)

IRAC #	Active ingredients	Activity	Selected trade names ^b	Use sites ^c	R.E.I. (hours) ^d
1A	Carbaryl	Contact	Sevin SL Sevin T&O	LFC N	12
1B	Chlorpyrifos	Contact	Dursban 50W	N	24
	Oxydemeton methyl	Systemic	Harpoon MSR Spray Concentrate	LFC NC	0 10 d
3A	Bifenthrin	Contact	OnyxPro	LNI	12
	<i>Tau</i> -fluvalinate	Contact	Mavrik Aquaflow	LGNI	12
3A+4A	Bifenthrin + clothianidin	Contact/systemic	Aloft LC, G, LC, SC	L	N/A
	Bifenthrin + imidacloprid	Contact/systemic	Allectus SC	LI	N/A
	Cyfluthrin + imidacloprid	Contact/systemic	Discus N/G	NGI	12
	<i>Lambda</i> -cyhalothrin + thiamethoxam	Contact/systemic	Tandem	L	N/A
	<i>Zeta</i> -cypermethrin + bifenthrin + imidacloprid	Contact/systemic	Triple Crown T&O	LI	N/A
4A	Acetamiprid	Contact	TriStar 8.5 SL	LNG	12
	Dinotefuran	Contact/systemic	Safari 2G; 20 SG Zylam Liquid	LNGI L	12 12
			Transtect 70	LF	N/A
	Imidacloprid	Contact/systemic	Xytect 75 WSP; 2F Marathon II; 60 WP Merit CoreTect	LNGI NGI LIF LNGIF	12 12 N/A N/A
	Thiamethoxam	Contact/systemic	Discus Tablets Flagship 25 WG Meridian 0.33G; 25 WG	NG NGC LI	12 12 N/A
6	Abamectin	Systemic	Aracinate TM	LNGIF	N/A
23	Spirotetramat	Contact/systemic	Kontos	NGI	24
28	Chlorantraniliprole	Contact/systemic	Acelepryn	LI	N/A
Unknown	Azadirachtin	Contact	Azatin O Tree-Azin	LNGI LF	4 Until dry
Unclassified	Horticultural oil	Contact	Ultra-Pure Oil	LNGIC	4
	Insecticidal soap	Contact	M-Pede	LNGI	12

^aAdapted from Southeastern U.S. Pest Control Guide for Nursery Crops and Landscape Plantings.

^bTrade names are provided as examples only. Check product labels for up-to-date restrictions and use requirements.

^cUse site codes: L = landscape, N = nursery, G = greenhouse, I = interiorscape, F = Forest, C = Christmas

trees. ^dR.E.I. = re-entry interval.

4. Planning and Prioritization

4.1 Landscape-level Analysis and Planning

4.1.1 Hemlock Conservation Network

Dr David Mausel, land manager and entomologist for the eastern USA region strongly advises the maintenance of a network of healthy hemlock forests across NS to best receive biocontrol predators when they are ready to be released. Predator insect populations must build and disperse as HWA populations fluctuate.

This broad-scale strategy hinges on an *integrated pest management approach* (IPM) that conserves healthy hemlock stands, so they are available to predators of HWA across NS. This implicates all land tenures to varying degrees. For example, where protected areas or Crown hemlock forests do not exist, privately- owned hemlock forests must provide the food for HWA biocontrol agents to survive. A network approach would also best ensure against local catastrophic disturbances such as fire or hurricanes that could wipe out the last remaining hemlocks and destroy conservation efforts if only a few high-quality forests were conserved. A network of hemlocks best conserves genetic diversity.

A Seed Conservation Map produced by the National Tree Seed Centre indicates the importance of this genetic diversity (Figure 5). Staff at the National Tree Seed Centre will endeavour to collect and preserve 15 genetically distinct hemlock seed collections from the region, with red areas showing high priority areas to conserve. As well, the ecosystem services provided by hemlock forests to wildlife and waterways justifies a network approach across the province.

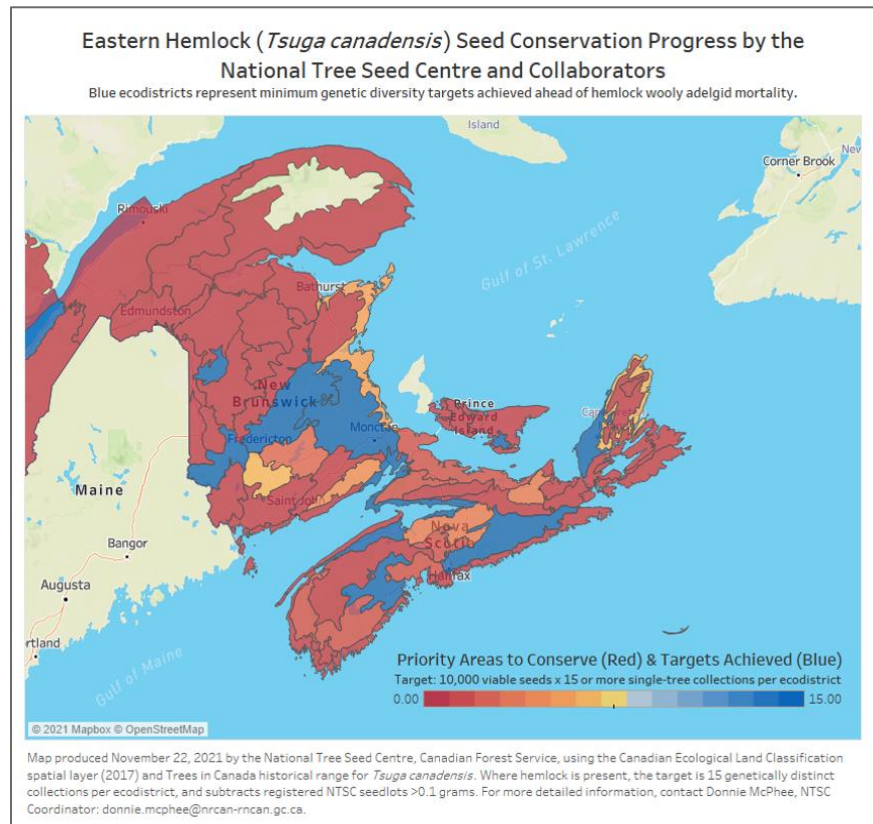


Figure 5: Seed Conservation Map produced by the National Tree Seed Centre (NRCAN 2021)

Where are the best forests located to serve in this conservation network, and how do we ensure a benefit to all regions with high value hemlock stands across NS? Treating hemlock stands located only in provincially protected areas would result in a very uneven hemlock distribution. Given this, it is important to ask - are there enough hemlock forests worthy of conservation in

some regions to sustain a network? Landscape level planning through spatial analysis of GIS data layers and in-the-field stand verifications are required to finalize and shape the hemlock conservation network across three broad land tenures:

1. Protected and conserved lands (protected areas on crown and private lands held within the Nature Conservancy of Canada (NCC) and the Nova Scotia Nature Trust (NSNT) and Federal protected lands);
2. Crown land forests, particularly very mature forests including lands under the Old Growth Forest Policy and those that are interpreted as multi-aged stands and;
3. Private lands, especially those with conservation easements or other types of protective easements.

Strategic planning a hemlock conservation network requires stepping back to assess what currently exists for high conservation value hemlock forests that would best receive treatment. A collaborative approach with partners is necessary as not all high value hemlock stands are located on provincially managed lands. Ranking forests that have highest ecological value and that are most likely to persist on the landscape to ensure investment of chemical funds, and bearing in mind jurisdictional obligations, priority landscapes of high value hemlocks may be loosely ranked as follows:

1. Protected and conserved lands in provincial nature reserves and wilderness areas,
2. Old growth on Crown lands designated under the Old Growth Forest Policy,
3. Federal lands (e.g., National Parks, IPCAs-(*pending* Mi'kmaq consultation)*,
4. Provincial park lands,
5. Conserved privately owned lands managed by the Nature Conservancy of Canada (NCC), Nova Scotia Nature Trust (NSNT) or other conservation-focused land trusts,^{2*}
6. Riparian buffers on all land tenures*,
7. Crown land forests that feature high value hemlocks that are not formally designated
8. Private lands should be considered, especially where no protected and conserved lands exist to fill a landscape void. Additionally, some private land owners will want to protect hemlocks whether or not they are officially part of the conservation network and incentives* to retain these stands in perpetuity should be considered as part of the planning.

Managing the big picture for long-term success requires a broad assessment before delving into fine details and tactics. This triage of conserved hemlock sites could be aided by a broad-scale analysis at the watershed, county level, or perhaps Ecodistrict level (Ecological Land Classification).

Not all hemlock forests within the network must have 'old growth' status. While old growth has proven through centuries that it has the genetics or site characteristics to survive most disturbances, young trees may respond better to treatments and may be more resilient to some disturbances that accompany climate change and other forces. Biocontrol scientists advise that

² *Collaborative approaches would be required to include these land tenures in a hemlock conservation network. Some States have formed excellent partnerships and cost share agreements with Nature Conservancy and private lands. Jurisdictional agreements would require a shared vision and presumably funding or other contributions toward a Hemlock Conservation Network. Regarding private lands, special agreements would be required to ensure treated trees would not be harvested.

young trees must be included as part of the mix for insect predator releases, and they are needed to ensure the full structure of the stands is retained. Generally, late successional, old growth forests become 'uneven aged' (i.e., feature a mix of age classes), so some younger trees will be treated and conserved in the mix.

4.1.2 Provincial Hemlock Distribution Statistics

Committing to treat and protect hemlock in a healthy state in preparation for a pending biocontrol program requires knowing where hemlock stands are concentrated (Figure 6). Extensive GIS analysis was not available as part of this contract but some useful numbers were obtained and are portrayed in Figure 7 and Table 1.

Several important considerations related to deployment of a hemlock conservation program were revealed by assessing the distribution of hemlock stands identified in NRR's provincial forest inventory data:

1. Nova Scotia has approximately 216,430 ha of forests that contain 10 % or greater hemlock composition. Hemlock-dominated forests (> 50 % hemlock) are identified in just 16, 894 ha or 8 % of hemlock forests across NS, indicating its rarity on the landscape, and of this, only 2,030 ha are currently under provincial protected status.
2. Rapid deployment of chemical control required in southwest NS: Just over half (52.7%) of the hemlock stands identified in provincial forest inventory data are found within the impacted counties in western NS (Annapolis, Kings, Digby, Yarmouth, Shelburne, Queens, and Lunenburg Counties). These areas require immediate attention to conserve hemlock and in many areas, will also require use of faster acting TreeAzin and dinotefuran products to knock down HWA populations and conserve heavily infested trees. Some stands may only contain sparsely distributed individual trees that are healthy enough to conserve.
3. Importance of supporting hemlock conservation for private woodlands: Approximately two-thirds (65.8%) of hemlock stands identified in provincial forest inventory data are located on privately stewarded woodlands.
4. Regional land tenure patterns and impacts on conservation strategies: Public lands are variably distributed across NS and this will impact approaches for hemlock conservation. For example, Lunenburg County contains 9.6% of the total hemlock identified in the provincial forest inventory data, 90% of which is located on privately owned lands. Digby, Hants, Cumberland, Colchester, and Pictou Counties displayed similar patterns of significant hemlock content and high private ownership of hemlock. Contrasting this was Queens County (13.4 % of hemlock, 62% located on Crown land) and Annapolis County (10.6% of total hemlock inventory, 59% located on Crown).

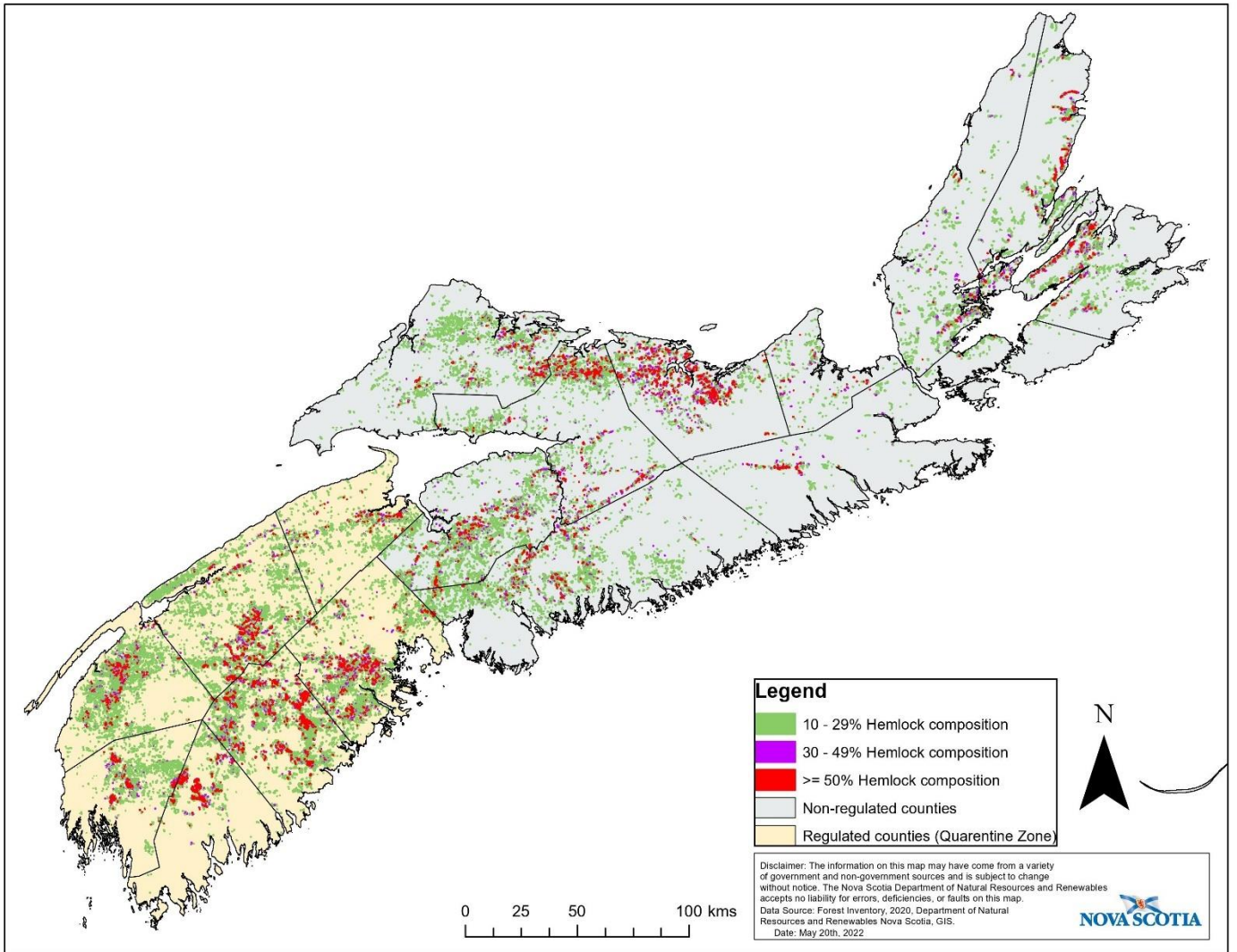


Figure 6. Distribution of eastern hemlock stands identified in Provincial Forest Inventory data by county and region (NRR 2022).

Table 1. Proportion of hemlock inventory by county and land tenure.

*PAPA (Parks & Protected Areas) includes Federal Parks, NRR Parks, ECC Protected Areas & Privately Protected Lands (Nova Scotia Nature Trust & Nature Conservancy of Canada).

Region	County	Proportion of Provincial Hemlock Inventory (%)			% Total Hemlock Inventory	Proportion of county total, by tenure	
		% PAPA*	% Crown	% Private		% Crown	% Private
Western	Queens	3.5	4.8	5.1	13.4	62%	38%
	Annapolis	3.6	2.6	4.3	10.6	59%	41%
	Lunenburg	0.3	0.6	8.6	9.6	10%	90%
	Digby	1.1	0.8	7.0	8.9	21%	79%
	Yarmouth	0.8	1.6	1.6	3.9	60%	40%
	Shelburne	0.8	1.1	1.3	3.2	61%	39%
	Kings	0.2	0.3	2.6	3.1	16%	84%
Central	Hants	0.6	1.2	6.8	8.6	21%	79%
	Halifax	1.2	1.6	3.8	6.6	43%	57%
	Cumberland	0.5	0.6	4.9	6.0	18%	82%
	Colchester	0.2	0.5	5.0	5.7	12%	88%
	Pictou	0.1	0.1	5.3	5.4	4%	96%
Eastern	Victoria	1.8	0.7	2.3	4.8	52%	48%
	Inverness	0.8	0.7	2.9	4.4	34%	66%
	Cape Breton	0.2	0.5	2.8	3.5	21%	79%
	Antigonish	0.1	0.1	0.7	0.9	22%	78%
	Guysborough	0.2	0.2	0.4	0.9	53%	47%
	Richmond	0.0	0.0	0.3	0.4	22%	78%
	Total	16.0	18.3	65.8			

4.1.3 Riparian network approach

A landscape level approach to treating and conserving hemlock can take advantage of the unique geology of NS, which forms an extensive network of rivers and lakes (e.g., Figure 6) that are commonly lined with fine hemlock growth. Much of this hemlock resource is too small and narrow to have been captured in Forest Inventory Data, though it contributes to significant total hemlock volumes on some river systems.

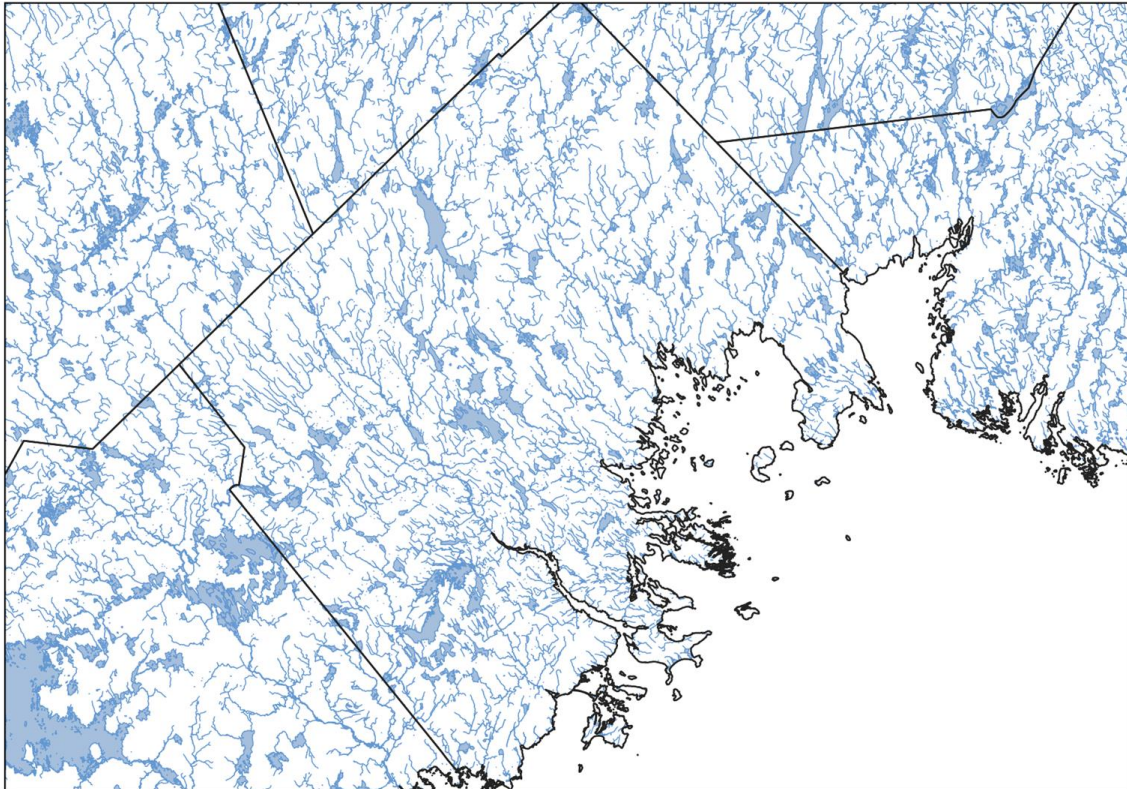


Figure 7. An example of Nova Scotia's great riparian network across the landscape as seen in Lunenburg County.

Rivers transect across all land tenures which may increase the degree of complexity to coordinate chemical injection treatments. However, it is already illegal nearly everywhere to carry out major harvests directly adjacent to these aquatic systems, so potentially only some minor tweaking of regulations may be required to allow riparian buffers to be integrated into the hemlock conservation network planning. Special management zones (SMZs) for riparian protection are legislated under the Nova Scotia Wildlife Habitat and Watercourse Protection Regulations. Forest harvest operators could be no longer authorized to selectively remove trees from the buffer, thereby safeguarding any treated hemlock resources while also benefiting the ecological function of the aquatic system.

On Crown lands under harvest, treated riparian hemlocks could receive added protection through the Integrated Resource Management (IRM) process, requiring additional "Special Management Practices" prescribed to operators that could stipulate no harvesting adjacent to water courses.

Ultimately an expansion of the ‘special management zone’ buffer width to be consistent with ecological principles would be the best long-term scenario. An expanded buffer of 50-100 m of streams and lake edges on Crown land would reduce risk of treated trees blowing down and losing the investment. It has long been requested and considered as part of ecological forestry (Lahey 2018).

Treating stream-side hemlocks and widening the riparian buffers offers a unique opportunity to provide connectivity for all other forest components that rely upon or utilize hemlocks. In terms of biocontrol objectives, those riparian corridors provide an excellent conduit for dispersal of predator insects, allowing them to move across the landscape as HWA food supply rises and falls, thereby enhancing success of a government-led biocontrol program.

On private lands the riparian buffers are similarly in place under the Wildlife Habitat and Watercourse Protection regulations. This provides similar opportunity to have treated hemlocks on private lands that are less likely to be harvested.

4.1.4 Managing for Regional climate control influences on HWA and its insect predators

Plant hardiness zones may function as a guidance tool for predicting how variations in regional climate can influence populations of HWA and its predator insects. Four plant hardiness zones span NS based on the coldest winter minimum temperatures. Each zone can alter the winter climate-related mortality of HWA and influence what may be expected when biological predators are released to feed on it.

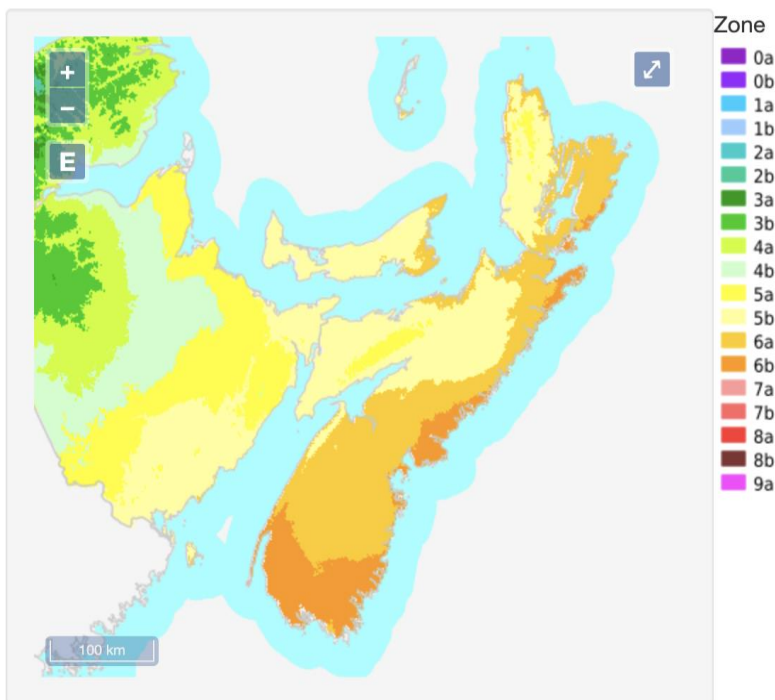


Figure 8. Plant hardiness zone map from NRCan, illustrating that NS ranges from zone 6b (warmest) to zone 5a (coldest).

Each zone can alter the winter climate-related mortality of HWA and influence what may be expected when biological predators are released to feed on it.

An examination of plant hardiness zones (Figure 9) leads to predictions that Yarmouth, Shelburne and Digby counties would be expected to decline at a much faster rate from HWA than hemlock forests in regions of neighbouring NB where winter temperatures reach -28 C or colder. Some of the milder zones such as 6a and b in the Southwest were predicted by US scientists (M. Whitmore and D. Mausel) to allow HWA populations to “explode” with little winter mortality to slow population growth. This prediction has since proven to be the case. Biological control agents, such as *Laricobius nigrinus* are forecasted to be suited to the winter climate in these zones.

Areas in plant hardiness zone 5a, such as in the northern sector of the Cobequids may have slower increases in HWA populations and be easier to control. Northwest NB will experience a different scenario than southwest NS according to David Mausel. Land managers may have more time to mobilize chemical treatment in zones 5 a-b than when working in zones 6 a-b.

4.2 Stand Prioritization

Time constraints and limited resources require provincial land managers to choose which stands will receive protection. The New York State Hemlock Initiative has developed a 'Hemlock Prioritization Tool Kit' that has been utilized by many land managers. It generates a ranking system to help prioritize hemlock stands to make an informed decision on where to focus hemlock conservation efforts.

This tool was modified by staff at ECC and NRR to address more local needs and attributes for Nova Scotia hemlock forests, and a finalized stand prioritization approach was fully implemented for field assessments in early 2022. It guides considerations of several factors simultaneously to reach an objective final decision on which stands should receive highest priority for chemical applications and ultimately long-term protection. According to experts at the New York State Hemlock Initiative and elsewhere, remnant old hemlock forests should always be conserved if possible and aggressively treated. Treating proactively is considered wise and causes these stands to go to the top of the candidate list, though no stand treatments in the southwest can be considered as "proactive intervention" any longer, with the current HWA distributions nearly everywhere and reaching high population densities with stand deterioration and mortality. Even without this consideration, the unique ecosystem and biodiversity that accompanies old growth hemlock is top priority to conserve.

Factors included for NS stand prioritization were:

- Old growth forests - highest importance to conserve
- Presence of HWA and infestation levels
- Stand composition
- Hemlock diameter classes
- Rare species and hemlock-dependent species
- Stand characteristics i.e., size and connectivity
- Environmental stresses from construction, roads, etc.
- Aquatic ecosystem services-proximity to water, watershed health, fish conservation, flood conservation
- Stand decline related to HWA (may increase urgency and level of priority to treat)
- Ecosystem services, and special biodiversity values.
- Steep slopes (stream bank erosion control, north-facing)
- Mi'kmaq cultural resources
- Land tenure (i.e., level of protection/investment risk)
- Accessibility
- Social values and tourism considerations.

Urgent treatment needs for some priority hemlock stands in 2022

Stand prioritization assessments of most of the protected areas in southwestern NS containing old growth hemlock have been completed. The results have increased the sense of urgency in actioning hemlock treatments as soon as possible.

Many of our oldest and finest hemlocks in western NS are under immediate threat from HWA and these stands are the immediate priority for 2022. However, some of our most prized old growth is in rapid decline now from having already been infested for several years. Some stands are already too far in decline to be treatable or they are dead, so some stands did not receive a full assessment, such as Pearl Lake, Tusket River Wilderness Area (Figure 1).

The urgency of treating hemlock stands in southwestern NS cannot be over-stated. Where canopy threshold values have declined below those recommended for effective imidacloprid use, the faster-acting chemical control options must be considered. This incurs additional chemical costs, increasing costs by 5-fold if using IMA-jet and 11-fold if using Xytect 2F, but it is worthy of consideration for some of the finest and last remaining stands in the southwest. All the heavily declined stands are located within the Southwest Nova Biosphere Reserve that was designated partly due to rare species associations that exist nowhere else. The southwest, under various protected areas designations, is the largest intact wild space in NS.

High value hemlock stands that are located deep inside the heaviest infested regions of Shelburne, Yarmouth, and Queens County are in the most critical stages of decline. These stands are identified as top priority to treat as early as possible in 2022 as a last-ditch opportunity to save:

1. Pollard's Falls, a site of Ecological Significance, within the Shelburne River Wilderness Area, long recognized as one of the foremost old-growth eastern hemlock stands in Nova Scotia.
2. Moosehead Island, Silvery Lake, Tobeatic Wilderness Area
3. Denis Boot locality, Tobeatic Wilderness Area (adjacent to Kejimikujik National Park & Historic Site)
4. McKay Lakes, Roseway Wilderness Area
5. Clamshell Lake, Indian Fields Park Reserve
6. North Bingay Lake Island, Tobeatic Wilderness Area
7. Various stands, Silver River Wilderness Area
8. Various stands, Sissiboo River Wilderness Area

Additional priority should be given to sites which have been identified of Mi'kmaq importance. A final sweep of the heaviest infested landscapes and riparian forests in the southwest should be conducted in 2022 to ensure that other remnant hemlock pockets of this region, if remaining in sufficiently healthy thresholds, may receive a final opportunity for treatment.

Depending on which products are authorized for use in NS, the strategy is to prioritize trees that appear to have new growth and sufficient canopy density scores. Other metrics may be added, or treatment thresholds adjusted to match whether fast-acting or only slower-acting chemicals are used. Mayfield et al. (2020) contains an excellent consolidated list. Particularly valuable trees may be selectively treated with TreeAzin or dinotefuran pending pesticide regulatory decisions. Care should be taken to avoid treating hemlock growing in stressed sites where hemlocks are more apt to succumb even with treatment (e.g., sites with compacted soils, ledge rock, poor drainage, drought prone sites).

High value hemlock stands located roughly east of trunk # 8 should be at minimum prepped for treatment in 2022 (i.e., measured DBH and tagged). Protected areas that would be ideally treated in 2022, but may be somewhat less urgent are:

1. Skull Bog Lake Nature Reserve
2. Medway Lakes Wilderness Area, including the 4 Mile Stillwater Hiking Trail
3. Snowshoe Lakes Nature Reserve

Many more sites across NS require field evaluations for prioritizing in advance of the HWA expanding front as well as for a pending hemlock conservation network approach.

Falling back to the big picture, more than 90 % of hemlock stands will not be treated since both time and funds are short. Many stands in the 5 southwestern counties are already too far in decline to conserve, while other stands can still be saved this year (2022) but not next year.

5. Strategies for the Chemical Treatment of Hemlock Woolly Adelgid

How best to conserve a network of healthy hemlocks through an aggressive interim chemical treatment program in 2022-2026.

The first action required is to complete prioritization of hemlock stands to meet a minimum target of 2000 ha annually for the next 5 years. Planning actions for chemical control across all land tenures will rely upon spatial analysis using forest inventory data, the old forest policy layer, and other information layers. Other strategies for a chemical treatment program include 'early detection' to lessen demand on chemical products, selecting the most efficient chemical delivery systems, and forming operational treatment crews or 'strike teams'.

Three main landscape level approaches were recommended in Section 3.1 for preserving high value hemlock stands that showcase Nova Scotia's best forests for aesthetic and tourism value, as well as preserving a sample of genetic stock and inherent biodiversity values across the provincial landscape incorporating connectivity so that biocontrol predators can more easily disperse from one area to another and ultimately maintain long-term health of hemlocks in a self-sustaining manner in future.

1. Designate the best, high value hemlock forests to the hemlock conservation network, choosing from all land tenures, with priority on provincial protected areas (Nature Reserves, Wilderness areas, Parks), Private protected areas, Crown land forests that will not be harvested in future (incl. lands under Old Forest Policy), followed by private lands where gaps exist in the network. Stands require further prioritization according to HWA infestation level/stand decline, and other metrics such as old growth, rare species, and ecosystem services). Focus on protecting old growth hemlock stands in protected areas.
2. Riparian buffer program. Treating trees along streams for the two-fold benefit for both forest resources and aquatic health that is critical for trout and salmon populations as well as other aquatic components. The storm occurrence in February 22, 2022 in NS reminded many of us that over harvesting within watersheds coupled with heavy rainfalls associated with climate change can destroy roads, culverts, and bridges, and cause tremendous bank erosion as witnessed in the Kentville Ravine. Repair costs were significant and can be expected to be

even more acute when hemlocks die on the steep banks and forested corridors of rivers across NS.

3. Maintain hemlock refugia. Areas that have geographical features that enable hemlocks growing there to resist environmental stresses from climate change, HWA, and other disturbance agents. Hemlocks in refugia are most likely to persist, allowing this formerly widespread species to remain in small relict populations, preventing complete disappearance and enabling it to re-expand again at some later date if conditions improve. Land managers should identify likely areas or refuge for hemlock where they would be able to persist, despite climate change. Identify cooler, moist sites, such as riparian areas, north facing slopes, lake edges, and wetlands.

5.1 Early Detection

Early detection of HWA through regular and careful monitoring is key for effective management of HWA, because it facilitates an earlier treatment intervention using cheaper tools. In USA, early detection of HWA before tree health begins to decline allows for treatment using imidacloprid alone. It's not necessary to combine it with the more expensive, fast-acting dinotefuran because the trees are still healthy and can wait for the slower-acting imidacloprid to reach the canopy. Since financial resources are always limited, this early intervention frees up more of the budget to treat more hemlock. In Canada, we have only one imidacloprid product registered for use at present, and so it is even more paramount to treat trees early before advanced decline, and therefore early detection of an outbreak is integral to planning and treatment success.

When HWA is detected but chemical treatment is delayed, tree canopy health may rapidly decline and HWA continues to spread requiring even more trees to be treated, incurring more expense. In situations with advanced canopy decline, imidacloprid that is applied by itself without a faster-acting chemical may result in the discovery months later that the trees were unable to recover, and the expense of chemicals and labour were wasted.

Early detection in NS is particularly essential since HWA populations can expand at a faster rate than in many other parts of North America. HWA can rapidly over-whelm Nova Scotia hemlocks, particularly in the milder temperatures of southwestern and coastal areas of NS. Mild winters that rarely attains – 20 C or colder, coupled with climate change, will allow HWA populations to explode.

Assessing canopy health and the presence of new growth, particularly in the upper canopy, can be challenging. Sometimes the tree canopy appears to be healthy, dense, with dark green foliage, but trees do not respond to treatment because, despite appearances, no new growth was present. The take home message in all cases is that *early detection* of HWA followed by early treatment prior to canopy decline is the best measure to ensure treatment success and that healthy, robust trees remain on the landscape that are ready to receive biocontrols.

Key steps in executing early detection programs include:

- Coordinate training and outreach sessions on early HWA detection. Organize late winter/early spring early detection surveys to take advantage of winter branch drop and high

visibility life stages of HWA in stands across NS. (*This is a good task for the Coordinator staff position.*)

- Create an 'Early Detection HWA team' of citizen scientists/volunteers that reports findings to an HWA early detection program. CFIA maintains a database on early detections so this can be coordinated between CFIA and the Province.
- Purchase some tools to enhance effectiveness of early HWA detection. The same tools can also be used for monitoring and follow-up in post-treated stands (searching for low amounts of HWA). HWA is a tiny, cryptic species, so the following tools greatly aid detection:
 - Hand lenses
 - Powerful 2000+ lumen headlamp with focusable beam more easily and rapidly detects the waxy residues of HWA.
- A priority staff position: A **Hemlock Conservation Extension-Outreach Coordinator** is required to organize volunteers, training, communications, website, social media, treatment training videos and advice to landowners and managers. The coordinator could also organize volunteers who want to participate in training and Strike Teams.

5.2 Chemical Application Methods and Delivery Systems

A variety of application and delivery systems are expected to be used for a comprehensive chemical treatment program for HWA in Nova Scotia. It's difficult to predict which methods and tools will be preferred without knowledge of which chemicals may be authorized for use pending requests to the PMRA, followed by decision outcomes.

Nova Scotia will likely begin its comprehensive chemical treatment program using mainly stem injection delivery systems since IMA-jet is the only chemical currently available. Injection methods are known to be slower than basal bark spray (estimated to be 3- 4 times slower depending on which injection system is used). Tree injection is employed next to aquatic systems and also in trees on sandy soils in the USA where soil applications are not authorized. Stem injections may also be used more widely if TreeAzin is authorized for use as a fast-acting knock down chemical in hemlocks with advanced decline. Injection delivery systems must be chosen based on speed and safety to the environment and operator. It is likely that two or more delivery systems, reviewed in the next section, will be utilized to meet all situations.

Basal bark spray applications of Xytect 2F (and possibly Safari) may be available in fall 2022. Hybrid applications using a basal bark spray system that is supplemented with stem injections for trees within in buffers along river and lake edges would be carried out to achieve a full stand treatment. Stem injection applications may supplement treatments where basal bark applications are unable to complete a treatment due to possible annual area limits imposed.

As previously explained (Section 3.0), if Xytect 2F use is authorized, but with a restriction of 1.89 L of product per ha per year, treatment crews would be required to selectively treat the same stand for several successive years until the entire stand treatment was completed, likely taking longer than Nova Scotia tree decline rates could sustain without mortality or reaching a state where other faster-acting products would be required (which increases costs significantly). This will necessitate use of both a back tank sprayer and injection treatments in the same stand.

The back tank sprayer used in basal bark spray operations during research trials in NS was a Hudson SPO backpack sprayer. It can agitate/mix wettable powders and spray is pressurized with a handpump. The sprayer is fitted with a 14.5 - psi Constant Flow Valve (CFValve). The valve is set to a droplet size that helps control drift. The treatment dose delivered to the tree is carefully measured through flow calibration and then timing the treatment.

The majority of HWA treatments in USA use soil drench because it is deemed the cheapest, easiest and least complicated treatment method. Gear requires only a Nalgene bottle, measuring cup, chemical packets, and a water source. Soil drench involves the duff layer being brushed away in the immediate area where the soil drench is poured. The imidacloprid suspension is applied to the soil within ~45 cm around the tree trunk. Basal bark spray was described as an “easy alternative” to soil drench (Walston 2021 Pers Comm.). Both these methods can use Xytext 2F.

Most states use very little stem injection, except for Michigan and Maryland. The advice of Dr Whitmore is to “*take a pragmatic approach*” to chemical applications. He uses injection very minimally in favour of basal bark spray. Though it is unlikely that Nova Scotia government or PMRA would consider using basal bark spray next to water, it is useful to know that expert opinion of Dr Whitmore is that basal bark spray can be quite safely used on trees near streams, with minimal risk of chemical getting into water. A good pesticide operator is required to avoid overshoot of product into the water. This is backed by research on soil residues that concluded there was minimal transfer in soil from the tree base to water sources, with most residues found within 50 cm of the trunk and amounts dropping to minute levels beyond that distance.

Injection delivery systems

There are many injection tools available. Early tree injection devices have been manufactured by several companies and are varied in their ease of use, speed of chemical deployment, and potential degree of tissue damage incurred to trunk wood. These tools have been improving over the past 5-10 years to become less laborious with faster delivery mechanisms, particularly aided through using pressurized air systems. Some earlier devices used spring-loaded syringes or hand tools with plungers and some are single-use canisters (e.g., Chemjet™, QUICK-jet™, TreeTech™, and Smart-shot™ by Maujet). Utilizing an injection system that is reloadable rather than single-use factors into cost and environmental considerations. Some of these tools may be considered by the home or cottage owner who has only a few trees to inject.

‘EcoJect’ system by BioForest allowed very efficient tree injection procedures in research trials conducted by CFS and at Sporting Lake Nature Reserve. This system uses small, 8 ml pressurized injection canisters placed over a nozzle that is easily inserted into a drill hole. It was safe, rapid, easy to use, and able to accommodate a large crew of up to 15 people, while also being readily adaptable for use by smaller crew numbers. The only drawback was the relatively high costs of equipment purchase and the cost of refurbishing the canisters after they had been used for 30-50 cycles.(BioForest refurbishes the canisters at a cost of \$4.95/canister.) For speed and ease of injection, EcoJect remains a top choice for injection delivery systems.

Other devices involved pressurized tubing resembling a medical I.V. system, such as Q Connect by Rainbow Ecoscience and TREE I.V. by ArborJet. Q Connect was favoured for treatments by the Great Smoky Mountain treatment teams because it offered a very cheap and light to carry system. (See photo below.) A drawback is that these systems can deliver unequal treatment amounts to the injection ports in the tree.



Smart shot injector by Maujet.

'QuickJet Air' is a pressurized syringe system by ArborJet recommended when using their chemical, IMA-jet. Extra time and costs are required to hammer in a plug with a one-way valve to a precise depth, which ensures against product leakage from the tree. This injection system has been used extensively in NS tree injections. Plugs remain permanently in the tree and are eventually incorporated into the trunk tissue. Some people have not embraced the idea of leaving plugs in pristine old growth stands. Use of QuickJet Air is likely more suited for urban tree situations and for treating individual trees rather than entire stands, especially given the very slow injection procedures associated with it. When deployed for paired injection treatments with EcoJect during CFS-led research, the QuickJet Air was noted to be nearly half the efficiency of the EcoJect canister system.

A 'modified QuickJet Air' was devised by Drew Rayner, Forester with the Department of Natural Resources, Michigan State. His modifications greatly improved treatment times, efficiencies, and breakage issues, allowing it to surpass performance of many other injection systems investigated. The alterations also negated the need for plugs and migrated the system to a comfortable backpack operation that allows several hours of treatment. While the standard factory settings for QuickJet Air render it inefficient for extensive, full stand treatment programs, the modified QuickJet Air should be explored. Further information is contained in Rayner's interview, Appendix 1.



QuickJet Air syringe. Photo D. Crossland



Q Connect injection set up by Rainbow Ecoscience.



Modified QuickJet Air system by Rayner Photo Michigan DNR

- Recommendation: Examine potential use of a modified Quickjet Air injection tool, which has potential to provide very fast trunk injection.

Table 3: Comparisons between chemical application tools

	Ecoject	Quick-Jet Air	*Modified Quick-Jet Air	Q Connect	Back tank sprayer for Basal Bark
Application speed	Very fast 1.3 mins/tree canisters are left on trees to absorb chemical while applicator moves on	Slow 10-20 mins/tree. Plugs, wait sometimes ~ 1 minute + for absorption at each injection port	Fast A larger diameter drill allows faster uptake/no waiting time.	Moderate speed. 10 mins/tree	Very Fast 1-2 mins/tree. Time added to walk for water refills and mixing.
Gear cost (1 kit)	Expensive (13 k +)	3.5 k plus plugs @ \$ 1.00 each for each hole	2.7 k	2.5 k	Cheap (\$ 250.00 +) Continual flow back tank and spray wand
Chemical cost	Expensive	Expensive	Expensive	Expensive	Cheap
Maintenance cost	High - canister refurbishments @ 5.00 per canister after ~ 50 cycles	High -broken parts and field time lost. Plugs add to high cost @ \$ 1.00 each	Minor costs Plugless. Cheap, common parts to purchase.	Very minor costs	Very minor costs
Risk of gear failure	Low	High	Moderate	Low	Low
Treatment quality	Lasts ~ 4 yrs. Can unevenly distribute in canopy.	Lasts ~ 4 yrs. Can unevenly distribute in canopy.	Lasts ~ 4 yrs. Can unevenly distribute in canopy.	Lasts ~ 4 yrs. Can unevenly distribute in canopy	Lasts 5-7 yrs. Possibly more even distribution in canopy.
Limitations	None	Must use plugs with a plug setter tool.	None	None	Probable application limit 1.89 L/ha/yr. Weather-No-rain
Ease of use	easy	moderate	moderate	easy	Easy-Tank is heavy to wear
Maximum potential for volunteer use	High - easily adjusts from low numbers up to 15 volunteers	Low - Possibly 2 volunteers may be used	Low - Possibly 2 volunteers may be used	Low - Possibly 1 volunteer	Low 2-person team with 1 volunteer
Buffer	No buffer	No buffer	No buffer	No buffer	Buffer- 3 m or more TBA
Potential tree damage	Injection wounds- cause cracking/ infection	Injection wounds. High pressure can damage tree-bark separation. Improper plug placement	Injection wounds- cause cracking/ infection	Injection wounds- cause cracking/ infection	None

	Ecoject	Quick-Jet Air	*Modified Quick-Jet Air	Q Connect	Back tank sprayer for Basal Bark
PPE	Just gloves, safety glasses. Applicator can work comfortably.	Just gloves, safety glasses. Applicator can work comfortably.	Just gloves, safety glasses. Applicator can work comfortably.	Just gloves, safety glasses. Applicator can work comfortably.	Requires a rain suit or spray suit, gloves, glasses. Can be hot & uncomfortable
Human safety	Low. Possible canister breakage or leakage	Low Some exposure from back spray from highly pressurized chemical	Low	Low	Moderate Increased exposure from spray. Tripping hazard-walking/spraying around tree
Environmental risk exposure-spillage, back spray, leakage	Very Low	Low Back spray risk from high pressure at injection site Plugs left in tree.	Low Possible during pouring chemical at each tree.	Moderate Chemical exposure to measure/pour dose at each tree	Moderate Increased exposure due to mixing with water and spray.

* After manufacture alterations to improve efficiency, mainly using a larger diameter drill bit size and viper end, and modified lead in line.

5.3 Chemical Field Operation Approaches

Some sage advice on HWA chemical control was provided by various USA researchers and strike team leaders, shared here:

- The goal is generally aimed to be a “blanket level treatment”, for hemlock treatments in the US, despite annual product use limitations when using Xytect 2F or IMLcide. ‘Go big’ on the initial treatment round”, advises Walston Hemlock Restoration Initiative (HRI), North Carolina.
- If stand is old growth, treat every tree. In younger, pure hemlock stands that are less valuable (i.e., not in protected areas, or possibly a woodlot), treating every tree may be unnecessary due to root grafting based on observations by Cowles and McCarty (Whitmore Pers comms.). No one has done any research on root grafting effects yet to determine thresholds.
- Re-treatments may be more selective once the adelgid population is curtailed lowered.
- Plan well in advance for subsequent treatments.
- Re-treatments will likely be needed every 5 years (maybe sooner for IMA-jet injection treatments.)
- Treatment intervals will require evaluation in NS for injection and basal bark applications (if used)

Recommendations for Operational Approach

Adopt a Strike Team Model

The deployment of 'Strike Teams' is a highly successful USA model that has been widely adopted for treating and conserving hemlocks. First formed in 2014-15 in Tennessee, we can now draw from Strike Team expertise in Tennessee, Kentucky, Ohio, North Carolina, and Michigan. Other States such as Pennsylvania are planning to adopt them. Many Strike teams are run through NGOs, like the Hemlock Restoration Initiative (HRI). Other teams are State run with employee team members. Some teams have partnered with US Nature Conservancy, while others focus on private land requirements.

The Strike Team model is simple, flexible, and uses mobile crews. They operate within a similar discipline and structure to a fire crew, and they work a similar season, though hemlock treatments can go to freeze up in the fall, after the fire season has ended. Some Strike Team leads perform winter timber cruising and tree tagging to have sites ready to go for spring treatments. The overlap of skills and timing have caused Great Smoky Mountains National Park to examine the possibility of combining some fire crew members with hemlock treatment tasks in periods of low fire risk, though fire crews remain ready to respond to wildfire as their top priority.

Strike teams generally consist of a 4-member crew, with a crew lead that has forestry skills for mapping and tree-marking (particularly useful for basal bark applications where an even distribution of trees throughout the stand must be selected against annual per hectare limits). All members (at least in Tennessee) have pesticide operator certification. "*Time is not your friend*", stated Tennessee Strike Team Coordinator, Jacqueline Broeker (Appendix 1). Hence getting the boots on the ground quickly to treat trees is best addressed through Strike Teams.

Much more practical information regarding Strike Team operations, planning, and set-up is included in Appendix 1 and can be obtained by operators in the USA.

Recommendations for Implementing Strike Teams

- Forming several NS Hemlock Conservation Strike Teams would allow treatment dollars to have maximum impact. Each team would have a crew lead and at least one member. Both persons would be licensed pesticide operators. Other team members could be staff, students, or volunteers.
- Provide practical hands-on training on tree marking and treatments.
- Hire some Strike Team crew leads to work during winter to prepare sites/ measure and tag trees.
- Facilitate private landowner training and pesticide certification to treat trees to expand capacity/spread resources widely to meet the sudden, rapid need to address widespread hemlock infestations.

5.4 Safety of Chemical Treatments

Concerns over chemical treatments in hemlock forests impacting other living organisms have been addressed extensively through research in the USA and also in Nova Scotia where it is led by scientists at CFS and the graduate entomology research program at Acadia University. The environmental fate of imidacloprid applications is being analyzed from NS research trials in needle

litter, soil, and aquatic residues. Non-target effects wild pollinators and ground beetles are being investigated.

Imidacloprid has been proven to be a safe chemical to use, particularly as it targets only insects rather than acting on a broad spectrum of living things as older groups of chemicals are known to do. Applications to hemlock trees are not expected to impact other animal species other than insects. It acts as a targeted insect neurotoxin through binding more strongly to insect neuron receptors than to vertebrate neuron receptors. This results in much higher sensitivity in insects than in vertebrates (e.g., birds and mammals, such as humans and pets).

When a hemlock stand is treated with imidacloprid, it might be assumed that the chemical will be broadly encountered throughout the forest and many living organisms may be exposed to it. Research has shown this is not the case when using systemic applications. Only the first 50 cm around the base of the treated tree, roughly 2 % of the forest floor of a treated hemlock stand, contains any concentrations of imidacloprid that may harm insects. The reach of chemicals to nontarget organisms is quite limited and transient.

Concerns have been expressed about impacts to insect-eating birds that forage in hemlock canopies. What has been observed is that hemlock-associated bird communities decline when their foraging habitat is lost with hemlock mortality (Becker *et al.* 2008; Toenies *et al.* 2018). In the larger picture, continued chemical treatment for HWA was concluded to be important for maintaining suitable habitat for hemlock bird associates (Brown and Weinkam 2014).



Many dog and cat owners use imidacloprid to protect against fleas and ticks.

Many citizens are already using imidacloprid products on cats and dogs. This chemical is commonly used for flea, tick, and lice treatments due to its low toxicity to mammals. These pet products can contain higher concentrations of imidacloprid than what is applied to hemlock. For e.g., Advantage 55™ and K9 Advantix II™ contain 9.1 % and 8.8 % imidacloprid respectively, applied topically once a month. In comparison IMA-jet contains 5 % imidacloprid applied every 4 years or longer.

A review of literature on imidacloprid can reveal many facts that may or may not be relevant to its specific use pattern for treating hemlocks in NS. Much of the available research is focused on soil drench and soil injection methods that will not be used here and that incur more environmental exposure than tree injections and basal bark applications. Imidacloprid use and research in agricultural settings is generally under very different circumstances with much more environmental exposure than systemic applications

for hemlock, so drawing of direct conclusions can lead to misinterpretations of risk.

Non-Target Effects

The following are some of the key points regarding nontarget impacts from chemical treatments that were reviewed and summarized by Dr Jon Sweeney, CFS, Fredericton, NB:

Terrestrial impacts

- Imidacloprid is not carcinogenic, based on studies in rats and mice.
- When used according to label hemlock forests can be protected without negative effects on water quality or aquatic insect fauna (McCarty and Adesso 2019).
- Imidacloprid concentrations at greater than 50 cm radius from a treated tree base dropped to < 0.02 mg/kg in soil in samples, indicating a very small part of the forest is exposed during systemic treatment of hemlocks.
- In tree canopy, no differences were found in arthropod abundance, species richness or community composition between imidacloprid-treated vs untreated trees 3 years after treatment. Furthermore, 9 years after treatment, there were significantly more arthropod species in the treated trees than in the untreated trees (Kung et al. 2015).
- Bird populations e.g., black-throated green warblers, black-throated blue warblers or blue-headed vireo were not affected when hemlocks were treated with soil drench, though population densities of foliage-feeding moth larvae and Hemiptera (true bugs) were reduced in the first-year post-application (Falcone and DeWald 2010).
- There may be a temporary impact to springtails (collembola), as some research has found that abundance and diversity was lower in the immediate area of imidacloprid treated trees (Reynolds 2008). However, other research found no difference in abundance of springtails, mites or total micro-arthropods in soil around treated vs. untreated trees (Knoepp et al. 2012).
- There are negative short term (1-3 years) effects on certain groups of terrestrial arthropods (e.g., some species of Lepidoptera that feed on hemlock foliage, but over the longer term, these groups fared better in treated stands because most of the hemlock died in the untreated control stands.
- Hemlocks are wind-pollinated and hemlock pollen is not likely to be collected by insect pollinators.
- Exposure of pollinators would be limited to flowering plants growing within 50-100 cm of treated trees, because imidacloprid concentrations in the soil diminish significantly with distance from application
- Breathing fumes or smoke from treated hemlock is not likely to increase health risk compared to breathing smoke from untreated hemlocks. Concentrations of imidacloprid and its breakdown products in smoke from burning hemlock would be lower still than the already very low concentrations of imidacloprid found in the tissues of imidacloprid-treated hemlocks (Benton et al. 2016a).

Aquatic impacts

- Insects and other stream invertebrates are very sensitive to imidacloprid, more so than most terrestrial insects, including bees (McCarty 2020).
- In jurisdictions in the US where they use a buffer of only 3 m from streams for imidacloprid soil drenches and soil injections, they have found no significant effects on aquatic invertebrates downstream from treated stands.
- Benton *et al.* (2017) found no difference in aquatic macroinvertebrate (Ephemeroptera, Plecoptera, Trichoptera) diversity and abundance measured upstream and downstream of hemlock stands that had been treated with imidacloprid soil drench (3 m buffer from streams, treated areas 14 to 42 ha, 1.8 to 112 kg applied, limit of 0.45 kg/ha/yr, 1 to 8 years before sampling) in nine different streams in the Great Smoky Mountains.
- In aquatic environment, imidacloprid photodegrades in water with a half-life of 1 hour to 3 days (Moza *et al.* 1998).

- Except in the extreme cases, environmental concentrations are 2 to 7 orders of magnitude lower than LC50 measurements for fish and amphibians, so it is unlikely that the mortality rates of these taxa will be directly affected by imidacloprid under normal exposure (Gibbons *et al.* 2015).
- Research on streams flowing through treated (soil injection) and untreated hemlock stands in the southern Appalachians found no significant effects on abundance or species richness of aquatic invertebrates (Churchel *et al.* 2011)

5.5 Chemical Approvals and Coordination

Legislation

Pesticide products and application methods of the nature proposed in this report to treat hemlocks are tightly administered for approval and safe use in Canada. All pesticide usage is restricted to products that have been approved by the Health Canada *Pesticide Management Regulatory Agency* (PMRA) and are classed under the *Pest Control Products Act*.

Pesticides approved to treat hemlocks in NS must be *Canadian* registered pesticides. There are many more pesticide products used in USA for HWA control, but they are not approved by Health Canada and the PMRA to use here. As previously stated in preceding sections, IMA-jet is the only effective regulated product presently authorized for HWA infestations in hemlock.

Nova Scotia pesticide use falls under the authority of the Environment Act, the *Activity Designation Regulations*, and the *Pesticide Regulations*. Furthermore, applications must strictly adhere to all instructions on the Pesticide Label that accompanies each product. “The Label is the Law.”

Provincial regulations and a Strike Team Model

Pursuant to the *Environment Act and Pesticide Regulations*, all applicators and/or mixers must hold a ‘Pesticide Certificate of Qualification’, Class III (A) Forestry, which authorizes the holder to use a pesticide by ground application methods that include site preparation, insect control, disease control and vertebrate control in a forest management operation.

The requirement to hold a Pesticide certificate is stated under Section 6 (1) of the Pesticide Regulations:

“No person shall apply a commercial class or restricted class pesticide unless that person holds a valid certificate of qualification” (i.e., Pesticide Certification Card), which is valid for 5 years.”

Where volunteers or other personnel assist with applying pesticides to hemlocks, they can do so under close supervision of a certified pesticide operator. Section 9 (1) of the Pesticide Regulations states that:

“A private applicator who is a certified applicator in Class III or VIII may directly supervise a non-certified applicator where [] the non-certified applicator performs the same use as authorized in the certificate of qualification held by the certified applicator”.

All applicators must also be at least 18 years of age. Transportation, handling, disposal, and storage are all carried out according to the Pesticide Regulations.

Obligations to use Chemical Manufacturer Applicator Systems

There has been some confusion in thinking that a product purchased from a manufacturer for systemic tree injection obliges the applicator to use the equipment sold by the manufacturer to apply the product. This is not the case. The purchase of an injectable product manufactured by a company (e.g., purchase of IMA-jet manufactured by Arborjet) does not oblige using that company's injection equipment. The Label provides the legal guidance and stipulates only the dosage and proper application to ensure the product is conducted inside the sapwood. The system utilized to achieve this outcome may be selected from a variety of manufacturers. The key is to ensure safe and effective treatment according to the Label and all provincial regulations. No special approvals are required.

Streamlining Approvals

The provincial compliance division has reviewed the *Activities Designation Regulations* with regards to hemlock treatments involving systemic use and concluded that an approval of pesticide use for conservation purposes in forestry is not required. Typically, the application of commercial or restricted pesticides to trees in a forested situation requires an approval, under the *Activities Designation Regulations*. But this pertains to forestry operations for cultivation/harvest production. This step in the regulatory process is omitted where forest conservation remains the objective. The challenge is proving to the provincial compliance division that the activity is not for cultivation or harvest.

The question is how to stream-line the approval process or pre-authorize pesticide use for hemlock conservation purposes so that each operation, regardless of land tenure, that conserves hemlock is enabled to proceed without waiting for approval or the submission of more forms/jumping through unnecessary hoops. Avoiding this unnecessary step to approve hemlock treatments would streamline the process for both government and the landowners.

Much of this administrative process has originated from public concerns over spraying pesticides in forested environments to kill spruce budworm, hardwood competition, etc. Systemic hemlock treatments are highly dissimilar, with a very different objective to conserve and protect biodiversity against a non-native pest and used in small amounts inside the tree which avoids many issues with nontarget impacts. Case in point, are members of the "Don't spray us" group who protested glyphosate spraying in fall 2021, joined the Sporting Lake crew to help administer chemical injections for old growth hemlock. Members of the public have noted the difference in treatment objectives, so it may be appropriate and timely to reflect this difference in administrative process.

Contract Pesticide Operators

A class IX business operator certificate is required for a person who is entering contracts to treat hemlocks on property they do not own (ref S.7(1)(l) and S.2(g) and (u) of Pesticide Regulations).

Approval under S. 2(a) of the *Activities Designation Regulations* would also still come into play unless the hemlocks are *not* intended for forestry production/products as defined in the *Activities Designation Regulations*:

“S. 6(a) “forested land” includes, but is not limited to, land used for the production of pulp, sawlogs, lumber or firewood, but does not include land used to grow Christmas trees”.

If the hemlocks are intended for forest production, an Approval will be required.

Buffer zones

Buffer zone widths can be established by the PMRA and indicated on product label directions, and also through provincial requirements of ECC. It is highly probable that buffers will be prescribed for Xytect 2F and Safari if approved for use in NS. Various chemicals and treatment applications require buffers to be set at varying widths depending on the chemical properties, the treatment method, and environmental risks. A range of buffer widths are prescribed in the USA, depending on the State.

Injection applications for IMA-jet presently require no buffers except for mixing, filling, or cleaning preparations which require a buffer of 30 m from all aquatic systems. This kind of systemic application method is completely contained and safe to inject adjacent to water.

Regulatory Process for Obtaining Chemical Products

Products proposed for use in this report, such as Xytect 2F and TreeAzin are not yet approved in Canada for HWA control in hemlocks. They will be reviewed by the PMRA under an Emergency Use Request and may be approved sometime in fall 2022. They have already been researched and field tested in NS. However, the process of attaining new products in Canada can be very lengthy, possibly taking months to a year or more to complete.

The urgency created with severe hemlock decline from HWA in southwest NS has caused scientists and government land managers to investigate emergency use registrations for both TreeAzin as well as Safari, each are fast-acting chemicals that are critical for advanced hemlock decline situations in different environments. A key hurdle with Safari is to have the manufacturer agree to participate in this new use pattern.

An alternative strategy for utilizing chemical products that are not yet approved is to submit a **research application** (which generally requires about 3 months). There are often additional questions around threshold uses and impacts of products that could benefit from additional research. A drawback of this approach is that there would presumably be limits to applying the chemical extensively across hemlock forests for operational control purposes.

Recommendations:

- Omit the provincial administrative review and approval process for systemic chemical applications for hemlock *conservation* under the Activities Designation for all land tenures.
- Consider the adoption of a ‘Restricted Use Pesticide Certification’ suited for narrow use of pesticide treatments and chemical purchase for tree *conservation*. This would possibly require an amendment to the *Activities Designation regulations*.
- Produce a separate manual with tailored training and an exam that is more specific to *systemic* pesticide applications required for tree conservation. This may be considered appropriate given the current ecological emergency and need for pesticide operators to treat high numbers of hemlock. The current pesticide certification training does not cover

systemic pesticide treatments, material pertinent for tree injection and basal bark methods required for conserving trees. Some changes should be examined to address challenges experienced by a high number of people who have taken the Core and Forestry exams for Pesticide Operator certification and found the process unreasonably challenging. It requires a pass mark set at 75 % and failure is common, despite otherwise keen and *competent* adults whose desire was to become a pesticide operator.

- A Restricted Use order could be placed on products such as Safari and Xytect 2F to restrict purchase of pesticide products to only those who are certified to conduct systemic tree applications.
- Devise a “Standard Operating Procedure” (SOP) for directing strike teams and volunteers, outlining adherence to regulations and safe practices.
- Authorize or facilitate points courses for maintaining pesticide certificates that are specific to systemic pesticide applications on hemlock and ash trees.

5.6 Chemical Treatment Costs & Application Scenarios

Chemical treatment costs were developed for a variety of application scenarios (Table 4). A range of chemicals, application equipment and staffing/volunteer deployments were assessed using data from a variety of sources, including NRR’s Cost & Productivity Analysis, CFS cost comparison, chemical and equipment manufacturer quotes, and interviews with practitioners. Assumptions used for each scenario are described in the table. Each scenario is described below, including some considerations relative to the development of a provincial chemical control program.

Scenario A: Xytect 2F (Xytect) *with* application limits, basal bark treatment deployed by 3-person, seasonal paid staff. (Application limits assumed to be 1.89L/ha/yr in line with annual application limits in the US.) This approach is recognized as one of the most cost-effective application approach in terms of chemical costs, productivity, equipment, and staff requirements. Xytect 2F is not yet approved for use in Canada, and it is unclear if application limits will be placed on the use of the product. If the limits are included in the potential approval, one drawback of this scenario is the need to return to the site to complete the treatment over multiple years. A limit of 1,629cm/yr could require 3-7 years to complete the required re-entries to achieve full stand protection. This would lead to increased travel costs, which were excluded from this analysis. In the USA Xytect 2F product label does not restrict use near water, stating only to “not apply directly to water”. Buffers are entirely voluntary and are applied in some states. In Canada, we envision a buffer restriction on the Canadian label, which would cause it to be used in combination with stem injection of IMA-jet to protect important riparian zones and to complete a full stand treatment in a single year. This scenario will be of limited use in the southwest, where some trees and/or stands have become so heavily infested that there is not enough time required to complete enough entries for full stand protection under an application limit scenario. Xytect is less applicable to volunteer engagement due to the difficulty of using the backpack application tank, however volunteers could be engaged to help with tree marking, measuring and application timing.

Scenario B: Xytect 2F *without* application limits, basal bark treatment deployed by 3-person, seasonal paid staff. Productivity (ha/day) is the most efficient, but the number of treated ha is lower than in Scenario B because crews are allowed to treat the entire stand without any application limits. If Xytect is approved without application limits this would allow for full stand

protection without additional travel costs associated with 4-7 years of stand re-entries to complete full stand protection. It would still likely require use in combination with IMA-jet to address riparian zone treatment. Xytect is less applicable to volunteer engagement due to some additional challenges and skills of using the backpack application tank, however volunteers could be engaged to help with tree marking, measuring and application timing.

Scenario C: Integrated Xytect 2F & IMA-Jet approach (with Xytect application limit). This scenario generally requires multiple years to complete assuming Xytect application limits of 1.89 L/ha/yr. This approach was taken from an analysis completed by NRR staff and assumes that Xytect would be applied on 95% of treated stands with IMA-jet applied in riparian zones, estimated at 5% of treated area. The results were very cost competitive. Similar to Scenario A, there would be increased travel costs and limited applicability in the heavily infested stands of the southwestern region due to application limits. Xytect is less applicable to volunteer engagement using the back tank application method, however volunteers could be engaged to help with tree marking, measuring and application timing. Volunteers could also be engaged in IMA-jet applications to help reduce labour costs and increase productivity of IMA-jet treatments.

Scenario D: Arborist treatment of IMA-jet applied with EcoJect system. This scenario represents the only commercial HWA treatment service currently offered in NS. The higher costs associated with this scenario relative to other IMA-jet/EcoJect scenarios are due to increased labour costs, however the costs associated with this scenario are potentially more comprehensive because the quoted price offered to landowners includes maintenance, travel and overhead in addition to chemical and labour costs. This scenario was included to illustrate the challenges of supporting private land hemlock conservation through a cost-sharing approach that relies on private operators to complete the work. Evidence from the US suggests that this is the least efficient use of public funds for supporting private land HWA treatments.

Scenario E: Two-person, seasonal paid staff crew injecting IMA-jet with EcoJect system. This scenario used similar equipment set up and productivity assumptions as Scenario D but was considerably more cost effective due to reduced labour relative to private arborist rates. Note that travel, maintenance, and overhead were not included. While this approach was more cost competitive than Scenario D, it does not capitalize on the cost reductions and productivity increases made possible by implementing volunteer labour when using the EcoJect system.

Scenario F: Staff-led volunteer crew injecting IMA-jet with EcoJect system. This scenario was modelled after the Sporting Lake project. Using the same staff and labour costs associated with Scenario E, productivity increased four-fold while treatment costs are reduced by 30% through the implementation of volunteers. The EcoJect system is simple to use and lends itself well to volunteer engagement and offers a compelling model for mobilizing quickly to address the backlog of stands to treat in the southwestern region.

Scenario G: Four-person staffed crew injecting IMA-jet using Quick Jet Air system. The Quick Jet Air system manufactured by Arborjet is currently in use at Kejimikujik National Park. The slow injection times of the system lead to low productivity and high labour costs, making this the least cost competitive option available.

Scenarios H & I: Modified Quick Jet Air for trunk injection (details in Appendix 1 in interview with D. Rayner, Michigan State). Scenarios H & I were designed to integrate this approach using two staff (H) and one staff with one volunteer (I). When integrating volunteer help, this system represents the most cost competitive stem injection option analyzed. One potential drawback of

integrating volunteers is the reduced treatment days that can reasonably be achieved annually relative to staffed crews (volunteers were assumed to only be available on weekends during the treatment season). In Michigan this trunk injection approach is used in combination with Xytect 2F basal bark spray to achieve full stand protection in just one site visit; smaller trees unsuitable for injections receive basal bark spray up to the application limits and the remaining trees are injected using the modified Quick Jet Air system.

Scenarios J & K: Injection of TreeAzin using EcoJect system for highly infested stands for fast knock down, treating 10 % (J) and 25 % (K) of stands. These scenarios were developed to model the limited inclusion of TreeAzin to protect heavily infested and declining trees that would not survive with slower-acting imidacloprid-based products alone. In this scenario, TreeAzin would be injected with EcoJect system under a volunteer mobilization scenario to address the advanced state of decline of some stands in the southwestern region. The remainder of the stand could be treated with imidacloprid products if remaining trees are not too far in decline, but this decision is excluded from these scenarios. The high cost of TreeAzin significantly increases treatment costs, even when only applied to a limited number of the most infested trees.

Scenario L: Basal bark treatment using Safari and Xytect 2F in stands with advanced decline away from water buffers. This scenario is not fully developed to include in Table 4 due to uncertainty that Safari will be authorized for use in Canada.

Conclusions:

- Xytect 2F applications using basal bark spray is the most cost-effective chemical control option, with lowest treatment and equipment costs and the highest productivity. However, it would be of limited use in some highly infested stands in the southwest due to potential application limits and the time delay associated with imidacloprid HWA control. It would likely have restrictions placed on it for use next to water, thus requiring trunk injection products within riparian areas.
- Volunteers can help reduce labour costs across multiple scenarios and increase productivity with EcoJect systems but are limited in terms of time required to organize volunteers, how many treatment days can be achieved during the treatment season due to limits on volunteer availability relative to staffed crews.
- The modified Quick Jet Air applicator deployed in Michigan is worthy of testing in Nova Scotia. This approach allows for full treatment of stands in one year at the most competitive cost for stem injections using staffed crews.
- Waiting too long to treat stands results in significant cost increases when TreeAzin is required to protect heavily infested stands. When considering even the most cost competitive treatment scenarios, treating 10% of the trees in a hectare increases costs by 83% and treating 25% of the trees in a hectare increases costs by over 200%.

Table 4: Chemical costs and application scenarios.

Chemical & Application Equipment Scenarios		Single Crew Treatment Cost & Productivity Data				Resources Required for Scaling to 2,000 ha/yr				
		\$/Ha	Ha/day	Ha/year	Gear Cost	Treatment Cost	Crews	Staff	Volunteers	Equipment Cost
A	Xytext - 1.89L/ha/yr*	\$ 260.00	5.0	390	\$ 250.00	\$ 520,000.00	5	15	n/a	\$ 1,282.05
B	Xytext - No limits	\$ 1,300.00	1.0	78	\$ 250.00	\$ 2,600,000.00	26	77	n/a	\$ 6,410.26
C	Combined Xytext (1.89L/ha/yr) + Ima-Jet via EcoJect (Riparian Areas)	\$ 2,000.28	0.45 ha (EcoJect) 5.0 ha (Xytext)*	17.6 ha/yr (EcoJect) 390 ha/yr (Xytext)*	\$ 5,266.28	\$ 4,000,560.00	3 x 3 (Ima-Jet) + 5 x 3 (Xytext)	24	n/a	\$ 16,298.84
D	ImaJet - EcoJect (Arborist)	\$ 9,000.00	0.28	33	\$ 5,016.28	\$ 18,000,000.00	61	122	n/a	\$ 306,244.20
E	ImaJet - EcoJect (Seasonal Staff)	\$ 4,590.00	0.28	33	\$ 5,016.28	\$ 9,180,000.00	61	122	n/a	\$ 306,244.20
F	ImaJet - EcoJect (Volunteer)	\$ 3,240.00	1.1	57	\$ 19,768.89	\$ 6,480,000.00	35	70	210	\$ 691,219.97
G	ImaJet - QuickJet Air (Seasonal Staff)	\$ 12,420.00	0.1	12	\$ 2,500.00	\$ 24,840,000.00	171	342	n/a	\$ 427,350.43
H	ImaJet - Modified QuickJet Air (Seasonal Staff)	\$ 3,510.00	0.72	84	\$ 3,100.00	\$ 7,020,000.00	24	47	n/a	\$ 73,599.24
I	ImaJet - Modified QuickJet Air (Volunteer Supported)	\$ 3,150.00	0.72	37	\$ 3,100.00	\$ 6,300,000.00	53	107	53	\$ 165,598.29
J	TreeAzin - EcoJect (10%)	\$ 1,663.20	11.1	577	\$ 3,570.00	n/a	n/a	n/a	n/a	n/a
K	TreeAzin - EcoJect (25%)	\$ 4,158.00	4.4	229	\$ 3,570.00	n/a	n/a	n/a	n/a	n/a

Assumptions

9,000 cm DBH/ha average

117 total treatment days/year (paid staff crews)

78 Xytect staff treatment days & 39 Ima-Jet staff treatment days (Scenario C)

52 treatment days/year (volunteer scenarios)

Xytect Product Cost = \$66/L

Ima-Jet Product Cost = \$198/L

TreeAzin Product Cost = \$600/L

Staff costs @ \$30/hour (seasonal government staff rate, not applicable to Scenario B)

No travel costs or equipment maintenance costs were included

Crew size for each scenario was normalized at two, except for Sporting Lake example

Treatment cost/ha includes chemical cost and labour cost

* Xytect application limits require 5 years to fully treat an average stand

Equipment Costs vary by system, based on manufacturer quotes

TreeAzin equipment cost was for cannisters and assumes use of existing EcoJect system

5.7 Integrated Pest Management

Biological Control

Implementing a biological control program in NS to address the HWA crisis is a critical step in addressing the long-term approach to resolving the threat of hemlock loss. The entire chemical control strategy hinges on the eventual support from biological control. The objective is that biocontrol populations expand in numbers, consuming HWA to become omnipresent in hemlock forests, so one day HWA will live in balance with eastern hemlock and chemicals will not be required.

Canadian and USA entomologists researching HWA biocontrols believe we can have an effective predator program in place within approximately 10 years. Devising a biocontrol program generally requires many more years to meet all the stringent testing and steps required to ensure environmental safety, but in this case, the predators that are demonstrating effective HWA control can be obtained from Canada and have already been released over several years in the eastern USA.

The less positive aspect is that it can take years for biocontrol predator populations to build up after release, so they effectively control HWA. Starting a biocontrol program in NS as soon as possible is critical.

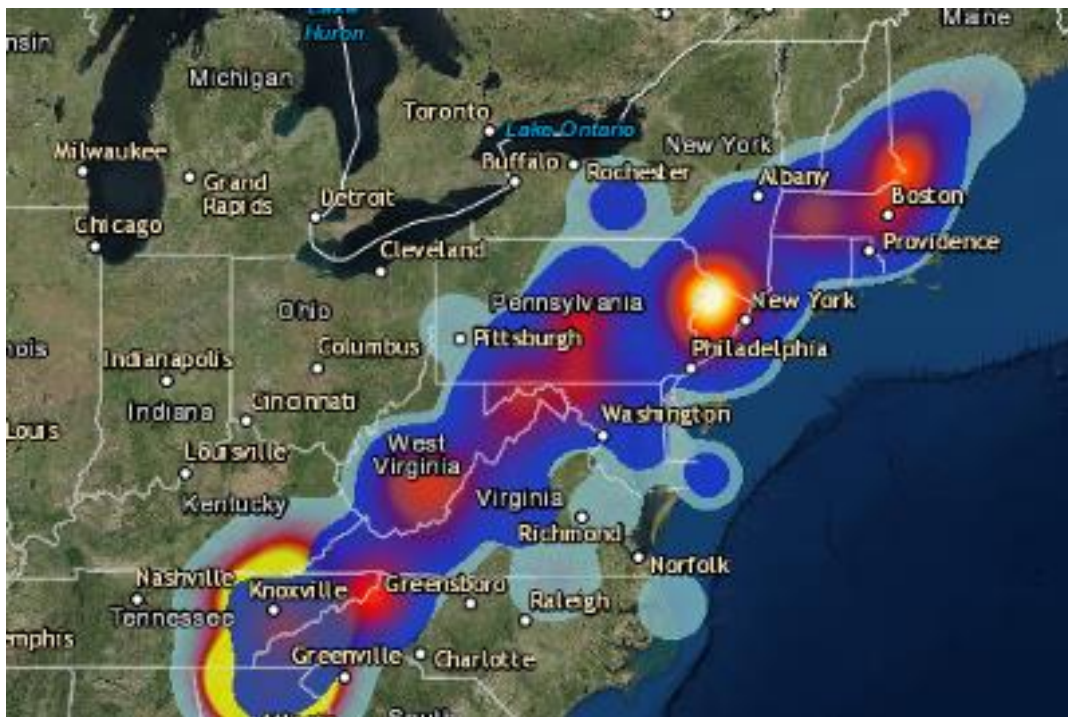


Figure 9. HWA predator distribution map maintained through Virginia Tech provides up-to-date distribution of HWA predators and their established populations (HWA Predator Database 2022).

While the Canadian Forest Service has been working in NS since the early discovery of HWA, they mainly provide scientific expertise in the biology of HWA and conduct chemical and biological control research. A biocontrol program requires provincial funding and support. Other Federal

input may be generated if a partnership support is established at the Kentville Research Station, Department of Agriculture, that is located next to one of the most coveted old growth hemlock stands in the province, the Kentville Ravine. This requires further exploration for its role in integrated HWA management. The proximity of entomologists at Acadia University may also assist with a biocontrol program.

University facilities may provide additional support through laboratory facilities. Another potential alliance may be fostered at Dalhousie Agricultural facilities in Truro and Victoria Park. However, HWA has not yet arrived there, so developing this location for a biocontrol program may incur unnecessary risk.

It is important to recognize the launch of a chemical treatment program is in anticipation of a larger biocontrol program that will soon be the dominant form of controlling HWA across NS. There are several examples from the US that can be drawn from when developing an integrated pest management approach.

- Some of the best guidance for how IPM may rollout once predators are available for release is outlined by Mayfield et al. (2020), available [on-line](#).

5.8 Database for Chemical Treatments and Biocontrol

Experts recommend setting up a central database as early as possible that contains geo-referenced information on chemical treatments and biocontrol information, predator releases, tracking predator dispersal, etc.

In creating the database it will be helpful to:

- Consult with Dr Mausel (whose budget funds the current predator database at Virginia Tech) to avoid repetition of the same database mistakes made in USA and to explore whether Canadian provinces might best join their current database platform. Their current “HWA Predator Database” is user-friendly, and nearly all-encompassing: <http://hiro.ento.vt.edu/pdb/index.php/home/>
- The database should also accommodate private land treatment information where possible. This is useful for biocontrol releases (i.e., creating the landscape patchwork).
- The treatment database can show the perimeter around treated areas (polygons), rather than individual tree waypoints. Information contained in the polygon approach might include: DBH, # trees treated, soil type, year treated, individual reporting etc.
- As well a database design/setup was shared for NS implementation by Pennsylvania practitioners (shared on the common drive).

6. Outreach and Engagement

6.1 Landowner Values

MCFC hosted a public engagement session on March 3rd, 2022 via Zoom for public engagement of HWA impact and management on privately stewarded lands in Nova Scotia. Donna Crossland and Matt Miller on behalf of the MCFC presented information on hemlock ecological significance

within a Nova Scotian context, details on hemlock woolly adelgid (HWA) and its impact, a summation of ongoing research, the treatment options that are available in NS, and other methods used elsewhere in regions impacted by HWA.

The session was promoted on social media targeting local cottage and lake groups, woodlot owners, and environmental groups (forest ecology, naturalists, trail associations, etc.) and circulated via email to regional municipalities and councilors and by partner organizations directed at 'Nova Scotians who consider hemlock a part of their life, whether it's around a home, a cottage, on a woodlot, or part of an ecotourism business.' After the session [the recording](#) was posted on MCFC's YouTube page. A follow-up survey with participants and the wider public after viewing the public presentation asked them, as stewards of lands, cottage, and homeowners in Nova Scotia with hemlock trees, to provide some additional opinions.

During the public session 183 people registered, 147 people joined the virtual meeting, and the session ran for an hour and twenty minutes. There was ongoing engagement in the chat function and through voting in six polling questions posed by the hosts.

During the public engagement session:

- 147 participants tuned in
- The chat was active with many questions asked & answered throughout
- 6 poll questions were asked by MCFC with >90% response rate

Public Session Poll Questions

1. What best describes your forested property?
2. What do your hemlocks mean to you?
3. How familiar are you with HWA?
4. Which statement best describes your concerns regarding the pest?
5. Which of the following HWA treatment options are you familiar with?
6. How do you feel about investing money and time into preserving hemlock using chemical treatments (ie. insecticides)?

Summary Notes from Polling Questions:

- Half the respondents chose old growth ecology as their highest hemlock value, wildlife habitat came next with 18%,
- For 9% of participants, this session was their first engagement with HWA information, all others were aware of HWA and accessing information resources,
- 75% of participants were interested in chemical treatments but had concern for the associated costs,
- 8% of participants were not interested in chemical treatment,
- 5% of participants were not worried about HWA impacts, 53% were worried and uncertain of what they can do to prevent hemlock loss, and
- 42% of participants were worried about HWA impacts and were prepared to protect their hemlocks.

Follow-up Survey Responses

After the presentation and poll questions, a follow-up survey of 15 questions was widely circulated through the registration list, social media and partner organizations (See full responses in Appendix 2).

- 109 people completed the follow-up survey
- 47.1% of respondents have a woodlot greater than 25 acres
- 41.5% of respondents have cottage or residential properties
- Less than 15% of respondents were new to learning about HWA
- 9.2% of respondents would choose not to treat their hemlock in any way
- 64.2% of respondents would treat their hemlock with a combination of chemical and biocontrol
- Cost of treatment was the largest barrier for people, though 15% of people faced no barriers and were prepared to treat.

The survey indicated that most (>85%) respondents are seeking treatment options, but they face financial barriers or are uncertain of costs for a long-term treatment plan. They are willing to commit to long-term conservation of their hemlocks. Much of the participant follow-up inquiries regard costs, site assessments for treatment consultation, and inquiring about who can begin their treatments today.

There was interest in having an alert system to notify people as the pest infestation spreads into new regions, and as well as for a list of certified pesticide operators in Nova Scotia or operators who are treating HWA.

The public response that was received pointed to a need for continued public engagement with an urgent need to receive more information specifically on treatments and how to access them.

Recommendations based on Survey Responses

1. Establish communications with potential hemlock stewards through existing woodlot service providers, cottage groups, municipalities, social media platforms, and through direct marketing.
 - a. Maintain a contact list of potential private hemlock stewards building off of the respondents who participated in this public session.
2. Keep information in one concise website that includes the following:
 - a. Tracking the infestation: set up an alert system by county that provides people with updates
 - b. A section with answers to frequently asked question (FAQ); and a box for other questions
 - c. Report a HWA detection (to be discussed with CFIA for streamlining)
 - d. Posting ongoing treatment research, outcomes, and recommendations
 - e. Contact information for treatment crews by region (or Provincial Coordinator contact information)
 - f. Financial incentives program for hemlock treatments
 - g. How to get involved: volunteer options, events and training sessions.

3. Provide a financial cost-sharing program to support the chemical treatment of hemlock and to make it accessible for people
 - b. Establish a program which subsidizes treatment and protects hemlock trees from harvest for long-term conservation.
4. Public engagement:
 - h. Host public engagement sessions for chemical treatment application on-site during pesticide application.
 - i. Create an accessible 'HWA in Nova Scotia Research Synthesis' info pack, making the research 'public friendly' (i.e., using common language and focusing on the broad 'take-away' conclusions) - to be shared on the platform suggested in point 2.
 - j. Create a tool outlining the costs of losing Eastern hemlock - cumulating the ecosystem implications, environmental services lost (soil stability along riparian zones, increased flooding, increased road and bridge reconstruction, etc.), property value decline, carbon loss and impacts to climate, etc.

6.2 Interviews with US & Nova Scotian Land Stewards

In addition to the surveys circulated to private landowners, interviews were conducted with large landowners, key partners, and stakeholders. These conversations proved invaluable to understanding support for chemical control, and overall fears regarding the loss of hemlock.

Key messages from United States interviews regarding private land treatments:

- The investigation into HWA programs aimed at private land stewards in the United States did not uncover any unique approaches to funding or incentivizing HWA treatments for private woodlands beyond direct government grants. However, there were differences in the structures and programs used to administer this funding that provide insights for Nova Scotia.
- Funds supported a range of programs, including cost sharing, training, demonstrations and equipment rentals, and state funded "Strike Teams" that completed treatments on behalf of landowners.

Key messages from Nova Scotia interviews with private forest stewards:

- Private woodland stewards are ready and willing to treat hemlock trees but there is currently a lack of leadership, capacity and support for land stewards who are ready to pursue chemical treatment. For example, there is currently only one private pesticide operator offering chemical treatments for private land stewards in the province. Education and outreach activities completed thus far have helped to raise the profile of the issue amongst landowners but there is not adequate programmatic support or treatment capacity to advance treatment at scale.
- While no single existing entity is ready to tackle this capacity gap on their own, numerous stakeholders from the private land sector with different strengths or capacities have indicated a willingness to participate in a hemlock conservation partnership initiative.
- Funding incentives are key to helping facilitate conservation activities on private lands as many land stewards identified cost as a barrier for treatment.

- Nova Scotia's existing private woodland service providers and forest stewardship programs provide established infrastructure for engaging landowners who are committed to hemlock conservation.
- Engagement of landowners for hemlock conservation needs to target landowners differently based on their geography. Landowners in the infested area need immediate assistance pursuing treatments. Properties along the infestation front need aggressive detection monitoring followed by immediate treatment aimed at slowing the spread and reducing costs and chemical use. Building awareness among landowners outside of the current infestation area was seen as an important step due to lack of awareness of the issue within landowners outside of the southwestern counties.

7. Implementation

7.1 Regionally Specific HWA Management Strategies

General Recommendations

In implementing a chemical control strategy for a minimum of 2,000 ha per year, there are several key take-aways that apply to all potential treatment scenarios regardless of land tenure.

Common elements that are key to across all HWA treatment program initiatives include:

- Strike Crews (as outlined in Section 5.6)
- HWA Education and Outreach Volunteer Coordinator (as outlined in Sections 5.2 & below)
- Regionally Specific HWA Management Strategies (see below)

Designing a comprehensive provincial hemlock conservation treatment program will require variations of strategies depending on the following circumstances at the stand level:

- infestation levels of HWA
- distribution of HWA (localized or widespread)
- hemlock decline
- hemlock distribution, volumes, accessibility, riparian forest distribution
- potential impacts from the functional loss of hemlocks
- land tenure

Regionally Specific HWA Management Strategies

The province can be divided into four zones, each with a unique strategy based on the state of the infestation (see Figure 13). Each region varies in amounts of hemlock that are present and the percentage found on private lands versus Crown and Protected Areas. Land tenure is addressed following the broader regional examination.

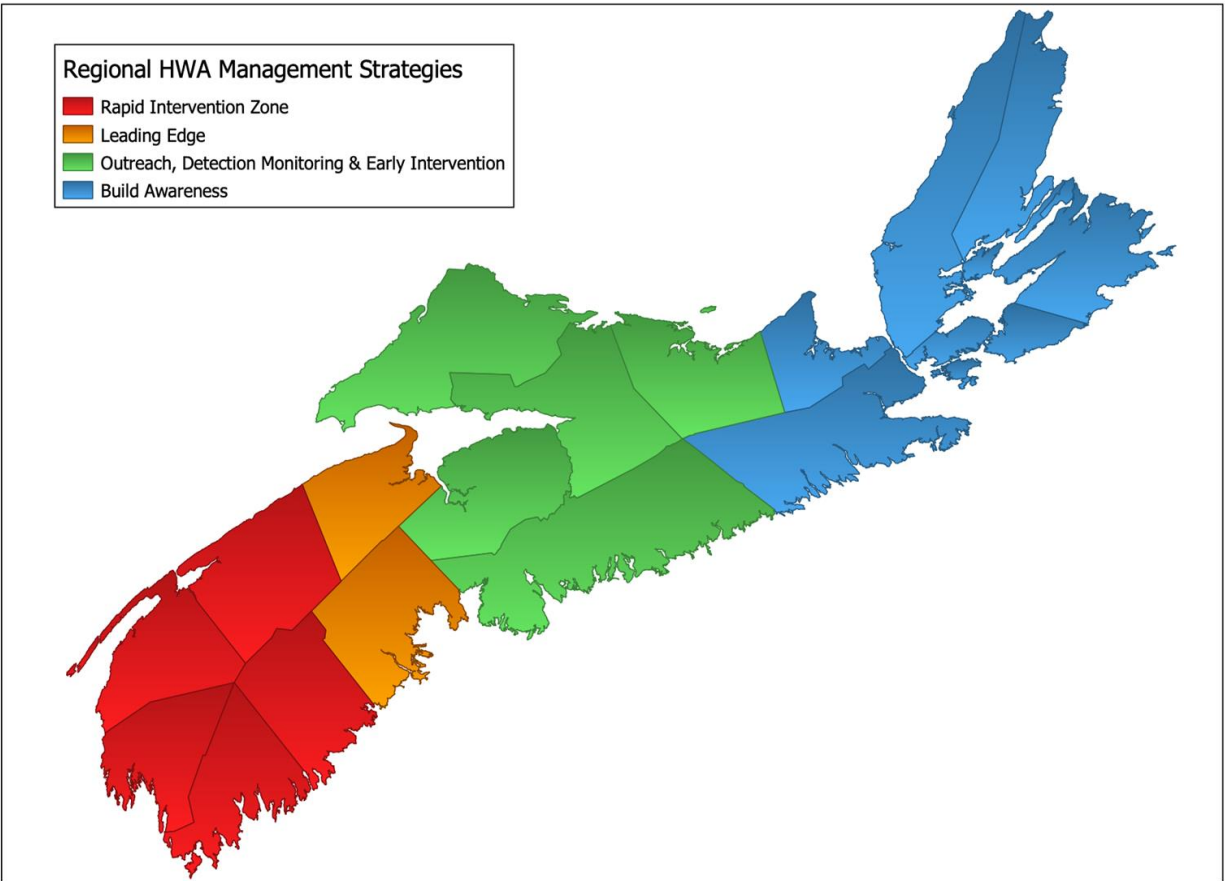


Figure 10: Regionally Specific HWA Management Zones

1. Rapid Intervention Zone (Annapolis, Digby, Queens & Yarmouth Counties)

The western region contains the most hemlock and is the most HWA-infested of the four zones, rendering it the most critical scenario to address. It has the largest protected area land base and has been classed as a biosphere reserve. West of highway 8, HWA populations have been present for the longest periods and have infested more than 17,000 ha. in 2019 and HWA has already caused extensive mortality in hemlock forests and other stands are in rapid decline. Protected areas that have been assessed using the 'Regional Stand Selection Tool' (i.e., stand prioritization protocol) within this zone found many hemlock stands in decline and some below the threshold required for successful treatment using imidacloprid. Many of these forests feature old growth. Remnant healthy hemlocks in this zone must be detected and saved as soon as possible to establish and maintain a network of conserved hemlock stands.

Partial stand treatments: Some stands that are in advanced deterioration may still support treatment of 30 + trees that are within healthy thresholds. Following the goal of having healthy pockets of hemlock across the landscape to best serve biocontrol predators, these partial stand treatments may be appropriate, particularly if there remain healthy old growth stems.

Old growth stands: Treat only after careful assessments of canopy health indicate minimum

thresholds are met. Consider fast-acting chemical product, TreeAzin.

Chemical use: Assuming a best-case scenario that all four chemical options will be available in 2022 (*IMA-jet, Xytect 2F, TreeAzin and Safari*), TreeAzin or Safari should be used in combination with IMA-Jet to provide the fast knock down control of HWA in trees that are below the thresholds for treatment using imidacloprid-based alone. Xytect 2F, as the cheaper and faster-applied chemical, should be used to the extent that is possible to lower costs. Assuming an application limit of 1.89 L/ha/year, then only 1,629 cm³/ha/year can be treated with Xytect. The advanced nature of the decline in many stands in this zone means that there is no time to wait to administer additional Xytect treatments in subsequent years. IMA-jet injections will have to address the remaining trees that have suitable thresholds, or resort to the faster-acting products.

Immediate and aggressive chemical control must be concentrated in this region to save the best of what remains of Nova Scotia's hemlock legacy. Canopy evaluations in most of the forests in this zone will require a tree-by-tree approach.

Recommended resources for implementation in the rapid intervention zone:

- Coordinator: Education and Outreach-Volunteer staff member to organize strike team crews, conduct education and outreach, organize volunteers
- Strike team crews of 2 to 3 persons. Minimum 5 strike teams (potentially 3-4 terrestrial, 1 riparian team). At least 1-2 strike team leaders year-round to conduct site preparations, early detection surveys in any remaining uninfested forests, report writing, data entry, etc.
- Consider Wildland Fire Crews when available.
- Volunteers
- Student positions

Hire sufficient crews to execute treatments in 2022 and 2023 in an intensive approach that can be tailored in later years to fewer crews depending on treatment needs.

2. Leading Edge of Infestation Zone (Kings & Lunenburg Counties)

Lunenburg and Kings Counties have recent detections and have been recently added to the CFIA regulated area to restrict movement of hemlock products leaving the zone. Current HWA distribution is in localized patches. A well-known and picturesque forest that has recently been infested is located on the LaHave River across from Park View Education Centre, which may serve to increase public concerns over HWA. On the leading edge of the infestation, early detection monitoring in combination with rapid deployment of treatment of infested trees and buffers can help to contain and slow the advance of the infestation front. Treating areas early at the leading edge of the front can help reduce costs by reducing the number of trees that require treatment within a given stand and relying on the cheaper chemical options.

Full stand treatments: If lightly infested stands are found.

Old growth stands: Treat old growth stems prophylactically if infestation is nearby or already in small numbers of trees. Monitor remainder of trees in follow-up surveys.

Delimitation buffers: Treat all hemlocks in a new HWA infestation site thoroughly, treating every tree within a "delimitation buffer to a width of approximately 240 m around infested tree(s) (buffer distance is based on the Michigan strategy). Results of using delimitation buffers is expected to be cheaper than allowing the outbreak to spread and then having to treat the entire stand.

Chemical use: Use Xytect2F as primary tool for all outbreaks unless near water. In small outbreaks, potentially only Xytect 2F will be required. IMA-jet would be used to top up the remaining treatment needs if an annual area limit is prescribed for Xytect 2F. Xytect 2F limitations will not allow treatment of many old growth stems. In prophylactic treatments, subsequent treatments in following years may be considered, or IMA-jet may be used though costs will increase.

Recommended resources for implementation in leading edge of infestation zone:

- Same as Rapid Intervention staff, using same Coordinators
- 1 Strike team crew as needed. Can assist Rapid Intervention Strike teams when all outbreaks are treated and/or hold treatment demonstration and training for private landowners.

Having sufficient staff to treat the leading edge may keep the infested area from expanding at the current pace witnessed, perhaps allowing years before infestations reach the central zone.

3. Outreach, Detection Monitoring and Early Intervention Zone (Hants, Halifax, Colchester, Cumberland and Pictou Counties)

In the central portion of the province (Hants, Halifax, Colchester, Cumberland, and Pictou Counties), significant hemlock inventory is present, the majority of which is located on privately stewarded woodlands. Interviews with Nova Scotia Forest stewardship proponents indicated that awareness of the threat of HWA amongst landowners in this region is low, and often the issue is considered a “southwest NS problem”. Targeted outreach and education efforts amongst private land stewards in central NS needs to begin in earnest ahead of the infestation front to address this knowledge and awareness gap. Early detection monitoring and immediate treatment to stamp out localized infestations can help slow the forward advance of the infestation front and reduce treatment costs and chemical use. Silvicultural interventions aimed at stand diversification could be promoted to help increase forest resilience ahead of the arrival of HWA.

Recommended resources for implementation in early intervention zone:

- Outreach and Education Volunteer Coordinator: Trains and raises public awareness, encourages citizens in this area to volunteer in the Rapid Intervention Zone
- Consider a student position for outreach activities

4. Build Awareness Zone (Antigonish, Cape Breton, Guysborough, Inverness, Richmond & Victoria Counties)

Further east, hemlock forests in some counties are not as significant as those found in the west and central regions, which will require much less of any potential provincial budget to control HWA in future. Antigonish, Guysborough and Richmond each contain less than 1% of the provincial hemlock total, while Cape Breton Regional Municipality, Inverness and Victoria counties do contain noteworthy hemlock populations. Awareness building through outreach and education as well as early detection and monitoring are key strategies to deploy in this region, although not with the same focus and urgency as in central region due to their distance from the current infestation front.

7.2 Riparian hemlock treatment scenarios

Within each zone, strike teams would target riparian hemlocks as a priority for treatment, beginning in the most degraded watersheds first. The objective would be to potentially maintain hemlock trees that benefit both terrestrial and aquatic integrity. In some cases, treatments would have added benefits of preventing bank erosion and mitigating flood damage.

Trees in riparian areas may be healthier than the remainder of the stand being evaluated since trees have more access to light and resources. In other cases, riparian trees may feature the most severe impacts since HWA infestations often begin next to water, where HWA was likely disseminated by birds or wind.

Riparian hemlock may be assessed from both the land and by water, with canoe assessments being attractive to volunteers. Watercraft travel, most likely by canoe and transporting treatment gear in double-contained carriers for over water travel is a possible scenario. Late May - early July may be the most rapid assessment of hemlock canopy health as the bright green new growth that is easily noticeable from the water. Lots of bright green new growth translates to the trees being treatable with IMA-jet alone.

Strike teams treat 1) prioritized old growth stands, making a careful evaluation of canopy health to select either imidaloprid-based products or TreeAzin + IMA-jet. "Effective and rapid control responses are required to save remaining hemlock forests using affordable methods and tools. Insecticides that can be applied efficiently and rapidly will allow licenced applicators to treat many more hectares of highly valued and scenic locations in Nova Scotia before the hemlocks die and

The screenshot shows a website with a light green background. At the top, there is a navigation menu with links: HOME, DONATE NOW, MEET THE PHHAT TEAM (with a dropdown arrow), SCIENCE OF SAVING HEMLOCKS, and CONTACT. The main content area is divided into two columns. The left column is titled "Meet the PHHAT Team" and contains a paragraph of text about the team's mission and partners. Below the text is a group photo of ten people in kayaking gear. The right column has a heading "Save a Hemlock Tree in the Green River Gorge" followed by a short paragraph and a "Make a donation." link. Below this is a green box titled "Adopt-a-Hemlock" featuring a large "\$30" and a small tree icon, with the text "Cost of Treating 3 Hemlock for 5 Years" below it.

HOME DONATE NOW MEET THE PHHAT TEAM SCIENCE OF SAVING HEMLOCKS CONTACT

Meet the PHHAT Team

To meet the challenge, we formed the Paddlers Hemlock Health Action Taskforce or **PHHAT** – a group of experienced kayakers and dedicated conservationists committed to saving the remaining eastern hemlocks of the Green River Gorge. Key partners such as **American Whitewater**, **Hemlock Restoration Initiative**, **MountainTrue** and the **NC Wildlife Resources Commission** contributed guidance, training and tools that are essential to this project.

Save a Hemlock Tree in the Green River Gorge

For as little as \$10 you can help us treat a hemlock and protect it from the ravenous hemlock woolly adelgid.

Make a donation.

Adopt-a-Hemlock

\$30

Cost of Treating 3 Hemlock for 5 Years

The PHHAT Team assembled on December 3rd, 2017 to treat the green. From left to right: Christoph Berenotto, Levi Rhodes, Kevin Colburn of American Whitewater, Regina Goldkahl of MountainTrue and AmeriCorps, Alex Harvey, Amy Little, Green Riverkeeper Gray Jernigan, Josh Goldbach and Ally Matts.

Figure 11. A volunteer paddle group treating hemlock in North Carolina: 'Paddlers Hemlock Health Action Taskforce' (PHHAT). Also note "Adopt-a-Hemlock" program to fund treatments (\$ 30.00 will treat 3 hemlocks for 5 years).

the unique habitat is forever changed” (Sweeney 2022). Maximize work with volunteers to lower labour costs. Places such as North Carolina have had success with volunteers that paddle and treat riparian hemlocks (Figure 11).

Rapid Intervention Zone

Strike teams would assess the hemlocks within riparian buffers, regardless of broad status of stand decline of more interior trees. The objective would be to save what is possible of riparian trees with TreeAzin + IMA-jet for degraded trees (*thresholds yet to be prescribed*) or IMA-jet alone. Since this is the most critical zone where many hemlock forests along water courses have already been lost, a rapid treatment of what remains is critical. Given the profound ecological consequences of riparian forest loss, **1-2 focused strike teams plus volunteers** may paddle all waterways known to support hemlock with the appropriate training and gear to treat the trees.

Leading Edge Zone

It is likely there are some infested riparian forests in this zone that have not yet been discovered. Volunteer support for early detection of HWA along waterways would be very attractive to some paddle enthusiasts and watercraft operators. It is unlikely that strike team support would be available to check these forests (being fully assigned to the forests most in need in the Rapid Intervention Zone), but a coordinated program for paddlers and cottage owners to conduct riparian detection surveys is a viable scenario. Some participants may be willing to become pesticide operators if provided some training through demonstrations and volunteer treatment days to show how easy treatment may be to carry out.

Zones 3 and 4

Riparian hemlock protection would be similar to the Leading Edge Zone. Since trout and salmon fishers and birds can accidentally bring HWA to new watersheds, HWA may first show up in riparian trees far from the core infestation. Building awareness about HWA among recreational boaters and fishers can help enhance early detections.

7.3 Implementation of a Treatment Program on Private Land

The large amounts of hemlock existing on private lands clearly necessitates implementation of strategies for treatment on private lands using a range of government assistance approaches. Of paramount importance to implementing a hemlock treatment program on private land is that it provides the information and tools being sought by landowners. Many landowners presently want to know how to treat hemlock, whether it is possible for them to treat their own trees, and what requirements and costs are involved. In the southwest, they are worried and saddened to see dead and declining hemlock forests. Some of the top tools and actions that may be relatively easy and low cost to provide, and that would facilitate private landowners to implement their own hemlock treatments are listed below.

Additional program elements for implementing hemlock treatments on private land will likely rely on a cost-sharing program and use of private land strike teams. Many landowners will not have the financial means, awareness, time, or physical capacity to treat their own hemlock trees. They will experience massive tree mortality, though given the preference, they would rather have the trees remain alive and healthy for wildlife habitat and other ecological values. Some of those private land holdings are highly suited or likely needed to complete a hemlock conservation

network across the province. There is little choice but to step in with some level of assistance in some situations, though a generous treatment program offer for all private holdings would not be possible.

The government has a responsibility to help treat hemlock for the ecological retention of forests and for the benefit of the 'common good'. Large old hemlock conifers are needed more than ever to be retained alive on our landscapes for climate change mitigation. Their functional loss will incur enormous cascading impacts to multitudes of species in both forest and stream. A cost-effective program is within reach, especially when capitalizing on the strike team model and a carefully tiered program.

A GIS analysis is required to provide a layer of privately-owned hemlock forests of 'best opportunity' for treatment and conservation within each region across NS, filling in the spatial gaps where Protected Areas and suitable Crown hemlock forests are lacking. Site visits would also likely be necessary in some cases to ground truth the analysis. Those lands would be triaged into 3 tiers in descending order of value for conservation and for proposed years of treatment, all predicated on whether owners would be willing to allow treatment. Owners of some of the most valuable hemlock woodlands could receive written notification, or personal contact through the 'HWA Outreach and Education Volunteer Coordinator' outlining the values their hemlock may potentially serve as part of a functional network of conserved hemlock across NS. Mechanisms to ensure trees are not harvested or destroyed following government-assisted treatments include a focus on land trust agreements and using a sliding scale of landowner financial contribution in a cost-share program.

A new cost-share program would require some rapid planning before a rollout and must build in assurances that treatments will not be lost when land management strategies change direction or ownership. Full cost coverage would be granted only to the most certain and enduring private land tenures with healthy hemlocks that are required for completion of the conservation network; those with trust agreements.

A cost-share hemlock conservation network may offer up to 75-100 % treatment costs for high value hemlocks (with owner agreement not to harvest or entering a land trust agreement). Less critical hemlock stands on private land, possibly classified as second tier according to spatial analysis, may receive 50-75 % of costs covered in a cost-share agreement. Most landowners with hemlock may fall in the 3rd tier for treatment assistance, holding less valuable, picked-over and fragmented hemlock forests of a working woodlot landscape. Administrative costs associated with treating and tracking these hemlock stands would be untenable. A cost-share approach for treatments may not be possible, or would involve much lower financial assistance, perhaps covering only 10- 25%. These landowners are still not entirely unassisted. They would have the tools listed below available to them. All landowners entering a cost-share program would sign an agreement for the long-term commitment involved. One-time treatments are not enough, chemical treatment commitments must be sustained for at least 10 years until biocontrols begin to take over and address long-term threats from HWA.

The *Strike team model* approach can be applied to private lands and has been done in places such as North Carolina and Michigan. Other States with strike teams do not treat private properties, but they offer advice, training and guidance to landowners (hence we included a list of tools to address this approach below). Devising government-funded strike teams that could treat private lands may be more complex than those who would operate on Crown lands, but they will be necessary for the top tier private hemlock stands identified to complete the hemlock conservation network at locations where the amounts of hemlock on Crown lands are lacking.

Without triaging private lands as outlined above, we can envision that employing one or two strike teams to treat private hemlock lands would rapidly fall short of a forecasted high treatment demand, since private lands in some counties hold, for example, 79 and 90 % of the land base in Digby and Lunenburg counties, respectively. Perceptions of unfairness may ensue for those whose land was not possible to treat before canopy decline advanced and trees died. Michigan encountered issues with inequitable strike team aid to landowners, when scheduled treatments were delayed due to under-estimating the forecasted time required to treat some private land parcels. Demand out-stripped strike team availability. It is best to avoid this situation. The 'first come-first serve' model used for other government-assisted forestry initiatives would be inappropriate as some resources are presently in critical need of treatment. The prioritization must be based on the tiers as we outlined above (based on natural resource value) and also based on time sensitivities with HWA rather than treating in order of requests.

Private land treatment implementation strategies recommended are:

1. *Facilitate private landowners to treat their own trees* through training, provision of equipment, and guidance tools that foster expanded capacity to conserve hemlocks at a more rapid pace.
 - a) *Offer a 'Restricted use Chemical Operator Certificate'* that is narrower in scope than the standard Certificate and would enable purchase of only systemic tree products permitted to treat HWA. (The province may consider adding Emerald Ash Borer to the list as well.) The course material and exam would be devised to test knowledge of ability to apply systemic chemicals safely, according to legislation and best environmental and human safety practices.
 - b) *Provide chemical applicator kits (for injection or basal bark spray) for rent or deposit for pesticide certified landowners.* The kits save the landowner significant costs for purchasing specialized gear and safety equipment. Kits could contain personal protective equipment (nitrile gloves, glasses), diameter tape, spill berm, wet knaps and paper towel, plasticized instructions including 'best practices', emergency numbers for spills, etc. A datasheet is returned with the gear when they return to retrieve their deposit. In this way, treatments could be tracked in the provincial treatment database, on where and approximately how many trees were treated. A variety of injection kits and a backpack sprayer (for Xytext 2F) could be made available. An Ecoject kit is approximately \$ 13,000-15,000, and suitable for large stands and working in groups. For the cottage owner with a few trees, a simple Q Connect kit could be available for \$1500.00. Supply enough kits to meet demand, ordering more as needed.
2. *Implement a cost-share program* that provides financial assistance on a tiered approach according to landscape needs and landowners commitment to long term conservation to complete a hemlock conservation network, assisting tier 1 and 2 landowners during in the interim period required to maintain tree health.
3. *Partner with land trust organizations* (e.g., Nova Scotia Working Woodlands Trust, Nova Scotia Nature Trust and Nature Conservancy of Canada) to secure conservation or working forest easements for treated properties to ensure conservation permanency and carbon sequestration in treated trees.
4. *Strike team program* for private lands to be offered to assist landowners with hemlock that fall within the tier 1 and 2 categories. A government program or NGO may supply a full strike

team or only a strike team lead with crew members to be occupied by landowner volunteers or program volunteers (using the signup sheet platform).

5. *Riparian buffer treatments on private lands by a government-led riparian strike team.* Watercourse buffer hemlocks are least likely to be harvested under current provincial regulations, thus providing the best assurances on an enduring investment. These private land expenditures are easily justifiable and equitable since they provide benefits that extend to downstream resources and other landowners indirectly.

Spin-off benefits to riparian buffer treatments include:

- Costs of riparian hemlock treatments may be less than repairing bridges and emergency responses to highway flooding.
- Benefits trout & salmon habitat and aquatic ecosystem function.
- Demonstrates to landowner recipients the ease of treatment applications. It's possible that this could encourage additional self-guided treatments on private land.

Additional private land support tools that should be offered:

1. Information regarding government funding and cost-sharing for treatments
2. Outreach materials on treatments provided through a more operationally focused HWA website
3. Training, including demonstration videos on 'how to save a hemlock' that are accessible on a dynamic website that clearly supports and demonstrates how to conserve hemlock using chemical treatment.
4. Holding training events, such as practical hands-on, in-field demonstrations and training on tree marking-site prep methods, assessing treatment thresholds, and learning how to carry out chemical treatments.
5. A public booking platform for reserving treatment kits and for signing up for training days and volunteer days. The on-line platform would be closely administered by an HWA coordinator.

7.4 Volunteer Coordination

Utilizing volunteer support is a great way to engage the public in a provincial treatment program and can greatly reduce labour costs. Creating a public campaign for volunteers to come together supporting the treatment of hemlock trees across NS can greatly increase productivity and the number of trees treated each year. Providing people an opportunity to participate through citizen science increases transparency and transfers information from scientists and government to the public, while informing them about HWA and the importance of hemlocks.

Examples from the USA volunteer experience

One of the most successful USA treatment initiatives is the Hemlock Restoration Initiative (HRI), an NGO in North Carolina. HRI uses a combination of paid HRI staff working with volunteer pools drawn from communities, and also draws from young offenders and in-mates. HRI uses a "Bridge" program that allows young offenders to help treat trees, which has been positive for providing young people with natural resource management skills. New York State also has had good

participation from volunteers, and particularly mentioned retired persons. The New York State Hemlock Initiative holds regular events to engage volunteers in early HWA detection and treating hemlock.

North Carolina trains in-mates for Resource Management protection, i.e., fire control and hemlock treatments. The Dept of Public Safety pays prisoners who opt into the program a \$1.00/day wage in return for training them to fight wildfire and conduct other forestry work. Margot Wallston, HRI Director shared that many members enjoy developing natural resource management skills that they learn through the program, and that the in-mates work very fast.

The Sporting Lake Nature Reserve Volunteer Experience

A volunteer-based treatment of 15 ha of hemlocks on a remote island at Sporting Lake in fall, 2021, received high volunteer interest, so high in fact that some volunteer interest on weekends had to be declined. The objective of “saving old growth” was a key attraction, plus the allure of a rare and beautiful wilderness setting. This was the strong conclusion drawn from the Sporting Lake experience where a volunteer pool has been trained to safely deploy EcoJect canisters. Many people from this pool are anxiously waiting for a new assignment or project in 2022. Volunteers at Sporting Lake ranged in age from 16-79 years, from highly skilled working professionals (Doctors, medics, lawyers, natural resource management instructors, and log home builders) to students and retired persons. News of this successful event has sparked interest from many others.



The nature of the trip to and from the Sporting Lake Nature Reserve required a high-level of coordination to ensure success, involving volunteers in extensive wilderness travel, paddling, and conducting extensive portages, and backcountry camping. Proper safety measures were required regarding reliable remote communications and medical response. The level of coordination and volunteer support required is partly dependent on treatment area location and its distance from the road network.

Jennika Hunsinger, staff member at the MCFC, assisting with the injection of trees at Sporting Lake (MCFC).

Capitalizing on Volunteer Enthusiasm for Hemlock Conservation

We learned several things from the Sporting Lake Nature Reserve hemlock treatment in October 2021, particularly that volunteers can come together under little advance notice, with a keenness to save old growth hemlock trees on uniquely valuable public conserved lands. Experiences using a volunteer contingent in both the USA and Canada to treat large areas of hemlocks conclude

that they can greatly speed up treatment applications while lowering costs, though more coordination is involved. When coordinating volunteers, having all pertinent information in one space where people can access it on their own, upload and download files as needed, and register for events greatly reduces the administrative requirements for organizing people.

It is recommended that a web platform is created and managed where the public can engage independently to:

1. Access and submit waivers: any volunteer forms, medical forms, pesticide applicators certification (if applicable), etc.
2. Sign up on a calendar of public event: training sessions, treatment days and locations
 - a. This should include number of volunteers needed, and spaces filled, safety gear-clothes required
3. Sites descriptions to be treated: Location, stand age and ecological value, land stewards or protection status, HWA infestation level, or other pertinent information to the prioritization of the stand for treatment.

People may be more inclined to support the treatment of old growth and hemlocks located on public lands that are under protection, rather than on privately stewarded lands.

Engaging volunteers in treatment application across the province on protected areas, crown lands, and privately stewarded lands may require different strategies for each. There may be difficulty in recruiting volunteers to treat privately stewarded lands. In this case, the landowner could facilitate gathering volunteers from within their own network and community. Cottage owners may, for e.g., get together on a lake and organize to help one another with treatments using the strike team approach.

There remains some uncertainty on how to best provide liability coverage to an NGO-led volunteer treatment program. The Sporting Lake Project proceeded without liability insurance and instead relied on volunteers signing a waiver release, however during interviews as part of this investigation, project proponents recommended that an enduring volunteer program would benefit from liability insurance coverage. Several insurance brokers that were interviewed for this investigation were currently not offering commercial coverage to licensed pesticide operators and were unable to find a provider willing to offer insurance to a volunteer-led treatment program.

It is recommended that the Nova Scotia government investigate options for providing blanket liability insurance coverage for program participants to allow for the development of a robust volunteer HWA treatment program.

Other potential sources of volunteers in NS

There's an opportunity to build off the volunteer list from the Sporting Lake mission and connect with several other groups across the province. More volunteers may be solicited through a broad public outreach effort using social media and radio, as well as direct requests through community groups and associations like recreational paddle groups, and fishing groups. Volunteer pools may originate from students and school groups, retirees, and the newly formed Mi'kmaq Earth Keepers program.

Mi'kmaq communities should continue to receive invitation to participate in a variety of ways toward conservation of hemlocks in Mi'kma'ki. Protection of old growth is of cultural interest to

some Mi'kmaq. Widespread mortality of hemlock forests at or near lands administered by the Acadia and Bear River Bands has brought the loss of hemlocks into sharp focus for some.

Inspired by the North Carolina 'Bridge' program for young offenders, the NS Youth Centre in Waterville was contacted and is receptive to exploring a 'Forest Conservation Program' for some of their youth. A preliminary discussion was held with Jim Nickerson, Youth Custody Manager, who is receptive to further dialogue. He also suggested Valley Integrated Youth Services, where many more youth participate. Among their goals is to assist youth to secure employment and work with community-based partners. He named a couple of community projects where they have already had success.

7.5 Leadership

Along with engaging landowners, there should be clear leadership to help execute treatments and provide information, data and track the early detection and progression of HWA across the landscape. Drawing from the example of the New York State Hemlock Initiative (NYSHI), the Hemlock Restoration Initiative (HRI), or Save MI Hemlocks, West Michigan Hemlock Woolly Adelgid Taskforce, an entity should be created for Nova Scotia that provides extensive information regarding treatment options for landowners, coordinates volunteer efforts and leads strike team treatments. Recognizing there is an existing Nova Scotia Hemlock Initiative (NSHI) website managed by the Mersey Tobeatic Research Institute, one option could be to build on and modify this existing platform, although this may not be feasible and addressing gaps in the NSHI platform may require launching a new initiative. Regardless of the approach taken, the envisioned platform should integrate some of the detailed data sharing required as witnessed on the aforementioned websites including:

- Detailed information regarding chemical control options, applications and non-target impacts
- Library of resources including past presentations, instructional videos and webinars
- Summary of current research on chemical and biocontrol options
- Volunteer opportunities for treating trees, with a signup platform and pertinent information required
- Training for landowners and stewards on how to treat hemlock that may prepare them for becoming a pesticide operator
- Citizen science research programs and data collection including online forms and database
- Opportunities to become a strike team leader, lead volunteers and expand awareness of HWA on a regional scale.

In recognition that the volume of work required to build and execute both the outreach and implementation components of a NS HWA treatment program, a clear leader and *preferably* a single website is required to manage landowner inquiries and launch a successful initiative. Our vision of a dedicated NS hemlock conservation society is a non-profit organization (or preferably a charity) staffed specifically to initiate the recommendations of this report and mirror the outreach approach of NYSHI.

The main activities of an organization should be:

- Serve as the main point of contact for landowners interested in treating their trees acting as a leader in providing information and answering questions regarding the progression of HWA and treatment options.
- Collect data to track the ongoing spread of HWA and manage a treatment database that will map treated areas and help coordinate priority areas.
- Coordinate injection efforts by building capacity with regional partners and helping recruit and manage volunteers to inject trees on Crown and private lands.
- Fundraise and apply for grants and administer funding for chemical treatments of priority hemlock stands.
- Oversee resources allocation and activities of regional partners and administer treatment kits.
- Create and manage a network of staffed Strike Teams that administer treatments on all land tenures.

A key component to the success of a dedicated group is ongoing collaboration with government, NGOs and academia, primary through the members of the NS HWA Working Group. The prospective NS hemlock conservation society preferably would have several members of the working group and Provincial government on the board of directors to advise staff and volunteers on the implementation of treatments across the province. In addition to these experts, the Board of Directors (BoD) should take nominations from woodlot owners, landowner organizations and land trusts. Ideally, the organization would also have a key partnership with an academic institution to help support research efforts and provide student assistance when necessary.

A conceptual organizational chart for the proposed initiative is presented below. Project management staff would oversee the program, with an initial focus on training, capacity building, stand prioritization/site set up and landowner outreach. Strike Teams would focus on stand treatments and all staff would participate in events and treatments. Additional Strike Teams could be added through partner organizations as funding allows.

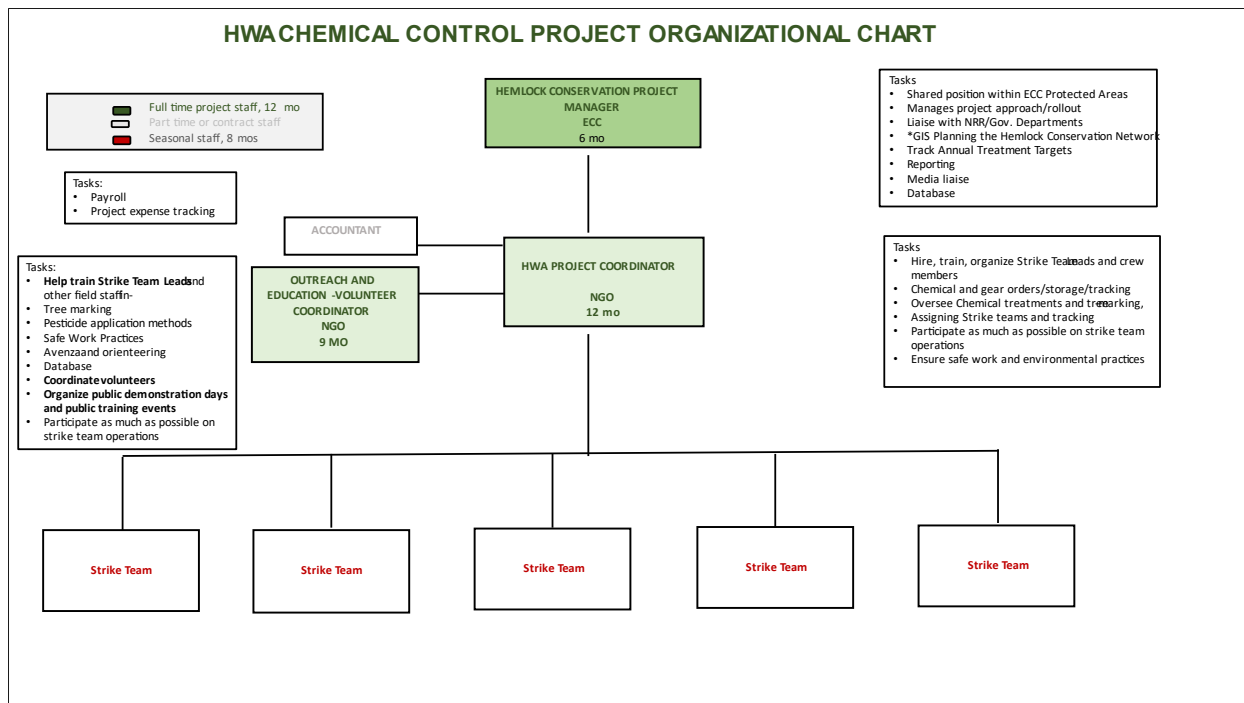


Figure 12. Conceptual Hemlock Conservation Staff Organizational Chart

Potential partner organizations

A list of potential project partners and prospective roles or contributions to the initiative follows.

Medway Community Forest Co-op (MCFC) is well-situated to provide leadership and coordination of the overall initiative. Staff and board members have gained professional experience in a wide range of HWA-related work and the organization was a key partner in the Sporting Lake Nature Reserve volunteer-led treatment in fall, 2021.

Preliminary conversations with the Clean Annapolis River Program (CARP), based in Annapolis County, St Margaret's Bay Stewardship Association (SMBSA) in southern HRM and Blomidon Naturalists Society (BNS) in Kings County have indicated that all three NGOs could potentially host Strike Teams that would work under the training & coordination of the treatment program, focusing on providing treatments in the local area of each organization.

The Nova Scotia Working Woodlands Trust (NSWWT) is in the process of launching a working woodland trust that will offer working forest easements for privately stewarded lands across the province. The easements are funded through the sale of carbon off-sets. This framework could allow for the permanent protection of treated trees via working forest easement agreements that ensure that treated trees are protected in perpetuity.

Nova Scotia's two conservation land trusts, Nova Scotia Nature Trust, and the Nature Conservancy of Canada, could assist with fundraising efforts as well as provide volunteer coordination for treatment support of their respective trust lands.

The Association for Sustainable Forestry (ASF) is ideally suited to administer cost-sharing or grant programs aimed at partially off-setting the cost of treatments for private land stewards.

ASF can also provide outreach and training services to a wide network of private land stewards and forest professionals.

The Family Forest Network of Nova Scotia (FFN) is a partnership of eleven organizations that serve private woodland stewards across Nova Scotia. The network will become the starting point for woodland stewards who want to learn more about forest practices that mimic natural processes, promote biodiversity, and restore ecosystem health. This platform and the wide-ranging network of the eleven partner organizations makes the FFN an ideal partner to reach small woodland stewards across the province with information and resources to promote hemlock conservation.

The Mersey Tobeatic Research Institute currently hosts the Nova Scotia Hemlock Initiative. Collaboration with MTRI for coordinated outreach and cross promotion as well as professional support services such as stand prioritization and monitoring is recommended.

Key program deliverables

Launching a hemlock conservation initiative in Nova Scotia over a 5-year time horizon will require a front-loaded effort in training and capacity building to develop the required treatment processes and protocols, education materials, communications platform and human resources required to deliver chemical treatments at scale. Some key deliverables and timelines are presented below.

Early Phase (Year 1 - Capacity Building):

- Develop Strike Team Training Program, including relevant Treatment Protocols and Safe Work Practices
- Establish communications platform (website, social media, educational materials, demonstration & promotional videos, and volunteer coordination)
- Run treatment training/demonstration program for government/NGO staff/land stewards
- Educate property owners and woodlands stewards to promote effective detection and monitoring
- Provide treatment planning consultations with interested land stewards

Second Phase (Year 1-2 - Launching Strike Teams)

- Establish a two-person, full time Strike Team, supported by volunteers wherever possible
- Coordinate and mobilize strike teams in the field to achieve treatment targets
- Provide training & logistical support to partner NGOs to establish additional Strike Teams (e.g. CARP, NSNT, NCC, others)
- Establish a network of trained volunteer "Hemlock Heroes" and run volunteer treatment/survey/tree marking events
- Establish a training/certification/equipment rental program for pesticide-certified property owners

Treatment Phase (Year 2-5)

- Administer Strike Team and volunteer-led treatments totaling ~550 hectares per team over a 5-year period

- Continue to engage private land stewards in education, training and equipment loan program to further advance hemlock conservation on private lands

Project cost estimates and proposed budget

Cost estimates and a budget for various program elements were explored and are presented below for a program that includes one project manager, an outreach/volunteer coordinator and one, two-person Strike Team. In addition to staff treatments, volunteer treatments would be led to bolster capacity. This scenario would lead to ~550 hectares of treatment over a 5-year project timeline.

Table 5. Annual cost estimates for a Hemlock Conservation Program.

Project Management Staff	Cost
Project Manager/Coordinator (12 mo, \$30/hr)	\$ 58,500.00
Operations/Outreach/Volunteer Coordinator (10 mo, \$25/hr)	\$ 41,250.00
	\$ 99,750.00
Strike Team Staff	
Strike Team Leader (8 mo, \$30/hr)	\$ 39,375.00
Strike Team Member (8mo, \$20/hr)	\$ 26,250.00
	\$ 65,625.00
Employee Benefits & Payroll Contributions	
	\$ 16,537.50
Strike Team Application Equipment Costs	
Eco-Ject Kit w 600 canisters/nozzles, drills, spill kit	\$ 20,000.00
Quick Jet Air injection system	\$ 3,000.00
Xytect Application Tank	\$ 500.00
Cruising Gear (D-Tapes, Vest, Angle Guages, headlamps, rain gear)	\$ 2,000.00
	\$ 25,500.00
Annual Strike Team Treatment Costs	
PPE (nitrile gloves, safety glasses, boots, first aid)	\$ 5,000.00
Cleaning Supplies	\$ 1,000.00
Flagging Tape (2 cases)	\$ 575.00
Tree Marking Paint (96 cans)	\$ 750.00
Travel	\$ 22,272.00
Eco-Ject Canister Mainatenance	\$ 14,280.00
	\$ 43,877.00
Annual Strike Team Chemical Cost	
Xytect	\$ 98,841.60
Ima-Jet	\$ 29,600.00
Ima-Jet (Volunteer Treatments)	\$ 76,032.00
	\$ 204,473.60

Table 6. Project budget for a 5 yr conceptual hemlock conservation program.

	Project Year				
	1	2	3	4	5
Project Management/Outreach Staff	\$ 99,750.00	\$ 99,750.00	\$ 99,750.00	\$ 99,750.00	\$ 99,750.00
Strike Team Staff (one team)	\$ 65,625.00	\$ 65,625.00	\$ 65,625.00	\$ 65,625.00	\$ 65,625.00
Benefits & Contributions (10% of payroll)	\$ 16,537.50	\$ 16,537.50	\$ 16,537.50	\$ 16,537.50	\$ 16,537.50
Application Equipment	\$ 25,500.00	\$ -	\$ -	\$ -	\$ -
Consumable Equipment	\$ 43,877.00	\$ 43,877.00	\$ 43,877.00	\$ 43,877.00	\$ 43,877.00
Chemical Cost (Staff Team)	\$ 204,473.60	\$ 204,473.60	\$ 204,473.60	\$ 204,473.60	\$ 204,473.60
Chemical Cost (Volunteer Treatments)	\$ 76,032.00	\$ 76,032.00	\$ 76,032.00	\$ 76,032.00	\$ 76,032.00
Admin/Overhead (10%)	\$ 53,179.51	\$ 50,629.51	\$ 50,629.51	\$ 50,629.51	\$ 50,629.51
Total	\$ 584,974.61	\$ 556,924.61	\$ 556,924.61	\$ 556,924.61	\$ 556,924.61

Total	\$ 2,812,673.05
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8. Funding Allocation and Incentive Programs

8.1 Funding Support

Governance in Nova Scotia that is visionary and supportive of chemical control is essential to conserving Nova Scotia's hemlock old growth. Adequate funding allocation will allow the early and aggressive strategies required to mitigate HWA spread and reduce forest damage. It will foster a successful template of strategies in other provinces as HWA moves to New Brunswick and westward. Mandates of both provincial departments of NRR, Forest Protection and ECC, Protected Areas will require long-term staff and funding support to benefit from biocontrol strategies that are presently on the cusp of being successfully implemented in the eastern USA. The latest advances in biocontrol show promise that a long-term solution is within our grasp in NS, but only if we keep some healthy hemlocks on the landscape.

Government framework in the USA differs from the Canadian Government approach, in that the United States Forest Service (USFS) is an agency that operates under the auspices of the U.S. Department of Agriculture (USDA). Hence there is more access to agricultural chemical tools and expertise and cross-pollination of strategies outside the traditional forest management approaches. Also, the USDA administers the nation's 154 national forests, so there is potential for more cohesive approaches and funding strategies.

Potential Funding Sources

Given the significant capacity for hemlock forests to sequester and store carbon, funding for HWA treatment could potentially be sourced from government programs such as the Nature Smart Climate Solutions Fund. Understanding that NSE has already applied to this program for Protected Areas, a second application - perhaps in partnership with the new organization - might also consider addressing potential habitat loss on small private woodlots that could be avoided with chemical treatment. The emphasis in developing a proposal should be the avoided carbon loss by chemically treating trees.

If we draw from examples in the US, there are several instances where government has made significant contributions to initiatives dedicated to chemical treatment³. The case for funding chemical control is stronger due to the work completed by the Department of Natural Resources and Renewables (NRR) to quantify the carbon emissions generated from the loss of hemlocks due to HWA (NRR, 2022), but also relates to government goals surrounding biodiversity, ecological forestry, conservation and climate adaptation. Nova Scotia Environment also developed a summary of potential funding sources that can be found in Appendix 4.

An important partner piloting ecological forestry on private lands in NS is the Family Forest Network (FFN), an initiative of the Nova Scotia Woodland Owners and Operators Association (NSWOOA). The FFN Steering Committee has extensive representation from woodlot owner organizations representing tens of thousands of acres of private woodlot owners. The FFN has secured over \$10M in funding through the Forest Innovation Transition Trust and NRR, however there was no direct tie to HWA within the funding proposal. Regardless, the FFN and the Steering Committee members will reach a very large number of woodlot owners and creates an opportunity

³ (North Carolina, Michigan, Maryland, Tennessee, New York, New Hampshire, Maine, among others)

to partner, specifically related to the proposed work on biodiversity monitoring and save valuable time and resources on outreach and marketing.

Incentive Programs

In considering different treatment options, researching methods to fund implementation is extremely important to ensuring success. In considering funding and incentive programs, our US partners did not have a silver bullet approach but referenced government support and framing programming placed heavily on volunteers. In preface to the recommendations in this section, the most effective and streamlined payment for chemical treatment of hemlocks would be provided through the government.

Tax Exemption Model

In searching for possible ways to both incentivize treatment, alleviate costs for landowners and ensure long-term conservation, our group found the Ontario Conservation Land Tax Incentive Program (2010). The program would require support from the Provincial and Municipal governments but could solve issues regarding the long-term conservation of hemlock stands following treatment.

In summary, the Ontario Conservation Land Tax Incentive Program provides a tax exemption to landowners who agree to maintain their land in a manner that contributes to the natural heritage and biodiversity objectives for conserving land. The program was created in recognition that, similar to Nova Scotia, the majority of Ontario's most significant conservation lands are privately owned. The tax exemption is offered to landowners as an incentive rather than compensation for potential losses of revenue, encouraging activities that maintain conservation features such as invasive species management, making it appropriate for a program focused on the chemical treatment of hemlocks for HWA.

The shortfalls of a land tax incentive program is the sheer volume of work required to consult municipalities, and developing new policies. Our recommendation is for government to research creating this type of program and begin engaging municipalities on potential implementation, especially those counties classified on the 'leading edge' - Lunenburg and Kings Counties. Engaging municipalities on the benefits of hemlocks, especially for the health of watersheds, could be quantified relative to value of quality of drinking water, and perhaps might be substantial enough to incentivize creating a tax program. Given the relatively low property tax fee per acre for lands classed as forest resource, this prospective tax incentive program may be quite affordable in terms of government expenditure.

8.2 Carbon Offsets in Hemlock Forests

Eastern hemlock plays a significant role in carbon sequestration in Nova Scotia's forests. Hemlock is one of the province's longest-lived tree species, and has a slow decomposition rate, adding value to above-ground carbon storage as coarse woody material in comparison to other softwood species (Kerbs 2014). There are natural carbon fluxes that occur in all forests, from natural disturbances to forest harvesting, however, the presence of HWA is set to dramatically impact carbon fluxes, affecting tree vigor, mortality and nutrient cycling (Kerbs 2014).

The presence of HWA also impacts carbon fluxes due to social factors, including the growing popularity of pre-salvage harvests on private lands across southwestern NS. If executed properly (individual tree selection or other low-level partial harvesting) there is some merit to utilizing silviculture as an adaptive management approach to encourage regeneration and to release of other species that might be able to replace hemlock in overall stand composition (Krebs et al. 2017). However, when pre-salvage harvesting is conducted using even-aged management techniques such as clearcutting, the implications to above and below-ground carbon storage is significant.

In the scenario at hand, and because hemlock is so effective at storing carbon and decays relatively slowly, there is limited additionality⁴ to simply treating trees with insecticides on a timeline less than 40 years. In a recent model developed for ECC by NRR, effects of HWA mortality has the most significant impact approx. 45 year following hemlock mortality (NRR 2022). Although preliminary, the model utilized permanent sample plots and photo-interpreted forest inventory to measure the potential impacts of widespread hemlock mortality in Western Nova Scotia. Results showed that although immediately following widespread HWA mortality dead organic matter is abundant, as time passes, the absence of hemlock from the canopy and entering

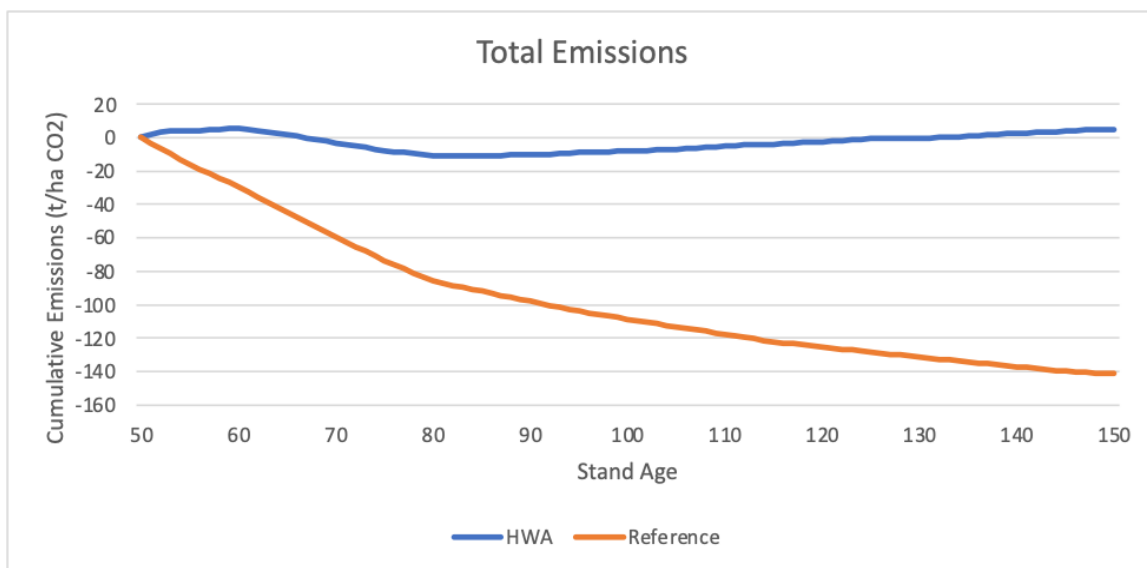


Figure 13: Carbon storage (t/ha CO₂) of dead organic matter over time (NRR 2022).

into natural senescence reduces the volume of carbon stored in dead organic matter (see Figure 13). Simply put, the dead organic matter becomes more of a finite resource since hemlocks are no longer a component of the landscape.

The cumulative additional emissions from declines in living forest biomass, dead organic matter and soil carbon result in significant volumes of CO₂, ranging from 5.4 Mt CO₂ at 10 years following mortality to 27.9 Mt CO₂ at 100 years (see Figure 15). Although the potential emissions resulting

⁴ Additionality proves that the reductions achieved by a carbon offset project are 'additional' to what would have happened if the project had not been carried out.

from widespread mortality is substantial, there are several obstacles in quantifying, measuring and verifying emissions that may limit the possibility of initiating a carbon project based on treating trees with insecticides. Sadly, the reality is as hemlocks decline and release CO₂ into the atmosphere, temperatures will continue to warm, decreasing the natural mortality of HWA that has until recently, kept the pest out of northern climates.

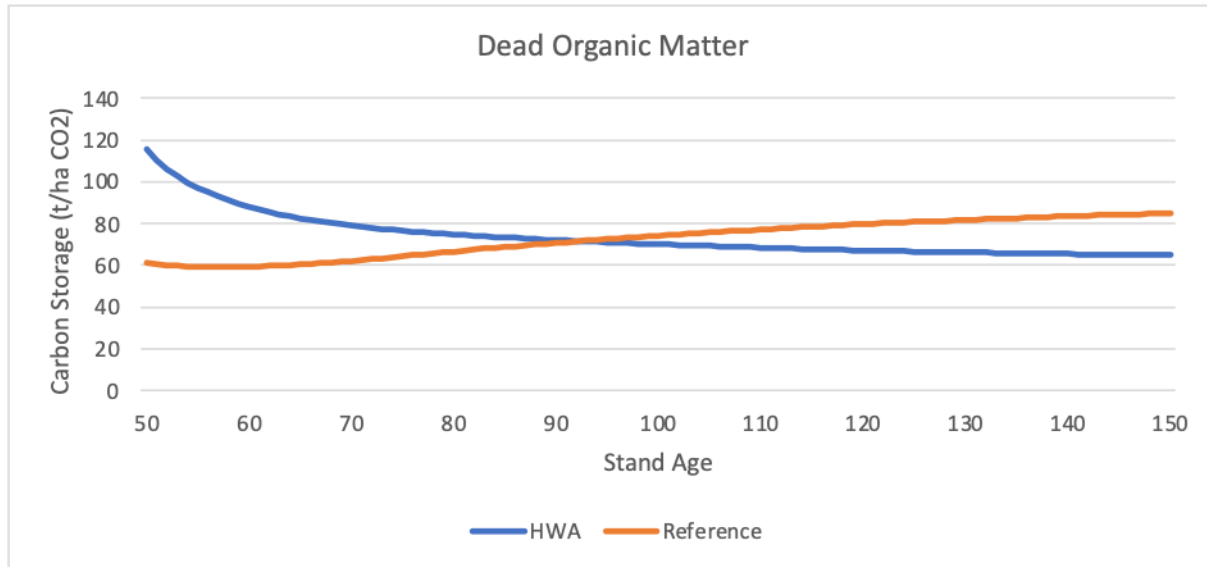


Figure 14: Total cumulative emissions (t/ha CO₂) over time (NS NRR, 2022)

Availability of Carbon Markets

Improved Forest Management on Private Lands

There is an inherent complexity to selling carbon offsets from Crown lands, especially those found within a protected area, or on Crown more broadly. The American Carbon Registry very recently developed a verification protocol for Improved Forest Management (IFM) on Canadian forestlands (ACR 2021). This protocol is for use on private lands, where there are fewer restrictions in terms land management policy. Improved Forest Management (IFM) involve forest management activities which result in increased carbon stocks within forests and/or reduce greenhouse gas emissions from forestry activities when compared to business-as-usual forestry practices. Therefore, IFM activities typically involve some level of forest harvesting, encouraging growth in multi-aged forest stands so they have the capacity to sequester more carbon as they grow.

NS Protected Areas would not be eligible for an IFM project because the baseline, or current land management protocol, restrict harvests therefore limiting the potential to showcase additionality, since there is no clear benefit in terms of minimizing risk of unsustainable forestry practices.

There is potential to launch a carbon project on private land, given the risk posed by pre-salvage logging (the baseline) and additionality offered through simply entering an IFM carbon agreement.

Given the ecological importance of hemlock, this type of project would be very attractive on the carbon market, through co-benefit certification⁵.

The process of entering a IFM project on private forestlands in Canada involves working with a third-party carbon developer to bring offsets to market. The process in which to develop the project involves several steps, including feasibility and education, listing development, inventories, modelling and documentation, verification, registration and issuance, and ongoing-support in execution. Up until recently, forest carbon offset projects have only been accessible to large private landowners, who can generate enough credits to make the costs of developing their projects worthwhile to developers, and at a scale that makes sense to those looking to purchase offsets. New methodologies now exist to allow small private landowners to aggregate and pool their resources into a larger land base that are more attractive to carbon purchasers.

To promote IFM with private landowners, support for organizations attempting to launch these programs is essentially to tackle the substantial development costs. The idea of developing an integrated pest management plan that balances chemical control with diversification efforts through ecological forestry is a novel way to help finance costs for landowners.

For private landowner to access carbon markets, they must come together as an aggregated pool (~10,000 acres) in order to make the project attractive to purchasers of offsets. These aggregated agreements are typically managed by an entity such as a land trust to organize the monitoring, verification and certification required to develop the project. Depending on the agreement between the landowner and the aggregator, the carbon offset project will earn significant revenue for the landowner, which can be used to chemically treat their trees.

The Nova Scotia Working Woodlands Trust (NSWWT) is a new initiative focused on placing Community Easements on working forests in Nova Scotia and will be developing an aggregated carbon pool in the near future. Working with a land trust such as NSWWT also assures the security of treated trees, as the easement is in place for perpetuity and the carbon agreement is typically in place for 40 years.

In addition to aggregated carbon projects, carbon markets will soon be accessible to landowners through tenure-based approach, using a deferred harvest method. This approach provides landowners with a cash payment for not harvesting their lands as carbon is sequestered, up to the point which total carbon sequestration plateaus and the landowner is encouraged to utilize a IFM harvest to continue to build their sequestered aboveground carbon. The downside to this methodology is the lack of long-term incentives since the agreements are only on an annual basis. The annual revenue would not be adequate to treat many trees, however, may be feasible if the landowner is able to.

Biodiversity Offsets and Credits

Biodiversity offsets have been a tactic used to mitigate loss of wetlands and freshwater ecosystems to development in Canada for years. However, the practice of combining biodiversity offsets with incentives based in the carbon offset market are quickly gaining momentum to help incentivize conservation, rather than as a last-resort effort. The early iterations of biodiversity offsets were often criticized as trading off high-conservation value areas, but modern offset programs are beginning to integrate 'no net Loss' or 'net gain' objectives (OECD 2014). If

⁵ Co-benefit certification implies that along with benefits related to carbon, the project also provides additional social or biological benefits.

developed properly, biodiversity offsets can offer a dual approach in both creating investment in biodiversity management and can provide governments comprehensive units of measurement to track biodiversity goals and commitments (IIED 2020).

9. Conclusion and Final Recommendations

A multi-faceted approach to conserving hemlock in a network across NS was designed to address this rapidly spreading invasive pest. The hemlock woolly adelgid is killing our largest and most aesthetic evergreen conifer, the eastern hemlock. The death of hemlock from HWA are permanent and catastrophic. Once old growth hemlock is lost, it cannot recover and cannot be restored to centuries-old structures that foster a unique environment and species assemblages. Our MCFC poll indicated that most Nova Scotian respondents are voicing support for protecting hemlock forests and saving some of our best and last old growth forests.

Forming a 'hemlock conservation network' is the over-arching strategy, Hemlocks will be treated with systemic chemicals to control HWA in an organized program delivery that aims to maintain some of the best hemlock stands in a healthy state for meeting long-term biocontrol objectives in 10-15 years. The network will be managed using a regional approach, dividing the province into four zones based on infestation status and threat level. Action-based scenarios were outlined for each region to control HWA and maintain healthy hemlock communities. The hemlock conservation network is further divided and administered where required for maintaining healthy hemlock across private lands.

Based on successful operational models in the US, consideration should be given to the use of tactical strike teams to provide an organized and rapid implementation of chemical treatments on the ground using three chemical products and several application methods to meet a range of situations. A triage of hemlock stands within each region will focus on old growth in protected areas that are storehouses of biodiversity as well as carbon and riparian hemlocks that protect both terrestrial and aquatic function. A tool kit with suggested strategies to render rapid and timely assistance to private landowners who want to treat and protect hemlocks has also been provided. Strategic emphasis is placed on education and outreach, fostering a more caring public, and engaging and coordinating volunteers to assist with saving old growth as inspired by the Sporting Lake Nature Reserve treatment event.

Government support for implementation of recommendations is integral to achieving a hemlock conservation network. A vision for protecting hemlock forests in the province is needed along with dedicated funding, provincial leadership, and people to support and make it happen. Funding and cooperation will be required from various sources – provincial, federal, municipal, charitable, and private sector. Finally, a team of professionals from federal and provincial departments, municipalities, researchers, landowners, and ordinary citizens working together is needed to achieve this vision.

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Appendices

Appendix 1. Lessons Learned on HWA Control: Advice from Scientists and Forest Managers in USA

Appendix 2. Landowner Survey Results

Appendix 3. HWA Treatment Decision Key

Appendix 4. Funding Resources

Appendix 1. Lessons Learned on HWA Control: Advice from Scientists and Forest Managers in USA

Ten interviews were held during February-March, 2022, with experts who research the biology and control strategies of HWA or who operationally work to protect hemlock forests through chemical applications on lands managed by various government bodies or protected areas in the USA. Some of them were top scientists who have led research on HWA for decades. Many of their messages were similar in nature. *Nearly all of them recommended getting an early start on setting protection goals and implementing treatments before extensive stand decline occurred to avoid making the same mistakes they have witnessed in some States.* Other recommendations were invaluable for selecting the right chemical application equipment that will ultimately save labour costs during chemical treatments.

Broad lessons learned are outlined below under general categories. Many of the best ideas were integrated into the Action Strategies of this report. All interview details are included in the Table 1 below, including contact information for obtaining additional information that shall be useful for planning field training and chemical treatment tactics.

HWA planning and early response strategies

- Set protection goals early.
- Devise a Hemlock Conservation Plan.
- Set the 'big picture' and long-term goals.
- Must have a landscape level conservation strategy in place with protected stands across the landscape to avoid hurricanes and other catastrophic events wiping out hemlock. Have a diversity of both young and old trees protected within stands. Stands are prioritized within the landscape.
- Regional climate based on plant hardiness zones dictates how HWA populations will respond and whether biocontrol predators required for long-term control will be successful here.
- Reach out to all land managers with heaviest hemlocks, including private landowners.
- The level of aggressiveness is critical to keeping our hemlocks alive. '*Laissez faire*' won't cut it. Places like Maryland treat every tree in the forest, and they are proactive with biocontrol, too - their trees look good as a result.
- It cannot be emphasized enough, according to Dr Salom, to get predator insects into our hemlocks early to allow them to build up populations.
- Nova Scotia hemlocks grow in a high-risk region for extremely rapid HWA-related mortality. Marine-modified temperatures create mild winters, particularly in southwest NS and in coastal areas. HWA populations can increase rapidly due to much less winter die-

off of adelgids than in many other areas of North America, such as the States of New York and Michigan. Negligible winter mortality across most of NS creates a more critical situation than in many other areas within the hemlock range in Canada. The rate of hemlock decline from HWA may be expected to be slower in NB, Quebec, and parts of Ontario.

- Focus on high value areas.
- There are several ways that one can prioritize stands/trees for treatment using a combination of ecological, economic and/or public values. Some stands are expected to be protected due to rare old growth status, and the trees further support rare associate species. Regardless of what is being treated, operational considerations remain the same, though some remote stands without road access will incur more operational planning and logistics.
- While treating entire stands may be the goal in some of the highest value stands, maintaining at least 30 trees/site may be a minimum in some cases contribute to the hemlock network, with a diversity of tree ages ranging from young to the very old. While this is not as ideal as treating and conserving an entire stand, it may be a reasonable alternative in landscapes where hemlocks are already in heavy decline and treating the entire stand is no longer plausible. Some stands in the southwest that are presently heavily infested may still have 30 trees per stand that are sufficiently healthy to treat. (Possibly discuss this some more with David Mausel.)

Communications

- Appealing to human emotion is part of a successful communications program. References to “saving hemlock” and “protecting old growth” are appealing to most Nova Scotians.
- To augment public support, focus on the potential destruction of forest resources that people love, rather than little known forested localities. The success in NY State support for treatment and a biocontrol program surged ahead when the HWA infestation struck the Adirondacks where wealthy citizens ‘lived and played’. Influential people from the Adirondacks garnered State support for Dr Mark Whitmore’s biocontrol lab, ongoing research, and his Extension Program.

Volunteer Support

- Garner public support and participation as volunteers for conserving hemlocks through an Education and Outreach Program.
- Contact fly fishing groups for support since hemlocks protect stream health/fish populations.

Chemical Treatments (some ‘take-home’ messages)

- Pollinators do not receive direct exposure to the chemical in *systemic* treatments unlike open applications with high environmental exposure in agricultural situations.

- Outline IPM strategies and field tactics (e.g., deployment of strike teams).
- *Make calculated decisions on what you will protect, inventory, prioritize, and try to get 'tier 1' stands treated as soon as possible.
- Xytect 2F is widely used in NY State.

Site Preparation

- *Survey all winter/Treat all summer.* This is the best strategy to be ready to go in the brief treatment window that may only be available in spring-fall. Summer treatments may take place but depends on weather.
- Some teams pre-mark and measure trees prior to commencement of treatment operations.
- The benefit to pre-marking trees with permanent tags is to facilitate faster chemical application and eliminating the need to remeasure DBH on subsequent treatments. However, if using Xytect with per ha limits, where not all trees can be treated the first year, then the spray paint color dots or some other marking scheme will be necessary.
- Draw upon treatment plans obtained from Hemlock Restoration Initiative (HRI) or from Jackie Broeker, Strike Team Coordinator, Tennessee Division of Forestry.

Chemical Operational Approaches

- Michigan is placing great energy into early defence tactics to stay ahead of HWA infestations. Michigan relies on extensive early detection surveys, followed by immediate and thorough chemical treatments of all infested trees, plus a delimitation buffer of treated trees within 240 m of each infested area. This way trees may remain in better health with more robust canopies when biocontrols are ready for release. The alternative is to wait until HWA populations build up, then resorting to broad scale chemical treatment on a few chosen high priority stands, with the hope that enough forest is conserved in good health for biocontrol releases. The first option sounds better for the trees and for future biocontrols, and possibly much cheaper.
- Adopting a Strike Team model for addressing the field work required to treat and conserve hemlocks is highly strategic and effective.
- Strike Teams address limits with staff time and budget capacity.
- Crew leader is ideally experienced in tree marking, mapping forest stands/treatment areas, generally a forester. (This will be more important if NS is able to use Xytect 2F and it has annual/ ha limits.)
- Strike Teams could treat on crown and be available to train and assist some operations with private landowner groups and private conserved lands.
- Strike Team training can require 2 weeks. There is particular training involved if Xytect is utilized under annual hectare limits.

- Given the efficiencies demonstrated with a volunteer-led operation at Sporting Lake, we recommend integrating volunteers into some Strike Team situations, particularly if employing the BioForest EcoJect treatment approach.
- Crew works together for 8 months unless there is drought. Treat Oct to May (not our NS season). They receive training and follow a fieldwork Standard Operative Procedure (SOP), which can be made available to NS on request. Crews are travelling crews who receive priority use of available cabins and wilderness facilities, similar to wildfire crews.
- Crew examines the whole stand in its entirety and then picks out the trees on a map using a 1-acre grid.
- The forester/crew lead prepares the treatment area, conducting a 'timber cruise', measuring Basal Area (BA) per acre, and marks/paints the trees to be treated. Since they can only use 181 fl oz in the soil drench application (the equivalent of 1.89 L/ha/yr in Canadian units), the crew lead stretches out that per acre limit throughout the stand to keep it intact. They don't want the first part of the stand totally drenched in chemical and the rest untreated. They have a 3 yr rotation to complete the whole stand. They save their shape files.
- If authorization for emergency use of Xytect 2F is achieved and it comes with similar usage limits as in USA, then explore options for using it only on the smaller trees that are too small for injection and continue to inject larger diameter trees since injections have no usage limits. (This was the approach adopted by Drew Rayner, Michigan DNR (see interview details). Small trees cannot be injected (will cause too much damage), so they basal bark spray small trees under 12.7 cm. *Since this uses only small amounts, they avoid exceeding the Xytect limits.
- Chemical control: Treat high-value sites and create a geodatabase of treated locations.
- Evaluate emerging least-toxic pesticides for efficacy and potential use as they become available.
- Best tree injection sites are the root flares - these provide the best uptake and product distribution to the canopy (D McCullough).
- Maintain a good database so that when areas are due for chemical re-treatment, they are not neglected/forgotten, which would negate the initial investment in pesticides. Re-treatments in some places in New York are becoming 'past-due', which is concerning.

Financial support

- Adopt a multi-pronged funding resource approach.
- Funding ranges widely from state to state. HRI receives ~ \$300, 000 annually.
- Cost sharing program for private lands works well.
- Reach out to private donors, bequeaths.
- Consider a cost share for both EAB and HWA biocontrols.

- Whitmore is in different economic situation ever since HWA arrived in the Adirondacks where private landowners who have wealth have funded ~80 % of his biocontrol program.
- Cost sharing program for private lands works well.
- New York State Hemlock Initiative (NYSHI) advises Dept of Environmental Conservation in conjunction with the PRISMS- to organize the treatments/allocate funds.
- For biocontrol efforts, some States allocate some funds to private land. There has been some cost sharing for EAB activities for private landowners. Sometimes there are off-sets to reduce the burden on private landowners. How these were set up requires further discussion with US land managers.

Database

- Dr Whitmore advises keeping all information in one place- treatments, how, when, etc. The database should contain both chemical treatment and biocontrol release and tracking information.
- Match USA database platforms (e.g., HWA Predator Database)
- Consider requesting to use the same map-based tracking database set up at Virginia Tech. (Contact Scott Salom or David Mausel to kickstart discussions. Their contact information is included in the interview table).
- Set up the database properly in the beginning. They are trying to reconstruct it in the USA since earlier treatment years were not properly recorded.

Monitoring

- “Impact Plots” in North Carolina are used for conducting follow-up monitoring after treatments, where a small, representative portion of the treated stand is selected for monitoring the ‘impacts’ of chemical treatments on HWA.
- Recent eDNA research holds promise for easily detecting and monitoring low levels of HWA. This technology may be particularly useful for determining survival of HWA predator insects. Scientists believe eDNA is a promising tool for the HWA biocontrol program. It may also help indicate the best time to retreat a stand. (eDNA or ‘Environmental DNA’ is DNA that is collected from a sample from the environment such as soil, air, or with regards to hemlock monitoring, can be the rain water that falls through hemlock canopies which may gather the DNA of the many insects living in a hemlock canopy including HWA predator insects. It negates the need for directly sampling an individual insect. As the insects interact with the environment, DNA is expelled and accumulates in their surroundings. In this case, DNA from HWA skeleton castings, the woolly masses, etc, may be found in the forest environment and be easily detected in eDNA.)
- Headlamps (high lumen/focusable beam) can speed up HWA monitoring and greatly facilitate detection in stands without available low branches to inspect.

Biocontrol Updates and Advice⁶

- Biocontrol predators are our best shot at controlling HWA.
- Our trees are not adapted to this sucking insect and there are no natural predators that feed in sufficient numbers on the adelgid.
- Decades of HWA biocontrol research south of the border may have nearly finalized the predators required to keep HWA populations in check.
- To preserve ecological function and eventual deployment of biocontrol agents, focus on all size classes, young and old.
- Biocontrols are even more essential in NS because our HWA populations will not generally experience high winter mortality (the winter of 2021-22 being the exception because it was colder than usual). In New York State, winter mortality ranges from 10-90 %, with the remainder of suppression assisted by *Laricobius* which has been having a continuous impact from generation to generation. But winters are colder in NY than in Nova Scotia's ocean-moderated climate. (Ithica, NY had 99 % winter mortality of HWA in 2022.) remainder of HWA suppression assisted by *Laricobius* which has been having a continuous impact from generation to generation. But winters are colder in NY than in Nova Scotia's ocean-moderated climate. (Ithica, NY had 99 % winter mortality of HWA in 2022.)
- Continued monitoring of over-wintering HWA mortality is required in different regions of NS (NRR Forest Protection). The winter mortality information is needed for insect predator releases.
- Troy Komoto, CFIA, has best knowledge on the west coast for finding HWA predators for Canada.
- Dr David Mausel was moderately cautious that HWA biocontrol will be successful because there had been no recovery of over-wintering silver flies.⁷ (Two spp of *Leucotaraxis* had been released but not re-found so there were concerns they do not survive winter.) A spring predator for the second generation of HWA is vital, or the HWA population rebounds quickly. Researchers will allocate 5 more years of effort before determining success or failure. If silverflies fail, they will have to start over searching for a predator for the second HWA generation, and a fully successful biocontrol program would be greatly delayed.
- Develop regional release strategies for high-value sites. Increase the *Leucotaraxis* spp. effort (e.g., understanding its biology, conducting releases, monitoring population establishment, and rearing requirements). Continue rearing and releases of *Laricobius osakensis* in the short-term (USA). Redistribute coastal/inland *L. nigrinus* in the east and augment with western collections if needed. Phase-out rearing of *Laricobius* spp. and retool labs for *Leucotaraxis* spp., if silver fly population establishment occurs (i.e., F3 generation). Continue annual biological control meeting and technical oversight.

⁶ Hemlocks must be kept healthy so the beetles will survive and disperse, and islands of healthy hemlocks should be preserved throughout the range.

⁷ Since Mausel's interview, Dr M. Whitmore reported that *Leucotaraxis* had survived the very cold winter (2022) and so success seems imminent.

- **Integrated pest management:** At high-value sites, maintain hemlock health by suppressing HWA below hemlock's physiological damage threshold through integrating biocontrol (*L. nigrinus* or *L. osakensis* paired with *Leucotaraxis* spp.), with chemical treatments, and possibly silvicultural/forest development practices (e.g., thinning, group selection).

- **HWA-resistant trees**

In the USA, resistant hemlock genotypes, either of putative susceptible species identified from devastated landscapes or through breeding with resistant species, are under evaluation and development.

- A project to search and mark potentially resistant trees may be beneficial as more stands die in the southwest, but environmental factors and delayed infestation can make detecting such trees very challenging.
- Land managers should be advised against pre-emptively harvesting live hemlock on the assumption they will die, as this negates the possibility of finding genetically resistant hemlocks.
- Finding truly resistant trees should not be counted on as a strategy but continue to look for them in case they exist. Understand that other environmental factors and the vagaries of HWA population fluctuations will serve to confuse interpretations on resistance. While some of the science by Pressier and others looks promising there are issues with the scientific approach and conclusions.
- Even if we did find resistant trees, it would be a monumental feat to repopulate hemlocks that are resistant to HWA throughout its range. And this does not aid the suites of species that currently live and depend on hemlock stands, nor protect against the ecosystem services lost in the century or more it would require to repopulate hemlocks.
- Dr Salom best sums up HWA resistance in hemlock as: "It's a long game. A very long game. It doesn't do anything for us now. It won't save the trees [we have now], but perhaps centuries from now, it will be useful."
- The only sure bet right now is preservation with insecticide of high conservation value areas. Don't count on genetic resistance but keep searching for it.

Preservation or "Backup" Strategy

- Ensure adequate seed preservation at National Seed bank to preserve adequate genetic diversity of eastern hemlock.
- Preserve entire intact hemlock groves so future generations can experience them, especially important when we think how many would have liked to see a Chestnut grove, towering elm trees along streams, or dark, smooth-barked American beech forests.
- Maintain healthy hemlock seed orchards as part of the 'backup plan'.

Table I. Details of Discussions with 10 HWA managers and scientists in USA, Feb-March 2022.

<p>Margot Wallston Director, <u>Hemlock Restoration Initiative (HRI)</u> % WNC Communities 594 Brevard Road, Asheville, NC 28806</p>	<p>(828) 252-4783 director@savehemlocksnc.org Facebook: <u>Save The Hemlocks</u> Instagram: <u>@hemlock_restoration_initiative</u></p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Background: The Hemlock Restoration Initiative (HRI) is a non-profit organization located within the Western North Carolina (WNC) Communities program. “WNC Communities” supports community development and agriculture initiatives across Western North Carolina. This group is closely tied with State Dept of Agriculture. They also have expertise and networking with the Forest Service. They can also work with ‘private conserved lands’. HWA arrived in 1995 in North Carolina. They now have 7 counties with HWA. Some sites got treated early. In 2002, Great Smokies N. Park witnessed massive mortality. It took 20 years to be actioned and by then 80 % hemlock mortality. Protection didn’t start until 2007. Margot began as the HRI coordinator, with email handle: coordinator@savehemlocksnc.org She is now Director, HRI, with email director@savehemlocksnc.org</p>	<p>The HRI website invites people to donate and participate in ‘saving hemlocks’, and may provide us with some useful templates, such as their treatment video and advice to landowners.</p> <p>-Consider hiring a ‘<u>Hemlock Conservation Extension-Outreach Volunteer Coordinator for NS</u>’.</p>
<p>Funding: They receive funds from county level grants, private foundations and donors. Sought long-term State support. Must have funding for the ‘long-game’. <u>HRI was founded with \$100,000 from the N.C. Department of Agriculture and Consumer Services in 2014.</u> HRI is assisted by State financial support. Requested \$300,000 of recurring funds for the HRI in the State’s fiscal year 2019-20 budget. “There is ongoing management that has to be planned for,” says Wallston. “Longevity will not only allow us to do that planning work, but it will also allow us to get some additional funding support from those who want to ensure that it will not die out in a year or two.</p>	<p>Hemlock management requires long-term government funded support, since longevity allows the required planning work to take place to achieve the long-term vision and allow long-term solutions to get underway.</p>
<p>Communications: Their website uses the effective handle “Save Hemlocks North Carolina”, providing an appeal to the emotional sense of North Carolinians who want to “save hemlocks” and information is placed under info@savehemlocksnc.org . Under the banner on their front webpage is a clearly stated goal: “Returning NC Hemlocks to Long-Term Health” -The HRI website is very active. It indicates lots of present and past events that engage people in hemlock stands, to educate, become aware, and some practical events to learn how to treat hemlocks.</p>	<p>- Appealing to human emotion is part of a successful communications program. References to “saving hemlock” is appealing to most humans. - A website for hemlock that contains lots of practical information and posts lots of ‘hands-on’ and ‘in-the-forest’ events for landowners is an engaging and useful tool. -Produce some educational videos on the HWA situation and treatments in NS similar to HRI videos.</p>

<p>-HRI has produced an excellent video for landowners on their website: How to Treat Hemlocks for HWA</p>	
<p>Hemlock Strike Team: Margot had no staff- a major pitfall in the beginning. You cannot ask other people to do more work. A Core team is required to go in and deal with the work involved to save hemlocks.</p> <ul style="list-style-type: none"> -They now have a crew that can go out and evaluate stands and facilitate treatment. -They have a team ready to go around to different properties, maintain treatment gear, etc. <p>Hemlock strike teams have a tablet with 1-acre square grid. They count stems in grid system. They create a polygon that represents the entire target area.</p> <ul style="list-style-type: none"> - They have to choose which trees to treat if using Xytect 2F because of acre limits/yr. - Tree marking is used if there is stand decline. Their primary objective is to cover the maximum amount of forest and get hemlock treated. -Licensed applicators take on the liability and responsibility. They work with unlicensed workers under their supervision. Volunteers have to work under the supervision of a licensed applicator. 	<p>Hemlock Strike Team:</p> <p>Forming a couple of NS Hemlock Strike Teams would allow treatment dollars to have maximum impact. Each team would have a crew lead and a licensed pesticide operator (who could be the same as the crew lead). Other team members could be volunteers.</p> <ul style="list-style-type: none"> -The crew lead would be someone ideally experienced in tree marking, mapping forest stands/treatment areas. (This will be more important if NS is able to use Xytect 2F and it has annual/ha limits.) -The Strike Team could treat on Crown and also be available to train landowner groups and lots of volunteers.
<p>Database: They have a centralized database with georeferenced information needed for follow up treatments and monitoring. Keep information simple.</p>	<p>Database: Set up a central database with georeferenced treatment information. The database should also accommodate private land treatment information. This is useful for subsequent biocontrol information (i.e., creating the landscape patchwork of healthy hemlock).</p>
<p>Chemical control:</p> <ul style="list-style-type: none"> - Chemical is stored with the State Forest Svc. <p>Who does the work? HRI works with volunteer groups.</p> <p>-HRI has successfully used the Young Offenders Forest Conservation Program — commonly known as BRIDGE — an initiative of the N.C. Department of Public Safety that pays prisoners who opt in \$1 per day while training them to fight wildfires and conduct other forestry work. Wallston stated that the BRIDGE work crews are “a huge asset” and notes that they have treated over 45,000 hemlocks over the past several years. <i>“When BRIDGE crews join us in the field, members frequently express their appreciation for being able to participate in the program and develop the natural resource management skills they learn through the program,”</i> she says.</p> <ul style="list-style-type: none"> - North Carolina also trains in-mates to help with Resource Mgt activities when they are not fire fighting. In-mate labour works v fast, but quality control has been an issue (e.g. treating dead trees or non-hemlock species). 	<p>Chemical Control: Who does the work?</p> <p>HRI has maximized work with volunteers.</p> <ul style="list-style-type: none"> * volunteers eliminate labour costs. -A “Bridge” program has allowed young offenders to help treat trees and been very positive for providing young people with natural resource management skills. - The NS Youth Centre in Waterville is receptive to exploring a ‘Forest Conservation Program’ for some of their youth. A preliminary discussion was held with Jim Nickerson, Youth Custody Manager (902 538-4202), who is receptive to further dialogue. He also suggested <i>Valley Integrated Youth Services</i>, where many more youth participate. Among their goals is to assist youth to secure employment and work with community-based partners. He named a couple of community projects where they have already had success.

Method: They don't have a lot of experience with stem injection. Soil drench is the cheapest and easiest, with least amount of complication if there are no flowering plants. Basal bark spray is an easy alternative.

- They do not pre-mark the trees since this requires visiting the trees twice. However, this does make treatment applications go faster.
- Volunteers must be able to accurately measure trees, if someone is not available to tree mark the stand.
- But tree marking is useful if stand is in decline.
- They don't tag or number trees. They treat all trees with paint. They treat entire stands. Hemlock Treatment Plans provide more information.
- Ohio has developed a stem-injection system with a disposable syringe (has a 1-pg pdf on this)

Productivity: Over past 10 yrs, treated > 100 000 trees.

- Can treat 50-200 trees/day with their crew.

Treatment costs: Treatment with just Imidacloprid alone typically costs about \$0.75-0.80 per diameter-inch.

Buffer: There are no "setbacks" for any applications for imidacloprid if soil is not saturated (remember these are soil drench applications). But they do have a 10 ft buffer when treating on flood plains that are going to be flooded or right up against a creek or places where there are flowering plants. Trees leaning over water- can't treat.

-North Carolina also trains in-mates for Resource Management protection, i.e., fire control and hemlock treatments.

Method: The benefit to pre-marking the trees with permanent tags is to facilitate faster chemical application and eliminating the need to remeasure DBH on subsequent treatments. However, if using Xytect with per ha limits, where not all trees can be treated the first year, then the spray paint color dots will be necessary.

It may speed NS planning to ask for a copy of one of HRI's Hemlock Treatment Plans.

Productivity: Can treat 50-200 trees/day with their crew.
Treatment costs: Treatment with just Imidacloprid alone typically costs about \$0.75-0.80 per diameter-inch.

Buffer: A 10 ft (3 m) buffer is required since they use the soil drench method. We could propose a 3 m buffer based on results of CFS and McCarty's research. Ensure buffer width is science-based.

Treatment strategy: Their first approach was to teach how to do hemlock treatments.

At first, they had a conservative approach of just maintaining the limited treatment they had. But now, they think they needed to treat more initially. Also, they did not treat little trees. Now they believe they should have treated "all trees" initially.

- Drought exacerbated their efforts to preserve trees with HWA.
- Stretch out re-treatment intervals. Return intervals for re-treatment did not have to be as frequent as originally thought (every 3 yrs), maybe every 5 yrs now. They are now re-treating campgrounds that have all super healthy hemlock and HWA poplins are low. Perhaps they could have waited longer until adelgid populations returned.

***Hemlock Treatment Plan Expansions**" When they do IPM, they don't retreat all trees.

Treatment Strategy: Try for a "blanket level treatment". **"Don't be selective. 'Go big' on the initial treatment round"**- advises Walston.

- If the adelgid population is curtailed, then be more selective.

***Preserve ecological function and focus on all size classes, young and old.**

-Re-treatments may be more selective once the adelgid population is lowered/ likely needed every 5 years (though USA uses mainly soil drench that produces more olefin and lasts longer. They tend to have higher winter mortality, so we will need to evaluate treatment intervals in NS.

- **"Hemlock Treatment Plan Expansions"** for retreatment where not all trees are treated, particularly for situations when using Xytect with per ha limits, or for IPM when biocontrols are ready and do not want to treat all trees.

<p>Private land treatments: It has become easier to convince landowners to protect their hemlock because HRI can provide a range of available options to them. Land owners are more interested than they were earlier.</p> <ul style="list-style-type: none"> -HRI program began with a list of approved contractors that were paid up to 50 % of the total cost. Contractors had to be licensed and insured. They were to submit a proposal to HRI. But contractors were expensive and treated less of the land base with their prices. There were 'front country' contractors (landscapers) but need backcountry contractors in many cases. All in all, the program was less successful than having an approved team to go out to private land. <p>*Suggest setting up a private land program where private landowners become certified- as a way of getting a lot more done.</p> <ul style="list-style-type: none"> - Improve the private land program with more advanced outreach and education and establish a private land program with an approved team. <p>-Private landowners fill out a survey on what was treated. That way we know which private lands were treated.</p> <p>-Run private program through an established program/Use an approved team rather than private contractors.</p> <ul style="list-style-type: none"> - Private lands- put a cost-share program in place. They do a lot of hands-on workshops to train private landowners. <p>*Provide kits for rent.</p> <ul style="list-style-type: none"> -Education is important. Tell people why these trees are so important. <p>* Also offer field trips to see untreated hemlocks</p> <p>An effective way to spread resources widely:</p> <p>*Provide workshops to help facilitate property owner associations/cottage owners so they can conduct the tree inventory and learn how to do the application. They contribute to the labor and knowledge and contribute to the costs with min 50 % contribution to cover chemical costs, transportation, staff time, spray paint. The rest is supported by grants.</p> <ul style="list-style-type: none"> -Incentives to ensure they won't harvest the trees: They were willing to invest so they must want to conserve the trees. Costs of treating the trees is cheaper than having an arborist fell the trees or doing roof repairs. Or focus on the common green spaces that are already protected. -West Virginia had a cost-share program with a state run crew to treat trees. 	<p>Private land treatments:</p> <ul style="list-style-type: none"> - Put a private land cost share program in place. Government or an NGO similar to HRI (an NGO that recognizes the need for chemical control and will facilitate rather than oppose) provides some practical outreach and education to landowners and cottage owners. (This will have to be offered regularly for landowners in many areas as HWA spreads.) -Education/Outreach begins with learning about the importance of hemlock, ecosystem function, wildlife habitat. Teaching people to care. Education is important. Tell people why these trees are so important. Show them untreated stands. -Provide practical hands-on training on tree marking and treatments. -Provide a cost-share program with oversight from the province. -Provide treatment kits for rent or a deposit. -Facilitate private landowner training and pesticide certification to treat trees to expand capacity/spread resources widely to meet the sudden, rapid need to address widespread hemlock infestations. (Consider a new limited pesticide operator card that permits only tree injection and basal bark treatment and chemical purchase-with a modified exam that is specific to hemlock and ash tree care.) - Publicly available kits for injection or basal bark spray for rent or deposit. (They could contain safety gear, plasticized instructions, etc.) The public kits could contain a datasheet that gets returned with the gear. Ideally devise a method to track what was treated on private land.
<p>Thresholds: 1) Live crown > 50 %, 2) moderate dense to dense foliage, 3) HWA infestation level mod to high. If tree has lost its pump, they don't treat. They use lower thresholds when using dinotefuran.</p>	<p>Thresholds: <i>It might be beneficial to question Margot some more.</i> If tree has lost its pump, they don't treat. They use lower thresholds when using dinotefuran.</p>

<p>Monitoring: Instead of taking notes on every tree they treat, they use “Impact plots” where a subset of trees are marked to serve as a measure of how the whole stand is responding. A sort of PSP method.</p>	<p>Monitoring: “Impact Plots” are an approach to monitoring a subset of the treated forest. Adopt a PSP-like approach. Devising a post-treatment monitoring plan to assess 1) treatment responses, 2) Ideal timing for retreatment. Also monitoring responses in different regions of NS with different weather patterns and soils. Monitoring responses of trees in various states of decline.</p>
<p>Biocontrol: They released beetles where stands were already stressed and declining, so the trees all died regardless.</p>	<p>Biocontrol: *If release biocontrols into stands already stressed and declining, efforts may be futile. *Hemlock must be kept healthy so the beetles will survive and disperse. * Must have islands of healthy hemlocks preserved throughout the range. Also maintain healthy Hemlock seed orchards.</p>
<p>HWA Resistant Trees: They have a local research project to find resistant trees. It’s almost impossible to know which trees may be resistant. Environmental conditions or delayed infestation are often factors for residual live hemlocks and so it is extremely hard to differentiate resistant trees.</p>	<p>HWA Resistant Trees - A project to search and mark potentially resistant trees may be beneficial as more stands die in the southwest, but environmental factors and delayed infestation can make detecting such trees very challenging.</p>
<p>Mark Whitmore, Forest Entomologist, Director New York State Hemlock Initiative (NYSHI) / Senior Extension Associate, Natural Resources and Environment, Cornell University</p>	<p>Contact info: C: (607) 280-4064 www.nyshemlockinitiative.info</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Background: Hemlock is the 3rd most common tree in NY. -He feels like he spent significant time “spinning wheels” without a lot of support. Mark regarded EAB as fortunate for making people aware of forest pests. He worked some in “extension” and people wanted to hear about EAB, but he would also talk about HWA. But he wasn’t getting people to care as much as they should about dead trees, even when dead trees fell across roads, closing them, etc. People didn’t pay much attention, didn’t recognize the threat. -HWA arrived in 1980s, but it was 2 decades before treatments began. -Everything changed when HWA reached the Adirondack’s where ‘rich people live and play’ and home to the “Adirondack Mtn Club”, etc, and where a state lawyer lived who had sued over acid rain that led to new envir. legislation. When this lawyer spoke to State Governor, ‘money flowed’. Suddenly in 2016, \$1 million was directed at Mark’s lab, 0.5 annually thereafter. He now has the wealthiest lab in the country. He was able to get the lab up and running at full speed, from having only 1 technician to hiring a</p>	<p>*Focus on the potential destruction of what people love. Often people do not recognize the threat of HWA until it reaches a stand that they personally care about. <i>In this case, the Adirondacks were loved and where rich people lived/played.</i> -Keep trying to reach people from difference angles. * It is useful to have a powerful ally who can speak to people in power. <i>This is what happened with the Adirondacks and what partly contributed to the success of Sporting Lake. When an MD and lawyer/CEO of a large law firm who shared strong connections to the place and to decision-makers, speaking directly to them, permission was granted to proceed, and large donor support procured.</i> *Outreach/Extension program is important on private land. No one was doing any targeted outreach, so no one</p>

<p>whole team. He's had to step away from outreach/extension tasks but this program remains very important. He now has someone dedicated to working on outreach, which is extremely strategic to success.</p>	<p>saw/understood the threat to the resource. You have to start at the very beginning. People don't know what hemlock are. Then they learn, "What? I could have saved that tree?" *Hire a Hemlock Conservation Extension-Outreach Coordinator: * who organizes volunteers, training, comms, website, social media, etc. Mark says hiring this staff position was his best investment at his lab.</p>
<p>Programs: <u>Detection mgt</u> is the 1st step. Detection for most of his career involved only a few people who were 'in the know'. But now the State has created PRISMS. PRISMS are funded by the State. PRISMS have discretion to spend where they want. They are putting together detection teams. They hired teenagers and got things done. Mark hired an <u>Outreach Coordinator</u>, Caroline Marshner. This was a strategic investment. They also hire an undergrad to help with Outreach and one also in the lab. They are also working on volunteers, really focusing on that. Retired people who want a mission. Doing amazing work! It requires one of his staff to organize and educate/train the people, make them feel good. You need to have a constant contact (not someone switched in/out). Volunteers need validation for their efforts. - It takes full time attention to keep those groups together. Takes burden off Mark to make presentations and provide the training. Early detection is essential because it allows for more effective management. If you get there early, the tools we have are much more appropriate. (Can just use lmid, without need for dinotefuran or some other expensive knockdown chemical.) Resources are limited, so need effective. The headlamp allows for faster detection by picking up residual wax.</p>	<p>*Early Detection monitoring is what allows for effective management, because it allows earlier intervention with cheaper tools/ reduces cost. (For e.g., they won't have to use the more expensive dinotefuran if they can detect and start treatment earlier.) Since resources are limited, this is most effective. * Purchase headlamps to more rapid, easy detection of HWA. Whitmore's most valuable tool: Coast XPH34R LED headlamp with a focus beam 2000 lumens. "It's a game changer," says Whitmore. The headlamps pick up the waxy residue. It can even be used during the day to search for HWA, but the best survey time is at dusk. HWA can be detected ~ 10 m into canopy. Uses it on west coast to help find HWA and predators, and on east coast for early detection. Focus the beam (don't use diffuse setting). Get an extra battery. When Mark has \$ 1 k left over, he orders 10 of these lights. -Students "get things done" re: Detection surveys. -Retired people who want a mission/purpose are doing amazing work. -The Extension-Outreach Coordinator- Coordinates these pools of volunteers. It requires a full focus to educate and train them, validate their efforts, organize them. Possibly hire an undergrad student to assist the Coordinator as they do at Mark's lab.</p>
<p>Chemical control: The farm lobby is responsible for keeping imidacloprid use in USA. The disaster in the Great Smokey Mountains National Park (GSMNP) informed our current use of insecticides. Hemlock mortality was rapid. Blozan developed the technique of using dinotefuran and imidacloprid because of his advocacy of saving the old trees. -TreeAzin may be over-marketed as an organic. The development of pyrethroids took the same approach. Just because it's organic doesn't mean it doesn't kill. Discussed whether the compound in TreeAzin is synthetically manufactured.</p>	<p>Chemical control: If stand is old growth, treat every tree. In other pure hemlock stands, you don't have to treat every tree due to root grafting (Cowles and McCarty Pers comms.). No one has done any research on this yet. Petition for the pesticides you need. They had to do this in New York State to use basal bark spray, dinotefuran to save stands that needed fast action, CoreTect tablets, etc.</p>

<p>- Dr. Richard (<i>Rich</i>) Cowles, Connecticut Agricultural Experiment Station & Elizabeth Benton (McCarty) (did all her research in GSMNP) have completed the most work on chemical treatments.</p> <p>-Dinotefuran ('Dino') was first illegal in NY and you couldn't apply Imidacloprid as a basal bark spray. Mark petitioned to change that. Rich Cowles 1st showed that basal bark spray works. Tank mix of both Imid + Dino -used in State Parks (that were <i>way behind in stand decline and needed emergency treatment</i>). In the south they had to use Dino, whereas in the north, die off was slower. Treated priority stands of OG.</p> <p>-CoreTect tablets were cheap and a lot easier to apply. Used in GSMNP. Use a bulb planter to get down to mineral soil, place the CoreTect tablet, then cover it up. It's a 2-year time release formulation. It takes ~3 years to get the full amount into the tree. They were allowed to apply 2X chemical bec/ of time release. If you have a heavy infestation, it might be good to consider these tablets.</p> <p>- Use injection occasionally when it is 'politically important'. He doesn't think the basal bark sprays threatens stream health. Just be careful about applying it. Mark would rather see the trees saved and the injection method costs way too much. The amount finding its way to the stream would not be a sig impact. Be pragmatic.</p>	<p>Basal bark spray can be quite safe. Dr Whitmore believes it is safe to use basal bark spray with a good operator on trees near streams, with minimal risk of chemical in water. Take a pragmatic and cheapest approach. For this reason, he uses injection very minimally.</p> <p>Plan well in advance for subsequent treatments. *Re-treatments in some places in NY are becoming past-due. This is a concern.</p>
<p>Biocontrol: 20, 000 flies and beetles were produced last year. Now starting a lab in Oregon, west coast, where he can avoid needing a quarantine facility. In the east, they must quarantine what is brought from the west because they don't want to bring the western strain of HWA out east.</p> <p>Must do the over-wintering mortality studies to see if we get a huge die off like NY. Makes a huge difference in the decision of where you release predators if there are huge die-off. David Mausel and Rusty Ray- they are ramping up predator populations.</p>	<p>Canada may want to mirror Whitmore's approach of producing HWA predator flies and beetles on the BC coast so we can avoid need for a quarantine facility. It would better ensure that the western HWA strain cannot be introduced in eastern forests. It may be both be safer and cheaper.</p> <p>-Conduct over-wintering HWA mortality research in different regions of NS. Winter HWA mortality information is needed for predatory releases. -Troy Komoto, CFIA, has best knowledge on the west coast for finding predator bugs for Canada.</p>
<p>Funding/Partners: Funding mostly comes from Federal and State funding, and now also private donations. The USDA Forest Service and the State of NY, Dept of Envir Conservation. There was no public funding in earlier years. The Great Lakes Restoration Initiative provides some. Allows money to be spent on private properties at the discretion of the group.</p> <p>-The concept of carbon credits did not advance due to governance by Trump.</p> <p>-Tax incentives have not been helpful so far. Monies to manage your forest pertains to how the State deems forest management to be; it always involves cutting the trees.</p>	<p>Funding: NYSHI advises Dept of Environmental Conservation in conjunction with the PRISMS- to organize the treatments/allocate funds.</p> <p>Contact fly fishing groups for support since hemlocks protect stream health/fish populations. Reach out to private donors, bequeaths.</p>

<p>-Private donors: Bequests-One of the volunteers who worked in the group a long time left a sizable donation to hemlock when he passed. Received funding from a fly-fishing group consisting of wealthy members. A Rockefeller got together with some of his friends and funded a position.</p>	
<p>eDNA works! Wash foliage in sterile water and then filter the water to collect DNA. Install trap (1 m² plastic tarp with a hole in the bottom and a carbon filter) Put traps out across the landscape, then collect filtered water and check for eDNA. Use the traps in areas where they release the predators so they can follow their population buildup and spread from release points.</p>	<p>Monitoring Tool: eDNA will make low levels of HWA very easy to detect/monitor, but most importantly will help detect survival of HWA predator insects. It's a promising tool for monitoring. It may help indicate the best time to retreat a stand.</p>
<p>Strike teams are forming in PRISMS. The idea began in Tennessee.</p>	<p>Strike teams- they are a successful approach used in several States.</p>
<p>Land trusts and Nature Conservancy: They are into buying land but are less involved with preserving it. This is troublesome.</p>	<p>USA Conservancy lands could broaden their focus to conserving the integrity of forests they have already purchased rather than just purchasing more land.</p>
<p>Database: Caroline Marshner keeps their database. They use iMAP invasives-enter all data there. It is challenging to keep track of treatments and efficacy data. Have to evaluate regularly. They've created Apps that can be used in Collector (ESRI product) in conjunction with a Garmin GO GPS- this is now being adopted by agencies in USA for treating trees. Can get all the information in one place- how it was treated/when, photos of the tree.</p>	<p>Database: Keep information all in one place- treatments, how, when, etc. Match USA platforms.</p>
<p>Resistant trees- They don't exist as far as he knows. Part of confusion in thinking trees are resistant is confounded with the vagaries of HWA population fluctuations. HWA can become locally extinct. HWA can build up in a stand, causes trees to decline to the point that they don't produce new shoots and causes population collapse and goes locally extinct. But later HWA migrates back into the stand. Genetic resistance research is with Evan Pressier's lab. He works with <u>young trees</u> and be aware that other researchers believe the results over-extrapolate what is going on in big trees. His lab has students out evaluating stands and drawing conclusions on resistance. Perhaps requires more scrutiny. Trees were out-planted when HWA populations were low. Conclusions were drawn from very few trees. The 'Bullet proof stand'- the scientific approach was questionable. U. of Rhode Island research may cloud reality.</p>	<p>Resistant trees- Don't count on finding truly resistant trees but look for them. They don't exist, as far as Dr Whitmore knows. Understand that other environmental factors and the vagaries of HWA popln fluctuations will serve to confuse interpretations on resistance. While some of the science by Pressier and others looks promising there are issues with the scientific approach and conclusions.</p>

<p>David L. Mausel, Ph.D. Regional Entomologist, Forest Service State and Private Forestry, Forest Health and Forest Markets, Eastern Region (R9)</p>	<p>c: 414-267-7136 david.mausel@usda.gov 626 East Wisconsin Avenue Milwaukee, WI 53202 (He's in Michigan, not yet in Wisconsin)</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>

<p>Managed ¼ million acre land base. Joined USDA Forestry about 1.5 yrs ago. David completed PhD research under Scott Salom on <i>Laricobius</i>. David questioned/examined plant hardiness zone maps to predict HWA behaviour in NS. The USDA plant hardiness zone map is a useful tool, based on lowest winter temps. Adelgids do not seem to kill trees in zone 5a. HWA in zones 6-7 will experience some winter mortality. (Dr Salom said that zone 6a is the minimum for beetles to survive.) There may be an international meeting of the NE Pest Council to gather all HWA folks together. They've worked on HWA since the early '90s.</p>	<p>Based on plant hardiness zone map, our forests are in a high-risk area with generally no winter die-off of adelgids. NB will be better off- the blue areas on the map indicate areas where HWA will be slow to impact hemlock. Use the USDA Plant hardiness zone map based on absolute winter minimum temps to forecast how HWA will perform.</p>
<p>General land management strategies: Focus on high value areas and use</p> <p>Devise a Preservation Plan. Funding limits us. Do we treat all trees? Therefore, try to get 30 trees/site. You want to have a diversity, with some young trees and some old trees. Have protected stands across the landscape- to avoid hurricanes, catastrophic disturbances that wipe out an entire stand that you may have preserved.</p> <p>Most states have a detailed conservation plan for 5 yr span or more. He was willing to send the plan.</p> <p>1. Set the 'Big Picture'-long-term goals and landscape level planning.</p> <p>2. Strategies</p> <p>3. Tactics</p> <p>Multiple strategies required. Silvicultural strategies are not a good idea by themselves- to selectively harvest, open up the growing space for the biocontrol. He sees it as a part of the IPM plan down the road when biocontrols are ready, after which you can then do a thinning, and in areas where climate is suitable with occasional cold blasts. It can be used in conjunction with biocontrol and selective biocontrol. But just to thin a stand and walk away is not going to help much/doesn't do anything other than potentially giving the trees a little extra boost and growing space. It can be in an IPM and recommended to a landowner in the right context. Hardly any money has been spent on silviculture.</p>	<p>Devise a Hemlock Preservation Plan.</p> <ul style="list-style-type: none"> ● Focus on high value areas. ● Set your protection goals early. ● Must have a landscape level conservation strategy in place with protected stands across the landscape to avoid hurricanes and other catastrophic events wiping out hemlock. Have a diversity of both young and old trees protected within stands. Stands are prioritized within the landscape. ● Dr Mausel recommends at least 30 trees/site. ● Set the 'big picture' and long-term goals ● Outline IPM strategies and field tactics (e.g., deployment of strike teams). <ul style="list-style-type: none"> ● Multiple strategies are required. Silvicultural strategies are not a good idea by themselves and need to be applied in the right context. He sees it as a part of the IPM plan 'down the road' when biocontrols are ready, after which you can then do a thinning. So best considered in conjunction with biocontrols in the IPM strategy.
<p>Biocontrol is not proven well enough yet to assume it will save those special places. When ready to release biocontrol in high value places, release it in a matrix with chemical control. They have a significant abundance of <i>Laricobius</i>, but it's still not enough to save trees. Employing <i>Laricobius</i> and silver flies together will work.</p>	<p>Biocontrol: Mausel remains cautious that HWA biocontrol will work because there has been no recovery of over-wintering silver flies (2 spp of <i>Leucotaraxis</i> released but not re-found). They will give research 5 more years to be sure of success/failure. If silverflies fail, they will have to start over in searching for a second predator, and a fully successful biocontrol program would be greatly delayed.</p>

<p>Need a progrediens predator- If <i>Leucopis</i> (now called <i>Leucotaraxis</i>) doesn't work, then they have to start all over again. Could be another 20 years.</p> <p>They have been working on biocontrol since 1995 (27 yrs) looking for 2 predators for both HWA generations. Sasajiscymnus releases was part of that attempt. They continue to be missing the 2nd spring predator that could get established and then become sufficiently abundant. Bringing in silver flies from the pacific NW is so much easier than bringing in predators from Japan/China.</p> <p><i>Sasajiscymnus tsugae</i> beetle release results points to high uncertainty because there has been little recovery after their release.</p> <p>When biocontrol releases are approved, think bigger- saving all trees across the landscape.</p> <p>We cannot bank on a classical biocontrol program yet. It might not work enough in the warmest places.</p>	<p>*Since this interview, Mark Whitmore discovered over-wintering of Leucotaraxis in New York state following one of the harshest winters in recent times. It seems at this point that those last doubts re: HWA biocontrols are now cleared!</p> <p>* Mausel makes the worthy point that until biocontrol is proven and fully <u>implemented</u>, the focus is on <u>hemlock preservation efforts</u>.</p> <p>Prioritization: *Make calculated decisions on what you will protect, inventory, prioritize, and try to get 'tier 1 stands' treated while they are still healthy.</p> <p>When biocontrol releases are approved, think bigger- saving all trees across the landscape.</p>
<p>Chemical control: Most do soil drench using Merit, but the best techniques are by NY and Michigan with tank mix basal bark applications.</p> <p>David would rather wear a backpack sprayer with a wand to spray from a root crown to waist height- than do soil drench and carry a Nalgene bottle around and scrape away duff. There is a 'treadmill' of going back to retreat the trees because of annual per acre limits.</p> <p>- 'Go big' but sustain the funding. Can you dedicate X funding dollars for X yrs?</p> <p>Riparian buffers are variable depending on Agency and State. (David oversees an entire region so wasn't specific.)</p>	<p>Chemical control: Dr Mausel mentioned that we have Merit already available in Canada (<i>A wettable powder Imidacloprid product</i>). It would simply need a <i>label expansion</i> to include hemlock on the label. It appears to be cheaper than some alternatives.</p> <p>-Explore the possibility of a label expansion for Merit 75WP or WSP product to include hemlock since these products are sold already in Canada. It is sold at \$ 35.95 for 30 lbs in Canada, according to a quick check on-line.</p> <p>"Pro" to basal bark spray: David would rather wear a backpack sprayer with a wand to spray from a root crown to waist height- than do soil drench and carry a Nalgene bottle around and scrape away duff.</p> <p>Riparian buffers are variable depending on Agency and State.</p>
<p>Funding: Primarily the States provide some funding and US Forest Service gives technical assistance and works with biocontrol. The State generally deals with Partners, tribal gov, NGO, universities, private landowners. HWA Initiative which is inter-agency. Useful to look at the structure of funding, committees, etc. Saving unique high conservation value stands.</p> <p>Budgeted 1.7 million for last few years. HWA used to receive 3 million dollars earlier on.</p>	<p>Funding: Canadian expenditures to protect old growth forests/hemlock stands vs USA expenditures of 1.7 annually?</p> <p>An HWA Initiative will likely work best if inter-agency.</p>
<p>Early Detection: Best way to do early detection, wait until storm goes through, pick up the branches. Efficient. No equipment needed! Cover</p>	<p>Early Detection: Organize late winter/early spring Detection surveys to take advantage of winter storm branch drop during the high visibility life stages of HWA. Mausel stated that the "best way to do</p>

<p>a lot of ground, get volunteers doing that work. After storm on top of good snowpack/ice. Shooting trees with tennis ball is too time-consuming.</p>	<p>early detection is to wait until storm goes through and pick up the branches.” It’s efficient. No equipment needed. You can cover a lot of ground, get volunteers doing that work. The best conditions are after storm with branches on top of a good snowpack/ice. Citizen scientists/volunteers can conduct HWA early detection surveys. Shooting trees with tennis ball is too time-consuming.</p>
<p>Carbon credits: He thinks they are hiring someone for C credits, not particularly for hemlock though.</p>	
<p>Data base: Have one data base. Did not build a national insecticide treatment database- where are the high conservation value areas. Mistake that they didn’t do that from beginning. Each State had that information. Need a biocontrol database +insecticide database. Geodatabase that shows a perimeter around treated areas, rather than individual tree waypoints. Information contained in the polygon- DBH, # trees, Soil type, Contact info, yr treated. Set up the database properly in the beginning. They are trying to reconstruct it in the USA.</p>	<p>Devise a proper data base early. Consult with Dr Mausel to avoid repetition of the same mistakes made in USA. The data base should contain both treatment and biocontrol info. Consider mapping polygons rather than waypoints for every treated tree.</p>
<p>HWA resistant hemlock: Research is starting up again. There was a lot of work early on. There hasn’t been anything very promising found yet. A couple of sites in New Jersey have putatively resistant trees that have been out-planted. There is no breeding program yet. They are examining this in the next 5 years. Researchers have been entomologists, not geneticists. Resistance breeding is part of the 4 main legs to the IPM stool. Resistance breeding. They know how to do cloning to vegetatively reproduce hemlocks. There are some hybrids from the Arboretum. It’s a nice line of work, but this strategy doesn’t contribute to saving the old growth systems we currently have. We don’t want to give up on our old growth. <u>The only real sure bet right now is preservation with insecticide of high conservation value areas.</u></p>	<p>HWA resistant hemlock: They are researching various aspects of HWA resistance and still searching for resistant trees, conducting some breeding. This strategy doesn’t contribute to saving the old growth systems we currently have. We don’t want to give up on our old growth. The only sure bet right now is preservation with insecticide of high conservation value areas. Don’t count on genetic resistance but keep searching for it.</p>
<p>Preservation: Ex-situ and In-situ preservation (i.e., protect seeds in the ground). Ex situ, i.e., send seeds to the freezer to try to preserve a genetic representation. Try to save representative genetic stock from stands throughout the province. Then build in the cycle and stay within what you can logistically manage. New Hampshire did this with EAB. Try to save 10 stands/clusters (pockets of heavy growth) per county in every county. Pick 5 stands/county for in situ preservation.... Then hope for something bigger than that. Do seed collection and send off to freezer, but this doesn’t help preserve what hemlock forests should look</p>	<p>Regional Network Preservation: Try to save 10 stands/clusters (pockets of heavy growth) per county in every county. Pick 5 stands/county for in situ preservation.... Then hope for something bigger than this bare minimum. -Ensure adequate seed preservation at National Seed bank to preserve adequate genetic diversity of eastern hemlock. -Preserve entire intact hemlock groves so future generations can experience them, especially important when we think how many</p>

<p>like to future generations. For example, with Dutch elm and Chestnut forests, it would have been extremely useful to have preserved some groves so people know what natural/original forests with those trees looked like.</p> <p>This is about genetic preservation for future generations. Hemlock forests are going to die in 4-20 years. We need medicine for the trees in situ because forest ecosystem will suffer.</p>	<p>would have liked to see a Chestnut grove, towering elm trees along streams, or dark, smooth-barked American beech forests.</p>
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<p>Scott M. Salom, Ph.D. Professor, Graduate Program Director, Department of Entomology, Virginia Polytechnic Institute and State University 216 Price Hall MC 0319 170 Drillfield Drive, Virginia Tech, Blacksburg, VA 24061</p>	<p>salom@vt.edu Phone: 540-231-2794 Dept. Website: https://www.ento.vt.edu/people/Faculty0/salom.html Global Change Center Website: http://www.globalchange.vt.edu/</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Chemical Control: They are still conducting soil applications. Have a student examining nontarget impacts. There are impacts in the immediate area around injection, but insect spp are not going extinct. No effect on pollinators detected, based on the soil injections. Pollinators are not getting direct exposure. He understands that Europeans don't want anything to do with neonicotinoids, but his research shows how safe it is in forested sites.</p> <p>Imidacloprid metabolizes into other toxic materials like Olefin which gives it long-term efficacy. That's why trunk injection doesn't work for as long, because you don't have the metabolites that formed from soil environment exposure. <u>You don't get that change in chemistry from direct trunk application.</u> Soil gives 5-7 years. The longer lasting approach is very appealing if you have a tight budget. Benton and Cowles went back to trees in GSMNP and examined long-term effects and how chemistry changed.</p> <p>Maryland and Pennsylvania are do a good job treating large hemlock forests. Maryland will treat every tree in the forest. Their trees look good. They are proactive with biocontrol, too. <u>The level of aggressiveness is critical to keep your trees alive. Laissez faire won't cut it.</u></p>	<p>Chemical Control: Petition to obtain special exemptions for using some chemicals *e.g. Xmas tree growers have done this. We have a one-of-a-kind resource that will be gone so we can make the case for getting some special chemical into the tree for long-term protection. Old growth goes so quickly without same level of resistance and vigor that younger trees feature. We need 5 years.</p> <p>- Pollinators do not receive direct exposure. While we must understand why Europeans don't want anything to do with neonicotinoids, research by Scott Salom and others shows how safe it is in forested sites</p> <p>- Dr Salom explained why trunk injection is not prescribed to last as long as basal bark spray and other types of treatment applications. Imidacloprid does not break down (alter its chemistry) into the longer-lasting metabolite olefin when the exposure to the soil does not take place to aid the breakdown. Soil exposure results in 5-7 years, which is very appealing on a limited budget. It certainly would seem to be an additional justification for using Xytect.</p> <p><u>"Be proactive with treatments. The level of aggressiveness is critical to keep your trees alive. Laissez faire won't cut it."</u> Places like Maryland treat every tree in the forest, and they are proactive with biocontrol, too. Their trees look good as a result.</p> <p>The Virginia Tech site is very informative: https://hiro.ento.vt.edu/hwa/</p>

<p>Buffers: 25 m buffer for soil drench. But around freshwater systems, you will be limited, so make the case for direct stem injections.</p>	<p>Buffers: 25 m buffer for soil drench. But around freshwater systems, you will be limited, so make the case for direct stem injections.</p>
<p>Imidacloprid is generic now, so the chemical is cheap. It's so much less expensive than earlier, and achieving longer protection is correspondingly cheaper than it used to be, too. There are different types of soil applications. Tablets, drench. They don't spend a lot of time fussing around. ArborJet- Don Grossman, product tester, was Scott's first PhD student.</p>	<p>Imidacloprid is generic, so the chemical is cheap, and so achieving longer protection is correspondingly cheaper than it used to be, too.</p>
<p>Other land tenures: In Virginia Tech, they focus on the research, but they do work with some of the land managers.</p>	
<p>Funding: The US Forest Service allocates State funding for suppression and for some research and development, but very applied research. They provide some funding to universities. They also have their own researchers. Connecticut has an evolutionary geneticist who is understanding HWA better. Bud Mayfield is in North Carolina. Both these scientists are impressive within the US Forest service- supporting HWA in a big way. Started with 3 million/yr, now down to 1.7 million/yr. Most of the funds are for suppression, but some suppression dollars come from other sources. Some funds for rearing beetles. Adopt a multi-pronged approach.</p>	<p>Funding: Started with 3 million/yr, now down to 1.7 million/yr. Most of the funds are for HWA suppression, but some suppression dollars come from other sources. Some funds are allocated for rearing beetles. Adopt a multi-pronged funding resource approach.</p>
<p>Biocontrol: Winter mortality ranges from 10-90 % in NYS. The remainder is helped by <i>Laricobius</i> which has a continuous impact on generation after generation. Scott can't emphasize enough about getting the insects out there on infested trees so they can build up populations. Rearing them is very arduous. It's a better short-term activity. They have multiple ways of producing them here. They rear them in labs. They can now go to eastern sites to collect. Collect around urban areas- they are great areas to collect, such as Blacksburg. They are pervasive now. They collected 1100 beetles, sent them off to Shenandoah National Park. They collect in the fall when they first emerge. Later in the fall, they are starting to lay eggs (end of Feb early March). So they want to get them early. Phenologically, he was uncertain what stage <i>Laricobius</i> beetles were at when we spoke. Ithica, NY had 99 % winter mortality of HWA. They had an HWA biocontrol working group session. Recorded on Virginia Tech. HWA initiative meetings website. Supports Managers.</p>	<p>Biocontrol: Find out what the plant hardiness zones- based on minimum winter temps. Tells you what to expect winter mortality is expected to be. 6a is the minimum for getting the beetles to survive. Map here. -Start early with predatory insects because insects will need time to build up populations. Rearing Lari is hard in the lab, but we may have to do this in the short-term. In many US localities, they can now go out and collect from the wild because they are pervasive now. Disseminate them from wild populations eventually-much easier than lab rearing which is expensive and arduous. -Collect beetles in fall when they first emerge and before they lay eggs later in the fall. Scott can't emphasize enough about getting the insects out there on infested trees so they can build up populations. Rearing them is very arduous. It's a better short-term activity. They have multiple ways of producing them here. They rear them in labs. They can now go to</p>

<p>He thinks the risk of <i>L. nigrinus</i> hybridizing with native beetle, <i>L. rubidus</i> may be beneficial. They do hybridize in <u>low numbers</u>, but it helps <i>L. nigrinus</i> survive. Scott described the hypothetical thinking of <i>L. rubidus</i> as "I am finding pine bark adelgid very hard to locate, so I will feed some on HWA where I can 'make do'. It's not a steak dinner, but it's okay. I can survive on HWA. The two species can produce reproductive hybrids. They were separated geographically, but they are siblings. You are bringing them back together again. It's been 10s of 1000s of years since I've seen my cousins!</p> <p>IPM: Scott is researching the integration of chemical and biocontrol. Laricobius is in the soil in the summer. Key question: Does the imidacloprid soil treatments kill the Laricobius beetles that have pupated in the duff?</p> <p>They advocate the combination of those tactics (Mayfield) of chemical-bio. Try to bring the best of both approaches to assist with longer term sustainable protection. The idea of integrating silviculture may come in as well eventually. Open grown trees, or plantation trees- hemlock flourish and do not support adelgids. Only branches in the shade support HWA. This is good for regenerating a site and encouraging the understory regrowth. Patches in direct sunlight. There are scientists looking to advocate that approach. Jeff Fidgen planted our plantation now 10 and 20 years old with the idea of growing plenty of adelgids for a field insectary. But hey, they could not get those trees infested! Then they started to shade the trees and they become infested. Otherwise, they die during their dormant stage in the summer, either from heat or direct sunlight. So this is why people decided to do some larger scale silviculture in forest stands- open them up and see how it works.</p> <p>Canada was an international leader in biocontrols at one point, but then something happened. There are new restrictions that regulate biocontrols. It should be a 'no brainer' to bring in the HWA biocontrols. The Laricobius beetles and silver flies are not going to bother anybody if they are brought in and they fail. These species are specialists. Worst case scenario is that they don't solve the problem. What other choices do you have? On the one hand you have a very imppt species that we value. Do nothing and lose it. Or make the effort and... if you value the tree in your country.</p>	<p>eastern sites to collect. Collect around urban areas- they are great areas to collect, such as Blacksburg. They are pervasive now.</p> <p>-Scott Salom would be excellent to consult if encounter biocontrol concerns. Dr Whitmore, D. Mausel, others, too.</p> <p>IPM: There is still some research to be completed on how to integrate the predator insects in areas that have been chemically treated. Scott and Mayfield are working on combinations of tactics.</p> <p>The idea of integrating silviculture may come in as well eventually. Open grown trees, or plantation trees- hemlock flourish and do not support adelgids. Only branches in the shade support HWA. This is good for regenerating a site and encouraging the understory regrowth.</p> <p>Canada had been an international leader in biocontrols at one point. It should be a 'no brainer' to bring in the HWA biocontrols. The Laricobius beetles and silver flies are not going to bother anybody if they are brought in and they fail. These species are specialists. Worst case scenario is that they don't solve the problem. What other choices do you have? On the one hand you have a very imppt species that we value. Do nothing and lose it. Or make the effort and... if you value the tree in your country.</p>
<p>Optimistic about biocontrol? It's better than having nothing. In some places the insects flourish. Other places may be less successful (e.g., die in cold winters). Ultimately, the biocontrols developed may not be full</p>	<p>Biocontrol predators are our best shot at controlling HWA.</p>

<p>force regulators, but if they can contribute a little toward regulation, it is your best shot. Are we going to knock down both generations of HWA by 40 %? (This is the level that Gov't wants.) We can't quite answer that yet. "This is what we have. It can contribute."</p>	<p>The ultimate government goal is to reduce HWA populations by 40 %. The biocontrols developed may not be full force regulators, but if they can contribute a little toward suppression, it is our best shot.</p>
<p>Private lands and Biocontrol: They don't release beetles on private land. All on public lands. Private lands do not have the benefit of having release of biocontrols unless they pay for it. They can hire someone to go out west and collect beetles and then release them in the east. There is someone who does this. Most private landowners rely on treating their trees. Some States allocate some funds to private. Cost share some EAB activities. Sometimes there are off-sets to reduce the burden on private landowners. Whitmore is in different situation with the Adirondacks where private landowners have funded ~80 % of his program.</p>	<p>Private lands and Biocontrol: It may be that private lands- they can go collect their own predators, or perhaps they can redistribute predators from local locations once the populations build up. They are doing this presently in USA. - Consider cost share for both EAB and HWA biocontrols controls?</p>
<p>Database: They have a predator database website. Canada could use the same database, and he encourages us to 'hop on'. It's not as polished as the EAB tracking website. It is map-based. They can track all the predator releases/recoveries, etc in all States. Database is at Virginia Tech. It was started by a former grad student of Salom's. The Gypsy Moth database people are also in his department. Predator Database website. David Mausel provides funding. We could speak with him to see if Provinces can join.</p>	<p>Database: Look into using the same map-based tracking database as they have set up at Virginia Tech. Check with David Mausel to see if provinces can join.</p>
<p>Genetic Resistance? It's a long game. A very long game. It doesn't do anything for us now. Won't save the trees in your park, but perhaps centuries from now, it will be useful.</p>	<p>Genetic Resistance: It's a "long game" that may be useful perhaps centuries from now.</p>
<p>Robert Jesse Webster- 'Jesse Webster' Forester, Resource Management and Science Great Smoky Mountains National Park (GSMNP)</p>	<p>Contact info: Great Smoky Mountains National Park, 107 Park Headquarters Road, Gatlinburg, TN 37738, Office: 865-436-1730</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Been working with HWA for ~ 10 yrs as the park vegetation mgt specialist.</p>	

<p>GSMNP hosted the perfect storm of heavy hemlock forests and a big wave of HWA in 2002. Dramatic decline. The wave went over them and now they have small surviving populations in watersheds that are hanging on. "It's chronic but no longer acute". Predicts that NS will see a shocking wave of mortality. Then it will subside, followed by another resurgence, after which people stop noticing and the trees start fading away (both on the landscape and from memory). After the first wave, the trees are still infested with the same population of HWA. They never really go away. At GSMNP, there was a sheen of adelgid on the water. People's eyebrows and clothing, hair had adelgids when they came out of the woods. Before GSNP, no one had really treated large forests before.</p>	<p>Strike teams are phenomenal. It's the model that the US has widely adopted in Tennessee, Kentucky, Ohio. Cheaper. Makes up for staff power. Can treat entire stands. Strike teams/Fire crews. Fire crews are typically traveling crews. Fits right in. The work season for both tasks lines up well. Predict that Nova Scotians will see a wave of mortality that shocks them. Then HWA will may subside for a short time, followed by another resurgence. People adapt to the 'new normal' and stop noticing the trees. Hemlocks will fade away, both on the landscape and from human memory-<i>unless work is undertaken to conserve some of the best stands.</i></p>
<p>Funding: They get a variety of funds. Some federal- USDA Forestry. Park funds.</p>	
<p>Prioritization: They used to go where the adelid was worst. But often those trees were too far gone and the effort was wasted. They didn't know the thresholds. They have now derived thresholds for GSMNP. They have to answer-What does too far gone look like? Trees tend to die from bottom up with LCR diminishing.</p>	<p>Prioritization. Get the sites lined up so you are ready to send crews. Thresholds are important to define. They use a Transparency rating, which is same (just the opposite way to look at it) as our crown density scoring. Two people stand on either side of the tree and derive a score. They should be within 5-10 % of each other's estimates.</p>
<p>Mortality rate: HWA kills in 3-4 years there, but they also have untreated trees that have survived for 15-20 years without treatment. However, they lost their highest quality areas early on. Hemlocks that were hanging on were the open grown trees, typically younger (75-100 yr) with LCR 70-90 %.</p>	<p>Mortality rate: Mixed stands that wouldn't necessarily be identified on maps as a hemlock stand- those hemlocks in the mixed stands with hardwoods tend to do better because they get more sunlight. Also trees with large crowns (70-90% LCR) and younger age classes can hang on longer without treatment.</p>
<p>After the initial wave and trees recover, there will be trees with very high transparency but may have a very low HWA count and may have new growth. OR they have high canopy density, but after treatment with dino and ima they may still die within a year. They learned the hard way and they lost trees.</p>	<p>Threshold, in general, 30 % live crown and 65 % transparency. DBH threshold is 20 inches (51 cm)- under that typically those trees are more receptive to treatments when they were heavily infested. Because of this, treat large diameter trees first. And treat smaller diameter trees that are getting more light.</p>
<p>Chemical Treatment: They treat about 40 000 trees/yr on a cycle, mainly using soil drench, with 2-3 % injection. The rest is soil injection or tablet treatments (Cortect), which requires no water. The trajectory for complete loss was 2050, including those that seem to be hanging on untreated (McAvoy). Jesse has appreciated Dr Whitmore speaking with passion about hemlocks to his park staff. He feels you cannot save hemlock forests without a level of passion involved.</p>	<p>Nontargets: No negative effects on nontarget organisms have been found in GSMNP. They have McCarty's work there. Public messaging- The trade-off of no chemical control is complete loss of trees. The treatment area is not the entire forest area. It's just little areas around the trees. People picture far- reaching contamination. Chemical cost is \$ 20/yr = cheaper than taking the trash out. Passion is so important! We cannot be 'science robots'.</p>

<p>In Te, they are still finding people who don't know how to keep their hemlocks alive, or notice HWA impacts too late.</p>	<p>-Strong public messaging on treatment options and how to treat is important.</p>
<p>Stem injections: They do ~2-3 % /yr stem injections- any trees within 10 ft (3 m) of water. They have never disinfected the drill, but this sounds like a good sanitation protocol. They use Rainbow system Q connect system, a no plug system. 15/64 drill bit. A tank system with lines that holds up to 'abuse'. It's a part of his regular workday now to take the Q connect along and treat some trees. Soil drench is more user-friendly than soil injection. They've had problems with the injector breaking. It is like a giant syringe. They've put those on the shelf now in favor of primarily soil drench and Cortect tablets-These are perfect for volunteer help. Michigan is using viper system (by ArborJet) but it uses higher pressure.</p>	<p>Buffer: 10 ft (3 m). This is park policy. Stem injections are highly effective. Chemjet (<i>a cheap reloadable syringe applicator system</i>) and Quickjet Air are about 10 minutes per tree.</p>
<p>Foliar spray horticultural oil. They can spray 100 ft in the air. It helped along roads. They did save some live crown.</p>	<p>Foliar spray horticultural oil. If you have horticultural oil, use it. But if you don't have it, don't bother. The oil will control it but need to spray 2X /yr for both HWA generations. Best used in combination with systemic treatment.</p>
<p>Biocontrol: Jesse is very encouraged that Laricobius beetles are establishing and spreading on the landscape. Now there are efforts with <i>L. osakensis</i> and silver flies. <i>L. osakensis</i> has established and he sees only <i>L. osakensis</i> where it exists, not hybridized Laricobius (referring to the hybrid risk with native bug- <i>L. rubidus</i>).</p>	<p>Biocontrol: -Participate in the Manager's meeting- very beneficial. Biocontrol seems to be establishing and working. Optimistic. Treatment monitoring has now switched to biocontrol monitoring.</p>
<p>Phytosanitization Removal of lower branches/reduce contact- Your efforts could be better utilized somewhere else.</p>	<p>While people do move HWA around, the birds likely do more of it.</p>
<p>Justifications for treatment costs: Ohio- they hit HWA early on and treated some natural areas with sandstone canyons and beautiful hemlocks where 4 million people/yr visit.</p>	<p>Justifications for treatment costs: Some of the most scenic tourism draws have hemlock that are worth treating for their unique beauty and tourism value. Convincing the value of treatment investment should not be obvious for generating tourism revenues. Ohio treated some of their most attractive tourism destinations that attract 4 million tourists annually.</p>
<p>Funding: They have dedicated funding with Parks Service using 3 personnel. They have a "friends" group (like Canadian parks) and a Great Smoky Mountain Group that provides funding. They have a restoration program. They also have some summer seasonals, interns, students.</p>	
<p>Timing: They can treat all year because hemlocks are never really dormant there. Soil treatments have been done as late as Dec 21st. The best treatment time there is Feb-March.</p>	
<p>Carbon: TN Working Woodlands is starting to look at this.</p>	

<p>Regrets? And leave up on some other areas. There are small stands of younger trees that they are just going to leave and see what happens. Hemlock can grow anywhere with sunlight and water. Treating less suitable sites- don't waste time. Weird forest types. The vegetation map- didn't know what to call them.</p>	<p>Regrets. Wish they'd done more sooner. Would have seen sites differently. Would have been able to focus on areas that needed more attention and go more bang for the buck. Treat the best sites and let the less suitable sites go.</p>
<p>Donald Eggen, Ph.D. Forest Health Manager Pennsylvania Department of Conservation and Natural Resources Also attending team meeting: Tomon, Timothy <ttomon@pa.gov> Johnson, Sarah <sarajohnso@pa.gov>; Liu, Houping <hliu@pa.gov>; Faulkenberry, Mark <mfaulkenbe@pa.gov>; Stitzer, Scott <ssstitzer@pa.gov>; David Mausel (David.Mausel@usda.gov)</p>	<p>Bureau of Forestry Division of Forest Health 400 Market Street, 6th Floor, PO Box 8552 Harrisburg, PA 17105-8552 Main Office: 717.783.2066 Direct: 717.787.2336 Cell: 717.514.6714 E-mail: deggen@pa.gov</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p><i>Don sent the PA State Hemlock Conservation Plan and other plans placed in doc file. Some notes taken on those docs below the table.</i></p>	<p>Planning: A "Hemlock Conservation Plan" could be a consideration for NS. It might have a slightly different focus from the current plan for NS on HWA?</p>
<p>Genetic Resistance: Identify naturally occurring specimens of <i>T. canadensis</i> which have survived in generally infested areas and explore the genetic basis of this resistance. Terpene chemistry is different. Next steps they are exploring are host resistance, researched at Rhode Island. Next steps new proposal to develop hemlock stock seed orchard of purportedly resistant trees.</p>	<p>"Provincial seed orchard"-Create a goal to set up a 'provincial seed orchard' of purportedly resistant hemlock stock, similar to what PA is planning. It could be located near lab facilities in Kentville or Truro.</p>
<p>Public outreach- they have public meetings on what they are doing but only give general location information for treatments. They report on results. They also conduct public training sessions.</p>	
<p>They only treat public lands (State parks and State forests). Have an IA completed. They treat 500-600 acres/yr. Chemical cost: ~ 10 c/inch spend about \$ 130, 000.00/yr They use 'staff only' treatments. 5 staff conduct soil injections. Some parks use volunteers. Contractors in Cook Forest State Park has contractors who can treat cheaper than staff can do it. Dinotefuran is \$ 1.57/in. It works on hemlock scale, whereas Imidacloprid does not.</p>	<p>Chemical cost: ~ 10 c/inch (~4 c/cm) Spend about \$ 130, 000.00/yr. They use 'staff only' treatments. 5 staff conduct soil injections. Some parks use volunteers. Contractors in Cook Forest State Park has contractors who can treat cheaper than staff do. Imidacloprid does not work on hemlock scale (in case we get that pest, too).</p>
<p>Chemical Control: They used pesticides as soon as they were able, but not all options were ready when HWA reached PA.</p>	<p>Chemical Control: They used pesticides as soon as they were able, but not all options were ready when HWA reached PA.</p>

<p>Basal spray- using Xytect 2F. Applies it mostly in spring, but avoiding spring ephemerals. -Majority of treatments are soil injection. Treatment numbers in State parks and State forests: Yr 2020. 5, 500 trees, 944 acres, 1,400 inches- All soil injections Yr 2019 1, 667 acres, 28, 075 inches Maryland uses stem injection and have information on time required.</p>	<p>Basal spray- using Xytect 2F. Applies it mostly in spring, but avoiding spring ephemerals. -Majority of treatments are soil injection.</p> <p>Maryland uses stem injection and has information on time required.</p>
<p>Biocontrol: They've been conducting predator releases since 1999. Optimistic on biocontrol? They are halfway there. They need a spring predator. After that they should have achieved a self-sustaining program. But Leucopus hasn't been recovered at all. If Leucopus doesn't work, then they will have to start over by going back to Japan. He will give Leucopus another 5 yrs of research trials.</p>	<p>Biocontrol: Same info as Mausel. Optimistic but need a spring predator, which at that point had not been recovered yet from release sites, so they are concerned with starting over to find another suitable spring predator. (Since then Leucotaraxis was determined to survive, so the biocontrol solution looks much more promising.)</p>
<p>Database Management: Their system is based on a central database. Used to be collector. Set up all treatment blocks in a layer.</p>	<p>Database: Sarah Johnson sent us their database framework. Please examine this file placed on the Google drive. Adopting the best of the existing USA platforms will save time.</p>
<p>Regrets: If they could start over what would they do differently? Set up database properly to collect technical and geospatial data. Formalize stand prioritization.</p>	<p>Regrets: Set up database properly early on to collect technical and geospatial data. Formalize stand prioritization.</p>
<p>Carbon: The Bureau is looking at Carbon. Lidar- obtaining specific measurements because method for measuring Carbon is imprecise. They have a climate change committee. The Nature Conservancy in PA has a Working Woodlands Program.</p>	
<p>Landscape management approach: PA wants to set up PRISMS. Don believes that using Strike Teams would get around limits of staff time and budget capacity.</p>	<p>-Explore PRISM approach. -Strike Teams could maximize budget capacity and address limits of government staff time.</p>

Penn State Hemlock Conservation Plan- *The following are some key notes from reviewing the plan.*

Monitoring for Private lands: The Bureau of Forestry coordinates training on detection and monitoring of HWA and other hemlock pests. They recommend that landowners should inspect their hemlock annually for HWA. Best timeframe for HWA inspections is from November to May when the white woolly material produced by the adelgid is more apparent. Inspect 10- 25 trees for a stand of a few acres, and two to four branches per tree. Note presence/absence of HWA on each branch inspected. **Once the proportion of infested branches reaches a specific threshold of 45 %, treatments should be applied.** (Hemlock growth is hampered or halted when the proportion of infested branches reaches 45%.)

Silviculture for hemlock forests in heavy decline from HWA, and where no chemical or biological controls are planned, **rapidly initiating regeneration to desired tree species has been suggested**, possibly mitigating many of the anticipated stream impacts from loss of hemlock. Establishing another conifer species may better mimic site conditions (i.e., microclimate) that existed when the hemlock was the dominant tree on site. Research is also being conducted on whether pre-emptive thinning of un-infested hemlock stands may boost tree vigor.

HWA-resistant eastern hemlock should be the ultimate goal, but this may be decades from fruition, if ever.

Restoration: Recommend influencing regeneration by native conifers. ***It will be more practical and cost effective to manage for tree species that are already present in the canopy or understory of the site, and supplement with some underplanting.** Attention should be made to promote conditions that favor the establishment of desired and appropriately adapted tree species (See plan for references.)

Eastern Hemlock Conservation Strategy in the understory. Potential conifer species for replanting can be found in a table compiled by the USDA Forest Service staff in Allegheny National Forest.

Thresholds: In general, there is a higher likelihood that **hemlock dies within a year if crown dieback exceeds 30%, or if foliar transparency exceeds 35%.**

Identify and Maintain Refugia (p. 43) Areas that are able to resist environmental changes that have otherwise decimated species in most of their former habitat. This allows for these formerly widespread species to persist in small relict populations, preventing complete disappearance. Landowners should identify likely areas or refuge for hemlock where they would be able to persist, despite climate change. **Focus should be made on identifying cooler, wetter sites, such as riparian areas, north facing slopes, lake edges, and wetlands.** These sites would have to be monitored and treated long term for hemlock woolly adelgid and any other threatening pests.

Government assistance: *A management initiative coordinated by a federal agency will improve efficiency and effectiveness. The USDA Forest Service has instituted the **HWA Initiative**, in part, at the request of the National Association of State Foresters and the National Plant Board. An action item we may request: Request Federal Government coordination and support for hemlock across it's range in eastern Canada(?)

Economics: The economic damage to property values in cottage owners around lake shores.

Biocontrol statements from "[Hemlock Woolly Adelgid National Initiative Strategic Plan: 2014-2018](#)" - a concise doc link on right side of web page for Penn State that summarizes it on the Penn State site.

Biocontrol: Protection of high-value hemlock trees and groups of trees should continue until natural enemies become established and provide control of HWA.

- A web-based HWA predator database was created to track all predator release locations and monitor establishment results.
- Although two predatory beetles have been established for biological control of HWA, these are spreading slowly. Additional species and better methods are needed to accelerate spread and to increase populations to levels that can suppress and maintain HWA below damaging levels.
- Utilize field collections of *L. nigrinus* from western North America and **field insectaries** in the East and continue to redistribute and augment existing release areas as needed. Once *Laricobius* is established on the landscape, phase out mass rearing of *L. nigrinus* in the laboratory to allow rearing of new predators as they become available.
- By 2016, we expect a much-reduced need for research and methods development in the area of classical biological control as we will have completed the necessary evaluations and initiated the establishment of all of the known summer and winter HWA predators believed necessary for long-term management. (*They may feel they have 'checked the box' on this.*)
- IPM: Evaluate the use of both chemical and biological control strategies in the same landscape to evaluate compatibility and efficacy in controlling HWA populations.
- Potential fungal candidate for biocontrol- pathogen *Lecanicillium muscarium*. Continue aerial field trials of fungal pathogens, including *L. muscarium* (formerly *Verticillium lecanii*) using newly developed formulation technology and evaluate efficacy and non-target impacts. (I

don't see many papers on this type of research and bear in mind that most of the researchers are entomologists rather than pathologists/mycologists. NS is known to have a healthy mycological diversity. Maybe that could be an advantage.)

<p>Andy Zadnik Director of Land Stewardship Western Pennsylvania Conservancy</p>	<p>800 Waterfront Dr. Pittsburgh, PA 15222 412-586-2318 (o); 412-977-9681 (cell)</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Owens/manages 14 000 acres with 4 staff. Dealing with HWA is just one of the things they do. Our conversation revealed that Mr Zadnik has not fully researched HWA and chemical options. He and a few staff focus on many challenges. He is waiting for direction and help from the State.</p>	<p>Land managers for private conserved lands are not necessarily up-to-date on HWA treatment options. They can be short-staffed and some may be waiting for external expert direction with HWA management. They would be best to partner with others or dive in and lead their HWA control strategies. Not wait.</p>
<p>Chemical Control: They've looked into using pesticides as the option and decided that it is not possible with chemicals and they don't have the capacity. They have taken a 'Tree by tree' approach. They have done some limited chemical treatment tree by tree. They can save individual trees, but not possible to use chemical pesticides for a forest- treating a complete forest ecosystem was beyond their grasp. -They have contracted out some stem injections and volunteers have used CoreTect tablets. They have maybe treated ~ 100 trees. They are hoping to keep the larger trees alive long enough to get predators for biocontrol.</p>	<p>Chemical Control New options and costs on chemical control are sometimes not communicated to all groups. This Conservancy was not up-to-date. They don't believe they can save a complete forest ecosystem. They are hoping to keep larger trees alive long enough to receive biocontrol predators. It's a tenuous strategy.</p>
<p>Carbon market. In USA there is no carbon market. It doesn't seem viable. Not clear what the expectation is as to how to manage forests for carbon. They have no plans to cut.</p>	
<p>Biocontrol: They did a first release of HWA predators (Laricobius) in Oct 2021 on Nature Conservancy properties. They don't want to release <i>L. osakensis</i> because it is not native. Beetles are effective on feeding on the adelgid over the winter. They have started insectaries, planting and spacing them properly as a hedge. Have topped them, fertilized them. The State provided lots of assistance on that.</p>	<p>Biocontrol: NS needs to start some field insectaries (hopefully from existing dense growths of hemlocks in some areas of NS). Perhaps Nature Conservancy lands would consider starting hedge insectaries.</p>

<p>Deborah McCullough Michigan State University MSU · Department of Entomology</p>	
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Contacted Dr McCullough (Deb) because we were informed that Michigan is using a modified injection system to treat hemlocks. Deb works at Michigan U. Has many students conducting research. She recommended interviewing Drew Rayner. Michigan has a lot of sandy shoreline dunes supporting hemlock stands so they cannot do soil</p>	<p>Check a pdf she wrote called: Options for protecting hemlock trees from HWA. The extensive sandy soils compel Michigan State to inject trees rather than use soil drench. A definite "con" of soil drench is that it cannot be used in sandy soils.</p>

<p>treatments due to the sandy soils. She has been researching residues of shoots and foliage using several treatment methods (soil drench, basal bark, CoreTect, dinotefuran trunk spray). They treated in 2016. Imidacloprid took 12-14 months to work. They resampled in 2020 and there was still plenty of imidacloprid present. (CoreTect doesn't work at all in sandy soils.) They use a lot of Transtect for dinotefuran.</p> <p>At Rainbow, Sean Bernier is the researcher.</p>	
<p>Chemical Control: They got rid of plug systems, so they don't need to be pounding and hammering all the time. Rainbow came out with a plugless injector first. *Basically, all you have to do is get into live tissue.</p> <p>**Keep it down in the buttress because there is very active tissue there", advises Dr McCullough for placement of injection ports.</p> <p>-Ash trees are "right-handed", treatment spirals up to the right in the active xylem tissue. Ash trees recover quickly from the injection wounds.</p> <p>- Hemlock is different than ash. You just need to get the treatment into the xylem.</p> <p>-Paul Bolland- researched/noted bad cracks and decay sets in.</p>	<p>Chemical Control: Avoid application systems that require plugs. Don't need to be spending efforts hammering plugs.</p> <p>*Basically, all you have to do is get the chemical into live tissue. Placement of injection- **Keep it down in the buttresses because there is very active tissue there", advises Dr McCullough.</p> <p>- Hemlock is a lot different from ash tree wood. All you have to do is get the treatment into the xylem.</p> <p>- <i>Will have to recontact Deb about Paul Bolland researching bad injection cracks where decay sets in.</i></p>
<p>Winter Mortality Thresholds: She agrees that – 25 C is about the right threshold for winter mortality. They get a lot of abrupt temp swings. Last Feb, they had – 14 F and had no mortality of adelgids. There are a lot of micro-climate factors. She finds that there can be large temp differences on upper south side of tree vs lower canopy north side of tree. Therefore, it's hard to forecast responses to blanket temperature readings. She believes that a cold night in January will have higher mortality than later in February, as if the adelgids have 'toughened up'. Has a grad student on this topic.</p>	<p>Winter Mortality Thresholds: It's hard to forecast responses to blanket temperature readings. Temperatures are variable, even on individual trees due to microclimate variations. She believes that – 25 C is about the right threshold for winter mortality. Michigan gets a lot of abrupt temp swings (like NS). Last Feb, they had – 14 F (-25C) and no mortality of adelgids. She believes that a cold night in January will have higher mortality than later in February. Possibly adelgids 'toughen up' as winter proceeds.</p>
<p>Jackie Broeker, Strike Team Coordinator, TN Division of Forestry</p>	<p>C 615 917-6504 Jacqueline.broeker@tn.gov 1084 Westel Rd, Westel Work Center, Rockwood, TN, 37854</p>
<p>Jackie is running 3 different programs. She has a wildfire background. She also leads a prescribed fire program. They have a lack of staff capacity.</p> <p>HWA task force began in 2008. A 5 yr plan was developed. Things really began to be implemented in 2013. Before then, they had some state parks and places that were already hiring contractors, but weren't doing any research, no database, etc.</p>	<p>HWA Management:</p> <ol style="list-style-type: none"> 1) Begin by prioritizing stands, according to health of the stand, level of infestation, other values, etc, and how long they thought it might be before they would need to treat the stand with chemical. There were waves of HWA that were hitting at different times in different localities. 2) Designate Hemlock Conservation Areas.

<p>HWA Management began by prioritizing stands, according to health of the stand, level of infestation and how long they thought it could be before they could hit the stand with chemical. They wanted to know where the waves of HWA were hitting, as it was not the same everywhere. They projected out which years they would do what. They have greater than 150 conservation areas that they will continuously treat. Designate Hemlock Conservation Areas.</p>	<p>3) Project which years they will need to treat which areas. - She is trying to write a 5-year management plan (but there has been little time.) -Jackie’s Strike Team treats > 150 conservation areas continuously.</p>
<p>Chemical control: They follow McCarty’s research and know about olefin which prolongs Imidacloprid efficacy. They no longer treat on a 3 yr rotation, now a 5-year rotation. They return to stands and assess when they really need to treat. In early March, she had a crew making forest health assessments. All treatments are soil drench. She hasn’t been treating riparian buffers because of the increased complexity of injection but she is interested in our setup if we have a fast, easy approach.</p> <p>Buffers: 100 ft (30 m) mixing buffer and 10 ft (3 m) application buffer, 3 ft (90 cm) flowering plant buffer. The Label is the Law. The flower buffer is not on the label, but they do it anyway.</p> <ul style="list-style-type: none"> - They use 75 % water soluble packets. - She is trying to write a 5-year management plan. Wants to take time to write a prescription and management plan for each area. V. little time. - She sets up a schedule with the parcels, roughly gauging 50 acres/week. -They used to do 10 acres/wk. Cost went from \$100.00 per acre to 40.00 acre. -She oversees 2 strike teams, but the other is a prescribed fire team. Team dynamics and development of cohesion is important. Goal/vision/rules. - Because they are funded by a grant, she has the crew prepare a simple, end of season report: How many acres treated, how many trees, how much chemical they went through. <p>Costs: Limited to 181 oz/yr/acre. This works out to 5, 1.4 packets. - 5 packets cost ~ \$ 40.00. Therefore, one acre costs ~ \$ 40.00 USA. -Private operators are charging \$10.00 per tree. Huge profits.</p> <p>Training for treatment teams: Jackie has made training videos. Other States want to hire Jackie to train their crews but she doesn’t have time. “Meet up and Gear up!” Jackie provides 2 weeks of boot camp training (1 wk of class and 1 wk of field training) to a seasonal crew where they learn what tree decline and recovery looks like, low to mod</p>	<p>Chemical control: Have a few staff out early assessing forest health in stands slated for treatment.</p> <p>Buffers: -We may want to establish a flowering plant buffer in a “Best Practices for Xytect”- distance from water for mixing. -Tennessee uses a 30 m mixing buffer, 3 m stream buffer, ~ 1 m flowering plant buffer.</p> <p>Productivity: She schedules her crew to treat roughly 50 acres/week (soil drench) -Her crew used to treat only 10 acres/wk, but now they are more proficient. Cost went from \$100.00 per acre to \$ 40.00 acre.</p> <p>Strike Team training/organizing: Jackie has practical advice on organizing, training strike team field crews and estimating their progress in the field. A Strike team contains a Crew lead (generally a forester) plus 3 crew members. Crews are mobile. -We discussed her sharing some of her training presentations and videos. She runs a two week “boot camp” (1 wk in class-1 wk in field)- for the field crew to become very tactical and efficient with time. All members take the pesticide exam. <i>(She has not gotten back to us with whether she has authorization to share training slide talks and videos, but it is sounded promising.)</i></p> <p>The end goal is to maintain an intact forest. Since they are using chemicals with annual per acre limits, they learn how to pick trees in order to keep the stand intact. (They have to return the stand 3X to get the entire stand treated.)</p>

to high HWA infestation. She avoids forestry jargon. Crew undergoes 'crew cohesion training'. They all take the pesticide exam.

- They review predatory beetle database, Avenza, radio, orienteering.
- They work 4, 10-hr days of field learning, plus a classroom day.
- They review the importance of picking trees to keep the stand intact. There is a whole lecture on "picking trees". *The end goal is to maintain an intact forest.*

Treatment logistics: Hires a crew lead who has a forestry background.

It's very humid and wet so smart phones and tablets don't work as well. Still use paper and Excel.

- Hires 3 crew members and a crew lead. It's the perfect number according to how they move through the stand, proper layout of command. Crew works together for 8 months unless there is drought. Treat Oct to May (not our NS season). They receive a fieldwork SOP.

*They are travelling crews, with a travel budget. If state parks have cabins, then this crew has priority to use those cabins for free.

- Crew examines the whole stand in its entirety and then picks out the trees on a map using a 1-acre grid.

- The forester/crew lead goes in and measures per acre BA treatment area, paints the trees to be treated. Since they can only use 181 fl oz in the ground. The crew lead stretches out that per acre limit throughout the stand to keep it intact. Don't want the first part of the stand totally drenched in chemical and the rest untreated. They have a 3 yr rotation to complete the whole stand. First round is a blue dot for whole treatment. Next treatment round is orange dots, etc, to cover 3 yrs. To paint trees, they have to remove moss off trees or will lose their dot!

- Time is not your friend. There is no time to write an indiv plan for each treatment area. They just hit a stand with BA and HWA infestation and **treat 12 in DBH (30 cm DBH) and up, then go back and treat 8 DBH (20 cm DBH) and up... the size limit depends on the stand size range.** You have to have someone on your team who knows how to adjust to that.

- They have maps downloaded on their phones. They must check weather. Have a forestry vest. They have a personal battery pack, first aid kit, extra pencils, sharpies, acre grid fishnet is overlaid on the map. They note DBH and how much chemical they used, then drop a pin on Avenza, and record their tracks in Avenza. They save their shape files.

- If you don't follow your exact tracks, you will miss trees and go over on someone's tracks. They can always go back next year and treat more

Costs: Limited to 181 oz/yr/acre. This works out to 5, 1.4 packets. - 5 packets cost ~ \$ 40.00. Therefore, one acre costs ~ \$ 40.00 USA.

Treatment logistics: *Review left column!* Contains very good tactical information to review/integrate.

- "Time is not your friend", Jackie stated. With HWA this is so true.

- Stands in sandy soils- we must inject.

<p>trees. A small problem with crew members who will put chemicals in the ground and not record it because they want to save a nice tree. It's hard, but that is breaking a law. - problems with mistakenly treating wP.</p> <ul style="list-style-type: none"> -always remember where you last saw water (for mixing) -Don't treat trees in sandy soils -Slippery and slick- not safe to have backpack sprayer on. - Cannot treat 24 hr before/after treatment rain. It depends on how much water is in the soil. 	<p>Weather stipulations: Cannot treat 24 hr before/after treatment rain. It depends on how much water is in the soil. (This would not be necessary for tree injections.)</p>
<p>Nature Conservancy and TN Division Forestry formed the TN Hemlock Conservation Partnership. Have 2 meetings/yr and lay out the treatment season. Winter meeting is a one-day short conference to talk about what they do and plan to do.</p>	<p>Private Conserved lands: Strike teams can be partnered with Nature Conservancy.</p>
<p>The first strike team was formed in 2014-15. Now in their 7th season. Treat only on publicly-owned lands and also some Nature Conservancy lands. That's because they have been partnering with Nature Conservancy.</p>	<p>Strike Teams first formed in 2014-15.</p>
<p>Private lands: Jackie provides some guidance to private lands. They reached out to those land managers/owners with heaviest hemlocks</p>	<p>Private lands: They reached out to those who owned the heaviest hemlock forests. They provide guidance to private land owners.</p>
<p>Nature Conservancy partnerships: Nature Conservancy paid for LidAR mapping to determine where the heaviest hemlocks were located on public lands.</p>	<p>Nature Conservancy: There are unusual ways to partner. In this case, they paid for LiDAR and received treatments/guidance.</p> <p>- Can NS forest LiDAR info be used to identify best hemlock stands?</p>
<p>Biocontrol: They keep predatory beetles in a lab in Knoxville, TN. Have started monitoring for predatory beetles. The best place to beat trees and aspirate for beetles is N. Carolina. They can easily be placed in a tube and shipped back. Biff Thompson (Forest Health Technician @ Maryland Department of Agriculture) knows how to transport them internationally.</p> <ul style="list-style-type: none"> - She is optimistic about biocontrols. As long as they can release silver flies, she is optimistic. If they cannot find the '1-2 punch', then she is not optimistic. They must have a biocontrol that is eating HWA at all points of the year. 	<p>Biocontrol: They are redistributing beetles from the wild. The best place to beat trees and aspirate for beetles is N. Carolina. They can easily be placed in a tube and shipped back. Biff Thompson (Forest Health Technician @ Maryland Dept of Ag) knows how to transport them internationally.</p>
<p>Private landowners: <u>They lend kits</u> for private landowners, consisting of Nalgene bottles, 2.5 gal bucket, DBH tape, flagging tape, a printout form grid what will give them how many oz to put in the soil, instructions for how to treat.</p> <ul style="list-style-type: none"> -<u>They provide training workshops</u> to show people how easy it is, so they are less over-whelmed. - No cost share supports in TN -Still have private land owners who want to treat but can't afford it. 	<p>Private landowners:</p> <ul style="list-style-type: none"> -<u>They lend kits</u> for private landowners. -<u>They provide training workshops</u> to show people how easy it is to treat trees, so they are less over-whelmed. - There are no cost share supports for private lands in TN.

<p>Database: They use ArcGIS Pro. -She needs a plan for the data. She suggests following a plan meticulously and ensuring she has a succession plan in place and a training program in place, in case something happened. Because <i>it's been a race since 2017</i>, this is not yet in place. -One of the faults of their program, they do not have an information holder beyond Jackie. Needs to be set up so someone can step in. Need an alternate person that is permanent, so program doesn't fall down.</p>	
<p>Carbon: They are looking at C off-sets.</p>	
<p>Thresholds: Don't want trees that have more than 30 % canopy loss. Even trees with only 10-20 % canopy loss, some don't bounce back. If you don't get there in time, some will die. They use both LCR and canopy density. If you can see through the crown there is not enough pump. Look at both. For e.g. 70 % LCR, but density was only 30 % would be bad; it is the combination of both or trees won't make it.</p>	<p>Thresholds: -Don't treat trees with > 30 % canopy loss. Sometimes even trees with only 10-20 % canopy loss don't bounce back. -They use both LCR and canopy density. If you can see through the crown there is not enough pump.</p>

<p>Drew Rayner, Michigan Gov <i>*Drew has excellent field tactical experience and provided a very different kind of information from the researcher info.</i></p>	<p>517-231-8763 RaynerD1@michigan.gov</p>
<p>Interview/Discussion Details</p>	<p>Best Advice and Action Items</p>
<p>Background: Left a local 'Conservation District' (Michigan has a conservation district in every county) where he ran an IAs program, writing grants and conducting field work since 2018. He had 2.5 million in grant funding to run local conservation projects. He worked for District for 6 yrs, but is now working for DNR -State Gov. He grew the District program a lot and built capacity before leaving it.</p>	<p>Michigan is taking a different approach of stamping out each and every detection of HWA, treating the infested trees plus a buffer. They are using natural barriers, the lake, etc, as part of the strategy. Their approach appears to be thorough and aggressive, striking early, completing early detection monitoring.</p>
<p>They had 'stamped out' HWA a few times since 2005 when it arrived on nursery stock from landscaping activities to areas in the SE and metro Detroit. They didn't get infestations into established hemlock forests until 2016.</p>	<p>Central and Eastern NS could consider using Michigan's early action tactics, trying to stay ahead of HWA by staying on top of early detection followed by immediate treatments and treatment buffers.</p>
<p>Chemical Control: Drew uses the Quickjet Air injection tool but has modified it to be more efficient and cost-effective. It was necessary to modify the tool for several reasons: 1) The plug system has its benefits but is expensive, and much too expensive on a hectare basis. 2) The gear was breaking down regularly and parts were very expensive to replace. 3) The carrying case was awkward and not efficient in backcountry situation.</p>	<p>Examine potential use of a modified Quickjet Air injection tool, which has potential to provide very fast trunk injection. Quickjet Air, as it comes from the factory, is a very slow injection system, and has several other major drawbacks. <i>(Both direct observation from using it at Keji and substantiated by Drew. We also know the slow performance of Quickjet Air at Keji where final statistics from fall injections during a ~ 2 month intensive treatment period were</i></p>

Quickjet Air modifications:

-The issue with Quickjet Air syringe is that it breaks. **Pressure valves on the regulators** are plastic. They break. The exact same pressure regulators that are metal can be found for only \$4.00. They saved a lot of money by buying their own parts. As well, the **output check valve**/one way valve fails regularly, and chemical must keep flowing the right way. If O-ring moves the smallest amount, must buy a new output check valve @ \$40 .00. Drew spent more than \$ 1000.00 on output check valves, and lost treatment time waiting for parts. Very annoying. Therefore, he spent his own time and money to achieve a rebuildable output check valve- you can unscrew it and there is a spring, ball bearing and an O-ring. He found the parts required at a local machine shop. For \$ 60.00 to purchase local parts, he has changed all the broken parts. All of the guns now have his modified set up. He buys a 20 cent O-ring instead of \$40.00 parts and replaces the O-rings 2X/season.

-Drew is the designated repair guy. If a part breaks, he has become the floating person that fixes the gear. Other people can be trained, but he is faster. **Maintenance is the hardest part to this system.** The only part they presently order from Arborjet is the in-line check valve.

- Drew has shared his revised specs on the Quickjet Air with other USA teams and is willing to share with NS teams. He uses a **7/32 diameter needle**- small size. 55 psi is required for injection on the tank so not a super high pressure. They were dosing on the higher end and with a small injection site hole diameter, they had to inject very deeply (on plug systems, he thinks they were running at 120 psi). On the standard plug system, you are pressuring and cramming/forcing in a high-volume.

-Drew obtained a **9/32 diameter needle** at a machine shop. That allows an extra 2 mL of chemical and avoids the leaking of chemical and pressurized back spray hitting the face. The inner diameter of that needle is larger by almost double the size of Arborjet's needle. He no longer has spray back issues. (Crossland *experienced this, too.*) This also likely reduces tree damage experienced by bark separation at times, given the high pressure of the original system.

-He has parts list for the revised, more efficient injection gun. We could assemble the modified Quickjet Air apparatus ourselves. With Arborjet the line comes out of the back of the syringe and causes the

under-whelming, with ~ 450-500 trees treated; what the Sporting Lake Ecoject approach could have accomplished in just 2 days using volunteers and saving enormous labour costs.)

Drawbacks of factory-made Quickjet Air are: 1) Uses plugs that stay in the tree @ ~ 1.00/plug, which greatly increases expenses and time required to pound in plugs at appropriate depth. 2) Injection gear breaks down frequently. Parts are expensive from ArborJet and causes losses in labour downtime. 3) The carrying case is awkward for backcountry situations. 4) Injection is at high pressure which can damage the tree.

The modifications outlined by Drew (see info in left column) should be evaluated for NS use.

-With the modifications, the system is good for the solitary applicator or crew of two, and it is fast!

-Drew is making an instructional video on using the modified Quickjet Air. Drew is willing to send the parts list and can set up a call to put it together. He has the instructions 'all worked out'.

-The larger drill diameter negates the waiting time that was originally experienced at each drill hole for tree uptake.

Explore treatment and chemical options with Mauget for competitive prices and potential use of Imicide as an alternative to

<p>line to kink. He has modified the 'silver part of the needle' where it meets the connector male coupler to the body. "<u>Arborjet needles break within a day or two.</u>" With Drew's modifications, they no longer break needles.</p> <ul style="list-style-type: none"> -Injectors break all the time and are easy to trouble shoot/ fix when you become experienced. -Drew has replaced the Arborjet carry pack with a backpack that works well for his modified Arborjet gear. He can easily carry enough gear to treat 1000+ inches (2, 540 cm) on his back. <p>Treatment: They use Imicide, a Mauget product. Mauget gives a discount that saves them a lot of money. 4 bottles of Imicide off shelf @ \$420.00/ L bottle. But they get it for < \$ 300.00 bottle. Mauget is super helpful and reduces the price so they have saved a huge amount of money for 160 000 inches, requiring over 300 bottles of chemical.</p> <ul style="list-style-type: none"> -Each bottle does 500 inches (1270 cm). The company saved them almost 40 k. -Imicide and IMA-jet are about the same price off the shelf, but Mauget gives a special discount. -When people start to inject, they are very slow. -His strike team crew treated 25, 000 trees and did not break any needles. They completed 160 000 inches/worked field 99 days (406, 400 cm in 99 days). Crew size 4- 4.5 people on average. -He can treat 1500 inches (3810 cm), ~ 125 trees by himself within 4-5 hours of injecting with his modified system. If someone is drilling for him, he could easily treat > 2000-2500 inches (5080-6450 cm) in a ~ 5 hr workday. A 10-inch tree (25 cm tree) takes only a minute to inject. <p>This is significantly faster than the original manufacturer setup of Quickjet Air where there is waiting required at each injection hole.</p>	<p>IMAjet. Mauget has the longest history as chemical company in the tree treatment business in USA.</p> <p>Productivity with modified Quickjet Air:</p> <ul style="list-style-type: none"> -Drew's crew of 4-4.5 people can treat 406, 400 cm in 99 field days. - Working by himself, he can treat 3810 cm, ~ 125 trees (av 30 cm diameter tree) by himself within 4-5 hours of injecting using his modified system. -If someone is drilling for him, he could easily treat > 5080-6450 cm in a ~ 5 hr workday (i.e., ~ 170 trees minimum in a 5 hr day with 2 people). A 25 cm tree "takes only a minute" to inject. <p>These are significantly faster stats than attained using the original manufacturer setup of Quickjet Air where there is waiting required at each injection hole.</p>
<p>Field methods: They survey stands all winter, tag and data collect. They already know what the site has for total cm. They treat all summer, and sites are ready to go. Crews base their work off the tag number, using IPads and add to dataset. Always 2 mL/inch (metric= 1.2mL/cm- For IMAjet, we have been using 1.6 mL/cm but label indicates can use less, so this may be a consideration in future injections. Presumably Drew is giving a Label dosage for Imicide).</p> <ul style="list-style-type: none"> -They nail in metal tags. -They survey in transects. The tags are in order with transects. 	<p>Field methods:</p> <p>Survey all winter/Treat all summer. This is the best strategy to be ready to go in the brief treatment window that may only be available in spring-fall. Summer treatments may take place but depends on weather.</p> <p>Treatment method considerations: If authorization for emergency use of Xytect is achieved and it comes with similar usage limits as in</p>

<p>Crew size: Two-person crew: one person maintains data and drills, the other injects. Three-person crew: one person injects, one drills, one data. Sometimes one person maintains data for <u>5 people injecting</u>. The injector people keep feeding numbers to the data person. - This year they will cross the million-inch mark.</p> <p>-It depends on the site how the transects are set up. Follow what makes sense in the field- the people in the field decide the transect. The tag numbers are more or less in consecutive order. Trees < 5 inches they basal spray. Above 5 inches (12.7 cm), inject. -Can't inject a small tree, so they put a threshold of 5 inches (12.7 cm), and basal bark spray all the small trees. Since this uses only small amounts, they avoid exceeding the Xytect limits. Costs ~ 6 cents/inch (2.4 c/cm) with basal bark. Inject everything bigger @ ~50 cents/inch (20 c/cm). - Can't treat trees in standing water, so it's not a perfect solution. But they can get 99 % coverage. Crews sometimes miss a tree here and there. Michigan has 5 counties infested, but they are only working in 2 counties.</p>	<p>USA, then explore options for using it only on the smaller trees that are too small for injection, and continue to inject larger diameter trees since injections have no usage limits. Consider the merits of using Drew's strategy (<i>see left column for details</i>).</p> <p>Crew size: Two-person crew: one person maintains data and drills, the other injects. Three-person crew: one person injects, one drills, one data. Sometimes one person maintains data for <u>5 people injecting</u>. The injector people keep feeding numbers to the data person.</p> <p>Can't inject a small tree, so they basal bark spray small trees under 12.7 cm. *Since this uses only small amounts, they avoid exceeding the Xytect limits. (Brilliant)</p> <p>Costs ~ 6 cents/inch (2.4 c/cm) with basal bark. Inject everything bigger @ ~50 cents/inch (20 c/cm).</p>
<p>Strike Teams: The majority of their hemlock are on private land. His old organization had a strike team. There's another grant funded organization that will be using a strike team. State parks have strike teams. Drew only works on state forests where he is helping to build capacity. -Another group who will charge very affordable rates on private land work: \$ 1.00/ inch. So 10 trees might be \$ 150.00- very affordable. The State is working on a Strike Team for government. Some other programs mirror his program. Another team is hired by the 'conservation district'. It was his 4-5 person crew who treated all private lands, so when an infestation pops up, they can now bring in the private strike team and a State team, too.</p>	<p>Strike Teams have caught on nearly everywhere. Michigan has a private land Strike Team and a State-run Strike Team. They can bring in both teams when an infestation pops up. They charge affordable rates: @ \$ 0.39/cm US (or \$ 1.00/in). This computes to a 40 cm tree costing only \$ 15.75. 10 average-sized trees (40 cm DBH) would cost ~ \$150.00.</p>
<p>Database: They use Arc on-line. Data for each site: Each tree is individually tagged using Excel or Survey 1, 2, 3. They collect tree lat-long, tag #, DBH, infestation status. He uses Survey 1-2-3- and can make a map in 5 mins, can see how big the tree is, etc.</p>	<p>Set up spatial treatment database similar to USA counterparts. Do not reinvent the wheel. Streamline one uniform treatment platform, regardless of user- government, NGO, etc. Use Survey 1-2-3. Apparently, a map can be made in 5 mins and can provide details on tree sizes, etc. Virginia Tech seems to be using this program also.</p>

<p>Basal bark spray vs Injection: Cons of basal bark are: 1) Must return to the site 5-6 years in a row. Can only treat 130 inches/acre/yr (or 330 cm/acre/yr = 815 cm/ha/yr) 2) During treatment, it can be a long walk with a 30 lb backpack to/fr treatment site and refilling water source. The travel distance is time-consuming and can be tiresome, especially if going up/down hills and commuting/walking over long distances. Pros of injection are: 1) He can easily carry 4 hours of injection gear & product. 2) He can 'fly around' and inject trees all day.</p> <p>-If they weren't limited by per year application limits basal bark spray would be more cost effective. -He does not think basal bark is slow, but his own injection system is fast! Injection is more efficient because of what he can carry on his back. -Injection just cannot be regarded as "slow". Must examine cost savings with backpack sprayer and cheaper chemical and consider site conditions/travel distances to water vs injection that is self-sufficient for 4 hours at a time. - Basal bark can achieve a more even distribution of chemical in the canopy, but he's seen small trees (treated with basal bark) with single branches left infested. Coverage is not 100% on basal bark because of steep hills and crawling around trees. They do find one branch that remains infested in a bunch of treated trees.</p>	<p>Adopt a variety of treatment strategies/methods to cater to all situations. It is likely that we will want to adopt at least two injection systems, plus a basal bark operation to meet a variety of environmental situations and team environments.</p> <p>A problem with basal bark is that one must return to the site 5-6 years in a row. Can only treat 130 inches/acre/yr (or 330 cm/acre/yr = 815 cm/ha/yr)</p>
<p>Volunteers: He's always worked with a paid crew but says it could easily be carried out with volunteers. It would "take 2 seconds to teach them".</p>	<p>Volunteers: Modified Quickjet Air would be easy to use with volunteers.</p>
<p>Thresholds: In Michigan, they do not score canopy health prior to treatment, just infested/uninfested. All infested are treated. They place an 800 ft (243 m) delimitation buffer around all infested trees/sites. Any tree within 800 ft of an infested tree gets treated. Waypoint positive points and then map 800 ft from it. Anything on the inside of the buffer gets treated and don't slow down to check them. Just tag the trees and DBH measured. Detected/not detected and proximity skip where don't check them thoroughly. Tree health? Unless the tree is going to be dead next week, treat it. Their goal is to slow the spread and contain. They have a natural barrier with Lake Michigan on one side and another barrier on the other side. They are trying to</p>	<p>Delimitation buffers may be a good strategy to use when HWA arrives to a new site and is still very patchy. This may be cheaper than letting the outbreak get larger and then having to treat the entire stand. Delimitation buffers require all trees to be treated within ~ 240 m around any outbreaks of HWA.</p> <p>Tree health/decline is not evaluated. They treat unless mortality is imminent. The reason is they do not want to leave a source of HWA that will reinfest.</p>

create a wall. They don't want to leave those trees untreated because they do not want that tree to be a source to reinfest.	
Carbon: No work on this.	
Biocontrol: Michigan is still trying to be proactive and just get rid of HWA. They have no biocontrol program. They are committed to treating areas and wiping out HWA. The State is waiting for studies to show better results before they invest in a program.	
Private lands: In Michigan, private lands were treated for free by the local District offices. They receive both State and federal grants to work on private lands. Licenced in the same way as for-profit organizations. Most of the infestations he has worked on in the past were on private land, but there is a lot of hemlock further north on State lands.	Private lands: In Michigan, private lands were treated for free by the local District offices.
If you could start over? He's encountered many hiccups, but he likes where he is now. He's figured out the drill bits. Commitments- he said he was dumb and thought some of those infestations were small when he was working in the district and supplying services to private landowners. He spread work crews way too thin. They should have started smaller with commitments on private land. What he thought was "just 1-2 properties" turned out to be 300 acres, which resulted in underestimating the extent of the infestations and how long it would take. Landowners grew frustrated because they thought the District crews were going to show up and it took 2 years longer to get there. An original estimate of 1-2 days of work took a year of work.	Regrets: They over-estimated time required to treat on private land. They needed a better work planning/assessment of HWA extents. -Very happy with his current efficient injection system.

More information on Michigan's 75 'Conservation Districts' (CDs): CDs are the **local providers of Natural Resource management** services -- similar to local fire, police, health, and school services. Created by the USDA in response to the 1930s Dust Bowl, Conservation Districts (CDs) **are local units of government** that utilize state, federal and private sector resources to solve conservation challenges. Best conservation practices vary widely depending on the region they're practiced, Conservation Districts were formed so that **decisions on conservation issues could be made at the local level, by local people**, with additional technical assistance provided by government-affiliated organizations. -Conservation District staff and technicians work hand-in-hand with local, state and federal organizations to roll out voluntary programs that directly assist and impact the environmental quality of the communities that make up their "incredibly unique peninsulas". 57% of Michigan's forested land base is owned by over 420,000 family forest landowners.

Funding: Environmental Quality Incentives Program (EQIP) The EQIP provides financial assistance to **address natural resource concerns on non-industrial private forestland**. Our Districts facilitate EQIP on the local level, aiding the USDA's Natural Resources Conservation Service (NRCS) in rolling out financial and technical assistance through this voluntary program.

The primary focus of the forestland fund pools within EQIP is to (including but not limited to) implement practices that:

- benefit honeybee populations and other pollinators,
- improve habitat for aquatic wildlife,
- control of noxious or invasive plant species,
- address wind and water erosion concerns,

- exclude livestock from forest land or environmentally sensitive areas, and
- establish conservation cover, windbreaks/shelterbelts, riparian herbaceous cover, riparian forest buffers, forest stand improvement.

Notes from Mayfield lecture (2015) available on Youtube. https://kaltura.uga.edu/media/t/1_07uzxsq8

Mayfield advises us to use all the tools available.

Genetic Resource Conservation: Build a hemlock insurance policy with seed banks and seed orchards.

i.) Seed bank: Put existing genetic material away in seed banks. Genetic Resource Conservation Banks.

Collect from as many populations as possible and implement seed collection and putting into long term cold storage

ii) Seed orchards. They have done conservation 'banking' through growing out seedlings. They have grown seedlings in Ash County, NC and also outside of the range in South America. This is a nice 'insurance policy'.

Host Plant Resistance: There is a low frequency of resistance detected and he is not sure how much of what has been observed is due to environmental factors vs natural genetic resistance. Research taking place at U. Rhode Island and NC State. Hybridization crosses to produce resistant eastern hemlock have not been successful. (Carolina hemlock X Asian hemlock has been somewhat successful but not with eastern hemlock.) In any case, it is more of a long-term strategy.

"Pesticides and Predators"- Mayfield has concentrated on integrating these two tools.

Chemical Control: Is the only reason why there are still green hemlocks in the Southern Appalachian forests.

(I ran out of time to continue watching the remainder of Mayfield's video lecture, but I recommend viewing it or speaking directly with Mayfield.)



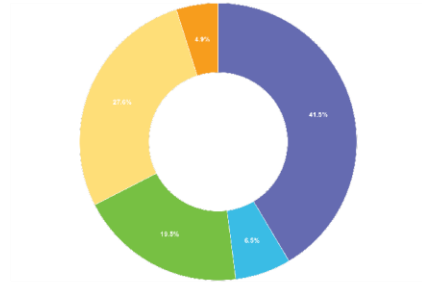
Modified QuickJet Air syringe by Drew Rayner, Michigan DNR.

Useful resources

- Managers Reports 2021- listed [here](#)
- [Treating Hemlock Trees](#) YouTube. U. Georgia Extension YouTube. Reviewed several treatment methods and refers to a *deposit to borrow a soil injector apparatus* that is kept in the town office.
- Hemlock Woolly Adelgid by Linda Blue' (YouTube). Key message: We “can apply imidacloprid during summer months if there has been adequate moisture in the soil so that hemlocks are still taking up water. Adequate rainfall is key in the summer months.”
- P.H.H.A.T. - Paddlers Hemlock Health Action Taskforce. email volunteer@savehemlocksnc.org. Learn more at <https://savehemlocksnc.org/april-2021-phhat-hemlock.../>

Appendix 2: Landowner Survey Results

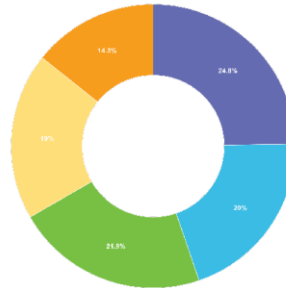
Q1 Which best describes your forested property?*



Answered: 109 Unanswered: 0

Choice	Total
a. Cottage or residential property	51
b. Woodlot less than 25 acres in size	8
c. Woodlot 25-99 acres in size	24
d. Woodlot 100+ acres in size	34
e. I have no property with hemlock, I'm interested in HWA impacts in NS	6

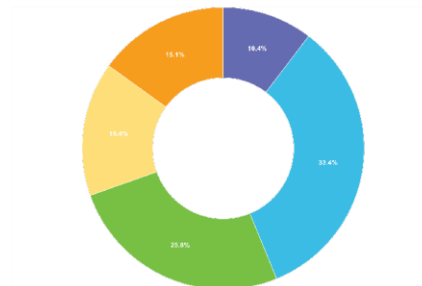
Q2 How much hemlock do you have on your property?



Answered: 105 Unanswered: 4

Choice	Total
a. Less than 5 hemlock trees around my cottage/house	26
b. More than 25 hemlock trees around my cottage/house	21
c. Less than 5 acres of my woodlot is hemlock	23
d. Between 5-20 acres of my woodlot is hemlock	20
e. More than 20 acres of my woodlot is hemlock	15

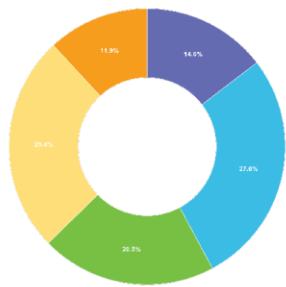
Q3 Which forest values are you most concerned for? (check all that apply)*



Answered: 109 Unanswered: 0

Choice	Total
a. Economic - timber value	31
b. Ecological - ecosystem value	100
c. Recreational - enjoyment value	77
d. Cultural - historic value	46
e. Spiritual - connection value	45

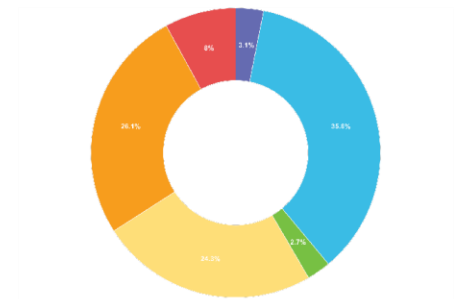
Q4 How familiar are you with HWA? (check all that apply)*



Answered: 109 Unanswered: 0

Choice	Total
a. This webinar & survey is my first exposure to information on HWA	27
b. I've heard about HWA on social media and news platforms	51
c. I've attended previous talks or webinars on HWA	38
d. I've visited a website or accessed other resources on HWA	47
e. Other	22

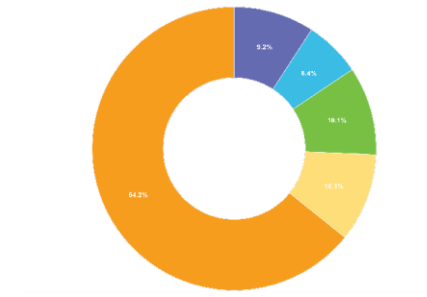
Q5 How do you assess your hemlock trees for HWA infestation? (check all that apply)*



Answered: 109 Unanswered: 0

Choice	Total
a. I don't know what to look for	7
b. Checking the undersides of branches (within reach)	81
c. Using pole pruners or methods to sample high in the tree canopy	6
d. Checking branches and tips that have fallen to the ground following storms	55
e. I look for declining hemlocks that are losing needles and colour	59
Other	18

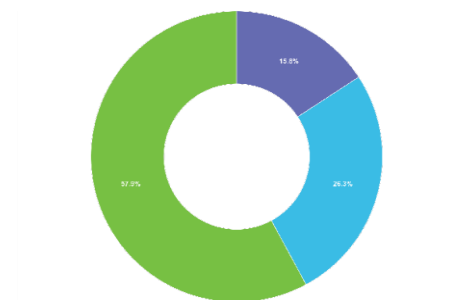
Q6 Which of the following options would you consider for managing HWA on your property?*



Answered: 109 Unanswered: 0

Choice	Total
a. No treatment	10
b. Chemical control - to conserve only the oldest hemlock trees, leaving younger trees untreated	7
c. Chemical control - to conserve specific hemlock stands	11
d. Biocontrol - introduced predator insects that eat HWA	11

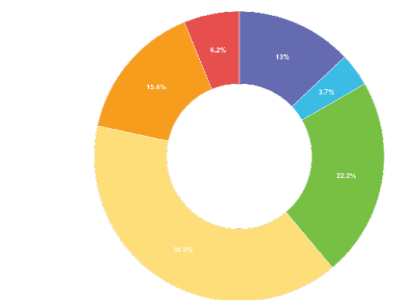
Q7 If you selected no treatment, which of the following are you considering? (otherwise skip this question)



Answered: 19 Unanswered: 90

Choice	Total
a. Do nothing	5
b. Pre-harvest harvest of hemlock	5
c. Silvicultural thinning to promote stand diversity	11

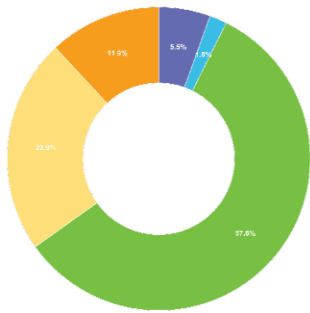
Q8 What barriers do you face to treating your hemlock? (check all that apply)*



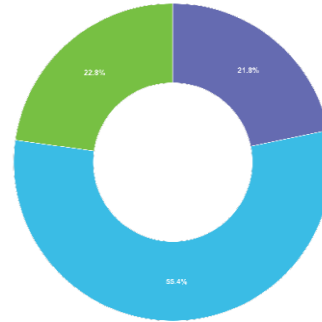
Answered: 109 Unanswered: 0

Choice	Total
a. I don't know my options	21
b. I don't reside near my property and don't know if HWA is there	6
c. I don't know where to go to access treatment options	36
d. I am uncertain and concerned about the costs of treatment options	64
e. I don't find I face any barriers - I'm ready to treat trees for as long as required	25
f. I'm not looking to treat my trees	10

Q9 If there was financial support available, would you use a chemical treatment on your hemlocks?*



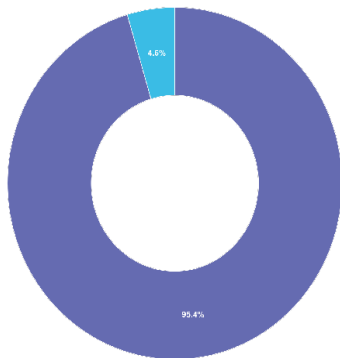
Q10 If you answered yes (c, d or e) to the previous question, how would you prefer to be involved in treating your trees?



Answered: 101 Unanswered: 0

Choice	Total
a. Hands off - I would hire people (experts and/or volunteers) to complete the treatment	22
b. I want to be involved - I would help with the treatments by working with a Pesticide Operator	56
c. I want to treat trees myself - I would like to obtain a Pesticide Applicator Certification	23

Q13 Are you interested in receiving follow-up resources and updates related to HWA in NS?*



Answered: 109 Unanswered: 0

Choice	Total
Yes	104
No	5

Q14 Do you have any questions?

Monday, March 21, 2022, 1:19 PM UTC

Would like to know more about the costs and feasibility of treatment.

Thursday, March 17, 2022, 8:45 PM UTC

Are the federal or provincial government surveying for HWA and planning any treatments?

Tuesday, March 15, 2022, 12:33 PM UTC

Should I start treatment before I notice any HWA?

Tuesday, March 15, 2022, 3:00 AM UTC

how close are we to biological introduction of predator insects

Monday, March 14, 2022, 10:31 PM UTC

I would like to know what and where to buy chemicals. Pyrethrum appears to maybe work in a drench? Dormant oils for smaller trees?the injection system seems to be US only?

Thank you

Monday, March 14, 2022, 6:55 PM UTC

When will we receive further instructions as to where and what products can be used to treat our Hemlocks, and whether or not government funding will be available ?

Monday, March 14, 2022, 6:40 PM UTC

You did not provide enough options in the questions. Should ask if compensation were available would you consider some form of reserve. Ask if interested in a biodiversity management zone.

Monday, March 14, 2022, 12:39 AM UTC

Where is the best up to date resource for new discoveries of HWA? Where do I go to check to see if it has been discovered? Or get regular updates?

Monday, March 14, 2022, 12:24 AM UTC

I have a commercial tree fruit orchards surrounded by forests so I am more than familiar using pesticides. Where can one purchase the products talked about in the broad cast?

Sunday, March 13, 2022, 6:45 PM UTC

We only have a small area of Hemlocks along Roundhill brook which Abby from the Tobeatic confirms last spring are infected. We want very much to treat these asap before its too late.

Saturday, March 12, 2022, 6:00 AM UTC

It saddens me to loose hemlock trees on and nearby our property. Please advise as to what we can do as property owners to dwarf the devastation of HWA and promote the longevity of these stately trees

Friday, March 11, 2022, 10:55 PM UTC

Need to act asap as our trees are showing decline. I look forward to being in a position to commence injections and hearing from someone to help us. Thank you.

Friday, March 11, 2022, 1:42 PM UTC

How is the Province involved in the HWA issue and what commitments, if any, have they made to assist private property owners in addressing the issue?

Friday, March 11, 2022, 4:35 AM UTC

I would like to know how to get started treating my trees.

Thursday, March 10, 2022, 8:44 PM UTC

Please contact me about treatment options and costs

Thursday, March 10, 2022, 8:27 PM UTC

How soon can HWA treatment be initiated, and by whom?

Thursday, March 10, 2022, 2:07 PM UTC

Is there any way that an alert can be sent out when the pests are nearing Truro

How can we find out the specific cost of treatment of old growth (approx. 200 years old)

Thursday, March 10, 2022, 11:40 AM UTC

Very interested in treatment options, what are our next steps.

Wednesday, March 9, 2022, 8:01 PM UTC

Would like to know more about the treatment options and possible other side effects

Wednesday, March 9, 2022, 3:21 AM UTC

Not at the moment.

Tuesday, March 8, 2022, 6:55 PM UTC

1. Will there be a list of certified pesticide operators in Nova Scotia?
2. Need a public awareness campaign ASAP, a simple poster/social media everywhere with what HWA is and urgency of situation

Tuesday, March 8, 2022, 4:32 PM UTC

With HWA in a small corner of my woodlot, Is there better times of the year to work near or in Infected areas so that I do not spread it to non infested areas?

Tuesday, March 8, 2022, 4:05 PM UTC

What would be involved in having someone view our properties to see if the HWA is present and then come up with a plan for treatment. We have 150, 21 and 2 acre (residential) properties. Thanks.

Tuesday, March 8, 2022, 3:18 PM UTC

We would need a consultation to determine which trees to treat. Who are the organisation's / people to reach out to?

Answered: 24 **Unanswered:** 85

Q15 Any additional comments or concerns:

Wednesday, March 16, 2022, 12:21 AM UTC

I am currently unsure of the quantity or health of hemlock on my property so planning a trip soon to assess the situation. Thanks for your efforts and info!

Tuesday, March 15, 2022, 7:01 PM UTC

to little to late you had your chance back when you banned firewood from coming into your parks

Monday, March 14, 2022, 7:38 PM UTC

i have a pesticide app. license, began elm injections in 1988 and i thoroughly approve of your efforts.

Monday, March 14, 2022, 6:55 PM UTC

I am concerned about time frames to begin treatments, and the risk of HWA spreading to new Hemlocks or killing those that have recently been infected but are still in a position to thrive if treated.

Monday, March 14, 2022, 6:45 PM UTC

Very informative webinar.

Presented with expertise and professionalism.

Monday, March 14, 2022, 6:40 PM UTC

Misleading re conservation because a landowner can not participate in Conservation in Nova Scotia without giving up their rights as a landowner. The Woodland Owner Easement Program still requires a landowner to give up some rights over their land and the easement is set up under control of others.

Monday, March 14, 2022, 6:36 PM UTC

New here, but open to learning and would love to have our property assessed to learn more on what we can do :)

Monday, March 14, 2022, 6:14 PM UTC

Very concerned about the state of hemlocks and would welcome biological control

Monday, March 14, 2022, 4:13 PM UTC

none on my tree in Dartmouth

Monday, March 14, 2022, 12:39 AM UTC

Thanks for all of your work around this. We found the online session very informative and helpful.

Monday, March 14, 2022, 12:24 AM UTC

Is Admire registered for HWA?

Sunday, March 13, 2022, 6:45 PM UTC

We would like to treat our trees this spring. Please direct us to someone that can help

Sunday, March 13, 2022, 12:46 AM UTC

I am still uncertain regarding the overall negative ecological impact that chemical treatment of HWA may have. i.e. Is it better for nature (insects, birds, flowers, water, etc.) to leave nature alone and let infected hemlock trees die?

Saturday, March 12, 2022, 6:00 AM UTC

Please help and guide property owners to do what we can to preserve our Hemlock Trees.

Friday, March 11, 2022, 1:42 PM UTC

I am most interested in the Province of Nova Scotia response. This seems like an opportunity for the Province to partner with private landowners to participate financially and otherwise for their mutual benefit.

Thursday, March 10, 2022, 11:40 AM UTC

The webinar was very informative and helpful. We have contacted NS forests in the fall of 2021 when we discovered our hemlocks had infection. Ready to protect them this spring.

Thursday, March 10, 2022, 1:07 AM UTC

What climatic conditions increase HWA in our area, and which will inhibit HWA? Would the ice storms (small branches encased in ice for 24-48 hours) have harmed the HWA?

Wednesday, March 9, 2022, 9:36 PM UTC

The hemlocks on our land are very old and large and are within a riparian zone or close to camp building

Wednesday, March 9, 2022, 2:17 PM UTC

The economic value of a stand of 90% Hemlock at a sawmill is about \$1200/ac. Therefore a treatment that costs more than this is not economical.

Wednesday, March 9, 2022, 3:21 AM UTC

No, thank you!

Tuesday, March 8, 2022, 11:08 PM UTC

Over mature and deceased will be cut as

Tuesday, March 8, 2022, 9:27 PM UTC

My first step is to find out if hemlocks grow on the property. I am physical unable to walk/check for any problems. I am trying to find an old survey that may have stands labelled. If there are hemlocks, would research staff be interested in checking the lot? 70-75 acres, Old Canaan Rd, Aylesford.

Tuesday, March 8, 2022, 9:03 PM UTC

Thank you. . .that was an excellent presentation.

Tuesday, March 8, 2022, 8:09 PM UTC

Although I own a Pictou County woodlot, my principal interest in participating was because I walk four days a week in Victoria Park, Truro, wherever there is a splendid stand of hemlocks, and I wanted to learn more about the HWA and fits treatment. I found the video very informative.

Tuesday, March 8, 2022, 7:24 PM UTC

Is either treatment regime a long term option for saving the hemlock or will treatments be required forever to maintain the species.?

Tuesday, March 8, 2022, 7:16 PM UTC

We have very mature (tall) hemlocks around our cottage and worry about trees deteriorating and falling on someone or our cottage, outbuildings, vehicles. How soon could treatment begin and at what cost/ tree?

Tuesday, March 8, 2022, 7:03 PM UTC

Forest Management Plan developed in 2012 is up for review this year (Federation of Nova Scotia Woodlot Owners). Athol Forestry Cooperative members. The HWA is of concern. Our Hemlock stands are +80 years old (core sample and oral history, pre 1944). Would they be a suitable seed/genetic source?

Tuesday, March 8, 2022, 6:55 PM UTC

..with info on effective, safe treatment this spring and who to contact. I bet lots of public interest in treating private land or donating to a GoFundMe campaign (\$40 "two twenties for a tree") to save a 300- year-old N.S.old-growth Tsuga "mother tree" (in time for Mother's Day?), "adopt-a-tree"...

Tuesday, March 8, 2022, 6:35 PM UTC

Great Presentation

Very informative

Liked the costing of treatment per tree

Tuesday, March 8, 2022, 6:11 PM UTC

Most of my hemlocks are young and too small to be considered for the current treatment. If I count only the trees that are large enough I probably have fewer than 25 trees.

Tuesday, March 8, 2022, 5:58 PM UTC

my neighbors treated some of their trees. I understood they were going to include us when they treated but that didn't happen. I don't know where to access treatment and I was told that the person treating would only come if we had a certain volume to treat. The cost would have been too high

Tuesday, March 8, 2022, 4:27 PM UTC

I am so impressed with the the knowledge of the professionals who presented. WELL DONE !! You gave a well-organized, super-informative presentation. Thank you so much. Please continue and keep me in the loop.

Tuesday, March 8, 2022, 4:05 PM UTC

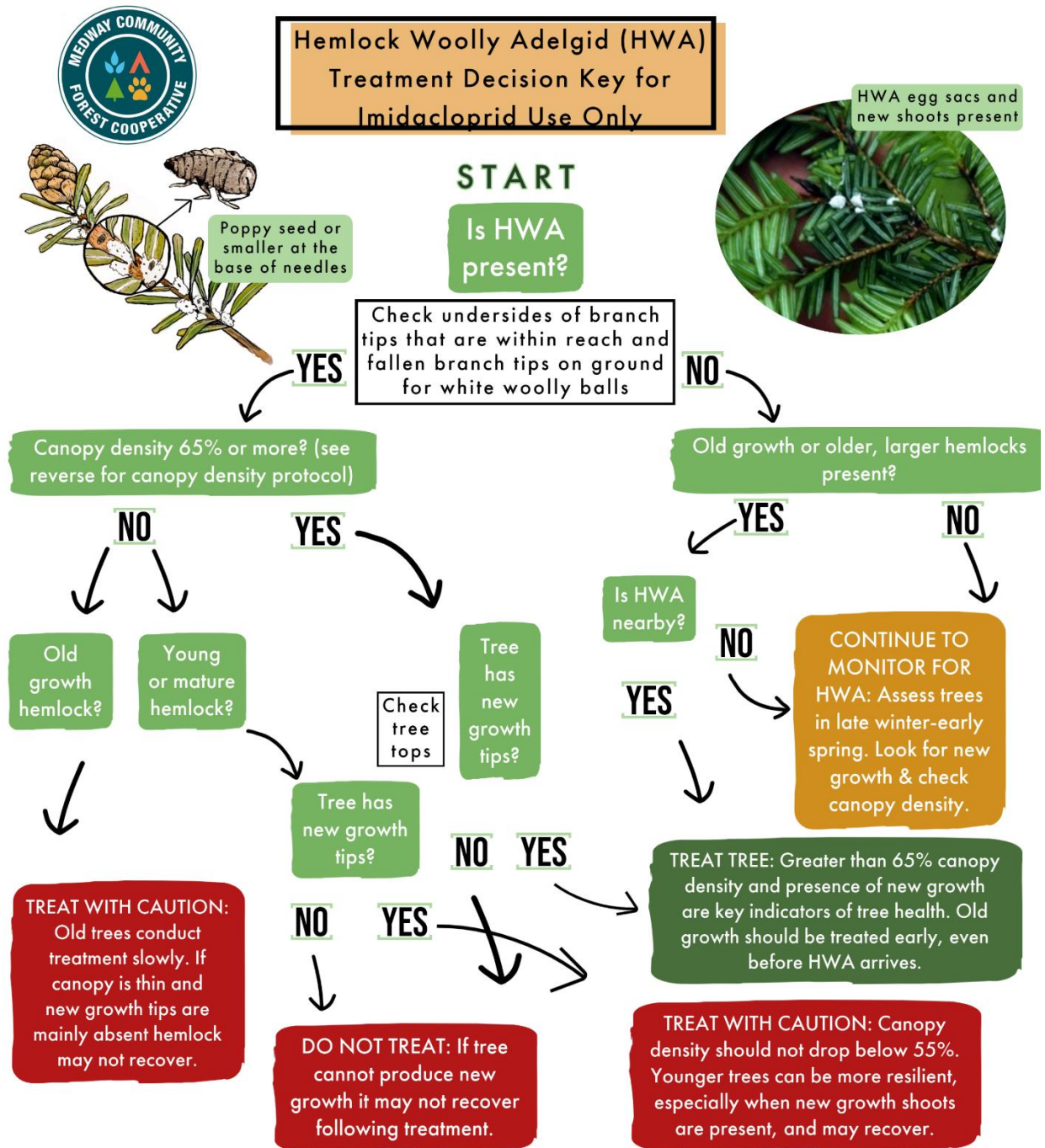
We really want to protect at least some of our trees. It would be so very sad to watch them die. We also want to do our part to help fight HWA in the bigger picture. I would also like to learn what would be involved in learning to apply chemicals myself and to possibly help others. Thanks.

Tuesday, March 8, 2022, 2:50 PM UTC

Thanks so much. As discussed with Donna, we, at Berwick Camp, are very interested in partnering and providing an environment for training. We have a dining hall, approx. 100 cottages, tent and trailer spaces, dorm rooms, on a 27 acre lot with 100's of hemlock. Hoping to meet up with her soon! Thanks

Answered: 34 **Unanswered:** 75

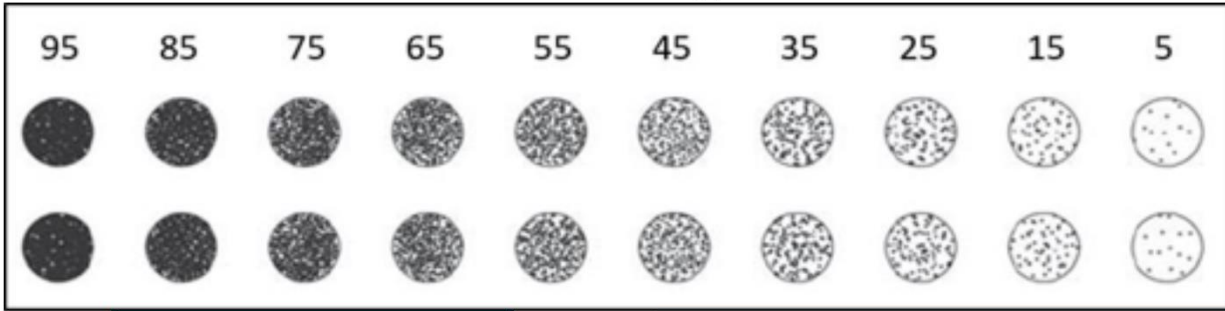
Appendix 3: HWA Treatment Decision Key



New Growth Tips: Presence of bright, lime green, tender branch tips, most visible late May-early July. New shoots may persist in tree tops (use binoculars to assist). Check on the ground for canopy samples. After July, all needles are the same colour, new are in better condition (more full) with fine texture twigs.



CANOPY DENSITY SCORE: Assess by standing at arm's length from tree & looking straight up through the canopy. Choose which best reflects the density you see.



1. TREE TREATMENT FACTS

1. Treatment using imidacloprid chemical is safely conducted inside tree sap wood.
2. There is little or no environmental exposure. Chemical amounts are small.
3. Treatments can last ~ 4-6 years.
4. Old growth should be treated early, even before HWA arrives.
5. The active product ingredient is the same used in some tick-flee medications.
6. The treatment is not toxic to birds or mammals.
7. Biocontrol agents are expected to control HWA in the long-term, but chemical treatment is presently essential or tree will die, likely within 3-5 years of infestation.

3. HWA INFESTATION LEVEL

Low Moderate High



1-4 sacs

5-20 sacs

>20 sacs

Why monitor your hemlocks for HWA 1-2 times annually?
HWA can spread quickly by birds, people and pets. Infestations in the upper canopy may go undetected. Canopy decline (needle drop) may be sudden and go unnoticed. Watch for changes in canopy density and amounts of new shoots produced.

Cost Considerations:

- Costs of Hemlock removal near buildings and powerlines may exceed treatment costs.
- Hemlocks on stream banks protect bank erosion, road and bridge infrastructure from increased storm runoff events. Dead trees falling into waterways can cause blockages at culverts and flooding to homes downstream. Costs to repair infrastructure may exceed treatment costs.
- Supports for landowners are in place in some US states where HWA is present (e.g. tree injection kit rentals)

2. EXTRA CONSIDERATION FOR TREATMENT

High Value Trees:

Old growth hemlock is irreplaceable. If there is old growth hemlock on your land, you own something very rare that will be almost nonexistent in future unless you treat it.

HWA causes permanent loss of hemlock. Hemlocks that line stream banks are of high value to both forest and stream, shading, cooling, and sheltering many other species: trout, salmon, marten, fisher, moose, deer, and birds.

HWA Infestation Levels:

Check undersides of branch tips for HWA levels, examining several branches on opposite sides of the tree. Moderate to high HWA populations on branches will damage hemlock and eventually impede the tree from producing new shoots in spring. Treatment uptake is eventually impeded.

Branch Dieback:

HWA infestation severity can also be gauged by amount of fine branch dieback where needles have recently dropped. Note: Healthy hemlock normally feature broken and jagged coarse lower branches.

Percent Live Crown Ratio (LCR):

Is the % of total tree height that supports live foliage. For e.g.: if live branches reached from the top of the tree all the way to the ground, that tree has a LCR of 100%. A tree with no living branches anywhere on the tree would have an LCR of 0% (dead). If LCR declines to < 25 % from HWA, the tree is less able of conducting a treatment to the canopy.

Percent HWA infestation on new shoots:

Count the total number of new shoots (i.e., new branchlet tips) growing along a 30 cm branch tip. Next, count the number of new shoots with wool present on the underside of the branchlets. Divide number of woolly shoots by total number of shoots. HWA infestations present on > than 30 % of new shoots growing along the sample branch may indicate greatly impeded new growth in the following yr. Trees may not respond to chemical control.

KEEP UP-TO-DATE:
WWW.NSHEMLOCK.CA & WWW.MEDWAYCOMMUNITYFOREST.COM

Appendix 4: Funding Resources

HWA Funding Opportunities

Working Draft April 2022

Summary of Annual Federal and Provincial Government Funding Programs

The selection of funding programs listed below include reference to the following criteria that may apply to HWA treatment and research: climate change mitigation and adaptation, species at risk and habitat conservation, restoration, Indigenous conservation leadership, forestry, community engagement, freshwater and invasive species.

All options are listed – including those not eligible for the Province, but that could be relevant to Mi'kmaw and NGO partners (could provide potential match in a collaborative proposal with province?).

Check <https://www.canada.ca/en/environment-climate-change/services/environmental-funding.html> for up-to-date information on current ECCC funding options.

Check <https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/22046> for up-to-date information on current NRCan funding options.

Federal Funding Options

Federal: Climate Change Mitigation

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
Nature Smart Climate Solutions Fund (NSCSF)	ECCC	\$631 million over 10 years Application launched in Fall 2021. Proposals due January 25th, 2022. The next opportunity, if any, to	Eligible groups include: <ul style="list-style-type: none"> • non-governmental organizations • universities and academic institutions • Indigenous organizations 	To support projects that restore and enhance lands to store and capture carbon. Focuses on 3 objectives to sequester carbon: <ul style="list-style-type: none"> • Restoring degraded ecosystems • Improving land management practices 	Under the Natural Climate Solutions Fund 1:1 match requirement January 2022: NSECC and NS NRR submitted proposal to the “Place-based” (land conservation) stream.

		<p>apply to this fund will not be until 2024.</p> <p>Part of the \$4 billion Natural Climate Solutions Fund to address climate change and biodiversity loss over the next ten years:</p> <ul style="list-style-type: none"> • 2 Billion Trees Program (2BT) led by Natural Resources Canada (\$3.19 billion) (see below) • Nature Smart Climate Solutions Fund led by ECCC (\$631 million) • Agricultural Climate Solutions led by Agriculture and Agri-Food Canada (\$185 million) 	<ul style="list-style-type: none"> • provincial, territorial and municipal governments 	<ul style="list-style-type: none"> • Conserving carbon-rich ecosystems <p>Also support the monitoring and reporting of GHG emission reductions.</p> <ul style="list-style-type: none"> • Budget 2021 allocated \$60m over 2 years from the fund to target protection of existing wetlands. <p>Funding under three streams: Indigenous partnerships, place-based actions, sector-based policy.</p>	
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<p>Climate Action and Awareness Fund</p> <p>Includes Environmental Damages Fund</p>	<p>ECCC</p>	<p>\$206 million over 5 years</p> <p>Community-based climate action request: \$100,000 to \$6 million up to \$50 million over 5 years.</p> <p>Advancing climate science: Maximum of \$6 million per project for up to \$59 million to eligible organizations over 5 years.</p>	<p>Eligible groups include:</p> <ul style="list-style-type: none"> ● non-governmental organizations ● universities and academic institutions ● Indigenous organizations 	<p>To support Canadian-made projects that create middle class jobs and help reduce GHG emissions. Priorities are:</p> <ul style="list-style-type: none"> ● Support climate youth awareness and community-based climate action (requests for proposals closed 2020) ● Support climate research at Canadian think tanks and in academia (requests for proposals spring/summer 2021) ● Advance climate science and technology (request for proposals open until June 10, 2021). <ul style="list-style-type: none"> ○ Projects funded in this stream must fall under one of the 5 themes. 	<p>Province not eligible (need to confirm).</p> <p>To date: 4.4 million to Clean Foundation’s Youth Climate Action Now (YouCAN) project.</p>
<p>Environmental Damages Fund (EDF)</p>		<p>Available funding varies according to the number of court awards and voluntary contributions directed to the EDF.</p>	<p>Eligible groups include:</p> <ul style="list-style-type: none"> ● non-governmental organizations ● universities and academic institutions ● Indigenous organizations ● provincial, territorial and municipal governments 	<p>Specified purpose account administered by ECCC to direct funds received from fines, court orders and voluntary payments to priority projects that will restore the environment and conserve wildlife and habitats in a scientifically sound, cost-effective, and technically feasible way.</p> <p>Priority is given to projects that restore the natural</p>	<p>While matching funds are not required, evidence of other funding sources such as matching contributions and the respective amounts, or demonstration of the applicant’s ability to raise funds from sources other than the federal government in a past project will be considered</p>

				<p>environment and conserve wildlife, followed by:</p> <ul style="list-style-type: none"> • environmental quality improvement initiatives • research and development on environmental restoration and improvement • education and awareness on issues affecting the health of the natural environment <p>There is no maximum project duration. The average length of a project is approximately two years.</p>	<p>as an asset at the proposal evaluation stage.</p> <p>General inquiries: Atlantic EDF Office 45 Alderney Drive 16th Floor, Queen Square Dartmouth, Nova Scotia B2Y 2N6 E-mail: ec.fdeqa-edfaq.ec@canada.ca</p> <p>Sally and Clare on mailing list.</p> <p>Spring 2022 RFP: New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador Application Deadline: April 20, 2022, 15:00 Eastern Standard Time (EST) Funds Available: \$44,874</p> <p>Fund Use Requirement: For a project related to the protection, conservation or restoration of the environment in Atlantic Canada. Priority will be given to projects related to the protection and</p>
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					conservation of migratory birds, or restoration of migratory bird habitat. Applicants must apply for the full funding amount of \$44,874 from ECCC in the proposal's budget to be eligible for funding.
Green Municipal Fund	FCM	Endowment established in 2000. Currently at \$946 million	Municipalities, municipal partners, and non-profit organizations	Supports capital projects that improve quality of air, water and land and reduce greenhouse gas emissions. \$175 000 up to \$5 million available in low-interest loans and grants (varies by project type: studies, pilot projects, capital projects). Focus: Municipal projects in the energy, land use, transportation, waste and water sectors.	Province not eligible. Suitable for municipal and NGO partners?
LC3-FCM (HCi3) Halifax Climate Investment, Innovation and Impact Fund.	FCM	\$15m endowment w/ \$2.7m operating grant.	Seven cities across Canada, including HRM	Collaboration between FCM and LC3, and seven urban centres across Canada, including HRM. To accelerate projects that result in GHG reductions, other environmental improvements, community benefits and the leveraging and mobilizing of financial capital.	Province not eligible. HRM HWA treatment?
Strategic Partnerships Initiative	ISC	\$14.45m in funding per year Ongoing intake.	Indigenous businesses/organizations/partnerships, Indigenous communities/local	Fills gaps in other funding programs by supporting opportunities not eligible for other federal funding and providing a way for federal	Province not eligible. HWA monitoring/treatment by Mi'kmaw Communities?

			<p>governments, academic institutions, provinces/territories</p> <p>Do not apply directly – federal partners work with Indigenous communities to identify opportunities to bring to committee for consideration.</p>	<p>partners to coordinate efforts, pool resources in support, and reduce administrative burden of Indigenous communities.</p> <p>Supports investments in:</p> <ul style="list-style-type: none"> • economic readiness • economic infrastructure • expanding viable businesses • pre-feasibility and feasibility studies • environmental diagnostics and evaluations • community economic development planning • skills development and training <p>Budget 2021 proposed to invest \$36m over 3 years starting 21/22 to build capacity for local, economically sustainable clean energy projects in Indigenous communities.</p>	
Low Carbon Economy Fund		<p>The \$2 billion LCEF is an important part of the Pan-Canadian Framework on Clean Growth and Climate Change. The Fund supports the Framework by leveraging</p>	<p>Fund is providing up to \$1.4 billion to provinces and territories that have adopted the Framework to deliver on their commitments to reduce greenhouse gas emissions.</p>	<p>This is a \$2 billion funding program over 2017 to 2022 for projects that will reduce emissions, create jobs and save Canadians and companies money by:</p> <ul style="list-style-type: none"> • making homes and buildings more efficient • helping companies innovate or use 	<p>Fully allocated for 2022 and no longer accepting applications.</p>

		investments in projects that: <ul style="list-style-type: none"> • generate clean growth • reduce greenhouse gas emissions • help exceed Canada's Paris Agreement commitments. 	Provinces and territories are each eligible to receive \$30 million plus funding based on population.	technologies to reduce their emissions and <ul style="list-style-type: none"> • supporting the forest and agriculture sectors to enhance stored carbon in forests and soils. 	
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Federal: Climate Change Adaptation

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
Disaster Mitigation and Adaptation Fund	INFC	<p>\$2 billion nationally to 27/28</p> <p>Budget 2021: received additional 1.375b over 12 years starting 21/22 to fund w/ 670m dedicated to new, small-scale projects between \$1m and \$20m in total eligible costs. Remaining funding envelope allocated to large-scale projects over \$20m.</p> <ul style="list-style-type: none"> • Minimum of 138m of fund allocated to Indigenous recipients. 	<p>Merit</p> <p>Open to provinces, Indigenous recipients, municipalities, public sector bodies, post-secondary, not-for profit, for profit.</p>	<p>For built and natural, large scale infrastructure projects (\$10m+) supporting mitigation of natural disasters and extreme weather events and climate resilience. Eligible projects include the new construction and/ or modification of existing public infrastructure, including natural infrastructure, that prevents, mitigates or protects against the impacts of climate change, natural disasters and extreme weather.</p> <p>Most recent intake was July 2021 (for 2022 projects). Now closed.</p> <p>Federal cost sharing limits vary depending on recipient. Up to 50% for provincial government.</p>	Not sure if HWA a good fit (for future?).

First Nations Adapt	CIRNA	\$20 million to 2019-2020 + \$25 million to 2021-2022 (flood risk mapping).	Merit FN communities, band councils, Indigenous organizations Ongoing basis.	Provides funding to First Nations communities below the 60 th parallel. For assessing and responding to climate change impacts, community infrastructure and emergency management. <ul style="list-style-type: none"> • \$20 million for projects in risk assessment, emergency management, developing adaptation options, cost-benefit analyses. • \$25 million for flood risk mapping projects in FN communities. 	Province not eligible. HWA monitoring/treatment by Mi'kmaw Communities? Part of Investing in Canada Plan.
Clean Growth Program	NRCan			The Clean Growth Program (CGP) is a \$155 million investment in clean technology research and development (R&D) and demonstration projects in three Canadian sectors: energy, mining and forestry. This program covers five areas focused on pressing environmental challenges and economic opportunities facing Canada's natural resource operations: <ul style="list-style-type: none"> • Reducing greenhouse gas and air-polluting emissions • Minimizing landscape disturbances and improving waste management • Producing and using advanced materials and bioproducts 	April 2022: The intake period for the Clean Growth Program is closed. Check back for the latest information on the program.

				<ul style="list-style-type: none"> Producing and using energy efficiently Reducing water use and impacts on aquatic ecosystems 	
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Federal: Species At Risk

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
Community Nominated Priority Places for Species at Risk	ECCC	CNPP is a 4-year (2019 to 2020 through 2022 to 2023) funding initiative. \$?	Kespukwitk / SWNS received this funding in 2019.	Funds projects with multiple partners working together to conserve species at risk and their habitat.	Opportunities to partner/match – or is all funding allocated? <i>-possibly check with Lesley Farrow</i>
Habitat Stewardship Program for Species at Risk	ECCC	The Habitat Stewardship Program (HSP) was established in 2000. It provides funding for projects submitted by Canadians that contribute directly to the recovery objectives and population goals of species at risk listed on Schedule 1 of the Species at Risk Act (SARA) and that prevent others from becoming a conservation concern. \$?	<ul style="list-style-type: none"> Canadian NGOs community groups Indigenous organizations and communities individuals private corporations and businesses educational institutions provincial, territorial and municipal governments provincial Crown corporations 	<p>Funds projects that contribute directly to the recovery of species at risk and prevent others from becoming a conservation concern.</p> <p>In order to be eligible, proposed projects must target the following species:</p> <ul style="list-style-type: none"> species listed on Schedule 1 of SARA (except those listed as extirpated), and/or species assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as endangered, 	The application submission period for projects commencing in 2022-2023 is now open and will close on January 25, 2022 at noon (Pacific Standard Time).

				<p>threatened, or of special concern but have not been listed on Schedule 1 of SARA</p> <ul style="list-style-type: none"> Up to 20% of the available funds will be directed towards projects targeting species that are not listed on Schedule 1 of SARA but assessed by COSEWIC as endangered, threatened or special concern. The majority of program funds (i.e., at least 80%) will be directed to projects targeting species listed on Schedule 1 of SARA. <p>Funding can be used for land securement.</p>	
Aboriginal Fund for Species at Risk	ECCC	The Aboriginal Fund for Species at Risk (AFSAR) was established in 2004 and supports the development of Indigenous capacity to participate actively in the implementation of the Species at Risk Act (SARA).	All Indigenous communities and organizations located in Canada are eligible for funding.	Supports Indigenous capacity with respect to species at risk and funds projects that prevent other species from becoming a conservation concern.	Province not eligible. HWA monitoring/treatment by Mi'kmaw Communities? The application submission period for projects commencing in 2022-2023 will close January 2022.
Critical Habitat Interdepartmental Program	ECCC	No info available at this time.	No info available at this time.	This program contributes directly to supporting Federal Government	No info available at this time.

				Departments and Agencies, as well as Crown Corporations by providing funding for implementation of conservation and recovery projects pertaining to species at risk and their critical habitat on the lands they manage.	HWA monitoring/treatment by Federal partners (PC, DND)?
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Federal: Ecosystems, Terrestrial and Aquatic Habitat

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
EcoAction Community Funding Program	ECCC		Non-profit and non-governmental groups and organizations are eligible to receive funding, examples include: <ul style="list-style-type: none"> • environmental groups • community groups • youth and seniors groups • community-based associations • service clubs • Indigenous organizations 	Supports community groups to take action and address environmental issues. Focus this year: freshwater management and increased climate resilience through action involving the development and/or restoration of natural infrastructure (not sure if themes change annually).	Province not eligible. HWA monitoring/treatment/ community engagement by Mi'kmaw Communities or other NGO partners? Now accepting applications for funding until January 19, 2022 at 12:00p.m. PST / 3:00p.m. EST for projects beginning summer 2022.
Atlantic Ecosystems Initiative	ECCC		Only Atlantic Canadian-based organizations are eligible to apply and include:	The Atlantic Ecosystems Initiatives (AEI) aims to improve the health, productivity and long-term sustainability of ecosystems in Atlantic Canada. It supports	Province not eligible. Not sure if this is a good fit. – but perhaps for collaborative HWA monitoring of treatment and/or

			<ul style="list-style-type: none"> ● Indigenous governments and organizations ● non-governmental organizations ● coalitions and networks of organizations ● research and academic institutions <p>Although business/industry, federal, provincial, and municipal governments are not eligible funding recipients, they are encouraged to partner with applicants on projects.</p>	<p>projects that use an ecosystem-based approach that includes broad partnerships and collaborative action leading to positive environmental results.</p> <p>Proposals submitted to other ECCC funding programs must be for activities that are different from those submitted under the AEI based on the “best fit” for the project.</p> <p>Projects must improve the assessment, monitoring, modeling and/or mitigation of multiple stressors and their cumulative effects on water quality in one of the priority ecosystems. Within this priority, projects are required to focus on specific stressors:</p> <ul style="list-style-type: none"> ● nutrients and/or ● bacteria and/or ● plastics <p>Funding will be provided for projects that enhance integrated ecosystem planning and decision-making, increase ecosystem knowledge and science, and undertake actions to conserve, restore and enhance the health of priority freshwater ecosystems in Atlantic Canada.</p>	<p>community engagement by Mi'kmaw Communities or other NGO partners?</p> <p>Call for proposals: 9 Feb 22 – 16 Mar 22.</p> <p>The current request for proposals is for projects that will begin on or after April 1, 2022 and completed no later than March 31, 2025. Projects are eligible for funding up to a maximum of \$200,000 per project and must be completed within 3 years.</p>
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Federal: Forestry

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
2 Billion Trees Program (2BT)	NRCan	\$3.2 billion Part of the \$4 billion Natural Climate Solutions Fund to address climate change and biodiversity loss over the next ten years: <ul style="list-style-type: none"> • 2 Billion Trees Program (2BT) led by Natural Resources Canada (\$3.19 billion) • Nature Smart Climate Solutions Fund led by ECCC (\$631 million) • Agricultural Climate Solutions led by Agriculture and Agri-Food Canada (\$185 million) 		This program supports tree planting projects as part of the Government of Canada’s commitment to plant two billion trees by 2030 (2BT) and establishes the nature-based building blocks needed to get to net-zero emissions by 2050. Focus: Long-term C sequestration with co-benefits such as biodiversity, cultural, riparian.	Proposals are due February 17th, 2022. Could this fund be an option for planting trees to help restore stands hit by HWA?
Indigenous Forestry Initiative	NRCan		Indigenous communities and governments such as: band and tribal councils, governments of self-governing First Nations,	Helps to increase the participation of First Nations, Inuit and Métis peoples in the Canadian economy and improve economic outcomes for	

			<p>local governments of Inuit communities, Métis organizations, economic development corporations, and national and regional Indigenous organizations.</p> <p>Indigenous (50% or greater ownership by Indigenous people) for-profit and not-for-profit corporations, businesses, joint ventures, partnerships, associations, co-operatives and institutions, non-Indigenous not-for-profit entities who are working with one or more endorsing Indigenous partner organization(s), provincial, territorial, municipal and regional governments working with an Indigenous partner organization academic institutions and research associations working with an Indigenous partner organization.</p>	<p>Indigenous peoples throughout Canada.</p> <p>The Indigenous Forestry Initiative (IFI) accepts applications throughout the year. Submissions are reviewed periodically, subject to the availability of funds.</p> <p>The scope of activities funded by the IFI is broad, with three general categories:</p> <ul style="list-style-type: none"> ● use and management of forest resources ● clean technology and participation in the forest bioeconomy (e.g. biomass for heat/energy, pellet manufacturing, etc.) ● environmental stewardship 	
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Federal: Invasive Species

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
Currently no funding programs listed.	CFIA			<p>In January 2021, the Government of Canada announced an investment of \$162.6 million in the Canadian Food Inspection Agency (CFIA) over the next five years and \$40 million per year on an ongoing basis:</p> <p><i>“This funding will increase the CFIA’s inspection, surveillance and oversight programs within Canada to respond to the detection of new food pathogens, invasive species and animal diseases that threaten Canada’s agricultural and natural resources.”</i></p> <p>Currently no funding programs are listed.</p> <p>Note from Ron Neville (CFIA):</p> <p><i>“...not for HWA treatment. If HWA was detected in a very small population, a few trees, very far removed from an existing population then I might be able to make a case for a small eradication. Say in PEI for example. I have been pushing for some research funds to go towards some hwa management either through testing treatments or biocontrol but these funds are not really for that either. My sense is that HWA in general needs some new funding... like they have allocated for mountain pine beetle for example. Something that would help support biocontrol along with management, that would be accessible to a number of levels of government and to NGOs.”</i></p>	Not applicable (see note from Ron).
Perhaps similar to Mountain Pine Beetle		\$68.4 million over three years to help control, research and	Dedicated funding announced in	Funding includes: <ul style="list-style-type: none"> • \$60 million to the Government of Alberta for forest management and research; 	Working group members with contacts out west?

Funding (2020)?		mitigate the impacts of the mountain pine beetle on Canada's forests.	October 2020.	<ul style="list-style-type: none"> • \$6.9 million to Parks Canada to mitigate mountain pine beetle impacts, including wildfire risks in the Rocky Mountain National Parks; and • \$1.5 million to Natural Resources Canada to enhance its core research program. <p>The organizations works together to address the challenges posed by the spread of the mountain pine beetle.</p> <p>This funding includes \$24 million for fiscal year 2020–2021 to address the outbreak of mountain pine beetle in Alberta and the Rocky Mountain National Parks while mitigating negative impacts on the forest sector and communities. Since 2010, Natural Resources Canada has invested \$12.9 million in mountain pine beetle–related research in Alberta, to assist provinces in monitoring and research to address the spread of this harmful insect and to identify recovery options for affected trees.</p> <p>Goal is to protect the forest sector and communities where mountain pine beetle outbreaks are prevalent and slow the eastward spread of the insect throughout Canada. Not only does this help the forest industry, but it also protects the environment, including wildlife habitat, biodiversity and water quality, all while reducing fire hazards resulting from the infestation. This investment also helps mitigate effects of climate change through enhanced carbon storage in forests.</p> <p>https://www.canada.ca/en/natural-resources-canada/news/2020/10/protecting-canadas-forests-from-the-mountain-pine-beetle.html</p>	Approach NS Liberal MPs or Natural Resources Committee?
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Provincial Funding Options

Provincial Climate Change Mitigation

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
Green Fund	ECC	<p>Amounts vary year to year (depending on provincial cap and trade auction surplus).</p> <p>2020/21: ~\$28 million.</p>	<p>Funded by provincial cap and trade auction. Goals of program is to fund work that will contribute to provincial target of net zero GHG emissions by 2050.</p> <p>Proceeds can be used to fund projects under 6 specific themes. Two are relevant to HWA: GHG emission reduction and adaptation to climate change.</p>	<p>Funded by provincial cap and trade auction. Goals of program is to fund work that will contribute to provincial target of net zero GHG emissions by 2050.</p> <p>Proceeds can be used to fund projects under 6 specific themes. Two are relevant to HWA: GHG emission reduction and adaptation to climate change.</p> <p>Application requirements: Project Description Anticipated outcomes:</p> <ul style="list-style-type: none"> ● What priorities does this project address? <ul style="list-style-type: none"> ○ Are there other social, economic, or environmental co-benefits. ● How are you measuring success/ outcomes? <p>Timing:</p> <ul style="list-style-type: none"> ● What time window could the project be delivered? ● Timelines of milestones <p>Budget:</p> <ul style="list-style-type: none"> ● Provide a range for the estimated cost of the project. If possible provide multiple estimates based 	<p>Green Fund could be best inter-provincial gov't option.</p> <p>Current plan:</p> <ul style="list-style-type: none"> ● Advance 5-year provincial hemlock treatment program to begin Spring 2022 ● Note: GF approval requires Treasury and Policy Board approval. ● Note: GF is only authorized for the next 2 years (2022/23). If the it is not extended, funding will have to come from General Revenue Fund for remaining 3 years in treatment program.

				<p>on scale/scope of proposed programming.</p> <ul style="list-style-type: none"> Are there other contributing partners? Could you leverage other funding sources? 	
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Provincial Habitat and Species At Risk

Fund	Lead Dept.	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date
NS Habitat Conservation Fund	NRR	Normally, proposals are not funded for more than \$25,000.00	Closed December 1 st .	Established under the Nova Scotia Wildlife Act to assist the funding of programs for the protection and enhancement of wildlife habitats.	HWA education, treatment and mitigation projects from partner organizations could be eligible?
NS Species at Risk Conservation Fund	NRR	Average amount awarded is \$10,000.00	Closed December 31 st (nothing funded since 2018).	Established under the Nova Scotia Endangered Species Act to assist the funding of projects related to species at risk.	HWA education, treatment and mitigation projects from partner organizations could be eligible?

Non-Government Funding Options

Fund	Amount	Eligibility	Summary	Notes on Likelihood/ Commitments to Date

Project Learning Tree Canada	50% or 80% wage match, with up to \$32,000 CAD in reimbursements, to employers hiring youth aged 15-30	You must register as a Green Jobs employer before you can apply for the 50% wage match and start searching for job candidates.	<p>Project Learning Tree Canada (PLT Canada) is a bilingual charity committed to fostering inclusive environmental education and growing a diverse and resilient Green Jobs workforce, using trees and forests as windows on the world. Our environmental education and professional development services, which include high-value work experiences and an industry-leading mentorship program, support youth across Canada on their green career pathways, including those in rural, Indigenous and urban communities. PLT Canada is an initiative of the Sustainable Forestry Initiative (SFI).</p> <p>“We offer a 50% or 80% wage match, with up to \$32,000 CAD in reimbursements, to employers hiring youth aged 15-30 into Green Jobs. A Green Job is one that supports nature-based solutions for a more sustainable planet. Green jobs are typically involved in, but not limited to, jobs in the forest sector, parks, conservation, natural resource management, environmental education, sustainable food systems, climate change, carbon sequestration, species maintenance and recovery, water quality and quantity, and more. See some examples of Green Jobs below.</p> <p><i>Indigenous communities, businesses, and non-profits are also eligible!</i></p>	
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Invasive Species Centre		Grant Opportunities	Clare signed up for info on grants as they are available.
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