SPORTING LAKE NATURE RESERVE HEMLOCK TREATMENT PILOT RESEARCH PROJECT

Final Report

ABSTRACT

Research on testing a novel tree injection method on eastern hemlock (*Tsuga canadensis*) for the chemical control of hemlock woolly adelgid (*Adelges tsugae*) was conducted at Sporting Lake Nature Reserve. IMA-Jet, an imidacloprid-based product, was injected into trees using the EcoJect canister system (BioForest). The approach of utilizing a contingent of volunteers was evaluated as a manner to enhance operational efficiency for large, stand-scale injection treatments.

Submitted on behalf of Hemlock Conservation Nova Scotia

Founders: George Kovacs MD, John Rogers QC, Scott Robinson, Donna Crossland, Matt Miller, Jennika Hunsinger, Mary Jane Rodger, Rod Burgar

“Hemlock Conservation Nova Scotia” founding members, from left; John Rogers QC, Matt Miller, Donna Crossland, George Kovacs MD, and Scott Robinson

Authors: Matt Miller & Donna Crossland

Suggested citation of this report:

Hemlock Conservation Nova Scotia. 2022. Sporting Lake Nature Reserve Hemlock Treatment Research Project Final Report. Unpublished report submitted to Nova Scotia Environment & Climate Change. Nova Scotia. 36 p.

Contents

Acknowledgements
Treating the old growth hemlocks at Sporting Lake Nature Reserve is a success story through the combined efforts of many people who supported our objectives. We are indebted to the critical staff support from the Protected Areas Division, Environment and Climate Change (ECC) and the Forest Protection Division, Natural Resources and Renewables (NRR). A special thanks to Peter Labor, Sally Steele, Neil Morehouse, Rob Cameron, and Clare Robinson at ECC and John Ross and Dan Lavigne at NRR. Shubenacadie Radio Operations Centre enhanced project operational safety through provision of dispatch services 24-7 and daily safety checks. Aviation Services under guidance by Ian Moore and Scott Healey greatly facilitated air transportation of heavy gear into the heart of the Tobeatic. Nick Johnson and Andy Young from the flight crew provided indispensable help with camp set up and take down. PRAXES Medical Group provided on-site paramedic services around the clock throughout the duration of the expedition.

Our gratitude is expressed to our cooperating charitable partner, the Nova Scotia Nature Trust for supporting the project and receiving/tracking donations. The generosity of kind donors and in-kind supporters were essential for saving this precious ecosystem.

We extend enormous gratitude to the **Hemlock Heroes**; more than 50 volunteers who came together on short notice to save old growth hemlocks, those who travelled deep into the backcountry to help ‘vaccinate’ trees to thwart a minute, but lethal invasive pest. We thank other dedicated volunteers who worked faithfully in the background keeping us fed and supplied. The memories made and friendships formed by all those involved with saving Sporting Lake hemlocks are deeply cherished.

'Circle root rock' Photo: Cameron Bell

Introduction

Hemlock woolly adelgid (HWA), an invasive insect is rapidly spreading and decimating eastern hemlock forests in southwest Nova Scotia. Many protected areas and old growth stands in NS support high volumes of eastern hemlock that are now under threat of permanent loss from the forest ecosystem. The only effective, short-term measure to maintain healthy hemlock stands is to employ chemical control using systemic injections of a neonicotinoid compound, imidacloprid (IMA-Jet™). Imidacloprid has been effectively used against HWA throughout the eastern USA, saving hundreds of thousands of hemlocks. Once it reaches the canopy, the pesticide can provide protection for 4-7 years (McCarty, 2020).

Hemlock Woolly Adelgid showing egg sacs at Sporting Lake Nature Reserve in 2021. Photo: Jennika Hunsinger

Various government departments and NGOs have been addressing the HWA issue in NS, but it has been difficult to take the effective action required to save hemlock forests, given lack of funding, the reluctance to use chemical control, and concerns of public acceptance of using pesticides in a protected area. The deployment of chemical control in protected areas is not an action that is taken lightly and requires consideration of many variables, particularly with regards to safety of the environment.

Despite IMA-jet being authorized for use in Canada to protect eastern hemlock since 2019, no active management to protect an entire stand of hemlock has yet been attempted on public lands in the province. Some research trials were being carried out, but they were limited to small areas rather than full stand treatments.

Sporting Lake Nature Reserve features an intact old growth stand of hemlocks that has recently become widely infested with HWA. Based on observations of other HWA infested hemlock stands in NS, the Sporting Lake stands were estimated to undergo rapid decline beginning in 2022. The hemlocks were still healthy during evaluations of canopy health in July 2021 despite broad infestation throughout the stand and some very heavily infested patches. An additional challenge associated with any work proposed at Sporting Lake Nature Reserve was its remote location. Accessing the area required an approximate 4-hour paddle and portage, making it difficult to transport equipment and to support a large network of volunteers. No facilities were present to support a large group of people.

A small core group of concerned citizens formed **Hemlock Conservation Nova Scotia** (HCNS) and submitted a request to NS Environment and Climate Change (ECC), Protected Areas Branch in August 2021. Their goal was to treat the entire stand of old growth hemlocks at Sporting Lake Nature Reserve. ECC provided a license and research application, as well as directional support. HCNS provided fundraising, logistics planning, pesticide expertise, and a volunteer callout. The expedition ran from October 4-16, 2021.

This report is submitted under research permit RL202113WANR to summarize the outcomes, learning points, and conclusions of treating an entire stand of old growth eastern hemlock spanning 15.3 ha using volunteers and a unique injection method at Sporting Lake Nature Reserve.

Research objectives

1) To evaluate the effectiveness of using a hybrid treatment method that employs Eco-Ject application equipment with the product IMA-Jet™ for HWA control.

2) To evaluate feasibility of using volunteers to safely and effectively treat a large stand of hemlock infested with HWA using a systemic insecticide.

Initial survey of hemlock condition and HWA infestation levels

An initial survey of Sporting Lake Nature Reserve was carried out on July 31-August 1, 2021. The goal of this survey was to assess the presence of HWA, assess canopy health and levels of HWA infestation to determine whether tree decline was below the threshold suitable for chemical control, to estimate hemlock volume and chemical amounts required and to derive a cost estimate for treatment (Figure 1 – Initial Site Survey Map). The initial survey indicated that the focus for control efforts should be directed to the largest island within Sporting Lake Nature Reserve, as the smaller islands did not contain significant populations of hemlock.

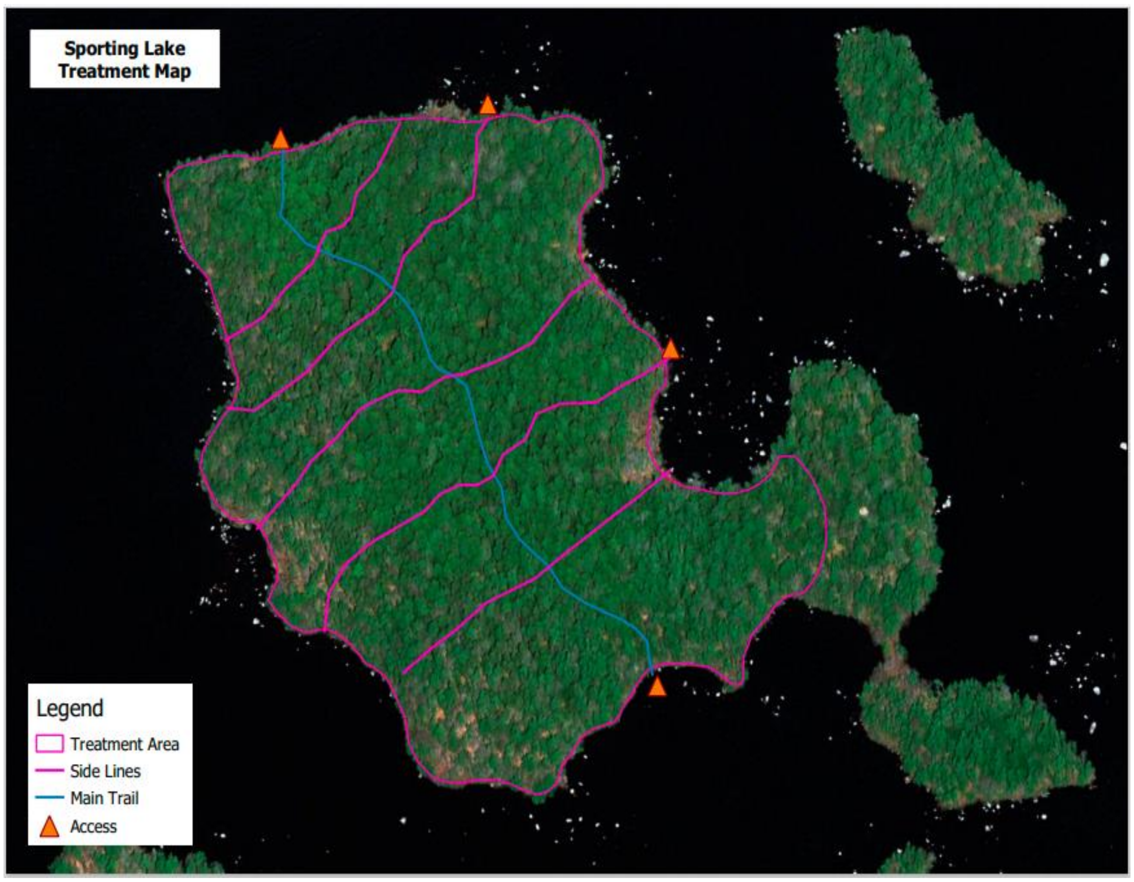

Figure 1. Sporting Lake HWA Treatment Area Map

A total estimate of hemlock diameter was obtained using a series of 13 prism plots (2 Basal Area Factor) placed randomly throughout the initially estimated 13-hectare (ha) treatment area (Table 1). Data was entered into the Department of Natural Resources & Renewables (NRR) Pre-Treatment Assessment

(PTA) program to derive an estimate of the quadratic mean diameter and number of hemlocks per hectare. Each tree tallied in the prism plots was also assessed for live crown ratio and crown density based on the canopy health survey protocols adapted from McAvoy et al. (2019). HWA ovisacs and aestivating sistens were surveyed on branch tips of young saplings, mature trees, and downed trees, drawing upon the Canadian Food Inspection Agency HWA detection survey protocol. HWA infestations in the mid- to high crown areas were not assessed due to time constraints as this would have been possible only using pole pruners or ball sampling.

Table 1 Results of site survey and Ima-Jet cost estimate.

Treatment Area (ha)	Quadratic Mean Diameter at Breast Height (QMDBH)	Trees/ ha	Total Trees	Total Hemlock QMDBH	Estimate ImaJet Volume Needed (L)	Mean Live Crown Ratio	Mean Crown Density Score
12.7	**40.4**	**183**	**2322**	**93,791**	**150.1**	**46%**	**77%**

The presence of HWA was found in all areas of the stand. Some mature, downed trees revealed very heavy infestations. Placement of ovisacs on some tress indicated that HWA has been present for at least 2 and likely 3 years already. Thinning of understory hemlock trees was widespread and advanced in some patches. There were some small patches of hemlock overstory that were notably thin, having already lost up to approximately 50 % of needles. However, most of the hemlock assessed within the prism plots featured a healthy live crown ratio and healthy crown density.

Donna Crossland assessing HWA populations on Sporting Lake during initial survey.

Some windfall on the island was present in patches, but it was relatively minimal despite several catastrophic windstorms over the past decade. The old growth in Sporting Lake was judged to be capable of enduring many more decades of growth, judging by the dense green crowns and lush growth, but would not succeed without mitigation to control the large populations of HWA.

Project proposal

Following the initial site survey, a formal proposal and research application was submitted to Environment and Climate Change (ECC) on August 8, 2021. The goal of the project was to protect the old growth hemlock stands at Sporting Lake Nature Reserve. This was proposed to be achieved through raising funds necessary to equip a volunteer-led initiative to inoculate all hemlock trees suitable for treatment during October 2021. A key secondary goal was to raise public awareness about the threat posed by HWA and test the safety and efficacy of a new, HWA chemical control method that was unique to Nova Scotia. Outcomes of this research may help provide government with a more cost-effective method for an expanded HWA treatment program. It was also hoped to increase public acceptance for HWA chemical control. The proposal was met with support from both provincial departments, ECC, Protected Areas Branch and NRR, Forest Protection Division. Work continued throughout August and September to advance the project goals.

Measuring tree diameters during the initial field reconnaissance. Photo: D Crossland

Permitting

A license to conduct scientific research was granted to Hemlock Conservation Nova Scotia on September 24, 2021. In keeping with applicable pesticide regulations, a Spill Contingency Plan was developed. To satisfy rules for remote work on Nova Scotia Crown lands the expedition also submitted a Remote Location Plan with Shubie Dispatch.

Fundraising

Funds to support the Sporting Lake Project were raised by HCNS, attaining approximately $ 125, 000.00 from private donations over a short period of mainly three weeks. The Nova Scotia Nature Trust (NSNT) supported the project by receiving all donations and administering charitable donor receipts through their website. The donation page was shared on NSNT and Medway Community Forest Co-op (MCFC) social media platforms.

The funds raised were used to purchase 280L of Ima-Jet product and associated EcoJect application equipment and remote camp equipment, along with food and supplies for the expedition. A significant number of resources are in place to support future HWA work. A list of remaining equipment and supplies is included in Appendix A.

Helicopter gear sling - NRR Air Services to support base camp operations. Photo: D. Crossland

Volunteer effort

Volunteers were solicited through personal networks of the HCNS organizing team and by a call-out distributed by the MCFC and shared via social media by various forest conservation organizations and numerous individuals (Appendix B). Approximately 58 volunteers signed onto a Google Drive Volunteer Dashboard for Sporting Lake volunteers administered by the MCFC (Appendix C). A limit of 12 volunteer persons per day was put in place due to limited camping spaces and food provisions, as well as span of control over the field operation.

Volunteers came to the island on very short notice to help with injections. Some stayed for one day, while others changed plans and remained for a week. There was also a significant "behind the scenes" volunteer contingent that supplied camp kitchen supplies, meal planning, and food for the expedition. High quality prepared meals were organized, packed, and delivered to a helicopter loading site. Volunteers also helped shuttle gear to/from a helicopter loading site for camp set up and take down. In addition to the significant volunteer contributions of the organizing team, the on-island and supporting "Hemlock Heroes" collectively contributed approximately **1,650 hours of volunteer effort** in support of the expedition.

Some of the many volunteers who treated hemlocks and assisted with camp set up/take down at Sporting Lake.
Photos: D. Crossland

In-kind support and other donations

A wall tent with stove, canoe, portable toilet, and Trunk Mobile Radio (TMR) were loaned by ECC. NRR loaned two TMR radios, helicopter support, and authorised use of Shubie Dispatch services. There were significant and essential contributions from local businesses and individuals such as: a photo-voltaic/solar panel system that provided electricity for lights and functioned as a charging station for cellphones, radios, pump for a propane heated shower, a cellphone booster that allowed people to stay in contact with family, generators, a boat and outboard motor, a propane cookstove, diameter tapes, cold water rescue equipment. Local citizens also collectively put together an entire camp kitchen. A list of items lent in support of the expedition is included in Appendix D.

Solar panel and cell phone booster. Photo Chris Penny

Treatment site and camp set-up

The first volunteers departed for Sporting Lake on October 4, 2021. A helicopter gear drop with camp gear and supplies took place on October 5. Camp and treatment site set up took place from October 5-7. Application gear and Ima-Jet product arrived on October 7, which enabled the treatment phase to begin on October 8. In advance of the chemical treatment operation the island was divided into 12 sectors for treatment (Figure 1). A main safety trail and side lines for each sector were flagged. Each sector was surveyed and evaluated by tree markers and trees to be treated were measured for diameter at 1.3 m-diameter breast height (DBH) and marked using flagging tape, with the diameter and number of injection ports recorded on the flagging. Usage of flagging tape on trees was minimized by pinning small pieces to the trees using thumb tacks and affixing them in a consistent direction. Some volunteers with more specialized training in forestry assisted with tree marking.

Setting up Sporting Lake Base Camp with Scott Robinson securing a bear pole. Photo: Jennika Hunsinger

Personal safety

A pesticide 'clean kit' was restocked daily with PPE and was transported to the site each day during pesticide operations. It contained moist sanitation wipes (e.g., Lysol wipes) for wiping away any chemical contamination on skin or surfaces, garbage bags for safe disposal of contaminated articles, paper towel, first aid kit, spare nitrile gloves, safety glasses, emergency phone numbers and a pesticide label containing First Aid instructions with regards to chemical exposure.

A volunteer waiver (Appendix E) was signed by each volunteer prior to departure to Sporting Lake. As an unincorporated group, we were unable to obtain liability insurance, which was a significant risk to the organizers given the nature of the project. Future projects would be advised to be set up in a manner that enables liability insurance coverage.

Due to the Covid pandemic, vaccination of participants was mandatory. All participants completed a Nova Scotia Covid 19 self assessment prior to departure.

A full safety briefing was provided for each volunteer prior to commencement of work. A 'safety first' approach was emphasized, with no volunteer being requested to perform activities beyond personal comfort level and ability. The pesticide label was reviewed, and time was taken to answer any questions concerning the chemicals and gear being used. Personnel were properly fitted for nitrile gloves and safety glasses. At the treatment area, training was provided on how to drill and inject trees.

Dr George Kovacs on the long portage to Sporting Lake.

A boat, motor and survival suit were on site in case a water rescue was required. A survival kit was available if sudden inclement weather caused volunteers to be storm-stayed on the island. A full medical kit and paramedic support was provided by Praxis Medical Group. TMR radio support and daily check-in/out with Shubie Dispatch allowed for rapid additional medical support and access to medivac transportation if required. A propane-heated shower was available at the campsite if/when personnel required full decontamination/ cleaning.

Environmental safety

Compliance with the terms and conditions on the ECC license were followed under all circumstances. Traveling and camping was conducted in a manner consistent with 'Leave No Trace' principles. The 'Licence Holder' took all measures to comply with the Wilderness Areas Protection Act and the Special Places Act and Regulations, as well as the Pesticide Act. Waste was properly stored/contained in garbage bags and hung or otherwise stored away from wildlife and was flown out weekly via helicopter. The campsite was maintained as clean as possible to ensure a pleasant and safe camping experience for all.

The IMA-Jet product label was followed under all circumstances, with any deviations from the label corrected immediately upon detection. Chemicals were transported over water in plastic, water-tight canoe barrels so that chemicals were double-contained and placed in the bottom of a canoe or zodiac. A chemical spill kit accompanied the transportation of chemicals over water and was taken to the treatment site for daily operations.

Sally Steele, Environment and Climate Change, with Spill Contingency Plan.

Treatment set up involved installing a mobile filling station located at a minimum of 30 m from water. Volunteers were instructed to not rinse their hands, boots, or gear in lake water. Toxicity of IMA-jet to freshwater invertebrates was impressed upon all personnel. During filling of the chemical tank, open containers of chemical product were held over a spill berm (plastic bin), opening only one container at a time to minimize spill risks. A certified pesticide operator performed all tank filling and supervised activities at the filling table.

Chemical storage at the campsite was placed more than 30 m from the lake and away from campsites. Without the benefit of a chemical storage building, a rudimentary storage was constructed containing the product bottles inside water-tight/bear-proof barrels that were set inside a plastic berm constructed of plastic sheeting with a roof that was also made of plastic sheeting that was lashed onto a wooden pole frame. The barrels were secured upright, with locking hinges tied shut. Injection gear was also stored near the chemicals and contained in leak-proof plastic bins.

BioForest EcoJect application system

The injection system selected for the project was the ‘EcoJect Microinjection System’ manufactured by BioForest, a Canadian company based out of Sault Ste. Marie, Ontario. A list of the components required to run this system and their estimated cost is included in Appendix K. The application of IMA-Jet using the EcoJect system at Sporting Lake was the first mass deployment of this hybrid approach for HWA treatment using volunteers to treat an entire stand within a Protected Area. The system was chosen because it is easy to operate and maintain and through early use by the Canadian Forest Service it had been proven to be a much more rapid method for tree injection compared to other injection methods used for chemical research trials carried out on hemlocks in NS. It had also been successfully used for IMA-jet treatments on private land in 2021 by Scott Robinson.

Scott Robinson demonstrating tree injection using the EcoJect system.

The EcoJect system features reusable canisters that load in seconds from the pressurized cylinder charged to ~ 150 PSI. The pressurized canisters were inserted on a nozzle that was firmly inserted into small drill holes that were evenly spaced around the tree. The chemical was left to be absorbed into the tree at its own pace, while operators turned attention to the next tree, injecting multiple trees simultaneously. Equipment and labor costs were further minimized because the additional step of using plugs in the trees was not required, unlike other injection systems, such as Quik-JET Air by ArborJet.

The EcoJect system consisted of a 6L tank with four 'loading guns' that received the chemical and was then pressurized by an air compressor (i.e., tire inflator). Rarely were all four loading guns used at one time, however the extra guns provided redundancy if a gun became clogged. In future, using an air compressor with an air filter system will help reduce clogging of loading guns.

Filling table showing filling tank and canisters-all contained against spillage.

The filling tank was used to fill 8 millilitre (mL) pressurized canisters for delivery of the product into the tree. The number of canisters required for treatment for each tree was calculated based on the dosage rate at 1.6mL per centimetre (cm) DBH, as stipulated on the IMA-Jet label and following the publication by Benton and Cowles 2016), as well as further consultation with the manufacturer (ArborJet). For example, a 40cm DBH tree requires 64mL of IMA-Jet (40cm*1.6ml/cm=64ml). The number of 8 mL canisters required for treatment was determined by the DBH of the tree divided by 5. A 40cm DBH tree requires 8, 8mL canisters to achieve the required IMA-Jet dose (40/5=8 canisters; 8*8mL canisters delivers a dose of 64 mL of IMA-Jet into the tree, per label application rate described above).

Using a battery-operated hand drill and a clean, sharp 15/64th inch, high helix drill bit, injection sites were drilled and evenly spaced around the tree. Sites in damaged areas on the trunk, such as in cracks or scars were avoided by adjusting injection sites slightly above or beside visible tree damage. Injection holes were drilled approximately 1.5 inches into sapwood tissue, with care taken to not exceed this depth. Professional grade drills and large, 5-amp hour batteries were used.

A nozzle was inserted into each pre-drilled injection site and pushed/twisted by hand until snug. A loaded canister was gently inserted over the nozzle. Best practices involved securing nozzles and canisters in injection sites as they were drilled. Otherwise, drill holes can be difficult to re-find and time is lost. Following treatment, it is best to visually examine the canisters to ensure injection is completed, and to wait a few minutes before removing canisters and nozzles. This allows the injection site to depressurize and avoids spillage and possible chemical exposure.

Each canister can be used for 30-50 cycles before BioForest recommends that they be refurbished. The manufacturer requires that the canisters be cleaned thoroughly on the outside and inside and emptied out before shipping. Once cleaned, they should be placed in a sealable bag, clearly labelled with the products used to clean them, and the product used in them (in this case, IMA-jet).

Injection team roles & team deployment

Pesticide Operator/Safety Officer

Certified pesticide operators oversaw the entire treatment operation and were always present or near the filling table. Only pesticide operators refilled and repressurized the tank/cylinder, as this procedure held the highest risk of product spill. The pesticide operator ensured the loading guns and canisters were maintained in proper working condition. Pesticide operators generally also adopted the role of Safety Officer, ensuring safe practices and proper wear of PPE.

Driller

Drillers were responsible for drilling injection holes and placing nozzles and canisters to deliver the IMA-Jet into the marked trees. Each driller carried a drill and a supply of nozzles and canisters. They checked the flag label for the required number of drill holes, spaced the drill holes evenly around the tree and fixed nozzles and canisters in place before moving onto the next tree.

Runner

Runners followed the drillers carrying a small claw hammer and a container to retrieve the nozzles and discharged canisters from treated trees once the product was fully discharged into the tree. The spent gear is returned to the filling table to be refilled and re-supply the drillers with reloaded canisters and nozzles to ensure uninterrupted treatment. Runners also removed flags and tacks from treated trees to track which trees had been treated, returning the flags to the filling table.

Filling Table

Fillers re-filled the spent canisters brought back by the runners to the filling table. Once refilled, canisters were placed into plastic trays or buckets for distribution back to the drillers. Team members at the filling table also recorded on data sheets the number of trees treated and tree diameters from the tree tags that were returned to the table by the runners.

Deployment

Throughout the course of the treatment the various roles assigned to treatment team members and the deployment of volunteers and certified applicators were adjusted as lessons were learned and feedback was solicited at the end of each treatment day. Fluidity and a willingness to try new approaches was a key aspect of the project and allowed the team to continue to improve efficiency and performance throughout the duration of the treatment. The various roles and team deployment described below and depicted in Figure 2 represents the approach that was the most productive and efficient deployment of personnel.

Stripping injection gear after treatment. Photo: Tristan Glen

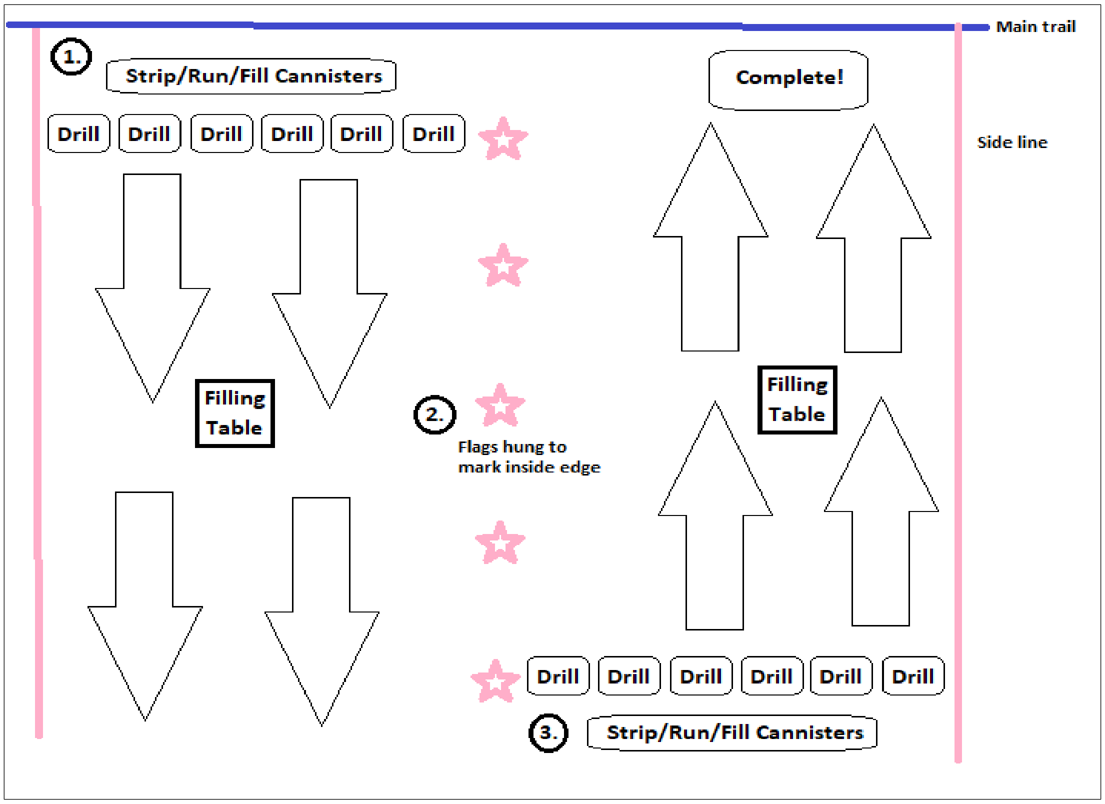

Figure 2. Deployment of drill-injection team members.

1. The drill team forms a line, with the outer member tied into a corner of the flagged treatment sector. Site the filling table ahead of the drillers such that they work their way towards the table and line up the runners behind the drill front. Advance the drillers through the treatment site towards the filling table, with runners coming along behind to complete the canister refilling cycle described above.
2. Advance past the filling table towards the far edge of the work site. If the drill front does not cover the full width of the treatment sector, the inside driller will hang flags to mark the inside edge of the drill swath.
3. Once the drillers reach the back of the treatment area, re-orient the drill front to cover the remaining work area, tying into the flag line left by the inside driller as described above. Reposition the filling table in the centre of the remaining work area to reduce running and filling cycle times.

Key learning points to ensure best possible production when using the approach described above;

- Ensure all trees to be treated in a sector are marked before treatment begins.
- When lining up drillers across a treatment front, ensure that each side of the drill front is occupied by drillers with the best possible spatial awareness to help keep cohesion of the drilling team as they move through the treatment area. When the drill front does not cover the whole width of the treatment area, have the driller on the inside edge of the drill front hang a flag to mark the internal

edge of the front. This will help orient the team when it is time to turn around and work back through the sector.

- Keep drillers close together and moving as one unit through the treatment area to ensure the most efficient site coverage and to avoid missing trees. Communication is key to maintaining cohesion.
- Ensuring there are ample canisters ready for drilling at the beginning of the workday and after the lunch break is key to keeping the drillers productive and avoiding downtime while they wait for canisters to be filled. Ensure all available empty canisters are returned to the filling table and filled before stopping for lunch.
- When scaling the treatment team, keep as many drillers on the line as possible, even if it means drillers need to occasionally stop drilling to help run or fill canisters. Maximizing the number of drillers treating trees is the key factor for increased production with this system.
- As much as possible, keep the filling table close to the drill front to help reduce cycle times for running and filling.
- Professional grade drills & compressors and larger 5 amp-hour batteries were key to ensuring good productivity. Select a compressor with an air filter to help maintain a clean filling tank system.
- Old growth trees with defects presented difficulties for beginner drill volunteers without advanced knowledge of tree physiology, relative to trees that lacked defects. To maintain productivity and efficacy during treatment, have more experienced drillers tackle the challenging trees while less experienced volunteers focus on the more straightforward treatments of healthy trees.

Productivity

Over the course of 10.5 treatment days, 2,160 trees were injected using a total of 129L of Ima-Jet to protect 77,417 cm of hemlock diameter (Table 2). Note that 17-October was a rain-shortened workday, and the tallied trees were combined with 18-October. Three core volunteers with pesticide certification were present for the duration of the treatment, with the overall injection team ranging from 6 to 14 total members. Treatment days averaged approximately 6 hours of treatment time.

A detailed analysis of the productivity of the EcoJect system was beyond the scope of the initial research project. High rates of volunteer turnover over the treatment phase meant a lot of time was spent with safety/site orientation, training, supervision, and camp maintenance. The remote nature of the work required numerous helicopter supply drops and the site was visited by government and First Nations visitors twice during the treatment phase. With so many variables to manage, the organizing team did not gather detailed productivity data. Some general observations about productivity can be determined based on data gathered, with a special focus on how the enrolment of volunteer labour can significantly improve the cost effectiveness of the EcoJect application system for HWA control.

Visiting Sporting Lake: Sherilyn Young- KMKNO and Jeff Purdy-Acadia Band with Matt Miller. Photo: D. Crossland

Productivity of the team increased as the treatment progressed and the deployment approach was refined, as described above. The production for October 15-18 was the highest despite not having as many volunteers as some previous treatment days. Using the production from these days as a guide, an 8-person crew led by two certified pesticide applicators working a 6-hour treatment day could reasonably be expected to treat upwards of 10,000 cm per day (equivalent to 250, 40 cm trees).

Table 2. Daily treatment productivity.

Treatment Day	Ima-Jet Injected (Litres)	Number of Trees Injected	DBH Tally (cm)	Injection Rate (ml/cm)
08-Oct	6.0	125	4,699	1.28
09-Oct	8.0	122	5,349	1.50
10-Oct	14.0	250	8,450	1.66
11-Oct	15.0	283	7,798	1.92
12-Oct	6.0	94	3,747	1.60
13-Oct	12.0	229	7,986	1.50
14-Oct	12.0	193	7,269	1.65
15-Oct	17.0	298	10,186	1.67
16-Oct	18.0	243	9,577	1.88
17 & 18 Oct	21.0	323	12,356	1.70
Total	**129**	**2,160**	**77,417**	**1.67**

Monitoring

Monitoring for treatment effectiveness is expected to be implemented in the spring, 2022. Selection of a minimum number of essential metrics is proposed since the remoteness of the site limits the time for sustained monitoring efforts by citizen scientists/volunteers.

I. **Three "*Impact plots*"** (monitoring plots) that are representative of the treated forest will be established in spring 2022. Impact plots will be widely spaced apart. Each impact plot will consist of 10 treated hemlock trees in closest proximity to a central tree waypoint. The sample trees must be a minimum DBH of 6 cm and no more than two trees less than 10 cm in DBH. This method is adapted from Eschtruth et al. (2013) for permanent sample plots established for hemlock monitoring in Pennsylvania and New Jersey.

Trees will be tagged using numbered metal tags nailed (or using tree wire) on the south side at tree base, with waypoints recorded. Two photos will be obtained for each tree (photo 1, taken directly under the canopy facing skyward, and photo 2 consisting of a lateral shot that includes full canopy and as much of the trunk as possible, and consistently taken from the south side).

Baseline metrics collected will address monitoring tree vigor and HWA populations. Tree vigor will include: DBH and canopy health (live crown ratio, canopy density, foliar health- including presence of new growth). HWA presence/absence can be assessed using a 2000+ lumen headlamp with focusable beam or binoculars, or by simple direct visual observations of lower branches.

Assessing HWA infestation levels is more challenging because it requires closer observation than that required for presence/absence, and it can be time-consuming. HWA levels will be recorded to the extent possible depending on ability to examine lower branches, or ability to sample fresh fallen branches. Alternatively, a pole pruner may be used to obtain branch samples. However, pole pruners are unwieldly to transport into remote areas, and pruning results in destructive sampling. HWA density may be assessed on three trees per plot by observing two opposite branches of each of three trees and measuring relative density of sistens per cm of new terminal branches. Alternatively, a method may be adopted from Evans (1996) and Costa (2006), deriving an index of HWA infestation by examining the proportion of two twigs infested with HWA on lower branches.

Obtaining the percentage of *live* sistens would be useful to assess in the fall but it would require obtaining samples to examine under the aid of a microscope. It is best for NRR staff to lead this monitoring if it is undertaken, likely during fall months. Live sistens are predicted to be absent resulting from treatments by spring 2023.

Two 1 m^2 understory vegetation plots will record understory vegetation changes and responses using Braun-Blanquet survey methods. Understory characteristics may rapidly change if hemlocks were to decline/die causing needle duff buildup and increased sunlight to the forest floor. It's expected that much of the bryophyte layer would disappear.

Data will be submitted in an excel database and photo database to ECC when complete.

II. Two permanent photo plots will be put in place using a permanent marker already present on the landscape such as a boulder or large fallen tree trunk, preferably facing eastward, with waypoints, and a description for how to re-find the photo point from year to year. This will provide a photo record of more subtle vegetation change through the years as tree and understory responses to disturbances ensue, and HWA potentially destroys understory and regenerating hemlocks.

III. Forest bird acoustic monitoring is a proven and rapid method to evaluate forest heath (O'Connell at al. 1998, Canterbury et al. 2000, Morrison 1986). Many of the neotropical songbird species are insectivore specialists that are adapted to forage on guilds of insects found in tall, closed canopy conditions of old growth hemlock (Mitchel 1999). We propose to survey breeding forest birds during spring using 10-minute point counts. A forest bird point count can be integrated into each of the Impact Plots, with potentially two additional point counts located elsewhere on the island.

Concerns have been expressed about songbirds being potentially negatively affected from chemical treatments. Neonicotinoids were developed for their lower toxicity to vertebrates than older insecticide products (e.g., mammals and birds) (Mayfield *et al.,* 2020; McCarty, 2020). No investigations thus far have concluded that foraging behaviour or health of hemlock associate birds are directly affected in hemlock stands treated by imidacloprid (Falcone and DeWald, 2010; Slezak, 2018). Indirect negative effects have, however, been identified on insect food sources; canopy insect abundance, and reduced species richness in the first two years after treatment (Kung *et al.* 2015). Although canopy insects declined following treatment, they recovered by the third year. We would assume similar recovery of insect communities at Sporting Lake and this may be reflected by increased breeding bird populations. Nine years after treatment, canopy insect diversity has been observed to be higher in treated trees than in the declining untreated trees (McCarty and Addesso, 2019; McCarty, 2020).

Donna Crossland, Matt Miller, and Scott Robinson in front of the last tree injected at Sporting Lake.

Forest bird monitoring is proposed using the protocol devised by ornithologist Dr Cindy Staicer, whereby all bird songs and identifiable calls are recorded during 10-minute point surveys that are conducted prior to 10 am. Ideally these surveys are conducted twice each spring between the fourth week of May and the first week of July, and at least two weeks apart (to compensate for poor survey mornings and to capture early vs later breeding species). Five plots are generally selected separated by 250 m to avoid double-counting birds, but Sporting Lake is too small to meet this criterion, so either fewer plots shall be chosen, or special notes made when double detection is suspected. Backup recordings of each point count are also recommended.

Autonomous recording devices may be used to 'supplement' bird counts made by human observers, but they are not considered an ideal alternative to be used by themselves (Klingbeil and Willing 2015). The use of audio moths is a type of recorder device presently being tested and in wide usage to detect hemlock-associated birds in the '<u>Listening Together Project</u>' coordinated by John Kearney. The approach has proven successful thus far, particularly in areas that would not otherwise be surveyed, but a sole reliance on this method is still not recommended as recorders can malfunction, be improperly programmed, or affected by adverse conditions. It can also be difficult to determine the number of individuals of each species by solely using recordings. Visual detection of non-singing birds or more vocally cryptic species is lost. Installation and retrieval of the devices requires a minimum of two trips to each site, the same number of trips required to conduct traditional point counts. A copy of bird data should be submitted to the 'Listening Together Project' which is tracking changes in bird populations that may correspond with responses to HWA infestations and canopy decline.

IV: Injection wound responses. Given that the injection method used a product not previously tested in Ecoject equipment (manufactured by BioForest), and the location of injection sites would benefit from more observation, BioForest has suggested some criteria for which to evaluate the subsequent responses and healing of injection wound sites. Some trees were injected in root flares while most trees received a spiral pattern of injection located higher on the tree trunk. Trees with lower injection placements will be inspected and compared with an equal number of injection wounds that were located higher on the trunk.

Furthermore, administering tree injections results in very small mechanical wounds on the trunk that can provide entry points for pathogens (Docolla et al. 2011). The injured vascular tissue caused by repeated injections has been known to be very damaging in some instances in ash trees. (Some damage is reviewed in this informative video link.) Generally observing when callus formation causes port closure in hemlock trees is potentially useful. Proponents of other types of systemic application methods, such as basal bark spray and soil drench, have criticized the risks of trunk injection.

Evaluating responses to the treatment wounds can be useful for a variety of factors. There were some inconsistencies in treatment holes caused by drilling at various angles. Most holes were drilled at a slightly downward angle, but others were oriented perpendicular to the tree trunk. Wasnieswski et al. (1993) determined that making injection wounds straight into trees slightly reduced the amount of weeping from the wound. However, the species of tree also likely plays a factor in vulnerability and responses.

Injection site criteria to evaluate:

- Bark cracking at injection sites, or cracks instead of wound wood (photos of ash were provided for guidance)
- Signs of weeping, or bacterial wet wood (slime flux) at the injection sites
- Lesions
- Wound wood sealing the injection site properly
- Any other abnormalities observed, e.g., fungal growth or insects present at wound site
- Take pictures and waypoints of recorded observations

Investigate tree wounds from drill hole injection sites. Photo: G. Kovacs

V: Nontarget effects. Additional monitoring metrics that can be useful focus on movement and persistence of imidacloprid in soils, water, or mycorrhizae. Monitoring for nontarget effects to benthic invertebrates and drone photography monitoring of stand change/decline.

These and other decisions rest with ECC and NRR and would likely require more oversight or fieldwork by staff and incur additional tools and costs, though they may be assisted by volunteers. We believe we have proposed some relatively simple methods that can be rapidly completed and are low cost while delivering clear outcomes.

Discussion

The benefit of treatments used to control HWA infestations on eastern hemlock extend far beyond simply keeping old trees alive on Sporting Lake to address broad ecosystem responses. The chemical control mitigates threats to biodiversity and ecosystem services associated with the unique environments provided by hemlock forests as a foundation species. It is important to bear in mind that chemical control is viewed as a stop-gap measure to maintain forest ecosystem health while longer term solutions are derived that will assist hemlock to return to its self-sustaining dynamic and attain a new harmony with the addition of HWA to its environment.

The tree trunk injection method researched was a novel hybrid between a microinjection apparatus manufactured by BioForest, *Ecoject*, and a neonicotinoid chemical manufactured by ArborJet, *IMA-jet*. The method provided a safe and effective delivery mechanism for applying the chemical directly inside the vascular system of old growth hemlocks using volunteer labour to significantly reduce costs. Only small amounts of chemicals were used in a targeted way with no exposure of chemical to the environment. The result is that Sporting Lake hemlocks have a multi-year control of HWA, allowing trees to continue growing and sheltering a dark, humid environment enshrouded in mosses and liverworts.

Determining the most suitable injection method for treating hemlock

The need to administer tree trunk injections to free them from invasive pests is a relatively new concept to most people in Nova Scotia. Before the recent insurgence of invasive forest pests, there was little requirement for the practice, other than treatments against Dutch elm disease. The arrival of HWA, emerald ash borer (*Agrilus planipennis*) and beech leaf-mining weevil (*Orchestes fagi*) have caused increased interest in finding the best means of treating trees to sustain a small portion of them in the ecosystem and to buy some time while developing longer term solutions.

Some knowledge of the range of injection devices used and their advantages is useful as this equipment can be very costly and some of them require more time to deliver the chemical to trees than others. The labour and maintenance of the equipment involved can vary widely. We hear dismissive statements that chemical control of HWA is “too expensive”, and indeed it may be the case if an inappropriate delivery system is chosen to carry out tree injections or only paid operators are used to carry out the work.

Early tree injection devices have been manufactured by several companies and are varied in their ease of use 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. Some earlier devices used spring-loaded syringes or hand tools with plungers (e.g., Chemjet™ video in 2017, Arbor Jet™ video in 2015, and TreeTech (video) in 2014 (uses single use canisters) and Smart-shot by Maujet (Figure 3). Other devices involved pressurized tubing resembling and resembled a hospital I.V. system, but this can deliver unequal treatment amounts to the tree. More recent injection devices that operate under pressurized containers has been advantageous for minimizing time and labor requirements. Utilizing an injection system that is reloadable rather than single-use factors into cost and environmental considerations.

Observations made during chemical research trials carried out on hemlocks by the Canadian Forest Service (CFS) and Parks Canada, where both the QuickJet Air (by Arborjet) and EcoJect were used on equal numbers of hemlocks pointed to the EcoJect system allowing field operations to be completed at roughly twice the speed.

Hundreds of thousands of hemlock trees require treatment as an initial step to remain alive in NS. The eastern USA faced this same reality, beginning in the 1960s-70s when HWA-related mortality was rapidly spreading and there were fewer injection devices on the market. It is of little wonder that scientists there looked to other more rapid, less laborious methods to apply treatments, such as soil drench and basal bark spray. These options have resulted in tree injections being less utilized, with only small percentages of hemlocks injected in the USA compared to other treatment methods.

Ideally, Nova Scotia's hemlocks will soon receive a much faster and cheaper option by using the product Xytect 2F administered by basal bark spray. There would be fewer concerns with harm from tree injection wounds, though exposure risk increases somewhat. Tree injection will likely remain the delivery mechanism for riparian buffers and lake edges. Finding the most effective manner to complete tree injection will ultimately save time, money, and more trees.

Figure 3. Smart-shot injection system

The safe and effective EcoJect method using pressurized canisters proved to be easy to train volunteers on how to use. The containers held up well to the 11 days of intensive usage. All canisters returned to the manufacturer for refurbishment were deemed safe for use again. The only draw back detected was 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. Each canister must be cleaned according to an established protocol prior to shipping.

Phytosanitary measures- additional care to avoid potential spread of infection

There may be some risk of spreading infection from drill bits as the applicator proceeds from tree to tree. There may some validity in adding a safe practice against spreading pathogens from one hemlock to another. The company Mauget suggested disinfecting the drill bit before injecting another tree in case of spreading pathogens. During the late 1990s, hemlocks in eastern New Brunswick spanning from the Miramichi to Buctouche area, rapidly died off for reasons that were never determined by scientists at CFS. Heavy damage to hemlocks had been sustained by a high porcupine population at the time. Yellow-bellied sapsucker damage was also high on some trees, which can cause mortality to hemlocks during drought years when this bird increases its reliance on hemlock to feed, causing in some cases severe cambial wounding. Groves of hemlocks in Kouchibouguac National Park were noted to rapidly die over a period of several years and it was theorized that a fungal pathogen may have been transferred by the woodpeckers or heavy porcupine feeding (Harrison 1998, Pers Comm).

Volunteer response and limitless enthusiasm for saving old growth

Volunteer response to the Sporting Lake Project was very high. Over 50 volunteers contributed over 1,650 hours of volunteer effort, vastly reducing total costs of chemical application. On advance notice of only ~ 2 weeks, volunteer interest came from all directions and from a wide variety of people in both urban and rural settings. Ages ranged from early 20's to late 70's. The project appeal stemmed from a high desire to save old growth trees and recognition that Nova Scotia has very little old growth remaining. Many of the volunteers were unfamiliar with hemlock and its plight with HWA, but they intuitively recognized that a project that allowed them to help keep an old growth forest alive was an extremely worthy goal.

Using the BioForest EcoJect system under professional oversight of certified pesticide operators with volunteers was the most cost-effective stem injection method as determined in recent analysis by Medway Community Forest Co-op. The significant donation of volunteer labour resulted in reducing treatment costs by more than 50 % when compared to a paid staff/arborist model (Medway Community Forest Co-op, 2022). The additional labour also significantly increased productivity and reduced the *time* needed to complete the full treatment. Ultimately, the project could not have been achievable in the short time frame available without the significant volunteer treatment effort.

Matt Miller provides some HWA outreach to the 'Annual Thanksgiving Turkey Run' by a local Scout group.

Marshalling over 40 volunteers on short notice required significant time for volunteer coordination. The publicly accessible self-signup sheet (Excel sheet on Google Drive) set up by our Volunteer Coordinator greatly reduced time allocations toward coordinating volunteers. The Google Drive contained the information and waivers required for trip preparation. Having assigned a Volunteer Coordinator (i.e., Jennika Hunsinger whose time was donated by the Medway Community Forest Co-op) to the Sporting Lake project greatly enhanced the efficacity of this treatment approach and freed up the pesticide operators to concentrate on operational details.

The volunteer interest exhibited surpassed daily operational treatment requirements, particularly over the Thanksgiving holiday weekend, causing some people to be turned away. Limits were placed on the number of volunteers that could be accommodated daily mainly due to camp site and food limitations. The volunteer uptake was surprisingly high considering that Sporting Lake required people to have a canoe, the ability to conduct long portages, and have strong backcountry skills. We conclude that volunteer availability would be even higher for projects that are less remote and physically demanding.

In summation, we conclude there is a very large contingent of volunteers available to treat hemlock forests. Most of the volunteers at Sporting Lake have expressed high interest in participating on the next project or returning to Sporting Lake for follow-up work. Some have expressed interest in becoming pesticide operators and leading their own operations and employing the same safe and effective methods learned at Sporting Lake. The caliber, not to mention the dedication, of volunteers was extremely high. As one very active volunteer noted, "I would never work this hard for money."

Nightly debriefs and laughter around the fire at Sporting Lake Base Camp.

Fundraising

A government-funded program is essential to coordinating hemlock conservation efforts on a broad scale across the province, but there will continue to be a need to secure additional funds from private donors to support local hemlock conservation efforts that are not prioritized and will remain untreated otherwise. Private fundraising allows greater flexibility to act when government is unable to respond with the speed required to save hemlock forests from rapid HWA-caused mortality, or no plans or funds exist to save a particular stand that citizens deem important. Most Nova Scotians want old growth hemlock forest to endure along with its inherent biodiversity values. They are easily motivated to donate funds to address threats to such a noble cause, protecting irreplaceable and rare hemlock forests. We have outlined elements that are needed for future endeavors similar to Sporting Lake.

The establishment of an enduring fundraising campaign with the ability to provide charitable receipts is key for scaling up hemlock conservation using contingents of concerned citizens and volunteers. Raising the funds for Sporting Lake would not have been possible without the ability to provide tax incentives for donors; thus, one or more charitable partners to support fundraising efforts is required.

The rapid and sizable funding support garnered for the Sporting Lake project suggests that significant fundraising support exists that can be leveraged to help conserve some of Nova Scotia's most iconic hemlock forests. The success of the fundraising efforts was also due to the high profile of Sporting Lake as an iconic site and Nature Reserve. Many other old hemlock forests would also receive this level of public support; among the highest profile are several more urban parks, such as Kentville Ravine, Oakfield Park, and Victoria Park, all with large contingents of users who care deeply about those spaces.

Crucial next steps for the development of a hemlock conservation program

Several key initiatives must be taken to significantly ramp up hemlock conservation efforts in the face of rapidly expanding HWA populations and extensive hemlock mortality already underway.

- A Government funded hemlock conservation program with significant expenditure is a crucial requirement to save key, iconic hemlock forests from rapid mortality. The immediacy of the need to act is acute in the southwestern counties where many hemlocks decline below treatment thresholds each day and die soon thereafter. Conserving such an important ecosystem cannot be left solely to the actions of donors and volunteers, especially when considering the wide range of ecosystem services provided by hemlock forests. Our hemlocks are worthy of public investment. Government coordination, guidance, record keeping of treatment history, and other oversights are required under a new hemlock conservation program.

- Given the high costs associated with hemlock treatments, establishing an enduring fundraising campaign through charitable partners is essential to addressing the mounting hemlock conservation efforts required.
- We recommend the rapid establishment of a province-wide hemlock conservation partnership built upon other successful models such as the 'Hemlock Restoration Initiative' in North Carolina and approaches taken in more northerly states that have more recently become HWA-infested, such as New York and Michigan which have adopted statewide coordinated responses using a network of partners to implement insecticide treatments, and conduct other activities to educate the public and slow the spread of HWA to ensure hemlock remains viable.
- Establishing an incorporated organizational umbrella is needed to provide *liability coverage* for volunteer participants. Organizations such as the New York State Hemlock Initiative (NYSHI) and the Hemlock Restoration Initiative (HRI) in Maryland offer compelling models. Ways to address the liability risk of the nature that was taken on by the organizers of the Sporting Lake project requires some additional legal guidance for more projects of this nature to move ahead.
- Establishing a regional network of volunteer-led HWA "Strike Teams" led by certified pesticide applicators and supported by a dedicated government staff person is recommended, modelled after the Sporting Lake example and USA strike teams (e.g., NYSHI & HRI). HCNS has some resources remaining to kickstart strike team training that can expand strike team leader capacity.
- Government-led conservation efforts should be directed toward establishing a province-wide network of chemically- protected hemlock stands and developing a biocontrol program as soon as possible to lessen reliance on chemical controls. Chemical control is seen as a short-term, stop-gap solution while biocontrol represents a long-term solution to conserving hemlocks in the face of HWA.
- Consideration must be given to supporting hemlock conservation on private lands. Two-thirds of all hemlock identified in provincial forest inventory data is on privately held lands, with several counties having over 80% of their hemlock forest located on private ownership (MCFC 2022). Given the broad public benefits derived from healthy hemlock forests, government should invest in cost sharing programs to help ease the financial burden of treatment.
- The Sporting Lake treatment approach could be easily adapted to treat trees along water courses, taking a watershed approach and using local volunteers residing within each watershed and potential sport fish groups. This would require comparatively minor government inputs in comparison to costs of repairing bridges and road infrastructure when hemlock die and result in increased stream flashiness and dead tree trunks clog waterways causing flooding. Watershed health is deeply affected by the die-off of hemlocks that line those shorelines. Paddle groups and other volunteers have treated riparian hemlocks in USA.
- Regulatory reform, such as a limited scope HWA pesticide certification and expanded label use of domestic pesticides suitable for HWA treatment, can help expand treatment capacity. Some volunteers from the Sporting Lake Project have expressed desires to become strike team leaders, themselves, and obtain their own pesticide operator certification, with at least two of them having obtained certification since last fall. Since many people will want only to conserve trees, they would benefit from a streamlined certification process that focuses on the knowledge and skill set required to save trees with limitations on broader pesticide applications.

- Faster acting chemicals would greatly assist hemlock conservation needs. The hemlock at Sporting Lake were treated in the brink of time, but many other valuable stands in the southwest have declined below effective use of imidacloprid-based products. Government aid to request/authorize faster-acting chemical products such as dinotefuran is needed.
- Some official government recognition of the valuable role hemlocks play in carbon sequestration, including recognition that old growth hemlock forests sequester more carbon than younger hemlocks do, and hence its important capacity to mitigate climate change would heighten awareness of this tree's superior value. This recognition might assist with garnering additional funding required to address the pending ecological collapse of the species.

Conclusion

The Sporting Lake project was born out of a growing concern for the fate of irreplaceable, old growth eastern hemlock and the obvious need for rapid intervention to save them in the face of rapidly growing HWA populations. The project provided a highly successful model for engaging volunteers in the fight to conserve hemlock. Expanding this model requires government support and leadership. Nova Scotians have shown their willingness to embrace chemical controls when they are safely deployed and essential for saving iconic hemlocks. Channelling the incredible energy witnessed at Sporting Lake Nature Reserve and empowering citizens to engage in more hemlock conservation is beneficial for all Nova Scotians, our forests, and long-term ecosystem health.

References

Benton, E. P., & Cowles, R. S., 2016. *Optimized insecticide dosage for hemlock woolly adelgid control in hemlock trees*. WSFNR-17-01, The University of Georgia Warnell School of Forestry and Natural Resources, Tifton, GA.

Canterbury, G.E., Martin, T.E., Petit, D.R., Petit, L.J. and Bradford, D.F., 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. *Conservation Biology*, *14*(2), pp.544-558.

Costa, S., 2006. *Standardized sampling for detection and monitoring of hemlock woolly adelgid in eastern hemlock forests*. Forest Health Technology Enterprise Team.

Doccola, J.J., Smitley, D.R., Davis, T.W., Aiken, J.J. and Wild, P.M., 2011. Tree wound responses following systemic insecticide trunk injection treatments in green ash (Fraxinus pennsylvanica Marsh.) as determined by destructive autopsy. *Arboriculture and Urban Forestry*, *37*(1), p.6.

Eschtruth, A.K., Evans, R.A. and Battles, J.J., 2013. Patterns and predictors of survival in Tsuga canadensis populations infested by the exotic pest Adelges tsugae: 20 years of monitoring. *Forest Ecology and Management*, *305*, pp.195-203.

Evans, R.A., Johnson, E., Shreiner, J., Ambler, A., Battles, J., Cleavitt, N., Fahey, T., Sciascia, J. and Pehek, E., 1996. Potential impacts of hemlock woolly adelgid (Adelges tsugae) on eastern hemlock (Tsuga canadensis) ecosystems. *Proceedings of the first hemlock woolly adelgid review. Charlottesville, Virginia, USA. 12 October 1995.*, pp.42-57.

Falcone, J. F., and DeWald, L. E., 2010. Comparisons of arthropod and avian assemblages in insecticide-treated and untreated eastern hemlock (Tsuga canadensis [L.] Carr) stands in Great Smoky Mountains National Park, USA. *Forest Ecology and Management*, *260*(5), 856-863.

Klingbeil, B. T., and M. R. Willig. 2015. Bird biodiversity assessments in temperate forest: the value of point count versus acoustic monitoring protocols. Peer J 3: e973.

Kung, W. Y., Hoover, K., Cowles, R., & Trotter III, R. T. (2015). Long-term effects of imidacloprid on eastern hemlock canopy arthropod biodiversity in New England. *Northeastern Naturalist*, *22*(1).

Mayfield III, A. E., Salom, S. M., Sumpter, K., McAvoy, T., Schneeberger, N. F., & Rhea, R. (2020). Integrating chemical and biological control of the hemlock woolly adelgid: a resource manager's guide. *FHAAST-2018-04. USDA Forest Service, Forest Health Assessment and Applied Sciences Team, Morgantown, West Virginia.*, *2020*, 1-40.

McAvoy, T. J., Mayfield III, A. E., & Salom S. M., 2019. Conducting Hemlock Health Assessments and Sampling for Hemlock Woolly Adelgid and Elongate Hemlock Scale. Virginia Tech & USDA Forest Service.

McCarty, E., & Addesso, K. M., 2019. Hemlock woolly adelgid (Hemiptera: Adelgidae) management in forest, landscape, and nursery production. *Journal of Insect Science*, *19*(2), p. iez031.

McCarty, E. 2020. Environmental Risks to Arthropods from Imidacloprid Applications for Hemlock Conservation. University of Georgia Warnell School Outreach Publication WSFNR-20-88A. 11 Pages.

Medway Community Forest Coop. 2022. Potential options for a comprehensive chemical treatment program to conserve eastern hemlock in Nova Scotia from hemlock woolly adelgid. Unpublished report to NS Environment and Climate Change.

Mitchell, J.M. 1999. Habitat relationships of five northern bird species breeding in hemlock ravines in Ohio, USA. Natural Areas Journal 19:3–11.

Morrison, M.L., 1986. Bird populations as indicators of environmental change. In *Current ornithology* (pp. 429-451). Springer, Boston, MA.

O'Connell, T.J., Jackson, L.E. and Brooks, R.P., 1998. A bird community index of biotic integrity for the mid-Atlantic highlands. *Environmental Monitoring and Assessment*, *51*(1), pp.145-156.

Slezak, P. 2018. Variation in bird foraging behavior and abundance between hemlock forested sites treated and untreated for hemlock woolly adelgid.

Wasniewski, T.A., Chaney, W.R. and Holt, H.A., 1993. Hole angle for trunk injection of tree growth regulators and its affect on weeping, wound closure and wood discoloration. *Journal of Arboriculture*, *19*, pp.131-131.

Personal Communication

Harrison, K. ,1998. Research Scientist, Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Centre, Fredericton, NB.

Appendix A – Inventory of Remaining Equipment

Quantity	Item
3	3'x6' Folding table
7	folding chairs
1	shower machine
3	propane hose
6	4 gallon buckets
1	Spill kit
1	3'x3' folding table
1	shower encloser
1	2 burner propane stove
1	new shipment cannisters in returnable condition
2	4 port dewalt fast chargers
6	cordless dewalt drills
8	5 amp hour dewalt batteries (1 damaged)
2	tire inflator style compressors
1	Eco-ject filler system with 4 filling guns
8	small hammers
6	60 litre recreational barrels
2	recreational barrel harneses
1	cooler
1	tank style dewalt battery compressor
5	canvas cprpenters aprons
16	freezer packs
1	12 volt cell booster
1	7 port USB charger
11	packs of lysol wipes
2	boxes of tin foil
6	part bottles of alchol for cleaning equipment
3	bottles of alchol for cleaning equipment
2	full 20 pound propane tanks
1	part full bottle of propane
1	empty bottle of propane
4	empty 25 litre gas cans
2	500 ml of 2 stroke mixing gas
2	bottles of sea foam
470	canisters (refurished)
363	nozzels

Appendix B – Volunteer Callout

Calling all Hemlock Heroes to Sporting Lake Nature Reserve

Do you love old growth forest? Do you enjoy wilderness canoeing and portaging to remote locations? Have you cherished the gentle stillness of towering hemlocks? Yes…??

YOU may wish to join volunteers to save old growth hemlocks from certain death from Hemlock Woolly Adelgid (HWA) infestations at Sporting Lake Nature Reserve located inside the Tobeatic Wilderness Area.

What's involved? Join volunteers with ***Hemlock Conservation- Nova Scotia*** to measure tree diameters (hugging trees is accepted social behaviour!), drill a few tiny holes in each tree trunk, and help insert tiny canisters containing chemical treatment; a type of 'tree vaccination'. Micro-injections of IMA-jet (containing imidacloprid, a chemical you may already use on pets to kill ticks and fleas) will eventually circulate to the crown to control HWA.

Accessing Sporting Lake requires an approximate 4 hr canoe trek on Sporting Lake Stream, a small rocky brook with two portages, the longest of which is 1100 m. The excursion will be physically demanding, but the beauty of irreplaceable old growth awaits.

Why are the hemlock dying? Hemlock forests across southwest NS are dying from HWA, a tiny, invasive, sap-sucking insect. The trees need more time to adapt to this newcomer and need our help to actively control HWA populations over the next decade or longer. Forest scientists are searching for a long-term cure by using tiny natural insect predators to control HWA, but chemical vaccination control is necessary in the interim.

Donate to save old growth hemlock Saving old growth at Sporting Lake Nature Reserve is entirely reliant on donations from caring people like you. The Nova Scotia Nature Trust is administering donations and tax receipts. Please help save old growth: DONATE or here **https://nsnt.ca/save-old-growth-hemlocks/**

What do I need to bring? You will need to be self-sufficient, though group meals are supplied. *You will also need to be double-vaccinated.

Gear required:

- canoe and all required safety gear
- tent
- warm sleeping bag
- clothing for cold, wet conditions
- wilderness gear (e.g., water purification, knife, fire starter, head lamp or flashlight, first aid kit, snacks
- water bottle(s)

Our ***Volunteer Coordinator*** will provide a full list of recommended gear and volunteer waiver.

Group meals are suitable for '*not-too-picky'* omnivores. Special dietary requirements cannot be accommodated due to remoteness, but volunteers can bring their own food.

How do I sign up? Contact ***Volunteer Coordinator:*** jennika@medwaycommunityforest.com

Jennika Hunsinger, Medway Community Forest Coop (MCFC) will send more information and help place you on the schedule. You can choose dates over 2-7 days. We accommodate up to 12 people each day.

When? **Oct 4th-22nd, 2021**

Who is 'Hemlock Conservation-Nova Scotia'? A diverse group of dedicated volunteers who have united to save hemlock forests. They are led by an emergency medical doctor, Dr George Kovacs, and a lawyer, as well as foresters and biologists. Together, a program of 'vaccinating hemlocks' is underway (not unlike vaccinations against COVID-19).

Departments of Environment and Climate Change and Natural Resources and Renewables are supporting this pilot project to treat hemlock trees. The Nova Scotia Nature Trust, Medway Community Forest Coop, and generous sponsors such as Sobeys are assisting.

Why save Sporting Lake Nature Reserve? This reserve features one of the most majestic old growth forests found anywhere in Nova Scotia. Tall, graceful hemlocks rise from a tapestry of moss on an island in Sporting Lake. Mortality from HWA will come quickly without **Hemlock Heroes** to render aid to these forest elders.

Appendix C – Volunteer Dashboard

	A	B	C	D
1	**Individuals should bring with them:**			
2				
3	**General backpack gear**			**Maps:**
4	hearty snacks (nuts, boiled eggs, jerky, etc)			It's advised you **download the app Avenza**, open both PDF maps in the app and you now have a navigable offline map
5	water bottles 2L			Open the PDF on your phone or email it to yourself and open with Avenza, it will import
6	Water purifier (filter or tablets)			Your location will appear as a blue dot
7	fire starter (lighter or water proof matches)			https://youtu.be/8lMLv-l4_0A
8	knife (jack knife or multi-tool)			
9	headlamp or flash light (spare batteries)			
10	compass and/or GPS			
11	map			Everyone will have to arrange or bring their own high clearance vehicle, canoe, life-jacket, bail buckets and all safety measures required
12	First aid kit (any meds required)			Review canoe and paddle safety information before you head out and travel in larger groups when you can - coordinate with others
13	spare warm socks			traveling in or our the same day as you.
14	tuque			https://www.mec.ca/en/explore/mandatory-paddling-gear
15	rain gear			https://www.adventuresmart.ca/paddling/
16	small tarp			
17	duct tape (for canoe repairs, etc)			
18	change of clothing			
19	water shoes or old sneakers (for hopping in/out of canoe)			
20	sleeping bag			
21	thermarest or preferred comfort			
22	tent			
23	*Note: *Tent Dwellers novel recommends always taking whisky into the woods.*			
24	**Personal Flotation Device (MANDATORY)**			
25	** Be prepared for near freezing overnight tempertatures & incement weather			

Add your availability here for NIGHTS you will be staying in the Nature Reserve with us - we will have a max of 12 people per night
*Everyone mu *Everyone must email Jennika@medwaycommunityforest.com their proof of double vaccination against Covid-19 prior to*
*We're prioritizing volunteers who can stay at least 3 nights to minimize orientation / training time - thank you for your help!

Day	Date	Core Group Members	Volunteers	Tentative	# people	Total people on site
Tuesday	October 5					
Wednesday	October 6					
Thursday	October 7					
Friday	October 8					
Saturday	October 9					

Appendix D – Donated Equipment

Items Lent in Support of Expedition
Generator (x2)/Power Bar/Extension Cords
Extra Spark Plug & Pull Cord
Gell Cell Battery
Battery Charger
Solar System
Tarp & Rigging Rope
Rope & Pulleys for Bear Hoist System
Tree Climbing Gear
Chain Saw/Chaps/Hardhat
Power Inverter
Round Mouth Shovel, Pulaski & Splitting Axe
Pulaski
Splitting Axe
Gas/Oil/Mixed Gas
Tool Kit
Boat & Motor
Survival Kit for Island
BBQ

Appendix E – Volunteer Waiver

General Waiver and Release of Liability ("Release")

BY SIGNING THIS RELEASE, YOU WILL WAIVE CERTAIN LEGAL RIGHTS, INCLUDING THE RIGHT TO SUE OR CLAIM COMPENSATION FOR INJURIES, DEATH OR PROPERTY DAMAGE OR LOSS WHILE ATTENDING:

Nova Scotia Hemlock Conservation: Sporting Lake Project (the "Event")

1. ASSUMPTION OF RISKS

I am aware and understand that participating in the Event may involve certain risks, including but not limited to the risk of serious injury, death, property damage or loss. I acknowledge that I am voluntarily participating in the Event. By choosing to participate in the Event, I freely accept and fully assume any and all of the risks involved and the possibility of injury, death, property damage or loss.

2. RELEASE AND WAIVER

I hereby expressly waive and release any and all claims which I have or may in the future have against each of the Event organizers, including George Kovacs, Scott Robinson, Donna Crossland, Mary Jane Rodger, Matt Miller, John Rogers, Rod Burgar and Jennika Hunsinger (collectively the "Organizers"), on account of injury, death, property damage or loss arising out of or attributable to my participation in the Event, due to any cause whatsoever, including without limitation the negligence or breach of any statutory or other duty of care of the Organizers. I covenant not to make or bring any such claim against the Organizers, and forever release and discharge the Organizers from liability under such claims.

3. INDEMNIFICATION

I shall defend, indemnify and hold harmless the Organizers against any and all losses, damages, liabilities, deficiencies, claims, actions, judgments, settlements, interest, awards, penalties, fines, costs, or expenses of whatever kind, including reasonable legal fees, in connection with any third party claim, suit, action or proceeding arising out of or resulting from my participation in the activities of the Event.

This Agreement is binding on and shall ensure to the benefit of the Organizers and me and our respective heirs, executors, administrators, trustees, legal and personal representatives, insurers, successors and assigns.

I acknowledge that I have carefully read and understood all of the terms of this Release and that I am voluntarily waiving substantial legal rights including the right to sue the Organizers in the event that I suffer injury, death, property damage or loss while attending the Event.

I wish to participate in the Event. As lawful consideration for being permitted by the Organizers to participate in the Event, I agree to all the terms and conditions set forth in this Release.

Date: ____________________

Name: ____________________

Signature: ____________________

Appendix F – Injection Gear & Price List

Item	Count	Cost Per Unit	Cost ($)	Tax (0.15)	Total Cost ($)
Drill	6	$ 189.00	$ 1,134.00	$ 170.10	$ 1,304.10
5 Amp Hour Battery (2 Pack	4	$ 239.00	$ 956.00	$ 143.40	$ 1,099.40
Compressor	1	$ 300.00	$ 300.00	$ 45.00	$ 345.00
Tire Inflator	1	$ 168.00	$ 168.00	$ 25.20	$ 193.20
Table	1	$ 157.00	$ 157.00	$ 23.55	$ 180.55
Small Hammer	6	$ 7.99	$ 47.94	$ 7.19	$ 55.13
4 Battery Dewalt Fast Charger	2	$ 219.00	$ 438.00	$ 65.70	$ 503.70
Cleaning Solution (1 Litre)	10	$ 11.00	$ 110.00	$ 16.50	$ 126.50
Drill Bits	15	$ 2.90	$ 43.50	$ 6.53	$ 50.03
Canisters (Dozen)	50	$ 143.95	$ 7,197.50	$ 1,079.63	$ 8,277.13
Eco-Ject (6 Litre System)	1	$ 1,195.00	$ 1,195.00	$ 179.25	$ 1,374.25
Eco-Ject Nozzels (Dozen)	50	$ 114.95	$ 5,747.50	$ 862.13	$ 6,609.63
Spill Kit	1	$ 71.23	$ 71.23	$ 10.68	$ 81.91
5 Gallon Bucket with Handle	12	$ 29.94	$ 359.28	$ 53.89	$ 413.17
					$ 20,613.69