MITIGATING THE EFFECTS OF THE WHITE SATIN MOTH (*LEUCOMA SALICIS*)
IN THUNDER BAY'S URBAN FOREST

by

Marian Scaffeo

FACULTY OF NATURAL RESOURCES MANAGEMENT

LAKEHEAD UNIVERSITY

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ABSTRACT

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Keywords: defoliation, host, *Leucoma salicis*, management, mitigate, moth, *Populus*, satin moth, Thunder Bay, urban forest, Waverly Park, white satin moth

The white satin moth, *Leucoma salicis* (L.), has been detected as a pest of urban trees in Thunder Bay, Ontario. Surveys were conducted in urban environments following the discovery of this introduced species to determine the extent of damage to urban trees and distribution within Thunder Bay. Further information was compiled to identify ways to locally mitigate the effects of the satin moth. Early management strategies, such as high-pressure water washing, Tanglefoot, and Btk should be utilized as short-term management approaches, and biological control agents, such as parasitoid wasps, should be implemented as a long-term management strategy to mitigate severe infestations.

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INTRODUCTION

Urban forests are defined as ecosystems characterized by the presence of trees and other vegetation in association with humans and their developments (Nowak *et al.* 2001). Urban canopies provide an array of environmental, social and economic benefits (KBM 2009). The ecosystem services of urban forests include an improvement in air quality, energy conservation, storm water management, wildlife habitat, and regulation of micro-climatic environment (ibid.). Society gains positive psychological effects of the urban forest from feeling connected with the natural environment (Jorgensen 1986). The economic benefits of urban trees include increased real-estate values, and savings due to energy conservation, carbon dioxide sequestration and air pollution removal. In recent years, an emphasis has been placed on urban forest management to reap the environmental, social and economic benefits, and offset the impacts of urbanization (Ordóñez and Duinker 2013).

The increase of globalization and global trade has made way for an increase in introduced species (Hulme 2009). The movement of people and automobiles, international trade, imported nursery stock and dunnage are often more concentrated in urban centres (Paap *et al.* 2017). Therefore, urban environments are often the first point of contact for invasive insects and pathogens. Urban trees are often planted in monocultures and they may occur on improper sites with unfavorable conditions. As a result, urban environments can be susceptible to invasive pests. Once established, invasive insects can disperse into natural forests and disrupt and damage the natural ecosystems.

In 2000, the City of Thunder Bay's Forestry and Horticulture department managed 20,000 municipally owned trees spanning across 884 kilometers of roadways and 129 municipal parks (Davey Resource Group 2011); presently, the number of municipally owned trees is projected to be over 30,000. Thunder Bay is in the Boreal Forest Region within hardiness zone 3A, which limits the diversity of the urban forest. Limited species are suitable for the harsh condition of the region which has led to the domination of four species: 26% green ash (*Fraxinus pennsylvanica* Vahl.), 18% silver maple (*Acer saccharinum* L.), 8% linden (*Tilia cordata* L. and *Tilia* spp.), 8% white birch (*Betula papyrifera* Marsh.), and a mixture of species represent the remaining 40% (ibid.). In 2011, poplar (*Populus* ssp.) trees accounted for 1.2% of the urban tree population on public property. A large proportion (80%) of the municipal trees had a DBH (diameter at breast height) of 45 centimeters or less and very few trees (1%) exceeded a DBH of 90 centimeters (ibid.). Until recently, trees in Thunder Bay were under appreciated. Many trees were damaged or removed prior to the implementation of urban forestry by-laws, which lead to a decline of mature and vigorous trees.

OBJECTIVE

The white satin moth, *Leucoma salicis* (L.) (Lepidoptera, Lymantriidae), was detected in Thunder Bay, Ontario by the City of Thunder Bay's Forestry and Horticulture department in the spring of 2020. Evidence of substantial defoliation was present on the mature eastern cottonwood trees (*Populus deltoides* Bartram ex Marsh.) and immature sundance popular trees (*Populus x* 'sundancer') in Waverly Park. Waverly Park was established in 1871, and is considered to be the oldest park in Thunder Bay (Stirrett 1980). The white satin moth was identified in its larval stage as the defoliator causing severe damage to the poplar trees. Tanglefoot® insect barrier and Btk (*Bacillus thuringiensis* var. *kurstaki*) were used as an effective deterrent on the immature poplar trees; the mature poplar trees were left defenseless due to their size. Preserving the integrity of the poplar population in Thunder Bay's urban environments is an important management objective because there are limited established poplar trees within Thunder Bay's urban forest. The mature poplar trees in Waverly Park account for some of the oldest trees in Thunder Bay.

Additionally, the infested host trees are planted for environmental and aesthetic purposes in parks and along roadways. Severe defoliation can lead to individual branch or whole tree death, which can decrease the aesthetic and environmental value of the tree. Therefore, a strategic management objective aims to minimize the environmental and aesthetic loss and economic cost to remove and replace the affected trees.

LITERATURE REVIEW

WHITE SATIN MOTH INTRODUCTION

The white satin moth, *Leucoma salicis* (L.) (Lepidoptera, Lymantriidae), was inadvertently introduced into North American from Europe and Asia. In 1920, it was simultaneously detected near Boston, Massachusetts, and in British Columbia, Canada. Gradually, it spread to New York and the Maritime Provinces of Canada in the east, and Washington, Oregon, northern California and Idaho in the west (Langor 1995). In 1994, the white satin moth was detected in St. Albert, Alberta; its population continues to travel towards the central portions of the continent. The distribution of white satin moths is not well documented in North America.

HOST, DAMAGE, SYMPTOMS AND BIOLOGY

The phyllophagous caterpillars feed on trees in the *Salicaceae* (Mirb.) family, and occasionally on oak (*Quercus* ssp.), crab-apple (*Malus* spp.), and saskatoon berry (*Amelanchier alnifolia* Nutt.) (Kratsch *et al.* 2018, NRCAN 2015). The initial signs of damage become evident in mid-May when overwintered second-instar larvae emerge from hibernation and resume feeding. As feeding progresses, larvae consume whole leaves except for the petiole and major veins. Damage is most evident after mid-June, when late-instar larvae consume the new foliage (NRCAN 2015). The next generation of larvae skeletonize the leaves in late summer, but cause little damage (Ziemnicka 2008a). Sometimes, leaves turn brown and drop when heavily infested. Repeated outbreaks of defoliation can result in top-kill and mortality. Pupae, silk webbing, and larval skins on branches, stems or rolled leaves are signs of infestations (Kratsch *et al.* 2018).

Defoliation of poplar trees resulting from the satin moth infestation does not present a particular threat to poplar stands (Ziemnicka 2008a). Often, the trees are capable of regeneration within several weeks. However, multiple-outbreaks can become a serious threat because the ability to regenerate rapidly decreases as reserves are depleted, and it results in a reduction of mean annual growth and resilience (ibid.). Weaker trees become more susceptible to opportunistic fungi and other insect pests (Kratsch *et al.* 2018).

Adult satin moths appear in July and August. They have a satiny white wingspan with no markings that are 24 to 47 millimetres in width (NRCAN 2015). The stout, black tagmata (body) is covered by a dense layer of white scales and hair (OMNRF 2020). After mating, light green, flat, oval clusters of 150 to 200 eggs covered with a glistening white secretion are laid on the boles and branches by the females (Humphreys 1996). After two weeks, eggs hatch and young larvae move to the leaves, which they skeletonize as they develop through two instars (NRCAN 2015). Second-instar larvae retreat to hibernation sites on the trunk or branches of a host tree, and moult after spinning hibernacula that are usually covered with bark particles, mosses, or lichens (Humphreys 1996). After overwintering, these larvae emerge in mid-May and commence feeding on newly flushed leaves (Langor 1995).

Larvae are 10 to 45 millimetres in length when fully grown. The body colour is pale grey to brown, with a dark head and back. There is one row of large, oblong white to pale-yellow patches along the middle of the dorsum and a set of subdorsal yellow lines; tufts of brown setae occur on the two lateral and two subdorsal rows of orange tubercles (Humphreys 1996). Mature larvae spin silken cocoons in the leaves in which they pupate (NRCAN 2015). Pupae are shiny black, 15 to 22 millimetres long, and have sparse tufts of yellow hairs. Moths emerge from pupae after approximately 10 days to complete the 1-year life cycle (ibid.).

MANAGEMENT APPROACHES

Bacillus thuringiensis var. *kurstaki*

The growth rate of the bio-pesticides industry has been forecasted to grow by 10 to 15 percent per annum within the next 10 years, while the synthetic chemical pesticides industry is only forecasted to grow 1 to 2 percent per annum (Menn 1996, Marrone 2014). Btk has proven to be an effective microbial insecticide pest management strategy in Poland and North America (Ramanujam *et al.* 2014). *Bacillus thuringiensis* (Bt) is a naturally occurring bacterium found in the soil. The HD-1 strain of the *kurstaki* variety (Btk) is used to control caterpillars (Kouassi *et al.* 2001).

This bacterial insecticide is commonly used to control Lepidopteran populations such as the gypsy moth (*Lymantria dispar* L.) and the white-marked tussock moth (*Orgyia leucostigma* Smith) (both Lymantriidae) in managed environments. The susceptibility to Btk varies with host diet. The larvae may be more susceptible to Btk when feeding on some species such as aspen than on others such as willow (*Salix* ssp.) (Appel and Schultz 1994). *Bacillus thuringiensis* var. *kurstaki* is more effective when ingested by larvae in the early developmental stage (Spears 2018). It must be consumed by caterpillars in the larval form as it's not an effective method to induce mortality in eggs, pupae, or adults. Once ingested, the bacterium multiples and releases toxic substances in the digestive system causing cell lysis (Boderick *et al.* 2010, Boderick *et* *al.* 2003). Shortly after ingestion, the larvae stop feeding due to midgut paralysis, and perish within 1 to 5 days.

Tanglefoot

Tanglefoot® was first introduced in 1923 by the Thum brothers. Tanglefoot® insect barrier is an organic, non-drying, oil-based adhesive compound that is applied over a band around the tree trunk, approximately 1.3 metres from the ground, to halt crawling insects. Tanglefoot® is comprised of tree resins, vegetable oil, Tanglefoot glue, and vegetable wax (Campbell and Campbell 2018). Tanglefoot® bands should be established by the end of April and monitored throughout the month of May to ensure the sticky surfaces do not become saturated with emerging caterpillars and other insects. The compound should remain on the tree for a minimum of 1 month up to a maximum of 2 months before removing or replacing the product. For Tanglefoot® to work, trees must be pruned so no branches are touching the ground or other trees or objects which are not banded (Alston *et al.* 2018). Crawling insects will get trapped in the compound while crawling up the tree and perish.

High-pressure Water Washing

Since 1920, high-pressure water washing techniques have been utilized to remove *Leucoma salicis* larvae, pupil, moths and egg clusters from structures (Burgess and Crossman 1927). Several western Canada municipalities used high-pressure water washing methods as an early management strategy to remove egg masses and caterpillars from the trunk and branches of host trees. Newly hatched larvae can be pressure washed off tree trunks and branches during their dispersal to the tree foliage in spring (Anon n.d). This technique involves using a high-pressure tree sprayer with a nozzle pressure of 400 PSI. This technique should only be carried out by trained professionals to mitigate mechanical damage to the tree (Pokorny and Albers 1992).

Biological Control

Natural enemies and predators are very important for controlling white satin moth population, especially in environments where broad-spectrum insecticides cannot be utilized. Several parasitoids and predators exert significant mortality on satin moths. Parasitoid wasps, flies, mites, predatory birds and beetles, and a cytoplasmic polyhedrosis viruses are among the most important naturally occurring predators that control the satin moth population (Magasi and Van Sickle 1984).

Parasitoid Wasps

Applying commercially available parasitoid wasps, such as the *Cotesia melanoscela* (Ratzeberg) and *M. versicolor* (Wesmael), is a proven suppression method in Calgary and Edmonton, Alberta Canada (Anon n.d). *Cotesia melanoscela* and *M. versicolor* are braconid wasps that are natural parasitoids of satin moth larvae and are commercially available for biological control purposes. *Meteorus versicolor* is a parasitoid of multiple Lepidoptera species, including the white satin moth (Griffiths 1976). Wagner and Leonard (1980) found *M. versicolor* to be bivoltine with larvae of the first generation emerging from 4th stage hosts in late May to mid-June and second generation *M. versicolor* emerging from 7th and 8th stage hosts, with adults ovipositing on pre-diapause larvae. *Meteorus versicolor* is of significant economic importance. The parasitism rates of *M. versicolor* are, on average, 37-45% on various Lepidopteran species (Eroglu 2003). Thus, it is considered an important natural enemy.

Cotesia melanoscela was introduced to North America in 1912, specifically for biological control of the gypsy moth (Burgess and Crossman 1929). It completes two lifecycles per year. The *C. melanoscela* wasp is considered to be a valuable biological control agent of Lepidoptera species, but it is limited by host availability (Muesebeck and Dohanian 1927). Laying 50-1,000 eggs, females deposit a single egg in first or second instar larvae. The female inserts a virus during egg deposition, which causes an immune response in the host, and prevents molting (Blackburn and Hajek 2018). The Lepidoptera larvae can live for several days following the departure of the parasite, but it eventually perishes.

<u>Nucleopolyhedrovirus (MNPV)</u>

Nucleopolyhedrovirus is an important epizootic factor in white satin outbreaks; it produces a polyhedral-shaped inclusion bodies inside the host and the diseases caused by the virus are called nucleopolyhedrosis (Ziemnicka 2008a). The *Leucoma salicis* Nucleopolyhedrovirus (LesaMNPV) is the most common pathogen in white satin moth populations (ibid.). The LesaMNPV virus powder is diluted into distilled water and sprayed on host trees. Larvae are exposed to LesaMNPV while feeding on sprayed foliage. Ziemnicka (2008b) concluded LesaMNPV induces a 6 to 28-fold reduction in female fecundity. Surviving offspring of infected parents show symptoms of the virus. The LesaMNPV solution is environmentally friendly and safe for humans.

Hirsutella gigantea

Hirsutella is a genus of asexually reproducing fungi in the family Ophiocordyceipitaceae (Reddy *et al.* 2020). *Hirsutella gigantea* Petch is one of the three species in the genus *Hirsutella*, and is of significance to satin moth populations. Wagner and Leonard (1980) discovered *H. gigantea* in overwintering larvae. However, mortality from *H. gigantea* never exceeded 2% (ibid.). *Hirsutella gigantea* is not commercially available at this time. Commercial use of this fungi is affected by the inability of this species of fungi to produce spores under water, which prevents liquid culture methods (Gams *et al.* 2004).

MATERIALS AND METHODS

STUDY AREA

The tree assessments were carried out in Waverly Park, as seen in Figure 1, located in Thunder Bay, Ontario. The park boasts mature eastern cottonwood trees and young sundancer poplars. The survey expanded from Waverly Park to determine the range of the white satin moth in Thunder Bay's urban environments. The data collection was undertaken in the summer of 2020 and was analyzed in the winter of 2020.

Figure 1. Overview of inventoried trees in study area

EXPERIMENTAL DESIGN

A localized inventory of poplar trees was conducted in Waverly Park to gather accurate information about the location, size, and health of the trees. Each poplar tree was thoroughly inspected for signs of the white satin moth, and all defoliation damage was documented.

Prior to the inventory, a base map was generated on the ESRI Collector Mobile Application on a Samsung Galaxy 8 to accurately document the inventory. The trees were systematically inventoried within each quadrate of the park, and assigned a tree identification number. To commence, the corresponding tree was identified; a thorough visual inspection was conducted around the circumference of the trunk and up to 5.5 metres in height. Several photos were taken of each tree and attached to the waypoint. The diameter at breast height (1.3 meters) was measured to one decimal place using a diameter tape in centimetres.

From Waverly Park, the inventory expanded in the four cardinal directions to establish the range of the white satin moth in Thunder Bay's urban environments. Urban poplar trees were systematically assessed for defoliation; the trees were thoroughly inspected if they presented defoliation symptoms. The urban trees on private property that presented symptoms of defoliation were noted for reference, but were not thoroughly inspected or included in the data.

RESULTS

Of the host trees in Waverly park, 41 of the 46 trees showed visible symptoms of defoliation to varying degrees. Various symptoms and evidence of *L. salicis* was noted such as skeletonized pupae (figure 2), silk webbing (figure 3), larval skins on branches (figure 4), skeletonized leaves, crown die-back, and larval and moth corpses caught in the Tanglefoot®. The defoliation was most substantial on the immature *Populus x* ‘sundancer’ (figure 5), the mature Eastern cottonwood trees had moderate to severe defoliation (figure 6), and the Lombardy poplar (*Populus nigra* L.) were mildly affected; only 2 of the 6 Lombardy poplar trees had mild defoliation.

Figure 2. Skeletonized *Leucoma salicis* on Sundancer Poplar bark

Figure 3. Silk webbing of *Leucoma salicis* on an exterior crevasse of a Sundancer Poplar and on the interior bark of a mature eastern cottonwood tree.

Figure 4. *Leucoma salicis* larval skins on the trunk of a *Populus x* ‘sundancer’

Figure 5. Defoliated *Populus x* ‘sundancer’(left) and *Populus nigra* (right) in Waverly Park

Figure 6. Defoliated *Populus deltoides* in Waverly Park

The inventory expanded in the four cardinal directions of the city once the inventory of the park was concluded. Significant defoliation was found on host trees to the east at Marina Park, defoliation was present on urban host trees up to the rural forested areas in the north and south, but there was no evidence of the satin moth to the west.

DISCUSSION

Eighty-nine percent of the host trees in Waverly Park exhibited moderate to severe signs of defoliation. The dense population of poplar trees with limited tree diversity has exacerbated the infestation of *L. salicis*. Evidence of infestation is prevalent since host trees are within close proximity to one another. The infestation was most predominant in trees located in the western portion of the park, while the Lombardy poplar situated in the eastern portion of the park, near Magnus Theatre, showed the fewest symptoms. This observation may be due to a variety of factors, such as: host preference, distribution, migration patterns, and other unknown variables.

The expansion of the inventory to the east revealed several immature poplar trees at Marina Park exhibited moderate to severe defoliation. The Marina Park defoliation was located 762 linear metres from the eastern edge of Waverly Park. *Leucoma salicis* is the likely suspect of the defoliation symptoms at Marina Park since it is within close proximity to an infested park. However, it is important to note that skeletonized pupae or larvae of *L. salicis* or any other Lepidoptera species was not present upon thorough inspect of the trees. There was inconspicuous webbing present on the trees, but the origin was inconclusive.

The expansion of the inventory to the north determined the presence of defoliation on host trees. Several ornamental urban trees were, on average, 25% defoliated. The trees were not thoroughly examined for evidence of the white satin moth because they were situated on private property. However, this trend extended 2.6 linear kilometres from the northern edge of Waverly Park to Highway 11/17. Similar observations were made in regards to the southern expansion of the study. However, evidence of *L. salicis* was detected in a stand of urban poplar trees situated next to Cherry Park, 4.4 linear kilometres south of Waverly Park. The trees exhibited mild defoliation, and few skeletonized larvae were retrieved from the trees.

To the west, evidence of the white satin moth was null. The streets to the west of Waverly Park are lined with an array of unsuitable host species such as green ash, paper birch, and silver maple. It was concluded that the lack of host trees prevented the spread to the west. A trembling aspen stand, situated 2.5 kilometers west of Waverly Park, did not appear to show signs of defoliation. *Leucoma salicis* may move westward as other sources dwindle.

MANAGEMENT APPROACHES

Management approaches must be implemented to mitigate defoliation damage caused by the white satin moth, and preserve the environmental, social and economic values of Thunder Bay's urban forest. Tanglefoot, Btk, high-pressure water washing, parasitoid wasps, Nucleopolyhedrovirus, and *Hirsutella gigantea* were reviewed and considered as management approaches to preserve the poplar species in Thunder Bay's urban forest.

Bacillus thuringiensis var. *kurstaki*

There are limited data pertaining to Btk and *L. salicis,* however, it has proven to be an effective management approach in the Lepidoptera order. *Bacillus thuringiensis kurstaki* should be carried out simultaneously with other management practices since it is not an effective method to induce mortality in eggs, pupae, or adults. The City of

Thunder Bay's Forestry and Horticulture department was actively using Btk on immature *Populus x* 'sundancer' when the trees were assessed in 2020. The trees were showing signs of severe defoliation despite the use of Btk. The Forestry and Horticulture department was contacted to verify the timing, reapplication and procedure of application, but the information was not confirmed. *Bacillus thuringiensis* var. *kurstaki* was not used on the mature eastern cottonwood trees as it is not a feasible solution due to their large stature.

Bacillus thuringiensis var. *kurstaki* can cause mortality in unintended hosts (Scriber 2001). The trade-offs of using Btk should be considered prior to applying Btk as an early management approach.

<u>Tanglefoot</u>

The City of Thunder Bay's Forestry and Horticulture department was actively using Tanglefoot® on immature *Populus x* 'sundancer' when the trees were assessed in 2020. This management strategy was not utilized on the mature cottonwood species in Waverly Park. The method is impractical and ineffective due their size in diameter and deep crevices. The trees were showing signs of severe defoliation despite the use of Tanglefoot®. The Forestry and Horticulture department was contacted to verify the timing and procedure of application, but the information was not confirmed. There are limited data pertaining to the efficiency of Tanglefoot® reducing white satin moth damage. However, a study conducted by Thorpe *et al.* (1993) determined there was a 28% reduction of late-instar gypsy moth population densities in oak canopies of banded plots. Otvos and Richard (1986) determined Tanglefoot® is most effective when applied over a securely fastened tree wrap. Further studies should be conducted to conclusively confirm the efficiency of Tanglefoot® in satin moth populations. In the interim, Tanglefoot® is a cost-effective management mechanism to reduce the number of crawling defoliators from reaching the foliage.

Tanglefoot® should be employed with other management strategies. The trees are still susceptible to young larvae that are dispersed by wind from tree to tree, and satin moths that are mobile by flight in their adult lifecycle (Otvos and Hunt 1986). Proper techniques should be employed to increase the effectiveness of Tanglefoot®; trees must be pruned so no branches are touching the ground or other trees or objects which are not banded, and should be free from overhead objects.

High-pressure Water Washing

High-pressure water washing has been utilized for many years as a successful management practice to remove larvae and egg masses from host trees. The pressure from the water can effectively remove unwanted pests. However, high-pressure water washing is not a long-term management solution. It is a time intensive strategy, requiring frequent visits to remove unwanted pests. In some cases, high-pressure water washing may not be the ideal solution for large trees. Sections of the trees may be missed if they are blocked by branches or other structures, or are too far to reach.

Furthermore, the pressure from the water can inflict wounds, and create openings for opportunistic pathogens and insects. High-pressure water washing should only be carried out by professionally trained individuals with the designated equipment to limit mitigate further damage to the tree.

Biological Control

Parasitoid Wasps

Meteorus versicolor and *Cotesia melanoscela* species are of significant importance to mitigate the white satin moth population. Commercially available parasitoid wasps are a recommended management strategy to control the white satin moth population; they provide a long-term management solution. The Calgary Urban Forestry Department claims a 90 to 95% mortality rate of white satin moth in urban environments (Anon n.d). No further control measures are required once parasitoid wasps establish a population. Furthermore, they have little impact on environmental and social values, and are economically feasible. Parasitoid wasps have been implemented as a pest management strategy in many settings across the globe with few repercussions. The utilization of commercially available wasps is a recommended long-term strategy to mitigate the effects of *L. salicis* in Thunder Bay's urban forest.

Nucleopolyhedrovirus (MNPV)

Currently, *Leucoma salicis* Nucleopolyhedrovirus is not a viable management recommendation as it is not commercially available in Canada. Furthermore, the white satin moth population endures for several years once the LesaMNPV virus is introduced (Ziemnicka 2008b); the virus does result in a continuous reduction in pest population numbers, and a reduction in female fecundity. The diluted LesaMNPV spray does not pose any significant risk to human safety or the environment, however, the economic feasibility is inconclusive.

Hirsutella gigantea

Currently, *Hirsutella gigantea* is not a viable management recommendation due to the low mortality rate and commercial unavailability of the product. Further studies will need to be conducted to determine the effectiveness, environmental and human risk, and economic feasibility if *Hirsutella gigantea* becomes available at a later date.

OTHER CONSIDERATIONS

Defoliation may be caused by other native and invasive defoliators within the same geographical region of Thunder Bay, Ontario. A study of greater magnitude would need to be conducted to conclusively derive the source of defoliation of host trees in Thunder Bay's urban environment. Although the presence of *L. salicis* is evident, other defoliators may be exacerbating symptoms.

CONCLUSION

Management approaches should be implemented in Thunder Bay's urban forest to preserve the integrity of the dwindling poplar population, and the environmental, social and economic value they bring.   Early management strategies, such as high-pressure water washing, Tanglefoot, and Btk should be utilized in the short-term, and biological control agents, such as the *Cotesia melanoscela*, should be implemented as a long-term management strategy.

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