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Canadian Forest Service
Pacific Forestry Centre

Information Report
BC-X-454

Canada

The Pacific Forestry Centre, Victoria, British Columbia

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2020

Canada

Fo143-2/454E-PDF
Fo143-2/454E (Print)
978-0-660-35866-6
978-0-660-35867-3

A pdf version of this publication is available through the Canadian Forest Service Publications website: http://cfs.nrcan.gc.ca/publications.

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Executive Summary

The Emerald Ash Borer (EAB) was likely introduced to North America in the early 1990s and has since become a highly destructive invasive forest pest. From 2002 onwards, federal quarantines have regulated the movement of at-risk ash commodities in both Canada and the United States (U.S.). Despite these regulations, the EAB has spread rapidly from Michigan and southern Ontario to much of eastern North America, leaving millions of dead ash trees in its wake. As of 2019, the EAB was present in 36 states in the U.S. and 5 Canadian provinces, including Manitoba, Ontario, Québec, New Brunswick and Nova Scotia.

The U.S. recently evaluated the effects of removing domestic EAB quarantine regulations. In this context, our study examined the costs and benefits of EAB regulations in Canada. We estimated the cost of EAB regulation by combining applicable Canadian Food Inspection Agency (CFIA) administrative costs and program compliance costs faced by participating wood product mills. The benefits of regulation were determined as the value of slowing its spread by delaying damage to high-valued street ash trees in communities and to rural trees. The model focused on the economic costs associated with the EAB and did not include an estimate of the environmental and social impacts of EAB regulation. An analysis of these non-monetary values would complement the current study and could be explored in future research but was not required to justify the regulatory efforts on allocative efficiency grounds.

We assessed the economic costs and benefits of EAB regulation by simulating differences in expected damage with and without quarantine regulations in place. The actual effectiveness of regulation was uncertain and difficult to quantify. We therefore explored a wide range of possible effectiveness levels to ensure that we captured the true level of regulation effectiveness. We did not comment on the effectiveness of current (and past) EAB regulations since this was beyond the scope of our analysis.

Estimated annual regulatory management costs to the CFIA were approximately $441,634, while estimated annual regulatory costs to industry varied between $0.39 million and $2.37 million. Street and rural tree damage cost estimates due to the EAB ranged from $1,422 million under a no regulation simulation to $1,170 million under a regulation with 95% effectiveness over this period. Results suggest if regulatory measures have even a 10% effect in slowing EAB spread to places not already affected, then the effort could be economically efficient, although the regulations as modeled did not stop EAB movement. It follows that the value of delayed damage of ash street trees and rural ash alone is large enough in most cases to justify continuing EAB regulation.

Résumé

L’agrile du frêne a probablement été introduit en Amérique du Nord au début des années 1990, et depuis, il est devenu un ravageur forestier envahissant très destructeur. Depuis 2002, des quarantaines imposées par le gouvernement fédéral ont permis de réglementer le mouvement des produits de frêne à risque au Canada et aux États Unis. Malgré cette réglementation, l’agrile du frêne s’est rapidement propagé depuis le Michigan et le sud de l’Ontario à une grande partie de l’est de l’Amérique du Nord, laissant dans son sillage des millions de frênes morts. En 2019, l’agrile du frêne était présent dans 36 États des États Unis et 5 provinces du Canada, soit le Manitoba, l’Ontario, le Québec, le Nouveau Brunswick et la Nouvelle Écosse.

Les États-Unis ont récemment évalué les effets de l’élimination de leur réglementation nationale sur la quarantaine relative à l’agrile du frêne. Dans ce contexte, nous nous sommes penchés sur les coûts et les avantages de la réglementation relative à l’agrile du frêne au Canada. Nous avons évalué le coût de cette réglementation en combinant les coûts administratifs de l’Agence canadienne d’inspection des aliments (ACIA) et les coûts que doivent assumer les usines de produits du bois participantes pour se conformer aux programmes. Les avantages de la réglementation ont été déterminés comme la valeur du ralentissement de la propagation de l’agrile du frêne en retardant

les dommages causés aux frênes de rues de grande valeur dans les collectivités et aux arbres ruraux. Le modèle est axé sur les coûts économiques liés à l'agrile du frêne et ne comporte pas d'estimation des impacts environnementaux et sociaux de la réglementation relative à l'agrile du frêne. Une analyse de ces valeurs non monétaires viendrait compléter l'étude actuelle et pourrait être prise en compte dans le cadre de recherches futures, mais elle n'est pas nécessaire pour justifier les efforts de réglementation sur la base de l'allocation optimale.

Nous avons évalué les coûts et les avantages économiques de la réglementation relative à l'agrile du frêne en simulant différents dommages attendus en présence et en l'absence d'une réglementation sur la quarantaine. L'efficacité réelle de la réglementation était incertaine et difficile à quantifier. Nous avons donc étudié un vaste éventail de niveaux d'efficacité possibles afin de nous assurer de saisir le véritable niveau d'efficacité de la réglementation. Nous n'avons pas formulé de commentaires sur l'efficacité de la réglementation relative à l'agrile du frêne actuelle (et antérieure), car ce sujet dépassait la portée de notre analyse.

L'estimation des coûts annuels de gestion de la réglementation assumés par l'ACIA s'élevait à environ 441 634 dollars, tandis que l'estimation des coûts annuels de la réglementation assumés par l'industrie variait entre 0,39 et 2,37 millions de dollars. Les estimations des coûts des dommages causés aux arbres de rues et de zones rurales par l'agrile du frêne allaient de 1 422 millions de dollars dans le cadre d'une simulation sans réglementation à 1 170 millions de dollars en présence d'une réglementation dont le taux d'efficacité était de 95 % pendant cette période. Les résultats laissent entendre que si les mesures réglementaires ont ne serait ce qu'un effet de 10 % pour ralentir la propagation de l'agrile du frêne aux endroits qui ne sont pas encore touchés, l'effort pourrait être efficace sur le plan économique, bien que la réglementation telle qu'elle a été modélisée n'ait pas arrêté les déplacements de l'agrile du frêne. Il s'ensuit que la valeur des dommages retardés aux frênes de rues et de zones rurales est suffisamment importante dans la plupart des cas pour justifier la poursuite de la réglementation relative à l'agrile du frêne.

Acknowledgements

We are thankful for the co-operation of surveyed companies, provincial and municipal governments, and many staff at the Canadian Food Inspection Agency (CFIA), especially the Science Branch and Inspection staff. The input from Arvind Vasudevan and Gordon Henry at the CFIA was particularly valuable. We also thank Michael Olson and Robyn Rose at the United States Department of Agriculture for providing useful information, and Bruno Couture from Québec Wood Products Promotion Office for his insight. Finally, we are grateful to Marcel Dawson of the CFIA for initiating and supporting this study.

Within the Canadian Forest Service, we are extremely grateful to Dr. Chris MacQuarrie and Ken Dearborn for their assistance with the details of EAB physiology, lifecycle and current distribution, and to Dr. Taylor Scarr for his expertise in pest management.

All errors and omissions are the responsibility of the authors.

Key Points

- The cost of EAB regulation to the CFIA has fluctuated over time. Between 2001 and 2006, CFIA regulatory costs were significant and included ash tree removal efforts as well as a tree removal compensation program. Regulatory costs peaked in 2005 at over $5 million but declined to less than $0.5 million by 2007. Regulatory costs have remained at roughly this level; we estimated aggregate CFIA regulatory costs to be around $441,634 at the time of our study.
- Estimated industry compliance costs varied between $0.39 million and $2.37 million annually, depending on the approach used to estimated costs, and whether companies will continue phytosanitary treatment of their products regardless of the regulation.
- The modeled spread of EAB suggests that the insect could be present across the country in 15 years, regardless of the level of regulation. Populations of the insect that currently exist will continue to grow, although spread of the EAB will be hampered by increasing levels of regulation effectiveness. EAB populations are likely to appear on the British Columbian coast by 2035, transported across the country via human-facilitated movement.
- The cost of removing and replacing urban street trees at risk in Canada was estimated to be around $1.384 billion to the year 2035 should no regulation occur. The estimate for rural ash tree losses was about $38 million, using approximate stumpage or standing timber values to estimate the rural tree loss values. The total value of EAB damage was approximately $1.422 billion. It should be noted explicitly that this estimate did not include backyard trees, ash trees in parks and recreational areas or, for example, other non-market or social values associated with loss of ash.
- EAB regulations generated economic benefits by delaying the damage/costs associated with EAB infestations. The avoided damage over the study period (2019–2035) was estimated to be between $34 million and $252 million for regulatory effectiveness levels ranging between 10% to 95%, using an economic discount rate of 4%. This analysis highlights the critical importance of research quantifying the plausible ranges (and costs) of regulatory effectiveness.
- Subtracting the costs of EAB regulation, avoided damage were predicted to be between $22 million and $240 million, depending on the assumed level of regulation effectiveness. Higher levels of assumed effectiveness resulted in greater levels of avoided damage, but an effectiveness level of ~10% delayed damage enough to generate a small net economic benefit under most simulations.
- This analysis implicitly highlights the distributive effects of invasive species problems. Invasive species have a direct financial effect on the CFIA and to industry through their compliance-related activities. Impacts felt by consumers and citizens are often much more disaggregated (e.g., tree removal and replacement on personal property, aesthetics, etc.). Regulatory agencies managing invasive species outbreaks face the challenge of enumerating and balancing the costs faced by all stakeholders.
- This study excluded potential environmental and social benefits associated with ash trees, including positive impacts of ash species on ecosystem function such as ash-specific nutrient cycles or biodiversity, increased property values, pollution interception, energy conservation, improved health and leisure, etc. related to tree cover in urban centres. Evaluation of the social and environmental benefits was beyond the scope of the current report. Neither did we include the potential for adjustments to business activities or substitution away from ash under the current regulation. The impacts of possible U.S. deregulation on Canadian EAB spread were also not addressed. Finally, we did not consider changes in the likelihood of high-risk materials being moved outside of current occupied areas over the time period of the analysis.

1 Introduction

At the request of the Canadian Food Inspection Agency (CFIA), the Canadian Forest Service (CFS) has conducted an economic analysis of current Emerald Ash Borer (EAB) regulations in Canada. This study was initiated in response to the recent EAB regulatory impact analysis report completed by the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA) (APHIS 2018). The effects of other CFIA approaches to the EAB (including for example a biological control program or an integrated pest management approach) are outside the scope of this analysis.

Native to north-eastern Asia, the Emerald Ash Borer (*Agrilus planipennis*) is an invasive forest pest in North America. This wood boring pest likely was introduced in North America in the early 1990s and first detected in Detroit, Michigan and Windsor, Ontario in 2002 (CFIA 2014a). It is believed to have been inadvertently introduced to North America via imported wood packaging or crating material (CFIA 2014a). As of 2019, 36 states in the U.S. and 5 provinces in Canada (Ontario, Québec, New Brunswick, Nova Scotia and Manitoba) were infested (see Appendix Figure A1).

The EAB is a highly fecund, destructive and mobile insect in the Buprestidae family that rapidly kills its ash (*Fraxinus*) host, making it extremely difficult to control in comparison to other quarantined pests. The insect has killed millions of ash trees in North America since its introduction in the 1990's (Cappaert et al. 2005, Siegert et al. 2014). While adult insects feed on foliage, the larvae bore into the tree's phloem — tissue that moves nutrients and water from the roots — ultimately girdling and killing the tree. Canadian experience to date suggests once the EAB becomes established in an area with ash (e.g., a municipality or rural setting), it rapidly multiplies, resulting in large-scale ash mortality within 5–10 years (Cuddington et al. 2018; Hodge et al. 2015). Although the insect is capable of flying up to 20 km (Herms and McCullough 2014; Taylor et al. 2006), new populations are generally the result of people moving infested ash materials (e.g., firewood, logs, branches, nursery stock, chips and other ash wood products).

To prevent the spread of the EAB, both the U.S. and Canadian plant protection agencies (APHIS and CFIA) restrict the movement of all firewood and ash articles from within a regulated area. After initial EAB detection in 2002, quarantine was quickly established by the Michigan Department of Agriculture restricting movement of ash from the six infested counties (Haack et al. 2002). In 2003, APHIS imposed federal quarantines in the U.S. (Poland 2007), preventing the legal movement of regulated articles outside of a quarantined area without a certificate or permit. Certificates and permits are only available by establishing a compliance agreement, which describes how a company will properly treat regulated articles to mitigate the spread of the EAB and adhere to the quarantine regulation. The U.S. has more than 800 active EAB compliance agreements that include sawmills, logging/lumber producers, firewood producers and pallet manufacturers. Articles may be moved if treated by bark removal, kiln sterilization, heat treatment, chipping, composting, or fumigation, depending on the product.

In Canada, regulations were first established in Southern Ontario in 2002. Like the U.S. regulations, the Emerald Ash Borer Approved Facility Compliance Program (EABAFCP) was created in 2007 for companies who distribute ash or firewood from regulated areas to non-regulated areas in Canada. In 2019, there were 38 companies participating in Canada's compliance program.

At the time of writing this report, the APHIS was examining the possibility of removing the domestic quarantine regulations for the EAB and redirecting the funding away from the implementation and enforcement of quarantine regulations (Federal Register 2018). Since the APHIS has concluded that regulatory zones are ineffective at preventing EAB spread (Federal Register 2018), quarantine funding would be re-routed towards non-regulatory research options and the deployment of biocontrol agents for the EAB. The expansion of the North American range of the insect over the last twenty years has led to a significant number of regulatory actions, placing additional counties under quarantine. In the 2016 fiscal year alone, the APHIS issued 16 Federal Orders establishing additional EAB quarantined areas (APHIS 2018). The APHIS launched a docket at regulations.gov for EAB deregulation to solicit comments from Sept 19–Nov 19, 2018 from the public and received 149 comments. The APHIS (2018) regulatory impact analysis study estimated that the removal of regulations would create a potential annual cost savings for U.S. companies between \$9.8 million and \$27.8 million. The APHIS did not attempt to quantify changes in the cost stream of potential damage caused by deregulating, although they did note in their study that "regulatory activities have slowed EAB spread, delaying losses" (page 20–21).

Like the U.S., the area regulated for the EAB in Canada continues to expand from the range originally established in 2003. The insect has caused both direct and indirect economic damage to Canada's urban and rural forests. In this study, we expanded the approach adopted by the APHIS to conduct a more comprehensive economic analysis of the current Canadian regulations, considering the potential EAB damage to Canadian rural and urban ash trees. We used a computer simulation model to estimate the benefits of regulation, defined as the value of avoided or delayed damage to ash caused by the EAB. The model was made up of three parts: a simulation of EAB movement across the country under various levels of regulation, an estimate of the costs of EAB-caused damage to urban and rural trees, and a comparison of the estimated value of EAB-caused damage avoided via regulation to CFIA regulatory and industry compliance costs. If the combined CFIA and industry costs were less than avoided (or delayed) damage costs, the regulation effort would be justified on economic efficiency grounds.

Note that our study used quantifiable and non-controversial economic values to evaluate Canadian EAB regulation. However, our analysis of economic impacts excluded changes in business activities (other than direct compliance costs) as a result of EAB regulation including industry substitution away from ash, business impacts of restrictions on domestic ash transportation, and additional business for tree removal companies. Moreover, we did not consider the economic welfare implications of environmental or social impacts of EAB regulatory efforts. Although environmental and social values associated with EAB regulation are likely to be of interest to decision makers, we omitted them for numerous reasons: they were difficult to quantify, often variable across stakeholders and hence likely to be controversial (e.g., Bromley and Vatn 1994). Examples of these values may include the loss of ash in forest habitats (generating impacts on species composition and nutrient cycles (NRCan 2019), and consequences for home-owners, communities, and First Nations (declines in property value, community aesthetics, and culturally important species). In addition, our results suggest that these values were unnecessary to justify maintaining at least some form of regulatory effort on economic efficiency grounds. That said, our analysis of EAB regulation in Canada also did not account for regulatory changes in APHIS's approach in the U.S. which may impact the effectiveness and cost of Canadian regulation measures. These possibilities were considered outside the scope of this study.

2 Estimation of Costs of Regulation

In section 2.1, we evaluate the costs of the regulations that the CFIA has put in place to limit the movement of ash materials in Canada. In section 2.2, we report on industry compliance costs using both an industry survey approach and a methodology comparable to the APHIS EAB regulatory impact analysis.

2.1 CFIA Regulatory Costs

As Canada's National Plant Protection Organization, the CFIA has the authority to make regulatory measures under the Plant Protection Act and Plant Protection Regulations to prevent the introduction and spread of pests in Canada. The CFIA published the program directive *D-03-08, Phytosanitary Requirements to Prevent the Introduction into and Spread within Canada of the Emerald Ash Borer,* Agrilus planipennis *(Fairmaire)* (CFIA 2014b). In this directive, the CFIA regulates the movement of ash articles and firewood of all tree species. Regulated ash articles include ash trees (whole or part), ash nursery stock, ash logs and branches, ash lumber, wood packaging materials (WPM) with an ash component of either ash wood/ bark or ash wood/bark chips.

The phytosanitary measures apply to regulated articles that are imported into Canada, move out of a regulated area, or transit through a non-regulated area, as specified in the conditions of movement (Movement Certificate) or on the Import Permit (CFIA 2014b). Companies that move ash articles or firewood within regulated areas or from non-regulated (i.e., no known EAB present) to regulated areas bear no restrictions or fees. When moving out of a regulated area, EAB regulated articles must meet the conditions of movement and be accompanied by a movement certificate[1] issued by the CFIA. The regulations differ depending on the time of year distribution occurs. Regulations and requirements are less strict in the low-risk season (Oct. 1–Mar. 31) and stricter in the high-risk season (Apr. 1–Sept. 30).

Conditions of Movement also differ based on the ash article or firewood being transferred. Treatment requirements include (CFIA 2014b):

- Processing to create bark free wood and removal of underlying sapwood to a depth of at least one (1.0) cm,
- Grinding or chipping to create chips to a size of less than two and a half (2.5) cm in any two dimensions,
- Article exclusion of ash for firewood and nursery stock,
- Heat treatment for regulated articles, to attain a minimum core temperature of 56°C throughout the profile of the wood (including the core) for a minimum of 30 minutes; and
- Secondary processing at a CFIA facility to produce wood by-products such as paper, fiber board, or oriented strand board to render the articles free from the EAB.

The CFIA established the Emerald Ash Borer Approved Facility Compliance Program (EABAFCP)—an audit based voluntary program—to mitigate EAB spread in Canada while facilitating the movement of regulated articles. Participants in good standing have movement certificates issued for a period of time based on audits, rather than submit to individual product inspections. This process requires no fees but imposes labour costs on both the CFIA and firms involved. Audit labour costs to the CFIA are summarized in Table 1, while firm labour costs are discussed in section 2.2.

In 2018, Canada imported approximately $90 million worth of ash, most of which originated in the U.S. (Global Trade Atlas 2018). All Canadian imports of ash and firewood products require an import permit, phytosanitary certificate or certificate of origin[2] (CFIA 2014b). Import permits are administered and verified by the CFIA, and dictate how the material must be packaged, transported, handled, controlled, and used to ensure that the EAB is not present in the product. Phytosanitary certificates and certificates of origin are issued by the country of origin, with the cost primarily placed on exporting companies (CFIA 2017). Required treatment details must appear in the "Treatment" section of the Phytosanitary Certificate. Imports of ash nursery stock and all species of firewood require special consideration; importing these products from non-regulated areas in the U.S. requires import permits and phytosanitary certificates, while importing these products from regulated areas in the U.S. is prohibited. All other ash products may be imported with a phytosanitary certificate or a certificate of origin.

1 Companies distributing ash lumber and WPM can either receive a movement certificate or be part of a Canadian Heat-Treated Wood Products Certification Program (CHTWPCP) or a Canadian Wood Packaging Certification Program (CWPCP) and follow their conditions of movement. Companies transferring firewood of any species require a movement certificate but must also be part of the Emerald Ash Borer Approved Facility Compliance Program (EABAFCP).

2 Stand alone wood packaging materials with an ash component could comply with the 15 requirements of the International Standard for Phytosanitary Measures (ISPM) as an alternative to a Certificate of origin or a Phytosanitary Certificate.

Table 1. CFIA regulatory expenditures on EAB regulation in 2018/2019

Task name	FTEs	Hours[a]	Costs
Domestic certificates issued	0.29[b]	507	$43,620
Domestic product inspection	0.15[b]	260	$22,335
Establishment verification/audits	0.60[b]	1,042	$89,639
Import establishment audit/inspection	0.70[b]	220	$104,929
Plant protection surveys – Emerald Ash Borer	1.01	1,766	$151,892
Total labour costs	**2.75**	**4,796**	**$412,414**
Total trapping material costs			**$29,220**
Grand total			**$441,634**

a One direct FTE = 1,743 hours; Hourly rate = $86.

b These account for other non-EAB compliance facility audits as well, but the majority was within EAB facilities.

Table 1 summarizes the CFIA regulatory costs in 2018/19. CFIA labour cost data were provided by the agency and are based on their MRRS (Management Resources and Results Structure) tracking tool. The data are estimated in terms of full-time equivalent (FTE) associated with specific activities such as issuing domestic certificates, inspecting domestic products, auditing/verifying production facilities, auditing/inspecting import facilities, surveying/trapping outside regulated areas, and responding to emergencies.[3] We used an hourly rate of $86 for FTEs, which included activities such as preparation, on-site visits, communication with industry, and consultation with internal stakeholders but excluded travel, training, leave (i.e., breaks, wash-up time, vacation, sick leave) and administration. In 2018/19, CFIA employed approximately 2.75 FTE personnel, equating to about 4,796 hours at a rate of $86/hour, which amounted to a total labour cost of about $412,414.

In addition to regulating ash and firewood movement, the CFIA also traps the EAB to evaluate pest-free areas and existing populations. In 2018/19, the CFIA placed 487 traps at various sites around the country at a cost of $60/trap,[4] totaling $29,220. Hence, the aggregate CFIA cost—including labour and trapping costs—was $441,634 in 2018/19. Although municipalities also trap for the pest, (in 2018/19 there were 259 partner sites), we did not include these costs in our calculations. It is likely that municipalities will continue to need EAB monitoring information to manage local trees if the CFIA ceases to regulate and monitor.

To understand trends in CFIA regulatory costs, we gathered CFIA labour hours for the past 17 fiscal years. The estimated labour costs were calculated based on the hourly rate of $86 and are shown in Figure 1. More detailed data from 2002/03–2018/19 are provided in the Appendix Table A1. CFIA labour costs were ~$4.8 million in 2003/04 and peaked in 2005/06 at approximately

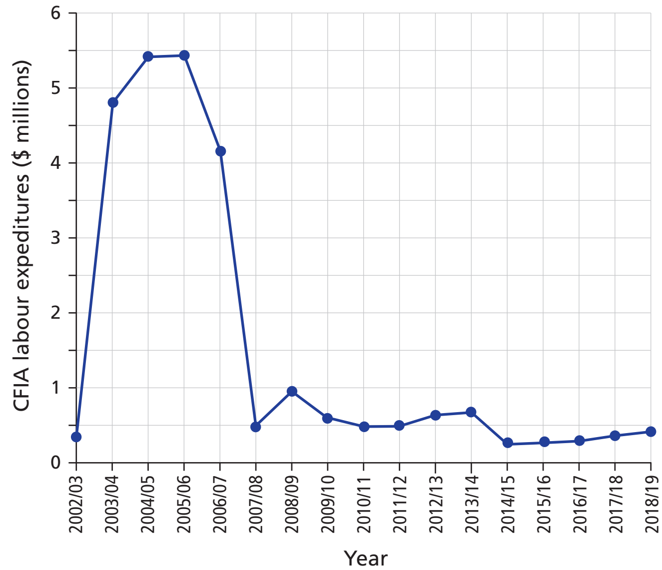


Figure 1. CFIA labour expenditures on EAB regulation from 2002/03–2018/19.

$5.4 million. In 2007/08 costs decreased to ~$0.5 million, from over $4.1 million in the previous year and have remained under $1 million since then.

High costs in the early years of EAB infestation were due to several factors. FTE data from 2002/03–2005/06 were not time tracked by inspectors but derived from formulas using time standards per inspection. The formulas likely overstated the resources allocated to forestry inspections for those fiscal years.

These high costs could also be a result of the early EAB eradication efforts in Southern Ontario. The CFIA cut down thousands of trees to create a host-free buffer zone in south western Ontario in 2004 with the intent of slowing the eastern progression of the EAB into Canada. The project, however, did not meet its objective; public movement of firewood and EAB's ability to fly relatively long distances contributed to EAB detection beyond the barrier zone in the following year (CFIA 2014c).

Between 2003/04 and 2006/07, the CFIA spent a significant amount of resources on tree removal, public communications, and enforcement to prevent EAB spread. Additionally, the CFIA offered compensation to private, corporate and municipal tree owners that proactively removed their ash trees. This practice, however, ceased in 2007/08 as the EAB continued to spread; tree removal activities no longer slowed the spread.

The average labour costs for the last five fiscal years were around $0.3 million. We expect a similar trend in the future. As the regulated area expands, there will be more companies that fall within the regulated area increasing the audit/inspection burden, but there will be others opting out of the program as the regulated area expands to include their products' movement. Similar dynamics are true for the plant protection survey.

3 Information provided by the CFIA.

4 In 2018/2019, the cost for a package including one green prism trap, the (Z)-3-hexanol lure, the trap hanger and the (3Z)-lactone was $46.99, which needs to be replaced annually. Other items such as metal trap spreaders and tree hooks, aerosol tangle trap spray/TAD shake and spray, a telescopic extension pole and paint roller are also needed and can be reused.

2.2 Industry Compliance Costs

Compliance costs for companies include audit costs, treatment costs, and import permit costs. The APHIS assessed these costs using a "top-down" approach by gathering statistics from sources such as the U.S. Census Bureau, U.S. Environmental Protection Agency, Bureau of Labour Statistics, published reports, and discussion with industry professionals. We modified this approach for the Canadian situation and augmented the results with a survey of individual companies to estimate the total compliance costs. Addressing the impacted industry directly allowed us to refine our industry compliance cost estimates and limited the number of assumptions required.

2.2.1 Survey of Businesses in the EAB Compliance Program

We invited 38 companies in the compliance program to complete our emailed survey (CFIA 2018a). The survey collected information on products, distribution, audit and compliance costs, and opinions on the current EAB regulations. We followed up by telephone with companies that did not respond, or those that replied with incomplete information. The survey is included in Appendix 2. In total, 30 companies completed the survey or responded to follow-up calls, representing a 79% response rate.

Of the 18 companies that responded to a preference question about continuing current EAB regulation, 11 indicated a positive response (61%). One respondent indicated that the program was a competitive advantage and increased their credibility with consumers. The positive response could also be because the capital investment on treatment compliance is viewed as a sunk cost. Firms that responded negatively towards the current regulation indicated that it imposed additional operational costs and was not effective at limiting the spread of the EAB.

Almost all companies who dealt with ash wood or firewood of any type in the regulated areas were enrolled in the Emerald Ash Borer Compliance Program, unless their product movement were mainly within the regulated area. The process of applying and being part of this program is illustrated in Appendix Figure A2. Companies reported spending an average of 26 hours to complete the compliance program application process. The application is followed by a facility evaluation audit, where a CFIA inspection (approximately 5 hours) is completed to determine if the firm and its practices meet the required standards. Once the firm has passed the facility evaluation audit and officially been accepted into the program, they must undergo two annual audits, which take approximately 2.5 hours each. If the firm is only operating in the low risk season (Oct.–March), they will have one surveillance audit and one clean-up surveillance audit; if the company operates year-round, two surveillance audits will be completed (CFIA 2014b). In total, 36 labour hours were reported by companies in their first year of the compliance program (26 hours to complete the application, 5 hours for a facility evaluation audit, and two audits of 2.5 hours per year). Compliance cost dropped to 5 hours each year after.

The survey included a question about the value of an average hour of work to the company; responses ranged from \$35/hour to \$250/hour, with median and mean values of \$70/hour and \$87/hour, respectively. We used the mean value to estimate our cost values. It follows that a typical company would spend $\$87 \times 36 = \$3,132$ in the first year, and $\$87 \times 5 = \$435$ in each following year, based on the yearly program compliance time commitments. From the survey, 22 companies provided annual audit cost information with a mean value of \$1,012 and median of \$145. We estimated non-respondent company costs based on the annual mean audit cost of \$1,012. Thus, the total estimated annual audit cost for all participating companies was \$48,567.[5]

Aggregate annual treatment costs for the industry were estimated to be \$2.3 million. Twenty-seven companies provided cost values, reporting a mean annual treatment cost of \$74,438 and a median cost value of \$23,025. The average reported unit cost (including labour, utilities, and overhead) for heat treatment/kiln dry, grinding/chipping, debarking, and separation of wood was $\$91/m^3$, $\$51/m^3$, $\$57/m^3$, and $\$17/m^3$, respectively. Annual treatment costs were estimated for non-respondent companies based on similar size companies producing the same products.[6] It is important to note that 15 of the 20 companies reported that they would incur these treatment costs regardless of the regulations, making the total treatment cost due to EAB regulations approximately \$578,277.

For importing ash articles or firewood, an import permit must be administered by the CFIA, at \$35 per permit. It took an average of 30 minutes to apply for the permit or \$43.5 labour cost per permit based on our survey results. Annually, the CFIA issues an average of 131 permits for a total cost of \$10,284[7] to industry.

Using these estimates, the total industry compliance costs due to the EAB regulations were predicted to be \$637,128 annually. Table 2 summarizes these results.

Table 2. Estimated industry annual compliance costs based on survey results

	Audit costs	Treatment costs	Import costs
Number of responding companies	22	27	10
Mean cost	\$1,012	\$74,438	\$585
Median cost	\$145	\$23,025	\$300
Total estimated costs of all companies	\$48,567	\$2,313,108	\$10,284
Total costs			**\$2,371,959**
% of companies continue the costs regardless of the regulation	0	75%	0
Total costs due to regulations	**\$48,567**	**\$578,277**	**\$10,284**
Total			**\$637,128**

5 $\$48,567 = $ Sum of audit costs of responsive companies + estimated audit costs of unresponsive companies $(\$32,375 + \$1,012 \times 16)$.

6 The median treatment cost per employee was calculated based on respondent companies. This coefficient multiplied by the employee numbers was used to estimate the annual treatment cost for non-responded companies.

7 $\$10,284 = (\$35/\text{permit} + \$87/\text{hour} \times 0.5 \text{ hour}) \times 131$

2.2.2 Top-Down Approach

In 2018, there were 638 sawmills[8] and about 65.6 million m^3 of lumber[9] produced in Canada; on average, each sawmill produced approximately 102,867 m^3 lumber.[10] Assuming that ash lumber comprises the same percentage of total lumber production in Canada as it does in the U.S. (i.e., 0.41%; APHIS 2018) and that all sawmills produce some ash lumber, then the typical sawmill would produce around 421.8 m^3 of ash lumber annually.[11] Based on our survey, heat treatment/kiln drying of logs and lumber was estimated to cost $91/$m^3$ on average. Hence, heat treatment costs of logs and lumber was determined to be $38,384 per producer.[12] In 2019, there were 27 facilities under the compliance program that produced ash logs or lumber. Among the 23 log or lumber companies who responded to this part of the survey, 15 (or 65%) used heat treatment/kiln drying to comply with the regulation. Hence, the total heat treatment/kiln drying cost for all log/lumber producers in the study was estimated to be $675,892 annually.[13]

Debarking (removing all bark and at least 1.0 cm of sapwood) is another method of treatment for ash log and lumber producers. Based on our survey, we approximated average debarking costs for logs and lumber at $57/$m^3$. Combining the volume of ash produced and the cost of debarking, we predicted that the average producer spends about $24,043 on EAB treatment via debarking. Among the 23 lumber/log companies that responded to the survey/interview, eight of them (or 35%) debarked their product, resulting in a total treatment cost estimate of $225,795.[14]

Approximately 3.4 million m^3 firewood was produced in Canada in 2017[15] (National Forestry Database 2017). At that time, there were 662 facilities producing miscellaneous wood products (including firewood) in Canada (Statistics Canada 2018). Including all 662 establishments, an average of 5,119 m^3 of firewood per year per establishment was produced.[16] Under EAB regulations, ash firewood movement is prohibited, although non-ash firewood movement is permitted under the EABAFCP. Firewood producers must separate their wood by species to remain in compliance with the EABAFCP; this was estimated to cost $17/$m^3$ based on the survey results. Hence, these costs per firewood producer were approximately $87,023 annually. At the time of the survey, there were nine facilities under the compliance program that produce firewood. Seven of these facilities were using wood separation to comply with the regulation, one employed heat treatment[17] and one did not incur any treatment cost as it bought pre-treated firewood from the U.S. Total wood separation costs for these firewood producers were roughly $609,161 annually.[18] One company produced ash bark and chips but used an additional process with other species to produce panels, and hence did not incur extra treatment costs. Another company's main product was wood packaging and we assumed it had similar annual heat treatment costs of a typical sawmill at $38,384.

The annual aggregate treatment costs for all these companies were estimated at $1.5 million. Our survey indicated that 75% of the companies would incur these treatment costs regardless of the regulations. Based on this assumption, total treatment costs due to EAB regulations were approximately $390,383. These results are summarized in Table 3. More detailed lumber and firewood production and business counts across provinces are provided in the Appendix Table A2.

Table 3. Estimated industry annual treatment costs using U.S. APHIS (top-down) approach

Product	Treatment	Number of companies	Estimated treatment costs
Logs/Lumber	Heat treatment/ Kiln drying	18	$675,892
	Debarking	9	$225,795
Firewood	Separation of wood	7	$609,161
	Heat treatment	1	$12,300
Wood packaging	Heat treatment	1	$38,384
Bark and chips		1	$0
Total		**37**	**$1,561,532**
Total due to EAB regulation (25%)			**$390,383**

3 Spread and Impact Model

The present study was informed by both Canadian and American research regarding the spread and impact of the EAB. The essence of the modelling problem was to estimate the possible spread and financial impact of this insect on homeowners, municipalities and rural forests with and without current regulations in place. Regulations restricting movement of ash-related materials are, at least partly, intended to slow EAB spread, thus delaying the impacts associated with infestations. The spread and impact model estimated the financial benefits of this delay for both urban and rural trees.

We built a three-phase model to assess the movement of the EAB across the country as well as the costs and benefits of regulation. The first part involved modeling EAB spread across Canada over time following a few relatively simple rules. The second component predicted the costs of ash trees affected by the EAB (street and rural

8 Statistics Canada. Table 33-10-0105-01 Canadian Business Counts, with employees, December 2018; NAICS code [321111]; https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3310010501.

9 Statistics Canada. Table 16-10-0017-01 Lumber production, shipments, and stocks by species, monthly (× 1,000); https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1610001701.

10 102,867 m^3 = 65,629,000 m^3/638.

11 421.8 m^3 = 102,867 m^3 × 0.41%.

12 $38,384 = 421.8 m^3 × $91/$m^3$.

13 $675,892 = $38,384 × 27 × (15/23).

14 $225,795 = $24,043 × 27 × (8/23).

15 Data for 2017 in Québec were unavailable as of January 31, 2019 therefore 2015 data have been carried over as estimated for 2017.

16 5,119 m^3 = 3,389,176 m^3/662.

17 Heat treatment cost for this company is estimated around $12,300 based on the survey results.

18 $609,161 = 5,119 m^3 × $17/$m^3$ × 7.

trees). The final component estimated the benefits of regulation resulting from slower EAB movement, including the cost of the regulatory efforts (both CFIA and industry costs). Further details on each of these steps are provided below.

3.1 The Spread Model

Our computer-based cellular spread model simulated the historical and possible future EAB spread across Canada (see Pitt et al. 2009, for a similar model developed for the spread of invasive ants in New Zealand). Operating at a 250m × 250m cellular resolution, the model simulated EAB spread based on existing populations, local movements generated by EAB flight, and long-distance movements driven by human activity. Our simulation incorporated a number of spatial features: the geographic range of ash in Canada (*F. americana*, *F. nigra*, and *F. pennsylvanica*) (Beaudoin et al. 2014), a spatial climatic variable influencing the EAB life cycle and subsequent population levels (Cuddington et al. 2018; Lyons and Jones 2005), road networks (Government of Canada 2017a), urban areas (Government of Canada 2011), areas regulated by the CFIA (Government of Canada 2015), and existing EAB populations as identified by the CFIA (Government of Canada 2017b). We limited our analysis spatially, excluding provinces and regions outside of the documented range of ash (Little, 1971). This excluded the northern portion of many provinces and all the Territories as well as Newfoundland and Labrador (we believe ash to be a very uncommon urban tree in Newfoundland, based on street tree survey data). The model simulated a 33-year time period, from 2002 when the EAB was originally identified in Canada, to 2035, a reasonable end point for near-term planning purposes. Further methodological details are provided by Hope et al. (in preparation).

Beginning with the EAB populations identified in 2002, the model established new satellite populations via EAB flight and anthropogenic movement. Both movement types operated in the same way: for each existing population capable of spawning a new population, the model selected a random direction and a distance value from one of two distance distributions (a short-distance distribution, and a long-distance distribution). If the cell at the resulting coordinate met certain criteria (described below), a new satellite population was established. If the cell did not meet the criteria, no new population was spawned.

For short distance movement via EAB flight, if there was some quantity of ash at the location specified by the direction and distance selected, a new EAB satellite population could be established. In the case of human-facilitated movement, the original population and the resulting satellite population had to be somewhere along the road network or within an urban area. We restricted long distance populations to road networks based on evidence that the EAB establishes around truck stops (Buck and Marshall 2008); adults may be hitchhiking on vehicles or emerging from wood products (e.g., dunnage and firewood) as they are shipped across the country. Similarly, the urban area restriction accounted for the prevalence of ash within urban canopies. Given that ash is a common street tree within urban areas across Canada, the model assumed that all urban areas within the natural and planted range of ash could support the EAB.

3.1.1 EAB Movement

Spread events driven by EAB flight are limited to distances between 0 km and 20 km, based on field observations of the insect's flight and laboratory testing (Herms and McCullough 2014; Taylor et al. 2006). The distribution of flight distances was skewed towards shorter distances with a long tail, representing more common EAB flight patterns, and the few longer flights that might occur. Spread events facilitated by human movements cover distances between 20 km and about 2,500 km, which represent maximum distances travelled by long-haul transportation trucks before stopping (for re-fueling or mandated driver rest (Motor Vehicle Transportation Act 1985)). This distribution was centred at approximately 900 km, a compromise between shorter passenger traffic travel distances, and the longer transport-truck movements. Long tails on either side of the distribution captured both short distance travel and very long-distance travel. See Figure 2 for an illustration of the short- and long-distance distributions used by the model to determine the distance (in km) from an existing population to a possible location for a satellite population. Figure 2 a) indicates the model was very likely to choose a short distance spread somewhere between zero and three km, although larger short-distance spreads were possible, although less common. Figure 2 b) indicates that the model was extremely likely to draw a number around 1,000 km, but shorter and longer distances could also have been chosen.

Human-influenced long-distance spread is further modified in the areas regulated for the EAB; the model assumed that short-distance spread, driven by EAB flight, is unaffected by regulations. The effectiveness of regulation activities in slowing or stopping spread was the essential question for the current study. Effective regulation was modelled as a reduction in the proportion of human facilitated EAB movements that successfully established new populations. Implicitly, this regulation captures the effects of outreach campaigns on human behaviour (e.g., "Don't move firewood campaigns"), and the restrictions placed on industrial ash product movement.

We modeled regulation by assuming that its effectiveness was proportional to the number of long distance spread events that would fail (e.g., a regulation level of 10% assumes that 90% of the spread attempts to cross from the regulated area to the un-regulated area were successful; 10% of the attempts were un-successful). The likelihood of regulation stopping EAB spread varied from 0%, which represented a regulation-free scenario, to 95%, which signified a best-case scenario for regulatory effectiveness. Specifically, we examined regulation effectiveness levels of 0%, 10%, 25%, 50%, 75%, and 95%. The model was very computer intensive thus only a limited a set of runs was possible. Nevertheless, this set of results provides a wide range of effectiveness levels to give readers a sense of the potential scope of economic impacts associated with EAB deregulation efforts. Importantly, limited data exist regarding the actual effectiveness of the current regulations. Moreover, experts and managers may have different beliefs about the effectiveness of regulatory measures. Our approach allows them to consider the implications of these different beliefs.

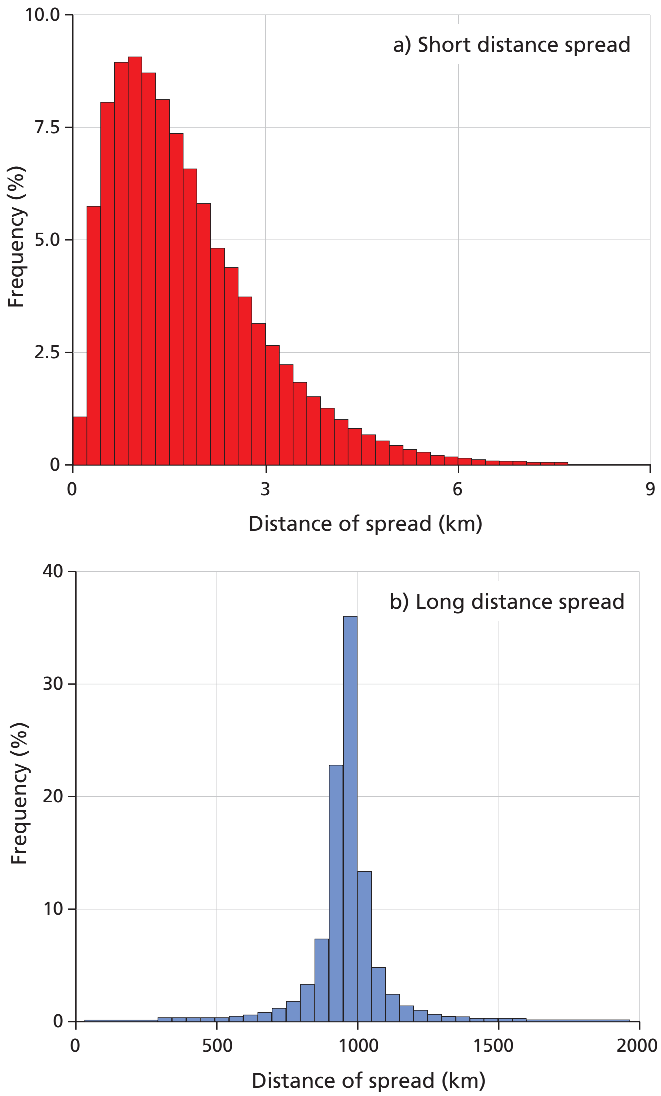


Figure 2. Distance distributions used within the spread model for a) short distance spread, b) long distance spread.

3.1.2 EAB Population Dynamics

Once an EAB population has been established, it undergoes a cycle that dictates when it may generate new satellite populations. New populations start small and grow over time, eventually reaching the maximum size that can be supported by the host ash on site. At that point, an increase in density-dependent migration away from the site is expected (McKenney et al. 2012). Ultimately, the lack of surviving ash hosts at the original site results in a population crash, though the EAB would still be expected to be present in low numbers surviving on available ash re-growth (Hodge et al. 2015; Prasad et al. 2010).

The length of this population cycle varies depending on the beetle's developmental rate at a given location. EAB individuals may require one or two years to complete their full life cycle (BenDor et al. 2006; Tluczek et al. 2011), depending on host stress, genetic variation, ambient temperatures, or egg laying dates (Cappaert et al. 2005; MacQuarrie et al. 2019; Poland et al. 2015). In the current model, a population mostly made up of one-year EABs would require four to six years before being capable of generating new satellite populations, and would rapidly decline to a background level after eight years (Cuddington et al. 2018; Klooster et al. 2014; Prasad et al. 2010; Sadof et al. 2017). For those populations that are mostly made up of EAB individuals requiring a two-year lifecycle, the model assumed that eight to twelve years would be required before the population spreads, and that the population would fall to background levels after about sixteen years. Figure 3 illustrates the population cycles used in the current work for one- and two-year lifecycle populations.

Our model distinguished between populations made up of one- and two-year lifecycles based on a spatial climate variable that represented the amount of heat received. We used growing degree days (GDD) to account for the heat received across the landscape. The model assumed that EAB individuals require a minimum amount of heat within a certain time frame to complete their development. Literature estimates suggest that peak EAB adult activity typically corresponds to 550 GDD, calculated from a base temperature of 10° C (Herms et al. 2019; Poland et al. 2015). If the population received 550 GDD prior to mid-July/early August, we assumed that adult individuals would have emerged early enough to lay their eggs while there were still enough growing degree days left in the season. EAB egg and larval stages require a set amount of heat to reach their over-wintering stage (Lyons and Jones 2005). If insufficient heat is received, the larvae will be forced to overwinter twice, resulting in a two-year lifecycle. For those regions that receive enough growing degree days, we assumed a single year life cycle, and for those regions that do not receive enough growing degree days by mid-July/early August, we used a two-year lifecycle.

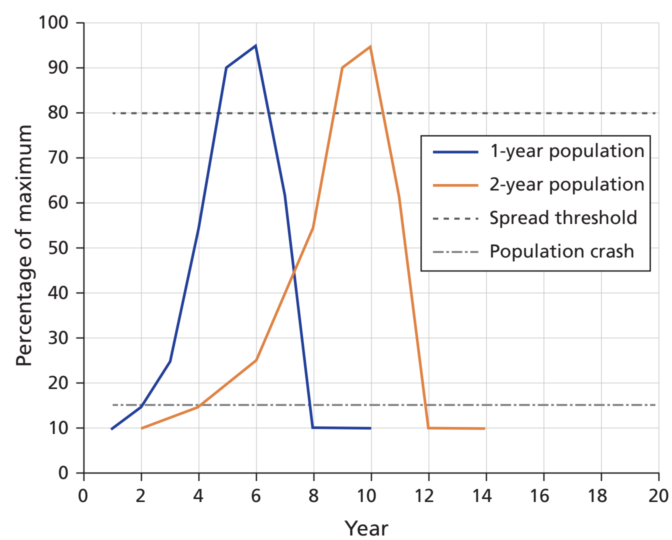


Figure 3. Population cycles for one-year and two-year EAB populations.

3.2 The Economic Model

Based on EAB spread across the country, the model estimated the year the insect would arrive at various locations under different levels of assumed regulation effectiveness. The date of EAB arrival was integrated in the economic model to predict the costs of dealing with ash trees (urban and rural trees) impacted by the EAB, and the benefits of delaying its presence via regulation. We focussed on the cost of removal and replacement of street trees, and the standing timber value of rural trees. The model did not, however, account for the economic value of additional ash re-growth in urban or rural areas. Note this re-growth would undoubtedly not have any commercial value within the time frame of the analysis should it survive.

Like McKenney et al. (2012), we assumed that street trees (within 10 m of road edge) attacked by the EAB would almost certainly need to be removed and in some cases replaced during outbreaks in municipalities. The analysis was simplified by presuming that all ash tree removals were a result of EAB with removals due to non-EAB related death, construction, and physical damage etc. thought to be negligible. Although this assumption may slightly overestimate EAB damage costs, we believe this overestimate to be small, with little impact on the results (e.g., Roman and Scatena (2011) estimated urban tree mortality rates at 5% for several U.S. cities; mortality rates are likely to be similar in Canada).

Trees outside of urban areas were categorized as rural and were valued based on their industrial use via a stumpage value estimate. Although this categorization did not delineate higher value suburban trees, park trees, etc., the spatial data necessary to sub-divide rural trees into more appropriate categories were unavailable at the time of our study. While urban trees damaged by the insect would likely necessitate a rapid response due to public safety concerns, a rural tree with EAB damage may not require an immediate removal response. Although trees may have many other values beyond those examined here (e.g., property values, shade, habitat, erosion prevention, etc.), the model focused solely on those costs that were almost guaranteed to be incurred. Other losses, such as those mentioned, would only serve to increase the loss estimates.

We calculated annual EAB costs and reported Net Present Values (NPV) (at a 4% discount rate) for each level of assumed regulation effectiveness. In principle, more effective regulation delays EAB infestations, providing additional EAB-free years. The difference between the NPV estimate for a no regulation scenario and another level of regulation effectiveness reflected the avoided damage associated with delaying EAB establishment. This avoided damage and the potential benefits may accrue to homeowners, municipalities and industry involved in harvesting ash.

3.2.1 Urban Trees

Within the urban context, we made use of data from an established survey that estimated the number and size of ash trees within 10 m of urban roadways (Pedlar et al. 2013). This effort was initiated in 2010 to gather information on street tree composition using both ground and vehicle-based surveys; since 2016, surveys have been carried out using Google Street View. A total sum of 125 communities, covering every province in Canada, were surveyed by 2018. For communities that had not been surveyed, estimates of ash composition were generated using an inverse distance weighted average of the ash composition from the five nearest surveyed communities (see Pedlar et al. 2019 for details).

Unfortunately, the street tree survey data likely overestimated the proportion of ash trees in some western cities that had not been surveyed at the time of our study. The values for these cities were derived from their five nearest neighbouring communities, which happened to be in areas where ash was a more abundant street tree (e.g., central and eastern Canada). To address this issue, we have replaced the street tree survey data for three large British Columbian cities (Kelowna, Vancouver, and Victoria) with municipal tree inventory data available online. Municipal tree inventory data capture a different set of trees (municipally managed trees) but are likely to be more representative of the true ash population within the area.

Using this data, we determined the total cost of removing and replacing ash street trees for each urban area. We combined these urban total cost values with estimates from the spread model of the proportion of new cells in each urban area impacted by the EAB annually. We then assumed that this annual proportion of newly populated cells corresponded to the same proportion of removal and replacement costs for each urban area. For example, if the spread model predicted that an additional 5% of the urban cells in Toronto were infected by new EAB populations in 2012, we presumed that 5% of the city's total removal and replacement costs were incurred, although they lagged by two to ten years. This lag is due to delays associated with EAB detection at low population levels (BenDor et al. 2006; DeSantis et al. 2013). Damage estimates were discounted over time and aggregated at the provincial level.

Removal and replacement cost estimates are provided in Table 4. These values are based on cost data used by McKenney et al. (2012), updated to 2019 Canadian dollars and varied through the stochastic modeling process to reflect cost uncertainty. We assumed that 50% of the ash trees that were removed within urban areas would be replaced. Cost data were further refined for small, medium and large trees. Table 4 also includes an estimate of the lag in EAB detection for urban areas. The detection lag value was assumed to be an average across all urban areas. We expected that some urban areas would be able to detect EAB presence soon after initial infestation, while other areas would be unable to detect the insect until the population is well established.

Although treating and protecting ash trees from the EAB is possible (e.g., TreeAzin®, BioForest Technologies, Inc. N.D.), we chose to simplify the cost analysis by focusing only on removal and replacement costs. In order to capture the effect of treatment on EAB impacted ash within urban areas, we would require data and assumptions regarding local government's positions on the application of chemical treatments, the number of trees treated, the frequency and duration of treatment, and the success rate of

Table 4. Economic model parameters used for urban and rural tree calculations

Parameter	Distribution type	Distribution parameters		
		Mean	Min	Max
Rural value ($/m³)	Triangular	$5	$0	$15
Removal cost – small	Triangular	$176	$65	$287
Removal cost – medium	Triangular	$587	$357	$809
Removal cost – large	Triangular	$1,175	$841	$1,520
Replacement cost	Triangular	$470	$295	$637
Detection lag (years)		4	2	10

treatment, aggregated for each urban area over the time period examined by the model, and forecasted into the future. In addition, the decision problem examined here and faced by the CFIA is not individual ash tree protection decisions but rather larger-scale regulatory practices. See McKenney and Pedlar (2012) for an examination of the decisions associated with protecting an individual ash tree.

3.2.2 Rural Trees

To address rural trees, we adopted a values-at-risk approach, estimating the standing timber value of rural ash trees as they are damaged by the EAB over time. To simplify this exercise, we based our calculations on the volume of ash predicted to be lost across the landscape and a cost metric that represented the commercial value of a cubic metre of ash to a landowner. The volume of ash predicted to be lost was based on the merchantable volume as calculated from the range of ash in Canada (Beaudoin et al. 2014) and the year of EAB infestation predicted by the spread model. We assumed that rural ash had a stumpage value of $\$0/m^3$ to $\$15/m^3$, based on government information (Government of Alberta 2020; Government of Nova Scotia 2018; Government of Ontario 2020). Aggregated at a provincial level, the NPV of the damage was then discounted across the model time period.

This calculation was based on the premise that as ash trees die as a result of EAB infestation, commercial interests will no longer be able to use ash lumber as they would have in the absence of the insect. We assumed that this loss in commercial value would be incurred two to ten years after EAB arrival, to account for delayed detection. Although ash lumber might retain some commercial use after EAB infestation, we did not include these values within the model for simplicity. We also excluded the possibility of salvage logging, nor did we account for pre-emptive harvests occurring before the arrival of the EAB.

3.2.3 Sensitivity Analysis

We explored the sensitivity of the model outputs to changes in several model assumptions, in addition to variations in the level of assumed regulation effectiveness. Moreover, we examined discount rates from 0% through to 12% that represent a range of time preference rates (or costs) for social goods (Kovacs et al. 2010) and public policy intervention (Treasury Board of Canada Secretariat 2007). With respect to the urban tree component of the model, we were uncertain what percentage of trees would be replaced, and therefore considered replacement rates of 0%, 50% and 100%. Similarly, under the rural tree portion, we investigated a range of increased values, implicitly reflecting possible benefits associated with carbon storage, environmental services and changes in the industrial demand for ash as it becomes scarcer across the landscape. See Table 5 for the range of values used.

Table 5. Variables and values used in the sensitivity analysis

Variable	Base case value	Minimum value	Maximum value
Discount rate	4%	0%	12%
Proportion of street trees replaced	50%	0%	100%
Rural tree value ($/m³)	$0–$15	$25–$75	$75–$125

3.2.4 Model Runs

The actual effects of the EAB and the simulated outcomes had some level of stochasticity. To address this uncertainty and a lack of definitive knowledge on both spread and economic outcomes, our modelling process made use of Monte Carlo simulations (random draws from possible parameter values for each model component). The spatial analysis of EAB spread was computationally intensive given the number of grid cells across the country. In this model component, we examined 30 iterations of each level of assumed regulation effectiveness. Since the economic portion was less computationally intensive, we ran the economic component 500 times for each iteration of the spread model generating a total of 15,000 outputs for each level of assumed regulation effectiveness. We believe 30 iterations sufficiently captured the variation inherent within the spread model and that 500 iterations provide a reasonable representation of possible economic outcomes. Therefore, our results are presented as distributions to give readers a sense of the range of results this analysis provides.

3.3 Results

3.3.1 Predicted Spread of the EAB Across Canada

The spread model outputs indicated that most of the ash that grows within the regulated area in southern Ontario and Québec would be attacked by the EAB before 2035. Many of the large cities within this region already have an EAB presence as of 2019. As might be expected, the model predicted that these populations would continue to grow and spread to surrounding rural areas, regardless of the level of assumed regulation effectiveness.

North of the regulated area in Ontario and Québec, rural ash is scarce, and the model predicted only occasional EAB introductions to urban and rural locations in this region. The level of assumed regulation effectiveness did not appear to have a significant impact on these outcomes. In western Ontario, the City of Thunder Bay has confirmed EAB populations (CFIA 2019) and the density of rural ash increases towards the Manitoba border. Our model predicted that this urban population would continue to grow and begin to spread to the surrounding rural ash by the end of the model timeframe. According to the model, the EAB will appear in a few other rural locations in the region by 2035, regardless of the level of assumed regulation, but the severity of the infestation would depend on the assumed effectiveness of the regulation level.

In the Maritimes, the spread model predicted that existing EAB infestations in Halifax, Nova Scotia, and Madawaska County, New Brunswick (CFIA 2019) would continue to grow, regardless of the assumed effectiveness of regulation. Additional populations appeared in surrounding urban centres as the assumed effectiveness of regulation decreased; when no regulation was presumed to be in place, the EAB emerged in St. John, Moncton, and Fredericton, New Brunswick by the mid-2020's. Coincidently, EAB detections were made in Moncton and Oromocto, New Brunswick, during the summer of 2019. Alternatively, when regulations were assumed to be 95% effective, few satellite populations successfully established in the surrounding urban centres, and those that were successful become established within the 2030's. Although this region has some rural ash, our simulations predicted few EAB populations outside of urban areas, likely a result of a less dense road network. If the model timeline was extended past 2035, human facilitated EAB movement would eventually result in satellite populations in rural areas.

In western Canada (i.e., west of the Manitoba-Ontario border), the only known EAB populations at the time of this study were in the city of Winnipeg, which was regulated in 2018 (CFIA 2019). In this region, EAB spread was largely dependent on the assumed level of regulation effectiveness. Ash is relatively uncommon in rural areas across the Prairies as compared to eastern Canada, but our spread results indicated that populations would likely become established in urban areas in western Canada soon. When regulation was assumed to be 0% effective, the spread model often predicted that the EAB would create populations in Vancouver and/or Victoria, British Columbia, before the end of the model timeline. These most westerly populations were often facilitated by the establishment of a few EAB populations within the Prairie provinces. The communities of Lethbridge, Alberta, and Regina, Saskatchewan were frequently predicted to be impacted by the EAB (driven by long-distance spread). If regulations were to be 95% effective, populations west of Winnipeg were rare, and if they did occur, usually appeared in large urban centres late in the model time horizon. However, the spread model often predicted an EAB presence in Vancouver/Victoria by 2035 even under a 95% regulation level—despite relatively low ash density in these cities. Figure 4 provides an illustrative example of one iteration of a regulation that is 0% effective (panel a), and an iteration of a regulation that is 95% effective (panel b). The colour legend indicates the year of EAB establishment at the given location, with the white epicentre and pink/purple colours representing the early outbreaks, blue and green representing populations established in the middle of the time frame (e.g., 2015 to 2025), and yellow and red representing those established between 2025 and 2035.

3.3.2 Value of Street Trees Vulnerable to the EAB

On a national scale, we predicted that there were approximately four million ash street trees in urban areas across the country. This estimate is likely conservative as it excluded backyard, park or greenspace trees that may also need to be dealt with in the event of EAB attack. Indeed, ash comprised about 20% of the urban forest in some cities (e.g., ash made up 20–25% of the urban forest in Ottawa (City of Ottawa 2017) and 30% of the boulevard and park trees in Winnipeg (City of Winnipeg 2019)). The cost of EAB impacts on street trees varies depending on the estimated number and size class of ash trees, the costs of removal and replacement, and the assumed proportion of trees replaced. The undiscounted removal and replacement value of these ash trees was around $4.5 billion, assuming 50% of the removed trees were replaced. This estimate represents a values-at-risk assessment, based on removal and replacement costs alone, and does not account for the rate of EAB spread across the country.

3.3.3 Value of Urban and Rural Trees Impacted by the EAB

Supposing that EAB spread across the country was unaffected by any regulatory effort, the present value estimate of the damage to urban trees would be about $1.384 billion, and around $0.038 billion to rural trees. Note that the present value was calculated based on costs incurred between 2019 and 2035; costs incurred prior to 2019 were considered sunk and were therefore excluded from the analysis. Combined, the mean present value estimate for the damage caused by EAB across the country was about $1.422 billion. These estimates were calculated under the base case scenario, a 4% discount rate, a 50% replacement rate for street trees, and a low predicted value for rural trees. Table 6 provides the details of the distributions predicted for urban and rural trees and the sum of the damage for both urban and rural trees across the examined levels of assumed regulatory effectiveness. Most of these costs were attributed to urban trees; the values associated with rural trees accounted for approximately 4% of the total NPV estimate.

Table 6 illustrates the decline in estimated NPV of EAB damage as the assumed level of regulation increases. This relationship was clearly visible with respect to urban trees, but somewhat harder to observe in the rural results. Indeed, the results of the rural calculations showed little correlation between the assumed level of regulation effectiveness and the estimated NPVs. We hypothesized that this lack of correlation was due to the location of most rural ash that could be impacted by the EAB since much of this rural ash existed *within* a regulated area. As a result, changes in the assumed level of regulation effectiveness had little to no effect on the rate at which these trees were damaged by the EAB. The effect of this on the overall results was minimal however, as the values associated with rural trees made up only a small portion of the total sum of urban and rural values.

When the assumed level of regulation effectiveness increased, the rate of spread of EAB across the country declined. In these cases, damage to ash in urban and rural areas was delayed. The avoided damage or monetary benefit of increasing the effectiveness of regulation is the difference in estimated present value of damage between the base case scenario with no regulation, and the scenarios with some level of effective regulation.

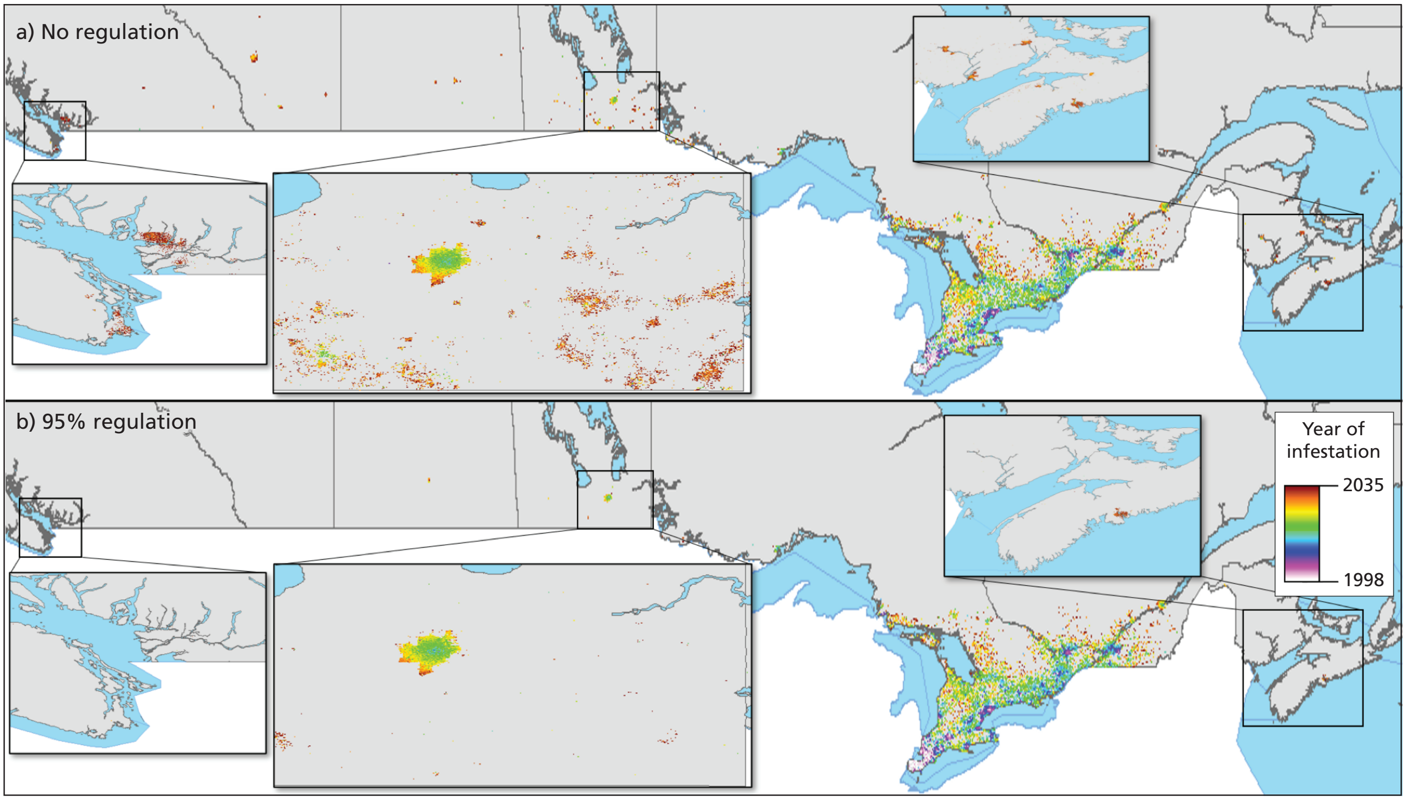


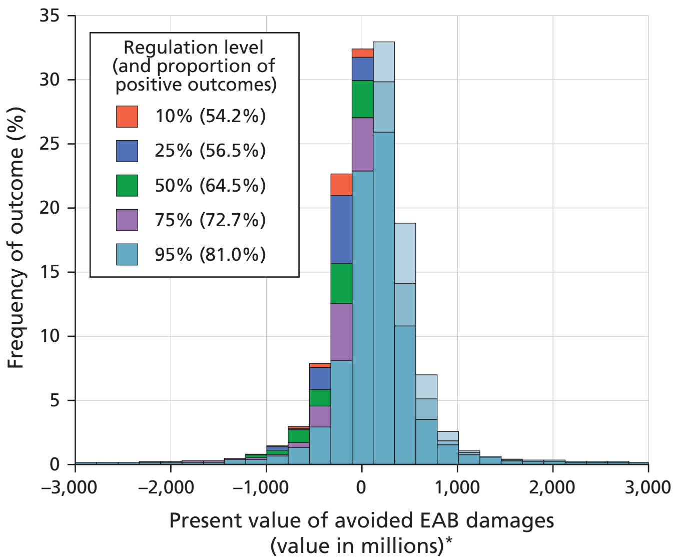
Figure 4. Iterations of the spread model with a) no regulation; b) regulation assumed to be 95% effective.

Table 6. Estimated present value of damage associated with EAB for urban and rural ash trees, in millions

Category	Regulation Level		0%	10%	25%	50%	75%	95%
Urban	Min		$949	$883	$874	$836	$728	$726
	Median		$1,318	$1,290	$1,274	$1,210	$1,147	$1,061
	Mean		$1,384	$1,348	$1,341	$1,290	$1,210	$1,131
	Max		$9,205	$11,091	$13,582	$9,561	$8,495	$8,801
	Percentile	5%	$1,088	$1,047	$1,032	$967	$898	$845
		95%	$1,882	$1,830	$1,850	$1,852	$1,717	$1,631
Rural	Min[a]		$2	$3	–$1	–$1	$3	–$1
	Median		$37	$38	$38	$36	$37	$38
	Mean		$38	$40	$39	$38	$38	$39
	Max		$94	$104	$97	$87	$94	$103
	Percentile	5%	$11	$12	$10	$10	$12	$12
		95%	$70	$72	$72	$72	$69	$69
Sum	Min		$977	$911	$907	$869	$748	$762
	Median		$1,355	$1,329	$1,313	$1,248	$1,185	$1,100
	Mean		$1,422	$1,388	$1,379	$1,328	$1,248	$1,170
	Max		$9,265	$11,115	$13,657	$9,590	$8,524	$8,827
	Percentile	5%	$1,125	$1,086	$1,071	$1,004	$936	$881
		95%	$1,921	$1,869	$1,894	$1,889	$1,754	$1,667

a Note that the model itself did not report negative values, but the triangular distribution fit to the model outputs required a negative minimum value to optimize fit.

Although the mean present values reported for each level of regulation in Table 6 are positive, the distributions representing the present value of avoided damage were wide and included negative values, driven by the stochastic nature of the model. This implies that the urban and rural costs incurred under a no regulation scenario were less than the costs incurred under an effective regulation in some cases. The likelihood of a negative outcome changed as the level of regulation effectiveness increased; 50% of the simulation outputs were positive under a regulation 10% effective, while more than 80% of the outputs were positive under a regulation 95% effective (Figure 5). The proportion of positive outcomes for the other levels of regulation effectiveness varied between these two extremes.



* Note that this figure was truncated at $3 billion, thereby eliminating extreme outliers.

Figure 5. Distribution results of avoided damage, for every effective level of regulation.

Table 7 illustrates our present value estimates of combined urban and rural damage, avoided damage associated with improvements in EAB regulation, and the Net Present Value (NPV) of regulation under various levels of effectiveness (calculated as the present value of avoided damage less the costs of regulation to the CFIA and industry), as the mean values from our output distributions. Examining the mean present value of avoided damage, the model suggests that regulation at any level effectively slows human-facilitated movement of the insect, and the benefit of this delay—the avoided damage—would be positive under most simulations. Regulatory levels with effectiveness of less than 50% failed to create a large delay in EAB movement, but the model did suggest that the regulations could generate a benefit (albeit small; between 2% and 3% of the no regulatory cost scenario) more often than a loss. Regulation levels above 50% frequently showed larger avoided damage estimates. Indeed, a 50% regulation effectiveness level produced a present value estimate for avoided damage of about $95 million (6% of the no regulatory cost). Further, cost-savings increased as the level of regulation effectiveness rose, with cost savings reaching $174 million, and $252 million at the 75% and 95% effectiveness levels, respectively (12% and 18% of the "no regulatory cost" value).

Table 7. Mean distribution results, in millions

Assumed effectiveness of regulation	Total present value (urban and rural trees)	Present value of avoided damage	Net present value (avoided damage less regulatory/industry costs of compliance)
0%	$1,422	N/A	N/A
10%	$1,388	$34	$22
25%	$1,379	$43	$31
50%	$1,328	$95	$83
75%	$1,248	$174	$162
95%	$1,170	$252	$240

The present value of avoiding damage was also compared to the present value of regulation efforts and industry compliance costs in Table 7. We forecasted CFIA and industry costs into the future based on the values reported in Section 2, with annual variation between the top-down and bottom-up estimated values. Comparing the benefits of regulation with these costs, we could estimate the NPV of regulation under different regulation effectiveness levels. NPVs were positive once present values of costs were incorporated indicating an economic benefit under most simulations. Indeed, for the 50% effectiveness assumption, the result suggests that delaying damage could generate an NPV of about $83 million, which represented 6% of the costs that would be incurred under the no regulation scenario. At an assumed effectiveness rate of 75%, cost savings were around $162 million (in 2019 dollars) or 11% of the total EAB expenditure predicted under a no regulation scenario. As the level of effectiveness increased to 95% the value of the delay in damage rose to $240 (17% of the total EAB expenditure under a no regulation simulation).

3.3.4 Sensitivity Analysis

The results of the sensitivity analysis for three regulation scenarios (no regulation, 50% and 95% regulation) are provided in Table 8 and are illustrated as the percentage change from the mean base case. The direction of changes was anticipated and unsurprising. For example, a decrease in the discount rate resulted in higher NPV estimates; as the discount rate approached zero, the costs of the damage caused by the EAB increased. A higher discount rate generated lower present value estimates, as costs incurred farther in the future were discounted at a greater rate. The magnitude of the change caused by an adjustment to the discount rate was amplified in the NPV column in Table 8, as both the estimated present value of avoided damage, and the projected CFIA and industry costs over time were impacted by a change in the discount rate.

The result of adjusting the proportion of street trees replaced was largely symmetric; reducing the number of trees replaced decreased present value estimates of urban damage while increasing the proportion of urban trees replaced to 100% subsequently enhanced urban present value in comparison to the base case values. Augmenting the value of rural trees increased the estimated present value of rural damage, although these results were not visible within the final NPV estimates, likely due to the small impact rural trees have on total damage estimates.

Table 8. Percentage change from the base case values for three regulation scenarios: no regulation, 50% regulation, and 95% regulation

Sensitivity analysis variable	Regulation levels	Present value of urban damage	Present value of rural damage	Total present value	Present value of avoided damage	Net present value
Discount rate: 0%	0%	51%	65%	51%	N/A	N/A
	50%	46%	68%	47%	110%	121%
	95%	36%	66%	37%	116%	120%
Discount rate: 8%	0%	–32%	–32%	–32%	N/A	N/A
	50%	–30%	–33%	–30%	–58%	–64%
	95%	–26%	–33%	–26%	–59%	–61%
Discount rate: 12%	0%	–46%	–53%	–46%	N/A	N/A
	50%	–45%	–54%	–46%	–50%	–52%
	95%	–40%	–56%	–41%	–71%	–73%
Urban tree replacement rate: 0%	0%	–24%	3%	–23%	N/A	N/A
	50%	–25%	–2%	–25%	–2%	–2%
	95%	–23%	–1%	–23%	–25%	–26%
Urban tree replacement rate: 100%	0%	21%	–3%	21%	N/A	N/A
	50%	22%	4%	21%	8%	9%
	95%	23%	–1%	22%	14%	15%
Rural tree value: High	0%	–4%	1,724%	43%	N/A	N/A
	50%	–2%	1,670%	46%	–4%	–5%
	95%	–4%	1,620%	49%	12%	12%
Rural tree value: Mid	0%	–6%	663%	12%	N/A	N/A
	50%	–6%	670%	13%	–5%	–5%
	95%	–7%	631%	14%	2%	2%

3.4 Discussion

This analysis suggests that the EAB will have a large impact on urban forests across Canada by 2035. Many urban areas in southern Ontario and Québec will likely lose much of their ash as existing EAB populations continue to grow, and urban areas outside of Ontario and Québec will face the prospect of EAB arrival via human-facilitated transport. Our spread model did not predict EAB presence in every Canadian city capable of supporting it but suggests that the EAB is likely to be established in almost every Canadian province with ash by 2035.

Model results also indicate that most of Canada's ash resource located within the regulated area in Ontario and Québec will be lost to the EAB. However, large areas of sparse rural ash were predicted to remain EAB free until 2035 offering hope that the species may not be completely lost from the Canadian landscape. Indeed, much of the rural ash outside of southern Ontario and Québec was not predicted to be impacted by the EAB by the end of the model time horizon. In the Maritimes, EAB spread was dependent on the effectiveness of regulation; when no regulation was assumed to be in place, the existing urban populations spread by forming satellite populations in surrounding urban areas. When regulation was assumed to have some level of effectiveness, the number of satellite populations established by 2035 was lower, although the existing populations continued to grow.

Based on our spread simulations, regulating the movement of ash did not appear likely to stop EAB spread across the country. Even with a simulated regulation with a 95% effectiveness level, the EAB typically appeared in British Columbia by the end of the model timeframe. Regulation did, however, slow the spread of the insect, allowing EAB associated costs to be deferred to a later date. Given the time value of money, this is an important result. The results of the analysis suggest that regulation at every level generated some economic benefit in most cases, although higher levels of regulation effectiveness result in larger, and more certain economic benefits. Indeed, as long as regulation had some level of effectiveness, the regulatory effort could often be justified on economic efficiency grounds. We did not attempt to evaluate the true effectiveness of the current regulations in place. This would require a counterfactual scenario, including data on EAB spread without any regulatory efforts, and was beyond the scope of our analysis.

The analysis illustrates the distributive costs associated with the EAB and other invasive species in general. Maintenance and expansion of the areas under EAB regulation impose a direct financial cost to CFIA operations and to the ash-related industry through their compliance efforts. While regulatory efforts may have limited success, individual citizens and municipalities would also be financially impacted by deregulation. Their costs include direct financial costs such as removal and replacement of damaged trees and often other non-commercial values such as the loss of aesthetic values, lowered property values and related environmental services.

There are limitations associated with both the spread model and the economic analysis presented here. The spread model did not account for any human-facilitated movement beyond road transportation. While we feel our model captures the majority of EAB movement, rail, air and shipping vectors (and incursions from the United States) were not considered. Our approach to modelling EAB spread was also urban-centric; it did not address wood movements associated with forestry activities in rural areas, nor did it consider campgrounds, which may act as important modes for EAB spread (Yemshanov et al. 2015). Additionally, the model only examined the regulation approach adopted by the CFIA; it did not account for the possible effects of biological control programs (CFIA 2018b). We note, however, regulatory efforts that slow EAB spread may "buy time" that help increase the likelihood of success for such programs.

The values addressed here represent the costs of removing and replacing urban street trees, and possible commercial values for rural ash trees. We stress again that these values only represent a small component of the overall worth (monetary and non-monetary) of Canada's ash resources. Indeed, the loss of a large portion of the urban forest canopy represents a significant investment to governments, businesses, and individual consumers and citizens. The economic portion of the model did not address all the costs that an urban municipal government may face, including EAB education costs, treatment efforts, or incentive programs. If the analysis were expanded to account for willingness-to-pay for non-monetary benefits associated with ash trees and their contribution to urban forests, the savings associated with delaying an EAB presence would likely grow significantly (e.g., property values, pollution interception, and energy conservation; see McKenney and Pedlar 2012). Additionally, there is literature evidence to suggest that urban forests decrease crime and mortality rates and have a positive effect on health and leisure time (Kondo et al. 2017; Jones and McDermott 2015; Jones 2016; Jones and Goodkind 2019). Unfortunately, quantifying the full scope of the benefits of urban forests and possible losses resulting from EAB infestations is extremely challenging and was beyond the scope of the current study. We note again that the analysis undertaken here demonstrated these benefits were not required to justify some level of regulatory effort on economic efficiency grounds.

4 International Trade Implications

Exports of Canadian ash (logs, firewood, bark or bark chips) are rare. Canada exported $38 million in ash lumber in 2018, representing about 0.5% of total lumber exports. The exports that did occur were bound for China (57%), the EU (20%), Asia (excluding China) (20%) and the U.S. (2%). Most of these exports originated in Québec (75%) and Ontario (24%) (Global Trade Atlas 2018, see Table A3).

We do not anticipate that the deregulation of the EAB in Canada would have significant implications on Canada's ash product exports. At the time of this study, the U.S. and EU had import restrictions with respect to EAB host material. Ash wood products require import permits to enter the U.S. The U.S. recognizes pest free areas and if the products were sourced and shipped from an EAB non-regulated area, the import requirements listed on the import permit would be minimal. If APHIS continues to regulate the EAB while the CFIA deregulates, we could potentially see the U.S. not recognizing any area in Canada as EAB free, causing trade implications. However, with the proposed U.S. deregulation, we do not expect to see this impact unless state level quarantine regulations are developed.

The EU does not recognize EAB free areas in Canada or the U.S., despite the current regulation. As such, facilities wishing to export ash products to the EU must be registered under CFIA directive D-14-02: Certification Program for the Export of Hardwood Species Regulated for Agrilus spp. to the EU (CFIA 2018c). Section 2 of this directive lists the requirements that *Fraxinus* lumber must meet in order to be shipped to the EU: export shipments must be accompanied by a CFIA-issued phytosanitary certificate and ash wood must be debarked, heated and kiln dried. Additionally, the export of logs with bark, bark and woodchips is prohibited.

5 Summary and Conclusions

Here we developed a multi-stage modelling approach to assess the economic implications of eliminating EAB quarantine regulations in Canada. The study was proposed by the CFIA, in response to the proposed deregulation of the EAB in the United States. We estimated the costs of the regulation to the CFIA and the impacted forest industry, and concluded that annual regulatory costs for industry ranged between $390,383 and $2.37 million, based on a top-down approach (in line with the methodology employed by APHIS for a similar analysis) and a self-reporting survey method. Our results indicate that aggregate annual costs to the CFIA would be approximately $400,000–$500,000 (found to be $441,634 in the current study).

The present analysis also compared the estimated regulatory costs to the benefits of the regulation. Benefits were calculated as the cost damage avoided/delayed as a result of regulation and were determined via the simulated EAB spread across the country. The modeled spread of the EAB was dependent on flight and human-facilitated transportation, climate, EAB biology, and the assumed effectiveness of regulation. We modeled "effective regulation" as a reduction in the proportion of human facilitated EAB movements that successfully establish new populations. These movements were only restricted when they originated inside the regulated area and moved to an unregulated area. The true effectiveness of regulation at slowing the spread of the insect is unknown, we therefore explored multiple effectiveness levels. This allows individual readers/decision makers to consider a wider range of possible outcomes and supports more vigorous discussion on this complicated subject.

Simulated arrival dates for EAB populations across the country were combined with estimates of the cost of removing and replacing urban street trees and the lost timber value associated with rural ash trees. Under a simulation with no regulation, we predicted that the mean present value of EAB damage was approximately $1,422 million while a simulated regulation level of 50% resulted in avoided damage of $95 million. Indeed, every level of simulated regulation, including an effectiveness level of 10%, resulted in avoided damage under most simulations. Most of the estimated damage was a result of the EAB attacking urban trees; rural trees comprised only a small proportion of this damage.

When we accounted for the cost of regulation to the CFIA and industry, the estimated benefit remained positive, although small. These results suggest that the costs of regulation do not outweigh the costs of the damage caused by the EAB that is delayed and/or avoided with regulation. EAB damage calculations were restricted to tree values that were readily and confidently monetized; additional environmental and social values were not included. These values are difficult to quantify and subjective, and beyond the scope of our analysis. As such, this analysis could be considered conservative and indicates that the benefits of regulation are likely to outweigh the costs, as long as regulation is somewhat effective.

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Appendices

Appendix 1

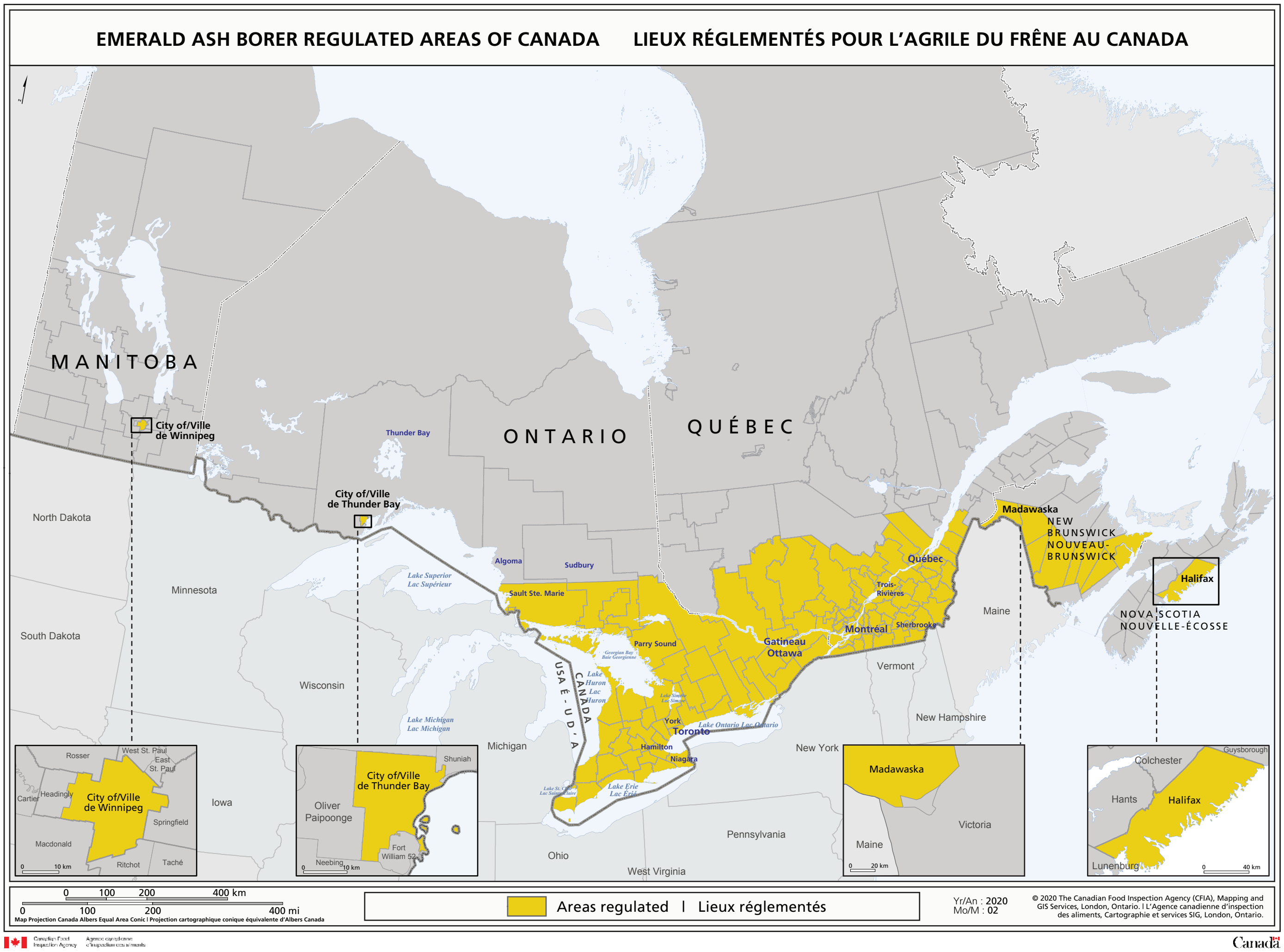

Figure A1. Emerald Ash Borer Regulated Areas in Canada as of February 6, 2020.

Available at: https://www.inspection.gc.ca/plant-health/plant-pests-invasive-species/insects/emerald-ash-borer/areas-regulated/eng/1347625322705/1367860339942.

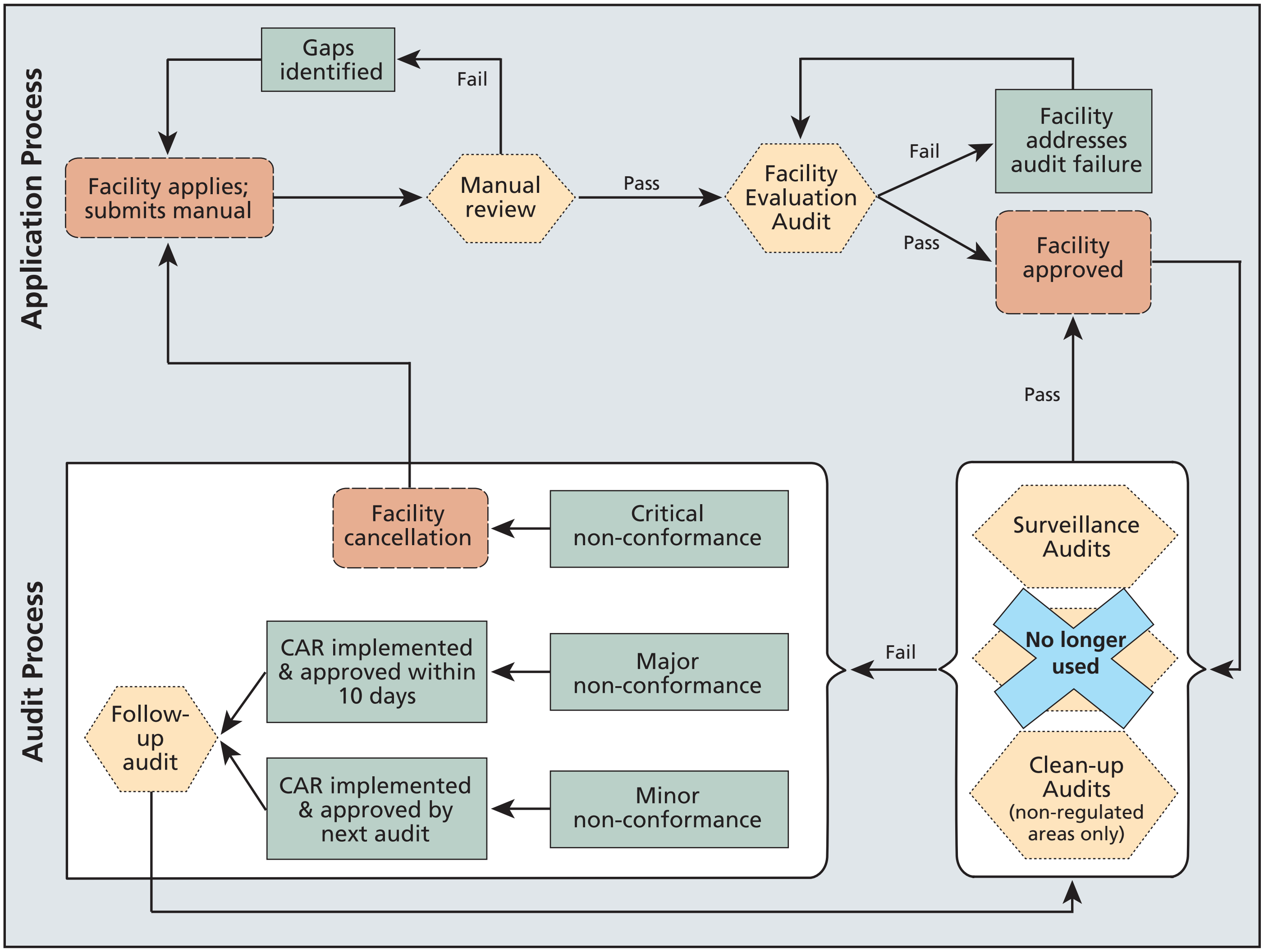

Figure A2. Emerald Ash Borer Approved Facility Compliance Program activities chart.

Available at: https://www.inspection.gc.ca/plant-health/plant-pests-invasive-species/directives/forest-products/d-03-08/qsm-07/eng/1347553733814/1355879699357#app4.

Table A1. CFIA labour costs associated with EAB regulation 2002/03–2018/19

Year	Task name	Task code	FTEs[a]	FTE hours	Labour costs
2002/03			**2.0**	**3,486**	**$299,796**
2003/04			**32.0**	**55,776**	**$4,796,736**
2004/05			**36.0**	**62,748**	**$5,396,328**
2005/06			**36.0**	**62,748**	**$5,396,328**
2006/07			**27.7**	**48,264**	**$4,150,676**
	Plant protection surveys – EAB	09a04.25	0.1	218	$18,737
	Establishment verification/audits	09a07	4.9	8,602	$739,747
	EAB Emergency response	09e03	22.6	39,444	$3,392,192
2007/08			**3.4**	**5,869**	**$504,707**
	Plant protection surveys – EAB	09a04.24	0.5	936	$80,495
	Establishment verification/audits – Forestry	09a06.01	0.6	1,103	$94,885
	Import facility audit – Forestry	09a10.01	0.1	237	$20,386
	EAB Emergency response	09e03	2.1	3,592	$308,940
2008/09			**6.4**	**11,105**	**$955,000**
	Plant protection surveys – EAB	09a04.24	1.3	2,222	$191,120
	Establishment verification/audits – Forestry	09a06.01	0.6	1,055	$90,688
	Import facility audit – Forestry	09a10.01	0.3	544	$46,768
	EAB Emergency response	09e03	4.2	7,284	$626,424
2009/10			**3.9**	**6,819**	**$586,401**
	Plant protection surveys – EAB	09.06.19	1.6	2,733	$235,040
	Establishments verification/audits – Forestry	09a05.01	0.9	1,536	$132,060
	Import facility audit – Forestry	09a11.01	0.2	275	$23,684
	EAB Emergency response	09e03	1.3	2,275	$195,617
2010/11			**3.2**	**5,654**	**$486,269**
	Establishment verification/audits – Forestry	09a05.01	0.4	629	$54,113
	Plant protection surveys – EAB	09a06.19	2.1	3,718	$319,732
	Import establishment audit/inspection – Forestry	09a11.01	0.1	244	$20,986
	EAB Emergency response	09e03	0.6	1,063	$91,438
2011/12			**3.2**	**5,607**	**$482,222**
	Domestic product inspection – Forestry	31a02	0.2	370	$31,778
	Establishment verification/audits – Forestry	31a10	0.2	265	$22,784
	Import establishment audit/inspection – Forestry	31c10	0.1	218	$18,737
	Plant protection surveys – EAB	31d01.18	1.7	3,022	$259,923
	EAB Emergency response	31g05	1.0	1,733	$148,999
2012/13			**4.2**	**7,362**	**$633,169**
	Domestic product inspection – Forestry	31a02	0.3	474	$40,772
	EAB Emergency response	31g05	0.4	727	$62,507
	Establishment verification/audits – Forestry	31a10	0.3	490	$42,121
	Import establishment audit/inspection – Forestry	31c10	0.2	268	$23,084
	Plant protection surveys – EAB	31d01.18	3.1	5,403	$464,684

Year	Task name	Task code	FTEs[a]	FTE hours	Labour costs
2013/14			**4.4**	**7,748**	**$666,297**
	Domestic product inspection – Forestry	31a02	0.1	256	$22,035
	EAB Emergency response	31a10	0.2	373	$32,078
	Establishment verification/audits – Forestry	31c10	0.1	206	$17,688
	Import establishment audit/inspection – Forestry	31d01.18	3.2	5,548	$477,125
	Plant protection surveys – EAB	31g05	0.8	1,365	$117,370
2014/15			**1.7**	**3,000**	**$258,019**
	Domestic product inspection – Forestry	31a02	0.3	437	$37,624
	Establishment verification/audits – Forestry	31a10	0.3	598	$51,415
	Import establishment audit/inspection – Forestry	31c10	0.3	521	$44,820
	Plant protection surveys – EAB	31d01.18	0.8	1,444	$124,161
2015/16			**1.9**	**3,237**	**$278,361**
	Domestic certificates issued – Forestry	31a23	0.2	303	$26,082
	Domestic product inspection – Forestry	31a02	0.2	272	$23,384
	Establishment verification/audits – Forestry	31a10	0.2	364	$31,329
	Import establishment audit/inspection – Forestry	31c10	0.3	497	$42,721
	Plant protection surveys – EAB	31d01.18	1.0	1,801	$154,845
2016/17			**1.9**	**3,334**	**$286,755**
	Domestic certificates issued – Forestry	31a23	0.2	333	$28,631
	Domestic product inspection – Forestry	31a02	0.1	234	$20,086
	Establishment verification/audits – Forestry	31a10	0.2	296	$25,483
	Import establishment audit/inspection – Forestry	31c10	0.3	437	$37,624
	Plant protection surveys – EAB	31d01.18	1.2	2,034	$174,931
2017/18			**2.4**	**4,258**	**$366,201**
	Domestic certificates issued – Forestry	31a23	0.2	326	$28,031
	Domestic product inspection – Forestry	31a02	0.3	593	$50,965
	Establishment verification/audits – Forestry	31a10	0.2	336	$28,930
	Import establishment audit/inspection – Forestry	31c10	0.4	657	$56,512
	Plant protection surveys – EAB	31d01.18	1.3	2,346	$201,763
2018/19			**2.8**	**4,796**	**$412,414**
	Domestic certificates issued – Forestry	31a23	0.3	507	$43,620
	Domestic product inspection – Forestry	31a02	0.1	260	$22,335
	Establishment verification/audits – Forestry	31a10	0.6	1,042	$89,639
	Import establishment audit/inspection – Forestry	31c10	0.7	1,220	$104,929
	Plant protection surveys – EAB	31d01.18	1.0	1,766	$151,892

a 1 Direct FTE = 1,743 hours. Hourly rate = $86. FTEs accounted for other non-EAB compliance facility audits as well, but the majority were EAB facilities.

Table A2. Sawmills and firewood business counts and production by regions in 2018

Geography	Sawmills[a]	Lumber production (1,000 m^3)[b]	Miscellaneous wood product manufacturing[c]	Firewood (m^3)[d]
Canada	**638**	**65,629**	**662**	**3,389,176**
Newfoundland and Labrador	14	–	4	264,654
Prince Edward Island	8	1	3	282,047
Nova Scotia	30	1,019	12	138,339
New Brunswick	45	1,771	19	36,332
Québec	210	14,777	212	1,854,906
Ontario	109	5,776	208	630,699
Manitoba	5	–	9	101,827
Saskatchewan	6	927	7	9,826
Alberta	39	5,551	47	26,293
British Columbia	171	16,200	141	–
Yukon	–	–	–	12,670
Northwest Territories	1	–	–	31,583
Nunavut	–	–	–	–

a Statistics Canada. Table 33-10-0105-01 Canadian Business Counts, with employees, December 2018; NAICS code [321111]; https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3310010501.

b Statistics Canada. Table 16-10-0017-01 Lumber production, shipments, and stocks by species, monthly (× 1,000); https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1610001701. Certain monthly production data was suppressed to meet the confidentiality requirements of the Statistics Act, hence the annual production number may not be accurate at the provincial level.

c Statistics Canada. Table 33-10-0105-01 Canadian Business Counts, with employees, December 2018; NAICS code [321999]; https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3310010501.

d National Forest Database Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction, tenure, category and species group; Data for 2017 in Québec were unavailable as of January 31, 2019 therefore 2015 data were carried over as estimated for 2017.

Table A3. Ash lumber (HS 44079500) exports from Canada by region

Province	Partner country	Value ($)	Quantity (m^3)
Québec	China	5,333,471	17,876
Québec	EU-28	7,425,907	5,990
Québec	Rest of Asia	4,061,903	3,583
Québec	United States	52,643	506
Ontario	China	6,639,462	7,613
Ontario	EU-28	232,183	205
Ontario	Rest of Asia	3,601,789	3,384
Ontario	United States	330,881	860
Manitoba	China	145,464	118
Manitoba	Rest of Asia	47,160	42
New Brunswick	United States	4,164	1
Total		**38,375,027**	**40,178**

Data source: Global Trade Atlas – https://www.gtis.com/gta/.

Appendix 2: Industry Survey on EAB Regulations

Introduction:

This survey collects manufacturing, distribution and related information on companies who deal with ash wood or firewood of any type. The goal is to look at the effects of Emerald Ash Borer (EAB) regulations on companies in Canada. The quantitative and qualitative data from this survey will be used for analyses to help the Canadian Forest Service (CFS) and the Canadian Food Inspection Agency (CFIA) better understand the costs and benefits of the current EAB regulations.

Confidentiality

All information collected will be treated as confidential and no data will be released which could identify any person, business, or organization, unless consent has been given by the respondent.

Section 1: General

1. Please give the location of your company.
   Complete a separate questionnaire for each of your mill sites/companies, if more than one. Please contact us if you have questions.

Address (number and street)	Province
Town/City	Postal Code

2. Does your company produce or manage ash tree material or firewood of any type? If Yes continue; if No you may submit the report as is.
   - ☐ Yes
   - ☐ No

3. If known, what type of ash is being used? ______________________

4. What type of ash products are you producing or managing?
   - ☐ Ash lumber
   - ☐ Ash logs
   - ☐ Firewood of any type
   - ☐ Ash bark and chips
   - ☐ Ash branches
   - ☐ Wood packing materials with an ash component
   - ☐ Other ______________________

5. Is your company operating in a regulated or non-regulated area?
   - ☐ Regulated
   - ☐ Non-regulated

6. Do you distribute these products to regulated areas, non-regulated areas or both?
   - ☐ Regulated area
   - ☐ Non-regulated areas
   - ☐ Both

7. Does your company run all year round or just during the low-risk season (October–March)?
   - ☐ Year round
   - ☐ Low risk

8. How much is 1 labour-hour of work worth in $ to the company on average?
   - ☐ $35/hr–$59/hr
   - ☐ $60/hr–$79/hr
   - ☐ $80/hr–$99/hr
   - ☐ $100/hr–$119/hr
   - ☐ $120/hr–$140/hr
   - ☐ Other $______ /hr

Section 2: Required treatment for distribution within Canada

1. What is the required treatment your company follows for distribution? If None, skip to Section 3.
   - ☐ Remove all bark and at least 1.0 cm of sapwood
   - ☐ Heat treatment
   - ☐ Kiln dried
   - ☐ Processed to less than 2.5 cm in any two directions
   - ☐ Separation of wood
   - ☐ None
   - ☐ Other ______________________

2. What is the total volume of **all** products your company is distributing per year on average?

Type of raw wood material	Volume	Units of measure
Logs		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Lumber		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Firewood		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Other (specify): _____________________		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Other (specify): _____________________		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________

3. What percentage of the total volume being distributed comes from ash?
   - ☐ 0–10%
   - ☐ 10–20%
   - ☐ 20–30%
   - ☐ 30–40%
   - ☐ 40–50%
   - ☐ 50–60%
   - ☐ 60–70%
   - ☐ 70–80%
   - ☐ 80–90%
   - ☐ 90–100%

4. What is your estimate of treatment cost per unit (Including labour, utilities and overhead)? ______________________

5. Would you be incurring these treatment costs regardless of the EAB regulations?
   - ☐ Yes
   - ☐ No

Section 3: Compliance Program

1. Are you currently in the Compliance Program? If No skip to Section 3 (alternative).
   - ☐ Yes
   - ☐ No

2. What year did you join this Compliance Program? ______________________

3. What are the labour-hours needed:
   - To finish the manual review application?
   - To accompany CFIA in a facility evaluation audit?
   - To accompany CFIA in a surveillance audit?
   - If necessary, to accompany in a cleanup audit?

Compliance Program Activities	Manual Review Application	Facility Evaluation Audit	Surveillance Audit	Cleanup Audit
Labour-hours needed:				

4. Has this company failed a Compliance Program audit?
   - ☐ Yes
   - ☐ No

5. How many times has this company failed the Compliance Program? ______________________

6. If so, did this result in a minor, major or critical non conformance?
   - ☐ Minor
   - ☐ Major
   - ☐ Critical

Section 3 (alternative): Non-Compliance Program

1. How often are you distributing ash products or firewood of any type per year? ______________________

2. How many Movement Certificates have you received per year? How long does it take to fill out one Movement Certificate?

Number of Movement Certificates	Time (minutes)

3. How many inspections have you had per year? How long did the average inspection take?

Number of inspections	Time (hours)

4. Does this inspection have to be monitored by the company (supervised by company employee)?
   - ☐ Yes
   - ☐ No

Section 4: International Import Costs

1. Does your company import ash products or firewood from other countries? If Yes continue; if No skip to Section 5.
   - ☐ Yes
   - ☐ No

2. What country(s), state(s) are they importing from? A regulated or non-regulated area?

Country		State/Province	Regulated	Non regulated
United States	☐		☐	☐
China	☐		☐	☐
European Union	☐		☐	☐
Other (specify): ______________	☐		☐	☐

3. What province(s) in Canada are the imports going to? A regulated or non-regulated area?

Province		Regulated	Non regulated
Ontario	☐	☐	☐
Québec	☐	☐	☐
Manitoba	☐	☐	☐
Other (specify): ______________	☐	☐	☐

4. What ash products are being imported?
   - ☐ Ash lumber
   - ☐ Ash logs
   - ☐ Firewood of any type
   - ☐ Ash bark and chips
   - ☐ Ash branches
   - ☐ Wood packing materials with an ash component
   - ☐ Other ______________________

5. How many import permits or any other permits/certificates are received yearly?

Permits/Certificates	Number per year
Import permit	
Other (specify): ______________________	
Other (specify): ______________________	

6. What is the cost ($ fees) or time (hrs) for your company to apply for one import permit or any other permit/certificate for imported ash articles?

Permits/Certificates	Fee ($)	Time (hours)
Import permit		
Other (specify): ____________________		
Other (specify): ____________________		

7. What is the total volume of **all** products your company is importing per year on average?

Type of raw wood material	Volume	Units of measure
Logs		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other _______
Lumber		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other _______
Firewood		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other _______
Other (specify): ____________________		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other _______
Other (specify): ____________________		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other _______

8. What percentage of the total volume being imported is ash?

☐ 0–10%

☐ 10–20%

☐ 20–30%

☐ 30–40%

☐ 40–50%

☐ 50–60%

☐ 60–70%

☐ 70–80%

☐ 80–90%

☐ 90–100%

Section 5: International Export Costs

1. Does your company export ash products or firewood to other countries? If yes continue, if No skip to Section 6.

☐ Yes

☐ No

2. What country(s), state(s) are the exports to? A regulated or non-regulated area?

Country		State/Province	Regulated	Non regulated
United States	☐		☐	☐
European Union	☐		☐	☐
Other (specify): ______________	☐		☐	☐

3. What ash products are being exported?
   - ☐ Ash lumber
   - ☐ Ash logs
   - ☐ Firewood of any type
   - ☐ Ash bark and chips
   - ☐ Ash branches
   - ☐ Wood packing materials with an ash component
   - ☐ Other ____________________

4. How many Phytosanitary Certificates, Certificates of origin or any other permits/certificates are received yearly?

Permits/Certificates	Number per year
Phytosanitary certificate	
Certificate of Origin	
Other (specify): ____________________	
Other (specify): ____________________	

5. What is the cost ($ fees) or time (hrs) for your company to apply for one Phytosanitary Certificate or Certificate of Origin, or any other permit/certificate for exporting ash articles?

Permits/Certificates	Fees ($)	Time (hours)
Phytosanitary certificate		
Certificate of Origin		
Other (specify): ____________________		
Other (specify): ____________________		

6. What is the required treatment your company follows, set by the export requirement?
   - ☐ Remove all bark and at least 1.0 cm of sapwood
   - ☐ Heat treatment
   - ☐ Kiln dried
   - ☐ Processed to less than 2.5 cm in any two directions
   - ☐ Separation of wood
   - ☐ None
   - ☐ Other ____________________

7. What is the treatment cost per unit (Including labour, utility and overhead cost)? ____________________

8. What is the total volume of **all** products your company is exporting per year on average?

Type of raw wood material	Volume	Units of measure
Logs		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Lumber		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Firewood		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Other (specify): ____________________		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________
Other (specify): ____________________		☐ m^3 ☐ oven dry ton ☐ green metric ton ☐ cord ☐ other ________

9. What percentage of the total volume being imported is ash?
   - ☐ 0–10%
   - ☐ 10–20%
   - ☐ 20–30%
   - ☐ 30–40%
   - ☐ 40–50%
   - ☐ 50–60%
   - ☐ 60–70%
   - ☐ 70–80%
   - ☐ 80–90%
   - ☐ 90–100%

Section 6: Comments on Current EAB regulations

1. Do you prefer to keep the current EAB regulation?
   - ☐ Yes
   - ☐ No

2. What are your perceived costs and benefits of the EAB regulation? What are your perceived costs and benefits of the deregulation?

Regulations		Non Regulations	
Benefits	**Costs**	**Benefits**	**Costs**

3. Any other questions/comments/concerns regarding the survey?

Contact Person (name of person to contact about this questionnaire):

First name: ______________________________ Last name: ______________________________

Title: ______________________________

Email: ______________________________

Telephone number ( ) _____________ Fax number ( ) _______________

Thank you for your time.

For more information about the Canadian Forest Service, visit our website at **nrcan.gc.ca/forests** or contact any of the following Canadian Forest Service establishments

nrcan.gc.ca/forests

Canadian Forest Service Contacts

1 Atlantic Forestry Centre
P.O. Box 4000
Fredericton, NB E3B 5P7
Tel.: (506) 452-3500 Fax: (506) 452-3525
nrcan.gc.ca/forests/research-centres/afc/13447

Atlantic Forestry Centre – District Office
Sir Wilfred Grenfell College Forestry Centre
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