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An Assessment of the Costs and Economic Impacts of Invasive Species in Ontario

An updated results summary can be found in '**Estimated Expenditures on Invasive Species in Ontario: 2019 Survey Results**'

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1.0 Introduction

The main purpose of this report is to provide an estimate of total expenditure by municipalities in Ontario for prevention, detection, and control and management of invasive species. This estimate is derived based on the results of the survey, "Economic Impacts of Invasive Species to Ontario Municipalities", which was conducted by the Invasive Species Centre during January and February of 2017. A copy of this survey is provided in Appendix A. Survey responses were received from 37 municipalities across the province, of which 35 are used for estimating total expenditure. This report also discusses other economic impacts of invasive species, for which estimates are compared with the estimated expenditure on prevention and control activities to provide an assessment of costs and benefits associated with these activities.

This report is comprised of seven sections. The next section outlines the results of the surveys, focusing in particular on the funding amounts reported for invasive species prevention, detection, and control and management, and also provides an assessment of the sample representativeness. The third section describes the methods used to estimate the total aggregated expenditure on invasive species by municipalities in Ontario, while the fourth section provides the results of this analysis. Section five provides an overview of other economic impacts of invasive species, including impacts on specific industries, while the potential costs and benefits of invasive species control activities are compared in the sixth section. Finally, the conclusions of this report are summarized in the seventh section.

2.0 Survey Data

Survey responses were received from 37 municipalities in Ontario, which included cities, towns, townships, counties, and regional municipalities. However, two surveys were omitted prior to the estimation of total expenditure. A survey received from the City of Guelph had to be omitted since the expenditure amount was not provided, while a survey received from Chippewas of Georgina Island First Nation was omitted because some data necessary for conducting the estimation of expenditure was not available for this municipality. As a result of these omissions, reported data from 35 surveys is used for the estimation of total expenditure by municipalities in Ontario. The description of survey results provided below is based on these 35 surveys.

In compiling the survey results, there are a few adjustments made or assumptions imposed to address minor ambiguities with the responses, such as incomplete information. For the City of Greater Sudbury, the amount spent on invasive species control activities was indicated as "unknown"; since the survey response for this municipality also indicated that no funding was allocated for these activities, the amount spent is assumed to be zero. The survey response from the City of Ottawa indicated that $50,000 was spent every few years for Dutch elm disease. Based on this response, it is assumed that this spending amounted to $10,000 annually. The County of Dufferin and the Town of Newmarket each provided amounts spent on invasive species for both 2015 and 2016; only the 2016 amounts are recorded in the data summary and are used for the estimation process. Two municipalities, the City of Thunder Bay and the City of Waterloo, indicated that invasive species management plans had been approved for 2017 with considerable increases in funding amounts. However, only the 2016 amounts are used for the analysis conducted in this study. Assumptions are also imposed to address ambiguities for two municipalities in the reported proportions of funding allocated to prevention activities, detection activities, and control and management activities (Questions 8-10). The City of Brampton did not indicate proportions allocated to each of these activities; however, since all reported costs associated with invasive species for this municipality were incurred for labour for control activities, it is assumed that 100% of funding is allocated to control and management activities. For the City of St. Thomas, it is also assumed that 100% of funding is allocated to control and management activities, since all reported expenditure was indicated to be spent on control activities. While prevention and detection activities were also reported by this municipality, the survey response indicated that these activities occurred through volunteer efforts; as such, it is assumed that no expenses were incurred by the municipality for these activities.

2.1 Survey Results

A summary of the survey results with respect to municipality expenditures on invasive species (Question 3) and allocation of these expenditures (Questions 8-10) is provided in Table 1. This table also provides some geographic and demographic information for each municipality. As evident in this table, reported expenditures range widely across municipalities, from $0 to $6,208,000. The average expenditure across all 35 responding municipalities is $521,857, while the total combined expenditure for these municipalities amounts to $18,264,984. The municipality with the highest expenditure is the City of Ottawa, with a reported expenditure of $6,208,000. There are 10 municipalities that did not spend anything on invasive species; only three of these municipalities indicated that invasive species were not a concern. The majority of expenditures for most municipalities were allocated to control and management activities: 17 municipalities indicated that 75-100% of expenditures were allocated to these activities,

while another 5 indicated 50-75%. Only two municipalities (City of Thunder Bay and County of Dufferin) indicated that greater proportions of expenditures were allocated to other activities (i.e., detection activities).

While survey questions regarding the proportions of expenditures allocated to prevention, detection, and control and management activities provided a set of percentage ranges from which respondents could select, these ranges are converted into specific percentages for the purpose of estimating the distribution of expenditures across these categories. A number of municipalities indicated that all funds were allocated to control and management activities; in these cases, expenditures for this category were specified to be 100%. In other cases, municipalities indicated actual funding amounts for each category, from which percentages could be calculated. For all other municipalities that reported expenditures allocated to multiple categories, the indicated percentage ranges are converted to specific percentages. In most cases, this involved selecting percentages for each category that are as close to the midpoint of the range as possible. For example, several municipalities selected the range of 'Up to 25%' for prevention, the range of 'Less than 10%' for detection, and the range of '75-100%' for control and management. The percentages assigned for these municipalities are 12.5% for prevention, 5% for detection, and 82.5% for control and management. While the assigned percentages may deviate from actual allocations, these differences are most likely quite small in magnitude; in the absence of actual amounts reported by municipalities, this approach may be the best way to estimate these allocations. Assigned percentages for municipalities that reported expenditures are provided in Table 1. The averages across these municipalities are 11.6% for prevention, 11.1% for detection, and 77.3% for control and management.

The survey results also indicate the priority invasive species for which expenditures were incurred (Question 6). Twenty-eight of the 35 responding municipalities indicated one or more invasive species that were considered a priority within their jurisdiction; all seven municipalities that did not indicate priority invasive species did not spend anything on invasive species. The most frequently reported priority invasive species include emerald ash borer (19 municipalities), giant hogweed (15), and phragmites (12). Figure 1 provides a list of invasive species that were reported as priority species and indicates the number of municipalities for which each of the species was reported to be a priority. Of the 25 municipalities that reported expenditures on invasive species, 21 indicated specific amounts that were spent on specific priority invasive species[1]. These reported amounts, which account for $16,593,382 of the total combined expenditure of $18,264,984, or 90.8%, are provided in Table 2. The vast majority (95.8%) of the reported species-specific expenditure is allocated to emerald ash borer (EAB), followed by wild parsnip (1.32%), Asian long-horned beetle (1.31%), and phragmites (0.84%). Table 2 also provides percentages of non-EAB species-specific expenditure to facilitate comparisons across the remaining invasive species.

2.2 Other Survey Notes

One issue that was highlighted by the survey results is that current funding for invasive species control activities is insufficient in many municipalities (Question 11). Only ten out of the 35 responding municipalities indicated that funding for invasive species control is sufficient. Many jurisdictions suggested that they could use considerably more funding, as in some cases there were invasive species that were not being addressed or controlled. Only one municipality, Northumberland County, provided an estimate

[1] It should be noted that the species-specific amounts did not fully account for the total expenditure for four of the 21 municipalities. The combined expenditure of $16,593,382 only includes the amounts allocated to specific invasive species.

of how much additional funding would be necessary. This municipality currently spends $7,000 per year, but indicated that at least $50,000 would be needed to adequately control all invasive species in the county. As a result of this issue, total expenditure necessary to adequately manage and control invasive species across municipalities in the province may be much higher than is estimated in this report. This issue is taken into consideration in the comparison of costs and benefits of invasive species control activities, described in section six, as the identified benefits would only be realized if invasive species are adequately controlled in the province, which may require considerably more funding than is currently being allocated. Unfortunately, it is not possible to discern from the surveys how much more funding would be required to adequately control invasive species.

2.3 Sample Representativeness

It is important to examine the representativeness of the sample, since the validity and accuracy of the extrapolated survey results is dependent to a large extent on the assumption of a representative sample. The sample representativeness is assessed based on factors such as population, land area, and income. This assessment is initially conducted for the full sample. Next, the sample municipalities are divided into four regions within the province: North, East, Central, and West (see Figure 2)[2]. The representativeness of the sample is then assessed within each region.

The sample includes 35 of 444 municipalities within Ontario, or 7.9%. These sample municipalities account for 43.3%[3] of Ontario's population of 12,851,821 (based on 2011 Census data[4]). The land area for the sample municipalities accounts for 9.8% of the total land area for all municipalities[5]. The average household income for the sample municipalities, as reported by the 2011 National Household Survey, is $85,036, which is within 1% of the provincial average household income of $85,772. Hence, based on population, the sample is not very representative of all municipalities within the province, but based on land area and household income, the sample municipalities comprise a relatively representative sample of all municipalities. However, it is possible that the lack of representativeness with respect to population could bias the results of this report, particularly since population influences expenditure on invasive species control and management activities, as described below in the results section. This influence is taken into account in the methods used to estimate total expenditure, which may reduce this bias.

Differences are found to exist across regions in the assessment of sample representativeness. For the North region, responses were received from six municipalities, representing 4.2% of all municipalities in the region. The population within the sample municipalities represents 43.6% of the region's population, while the land area within these municipalities accounts for 8.4% of total area in the northern municipalities. Household income within the sample municipalities of $68,153 is 99.1% of average household income across the North region.

Only three survey responses were received from municipalities in the East region, accounting for 2.6% of municipalities within this region. This is the lowest sample proportion among the four regions. Despite

[2] The region in which each of the sample municipalities is located is provided in Table 1.

[3] Survey respondents included the Regional Municipalities of Peel and York as well as a number of census subdivisions located within these regional municipalities. The populations of these CSDs are not double counted in the calculation of this proportion.

[4] Data is derived from the 2011 Census since not all data required for this study is currently available for the 2016 Census.

[5] Land area, in square kilometres, is derived from Statistics Canada's Community Profiles for the 2011 Census.

this low proportion, the three sample municipalities account for 52.1% of total population in this region. Household income is almost 10% higher for the sample municipalities, relative to average income across the region. These municipalities comprise an area equal to 8.4% of total area of municipalities in the region. Overall, based on these factors, the sample for the East region is not very representative of municipalities within this region, which highlights a prominent issue with small sample sizes.

The Central region has a much larger sample proportion, with responses received from 20% of municipalities within this region. These municipalities account for 43.7% of the region's population, which is not nearly as disproportionate as the samples in the other regions, but is still substantially biased toward municipalities with relatively higher populations. There is also upward bias for these municipalities in terms of area, at 30.2% of total area in the region, and household income, which is 11.8% higher than the regional average.

The West region has the largest number of municipalities in the sample (15), comprising 11.5% of all municipalities in the region. As with the samples in the other three regions, the sample municipalities account for a much higher proportion of the population (37.6%). However, contrary to the other regions, the proportion of land area covered by the sample municipalities is relatively lower (7.9%). Household income for these municipalities is relatively close to the regional average, at 2.7% lower than the average.

It is evident that the small sample size has hindered the representativeness of the sample to some extent. The level of representativeness varies across the factors used for this assessment. It appears that higher populated municipalities are over-represented in the sample. It may be the case that the higher population in these municipalities and the corollary higher tax base permits a larger amount of staff in municipal offices, which may increase the likelihood of receiving a response to the survey, while the higher tax revenue may increase the likelihood that funding is allocated to invasive species in these municipalities.

Based on the land area and household income factors, the sample is more representative of the full set of municipalities in the province, though the degree of representativeness based on these factors diminishes to some degree for the regional samples. This is to be expected, however, given that breaking down the full sample by region results in four much smaller samples. There also appears to be variation in regional representativeness, as the Central and West regions are over-represented in the full sample while the North and East regions are under-represented, based on the proportions of municipalities included in the samples for each region.

3.0 Methods for Estimating Total Expenditure

The sample size of survey respondents is quite small relative to the total population of municipalities in Ontario. Usable survey responses were received from 35 municipalities across the province, both census divisions (CDs) and census subdivisions (CSDs), out of a total of 444 municipalities (CDs and CSDs) in the province. This issue may significantly impact the accuracy of estimating total municipal expenditure in the province through a simple extrapolation process. The margin of error for this sample size based on the total population is 15.92%[6], which is relatively high. To address this issue, the estimation process involves a regression modeling approach for small area estimation, an approach that has been used in the literature on poverty for the purpose of estimating poverty levels at a small scale, or low levels of aggregation, where household expenditure is used as an indicator of poverty (e.g., Elbers et al., 2000; Demombynes et al., 2002; Elbers et al., 2003). The regression modeling approach is the primary approach used in this study to estimate total expenditure by municipalities in the province. However, for comparison purposes, extrapolations of the survey results are also conducted to estimate total expenditure.

3.1 Regression Model Approach

Based on previous studies on small area estimation, the estimation process for this study involves regressing observed expenditure (as reported by responding municipalities) on a set of factors that are likely to influence the level of expenditure and that are observable for both sample and non-sample municipalities. The parameter estimates from the regression model are then applied to each municipality to predict the level of expenditure for each municipality based on the observable factors included in the regression model. This involves multiplying the parameter estimate for each factor by the observed level of the factor for each municipality and summing these products across all factors (including a constant term) to derive a predicted expenditure for the municipality. These predicted expenditures are then aggregated for all municipalities to generate an estimate of total expenditure for municipalities across the province.

A log-linear functional form is used for the regression model estimated in this analysis. This involves log-transforming the dependent variable (expenditure), while the explanatory variables (i.e., factors that influence expenditure) remain in their level form. The explanatory variables included in the regression model include population of the municipality (in thousands), average household income of the municipality (in thousands of dollars), variables indicating whether the municipality is a city and whether the municipality is located in the east, central, or west regions of the province, and a variable indicating whether emerald ash borer has been detected in the municipality[7]. In addition, a constant term is included in the regression model.

The specification of the explanatory variables to include in the model is based on observations from the survey responses. From the survey results (see Table 1), it appears that expenditure on invasive species control and management is greater in municipalities with higher populations, particularly for cities. This

[6] This margin of error is calculated based on a 95% confidence level, using the calculator available at: https://www.checkmarket.com/sample-size-calculator/.

[7] This variable is specified based on municipalities for which detections have been reported by the Emerald Ash Borer Information Network (http://www.emeraldashborer.info/).

stands to reason, since a higher population would likely result in a larger tax base for the municipality, which could increase the ability to allocate funds to invasive species control activities. The level of household income may also influence the ability to allocate funds to these activities. Population data for all municipalities in Ontario is derived from Statistics Canada's Community Profiles, based on the 2011 Census, while household income data is derived from the 2011 National Household Survey. There also appears to be regional differences across sample municipalities in the amount of funding allocated for invasive species prevention and control activities. As a result, variables are created to represent each of the four regions of the province, where each variable is set equal to 1 for municipalities located within the region, and 0 otherwise. Only three of the region variables are included in the regression model in order to avoid a multicollinearity issue. The variable for the North region is omitted from the model; as a result, parameter estimates for the other three region variables indicate the differences in expenditures relative to those of municipalities in the North region. Emerald ash borer (EAB) is the most common invasive species among survey respondents for which funding is allocated for control and management activities. As indicated in the previous section, expenditures reported for EAB were much higher than for other invasive species. As a result, a variable is included to account for municipalities in which EAB has been detected (equal to 1, 0 otherwise), as expenditure may be higher in these municipalities relative to those in which EAB has not been detected.

Summary statistics for the explanatory variables for all 444 municipalities in Ontario are provided in Table 3. The population of these municipalities ranges from 10 to just under 1.3 million, with an average of 38,768. Average household income within these municipalities ranges from $40,719 to $163,017, with an average of $76,335. The regional distribution of municipalities includes 25.9% in the East region, 12.4% in the Central region, and 29.3% in the West region, with the balance of 32.4% in the North region. Approximately 10% of municipalities in Ontario are categorized as cities. Finally, emerald ash borer has been detected in 61.7% of municipalities.

3.2 Extrapolation Methods

Invasive species expenditures reported on the surveys are extrapolated to the provincial level through two approaches. The first approach involves a simple extrapolation based on the average expenditure for the sample municipalities and the total number of municipalities in the province, where the average expenditure is multiplied by the number of municipalities (444) to estimate the total expenditure by municipalities across the province. The second approach involves an extrapolation based on per capita expenditure within the sample municipalities and the total population of the province, where the expenditure per person is multiplied by the total population. This approach is used for two reasons: first, the sample is heavily biased toward higher populated municipalities; and second, population has a significant impact on the level of expenditure, as evident from the results of the regression model (provided in the following section). Hence, accounting for the influence of population in the extrapolation process may reduce the bias inherent in the simple extrapolation approach and generate a more accurate estimate of total expenditure. These two approaches are also used to conduct extrapolations from the sample municipalities within each region to the regional level. These regional extrapolated amounts are then aggregated to estimate the total provincial expenditure. This may generate more accurate estimates relative to the extrapolations to the provincial level.

4.0 Results

4.1 Regression Model Results

The parameter estimates for the regression model are provided in Table 4. The *F*-statistic for this model (8.78; $p<.001$) indicates that the parameter estimates are jointly different from zero. These estimates indicate that population has a positive impact on expenditure while household income has a negative impact. The negative estimate for household income is contrary to the hypothesized effect on expenditure, but this effect may be due to correlation between some of the explanatory variables. For example, there is a relatively high correlation between household income and the Central region (0.69), as well as between population and the Central region (0.44). As a result, the negative estimate for income may be offsetting to some degree the positive impacts of the Central region and population. Expenditure is higher for municipalities that are categorized as cities, while the results of the region variables indicate that expenditure is significantly higher for municipalities in the Central and West regions, relative to municipalities in the North region. While the estimate for the East region indicates that expenditure is higher relative to the North region, this difference is not statistically significant. Finally, expenditure is higher in municipalities in which emerald ash borer has been detected.

The regression model results indicate an adjusted *R*-squared value of 0.6158, which implies that the variables included in the model explain approximately 62% of the variation in expenditure. Hence, while the number of factors included in the model to explain variation in expenditure is relatively low, these factors account for a relatively large share of the variation, which enhances confidence in the subsequent estimated total municipal expenditure for the province.

The parameter estimates are then used to predict expenditure on invasive species for each of the 444 municipalities in Ontario. During this process, an extreme outlier was found for one municipality: the City of Toronto. Due primarily to a much higher population than any other municipality, the predicted expenditure for Toronto was more than double the combined total predicted expenditure for all other municipalities in the province. Rather than dropping this outlier, the measure of population for Toronto is adjusted such that its population density is equivalent to the average population density of the three surrounding regional municipalities: Halton, Peel, and York. This results in a much more reasonable prediction of expenditure for Toronto, which still ranks among the top five municipalities in terms of predicted expenditure. Aside from the City of Toronto, there are no other obvious outliers.

Aggregating the predicted expenditures across all municipalities generates a total estimated expenditure by Ontario municipalities on invasive species prevention and control activities of $55.0 million per year. Based on the average percentages of expenditures allocated to each of the three categories of activities by the sample municipalities (see Table 1), the distribution of this total expenditure would include $6.4 million for prevention activities, $6.1 million for detection activities, and $42.5 million for control and management activities. Based on the percentages of reported species-specific expenditure (see Table 2), approximately $52.7 million of this total amount is spent on emerald ash borer, while $726,000 is spent on wild parsnip, $720,000 is spent on Asian long-horned beetle, and $462,000 is spent on phragmites.

The estimated expenditures for individual municipalities range from $0 to $6,376,582. There are 125 municipalities, or 28.2% of all municipalities, for which the estimated expenditure is less than $10 (which essentially implies no expenditure). This percentage is consistent with the percentage of survey

respondents that reported no expenditure (28.6%). On the other end of the scale, there are 17 municipalities for which the estimated expenditure is greater than $1 million.

4.2 Extrapolation Results

The method of extrapolation is found to have a substantial impact on the estimated expenditure at the provincial level. Conducting the extrapolation based on average expenditure for the sample municipalities generates an estimated total provincial expenditure of $231.7 million, while conducting the extrapolation based on expenditure per capita generates an estimated total provincial expenditure of $42.2 million.

Since it is evident from the regression model results that significant differences exist across regions in the level of expenditure on invasive species control and management activities, extrapolations are also conducted to the regional level prior to aggregation at the provincial level. This extrapolation process results in an estimated total expenditure of $319.6 million based on an extrapolation of average municipality expenditure and an estimated total expenditure of $40.9 million based on an extrapolation of per capita expenditure. However, due to the low numbers of sample municipalities within each region, particularly the East region (3 municipalities), these estimates may not be any more accurate than the estimates based on the extrapolation of the survey results to the provincial level.

The estimates based on per capita expenditure are likely more accurate since expenditure is significantly impacted by the population of the municipality. In addition, the per capita expenditure estimates are similar to the estimated expenditure generated through the regression model approach ($55.0 million), which enhances confidence in these estimates. For the estimated expenditure based on the extrapolation of per-capita expenditure to the provincial level ($42.2 million), approximately $4.9 million would be allocated to prevention activities, $4.7 million to detection activities, and $32.6 million to control and management activities.

4.3 Limitations and Other Considerations

The primary limitation of this study is the relatively small sample size. This issue may negatively impact the accuracy of the estimated total provincial expenditure on invasive species prevention and control activities. As such, this estimate should be viewed with caution. The small sample size also increases the likelihood and magnitude of potential bias due to outliers. A large proportion of the total combined expenditure on invasive species reported in the surveys occurs in two municipalities: the City of Ottawa and the City of Mississauga. The combined expenditure in these two municipalities accounts for 62.1% of the total across all sample municipalities. This does not necessarily imply that these municipalities are strictly outliers, as they are both among the highest populated municipalities in the sample, but they likely have a considerable influence on the results of this study.

There are other potential sources of bias for the estimated expenditure. The sample in this study is not a randomized sample, as municipalities that were contacted could choose whether or not to respond to the survey. Bias is more likely to be an issue with voluntary response samples. There could be factors influencing the decision to respond that also impact the estimated expenditure. For example, municipalities with funding for invasive species control activities may be more likely to respond, while municipalities that do not incur expenditures for invasive species may be less likely to respond. This would cause the resulting estimate of total expenditure to be biased upward. However, it should be noted that ten municipalities that responded to the survey reported no expenditures on invasive species, which suggests that this issue is unlikely to be a significant source of bias. Higher populated municipalities may

have more staff, which could increase the likelihood of a response. These municipalities are also more likely to have higher funding for invasive species activities, which could contribute to upward bias in the estimated total expenditure.

There may be other factors that could influence expenditure on invasive species at the municipality level. However, factors that are either not observable or for which data is not available for all municipalities cannot be accounted for in the model. This may impact the ability of the modeling approach to generate an accurate estimate of expenditure. However, the level of the adjusted *R*-squared (0.6158) suggests that the most important factors that influence expenditure are likely included in the model. In addition, while increasing the number of explanatory variables may enable the model to explain more of the variation in expenditure, this would also reduce the number of degrees of freedom, which would reduce the likelihood of finding statistically significant impacts (especially since the sample size is small) and increase the estimated error of the regression model.

It should be noted that the estimated expenditure for the province is for spending at the municipality level. As such, this estimate does not include or account for provincial or federal level funding for invasive species control and management. While it is difficult to estimate the total spent by the federal and provincial governments on invasive species control in Ontario, examples can be found of costs incurred or funding provided by federal or provincial agencies. One example is the expenditure associated with zebra mussels in the Great Lakes, where $250 million is spent annually to control zebra mussels in water intake pipes[8]. Another example is costs that were incurred by the federal government to control Asian long-horned beetle, where the Canadian Food Inspection Agency (CFIA) was spending approximately $3.3 million per year to cut down affected trees in the GTA[9]. The CFIA has also allocated funding of approximately $60 million per year from 2014/15 to 2016/17 for controlling or eradicating invasive plant pests and diseases[10]. Funding has also been provided periodically to combat invasive species by government agencies such as Natural Resources Canada and the Ontario Ministry of Natural Resources and Forestry. These examples of funding for and expenditures on invasive species control and management by other levels of government, for which funding is typically separate from expenditure at the municipal level, provide evidence that total expenditure on invasive species control in Ontario likely far exceeds the estimated expenditure by municipalities in the province.

[8] As reported by Global News on October 9, 2015: http://globalnews.ca/news/2269026/zebra-mussels-cost-canadians-billions-each-year-cost-to-manitobans-still-unknown/.

[9] As reported by the Globe and Mail on February 21, 2014: http://www.theglobeandmail.com/news/toronto/a-battle-against-time-to-clear-out-asian-long-horned-beetle/article17024577/.

[10] CFIA 2014-15 Report on Plans and Priorities: http://www.inspection.gc.ca/about-the-cfia/accountability/reports-to-parliament/2014-15-rpp/eng/1392305502104/1392305571559.

5.0 Economic Impacts of Invasive Species

As evident from the survey responses and from the estimated total expenditure by municipalities, the costs associated with invasive species control and management are substantial. However, the economic impacts of invasive species extend well beyond these costs. A growing body of literature has identified other economic impacts, such as impacts on specific industries that are affected by the presence of invasive species, and has estimated the magnitude of these impacts. This section provides a brief overview of the results of some of these studies, particularly those that relate to invasive species that are prominent in Ontario or that have been identified as priority species by survey respondents.

The invasive species that is identified as a priority species by most responding municipalities is emerald ash borer (EAB). A number of studies on the economic impacts of EAB have been conducted in Canada and in the United States. For example, McKenney et al. (2012) estimated the potential costs of treatment and removal of EAB in Canadian urban areas over a 30-year time horizon. This study estimated that these costs could range from $451 million to $2,001 million over this period (for street trees as well as backyard trees), depending on the assumptions for the rate of spread of this species, the percentage of trees treated, and the discount rate. The equivalent annual costs range from $31 million to $77 million. Based on a spread rate of 30 km/year (the medium spread rate), a treatment rate of 10% of trees, and a discount rate of 4%, the estimated cost was $891 million, of which approximately 84% would be incurred in Eastern Canada. This works out to the equivalent of an annual cost of approximately $43 million for Eastern Canada. The authors noted that these estimated costs provide some justification for investing in activities to reduce the spread of this invasive species in Canada.

Similar studies have been conducted in the United States. Kovacs et al. (2010) estimated the cost of treatment and tree removal over a 10-year time horizon in communities across 25 states that could potentially be affected by EAB. Based on the predicted 17 million ash trees that would need to be treated, removed, and replaced, the discounted cost over the 10-year period was estimated to be $10.7 billion. Sydnor et al. (2007) estimated the potential economic impacts of EAB in the state of Ohio, assuming the complete loss of the native ash population. The estimated costs for tree removal were between $0.7 and $2.9 billion and the estimated costs for tree replacement were between $0.3 and $1.3 billion. In a subsequent related study on these potential costs in the states of Illinois, Indiana, Michigan, and Wisconsin, Sydnor et al. (2011) estimated the costs of tree removal to be $3 to $5.8 billion and the costs of tree replacement to be $2.7 to $5.2 billion, assuming the complete loss of ash trees.

In addition to costs to local governments of tree removal and replacement, studies have identified and estimated other economic impacts associated with EAB. Impacts identified in a study by Aukema et al. (2011) included increased household expenditures (to treat or remove affected trees), residential property value loss, and timber loss. This study estimated the annual value of these costs and impacts in the U.S., the results of which indicated local government expenditures of $850 million, household expenditures of $350 million, property value loss of $380 million, and timber loss of $60 million. Sydnor et al. (2007) estimated the loss of landscape value due to EAB, which could occur due to factors such as increased heating and cooling costs, reduced property values, increased stormwater runoff, and reduced habitat and aesthetic quality. The landscape value for an ash tree on private property or along the street was conservatively estimated to be $807. This figure was used to estimate total loss of landscape value for the state of Ohio of between $0.8 and $3.4 billion, an amount which surpassed the costs of tree

removal. Potential losses of landscape value were also estimated per 1,000 residents, ranging from $71,045 to $301,249. These estimates could be applied to Ontario to estimate the potential economic impacts of EAB for individual municipalities or for the province as a whole. For example, based on the low end of this estimated range (assuming a similar value in Canadian currency) and based on the population of Ontario reported by Statistics Canada for the 2016 Census of 13.45 million, the estimated loss of landscape value across the province due to EAB would be $955.6 million.

Studies on the economic impacts of invasive species have focused primarily on costs of control and the loss of marketable goods and services (Colautti et al., 2006). Many impacts of invasive species are difficult to quantify economically, particularly impacts on non-market goods such as water quality and ecosystem services, due to a lack of data and the resulting impediment to accurately estimating these impacts. For example, the impacts of giant hogweed include reduced native plant diversity, increased erosion in river banks, and potential health hazard when its sap comes into contact with human skin (Henry et al., 2009). However, it can be difficult to place an economic value on some of these impacts, with the possible exception of health care costs incurred due to this species. In one study on these impacts, Reinhardt et al. (2003) estimated annual health costs associated with skin burns from giant hogweed to be over €1,000,000 in Germany, based on assumptions for the number of people affected and the costs for hospital and outpatient care. Applying these assumptions to Ontario would generate a similar economic impact in the province (approximately $1.4 million per year).

Invasive species can have economic impacts on the tourism and recreation industry. The presence of giant hogweed and Japanese knotweed in riparian areas can cut off access to these areas, which can restrict tourism and leisure activities (Williams et al., 2010). There have been studies conducted in other jurisdictions to estimate impacts of invasive species on tourism and recreation, primarily through survey approaches[11]. For example, a study by Bell (2006) found that recreational lake users in Florida would be willing to pay an additional $5.06 per visit if a program to control invasive aquatic weeds was maintained. Assuming a similar willingness to pay for recreational lake users in Ontario, and based on the number of annual visitors to Ontario provincial parks, Vyn (2016) estimated an economic benefit to the tourism and recreation industry in Ontario of $68.9 million per year if invasive aquatic weeds are controlled.

Invasive weed species can impact the agriculture industry, with economic impacts occurring through yield losses and increased herbicide costs. Williams et al. (2010) estimated the cost of non-native weed control in Great Britain to be £90 million per year and the value of yield loss due to non-native weeds to be £104 million per year. The yield loss estimate was based on assumed yield losses of 5% for cereal crops and potatoes, 4% for oilseed crops and vegetables, and 3% for sugar beet and fodder crops. According to Pimental et al. (2001), crop yields in the U.S. are reduced by 12% because of weeds, of which 73% are non-indigenous. The resulting value of the yield reduction due to invasive weed species (8.76%) is $27.9 billion per year. The value of crop yield loss in Ontario due to invasive weed species can be estimated using the same assumptions for percentage reduction in yields and proportion attributable to non-indigenous species. Based on the estimated yields and values of field crops for 2015 reported by the Ontario Ministry of Agriculture, Food & Rural Affairs (OMAFRA)[12], the estimated annual economic impact of invasive species on the field crop sector in Ontario is $408 million.

[11] Lapointe et al. (2011) noted that estimating impacts by conducting surveys of local experts and stakeholders is likely to be viewed as subjective.

[12] Available at: http://www.omafra.gov.on.ca/english/stats/crops/estimate_new.htm.

Pimental et al. (2005) compiled estimates of environmental damages and losses in the U.S. from a variety of invasive species, which added up to almost $120 billion per year. Affected industries identified in this study include tourism and recreation, agriculture, forestry, fishing, and energy. Further, this estimate does not include the value of losses in biodiversity, ecosystem services, and aesthetics, which would increase the estimated impacts substantially. In a similar study for Canada, Colautti et al. (2006) estimated an annual economic impact of $16.6 billion for 16 prominent "nuisance" invasive species on the fisheries, agriculture, and forestry industries. This estimate was based on the value of each affected resource and the proportion of value lost due to the invasive species. However, they acknowledged that their model is crude, and that there are a number of caveats to consider in their process of generating cost estimates. For example, they only accounted for costs incurred by resources or industries that are directly impacted by the invasive species, and did not account for indirect costs on other related industries (e.g., tourism, health care) or non-market values (e.g., loss of aesthetic value). In addition, there was a serious lack of data from which to track or estimate direct and indirect market and non-market impacts. The damage calculations in this study were based only on reduced production. The proportions of production losses were based on studies of individual invasive species in Canada. Based on these proportions, Colautti et al. (2006) estimated a range of losses between 20% and 52% of the impacted resources.

The results of the study by Colautti et al. (2006) can be applied to the fisheries and forestry industries in Ontario. For example, using the low end of the range indicated in this study and assuming that invasive species in the province have a 20% impact on production in these industries, and based on the estimated value of the contribution of commercial and recreational fishing to Ontario's economy of $2.5 billion annually[13], the potential economic impact of aquatic invasive species such as Eurasian water milfoil and water soldier on the fisheries industry would be $500 million per year. Similarly, based on the estimated annual value of the provincial forestry industry of $12.9 billion[14], the potential economic impact of forest invasive species such as Asian long-horned beetle and emerald ash borer would be $2.6 billion per year.

Property values may also be negatively impacted by invasive species. As mentioned above, emerald ash borer is an example of an invasive species that could cause such an impact. There have also been studies that have estimated the impacts of aquatic invasive species on waterfront property values (e.g., Horsch and Lewis, 2009; Zhang and Boyle, 2010). The results of these studies were used by Vyn (2016) to estimate a potential impact of aquatic invasive species of $1.7 billion on waterfront properties in Ontario[15].

As described in this section, potential economic impacts of invasive species can be estimated for specific industries based on a number of assumptions regarding the nature and extent of these impacts. This approach has allowed for providing crude estimates of impacts on Ontario's agriculture, fisheries, forestry, and tourism and recreation industries. However, there are a number of non-market impacts, such as the value of ecosystem services or aesthetics, for which economic impacts are very difficult to estimate. As such, the combined value of the economic impacts estimated in this section may substantially underestimate total economic impacts associated with invasive species in the province.

[13] This amount was estimated by the Ministry of Natural Resources and Forestry in their strategic plan for Ontario fisheries published in 2015, entitled, "Ontario's Provincial Fish Strategy: Fish for the Future." Available at: https://www.ontario.ca/document/strategic-plan-ontario-fisheries.

[14] Based on figures reported by the Ministry of Natural Resources and Forestry: https://www.ontario.ca/page/forestry-facts.

[15] This would be a one-time impact rather than an annual impact.

6.0 Comparison of Costs and Benefits of Invasive Species Control

The primary benefits realized through invasive species control and management activities is the reduction in costs and ecological damage (Reinhardt et al., 2003). These benefits can be quantified by estimating the economic value associated with these costs and damages, which, as mentioned above, may be difficult to do. Additional benefits can accrue through a reduction in economic impacts of invasive species on specific industries, which may be easier to estimate (e.g., Pimental et al., 2005). A number of these impacts were estimated for Ontario in the previous section.

Results of previous studies have suggested that the potential benefits of invasive species control outweigh the costs. In the study by Sydnor et al. (2007) on the economic impacts of EAB, the loss of landscape value was found to exceed the tree removal costs, which suggests that the costs of eradication through removal of ash trees may be outweighed by the benefits associated with reducing the loss of landscape value. An analysis by Kovacs et al. (2011) on the cost of potential EAB damage suggested that spending on activities to slow the spread of EAB can be cost-effective, as it can reduce future costs of removal and replacement.

A rough and rudimentary cost-benefit analysis can be conducted based on the results of the survey analysis, which provide an estimate of the costs of invasive species control activities, and the estimated economic impacts provided in the previous section, which provide an estimate of the potential benefits of invasive species control. A major caveat of this analysis is that its outcome is based on the assumption that the magnitudes of these estimated costs and benefits associated with invasive species control are relatively accurate. In fact, this may not be the case, given the rough nature of the estimated economic impacts of invasive species in Ontario and the limitations associated with the estimate of total expenditure in Ontario, as discussed earlier. In addition, this analysis requires the assumption that the incurred costs will result in the identified benefits (i.e., reduced economic impacts). Since many of the responding municipalities indicated that current funding for invasive species was insufficient, this implies that this assumption may not hold. As such, the estimated provincial expenditure may not achieve full control of invasive species, which would reduce the accrued benefits. Conversely, to address this issue, an assumption could be made regarding the required increase in expenditure to achieve the estimated level of benefits.

Aggregating the economic impacts on the agriculture, fisheries, forestry, health care, and tourism and recreation industries in Ontario that were estimated in the previous section yields a total estimated benefit for these industries associated with invasive species control of approximately $3.6 billion per year[16]. The magnitude of the estimated potential impacts of invasive species on various industries in Ontario suggests that a considerable amount could be spent on prevention and control of invasive species in the province. Assuming that the estimated annual expenditure on invasive species by municipalities in Ontario of $55.0 million is even remotely accurate, there could be a considerable net benefit to expenditure on prevention, detection, and control and management of invasive species in the province. However, this estimated expenditure does not include federal and provincial government funding or expenditure for invasive species control activities. In addition, since most responding municipalities indicated that current funding for these activities was insufficient, this suggests that expenditures may

[16] Note that this figure includes only annual impacts and does not include one-time estimated impacts on landscape values and property values.

need to be increased substantially in order to adequately control invasive species and avoid or minimize the economic impacts on various industries in the province. But even if ten times this estimated amount is required each year to prevent and control invasive species and to avoid the economic impacts described in the previous section, there would still be a net benefit to the province. In addition, the actual level of benefits associated with reducing the impacts of invasive species may exceed the sum of the estimated amounts for specific industries provided in the previous section, since there are likely other impacts that have not been accounted for in this measure of benefits. Hence, despite the rough nature of both the estimated costs and estimated benefits associated with invasive species control, it appears quite likely that incurring considerable costs to control invasive species would generate a net benefit to the province.

7.0 Conclusions

The main purpose of this report is to provide an estimate of the total expenditure by municipalities in Ontario on invasive species prevention and control activities. The primary approach used to estimate this expenditure is a regression model approach, which is conducted based on the results of the surveys and based on a number of factors that are identified to influence the level of expenditure by municipalities. The results of the regression model are used to generate an estimate of the total expenditure of $55.0 million. For comparison purposes, an extrapolation approach is also used to estimate the total expenditure. For extrapolations based on per capita expenditure, total expenditure is estimated to be $42.2 million based on a direct extrapolation to the provincial level and $40.9 million based on an aggregated total of extrapolations to the regional level. The fact that these estimated totals are relatively similar across the different approaches enhances confidence in these estimates. However, it should be stressed that the results of this report must be viewed with extreme caution, as the small sample size may have substantially impeded the ability to estimate a relatively accurate total expenditure for municipalities in Ontario.

In addition, it should be noted that this estimated total only includes municipal level expenditures and would not include funding provided for invasive species control by provincial and federal government agencies. Hence, the total amount spent in the province would be greater than the amount estimated in this report, assuming that this amount is relatively accurate.

It is evident from the previous section that the potential estimated economic benefits associated with invasive species control may easily outweigh the estimated costs of control that are currently being incurred at the municipality level. However, it should be noted that this estimate does not include costs incurred at the provincial level or federal level for control of invasive species. In addition, given the number of responding municipalities that indicated insufficient funds for invasive species control, a considerable increase in expenditure on invasive species control may be necessary to achieve the estimated economic benefits, as these benefits are estimated based on the assumption that impacts of invasive species on specific industries in the province are eliminated.

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Tables and Figures

Table 1: Expenditure and demographic data for sample municipalities

Municipality	Region	Expenditure on Invasive Species	Expenditure Breakdown (%)			Population	Land Area (sq km)	Household Income	Per Capita Expenditure ($/person)
			Prevention	Detection	Control & Management				
City of Brampton	Central	$5,440	0.0	0.0	100.0	523,911	266.34	$89,010	$0.01
City of Greater Sudbury	North	$0				160,274	3,227.38	$76,772	
City of Hamilton	West	$2,610,000	15.0	17.5	67.5	519,949	1,117.23	$76,742	$5.02
City of London	West	$240,000	8.0	13.0	79.0	366,151	420.57	$73,107	$0.66
City of Markham	Central	$15,000	12.5	5.0	82.5	301,709	212.58	$108,520	$0.05
City of Mississauga	Central	$5,129,000	30.0	15.0	55.0	713,443	292.40	$95,052	$7.19
City of North Bay	North	$0				53,651	319.05	$70,804	
City of Ottawa	East	$6,208,000	5.0	5.0	90.0	883,391	2,790.22	$96,815	$7.03
City of Peterborough	East	$230,000	15.0	17.5	67.5	78,698	63.80	$66,284	$2.92
City of Pickering	Central	$300,000	12.5	5.0	82.5	88,721	231.59	$109,791	$3.38
City of Sarnia	West	$54,450	0.0	0.0	100.0	72,366	164.71	$75,892	$0.75
City of St. Thomas	West	$13,000	0.0	0.0	100.0	37,905	35.52	$64,621	$0.34
City of Stratford	West	$155,000	12.5	5.0	82.5	30,886	26.95	$71,523	$5.02
City of Thunder Bay	North	$35,000	25.0	50.0	25.0	108,359	328.24	$71,142	$0.32
City of Waterloo	West	$307,000	8.0	33.0	59.0	98,780	64.02	$100,414	$3.11
City of Woodstock	West	$128,000	0.0	0.0	100.0	37,754	49.00	$68,492	$3.39
County of Dufferin	West	$1,150	8.0	59.0	33.0	56,881	1,486.31	$94,295	$0.02
County of Simcoe	Central	$88,700	15.0	17.5	67.5	446,063	4,859.16	$80,842	$0.20
Mun. of Northern Bruce Peninsula	West	$30,000	0.0	0.0	100.0	3,744	781.77	$66,873	$8.01
Northumberland County	East	$7,000	12.5	5.0	82.5	82,126	1,905.34	$74,998	$0.09
Regional Municipality of Peel	Central	$366,719	12.5	5.0	82.5	1,296,814	1,246.89	$93,916	$0.28
Regional Municipality of York	Central	$1,419,000	47.5	5.0	47.5	1,032,524	1,762.17	$110,751	$1.37

Table 1: Expenditure and demographic data for sample municipalities (cont'd)

Municipality	Region	Expenditure on Invasive Species	Expenditure Breakdown (%)			Population	Land Area (sq km)	Household Income	Per Capita Expenditure ($/person)
			Prevention	Detection	Control & Management				
Town of Aurora	Central	$0				53,203	49.78	$130,552	
Town of East Gwillimbury	Central	$80,000	12.5	5.0	82.5	22,473	245.03	$108,663	$3.56
Town of Erin	West	$0				10,770	297.75	$116,434	
Town of Fort Erie	West	$400,000	12.5	5.0	82.5	29,960	166.24	$65,104	$13.35
Town of Goderich	West	$0				7,521	7.91	$69,152	
Town of Kingsville	West	$60,000	12.5	5.0	82.5	21,362	246.84	$78,942	$2.81
Town of Kirkland Lake	North	$0				8,133	262.54	$65,108	
Town of Newmarket	Central	$381,412	12.5	5.0	82.5	79,978	38.33	$103,414	$4.77
Town of Parry Sound	North	$1,113	0.0	0.0	100.0	6,191	13.36	$57,991	$0.18
Town of Southwold	West	$0				4,494	301.71	$91,030	
Town of Whitchurch-Stouffville	Central	$0				37,628	206.41	$113,571	
Township of Laird	North	$0				1,057	102.43	$69,862	
Township of Strathroy-Caradoc	West	$0				20,978	274.12	$69,779	
Total		$18,264,984				4,684,424	20,119.65		
Average		$521,857	11.6	11.1	77.3			$85,036	$2.95

Table 2: Species-specific expenditures reported by sample municipalities

Invasive Species	Reported Expenditure	Percentage of Reported Expenditure	Percentage of Non-EAB Expenditure
Emerald Ash Borer (EAB)	$15,898,000	95.81%	--
Wild Parsnip	$219,088	1.32%	31.51%
Asian Long-horned Beetle	$216,719	1.31%	31.17%
Phragmites	$139,850	0.84%	20.11%
Giant Hogweed	$49,681	0.30%	7.14%
Gypsy Moth	$37,000	0.22%	5.32%
Manitoba Maple	$12,760	0.08%	1.83%
Dutch Elm Disease	$10,000	0.06%	1.44%
Dog Strangling Vine	$7,810	0.05%	1.12%
Common Buckthorn	$1,779	0.01%	0.26%
Japanese Knotwood	$564	0.00%	0.08%
Garlic Mustard	$132	0.00%	0.02%
Total	$16,593,382	100.00%	100.00%

Table 3: Summary statistics across Ontario municipalities (*n* = 444) for the variables included in the regression model

Variable	Description	Mean	Standard Deviation	Minimum	Maximum
Population	Population of the municipality, in thousands	38.768	119.677	0.010	1,296.814
Income	Average household income ($000)	76.335	16.167	40.719	163.017
City	= 1 if the municipality is a City	0.099	0.299	0.000	1.000
East	= 1 if the municipality is in the East region	0.259	0.439	0.000	1.000
Central	= 1 if the municipality is in the Central region	0.124	0.330	0.000	1.000
West	= 1 if the municipality is in the West region	0.293	0.456	0.000	1.000
EAB	= 1 if emerald ash borer has been detected	0.617	0.487	0.000	1.000

Table 4: Results of the regression model (dependent variable: ln(Expenditure))

Variable	Parameter Estimate		Standard Error
Population	0.004	*	0.002
Income	-0.102	**	0.046
City	2.955	**	1.237
East	4.493		2.804
Central	6.628	**	2.695
West	4.903	**	1.806
EAB	5.128	***	1.392
Constant	7.364	**	3.591

Note: Asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Figure 1: Priority invasive species reported by sample municipalities

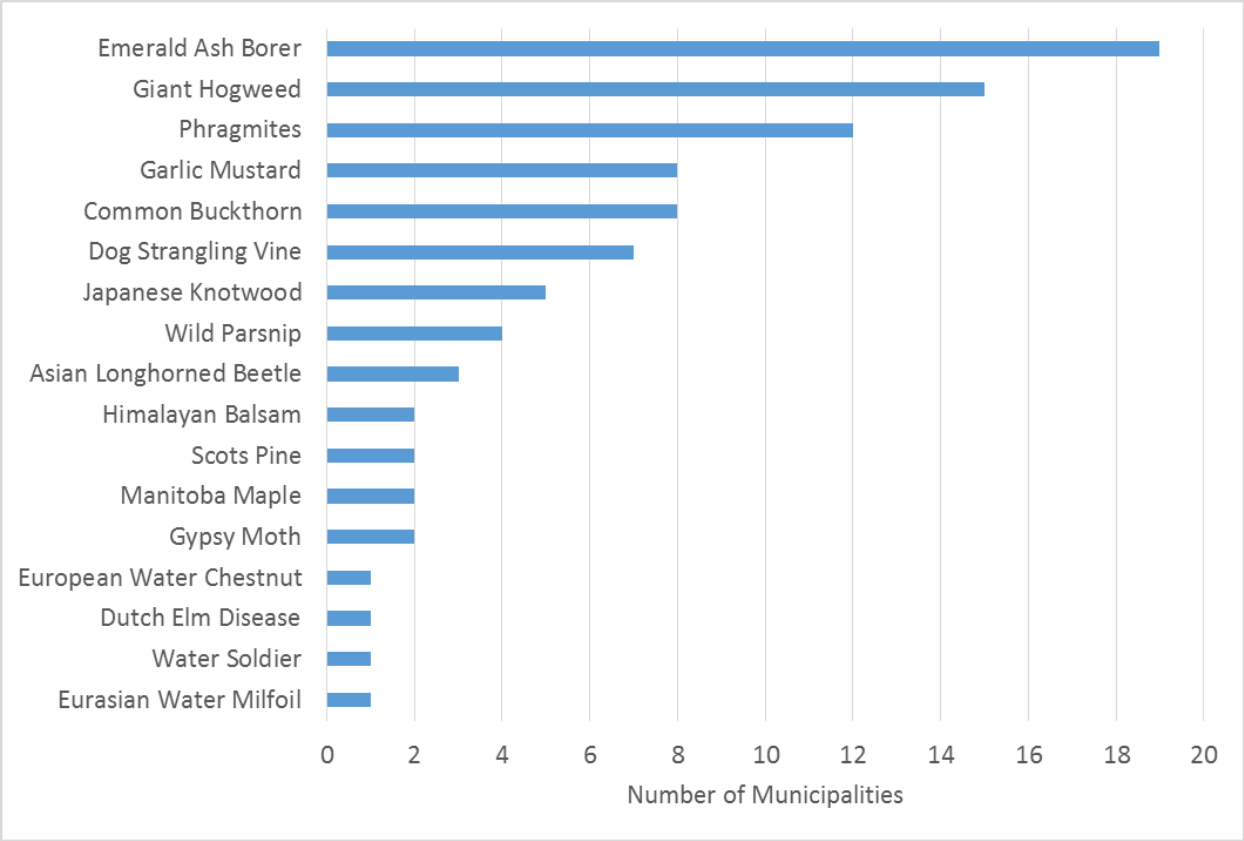
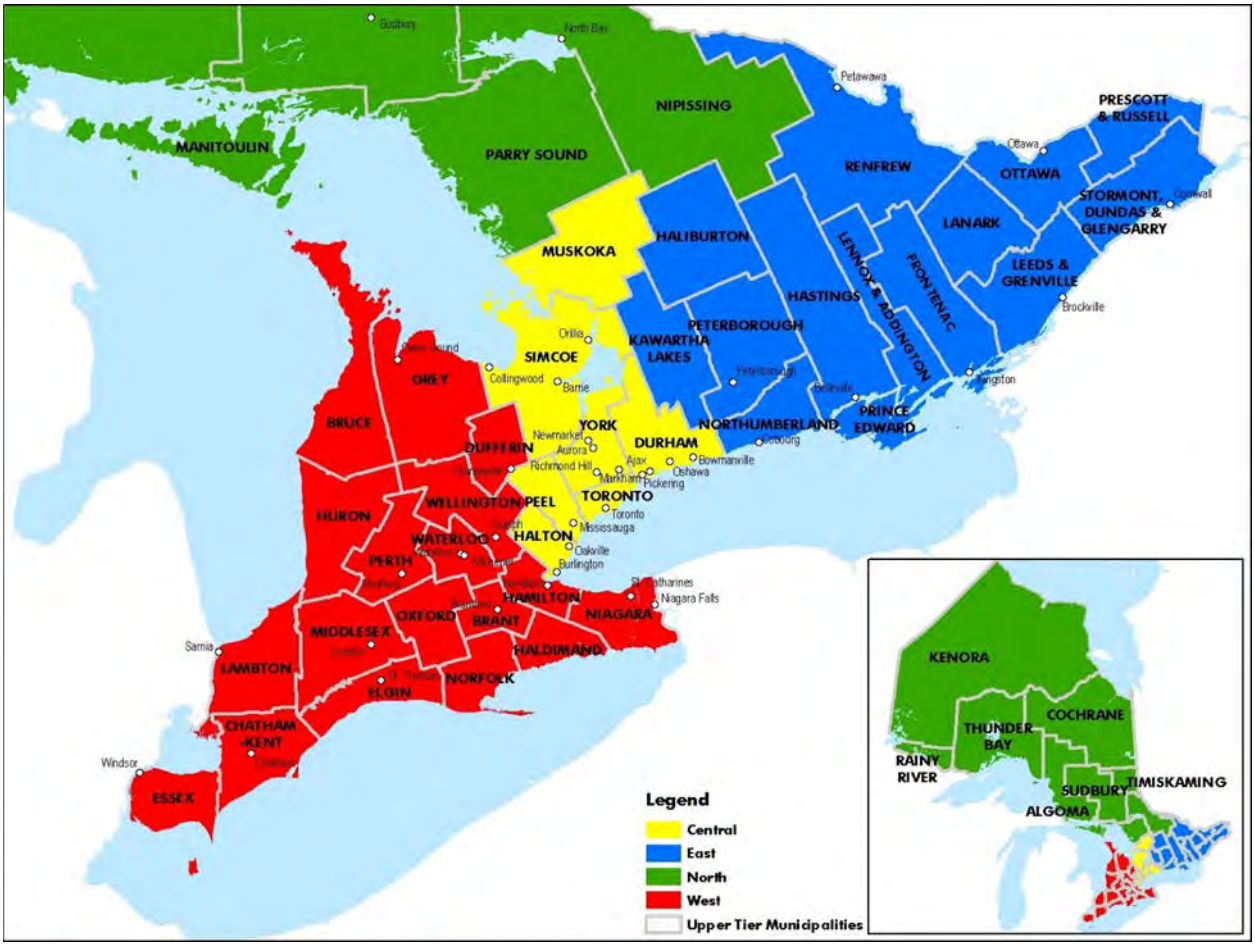


Figure 2: Regional divisions for Ontario municipalities



Source:
https://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwjFiIuZupXSAhWH7oMKHaK_B60QjRwIBw&url=http%3A%2F%2Fwww.billavista.com%2Fatv%2FArticles%2FOntario_Trails%2Findex.html&psig=AFQjCNGJ8T90836z21U9pyNWLOwDXnVFCw&ust=1487363283527026

Appendix A: Copy of Economic Impacts Survey

Economic Impacts of Invasive Species to Ontario Municipalities

1. Is your municipality concerned with invasive species?

   ☐ Yes
   ☐ No

2. Does your municipality have dedicated funding to invasive species management? (If yes, continue, if no, complete only question 12 and 13).

   ☐ Yes
   ☐ No

3. How much money did your organization spend in 2015/2016 on invasive species in your municipality?

4. Describe the nature of the funding used in your municipality to address invasive species. Is there council approved funding specific to invasive species (i.e., EAB Management plan) or is management included in municipal budgets not specific to invasive species? Examples: Forest management, parks maintenance. (If yes, specify and return to questions 2-10).

   ☐ No funding allocated
   ☐ Yes (please specify)

5. What species were managed? (Select all that apply)

   ☐ Terrestrial Invasive Plants
   ☐ Invasive Insects & Diseases
   ☐ Aquatic Invasives (ie. Plants, fish, etc.)

6. What were your priority invasive species? (Select all that apply)

☐ Phragmites

☐ Giant Hogweed

☐ Japanese Knotweed

☐ Asian Longhorned Beetle

☐ Emerald Ash Borer

☐ Sea Lamprey

☐ Zebra Mussels

☐ Rusty Crayfish

☐ Eurasian Water Milfoil

☐ Water Soldier

☐ European Water Chestnut

☐ Other (please specify)

7. Do you think others should be considered a priority? If so, which ones?

8. What proportion of the funding was dedicated to prevention? (Examples include education and outreach, management plans, etc.)

☐ Up to 25%

☐ 25-50%

☐ 50-75%

☐ 75-100%

9. What proportion of the funding was dedicated to detection? (Examples include detection trapping, monitoring surveys, etc.)

☐ Less than 10%

☐ 10-25%

☐ 25-50%

☐ 50-75%

☐ 75-100%

10. What proportion of the funding was dedicated to direct control and management? (Examples include insecticide treatments, tree removal, biocontrol release, etc.)

☐ Up to 25%

☐ 25-50%

☐ 50-75%

☐ 75-100%

11. In your opinion, is your current funding sufficient to combat invasive species in your municipality?

☐ Yes
☐ No

Additional Comments

12. Is invasive species management included in other funding sources? Examples: Forest management, parks maintenance, etc. (if yes, specify and return to questions 3-11)

☐ No

☐ Yes (please specify)

13. Are you aware of any local groups or organizations conducting invasive species management in your municipality?

☐ No

☐ Yes (please specify)