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Estimated Expenditures on Invasive Species in Ontario: 2019 Survey Results

BY: RICHARD J. VYN, PHD

FOR: INVASIVE SPECIES CENTRE, SAULT STE. MARIE, ON

Table of Contents

Executive Summary.....	iv
1.0 Introduction	1
2.0 Survey Data	3
2.1 Survey Results: Municipalities	3
2.1.1 Natural Areas	3
2.1.2 Aquatics.....	4
2.1.3 Public Works	4
2.1.4 Summary	6
2.2 Survey Results: Conservation Authorities.....	6
2.2.1 Natural Areas	6
2.2.2 Aquatics.....	7
2.2.3 Public Works	8
2.2.4 Summary	8
2.3 Aggregated Survey Results.....	8
2.3.1 Municipalities.....	9
2.3.2 Conservation Authorities	13
2.3.3 Survey Results by Region	13
2.3.4 Summary of Results	14
2.4 Data Issues and Limitations	16
2.5 Sample Representativeness.....	16
2.5.1 Sample Representativeness: Municipalities	17
2.5.2 Sample Representativeness: Conservation Authorities.....	17
2.6 Combined Survey Results: 2017-2019	18
2.6.1 Municipalities.....	18
2.6.2 Conservation Authorities	20
2.6.3 Summary	20
3.0 Methods for Estimating Total Expenditure.....	22
3.1 Extrapolation Approaches.....	22
4.0 Results.....	24
4.1 Extrapolation Results for 2019 Survey Data	24
4.1.1 Summary.....	26
4.2 Extrapolation Results for Combined 2017-2019 Survey Data.....	26

4.2.1 Summary	27
4.3 Limitations and Potential Bias.....	27
5.0 Conclusions	29
Appendix A.....	32

List of Tables

Table 1: Summary of 2019 survey results for municipalities and conservation authorities, by department category	5
Table 2: Summary of reported expenditures by departments on invasive species, by category of expenditure.....	5
Table 3: Expenditure and demographic statistics for municipalities and conservation authorities, by region and by municipality category: 2019 survey data.....	11
Table 4: Species-specific expenditures reported by sample municipalities and conservation authorities	12
Table 5: Expenditure statistics for municipalities and conservation authorities, by region and by municipality category: 2017-2019 survey data.....	19
Table 6: Comparison of expenditure statistics for municipalities and conservation authorities, 2019 survey data vs. 2017-2019 survey data	21
Table 7: Summary of extrapolation results for estimated total expenditure on invasive species by all municipalities and conservation authorities in Ontario	25
Table 8: Estimated expenditures on individual invasive species by all municipalities and conservation authorities (based on the estimated total annual expenditure in Ontario of \$50.8 million).....	30
Table A1: Expenditure, geographic, and demographic data for sample municipalities	32
Table A2: Expenditure and geographic data for sample conservation authorities	36

List of Figures

Figure 1: Summary of responses to the question “How would you best characterize the impacts of invasive species in your department?”	4
Figure 2: Map of conservation authorities in Ontario	7
Figure 3: Regional divisions for Ontario municipalities	14
Figure 4: Invasive species of concern reported by sample municipalities and conservation authorities	15

Executive Summary

The purpose of this report is to estimate expenditures on invasive species by municipalities and conservation authorities (CAs) in Ontario. Surveys were conducted in 2019 to obtain information on expenditures in 2018 for invasive species prevention, detection, and control and management activities by municipalities and CAs across the province. Survey data on reported expenditure amounts were then extrapolated to estimate total annual expenditure on invasive species across all municipalities and all CAs in Ontario.

This report builds on similar studies conducted in 2017 and in 2018 for the Invasive Species Centre. The numbers of respondents have increased with each successive survey, which may increase the accuracy of the estimated total provincial expenditure. The 2019 survey received 117 usable responses from 88 municipalities and 21 responses from 16 CAs, while the 2018 survey received responses from 68 municipalities and 13 CAs and the 2017 survey received responses from only 35 municipalities.

The 2019 survey results indicate that expenditures on invasive species were reported by 75 of 88 municipalities, with an average expenditure of \$282,064, and by 15 of 16 CAs, with an average expenditure of \$453,132. Total expenditures were \$24,821,670 for responding municipalities and \$7,250,112 for responding CAs, and per capita expenditures were \$1.88 for municipalities and \$0.72 for CAs. For both groups, the majority of reported expenditures were incurred for control of emerald ash borer (53.0% for municipalities; 86.7% for CAs). These survey results were also combined with those of the 2017 and 2018 surveys. The combined survey data included 147 municipalities, of which 101 reported expenditures on invasive species, and 23 CAs, of which 20 reported expenditures. Average expenditures were \$218,148 for municipalities and \$314,724 for CAs, while per capita expenditures were \$1.98 for municipalities and \$0.65 for CAs.

Both the 2019 survey results and the combined survey results were used to estimate the total expenditure on invasive species across the province, based on an extrapolation approach. Extrapolations to the provincial level were conducted separately for municipalities and for CAs based on average expenditures and based on per capita expenditures, which account for the influence of population on reported expenditure amounts. Extrapolations were also conducted to the regional level and to the municipality category level, to account for observed variation across regions and types of municipalities.

Due to the influence of population on invasive species expenditures, the extrapolations based on per capita expenditures are more likely to generate accurate estimates of total expenditure than the extrapolations based on average expenditures. The estimates based on these extrapolations were between \$49.5 million and \$53.3 million. This narrow range of estimates across various extrapolation approaches enhances confidence in the potential accuracy of the estimated total expenditure in Ontario. The estimate that is assumed to be most representative is that of the extrapolation to the provincial level of per capita expenditure for the combined 2017-2019 survey data, which has a much larger sample size than the 2019 survey. **This estimate of total annual expenditure by municipalities and CAs in Ontario is \$50.8 million.**

It should be noted that this estimated total expenditure accounts only for expenditures by municipalities and CAs in the province, and does not include expenditures on invasive species by the provincial government or federal government. In addition, it is important to note that the 2019 survey results

indicated that additional funding was needed to effectively manage invasive species. There were 59 respondents from municipalities and 15 respondents from CAs that indicated that insufficient funding was received for combating invasive species. This implies that considerably more could be spent on invasive species in Ontario.

1.0 Introduction

A survey of municipalities and conservation authorities (CAs) across Ontario was conducted in early 2019 by the Invasive Species Centre to estimate expenditures incurred (in 2018) related to invasive species. This survey involved contacting staff members at specific municipalities and CAs to acquire information on the types of invasive species that were of concern within their jurisdictions and the amounts and types of expenditures that were incurred on invasive species prevention, detection, and control and management activities. The expenditure amounts provided by the surveyed municipalities and CAs were then extrapolated to estimate total annual expenditure across all municipalities and CAs in Ontario on invasive species activities.

This survey followed up on similar surveys that were conducted in 2018 and 2017, each of which was also used to generate estimates of total expenditure on invasive species across the province. However, as described in the reports conducted based on these prior surveys, there were issues associated with the survey results that may have negatively impacted the accuracy of these estimates. In particular, the relatively small sample sizes created challenges in generating accurate estimates. The 2017 survey had responses from 35 out of 444 municipalities in Ontario, while the 2018 survey had responses from 68 municipalities. In addition, the samples in for each of the 2017 and 2018 surveys had concerns related to sample representativeness. As described in this report, the 2019 survey results may address these issues.

The 2019 survey took a different approach than the previous two surveys by targeting specific departments within each municipality and CA rather than requesting a single response from each. Responses in the previous two surveys were received primarily from forestry departments. Targeting other departments, such as roadside maintenance or aquatics departments, allowed for collecting information from a variety of departments that are involved in invasive species activities. Another reason for this approach is that different departments deal with different types of invasive species, for which budgets and incurred expenditures for control and management activities may vary widely. In addition, staff in one department may not be fully aware of expenditures incurred by other departments within their municipality or CA; as a result, they may not be able to provide an accurate estimate of total expenditures on invasive species activities by the municipality or CA. This may adversely affect the accuracy of the estimated total expenditure on invasive species activities across the province.

To address this issue and attempt to generate a more accurate estimate of total expenditure, surveys were targeted to three categories of departments, each of which may deal with different types of invasive species. These categories include: 1) Natural Areas – e.g., forestry, parks, recreation, environmental services; 2) Aquatics – e.g., water and sewer, wastewater management, rivers and streams; and 3) Public Works – e.g., roads, transportation, infrastructure, engineering. Some survey questions were tailored to each category to account for differences in the invasive species managed by different departments. For example, the set of invasive species from which respondents could select species of concern within their department varied across the three categories.

The purpose of this report is to build on the previous two surveys and generate a more accurate estimate of total expenditure on invasive species by municipalities and CAs across Ontario. This involves using the 2019 survey results, which are broader and more balanced than the previous two surveys, to generate an estimate of total expenditure, as well as combining the 2019 survey results with those of the 2017 and

2018 surveys to provide an additional estimate of this expenditure. Estimates based on each of these sets of survey results may be more accurate than those of the previous two surveys, due to the larger and more balanced samples.

The survey responses are summarized in the following section for each of the three categories of departments as well as for all categories combined, for both municipalities and CAs. This section also provides a summary of the combined survey data from the 2017, 2018, and 2019 surveys. The extrapolation methods used to estimate total expenditure by municipalities and CAs in Ontario are described in the third section, the results of which are provided in the fourth section. The final section provides a discussion of the conclusions of this report.

2.0 Survey Data

The survey process involved soliciting responses from different types of departments within municipalities and within CAs, as there may be multiple departments within each jurisdiction that are involved in invasive species activities. Respondents were asked to provide information on amounts and types of expenditures related to invasive species management activities as well as species of concern. As described in the previous section, three categories of departments were targeted: Natural Areas, Aquatics, and Public Works. The survey results for each of these categories are described below, following which a description is provided of the aggregated results for municipalities and for CAs. The aggregated results are then broken down by region to examine for regional trends and differences. The results of the survey are also combined with those of the two previous surveys in 2017 and 2018. The combined survey results are summarized and compared with those of the 2019 survey.

2.1 Survey Results: Municipalities

Survey responses were received from 88 municipalities, which represent 19.8% of the 444 municipalities in Ontario.¹ In some cases, responses were received from multiple departments within the same municipality, which are later aggregated. Responses were received from 42 Natural Areas departments, 12 Aquatics departments, and 63 Public Works departments, for a total of 117 responses from municipalities. Of these responses, only 13 indicated that invasive species had low or no impacts on their department and that it was not a priority to prepare for future invasions. The majority of respondents indicated either that invasive species were currently impacting their department or that it was a high priority to prepare for future invasions (see Figure 1). A summary of the survey results for each of the three categories of departments is provided in Tables 1 and 2. Table 1 provides statistics on the numbers of respondents and on the expenditures reported by each department category, along with proportional allocations of expenditures among prevention, detection, and control and management activities, while Table 2 summarizes the reported expenditures by category of expenditure.²

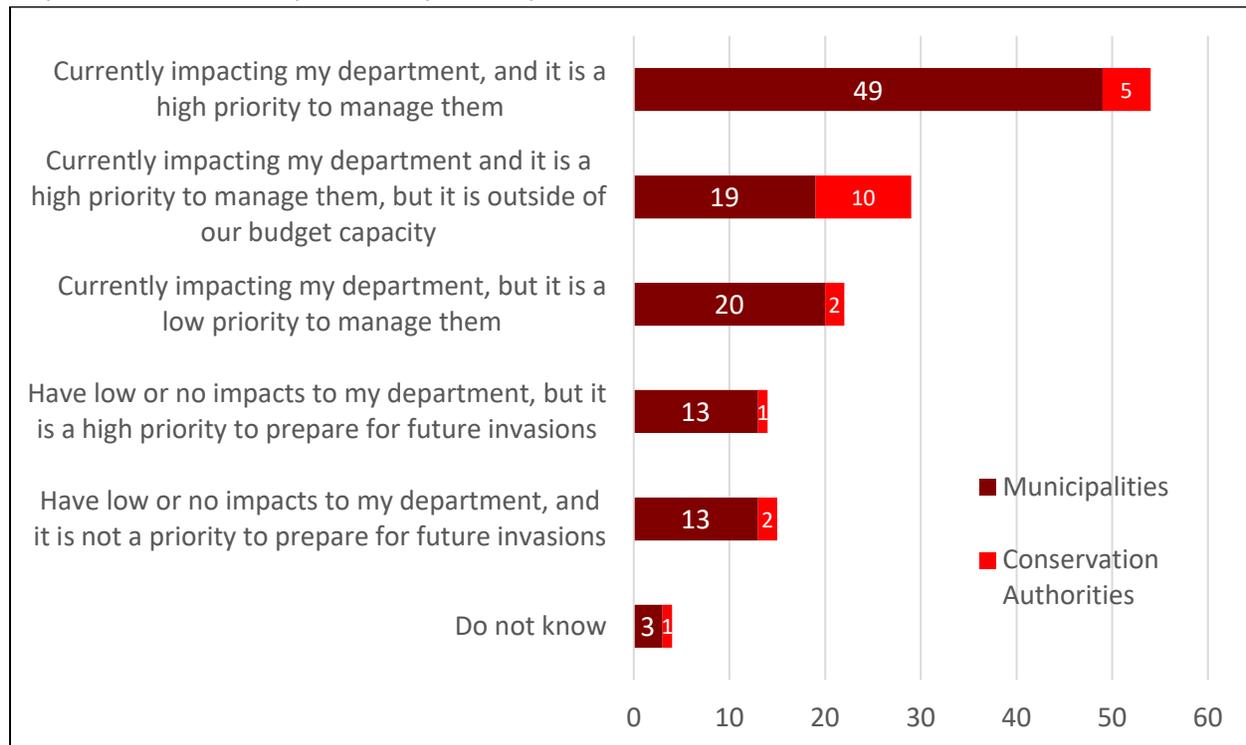
2.1.1 Natural Areas

There were 42 responses from departments in the Natural Areas category. Expenditures on invasive species were reported by 40 of these respondents (95.2%), with total reported expenditures of \$14,298,027. Expenditures ranged from \$1,500 to \$4,250,000, with an average across the 42 responding municipalities of \$340,429. The majority of expenditures were incurred for control and management activities (81.9%), while 7.2% of expenditures were for prevention activities and 10.9% of expenditures were for detection activities. The categories with the largest expenditures (see Table 2) were payments to contractors (53.8%) and staff wages (22.9%). The primary species of concern for these departments were emerald ash borer (36 respondents) and phragmites (33 respondents). Emerald ash borer accounted for almost two-thirds of all reported species-specific expenditures (64.1%).

¹ By comparison, the 2018 survey received responses from 68 municipalities and the 2017 survey received responses from 35 municipalities.

² Not all respondents provided expenditures by category, so the sum of reported expenditures across all expenditure categories in Table 2 is not equal to the total expenditure reported for each department category in Table 1.

Figure 1: Summary of responses to the question “How would you best characterize the impacts of invasive species in your department?”



2.1.2 Aquatics

There were 12 responses from Aquatics departments. Expenditures on invasive species activities were reported by 10 of these respondents (83.3%), for which the total of these expenditures was \$4,675,979. These expenditures ranged from \$1,300 to \$3,920,000, with an average across the 12 responding municipalities of \$389,665. Prevention activities accounted for 12.2% of the reported expenditures, detection activities accounted for 17.2%, and control and management activities accounted for 70.6%. The vast majority of the reported expenditures were for payments to contractors (90.1%). Among the expenditures reported for individual species, zebra mussels accounted for 45.9% while quagga mussels accounted for 45.6%. The top three species of concern that were identified included zebra mussels (7 respondents), phragmites (5), and quagga mussels (4).

2.1.3 Public Works

There were 63 responses from departments in the Public Works category. Expenditures on invasive species activities were reported by 47 of these respondents (74.6%), with total reported expenditures of \$3,201,807. The reported expenditures ranged from \$200 to \$1,000,000, with an average across the 63 responding municipalities of \$50,822. Payments to contractors accounted for 73.0% of reported expenditures, while staff wages accounted for 15.5%. As with the previous two categories, the majority of expenditures were incurred for control and management activities (71.2%), while prevention activities accounted for 12.0% of expenditures and detection activities accounted for 16.8%. The top three identified species of concern were phragmites (36 respondents), wild parsnip (32), and emerald ash borer (29). Emerald ash borer accounted for 58.0% of all reported species-specific expenditures.

Table 1: Summary of 2019 survey results for municipalities and conservation authorities, by department category

	Responses	Expenditures Incurred		Funding for Invasive Species		Expenditure on Invasive Species Activities		Expenditure Allocation		
	#	#	%	#	%	Total	Average	Prevention	Detection	Control & Management
Municipalities										
Natural Areas	42	40	95.2%	30	71.4%	\$14,298,027	\$340,429	7.2%	10.9%	81.9%
Aquatics	12	10	83.3%	4	33.3%	\$4,675,979	\$389,665	12.2%	17.2%	70.6%
Public Works	63	47	74.6%	35	55.6%	\$3,201,807	\$50,822	12.0%	16.8%	71.2%
Conservation Authorities										
Natural Areas	16	15	93.8%	7	43.8%	\$3,605,533	\$225,346	18.7%	9.5%	71.8%
Aquatics	3	3	100.0%	2	66.7%	\$221,260	\$73,753	5.0%	45.0%	50.0%
Public Works	2	0	0.0%	0	0.0%	\$0	\$0	-	-	-

Table 2: Summary of reported expenditures by departments on invasive species, by category of expenditure

Expenditure Category	Municipalities						Conservation Authorities					
	Natural Areas		Aquatics		Public Works		Natural Areas		Aquatics		Public Works	
	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%
Staff wages	1,952,227	22.9%	31,550	0.7%	478,110	15.5%	1,409,545	42.2%	78,016	39.7%	0	-
Tools and equipment	637,585	7.5%	220,619	4.8%	191,900	6.2%	229,650	6.9%	14,884	7.6%	0	-
Maintenance of equipment and facility	74,800	0.9%	80,000	1.7%	55,950	1.8%	70,500	2.1%	1,560	0.8%	0	-
Travel and conferences, workshops, training	37,365	0.4%	0	0.0%	11,900	0.4%	19,500	0.6%	1,040	0.5%	0	-
Educational/outreach materials and activities	358,922	4.2%	8,694	0.2%	8,850	0.3%	10,020	0.3%	101,040	51.4%	0	-
Payment to contractor	4,595,240	53.8%	4,154,116	90.1%	2,247,197	73.0%	1,438,538	43.1%	0	0.0%	0	-
Private consultation and services	354,270	4.2%	100,000	2.2%	72,500	2.4%	750	0.0%	0	0.0%	0	-
Other	526,033	6.2%	16,000	0.3%	13,200	0.4%	159,200	4.8%	0	0.0%	0	-
Total	8,536,442		4,610,979		3,079,607		3,337,703		196,540		0	

2.1.4 Summary

It is evident from the survey results provided in Tables 1 and 2 that some differences exist across department categories in the nature of expenditures on invasive species and funding provided for these expenditures. Almost all of the respondents from Natural Areas departments (95.2%) indicated the expenditures on invasive species were incurred by their departments, while the proportion of respondents indicating that expenditures were incurred was lowest (74.6%) for Public Works departments. Aquatics departments were by far the least likely to have funding provided for invasive species expenditures (33.3%), while Natural Areas departments were most likely to have funding (71.4%). Despite the lack of funding, the average expenditure incurred by Aquatics departments (\$389,665) was quite similar to the average expenditure incurred by Natural Areas departments (\$357,451). In comparison, the average expenditure was considerably lower for Public Works departments (\$50,822). The allocations of expenditures among the three types of activities (prevention, detection, and control and management) were quite similar across all department categories. For all three categories, the vast majority of expenditures were incurred for control and management activities, with proportions ranging from 70.6% to 81.9%. Across most department categories, the expenditure category with the highest proportion of reported expenditures was payment to contractor.

The survey results also indicated that considerable non-financial costs are being incurred by departments within municipalities related to invasive species activities, such as volunteer time or other in-kind contributions. There were 28 respondents (23.9%) that indicated non-financial costs, of which 6 provided estimates of these costs, totaling \$113,200. In addition, 16 respondents (13.7%) indicated that volunteers were involved with invasive species activities. However, since many respondents did not provide estimates of non-financial costs, it is difficult to generate an accurate estimate of these costs.

2.2 Survey Results: Conservation Authorities

Survey responses were received from 16 CAs, which represent 44.4% of the 36 CAs in Ontario. The CAs are concentrated in the southern part of the province, with only a few located in the northern region (see Figure 2). As with the municipalities, multiple responses were received from CAs, with three responses from one CA and four from another. Responses were received from 16 Natural Areas departments, three Aquatics departments, and two Public Works departments, for a total of 21 responses from CAs. Only two of these respondents indicated that invasive species had low or no impacts on their departments and that it was not a priority to prepare for future invasions, while almost half of respondents (10) indicated that invasive species impacted their department but they didn't have the budget capacity to manage them (see Figure 1). The survey results for each category of departments for CAs, which are described below, are summarized in Tables 1 and 2.

2.2.1 Natural Areas

There were 16 responses from departments in the Natural Areas category. Expenditures on invasive species were reported by 15 of the respondents (93.8%), with these expenditures totaling \$3,605,533. Reported expenditures ranged from \$1,180 to \$1,306,000, with an average across the 16 responding departments of \$225,346. The top two expenditure categories were payments to contractors (43.1%) and staff wages (42.2%). The majority of expenditures were incurred for control and management activities (71.8%), while prevention activities accounted for 18.7% of expenditures and detection activities accounted for 9.5%. The respondents reported many of the same species of concern, including phragmites

(16 respondents), emerald ash borer (13), garlic mustard (12), European buckthorn (12), beech bark disease (11), Japanese knotweed (11), and dog strangling vine (11). Despite having many species of concern, the vast majority of reported species-specific expenditure was for emerald ash borer (86.0%).

2.2.2 Aquatics

There were three responses from Aquatics departments, all three of which reported expenditures on invasive species. These expenditures totaled \$221,260, ranging from \$52,000 to \$100,000, with an average of \$73,753. Expenditures were incurred primarily for educational/outreach materials and activities (51.4%) and for staff wages (39.7%). Prevention activities accounted for 5.0% of these expenditures, detection activities accounted for 45.0%, and control and management activities accounted for 50.0%. Species of concern that were reported by at least two of the respondents included zebra mussels, phragmites, Eurasian milfoil, Asian carp, round goby, sea lamprey, reed canary grass, and European frogbit. Reported species-specific expenditures were incurred primarily for sea lamprey (58.2%) and Asian carp (36.4%).

Figure 2: Map of conservation authorities in Ontario



Source: <http://watershedcheckup.ca/conservation-authority-map>

2.2.3 Public Works

There were two responses from departments in the Public Works category, both of which reported no expenditures on invasive species. Both of these responses were from the same CA – Nottawasaga Valley Conservation Authority. However, responses were also received from departments in the other two categories for this CA, both of which reported expenditures on invasive species (these responses are aggregated below). Both of the Public Works respondents indicated that invasive species had low or no impacts, and only phragmites was identified as a species of concern.

2.2.4 Summary

While some differences across department categories are evident (see Tables 1 and 2), it is important to note the very low numbers of responses from Aquatics departments (3) and Public Works departments (2). As such, it is difficult to effectively make comparisons between the different categories of departments. As with municipalities, the numbers of departments that reported expenditures on invasive species exceeds the numbers that indicated that funding was provided. For example, of the 16 Natural Areas departments, 15 reported expenditures while only 7 reported funding for invasive species.

The majority of respondents (16 out of 21, or 76.2%) indicated that non-financial costs were incurred by their department. Only four of these respondents provided an estimate of in-kind costs, totaling \$63,665. Volunteer time was reported by 13 of the respondents (61.9%). Compared to the municipality survey results, non-financial costs and volunteer time were reported by much higher proportions of respondents from CAs.

2.3 Aggregated Survey Results

After summarizing the survey results for each of the three categories of departments, the responses across these categories were aggregated for all sample municipalities and for all sample CAs. For municipalities and CAs that had responses from multiple departments, the aggregation process involved adding reported total expenditures across the departments within each municipality and CA, and adjusting the percentages spent on the three categories of invasive species activities (i.e., prevention, detection, and control and management) accordingly. Aggregating responses from multiple departments within a municipality or CA may increase the accuracy of the reported expenditures on invasive species within these jurisdictions as well as the estimated total expenditure by municipalities and CAs across the province.

The aggregation process also involved estimating the total expenditure on invasive species by each sample municipality and CA, as the expenditure reported by the responding department may not account for all expenditures on invasive species within the municipality or CA. As described earlier, there may be multiple departments within a municipality or CA that are involved in invasive species activities. Particularly in larger organizations, staff in one department may only be aware of expenditures incurred by their department and may not be aware of expenditure incurred by other departments. As a result, the reported expenditure from one respondent (or department) may under-represent the total expenditure within the municipality or CA, which could bias the estimated total provincial expenditure downward. To address this potential issue, respondents were asked to estimate the percentage of total invasive species expenditures in the jurisdiction that are incurred within their department. This percentage, applied to the reported expenditure incurred within the department, allowed for calculating total estimated expenditure

within the municipality or CA. For example, if a respondent indicated that their department spent \$50,000 on invasive species activities and that this amount accounted for 80% of all expenditures within the jurisdiction, the estimated total expenditure for that jurisdiction would be \$62,500.³

For the aggregated municipality data and CA data, the total expenditure for each municipality or CA was based on this calculation rather than on the reported departmental expenditure, since the calculated amount would more accurately represent or estimate the total amount spent within the municipality or CA on invasive species activities. In a number of cases, the reported percentage of total municipality or CA expenditures incurred within the responding department was 100%, indicating that no other departments within the municipality or CA incurred expenditures on invasive species. In these cases, the aggregated municipality or CA expenditure was set equal to the reported amount for the responding department. In a few cases, respondents indicated that the percentage of total municipality or CA expenditures that were incurred within their department was unknown. Rather than omitting these responses from the survey data, the percentages used in these cases were estimated based on the average percentage for respondents from the same category of departments across other municipalities or CAs. For example, the average reported percentage of total municipality expenditures incurred by Natural Areas departments was 85.7%; this percentage was applied to any survey response within this category that did not provide a percentage.

Table 3 provides a summary of expenditure statistics for the aggregated 2019 survey data for sample municipalities and CAs, along with demographic statistics that are later used to assess sample representativeness. In addition to the totals across all sample municipalities and sample CAs, this table also provides expenditure statistics broken down by region and by municipality category, which are described later in this section.

2.3.1 Municipalities

Responses from multiple departments were received from 19 municipalities, with two responses received from 12 municipalities, three responses received from six municipalities, and four responses received from one municipality. After combining responses from departments within the same municipalities, the aggregated data consisted of 88 municipalities.

The estimated expenditures for each of the 88 sample municipalities and the percentage allocations of expenditures among the three types of invasive species activities are provided in Table A1 in Appendix A. As described above, the estimated expenditure for each municipality is derived by dividing the reported expenditure by the reported percentage of total municipality expenditures on invasive species incurred by the responding department. For municipalities with multiple responses, the expenditure amounts were aggregated and the percentage adjusted accordingly prior to the estimation process. For example, if one department within a municipality reported an expenditure of \$100,000 that accounted for 50% of total municipality expenditure, and another department in the same municipality reported an expenditure of \$50,000 that accounted for 25% of total expenditure, the estimated total municipality expenditure would be estimated by dividing the reported \$150,000 by the combined percentage of total expenditure of 75%. The allocations were also adjusted accordingly for municipalities with multiple responses, based on the allocations reported by each respondent and the reported expenditure amounts.

³ This amount was calculated as follows: $\$50,000 / 80\% = \$62,500$.

Table A1 also includes geographic and demographic information for each of the sample municipalities, including region, population, land area, and household income. This information is used below in assessing the sample representativeness. Population is also used to calculate per capita expenditure for each of the municipalities in which expenditures on invasive species were reported. The regions in which the sample municipalities are located are used for breaking down survey results by region.

A summary of the expenditure statistics for the sample municipalities is provided in Table 3. Expenditures on invasive species activities were reported by 75 of the 88 sample municipalities. Total estimated expenditures across these municipalities was \$24,821,670, while the average expenditure across all sample municipalities was \$282,064. Based on the combined population of the sample municipalities, the per capita expenditure was calculated to be \$1.88. Average allocations of expenditures included 76.8% for control and management activities, 14.9% for detection activities, and 8.2% for prevention activities. Applying these percentage allocations to the total expenditures across sample municipalities generated estimated expenditures of \$19.1 million for control and management activities, \$3.7 million for detection activities, and \$2.0 million for prevention activities.

In addition to reporting total expenditures on invasive species, survey respondents were asked to report expenditure amounts for specific invasive species. Species-specific expenditures reported by sample municipalities (as well as sample CAs) are aggregated in Table 4. It is evident from this table that just over half of species-specific expenditures⁴ reported by municipalities was for emerald ash borer (53.0%). Zebra mussels and gypsy moth each accounted for 10.6% of reported species-specific expenditure, quagga mussels accounted for 10.5%, and phragmites accounted for 6.6%.

To provide more detail on the distribution of reported expenditures across sample municipalities, these municipalities were divided into three categories: 1) counties, which include all upper-tier municipalities; 2) urban areas, which include cities and towns with a population of at least 50,000; and 3) townships, which include all lower-tier municipalities with a population of less than 50,000. The sample municipalities included 15 counties, 15 urban areas, and 58 townships. The distribution of the sample municipalities across the three categories was more heavily weighted toward counties and urban areas, as the sample included 44.1% of all counties in the province and 38.5% of urban areas, but only 15.6% of townships.

There was considerable variation in expenditures across the three categories of municipalities, as evident in Table 3. Expenditures on invasive species activities were reported by 14 counties (93.3%), 15 urban areas (100.0%), and 46 townships (79.3%). Of the total estimated expenditures of \$24.8 million for the sample municipalities, \$17.9 million was incurred by urban areas, \$4.6 million by counties, and \$2.3 million by townships. Average expenditure was highest by far for urban areas (\$1,190,515), while counties had an average expenditure of \$309,916 and townships had an average expenditure of only \$39,917. Conversely, per capita expenditure was highest for townships, at \$3.25. By comparison, per capita expenditure was \$2.76 for urban areas and \$0.77 for counties. It is likely that much of the variation in expenditures across the three categories of municipalities is related to differences in population. Total and average expenditures are highest for urban areas, which are the highest populated municipalities, and lowest for townships, which are the lowest populated municipalities.

⁴ Not all respondents provided expenditure amounts for specific invasive species. As a result, the total reported species-specific expenditure in Table 4 is less than the sum of all expenditures across sample municipalities.

Table 3: Expenditure and demographic statistics for municipalities and conservation authorities, by region and by municipality category: 2019 survey data

	Total	Region				Municipality Category		
		North	East	Central	West	Counties	Urban Areas	Townships
Municipalities	444	144	114	55	131	34	39	371
Population	13,448,494	780,140	2,080,505	6,957,765	3,630,084			
Household Income	\$74,287	\$65,346	\$67,464	\$85,517	\$76,216			
Sample Municipalities	88	14	18	28	28	15	15	58
% of Total	19.8%	9.7%	15.8%	50.9%	21.4%	44.1%	38.5%	15.6%
Expenditures Incurred	75	6	16	27	26	14	15	46
% of Sample	85.2%	42.9%	88.9%	96.4%	92.9%	93.3%	100.0%	79.3%
Total Expenditures	\$24,821,670	\$444,488	\$923,389	\$14,324,123	\$9,129,669	\$4,648,743	\$17,857,731	\$2,315,196
Average Expenditure	\$282,064	\$31,749	\$51,299	\$511,576	\$326,060	\$309,916	\$1,190,515	\$39,917
Per Capita Expenditure	\$1.88	\$2.57	\$0.68	\$1.68	\$2.91	\$0.77	\$2.76	\$3.25
Conservation Authorities	36	5	11	6	14			
Population	12,925,441	438,142	1,960,049	6,897,166	3,630,084			
Sample CAs	16	3	3	6	4			
% of Total	44.4%	60.0%	27.3%	100.0%	28.6%			
Expenditures Incurred	15	3	3	6	3			
% of Sample	93.8%	100.0%	100.0%	100.0%	75.0%			
Total Expenditures	\$7,250,112	\$56,181	\$2,010,000	\$4,366,335	\$817,597			
Average Expenditure	\$453,132	\$18,727	\$670,000	\$727,722	\$204,399			
Per Capita Expenditure	\$0.72	\$0.19	\$2.56	\$0.63	\$0.39			

Table 4: Species-specific expenditures reported by sample municipalities and conservation authorities

Invasive Species	Municipalities		Conservation Authorities		Combined		% of Non-EAB Expenditure
	\$	%	\$	%	\$	%	
Emerald Ash Borer (EAB)	\$9,923,875	53.0%	\$2,159,520	86.7%	\$12,083,395	56.9%	--
Zebra Mussels	\$1,985,398	10.6%	\$0	0.0%	\$1,998,179	9.4%	21.7%
Gypsy Moth	\$1,980,000	10.6%	\$0	0.0%	\$1,985,563	9.3%	21.7%
Quagga Mussels	\$1,972,782	10.5%	\$0	0.0%	\$1,980,000	9.3%	21.6%
Phragmites	\$1,241,733	6.6%	\$103,263	4.1%	\$1,344,996	6.3%	14.7%
Wild Parsnip	\$478,425	2.6%	\$1,401	0.1%	\$479,826	2.3%	5.2%
European Buckthorn	\$368,302	2.0%	\$61,101	2.5%	\$429,403	2.0%	4.7%
Dutch Elm Disease	\$260,000	1.4%	\$0	0.0%	\$260,000	1.2%	2.8%
Dog Strangling Vine	\$39,300	0.2%	\$69,500	2.8%	\$108,800	0.5%	1.2%
Asian Longhorned Beetle	\$100,792	0.5%	\$0	0.0%	\$100,792	0.5%	1.1%
Giant Hogweed	\$92,667	0.5%	\$6,500	0.3%	\$99,167	0.5%	1.1%
Autumn Olive	\$91,000	0.5%	\$2,000	0.1%	\$93,000	0.4%	1.0%
Japanese Knotweed	\$72,505	0.4%	\$5,501	0.2%	\$78,005	0.4%	0.9%
Garlic Mustard	\$24,508	0.1%	\$11,581	0.5%	\$36,089	0.2%	0.4%
Sea Lamprey	\$0	0.0%	\$32,000	1.3%	\$32,000	0.2%	0.3%
Linden Bark Borer	\$27,300	0.1%	\$0	0.0%	\$27,300	0.1%	0.3%
Oak Wilt	\$22,512	0.1%	\$1,000	0.0%	\$23,512	0.1%	0.3%
Asian Carp	\$0	0.0%	\$20,000	0.8%	\$20,000	0.1%	0.2%
Beech Bark Disease	\$10,492	0.1%	\$8,300	0.3%	\$18,792	0.1%	0.2%
Brown Spruce Longhorned Beetle	\$13,500	0.1%	\$0	0.0%	\$13,500	0.1%	0.1%
Hemlock Woolly Adelgid	\$4,792	0.0%	\$8,500	0.3%	\$13,292	0.1%	0.1%
Glossy Buckthorn	\$13,000	0.1%	\$0	0.0%	\$13,000	0.1%	0.1%
Manitoba Maple	\$5,000	0.0%	\$0	0.0%	\$5,000	0.0%	0.1%
European Chafer	\$5,000	0.0%	\$0	0.0%	\$5,000	0.0%	0.1%
Scots Pine	\$4,960	0.0%	\$0	0.0%	\$4,960	0.0%	0.1%
Total	\$18,737,842	100.0%	\$2,490,166	100.0%	\$21,228,008	100.0%	100.0%

2.3.2 Conservation Authorities

Responses from multiple departments were received from two CAs. Three responses were received from one CA and four from another. After combining these responses, the aggregated data consisted of 16 CAs. Expenditures for each of the sample CAs were estimated through a similar approach to that of municipalities, as described above. The estimated expenditures for each of the 16 sample CAs are provided in Table A2 in Appendix A, along with percentage allocations among the three types of invasive species activities and geographic information for the CAs. Expenditure statistics are also summarized in Table 3.

Expenditures on invasive species activities were reported by 15 of the 16 sample CAs. Total estimated expenditures for these CAs was \$7,250,112, with an average of \$453,132 and a per capita expenditure of \$0.72. The largest estimated expenditure was \$2,000,000. Average allocations of expenditures were 65.7% for control and management activities and 17.1% each for prevention activities and detection activities. Applying these percentage allocations to the total expenditures for the sample CAs generated expenditures of \$4.8 million for control and management activities and \$1.2 million each for prevention activities and detection activities. The vast majority of reported species-specific expenditures, which are summarized in Table 4, was for emerald ash borer (86.7%). Phragmites accounted for 4.1% of reported species specific expenditures, followed by dog strangling vine (2.8%) and European buckthorn (2.5%).

2.3.3 Survey Results by Region

The survey results for municipalities and CAs were broken down by region to examine for differences across regions. Municipalities were divided into four regions: North, East, Central, and West (see Figure 3). While CA boundaries do not follow municipality boundaries, CAs were assigned to these same four regions based on the region that contained the majority of the area of the CA. A summary of the results for each region is provided in Table 3, along with some demographic statistics.

Statistics for municipalities on population and household income were derived from Statistics Canada's 2016 Census data. Since CA boundaries do not align with municipality boundaries, and since population data is not collected specifically for CAs, these figures had to be estimated. For some CAs, population estimates were provided on their websites. For other CAs, the population was estimated based on the population of municipalities within the boundaries of each CA. In some cases, adjustments were made if only part of a municipality was within a CA boundary. For example, if half the area of a municipality was within a CA boundary, then half of the population of the municipality was included in the estimated CA population. It should be noted that because CAs do not cover the entire land base in Ontario, the total population across all CAs is less than the total across all municipalities.

As evident in Table 3, considerable variation exists across the four regions. The Central and West regions each had 28 responding municipalities, while the East region had 18 and the North region had 14. The proportions of total municipalities that responded ranged from 9.7% in the North region to 50.9% in the Central region. The proportion of sample municipalities that reported expenditures on invasive species was much lower in the North (42.9%) than in the other regions, where proportions ranged from 88.9% to 96.4%. Average expenditures for municipalities were much higher in the Central (\$511,576) and West (\$326,060) regions than in the East (\$51,299) and North (\$31,749) regions. Expenditures per person⁵ were

⁵ These figures are based on the combined populations of the sample municipalities within each region rather than the total population of the region.

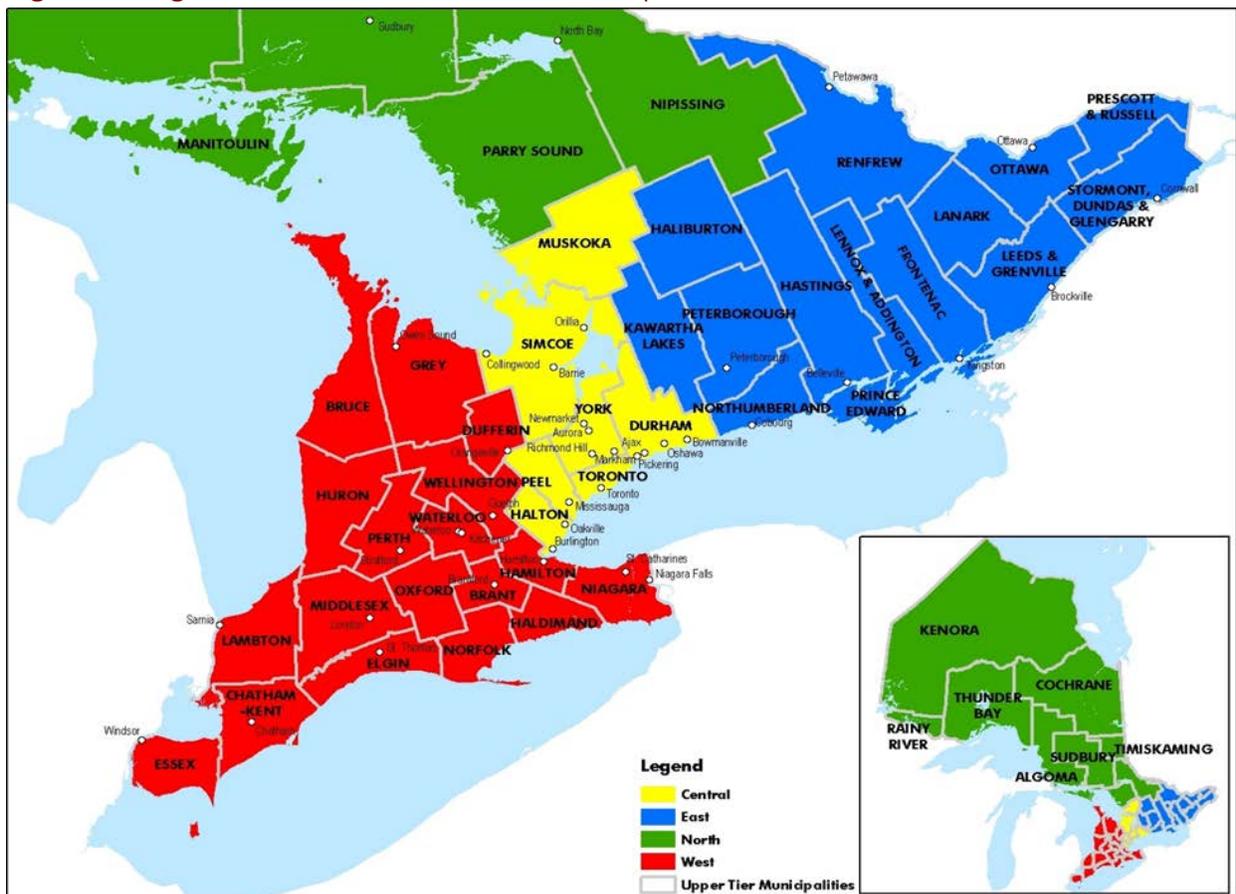
highest in the West region (\$2.91) and lowest in the East region (\$0.68). Despite a much lower average expenditure per municipality, the expenditure per person in the North region (\$2.57) was higher than in the Central region (\$1.68), where the highest average expenditure was found.

Regional variation was also found for the CAs (see Table 3). Responses were received from all 6 CAs in the Central region, while only 3 of 11 CAs in the East region (27.3%) and 4 of 14 CAs in the West region (28.6%) submitted survey responses. Average expenditures were highest in the Central (\$727,722) and East (\$670,000) regions, and were only \$18,727 for CAs in the North region. Expenditure per person was by far the highest in the East region (\$2.56), and was lowest in the North region (\$0.19).

2.3.4 Summary of Results

Expenditures on invasive species were reported by the vast majority of both municipalities and CAs. Average expenditure for CAs (\$453,132) was greater than for municipalities (\$282,064), while per capita expenditure was higher for municipalities (\$1.88) than for CAs (\$0.72). The higher average expenditure for CAs differs from the results of the 2018 survey, where average expenditure was higher for municipalities. This difference from one survey year to the next occurred primarily due to responses from more of the highly populated CAs in the Central region, most of which reported relatively high expenditures on invasive species. Overall, highly populated municipalities and CAs tended to have much higher expenditures on invasive species activities than less populated municipalities and CAs.

Figure 3: Regional divisions for Ontario municipalities



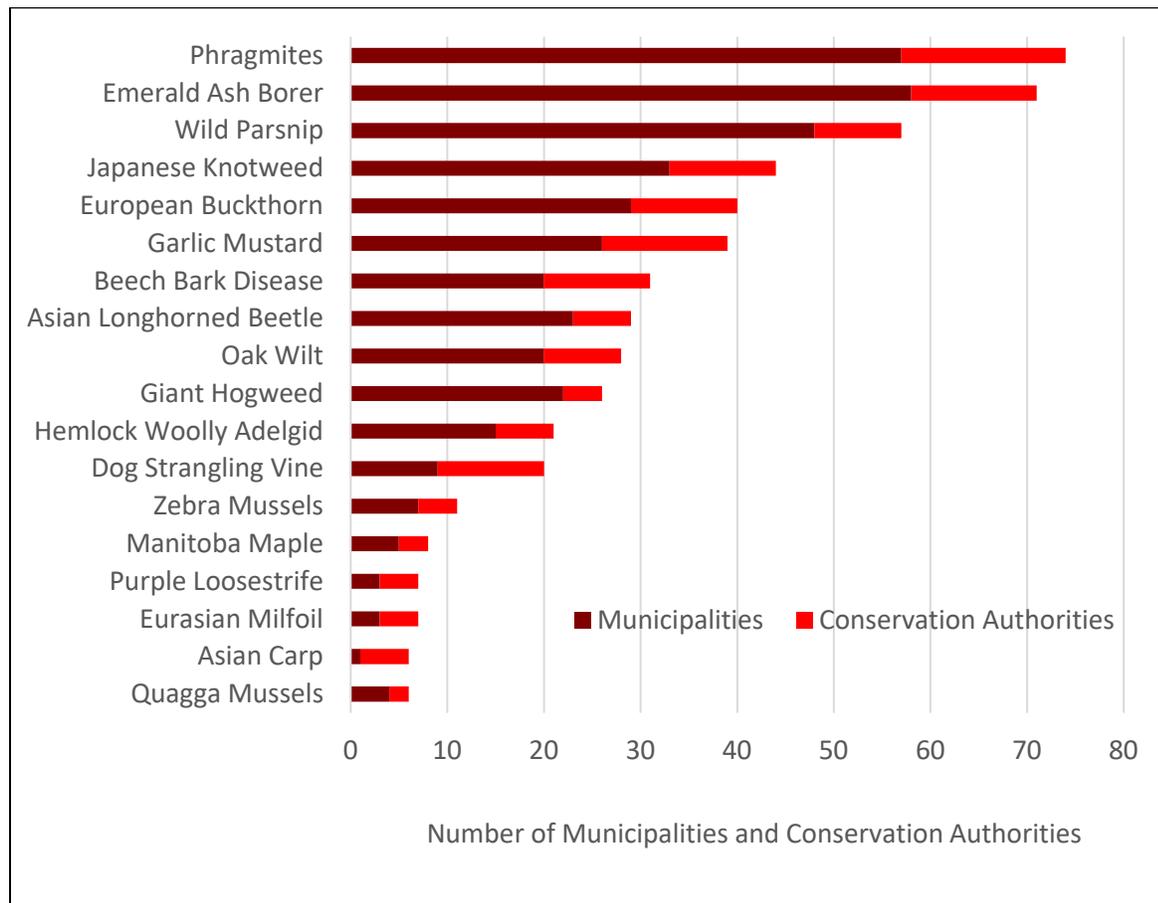
Source: <http://www.payequity.gov.on.ca/en/AboutUs/Pages/Assesing-Proxy-Use-Map-of-Ontario-Regions.aspx>

Average expenditures for the sample municipalities were highest in the Central and West regions, and for sample CAs these expenditures were highest in the Central and East regions. While per capita expenditure was lowest in the East region for municipalities (\$0.68), it was highest for CAs (\$2.56). This suggests that in this region CAs play a greater role in invasive species management than do municipalities.

As with the previous surveys in 2017 and 2018, reported expenditures were highest for emerald ash borer. In the 2019 survey, expenditures on emerald ash borer accounted for 56.9% of all reported species-specific expenditures across the sample municipalities and CAs (see Table 4). Considerable expenditures were also reported for zebra mussels (9.4%), gypsy moth (9.3%), quagga mussels (9.3%), and phragmites (6.3%).

Overall, a large number of invasive species of concern were identified by survey respondents. Figure 4 indicates the invasive species that were most frequently reported by sample municipalities and CAs as species of concern within their jurisdictions. As evident in this figure, the most frequently reported species of concern were phragmites, emerald ash borer, and wild parsnip. The top three species of concern reported by respondents from the sample municipalities were emerald ash borer (58 municipalities), phragmites (57), wild parsnip (48), Japanese knotweed (33), and European buckthorn (29), while the top three species of concern reported for the sample CAs were phragmites (15 CAs), emerald ash borer (13), and garlic mustard (13).

Figure 4: Invasive species of concern reported by sample municipalities and conservation authorities



2.4 Data Issues and Limitations

Survey data reliability is heavily dependent on the accuracy of information provided by respondents. While follow-up was conducted with some respondents to clarify their responses, it remains a possibility that some information provided in the survey responses may not be completely accurate. Hence, it must be acknowledged that the accuracy of the total provincial expenditure on invasive species estimated in this report is dependent on the assumption that the information provided through the surveys is accurate.

Some survey respondents did not provide answers for all questions. This was addressed in various ways, depending on the nature of the missing or unknown information. In one case, the survey response had to be dropped from the survey data because the respondent indicated that the expenditure amount was unknown. In this case, there was no other information provided by the respondent that could be used to reasonably estimate this expenditure amount. In another case, the total expenditure amount was not provided by the respondent, but species-specific expenditure amounts were reported. In this case, it was assumed that the reported species-specific amounts accounted for all expenditures on invasive species within the municipality, and the total expenditure amount was entered accordingly.

In some cases, assumptions were applied to fill in missing data. As described above, in cases where respondents did not provide or know the percentage of total expenditure for their jurisdiction that was incurred by their department, the average percentage reported by other respondents within the same category of departments was used to estimate total expenditure by the jurisdiction. It should be acknowledged that this process may lead to inaccurate estimates of expenditures by these jurisdictions. However, given the relatively low number of cases where these assumptions were imposed as well as the relatively small differences between the reported department expenditures and the resulting estimated total expenditures by the jurisdictions (since average percentages were between 80% and 90% for all department categories), it is unlikely that the potential errors would have a substantial impact on the estimated total provincial expenditure.

There were other cases where data was aggregated or where calculations were made based only on responses where the required information was provided. For example, not all respondents that reported expenditures on invasive species activities provided the allocations for the three categories of activities. As a result, the average allocations discussed above are based only on the responses that provided percentage allocations. Similarly, not all respondents that reported expenditures provided expenditure amounts for specific invasive species. As a result, the reported percentages of species-specific expenditures (Table 4) are based only on responses with these expenditure amounts provided. Approximately 75% of expenditures reported by the sample municipalities and 34% of expenditures reported by CAs were allocated to specific species.

2.5 Sample Representativeness

The accuracy of an estimated value for an entire population based on a sample of that population may be affected by the representativeness of that sample, or how well the sample reflects the characteristics of the entire population. For this report, the accuracy of the estimated value for total expenditure on invasive species for all municipalities and CAs in the province may depend on how well the characteristics of the sample municipalities represent those of all municipalities in the province and how well the characteristics of the sample CAs represent those of all CAs. As a result, it is important to assess the representativeness

of the samples of municipalities and CAs. The representativeness is assessed based on a number of factors, such as population, household income, and land area.

2.5.1 Sample Representativeness: Municipalities

The municipality sample comprises 88 of the 444 municipalities in Ontario, or 19.8%. The combined population of the sample municipalities represents 61.8% of the total combined population of all municipalities in the province. The average of the median household income for each of the sample municipalities is 99.9% of the provincial median household income. The land area covered by the 88 sample municipalities accounts for 31.3% of the combined land area of all municipalities in the province. As such, the sample is very representative of the population based on household income and is somewhat representative based on land area. However, the sample does not appear to be very representative in terms of population. As a result, it is important to account for the influence of population when estimating based on this sample. This coincides with the 2017 and 2018 surveys, where the samples were not found to be very representative based on population. The results of the previous surveys also demonstrated the importance of accounting for the influence of population, and how this may generate a more accurate estimate of total expenditure.

It is evident from the survey results by region that the municipality sample is more heavily weighted toward the Central region. Just over half of all municipalities in this region are included in the sample, while the proportions included in the sample for the other three regions range from 9.7% to 21.4%. The Central region is also the most populated region, so this bias is correlated with the population bias. This again demonstrates the need to account for the influence of population in order to minimize the potential bias in the estimation of total expenditure on invasive species. The methods used for this estimation are described in Section 3.1.

2.5.2 Sample Representativeness: Conservation Authorities

The CA sample comprises 16 of the 36 CAs in Ontario, or 44.4%. The larger proportional sample may be necessary since the population (total number of CAs) is quite low. Finding a representative sample may be challenging if the sample is too small. While Census data on population is not collected at the CA level, population estimates were generated for each CA, as described above. This allows for assessing the representativeness of the sample based on population. The population of the sample CAs represents 77.8% of the combined estimated population of all CAs in the province. Sample representativeness for CAs is also assessed based on land area. The land area of the sample CAs accounts for 40.2% of the total land area across all CAs. As such, the sample is quite representative of the population based on land area, but is not very representative based on population. This indicates the importance of accounting for the influence of population when generating the estimated total expenditure on invasive species across all CAs based on the sample CAs.

As with the municipality sample, the CA sample is more heavily weighted toward the Central region. All 6 CAs in this region are included in the sample, while only 27.3% of CAs in the East region and 28.6% of CAs in the West region are included in the sample. This contributed to the lack of representativeness based on population, as the Central region is the most populated region in the province.

2.6 Combined Survey Results: 2017-2019

To increase the sample size and potentially enhance the accuracy of the estimated total annual expenditure, the survey results from 2019 were combined with those of the 2018 and 2017 surveys. This may also address sampling representativeness issues from individual years. As discussed in the 2018 report, high expenditure (and high population) municipalities were over-represented in the 2017 sample and were under-represented in the 2018 sample. Specifically, four out of 35 sample municipalities in the 2017 survey reported expenditures of over \$1 million, including two that were over \$5 million, while only one of the 68 sample municipalities in the 2018 survey reported an expenditure of at least \$1 million. By comparison, four out of 88 sample municipalities in the 2019 survey reported expenditures of \$1 million or greater, one of which was over \$5 million.

Over the three years in which the surveys were conducted, 191 responses were received from municipalities and 29 from CAs. However, a number of municipalities and CAs responded to the surveys in multiple years. To avoid duplication, multiple responses from individual municipalities and CAs were combined by averaging the expenditure amounts from the two or three years of responses. A summary of expenditure statistics for the combined survey data for both municipalities and CAs is provided in Table 5, including a breakdown by region and by municipality category.

2.6.1 Municipalities

There were 30 municipalities that responded to the survey in two of the three years and another 7 municipalities that responded in all three years. After combining the multiple responses for each of these municipalities, the data consisted of responses from 147 individual municipalities. This combined sample represents 33.1% of all municipalities in Ontario.

Expenditures on invasive species activities were reported by 101 of the 147 responding municipalities (68.7%) over the three survey years. Total expenditures were \$32,067,828, with an average across all responding municipalities of \$218,148. Per capita expenditure for the combined sample was \$1.98. Average reported allocation of expenditures included 79.6% for control and management, 12.6% for detection, and 7.8% for prevention. Applying these percentage allocations to the total expenditures for the responding municipalities resulted in estimated expenditures of \$25.5 million for control and management activities, \$4.0 million for detection activities, and \$2.5 million for prevention activities.

The combined sample included 30 municipalities in the North region (20.8% of all municipalities in this region), 31 in the East region (27.2%), 36 in the Central region (65.5%), and 50 in the West region (38.2%). Average expenditure for sample municipalities was highest in the Central region, at \$527,573, and lowest in the North region, at \$10,770. Per capita expenditure was highest in the East region, at \$2.44, followed closely by the West region, at \$2.22, and was lowest in the North region, at \$0.76.

The distribution of the combined sample across the three types of municipalities included 20 counties (58.8% of all counties in the province), 23 urban areas (59.0% of all urban areas), and 104 townships (28.0% of all townships). As with the 2019 sample, the combined sample is heavily weighted toward counties and urban areas. Expenditures were incurred by 95.0% of counties, 87.0% of urban areas, and 59.6% of townships. Average expenditure was by far the highest for urban areas (\$1,077,562), and was lowest for townships (\$28,976). Per capita expenditure was highest for urban areas (\$2.98) and lowest for counties (\$0.65), which is consistent with the results of the 2019 sample.

Table 5: Expenditure statistics for municipalities and conservation authorities, by region and by municipality category: 2017-2019 survey data

	Total	Region				Municipality Category		
		North	East	Central	West	Counties	Urban Areas	Townships
Municipalities								
Total	444	144	114	55	131	34	39	371
Sample	147	30	31	36	50	20	23	104
% of Total	33.1%	20.8%	27.2%	65.5%	38.2%	58.8%	59.0%	28.0%
Expenditures Incurred	101	7	21	32	41	19	20	62
% of Sample	68.7%	23.3%	67.7%	88.9%	82.0%	95.0%	87.0%	59.6%
Total Expenditures	\$32,067,828	\$323,096	\$4,105,157	\$18,992,611	\$8,646,964	\$4,270,360	\$24,783,934	\$3,013,533
Average Expenditure	\$218,148	\$10,770	\$132,424	\$527,573	\$172,939	\$213,518	\$1,077,562	\$28,976
Per Capita Expenditure	\$1.98	\$0.76	\$2.44	\$1.86	\$2.22	\$0.65	\$2.98	\$2.24
Conservation Authorities								
Total	36	5	11	6	14			
Sample	23	3	7	6	7			
% of Total	63.9%	60.0%	63.6%	100.0%	50.0%			
Expenditures Incurred	20	3	5	6	6			
% of Sample	87.0%	100.0%	71.4%	100.0%	85.7%			
Total Expenditures	\$7,238,659	\$29,206	\$2,056,300	\$4,261,335	\$891,819			
Average Expenditure	\$314,724	\$9,735	\$293,757	\$710,222	\$127,403			
Per Capita Expenditure	\$0.65	\$0.10	\$1.69	\$0.62	\$0.33			

2.6.2 Conservation Authorities

Surveys of CAs were only conducted in 2018 and 2019. There were 6 CAs that responded to the survey in both years. After combining the multiple responses for each of these CAs, survey data was received from 23 individual CAs. This combined sample represents 63.9% of all CAs in the province.

Expenditures on invasive species were reported by 20 of the 23 CAs (87.0%) that responded to the surveys in 2018 and 2019. Total expenditures for the responding CAs were \$7,238,659, which was an average of \$314,724 for each of these CAs. Per capita expenditure was \$0.65. Average allocations of expenditures were 65.8% for control and management activities, 18.1% for detection activities, and 16.1% for prevention activities. Applying these percentage allocations to the total expenditures for the responding CAs resulted in estimated expenditures of \$4.8 million for control and management activities, \$1.3 million for detection activities, and \$1.2 million for prevention activities.

The combined sample of CAs included 3 CAs in the North region, 7 in the East region, 6 in the Central region, and 7 in the West region. Average expenditure for responding CAs was highest in the Central region, at \$710,222, and lowest in the North region, at \$9,735. Per capita expenditure was highest in the East region, at \$1.69, and lowest in the North region, at \$0.10.

2.6.3 Summary

The combined survey results from 2017-2019 are compared with the 2019 survey results in Table 6. For municipalities, average expenditure was somewhat higher for the 2019 survey data (\$282,064) than for the combined survey data (\$218,148). This was due in part to the relatively larger number of municipalities in the 2018 survey that did not report any expenditures on invasive species. Conversely, the per capita expenditure was slightly higher for the combined data (\$1.98) than for the 2019 data (\$1.88), as many of the municipalities with no expenditure in the 2018 survey were townships with relatively low populations.

For both the 2019 data and the combined data, average expenditure was highest in the Central region and lowest in the North region. Differences between the two data sets were found for per capita expenditure. For the 2019 data, per capita expenditure was highest in the West region and lowest in the East region, while for the combined data, per capita expenditure was highest and in the East region and lowest in the North region. These differences occurred in part due to multiple responses from the same municipalities for which the reported expenditures were averaged in the combined data. For example, there was one municipality in the East region that had the highest reported expenditure in the 2017 data but a much lower expenditure in the 2019 data. As a result, the much higher expenditure for this municipality in the combined data contributed to a much higher per capita expenditure for the East region. This also contributed to a much higher average expenditure for the East region in the combined data, relative to the 2019 data, though this did not affect the relative ranking of average expenditure by region.

For CAs, as with municipalities, average expenditure was higher for the 2019 data (\$453,132) than for the combined data (\$314,724). This was due in part to a greater number of responses in 2019 from higher populated CAs that had relatively high expenditures on invasive species. The per capita expenditure was slightly higher for the 2019 data (\$0.72) than for the combined data (\$0.65). There were no differences between the 2019 data and the combined data in the regional rankings for average expenditure and for per capita expenditure. Average expenditure was highest in the Central region and lowest in the North region, while per capita expenditure was highest in the East region and lowest in the North region.

Combining the survey results from the three years creates much larger samples for both municipalities and CAs, relative to the 2019 samples. While this may enhance the accuracy of the estimated total annual expenditure, there are some potential issues inherent in combining the survey results, which are discussed in Section 4.3.

Table 6: Comparison of expenditure statistics for municipalities and conservation authorities, 2019 survey data vs. 2017-2019 survey data

	Total	Region			
		North	East	Central	West
Municipalities					
Average Expenditure					
2019 Data	\$282,064	\$31,749	\$51,299	\$511,576	\$326,060
2017-2019 Data	\$218,148	\$10,770	\$132,424	\$527,573	\$172,939
Per Capita Expenditure					
2019 Data	\$1.88	\$2.57	\$0.68	\$1.68	\$2.91
2017-2019 Data	\$1.98	\$0.76	\$2.44	\$1.86	\$2.22
Conservation Authorities					
Average Expenditure					
2019 Data	\$453,132	\$18,727	\$670,000	\$727,722	\$204,399
2017-2019 Data	\$314,724	\$9,735	\$293,757	\$710,222	\$127,403
Per Capita Expenditure					
2019 Data	\$0.72	\$0.19	\$2.56	\$0.63	\$0.39
2017-2019 Data	\$0.65	\$0.10	\$1.69	\$0.62	\$0.33

3.0 Methods for Estimating Total Expenditure

Total annual expenditure on invasive species activities by municipalities and CAs across Ontario is estimated using an extrapolation approach. This was the primary estimation approach used for the 2017 and 2018 surveys. While a regression approach was also used for the prior surveys, it was used for comparison purposes with the results of the extrapolation approach, and was only used in the estimated expenditure for municipalities. As the sample sizes have increased with each successive survey, this enhances confidence in the results of the extrapolation approach due to the lower margin of error. As such, only the extrapolation approach is used for the 2019 survey data.

Based on a population of 444 municipalities in Ontario and a sample size of 88 municipalities, the margin of error is 9.36%.⁶ By comparison, the margin of error for the 2017 survey (35 municipalities) was 15.92% and the margin of error for the 2018 survey (68 municipalities) was 10.95%. The smaller the margin of error, the greater confidence that an extrapolation of the survey data will generate an accurate estimate for the entire population.

The sample of CAs includes 16, or 44.4%, of the 36 CAs in the province. Despite the fact that this sample represents such a large proportion of the population, the margin of error is relatively large, at 18.52%. This is due to the low population size; a sample size of 75% all CAs would be needed to bring the margin of error below 10%.

The extrapolation process is conducted separately for municipalities and for CAs. The results of each are aggregated to generate an estimate of total expenditure on invasive species by all municipalities and CAs in Ontario. Estimates are first generated based on the 2019 survey data, following which estimates are generated using the combined data from the three survey years.

3.1 Extrapolation Approaches

For each of the samples of municipalities and CAs, two extrapolation approaches are used. The first approach is a simple extrapolation based on the average expenditure for the sample municipalities or sample CAs and the total number of municipalities or CAs in the province. Hence, for municipalities the average expenditure is multiplied by 444, while for CAs the average expenditure is multiplied by 36. The extrapolated amounts for each are then added together to generate the estimated total expenditure for Ontario.

The second approach involves an extrapolation based on per capita expenditure. For both the sample municipalities and the sample CAs, the expenditure per person is multiplied by the total population. The total population differs between municipalities and CAs, since CAs do not cover the entire area of the province (see Figure 2). As a result, the total population used for the extrapolation across all CAs is adjusted to include only the population within the areas covered by CAs. This extrapolation approach is used because both samples are heavily weighted toward higher populated municipalities and CAs, which may influence the level of expenditure. As demonstrated by the discussion of the survey results, as well as by the analysis conducted for the prior surveys, population has a significant impact on the level of expenditure, as municipalities and CAs in urban areas tend to spend more on invasive species activities

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/>.

than do less-populated jurisdictions. By accounting for the influence of population in the extrapolation process, this may reduce the potential bias inherent in the simple extrapolation approach and potentially generate a more accurate estimate of total expenditure.

Two alternate extrapolation processes are used to account for variation in expenditures observed in the survey results and to test the sensitivity of the results of the original extrapolation approaches. First, to account for the observed regional variation in the municipality and CA samples (see Tables 2 and 4), the two extrapolation approaches described above are also used to conduct extrapolations to the regional level. The regional extrapolated amounts are then aggregated to generate an estimated total expenditure for municipalities and CAs in the province.

Second, to account for variation in expenditures on invasive species across different types of municipalities, estimated expenditure amounts are generated for each type and then aggregated up to the provincial level. As described in the previous section, sample municipalities are divided into three categories: counties, urban areas, and townships. Sample municipalities for both the 2019 survey and the combined 2017-2019 surveys are more heavily weighted toward higher populated municipalities (i.e., counties and urban areas). The two extrapolation approaches (based on average expenditure and based on per capita expenditure) are then used to conduct extrapolations to the municipality category level. The extrapolated amounts for each category are then aggregated to generate estimates of total expenditure for all municipalities.⁷ Since this extrapolation process applies only to municipalities, the estimates of total expenditure for CAs are the same as those of the original extrapolation approaches to the provincial level. These estimates for CAs are then added to the estimates of total expenditure for municipalities based on this alternate extrapolation process to generate the estimated total expenditure by municipalities and CAs in the province.

Each of the extrapolation approaches described above are applied to the 2019 survey data and to the combined 2017-2019 survey data. The results of these extrapolations are described in the following section.

⁷ Since this extrapolation process applies only to municipalities, the estimates of total expenditure for CAs are the same as those of the original extrapolation approaches to the provincial level.

4.0 Results

Extrapolations are conducted separately for sample municipalities and sample CAs, using the approaches described in the previous section. The extrapolated amounts are then aggregated to generate an estimate of total annual expenditure on invasive species across all municipalities and CAs in Ontario. Extrapolations are first conducted based on the 2019 survey data, and then based on the combined data from the 2017, 2018, and 2019 surveys. Considerable variation is evident in the estimates across the different extrapolation approaches. The extrapolation results, which are described below, are summarized in Table 7.

4.1 Extrapolation Results for 2019 Survey Data

Two primary extrapolation approaches are used for the sample municipality and sample CA data, which include a simple extrapolation based on average expenditure and an extrapolation based on per capita expenditure. In addition, two alternate extrapolation processes are used to account for variation in expenditures.

The simple extrapolation approach involves taking the average expenditures for the sample municipalities and sample CAs and extrapolating these amounts across all municipalities and CAs in the province. The average estimated expenditure for sample municipalities is \$282,064. Extrapolating this amount across all 444 municipalities generates an estimated total expenditure by municipalities of \$125.2 million. Extrapolating the average estimated expenditure for sample CAs of \$453,132 generates an estimated total expenditure by CAs of \$16.3 million. Aggregating these extrapolated amounts results in an estimated total expenditure for all municipalities and CAs in Ontario of \$141.5 million.

The second extrapolation approach involves taking the per capita expenditures for the sample municipalities and sample CAs and extrapolating these amounts based on the populations of all municipalities and all CAs in the province. The per capita expenditure on invasive species for the sample municipalities is \$1.88. Extrapolating this amount across the combined population of all municipalities in Ontario generates an estimated total expenditure by municipalities of \$40.2 million. Extrapolating the per capita expenditure for sample CAs of \$0.72 across the combined population of all CAs generates an estimated total expenditure by CAs of \$9.3 million. Aggregating these extrapolated amounts results in an estimated total expenditure for all municipalities and CAs in Ontario of \$49.5 million.

To account for regional differences in expenditure amounts for municipalities and CAs, extrapolations of expenditures up to the regional level are conducted prior to aggregating up to the provincial level. The estimated expenditure amounts for sample municipalities and sample CAs within each of the four regions are extrapolated using the two approaches described above. The extrapolated amounts for each region are aggregated to generate an estimate of total provincial expenditure for municipalities and CAs. The extrapolations based on average expenditures by municipalities within each region, which are provided in Table 3, generate an estimated total expenditure by municipalities of \$81.3 million. Extrapolating the average expenditures for CAs within each region generates an estimated total expenditure by CAs of \$14.7 million. Combining these figures results in an estimated total provincial expenditure by municipalities and CAs of \$96.0 million.

Table 7: Summary of extrapolation results for estimated total expenditure on invasive species by all municipalities and conservation authorities in Ontario^a

Survey Data	Extrapolation Level	Extrapolation Approach	Municipalities	Conservation Authorities	Total
			(\$ millions)	(\$ millions)	(\$ millions)
2019	Provincial	Average Expenditure	\$125.2	\$16.3	\$141.5
	Provincial	Per Capita Expenditure	\$40.2	\$9.3	\$49.5
	Regional	Average Expenditure	\$81.3	\$14.7	\$96.0
	Regional	Per Capita Expenditure	\$41.2	\$10.9	\$52.1
	Municipality Category ^b	Average Expenditure	\$71.8	\$16.3	\$88.1
	Municipality Category ^b	Per Capita Expenditure	\$44.0	\$9.3	\$53.3
2017-2019	Provincial	Average Expenditure	\$96.9	\$11.3	\$108.2
	Provincial	Per Capita Expenditure	\$42.3	\$8.4	\$50.8
	Regional	Average Expenditure	\$68.3	\$9.3	\$77.6
	Regional	Per Capita Expenditure	\$43.1	\$8.8	\$52.0
	Municipality Category ^b	Average Expenditure	\$60.0	\$11.3	\$71.3
	Municipality Category ^b	Per Capita Expenditure	\$42.3	\$8.4	\$50.7

^a The bolded row of results indicates the estimate of total expenditure that is reported as the primary result (see explanation in the conclusion section).

^b Extrapolations based on municipality category are conducted only for municipalities as this extrapolation level cannot be applied to CAs. Instead, the estimated expenditure for CAs for this extrapolation level is set equal to that of the provincial level extrapolation.

Extrapolations based on per capita expenditures for sample municipalities within each region generate an estimated total expenditure by municipalities of \$41.2 million, while similar extrapolations for sample CAs within each region generate an estimated total expenditure by CAs of \$10.9 million. Aggregating these extrapolated amounts results in an estimated total provincial expenditure for municipalities and CAs of \$52.1 million.

The final extrapolation process accounts for differences in expenditures between different types of municipalities (i.e., counties, urban areas, and townships). This process involves extrapolating average and per capita expenditures for municipalities up to the municipality category level prior to aggregating up to the provincial level. Since this process only applies to municipalities, these estimates are added to the estimates for CAs based on extrapolations to the provincial level. Extrapolating average expenditures to the municipality category level generates an estimate of total expenditure by municipalities in the province of \$71.8 million. The estimate of total expenditure for all municipalities and CAs is generated by combining this estimate with the estimate for CAs based on the extrapolation of average expenditure to the provincial level of \$16.3 million. The resulting estimate of total expenditure by all municipalities and CAs based on this process is \$88.1 million. Extrapolating per capita expenditures for each category of municipalities generates an estimate of total expenditure by municipalities of \$44.0 million. Combining this estimate with the estimated expenditure for CAs of \$9.3 million, based on the extrapolation of per capita expenditure to the provincial level, generates an estimate of total expenditure by municipalities and CAs of \$53.3 million.

4.1.1 Summary

As evident in Table 7, the estimates of total expenditure on invasive species by municipalities and CAs in the province vary considerably across the different extrapolation approaches. However, the results of the simple extrapolation are highly unlikely to be accurate estimates of total expenditure on invasive species across the province, due to the samples being heavily weighted toward highly populated jurisdictions that tend to have higher expenditures on invasive species. As a result, the extrapolation approaches that account for the influence of population through an extrapolation of per capita expenditure is much more likely to generate accurate estimates of total expenditure. Thus, based on the results of the per capita expenditure extrapolations for the 2019 survey data, estimates of total expenditure on invasive species by municipalities and CAs across Ontario range between \$49.5 million and \$53.3 million. The relatively low degree of variation across these estimates enhances confidence in their accuracy.

4.2 Extrapolation Results for Combined 2017-2019 Survey Data

The same set of extrapolation approaches is conducted based on the combined data, for which the results are summarized in Table 7. The simple extrapolation process up to the provincial level generates estimates of \$96.9 million for municipalities and \$11.3 million for CAs, for a total estimated expenditure on invasive species by all municipalities and CAs in Ontario of \$108.2 million. The extrapolation process up to the provincial level based on per capita expenditure generates estimates of \$42.3 million for municipalities and \$8.4 million for CAs, for a total estimated expenditure of \$50.8 million.

Extrapolations are then conducted up to the regional level prior to aggregating up to the provincial level. The simple extraction process based on average expenditures and numbers of municipalities and CAs generates estimates of \$68.3 million for municipalities and \$9.3 million for CAs, for a total estimated

expenditure by all municipalities and CAs in Ontario of \$77.6 million. Extrapolations based on per capita expenditures generates estimates of \$43.1 million for municipalities and \$8.8 million for CAs, for a total estimated expenditure of \$52.0 million.

Finally, extrapolations of average and per capita expenditures are conducted for each category of municipalities, which are then aggregated up to the provincial level and combined with estimates for CAs based on extrapolations to the provincial level. Extrapolation of average expenditure generates an estimate of total expenditure across all municipalities in the province of \$60.0 million. This estimate is combined with the estimate for CAs of \$11.3 million for an estimate of total expenditure by municipalities and CAs in Ontario of \$71.3 million. Extrapolation of per capita expenditure generates an estimate of total expenditure for municipalities of \$42.3 million. This estimate is added to the estimated expenditure for all CAs of \$8.4 million for an estimate of total expenditure on invasive species by all municipalities and CAs in Ontario of \$50.7 million.

4.2.1 Summary

As with the results based on the 2019 survey, the estimates of total annual expenditure on invasive species in the province based on the combined 2017-2019 surveys vary considerably. The estimates based on the simple extrapolations are much higher than those based on per capita extrapolations, although they are not quite as high as the estimates based on simple extrapolations of the 2019 survey data. But as with the estimates based on the 2019 data, the estimates based on the per capita extrapolations are likely to be much more accurate than those based on simple extrapolations, due to the influence of population on expenditure amounts. As such, based on the results of the per capita extrapolations of the combined 2017-2019 survey data, estimated total annual expenditure on invasive species by all municipalities and CAs in Ontario ranges from \$50.7 million to \$52.0 million. This range falls within the range of estimates based on extrapolations of the 2019 survey data, which further enhances confidence in these estimates.

4.3 Limitations and Potential Bias

There are limitations associated with this study that may be a source of bias for the estimated total expenditure on invasive species. The sample used to estimate total expenditure is not a randomized sample, as municipalities and CAs chose to respond to the surveys. With voluntary response samples, bias is more likely to be an issue. Bias may also arise if there is correlation between the decision to respond to the survey and the level of expenditure. For example, jurisdictions that incur expenditures on invasive species may be more likely to respond to the survey than jurisdictions that do not incur expenditures, which could bias the estimated total expenditure upward. In addition, as discussed earlier, the potential accuracy of the estimated total expenditure is largely dependent on survey respondents providing accurate and appropriate information in their responses to questions.

A potential limitation associated with estimating total expenditure based on the combined survey results is that there are differences from year to year in the survey structure and questions, which may influence the nature of the responses. In addition, the expenditure amounts used to conduct extrapolations to the provincial level differ between the 2019 survey and the 2017 and 2018 surveys. For the 2017 and 2018 surveys, extrapolations were conducted based on the reported expenditure amounts. For the 2019 survey, expenditure amounts are estimated for the entire jurisdiction based on the amount reported by the responding department and the percentage of total jurisdiction expenditure represented by the

department amount. The resulting estimated expenditures for the responding jurisdictions are often greater than the reported amounts. Since this approach was only used for the 2019 survey data, the expenditure amounts used for jurisdictions in the 2017 and 2018 surveys may be under-reported if they did not include expenditures incurred by all departments within the jurisdiction. This could cause the results in Table 7 based on the combined survey data to be under-estimated. However, given that the results based on the combined survey data are very similar to those based on only the 2019 survey data, this issue may not have contributed to a significant bias in the estimated total provincial expenditure.

5.0 Conclusions

It is evident from the results that the extrapolations of per capita expenditure are likely to generate more accurate estimates of total annual expenditure on invasive species than the simple extrapolations, as the per capita extrapolations account for the influence of population on expenditure amounts. It is also evident from the results that estimates based on the 2019 survey are quite similar to those based on the combined 2017-2019 surveys. Using the combined survey data to generate the estimate may be preferable due to the larger number of observations for both municipalities and CAs and the resulting lower margin of error. **Hence, based on the extrapolation of per capita expenditure to the provincial level for the combined 2017-2019 survey data, the estimated total annual expenditure for all municipalities and CAs in Ontario is \$50.8 million.** This works out to an estimated per capita annual expenditure of \$3.55, based on the 2018 Ontario population of 14.3 million.

To account for observed variation across regions and across municipality types, alternate extrapolation approaches were used to initially extrapolate to these levels prior to aggregating up to the provincial level. However, the results for the extrapolations to the provincial level were not found to be particularly sensitive to these alternate approaches. Specifically, for the combined survey data, the extrapolation of per capita expenditure to the regional level generated an estimate of \$52.0 million, which was only \$1.2 million (2.4%) higher than the estimate based on the extrapolation to the provincial level, while the extrapolation to the municipality category generated an estimate of \$50.7 million, which was only \$0.1 million (0.2%) lower. This minimal variation across extrapolation approaches enhances confidence in the estimate of total expenditure based on the extrapolation to the provincial level.

Applying the average expenditure allocations for the three different types of activities reported by municipalities and by CAs to the estimated total annual expenditure of \$50.8 million generates expenditure estimates of \$39.2 million for control and management activities, \$6.9 million for detection activities, and \$4.7 million for prevention activities. Based on the percentages of total reported expenditures for individual invasive species (see Table 4), the estimated total annual expenditure of \$50.8 million can be broken down by species. The resulting estimates of total annual expenditures by all municipalities and CAs for specific invasive species are provided in Table 8. As evident in this table, it is estimated that \$29.7 million was spent annually on emerald ash borer, \$4.5 million on zebra mussels, \$4.5 million on gypsy moth, \$4.5 million on quagga mussels, and \$3.2 million on phragmites.

The estimated total expenditure of \$50.8 million is higher than the estimate provided in the 2018 report of \$38.8 million, which was based on the 2017 and 2018 surveys. Part of the reason for this difference is that the 2019 survey enabled the estimation of total expenditure on invasive species for each of the responding municipalities and CAs. Respondents in the 2019 survey were asked to report the proportion of total expenditures within their jurisdiction that were incurred by their department. Based on their responses, the reported amounts were adjusted accordingly to estimate total expenditure within the jurisdiction. By comparison, estimates from the 2018 and 2017 surveys were based only on the expenditures reported by the responding department within the jurisdiction. As such, in some jurisdictions where multiple departments incur expenditures on invasive species, this may have caused expenditures to be under-reported, which would in turn cause total annual expenditure across the province to be under-estimated.

Table 8: Estimated expenditures on individual invasive species by all municipalities and conservation authorities (based on the estimated total annual expenditure in Ontario of \$50.8 million)

Invasive Species	Estimated Total Expenditure		
	Municipalities	Conservation Authorities	Total
Emerald Ash Borer	\$22,426,763	\$7,300,615	\$29,727,378
Zebra Mussels	\$4,486,761	\$0	\$4,486,761
Gypsy Moth	\$4,474,562	\$0	\$4,474,562
Quagga Mussels	\$4,458,250	\$0	\$4,458,250
Phragmites	\$2,806,166	\$349,098	\$3,155,264
Wild Parsnip	\$1,081,183	\$4,736	\$1,085,919
European Buckthorn	\$832,318	\$206,561	\$1,038,880
Dutch Elm Disease	\$587,569	\$0	\$587,569
Dog Strangling Vine	\$88,813	\$234,956	\$323,770
Giant Hogweed	\$209,416	\$21,974	\$231,390
Asian Longhorned Beetle	\$227,778	\$0	\$227,778
Autumn Olive	\$205,649	\$6,761	\$212,410
Japanese Knotweed	\$163,851	\$18,596	\$182,448
Sea Lamprey	\$0	\$108,181	\$108,181
Garlic Mustard	\$55,385	\$39,151	\$94,536
Asian Carp	\$0	\$67,613	\$67,613
Linden Bark Borer	\$61,695	\$0	\$61,695
Oak Wilt	\$50,874	\$3,381	\$54,255
Beech Bark Disease	\$23,711	\$28,060	\$51,770
Hemlock Woolly Adelgid	\$10,829	\$28,736	\$39,565
Brown Spruce Longhorned Beetle	\$30,508	\$0	\$30,508
Glossy Buckthorn	\$29,378	\$0	\$29,378
Manitoba Maple	\$11,299	\$0	\$11,299
European Chafer	\$11,299	\$0	\$11,299
Scots Pine	\$11,209	\$0	\$11,209
Total	\$42,345,268	\$8,418,420	\$50,763,687

It should be noted that the total annual expenditure estimated in this study accounts only for expenditures by municipalities and CAs in the province and not by other government bodies or institutions. Expenditures by provincial and federal government departments on invasive species would not be accounted for in these estimates, which suggests that total expenditure on invasive species incurred across all levels of government likely exceeds the total expenditure estimated in this study.

It is evident from the survey responses that funding for invasive species activities is an issue facing a number of municipalities and CAs. Of the 117 responses from municipalities in the 2019 survey, 97

indicated that expenditures on invasive species activities were incurred, but only 46 of these respondents indicated that dedicated funding was provided in their departments for these activities, while another 23 indicated that funds for these activities came from other departments within the municipality. Of the 21 responses from CAs, 18 incurred expenditures on invasive species, but only 3 of these respondents indicated that dedicated funding was provided in their departments, while another 6 respondents indicated that funds for these expenditures came from other departments. In addition, 59 respondents from municipalities and 15 respondents from CAs indicated that the funding received was not enough to cover the costs of combating invasive species. This implies that expenditures incurred by municipalities and CAs in Ontario could be much higher than the estimated total expenditure if funding were available.

As described in the 2017 report, there are tremendous economic benefits associated with controlling invasive species in Ontario, as the annual economic impacts of invasive species were estimated to be \$3.6 billion. As such, additional funding for invasive species activities, even a substantial increase over and above the total annual expenditure estimated by this study, could generate a net economic benefit to the province.