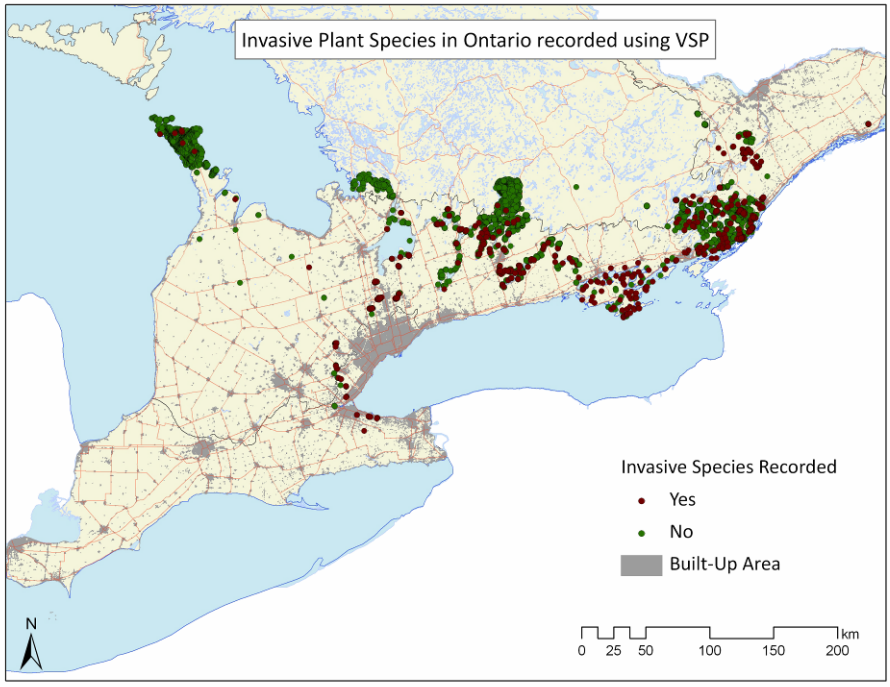
TOWARDS IMPROVED UNDERSTANDING OF THE DISTRIBUTION AND ABUNDANCE OF INVASIVE PLANT SPECIES IN SOUTHERN ONTARIO FORESTS



March 2012

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With assistance from Harold Doran and Julia Buck

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We would like to thank Harold Doran for compiling and standardizing VSP data and Julia Buck for making the maps.

Final report to the Invasive Species Centre Partnership Fund 2011-2012

Date: March 31st, 2012

Project Description:

Management actions to control invasive species and reduce their negative impacts must be based on sound inventory and monitoring information. Data collected using the Vegetation Sampling Protocol or VSP (http://www.forestry.utoronto.ca/imsa/VSP/) is one of the most comprehensive terrestrial vegetation databases for southern Ontario forests with over 5,000 plots collected from 2005 to 2011. This project assessed the quality of currently available VSP data on terrestrial invasive plant species. This report demonstrates that VSP data can be used to determine location, frequency and abundance of invasive species, and hence can support invasive species management decisions. Recommendations on modifications and additions to the VSP protocols to better sample terrestrial invasive species are also made.

Project Duration: Three months

Fiscal year: 2011-2012

Project Start Date: January, 2012

Project End Date: March 31st, 2012

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INTRODUCTION

Invasive species have been a constant and growing concern in natural resource management and conservation for over fifty years (Elton 1958). Invasive species stresses to natural systems and biodiversity, as well as the growing economic cost of controlling these species and mitigating their negative impacts have become pronounced in the past twenty years. Adaptive management, either tailored to detect and eradicate invasive species and/or to reduce negative impacts to native ecosystems, needs to be prioritized and based on sound inventory and monitoring information. Management actions to control and reduce invasive species impacts must be based on comprehensive quantitative and spatial data, otherwise they will be ad hoc at best. Inventory and monitoring are needed to detect and monitor invasive species, measure effectiveness of management actions, and develop appropriate management practices.

Integrated inventory and monitoring efforts are required to systematically measure the extent and abundance of invasive species, but also associated responses of native flora and fauna. Inventory information needs to be standard across spatial and temporal scales, and yet cost-effective and robust enough to support timely, adaptive and informed decision-making. The information also needs to be relatively easy to obtain, but yet reliable, systematic and scientifically rigorous.

The Vegetation Sampling Protocol (VSP) is an inventory and monitoring approach for collection of data on vegetation communities that also collects information on the distribution and abundance of invasive plant species in southern Ontario. VSP was designed and developed to support strategic, diverse and long-term vegetation management and conservation needs. VSP is an integrative, spatial and quantitative vegetation inventory and monitoring method that includes invasive species sampling. VSP is a fixed area plot-based inventory protocol with a proven field application and a data record. Through the combined efforts of partners and Southern Science and Information Section staff at the Ontario Ministry of Natural Resources (OMNR), the Vegetation Sampling Protocol (VSP) database, with over 5,000 spatially geo-referenced plots collected over the period 2005 to 2011, is one of the most comprehensive vegetation databases for southern Ontario.

The main goals of this project were to examine the available VSP information, assess to what extent and detail it captures invasive species, and demonstrate how it can inform invasive species

management and related conservation needs. The VSP data collection protocol was also reviewed to identify to what degree and extent it can be used to support invasive plant species inventory and monitoring. Finally, based on gaps identified by analysing both available VSP data and the protocol, additions and modifications were made to the protocol to better sample invasive plant species. Recommendations on how VSP can support invasive species tracking and management and how to integrate invasive plant inventory with regular vegetation inventory and monitoring, and sampling design were also made.

Specific objectives of this project were to:

1. Assess the quality of available data on invasive plant species in the VSP databases by summarizing how often invasive species are recorded in VSP inventories that vary in sampling intensity and effort.
2. Recommend additions/modifications to the VSP protocol that will better sample terrestrial invasive species based on gaps identified by reviews of both the VSP databases and relevant literature.
3. Develop an invasive species VSP inventory module that will incorporate invasive plant species sampling as part of VSP inventory.
4. Enhance the existing VSP field data capture tools (e.g., spatial accuracy and use of high-resolution GPS units, scanable data capture forms) to more comprehensively support invasive species inventory needs.
5. Adjust the existing VSP inventory information management system to support regular reporting of invasive species distribution and extent and incorporate new data tables and fields to accommodate new invasive species sampling protocols.

METHODS

Through partner landowner contact and field sampling efforts the VSP database presently comprises information on over 5,000 vegetation plots collected from 2005 to 2011. This data base was used to conduct the analysis and assess how current VSP sampling protocols support invasive species inventory. To conduct the analysis an invasive species list was compiled based on a review of the most recent literature and web based resources. The VSP data was then queried for species on this list. In addition, the VSP protocol, field sampling procedures and sampling design were reviewed and refined to support enhanced invasive species sampling in the future.

VSP SAMPLING PROTOCOL

Southern Science and Information Section (SSIS), OMNR developed the VSP protocol (http://www.forestry.utoronto.ca/imsa/VSP/index.html) and support implementation of VSP by building partnerships, training and mentoring field staff, developing statistical sampling designs, providing access to and training on high resolution GPS units, transcribing and checking quality of data on field sheets, providing botanical expertise, and managing the information to facilitate analysis and reporting. This level of SSIS staff support ensures that data collected is quantitative, meets numerous quality control standards, is spatially accurate, and is well-managed.

VSP data was collected by many partners, organizations and groups over the period 2005 - 2011. Partners that have used/are using the VSP for vegetation inventory and monitoring in southern Ontario include: St. Lawrence Islands National Park, Bruce Peninsula National Park, Trent-Severn Waterway National Historic Site, Nature Conservancy of Canada (Eastern Ontario Region), Eastern Ontario Model Forest, Frontenac Arch Biosphere Reserve, Ontario Parks - Provincial Parks and Nature Reserves, OMNR Kemptville District, MNR Aurora District[1], OMNR Midhurst District[1], OMNR Peterborough District, Prince Edward County Stewardship Council, Stormont, Dundas & Glengarry Stewardship Council, Niagara Escarpment Commission and Niagara Escarpment Biosphere Reserve.

All VSP field data is collected within a fixed area plot that is typically 400m^2 for forest communities, but can be smaller or larger to accommodate sampling other vegetation types (Puric-

[1] As part of the proposed Comprehensive Monitoring Program for the Lake Simcoe Protection Plan.

Mladenovic et al. 2009). VSP collects plant information along with precise geographic (GPS) location information, topographic description, soil and other habitat characteristics. The current VSP sampling protocol captures invasive plant species, as a part of the overall plant inventory, in five different ways:

1. Dominant species abundance within a plot: Within a plot boundary, abundance of up to four dominant species for each vertical vegetation strata is collected. Abundance is expressed as an absolute percent cover per plot area (from 0 to 100%). If invasive plant species are among the four dominants within a vertical vegetation stratum, their abundance is captured. If invasive plant species are not among the four dominants, they are not recorded. This data was collected in all plots sampled over the period 2005- 2011.
2. Abundance of all species within a plot: Within a plot boundary, abundance of all species for each vertical vegetation stratum is collected. Abundance is expressed as an absolute percent cover per plot area (from 0 to 100%). If an invasive plant species occurs within the plot, it is recorded along with its abundance by vegetation stratum. These abundance values can be used to indicate the dominance of an invasive species in relation to other species within the sample plot and across all sample plots. This data was collected in all plots sampled in 2011.
3. Woody species (trees, tall shrubs and vines) measurements are normally recorded for VSP forest inventory. Within a VSP sample plot, each woody species with a diameter of 5 cm or larger is recorded and its diameter is measured. DBH measurements are taken at 1.3 m above ground level to be consistent with other forest monitoring protocols (e.g., OMNR's Forest Productivity Program and the National Forest Inventory programs). This data was collected in most forest plots, including swamps, sampled during the period 2005- 2011.
4. The optional VSP regeneration sampling protocol quantifies forest regeneration at a site and over time to support forest and vegetation management decisions. Within the main VSP plot, four one-metre square sub-plots are established. These sub-plots are located along the four cardinal directions or compass points, with their centre being located half way between plot centre and the perimeter. Seedlings and saplings are counted and recorded for each woody plant species observed within each of the four regeneration sub-plots. This data was collected in all plots sampled in 2011.
5. A species of interest (e.g., species at risk or invasive species) can be captured on the

optional VSP Tracked Species and Incidental Observations sampling form. This sampling can be used independently of the main VSP plot data since it captures geographic location information. Thus invasive species can be documented anywhere where they are observed within a VSP study area. Alternatively, this form can be integrated into the sample plot data. However, because field crews were not specifically instructed to document invasive species occurrences in VSP campaigns from 2005-2011, this report does not evaluate the effectiveness of this type of sampling.

The geographic location of the VSP plot center is recorded with high accuracy (sub-metre) GPS units that facilitate relocation of sites for future visits and monitoring. Precise geographic location information is necessary to support use of field data for subsequent spatial analysis, including predictive vegetation and species distribution modeling and mapping.

In addition to vegetation information collected within each plot, a general description of the site, structural characteristics of vegetation, mode of deposition of the substrate, slope and micro-topographic features are also documented. Soils data is collected for the site using a Dutch soil auger. The effective soil texture is recorded along with any indicators of moisture, and the depth to bedrock (if applicable). For additional details on the sampling methodology see Puric-Mladenovic et al., 2009 available from http://www.forestry.utoronto.ca/imsa/VSP/index.html.

VSP DATABASE

The VSP database comprises information on more than 5,000 vegetation plots collected for the period 2005 to 2011. The VSP database contains vegetation and plant information on a range of different vegetation types: from terrestrial forests to wetlands, natural to semi-natural to anthropogenic (e.g., plantations), early successional to late-seral.

The VSP database contains plot data collected as part of spatially extensive regional vegetation inventories that sampled hundreds of plots over a specific geographic area (e.g., ecodistrict 6e10) in southern Ontario. In addition it includes plot data collected to support fine-scale inventories and applications relevant to a specific land parcel or forest stand (e.g., Nature Conservancy of Canada conservation properties).

VSP inventories conducted from 2005 to 2010, collected "dominant" plant species (up to four dominant species in each vertical vegetation stratum), DBH and site and soils information. VSP information collected from 2005 to 2010 was spatially extensive and designed primarily to

support predictive vegetation modeling and mapping. Recent projects on the Niagara Escarpment and in the Lake Simcoe basin in 2011 directed VSP sampling towards both inventory and monitoring and incorporated additional sampling to include all species and their abundance per plot, along with tree and forest regeneration measurements.

For each VSP plot, vegetation information, substrate data, and geographic coordinates were standardized, validated and checked for errors. The VSP database provided information that was used to assess to what degree the VSP protocol captured invasive species information.

INVASIVE SPECIES DESIGNATIONS AND VSP INVASIVE SPECIES LIST

With over 700 introduced plant species in Ontario, it is not surprising that conservation and management organizations with diverse mandates have differing opinions as to what constitutes an 'invasive plant species'. The differences in opinion are reflected in the variety of species included in various sub-national, regional and local invasive species lists.

The Ontario Invasive Plant Council defines invasive species as "*Alien species whose introduction or spread negatively impact native biodiversity, the economy and/or society, including human health*" . The council defines alien species as "*Plants, animals and micro-organisms that have been accidentally or deliberately introduced into areas beyond their native range*".

Invasive Species Councils have been established in each Canadian province, and have produced invasive species lists for each geographical region. In addition to this, a wealth of detailed information for individual invasive species is available from Invasive Species Councils' web sites. In the United States, the National Invasive Species Information Center serves a similar function and provides links to individual state noxious weed lists, plant species summaries, regional distribution maps, and many other resources.

The Ontario Invasive Plant Council provides a list of invasive plant species for Ontario. However, based on the review of this list and a number of different invasive species lists relevant to southern Ontario, slight differences in invasive plant designations were readily apparent. Agencies produce invasive species lists to reflect their mandate and management interest. Hence, other authoritative sources of invasive lists were reviewed including those from the adjacent jurisdictions of Quebec, Manitoba, New York and Michigan with similar environmental conditions to Ontario (Table 1). Species lists from these areas were examined and used to create a more

comprehensive, flexible and adaptable invasive species list (Appendix A). Most noxious invasive species found in Ontario are also considered invasive in neighbouring administrative regions. Local invasive species lists are available from some conservation organizations in the Greater Toronto Area (e.g., Credit Valley, Halton Region, and Toronto Region Conservation Authorities), however, for this analysis only regional lists and the Ontario Invasive Plant Council definition of 'invasive plant species' were used.

TABLE 1: WEB-BASED RESOURCES USED TO COMPILE VSP INVASIVE PLANT SPECIES LIST IN FEBRUARY 2012.

Title of the document and invasive species list	Web Address	Agency or Organization
Invasive Plants in Canada - 1997	http://archive.rbg.ca/cbcn/en/projects/invasives/i_list.html	Canadian Botanical Conservation Network
Invasive Species List	http://ufora.net/index.php/resources/invasive-species/	Urban Forest Associates Incorporated
Landowner's Guide to Controlling Invasive Woodland Plants	http://www.ontarioinvasiveplants.ca/	Ontario Invasive Plant Council (OIPC)
Terrestrial Invasive Species	http://www.mnr.gov.on.ca/en/	Ontario Ministry of Natural Resources
Great Lakes United - Invasive Plant Watch Network	http://rspee.glu.org/autres/index.php	University of Montreal
Invasive Species List	http://invasivespeciesmanitoba.com/site/	Invasive Species Council of Manitoba
Michigan Invasive Plant Assessment	http://invasiveplantsmi.org/	Michigan Invasive Plant Council
Nuisance and Invasive Species	http://www.dec.ny.gov/animals/265.html	New York Invasive Species Council
Global Invasive Species Database	http://www.issg.org/database/welcome/	Invasive Species Specialist Group

Rather than favouring one list, we resolved discrepancies and similarities among different lists by compiling a consolidated invasive plant species designation list that incorporates lists from the nine agencies noted in Table 1. From the nine selected references we chose species that occur in Ontario and were consistently classified as 'invasive'. Thus, the consolidated invasive species list for southern Ontario is based on consensus, determined by the number of times a plant species was listed as invasive in the Great Lakes region.

Ontario's information in the Canadian Invasive Plant List (1997) found at the Canadian Botanical Conservation Network website was used as a base. Additional plant species were appended if

they were cited in three or more of the other eight reference sources. Species that were cited by only two sources will be tracked (TR). While these species may not be serious invaders in Ontario at present, they may become more widespread and abundant in the future with climate change. Species that are not currently known in Ontario, but have a distribution in adjacent jurisdictions, were noted as potential invaders given the potential for plant introductions.

The origin of some plant species listed in the reference sources is debatable, for example some sources list native species such as Manitoba maple (*Acer negundo*), reed canary grass (*Phalaris arundinacea*), and Kentucky bluegrass (*Poa pratensis ssp. pratensis*). Morton and Venn (1990) listed Manitoba maple as a native species in Ontario, as do the FOIBIS and VASCAN databases. It is thought to be a Midwestern species that expanded its range since the beginning of the Twentieth century. Currently, in the NatureServe database Manitoba maple is mapped as an exotic species in Quebec, New Brunswick and Nova Scotia. However, this species has also been listed as an invasive species by some authors, and the Natural Heritage Information Center lists it as non-native for Ontario. For the purposes of this VSP invasive species listing, Manitoba maple is classed as a native plant species.

In contrast, Carolina fanwort (*Cabomba caroliniana*) is considered to be native by both the VASCAN and PLANTS databases and Morton and Venn (1990) yet the NatureServe database lists it as an exotic introduction and Wilson (2007) describes it as an invasive species. Since this species has a very limited distribution in Ontario (Peterborough County), it seems prudent to track since it may spread in the future. Water soldier *(Stratiotes aloides)* is an example of invasive species that is not currently listed in either the VASCAN or FOIBIS databases, but is mapped as an exotic by the NatureServe database. Water soldier is native to central Siberia and Europe. In 2008 a population was observed in the Trent Severn Waterway near Hoard's Station, east of Hastings, Ontario. As of 2011, this species is found only in this one location in all of North America. However the species has the potential to spread along the Trent Severn Waterway and become problematic in other regions of eastern North America.

INVASIVE SPECIES RANK

To help determine a species' potential negative impact on natural communities a simple ranking system has been developed (Morse 2004). This ranking system is based on a series of 20

questions in four subject areas: ecological impacts, current distribution and abundance, trend in distribution and abundance and management difficulties. Answers generate a weighted score, and the total score is used to calculate invasiveness of a species according to the following classes:

High: Species represents a severe threat to native species and ecological communities.

Medium: Species represents a moderate threat to native species and ecological communities.

Low: Species represents a significant but relatively low threat to native species and ecological communities.

Insignificant: Species represents an insignificant threat to native species and ecological communities.

Some publications use a modified numerical ranking system to represent these categories. For example, Urban Forest Associates Inc. uses four categories to present its list of invasive species (http://ufora.ca/index.php/resources/invasive-species/). These categories are in use by many other agencies that track invasive species, including the consolidated VSP invasive species list (Appendix A).

High = 1
Aggressive invasive exotic species that can dominate a site to exclude all other species and remain dominant on the site indefinitely. These are a threat to natural areas wherever they occur because they can reproduce by means that allow them to move long distances. Many are dispersed by birds, wind, water or vegetative reproduction. They are the top priority for conservation measures, but control may be difficult. Eradication may be the only option for long-term success.

Medium = 2
Exotic species that are highly invasive but tend to only dominate certain niches or do not spread rapidly from major concentrations. Many of these spread vegetatively, or by seeds that drop close to parent plants. They may have been deliberately planted and persist in dense populations for long periods.

Low = 3
Exotic species that are moderately invasive but can become locally dominant when the proper conditions exist. Control where necessary and limit their spread to other areas.

Insignificant = 4
Exotic species that do not pose a serious threat to natural plant communities unless they are competing directly with more desirable vegetation. These can often be tolerated in restoration projects if they are already present. They may eventually be replaced through natural succession or management.

SUB-NATIONAL RANKING

In addition to the ranking of species invasiveness, a provincial ranking system also assesses a species' conservation status, relative to other species found in the flora (Oldham 2009). There are over 700 plant species which have been introduced into the flora of Ontario. These have been assigned a SNR or SNA ranking by the Natural Heritage Information Centre in Peterborough. A SNA rank represents a **S**ub-national rank **N**ot **A**pplicable, which is a conservation rank assigned because the species is not suitable for conservation activities. This category generally applies to plants that are clearly introductions into our flora. A SNR (**S**ub-national **N**ot **R**anked) label is used to identify species that currently have no assigned conservation status. It is sometimes difficult to determine the origin of a species, so these species are given this temporary SNR placeholder. As information about a species becomes available, it will be assessed and ranked.

Many regional sources included introduced species in their invasive species list. However, most of these species do not aggressively invade and displace native species. Species such as oxeye daisy (*Chrysanthemum leucanthemum*), common plantain (*Plantago major*) and helleborine (*Epipactis helleborine*) are introductions to our flora, but do not have a major impact on existing native plant communities. These species have become part of the Ontario flora and have not been assigned an invasive plant ranking.

RESULTS AND DISCUSSION

VSP field data collection, 2005-2011, and the invasive species list compiled for this project formed the base of the analysis. VSP inventory and monitoring efforts (2005-2011) were undertaken by partners to support multiple business needs ranging from regional to site-specific inventories of vegetation communities, biomass, and species at risk; to developing a framework for long-term monitoring; input to park and vegetation management plans, and more. Some partners used a statistical sampling design while others were opportunistic and targeted specific areas and/or vegetation types. Though these efforts did not specifically look for invasive species, nor specifically sample invasive species, they were still effective in capturing fairly comprehensive information on the distribution of invasive plant species across southern Ontario.

The results and discussion are first presented for the four VSP sampling efforts and their ability to capture invasive species distribution and abundance records. Then the distribution and abundance of the most frequent invasive species recorded by VSP is discussed

INTENSITY OF VSP SAMPLING AND INVASIVE SPECIES CAPTURE

The plot data was analyzed and reviewed to assess how four VSP inventory sampling intensities, (1) dominant species/plot, (2) full species list, (3) woody species measurements and (4) regeneration sub-plots, captured occurrence and abundance data for the invasive species listed in Appendix A. For example, in the most recent projects (Niagara Escarpment and Lake Simcoe inventory and monitoring projects 2011), invasive species and their absence were sampled by all four VSP inventory sampling intensities. This data was compared to the quantitative abundance data collected for the "dominant" plant species in each of four height strata in each main plot to determine the degree and extent of invasive species capture with this protocol. The findings from this review show that each of the VSP sampling protocols is effective in capturing invasive species distribution and abundance.

1. INVASIVE SPECIES RECORDED BY VSP DOMINANT SPECIES SAMPLING

For the 5,267plots sampled during the period 2005-2010, sampling four dominant species in each vegetation height strata in the plot recorded presence of invasive species in 11% or 513 of plots. Thirty (30) invasive species were recorded of which 67% are highly invasive or aggressively invasive. Among the 30 invasive species recorded, European buckthorn was most

commonly recorded (333 plots), followed by purple loosestrife (85 plots), European frog-bit (78 plots), Tartarian honeysuckle (66 plots), garlic mustard (50 plots), cow vetch (39 plots), and bittersweet nightshade (33 plots). Frequency of other invasive plant species is provided in Table 2.

TABLE 2: INVASIVE SPECIES RECORDED BY DOMINANT SPECIES SAMPLING (2005-2010).

Common Name	Scientific Name	Invasive Ranking[1]	No. of plots	Average % cover	Max. % cover
European buckthorn	*Rhamnus cathartica*	1	333	9	80
Purple loosestrife	*Lythrum salicaria*	1	85	5	32
European frog-bit	*Hydrocharis morsus-ranae*	1	78	3	40
Tartarian honeysuckle	*Lonicera tatarica*	1	66	4	45
Garlic mustard	*Alliaria petiolata*	1	50	9	61
Cow vetch	*Vicia cracca*	2	39	7	35
Bittersweet nightshade	*Solanum dulcamara*	3	33	3	10
White sweet clover	*Melilotus alba*	2	19	9	30
Glossy buckthorn	*Rhamnus frangula*	1	17	8	85
White bedstraw	*Galium mollugo*	2	15	13	55
St. John's wort	*Hypericum perforatum*	4	11	2	5
Scots pine	*Pinus sylvestris*	2	9	9	19
Bull thistle	*Cirsium vulgare*	3	9	1	3
Smooth brome grass	*Bromus inermis ssp. inermis*	4	9	27	90
Japanese barberry	*Berberis thunbergii*	3	9	1	6
Eurasian water milfoil	*Myriophyllum spicatum*	1	8	1	1
Bird's-foot Trefoil	*Lotus corniculatus*	2	7	21	58
Moneywort	*Lysimachia nummularia*	2	6	6	20
Dog-strangling vine	*Cynanchum nigrum*	1	6	1	2
Canada thistle	*Cirsium arvense*	1	5	8	10
Wild marjoram	*Origanum vulgare*	4	4	36	60
Field bindweed	*Convolvulus arvensis*	3	3	4	10
White poplar	*Populus alba*	2	3	1	3
Common barberry	*Berberis vulgaris*	3	3	1	2
Lilac	*Syringa vulgaris*	2	3	15	20
Black locust	*Robinia pseudo-acacia*	2	2	7	10
Morrow's honeysuckle	*Lonicera morrowii*	1	2	10	10
Butter-and-eggs	*Linaria vulgaris*	4	1	1	1
Yellow sweet clover	*Melilotus officinalis*	2	1	5	5
Great manna grass	*Glyceria maxima*	1	1	2	2

[1] Invasive Ranking: 1 = Aggressive Invasive, 2 = Highly Invasive, 3 = Moderately Invasive, 4 = Of Concern.

The maximum abundance (percent cover) for many of these invasives was often high (> 50%), and is partly a function of the sampling protocol that targets the four dominant species per vegetation height strata. However, as recording of abundance was not based on a threshold (i.e., dominant species must cover >5% of the plot), invasives with lower abundances were often captured (Table 2).

2. INVASIVE SPECIES RECORDED BY SAMPLING ALL SPECIES

Two VSP partnership projects in 2011, on the Niagara Escarpment and in the Lake Simcoe basin, included collecting abundance for all species within a VSP plot. Of the approximately 180 plots sampled in 2011 by these two projects, 42% had at least one invasive species. Although these plots represent a much smaller and more geographically restricted sample size than the VSP plots sampled during 2005-10, the full species list still captured 16 unique invasive species. Of those recorded, the majority (75%) are highly invasive or aggressively invasive (Table 3).

Similar to the results for dominant species sampling, the most frequently recorded invasive species were European buckthorn, garlic mustard, Tartarian honeysuckle and bittersweet nightshade (Table 3). As expected with full species sampling, lower abundances and traces (0.1) of invasive species were captured, indicating that this protocol is better suited to detecting early invasions.

TABLE 3: INVASIVE SPECIES RECORDED BY VSP FULL SPECIES LIST SAMPLING (2011).

Common Name	Scientific Name	Invasive Ranking	No. of plots	Average % cover	Max. % cover
Bird's-foot trefoil	*Lotus corniculatus*	2	1	35	35
Bittersweet nightshade	*Solanum dulcamara*	3	16	2	10
Butter-and-eggs	*Linaria vulgaris*	4	2	2	3
Canada thistle	*Cirsium arvense*	1	3	1	2
Coltsfoot	*Tussilago farfara*	4	2	12	20
Cow vetch	*Vicia cracca*	2	9	18	70
Dog-strangling vine	*Cynanchum nigrum*	1	1	0	0.1
European buckthorn	*Rhamnus cathartica*	1	51	6	45
Garlic mustard	*Alliaria petiolata*	1	25	9	45
Goutweed	*Aegopodium podagraria*	1	1	3	3
Purple loosestrife	*Lythrum salicaria*	1	6	4	8
Scots pine	*Pinus sylvestris*	2	7	10	50
Smooth brome grass	*Bromus inermis ssp. inermis*	4	6	34	70
Tartarian honeysuckle	*Lonicera tatarica*	1	12	2	5
White mulberry	*Morus alba*	1	1	2	2
White swallow-wort	*Cynanchum rossicum*	1	6	5	8

3. INVASIVE SPECIES RECORDED BY TREE DIAMETER INVENTORY

VSP forest inventory includes recording the species and measuring all woody stems that have a diameter at breast height (DBH) of 5 cm or greater. Diameter information is collected to support diverse forest management, conservation and planning needs in southern Ontario, including estimates of biomass and carbon sequestration. Tree counts and associated diameter measurements can also provide information about invasive woody species. DBH was collected in 3,160 plots over the period 2005-2011. Invasive species were recorded in the diameter measurements of 60 plots or less than 2%, providing an indication of the extent of invasive woody species presence in the sub-canopy and tall shrub layer within southern Ontario forests in ecoregion 6e. At some plots the frequency of European buckthorn and Scots pine tree stems was as high as 12-13 stems per plot. In the 60 plots that recorded invasive woody species, European buckthorn (*Rhamnus cathartica*) was measured at 47 plots (78%). About 140 stems of this species had a DBH range of 5 to 11.7 cm indicating that this invasive had been well-established for many years as might be expected of a species that was introduced prior to 1913 (Ontario Nature). Scots pine stems ranged from 17.3 to 28.4 cm. The DBH measurements and data also show that it is not unusual for Tartarian honeysuckle (*Lonicera tatarica*) to reach a DBH of over 5 cm (Table 4).

TABLE 4: NUMBER OF STEMS, AVERAGE DBH AND MAXIMUM DIAMETER OF WOODY INVASIVE SPECIES RECORDED BY VSP TREE DIAMETER INVENTORIES.

Common Name	Scientific Name	No. of stems	Average DBH (cm)	Max DBH (cm)	Invasive	Invasiveness Category
Tartarian honeysuckle	*Lonicera tatarica*	7	5.8	8.2	IN	Aggressive Invasive
Scots pine	*Pinus sylvestris*	35	17.3	28.4	IN	Highly Invasive
White poplar	*Populus alba*	6	17.9	28.8	TR	Highly Invasive
European buckthorn	*Rhamnus cathartica*	137	6.4	11.7	IN	Aggressive Invasive
Glossy buckthorn	*Rhamnus frangula*	1	5.9	5.9	IN	Aggressive Invasive
Lilac	*Syringa vulgaris*	5	6.2	8.2	TR	Highly Invasive

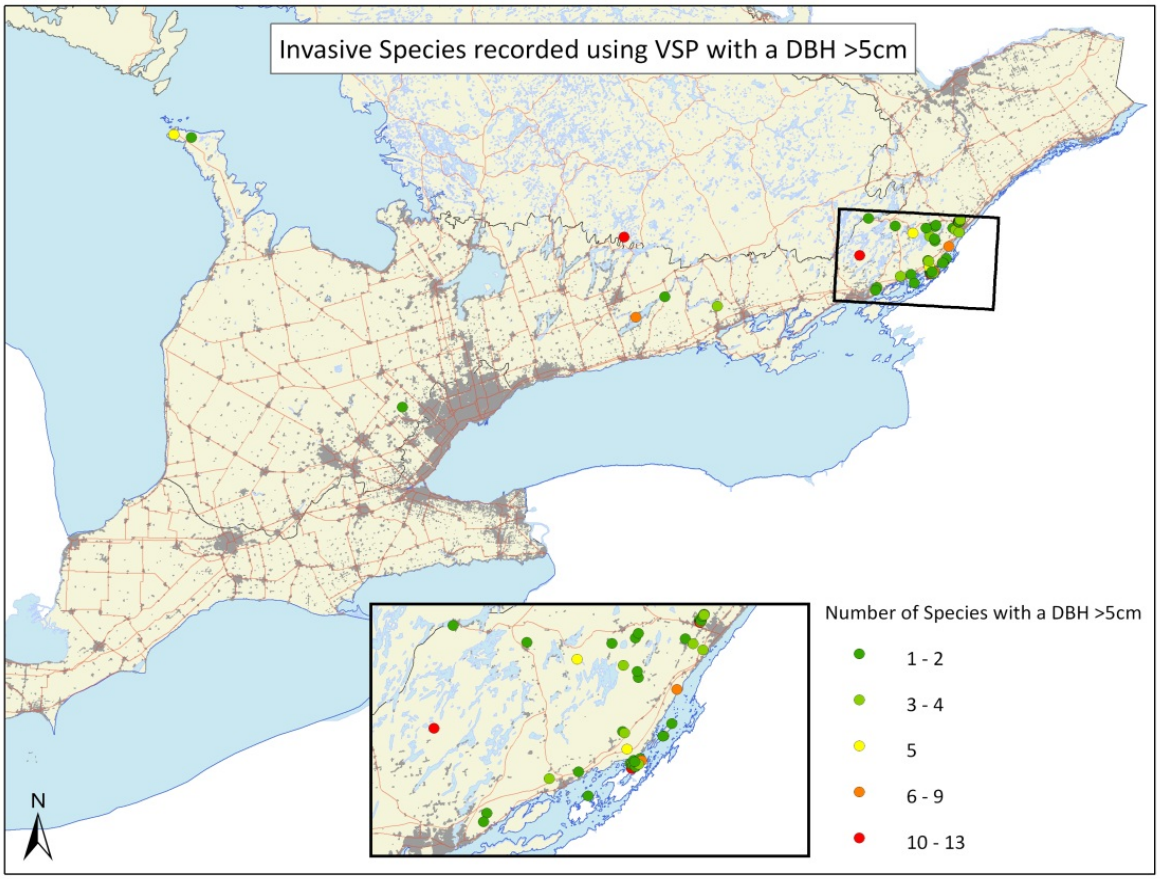


FIGURE 1: WOODY INVASIVE SPECIES WITH A DBH GREATER THAN 5 CM AS RECORDED AND MEASURED BY VSP INVENTORY.

4. INVASIVE SPECIES RECORDED IN REGENERATION SUB-PLOTS

Conservation planning and forest management in southern Ontario requires comprehensive and accurate vegetation information including data on forest regeneration. The VSP data incorporates a series of four sub-plots in which measurements are recorded for woody stems below 5 cm DBH. Data collected identifies species present, abundance and height class and can be used to monitor recruitment.

For example, European buckthorn is an invasive species which posses a considerable threat to the ecological functions and regeneration of forested ecosystems. This species has the ability to form

dense monocultures under varying levels of light availability in the understorey (Knight et al. 2007). As shown by the diameter data (Figure 1), buckthorn can also grow into the sub-canopy and have significant impacts on the structure, composition, and function of the ecosystem (Knight et al. 2007). This can subsequently affect regeneration of native tree species, potentially altering or hindering natural succession of native tree species in the stand. In 2011, VSP sampling using the regeneration protocol captured European buckthorn in a number of sub-plots, suggesting this invasive may be competing with native tree seedlings and saplings. However, though information from regeneration plots captures invasive species, it is more important to measure success of native species regeneration in relation to invasive species and their abundance across different forest conditions. This can only be done by continuing to monitor selected VSP plots with European buckthorn in the understorey over a period of time.

5. INVASIVE SPECIES RECORDED BY VSP INVENTORIES 2005-2011

Of the 5,627 VPS plots analyzed, 11% (597 plots) had at least one invasive species. Only dominant species were sampled at most locations (96 % or 5,430 plots), hence invasive species with trace or low abundance may have been missed. Figure 2 shows that clusters of invasive species are observed in more urbanized and agricultural areas and along well-travelled water bodies such as the Trent-Severn Waterway. Figure 2 also shows that areas with higher natural cover and larger natural area patches such as the Bruce Peninsula, Kawartha Highlands Signature Site and areas north of Lake Simcoe, have fewer observed invasive species. However, without detailed spatial analysis, it is not quite clear if this is due to the fact that VSP sampling captured only dominant species or if it is due to past and current land use practices that support greater natural cover in large natural area patches in these regional landscapes.

Standardized VSP data, even if only based on dominant species information, indicates that invasive species abundance is higher in eastern Ontario. Figure 2 provides a comprehensive picture of the level of VSP sampling to date. Unfortunately, few partners in southwestern Ontario have been engaged in collecting quantitative vegetation inventory data, and hence little information about distribution of invasive plant species in ecoregion 7e is available.

MOST FREQUENT INVASIVE SPECIES SAMPLED BY VSP

The VSP inventory 2005-2011, captured 33 unique invasive plant species in total (Table 5). The

most frequently observed species are European buckthorn, purple loosestrife, European frog-bit, Tartarian honeysuckle, garlic mustard, bittersweet nightshade, cow vetch, and white sweet-clover (Table 5 and Figures 2 and 3). The distribution and abundance of these invasive species, relative to all VSP sampling protocols, is discussed in the following.

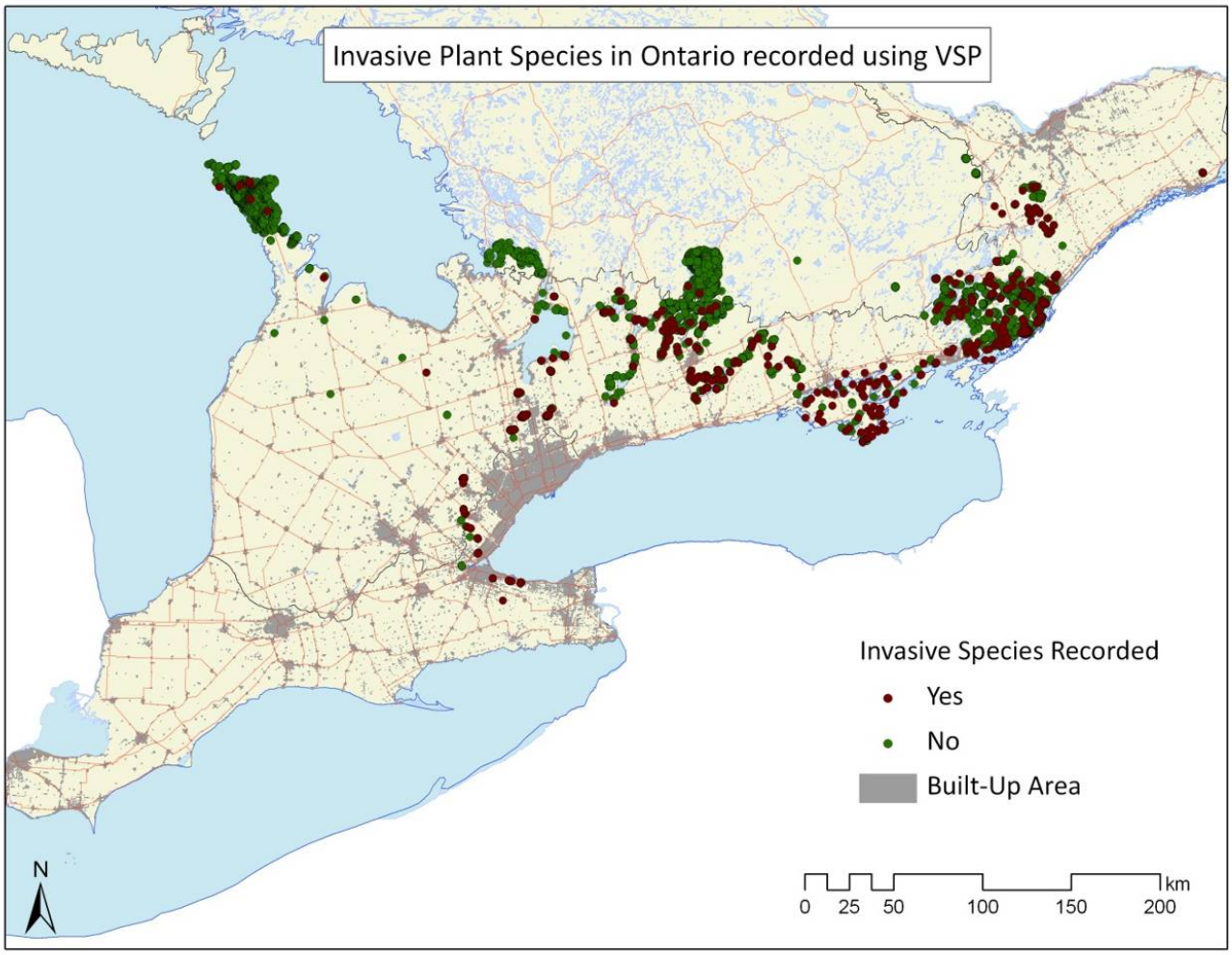


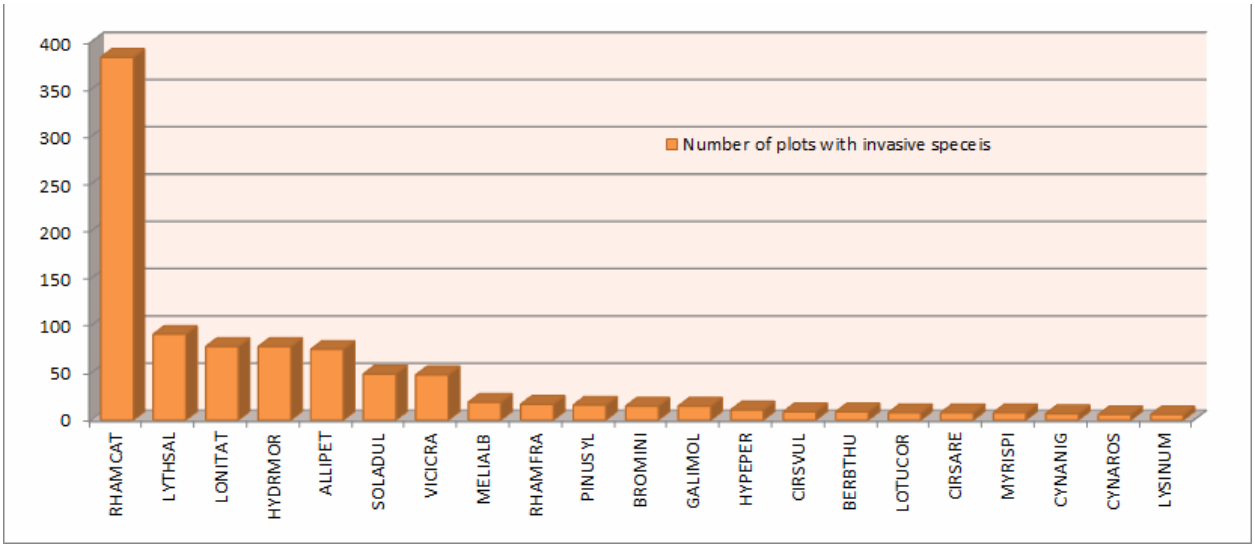
FIGURE 2: LOCATION OF VSP PLOTS SAMPLED FROM 2005-2011 SHOWING THOSE WHERE INVASIVE SPECIES WERE RECORDED (RED) AND NOT RECORDED (GREEN).

TABLE 5: INVASIVE SPECIES RECORDED BY VSP (2005-2011).

Common Name	Scientific Name	Invasive Ranking[1]	No. of plots	Average % cover	Max. % cover
Goutweed	*Aegopodium podagraria*	1	1	3	3
Garlic mustard	*Alliaria petiolata*	1	75	9	61
Japanese barberry	*Berberis thunbergii*	3	9	1	6
Common barberry	*Berberis vulgaris*	3	3	1	2
Smooth brome	*Bromus inermis ssp. inermis*	4	15	30	90
Canada thistle	*Cirsium arvense*	1	8	5	10
Bull thistle	*Cirsium vulgare*	3	9	1	3
Field bindweed	*Convolvulus arvensis*	3	3	4	10
Black Swallow-wort	*Cynanchum nigrum*	1	7	1	2
White Swallow-wort	*Cynanchum rossicum*	1	6	5	8
Smooth bedstraw	*Galium mollugo*	2	15	13	55
Tall glyceria	*Glyceria maxima*	1	1	2	2
European Frog-bit	*Hydrocharis morsus-ranae*	1	78	3	40
Common St. John's-wort	*Hypericum perforatum*	4	11	2	5
Butter-and-eggs	*Linaria vulgaris*	4	3	1	3
Morrow's honeysuckle	*Lonicera morrowii*	1	2	10	10
Tartarian honeysuckle	*Lonicera tatarica*	1	78	4	45
Bird's-foot Trefoil	*Lotus corniculatus*	2	8	23	58
Moneywort	*Lysimachia nummularia*	2	6	6	20
Purple loosestrife	*Lythrum salicaria*	1	91	5	32
White Sweet-clover	*Melilotus alba*	2	19	9	30
Yellow Sweet-clover	*Melilotus officinalis*	2	1	5	5
White mulberry	*Morus alba*	1	1	2	2
Spiked Water-milfoil	*Myriophyllum spicatum*	1	8	1	1
Wild marjoram	*Origanum vulgare*	4	4	36	60
Scots pine	*Pinus sylvestris*	2	16	9	50
European white poplar	*Populus alba*	2	3	1	3
Common buckthorn	*Rhamnus cathartica*	1	384	8	80
Glossy buckthorn	*Rhamnus frangula*	1	17	8	85
Black locust	*Robinia pseudo-acacia*	2	2	7	10
Bittersweet nightshade	*Solanum dulcamara*	3	49	2	10
Common lilac	*Syringa vulgaris*	2	3	15	20
Coltsfoot	*Tussilago farfara*	4	2	12	20
Cow vetch	*Vicia cracca*	2	48	9	70

[1] Invasive Ranking: 1 = Aggressive Invasive, 2 = Highly Invasive, 3 = Moderately Invasive, 4 = Of Concern.

FIGURE 3: FREQUENCY OF INVASIVE SPECIES EXPRESSED AS NUMBER OF VSP PLOTS



IN WHICH A SPECIES WAS SAMPLED. SPECIES NAMES ARE COMPOSED BY THE FIRST FOUR LETTERS OF THE GENUS NAME AND THE FIRST THREE LETTERS OF THE SPECIES NAME. FOR EXAMPLE, GARLIC MUSTARD IS "ALLIPET".

GARLIC MUSTARD

Garlic mustard (*Alliaria petiolata*) was recorded in 75 VSP plots, of which 33 plots were sampled in 2011, indicating a higher presence of garlic mustard on the Niagara Escarpment and in the Lake Simcoe basin. This could either be due to the fact that the full species list was only collected in 2011 inventories and / or that there is more garlic mustard in this region as might be suspected given the close proximity of both areas to high density urban areas and human corridors. The average percent cover for this species across all 75 plots was 6% and the maximum was 61% (Table 5; Figure 4). The full species sampling conducted in 2011, captured traces or lower abundance of this species indicating the usefulness of this protocol for identifying early invasions that might be effectively controlled.

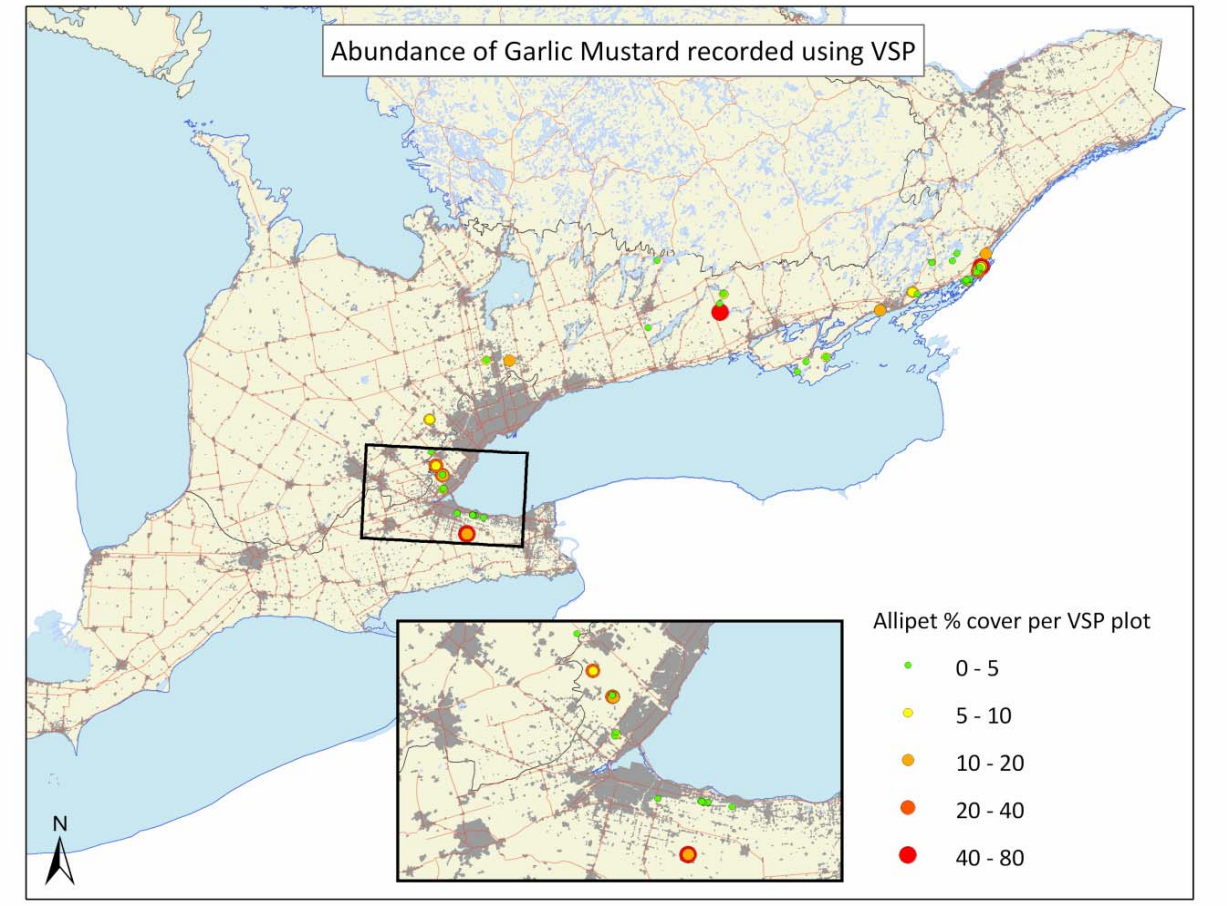


FIGURE 4: ABUNDANCE OF GARLIC MUSTARD (*ALLIARIA PETIOLATA*) IN 75 PLOTS.

EUROPEAN FROG-BIT

European frog-bit (*Hydrocharis morsus-ranae*) was observed in 78 wetland VSP plots in eastern Ontario and along the Trent-Severn Waterway southeast of the Lake Simcoe (Figure 5). The observed abundances of this species are higher in eastern Ontario and at some locations approach 40% absolute cover, while along the Trent-Severn Waterway the recorded abundances are lower, ranging from 0.1 (trace) to 5%.

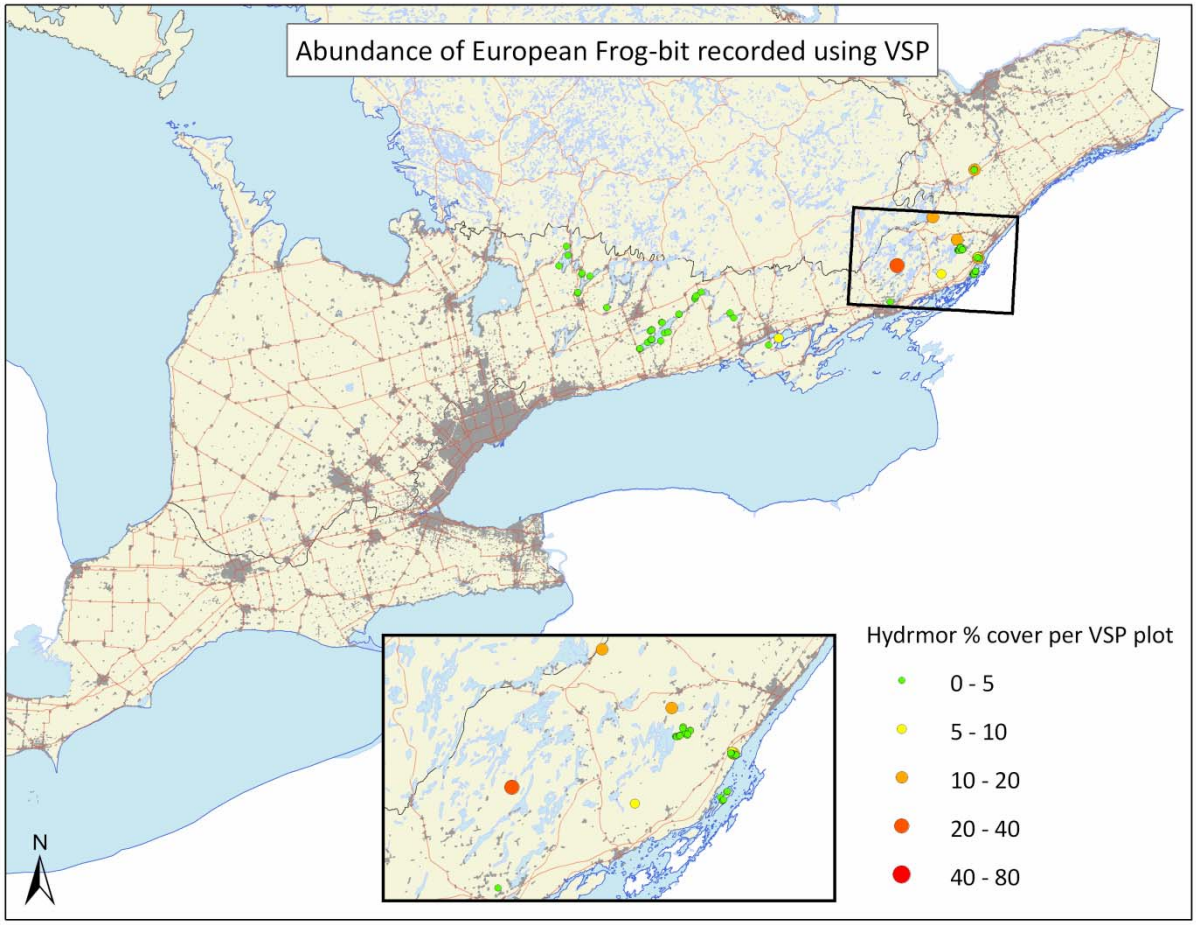


FIGURE 5: ABUNDANCE OF EUROPEAN FROGBIT (Hydrocharis morsus-ranae) IN 78 VSP PLOTS.

TARTARIAN HONEYSUCKLE

Tartarian honeysuckle (*Lonicera tatarica*) was observed in 78 VPS plots (Figure 6). The cluster of VSP observations for this species is within the St. Lawrence Islands National Park Greater Ecosystem and ecodistrict 6e10. Since there were no VSP sampling sites in the Carolinian zone it should not be concluded that this well-established invasive doesn't occur in southwestern Ontario or ecoregion 7e. Average abundance of this invasive shrub was 4%, with some plots having up to 45%.

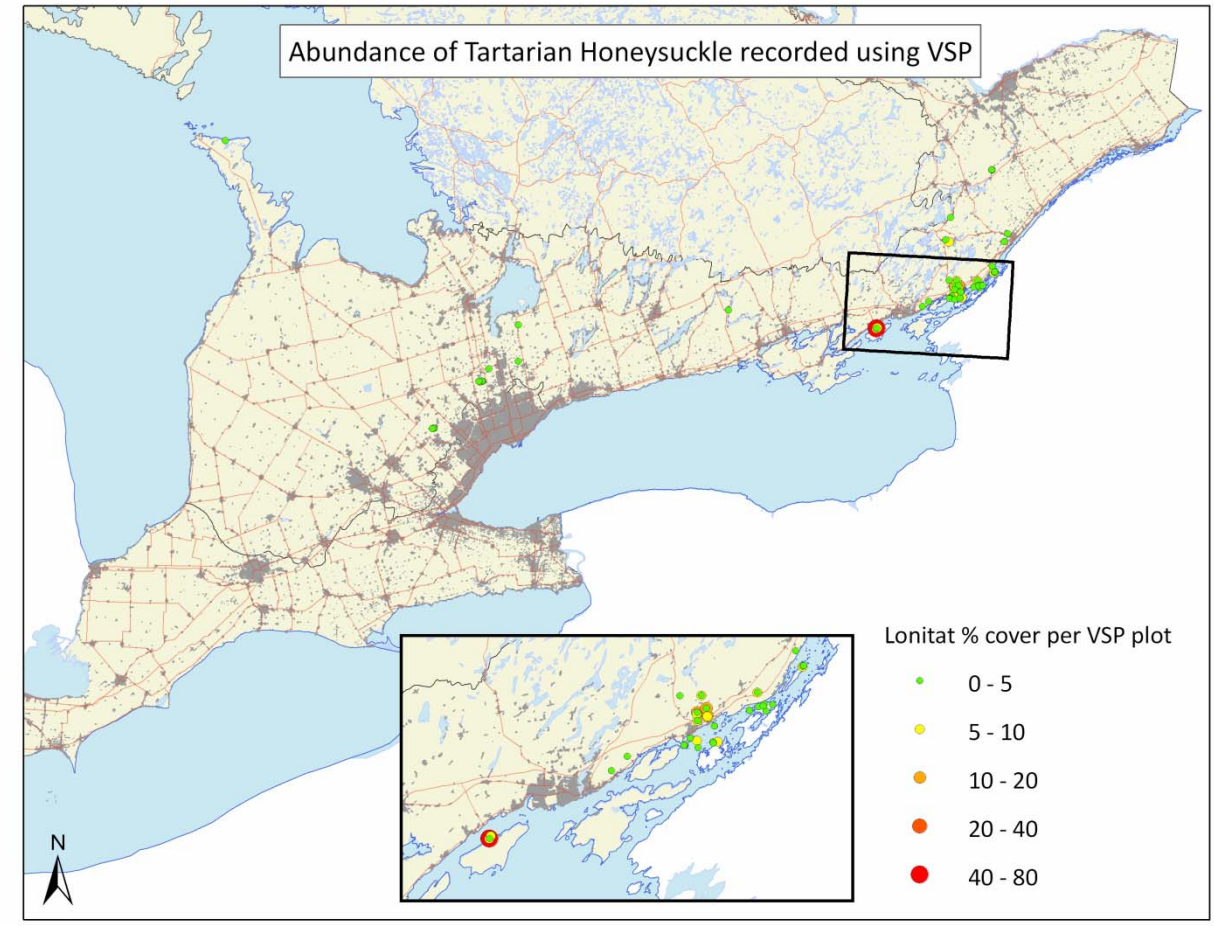


FIGURE 6: TARTARIAN HONEYSUCKLE (*LONICERA TATARICA*) ABUNDANCE OBSERVED IN 78 VSP PLOTS.

PURPLE LOOSESTRIFE

Purple loosestrife (*Lythrum salicaria*) was recorded as part of wetland sampling during 2006-08 along the Trent-Severn Waterway and during 2008 in the St. Lawrence Islands National Park Greater Ecosystem and ecodistrict 6e10. It was observed as a dominant species at 91 locations, with an average percent cover of 5%. Along the Trent-Severn Waterway abundance of this invasive was higher often approaching 30% per a plot (Figure 7).

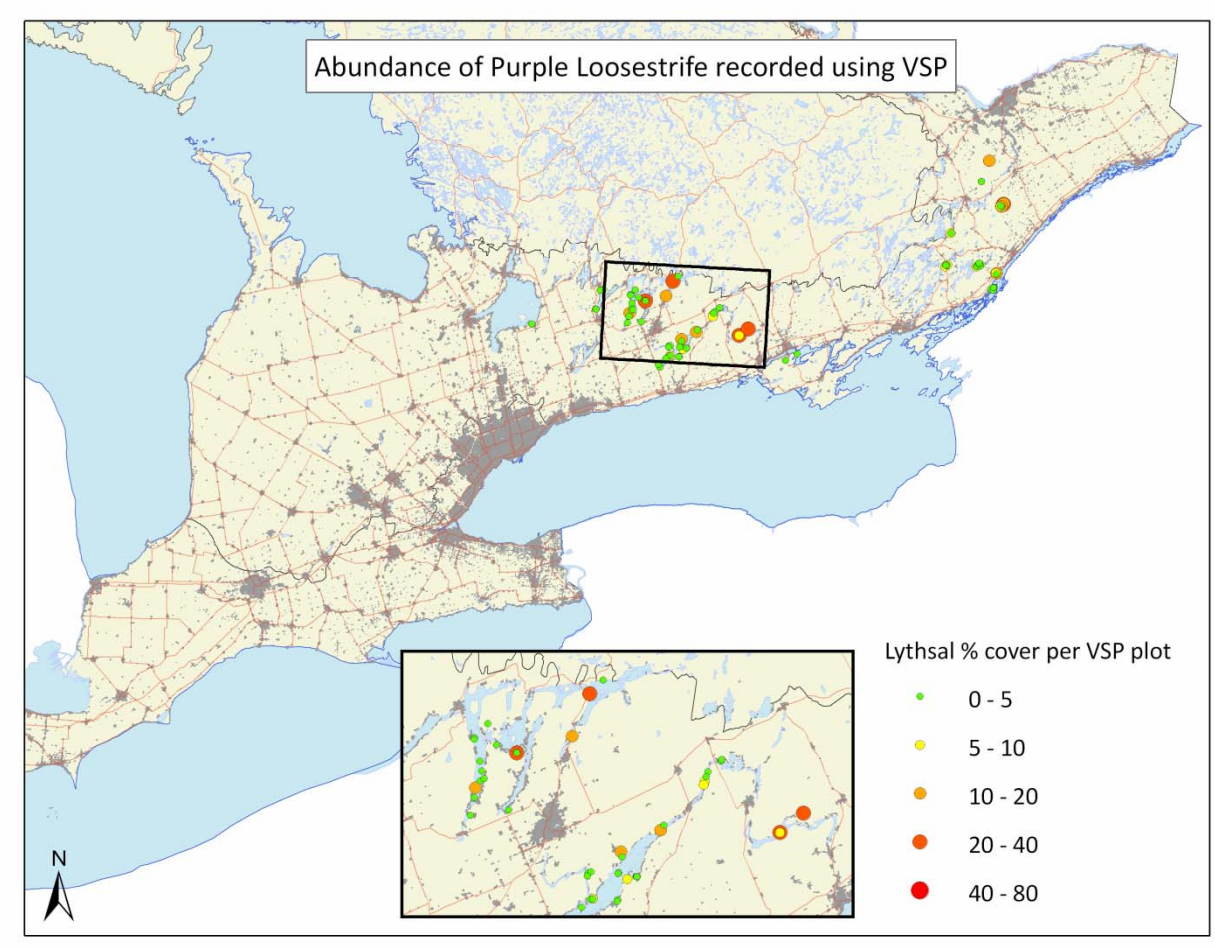


FIGURE 7: PURPLE LOOSESTRIFE (*LYTHRUM SALICARIA*) ABUNDANCE OBSERVED IN 91 VSP PLOTS.

EUROPEAN BUCKTHORN

One of the most frequently observed invasive plant species is European or common buckthorn (*Rhamnus cathartica*) Figure 8 shows the this species was observed in 384 plots. Though VSP sampling in 2005-2010 was aimed at targeting dominant species, distribution and abundance of European buckthorn was still well captured. Across all sample plots with European buckthorn, average abundance for this species was 8.5% and maximum abundance was 80%. In half of the plots with European buckthorn, abundance was recorded as less than 5%, however in the other half of plots abundance often exceeded 30%.

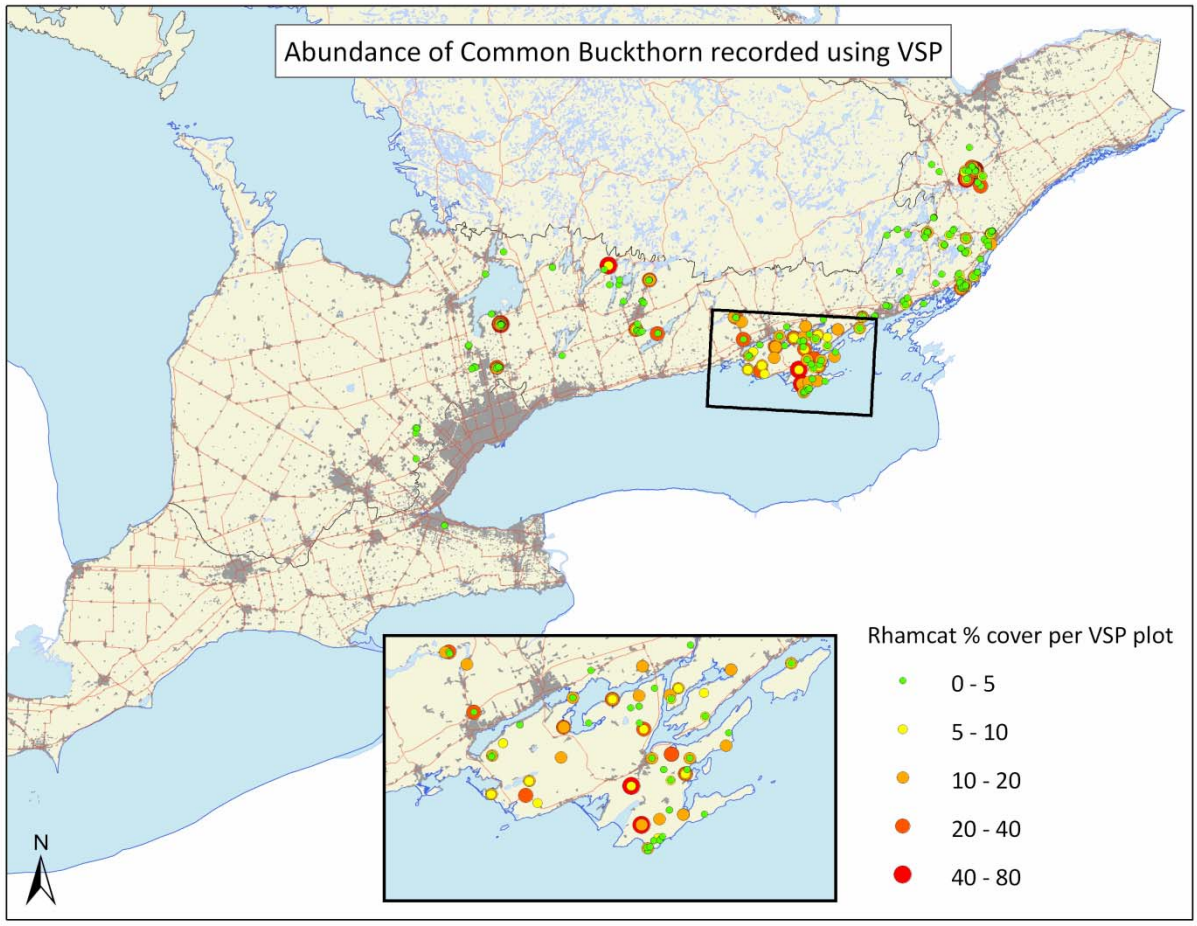


FIGURE 8: COMMON OR EUROPEAN BUCKTHORN (*RHAMNUS CATHARTICA*) ABUNDANCE OBSERVED IN 384 VSP PLOTS.

BITTERSWEET NIGHTSHADE

Bittersweet nightshade (*Solanum dulcamara*) was recorded in 49 VSP plots across a range of habitats (Figure 9). The average abundance was 2% and the maximum abundance was 10%. Over 30% of all observations for this species were made through VSP full species list sampling done in 2011, providing further evidence that invasive species with lower abundance are best detected with this VSP sampling protocol.

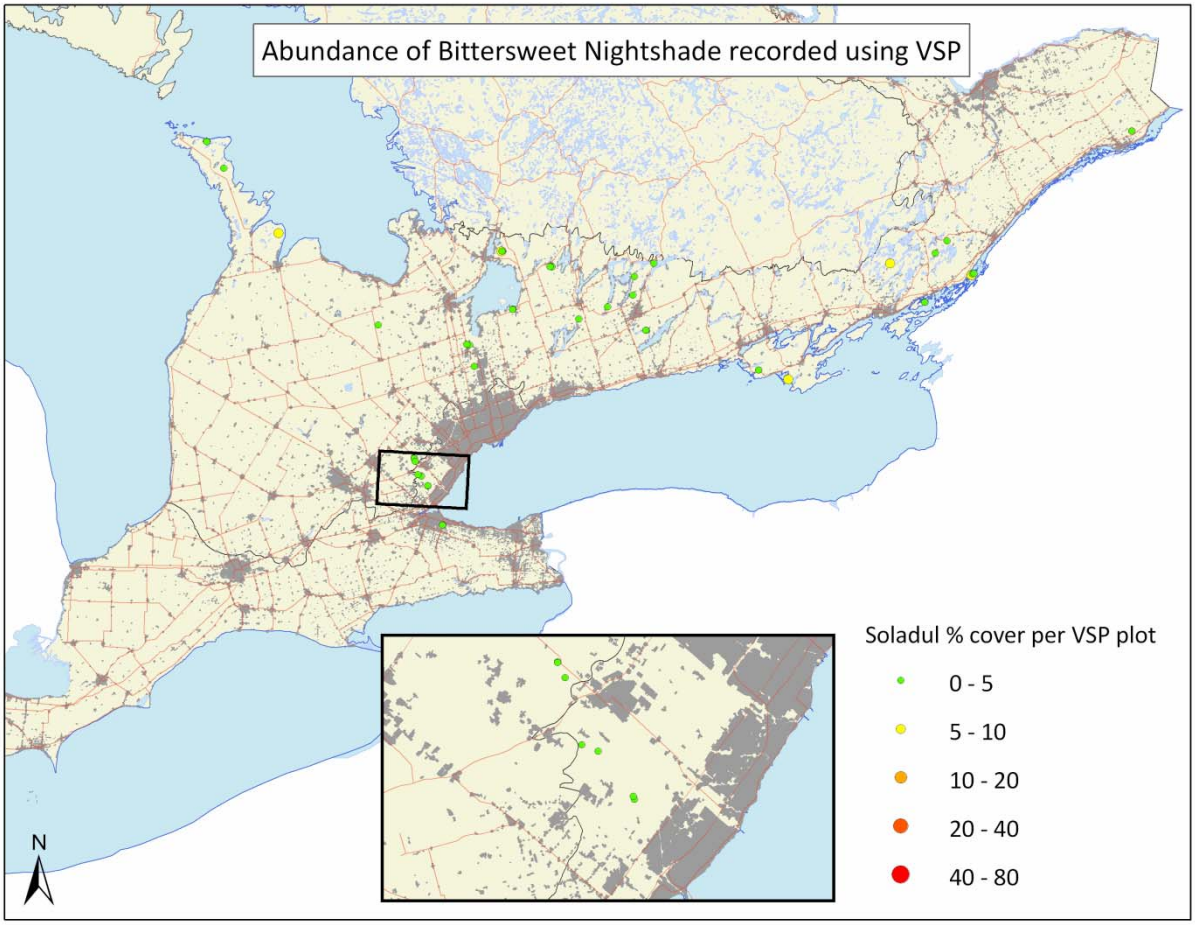


FIGURE 9: ABUNDANCE OF BITTERSWEET NIGHTSHADE (*SOLANUM DULCAMARA*) IN 49 VSP PLOTS.

COW VETCH

Cow vetch (*Vicia cracca*) was recorded at 48 VSP plots (Figure 10). The average abundance of this species was 9.5 % and the maximum was 70%. At a majority of plot locations this species had abundances approaching or over 10%. Normally found in open meadows, along roadsides and in disturbed sites, this species can also occur in semi-open and disturbed woodlands.

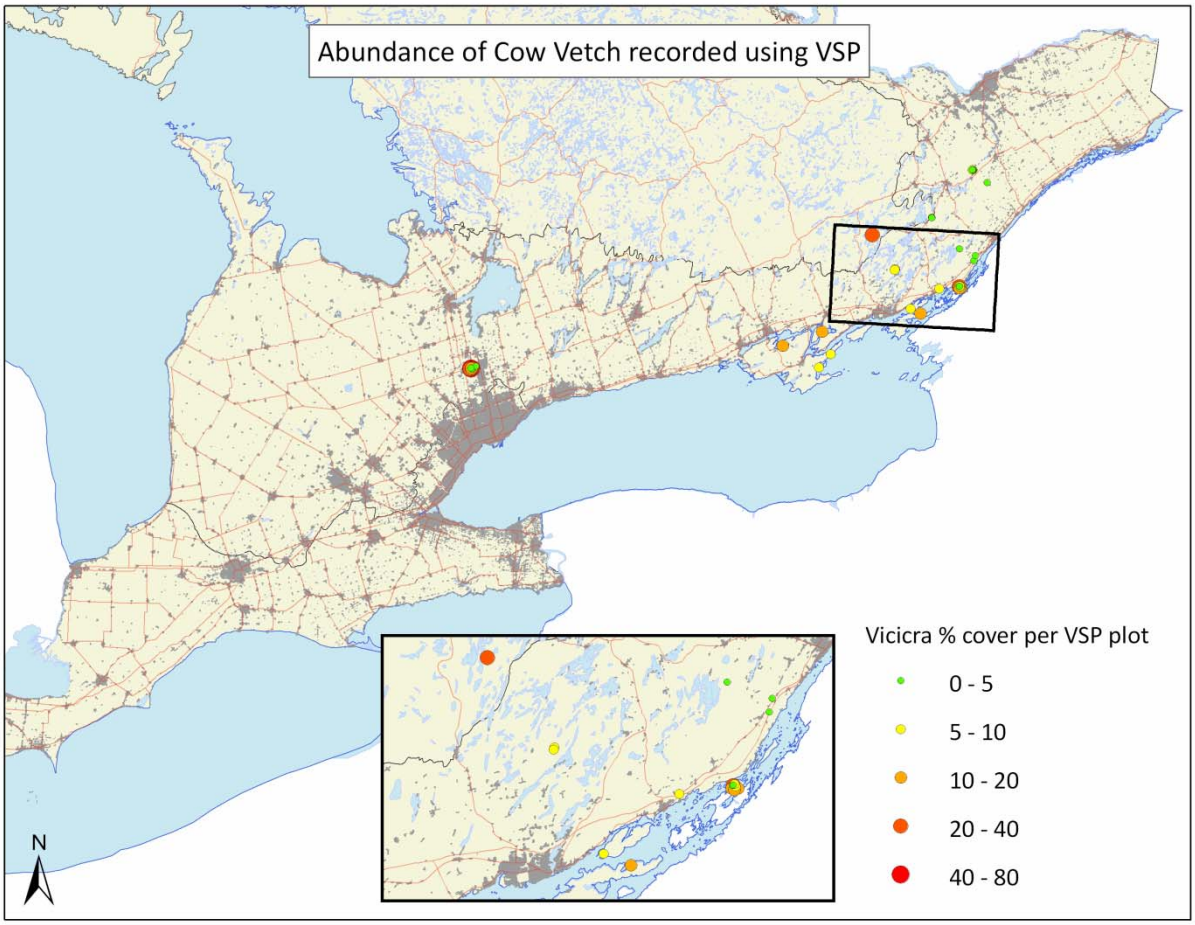


FIGURE 10: ABUNDANCE OF COW VETCH (*VICIA CRACCA*) IN 48 VSP PLOTS.

RECOMMENDATIONS

Based on the extent of invasive species distribution and abundance detected by the four VSP sampling intensities several recommendations to facilitate more comprehensive sampling in the future are made in the following. These guidelines will be added to the VSP manual and are already available from the VSP web page (http://www.forestry.utoronto.ca/imsa/VSP/invasiveVSP.pdf)

Updates to the VSP manual will incorporate applicable modifications to the VSP data cards, information management system, web page, and training curriculum.

1. INTEGRATE INVASIVE SPECIES SAMPLING INTO VSP INVENTORIES

Since resources available to conduct field-based vegetation inventories in southern Ontario are already limited, invasive species inventory should be integrated into regular VPS inventory and monitoring efforts. This requires minor adjustments to the VSP protocols, VSP training and in some cases VSP sampling design. With these adjustments VSP can be successfully used to address three related objectives specific to invasive species tracking:

1. Detection of invasive presence and absence.
2. Monitoring changes to sites with high susceptibility of invasion where there is a high risk of invasion, or it is known that invasive species already exist in close proximity
3. Monitoring changes in invasive species abundance after they have become established.

Based on information gaps identified through an assessment of VSP data and a review of relevant literature and sampling methods, an invasive species sampling module was developed for the VSP protocol. This module could assist agencies to incorporate invasive plant species sampling either as part of VSP inventory or as a stand-alone invasive species inventory. In either case the data collected would be compatible and complementary to any VSP data collected by a variety of organizations across different regions of the province.

The VSP protocol has been updated to support invasive plant sampling, inventory and monitoring with the following five recommendations for future sampling efforts (Tables 6 and 7):

1. Collect the full species list and species percent cover for each sample plot. The VSP 2011 data show that by recording the full species list about 60% more locations with invasive species were captured. More importantly for objectives 1 and 2 above the full species list is more effective at capturing early invasions when abundance is low. Based on crew experience in 2011, recording the full species list takes on average of 15 to 30 minutes of additional time and automatically documents invasive species absence. Recording invasive species absence provides critical information for monitoring and understanding how invasives move through the landscape.
2. Continue to collect DBH measurements in forested plots to provide additional data on frequency and size of woody invasive species that supports vegetation control decisions. More importantly, this data can be coupled with other VSP information to quantify the negative impacts of invasive plants on native forests and natural succession.
3. In plots established as part of a long-term monitoring network, the VSP regeneration sub-plot protocol should be used in addition to DBH measurements and the full species list.
4. Continue to collect data relevant to understanding invasive species distribution such as geographic location, soil properties, topography, and habitat characteristics.
5. Continue to update the consolidated invasive plant species list with relevant information to support various VSP analyses and reporting needs.

TABLE 6: GUIDELINES FOR INCORPORATING INVASIVE SPECIES SAMPLING INTO VSP.

VSP sampling intensity	Guidelines for invasive species capture	Inventory	Monitoring
Full species list and species abundance	Collect the full species list and species abundance in each plot. This ensures that invasive species absence is collected too.	√	√
Tree diameter inventory	Measure all woody plants ≥5cm DBH in the plot (in forested communities).	√	√
Regeneration sub-plots	Optional for inventory, but required for monitoring.		√
Incidental or Tracked Species	This is an option that can be used to capture invasive species presence and geographic location. The efficacy of this approach was not analyzed in this report since field crews were not instructed to specifically record sightings of invasive species in VSP campaigns from 2005 -2011.		

2. SPATIAL EXTENT OF INVASIVE SPECIES SAMPLING

Management actions to control and eradiate invasive species are usually taken at a range of scales: from broad geographic areas (e.g., southern Ontario, eco-region, watersheds) to the site-specific level of parks and protected lands, trails, private lands and small parcels. Accordingly, the extent of invasive species distribution and abundance should be sampled and mapped at diverse spatial scales: from landscapes to stands to invaded patches. At either scale, the basis for VSP sampling is a fixed-area plot and the plot size is adapted to the type of vegetation sampled. However, depending on sampling design and information needs, plots can be established and aggregated across different spatial scales: from landscapes and regions to transects and areas/ patches (polygons). A single VSP plot represents the minimum mapping area. Point-based vegetation mapping is the simplest and fastest way of displaying and using field data collected with VSP. Plot-based information can be used directly to produce a simple point-based invasive species map where each point is attributed with field information such as species abundance, number of invasive species as demonstrated in this report (Figures 1 to 10).

However, for some more specific management needs, VSP plots and plot information can be extrapolated and/or modeled from a plot to a vegetation patch and even to the southern Ontario landscape.

LANDSCAPE / REGIONAL SAMPLING

Depending on the sampling design, management needs and objectives of the invasive sampling project, plot sampling can be organized across larger areas and landscapes as has been done in most of the 2005-2011 VSP campaigns. For example, to address the need for a comprehensive vegetation inventory in southern Ontario, a statistically-based sampling design was developed for ecodistricts 6e10, 6e11, 6e12, 6e14 and the Kawartha Highlands Signature Site. Sampling designs maximize the value of a relatively small number of sampling points to produce vegetation and distribution maps across an entire study area through the use of statistical techniques, data mining, and spatial data (Figure 12). In addition, the random VSP plot locations ensure that collected information can be used for various vegetation analyses. For example, based on VSP data for ecodistrict 6e10 and statistical modeling, the distribution of European buckthorn was modeled and mapped (Figure 12). However, these regional inventories can be supplemented with additional sampling designed to capture and explain the distribution of invasive species. For

example, additional VSP plots can be established along known gradients (transects) influencing invasive species distribution, for example, perpendicular to roads, urban areas, public spaces, or waterways.

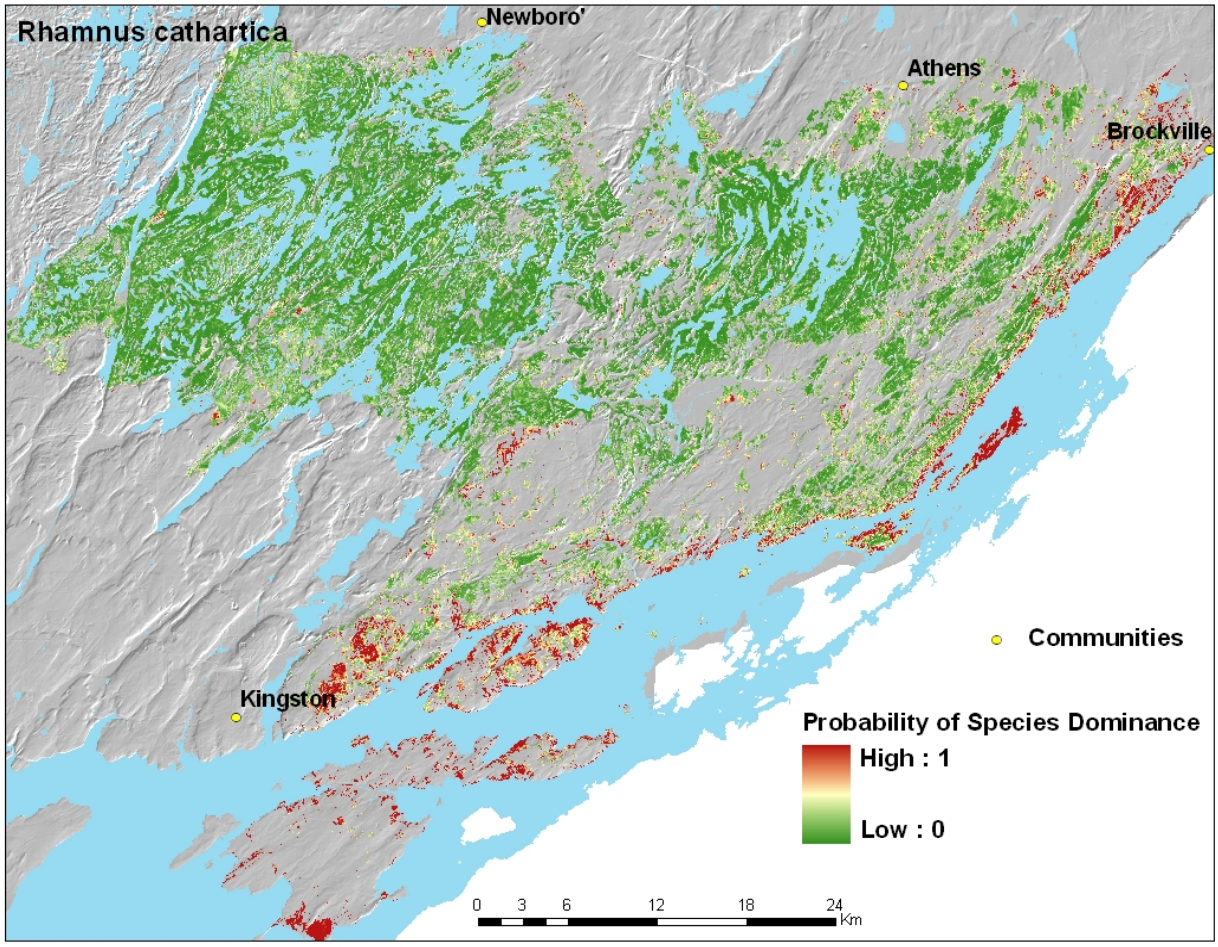


FIGURE 11. MODELED DISTRIBUTION OF EUROPEAN BUCKTHORN (*RHAMNUS CATHARTICA*) FOR ECODISTRICT 6E10. THE MODEL WAS DEVELOPED USING VSP PLOT DATA SAMPLED IN THE AREA DURING THE PERIOD 2005-2008. RED INDICATES AREAS WITH A HIGH PROBABILITY THAT EUROPEN BUCKTHORN IS A DOMINANT SPECIES, AND ARE MOSTLY CONFINED TO AREAS ADJACENT TO THE ST. LAWRENCE RIVER CORRIDOR.

STAND/ PATCH SAMPLING

For fine-scale invasive species management applications such as managing a stand, a strip of riparian vegetation, a land parcel, patch or a trail, it might be necessary to stratify the area of interest into stands, vegetations zones or even to outline (polygons) of invaded areas.

Delineation of vegetation boundaries and polygon creation are one method of vegetation mapping that is particularly well-suited for smaller planning and management areas and site specific applications. A number of VSP plots can be established within vegetation patches or stands that were previously mapped as GIS polygons. If necessary, the extent of a plant invasion can also be mapped on the ground using GPS coordinates or possibly from aerial photography (Figure 12). For example, if the spread of an invasive species is significant and covers a larger area, it can be mapped in the field simply by walking along the area affected by the species (e.g., garlic mustard) with a GPS unit in the track route or polyline mode. This will result in a GIS polygon that represents the spatial extent of the invasion.

The polygon sampling methodology is the same as a plot-based approach, but polygons serve as the units by which plots are stratified. Plot-based data can be extrapolated across polygons, enabling the attribution of the polygon with quantitative, statistically valid data. The net result is polygon based invasive species maps that can be standardized at either the plot or polygon level

Once polygons are outlined and mapped as GIS polygons the extent of invasive species can be mapped by conducting VSP sampling as follows:

a) Record the full plant species list for each stand/polygon. Experience from 2011 sampling indicates that the time required to compile the full species list for a stand can take from 5 to 30 minutes depending on the complexity and size of the sample area.

b) Establish a small number of random VSP plots within each mapped patch/ stand (polygon) and sample using the VSP protocol including the full species list.

c) Follow a rigorous plot-in-polygon sampling method of data collection. Plot locations within polygons should follow some sort of sampling design (e.g., random or systematic). However, plots could also be subjectively selected (i.e., tactical plots) with an understanding that in this case there is a sampling bias and as a result, while data is informative, it has limited use for statistical analysis and modeling.

FIGURE 12: SCHEMATIC SHOWING HOW THE EXTENT OF AN INVASION CAN BE SAMPLED AND MAPPED AT A POLYGON LEVEL. WITHIN THE OUTLINED POLYGONS THAT REPRESENT EITHER A VEGETATION TYPE WITH AN INVASIVE SPECIES OR THE SPATIAL SPREAD OF INVASIVE SPECIES, SEVERAL VSP PLOTS ARE ESTABLISHED TO CAPTURE QUANTITATIVE DATA. THE GREEN POLYGONS REPRESENT THE OUTLINED VEGETATION POLYGON WHILE THE PINK CIRCLES REPRESENT INVASIVE SPECIES ABUNDANCE WITHIN THE PLOT. THE SIZE OF THE PINK CIRCLE CORRELATES TO RELATIVE ABUNDANCE OF THE INVASIVE SPECIES WITHIN THE PLOT.

CONCLUSIONS

The quantitative and spatial nature of Vegetation Sampling Protocol (VSP) data and information can be used to support a range of objectives in the Canadian Alien Invasive Species Strategy, including:

1. Detect and identify new invaders
2. Respond rapidly to new invader awareness
3. Manage established and spreading invaders through eradication, containment and control.

Data collected using VSP can be used to answer many questions associated with the ecology and distribution of invasive plant species. The plant species list recorded for each VSP sample plot reveals if any invasive species are present. Environmental variables that are also recorded at each plot can improve understanding the autecology of invasive species. For example, it is known that disturbance can favour the establishment of most invasive species. However, it is still unclear if invasive species pose a high threat on specific soil types (e.g., can invasive plants become established in less-fertile soils on the Canadian Shield). Some invasive species may require specific substrate conditions while others may grow on any substrate type provided the moisture regime is optimum. In either case, VSP information can support such analysis as comprehensive soil type, moisture regime, disturbance and vegetation structure information are collected.

To ensure invasive plants are fully detected in future VSP campaigns, VSP sampling should always include the full species list. Based on experience in 2011, collecting the full species list per plot requires approximately 15 to 30 minutes of additional time—an insignificant amount of time relative to the time spent overall on combined plot sampling, travel and landowner contact efforts. This analysis has shown that by collecting the full species list per plot, invasive species would have been detected in approximately 60% more plots.

VSP enables collection of standardized, cost-efficient invasive species data by encouraging collaboration of numerous organizations and groups while they conduct field sampling to support other vegetation inventory needs. However, VSP sampling design could also be altered in order to target invasive species should they become a serious threat requiring more intensive inventories.

This could include establishing additional plots across an area and mapping the extent of the invasion (delineating the GIS polygon) as well as establishing monitoring plots.

Continued inventory and monitoring of invasive species using previously established VSP plots would provide critical information for assessing the spread and abundance of invasive plants in southern Ontario, as well as elucidating impacts to native vegetation. Invasive species monitoring and control is an extremely important component of natural vegetation management and conservation in southern Ontario. Climate change is predicted to exacerbate the effects of invasive species on natural vegetation composition, structure and function. However, monitoring invasive plants separately is neither cost-efficient nor advisable. Inventory and monitoring of invasive species should be part of regular vegetation inventory efforts that support vegetation information needs for conservation, management and planning. Any vegetation plant inventory collected at two time periods and over the same geographic location automatically supports invasive plant monitoring and can serve to detect trends over time. Thus previously established VSP plots can serve as a baseline for assessing both climate change and native ecosystem vulnerability to invasive species. Continued monitoring using the established VSP plots will be critical in assessing the spread of invasives and supporting quantitative impact assessments.

VSP also collects additional plant information that is important for detecting and managing invasive insects and pathogens. For example, in the absence of a comprehensive fine-scale vegetation inventory in southern Ontario VSP data provides a basis for mapping the distribution of ash species (Figure 13) that may be negatively affected by increases in the range of emerald ash borer and hence support risk management assessments for evaluating control options.

Given limited funding, and the fact that field sampling in southern Ontario is mainly done by partner conservation agencies, OMNR should continue to promote and support VSP as it provides valuable fine-scale vegetation information. With its record of over 5, 000 plots, VSP has demonstrated numerous practical and scientific applications. OMNR could establish VSP as a southern Ontario inventory and monitoring program and provide dedicated support for training, information management and further development of applications of VSP data. In addition, it may be possible to provide specific incentives to improve the comprehensiveness of VSP sampling in southern Ontario, for example, by ensuring that proponents of OMNR funding programs (e.g., Ontario Species at Risk Stewardship Fund) apply VSP sampling in projects.

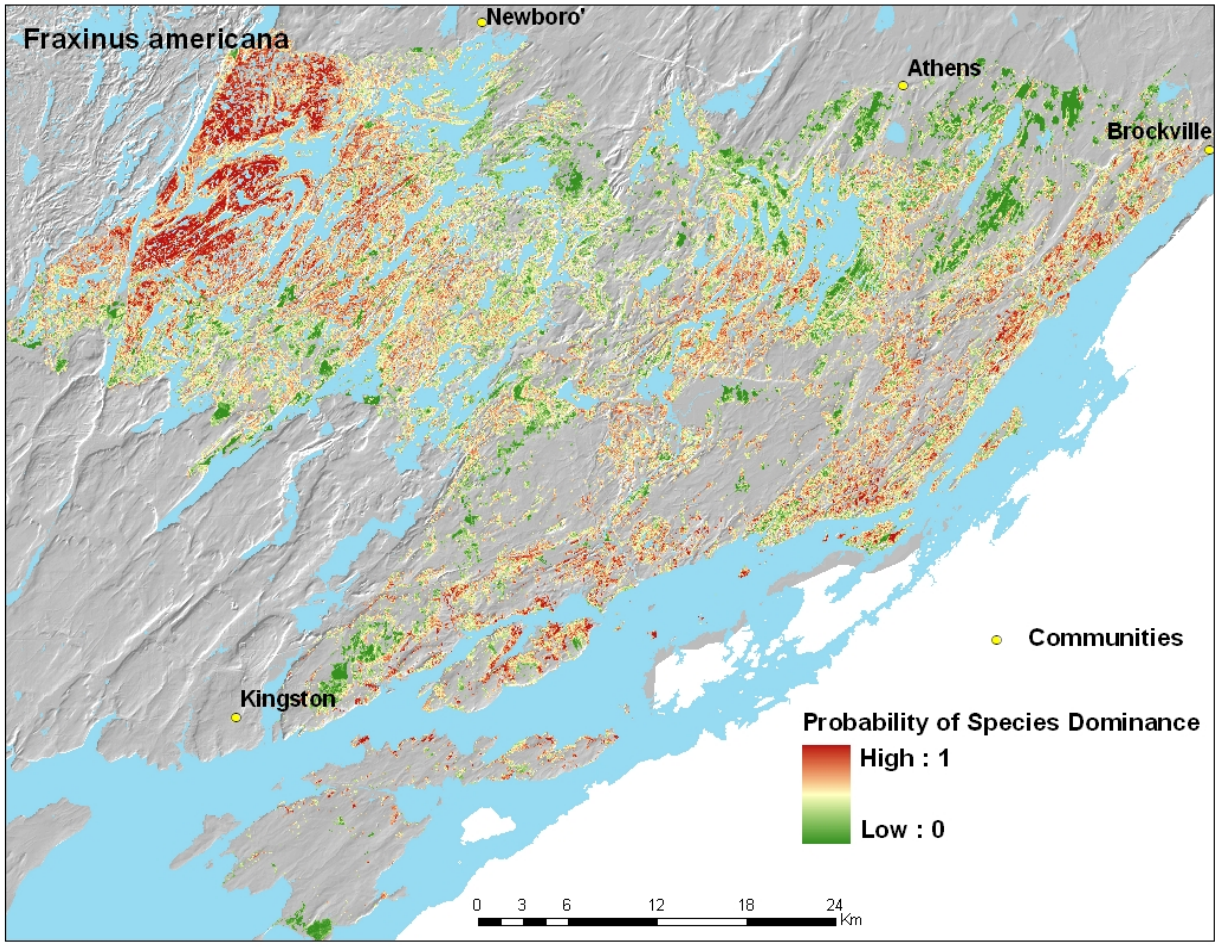


FIGURE 13: MODELED DISTRIBUTION OF WHITE ASH (*FRAXINUS AMERICANA*) IN ECODISTRICT 6E10. THE MODEL WAS DEVELOPED USING VSP PLOT DATA SAMPLED IN THE AREA DURING THE PERIOD 2005-2008. RED INDICATES AREAS WITH HIGH PROBABILITY THAT WHITE ASH IS A DOMINANT SPECIES.

Additional sampling is needed to better understand the distribution and abundance of invasive species, especially in southwestern Ontario and the Greater Toronto Area where most inventory efforts do not currently collect quantitative, multi-use vegetation data. Establishment of VSP monitoring plots within urban areas and along transects from urban centers to rural farmlands and parks and protected areas are also required to better understand the vectors that facilitate invasive species establishment.

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APPENDIX A

The VSP invasive plant species lists complied based on WWW based resources, February 2012. Table classes (column headings) are explained at the bottom of the table. The list of references used to derive the species list is provided on page A-9 so that this appendix can serve as a stand-alone document. It was previously provided in Table 1 in the main body of this report.

Additional web-based references reviewed and relevant to invasive species designations and listings are provided in this Appendix on page A-10.

THE VSP INVASIVE SPECIES LISTS COMPLIED BASED ON WEB BASED RESOURCES, FEBRUARY 2012. THE SPECIES ARE LISTED BY SCIENTIFIC NAME.

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNR List	Urban FA	Great Lakes	Manitoba	Michigan	Global	New York
Velvetleaf	*Abutilon theophrasti*	herb	TR	3	2			x			x		
Norway maple	*Acer platanoides*	tree	IN	2	6	x	x	x				x	x
Mother-of-thyme	*Acinos arvensis*	herb	TR	3	2	x		x					
Goutweed	*Aegopodium podagraria*	herb	TR	1	2	x		x					
Horse chestnut	*Aesculus hippocastanum*	tree	TR	3	2	x		x					
Tree-of-heaven	*Ailanthus altissima*	tree	IN	2	3			x					x
Bugleweed	*Ajuga reptens*	herb	TR	4	2								
Garlic mustard	*Alliaria petiolata*	herb	IN	1	5	x	x	x					x
European alder	*Alnus glutinosa*	tree	TR	1	2	x		x					
Absinth wormwood	*Artemesia absinthium*	herb	TR	3	2								

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNR List	Urban FA	Great Lakes	Manitoba	Michigan	Global	New York
Japanese barberry	*Berberis thunbergii*	shrub	IN	3	5	x		x				x	x
Common barberry	*Berberis vulgaris*	shrub	IN	3	3			x			x		
Hoary-alyssum	*Berteroa incana*	herb	IN	3	3	x		x			x		
European white birch	*Betula pendula*	tree	TR	1	2	x		x					
Smooth brome grass	*Bromus inermis ssp. inermis*	gram	TR	4	2			x				x	
Flowering rush	*Butomus umbellatus*	herb	IN	1	7	x	x	x	x	x		x	x
Carolina fanwort	*Cabomba caroliniana*	herb	TR	3	5		x	x	x			x	x
Creeping bellflower	*Campanula rapunculoides*	herb	TR	4	2	x		x					
Nodding thistle	*Carduus nutans ssp. leiophyllus*	herb	IN	3	4								
Oriental bittersweet	*Celastrus orbiculatus*	vine	IN	2	4			x				x	x
Diffuse knapweed	*Centaurea diffusa*	herb	TR	3	2					x		x	
Spotted knapweed	*Centaurea maculosa*	herb	IN	3	6	x		x		x	x	x	
Yellow knapweed	*Centaurea solstitialis*	herb	TR	3	2					x		x	
Canada thistle	*Cirsium arvense*	herb	IN	1	6	x		x		x	x	x	
Bull thistle	*Cirsium vulgare*	herb	IN	3	3		x				x		x
Field bindweed	*Convolvulus arvensis*	vine	TR	3	2			x			x		

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNR List	Urban FA	Great Lakes	Manitoba	Michigan	Global	New York
Crown vetch	*Coronilla varia*	vine	IN	1	3	x		x					x
Dog-strangling vine	*Cynanchum nigrum*	vine	IN	1	6	x	x	x	x				x
White swallow-wort	*Cynanchum rossicum*	vine	IN	1	7	x	x	x	x			x	x
Teasel	*Dipsacus fullonum ssp. sylvestris*	herb	IN	3	3								
Russian olive	*Elaeagnus angustifolia*	shrub	IN	3	4			x				x	x
Autumn olive	*Elaeagnus umbellata*	shrub	IN	1	4			x				x	x
Leafy spurge	*Euphorbia esula*	herb	IN	4	6	x		x		x	x	x	
White bedstraw	*Galium mollugo*	herb	TR	2	2	x		x					
Great manna grass	*Glyceria maxima*	gram	TR	1	2	x		x					
English ivy	*Hedera helix*	vine	IN	3	3	x		x					
Orange daylily	*Hemerocallis fulva*	herb	TR	4	2	x		x					
Giant hogweed	*Heracleum mantegazzianum*	herb	IN	2	5		x		x		x	x	x
Dame's rocket	*Hesperis matronalis*	herb	IN	1	3	x	x	x					
European frog-bit	*Hydrocharis morsus-ranae*	herb	IN	1	8	x	x	x	x	x	x	x	x
St. John's wort	*Hypericum perforatum*	herb	IN	4	3	x		x				x	
Himalayan balsam	*Impatiens glandulifera*	herb	IN	1	4	x		x		x		x	
Yellow flag	*Iris pseudacorus*	herb	IN	4	7	x	x	x		x	x	x	x
Common privet	*Ligustrum vulgare*	shrub	IN	4	3		x	x					
Butter-and-eggs	*Linaria vulgaris*	herb	TR	4	2			x		x			

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNR List	Urban FA	Great Lakes	Manitoba	Michigan	Global	New York
Japanese honeysuckle	*Lonicera japonica*	vine	IN	1	4	x		x					x
Amur honeysuckle	*Lonicera maackii*	shrub	IN	1	5		x	x				x	x
Morrow's honeysuckle	*Lonicera morrowii*	shrub	IN	1	4		x	x					x
Tartarian honeysuckle	*Lonicera tatarica*	shrub	IN	1	4		x	x					x
Showy fly honeysuckle	*Lonicera X bella*	shrub	TR	1	2		x						x
Bird's-foot trefoil	*Lotus corniculatus*	herb	TR	2	2			x				x	
Moneywort	*Lysimachia nummularia*	herb	IN	2	3	x		x					
Purple loosestrife	*Lythrum salicaria*	herb	IN	1	9	x	x	x	x	x	x	x	x
Alfalfa	*Medicago sativa ssp. sativa*	herb	TR	4	2	x		x					
White sweet clover	*Melilotus alba*	herb	IN	2	3	x		x				x	
Yellow sweet clover	*Melilotus officinalis*	herb	TR	2	2	x		x					
White mulberry	*Morus alba*	tree	TR	1	2	x		x				x	
Eurasian water milfoil	*Myriophyllum spicatum*	herb	IN	1	7	x	x	x	x	x		x	x
Brittle naiad	*Najas minor*	herb	IN	3	3				x			x	x

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNR List	Urban FA	Great Lakes	Manitoba	Michigan	Global	New York
Yellow Floating heart	*Nymphoides peltata*	herb	IN	1	6								
Wild marjoram	*Origanum vulgare*	herb	TR	4	2	x		x					
Common reed	*Phragmites australis ssp. australis*	gram	IN	1	7								
Scots pine	*Pinus sylvestris*	tree	IN	2	3	x		x				x	
Japanese knotweed	*Polygonum cuspidatum*	herb	IN	2	8	x	x	x	x		x	x	x
Giant knotweed	*Polygonum sachalinense*	herb	TR	2	2		x						x
White poplar	*Populus alba*	tree	TR	2	2	x		x					
Curly pondweed	*Potamogeton crispus*	herb	IN	1	7	x	x	x	x	x		x	x
Kudzu	*Pueraria montana var. lobata*	vine	TR	2	2								
European buckthorn	*Rhamnus cathartica*	shrub	IN	1	7	x	x	x	x	x			x
Glossy buckthorn	*Rhamnus frangula*	shrub	IN	1	7	x	x	x	x			x	x
Black locust	*Robinia pseudo-acacia*	tree	IN	2	4	?	?	x				x	x
Multiflowered rose	*Rosa multiflora*	shrub	IN	1	4	x		x					x
Mossy stonecrop	*Sedum acre*	herb	TR	2	2		x	x					
Bittersweet nightshade	*Solanum dulcamara*	vine	TR	3	2			x			x		
European mountain ash	*Sorbus aucuparia*	shrub	TR	4	2	x		x					
Johnson grass	*Sorghum halepense*	gram	TR	3	2						x	x	

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNR List	Urban FA	Great Lakes	Manitoba	Michigan	Global	New York
Water soldier	Stratiotes aloides	herb	IN	1	1		x						
Lilac	*Syringa vulgaris*	shrub	TR	2	2	x		x					
Common tansy	*Tanacetum vulgare*	herb	TR	3	2			x		x			
Water chestnut	*Trapa natans*	herb	IN	2	4		x	x	x		x		
Coltsfoot	*Tussilago farfara*	herb	IN	4	3	x		x				x	
Siberian elm	*Ulmus pumila*	tree	TR	2	2		x	x					
European Guelder rose	*Viburnum opulus*	shrub	IN	4	3	x		x					
Cow vetch	*Vicia cracca*	vine	TR	2	2			x		x			
Periwinkle	*Vinca minor*	vine	IN	2	3	x		x					

1 Invasive : IN = Invasive Species TR = Tracked Species

2 Category: 1 = Aggressive Invasive, 2 = Highly Invasive, 3 = Moderately Invasive, 4 = Of Concern

3 Count: No of literature (websites) sources which list a species as 'Invasive'

ON ON list of invasive plants listed by the Canadian Botanical Conservation Network - 1997

UrbanFA Urban Forest Assoc (Ontario - 2002)

MNRList OMNR list

GreatLakes Great Lakes United (Quebec)

Manitoba Invasive species found in both Manitoba and Ontario

Michigan Michigan Invasive Plant Council

Global the Global Invasive Species Database – 2011

NewYork	**Invasive species listed for New York State**

THE VSP INVASIVE SPECIES LISTS COMPLIED BASED ON WEB BASED RESOURCES, FEBRUARY 2012. SPECIES ARE LISTED BY COMMON NAME.

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNRList	UrbanFA	GreatLakes	Manitoba	Michigan	Global	New York
Absinth wormwood	*Artemesia absinthium*	herb	TR	3	2								
Alfalfa	*Medicago sativa ssp. sativa*	herb	TR	4	2	x		x					
Amur honeysuckle	*Lonicera maackii*	shrub	IN	1	5		x	x				x	x
Autumn olive	*Elaeagnus umbellata*	shrub	IN	1	4			x				x	x
Bird's-foot trefoil	*Lotus corniculatus*	herb	TR	2	2			x				x	
Bittersweet nightshade	*Solanum dulcamara*	vine	TR	3	2			x			x		
Black locust	*Robinia pseudo-acacia*	tree	IN	2	4	?	?	x				x	x
Brittle naiad	*Najas minor*	herb	IN	3	3				x			x	x
Bugleweed	*Ajuga reptens*	herb	TR	4	2								
Bull thistle	*Cirsium vulgare*	herb	IN	3	3		x				x		x
Butter-and-eggs	*Linaria vulgaris*	herb	TR	4	2			x		x			
Canada thistle	*Cirsium arvense*	herb	IN	1	6	x		x		x	x	x	
Carolina fanwort	*Cabomba caroliniana*	herb	TR	3	5		x	x	x			x	x
Coltsfoot	*Tussilago farfara*	herb	IN	4	3	x		x				x	
Common barberry	*Berberis vulgaris*	shrub	IN	3	3			x			x		

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNRList	UrbanFA	GreatLakes	Manitoba	Michigan	Global	New York
Common privet	*Ligustrum vulgare*	shrub	IN	4	3		x	x					
Common reed	*Phragmites australis ssp. australis*	gram	IN	1	7								
Common tansy	*Tanacetum vulgare*	herb	TR	3	2			x		x			
Cow vetch	*Vicia cracca*	vine	TR	2	2			x		x			
Creeping bellflower	*Campanula rapunculoides*	herb	TR	4	2	x		x					
Crown vetch	*Coronilla varia*	vine	IN	1	3	x		x					x
Curly pondweed	*Potamogeton crispus*	herb	IN	1	7	x	x	x	x	x		x	x
Dame's rocket	*Hesperis matronalis*	herb	IN	1	3	x	x	x					
Diffuse knapweed	*Centaurea diffusa*	herb	TR	3	2					x		x	
Dog-strangling vine	*Cynanchum nigrum*	vine	IN	1	6	x	x	x	x				x
English ivy	*Hedera helix*	vine	IN	3	3	x		x					
Eurasian water milfoil	*Myriophyllum spicatum*	herb	IN	1	7	x	x	x	x	x		x	x
European alder	*Alnus glutinosa*	tree	TR	1	2	x		x					
European buckthorn	*Rhamnus cathartica*	shrub	IN	1	7	x	x	x	x	x			x
European frog-bit	*Hydrocharis morsus-ranae*	herb	IN	1	8	x	x	x	x	x	x	x	x
European Guelder rose	*Viburnum opulus*	shrub	IN	4	3	x		x					
European mountain ash	*Sorbus aucuparia*	shrub	TR	4	2	x		x					
European white birch	*Betula pendula*	tree	TR	1	2	x		x					
Field bindweed	*Convolvulus arvensis*	vine	TR	3	2			x			x		

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNRList	UrbanFA	GreatLakes	Manitoba	Michigan	Global	New York
Flowering rush	*Butomus umbellatus*	herb	IN	1	7	x	x	x	x	x		x	x
Garlic mustard	*Alliaria petiolata*	herb	IN	1	5	x	x	x					x
Giant hogweed	*Heracleum mantegazzianum*	herb	IN	2	5		x		x		x	x	x
Giant knotweed	*Polygonum sachalinense*	herb	TR	2	2		x						x
Glossy buckthorn	*Rhamnus frangula*	shrub	IN	1	7	x	x	x	x			x	x
Goutweed	*Aegopodium podagraria*	herb	TR	1	2	x		x					
Great manna grass	*Glyceria maxima*	gram	TR	1	2	x		x					
Himalayan balsam	*Impatiens glandulifera*	herb	IN	1	4	x		x		x		x	
Hoary-alyssum	*Berteroa incana*	herb	IN	3	3	x		x			x		
Horse chestnut	*Aesculus hippocastanum*	tree	TR	3	2	x		x					
Japanese barberry	*Berberis thunbergii*	shrub	IN	3	5	x		x				x	x
Japanese honeysuckle	*Lonicera japonica*	vine	IN	1	4	x		x					x
Japanese knotweed	*Polygonum cuspidatum*	herb	IN	2	8	x	x	x	x		x	x	x
Johnson grass	*Sorghum halepense*	gram	TR	3	2						x	x	
Kudzu	*Pueraria montana var. lobata*	vine	TR	2	2								
Leafy spurge	*Euphorbia esula*	herb	IN	4	6	x		x		x	x	x	
Lilac	*Syringa vulgaris*	shrub	TR	2	2	x		x					
Moneywort	*Lysimachia nummularia*	herb	IN	2	3	x		x					

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNRList	UrbanFA	GreatLakes	Manitoba	Michigan	Global	New York
Morrow's honeysuckle	*Lonicera morrowii*	shrub	IN	1	4		x	x					x
Mossy stonecrop	*Sedum acre*	herb	TR	2	2		x	x					
Mother-of-thyme	*Acinos arvensis*	herb	TR	3	2	x		x					
Multiflowered rose	*Rosa multiflora*	shrub	IN	1	4	x		x					x
Nodding thistle	*Carduus nutans ssp. leiophyllus*	herb	IN	3	4								
Norway maple	*Acer platanoides*	tree	IN	2	6	x	x	x				x	x
Orange daylily	*Hemerocallis fulva*	herb	TR	4	2	x		x					
Oriental bittersweet	*Celastrus orbiculatus*	vine	IN	2	4			x				x	x
Periwinkle	*Vinca minor*	vine	IN	2	3	x		x					
Purple loosestrife	*Lythrum salicaria*	herb	IN	1	9	x	x	x	x	x	x	x	x
Russian olive	*Elaeagnus angustifolia*	shrub	IN	3	4			x				x	x
Scots pine	*Pinus sylvestris*	tree	IN	2	3	x		x				x	
Showy fly honeysuckle	*Lonicera X bella*	shrub	TR	1	2		x						x
Siberian elm	*Ulmus pumila*	tree	TR	2	2		x	x					
Smooth brome grass	*Bromus inermis ssp. inermis*	gram	TR	4	2			x				x	
Spotted knapweed	*Centaurea maculosa*	herb	IN	3	6	x		x		x	x	x	
St. John's wort	*Hypericum perforatum*	herb	IN	4	3	x		x				x	
Tartarian honeysuckle	*Lonicera tatarica*	shrub	IN	1	4		x	x					x
Teasel	*Dipsacus fullonum ssp. sylvestris*	herb	IN	3	3								

Common Name	Scientific Name	Form	Invasive[1]	Category[2]	Count[3]	ON	MNRList	UrbanFA	GreatLakes	Manitoba	Michigan	Global	New York
Tree-of-heaven	*Ailanthus altissima*	tree	IN	2	3			x					x
Velvetleaf	*Abutilon theophrasti*	herb	TR	3	2			x			x		
Water chestnut	*Trapa natans*	herb	IN	2	4		x	x	x		x		
Water soldier	Stratiotes aloides	herb	IN	1	1		x						
White bedstraw	*Galium mollugo*	herb	TR	2	2	x		x					
White mulberry	*Morus alba*	tree	TR	1	2	x		x				x	
White poplar	*Populus alba*	tree	TR	2	2	x		x					
White sweet clover	*Melilotus alba*	herb	IN	2	3	x		x				x	
White swallow-wort	*Cynanchum rossicum*	vine	IN	1	7	x	x	x	x			x	x
Wild marjoram	*Origanum vulgare*	herb	TR	4	2	x		x					
Yellow flag	*Iris pseudacorus*	herb	IN	4	7	x	x	x		x	x	x	x
Yellow Floating heart	*Nymphoides peltata*	herb	IN	1	6								
Yellow knapweed	*Centaurea solstitialis*	herb	TR	3	2					x		x	
Yellow sweet clover	*Melilotus officinalis*	herb	TR	2	2	x		x					

TABLE A-1: LIST OF WEB-BASED RESOURCES USED TO COMPILE CONSOLIDATED VSP INVASIVE PLANT SPECIES LIST, FEBRUARY 2012.

Title of the document and invasive species list	Web Address	Organization
Invasive Plants in Canada - 1997	http://archive.rbg.ca/cbcn/en/projects/invasives/i_list.html	Canadian Botanical Conservation Network
Invasive Species List	http://ufora.net/index.php/resources/invasive-species/	Urban Forest Associates Incorporated
Landowner's Guide to Controlling Invasive Woodland Plants	http://www.ontarioinvasiveplants.ca/	Ontario Invasive Plant Council (OIPC)
Terrestrial Invasive Species	http://www.mnr.gov.on.ca/en/	Ontario Ministry of Natural Resources
Great Lakes United - Invasive Plant Watch Network	http://rspee.glu.org/autres/index.php	University of Montreal
Invasive Species List	http://invasivespeciesmanitoba.com/site/	Invasive Species Council of Manitoba
Michigan Invasive Plant Assessment	http://invasiveplantsmi.org/	Michigan Invasive Plant Council
Nuisance and Invasive Species	http://www.dec.ny.gov/animals/265.html	New York Invasive Species Council
Global Invasive Species Database	http://www.issg.org/database/welcome/	Invasive Species Specialist Group

Note: The Natural Heritage Information – Invasive Species List, Great Lakes United, and invasive species lists for New York and Michigan were also surveyed.

Web based references reviewed and relevant to invasive species designations and listings:

ONTARIO:

Credit Valley Conservation

http://www.creditvalleyca.ca/

Has several PDF files relating to invasive plants in southern Ontario

Flora Ontario – Integrated Botanical Information System (FOIBIS)

http://www.uoguelph.ca/foibis/

University of Guelph, Guelph, Ontario

Searchable database, which provides native or introduced species status for plant species

Halton – Peel Biodiversity Network

http://www.powerhalton.ca/

Protect Our Water and Environment Resources (POWER)

Georgetown, Halton Hills

List of invasive plants in Ontario

Invading Species Awareness Program

http://www.invadingspecies.com/indexen.cfm

Ontario Federation of Anglers and Hunters in partnership with the Ontario Ministry of Natural Resources

Natural Heritage Information Centre (NHIC)

http://nhic.mnr.gov.on.ca/

Nature Conservancy of Canada and the Ontario Ministry of Natural Resources

Ontario Invasive Plant Council (OIPC)

P.O. Box 2800

4601 Gauthrie Drive

Peterborough, Ontario

http://www.ontarioinvasiveplants.ca/

Has a listing of additional websites with factsheets and other links for invasive species.

http://www.ontarioinvasiveplants.ca/index.php/publications

Two publications used to identify invasive species in Ontario:

Landowners Guide to Controlling Invasive Woodland Plants

Quick Reference Guide to Invasive Plant Species

(This last publication is a joint effort by the Toronto Region Conservation Authority, Credit Valley Conservation Authority and the OIPC)

A third publication produced by the MNR and OFAH is also listed at this site.

Field Guide to Aquatic Invasive Species

Ontario Ministry of Agriculture, Food and Rural Affairs

http://www.omafra.gov.on.ca/english/crops/facts/noxious_weeds.htm

Noxious Weeds in Ontario – fact sheets

Ontario Ministry of Natural Resources

http://www.mnr.gov.on.ca/en/

Biodiversity, Invasive Species

Two lists available: Aquatic Invasive Species

Terrestrial Invasive Species

Royal Botanical Gardens

http://www.rbg.ca/Page.aspx?pid=193

Provides link to the Canadian Botanical Conservation Network

Urban Forest Associates Inc.

http://ufora.net/index.php/about/

Toronto's Ravine and Tree Specialists

Site provides a list of Invasive Species listed by I Rank values

CANADA:

Canadian Botanical Conservation Network (CBCN)

http://www.rbg.ca/Page.aspx?pid=329

Based out of the Royal Botanical Gardens, Burlington, Ontario

Link leads to Invasive Plants in Canada webpage

Great Lakes United – Invasive Plant Watch Network (Quebec)

http://rspee.glu.org/autres/index.php

University of Montreal – track 20 invasive aquatic plants which are found in the Great Lakes

Invasive Species Council of Manitoba
http://invasivespeciesmanitoba.com/site/
Has two lists: Invasive Aquatic Species List
Invasive Terrestrial Species List

(VASCAN), the Database of Vascular Plants of Canada
http://data.canadensys.net/vascan/search
Brouillet, L. , F. Coursol, M. Favreau, M. Anions, P. Bellisle and P. Desmet
Universite de Montreal Biodiversity Centre, Montreal, Quebec
Provides searchable database, indicating native status in each province

UNITED STATES:

National Institute of Invasive Species Science
http://www.niiss.org/cwis438/websites/niiss/Home.php?WebSiteID=1
U.S. Geological Survey, Fort Collins Science Center, Colorado
Primarily for invasive plants in the western United States
Provides list of invasive species sampling methodologies (Whittaker, P Plot, NAWMA)

National Invasive Species Information Center
United States Department of Agriculture
http://www.invasivespeciesinfo.gov/unitedstates/main.shtml

Invasive Plant Atlas of the United States

http://www.invasiveplantatlas.org/index.html

The University of Georgia – Center for Invasive Species and Ecosystem Health and

The National Park Service

Michigan Invasive Plant Council (MIPC)

http://invasiveplantsmi.org/

List of plants assessed through the Michigan Plant Invasiveness Assessment System (32 species)

New York State

Department of Environmental Conservation

New York Invasive Species Council

http://www.dec.ny.gov/animals/265.html

Nuisance and Invasive Species – Interim Invasive Species Plant List (54 species)

Ohio Invasive Plants Council

http://www.oipc.info/specieslist.html

List of invasive plants in the state of Ohio

North America:

NatureServe Explorer – The Nature Conservancy

http://www.natureserve.org/explorer/servlet/NatureServe?init=Species

NatureServe website is part of the National Biological Information Infrastructure (NBII)

Database which can be searched by species, providing distribution maps and status for each province

PLANTS Database – United States Department of Agriculture

http://plants.usda.gov/java/

Natural Resources Conservation Service

Database which can be searched by species, providing distribution maps and taxonomic rank

World:

Global Invasive Species Database

http://www.issg.org/database/welcome/

Invasive Species Specialist Group (ISSG), under the Global Invasive Species Program (GISP)

Searchable database, print out list of invasive plant species for Ontario