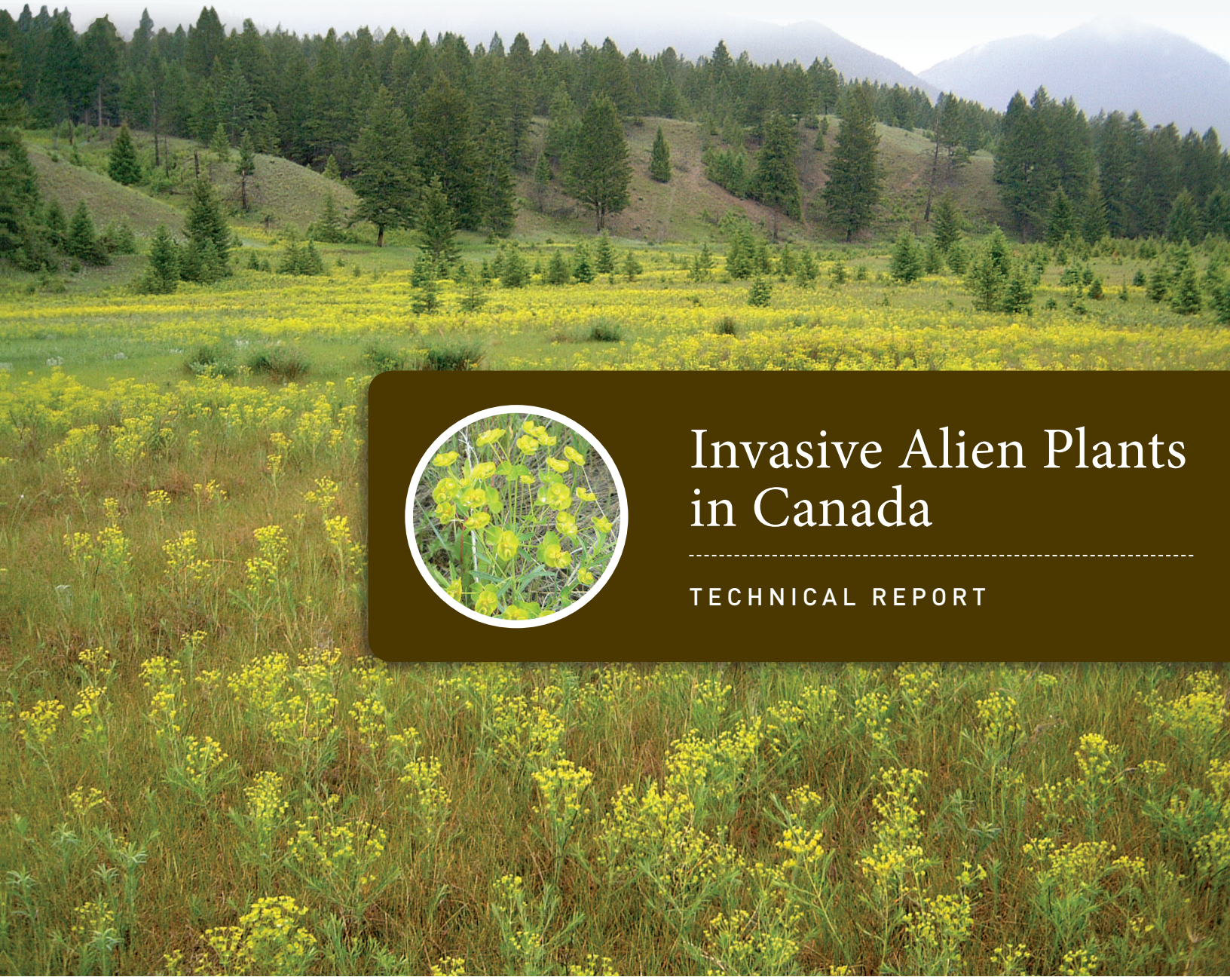
Canadian Food Inspection Agency
Agence canadienne d'inspection des aliments

INVASIVE ALIEN SPECIES



Invasive Alien Plants in Canada

TECHNICAL REPORT

Canada

Invasive Alien Plants in Canada

This document is based primarily on an initial report prepared for the Canadian Food Inspection Agency by McClay Ecoscience (www.mcclay-ecoscience.com)

Staff of the Canadian Food Inspection Agency edited the original report and contributed additional material for this publication.

Canadian Food Inspection Agency

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Leafy spurge (*Euphorbia esula*) dominating rangeland near Invermere, British Columbia. Larry Halverson, Parks Canada.

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Acknowledgments

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Executive Summary

Invasive alien plants represent a serious threat to Canada's environment and economy, affecting biodiversity, ecosystem functioning, agricultural productivity, economic activities, trade, and human health and well-being. In 2005, the Government of Canada approved funding of $85 million over five years (2005–2010) to implement *An Invasive Alien Species Strategy for Canada*.

This report documents the current status of invasive plant species in Canada as a starting point to track the progress of the strategy in assessing and addressing problems related to invasive plants. The report also reviews Canadian programs that are underway for understanding and addressing the invasive plant problem. Program information was gathered during the period 2001–2005 from federal, provincial, territorial, municipal, academic, non-governmental, and private sector agencies through a questionnaire, literature search, web search, and discussions with experts. A list of invasive vascular plant species in Canada was compiled from a variety of sources, and information was collected on origins, times and pathways of introduction, sectors affected, and impacts.

There are 1,229 alien vascular plant species in Canada, representing about 24% of the total Canadian vascular flora, and 486 of these alien species are considered to be weedy or invasive. Ontario, Quebec, and British Columbia have the highest numbers of invasive species, while Nunavut has the lowest. On an ecozone basis, the Mixedwood Plain, Atlantic Maritime, and Pacific Maritime ecozones have the highest numbers of invasive plant species, while the Arctic Cordillera, Northern Arctic, and Taiga Cordillera have the lowest.

The major families of invasive plants in Canada are Asteraceae (daisy or composite family), Poaceae (grass family), Brassicaceae (mustard family), Fabaceae (pea family), and Lamiaceae (mint family). Families whose members are particularly likely to become invasive when introduced into Canada are Asteraceae, Brassicaceae, Boraginaceae, and Amaranthaceae. The vast majority of invasive plant species in Canada are forbs, with annual and perennial species about equally represented. Once established, plants in all life history and growth form categories are, more or less, equally likely to become invasive.

About 58% of invasive plant species appear to have arrived in Canada as the result of deliberate introduction — a lower proportion than has been found in some other countries. Over 80% of invasive plant species in Canada originated in the West Palaearctic region (primarily western Europe), with the second largest group being from the East Palaearctic (primarily China and Japan). This reflects past rather than current patterns of trade and colonization. A climatic analysis and trade statistics were used to identify areas that are potential sources of new invasive plant species for each ecozone of Canada, and eastern Asia and southern South America were identified. The largest source of new alien plant introductions into Canada is likely to be the United States, however, because of its proximity, the volume of trade, and climatic and environmental similarities.

It is estimated that during the past century, 0.58 new invasive plant species have become established per year in Canada. This is lower than the historical average, of 1.2 new invasive species per year over the last 400 years. It is important to note, however, that an alien plant does not have to be a new incursion into Canada to represent a new problem for invasive plant managers. Many species that have been in Canada for decades or centuries are still expanding and filling in gaps in their ranges, and so at a local level, the majority of new problems are due to species that have long been established in Canada.

The impacts of invasive plant species are varied and can include economic, environmental, and social consequences. These impacts are a function of the range, abundance, and per capita effects of each species. A broad range of economic sectors is affected, including agriculture, forestry, public administration, private households, construction, and transportation. These impacts are best documented in agriculture, where, based on surveys and weed-crop competition studies in the Prairie provinces, it has been estimated that 99% of yield loss and herbicide expenditure in annual crops is due to alien plant species. Damage by and control of weeds in crops and pastures has been estimated to be $2.2 billion annually on an agricultural land base that produces $15 billion of plant products per year. Invasive plants can also affect the environment in terms of ecosystem diversity, structure, and function. Forty-four species at risk have been identified for which invasive plants

appear to be factors in their at-risk status. These include vascular plants, birds, amphibians, insects, and one reptile. Social impacts of invasive plants have not been well documented, but include a diverse group of effects including human health problems; interference with traditional lifestyles; and a reduction in property values, tourism, employment, aesthetic values, and enjoyment of natural areas. Further research in all areas is needed to quantify the diverse range of impacts of invasive plants in Canada.

Regulatory measures are an important component for managing the movement of invasive alien species. Canada's actions for addressing invasive plants are influenced by certain international agreements. Many domestic legislative instruments assist in fulfilling international obligations and have the potential benefit of minimizing the risk of invasive plants to Canada's economy, environment, and society.

A wide range of federal, provincial, territorial, and municipal government departments and agencies, universities and colleges, non-governmental organizations, multi-stakeholder groups, private industry, and private individuals are involved in Canada's response to invasive plants. This response includes surveying and monitoring work to assess the occurrence and effects of invasive plants; research to develop management methods; prevention of new invasions; early detection and rapid response to new invaders; managing established populations; and public awareness and education. Multi-stakeholder groups formed in response to particular invasive plant threats, or organized around ecosystems under threat by invasive plants, have been an effective organizational model in Canada.

1 Introduction

Invasive alien plants present an immediate and growing threat that is detrimental to Canada's environment, economy, and society. Invasive plants are one of the greatest threats to croplands, rangelands, and natural areas in Canada, degrading their productivity and biological diversity, incurring significant economic costs, and affecting our trade relationships with foreign countries. The list of invasive plants already having harmful impacts in Canada is long, and there are numerous others currently threatening our borders. A 2002 report by the Commissioner of the Environment and Sustainable Development (Auditor General of Canada 2002) outlined the seriousness of the economic and environmental impacts of invasive alien species in Canada, highlighting plant species such as purple loosestrife (*Lythrum salicaria*), leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea stoebe ssp. micranthos*), and Canada thistle (*Cirsium arvense*). Global warming will encourage further incursions of invasive plants, allowing them to establish and spread into Canada over the coming years. There is an urgent need to address these invasions.

> *Invasive alien species* are those harmful alien plants, animals, and micro-organisms whose introduction or spread threatens the environment, the economy, or society, including human health.
>
> *Invasive Alien Species Strategy for Canada* (Government of Canada 2004)

In 2005, the Government of Canada approved funding of $85 million over five years (2005–2010) to implement *An Invasive Alien Species Strategy for Canada*. A large portion of these funds was allocated to the Canadian Food Inspection Agency (CFIA), Canada's national plant protection organization under the *International Plant Protection Convention*.

This report compiles benchmark data against which progress in prevention, early detection, management, and communications can be assessed. A detailed description and analysis of the current state of invasive plants in Canada is needed to meet the following objectives:

- to provide baseline data to support a monitoring and reporting system to track the effectiveness of present programs;
- to establish prevailing trends in order to provide direction for future efforts; and
- to enable future measurement of progress on the Government of Canada's commitment to deal with invasive plants.

1.1 Methodology

This report is based on a review of published literature — information provided by a wide range of departments and agencies in their reports and websites — and 63 responses to questionnaires that were sent out to federal, provincial, territorial, and municipal government departments, non-government organizations, universities, and corporations across Canada (see Appendices I and II). The questionnaire and data gathering focused on the period 2001–2005. It was not possible to contact all the appropriate people and agencies, but future reports may build on the contacts developed during the course of this project. The private sector and municipal governments are strongly involved in the management of invasive plants, but because their activities are local and diffused across many different sectors, it was not possible to get a full picture of their involvement.

1.2 Focus of the Report

This report covers two main areas: the current state of our knowledge of invasive plant species and their impacts in Canada, and the status of programs that address invasive plant problems. Our knowledge of invasive plants includes our ability to answer such questions as:

European frog's-bit (*Hydrocharis morsus-ranae*)
Wasyl Bakowsky, Ontario Ministry of Natural Resources

- What kinds of invasive plants are present in Canada?
- Where are they distributed?
- Where did they come from?
- How and when did they get here?
- What effects are they having?
- How is their status changing over time?

Programs responding to invasive plants include activities that help to improve our knowledge of invasive plants and their effects, as well as those that aim to reduce their impacts. This includes activities such as:

- research, surveys and monitoring;
- public awareness and education;
- prevention and exclusion;
- early detection and rapid response; and
- management (including containment, eradication, and control).

2 Invasive Alien Plants in Canada

A list of alien plant species in Canada was created based primarily on information obtained from the *Wild Species 2005* website available at www.wildspecies.ca/wildspecies2005/ (Canadian Endangered Species Conservation Council 2006). Scientific names follow recent taxonomic treatments in the Flora of North America (Flora of North America Editorial Committee 1993–2003), and Kartesz (1999) for other groups that have not yet been addressed. *Wild Species 2005* includes national, provincial, and territorial status information for each species.

All vascular plant species whose status was listed as alien to Canada as a whole were extracted, as well as those listed as alien in any province or territory. The latter group includes species introduced to parts of Canada outside their native range, as well as some species where opinions differ about their status as natives or aliens. In addition to distributional information, data on family, life history (annual, biennial, or perennial), and growth form (forb, graminoid, subshrub, shrub, tree, vine, or aquatic) were recorded. This information was obtained mainly from Kartesz (1999) and the USDA PLANTS database (USDA-NRCS 2007).

A number of sources were then consulted to determine which alien plant species in Canada were considered to be weedy or invasive. In addition, a general literature search was conducted and several experts were consulted. The major sources used were:

- provincial and territorial lists of noxious or other regulated weeds;
- articles in The Biology of Canadian Weeds and The Biology of Invasive Alien Plants in Canada series published in the *Canadian Journal of Plant Science*;
- the Canadian Wildlife Service report *Invasive Plants of Natural Habitats in Canada* (White et al. 1993);
- the *Inventory of Canadian Agricultural Weeds* (Darbyshire 2003);
- a prioritized list of the invasive alien plants of natural habitats in Canada by Catling and Mitrow (2005), ranked according to NatureServe's I-ranking system (Morse et al. 2004);
- postings on the *Botanical Electronic News* archive at www.ou.edu/cas/botany-micro/ben/;
- a list of invasive plants produced by the Canadian Botanical Conservation Network (www.rbg.ca/cbcn/en/projects/invasives/i_list.html).
- a list of invasive species in southern Ontario produced by Urban Forest Associates Inc. in 2002 (www.serontario.org/pdfs/exotics.pdf);
- the Global Invasive Species database at www.issg.org/database/welcome/;
- a list of invasive plants in British Columbia produced by Tania Perzoff for E-Flora BC, with information from a variety of sources, including the BC Ministry of Forests, the BC Ministry of Agriculture, and the Canadian Wildlife Service (www.geog.ubc.ca/~brian/florae/invasives.html); and
- "A Rogue's Gallery of Invasive Non-native Plants" (Alberta Native Plant Council 2000).

There are 1,229 alien vascular plant species reported in Canada, of which 486 are considered invasive.

As a result of this research, it is estimated that there are 1,229 vascular plant species alien to Canada, in addition to a native vascular plant flora of approximately 3,858 species. Thus, about 24% of the Canadian vascular flora consists of alien plants. Of the alien species, 473 are considered weedy or invasive, according to the sources listed above. Another 13 species were considered alien invasive plants in this study, either because they are not listed in the *Wild Species 2005* website, or they are listed as native but are considered alien by other authors, or because alien genotypes of species native to some part of Canada were introduced elsewhere in Canada and have become invasive. The latter category is sometimes referred to as *cryptogenic* species. Examples in Canada include Kentucky bluegrass (*Poa pratensis*) (Alaska Natural Heritage Program 2004), common reed (*Phragmites australis*

ssp. *australis*) (Saltonstall 2002), stinging nettle (*Urtica dioica* ssp. *dioica*) (Boufford 1997), and reed canary grass (*Phalaris arundinacea*) (Lavergne and Molofsky 2007).

In some cases it is difficult to determine whether a species is introduced or native. For example, narrow-leaved cat-tail (*Typha angustifolia*) is sometimes referred to as an invasive European species (Galatowitsch et al. 1999; Selbo and Snow 2004; Smith 2000), and sometimes as a native (Houlahan and Findlay 2004). In this report, narrow-leaved cat-tail is considered an alien based on the taxonomic treatment by Smith (2000) in the Flora of North America. A total of 486 alien plant taxa are considered weedy or invasive in Canada (Table 1).

In addition, 316 species are recorded as being native to some part of Canada but introduced into others, of which 69 are considered invasive. A few of these are considered significant invaders in some regions, such as common ragweed (*Ambrosia artemisiifolia*) in Quebec, and Manitoba maple (*Acer negundo*) in Alberta and British Columbia.

Thus, the vast majority of significant invasive plant problems are due to species that are not native to any part of Canada, and these species are the major focus of this report. For all species identified as weedy or invasive, the following additional attributes were recorded: area of origin according to major biogeographic realms (Udvardy 1975), sectors affected by the species, estimated dates of first introduction into Canada or North America, and the probable pathway of introduction.

2.1 Taxonomic Analysis

The major families of invasive alien plants in Canada are Asteraceae (daisy or composite family: 78 species), Poaceae (grass family: 60 species) Brassicaceae (mustard family: 42 species), Fabaceae (pea family: 34 species), and Lamiaceae (mint family: 18 species). The number of reported weedy or invasive plants in 25 families was compared with the total number of naturalized alien species in those families present in Canada (Table 2). Overall, about 39.5% of naturalized alien species in Canada have been reported as weedy or invasive. Thus, if there were no taxonomic differences in the tendency to become invasive, 39.5% of species in each family would be expected to be reported as invasive. While many families are close to this proportion, some appear to have produced more or fewer invasives than would be expected. This analysis indicates that families particularly likely to become invasive are Asteraceae, Brassicaceae, Boraginaceae, and Amaranthaceae. Other families such as Papaveraceae, Ranunculaceae, Cyperaceae, Crassulaceae, and Rosaceae have produced fewer invasives than would be expected, based on the number of species that have become naturalized.

Table 1. Breakdown of invasive alien species in Canada compared with listings in the Wild Species 2005 website.

	Invasive	Non-invasive	Totals
Species alien to Canada according to *Wild Species 2005*	473	743	1,216
Alien spp. not listed in *Wild Species 2005*[1]	2	n/c	2[2]
Species listed as native in *Wild Species 2005* but considered by other authors as alien[3]	5	n/c	5[2]
Species listed as native in *Wild Species 2005* but with invasive alien genotypes in Canada[4]	6	n/c	6[2]
Total of above	486	--	1,229[2]
Species listed as native and non-native within Canada	**69**	**247**	**316**

n/c: not counted

[1] *Fallopia* × *bohemica, Hieracium glomeratum*
[2] Totals do not include uncounted non-invasive species.
[3] *Galium aparine, Plantago major, Polygonum aviculare, Taraxacum officinale, Typha angustifolia*
[4] *Phalaris arundinacea, Phragmites australis* subsp. *australis, Poa pratensis, Rumex acetosa, Tripleurospermum maritima, Urtica dioica*

Table 2. A comparison of the frequency of introduced species becoming invasive in Canada among 25 frequently introduced families.

Family	Number of species naturalized	Number of species invasive	Expected number of species invasive	χ^2 contribution
Asteraceae	153	78	60.68	4.94
Brassicaceae	77	42	30.54	4.30
Amaranthaceae	10	7	3.97	2.32
Boraginaceae	27	15	10.71	1.72
Malvaceae	15	9	5.95	1.56
Euphorbiaceae	18	10	7.14	1.15
Poaceae	134	60	53.14	0.88
Polygonaceae	31	15	12.29	0.60
Rubiaceae	11	5	4.36	0.09
Chenopodiaceae	28	12	11.1	0.07
Solanaceae	27	11	10.71	0.01
Caprifoliaceae	15	6	5.95	0.00
Geraniaceae	10	4	3.97	0.00
Fabaceae	87	34	34.5	0.01
Apiaceae	29	11	11.5	0.02
Lamiaceae	48	18	19.04	0.06
Scrophulariaceae	46	15	18.24	0.58
Salicaceae	12	3	4.76	0.65
Caryophyllaceae	56	16	22.21	1.74
Liliaceae	24	5	9.52	2.14
Papaveraceae	11	1	4.36	2.59
Ranunculaceae	30	6	11.9	2.92
Cyperaceae	12	1	4.76	2.97
Crassulaceae	14	1	5.55	3.73
Rosaceae	76	12	30.14	10.92

The families are arranged so that those with the greatest number of invasives relative to the expected number (if species in all families were equally likely to become invasive) are at the top, and those with the fewest are at the bottom. Individual χ^2 values are a measure of departure from the expected number of invasives. The frequency of invasiveness differs significantly among families (overall χ^2 45.98 for 24 d.f., p=0.0044).

A similar analysis was conducted by Cadotte and Lovett-Doust (2001) on the native and introduced flora of southwestern Ontario, except that the taxonomic make-up rather than the invasive and non-invasive components were compared. They found that Asteraceae, Brassicaceae, Boraginaceae, and Amaranthaceae were among those over-represented in the introduced flora compared with the native flora, suggesting that these families are particularly likely to be introduced and established, as well as to become invasive. They also found that Cyperaceae and Ranunculaceae were among families under-represented in the introduced flora.

2.2 Growth Forms and Life Histories

Growth forms and life histories of invasive plants in Canada were examined (Table 3). The vast majority (about 71%) of invasive plant species in Canada are forbs (herbs), which are more or less evenly divided between annuals and perennials. The second largest category (13%) are the graminoids (plants with a grass-like growth habit), most of which belong to the grass family (Poaceae) — and again, these are evenly split between annuals and perennials.

Table 3. Growth forms and life histories of invasive alien plant species in Canada.

Growth form	Life history			
	annual	biennial	perennial	Total
aquatic[1]	2	0	7	9
forb	152	42	150	344
graminoid	31	0	30	61
shrub	0	0	31	31
subshrub	0	0	3	3
tree	0	0	19	19
vine	4	0	15	19
Total	189	42	255	486

[1] Includes submergent, floating-leaved, and free-floating.

A comparison was made between the life histories and growth habits of non-invasive species and invasive species. In general, the frequency of becoming invasive was similar across all life-history/growth-habit categories, as reflected in the non-significant overall χ^2 value. There is a slight trend for annual forbs to be more likely to become invasive, and annual vines and sub-shrubs less likely (Table 4).

2.3 Distribution of Invasive Plant Species in Canada

Information on distribution in Canada was compiled for each of the 486 identified invasive alien plant species. Data on presence or absence on a provincial and territorial basis are available for all these species in the **Wild Species 2005** website. The distribution of 162 invasive species was recorded by ecozone based on more detailed mapping in papers in the *Biology of Canadian Weeds* and *Biology of Invasive Alien Plants in Canada* series, as well as the Brassicaceae of Canada database (www.cbif.gc.ca/spp_pages/brass/index_e.php). Canada has been divided into 15 terrestrial ecozones that are defined by major plant formations, physiographic features such as plains and mountain ranges, and soil types (Wiken 1986).

Table 4. A comparison of the frequency of alien plant species becoming invasive in Canada according to their growth forms and life histories.

Habit	Number of species Naturalized	Number of species invasive		χ^2 contribution
		Observed	Expected	
annual forb	339	152	134.06	2.40
annual graminoid	67	31	26.49	0.77
perennial aquatic	13	7	5.14	0.67
annual aquatic	3	2	1.19	0.56
biennial forb	99	42	39.15	0.21
perennial vine	37	15	14.63	0.01
perennial forb	391	150	154.62	0.14
tree	50	19	19.77	0.03
biennial vine	1	0	0.4	0.40
perennial graminoid	84	30	33.22	0.31
shrub	88	31	34.8	0.41
annual vine	23	4	9.1	2.85
sub-shrub	34	3	13.45	8.11

Categories are arranged so that those with the greatest number of invasives relative to the expected number (if species in all categories were equally likely to become invasive) are at the top, and those with the fewest are at the bottom. There is no significant difference in frequency of invasiveness among categories (overall χ^2 16.87 for 12 d.f., p=0.1544). Categories with high individual χ^2 values depart from the expected number of invasive species if species in all categories were equally likely to become invasive.

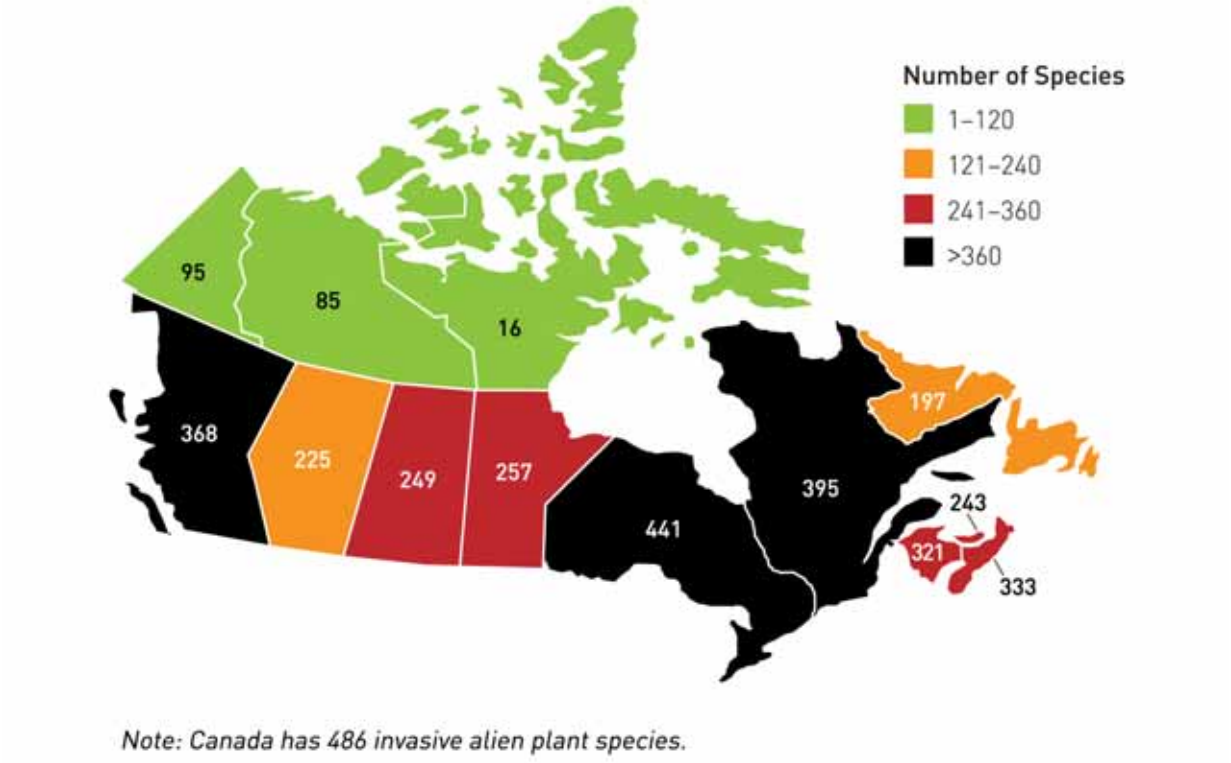
The numbers of invasive plant species are shown by province or territory in Figure 1 and Table 5, and by ecozone in Figure 2. The provinces with the highest numbers of invasive plant species are Ontario, with 441; Quebec, with 395; and British Columbia, with 368. The lowest numbers are in Nunavut, with 16 species. It should be noted that these species are not necessarily invasive or weedy everywhere that they are found in Canada. However, for the purpose of compiling the distributions, species were counted as invasive if they were recorded as such anywhere in Canada. Several of the Nunavut species are recorded only from Akimiski Island in James Bay (Blaney and Kotanen 2001), which falls in the Hudson Plains ecozone and is politically part of Nunavut, although geographically disjunct from it.

Based on the 162 species with Canadian distribution maps, the ecozones most heavily colonized by invasive plant species are the Mixedwood Plains, Atlantic Maritime, and Pacific Maritime (Figure 2). The Prairie, Montane Cordillera, and Boreal Shield also have relatively high numbers of invasives. Very few invasive plant species are recorded from the Northern Arctic, Taiga Cordillera, and Arctic Cordillera ecozones. The few records from these ecozones are generally of species listed as invasive because of their status in other ecozones, rather than because they are known problems in Arctic areas. The limited number of alien or invasive plant species in Arctic areas reflects the climatic limitations on establishment of alien species in these areas as well as the low levels of trade with potential source areas. Comparing Figure 2 with the climatic match information in Figure 5, it can be seen that ecozones with more extensive areas of good climate matching elsewhere in the world also tend to have higher numbers of invasive plant species.

2.4 Areas of Origin

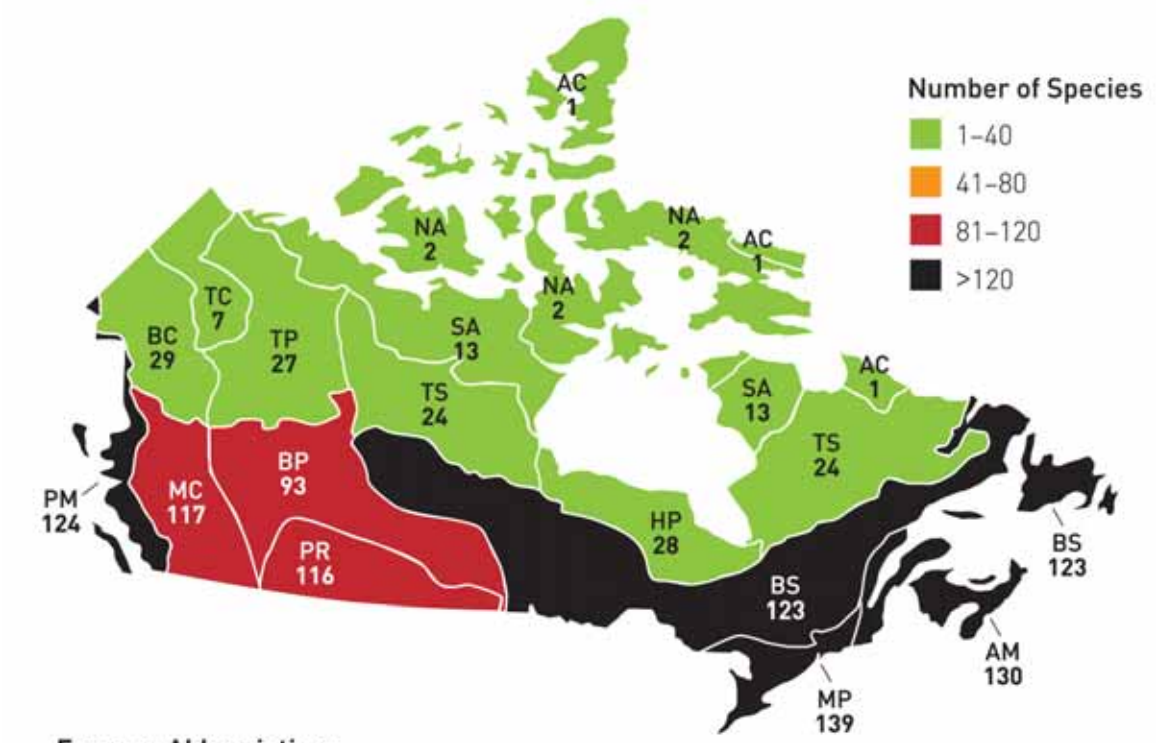
More than 80% of invasive plant species in Canada originate from the West Palaearctic region (Figure 3). This undoubtedly reflects past patterns of colonization from, and trade with, Western Europe, as well as climatic suitability. The second largest group is species from the East Palaearctic, primarily China and Japan. Many species cannot be assigned definitely to a single region of origin because the literature sources cite their origin simply as "Eurasia." Some of these species have been assigned to more than one category. There is a relatively

Figure 1. Numbers of invasive plant species by province and territory.



Note: Canada has 486 invasive alien plant species.

Figure 2. Numbers of invasive plant species by ecozone, based on the 162 species for which distribution maps were available.

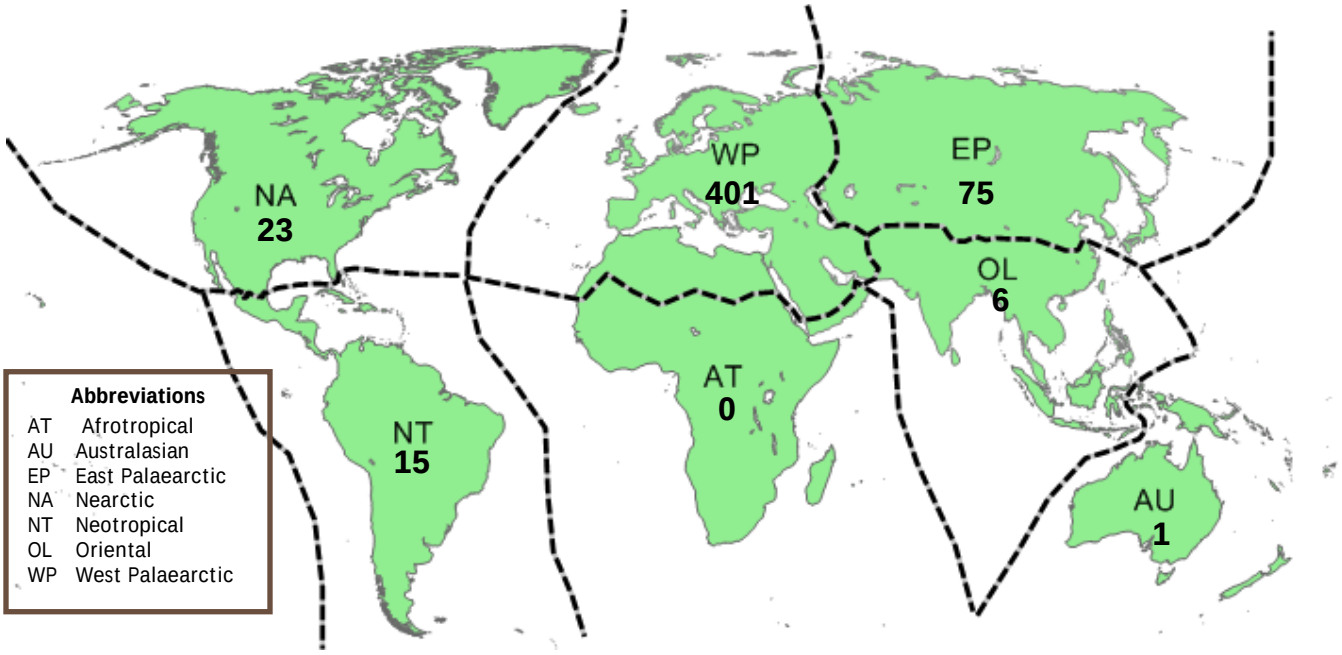


small group of Nearctic species considered to be aliens in Canada; this may reflect some difficulty in distinguishing Nearctic species that are actually native to Canada from those that have been introduced from the United States by human activities. There are a few species introduced from the Neotropics, and few or none that can be definitely traced to the Australasian or Afrotropical regions.

2.5 Pathways of Introduction

Information on pathways of introduction and dates of entry to Canada is not well documented, and it was often necessary to assume that the original pathways of entry to Canada were the same as those to the United States. As the early settlement history and trade patterns of eastern Canada were broadly similar to those of the eastern United States, this assumption seems reasonable. In some cases it is possible that species arrived by one pathway in the United States, such as ballast soil, and were then spread to Canada by another (such as seed contamination or natural spread), although information is not readily available on this type of dispersal.

Figure 3. Areas of origin of alien plant species introduced into Canada, based on Udvardy (1975), Olson and Dinerstein (2002), and Morse (2006).



Of the 245 invasive plant species for which some information on pathways could be inferred, it is estimated that 141 were introduced intentionally (e.g., as agronomic crops, landscape plants, ornamentals, or medicinal plants), while 120 were introduced unintentionally (e.g., through movement of weed seeds in imported soil or crop seeds) (Figure 4).

About 58% of the invasive plant species in Canada are the result of deliberate introductions.

The total adds to more than 245 because multiple modes of introduction were suggested for several species. This means that about 58% of the invasive plant species in Canada are the result of deliberate introductions. This is consistent with, although somewhat lower than, rates reported from several other countries and areas where European colonization has been a major factor affecting the flora. In various regions of the United States, the percentage of alien plants that were deliberately introduced ranges from 57% to 67% (Mack and Erneberg 2002). In Australia, escaped garden plants alone make up 70% of the combined agricultural, noxious and natural ecosystem weeds (Groves et al. 2005), while an additional 60 species introduced as pasture or forage plants became invasive or weedy (Lonsdale 1994; Paynter et al. 2003). Examples of some invasive plant species believed to have been introduced by various pathways are shown in Table 5.

2.6 Role of Climate

Matching of climates between source and recipient areas is a way of predicting potential invasive plants risks (Richardson and Thuiller 2007). The Climex® program (Sutherst et al. 2004) was used to identify areas of the world matching the climates of each Canadian ecozone, as a guide to potential source areas from which invasive plant species might be likely to establish in Canada. Climex uses a database of climate information for 2,218 locations around the world. For most of the Canadian ecozones, one to seven representative locations in that ecozone were selected as "home" locations; there were, however, no representative locations available for the Arctic Cordillera, Southern Arctic, and Taiga Cordillera.

Figure 4. Suspected pathways of introduction for invasive alien plants in Canada.

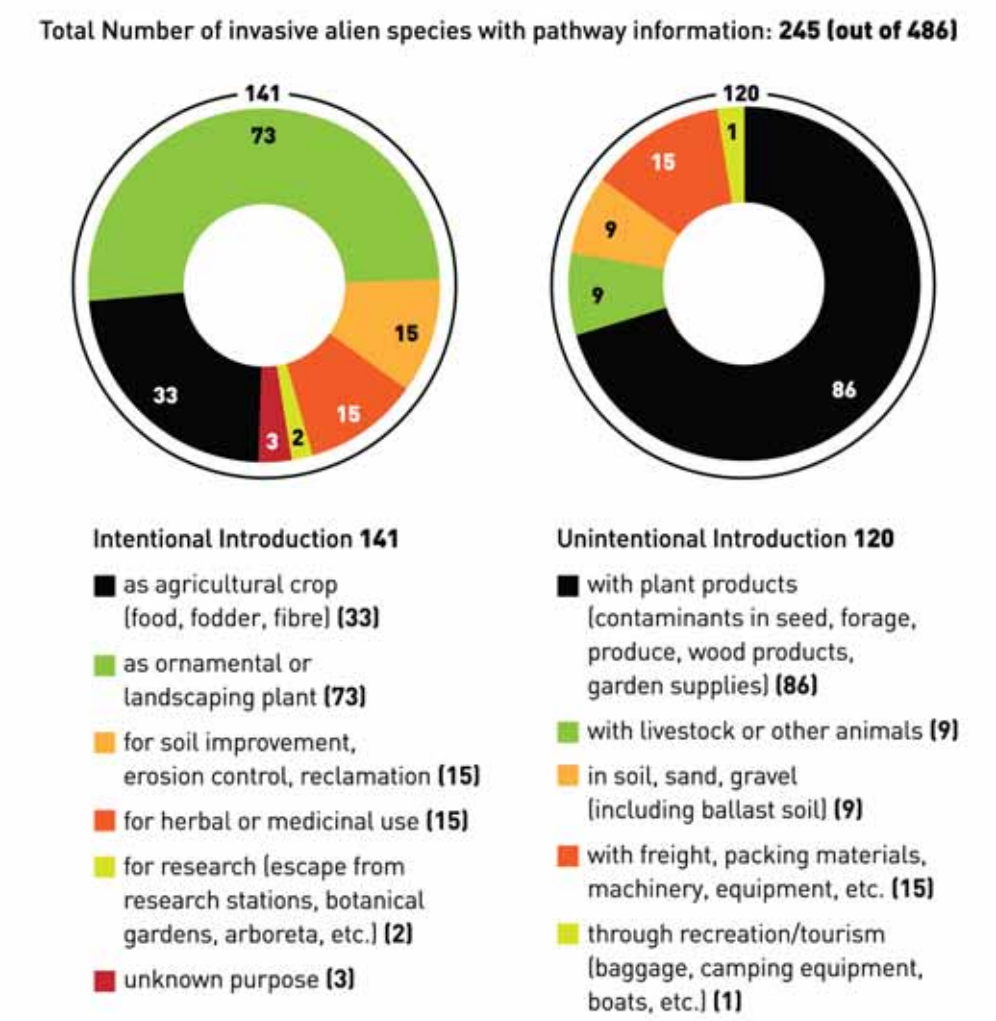


Figure 5 indicates areas of the world that are potential sources of invasive alien plants on the basis of climatic matching. This analysis gives only a very broad indication of potential source areas for invasive plants, as climate is only one factor influencing the ability of introduced plants to establish — and species can often establish in areas that do not exactly match the climate of their native range. It is reasonable to assume, however, that introduced species are more likely to establish in areas that match the climates to which they are adapted.

2.7 Influence of Trade Patterns

International trade can be an important source of new invasive species (Levine and D'Antonio 2003). Trade data for 2001 to 2005 from Industry Canada's Trade Data Online website (strategis.ic.gc.ca/sc_mrkti/tdst/engdoc/tr_homep.html) were used to examine imports to Canada of materials that might have the potential to introduce invasive plants. These included: live animals; live plants, including cut flowers and ornamental foliage; edible vegetables and roots; edible fruits and nuts; seeds, fruits, and spores for sowing; cereal straw and husks; hay, fodder, and forages; vegetable plaiting material such as rattan; and wood products.

An average $8.44 billion worth of these products were imported into Canada each year during the period 2001–2005. As can be seen in Figure 6, the United States is by far the largest source, representing 67% of the total value of imports over the five-year period. Central and South America and the Caribbean together form the second major source, with 16.1% of the total value, while Western Europe was the source of 6.2% of the total.

Table 5. Suspected pathways of introduction for selected invasive alien plant species in Canada.

As crops or forages	As ornamentals or landscaping plants	For herbal or medicinal use	Accidentally introduced as seed contaminants etc.
Anethum graveolens	*Acer ginnala*	*Alliaria petiolata*	*Acroptilon repens*
Armoracia rusticana	*Aesculus hippocastanum*	*Artemisia absinthium*	*Agrostemma githago*
Asparagus officinalis	*Ailanthus altissima*	*Berberis vulgaris*	*Amaranthus albus*
Avena sativa	*Ajuga reptans*	*Cannabis sativa*	*Amaranthus retroflexus*
Bromus inermis	*Alnus glutinosa*	*Carum carvi*	*Anthoxanthum odoratum*
Bromus tectorum	*Berberis thunbergii*	*Hesperis matronalis*	*Artemisia vulgaris*
Cannabis sativa	*Betula pendula*	*Hippophae rhamnoides*	*Avena fatua*
Cichorium intybus	*Buddleja davidii*	*Hyssopus officinalis*	*Barbarea vulgaris*
Dactylis glomerata	*Butomus umbellatus*	*Inula helenium*	*Berteroa incana*
Fagopyrum esculentum	*Clematis tangutica*	*Linum usitatissimum*	*Bromus secalinus*
Fagopyrum tataricum	*Crataegus monogyna*	*Rosa eglanteria*	*Capsella bursa-pastoris*
Holcus lanatus	*Cynanchum rossicum*	*Saponaria officinalis*	*Cardaria draba*
Hordeum vulgare	*Daphne mezereum*	*Solanum dulcamara*	*Carduus acanthoides*
Isatis tinctoria	*Digitalis purpurea*	*Tanacetum vulgare*	*Carex acutiformis*
Lespedeza cuneata	*Dipsacus fullonum*	*Trifolium pratense*	*Centaurea diffusa*
Melilotus albus	*Elaeagnus angustifolia*		*Chenopodium album*
Melilotus officinalis	*Euonymus alata*		*Cirsium arvense*
Morus alba	*Fallopia japonica*		*Convolvulus arvensis*
Nepeta cataria	*Frangula alnus*		*Crepis tectorum*
	Galium mollugo		*Cynoglossum officinale*
	Glechoma hederacea		*Descurainia sophia*
	Gypsophila paniculata		*Elymus repens*
	Hemerocallis fulva		*Erucastrum gallicum*
	Heracleum mantegazzianum		*Euphorbia esula*
	Hesperis matronalis		*Fallopia convolvulus*
	Impatiens glandulifera		*Galinsoga parviflora*
	Iris pseudacorus		*Lamium amplexicaule*
	Ligustrum vulgare		*Lappula squarrosa*
	Linaria dalmatica		*Leucanthemum vulgare*
	Lonicera tatarica		*Lolium perenne*
	Miscanthus sinensis		*Lotus corniculatus*
	Pachysandra terminalis		*Malva rotundifolia*
	Rhamnus cathartica		*Neslia paniculata*
	Robinia pseudoacacia		*Plantago lanceolata*
	Rosa multiflora		*Ranunculus acris*
	Syringa vulgaris		*Raphanus raphanistrum*
	Ulex europaeus		*Senecio vulgaris*
	Viburnum lantana		*Setaria italica*
	Vinca major		*Silene latifolia*
			Sisymbrium officinale
			Sonchus arvensis
			Sorghum halepense
			Stellaria media
			Thlaspi arvense
			Tripleurospermum perforata

There were substantial changes in source areas over this five-year period. Most notably, imports from east Asia (including China, Japan, Korea, and Mongolia) rose rapidly, from $197 million in 2001 to $556 million in 2005 — a 182% increase. By 2005, imports from East Asia had overtaken those from Western Europe. Although they form a very small proportion of the total, imports from Eastern Europe, Russia, and Central Asia also increased substantially, from $37 million in 2001 to $96 million in 2005. Over the same time period, imports from the United States, Western Europe, the Middle East, Southeast Asia, and Africa remained more or less steady, while those from Oceania and Australasia declined.

The present picture of imports into Canada is very different from the make-up of the alien invasive plant flora. Western Europe is much more strongly represented in the alien plant flora than in current imports of material that might bring in invasive plants, while North America and other regions are greatly under-represented. Clearly, the composition of the alien plant flora in Canada represents past rather than current trade patterns. This suggests that future introduction of alien and potentially invasive plants into Canada may be more likely to occur from source areas other than Western Europe.

The climatic analysis in Figure 5 and the data in Figure 6 suggest that East Asia and southern South America are potential source areas for invasive plant introductions, since they are climatically matched with areas of Canada that import large volumes of material that could contain invasive plants.

It should be remembered that Canada's largest and closest trading partner is the United States, and therefore many potential invasive plants may arrive in Canada from there rather than directly from the plants' source areas. According to Kartesz (1999), there are 2,039 alien species in the continental United States that do not occur in Canada. Of these, 615 occur in the states bordering Canada or the Great Lakes. These species probably represent a greater risk to Canada than species directly introduced by trade from more distant areas — for two reasons. First, these species have been "pre-selected" for their ability to survive in climatic and environmental conditions similar to those of Canada. Secondly, many of these species will have multiplied in the field so that their propagule pressure (Rouget and Richardson 2003) is much higher than it was at the time of their initial introduction.

As can be seen in Figure 7, by far the largest destination for imports of materials with potential for invasive plant introduction was Ontario, with Quebec and British Columbia approximately equal in second place. Imports of these materials into all other provinces are considerably lower. The relative levels of imports into provinces did not change in a major way over the five-year period.

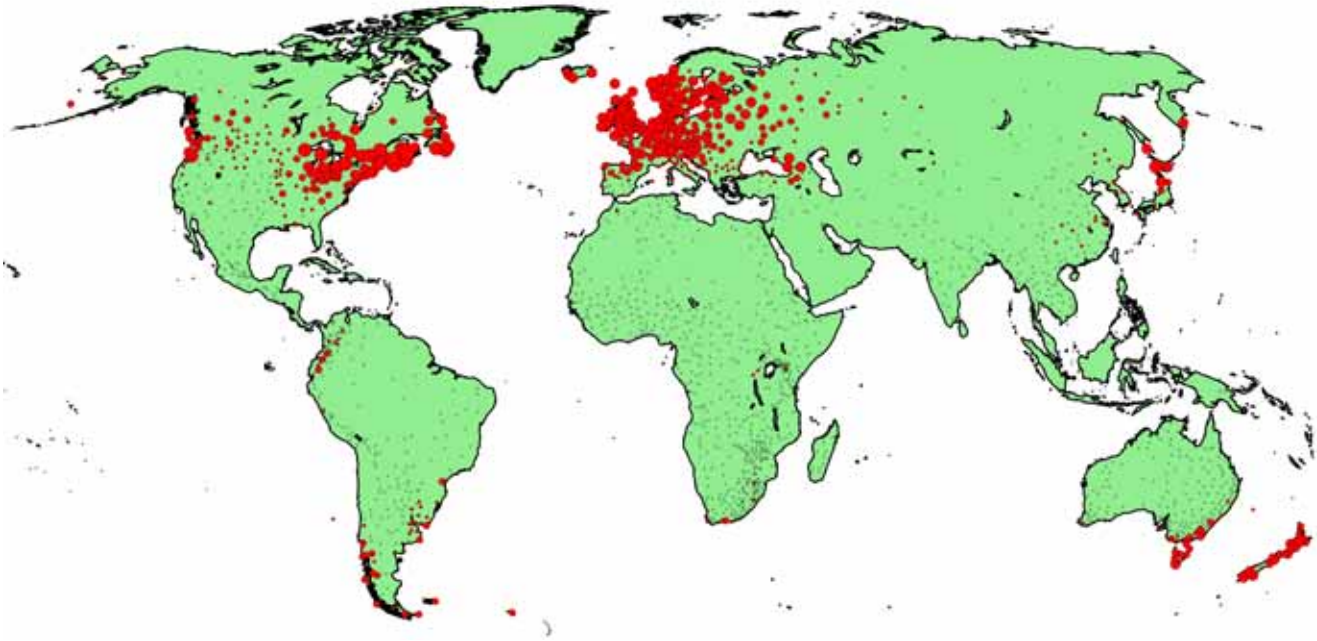
2.8 Trends in Numbers

The alien and invasive plant flora of Canada has established over a period of approximately 400 years, if it is assumed that introductions of alien plants began with the settlements of Samuel de Champlain in 1605 and 1608. It is possible that some plant species were introduced by earlier European visitors such as the Vikings (Chapman et al. 1974; Byrne and McAndrews 1975; Jacobson et al. 1988) or by Aboriginal peoples during the first settlement of North America beginning around 12,000 years ago; however, such introductions were probably very few. Thus, on average, over the last 400 years the Canadian flora has acquired about 3.0 alien plant species per year, of which about 1.2 species per year have become invasive.

There is relatively little historical information on the dates of entry of invasive plant species into Canada. Information was compiled on the estimated first dates when the 486 invasive species entered or were first recorded in Canada from several sources — in particular, the Biology of Canadian Weeds articles (1972–), Mack and Erneberg (2002), Mack (2003), postings on *Botanical Electronic News* (1997 onwards), and a database produced by Dr. Erich Haber for WWF Canada as part of the material used for the Nature Audit project (World Wildlife Fund Canada 2003). If information specific to Canada could not be found, the date when the species was first recorded in North America was used. Estimated dates were obtained for 285 species, and the cumulative number of these species recorded over time is shown in Figure 8.

Figure 5. Regions of the world showing levels of climate matching each Canadian ecozone based on the CLIMEX® modelling system.

Atlantic Maritime



Boreal Cordillera

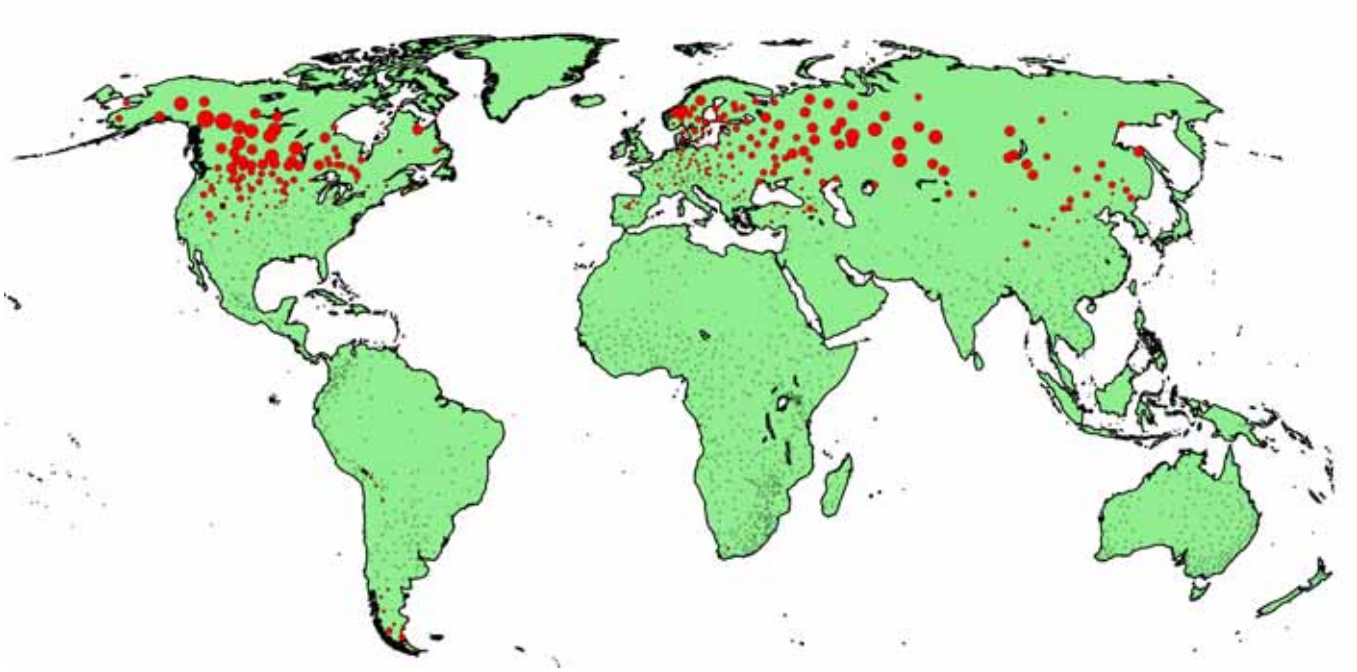


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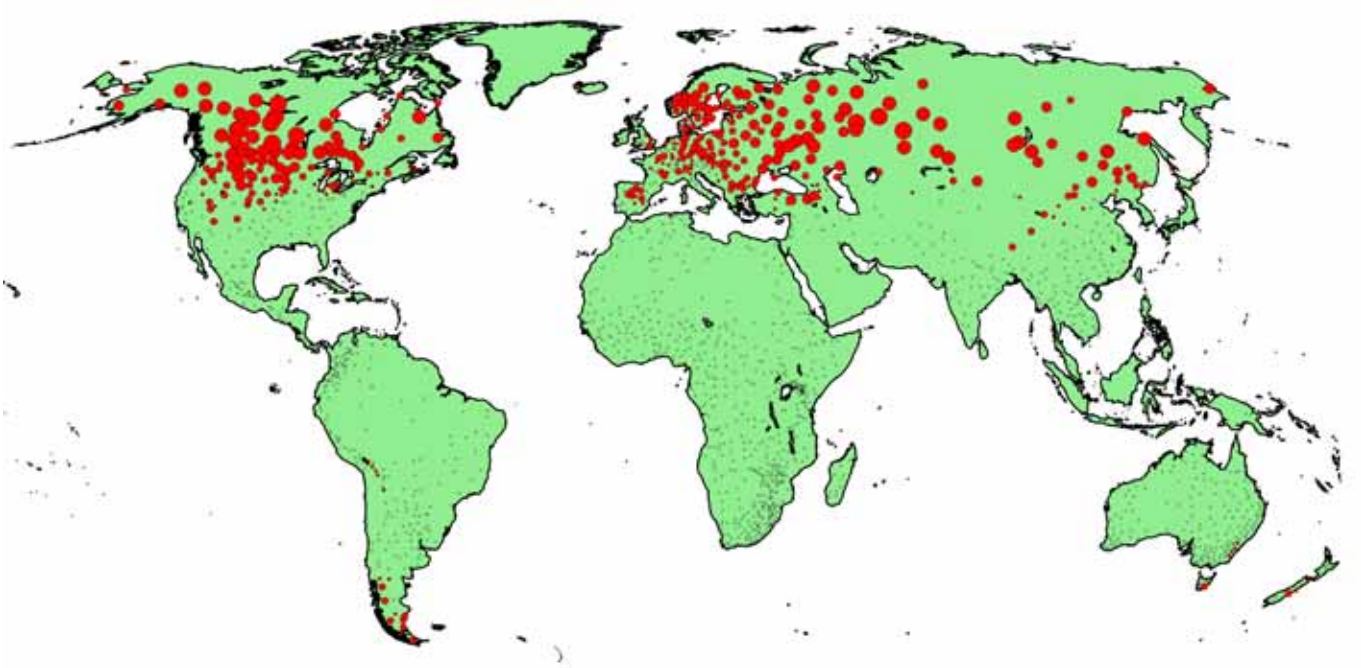
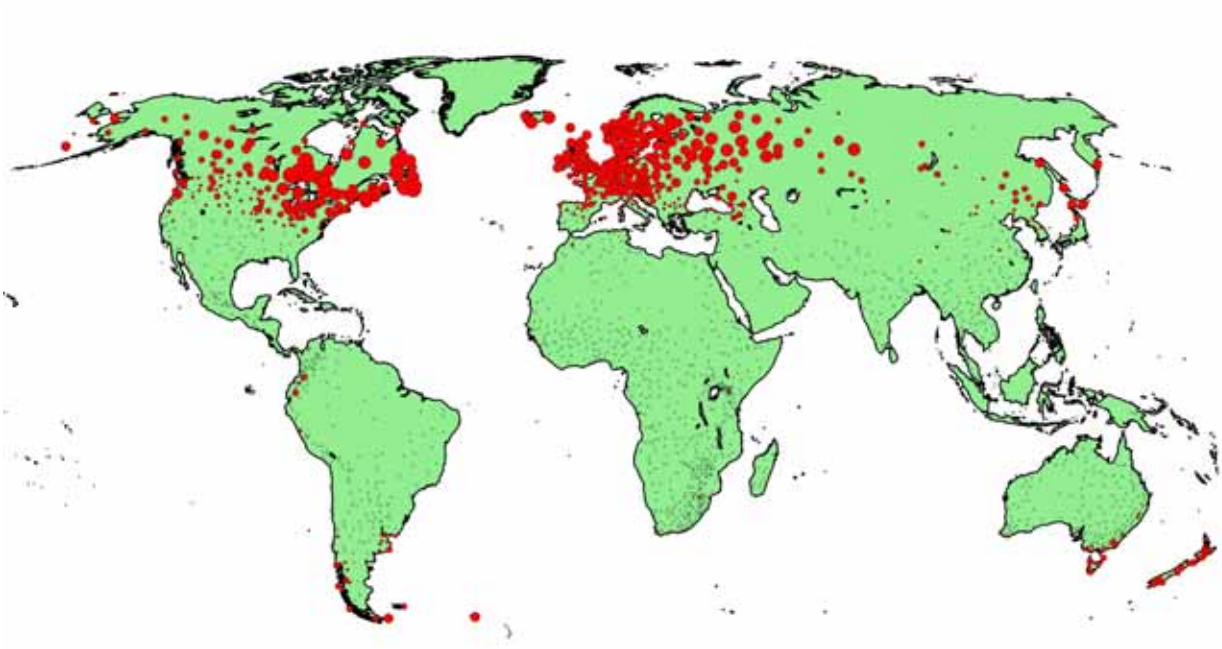
Figure 5, continued.

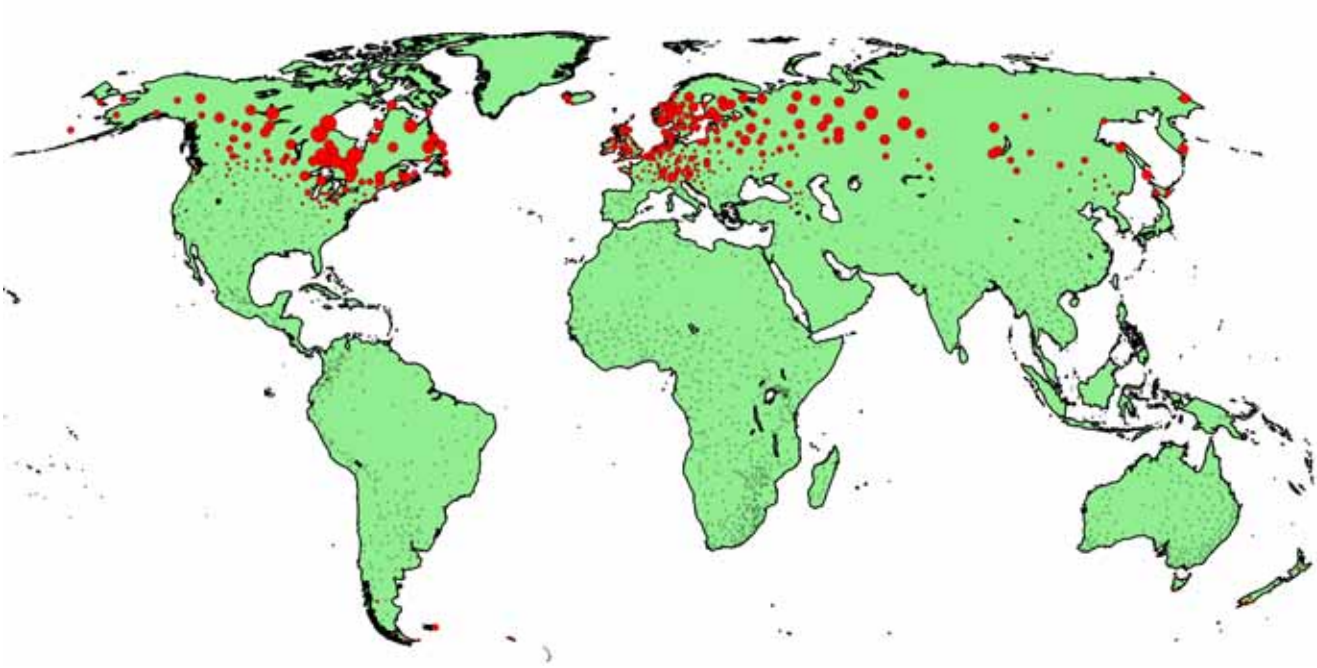
Boreal Plains



Boreal Shield



Hudson Plains



Mixedwood Plains

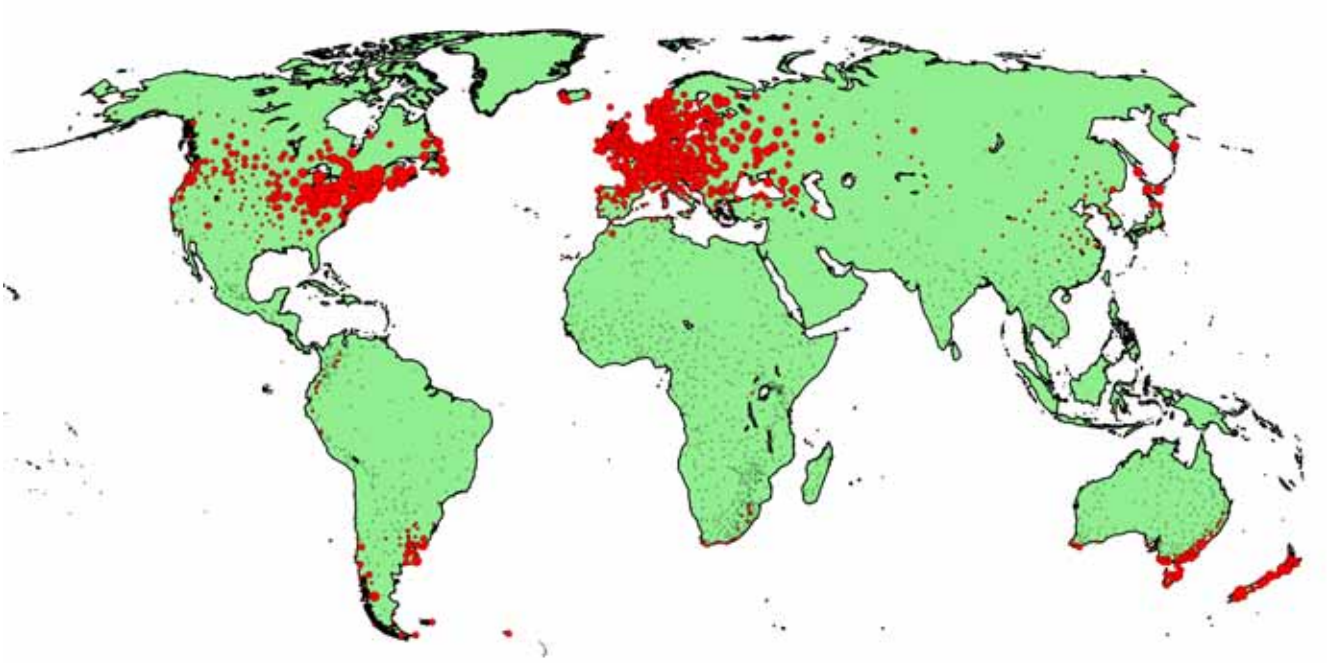


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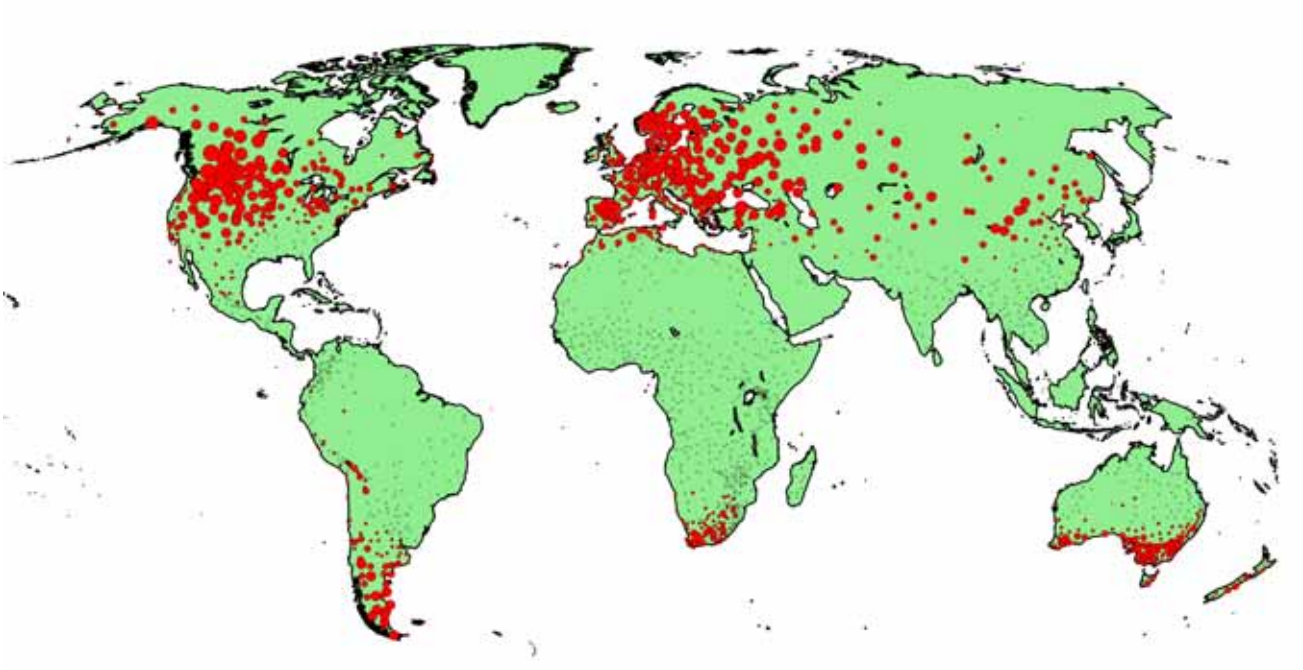
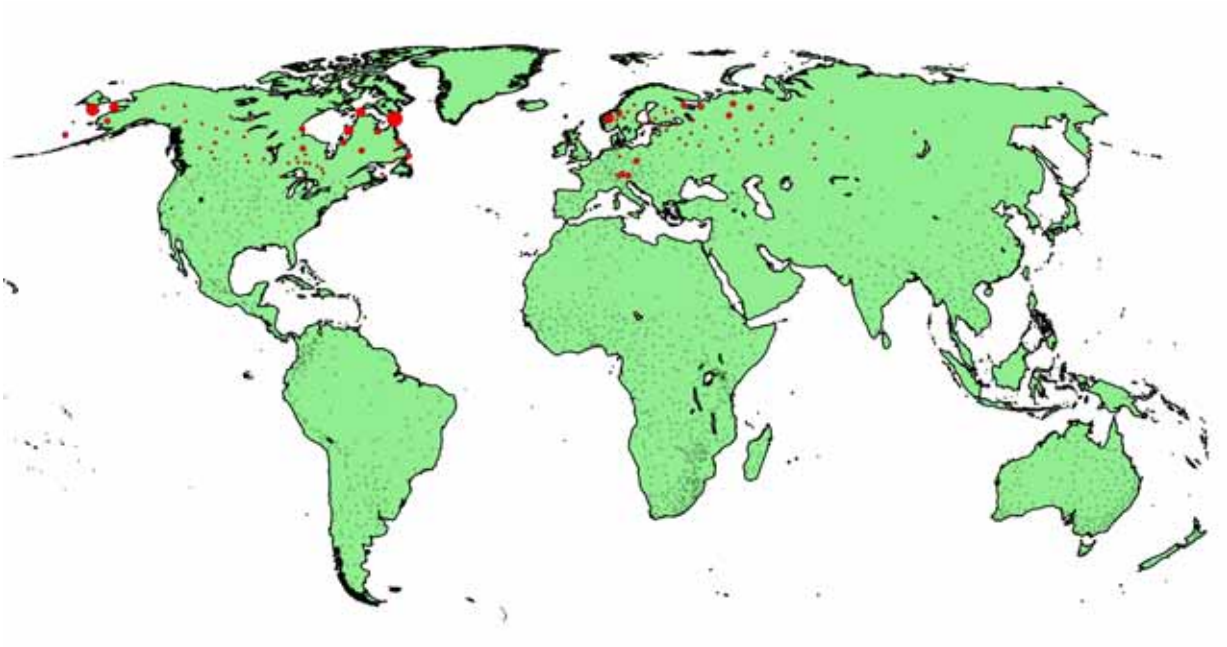
Figure 5, continued.

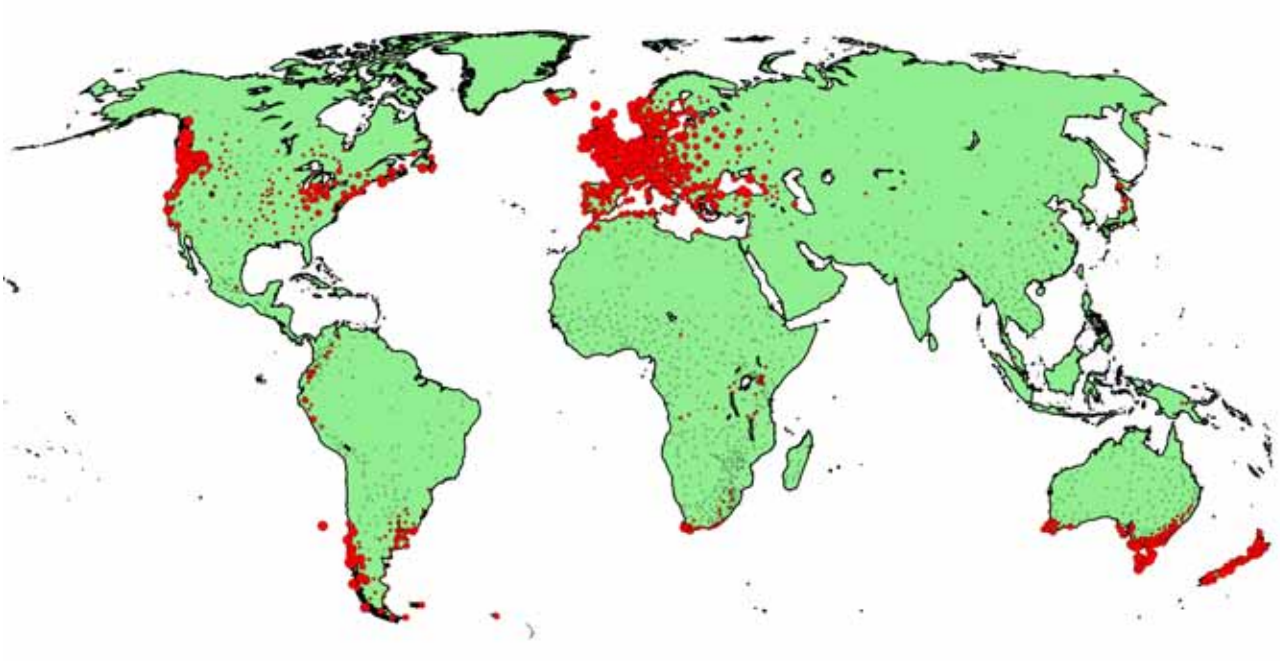
Montane Cordillera



Northern Arctic



Pacific Maritime



Prairies

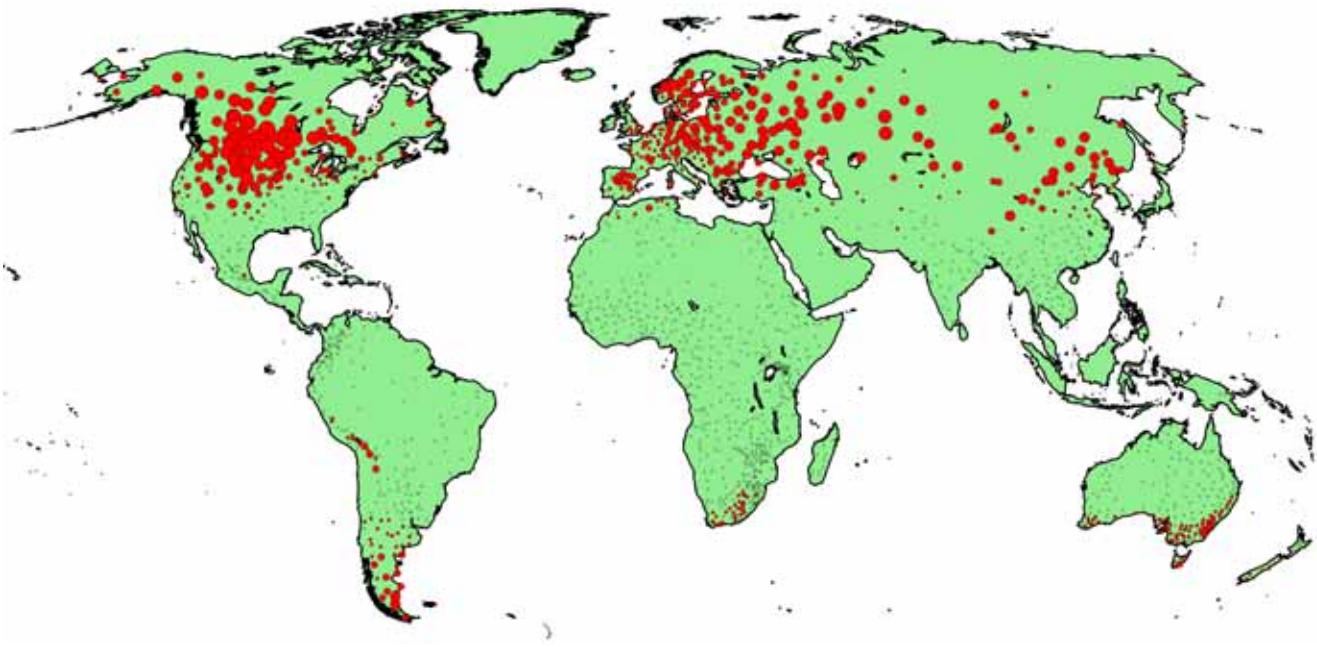


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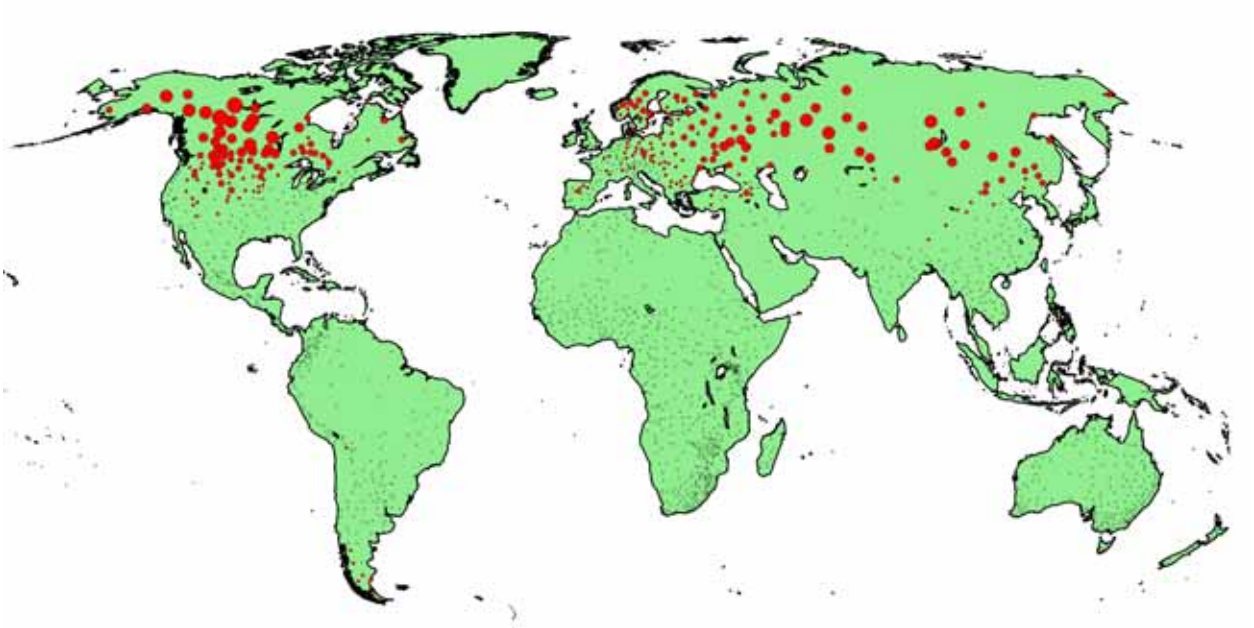
Figure 5, continued

Taiga Plains



Taiga Shield

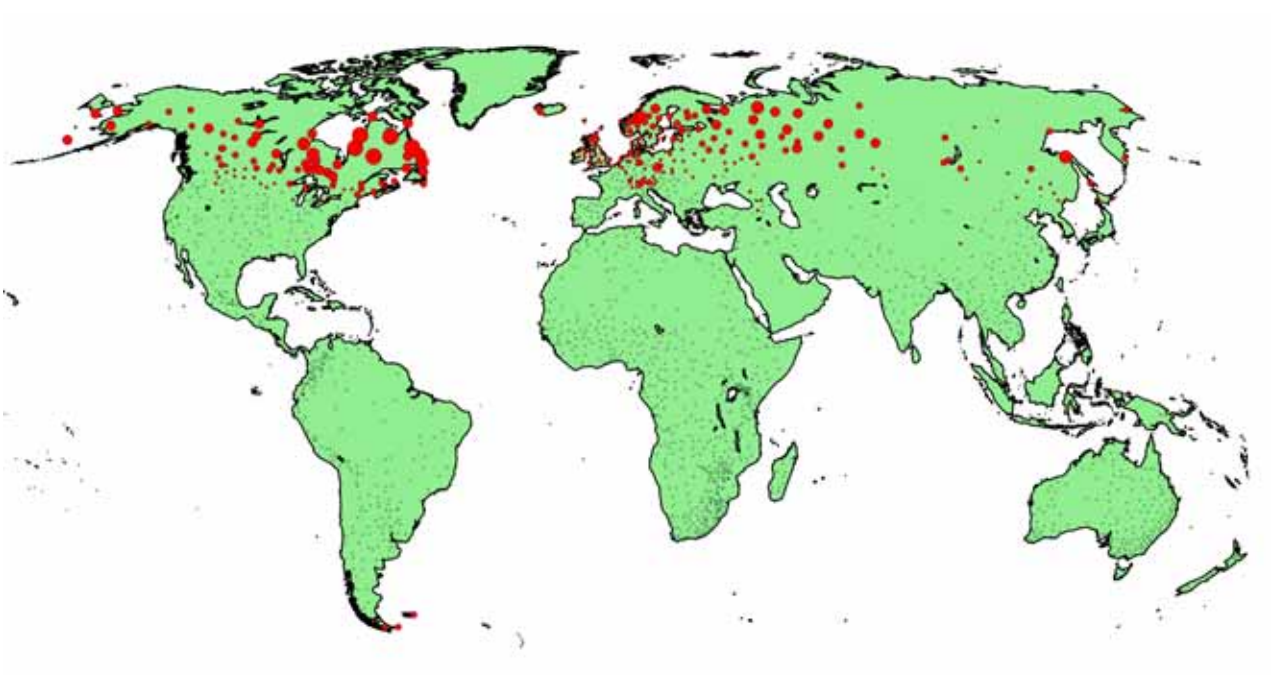
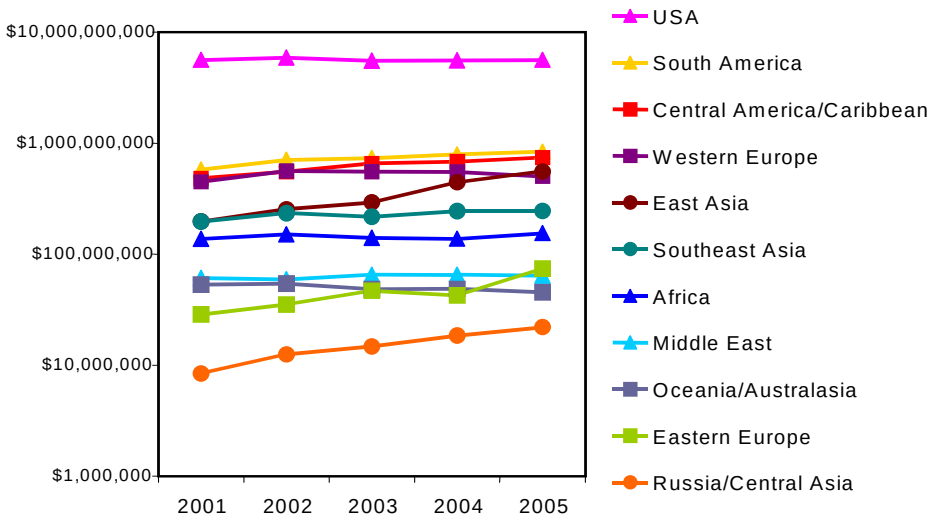


Figure 6. Value of imports of materials with potential for introduction of invasive plant species to Canada by source regions for 2001-2005.

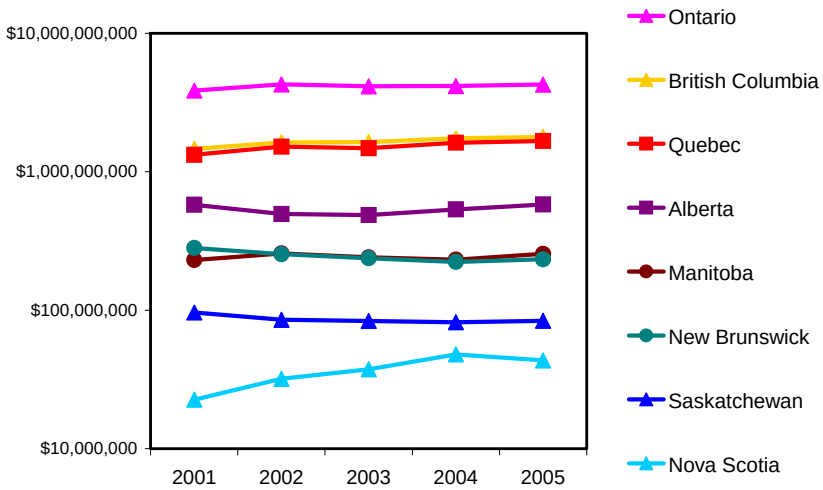


Value of imports is plotted on a logarithmic scale.

Although there are many uncertainties associated with the data for Figure 8, it appears to show three phases:

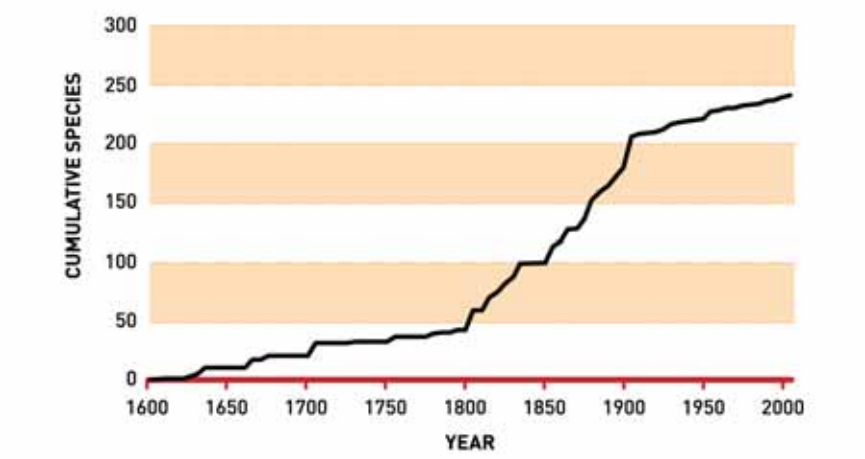
- A period of relatively slow accumulation of new invasive species, from about 1600 to 1800.
- A period of more rapid accumulation from about 1800 to 1900. This probably reflects both the increased pace of trade, immigration, and colonization during this period, as well as the beginning of more detailed botanical study and documentation of the flora. Many plant species first recorded during this period were probably introduced earlier, so the apparent increase in the rate of introductions from around 1800 is probably to some extent artificial. A similar analysis for South Africa (Wilson et al. 2007), however, also shows an increase in the rate of introductions in the early 19th century.

Figure 7. Value of imports of material with potential for introduction of invasive plant species, according to their destinations in Canada, 2001-2005.



Value of imports is plotted on a logarithmic scale. Only jurisdictions with more than $10 million in annual imports are included.

Figure 8. Cumulative number of invasive alien plant species in Canada from 1605 to 2005 for which dates of introduction can be estimated.



- A period of slower, linear accumulation occurred from 1900 onwards. By this time, the flora of Canada and the U.S. were relatively well known, so this increase most likely reflects new introductions over this period, as well as, to some extent, the results of more detailed taxonomic studies revealing previously unrecognized species. The slowing in the rate of new invasions probably also reflects increasing regulatory control over the importation of material that might be contaminated with alien plant seeds.

From 1905 to 2005 the total number of invasive species for which dates are available rose from 251 to 285, an increase of about 0.34 species per year. As dates of introduction were obtained for 59% of the invasive species on the list, and assuming that these species are representative, it is estimated that during the 20th century the rate of establishment of new invasive plant species in Canada was about 0.58 species per year. This suggests that the current rate of new establishment is about half the historical average of 1.2 new invasive species per year. An obvious explanation is that many species from the pool of those likely to be introduced became established early on. A study of alien species in North American vascular flora by Palmer (2005) found that the proportion of alien species in 1,410 flora published between 1875 and 2004 increased only slightly over that time. This again suggests that many aliens became established before the late 19th century.

Some invasive plant species believed to have become established in Canada since 1900 are listed in Table 6. This list was compared with the plants that were considered by questionnaire respondents as new or emerging weed problems (Table 7). Many of these species have been present in Canada for decades or centuries, but are still expanding their ranges or increasing in numbers, so that at a local level they can represent new problems. This shows that a plant does not have to be a new incursion into Canada in order to represent a new invasive plant problem, and that for those involved in managing invasive plants, the largest source of new problems is the spread of species already present in Canada.

There are a number of processes involved in the escape, establishment, and spread of alien species that can lead to prolonged lags between introduction and the development of major impacts (Crooks 2005). Wilson et al. (2007) found that residence time in South Africa had a significant positive effect on the range of invasive plant species. In contrast, Carpenter and Cappuccino (2005), in a study in the Ottawa area, found that there was a slight tendency for more recently introduced plant species to be ranked as more invasive, as measured by the frequency of listing on government invasive species websites. They suggested that the more recently introduced plant species may contain a higher proportion of species introduced for landscaping or erosion control, which might be more likely to become invasive.

Table 6. Examples of invasive alien plant species first recorded in Canada since 1900.

Scientific name	Common name	Date of introduction	
Carduus acanthoides	spiny plumeless thistle		1907
Ulex europaeus	common gorse	Approx.	1915
Phragmites australis subsp. *australis*	common reed	Before	1920
Erucastrum gallicum	common dog mustard	Before	1922
Berteroa incana	hoary alyssum		1925
Coronilla varia	purple crown-vetch		1925
Crataegus monogyna	one-seeded hawthorn	Approx.	1925
Cardaria pubescens	globe-podded hoarycress	Before	1926
Agropyron cristatum	crested wheat grass	Before	1930
Hydrocharis morsus-ranae	European frog's bit		1932
Centaurea diffusa	white knapweed	Before	1936
Ammophila arenaria	European beach grass		1947
Elaeagnus umbellata	autumn olive	Approx.	1950
Euonymus alata	winged euonymus	Before	1950
Hippophae rhamnoides	sea buckthorn	Approx.	1950
Lonicera morrowii	Morrow's honeysuckle	Approx.	1950
Odontites vernus	red bartsia	After	1950
Rubus discolor	Himalayan blackberry	Approx.	1950
Sorghum halepense	Johnson grass	Approx.	1959
Myriophyllum spicatum	Eurasian water milfoil	Before	1961
Heracleum mantegazzianum	giant hogweed		1964
Fallopia × *bohemica*	Bohemian knotweed	Before	1971
Lonicera japonica	Japanese honeysuckle		1974
Apera spica-venti	silky bent grass	Approx.	1975
Chondrilla juncea	rush skeletonweed		1983
Carex acutiformis	lesser pond sedge		1987
Taraxacum palustre	marsh dandelion	Before	1989
Cabomba caroliniana	fanwort		1991
Sonchus palustris	marsh sow-thistle		1993
Soliva sessilis	carpet burweed		1996
Trapa natans	water chestnut		1998
Hieracium glomeratum	hawkweed	Before	2001
Spartina anglica	English cord grass	Before	2003

Table 7. Examples of weed or invasive plant species reported by questionnaire respondents as new or emerging concerns.

Invasive plant species reported in questionnaire as new or emerging problems		Province/territory where reported	Date species first recorded in Canada (or North America)
Abutilon theophrasti	velvetleaf	New Brunswick	Before 1860
Alliaria petiolata	garlic mustard	British Columbia, Ontario	Before 1879
Angelica sylvestris	angelica	New Brunswick	
Artemisia absinthium	wormwood	New Brunswick	Before 1860
Berteroa incana	hoary alyssum	British Columbia, Saskatchewan	1925
Bromus inermis	smooth brome	Alberta	1875
Bromus japonicus	Japanese brome	Manitoba	
Bromus tectorum	downy brome	Manitoba	Before 1886
Carum carvi	wild caraway	Alberta	
Celastrus orbiculatus	oriental bittersweet	Ontario	1875 (NA)
Centaurea diffusa	diffuse knapweed	Manitoba	Before 1936
Cirsium palustre	marsh plume thistle	British Columbia	
Cirsium vulgare	bull thistle	Alberta	Before 1832 (NA)
Cynanchum rossicum	European swallow-wort	Ontario	Approx. 1880
Digitaria ischaemum	smooth crabgrass	New Brunswick	
Echium vulgare	common viper's bugloss	Alberta	Before 1862
Eriochloa villosa	woolly cupgrass	Quebec	
Euphorbia esula	leafy spurge	Manitoba	Before 1889
Fallopia japonica	Japanese knotweed	British Columbia	1901
Fallopia sachalinensis	giant knotweed	British Columbia	
Galium aparine	cleavers	Manitoba, New Brunswick, Quebec	
Galium mollugo	smooth bedstraw	Quebec, New Brunswick	1873
Heracleum mantegazzianum	giant hogweed	Ontario	1964
Hieracium aurantiacum	orange hawkweed	British Columbia, Alberta	Approx. 1875
Hieracium pilosella	mouse-ear hawkweed	British Columbia	Before 1902 (NA)
Hieracium spp.	yellow hawkweed	British Columbia	
Hippophae rhamnoides	sea buckthorn	Manitoba	Approx. 1950
Hypericum perforatum	St. John's wort	Manitoba	Approx. 1725
Knautia arvensis	field scabious	British Columbia, Saskatchewan	
Lactuca serriola	prickly lettuce	Saskatchewan	Before 1891
Leucanthemum vulgare	oxeye daisy	British Columbia, Yukon	Before 1900
Linaria vulgaris	yellow toadflax	Alberta	Before 1820
Lythrum salicaria	purple loosestrife	Manitoba	Before 1814
Melilotus alba	white sweet clover	Yukon	Before 1850
Myriophyllum spicatum	Eurasian watermilfoil	Quebec	Before 1961
Odontites vernus	red bartsia	Manitoba	After 1950
Pastinaca sativa	wild parsnip	Saskatchewan	Approx. 1850
Persicaria wallichii	Himalayan knotweed	British Columbia	
Prunus padus	European bird cherry	Yukon	
Silene csereii	biennial campion	Manitoba	
Silene vulgaris	bladder campion	Manitoba	
Soliva sessilis	carpet burweed	British Columbia	1996
Sonchus arvensis	perennial sowthistle	New Brunswick	Approx. 1890
Sorbus aucuparia	European mountain ash	Alberta	
Stachys palustris	marsh hedgenettle	New Brunswick	
Trapa natans	water chestnut	Quebec	1998
Tripleurospermum perforata	scentless chamomile	British Columbia, Manitoba	Before 1872

3 Impacts of Invasive Alien Plants

3.1 Economic Impacts

Invasive alien plant species can cause enormous economic damage over a broad range of economic sectors. The most obvious economic impacts are direct, quantifiable costs such as losses in potential economic output or costs of control. Additional costs related to indirect effects or less tangible values such as ecosystem services (e.g., water purification, soil stability, carbon sequestration) are more difficult to quantify. Worldwide, few studies have attempted to quantify the economic impacts of invasive alien plant species, and in Canada there are fewer still. In this section, we explore the economic sectors potentially affected by invasive alien plant species and describe the current state of knowledge of their economic impacts in Canada.

A preliminary breakdown of the range of effects of invasive plants on economic activity was made by recording the economic sectors in Canada affected by each invasive alien plant species (Table 8). Classification was difficult from sources that indicated species' presence in habitats representing various economic sectors without specifying economic impact. Regardless, the analysis reflects the level of attention given to assessing the economic effects of invasive plants in different sectors. There is extensive, accessible literature on the impacts of invasive plants in agriculture (e.g., crop and animal production), whereas less attention has been paid to their effects in other sectors (e.g., mining and transportation).

Crop and animal production are the sectors most directly affected by invasive plants, and for which impacts are best known. In many areas the range and abundance of cropland weeds is known from surveys, while impacts have been estimated through experimental studies on weed-crop competition. Examples of economic costs of invasive plants on crop production are yield losses and herbicide costs. Invasive plants can also endanger the health of livestock, reduce weight gains in livestock, and reduce carrying capacity of rangelands. Examples of significant invasive agricultural weeds in Canada include Canada thistle (*Cirsium arvense*), oxeye daisy (*Leucanthemum vulgare*), leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea stoebe*), quackgrass (*Elytrigia repens*), wild oats (*Avena fatua*), and green foxtail (*Setaria viridis*).

Of the few invasive plant species listed as forest invaders, even fewer are actually reported as having economic impacts on the forest industry. No vascular plants were among the non-indigenous species identified as threatening Canada's forest economy by Allen and Humble (2002). Similarly, of 13 "key competitor species" identified by Thompson and Pitt (2003) as problems in forest vegetation management in Canada, only Scotch broom (*Cytisus scoparius*) and gorse (*Ulex europaeus*) are aliens. The profile of invasive plant species in Canada's forests may rise in the future with increasing development in the boreal forest. Vegetation management in forest

Table 8. Numbers of invasive alien plant species affecting various economic sectors in Canada.

Economic sector		Number of invasive plant species
CP	Crop Production	173
AP	Animal Production	210
FL	Forestry and Logging	16
HT	Hunting, Fishing and Trapping	9
MO	Mining and Oil and Gas Extraction	0
UT	Utilities	10
CO	Construction	78
TR	Transportation	78
AE	Arts, Entertainment and Recreation	162
PH	Private Households	169
PA	Public Administration	281

Economic sectors are based on the North American Industry Classification Standard (Statistics Canada, 2003).

regeneration is a major concern, and while most competing species are native, alien species are increasing and spreading, as found in surveys by Alberta Sustainable Resource Development (see 5.1.1, below). Silvicultural operations such as clear-cutting, site preparing, planting single species, and tending provide opportunities for the establishment of alien species, mostly in the herbaceous layer (Bell and Newmaster 2002). In addition to hampering forest regeneration, invasive plants — particularly grasses — may increase fire risk to forests (Chornesky et al. 2005).

The few invasive alien plants recorded as affecting the hunting, fishing, and trapping sector are all aquatic. These plants have probable, though unquantified, effects on freshwater fisheries. Invasive plants affecting mining, utilities, construction, and transportation are probably also under-reported. In northern Alberta, oil and gas wells and pipelines are often foci of invasive plant species. All of these sectors have major involvement with vegetation management and land reclamation that frequently involve invasive species, but there is little information on this in the literature.

Within the arts, entertainment and recreation sector, heritage sites such as conservation areas experience the effects of invasive species. In addition to their ecological effects, invasive plants can have an economic effect by reducing the attractiveness and utilization of such areas, as well as in increasing their management costs (Eiswerth and van Kooten 2002). Impacts of invasive plants in home gardens and grounds are included in the private households sector. A large number of weeds are recorded under the public administration sector due to the many ways in which public bodies are involved with invasive plant issues: as managers of parks, highways, military bases, and conservation areas; and as enforcers of weed and invasive plant legislation.

In addition to their effects on various economic sectors in Canada, invasive alien plant species can have a profound indirect effect on domestic and international trade. Seed commodities that contain prohibited weed seeds listed on the *Weed Seeds Order*, 2005 (laws.justice.gc.ca/en/S-8/SOR-2005-220/220485.html) of Canada's *Seeds Act* cannot be sold in Canada nor imported into Canada as seed for planting. The presence and quantity of primary or secondary noxious weed seeds, as defined by the *Weed Seeds Order*, can also lead to downgrading and lowered market value of seed lots. Similarly, Canada cannot export seed for planting or other regulated commodities, such as grains, that are contaminated with weed seeds considered to be quarantine pests by the destination country.

Quantification of the economic impacts of invasive alien species in Canada has been attempted only very recently, and these estimates include collective losses due to insects and pathogens as well as plants. At best, estimates are crude due to the variety of economic impacts that invasive alien species can have, as well as the incomplete and fragmented nature of the information available to describe them. Most authors consider their estimates to be conservative. Dawson (2002) provided one of the first estimates of economic losses due to invasive species in Canada. Losses were calculated based on a U.S. study by Pimentel et al. (1999) and by substituting Canadian dollar values for plant resources. From an overall agriculture and forestry land base producing $86 billion worth of plant products, annual losses to these sectors alone were estimated at $7.3 billion.

Additional reports have calculated the economic costs incurred by Canada due to invasive species where such information is available. A report by RNT Consulting Inc. (2002), for instance, estimated annual economic costs for only nine invasive alien species in Canada to be $22 million. A more recent study commissioned by the Office of the Auditor General of Canada estimated the economic costs of 11 invasive alien species — to fisheries, agriculture, and forestry resources — at $187 million per year (Colautti et al. 2006). The same authors made a second estimate, using an empirical model that projected percentage impacts of 16 invasive alien species on resources at risk. This estimate, termed an "invisible tax" on natural resources, was much higher, and ranged from $13.3 to $34.5 billion per year, depending on the percentage impact used to determine the economic loss. While these figures will likely undergo further refinement in the future, it is already clear from these studies that invasive alien species have an enormous detrimental impact on the Canadian economy.

Economic impacts specifically due to invasive alien plants represent a significant portion of the figures presented above. Of the $7.3 billion in losses to agriculture and forestry estimated by Dawson (2002), $2.2 billion, or 30% of those losses, are due to weeds alone, and the remainder is due to insects and pathogens. The $2.2 billion in losses is attributed to damage by ($1.3 billion) and control of ($0.3 billion) weeds in crops, as well as damage by ($0.1 billion) and control of ($0.5 billion) weeds in pastures. These losses occur on an agricultural

land base that produces $15 billion worth of plant products annually (Dawson 2002). Estimated losses attributed to damage by and control of weeds in crops appear to be conservative in light of a second study by Leeson et al. (2006), who estimated the economic impact of invasive alien weeds on wheat, barley and canola production in the Prairie provinces alone to be over $1 billion per year due to herbicide product costs, application costs and yield losses.

It is estimated that invasive alien plants cost the Canadian agricultural community approximately $2.2 billion each year.

Although the establishment and spread of invasive alien plants in Canada result in adverse economic impacts, few additional sources directly quantify those impacts (RNT Consulting Inc. 2002). The reports by RNT Consulting Inc. (2002) and Colautti et al. (2006) highlight the economic costs attributed to specific invasive alien species, including a limited number of invasive plants for which information is available. Canada thistle (*Cirsium arvense*), which, despite its common name is native to Europe and temperate Asia, is estimated to cause $3.6 million in wheat losses in Saskatchewan per year, and $320 million in canola yield losses and treatment costs in the Prairies per year (RNT Consulting Inc. 2002) (Table 9). This aggressive weed has the potential to reduce crop yields by 100% (Royer and Dickinson 1999) and make pastures unfit for grazing. Leafy spurge (*Euphorbia esula*), also native to Europe and temperate Asia, causes an estimated $19 million per year in economic impacts to grazing land, public land, and right of ways in Manitoba alone, where it infests 340,000 acres of land (Zehtab-Jadid and Landry 2003). Cattle will avoid grazing on pastures with more than 10% coverage of leafy spurge, which is poisonous to most livestock (RNT Consulting Inc. 2002). The studies by RNT Consulting Inc. (2002) and Colautti et al. (2006) also reported economic costs from knapweeds (*Centaurea* spp.) and purple loosestrife (*Lythrum salicaria*) (Table 9).

A comprehensive, nationwide estimate of the economic impacts of invasive alien plants, and of invasive alien species in general, is needed in Canada. In the United States, two studies have attempted to estimate these costs on the national level. In the first study, economic losses due to 79 alien species between 1906 and 1991 were estimated to be about US$96.9 billion (Office of Technology Assessment (OTA) 1993). In the second study (Pimentel et al. 2000, 2001), economic losses due to all alien species in the U.S. were estimated at US$137 billion per year, of which almost US$35 billion, or 25%, was due to invasive alien plants. The authors also estimated a collective loss of over US$314 billion due to alien species for the United States, United Kingdom, Australia, South Africa, India, and Brazil. One of the major obstacles to evaluating these impacts for Canada, as elsewhere, is the severe lack of quantitative data (Colautti et al. 2006). Moreover, most studies consider direct costs associated with marketable goods or services and fail to address additional, indirect, and/or non-market costs and values of invasive species (Colautti et al. 2006). Development in both these areas, including progress toward an accepted means of valuation of non-market goods and services, will serve to improve estimates in the future.

Table 9. Economic impacts of invasive alien plants. Based on RNT Consulting (2002) and Colautti et al. (2006) and references therein.

Species	Location	Impacted area	Estimated Annual Costs ($ millions)
Canada thistle	SK	Wheat production	$3.6
	Prairies	Canola production	$320
leafy spurge	MB	Reduced yields, recreation revenues, control costs	$19
	MB	Reduced land values	$30*
	AB, SK	Reduced yields, recreation revenues, control costs	$19
	AB, SK	Reduced land values	$30*
spotted knapweed	BC	Hay production	$0.4
	BC	Grazing livestock	$0.079
knapweeds	Western Canada		$58
purple loosestrife	AB	Control costs	$0.02
	SK	Eradication project	$0.1
	ON	Biological control program	$0.09

*one-time cost

3.2 Environmental Impacts

Non-native plant invasion is considered to be a major threat to natural habitats (Randall 1996). Invasive alien plant species can impact many aspects of ecosystem diversity, structure, and function. They can compete with and, in some cases, displace native plant species, potentially changing the floristic composition of an ecosystem and endangering species of concern. Hybridization with related species can alter and degrade native gene pools. In terms of structure, thick stands of invasive plants can add or remove one or more canopy layers of a natural ecosystem, changing the dynamic in which wildlife, insects, and micro-organisms use those layers and, ultimately, reducing habitat for wildlife. Functional changes may also occur in ecosystems as a result of invasive plants, in terms of primary productivity and nutrient cycling, hydrology, erosion, and fire regimes (Keenleyside et al. 2006). Many of these environmental impacts also have potential economic consequences, and many fall under the category of non-market values.

Stronen (2002) reviewed the effects of invasive alien species on species at risk in Canada and identified four insect species (butterflies), one reptile, two amphibians, two birds, and 35 vascular plants for which invasive plant species appeared to be factors in their at-risk status (Table 10). The invasive plant species that have been implicated in negatively affecting one or more at-risk species are given in Table 11. A second report, The Nature Audit (WWF 2003), compiled a list of 150 invasive alien species, of which 92 are vascular plants, with known or suspected impacts on native biodiversity in Canada.

Invasive plants are responsible for the decline of at least 44 species at risk, and threaten numerous habitats and ecosystems in Canada.

However, high densities of invasive plants do not always impact the densities of rare native species. Henderson's checker-mallow (*Sidalcea hendersonii*) — a rare native species growing in tidal marshes in British Columbia — competes with invading purple loosestrife (*Lythrum salicaria*) as well as with native species, and is able to persist in the invaded habitat because of small differences in habitat preferences and phenology (Myers et al. 2004).

Table 10. Species at risk in Canada for which invasive plants were cited as possible risk factors (Stronen 2002).

Amphibians	Vascular Plants	
northern leopard frog	American ginseng	red mulberry
Oregon spotted frog	American Hart's-tongue fern	sand verbena
	bashful bulrush	seaside birds-foot lotus
Birds	bear's-foot sanicle	slender mouse-ear-cress
mountain plover	bearded owl-clover	small white lady's slipper
sage thrasher	bird's-foot violet	smooth goosefoot
	deltoid balsamroot	swamp rose-mallow
Invertebrates	dense blazing star	Van Brunt's Jacob's-ladder
Behr's hairstreak	drooping trillium	water-plantain buttercup
dun skipper	eastern prairie white-fringed orchid	western blue flag
island blue	false rue-anemone	western silver-leaf aster
Taylor's checkerspot	golden paintbrush	western spiderwort
	hairy prairie-clover	white-top aster
Reptiles	hoary mountain-mint	white wood aster
northern prairie skink	Lyall's mariposa lily	wild hyacinth
	Macoun's meadowfoam	wood poppy
	pink milkwort	yellow montane violet
	prairie lupine	

Table 11. Invasive alien plant species of primary concern to one or more species designated nationally at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Stronen 2002).

Invasive Alien Plant Species	Potentially Threatened		
	Species	Habitats	Ecosystems
Grasses			
barren brome	bear's-foot sanicle		Garry oak meadow
bristly dog's tail grass	deltoid balsamroot, water-plantain buttercup, white-top aster		Garry oak meadow
common reed		freshwater, brackish and alkaline wetlands	
crested wheatgrass	slender mouse-ear-cress		Prairie
early hairgrass	bearded-owl clover, deltoid balsamroot, Macoun's meadowfoam, prairie lupine, white-top aster		Garry oak meadow
orchard grass			Garry oak meadow
reed canarygrass	eastern prairie white-fringed orchid	wetlands	
smooth brome			Prairie
sweet vernal grass	bear's-foot sanicle, deltoid balsamroot, Macoun's meadowfoam, prairie lupine, yellow montane violet		Garry oak meadow
timothy	Van Brunt's Jacob's ladder	fields, grasslands, roadsides, aspen and conifer stands	
Herbs			
bishop's goutweed	false-rue anemone	roadsides and waste places	
Canada thistle		agricultural lands, western prairie and rangeland areas	
celandine	American Hart's-tongue fern	rich, damp soils	
common buttercup	Van Brunt's Jacob's-ladder	fields, meadow, disturbed areas	
creeping bellflower		moist, shady locations	
dalmation toadflax		rangelands, dry forests, roadsides	
filago	Lyall's mariposa lily	overgrazed lands, roadsides and waste places in steppe and montane habitats	
garlic mustard	American ginseng, drooping trillium, hoary mountain-mint, white wood aster	open deciduous woodland, gardens, forest edges, roadsides	
hound's-tongue	Lyall's mariposa lily	roadsides, meadows, forest rangelands	
leafy spurge			Prairie
mullein	Lyall's mariposa lily		
prickly lettuce	Lyall's mariposa lily		
purple loosestrife		wetlands	
Russian thistle		roadsides, agricultural fields	

Continued on next page

Table 11, continued.

Invasive Alien Plant Species	Potentially Threatened		
	Species	Habitats	Ecosystems
Herbs (continued)			
spotted knapweed		grasslands, rangelands	
St John's wort		rangelands, pastoral areas	
subterranean clover	Macoun's meadowfoam		
sweet clovers (yellow and white)		meadows, roadsides, agricultural areas	Prairie ecosystems
tall blazing star	dense blazing star		
Shrubs			
common gorse	bearded-owl clover, golden paintbrush		Garry oak meadow
glossy buckthorn		wetlands	
Himalayan blackberry	golden paintbrush		Garry oak meadow ecosystem
honeysuckles	bashful bulrush, hoary mountain-mint		
Scotch broom	bearded owl-clover, deltoid balsamroot, Taylor's checkerspot		Garry oak meadow
Trees			
black locust	pink milkwort	dry and sand prairies, oak savannahs, upland forest edges	
Norway maple	wild hyacinth	forest habitats	
Russian olive		streams, fields, open areas	
Scotch pine		old fields, roadsides, open bogs and woods	
white mulberry	red mulberry	fence rows, forest edges, waste areas	

Most invasive alien plant species that are capable of forming dense monocultures or thickets can potentially alter community structure. Glossy buckthorn (*Rhamnus frangula*), for instance, can rapidly form dense, even-aged thickets that create a continuous canopy and shade the undergrowth (White et al. 1993; Stronen 2002). Himalayan blackberry (*Rubus discolor*), a threat to the endangered Garry oak meadow ecosystem in British Columbia, forms thickets so dense that they become impenetrable and unusable to humans and many wildlife species.

Crested wheatgrass (*Agropyron cristatum*) is just one example of the many invasive plant species that can potentially alter ecosystem functioning. This species has been considered responsible for reducing the carbon-sequestering capacity of Prairie grasslands due to a lower root-shoot ratio than that of native grasses (Christian and Wilson 1999). It is suggested that replacement of native grasses by crested wheatgrass has caused the release into the atmosphere of approximately 4×10^8 tonnes of carbon that would have otherwise been stored in the soil, implying a possible role for this species in global climate change (Christian and Wilson 1999; McClay et al. 2004). Another species, garlic mustard (*Alliaria petiolata*), impacts ecosystem functioning in a different way. This species spreads under forest canopies, and has recently been discovered to disrupt beneficial mutualisms between native hardwood trees and mycorrhizal fungi, thereby impairing their growth, survival, and recruitment (Stinson et al. 2006).

The complexity and variety of environmental impacts caused by invasive plants make their valuation more difficult than the direct economic impacts on traditionally marketed commodities such as agricultural crops and

forest products. However, the natural environment is clearly important to Canadians. Residents spent $11.0 billion on nature-related activities in 1996, and U.S. tourists spent an additional $705 million on wildlife viewing and recreational fishing alone in the same year (Gray et al. 2003). Large expenditures are made in Canada's national, provincial, and territorial parks — to the amount of $3.6 billion in 2000, a figure that represents a combination of direct spending by park agencies and visitors (Canadian Parks Council 2006). Invasive alien plant species have the potential to endanger the value of Canada's protected areas by compromising their natural integrity and diminishing their quality (Keenleyside et al. 2006).

3.3 Social Impacts

Social impacts of invasive plants include a diverse group of effects such as human health problems (allergies, dermatitis, etc.); interference with traditional lifestyles; reduction or loss of tourism, employment, aesthetic values, property values; and enjoyment of natural areas in general. Few studies from Canada have focused on social impacts of invasive plants. Like environmental impacts, social impacts of invasive alien plants are often linked to economic impacts that are difficult to quantify.

Only two questionnaire respondents in our survey indicated that they had assessed social impacts. Common ragweed (*Ambrosia artemisiifolia*) is a medically important allergenic plant that is sometimes considered an alien in Canada, although in this study it is treated as a native species spread outside its range. There has been extensive research in Quebec on methods of managing common ragweed, including the use of competing vegetation (Massicotte et al. 2001; DiTommaso and Massicotte 2002), biological control with insects and fungi (Teshler et al. 2002), and salt treatment (Watson 2003). Giant hogweed (*Heracleum mantegazzianum*), secondly, is an escaped garden ornamental that can cause serious skin inflammation due to ultraviolet photo-activation of furanocoumarins present in the sap. This species is established and spreading in southern British Columbia and Ontario (Page et al. 2006), and was reported as an emerging problem by several questionnaire respondents.

Giant hogweed (*Heracleum mantegazzianum*)
Donna Ellis, University of Connecticut, www.bugwood.org

Carpet burweed (*Soliva sessilis*) is another good example of an invasive alien plant species with social consequences. Native to South America, carpet burweed has become a serious nuisance weed on Vancouver Island and the Gulf Islands since its discovery in 1996 (Castro 2006). Despite its diminutive size, this species has spiny seeds that cause physical discomfort when stepped on, resulting in reduced enjoyment of parks, beaches, sports fields, and golf courses. It also forms unsightly brown patches in summer, reducing the aesthetic value of parks and golf courses.

Social impacts of invasive plant species in Canada are rarely quantified, although economic cost estimates of leafy spurge included impacts on recreation values and property values (see Table 9). More often, descriptions of social impacts are qualitative. Overall, developments in the analysis of both social and environmental impacts of invasive alien plant species will contribute to better understanding of the consequences of the introduction and establishment of these species (IPPC 2007).

4 International Agreements and Domestic Legislation

An Invasive Alien Species Strategy for Canada (2004) recognizes the use and enforcement of regulatory measures as important tools for managing the movement of invasive alien species both within and from outside Canada. This section broadly highlights, first, the principal international instruments guiding Canada's actions for addressing invasive plants and, second, the principal domestic legislative instruments that minimize or have the potential to minimize the risk of invasive plants to the economy, environment, and society. It is beyond the scope of this report to include a comprehensive legal review and analysis of all legislation relevant to invasive plants.

Since authority in Canada for addressing invasive plants is not restricted to one level of government, aspects of both federal and provincial legislation are highlighted. Although not covered in this section, it is noteworthy that local governments and First Nation bands also possess such authority. In fact, in some jurisdictions a complex regulatory landscape results from the interface between local government by-laws and the provincial weed control act (see Lewis 2006).

4.1 International

The two most important international agreements regarding invasive plants are the *International Plant Protection Convention* (IPPC) and the *Convention on Biological Diversity* (CBD). The IPPC relates to plant health, and seeks to secure action to prevent the introduction and spread of pests of plants and plant products and to promote appropriate measures for their control. The CBD promotes the conservation of biological diversity, the sustainable use of its components, and the equitable sharing of the benefits arising out of the utilization of genetic resources.

The IPPC, governed by the Commission on Phytosanitary Measures, came into force in April 1952. As of February 5, 2008, there were 166 parties to the IPPC; Canada signed and ratified the agreement in 1951 and 1953, respectively. Through the Commission on Phytosanitary Measures, contracting parties to the IPPC adopt International Standards for Phytosanitary Measures (ISPMs), which are the standards, guidelines, and recommendations recognized as the basis for phytosanitary measures to be applied by Members of the World Trade Organization under the Agreement on the Application of Sanitary and Phytosanitary Measures.

The term "pest" is integral to the structure of the IPPC. ISPM No. 5 (Glossary of phytosanitary terms) defines "pest" as "[a]ny species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products." The determination of the regulatory status of pests, and in particular of their quarantine significance, is largely influenced by their potential economic importance. The focus of the IPPC is broader, however, than the commercial aspects of plant health, applying to the protection of wild flora and as such contributing to the conservation of biological diversity (ISPM No. 5 and 11).

The CBD shares similarities with the IPPC in that regard. Coming into force in December 1993, the CBD has 190 parties as of February 5, 2008. Canada signed and ratified this agreement in 1992. The CBD stresses the importance of anticipating, preventing, and attacking the causes of significant reduction or loss of biological diversity at source. Of particular importance, Article 8(h) of the CBD states: "Each Contracting Party shall, as far as possible and as appropriate, [p]revent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." The CBD is thus very much relevant to its adhering parties' actions to address the risk of invasive plants.

As illustrated above, the IPPC and the CBD present similarities in their respective mandates (Lopian 2003). In light of the overlap between these two agreements, efforts to enhance collaboration have resulted in the signing of a Memorandum of Cooperation between the Food and Agriculture Organization of the United Nations and the Secretariat of the CBD. The stated purpose of this Memorandum is to encourage cooperation with a view of promoting synergy, avoiding overlaps and unnecessary duplication, and ensuring effective cooperation in joint activities. Together, the IPPC and the CBD provide strong incentive for its adhering parties to address the risk of invasive plants.

Canada thistle (*Cirsium arvense*)
Mary Ellen (Mel) Harte, www.bugwood.org

4.2 Federal

A number of federal legislative instruments, administered by various departments, have the potential for providing tools to address invasive plants, and thus contribute to meeting Canada's international obligations arising from the conventions noted above. A few noteworthy examples are provided below.

The *Plant Protection Act* (S.C. 1990, c. 22) is one of the more important federal legislative tools with the potential for addressing invasive plants. Its purpose is to protect plant life and the agricultural and forestry sectors of the Canadian economy by preventing the importation, exportation and spread of pests and by controlling or eradicating pests in Canada. The *Plant Protection Act*'s definition of "pest" includes plants as pests within its scope, although traditionally invasive plants have not been comprehensively addressed in its application. The *Plant Protection Act*'s effectiveness for addressing invasive plants will become clearer with enhanced policy development on the topic of invasive plants, and with its increased use in that regard.

The *Seeds Act* (R.S.C., 1985, c. S-8) is also a tool for addressing invasive plants. This Act relates to the testing, inspection, quality, and sale of seeds. Enacted under the authority of the *Seeds Act*, the *Weed Seeds Order, 2005* (SOR/2005-220) designates a number of species as weed seeds, including prohibited noxious weed seeds. One of the standards applying to seed is that it shall not contain prohibited noxious weed seeds. Part V of the *Seeds Regulations* (SOR/96-252) may also address certain invasive plants. With some exceptions, notification and evaluation of the potential impact on and risk to the environment are required before a person can undertake either the confined or unconfined release of seed.

The *Wild Animal and Plant Protection and Regulation of International and Inter-provincial Trade Act and Regulations* (S.C. 1992, c. 52, WAPPRIITA) has the legislative potential to prevent the importation of invasive plants into Canada or the inter-provincial transportation of such plants. Although the definition of "plant" in WAPPRIITA relates to plants listed as "flora" in an appendix to the *Convention on International Trade in Endangered Species of Wild Fauna and Flora*, WAPPRIITA provides the possibility for this definition to be amended either by regulation or by order. The definition may be amended by regulation to protect certain species or the environment of a province

into which a plant is to be transported, while an order may be made to amend the definition for a specified timeframe if the import of a specimen would be harmful to Canadian ecosystems or to any species in Canada and that urgent action was necessary. In fact, the *Wild Animal and Plant Trade Regulations* (SOR/96-263) prescribe at the present different definitions of "plant" for different purposes.

The *Canada National Parks Act* (S.C. 2000, c. 32) provides guidance in the management of parks, which may include the necessity to address invasive plants that threaten their ecological integrity. In that regard, the Act requires maintenance or restoration of ecological integrity to be the first priority when considering all aspects of the management of parks. In relation to a park, ecological integrity refers to a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes.

The *Species at Risk Act* (S.C. 2002, c. 29) is also a notworthy instrument, in particular if an invasive plant threatens the survival of a listed wildlife species. For listed extirpated, endangered or threatened species a recovery strategy must be prepared. If recovery of a species is deemed feasible its recovery strategy must address the threats to its survival, including the identification of those threats and threats to its habitat in addition to a description of the broad strategy to be taken to address those threats. One or more action plans must then be prepared based on the recovery strategy which would include a statement of the measures to be taken to address the threats to the species.

In addition to the above, other instruments are relevant, either directly or indirectly, to invasive plants, including, for example, the *Canadian Environmental Protection Act, 1999* (S.C. 1999, c. 33), the *Indian Act* (R.S.C. 1985, c. I-5), the *Pest Control Products Act* (S.C. 2002, c. 28) and the *Customs Act* (R.S.C. 1985, c. 1 (2nd Supp.)).

4.3 Provincial

An instrument found in most provinces for dealing with invasive plants is a weed act. The establishment of the weed acts was primarily to control weeds that have the potential of impacting agricultural land use or crop values, but their use has not been so restricted (White et al. 1993). The provisions of most provincial weed acts include:

- prescription of plants as weeds;
- prohibition of selling, exchanging, and/or disposing of infected things;
- prohibition of transporting and/or using infected things;
- regulation of handling, buying, selling, disposing, and/or storing of screenings or refuse containing weed seeds;
- requirement for weed destruction and/or control;
- compliance and enforcement powers, including inspecting, searching, investigating, surveying, and/or sampling;
- control options, including disinfection, treatment, destruction, control, prohibition of movement, prohibition of sowing a crop, quarantine, detainment, and/or stop order; and
- delegation of authorities to local governments.

In addition to weed acts, provinces have other legislation of interest for addressing the risk of invasive plants. For example, New Brunswick's *Plant Health Act* (S.N.B. 1998, c. P-9.01) includes weeds in its definition of "pest", while Newfoundland and Labrador's *Plant Protection Act* (R.S.N.L.1990, c. P-16) includes plant organisms within its definition of "pest". Provincial legislation pertaining, for example, to protection of natural areas, provincial parks, ecological and forest reserves, wildlife conservation, pest control, and pesticides also include components relevant to invasive plants.

More in-depth analysis of the sub-national regulatory framework relevant to invasive plants may be found in "Protecting Canada's Natural Ecosystems from Invasive Alien Plant Species: Is Sub-National Weed Control Legislation Up to the Task" (Lewis 2006). Also, it is noteworthy that the Invasive Plant Council of British Columbia recently published "A Legislative Guidebook to Invasive Plant Management in BC," which surveys

the legislative framework relevant to British Columbia (www.invasiveplantcouncilbc.ca/publications/ipcbc-reports/IPC3-Legislative-Guidebook.pdf).

5 Canada's Response to Invasive Alien Plants

This section discusses the current status of programs that deal with the invasive alien plant problem in Canada, including:

- activities that contribute to furthering our knowledge and understanding of invasive plants and their effects and management such as surveys, floristic studies, mapping, monitoring, and basic and applied research;
- activities that aim to mitigate the effects of invasive plants such as prevention, early detection, rapid response, and management; and
- activities that contribute to public awareness of invasive plants and how to reduce their impacts.

It is not possible to include a comprehensive account of all of these activities. But the main organizations involved in each of these areas are identified, and representative examples of work being done by the various sectors and across different regions of the country are provided. In Canada, organizations dealing with invasive plant issues include: federal, territorial, provincial, and municipal governments; universities, colleges, and government research stations; museums, botanical gardens, and herbaria; environmental non-government organizations (ENGOs); corporations and consultancies; and First Nations groups. Every province and territory has government, university, and ENGO agencies working on invasive plant issues. The depth and breadth of programming, quality and quantity of invasive plant lists, and organizational funding and available support vary widely among provincial and territorial jurisdictions.

This section is based primarily on information provided by respondents to a questionnaire (see Appendix I) as well as a literature search, agency reports and websites, and inquiries sent to university researchers. Because many invasive plant programs involve a high level of cooperation and networking among different levels of government and non-government bodies, as well as the academic sector, this review is organized by type of functional activity rather than by agency. Even on this basis, many programs serve multiple functions. For example, invasive plant management programs often collect and store detailed information on the distribution and occurrence of the species they manage, and in this way contribute to our knowledge of the invasive plant situation.

A summary of responses to the questionnaire is given in Table 12. The time available for design, distribution, response, and analysis of this survey was limited, and the results should therefore be taken as illustrative rather than comprehensive. An earlier survey by Haber (2000) also gives an overview of agencies and programs involved with invasive plants in Canada.

5.1 Research and Assessment

5.1.1 Weed or Invasive Plant Surveys

A total of 31 respondent ENGOs, corporations, governments (provincial, territorial, federal, and municipal), university researchers and herbaria/museums reported conducting weed surveys, or related activities such as inventorying, mapping, and monitoring (Table 13). The purpose, scope, approach, and scale of these activities, however, varied widely, as did the availability and accessibility of their results.

The largest-scale weed surveys done in Canada are the Prairie Weed Surveys, conducted periodically in Alberta, Saskatchewan, and Manitoba by the provincial Departments of Agriculture in cooperation with Agriculture and Agri-Food Canada's Saskatoon Research Centre. During the period covered by this report, weed surveys of the major annual crops were conducted in Alberta (2001), Manitoba (2002), and Saskatchewan (2001) as part of an ongoing program of surveys that began in the 1970s. Surveys are done in cultivated agricultural land seeded to a number of different crops at sites selected by a stratified random sampling process. A standardized transect count methodology is used. Surveys are conducted after normal spring in-crop herbicide treatments; the results therefore estimate the residual weed populations in the crop after herbicide application.

Table 12. Summary of responses to the questionnaire.

	Number responding
Total questionnaires returned	63
Organization types	
ENGOs	12
Corporations	4
Provincial government agencies	20
Territorial government agencies	4
Federal government agencies	3
Municipalities	5
Multi-stakeholder groups	2
Universities	6
Museums and herbaria	6
Respondents with invasive plant programs	47
Involved in managing invasive plants	34
Exclusion or prevention	17
Rapid response to newly detected invasives	22
Eradication	19
Management or control of established invasives	31
Communication activities about invasive plants	45
Public awareness	38
Facilitation	36
Enforcement	17
Field data collection on invasive plants	37
Early detection	14
Weed or invasive plant surveys	31
Assessing effects of invasive plants	18
Assessing efficacy of control methods	24

The abundance of weeds found in the surveys is linked to yield loss equations (e.g., O'Donovan et al. 2005) and economic costs are estimated. A farm management practices questionnaire is completed by the farmer for the fields included in the weed survey. Information on seeding practices, crop rotations, tillage systems, herbicide use, fertilizer use, and pest problems is collected and used to estimate control costs, adoption of integrated weed management, herbicide use, and environmental impact. Information is published as reports in the Weed Survey Series (e.g., Leeson, Thomas, Andrews et al. 2002; Leeson, Thomas and Hall 2002; Leeson et al. 2003). The reports contain quantitative information on the abundance of approximately 150 weed species in 10 crops in Prairie ecodistricts and ecoregions, and distributions of the 50 most abundant species are mapped.

A report summarizing results of the Prairie Weed Surveys (Leeson et al. 2005) shows changes in weed populations and distribution from the 1970s to the 2000s. Figure 9 shows an example. The Prairie Weed Surveys are unique in Canada in estimating all the components of invasive plant impact (range and abundance directly from the survey data, and per capita effects via yield loss equations) simultaneously and repeatedly over a large area using a systematic, quantitative methodology.

Invasive plants have been mapped extensively in British Columbia. Inventories and weed surveys at various scales (qualitative, semi-qualitative, and quantitative transect work) have been completed and are ongoing throughout the province. The Ministry of Forests and Range has established permanent vegetation transects to document changes in plant communities following biocontrol treatment, plus permanent vegetation transects in the range reference area program that track vegetation change (including invasive plants) exclusive of treatments. The main attributes captured include species present, area infested, density (plants per square metre) and a distribution code. Information is stored on the provincial Invasive Alien Plant Program Application (IAPP) (www.for.gov.bc.ca/hfp/invasive/intro.htm), a web-based application created to coordinate invasive alien plant management activities across British Columbia. The IAPP's Map Display module is an interactive mapping system that allows the user to create custom maps showing known locations of invasive plant communities throughout British Columbia, based on the data contained within the IAPP application.

Table 13. Summary of weed and invasive plant surveying, monitoring, and inventorying activities reported by questionnaire respondents for the period 2001 to 2005.

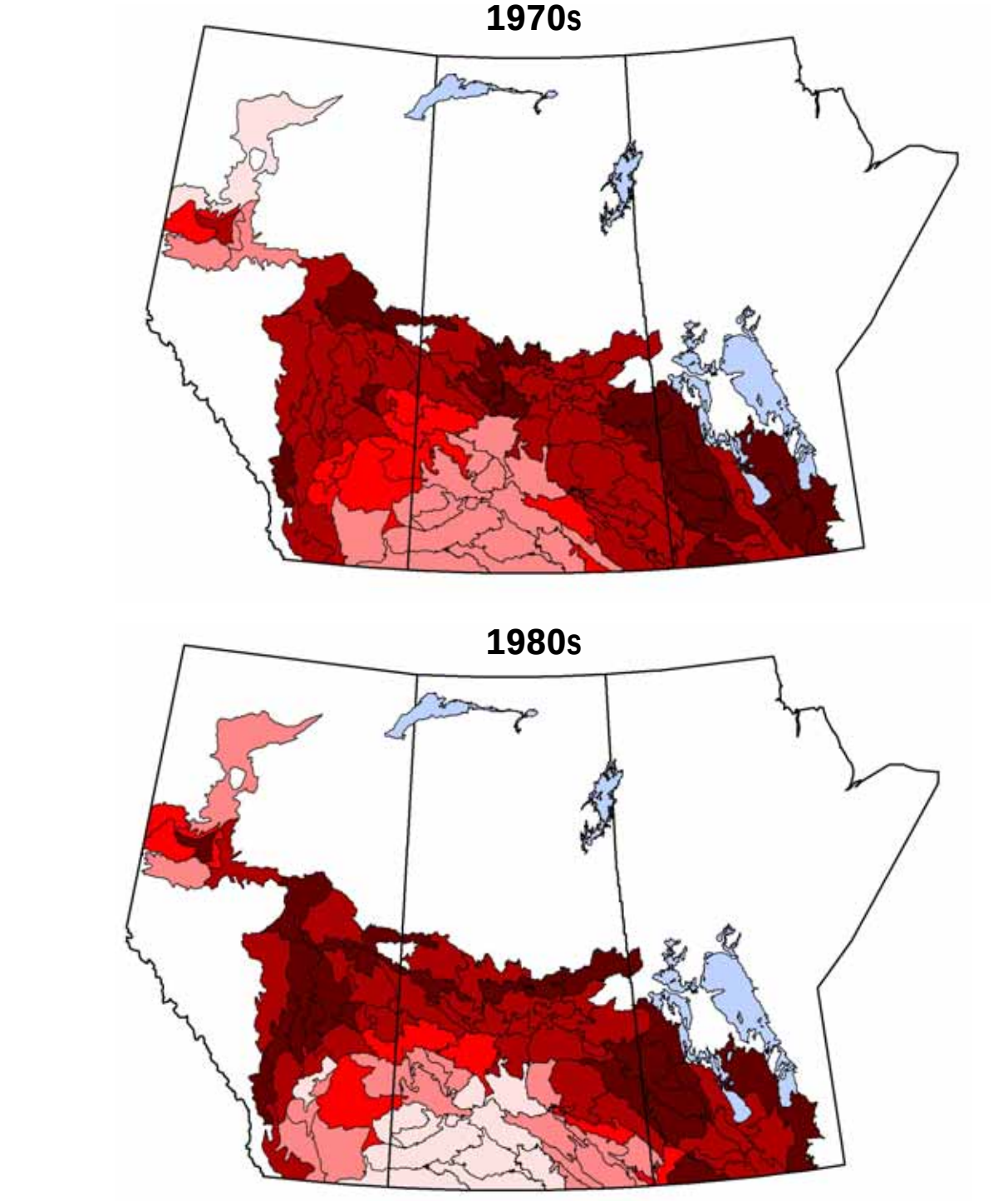
Habitats surveyed	
Cultivated agricultural land	15
Range or pasture	16
Forest	20
Roads and rights of way	15
Protected natural areas	21
Urban areas	22
Aquatic habitats	18
Other	13
Types of invasive plants surveyed	
All	8
Agricultural weeds	9
Aquatic weeds	3
Noxious or regulated weeds	9
Invasive species of natural habitats	10
Particular species	3
How were field data collected?	
Field surveys designed to collect weed or invasive plant information	27
In the course of weed or invasive plant management operations	12
In the course of other field operations	13
In response to calls or complaints from the public	11
In the course of regulatory or enforcement activities	8
Phone surveys or questionnaires	3
Specimens or samples submitted by the public	6
Other methods	4

Kinds of data collected	
Qualitative data	
Species presence only	15
Species presence and absence	10
Semi-quantitative data (e.g., visual estimates)	19
Quantitative data:	
Density	14
Cover	13
Infested area	14
Biomass	1
Approaches to recording spatial data	
Paper maps	13
Global Positioning System (GPS)	19
System used for recording locations	
Legal descriptions (township and range)	11
Latitude/longitude or UTM	11
Others	1
Data collected on impacts	
Ecological or environmental effects	12
Crop yield losses	2
Control or management costs	8
Other economic impacts	1
Social effects	2

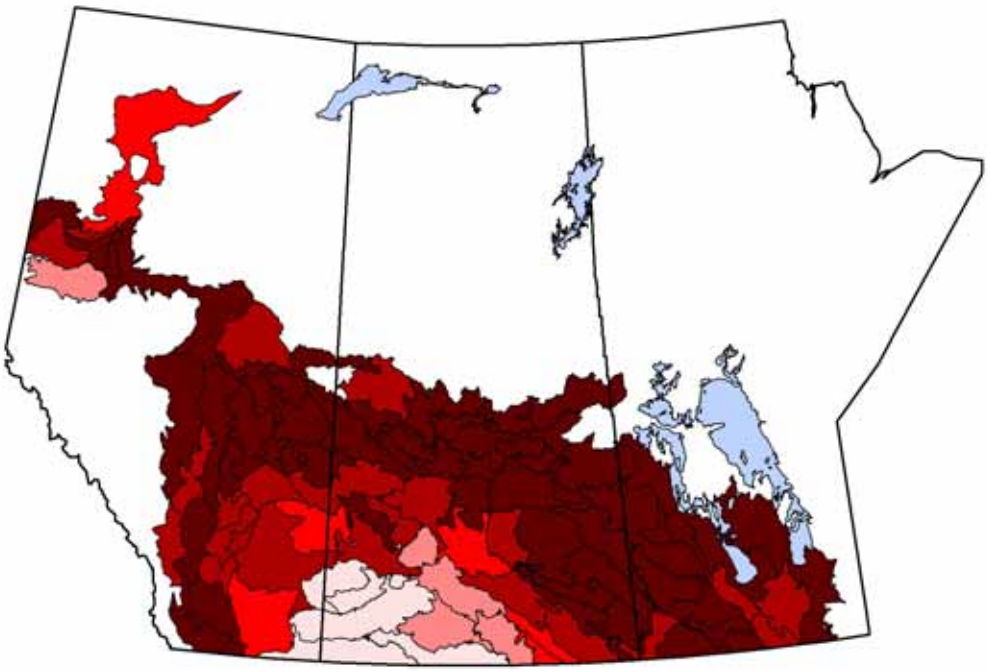
A recent development related to mapping invasive alien plants is the increasing use of online Geographic Information System (GIS) mapping applications linked to specimen databases. These capture location data from specimen labels in herbaria and use them to plot the distribution of a species. These applications are not always specifically developed for invasive or alien plants, but include them when they are present in the collections from which data are captured. These initiatives increase the accessibility of information on the distributions of invasive plants. In addition to generating distribution maps, such databases can be used to organize and deliver other biological information, including data on abundance and effects. They thus have the potential to be a valuable tool in evaluating the impact of invasive plants. Some examples are:

- Brassicaceae of Canada database (Warwick et al. 2003);
- specimen-based online mapping of British Columbia plants, including alien and invasive species, accessible through the E-Flora of BC (Klinkenberg 2006);
- a database in preparation for leafy spurge (Leafy Spurge Stakeholders Group 2005); and
- herbarium records used by Lavoie et al. (2005) to reconstruct the historical spread of reed canary grass (*Phalaris arundinacea*) in Quebec.

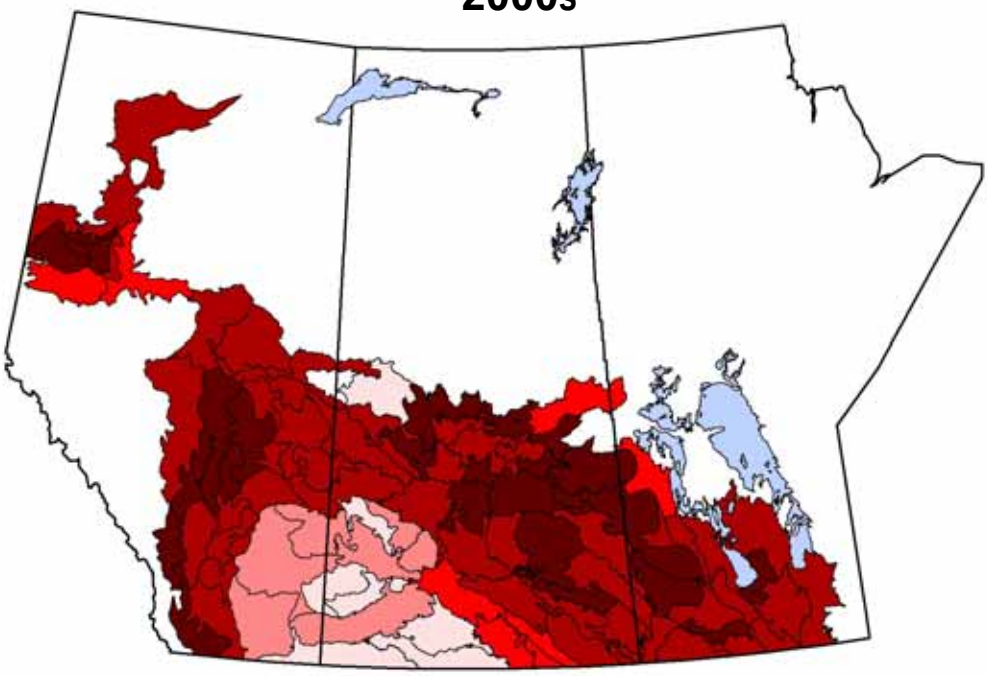
Figure 9. Changes in field frequency of Canada thistle in the Prairie provinces from the 1970s to the 2000s, from the Prairie Weed Surveys (Leeson et al. 2005).



1990s



2000s



Frequency					
	Species not surveyed		0.1 to 10.0%		20.1 to 50.0%
	Absent		10.1 to 20.0%		More than 50%

An ambitious systematic survey that is not specifically targeted to invasive plants, but that will document them along with other components of biodiversity, is the Alberta Biodiversity Monitoring Program (ABMP). This program was in the prototype phase from 2003 to 2006, with 26 partners participating, including Alberta government departments, the Alberta Research Council, Environment Canada, private industry (from the forestry and energy sectors), Nature Conservancy Canada, and the University of Alberta. The ABMP provides an unbiased sample of non-native plants in Alberta's terrestrial habitat and freshwater wetlands. Detailed protocols have been developed for vascular plant data collection, and include reports of species' presence and visual assessments of abundance. The program will collect data every five years on a 20-kilometre systematic grid across Alberta, with a total of 1,650 sites when fully operational. Initial prototyping is focusing on the forested area of northern Alberta (ABMP 2005). The ABMP monitoring design and communication tools include monitoring, assessment, mapping, and reporting on the status of non-native plants. ABMP data can be used to correlate the presence of non-native plants with other ecological characteristics, assessing at large spatial scales (1 million hectares or greater) relationships such as the distribution and response of non-native plants to changing land-use practices.

The Forestry Division of the Alberta Sustainable Resource Development Department conducts field surveys for noxious or regulated weeds and environmental weeds in the forested area of Alberta. Data collected through specific surveys, as well as in the course of management operations and enforcement activities, include species presence, cover, and areas infested.

Other surveys were targeted more specifically to particular invasive plants, habitats, jurisdictions, or management units:

- A biologist with the Yukon Department of Environment did a survey of Yukon's Arctic coast in 2005–2006 and found no introduced species.
- The Yukon Department of Highways and Public Works did a survey for sweet clover (*Melilotus* spp.) along highways.
- Some energy and utility operators and regulators, such as the British Columbia Oil and Gas Commission and the Columbia Power Corporation, surveyed for invasive plant species on rights of way, transmission lines, and well sites.
- The Parks Division of Alberta Tourism, Parks, Recreation and Culture is initiating a project to identify which invasive species have been documented in protected areas. Two pilot projects that included mapping were done to test inventory techniques in three selected protected areas. Species lists done through the years in protected areas are being compiled, with invasives noted and mapped by site (i.e., specific locations are not generally documented).
- The City of Calgary collected invasive plant data through field surveys and during management and enforcement operations, and found that a number of invasive plant species (e.g., black henbane, golden clematis, asparagus, dame's rocket, and cicer milkvetch) are becoming increasingly common in the city.
- The Saskatchewan Department of the Environment conducted a survey in the Great Sand Hills to assess the link between human-related disturbance and the presence of exotic plants (Gerry and Andersen 2003).
- In Manitoba, the Leafy Spurge Stakeholders Group (1999) surveyed the distribution and abundance of leafy spurge (*Euphorbia esula*) through field and telephone surveys as part of its economic impact assessment study.
- Environment Canada's St. Lawrence Centre in Quebec mapped the spread of common reed (*Phragmites australis*) on the Boucherville Islands using aerial photographs and remote sensing (Hudon et al. 2005).

Environmental groups, community organizations, and interested individuals are involved in local surveys of invasive plants, often in cooperation with government agencies, as listed below:

- The Alberta Wilderness Association surveyed for invasive plants, including escaped forage species such as clovers, smooth brome, and timothy, in the Bighorn Wildland in the Blackstone Wapiabi Forest Land Use Zone in southwestern Alberta.

- The Saskatchewan Purple Loosestrife and Invasive Species Project surveyed purple loosestrife throughout the province, as well as some other invasives threatening natural habitats such as common buckthorn, dame's rocket, and flowering rush.
- ReForest London surveyed natural areas in London, Ontario, for common and glossy buckthorn, adding to several decades of accumulated quantitative data (density and cover, infested areas).
- In Ontario, the Invading Species Awareness Program, a partnership between the Ontario Federation of Anglers and Hunters and the Ontario Ministry of Natural Resources, launched Fanwort Find, a volunteer monitoring protocol to find and track the spread of fanwort (*Cabomba caroliniana*) in lakes and rivers near known infestation sites (Ontario Federation of Anglers and Hunters 2003).

Invasive plant surveys were also done by some university and museum research staff. Staff of the New Brunswick Museum in Saint John conducted surveys of freshwater macrophyte communities in the lower Saint John River estuary, including native and introduced species. A PhD student at the University of Alberta's Department of Renewable Resources surveyed 84 forest stands in a 1,600-square-kilometre area encompassing the City of Edmonton and surrounding natural areas. Exotic plant species were identified and percentage of cover recorded. Field data were analyzed to determine the impact of exotic plants on native plant species' richness and the degree to which native vegetation structure resisted exotic plant establishment (Mandryk and Wein 2006). The University of British Columbia's Botanical Garden surveyed its land for invasive plants. At the University of Western Ontario, Arzandeh and Wang (2003) used satellite data to monitor changes in the distribution of invasive common reed (*Phragmites australis*) in cat-tail marshes around Walpole Island in southern Ontario. Staff at the Nova Scotia Agricultural College, in cooperation with Agriculture and Agri-food Canada, conducted weed surveys for invasive plant species in blueberry and cranberry plantations as well as in non-crop areas.

Many management agencies survey and map weeds and invasive plants as part of their operations, but do not make the data available to the public. This is probably primarily due to a lack of resources and lack of a perceived need, although privacy issues may also be involved. For instance, the Manitoba Weed Supervisors Association reported that individual weed districts maintain maps of their own programming, and that the types of data collected vary from district to district. Most data are collected directly onto paper maps, but the use of GPS is increasing.

5.1.2 Assessing the Impacts of Invasive Plants

Sixteen questionnaire respondents, including ENGOs, municipalities, provincial and federal government departments, and universities, reported that they were working on assessing the impacts of invasive plants. Twelve of these were concerned with assessing ecological impacts, although most respondents gave few details of the specific impacts of concern to them, or of how these were assessed. The Leafy Spurge Steering Committee conducted a three-year study on the effects of leafy spurge on species at risk, as well as a series of agro-environmental projects and an economic impact assessment (Leafy Spurge Stakeholders Group 1999; Pachkowski 2003; Zehtab-Jadid and Landry 2003). ReForest London assessed impacts of common buckthorn (*Rhamnus cathartica*) through biological inventory data accumulated at over 200 vegetation patches in London and detailed data collected in 2005 at five locations as part of a graduate research project (ReForest London 2006).

Swanton et al. (1993) estimated the annual economic impact of yield losses due to weeds in crops in Canada at $984 million (1993 dollars). No overall estimate of these losses for Canada has been made more recently, although crop production and weed management practices have changed significantly since 1993, in particular with the widespread adoption of reduced tillage and herbicide-resistant crops. The estimate by Swanton et al. did not specifically identify losses due to alien weed species. However, a recent unpublished study by Leeson, Thomas and O'Donovan of Agriculture and Agri-Food Canada used data from the Prairie Weed Surveys (Leeson et al. 2005) to estimate the economic impact of alien and native weeds on spring wheat (including durum), barley, and canola production in the Prairie provinces. This study showed that 99% of yield losses and herbicide expenditures were due to alien weeds, and only one native species (field horsetail, *Equisetum arvense*) figured among the 28 most abundant and widespread weeds in these crops. The study estimated the annual

economic impact (production losses and costs of control) of alien weeds in these three crops on the Prairies at over $1 billion (pers. comm., A.G. Thomas, Saskatoon Research Centre, Agriculture and Agri-Food Canada, 2007).

There are fewer economic impact assessments of invasive plants in uncultivated land. A study by the Leafy Spurge Stakeholders Group (1999) estimated the total annual cost of leafy spurge in Manitoba on grazing land, public land, and rights of way at $19 million. Grekul and Bork (2004) estimated yield losses in perennial pasture in central Alberta due to Canada thistle (*Cirsium arvense*) and found that they could be substantial (up to 4.3 kg/ha with each additional thistle stem per square metre). This study is an example of estimating per capita impact: if information on the range and abundance of Canada thistle in pasture were available, it could be used in conjunction with the data on per capita effects to estimate overall impact.

Farmers of spring wheat, barley, and canola in the Canadian Prairies lose an estimated $1 billion each year in production and control costs due to alien weeds.

The ecology of plant invasions has been a particular interest of academic researchers in plant ecology in Canada. A number of studies have focused on the concept of natural enemy release as a mechanism for invasiveness. For instance, Agrawal and Kotanen (2003) compared levels of herbivory between native and congeneric introduced plants and found that the non-native species suffered as much herbivory as the native species, suggesting that natural enemy release may not always be an important mechanism for invasiveness. Some other Canadian studies of potential relevance are Maheu-Giroux and de Blois (2007), Moffatt et al. (2004), and Stockton et al. (2005).

5.1.3 Developing Management Methods for Invasive Plants

Research assessing the effectiveness of control and management methods for weeds and invasive plants was reported by 24 respondents, including ENGOs; corporations; provincial, territorial, and municipal governments; and universities. As with other aspects of research on invasive plants, the scope, scale, and approach of these studies varied widely, as did the extent to which results were made available. Most organizations involved with weed or invasive plant management conducted some studies to evaluate the effectiveness of different control methods. Results of these may remain in-house or may be published as reports or in the scientific literature. Agencies such as the Columbia Power Corporation, Alberta Sustainable Resource Development (Forestry Division), the City of Victoria, the Manitoba Weed Supervisors Association, the Ontario Ministry of Natural Resources, New Brunswick Department of Agriculture and Aquaculture, Saskatchewan Agriculture and Food, Nova Scotia Agricultural College, and the Saskatchewan Purple Loosestrife and Invasive Species Project reported that they were involved in field evaluation of a variety of chemical, mechanical, cultural, and biological control methods.

Evaluation of herbicides and other weed management practices has been a traditional and major activity of agricultural weed scientists at university and government research stations, and there is extensive Canadian literature in this area. Extensive efficacy data are also generated by private industry in support of the registration and labelling requirements for herbicides. In recent years the research focus has shifted from the evaluation of weed management methods in isolation to integrated studies of the cropping systems in which weeds are components. These involve the effects of crop management practices such as variety selection, tillage, seeding rates, fertilization, and rotation on crop yield and sustainability, and on weed population dynamics (e.g., Derksen et al. 2002; Harker et al. 2003; Swanton and Booth 2004; Blackshaw et al. 2005).

Chemical control has also been evaluated for some invasive plant species in non-agricultural environments. Meloche and Murphy (2006) tested several management methods for tree-of-heaven (*Ailanthus altissima*) in an Ontario provincial park and found that cut stump and glyphosate treatment was the most effective. Sinclair and Catling (1999) reported on the value of cutting in the management of an invasive shrub, glossy buckthorn, in Ontario.

Non-chemical methods of invasive plant management have been primarily developed in the public sector by university and government research centres. Agriculture and Agri-Food Canada has been involved for many years in the development of biological control agents for weeds and invasive plants. Research at the Lethbridge

Research Centre has focused on the introduction of insects as classical biological control agents for plant species such as leafy spurge, Dalmatian toadflax, hound's-tongue (*Cynoglossum officinale*), and knapweeds (e.g., De Clerck-Floate and Schwarzlander 2002; Kalischuk et al. 2004; De Clerck-Floate et al. 2005; Van Hezewijk and Bourchier 2005). These studies are carried out in cooperation with several provincial agencies, as well as the CABI laboratory in Delémont, Switzerland, and the USDA Agricultural Research Service. Field work to evaluate effectiveness of biological control also includes quantitative studies on weed populations and ecological impacts. This research has resulted in some recent dramatic successes against significant invasive plants of rangeland and natural areas, such as the use of the weevils *Mogulones cruciger* against hound's-tongue and *Mecinus janthinus* against Dalmatian toadflax.

At the AAFC Saskatoon Research Centre, studies have been undertaken to develop microbial agents for control of species such as Canada thistle, scentless chamomile, and green foxtail (e.g., Bailey et al. 2000; Green and Bailey 2000; Green et al. 2001; Green et al. 2004; Peng et al. 2005; Graham et al. 2006a; Graham et al. 2006b). These have been geared toward the development of products that could be commercialized as bioherbicides. Work at McGill University has led to the development of a fungal isolate with potential for control of common dandelion (*Taraxacum officinale*), one of the most abundant and frequent turfgrass weeds in Canada (Abu-Dieyeh and Watson 2007).

Grazing management can be an effective method of controlling invasive plant species in pastures. De Bruijn and Bork (2006) found that high intensity–low frequency rotational grazing could almost eliminate populations of Canada thistle (*Cirsium arvense*) over a two- to three-year period. Grazing by sheep has been used for managing leafy spurge with promising results in a Saskatchewan study by the Prairie Farm Rehabilitation Administration (Gallivan 2003).

Cultural and mechanical methods of control, such as pulling and mowing, are often practised in invasive plant management programs, but there seems to have been little systematic research into their effectiveness. Meloche and Murphy (2006) found that both cutting without herbicide treatment, and hand-pulling and mulching, led to increased recruitment of tree-of-heaven (*Ailanthus altissima*) because the soil disturbance and canopy opening resulted in increased seed germination and suckering. Prasad (2005) evaluated several control methods for Scotch broom (*Cytisus scoparius*), gorse (*Ulex europaeus*), daphne spurge (*Daphne laureola*), and English ivy (*Hedera helix*) in coastal British Columbia, and found that the herbicide triclopyr was the most effective treatment against all four species. Cutting alone was not effective as it promoted resprouting and emergence of new seedlings; mulching with black plastic after cutting suppressed regrowth, but was not practical on a large scale. A fungus, *Chondrostereum purpureum*, gave variable results when used as a bioherbicide, but another fungus, *Phomopsis* sp., was very effective against daphne spurge.

5.2 Mitigating the Effects of Invasive Plants

5.2.1 Prevention

Prevention programs for invasive plants usually take the form of regulations or best practice guidelines. Seventeen of 47 respondents to the questionnaire reported that they were involved in prevention activities. Many of these are better described as early detection, however, and are considered in section 5.2.2.

Some examples of regulatory and best practice approaches include:

- The Canadian Food Inspection Agency currently regulates 21 invasive plant taxa by listing them as Class 1 Prohibited Noxious Weed Seed under the *Weed Seeds Order* (2005) of the *Seeds Act*.
- The British Columbia Oil and Gas Commission requires oil and gas construction companies to have heavy equipment cleaned when entering British Columbia from Alberta, and when moving from site to site.
- In Alberta, both the Forestry Division of Sustainable Resource Development and the Parks, Conservation, Recreation and Sport Division of Tourism, Parks, Recreation and Culture are developing policies and guidelines to prevent the introduction of invasives. These practices include the use of certified weed-free seed for reclamation, cleaning equipment and materials before moving them to new sites, the use of weed-

free hay for feeding and erosion control, and inspecting gravel pits and soil stockpiles for invasive plants before moving these materials to new sites.

- In Alberta, Ducks Unlimited prohibits the seeding of forage mixes containing invasive species such as smooth brome (*Bromus inermis*) on sites that they manage.
- The weed-free hay program in Alberta is offered in partnership with municipalities and Alberta Agriculture, and is based on inspection of hay fields for invasive plants before cutting. Hay is certified to be free of seeds of 73 species of designated weeds or undesirable plants, and is bound with a special coloured twine to identify it.
- In Saskatchewan's provincial forest lands, the Saskatchewan Environment Lands Administration prohibits noxious weeds in hunting bait and reclamation seed, and requires that native species be used for reclamation.

Invasive plant prevention is also carried out at a local level. Two botanical gardens (University of British Columbia in Vancouver, and Memorial University in St. John's, Newfoundland and Labrador) reported that they exclude weeds by growing plants in their own nurseries with strict sanitation procedures in place, or by inspecting all incoming stock.

Prevention may involve putting in place physical barriers to invasive plant spread. In 2004–2005, the Quebec ministère du Developpment durable, de l'Environnement et des parcs (ministry of sustainable development, environment and parks) contributed to a project to construct a screen to prevent the spread of water chestnut (*Trapa natans*) from the Rivière du Sud.

Risk assessment of potential new invaders is an important means of prevention. The Plant Health Risk Assessment Unit of the Canadian Food Inspection Agency conducts weed risk assessments of exotic plants, and during the period under review had 11 weed risk assessments completed or in progress (O'Driscoll 2006). In 2005, Alberta Sustainable Resource Development began work on the development of an Alberta risk assessment tool to quantitatively assess environmental, social, and economic impacts of invasive plants.

5.2.2 Early Detection and Rapid Response

Fourteen survey respondents reported that they had early detection programs or policies in place and 21 reported practices described as rapid response. These were predominantly at a local level, such as municipalities, parks, or conservation groups. None of the territorial government agencies had early detection policies in place. Yukon government and ENGO respondents, however, expressed a desire for support to develop networks and partnerships to monitor invasive species.

At the provincial level, the British Columbia Ministry of Forests and Range (MOFR) promotes preventive measures with client groups and has an early detection and rapid response internal protocol. When new invasive plants are detected within the provincial forest land base, MOFR crews and/or contractors are directed to control populations on the site with the objective of eradication. MOFR is currently working with other ministries through the Inter-Ministry Invasive Plant Working Group (IMIPWG) to formalize an early detection and rapid response framework.

In Saskatchewan, the Department of Agriculture and Food does not conduct early detection itself due to lack of resources, but has delivered to municipalities programs that promote prevention, early detection, and eradication, followed by containment and control of established infestations — should eradication efforts become impractical due to the size of the infestation. In earlier programs, these elements were merely presented to municipalities as a means to improve the cost-effectiveness of noxious weed control. The current program promotes the development of long-term management plans that include scouting for new weed infestations, rapid response to the detection of any populations with eradication as the goal, and follow-up to those activities to gauge effectiveness. Both programs promote integrated strategies for managing established invasive plants, and both programs monitor and redistribute biological control agents that have been screened and released through previous screening projects.

Several ENGOs are also involved in early detection and rapid response at a provincial level. The Invasive Plant Council of British Columbia has produced an early detection and rapid response plan, together with a set of

best management practices, for carpet burweed (*Soliva sessilis*). The Saskatchewan Purple Loosestrife and Invasive Species Project has followed up on reports of sightings of invasive plants from the public, ENGOs, and government departments to confirm their identity and undertake control measures. Conservation groups, such as Ducks Unlimited, have inspected habitat lands under their management to detect invasive plants.

Early detection protocols were conducted by ENGOs, corporations, provincial and municipal governments, and university researchers. Researchers at the University of Western Ontario, for example, surveyed British Columbia, Alberta, and Saskatchewan for new invasions of salt cedar and Russian olive.

5.2.3 Management: Rapid Response and Eradication

Thirty-one respondents were involved in managing established populations of invasive plants. This includes activities described in *An Invasive Alien Species Strategy for Canada* as eradication, containment, and control, and it is difficult to draw firm lines between these approaches. There is a continuum from rapid response (implying the elimination of newly discovered patches before they are able to disperse and spread) to eradication of larger but still confined populations, to containment operations aimed at preventing spread out of a core area, through to ongoing control of widely established species.

"Eradication" refers to the complete elimination of populations of an alien plant from a defined geographic area. A recent paper by Regan et al. (2006) provides a discussion about when eradication should be attempted. Rejmánek and Pitcairn (2002) report that the success rate for eradication of alien plants begins to drop and the costs begin to rise dramatically, as the infested area increases above one hectare. Sixteen questionnaire respondents reported that they were involved in eradication programs or had eradication as a policy goal for some invasive plant situations. It was not clear, however, if some respondents were using the term in its strictest sense or if it was used as a synonym for control or management.

Several organizations reported that eradication of invasive plants was a policy objective under some circumstances. For example:

- In British Columbia, the Ministry of Forests and Range sets eradication as a goal for populations of invasive plants that are new to the province or new to a large geographic area, such as when marsh plume thistle (*Cirsium palustre*) is discovered outside the current infestation containment line.
- Saskatchewan Agriculture and Food promotes early detection and eradication in invasive plant programs delivered to municipalities.

Successful or promising eradication efforts were reported for specific weeds in restricted areas:

- In Quebec, the ministère du Développement durable, de l'Environnement et des Parcs cooperated with the Centre d'interprétation du milieu écologique du Haut-Richelieu (CIME), la Société de la faune et des parcs du Québec (FAPAQ), and Ducks Unlimited Canada in a campaign, starting in 2001, to eradicate water chestnut (*Trapa natans*) from the Rivière du Sud, where it had first been observed in 1998. Initially, hand-picking by volunteers was used and later, a mechanical harvester was brought in. By 2004 the density of viable nuts on the river bed had been reduced from 13.49 m^{-2} (in 2002) to 0.04 m^{-2}, but monitoring continues (Ministère du Développement durable de l'Environnement et des Parcs 2006).
- Also in Quebec, the ministère de l'Agriculture, des Pêcheries et de l'Alimentation (ministry of agriculture, fisheries and food) cooperated with the Canadian Food Inspection Agency on eradication of woolly cupgrass (*Eriochloa villosa*), discovered in 2000 in a field near Montreal.
- In Alberta, the Alberta Native Plant Council, Ducks Unlimited, a number of other ENGOs, and provincial and federal government departments together undertook the Purple Loosestrife River Survey & Eradication Project. The river survey teams inspected approximately 1,490 kilometres of riverbank, removing close to 700 plants from wetland areas along the North and South Saskatchewan Rivers, Sturgeon River, Oldman River, St. Mary's River, Red Deer River, Whitemud Creek, and Mill Creek. (www.mb.ec.gc.ca/community/ecoaction/fp-pf/page.asp?lang=en&id=AB-11178).
- Also in Alberta, the Edmonton Naturalization Group reported that it had eradicated Canada thistle (*Cirsium arvense*) from small areas of native vegetation in Edmonton's Mill Creek Ravine by hand pulling.

- In Saskatchewan, Ducks Unlimited reported that scentless chamomile (*Tripleurospermum perforata*) was eradicated from one of its sites.

Larger-scale eradication projects were more problematic. The Saskatchewan Purple Loosestrife and Invasive Species Project reported that its initial goal when the group was formed in 1996 was eradication of purple loosestrife, but that after a few years it became evident that the goal was not feasible because of the number of established populations. The project did conduct hand pulling and digging at some small, recently reported purple loosestrife sites, as well as for new infestations of dame's rocket (*Hesperis matronalis*) and flowering rush (*Butomus umbellatus*). These efforts could not be followed up due to lack of funding.

Another large-scale project targeted carpet burweed (*Soliva sessilis*), which was first discovered in a park on Salt Spring Island, British Columbia, in 1996, where various control measures were tested. It is believed that the plant is spread by attachment of the spiked seeds to recreational vehicle mats and camping equipment (D. Polster, pers. comm.). The City of Victoria has an eradication program for carpet burweed within the city limits. Two areas in a park were fenced off from the public to prevent seed dispersal and were burned repeatedly to kill newly germinating seedlings. Other likely areas were searched by a team of botanists, who located six or seven small spots that were also burned or hand pulled. Currently carpet burweed is not considered established in the City of Victoria. Efforts to eradicate carpet burweed on a wider scale in southern British Columbia, however, have not been successful to date.

5.2.4 Management: Established Populations

Management of existing, established populations of invasive alien plants is the largest single component of Canada's response to these species. Questionnaire respondents reported using all forms of control for invasive plants, including chemical, cultural, mechanical, and biological. Weed and invasive plant management is the responsibility of owners and occupiers of land, whether private or public, and thus all sectors are involved in invasive plant management operations. Twenty-eight questionnaire respondents reported involvement with invasive plant management, including federal, provincial, and territorial government departments, municipalities, utilities, ENGOs, and multi-stakeholder groups. Weed control in agriculture is a major cost of production. Thomas et al. (pers. comm. 2007) found that annual expenditures by farmers for herbicides on

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spring wheat, barley, and canola in the Prairie provinces were $923 million (including products and cost of application), of which 98% was targeted to alien weed species. Total herbicide sales in Canada in 2005, not including application costs, were $1.04 billion (CropLife Canada 2005), of which most was probably for use on alien plants.

Municipalities in many provinces play a major role in invasive plant management, both as managers of land in their own right and in some cases as the agencies responsible for enforcing noxious weed or invasive plant legislation. In Alberta, responsibility for enforcing the provincial *Weed Control Act* is delegated to municipalities that exercise this authority through Agriculture Service Boards, by appointing agriculture fieldmen and weed inspectors. The Association of Alberta Agriculture Fieldmen (www.aaaf.ab.ca), which acts as a coordinating body for these activities at the provincial level, has been active in coordinating weed control strategies and raising invasive plant issues. In Manitoba, the Manitoba Weed Supervisors Association plays a similar role.

5.3 Public Awareness

Most respondents to the questionnaire (45) were involved in communication or public awareness activities related to weeds or invasive plants. Public awareness is one of the major roles of non-government and multi-stakeholder groups such as the provincial invasive plant councils and native plant societies, as well as special-purpose groups focused on particular invasive plants or vulnerable ecosystems. The following are some examples of the public awareness activities undertaken:

- A Yukon Invasive Species Committee has been established by concerned individuals to help coordinate activities and information.
- The Invasive Plant Council of British Columbia provides an information compendium on its website (www.invasiveplantcouncilbc.ca/compendium) with a wide range of fact sheets, educational materials, brochures, technical reports, and other publications.
- Two main goals of the Alberta Invasive Plants Council (www.invasiveplants.ab.ca) are to foster awareness and understanding of invasive plant issues, and to serve as a repository of credible information and resources on invasive plants in Alberta.
- The Native Plant Society of Saskatchewan, in cooperation with the Saskatchewan Purple Loosestrife and Invasive Species Project, is planning to take on the role of a provincial invasive plants council.
- The Saskatchewan Purple Loosestrife and Invasive Species Project has used a purple loosestrife display and an invasive species tabletop display at numerous trade shows, and has distributed fact sheets, an invasive species brochure, and many press releases on its purple loosestrife swap and biocontrol programs.
- In Manitoba, the Leafy Spurge Stakeholders Group has produced a variety of materials aimed at public awareness such as brochures, signs, displays, news releases, a website, and promotional items such as pens, notepads, magnets, and placemats. Awareness activities during the last two years have been directed at zero-to-low infestation areas of Manitoba.
- The Ontario Federation of Anglers and Hunters, in partnership with the Ministry of Natural Resources, created the Invading Species Awareness Program in 1992 to address the threats from exotic invading species, including plants. This program has an extensive public awareness component including a website (www.invadingspecies.com) with fact sheets on several invasive aquatic and wetland plants.

Field activities and volunteer events are often used as occasions to promote public awareness of invasive plants:

- The Alberta Wilderness Association worked with local environmental groups on hand-pulling projects for invasive plants in the Blackstone Wapiabi Forest Land Use Zone.
- Other local and regional groups that have organized similar events include ReForest London, the Edmonton Naturalization Group, Fish Creek Provincial Park and the Weaselhead Society in Calgary, the Saskatchewan Purple Loosestrife and Invasive Species Project, Friends of Lemoine Point in Kingston, Ontario, (www.cataraquiregion.on.ca/lands/friendsoflemoine.htm), the High Park Community Advisory Council and Downsview Park in Toronto, and Les Amis and the Centre de la montagne in Montreal.

All provincial Departments of Agriculture, as well as Agriculture and Agri-Food Canada, provide information on weed management, usually focused on species of importance to agriculture, but often covering species that are invasive in natural habitats as well. These are delivered through a wide range of media: fact sheets, manuals, websites, talks, field days, media articles, etc. There is often collaboration between different levels of government in delivering these initiatives. For instance:

- In Saskatchewan, the Department of Agriculture and Food partners with the Saskatchewan Association of Rural Municipalities to offer a program that delivers awareness activities to rural municipalities.
- The Manitoba Weed Supervisors Association presents a Weed Identification booth at Manitoba AgDays, makes presentations to other organizations, and produces educational materials including *Top Weed Concerns & Best Management Practices*, and an *Urban Guide to Weed Control*. They also organize annual training seminars and a summer tour for weed supervisors, as well as an annual meeting on municipal weed control issues for elected officials and other interested municipal personnel.

Other provincial and territorial departments also undertake public awareness activities:

- Environment Yukon produced a brochure on reducing the spread of invasive plants in Yukon (www.environmentyukon.gov.yk.ca/pdf/Invasive_Plants_web.pdf).
- In British Columbia, the Ministry of Forests and Range has produced brochures, media releases, and websites, and has given talks to various audiences on all aspects of invasive plant management.
- Alberta Parks developed posters on invasive species in protected areas, focusing on the problem of agricultural species moving into natural habitats.

Many research institutions are also involved in public awareness. For instance, researchers in the biological control program at Agriculture and Agri-Food Canada's Lethbridge Research Centre gave media interviews; organized field days, field courses and tours; and maintained a website (res2.agr.ca/lethbridge/weedbio/index_e.htm) to provide information on biological control methods for invasive plants. Similar activities are undertaken by the Nova Scotia Agricultural College.

6 Discussion

Although it has not been possible to compile a comprehensive account of invasive plant problems and programs in Canada, a number of themes can be pointed out in our findings:

- Impacts of invasive plants on the agricultural sector in Canada have been highlighted, both in terms of economic importance and the number of resources dedicated to their management. The impacts of invasive plants are much better documented in agriculture than in any other sector. Recent results from weed surveys confirm quantitatively what has been suspected before: that the vast majority of crop yield losses and control costs due to weeds in Canadian agriculture are caused by alien plant species.
- The impact of invasive plants is less well known for non-cropland systems, including rangelands and pasture, and in non-agricultural land. For many invasive plant species, geographic range is reasonably well known, but there is a shortage of data on abundance and per capita effects. More comprehensive studies on environmental impacts of invasive alien plants in Canada are required.
- Information on the distribution, effects, and management of invasive alien plants is often very fragmented and dispersed. GIS databases, such as that of the Invasive Alien Plants Program set up in British Columbia, offer a potential way to share these data across a range of agencies and stakeholders in such a way that research and management programs can work with, and add to, a common pool of data.
- From the perspective of local invasive plant managers, an alien plant does not have to be a new incursion into Canada to represent a new problem. Even species that have been present in Canada for hundreds of years are still dispersing, expanding their ranges, and filling in gaps, so that at a local level they can still be considered emerging problems. It is thus necessary to keep a balance between developing management methods and strategies for established invasives, and responding to new incursions into Canada.
- Multi-stakeholder groups such as the provincial Invasive Plant Councils, the Garry Oak Ecosystem Recovery Team in British Columbia, the Bow Valley Project in Alberta, the Saskatchewan and Manitoba Purple Loosestrife Projects, and the Leafy Spurge Stakeholders Group in Manitoba have played a major role in Canada's response to invasive alien plants.
- Very few agencies reported that they were involved in risk assessment of potential new invasive plants. In particular, new crop species, ornamentals, and landscaping plants often seem to be introduced without any systematic risk assessment process.

7 Glossary

Many of the definitions below follow those outlined in *An Invasive Alien Species Strategy for Canada* (Government of Canada 2004). A number of other terms are used in the invasion biology literature and in this report, and several terminological schemes have been proposed (e.g., Davis and Thompson 2000; Colautti and MacIsaac 2004; Pyšek et al. 2004).

Adventive species — Alien species that reproduces temporarily or occasionally outside cultivation, without forming permanent populations. The terms *casual*, *waif* and *ephemeral* are also used for such a species.

Alien species — Species of plant, animal, or micro-organism introduced by human action to an environment outside its natural past or present distribution. Also referred to as *exotic*, *non-native* or *non-indigenous*.

Biodiversity — Variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems (*Convention on Biological Diversity*, 1992).

Carbon sequestration — The storage of carbon dioxide either biologically (carbon dioxide is naturally stored in plants, soils, and in ocean life), or geologically (carbon dioxide is stored directly in rocks or underwater).

Convention on Biological Diversity — A convention signed by world leaders at the 1992 Earth Summit in Rio de Janeiro. The key points of the convention are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources.

Dispersal — The process by which plant species move away from their original location and establish in new sites. This includes natural processes such as the movement of seeds by wind and water, or the carrying of seeds or other propagules by vectors such as birds and livestock, as well as human actions that deliberately or inadvertently bring plants into new locations. Dispersal can occur by the same pathways as introduction and, on a local or regional scale, they can be hard to distinguish. In fact, an introduction is simply a human-mediated dispersal event that happens to bring a plant species into a political jurisdiction or ecological region where it is not native.

International Plant Protection Convention — An international treaty to promote action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control. It originally came into force in 1951, but has been revised.

Introduction — The entry of a plant species into a country or region outside its natural range as a result of human action. Introductions may be intentional (also referred to as deliberate), such as the importation of a plant as a new crop or ornamental, or unintentional (also said to be inadvertent or accidental) such as when seeds arrive as contaminants in imported products. Some introduced species do not survive or reproduce, while others do so only in sites where they have been planted and protected by humans (such as in farms, gardens, orchards, botanical gardens, and parks). These species are said to survive in cultivation.

Invasive alien species — Those harmful alien species whose introduction or spread threatens the environment, the economy, or society, including human health. Invasive alien species can originate from other continents, neighbouring countries, or from other ecosystems within Canada. In some other reports, the term "invasive" may be applied primarily to alien plant species that spread and cause negative effects in relatively natural or undisturbed areas (such plants are sometimes called environmental weeds), and the term "weed" is used for species that survive only in disturbed or managed habitats such as cropland. In this report, consistent with the definitions in An Invasive Alien Species Strategy for Canada, all established alien plants that have harmful effects on the environment, economy, or society are considered to be invasive, and the term invasive plants thus includes agricultural weeds.

Native species — Species that are within their natural past or present distribution and are not alien.

Naturalized species — Species that form permanent populations, regularly reproducing or spreading without human help outside their current or historic range. This includes alien species (both intentionally and unintentionally introduced) that survive, reproduce and spread to sites where they have not been intentionally planted. These species may also be referred to as established. Those naturalized species that become widespread and abundant enough to cause environmental, economic, or social impacts are invasive species.

Palaearctic — An ecological region that includes the land masses of Europe, Asia north of the Himalaya foothills, northern Africa, and the northern and central parts of the Arabian Peninsula.

Pathway — The route or mechanism by which the alien species arrives in a country.

Pest — Any species, strain, or type of plant, animal, or pathogenic agent (disease-causing agent, such as a virus or bacterium) that can damage plants or plant products.

Species at risk — Any species that has been endangered, threatened, or is extinct in Canada but may occur elsewhere, as well as any species that merits special concern because of environmental conditions that may harm its habitat.

Weed — This term is used in many different ways; however, a popular definition is simply "a plant growing in the wrong place." This tends to refer to species that have negative economic impacts on agriculture, or otherwise adversely affect human interests. Weeds in this sense are not necessarily alien species, although in Canada many of the most important ones are.

8 References

8.1 Works Cited

Abu-Dieyeh, M. H., and A. K. Watson. 2007. Grass overseeding and a fungus combine to control *Taraxacum officinale*. *Journal of Applied Ecology* **44**: 115–124.

Agrawal, A. A., and P. M. Kotanen. 2003. Herbivores and the success of exotic plants: a phylogenetically controlled experiment. *Ecology Letters* **6**: 712–715.

Alaska Natural Heritage Program. 2004. Non-Native Plant Species of Alaska. Kentucky bluegrass (*Poa pratensis* ssp. *pratensis* L.), spreading bluegrass (*Poa pratensis* ssp. *irrigata* (Lindm.) Lindb. f.), rough bluegrass *(Poa trivialis* L.). Available at akweeds.uaa.alaska.edu/pdfs/species_bios_pdfs/Species_bios_POPR&POTR.pdf.

Alberta Biodiversity Monitoring Program. 2005. *2005 Program Report*. Alberta Research Council, Vegreville, AB.

Alberta Native Plant Council. 2000. *A Rogue's Gallery of Invasive Non-native Plants*. Alberta Native Plant Council, Edmonton, AB.

Allen, E. A., and L. M. Humble. 2002. Nonindigenous species introductions: a threat to Canada's forests and forest economy. *Canadian Journal of Plant Pathology* **24**: 103–110.

Arzandeh, S., and J. Wang. 2003. Monitoring the change of *Phragmites* distribution using satellite data. *Canadian Journal of Remote Sensing* **29**: 24–35.

Auditor General of Canada. 2002. *Report of the Commissioner of the Environment and Sustainable Development to the House of Commons. Chapter 4: Invasive Species*. Office of the Auditor General of Canada, Ottawa, ON.

Bailey, K. L., S. M. Boyetchko, J. Derby, W. Hall, K. Sawchyn, T. Nelson, and D. R. Johnson. 2000. Evaluation of fungal and bacterial agents for biological control of Canada thistle. pp. 203–208 *in* Spencer, N. (Ed.) *Proceedings of the 10th International Symposium on Biological Control of Weeds*, July 4–9, 1999, Bozeman, MT.

Bakker, J., and S. Wilson. 2001. Competitive abilities of introduced and native grasses. *Plant Ecology* **157**: 117–125.

Bell, F. W., and S. G. Newmaster. 2002. The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. *Canadian Journal of Forest Research* **32**: 1180–1191.

The Biology of Canadian Weeds. 1972 – onwards. [irregular series]. *Canadian Journal of Plant Science*.

The Biology of Invasive Alien Plants in Canada. 2003 – onwards. [irregular series]. *Canadian Journal of Plant Science*.

Blackshaw, R. E., L. J. Molnar, and F. J. Larney. 2005. Fertilizer, manure and compost effects on weed growth and competition with winter wheat in western Canada. *Crop Protection* **24**: 971–980.

Blaney, C. S., and P. M. Kotanen. 2001. The vascular flora of Akimiski Island, Nunavut Territory. *Canadian Field-Naturalist* **115**: 88–98.

Botanical Electronic News (BEN) Archive. 1997 – onwards. Available at www.ou.edu/cas/botany-micro/ben.

Boufford, D. E. 1997. 26. Urticaceae Jussieu. Nettle Family. pp. 400–413 *in* Flora of North America Editorial Committee (Ed.), *Flora of North America, Vol. 3*. Oxford University Press, New York, NY.

Byrne, R., and J. H. McAndrews. 1975. Pre-Columbian purslane (*Portulaca oleracea* L) in the New World. *Nature* **253**: 726–727.

Cadotte, M. W., and J. Lovett-Doust. 2001. Ecological and taxonomic differences between native and introduced plants of southwestern Ontario. *Ecoscience* **8**: 230–238.

Canadian Botanical Conservation Network. 1997. Available at www.rbg.ca/cbcn/en/projects/invasives/invade1.html.

Canadian Endangered Species Conservation Council. 2006. *Wild Species 2005: The General Status of Species in Canada*. Available at www.wildspecies.ca/wildspecies2005.

Canadian Parks Council. 2006. The Economic Impact of National, Provincial and Territorial Parks. Research Bulletin. May 2006. Available at www.scics.gc.ca/cinfo06/830893004a.pdf. Accessed July 17, 2007.

Carpenter, D., and N. Cappuccino. 2005. Herbivory, time since introduction and the invasiveness of exotic plants. *Journal of Ecology* **93**: 315–321.

Castro, K. 2006. Carpet burweed (*Soliva sessilis* Ruiz & Pav.). PRA request No. 06-30, Plant Health Risk Assessment Unit, Canadian Food Inspection Agency. Unpublished report submitted to CFIA's Plant Health Division in September 2006.

Catling, P. M., and B. Kostiuk. 2003. *Carex acutiformis* dominance of a cryptic invasive sedge at Ottawa. *Botanical Electronic News* **315**: 1-6.

Catling, P. M., and G. Mitrow. 2005. A prioritized list of the invasive alien plants of natural habitats in Canada. *Canadian Botanical Association Bulletin* **38**: 55–57.

Catling, P. M., G. Mitrow, L. Black, and S. Carbyn. 2004. Status of the alien race of Common Reed in the Canadian Maritime Provinces. *Botanical Electronic News* **324**: 1-3.

Chapman, J., R. B. Stewart, and R. A. Yarnell. 1974. Archaeological evidence for precolumbian introduction of *Portulaca oleracea* and *Mollugo verticillata* into eastern North America. *Economic Botany* **28**: 411–412.

Chornesky, E. A., A. M. Bartuska, G. H. Aplet, K. O. Britton, J. Cummings-Carlson, F. W. Davis, J. Eskow, D. R. Gordon, K. W. Gottschalk, and R. A. Haack. 2005. Science priorities for reducing the threat of invasive species to sustainable forestry. *BioScience* **55**: 335–348.

Christian, J. M., and S. D. Wilson. 1999. Long-term ecosystem impacts of an introduced grass in the northern Great Plains. *Ecology* **80**: 2397–2407.

Colautti, R. I., S. A. Bailey, C. D. A. van Overdijk, K. Amundsen, and H. J. MacIsaac. 2006. Characterised and projected costs of nonindigenous species in Canada. *Biological Invasions* **8**: 45–59.

Colautti, R. I., and H. J. MacIsaac. 2004. A neutral terminology to define 'invasive' species. *Diversity & Distributions* **10**: 135–141.

Convention on Biological Diversity. 1992. *Convention on Biological Diversity*. Concluded in Rio de Janeiro, Brazil June 5, 1992, entered into force December 29, 1993. Available at www.cbd.int/convention/convention.shtml.

Crooks, J. A. 2005. Lag times and exotic species: The ecology and management of biological invasions in slow-motion. *Ecoscience* **12**: 316–329.

CropLife Canada. 2005. *Annual Report*. CropLife Canada, Etobicoke, ON.

Darbyshire, S. J. 2003. Inventory of Canadian agricultural weeds. Agriculture and Agri-Food Canada Research Branch. Available at res2.agr.ca/ecorc/weeds_herbes/pdf/inv_e.pdf.

Davis, M. A., and K. Thompson. 2000. Eight ways to be a colonizer; two ways to be an invader: a proposed nomenclature scheme for invasion ecology. *Bulletin of the Ecological Society of America* **81**: 226–230.

Dawson, M. 2002. Plant quarantine: Preventing the introduction and spread of alien species harmful to plants. pp. 243–241 *in* Claudi, R., P. Nantel and E. Muckle-Jeffs. *Alien Invaders in Canada's Waters, Wetlands and Forests*. Natural Resources Canada. Ottawa, ON.

De Bruijn, S. L., and E. W. Bork. 2006. Biological control of Canada thistle in temperate pastures using high density rotational cattle grazing. *Biological Control* **36**: 305–315.

De Clerck-Floate, R., and M. Schwarzlander. 2002. Host specificity of *Mogulones cruciger* (Coleoptera: Curculionidae), a biocontrol agent for houndstongue (*Cynoglossum officinale*), with emphasis on testing of native North American Boraginaceae. *Biocontrol Science & Technology* **12**: 293–306.

De Clerck-Floate, R. A., B. Wikeem, and R. S. Bourchier. 2005. Early establishment and dispersal of the weevil, *Mogulones cruciger* (Coleoptera: Curculionidae) for biological control of houndstongue (*Cynoglossum officinale*) in British Columbia, Canada. *Biocontrol Science and Technology* **15**: 173–190.

de Gruchy, M. A., R. J. Reader, and D. W. Larson. 2005. Biomass, productivity, and dominance of alien plants: A multihabitat study in a national park. *Ecology* **86**: 1259–1266.

Derksen, D., R. Anderson, R. Blackshaw, and B. Maxwell. 2002. Weed dynamics and management strategies for cropping systems in the Northern Great Plains. *Agronomy Journal* **94**: 174–185.

DiTommaso, A., and R. Massicotte. 2002. *Vers une gestion intégrée et durable des dépendances vertes: le contrôle biologique de la petite herbe à poux par l'établissement d'un couvert végétal compétitif – rapport final*. Université McGill: Ministère des transports, Service de l'environnement et des études d'intégration au milieu, Montreal, QC.

Eiswerth, M. E., and G. C. van Kooten. 2002. Uncertainty, economics, and the spread of an invasive plant species. *American Journal of Agricultural Economics* **84**: 1317–1322.

Flora of North America Editorial Committee (ed.), 1993+. *Flora of North America North of Mexico. 12+ vols*. New York and Oxford.

Galatowitsch, S. M., N. O. Anderson, and P. D. Ascher. 1999. Invasiveness in wetland plants in temperate North America. *Wetlands* **19**: 733–755.

Gallivan, C. 2003. Leafy spurge control: Elbow, Saskatchewan. *Leafy Spurge in Manitoba: Newsletter of the Leafy Spurge Stakeholders Group* **1**: 6–7.

Gerry, A., and M. Andersen. 2003. *The Ecological Impact of Human-Related Disturbance in the Great Sand Hills: Exotic Plants as Indicators of Integrity*. Fish and Wildlife, Saskatchewan Environment. Regina, SK.

Global Invasive Species Database. Available at www.issg.org/database/welcome.

Government of Canada. 2004. An Invasive Alien Species Strategy for Canada. Available at www.ec.gc.ca/eee-ias/Default.asp?lang=En&n=98DB3ACF-1.

Graham, G. L., G. Peng, K. L. Bailey, and F. A. Holm. 2006a. Effect of dew temperature, post-inoculation condition, and pathogen dose on suppression of scentless chamomile by *Colletotrichum truncatum*. *Biocontrol Science and Technology* **16**: 271–280.

Graham, G. L., G. Peng, K. L. Bailey, and F. A. Holm. 2006b. Interactions of *Colletotrichum truncatum* with herbicides for control of scentless chamomile (*Matricaria perforata*). *Weed Technology* **20**: 877–884.

Gray, P. A., E. Duwors, M. Villeneuve, S. Boyd, D. Legg. 2003. The socio-economic significance of nature-based recreation in Canada. *Environmental Monitoring and Assessment* **86**: 129–147.

Green, S., and K. L. Bailey. 2000. Effects of leaf maturity, infection site, and application rate of *Alternaria cirsinoxia* conidia on infection of Canada thistle (*Cirsium arvense*). *Biological Control* **19**: 167–174.

Green, S., K. Mortensen, and K. L. Bailey. 2001. Host range, temperature response, survival, and overwintering of *Alternaria cirsinoxia*. *Biological Control* **20**: 57–64.

Green, S., G. Peng, T. Connolly, and S. M. Boyetchko. 2004. Effect of moisture and temperature on disease of green foxtail caused by *Drechslera gigantea* and *Pyricularia setariae*. *Plant Disease* **88**: 605–612.

Grekul, C. W., and E. W. Bork. 2004. Herbage yield losses in perennial pasture due to Canada thistle (*Cirsium arvense*). *Weed Technology* **18**: 784–794.

Groves, R. H., R. Boden, and W. M. Lonsdale. 2005. *Jumping the Garden Fence: Invasive Garden Plants in Australia and their environmental and agricultural impacts. CSIRO report prepared for WWF-Australia*. WWF Australia, Sydney, Australia.

Haber, E. 2000. Invasive Plants of Canada: Survey 2000: An Overview of People and Projects. National Botanical Services.

Harker, K. N., G. W. Clayton, R. E. Blackshaw, J. T. O'Donovan, and F. C. Stevenson. 2003. Seeding rate, herbicide timing and competitive hybrids contribute to integrated weed management in canola (*Brassica napus*). *Canadian Journal of Plant Science* **83**: 433–440.

Heidinga, L., and S. D. Wilson. 2002. The impact of an invading alien grass (*Agropyron cristatum*) on species turnover in native prairie. *Diversity & Distributions* **8**: 249–258.

Houlahan, J. E., and C. S. Findlay. 2004. Effect of invasive plant species on temperate wetland plant diversity. *Conservation Biology* **18**: 1132–1138.

Hudon, C., P. Gagnon, and M. Jean. 2005. Hydrological factors controlling the spread of common reed (*Phragmites australis*) in the St. Lawrence River (Quebec, Canada). *Ecoscience* **12**: 347–357.

Industry Canada. 2005. Trade Data Online. Available at strategis.ic.gc.ca/sc_mrkti/tdst/engdoc/tr_homep.html.

International Plant Protection Convention (IPPC). 2007. Pest Risk Analysis (PRA) Training. Participant Manual. Food and Agriculture Organization, Rome, Italy.

Jacobson, H. A., J. B. Petersen, and D. E. Putnam. 1988. Evidence of pre-Columbian Brassica in the northeastern United States. *Rhodora* **90**: 355–362.

Kalischuk, A. R., R. S. Bourchier, and A. S. McClay. 2004. Post-hoc assessment of an operational biocontrol program: efficacy of the flea beetle *Aphthona lacertosa* Rosenhauer (Chrysomelidae: Coleoptera), an introduced biocontrol agent for leafy spurge. *Biological Control* **29**: 418–426.

Kartesz, J. T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland *in* Kartesz, J. T. and C. A. Meacham (Eds.), *Synthesis of the North American Flora, Version 1.0*. North Carolina Botanical Garden. Chapel Hill, NC.

Keenleyside, K., S. Meakin, and H. Moore. 2006. *State of Invasive Alien Species in Canada's Protected Natural Areas*. Unpublished report prepared for the Ecological Integrity Branch, Parks Canada Agency, Gatineau, QC.

Klinkenberg, B. 2006. E-Flora BC: Electronic Atlas of the Plants of British Columbia. Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia, Vancouver, BC. Available at www.eflora.bc.ca.

Lavergne, S., and J. Molofsky. 2007. Increased genetic variation and evolutionary potential drive the success of an invasive grass. *Proceedings of the National Academy Sciences* **104**: 3883–3888.

Lavoie, C., C. Dufresne, and F. Delisle. 2005. The spread of reed canarygrass (*Phalaris arundinacea*) in Quebec: A spatio-temporal perspective. *Ecoscience* **12**: 366–375.

Leafy Spurge Stakeholders Group. 1999. *Leafy Spurge Impact Assessment*, Brandon, MB.

Leafy Spurge Stakeholders Group. 2005. GIS & on-line spatial database for leafy spurge. *Leafy Spurge in Manitoba: Newsletter of the Leafy Spurge Stakeholders Group* **4**: 6–7.

Leeson, J. Y., A. G. Thomas, and L. M. Hall. 2002. *Alberta Weed Survey of Cereal, Oilseed and Pulse Crops in 2001*, *Weed Survey Series Publication 02-1*. Agriculture and Agri-Food Canada, Saskatoon, SK.

Leeson, J. Y., A. G. Thomas, T. Andrews, K. R. Brown, and R. C. Van Acker. 2002. *Manitoba Weed Survey of Cereal and Oilseed Crops in 2002*, *Weed Survey Series Publication 02-2*. Agriculture and Agri-Food Canada, Saskatoon, SK.

Leeson, J. Y., A. G. Thomas, and C. A. Brenzil. 2003. *Saskatchewan Weed Survey of Cereal, Oilseed and Pulse Crops in 2001*, *Weed Survey Series Publication 03-1*. Agriculture and Agri-Food Canada, Saskatoon, SK.

Leeson, J. Y., A. G. Thomas, L. M. Hall, C. A. Brenzil, T. Andrews, K. R. Brown, and R. Van Acker. 2005. *Prairie Weed Survey. Cereal, Oilseed and Pulse Crops 1970s to the 2000s. Weed Survey Series Publication 05-1*. Agriculture and Agri-Food Canada, Saskatoon Research Centre, Saskatoon, SK.

Leeson, J. Y., A. G. Thomas, and J. O'Donovan. 2006. Economic impact of alien weeds on wheat, barley and canola production. Poster presented at Canadian Weed Science Society Meeting, November 27-29, 2006. Victoria, BC.

Levine, J. M., and C. M. D'Antonio. 2003. Forecasting biological invasions with increasing international trade. *Conservation Biology* **17**: 322–326.

Lewis, G. 2006. *Protecting Canada's Natural Ecosystems From Invasive Alien Plant Species: Is Sub-national Weed Control Legislation Up to the Task*. LL.M. Thesis, University of Ottawa. Unpublished.

Lonsdale, W. M. 1994. Inviting trouble: Introduced pasture species in northern Australia. *Australian Journal of Ecology* **19**: 345–354.

Lopian, R. 2003. The International Plant Protection Convention and invasive alien species. pp. 6–16 *in* Proceedings of a workshop on Identification of risks and management of invasive alien species using the IPPC framework. September 22–26, 2003, Braunschweig, Germany. Available at ftp.fao.org/docrep/fao/008/y5968e/y5968e00.pdf.

Mack, R. N., and M. Erneberg. 2002. The United States naturalized flora: Largely the product of deliberate introductions. *Annals of the Missouri Botanical Garden* **89**: 176–189.

Mack, R. N. 2003a. Plant naturalizations and invasions in the eastern United States: 1634–1860. *Annals of the Missouri Botanical Garden* **90**: 77–90.

Mack, R. N. 2003b. Global plant dispersal, naturalization and invasion: pathways, modes and circumstances. pp. 3–30 *in* Ruiz, G. and J. Carlton (Eds.), *Global Pathways of Biotic Invasions*: Island Press, Washington, DC.

Maheu-Giroux, M. and de Blois, S. 2007. Landscape ecology of *Phragmites australis* invasion in networks of linear wetlands. *Landscape Ecology* **22(2)**: 285–301.

Mandryk, A. M., and R. W. Wein. 2006. Exotic vascular plant invasiveness and forest invasibility in urban boreal forest types. *Biological Invasions* **8**: 1651–1662.

Massicotte, R., A. DiTommaso, J. P. Beaumont, Y. Bédard, and A. K. Watson. 2001. Establishment of competitive vegetation cover to reduce common ragweed (*Ambrosia artemisiifolia* L.) along roadsides. pp. 46 *in* Bernier, D., R. A. Campbell and D. Cloutier (Eds.) Proceedings of the 2001 National Meeting, Expert Committee on Weeds, 25-28 Nov. 2001, Quebec City, QC. Available at www.cwss-scm.ca/pdf/ECW2001Proceedings.pdf

McClay, A. S., K. M. Fry, E. J. Korpela, R. M. Lange, and L. D. Roy. 2004. *Costs and threats of invasive species to Alberta's natural resources*. Alberta Sustainable Resource Development. Edmonton, AB.

Meloche, C., and S. D. Murphy. 2006. Managing tree-of-heaven (*Ailanthus altissima*) in parks and protected areas: A case study of Rondeau Provincial Park, ON. *Environmental Management* **37**: 764–772.

Ministère du Développement durable de l'Environnement et des Parcs. 2006. *Rapport annuel 2004–2005 sur la mise en oeuvre de la Stratégie et du Plan d'action québécois sur la diversité biologique (2004–2007)*, Quebec City, QC.

Moffatt, S. F., S. M. McLachlan, N. C. Kenkel. 2004. Impacts of land use on riparian forest along an urban-rural gradient in southern Manitoba. *Plant Ecology*. **174**(1): 119–135.

Morse, J. C. 2006. *The Trichoptera World Checklist*. Trichoptera Checklist Coordinating Committee. Available at entweb.clemson.edu/database/trichopt/index.htm.

Morse, L. E., J. M. Randall, N. Benton, R. Hiebert, and S. Lu. 2004. *An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity. Version 1*. NatureServe, Arlington, VA.

Myers, J. H., M. Denoth, and J. Shaben. 2004. *Invasive Plants: Their Impacts and Control in Changing Environments*. pp. 1–6 *in* Hooper, T. D. (Ed.) Proceedings of the Species at Risk 2004 Pathways to Recovery Conference, March 2–6, 2004, Victoria, BC.

National Invasive Species Council. 2007. *Training and Implementation Guide for Pathway Definition, Risk Analysis and Risk Prioritization*. Riverdale, MD.

O'Donovan, J. T., R. E. Blackshaw, K. N. Harker, G. W. Clayton, and D. C. Maurice. 2005. Field evaluation of regression equations to estimate crop yield losses due to weeds. *Canadian Journal of Plant Science* **85**: 955–962.

O'Driscoll, C. W. 2006. *Risk Assessment Models for Weeds and Invasive Plants*: Presentation to the North American Weed Management Association Conference, Calgary, AB. September 2006.

Office of Technology Assessment (OTA). 1993. *Harmful Non-indigenous Species in the United Status*. Government Report, OTA-F-565, Washington, DC.

Olson, D. M., and E. Dinerstein. 2002. The Global 200: Priority Ecoregions for Global Conservation. *Annals of the Missouri Botanical Garden* **89**: 199–224.

Ontario Federation of Anglers and Hunters. 2003. *Fanwort Find: Volunteer Monitoring Protocol*. Available at www.invadingspecies.com/Downloads/Fanwort_Pro.pdf.

Pachkowski, J. 2003. *Bio-control of Leafy Spurge in Support of Recovery of Species at Risk. Year III. 2003 Field Research Results*. Rural Development Institute, Brandon University, Brandon, MB.

Page, N. A., R. E. Wall, S. J. Darbyshire, and G. A. Mulligan. 2006. The biology of invasive alien plants in Canada. 4. *Heracleum mantegazzianum* Sommier & Levier. *Canadian Journal of Plant Science* **86**: 569–589.

Palmer, M. W. 2005. Temporal trends of exotic species richness in North American floras: An overview. *Ecoscience* **12**: 386–390.

Parker, I. M., D. Simberloff, W. M. Lonsdale, K. Goodell, M. Wonham, P. M. Kareiva, M. H. Williamson, B. Von Holle, P. B. Moyle, J. E. Byers, and L. Goldwasser. 1999. Impact: toward a framework for understanding the ecological effects of invaders. *Biological Invasions* **1**: 3–19.

Paynter, Q., S. M. Csurhes, T. A. Heard, J. Ireson, M. H. Julien, J. Lloyd, W. M. Lonsdale, W. A. Palmer, A. W. Sheppard, and R. D. van Klinken. 2003. Worth the risk? Introduction of legumes can cause more harm than good: an Australian perspective. *Australian Systematic Botany* **16**: 81–88.

Peng, G., K. L. Bailey, H. L. Hinz, and K. N. Byer. 2005. *Colletotrichum* sp: a potential candidate for biocontrol of scentless chamomile (*Matricaria perforata*) in western Canada. *Biocontrol Science and Technology* **15**: 497–511.

Perzoff, T. 2006. Invasive, alien and noxious plants of British Columbia. Available at www.geog.ubc.ca/~brian/florae/Invasive_species_list.htm.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 1999. Environmental and Economic Costs Associated with Non-indigenous Species in the United Status. College of Agriculture and Life Sciences, Cornell University. Ithaca, NY. June 12, 1999. Available at www.news.cornell.edu/releases/Jan99/species_costs.html.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and Economic Costs of Nonindigenous Species in the US. *BioScience* **50**(1): 53–65.

Pimentel, D., S. McNair, J. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, and T. Tsomondo. 2001. Economic and environmental threats of alien plant, animal and microbe invasions. *Agriculture, Ecosystems and Environment* **84**: 1–20.

Polster, D. 2007. Carpet burweed (*Soliva sessilis* Ruiz & Pav.) in Canada. *Botanical Electronic News,* No. 373. Available at www.ou.edu/cas/botany-micro/ben/ben373.html.

Prasad, R. 2005. Current status and management options of exotic and invasive weeds of forestry in coastal British Columbia, Canada. *Outlooks on Pest Management* **16**: 225–229.

Pyšek, P., D. M. Richardson, M. Rejmánek, G. L. Webster, M. Williamson, and J. Kirschner. 2004. Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. *Taxon* **53**: 131–143.

Randall, J. M. 1996. Weed control for the preservation of biodiversity. *Weed Technology* **10**:370–383.

ReForest London. 2006. *Annual Report*. ReForest London, London, ON.

Regan, T. J., M. A. McCarthy, P. W. J. Baxter, F. D. Panetta, H. P. Possingham. 2006. Optimal eradication: When to stop looking for an invasive plant. *Ecology Letters* **9(7)**: 759–766.

Rejmánek, M., and M. J. Pitcairn. 2002. When is eradication of exotic pest plants a realistic goal? pp. 249–253 *in* Veitch, C. R. and M. N. Clout (Eds.), *Turning the Tide: the Eradication of Invasive Species*. IUCN SSC Invasive Species Specialist Group. Gland, Switzerland, and Cambridge, UK.

Richardson, D. M., and W. Thuiller. 2007. Home away from home – objective mapping of high-risk source areas for plant introductions. *Diversity and Distributions* **13**: 299–312.

Robichaud, F. W., and P. M. Catling. 2003. Potential value of first glume length in differentiating native and alien races of Common Reed, *Phragmites australis*. *Botanical Electronic News* **310**: 1-3.

RNT Consulting Inc. 2002. Environmental and economic costs of alien invasive species in Canada. Picton, ON. Available at www.cise-scie.ca/english/library/bg_papers/biodiversity/enviro_economic_costs_alien_invasive_species/Invasives.pdf.

Rose, M., and L. Hermanutz. 2004. Are boreal ecosystems susceptible to alien plant invasion? Evidence from protected areas. *Oecologia* **139**: 467–477.

Rouget, M., and D. M. Richardson. 2003. Inferring process from pattern in plant invasions: A semimechanistic model incorporating propagule pressure and environmental factors. *American Naturalist* **162**: 713–724.

Royer, F. and R. Dickinson. 1999. Weeds of Canada and the Northern United States. University of Alberta Press and Lone Pine Press. Edmonton, AB.

Saltonstall, K. 2002. Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *Proceedings of the National Academy of Sciences* **99**: 2445–2449.

Selbo, S. M., and A. A. Snow. 2004. The potential for hybridization between *Typha angustifolia* and *Typha latifolia* in a constructed wetland. *Aquatic Botany* **78**: 361–369.

Sinclair, A., and P. M. Catling. 1999. The value of cutting in the management of glossy buckthorn (Rhamnus frangula E.). *The Wetland Journal* **11**(2): 25–27.

Smith, S. G. 2000. *Typha*. In: Flora of North America Editorial Committee (eds.), *Flora of North America North of Mexico*. Magnoliophyta: Alismatidae, Arecidae, Commelinidae (in part), and Zingiberidae. Oxford University Press, New York and Oxford. Vol. 22, pp. 283–284.

Statistics Canada. 2003. *North American Industry Classification System – NAICS Canada 2002. Publication 12-501-XPE*. Ottawa, ON.

Stinson, K. A., S. A. Campbell, J. R. Powell, B. E. Wolfe, R. M. Callaway, G. C. Thelen, S. G. Hallett, D. Prati, and J. N. Klironomos. 2006. Invasive plant suppresses the growth of native tree seedlings by disrupting belowground mutualisms. *Public Library of Science Biology* **4**(5): e140: 0727–0731.

Stockton, S. A., S. Allombert, A. J. Gaston, J. L. Martin. 2005. A natural experiment on the effects of high deer densities on the native flora of coastal temperate rain forests. *Biological Conservation* **126**(1): 118–128.

Stronen, A. V. 2002. *Impacts on Canadian Species at Risk from Invasive Alien Species (draft report)*. Canadian Wildlife Service, Hull, QC.

Sutherst, R. W., G. F. Maywald, W. Bottomley, and A. Bourne. 2004. *CLIMEX v2 CD and User's Guide*. Hearne Scientific Software, Melbourne, Australia.

Swanton, C. J., K. N. Harker, and R. L. Anderson. 1993. Crop losses due to weeds in Canada. *Weed Technology* **7**: 537–542.

Swanton, C. J., and B. D. Booth. 2004. Management of weed seedbanks in the context of populations and communities. *Weed Technology* **18**: 1496–1502.

Teshler, M. P., A. DiTommaso, J. A. Gagnon, and A. K. Watson. 2002. *Ambrosia artemisiifolia* L., common ragweed (Asteraceae). pp. 290–294 *in* Mason, P. G. and J. T. Huber (eds.), *Biological Control Programmes in Canada, 1981–2000*. CABI Publishing. Wallingford, UK.

Terrestrial Plants and Plant Pests Working Group. 2004. *Proposed Action Plan for Invasive Alien Terrestrial Plants and Plant Pests — Phase 1*. Ottawa, ON. [Available online] www.ec.gc.ca/eee-ias/default.asp?lang=En&n=4C8E46C8-1

Terrestrial Plants and Plant Pests Working Group. 2005. *Action Plan for Invasive Alien Terrestrial Plants and Plant Pests — Phase 2: Proposed Implementation Plan*. Ottawa, ON. [Available online] www.ec.gc.ca/eee-ias/default.asp?lang=En&n=4C8E46C8-1

Thompson, D. G., and D. G. Pitt. 2003. A review of Canadian forest vegetation management research and practice. *Annals of Forest Science* **60**: 559–572.

Udvardy, M. D. F. 1975. *A classification of the biogeographical provinces of the world. Occasional paper No. 18*. IUCN, Morges, Switzerland.

United States Department of Agriculture – Natural Resources Conservation Service (USDA-NRCS). 2007. The PLANTS Database. National Plant Data Center, Baton Rouge, LA. Available at plants.usda.gov.

Urban Forest Associates. 2002. Invasive exotic species ranking for Southern Ontario. Available at www.serontario.org/pdfs/exotics.pdf.

Van Hezewijk, B., and R. S. Bourchier. 2005. Is two company or a crowd: how does conspecific density affect the small-scale disposal of a weed biocontrol agent? *Biocontrol Science and Technology* **15**: 191–205.

Warwick, S. I., A. Francis, and G. A. Mulligan. 2003. Brassicaceae of Canada. Agriculture and Agri-Food Canada Research Branch, Eastern Cereal and Oilseed Research Centre. Available at www.cbif.gc.ca/spp_pages/brass/index_e.php.

Watson, A. K. 2003. *Vers une gestion intégrée et durable des dépendances vertes: la suppression de la petite herbe à poux par l'utilisation d'un produit naturel*. McGill University, Department of Plant Science; Quebec: Ministère des Transports, Direction de la recherche et de l'environnement, Montréal, QC.

White, D. J., E. Haber, and C. Keddy. 1993. Invasive Plants of Natural Habitats in Canada: An Integrated Review of Wetland and Upland Species and Legislation Governing their Control. Canadian Wildlife Service, Environment Canada. Available at www.cws-scf.ec.gc.ca/publications/inv/cont_e.cfm.

Wiken, E. B. 1986. *Terrestrial EcoZones of Canada. Ecological Land Classification Series No. 19*. Lands Directorate, Environment Canada, Hull, QC.

Wilson, J. R. U., D. M. Richardson, M. Rouget, S. Proches, M. A. Amis, L. Henderson, and W. Thuiller. 2007. Residence time and potential range: crucial considerations in modelling plant invasions. *Diversity and Distributions* **13**: 11–22.

Wittenberg, R., and M. J. W. Cock, eds. 2001. *Invasive Alien Species: A Toolkit of Best Prevention and Management Practices*. CABI. Wallingford, UK.

World Wildlife Fund Canada. 2003. *The Nature Audit. Setting Canada's Conservation Agenda for the 21st Century. Report No. 1*, Toronto, ON. Available at wwf.ca/aboutwwf/whatwedo/thenatureaudit/resources/pdf/thenatureaudit-may2003.pdf. Accessed July 17, 2007.

Zehtab-Jadid, F., and G. Landry. 2003. A Preliminary Assessment of the Economic Impact of Leafy Spurge in Manitoba. pp. *in* Proceedings of the Leafy Spurge Forum, January 16–17, 2003, Brandon, MB. Available at www.brandonu.ca/rdi/LSSG/for_proc/papers.html.

8.2 Legislation Cited

A. International

International Plant Protection Convention

ISPM No. 05 (2007) Glossary of phytosanitary terms

ISPM No. 11 (2004) Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms

Convention on Biological Diversity

B. Federal

Plant Protection Act, 1990, c. 22

Seeds Act, R.S., 1985, c. S-8

Weed Seeds Order, 2005, SOR/2005-220

Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act, 1992, c. 52

Wild Animal and Plant Trade Regulations, SOR/96-263

Canada National Parks Act, 2000, c. 32

Species at Risk Act, 2002, c. 29

Canadian Environmental Protection Act, 1999, 1999, c. 33

Indian Act, R.S., 1985, c. I-5
Pest Control Products Act, 2002, c. 28
Customs Act, 1985, c. 1 (2nd Supp.)

C. Provincial

Plant Health Act, S.N.B. 1998, c. P-9.01
Plant Protection Act, R.S.N.L. 1990, c. P-16

Appendix I: Questionnaire

Survey on weed and invasive plant problems and programs in Canada 2001–2005

As part of *An Invasive Alien Species Strategy for Canada*, we have been asked by the Canadian Food Inspection Agency to prepare a report on the status of invasive plant problems, and programs dealing with them, in Canada. This survey is designed to help gather information needed for this report. As the time frame for the project is short, we have tried to make this survey as easy as possible to complete. Most questions can be answered just by marking an X in the appropriate boxes. However, space is provided for you to enter more detailed information and comments if you wish.

For the purposes of this survey, invasive plants are any plant species not native to Canada that cause negative environmental, economic, or social effects. These include agricultural weeds, and non-native plants that invade natural ecosystems, parks, gardens, water bodies, etc.

You may provide this information in whichever way is most convenient for you:

- You may complete the questionnaire and return it by email or fax.
- If you would prefer to provide information by telephone, please indicate when would be a convenient time to schedule a call.
- If the information is available from a report or website produced by your organization or agency, please provide this or indicate where it can be found, and we will extract the information ourselves.

Completed questionnaires may be returned by email to info@mcclay-ecoscience.com or by fax to (780) 410-0496.

This survey is entirely voluntary; however, your assistance in providing this information is very much appreciated. A report based on information provided in the survey will be published by the Canadian Food Inspection Agency, and will help to assess progress in our knowledge and management of invasive plant problems in Canada.

If you have any questions, please contact us at any of the phone numbers and email addresses below.

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A. Identification information

Please use the shaded areas to enter your answers.

1.	**Organization/Agency/Company**	
2.	**Address or location**	
3.	**Contact person**	
4.	**Position**	
5.	**Phone**	
6.	**Email**	
7.	**Date of survey completion or interview**	
8.	**Interviewer**	
Did your organization or agency deal with weed or invasive plant issues in any of your activities or initiatives during 2001-2005 (see the following questions for examples)? Enter an X in the box for yes or no.		
9.	Yes ☐ No ☐	If no, stop here. Thank you!

B. Types of invasive plant programs

During the period 2001-2005, did your agency or organization deal with weeds or invasive plants in any of these ways? Enter an **X** in the box for any that apply		
10.	Exclusion or prevention ☐ (programs to keep new invasive plant species out, such as quarantines, barriers, inspection, sanitation)	Details and comments:
11.	Rapid response ☐ (programs to deal rapidly with newly detected invasive plants before they spread, e.g. by spot spraying, hand pulling, etc.)	Details and comments:
12.	Eradication ☐ (programs to completely destroy or remove an established invasive plant species from a given area)	Details and comments:
13.	Management or control ☐ (managing established invasive plants, by chemical, biological, cultural, mechanical, integrated methods)	Details and comments:
During the period 2001-2005, was your agency or organization involved in communication about weeds or invasive plants in any of these ways? Enter an **X** in the box for any that apply		
14.	Public awareness ☐ (e.g., brochures, talks, signs, displays, media items, websites, educational material)	Details and comments:
15.	Facilitation ☐ (e.g. organizing conferences, meetings, workshops, planning, networking, funding)	Details and comments:
16.	Enforcement ☐ (of noxious weed legislation, pesticide regulation, etc.)	Details and comments:

C. Field data on invasive plants and their impacts

During the period 2001-2005, did your agency or organization collect field data on weed or invasive plant problems in any of these ways? This includes activities that might be described as weed surveys, weed mapping, scouting, monitoring, inventories, etc., as well as field work to assess the effects, impacts, or management of weeds. Enter an [X] in the box for any that apply		
17.	Early detection ☐ (specific efforts to find *newly introduced* plant species *before* they can spread or become a problem)	Details and comments:
18.	Weed or invasive plant surveys ☐ (collecting field data on the distribution or abundance of weeds or invasive plants: including mapping, monitoring, inventorying, etc.) See also questions 21 to 26.	Details and comments:
19.	Assessing effects of weeds ☐ or invasive plants (measuring yield losses due to weeds, ecological effects of invasive plants, control costs, economic impacts, socio-economic impacts, health effects, etc.) See also question 27.	Details and comments:
20.	Assessing the effectiveness ☐ of control or management methods (e.g., field trials for chemical, biological, or cultural control)	Details and comments:

If you answered "yes" to question 18, please answer questions 21 to 26 about your weed or invasive plant field data.		
21.	**What geographic area or jurisdiction did your field data cover?** (e.g. a province, municipality, conservation area, etc.)	Area covered:
22.	**What habitats were your field data collected from?** Check any that apply. cultivated agricultural land ☐ rangeland and pasture ☐ forested areas ☐ roadsides and rights of way ☐ protected natural areas ☐ urban areas ☐ aquatic habitats ☐	Others (describe)
23.	**What categories of weeds or invasive plants did your field data cover?** for instance: all; weeds of cultivated agricultural land; particular species (name them); aquatic weeds; noxious or regulated weeds; environmental weeds; etc.	Categories:
24.	**How did you collect your field data?** through field surveys specifically designed to collect weed or invasive plant information ☐ in the course of weed or invasive plant management operations ☐ in the course of other field operations ☐ in response to calls or complaints from the public ☐	in the course of regulatory or enforcement activities ☐ through phone surveys or questionnaires ☐ by examining specimens or samples submitted by the public ☐ other methods (use space in question 25 to describe) ☐

25.	**What kind of data did you collect on the abundance of weeds or invasive plants?**	
	Qualitative data: Species presence only ☐ Species presence and absence ☐ Semi-quantitative data: e.g. visual estimates of high/ medium/low abundance ☐ Quantitative data: Density (actual numbers or counts of plants in a given area) ☐ Cover (percentage of ground covered by the plant) ☐ Infested area (size of infested patches in square metres, acres, etc.) ☐ Biomass (weight of plant tissue) ☐	Details and comments for questions 24 and 25:
26.	**How did you record information on the location of weed populations and sites?**	
	Paper maps ☐ GPS ☐ Legal descriptions (township and range system) ☐ Lat/long or UTM ☐	Other (describe)
27.	**If you answered "yes" to question 19, what kind of data did you collect on the impact or effects of weeds or invasive plants?**	
	Ecological or environmental effects (e.g. on biodiversity, water quality, habitat quality) ☐ Crop yield losses in agriculture ☐ Control or management costs ☐ Other economic impacts (e.g. effects on transportation, land values, recreation, etc.) ☐ Social effects (e.g. human health, allergies, amenity losses) ☐	Details and comments:

28.	**Do you maintain a list of problem weeds or invasive plant species?** Yes ☐ No ☐ Please paste the list in this space, attach the list as a separate file, or provide a link at which the list can be accessed.	Species:
29.	**What plant species, if any, became new or emerging weed or invasive problems for you during the period 2001-2005?** This would include species that were found for the first time in your area and are considered a potential threat, or those that were previously known to be present but had not been considered a problem.	Species:
30.	**What other agencies or organizations did you cooperate with on weed or invasive plant programs during the period 2001 - 2005?**	Cooperating agencies:
31.	**Has one agency or department in your province/territory been officially designated as the lead agency in dealing with weed or invasive plant issues?** Yes ☐ No ☐	Lead agency:

Thank you very much.

Appendix II: List of Questionnaire Respondents

Agricultural Credit Corporation of Saskatchewan
3085 Albert Street
Regina, SK S4S 0B1

Agriculture and Agri-Food Canada, Saskatoon
Saskatoon Research Centre
107 Science Place
Saskatoon, SK S7N 0X2

Agriculture and Agri-Food Canada, Lethbridge
Lethbridge Research Centre
5403 1st Avenue South
Lethbridge, AB T1J 4B1

Alberta Biodiversity Monitoring Program
L1-364 CCIS, Biological Sciences Building
University of Alberta
Edmonton, AB T6G 2E9

Alberta Government
Lands Division, Rangeland Management Branch
4th floor, Great West Life Building
9920 108 Street
Edmonton, AB T5K 2M4

Alberta Infrastructure and Transportation
Technical Standards Branch – Environmental Management Services
2nd Floor, Twin Atria Building
4999 98 Avenue
Edmonton, AB T6B 2X3

Alberta Invasive Plants Council
Box 79066, 926 Ash Street
Sherwood Park, AB T8A 2G1

Alberta Sustainable Resource Development
Forestry Division
9920 108 Street
Edmonton, AB, T5K 2M4

Alberta Wilderness Association
455 12 Street NW
Calgary, AB T2N 1Y9

BC Hydro
6911 Southpoint Dr.
Burnaby, BC V3N 4X8

BC Ministry of Forests and Range
Range Branch
1907 Ridgewood Road
Nelson, BC V1L 6K1

BC Oil & Gas Commission
200-10003 110th Avenue
Fort St. John, BC

British Columbia Ministry of Environment
P.O. Box 9398 STN PROV GOV
Victoria, BC V8W 9M9

City of Calgary # 210
P.O. Box 2100 Station M
Calgary, AB T2P 2M5

City of St. John's
10 New Gower Street
P.O. Box 908
St. John's, NL A1C 5M2

City of Victoria
#1 Centennial Square
Victoria, BC V8W 1P6

City of Winnipeg
Public Works Dept., Parks and Open Space Division
105-1155 Pacific Avenue
Winnipeg, MB R3E 3P1

Clean Annapolis River Project (CARP)
151 Victoria Street
P.O. Box 395
Annapolis Royal, NS B0S 1A0

Columbia Power Corporation
200-445 13th Avenue
Castlegar, BC V1N 1G1

Connell Memorial Herbarium UNB
Dept. of Biology, University of New Brunswick
Fredericton, NB E3B 6E1

Department of Biology
University of Western Ontario
Biological & Geological Sciences Building
London, ON N6A 5B7

Department of Geography
University of Western Ontario
Rm 2403, Social Sciences Centre
London, ON N6A 5C2

Ducks Unlimited Canada
5015 49th Street
Camrose, AB T4V 1N5

Ducks Unlimited Canada
509 Pioneer Avenue
North Battleford, SK S9A 0V6

Edmonton Naturalization Group
6608 84 Street NW
Edmonton, AB T6E 2W9

Environment Saskatchewan
3211 Albert Street
Regina, SK S4S 5W6

Forest Resources, Forest Management Division
Department of Environment and Natural Resources
Government of the Northwest Territories
Box 4354,173 Hay River Dene Reserve
Hay River, NT X0E 1G3

Government of Nunavut
Department of Environment
P.O. Box 209
Igloolik, NU X0A 0L0

Leafy Spurge Stakeholders Group
c/o Rural Development Institute,
Brandon University
270 18th Street
Brandon, MB R7A 6A9

Louise-Roblin Weed Control District
P.O. Box 429
26 South Railway Avenue East
Crystal City, MB R0K 0N0

Manitoba Hydro
35 Sutherland Avenue
Winnipeg, MB R2W 3C5

Manitoba Museum of Man and Nature
Herbarium, Botany Department
190 Rupert Avenue
Winnipeg, MB R3B 0N2

Manitoba Weed Supervisors Association
Box 126
Sanford, MB R0G 2J0

Memorial University of Newfoundland Botanical Garden
306 Mount Scio Road
St. John's, NL A1C 5S7

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
Direction de l'innovation scientifique et technologique
200, chemin Sainte-Foy, 9e étage
Québec, QC G1R 4X6

Ministère du Developpement durable, de l'Environnement et des Parcs
Direction du patrimoine ecologique et des parcs
675 boulevard René Levesque E.
Quebec, QC G1R 5V7

Native Plant Society of Saskatchewan
Box 21099
Saskatoon, SK S7H 5N9

Natural Resources Canada
Canadian Forest Service
Northern Forestry Centre
5320-122 Street
Edmonton, AB T6H 3S5

New Brunswick Department of Agriculture and Aquaculture
850 Lincoln Road, P.O. Box 6000
Fredericton, NB E3B 5H1

New Brunswick Museum
277 Douglas Avenue
Saint John, NB E2K 1E5

Nova Scotia Agricultural College
P.O. Box 550
Truro, NS B2N 5B2
Nova Scotia Environment and Labour
Protected Areas Branch
5151 Terminal Road, P.O. Box 697
Halifax, NS B3J 2T8

Ontario Ministry of Agriculture, Food and Rural Affairs
Crop Science Building
University of Guelph
Guelph, ON N1G 2W1

Ontario Ministry of Natural Resources
64 Church Street
Sault Ste Marie, ON P6A 3H3

Ontario Ministry of Northern Development and Mines
933 Ramsey Lake Road
Sudbury, ON P3E 6B5

Parks, Conservation, Recreation and Sport Division
Alberta Tourism, Parks, Recreation and Culture
2nd flr, 9820 106 Street
Edmonton, AB T4K 2J6

Parks, Conservation, Recreation and Sport Division
Alberta Tourism, Parks, Recreation and Culture
Suite 1, 250 Diamond Avenue
Spruce Grove, AB T7X 4C7

Polster Environmental Services Ltd.
5953 Deuchars Drive
Duncan, BC V9L 1L5

ReForest London
PO Box 1852 Stn B
London, ON N6A 5H9

Royal Alberta Museum
12845 102 Avenue
Edmonton, AB T5N 0M6

SASK Herbarium
Department of Plant Sciences
University of Saskatchewan
51 Campus Drive
Saskatoon, SK S7N 5A8

Saskatchewan Agriculture and Food
3085 Albert Street
Regina, SK S4S 0B1

Saskatchewan Purple Loosestrife and Invasive Species Project (SPLISP)
P.O. Box 20199
Saskatoon, SK S7H 5N9

Saskatchewan Research Council
125-15 Innovation Boulevard
Saskatoon, SK S7N 2X8

Sierra Club of Canada (National Office)
1 Nicholas Street, Suite 412
Ottawa, ON K1N 7B7

The Bruce Trail Association
P.O. Box 857
Hamilton, ON L8N 3N9

UBC Botanical Garden
6804 Southwest Marine Drive
Vancouver, BC V6T 1Z4

University of Alberta
Department of Renewable Resources
5505 93A Avenue
Edmonton, AB T6B 2K5

Vascular Plant Herbarium
Department of Biological Sciences
University of Alberta
Edmonton, AB T6G 2E9

Wildlife Division
Newfoundland and Labrador Department of Environment and Conservation
117 Riverside Drive, P.O. Box 2007
Corner Brook, NL A2H 7S1

Yukon Conservation Society
302 Hawkins Street
Whitehorse, YT Y1A 1X6

Yukon Department of Environment
Box 2703
Whitehorse, YT Y1A 2C6

Yukon Department of Highways & Public Works
Transportation Engineering
461 Range Road
Whitehorse, YT Y1A 6N5

The Canadian Food Inspection Agency (CFIA)

The mandate of the Canadian Food Inspection Agency (CFIA) is to safeguard food, animals, and plants, which enhances the health and well-being of Canada's people, environment, and economy. As part of this mandate, CFIA develops and delivers programs and services designed to protect Canada's plant resource base, under the *Plant Protection Act.* As a signatory party to the *International Plant Protection Convention* (IPPC) and to the *Convention on Biological Diversity* (CBD), Canada is responsible for administering a plant health program that includes addressing the threats of invasive species. As Canada's national plant protection organization, the CFIA bears primary responsibility for delivering this program, but works in co-operation with other government departments or agencies as well as provinces and municipalities.

The Invasive Alien Plants Program at CFIA

In September 2004, the Canadian federal and provincial governments developed *An Invasive Alien Species Strategy for Canada* and proposed a more detailed *Action Plan for Invasive Alien Terrestrial Plants and Plant Pests*. To implement its part of the strategy, the CFIA created an Invasive Alien Species (IAS) Section under its Plant Products Directorate to support existing national efforts that address plant pests and pest plants and enhanced areas in other branches to address the threats of IAS. The CFIA is a science-based regulator, committed to sustaining Canada's plant resource base and protecting Canada's agricultural and forestry resource bases.

In keeping with international standards, IAS programs incorporate input from national partners and stakeholders, and are based on science advice and risk analysis outcomes. Key initiatives fall under the broad headings of leadership and co-ordination, legislation and regulation, risk management (including information management, border controls, and emergency planning), and international co-operation.