EVALUATION OF A COLLECTIONS NETWORK AS A SOURCE OF INFORMATION ON ECONOMICALLY IMPORTANT PLANTS

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Abstract.—We compared a collections network with six other sources to provide quantitative evidence of its relative value in gathering essential information on economically important plants. The collection network included 30 Canadian herbaria. The other sources included: 1) eight Canadian Conservation Data Centers; 2) 12 provincial Invasive Species Councils; 3) 18 of the largest Canadian botanical gardens and arboreta; 4) 14 Canadian botanical clubs; 5) a Web search; and 6) a search of scientific journals. We used two major invasive plants as an example: sea buckthorn (*Hipppohae rhamnoides* L.) and scotch broom [*Cytisus scoparius* (L.) Link]. For each of the sources involving communication we asked five questions. For the Web and literature searches we provided word strings. The results were evaluated on the basis of five criteria: 1) amount of information gathered; 2) currency of information; 3) uniqueness of useful information; 4) response time; and 5) association with experts. Two aspects of the results are particularly important: 1) all sources provided some useful and unique information; and 2) a collection network can be the very best source of information to guide the management of economically important plants. In a world of ever-increasing information sources, collections often remain at the forefront.

INTRODUCTION

Value of and Support for Collections

The importance of collections and their contributions of information have increased in the recent years due to greater impacts of a changing environment. Collections play a vital role for society by contributing to management of environmental problems, public health and safety, monitoring environmental changes, and enhancing national security. Unfortunately, many herbaria and other biological collections throughout the world have experienced reduced financial support over the past few decades. The consequences of this include not only serious damage to irreplaceable national heritage, but also a diminished capability to deal with increasing environmental problems. The reasons for this reduced support are both economic and trend-related. An underappreciation of the value of collections has become widespread (Suarez and Tsutsui 2004). Collection managers and curators now need to spend substantial time explaining value that was much more generally accepted and understood only a few decades ago.

Explanations and Intentions

A large number of articles have acknowledged the value of biological collections (Holland 1965, Cohen and Cressy 1969, Genoways et al. 1976, Miller 1985, Nudds and Pettitt 1986, Catling et al. 1989, Danks 1991, Morin et al 1989, Cato 1991, Wiggins et al. 1991, Catling and Dang 1992, Catling 2001, Funk 2003a, 2003b; Prather et al. 2004a, 2004b; Suarez and Tsutsui 2004, Chapman 2005a, Funk et al. 2005). As recently as 1995, Canada's response to the Convention on Biological Diversity included strategic direction 2.7 "... maintain the capacity of museums and other institutions to ... store collected specimens, as well as maintain their ability to effectively disseminate information" (Biodiversity Convention Office 1995). In the key actions of the Invasive Alien Species

Strategy for Canada (Environment Canada 2004) a priority key action is "support existing diagnostic tools of biological collections and taxonomic libraries."

These articulate explanations and well-conceived intentions are very useful, but there is a need for evidence to support them in the form of quantitative analysis that includes considerations of recent developments, such as the increases in information accessibility through the Web. Because new, quantitative evidence is an important part of the explanation of value, we designed an experiment to evaluate a collections network of 30 cooperating Canadian herbaria and their specimens (Fig. 1). This was done through comparison with other sources with respect to five questions regarding two invasive alien plants: sea buckthorn (*Hippophae rhamnoides* L.) and scotch broom [*Cytisus scoparius* (L.) Link], both of which have been rated as the top 100 most serious invasive plants of natural habitats in Canada (Catling 2005, Catling and Mitrow 2005). The economic importance of invasive plants, including those of natural habitats, is generally well-known, and management costs reach hundreds of millions of dollars in North America each year (Pimentel et al. 2005, Colautti et al. 2006).

Our hypothesis was that the herbarium collections network remains a superior source of information on invasive plants, despite a substantial recent increase in other sources of information on this subject.

Material and Methods

Subject Plants

Sea buckthorn (Fig. 2) is a remarkable plant that has huge economic potential (Small and Catling 2002). Its cultivation could expand into a new industry for Canada. It has turned into a significant fruit crop in North America only in the last decade (Li and McLoughlin 1997, Li and Shroeder 1999, Li and Beveridge 2003). The orange berries are produced in abundance and contain medicinal and nutritious substances. As well as being a very valuable plant, sea buckthorn can escape to threaten native biodiversity (Yaki 2007, 2010). Scotch broom (Fig. 3), has dominated rocky headlands and Garry Oak openings on Vancouver Island, and as a result, at least 100 native plant species are at risk and some have been lost at their only Canadian sites (Peterson and Prasad 1998). This plant is also a serious threat to agriculture, forestry, health, and to the general economy. (Catling and Mitrow 2011c). For both of these species there are questions about current status in Canada and the extent to which they can be expected to cause environmental damage in the future.

Specific Information Solicited

The queries used were the following:

1) We are studying occurrence of two plants cultivated in Canada. These are sea buckthorn (*Hipppohae rhamnoides*) and scotch broom (*Cytisus scoparius*). We would appreciate receiving any information on occurrence in Canada that you may have for these two species.
2) Are they grown in your area, and if so, for how long?
3) Are they cultivated in the general region?
4) Has either of them escaped from cultivation in your area?
5) Do you have any other related information which you think might be useful for our study?

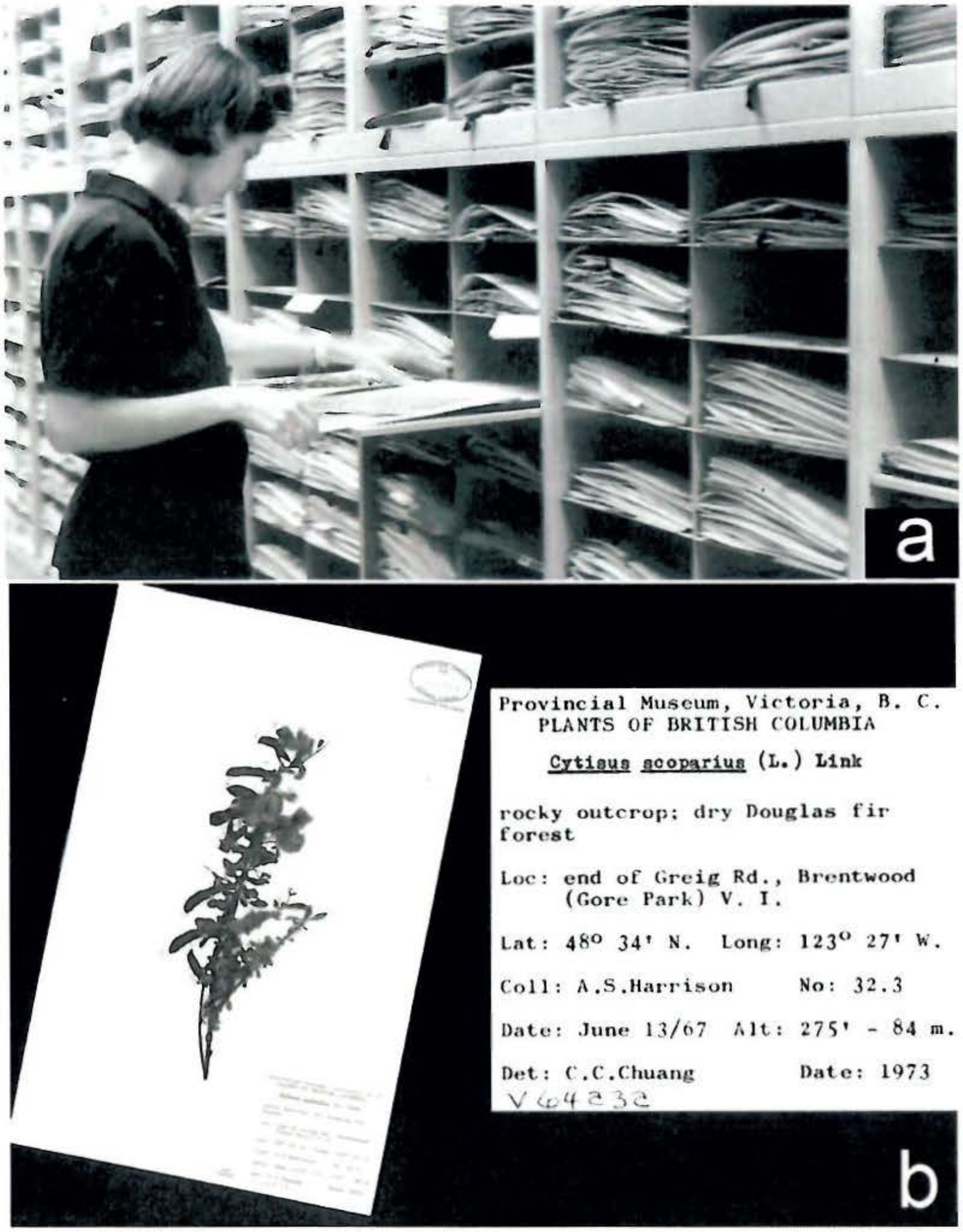

Figure 1. A herbarium is a collection of dried and pressed plant specimens with labels mounted on sheets of light cardboard. (a) Gathering information from the DAO herbarium. (b) Specimen of scotch broom with label enlarged.

Communicating Groups and Electronic Sources

The five communicating groups utilized are listed below; more information on the approach to each is available in Appendix 1. In addition, two electronic sources were used. All communications and data searches that were part of this study were conducted from January to April 2011.

Figure 2. Sea buckthorn (*Hippophae rhamonides*). (a) Branches with berries. (b) Habit of shrub. Photographs taken in Indian Head, Saskatchewan, Canada, in September 2009 by William (Bill) Schroeder.

1) The Canadian Herbarium Network included 30 herbarium collections across Canada. These are managed by universities, museums, provincial and federal governments, and support local floristic studies, identification, and systematic research worldwide. The term "Network" here refers to a directly interacting group of people and contact by individual phone calls and e-mails, rather than a query to a central portal. We could have, in addition, posted queries on a list serve such as "Herbaria" to obtain information from outside Canada, but did not because the questions here pertained only to Canada.
2) The Canadian Conservation Data Centers. There are eight across Canada, and their mandate mainly is to track and document populations of rare species. They also provide information on conservation issues.
3) The Provincial Invasive Species Councils. There are 12 across Canada and they work to minimize the negative ecological, social, and economic impacts of invasive species.
4) The Canadian Botanical Gardens and Arboreta. We selected the 18 larger ones from across Canada. They are living museums that provide information on cultivation and their key roles are in the area of horticulture, conservation, and education.
5) The Canadian Botanical Clubs. We selected 13 major clubs across Canada for this study. These botanical clubs were established for social activities, education, and to preserve biodiversity. Members of botanical clubs are devoted people ranging from professionals to amateurs.

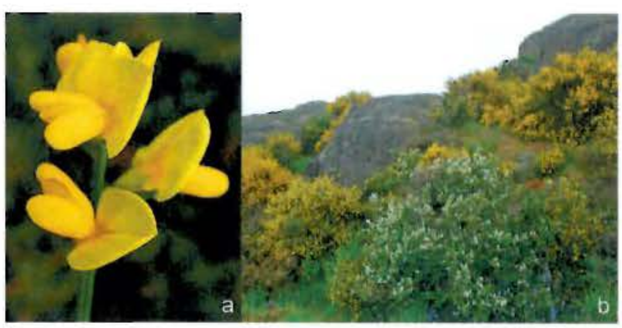

Figure 3. Scotch broom (*Cytisus scoparius*). (a) Flowering branch. (b) Rocky headland where scotch broom dominates the landscape. The white-flowered shrub in the foreground, the Puget Sound Saskatoon (*Amelanchier florida* Lindl. var. *humptulipensis* G. N. Jones) is a relative of the Canadian crop called "Saskatoon." This crop relative might provide useful germplasm for crop improvement, but it is being overwhelmed by scotch broom. Photographs taken in Victoria, British Columbia, Canada on 26 April 2010 by P. M. Catling.

Table 1. Summary of ratings for seven sources using five criteria. CDC = Conservation Data Center. For details on all sources, see Appendix 1.

Criteria	30 Herbaria	8 CDCs	18 Botanical gardens/ arboreta	13 Invasive Species Councils	14 Botanical clubs	Web searches	Library literature searches
Amount of information gathered (% of total), max. = 10	9	5	6	9	5	7	5
Currency of information (−2 for each 5 years old), max. = 10	10	9	7	10	6	6	5
Uniqueness of useful Information (% unique to source), max. = 10	9	2	8	9	3	5	6
Response time (−2 for each week after 1), max. = 10	10	10	7	10	4	10	10
Association with experts (10 = high, 0 = low), max. = 10	10	10	10	10	7	6	10
Total	48	36	38	48	25	34	36

6) Web Searches. We did on-line searches using key words and phrases (See Appendix 1). For example, we used "alien" or "invasive" and "Canada sea buckthorn," "alien" or "invasive" and "British Columbia sea buckthorn" when searching for each province, and we also exchanged the common names for the Latin plant names. We examined the first 25 to 50 hits because those after this point generally were much less relevant. Some sites with botanical information, such as Global Biodiversity Information Facility (GBIF), the Database of Vascular Plants of Canada (VASCAN), US Department of Agriculture Plant Database, and e-Flora of British Columbia, either did not appear among the early hits and their information was lost, or these sites had mostly general information and failed to provide answers to most of the study questions. As these and similar sites mature, they could become more useful and occupy positions among the early hits. Although the Web might be sold a little short by our method, we think that it still is a fair test of information that is readily available.
7) Library Literature Searches. The library searches were done from the Agriculture and Agri-Food Canada on-line system which allows searches on the Biosis System (including biological abstracts) for scientific journal articles. Words used were the similar to those used for the Web searches.

Scoring System

In order to evaluate the different sources, we decided on five criteria (Table 1). We used a simple rating scale of 1 to 10 points for each of these criteria (Table 1).

Results

Information acquired from different sources varied in depth, return time, and amount, and varied according to the nature of the question. The following are the results of the five selected criteria used for evaluating the information received from each of the sources.

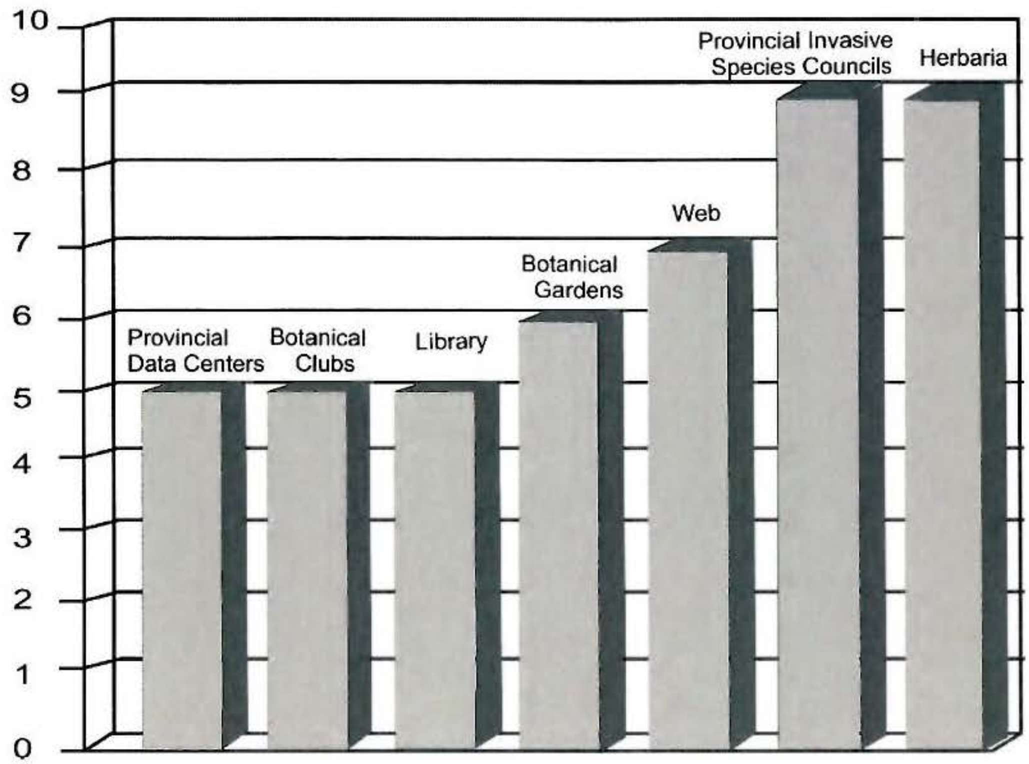

Figure 4. Histogram portraying the amount of information gathered from seven major information sources.

Amount of Information Gathered

First, we considered the amount of useful information. The fact that the herbarium network and invasive species councils did well (Fig. 4) can be attributed to the more specific invasive mandate of the latter and the broad mandate of the former. The others were able to send us useful information but provided less because their mandate was less focussed on the subject area. Provincial data centers, for example, are strongly focussed on rare species. It is notable that the Web, despite holding huge amounts of information, was not a major source for the subject areas used here.

Currency of Information

The Invasive Species Council and herbaria scored a 10 because of many recent plant records and current information (Fig. 5). The Conservation Data Center placed third because the information received was current due to ongoing communication and field work. The library rated the lowest in this category because there was very little relevant recent literature available.

Uniqueness of Useful Information

The Herbarium Collections Network and Provincial Invasive Species Councils rated the highest on uniqueness of useful information provided (Fig. 6). The information received mainly included records of specific occurrence for each of the species, which makes it possible to produce a distribution map and predict spread. The herbarium collections network provided a long historical record enabling certain kinds of analysis that could not be done without historical data. Botanical Gardens rated slightly lower than the two top sources because they provided fewer occurrences but

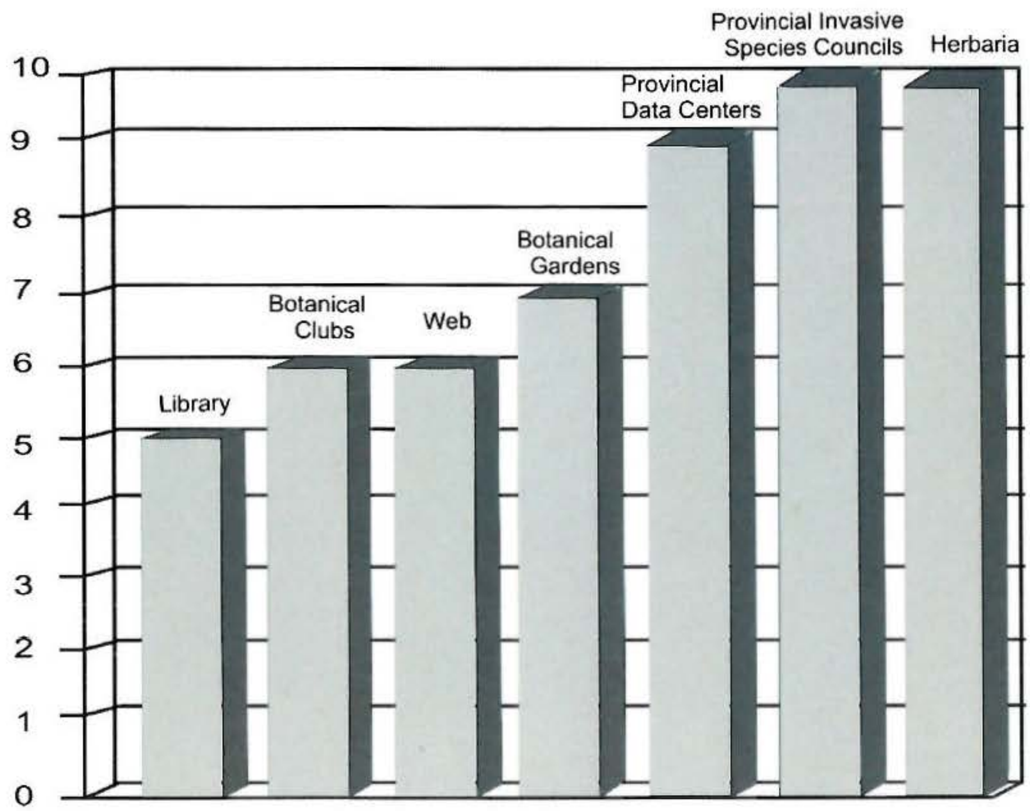

Figure 5. Histogram portraying the currency of information gathered from seven major information sources.

they did provide some feedback on their personal experience of cultivation and escape to the wild.

Response Time

Botanical clubs are slow in response time because they communicate with members periodically (e.g., sending out quarterly newsletters). Botanical gardens were also slow because most communication activity is on-site (visitors) rather than external (Fig. 7). The Invasive Species Councils were rapid because early detection is an issue as is rapid information exchange. They copied emails to large groups of supporters. Web and library self searching is rapid because all information is received within minutes. Conservation Data Centers (CDCs) had little to provide and their support depends on being useful, so their response to questions tends to be rapid. The Herbarium network is an interdependent cooperative group that is anxious to ensure that collections are used to maximum advantage—this attitude and a continuous ongoing exchange of information ensures rapid response.

Association with Experts

Only two sources had conspicuously less association with experts (Fig. 8). These were the botanical clubs and the Web (where information came from both amateurs and experts, and often lacks peer review).

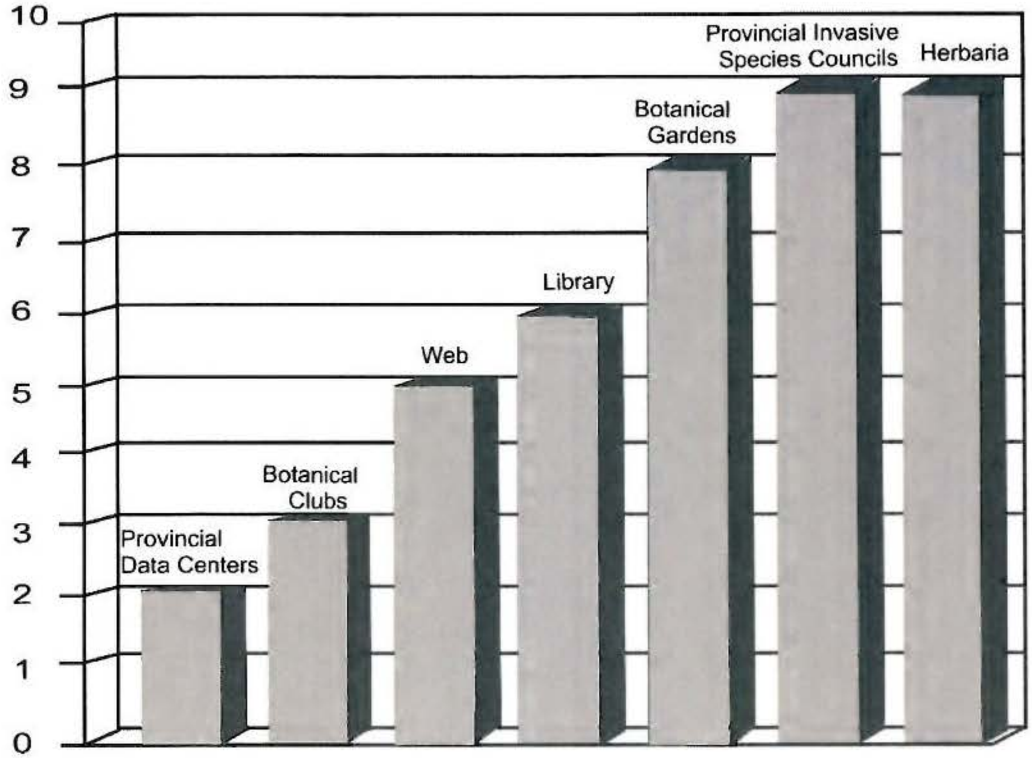

Figure 6. Histogram portraying the uniqueness of useful information gathered from seven major information sources.

Overall Rating

With regard to the questions, the best sources are the herbarium and Provincial Invasive Alien Councils networks (Fig. 9). The Web turned out to be less useful than anticipated and botanical clubs varied in the extent of a proactive role in problems relating to the flora.

Discussion

Answers to the Basic Questions

We found that, although widely planted in Canada for many decades, sea buckthorn has escaped only in local regions of southern Alberta. This suggests a limited ability to become a serious invasive. However, the taxonomic complexity of the group (Swenson and Bartish 2003) and the possibility of the different taxa having differing capabilities to be invasive in Canada indicate a need for more study. Scotch broom also has been widely introduced in Canada over a long period but has become a serious problem only in southwestern British Columbia. This might seem to suggest that it need not be a concern elsewhere. However, climate warming and development or introduction of adapted genotypes could be a problem. This is based on recent indications of spread into parts of both British Columbia and the Canadian Maritime Provinces where it did not occur previously. In the latter region, heathlands (including coastal and interior barrens) and blueberry cultivation could be impacted. This information provides a clear basis for future management actions for both species, including both field experiments and monitoring. Although the present examples are pertinent, there are other aspects of using collections to provide information on invasive plants; for example, to predict spread

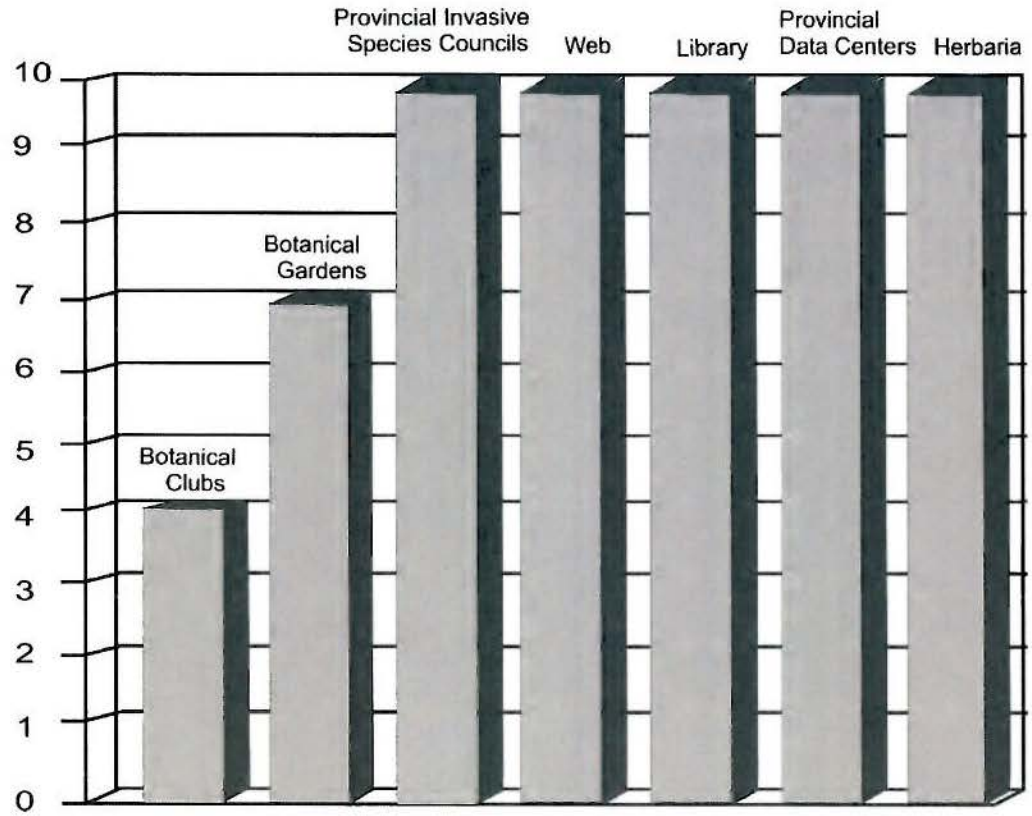

Figure 7. Histogram portraying the response time for seven major information sources.

using climate and climate-change models (Catling and Mitrow 2011a, 2011b) and for studying the characteristics of invasions using proportion curves (Deslisle 2003).

Quality and Quantity of Information

Management can be costly and should be based on information of the highest quality. Of course, the quality of information varies with the source. The collection-based information not only is closely associated with experts, but it also meets internationally accepted standards of accuracy (Chapman 2005b, c). Furthermore, the information from collections was usually accurate, specific, and represented a sample of effort over a long time period playing an extraordinary role in providing useful data. The high quality and quantity of data from the Invasive Species Councils relates to their specific mandate of invasive species management.

Collections Are Underrated

Although this study suggests that collections can be the best source of information, they and their associated network are underrated because a number of aspects were not considered. For example, there is a huge amount of unrealized information content in a collection. It is not just compilation of information, but contains vouchers that can be checked to avoid confusion and can provide additional and improved information.

Another way in which collections and collection network can act more effectively as a source, is through arrangement for acquisition of an orphan collection in the case of a complete lost of funding of one of the network members. This kind of preservation of

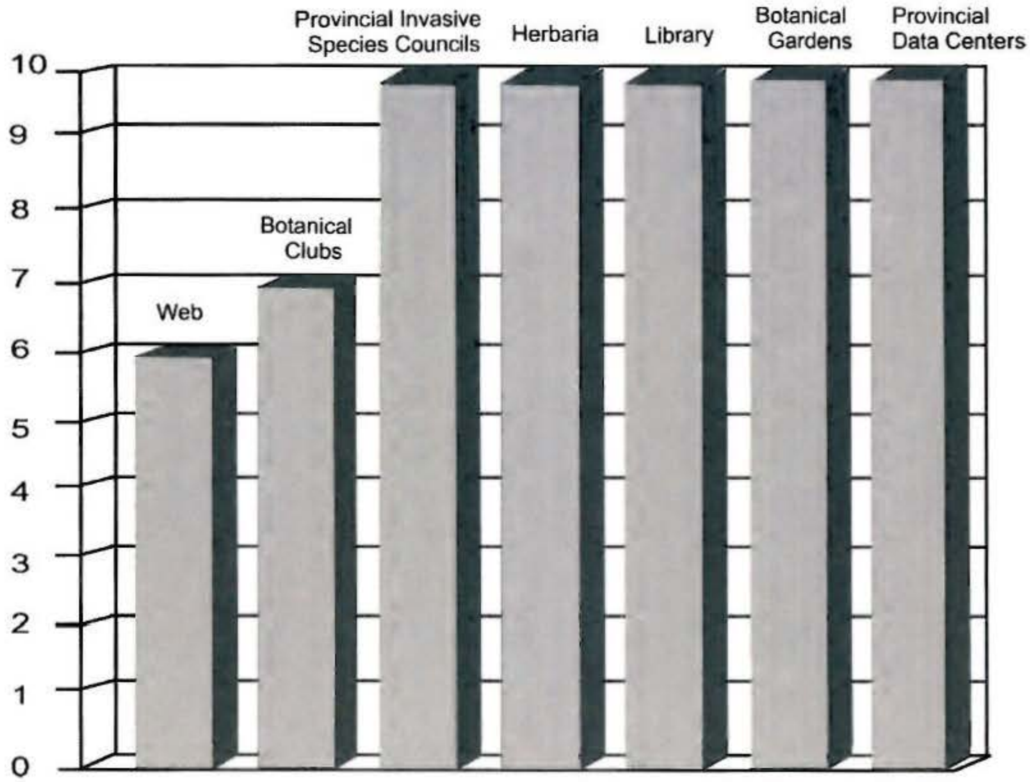

Figure 8. Histogram portraying the association with experts for information gathered from seven major sources.

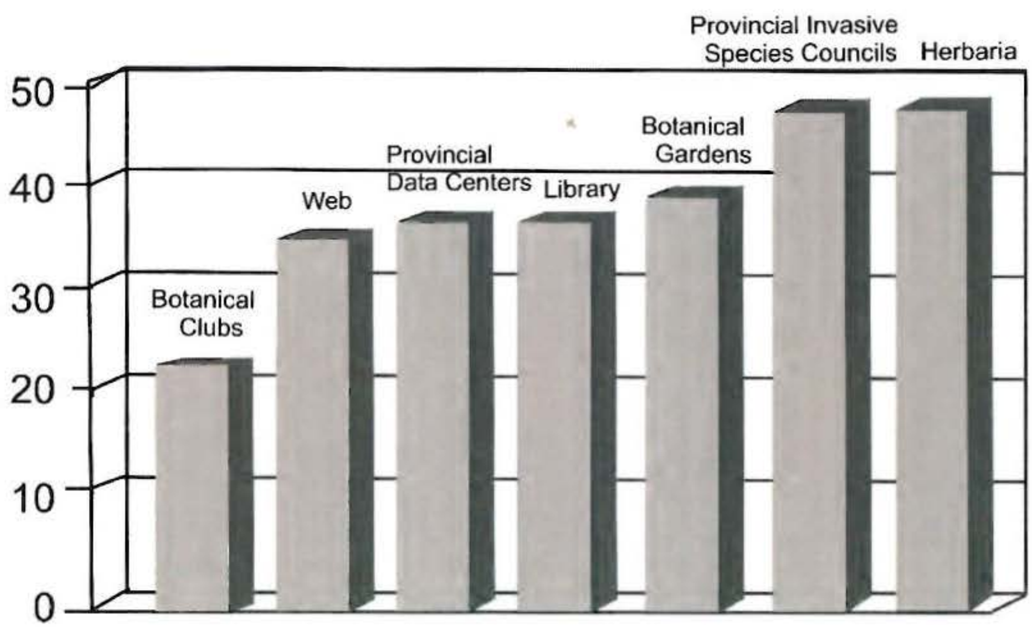

Figure 9. Histogram illustrating the overall rating for information gathered from seven major sources.

records (specimens) by arrangement for deposition is less likely to occur among members of other data-providing groups.

Because collections are a primary source, the data have not been copied or manipulated, so errors are minimized. This could be taken into account as a measure of the efficiency of data transcription or in other ways. Regardless of the level of efficiency, collections with primary data always will be the most accurate source.

Many Sources of Value

The seven sources differ in their mandates and all are very useful in addressing their primary mandate. For example, the CDC might have achieved the highest rating for information on the occurrence and status of endangered plants in Canada. The herbarium network provides the unique contribution of supplying information that only can be derived from older material, as well as new information from other sources (e.g., molecular analyses indicating the patterns of variations that need to be protected).

Some sources likely will increase in value in the future. For example, as increasing data from collections becomes available on the Web, it could increase the importance of the Web as a source. Within Canada, as projects such as "Canadensys" become more mature and serve data from multiple sources, Web-based information will be more robust. It could become equivalent to that in other parts of the world (e.g., Consortia of California Herbaria).

Two aspects of the results are particularly important: 1) All of the sources provided some useful and unique information, including those whose mandate would seem restrictive to the subject area; and 2) The results suggest strongly that a collection network can be the very best source of information on certain important ecological questions. Our hypothesis that the herbarium collections network remains a superior source of information on invasive plants, although there has been a substantial recent increase in other sources of information on this subject, was clearly supported. We speculate that analyses would reveal the collections network to be of major, if not central, importance in many other subject areas involving economy and environment. In a world of ever-increasing information sources, collections remain at the forefront.

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The Canadian herbaria, the Canadian Conservation Data Centers, the provincial Invasive Species Councils distributed across Canada, the selected Canadian botanical gardens and arboreta, and Canadian botanical clubs kindly participated in this analysis, which would have been impossible without their extensive help. Dr. Richard K. Rabeler of the University of Michigan and Dr. F. R. Cook of the Canadian Museum of Nature provided helpful comments on the manuscript.

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Appendix 1

The Sources Utilized, Including Both the Communicating Group and Electronics

Canadian Herbarium Network.—The herbarium network consists of 30 Canadian herbaria listed in Index Herbariorum (Thiers 2012) and elsewhere (Boivin 1980, Rothfels 2003). These Canadian herbaria are curated by staff at universities and museums, one in a provincial ministry and another in a federal department. Their holdings range from 12,000 to 1.5 million specimens. The herbarium staffs vary from one part-time to five full-time employees, and all have associated scientific experts. The larger collections tend to have more diverse coverage, whereas the smaller ones often have specific provincial and/or regional coverage.

- ACAD: Acadia University; http://herbarium.acadiau.ca/
- ALTA: University of Alberta; http://vascularplant.museums.ualberta.ca/
- CAN: Canadian Museum of Nature; http://nature.ca/en/research-collections/our-collections/botany-collection
- DAO: Agriculture and Agri-Food Canada; http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1251393521021&lang=eng
- HAM: Royal Botanical Gardens; http://www.rbg.ca/Page.aspx?pid=319
- LKHD: Lakehead University; http://www.lkhdherbarium.ca/
- MMMN: The Manitoba Museum; http://www.manitobamuseum.ca/main/botany/2010/05/27/41-uses-for-a-dead-plant/
- MT: University of Montréal; http://www.biodiversite.umontreal.ca/center/collections/herbier-marie-victorin?lang=en

- MTMG: McGill University, Macdonald Campus; http://www.mcgill.ca/herbarium/
- NBM: New Brunswick Museum; http://www.nbm-mnb.ca/index.php?option=com_content&view=article&id=133&Itemid=1196
- NFLD: Memorial University of Newfoundland; http://collections.mun.ca/cdm4/description.php?phpReturn=typeListing.php&id=63
- NFM: Provincial Museum of Newfoundland and Labrador; http://www.therooms.ca/museum/
- NSAC: Nova Scotia Agricultural College; http://nsac.ca/envsci/collections/herb.asp
- NSPM: Nova Scotia Museum of Natural History; http://museum.gov.ns.ca/mnhnew/en/home/whattoseedo/collections/botany.aspx
- PMAE: Royal Alberta Museum; http://www.royalalbertamuseum.ca/natural/botany/collects/collects.htm
- QFA: Université Laval; http://www.herbier.ulaval.ca/news.php
- QK: Queen's University; http://www.queensu.ca/biology/facilities/herbarium.html
- QUE: Herbier du Québec, Complexe scientifique; http://www.formulaire.gouv.qc.ca/cgi/affiche_doc.cgi?dossier=1846&table=0
- SASK: University of Saskatchewan; http://www.herbarium.usask.ca/
- TRT: Royal Ontario Museum; http://www.rom.on.ca/collections/curators/dickinson.php
- TRTE: Erindale College, University of Toronto; http://www.erin.utoronto.ca/~trteherb/index.htm
- UAC: University of Calgary; http://www.ucalgary.ca/herbarium/node/8
- UBC: University of British Columbia; http://www.beatymuseum.ubc.ca/herbarium/index.html
- UNB: University of New Brunswick; http://www.unb.ca/herbarium/herbarium_highlights.html
- UPEI: University of Prince Edward Island; http://islandora.ca/node/327
- UWO: University of Western Ontario; http://www.uwo.ca/biology/facilities/herbarium/herbarium.htm
- V: Royal British Columbia Museum; http://www.royalbcmuseum.bc.ca/Natural_History/Plants.aspx
- WAT: University of Waterloo; http://biology.uwaterloo.ca/services-and-resources/herbarium
- WIN: University of Manitoba; http://home.cc.umanitoba.ca/~bford/herbarium.html
- WLU: Wilfrid Laurier University; http://www.wlu.ca/homepage.php?grp_id=2147

Canadian Conservation Data Centers (CDCs).—There are eight independent CDCs covering all ten provinces and the Yukon Territory. The CDCs, also known as Natural Heritage Information Centers usually represent a single province or territory, with the exception of the Atlantic Canada Conservation Data Center, which represents the provinces of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland–Labrador. A significant equivalent exists in the government of the Northwest Territories (NT), and Nunavut (NU) also was contacted. The CDC's mandate largely is to conduct biological inventories to track and document populations of species at risk, study and classify communities, analyze conservation issues, provide conservation services, and make their data widely available. The main Web site is: http://www.natureserve-canada.ca/en/cdcs.htm. The eight CDCs are as follows east to west across Canada:

- Atlantic Canada Conservation Data center; http://www.accdc.com/home.html

- center de données sur le patrimoine naturel du Québec; http://www.cdpnq.gouv.qc.ca/
- Ontario Natural Heritage Information center; http://nhic.mnr.gov.on.ca/
- Manitoba Conservation Data center; http://www.gov.mb.ca/conservation/cdc/pubs.html
- Saskatchewan Conservation Data center; http://www.biodiversity.sk.ca/
- Alberta Conservation Information Management System; http://www.tpr.alberta.ca/parks/heritageinfocenter/ecocommunities/default.aspx
- British Columbia Conservation Data center; http://www.env.gov.bc.ca/cdc/
- Yukon Conservation Data center; http://www.env.gov.yk.ca/wildlifebiodiversity/cdc.php

We also contacted the Department of Environment and Natural Resources in NT (http://www.enr.gov.nt.ca/_live/pages/wpPages/home.aspx) and the Department of Environment in NU (http://env.gov.nu.ca/).

Provincial Invasive Species Councils and Committees across Canada.—There are 12 established Provincial Invasive Species Councils across Canada and one (Nunavut) that has an equivalent organisation (see below from east to west across Canada). These committees are working to minimize the negative ecological, social, and economic impacts caused by the introduction, establishment, and spread of invasive plants. They are dedicated to protection and management of natural areas. Their work involves awareness and understanding of invasive plant issues and encourages action to assist in early detection, prevention and education regarding invasive alien species. Management practices in order to control and eradicate further spread of invasive alien species are also highlighted. Main Web site: http://mymotiontide.com/invasiveplantcouncilbc.ca/images/stories/documents/Nat_Map_Contacts_Dec09.pdf.

- Memorial University of Newfoundland Botanical Garden; www.mun.ca/botgarden/home.php
- Prince Edward Island Nature Trust; www.islandnaturetrust.ca
- Invasive Species Alliance of Nova Scotia (ISANS); www.invasivespeciesns.ca
- New Brunswick Invasive Species Council; www.unb.ca/herbarium/Invasives/Home.html
- Québec Interdepartmental Committee on Invasive Species; www.mddep.gouv.qc.ca
- Ontario Invasive Plant Council (OIPC); www.ontarioinvasiveplants.ca
- Invasive Species Council of Manitoba (ISCM); www.invasivespeciesmanitoba.com
- Saskatchewan Invasive Species Council (SISC); www.saskinvasives.ca
- Alberta Invasive Plant Council (AIPC); www.invasiveplants.ab.ca
- Invasive Plant Council of British Columbia (IPCBC); http://www.invasiveplantcouncilbc.ca/
- Yukon Invasive Species Council (YISC); http://environmentyukon.gov.yk.ca/wildlifebiodiversity/invasivespecies.php
- Government of the Northwest Territories; www.gov.nt.ca
- Nunavut: Currently there is no established invasive plant group in Nunavut but the equivalent would be at the NU Department of Environment; http://env.gov.nu.ca/

Canadian Botanical Gardens/Arboreta.—We selected a group of the largest Canadian botanical gardens and arboreta from different provinces across Canada (from east to west):

- Memorial University of Newfoundland Botanical Garden, Newfoundland; http://www.mun.ca/botgarden/

- The Fredericton Botanic Garden, New Brunswick; http://www.frederictonbotanicgarden.com/about.html
- Jardin botanique de Montréal, Québec; http://www2.ville.montreal.qc.ca/jardin/jardin.htm
- Morgan Arboretum, Québec; http://www.morganarboretum.org/
- CEF Dominion Arboretum, Ontario; http://dsp-psd.pwgsc.gc.ca/Collection/A42-104-2005E.pdf
- Great lakes Forest Research Center Arboretum, Ontario; http://scf.rncan.gc.ca/subsite/glfc-arboretum/the-arboretum/5
- Niagara Park Commission, Ontario; http://www.niagaraparks.com/
- Oshawa Valley Botanical Gardens, Ontario; http://ovbgoshawa.ca/
- Royal Botanical Gardens, Ontario; http://www.rbg.ca/Page.aspx?pid=193
- University of Guelph Arboretum, Ontario; http://www.uoguelph.ca/arboretum/
- Morden Arboretum Research Station, Manitoba; http://www.mordenmb.com/residents/researchstation.shtml
- Devonian Botanic Garden, Alberta; http://www.ales.ualberta.ca/devonian/
- Olds College Botanic Garden, Alberta; http://www.bgci.org/garden.php?id=3177
- Butchart Gardens, British Columbia; http://www.butchartgardens.com/index.php?option=com_frontpage&Itemid=1
- Royal Roads University Botanical Gardens, British Columbia; http://www.bgci.org/garden.php?id=4489
- University of British Columbia Botanical Garden and center for Plant Research, British Columbia; http://www.botanicalgarden.ubc.ca/
- VanDusen Botanical Garden, British Columbia; http://www.vandusengarden.org/
- Woodland Gardens Arboretum, British Columbia; http://www.arbnet.org/morton-register/canada/woodland-gardens-arboretum.html

Canadian Botanical Clubs.—These clubs were established for social activities, education, and to preserve biodiversity. Members of botanical clubs are devoted people from professionals to amateurs. They organize plant exhibitions, shows, competitions, field trips, and seminars. The sample of clubs which were selected across Canada was as follows (from east to west across Canada):

- New Brunswick Botanical Club; http://www.macbe.com/botanyclub/home.html
- Flora Quebeca, Québec; http://www.floraquebeca.qc.ca/
- Ottawa Field Naturalist Club, Ontario; http://www.ofnc.ca/
- Ontario Horticulture Association, Ontario; http://www.gardenontario.org/
- Garden Club of Ontario; http://www.gardenclubsofontario.ca/
- Field Botanists of Ontario; http://www.trentu.ca/org/fbo/
- Manitoba Horticultural Association; http://www.icangarden.com/document.cfm?task=viewdetail&itemid=4998
- Saskatoon Horticultural Society, Saskatchewan; http://www.saskatoonhortsociety.ca/About_Us.html
- Alberta Horticultural Society, Alberta; http://www.icangarden.com/clubs/AHA/
- Calgary Horticultural Society, Alberta; http://www.calhort.org/
- Pacific Northwest Palm and Exotic Plant Society, British Columbia; http://www.hardypalm.com/
- Sunshine Coast Conservation Association, British Columbia Sunshine Coast; http://www.thescca.ca/index.php?option=com_content&task=view&id=207&Itemid=1

- Conservation Association, British Columbia; http://www.thescca.ca/
- Master Gardeners Association, British Columbia; http://www.bcmastergardeners.org/

Web Searchs.—The searches, done online using Boolean logic keywords and phrases, was as follows:

- "alien" or "invasive" and "Canada sea buckthorn"
- "alien" or "invasive" and "British Columbia sea buckthorn"
- "alien" or "invasive" and "Alberta sea buckthorn"
- "alien" or "invasive" and "Saskatchewan sea buckthorn"
- "alien" or "invasive" and "Manitoba sea buckthorn"
- "alien" or "invasive" and "Ontario sea buckthorn"
- "alien" or "invasive" and "Quebec sea buckthorn"
- "alien" or "invasive" and "Maritimes sea buckthorn"
- "alien" or "invasive" and "New Brunswick sea buckthorn"
- "alien" or "invasive" and "Nova Scotia sea buckthorn"
- "alien" or "invasive" and "Prince Edward Island sea buckthorn"
- "alien" or "invasive" and "Newfoundland sea buckthorn"
- "alien" or "invasive" and "Yukon sea buckthorn"
- "alien" or "invasive" and "Northwest Territories sea buckthorn"
- "alien" or "invasive" and "Nunavut sea buckthorn"
- "alien" or "invasive" and "Canada *Hippophae rhamnoides*"
- "alien" or "invasive" and "British Columbia *Hippophae rhamnoides*"
- "alien" or "invasive" and "Alberta *Hippophae rhamnoides*"
- "alien" or "invasive" and "Saskatchewan *Hippophae rhamnoides*"
- "alien" or "invasive" and "Manitoba *Hippophae rhamnoides*"
- "alien" or "invasive" and "Ontario *Hippophae rhamnoides*"
- "alien" or "invasive" and "Quebec *Hippophae rhamnoides*"
- "alien" or "invasive" and "Maritimes *Hippophae rhamnoides*"
- "alien" or "invasive" and "New Brunswick *Hippophae rhamnoides*"
- "alien" or "invasive" and "Nova Scotia *Hippophae rhamnoides*"
- "alien" or "invasive" and "Prince Edward Island *Hippophae rhamnoides*"
- "alien" or "invasive" and "Newfoundland *Hippophae rhamnoides*"
- "alien" or "invasive" and "Yukon *Hippophae rhamnoides*"
- "alien" or "invasive" and "Northwest Territories *Hippophae rhamnoides*"
- "alien" or "invasive" and "Nunavut *Hippophae rhamnoides*"
- "alien" or "invasive" and "Canada *Cytisus scoparius*"
- "alien" or "invasive" and "British Columbia *Cytisus scoparius*"
- "alien" or "invasive" and "Alberta *Cytisus scoparius*"
- "alien" or "invasive" and "Saskatchewan *Cytisus scoparius*"
- "alien" or "invasive" and "Manitoba *Cytisus scoparius*"
- "alien" or "invasive" and "Ontario *Cytisus scoparius*"
- "alien" or "invasive" and "Quebec *Cytisus scoparius*"
- "alien" or "invasive" and "Maritimes *Cytisus scoparius*"
- "alien" or "invasive" and "New Brunswick *Cytisus scoparius*"
- "alien" or "invasive" and "Nova Scotia *Cytisus scoparius*"
- "alien" or "invasive" and "Prince Edward Island *Cytisus scoparius*"
- "alien" or "invasive" and "Newfoundland *Cytisus scoparius*"
- "alien" or "invasive" and "Yukon *Cytisus scoparius*"

- "alien" or "invasive" and "Northwest Territories *Cytisus scoparius*"
- "alien" or "invasive" and "Nunavut *Cytisus scoparius*"
- "alien" or "invasive" and "Canada scotch broom"
- "alien" or "invasive" and "British Columbia scotch broom"
- "alien" or "invasive" and "Alberta scotch broom"
- "alien" or "invasive" and "Saskatchewan scotch broom"
- "alien" or "invasive" and "Manitoba scotch broom"
- "alien" or "invasive" and "Ontario scotch broom"
- "alien" or "invasive" and "Quebec scotch broom"
- "alien" or "invasive" and "Maritimes scotch broom"
- "alien" or "invasive" and "New Brunswick scotch broom"
- "alien" or "invasive" and "Nova Scotia scotch broom"
- "alien" or "invasive" and "Prince Edward Island scotch broom"
- "alien" or "invasive" and "Newfoundland scotch broom"
- "alien" or "invasive" and "Yukon scotch broom"
- "alien" or "invasive" and "Northwest Territories scotch broom"
- "alien" or "invasive" and "Nunavut scotch broom"

Library Literature Searches.—Journal searches of the BIOS system were done using the following keywords:

- invasive and scotch broom
- weed and scotch broom
- crop and scotch broom
- alien and scotch broom
- Canada and scotch broom
- scotch broom
- *Cytisus scoparius*
- invasive and *Cytisus scoparius*
- weed and *Cytisus scoparius*
- crop and *Cytisus scoparius*
- alien and *Cytisus scoparius*
- Canada and *Cytisus scoparius*
- invasive and sea buckthorn
- weed and sea buckthorn
- crop and sea buckthorn
- alien and sea buckthorn
- Canada and sea buckthorn
- sea buckthorn
- *Hippophae rhamnoides*
- invasive and *Hippophae rhamnoides*
- weed and *Hippophae rhamnoides*
- crop and *Hippophae rhamnoides*
- alien and *Hippophae rhamnoides*
- Canada and *Hippophae rhamnoides*