GUIDE TO MONITORING EXOTIC AND INVASIVE PLANTS

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Prepared for:
Ecological Monitoring and Assessment Network
Environment Canada

1997

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Abstract

Monitoring the expansion and impact of exotic and invasive plants is a task that can be accomplished at various levels. Traditionally, activities to study and monitor exotic plants have been the domain of research scientists, biologists and other professionals ithin government agencies, academic institutions and museums. The increasing impact of exotics on natural habitats requires that a broader level of participation in monitoring their spread is required. Naturalists, in particular, could greatly assist by contributing to he development of a comprehensive base of information that would facilitate efforts to control or slow the spread of exotic plants.

The monitoring protocol for exotic and invasive plants has been prepared in the form of a semi-popular guide aimed at promoting the collaboration of naturalists and trail ssociations in the process of recording the presence, spread and impact of exotic plants on natural habitats. To promote such initiatives, the guide presents example projects of monitoring activities and provides descriptions of simple tools and techniques that can be used to record valuable information on invasive plants. The monitoring activities described are aimed not only at providing useful information on invasive plants but, as well, serving as a means of raising awareness within the naturalist communities of the impact of invasive plants on natural habitats and Canadian biodiversity. Monitoring activities are promoted as a means of initiating local actions to control the spread of invasive plants and as a way of contributing to national initiatives to reduce the impact of exotic species on native ecosystems.

Introduction

What are invasive plants?

Any plant growing where it is not wanted and where it becomes a nuisance because of its presence in large numbers or because of objectionable attributes is considered to be a weed. These pests tend to grow aggressively in agricultural lands, home gardens, roadsides and other disturbed sites. Some also possess noxious properties that cause allergic reactions or poisoning if contact is made or if they are eaten. The majority of weeds are exotic species having their origins in other countries.

There are about 4200 species of vascular plants in Canada (Scoggan 1978-1979). Of this total, about 30% are exotic species whose origins are from other countries and regions with a similar climate. Most of these come from Europe or Eurasia. Their introduction to North America dates from the earliest arrivals of explorers and settlers. These immigrants brought with them a variety of common agricultural weeds stowed as contaminants in natural packing materials, as fodder for livestock, within bags of seeds and in the ballast of the ships transporting them to the New World. Even some of the herbs brought for cooking and medicines and some of their favourite garden ornamentals, in time, were also to become troublesome pests. This invasion of exotics has continued to the present time.

There are also native species, however, that are considered to be weeds. The common milkweed (Asclepias syriaca) is one example. This species has been able to expand its range naturally and to proliferate in agricultural crop lands and pastures that serve as artificially-created clearings suitable for colonization. Manitoba maple, another native species, has expanded its range both through natural range extension and through its use and transplantation as a rapidly-growing, adaptable, boulevard and windbreak tree. This maple is now widespread in urban areas and rapidly colonizes disturbed sites in cities to the east and north of its natural range, particularly in eastern Canada and northeastern United States.

Native species that are now found in areas outside of their traditional areas of occurrence are considered to be non-indigenous species. All exotic or alien species are also non-indigenous in origin. Those native, non-indigenous species and exotics that are able to successfully compete with native vegetation to form dominant growths in natural habitats are considered to be invasive species. It is such invasive plants that are of greatest concern because of their impact on biological diversity and the natural functioning of ecosystems. The majority of invasives are exotics but only a small proportion of all the exotics are invasive. Most exotics are roadside and agricultural weeds or noxious species that affect humans or livestock. Their economic impact has been felt from the early days of agriculture in North America. The fact that invasive plants and animals are having a dramatic impact on natural ecosystems has only been recognized in recent years.

Invasive plants generally exhibit the same kinds of biological characteristics as common weeds. They grow rapidly under a wide range of climate and soil conditions. Some, such as the biennial garlic mustard (Alliaria petiolata), overwinter as rosettes and begin to flower and set seed early in the spring before many of the native plants begin to grow. Most produce abundant seeds and also may have adaptations such as the long hairy plumes on the seeds of dog-strangling vine (Vincetoxicum spp.) that promote easy dispersal. Commonly, the seeds of weedy species stay viable for many years when buried in the soil. Many, such as European frog-bit (Hydrocharis morsus-ranae), are perennial and reproduce by vegetative propagation that enables them to form large clones of genetically identical plants adapted to local conditions. Some herbs, such as leafy spurge (Euphorbia esula), have a disagreeable taste or odour. Others, like Canada thistle (Cirsium arvense), possess spiny leaves and stems or, as in the shrub common buckthorn (Rhamnus cathartica), spines that reduce the degree of herbivory by larger animals. Many also lack insect pests or pathogens in their adopted countries that could keep them under control. The adaptability and success of many exotic species, both plants and animals, in their adopted countries has resulted in international concern over the impact such species are having on biological diversity and on the cost of their control.

Exotic Species - an International Issue

The spread of exotic species has become an issue of international importance. Their global impact has been recognized in the Convention on Biological Diversity which calls for the control and monitoring of exotic species that threaten ecosystems, habitats and species (UNEP 1994). It also recognizes the need to establish information systems that compile data on species that have significant environmental impacts. Specific initiatives that have responded to this need include the establishment of an invasive species specialist group by The World Conservation Union (IUCN) to facilitate information exchange and work being done on invasive species (Macdonald, 1994). In July 1996, a United Nations conference on alien species was held in Norway to galvanize the international conservation community in an attempt to find ways of addressing this critical issue. A workshop on invasive alien species was also held at the Montreal IUCN Congress in October, 1996.

One of the most comprehensive reviews of the impact of harmful non-indigenous species within a country is that compiled for the United States (U.S. Congress 1993). This publication provides an excellent overview of a broad range of issues and includes, among others: basic summaries by groups of organisms; examples of rates of introduction; technologies for preventing and managing problems; federal, state and local approaches to the problem; case studies; and a summary of the problem of the movement of harmful non-indigenous species in a global marketplace.

Within the Canadian context, one of the strategic directions proposed in the Canadian Biodiversity Strategy (1995) specifically addresses the issue of harmful alien organisms. Steps are proposed to prevent the introduction of harmful alien organisms and eliminate or reduce their adverse effects by developing and implementing means to identify and monitor alien organisms and implement effective controls. The Biodiversity Convention Office (BCO) and the Canadian Wildlife Service (CWS) held an initial workshop, in May 1996, to explore the needs for a national strategy to address harmful alien organisms (Anonymous 1996).

For vascular plants, specific actions have already been taken in recent years to identify some of the major invasive plants that occur in Canada and to compile data for public information purposes and computer analysis. A publication on invasive plants in Canada, produced through the sponsorship of the CWS, provides an overview and assessment of non-indigenous species and the degree of invasiveness as determined on the basis of a national survey of botanists and naturalists (White et al. 1993).

The establishment of an Invasive Plants of Canada Project (IPCAN), in 1995, through the sponsorship of several federal departments in Environment Canada (BCO, CWS and Environmental Monitoring and Assessment Network (EMAN)), Canadian Heritage (Parks Canada) and Natural Resources Canada (GeoAccess Division) has resulted in a number of products. As part of this project, databases of georeferenced historic collections and recent sight records were developed for several major invasives. As well, the results of a new national survey of invasive plants were summarized, updated references to invasive plants were compiled and a series of fact sheets were completed as part of a public information internet site (Haber 1995, 1996a, 1996b, 1996c, 1997).

The Need for Monitoring

Why Monitor?

In general, there is very limited information available on most exotic plants, with the exception of some agricultural pest species that have been the subject of long-term control efforts. Biological monitoring, the activity of recording specific information about a species in a consistent manner over time, provides data that lead to a better understanding of exotic species and contribute towards their more effective management. A broad range of information is needed on exotics, including data on the ranges of species, their abundance, habitat preferences, rate of spread, impact on other species, value to native fauna, natural control agents and response to control attempts. Information on seasonally influenced events such as first flowering and fruiting in different climatic zones is also valuable and sheds light on developmental aspects and the life cycles of exotic plants.

Monitoring exotic plants is also required in order to determine what new species are becoming established in an area. Themonitoring of local areas and regions for establishment and proliferation of new exotics serves as an early warning system. The subsequent monitoring of the rate of expansion of such newly arrived species, based on individual populations and clones, allows for extrapolation on the future impact and possible need for controls for those exotics that are particularly aggressive and invasive. Knowledge gained from such studies may indicate that immediate actions need to be taken to eradicate certain species at an early stage before they become established over a broad geographical area and develop numerous sites of infestation that may be difficult to control or eliminate.

Of particular importance is the need to monitor the occurrence and spread of exotics in conservation lands such as parks and nature reserves. These have been set aside specifically because of their importance as representative sites of various natural history features, important areas of biological diversity or as sites for rare and possibly endangered species. Information from the monitoring of such sites can be used to develop effective control programmes that will lead to protecting the biological diversity within such special wildlife areas.

The negative impact of some invasive plants on species that are recognized nationally at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is another important reason for undertaking monitoring of exotic plants and their impacts. Garlic mustard (Alliaria petiolata) has been identified as being a threat to a number of Ontario woodland plants at risk, including wood poppy (Stylophorum diphyllum) and white wood aster (Aster divaricatus). In the prairies, the spread of leafy spurge (Euphorbia esula) in certain sand dune complexes has been identified as a threat to western spiderwort (Tradescantia occidentalis) and introduced forage grasses such as crested wheatgrass (Agropyron pectiniforme) and smooth brome grass (Bromus inermis) are troublesome invasives in native grasslands. Similarly, introduced grasses and shrubs such as Scotch broom (Cytisus scoparius) have dramatically altered the remnant Garry oak savannahs in southeastern Vancouver Island and adjoining Gulf Islands, an ecosystem that supports many nationally rare plants.

Monitoring Timeframe

Scientific studies that document biological diversity most commonly span only a single or, at best, several growing seasons. Even when based on numerous samples supplemented with additional data, for example, the climate and soils of the area, such studies only provide an insight into the structure of a complex and dynamic system during one short period of time. Changes over the long-term and the influences of climate, biotic cycles and anthropogenic impacts can only be determined by long-term monitoring.

Monitoring at regular intervals for a minimum of five years, allows significant fluctuations in observed values to be recognized as unusual events rather than as normal responses. Such data lead to much more informed conclusions about the biology of an organism or the interactions within an ecosystem in response to abiotic and biotic variables. In some cases, in order to gain definitive answers, monitoring is required over many decades, as in the study of seed longevity under various storage conditions.

The Role of Naturalists

This guide to monitoring non-indigenous vascular plants has been prepared primarily as a means of encouraging naturalists, young and old, to participate in some form of observation and recording of data on exotics and invasive plants within their local area or region. Those who love the outdoors, whether as observers of wildlife, as hikers, nature photographers, hunters or anglers, all have a particular stake in ensuring that Canadian landscapes are maintained in as natural a state as possible for future generations. Individuals who participate in outdoor activities tend to visit the same favourite places repeatedly or travel far afield in the search of those wonders of nature that are of particular interest to them. Such a group of individuals are excellent potential candidates as monitors of change in natural habitats.

The fact that there are numerous individuals that participate in outdoor activities leads one to hope that many will undertake the recording of data that will lead to a better understanding of how non-indigenous plants are affecting natural landscapes. Various kinds of observations can be recorded by individuals with different skill levels and interests. Examples of monitoring activities are provided in this guide with details on how to conduct the studies and report information. A variety of monitoring activities, many involving birds and amphibians are already underway in Ontario (Wildlife Watchers 1996). Nationally, other volunteer ecological monitoring programmes are being conducted and include the monitoring of ladybugs, the recording of flowering dates in the prairies and the quality of vegetation along Canadian Heritage River

Systems. Internationally, a popular activity is the monitoring of the migration pattern of monarch butterflies in Mexico, the United States and Canada.

Naturalists commonly have a forum for reporting their findings in their local club newsletters or other publications. The more serious students may wish to publish significant findings or summaries of notable monitoring results in natural history or conservation journals. Hunters and anglers have a range of publications where their observations on habitat change to their favourite haunts, caused by invasive exotic species, can be published, even if only as letters to editors. Hiking is a growing pastime that leads individuals into out-of-the-way places where there are opportunities to record the spread of exotic species. An "early warning patrol" of trained individuals within a hiking club or naturalist club could do much to alert the membership to incursions of invasive plants. In response to reports of the establishment of important invasives along trails, clubs can undertake an eradication or control programme in order to maintain the natural history integrity of the sites through which the trails lead. The development of such an early warning system and control programme could do much to prevent or forestall the infestation of natural areas.

Information derived from local studies also have broader application at the regional and national levels. Information provided through club activities can be compiled as part of national monitoring activities within the context of the Ecological Monitoring and Assessment Network (EMAN) of Environment Canada. Data gathered can also be summarized within the various ecozones, ecoregions and ecodistricts of "A National Ecological Framework for Canada" (Ecological Stratification Working Group 1996). This ecological framework provides a means of reporting data within a nationally recognized system that integrates features of geology, landform, soil, vegetation, climate, wildlife and other factors into a hierarchical ecological classification system.

The regular monitoring of a plant, population or specific habitat in a structured and reproduceable manner is not an activity that appeals to everyone. However, even occasional reports to wildlife agencies or groups monitoring the spread of a species or the occurrences of large infestations of an exotic plant are valuable contributions. Monitoring data lead to a better understanding of how the distributional patterns and abundances of exotic species are changing. They also allow for a more informed approach to the control of exotics and provide information about the efficacy of control programmes. This is, after all, the main reason for gathering data — the control and, where feasible, the early eradication of potentially serious pests that markedly impact natural areas. Even if this attempt to foster an interest in invasive plant occurrences has no other immediate effect than to increase awareness of their impact and spread in Canadian ecosystems, it will ultimately bring tangible results.

The Value of Research Collections in Monitoring

The primary source of information on plant occurrences within a country or region comes from the information stored on the labels of research collections. These are housed at institutions such as universities, museums, botanical gardens, and at facilities of federal and provincial government agencies. Research collections, however, vary in their geographical coverage and comprehensiveness. Their development is dependent on the scope and nature of the research conducted at the institutions. Because of these shortcomings, determining the detailed range limits as well as abundances of a species are hampered by the lack of recent and sufficiently comprehensive data. This is particularly true for common native and exotic species.

This anomaly, with regard to common species, results from the fact that those conducting inventories generally do not collect species that they know or assume to be widespread. Consequently, such species are often not represented in research collections to the extent that might be inferred from their widespread occurrence. Range maps determined solely on the basis of plant collections tend to reflect the collection habits and frequency of collectors in a region. Except for agricultural weeds and marketable forest tree species, which have been the subject of on-going surveys, published ranges for non-commercial species generally only reflect the historical ranges based on records many years old. In the context of exotic species documentation, however, research collections serve as valuable repositories of data that provide a historical perspective of the arrival and geographical spread of exotic plants with time. Such information could not readily be obtained otherwise.

Up-to-date distributional patterns for exotic species, or native species, can be determined only through the addition of current sight records compiled as part of national or regional surveys, as part of biological inventories and through monitoring activities by individuals and groups. Knowledge of the accurate limits and habitat preferences for exotic species provides a better understanding of their climatic and edaphic tolerances that may be helpful in forecasting future expansion or possible limits to expansion.

Basic Monitoring Considerations

Project Design and Monitoring Aids

To assist in the development of monitoring projects, four Appendices are provided. Appendix 1 lists, by region of geographical occurrence, some of the major exotic plants that have been identified as invasive to various extents. This can be used to select one or more species for monitoring. Appendix 2 documents some techniques that can be used for monitoring, plot establishment and data tabulation. Appendix 3 reviews the basic techniques of making plant collections. Appendix 4 consists of a bibliography of technical and popular works to help an individual identify non-indigenous plants and find basic information on their structure, habitat preferences, biology and distribution.

A classic book on plant ecology by Weaver and Clements (1938; see p. 32) provides some guidelines on the sizes of quadrats suitable for sampling different vegetational types. In mixed prairie sites, such as areas dominated by wheat grass (Agropyron sp.), a one metre square quadrat is suitable. Similarly, when sampling herbaceous vegetation under forest canopies and for studying weeds, a one metre square quadrat is best. For the study of scrub vegetation and saplings and shrubs within forests, monitoring protocols being developed for EMAN recommend quadrats 5 x 5 metres in size.

Trespass and Permits

When undertaking monitoring studies, a number of issues must be kept in mind. Permission to enter private or restricted public lands should be obtained prior to undertaking an inventory or setting up monitoring plots. By contacting landowners or managers of public lands, such as parks, information can also be obtained on areas that should be avoided because of specific hazards that may exist. There may also be areas that should not be disturbed because of the presence of actively used nests or den sites of sensitive species or because of the presence of species provincially or nationally at risk. On the other hand, wildlife habitat managers may also be able to suggest certain kinds of monitoring activities that would be particularly useful. A collaboration with site authorities on monitoring exotic plants already underway might also be a productive approach.

If destructive sampling, such as the collection of plants for vouchers and identification purposes, is necessary, permission or permits must be obtained. Local authorities should be contacted. If permission is required from headquarters or regional offices, local authorities can assist. Most parks will require a report as part of the authorization to conduct studies. Consistent recording of information using standardized forms will be particularly useful and likely a necessity for proper documentation of results. The collection of voucher specimens of exotic plants recorded in a park may also be a requirement, especially if no inventory has been undertaken previously. Instructions on collecting plants and making a reference collection is provided in Appendix 3.

Establishment of Monitoring Plots

Careful consideration must be given to the placement of monitoring plots. Long-term monitoring requires that plots remain undisturbed so that consistent and comparable observations can be made. Plots that require the collection of detailed information over a long time period and plots that require visible demarcation or subdivision, should be established within protected areas or at least carefully supervised sites such as parks and nature reserves. Such sites would be less prone to disruption by vandals. The loss of a plot that has served as the basis of many months or years of data compilation can be a major set-back.

Exotic plants, even ones considered to be invasive, are most commonly found in disturbed areas and on lands used by the public. When establishing monitoring plots or the monitoring of individual specimens or clones in or near public access areas, the main consideration is to demarcate the plot or specimen so as to draw as little attention as possible. In public areas, it may also be necessary to determine through consultation with grounds keepers or municipal officials where and when weed or shrub control is practised so as to avoid such areas. Of course, property managers should know where study plots or specimens are located so that they can also assist in minimizing disturbance to the site. Where possible, plots should be located away from areas of highest public use. Smaller replicate plots scattered throughout areas used by the public would likely draw less attention or be less recognizable to the casual observer than lerger plots. Establishing replicate plots will minimize impacts on the project if one or more plots were to be disturbed or destroyed. Replicates also improve the reliability of the data generated from the studies.

Urban sites, such as ravines and parks, as well as shrubby forest remnants in greenbelt areas of cities, are readily accessible and suitable for monitoring biological attributes such as longevity of perennial species or first flowering times or seedling emergence. Backyard gardens can also serve as protected areas for monitoring exotics. Natural or little disturbed sites in protected, remote sites are needed for studies on the impact of invasive species on the native flora.

Examples of Monitoring Projects

Monitoring of exotics has been an on-going activity since the early decades of this century, but has focused almost exclusively on agricultural and forestry pest species. These include weeds, destructive insects and other invertebrate pests and plant pathogens that have a substantial impact economically.

Phytosanitary inspection of in-coming plant materials by government officials is one form of long-term monitoring that minimizes the risk of exotic pest entries into a country. Inspections and federal and provincial weed and seed acts regulate the entry and movement of exotic plants, especially those that are considered harmful or noxious. Major efforts have also been made in the first half of the 1990s to document the spread of some high profile invasive species such as zebra mussels and purple loosestrife. The national purple loosestrife survey campaign encouraged public participation through the reporting of sightings using a standard report form. Many other plant exotics that do not have a direct agricultural or forest industry connection warrant more extensive data compilation than is presently available in order to clarify the extent and degree of infestation and impact on native ecosystems.

Some of the major invasive or potentially invasive exotic plants are tabulated in Appendix 1 by geographical occurrence. This listing supplemented by reading a booklet such as that on Invasive Plants of Natural Habitats in Canada (White, Haber and Keddy 1993) can be used to select species of interest for possible monitoring studies. Specific examples of monitoring activities are given here that can be adapted to local circumstances and species present. Monitoring aids are briefly outlined and illustrated in Appendix 2.

Each monitoring project undertaken should have a clear purpose established. This will make it easier to set out a course of action for monitoring so that useful information can be compiled and, where warranted, specific control actions can follow. Some projects may be initiated to monitor the spread of a species in an area of establishment with the view to eradicating small infestations to slow the spread. Monitoring could also be done as part of an early warning system so that any newly established plants or populations in an area previously beyond the range of occurrence can be readily identified and removed to prevent their spread. Other types of monitoring, such as the study of the rate of population or clump expansion or first flowering, provide valuable biological information that may allow for improved control measures. As well, monitoring activities can be directed at determining the impact invasive species have on the native flora of monitored plots.

The following project examples and supplementary ideas represent five main types of monitoring activities that can be undertaken to document exotic plants:

Occurrences — determining the presence of all exotics in a region, plot or natural area and the recording of new exotic arrivals with time.
Abundance — recording changes in numbers or area covered within specified areas or plots.
Expansion — measuring the rate of expansion of a clump or population.
Biology — recording seasonal flowering events; longevity of a perennial exotic; seedling survival; seed production in different habitats; presence of herbivores/pollinators.
Impact — replacement of native plants in plots; change in use of the plot by animals as the exotic becomes dominant.

The examples provide a basic framework for monitoring activities that can be modified to suit individual interests or needs of the region. Projects can be undertaken solely on species that are presently known to be invasive in natural habitats or a broader focus can be maintained by monitoring other exotics whose invasive potential have not been clearly, or at all, established.

Unlike monitoring activities that record the change in biodiversity of native fauna and flora within a region or specified plot, the monitoring of exotic species commonly has, as its ultimate purpose, the control or eradication of such species. The following projects generally are based on this principle or on the gathering of data that may ultimately be of value in providing a better understanding of the biology of exotics so that their proliferation can be controlled.

Project 1. Linear Highway Surveys

Purpose: The monitoring and eradication of recently established plants or small populations of a species (or more than one species) to slow the spread within a region or to prevent the establishment within an area not previously occupied. This project can be considered as a variation of the "Adopt a Highway" programme. Instead of keeping the highway clean of refuse, the project is aimed at controlling the spread of troublesome non-indigenous plants.

Overview: In order to take action in controlling an exotic plant, its current distribution must be known. This requires the mapping of occurrences and recording of some rough measure of population size so that individual plants or relatively small populations that are most amenable to eradication can be identified. As well, yearly monitoring of the same roadsides or study areas will indicate the establishment of new plants or populations that are also suitable candidates for eradication. Such monitoring along stretches of roadways within a specified geographical area, together with control actions, will slow or prevent the spread of nuisance plants.

Methods: For roadside wetland or woodland edge surveys, a stretch of primary or secondary highway is selected where suitable habitats for monitoring occur. Specific start and end points are selected so that a reasonable monitoring distance is included. Ten to 50 km routes, or even longer, may be manageable, depending on the kind of transportation to be used. In some areas, monitoring by bicycle may be possible or preferred. The frequency of the habitats present and time and effort to be expended are other considerations that will determine the lengths of monitoring routes.

A new road map can be used to record the positions of the species sightings. A site number should be placed on the map at the approximate kilometric position from a landmark such as a local town or major crossroad indicated on the map. A log entry should also be recorded in a field book or on a special monitoring records form such as that in Appendix 2 (Exotic Plants Roadside Monitoring and Action Form) for all sites located during a particular monitoring survey. To help prioritize sites for eradication, it is useful to record whether the sites are near park boundaries or in areas where further spread might result in infestation of natural areas of particular significance. For each significant site, a detailed Exotic Plant Survey Record Form, similar to that in Appendix 2 should be completed to document the occurrence in detail.

If the intent is to promote action on small, easily eradicated sites, then the approximate number of plants or area in square metres occupied, together with a brief indicator of the type of habitat, should be recorded. This will allow for the selection of sites that might be most amenable to eradication or control. A reasonable estimate of the area can be obtained by determining, through experimentation, the size of pace required to approximate one metre and then pacing off two sides of the sites. To ensure a somewhat greater accuracy, a small inexpensive retractable tape measure can be helpful as part of the field equipment to establish pace length and, as well, to measure plant heights, diameter of clumps or depth of water. Actual measurements with a long tape measure can also be made if precise quantification is desirable.

A standard form can be prepared in a tabular layout that can be used to record excursion results. To avoid confusion between surveys of different years, no duplicate numbers should be used. A sequential number should be used without duplication from year to year. A common convention in ecological studies is to adopt the two digit abbreviated year as a prefix for the site identifier with the subsequent digits representing the specific site location for that year (e.g., 9723 for site 23 during 1997). This site location number should remain a unique number from year to year so that the fate of individual sites can be properly monitored. A different colour of pen or pencil can also be used to distinguish sites recorded in subsequent years on the reference map.

For those interested in greater precision in recording population positions, one or more topographic maps of a suitable scale such as the 1:50,000 NTS (National Topographic System) maps can be used to record the localities along the roadside. This will also allow for precise coordinates, either latitude and longitude or the UTM military grid easting and northing values to be determined readily. Such coordinates will allow for computer mapping of localities and the development of databases that can be used for mapping and record management. If data are to be recorded in a database or spreadsheet format, site numbers in the format suggested above can also be readily sorted by computer if no other characters are placed between the year and the site identifier. When coordinates are required for a study, the tabular record form should have a place for this information. The inclusion of standard coordinates on labels of voucher collections is also a valuable and precise means of identifying site locations.

Although expensive and beyond the normal scope of use by naturalists, a hand-held GPS (global positioning system) can be purchased that provides easily captured coordinates for roadside localities and open area surveys. These units work best where there is little interference from trees blocking signals from the overhead satellites that make possible geolocation to within approximately 10 m for ordinary portable units. Storage of site coordinates and direct transfer to computer databases is possible for computer mapping purposes and analyses using GIS (geographic information systems).

With information compiled on population location and size in square metres, decisions can be made on which sites might be suitable for eradication or control by manually sorting sites based on the maximum size of area that can be most readily treated by an individual or group. Information stored in database or spreadsheet form is much more readily retrievable, especially if there is a large data set.

The methods outlined here can be applied also to recording and monitoring species occurrences within a region of defined aerial extent. Surveys can be conducted along all of the roadways within a township, for example, and frequency of occurrence of populations of a specified minimum size can be calculated for the region per km of road length. Most projects that require the calculation of abundance within an area would require some form of careful notation of population sizes as part of the inventory of a species. A general notation of frequency per linear km of distance surveyed along a highway could be recorded by using a simple set of relative frequencies. Examples of categories of frequencies are absent, infrequent, sparse, common and abundant, with each category representing an occurrence based on a defined level of plant or patch frequencies (see Groh and Dore 1945).

Project 2. Trail Monitoring

Purpose: The establishment of an early warning and exotic species eradication programme for hiking and nature trails.

Overview: The development and use of hiking and nature trails in natural areas of vegetation results in opening corridors that allow weedy and invasive plants an opportunity to become established in places normally not readily accessible. Monitoring the spread and possible invasion of natural areas by non-indigenous species allows for the early detection of potentially troublesome species that can be eradicated before they become firmly established and have a negative impact on the native flora. Subsequent monitoring of sites where exotics are removed will ensure that complete eradication can be effected. A monitoring plot can also be established as a study project to determine the impact of an established population of an invasive plant on the native ground flora of the site.

Methods: Volunteer monitors from a club are assigned to specific portions of hiking or nature trails that pass through relatively undisturbed wooded or other types of vegetation for the purpose of recording significant incursions of non-indigenous plants. A programme of monitoring trail sections is established whereby each monitor records the location of significant patches of weeds or of newly established plants of an invasive species for the purpose of eradicating such point sources of invasion.

Aids to monitoring could include a photocopy of the official trail map with landmarks clearly indicated. These will be used as reference points for pacing off distances to identify the location of infestations. The use of an NTS map sheet with the trail position indicated provides a more accurate means of identifying infestation positions. Such a topographic map allows for latitude and longitude or UTM coordinates to be recorded for precisely locating sites of establishment. This may be particularly desirable in areas where obvious trail landmarks are not available. A survey report form similar to the Exotic Plant Survey Record Form (Appendix 2) can be used to record information on the exotic species localities found. A specific trail form similar to that in Appendix 2 can also be prepared that provides a running account of infestations and actions taken. A unique site occurrence number should be used to keep track of each point of infestation over subsequent years. A specific identification number such as described in project 1 is recommended.

When weeds or invasives are located, their positions can be indicated along the trail with a short length of colourful flagging tape attached to a nearby shrub or branch. The unique site number should be written with a waterproof felt marker on the tape. The site is then indicated on the trail map and recorded in the field notebook or special report form. If the infestation consists of only a few herbaceous plants, these can be uprooted by the monitor and bagged for later disposal in a public landfill site or by burning. Larger infestations or specimens such as invasive shrubs that are more difficult to remove can be scheduled for action at a later time by the club's volunteer "Weed Eradicators". Subsequent monitoring of each identified site of infestation will allow newly emerged seedlings to be removed to ensure complete eradication.

As an additional activity of club members, the impact of an infestation on the local flora can be monitored by establishing a plot in a manner similar to that described in project 4.

Project 3. Plant and population expansion

Purpose: To document the rate of expansion of a single plant, patch (clone) or population of an invasive plant.

Overview: An understanding of the rate of expansion of an exotic plant can be useful in making inferences on the history of establishment of a population and can provide data useful in determining the potential threat of a species. The faster the rate of expansion of a species the greater is its potential for becoming a troublesome weed or, in some cases, a troublesome invasive. To determine the rate of spread, a point source of establishment and of potential infestation within an area is located and the expansion is monitored over a period of several years. A point source can be an individual plant, colony or small population. The rate of spread can be determined within a single habitat type or within different habitat/substrate types to compare the species' response under varying conditions. Such information is valuable in determining priority species for control within a region.

Formulas for patch expansion have already been developed for leafy spurge that permit the determination of the age of a patch or the total number of stems if its area is calculated (Bangsund, Stroh and Leitch 1993). The rate of patch expansion, as well as the stem counts per unit area, were the underlying variables that needed to be calculated based on field observations. The simple procedures outlined here can be used to determine the rates of invasion of a species within a habitat. If statistical reliability of data is an important factor, professional assistance should be obtained for the appropriate selection of sample sizes for monitoring.

Methods: The monitoring of expansion rates will vary with the species to be investigated. For perennial terrestrial species, the growth and expansion of a single plant can be followed as it increases in size and produces additional aerial stems to form a patch (clone) that increases yearly in size. This is easiest for shrubs and those species with a prominent underground rootstock such as is found in flowering rush, leafy spurge, Canada thistle and various grasses that tend to reproduce vigorously through vegetative propagation to form discrete clumps. Even for such species, one needs to keep in mind that their spread across the landscape, in general, also depends on the ease of seed dispersal, seedling establishment and other factors related to human activities that promote spreading of plants.

To monitor an exotic that is an annual, biennial or short-lived perennial, the rate of expansion of the species must be determined based on the overall spread of the local population from the initial point of introduction. The vegetative reproductive capacity of an aquatic such as European frog-bit can be studied by following the yearly growth of one or more individual plantlets that forms in the spring.

In every case, the plant or population being monitored should represent an isolated occurrence where data collected on expansion will be based on that selected individual or population. There should be minimal chance of including plants in the expansion data that have originated from an outside source of seed or other means of establishment.

a) **Basal area expansion of a perennial plant**. The expansion of area occupied by an individual plant, such as a shrub, can be determined simply by measuring the yearly diameter, each fall or spring, with a metric measuring tape held at the widest point of the branches on opposite sides of the plant. For a large shrub, either an assistant holds the tape at the outer edge of shrub growth on one side or a marker is placed on the ground directly in line with the outer limit of branch growth (the drip line) and the measurement is taken from this point to the outer limits at the other side.

To ensure that the same individual is recorded, a ribbon of flagging tape, for better visibility, can be used together with a plastic label that is securely attached and marked with an identification number. If fading is a problem, the label may have to be replaced on a yearly basis to ensure correct identification and monitoring. In forested areas, aluminum labels should not be used because deer tend to chew on these. An additional notation of the exact position of the plant should also be made based on distances from a readily discernible marker point. A topographic map would be very useful in recording the position of the plant.

The yearly increment in area occupied by the plant can be approximated and determined by using the standard formula for the area of a circle ($pi * r^2$). If the species occurs in widely different soil types and moisture regimes, monitoring of individuals in different sites will provide a better understanding of the species' potential for growth under different conditions. If desired, the yearly increase in height can also be measured and graphed. To eliminate individual variability within a site, several plants, perhaps as many as 5-10 should be monitored and the results averaged. To determine whether there is a meaningful difference in expansion of plants between sites, will require a more technical approach based on using statistical tests of significance. Such tests can be obtained from basic statistical reference books.

If the species does not seem to have clearly delimited substrate preferences, 10 or more plants can be monitored across a range of sites within one of the ecoregions described in A National Ecological Framework for Canada (Ecological Stratification Working Group 1996). A yearly average can be determined and plotted to show the increase in ground space occupied by the exotic being monitored.

A simpler alternative approach to determining the change in basal area occupied by a woody exotic as it ages is to measure the diameters of a sizeable number of shrubs. A total of 30 shrubs of different sizes, from very small to the largest available within a site or area should be measured. The thickest stem within the centre of each shrub is cut off near its base and the annual growth rings counted so that basal area can be compared with age. A graph with age on the x-axis and diameter on the y-axis can be plotted to show the increase in basal area with age.

b) **Basal area expansion of a clump or distinct patch**. When dealing with herbaceous perennial invasives that tend to form expanding patches as the result of the vegetative spread of the rootstock, a similar technique to that outlined for a single shrub can be used. The main difference is that the centre of the clump should be marked with a plastic or metal stake and a plastic label attached with the patch identifier written in pencil or waterproof ink. The expansion of clump diameter should be monitored for different initial sizes of clumps over a period of perhaps 3-5 years, or more if possible. As well, to minimize individual patch differences or unforeseen factors, it is always preferable to monitor several patches. It would be preferable to monitor 3-5 clumps for each of several initial size classes ranging including small, medium and large. The results of yearly expansion within the classes can be combined and averaged as long as the clumps that were selected within each category were of relatively identical initial diameters.

It would be preferable to select clumps for monitoring in areas not heavily infested by the species to ensure that within-species competition is not one of the variables that is controlling or limiting expansion. A worthwhile monitoring activity would be to compare patch expansion in areas dominated by certain assemblages of other native or exotic species to determine potential impact on growth rate of the exotic being monitored.

Monitoring results can be graphed, as for individual shrubs, to show the yearly expansion. Based on the recorded expansion rates per year, a formula similar to that developed for leafy spurge may be used for determining the potential rate of coverage of an infested area over a specified period of time (Bangsund, Stroh and Leitch 1993).

c) **Rate of propagation of a floating aquatic (European frog-bit)**. In the course of a season, a single overwintering bud of European frog-bit (Hydrocharis morsus-ranae) produces many floating plantlets, all attached to a common stem. At the end of a growing season, in some areas, thick dense mats are formed by the accumulated vegetative biomass. The current distributional pattern of this species in Ontario indicates that it may be limited to watersheds primarily to the south of the Canadian Shield.

Monitoring the rate of vegetative expansion and biomass productivity in different watersheds where the species is established would be useful in understanding the limiting factors that may restrict the species' spread. By tagging an individual plantlet early in the season, the number of plantlets produced by the end of the season when first frost arrives, or by a specific date, will give an idea of the vegetative reproductive capacity of an overwintering bud. Careful separation of the tagged plants and their offshoots from other plants is required to determine accurately the number of plantlets produced in one season. The individual plantlets must be properly identified with a suitable plastic tag with identifier numbers written in pencil or waterproof ink. The tags may need to be attached with thin, flexible monofilament fishing line that will not decay in the water over the course of the season.

A more complex field study that could be suitable for a graduate student project would be the monitoring and determination of the propagation capacity based on numbers of plants and biomass produced by a single plantlet in different watersheds with different nutrient levels and pH. Sites in watersheds throughout the species' range in Ontario are selected on the basis of differing nutrient and pH levels. Individual plantlets are weighed in a standard quantity of water early in the season, tagged and monitored over the course of the summer.

At the end of the season, the progeny of the parent plantlet are carefully extricated from the surface mat of plants and weighed. The water is drained off and the plants are dried with absorbent towelling and left in the air for a short period to remove additional films of moisture. The fresh weight of the season's growth can be compared with the initial weight of the plantlet itself and, as well, the dry weight of the biomass can be determined following standard procedures for such determinations.

The results can then be evaluated in reference to the nutrient levels and pH in the water column below or within the mat. Additional information can be gathered over the season on nutrient and pH changes to evaluate further the changes in the environment as plant mats proliferate. Control water samples should also be evaluated for nutrient and pH changes from adjacent sites where European frog-bit is not growing.

The results from such field monitoring studies will contribute to an understanding

of nutrient requirements and potential limiting factors for the growth of European frog-bit.

d) **Expansion of herbaceous plants (annuals or biennials).** Annuals and biennials tend to spread primarily by seed and therefore produce local populations of plants. This is in contrast with some herbaceous perennial exotics that form discrete patches (clones) primarily by vegetative propagation. A perennial exotic will remain in place and expand its area of coverage vegetatively with time. An annual or biennial, however, depends primarily on seed production and its dispersal. Reliance on seed dispersal results commonly in the movement of populations from the original point of introduction outward depending on factors such as dispersal agents for the seeds. For annuals and biennials, change in population size and spatial displacements must be monitored.

To monitor expansion of such populations, it is desirable to select isolated populations to minimize risks of entry of outside seed sources during the course of the monitoring study. It may also be preferable to select a recently established, small population or site where only a single or few clustered specimens are growing. This is more likely to ensure that no other seeds are present in the vicinity that might lead to misinterpretation of the rate of spread from the initial parent population or plant.

Depending on the size of the population, a monitoring plot 1 m^2 is established centred over the parent plant or population. The corner posts of the plot can be marked with metal pegs but bright plastic pegs, such as thick durable tent pegs, are preferable. If discreetness is a necessity, only the tops of the pegs are left visible above the ground. As the population expands, this initial 1 m^2 plot can form the centre of a larger plot based on a 5 x 5 m grid. A small plastic stake can be used to mark the position of the initial plant or centre of the small population. The location of the plot should also be recorded in a field notebook using distance measurements from readily identifiable marker points or landmarks. If it seems desirable not to leave a permanent indicator of the centre of the original population, the location will have to be recorded through measurements based on the corner post locations.

The expansion of the population can be monitored in a number of ways. If the population spreads symmetrically, a metric tape is used to measure the distances from the original centre to the stems of the outermost plants that have become established. An average distance of spread is then determined in cm or metres per year from the original centre. These measurements are repeated yearly at the end of the season when mature plants have developed or first year rosettes have formed. The total area of spread can also be approximated by calculating the area of a circle (pi * r^2) using the total linear expansion from the original centroid to the outer margin as the radius.

If a population tends to expand asymmetrically under the influence of the wind carrying seeds primarily in one direction, a convenient method of tracking its movement is by overlaying a 1 m quadrat divided up into a 10 or 20 cm metric grid (see Appendix 2). The outermost periphery within which all of the plants are found is recorded and transcribed at a reduced scale to a sheet of graph paper. The approximate total area of coverage by the population can be determined by summing the number of square cm on the paper graph. A more detailed yearly coverage can be determined by summing the basal areas of individual plants in the population. This more detailed calculation will require the transfer of basal area data for each plant to a paper grid. This can be done with the use of a pantograph. This is a specially designed armature that enables one to copy the outline of an object at the same or different scale (see Weaver and Clements 1938). The basal areas of individual plants can also be carefully transferred to the graph paper by visual inspection of the outlines in relation to the grid lines. The rate of movement of such a population can be determined by measuring the distance of its mid-point from that of the original centre of the population. The number of flowering stems within the total area occupied at the end of a season can also be recorded as part of the data gathered to document population expansion.

An overhead photographic record of a quadrat can also be made using a low stepladder to gain enough elevation to take the picture. The four corners of a 1 m^2 plot should be demarcated and visible in the field of view. By taking an overhead photograph aided by a wide angle lens, the enlarged print can be used to record the positions of the plants within the plot. It is important to ensure that the same height is used for repeat photographs and that the camera is held above the centre of the quadrat. Some improvisation will be necessary in order to hold the camera directly over the quadrat and to ensure that the entire plot is in view and in focus. If a string grid is already in place on the quadrat this will aid in recording basal areas from the photo.

The print should be enlarged to an appropriate scale to facilitate conversion of areas from the quadrat to the print. A 35 mm single reflex camera can be used for this photography but a camera with a larger film format would be preferred in order to allow for clear print enlargements to be made. If the quadrat is within a shaded woodland site, the use of one or more electronic flash units may be required or a film with a high ISO value must be used to ensure that available light will provide a proper exposure.

Project 4. Monitoring impacts on native vegetation

Purpose: To monitor the impact of the spread of an invasive plant on native vegetation.

Overview: Few studies are available that document the effect of an invasive plant on native species within natural habitats. Such studies require careful monitoring of individual plants within a plot over a number of years. The following procedure can be used to document changes in numbers of plants and species composition within a plot where an invasive plant has become established. Such studies may be most readily undertaken for terrestrial species within open and wooded habitats. The size of the monitoring plot (quadrat) needs to be selected to accommodate the size of plants being monitored. If the invasive is a shrub, the size of the plot may need to be in the order of 5 x 5 metres square so that ample vegetation is included for study. For the study of grasses and herbaceous vegetation in fields and woodlands, a quadrat of 1 square metre is commonly used (Weaver and Clements 1938). The methods described for recording and charting plant numbers and positions within a plot allow for the compilation of both simple observations on the numbers of plants and species that are present with time as well as changes in area occupied by each respective species.

Methods: If monitoring an invasive shrub and its impact, a quadrat should be set up that includes one or more young shrubs and other native vegetation whose change with time will be monitored. If a herbaceous species is selected, the quadrat should include only one or a few stems or a small clump of the invasive among a suitable mixture of native species. The quadrat should be selected with due precaution to avoid disturbance through human activities. Permanent corner stakes should be fixed in place and the layout verified that it is a square.

Ensuring that a quadrat is square is readily accomplished. A quadrat is square when the diagonals are equal in length. The initial corner lines can be established at right angles, especially for a large quadrat, by using the Pythagorean theorem — the 3/4/5 rule — that deals with the square on the hypotenuse. If two lines are extended at an acute angle from a common point, with one being 3 units and the other four units long, the angle becomes a right angle when the measurement of the third side of the triangle, the hypotenuse, reaches five units. When monitoring herbaceous vegetation, one need not be restricted to using replicates of individual quadrats. If a suitable area is found with a number of the invasive plants scattered within an elongate area, a linear series of two or more metre square quadrats can be established.

For recording the exact centres and basal area coverage of plants or clumps of both invasive species and all native species in the quadrat, a grid is established. For a larger quadrat this may entail delimiting the area within the corner posts by a strong cord. A metric grid is then established subdividing the area into appropriate units depending on the size of the quadrat and the abundance and location of plants in the quadrat.

A letter code is then assigned to each species, perhaps representing the genus or scientific binomial of a species. The centre point of each plant and the species designation is indicated on graph paper of suitable size to adequately record the number of plants present. If the basal area, representing the amount of space occupied by a plant, is to be recorded, a special ruler can be devised (see Appendix 2) that will give the approximate basal area when the diameter of the plant or clump is measured. A unique number can also be assigned to each plant to track its presence and change with time.

Setting up individual square metre quadrats can be done perhaps most readily by cutting out a template from a thin sheet of plywood or hardboard with a square hole with one metre sides. This can be used to place the four corner pegs and as well to establish a 10 cm grid across the open area of the template. To do this, small galvanized nails are fixed to the template at 10 cm intervals along all four sides and left to protrude above the surface. Cord is then wound back and forward to create the grid. Each 10 cm unit is numbered around the perimeter as indicated in the example in Appendix 2. Other simple methods of demarcating one metre quadrats using narrow strips of wood or metal are also reviewed in Appendix 2.

Yearly data can be recorded in a tabular manner such as in the quadrat record form provided in Appendix 2. The fate of individuals for both the invasive and the native plants can be monitored and recorded in this fashion. Also, a photographic record can be made to record the change in plant occurrences and size within a plot. The method of overhead photography can be readily applied to a small quadrat as described in Project 3D.

A simple means of providing a photographic record of seasonal and yearly changes in growth and expansion of invasives within a site is to use the technique of camera sets. A series of photographs are taken at the same location at regular intervals throughout the seasons and in successive years. A tripod is set on three reference stakes or pegs in the ground with the camera adjusted to a standard height and facing in the same direction for every photograph. Such a technique provides a unique photographic record of changes in vegetational growth as well as the expansion or retreat of exotics and their impact on native species and habitats.

Another way of recording changes in the landscape is to use a modern video camera. Even the less expensive units permit the addition of date signatures to indicate when the segments were recorded. As well, a voice-over will record pertinent field observations to help interpret the status of vegetation changes. The same film is used to monitor the same site throughout the growing season and over a period of several years. The film is relatively inexpensive and can be used to provide footage from a number of angles and at various zoom positions.

Supplementary Project Ideas

Other projects can be undertaken that provide interesting facts that will add to the understanding of the biology of exotic plants. The following are suggestions for possible monitoring studies:

> recording first flowering dates of one or more exotics for comparison with native species in the same habitat
> date of first sign of senescence or dormancy
> seasonal frequency of use of an exotic by insects recorded by major groups
> use of an exotic by native wildlife
> change in seed/fruit production with age of a perennial exotic survivorship of seedlings within a plot
> longevity of a clonal exotic

Species Identification

As an aid to ensure that correct identifications are made of the exotic plants proposed for monitoring, a bibliographic listing is provided (Appendix 4). This list includes standard manuals and floras for Canada, references to plant groups of special interest, as well as some popular field guides for plant identification. There are also numerous sources of information on exotic species on the Internet that can be readily found through the use of key search words such as: alien, weed, noxious, non-indigenous, pest and biological control. The common names of plants can also be used to search for information. An important and useful site that provides information on the current scientific names, common names and general North American distribution of plants is that for the National PLANTS Database maintained by the U.S. Department of Agriculture (http://plants.usda.gov/plants/fr_access_main.html) and the Biota of North America Program (BONAP) database. The latter is located at the University of North Carolina at Chapel Hill (http://www.mip.berkeley.edu/query_forms/browse_checklist.html).

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Appendix 1

A Selection of Common Invasive or Potentially Invasive Plants of Canada

Common Name	Scientific Name	NT	YT	BC	AB	SK	MB	ON	QC	NB	PE	NS	NF
Flowering Herbs													
Canada thistle	*Cirsium arvense*	+	+	+	+	+	+	+	+	+	+	+	+
Celandine	*Chelidonium majus*			+				+	+	+	+	+	
Common buckthorn	*Rhamnus cathartica*					+		+	+	+	+	+	
Dame's-rocket	*Hesperis matronalis*			+	+	+	+	+	+	+	+	+	+
Dog-strangling vine	*Cynachum sp.*			+				+	+				
English ivy	*Hedera helix*			+				+					
Eurasian watermilfoil	*Myriophyllum spicatum*			+				+	+				
European frog-bit	*Hydrocharis morsusranae*							+	+				
Flowering-rush	*Butomus umbellatus*			+	+		+	+	+	+	+	+	
Garlic mustard	*Alliaria petiolata*			+				+	+	+			
Glossy buckthorn	*Frangula alnus*					+	+	+	+	+	+	+	
Goutweed	*Aegopodium podagraria*			+			+	+	+	+	+	+	
Leafy spurge	*Euphorbia esula*		+	+	+	+	+	+	+	+		+	
Moneywort	*Lysimachia nummularia*			+				+	+	+	+	+	
Purple loosestrife	*Lythrum salicaria*			+	+	+	+	+	+	+	+	+	+
Russian knapweed	*Centaurea repens*			+	+	+	+	+					
St.John's-wort	*Hypericum perforatum*			+			+	+	+	+	+		
Scotch broom	*Cytissus scoparius*			+							+	+	
Spotted knapweed	*Centaurea maculosa*			+	+	+	+	+	+	+	+	+	
Sweet Clover	*Melilotus sp.*	+	+	+	+	+	+	+	+	+	+	+	+
Tartarian honeysuckle	*Lonicera tatarica*				+	+	+	+	+	+	+	+	
Wild marjoram	*Origanum vulgare*			+				+	+	+	+	+	

Common Name	Scientific Name	NT	YT	BC	AB	SK	MB	ON	QC	NB	PE	NS	NF
Trees and Shrubs													
Black locust	*Robinia pseudo-acacia*			+				+	+	+	+	+	
Manitoba maple	*Acer negundo*				+	+	+	+	+	+	+	+	
Norway maple	*Acer platanoides*							+	+	+	+	+	+
Siberian peashrub	*Caragana arborescens*				+		+	+	+				
White poplar	*Populus alba*			+	+	+	+	+	+	+	+	+	+

Exotic invasive grasses are not listed because of the greater difficulty in their identification by novice botanists.

Appendix 2

Tools and Techniques for Monitoring

Brief mention is made here of professional aerial remote sensing techniques for leafy spurge mainly as a point of general interest. The papers by Armstrong (1979) and Everitt et al.(1995) referenced here provide an insight into how advanced aerial photographic techniques can be applied to assist in the detection and quantification of leafy spurge occurrences within an area. The techniques applied consisted in the use of colour infrared photography, conventional colour photography and conventional colour video imagery. Although the techniques, as applied in the studies, relied on aerial photography with large format cameras, 35 mm colour infrared film is available. This can be used by an interested amateur photographer as an alternate means of recording leafy spurge based on repeat ground-level photos taken during a season to show developmental changes. A yellow #12 filter was used for recording leafy spurge on infrared film by Armstrong (1979). Leafy spurge appears as a hot pink colour in the photographs. Experimentation with different filters may lead to the use of this technique for monitoring other species of exotics.

Armstrong, D.W. 1979. Aerial infrared imagery of leafy spurge (Euphorbia esula) Proc. Leafy Spurge Symp., June 26-27, 1979. Bismark, North Dakota. pp. 68-69.

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Database/spreadsheet data recording

The careful and consistent recording of data within field notebooks or standardized report forms is the first step in ensuring proper data organization and may be all that is required for simple projects. However, when undertaking a long-term project by oneself or one that is a collaborative effort with other members of a club where a sizeable data set will accumulate, consideration should be given to recording data in digital form. This will make data analysis simpler and information can be output readily in different report formats once it is in digital form. An added plus is the ability to exchange the data with others who may be able to use it with minimal manipulation to adapt it to other purposes.

Modern database and spreadsheet software are very powerful tools for organizing data. The main considerations in their use is in deciding what fields of information must be in a standard format to allow for accurate sorting or calculation of numeric values and what kind of monitoring data are best recorded in free-form notation. If geographical coordinates are recorded for sites of species occurrences, this allows for the sorting of data by latitude and longitude. If computer mapping is an option, the coordinates will have to be recorded in a specific manner used by the mapping software.

When establishing a database, a proper description of the fields, the kind of data to be entered in each and the standard manner of data entry should be recorded as background documentation. Proofreading of data fields is particularly important to ensure that all data are in the correct format and that no typographical errors exist. This is particularly true when certain place names or species names, for example, will be used to search the database. Errors in spelling of key names or words will result in records not being retrieved when searches are performed.

Mapping of species occurrences

Map sources. Provincial road maps are commonly available free from motor vehicle licensing agencies and for purchase from commercial retail outlets. Local municipal offices may also be able to provide regional road maps of a larger scale. Topographic maps are often sold by specialty camping equipment outlets for areas covered by canoe routes and trails and detailed trail maps are also commonly available at such retail outlets. Local dealers selling maps are generally listed in the yellow pages in larger centres under maps and charts. In Canada, the Canada Map Office, located at 130 Bentley Avenue, Nepean, ON, K1A 0E9 (Tel: 613-952-7000), can be contacted for a list of dealers in a specific region. Maps of the National Topographic System of Canada (NTS) can also be ordered from this office.

A series of maps and other products have been produced as part of the National Ecological Framework for Canada. In particular, maps are available for the Terrestrial Ecozones, Ecoregions and Ecodistricts for provinces or groups of provinces at a scale of 1:3,500,000. Information on their cost and availability can be obtained by contacting: Agriculture and Agri-Food Canada, Research Branch, Canadian Soil Information System (CanSIS), K.W. Neatby Building, Room B 73, Central Experimental Farm, Ottawa, ON, K1A 0C6 (tel: 613-759-1878; fax: 613-759-1924; internet: CanSIS@res.agr.ca).

Pre-printed base maps for North America, Canada and provinces can often be obtained from university book stores. Simple base maps are also available as CD-ROM clipart files for use in computer graphics or paint software.

Map uses. Maps are useful in a variety of ways for documenting the occurrences of exotic plants. Species locations can be marked on road maps during highway surveys and trail maps can be used in a similar fashion. For those with access to a hand scanner or flat-bed scanner, portions of a topographic map can be scanned, reduced in size and printed on a laser printer. Such maps can be attachment to a mounted specimen or included within a newsprint folder with the specimen whose precise location is marked on the map. A miniature map can also be included as part of a specimen label in making a reference collection.

Standard pre-printed base maps have been used traditionally for preparing maps of species distributions by phytogeographers and plant taxonomists as part of the documentation of species' ranges. Each locality of a voucher specimen is graphically represented on a map as a small solid black circle or other symbol. This can be done with a pen and special plastic template, with symbols of various sizes, that can be purchased at drafting supply outlets. A similar map can be prepared for each non-indigenous species whose occurrence in a province, county or other geographical region is being recorded as part of a monitoring project.

Computer mapping. A traditional "dot" distribution map (Figure 1) can also be prepared with a computer paint programme as long as a suitable graphics map file is available or can be scanned for use with computer software. Such a PCX graphics file, for instance, can be used by a paint programme to add b/w solid circles or small squares on the map representing the place where the species was found. This can then be printed on a laser printer as a distribution map. A more comprehensive graphics programme such as COREL DRAW can import files in many different formats and can be used to create very professional maps if a good base map is available as a graphics file. Mapping software for personal computers has been available for about ten years.

Most of these programmes, however, such as MapInfo, ArcView, SPANS and QUIKMAP are still relatively expensive at close to $1000 CAN. They can be used to map large data sets organized in databases of a specific structure. Species records can be sorted in various ways and mapped with a variety of symbols and colours and printed on a laser printer. Information on such software can be obtained by searching on the internet using the name of the software programme.

Practical Tools for Monitoring

A variety of simple tools can be purchased that will increase the range of information that can be recorded as part of a monitoring project. A simple, glass, alcohol thermometer can be used to record water temperatures and air temperatures at the plot sites. Such recordings are likely only useful if the project requires frequent monitoring of a site during the course of a season. If insect visitations to a population of an invasive species are being monitored, the air temperature and general weather conditions will be important to record. The change in the relative acidity (pH) of an aquatic site over the course of a season may be of interest and value. Litmus paper purchased from a scientific equipment supply company, covering a range of pH values, is an inexpensive method of recording such data. For more precise readings, a relatively inexpensive hand-held and battery operated pH meter can be purchased from the same suppliers.

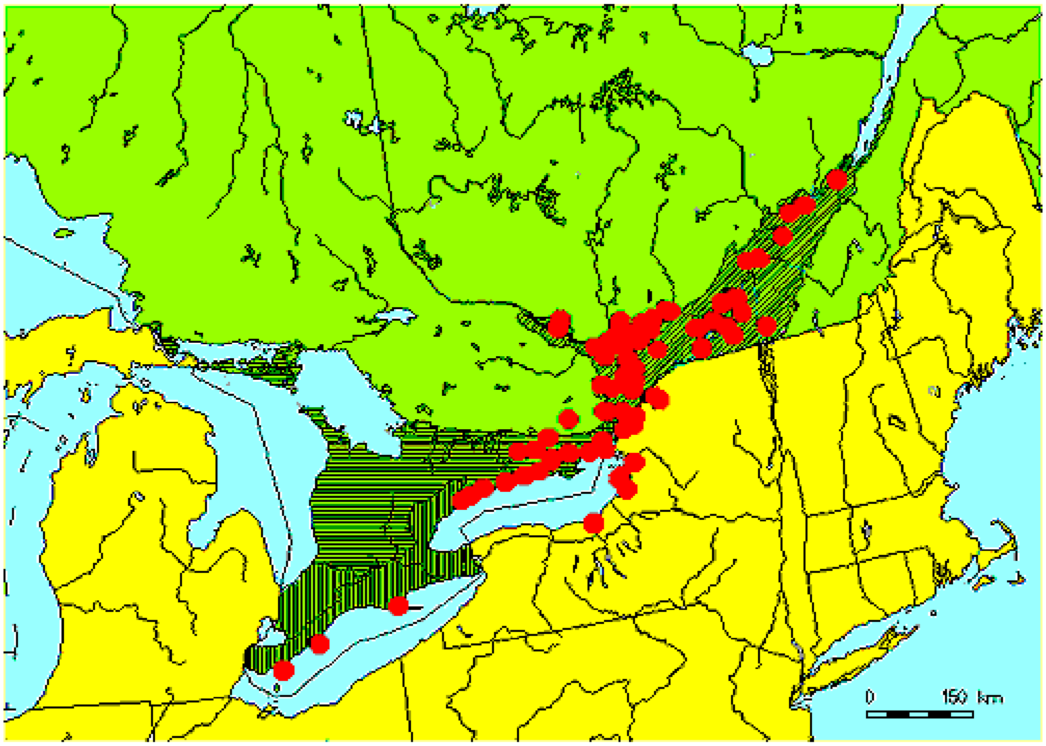


Figure 1. Example of a distribution map: European frog-bit (Hydrocharis morsus-ranae) in northeastern North America in relation to the Canadian Ecoregions within which it occurs in Ontario and Quebec (see Ecological Stratification Working Group 1996).

The few tools and supplies that are needed when collecting plants for identification purposes and as voucher specimens are outlined in Appendix 3.

A quadrat is a square area of any suitable size marked off on the ground for the purpose of recording the contents. A simple, rigid one metre quadrat template can be cut out of a thin sheet of plywood or hardboard. Small galvanized nails can be fastened at 10 cm intervals along the frame to be used as pegs for stringing twine that can be used to divide up the entire quadrat area into 10 x 10 cm subunits (Figure 2). A non-rigid template for a one metre square quadrat can be made by constructing a simple frame from four separate strips of straight pieces of wood or aluminum, slightly longer than one metre, purchased at home building supply outlets. Holes are bored in the middle of each end of the strips so that when the four are overlapped on the ground to enclose a square the measurements between the inside edges equal one metre. The strips are held in place by four metal pegs, with loops on the ends,made out of coat hanger wires or metal rods that are pushed through the four corner holes (Figure 3). The space between the inside edges can be marked off from left to right at 10 cm intervals. Two additional strips can be used to subdivide the one metre quadrat into 10 x 10 cm subunits by aligning these strips at the appropriate markings on the perimeter strips.

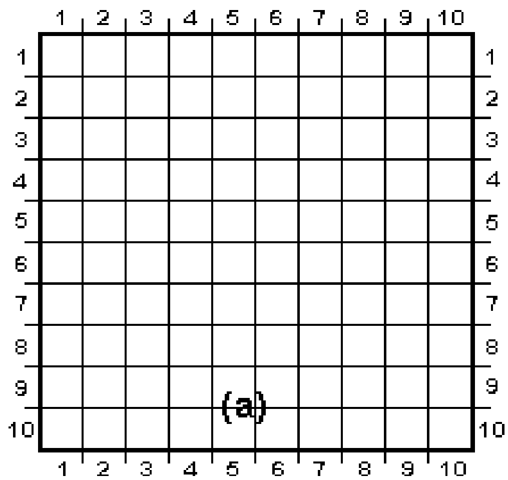


Figure 2a

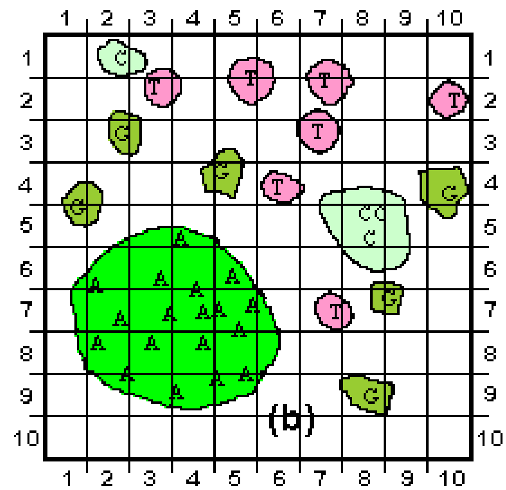


Figure 2b

A One Metre Quadrat Species and Area Monitoring Form

Species	1995			1996			1997		
	No. of Plants	Area cm^2	% Area	No. of Plants	Area cm^2	% Area	No. of Plants	Area cm^2	% Area
White trillium									
Sedge (*Carex* sp.)									
Grass									
Garlic mustard (invasive)									
Total									

(c)

Figure 2. Examples of one metre quadrats with reference grids. (a) Quadrat formed from a plywood sheet with string grid applied. (b) Quadrat in use with outline of basal areeas for trillium (T), grass (G), sedge (C) and for a small population of garlic mustard (A). In the field, the string grid is applied after the quadrat is put into place with the aid of the four corner marker posts. The string is wound back and forward around protruding galvanized nail heads. (c) Example of a form for recording yearly changes in numbers of plants and basal areas in a one metre square quadrat containing a population of the invasive garlic mustard.

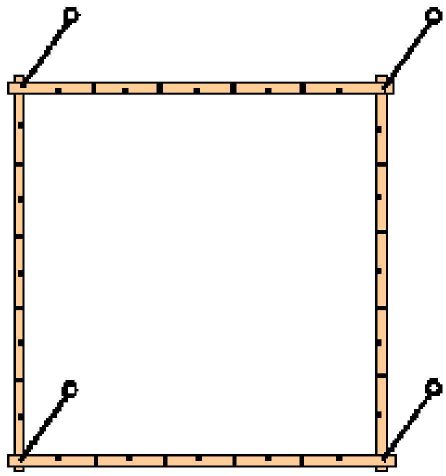


Figure 3. Example of a one metre square quadrat laid out using a template made of four uniform strips of metal or wood marked with 10 cm intervals and held in place by four metal pegs with loops at the top.

An alternate way to construct such a template is to purchase one or more inexpensive retractible metric tape measures and cut the metallic tape into suitable lengths for the four sides. Holes are punched or drilled in the appropriate places at the ends to give a one metre square quadrat. To ensure that the quadrat is square when in use, a tape measure is used to measure the diagonals. When both are equal, the area is perfectly square. The construction and use of such quadrats is described in greater detail by Weaver and Clements (1938).

The recording of data within sample quadrats similarly can be done with minimal equipment. A specialty ruler for determining basal areas for smaller plants is illustrated in Figure 4. A few other minor aids such as a tape measure, ball of cord and plastic or non-corrosive pegs for marking the positions of quadrats are the main requirements for setting up monitoring plots and quadrats. Forms for recording data are easily prepared with wordprocessing software. A few examples of forms are provided. The more important aspect of monitoring, however, is that data should be recorded carefully, in a consistent manner and over a long enough period of time so that valid conclusions or inferences can be drawn.

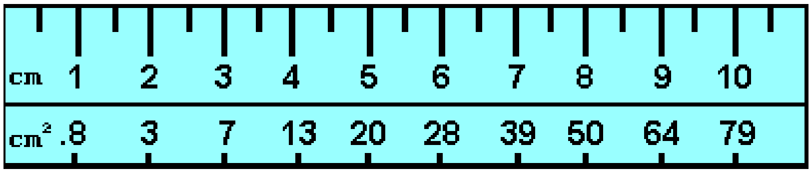


Figure 4

Figure 4. Example of a "listing ruler" that shows the linear measurement along the top edge and the corresponding square centimetres of the basal area along the bottom edge. The approximate maximum diameter of a plant is determined with the ruler and the basal area is recorded directly into a field book. The diameters of plants can also be recorded in a field book and the basal areas determined later from a detailed reference chart that is prepared for such a purpose in a similar manner to that for the listing ruler.

Appendix 3

Making Plant Collections

Introduction

Plant specimens that are pressed, dried rapidly and then stored in the dark away from insect pests under normal levels of humidity found in temperate countries will remain in good condition for hundreds of years. Such specimens, from the early 1700s, have served as vouchers, commonly called type specimens, of plants that served as the basis for many of the scientific names presently in use. Such collections of dried plants, whether small and stored within a scrap book or box or large and occupying many rows of specially constructed metal cases within a room or building of a research institution, constitute a herbarium - a hortus sicus - or dried garden. Some of the earliest such collections were made of specimens from the gardens of nobility and wealthy merchants.

No specialty equipment is required for making good plant collections. Much of the equipment and supplies are usually available within the home or canbe obtained and assembled at minimal cost.

Collecting Plants

Precautions

Novice plant collectors should be aware that permission is required for anyone wishing to collect on private property. In the case of parks, nature reserves and conservation areas on public lands, special permits are invariably required. Collecting permits may only be granted, however, to those involved in serious studies that contribute to the better understanding of the flora of such special lands.

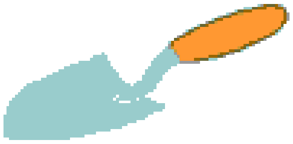
Collectors should also become familiar with what species are considered to be provincially or nationally rare and possibly at risk so that their collecting activities do not contribute to the decline of populations at risk. Information on such species can be obtained by contacting the Secretariat of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 1997) for species at risk nationally and for contacts within the various provincial addresses of wildlife agencies that participate in COSEWIC. Six provincial Conservation Data Centres and Natural Heritage Information Centres have also been established (AB, BC, MB, ON, QC, SK). These agencies can provide comprehensive listings of species that are at risk in their provinces (CDCs 1997).

When to Collect

Although plants and plant parts can be collected at all seasons and under all weather conditions, it is best to collect plants during dry sunny weather. Plants collected when there is no surface water present will dry more quickly and retain their colour better and there is less chance of moulds developing.

How to Collect

Uproot small specimens carefully with a large blunt hunting knife or trowel and remove soil and debris. Root systems and underground stem modifications such as rhizomes and tubers should be included because they may be diagnostically important. Tall herbaceous specimens should be uprooted and, if necessary for ease of pressing, a portion of the stem may be discarded as long as the total height and any pertinent features are recorded in the field notes. The stems and leaves of tall herbs can generally be folded one or more times so that they will fit within the field storage container being used. Collections from shrubs and trees may be made by cutting off a suitable portion of a branch about 30 cm long. Notes on the size and growth habit of the plant should be made in a field record book. This should be done in pencil or waterproof ink or on a slip of paper that is kept with the specimen until the data are recorded at the time of pressing.



Unless required as vouchers for ecological or other detailed survey projects, only plants or portions of large specimens with reproductive structures should be collected. Reproductive structures include flowers, fruits, cones, and the fertile leaves or shoots of ferns. Bulky structures, such as cones, should be placed in paper bags and numbered to correspond with the leafy branchlets taken from the same specimens.

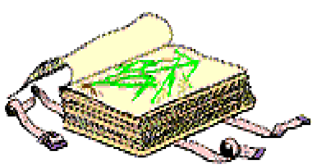
One of the simplest and most effective means of carrying plants that have been collected is to place them into plastic bags. Freezer bags of a size normally used for turkeys or chickens are convenient for collecting purposes. However, any reasonably-sized bags that are readily available, such as grocery store packing bags, can be used. For convenience in seeing the contents, clear bags are preferable. If large numbers of plants are to be collected at one site, the delicate plants should be placed in a separate bag. Similarly, plants from different habitats or from different monitoring plots should be stored in separate bags. A brief note with the locality and habitat description and other pertinent data placed in the bag is an easy means of recording such field data and avoiding later confusion. Groups of plants or replicate samples from a shrub or tree can be held together with commercially available tags with a looped string attached. This is used to fasten the stems or plants into a small bundle. Pertinent information is written on the label in pencil or waterproof ink.

If separate bags are used for grouping specimens from different habitats or from different monitoring plots, a number of them can be conveniently carried within a larger plastic bag, preferably white or light-coloured to minimize overheating within the bags as they are carried about in the sun during the course of the day. Plastic bags containing specimens should be kept shaded as much as possible while in the field to avoid undue heat stress and wilting. Plants are easier to arrange for pressing and make better specimens when they are still quite fresh. If delicate submersed aquatic plants are collected, these can be kept separately in small clear bags. If flowers are present on the aquatic plants, care should be taken that they do not get wet from contact with the submersed parts.

Pressing

The outer covers of a traditional press are 30 x 45 cm and consist of a rectangular latticework of thin hardwood slats riveted together to form rigid lightweight surfaces that permit the layers of press materials and plants to be firmly strapped together for drying. However, two pieces of 6 mm plywood, cut to size, also make suitable press covers. The press materials consists of a stack of alternating layers of thick blotting felts or sheets of 6 mm thick polyurethane foam and cardboard ventilators, with about 25-30 of these felt or foam units making up a complete press.

The standard press size was based roughly on the traditional size of one half of a fully opened sheet of newspaper cut in half and folded in half at right angles to its length.



Such a folded sheet made a convenient size for drying and storing a specimen that would be mounted on a stiff mounting sheet of paper that measured around 29 x 42 cm. Mounting sheet standards, however, vary somewhat between institutions. As well, presses for work in alpine or arctic areas were made smaller to take into account that tundra plants tend to be shorter in stature. Current newspaper page sizes also tend to be smaller. Any convenient size of press will do.

The cardboard ventilators in professional presses used by institutions have continuous open channels running between the short dimensions of the cardboard. This allows heated air to travel through the press as it lies on one of its open sides over a source of heat. Such ventilators can be made from large discarded packing boxes. Sheets of felt driers were once the commonly used absorbents in presses. They also help to flatten plant parts so that they do not wrinkle excessively in drying. Sheets of foam obtained from upholstery supply companies, however, are superior for flattening plant parts and allowing fast drying. Unlike the felts or additional layers of newsprint that can be used to absorb the moisture from the plants as they dry, foam sheets do not absorb themoisture and do not have to be replaced during drying as was once the case with felt driers, especially when no artificial heat was used.

Specimens should be pressed as soon as possible after they have been collected. They are prepared for pressing and drying by arranging each neatly between a folded sheet of newsprint of suitable size to fit the press. Several small specimens can be pressed within a single sheet. The print from a newspaper will not come off during the drying process. Plants with fleshy bases or with thick bulbs or root systems may be dried best by cutting these unwieldy structures in half lengthwise or into thin sections as an aid to drying. Delicate aqautic plants may need to be placed in a tray of water in order to separate the parts. A sheet of wax paper is then submersed under the plants and the leaves and stems of the aquatic are spread out to minimize overlap that would hinder examination of critical parts for identification. The wax paper with the fragile aquatic is then placed within a newsprint folder and placed in the press.

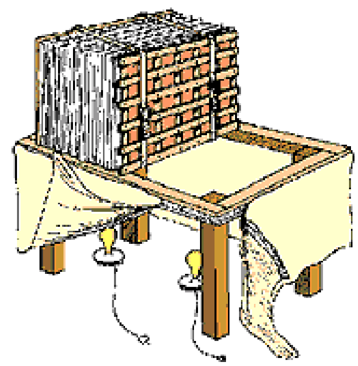
A unique collection number should be written on the outside of each newsprint folder and this same number, and data on flower colour or growth habit that will likely change in drying, should also be entered into a record book or the field notebook. Flower colours will fade or change on drying and should be recorded as aids to identification. Other pertinent notes on the locality and habitat should also be written in the field book. If the identity of the plant is known, the name can be written on the outside of the newsprint folder.

The newsprint folder containing the suitably arranged specimen with leaves separated and examples of both upper and lower leaf surfaces evident is placed on a cardboard ventilator followed by a drier felt or foam sheet. If the felts are relatively thin or the foam sheets are old and compressed, felts or foam may be required on either side of the newsprint folder containing the plant. The overall dimensions of the press materials are of a size slightly larger than that of the newsprint folder. When a manageable bundle has been stacked up the press is cinched tightly with straps ready for drying.

Drying

When in the field, the press may be placed in the sun for drying or on the roof rack of an auto with the open end facing the direction of movement so that air is forced through the press. It is preferable, however, to use a source of flameless heat such as a tent heater or, where electricity is available, a low wattage hot plate or 2-100 watt light bulbs in shallow fixtures. The press is supported on a frame at least 20-30 cm above the heat source, depending on intensity, to avoid scorching the lower side of the press and the plants within. The frame and heat source are enclosed by a cloth to create a vertical draft through the press. Thumb tacks or velcro strips fixed to the frame and cloth can be used to attach the cloth. The edge of the cloth can also be fitted along the top edge of the press to enclose both the sides of the press, or presses, and the drier stand. This extends the chimney effect in maintaining the heat within the press. This is particularly advantageous in keeping the entire press warm when in the field and nights have become cool. If only one portion of the top of the drier frame is used, the portion not covered by a press should be closed with a piece of cardboard to keep the heat in.

To promote efficient drying, the corrugations of the cardboard ventilators must run between the short width of the press. The press is placed on its side with the corrugations vertical to allow the warm air to rise through its centre. The straps should be tightened periodically because the press becomes loose as the plants dry, especially when felt driers are used. When foam sheets are used, they tend to expand as plants shrink and dry, thereby maintaining tension in the press. It is generally good practice to rotate the press 180 during the drying process if the heat source is relatively weak.



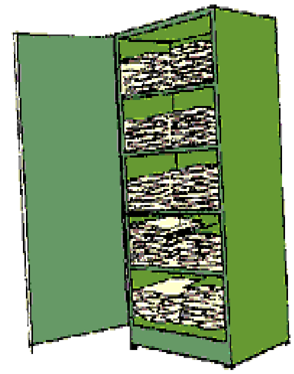
Presses can be elevated above the heat source in many improvised ways. A simple wooden frame with rigid or folding legs can be constructed with a cotton skirt around its bottom. Two chairs can be used to support the edges of the press with a blanket used to form a skirt enclosing the chairs and press with the electric heat source in the centre. The main requirement is that there should be ample heat and it should be directed through the corrugated channels of the press. Trial and error will quickly indicate how far from the heat source the bottom of the press should be positioned so as to avoid scorching but still provide adequate heat to dry the plants within about 24 hours. Care must always be taken that the heat source is not too strong and that no paper or other inflammable materials are close to or in contact with the heat source.

Most thin-textured plants or plant parts dry within 24-48 hours. More succulent specimens may require a longer period of time. When suitably dry, most plants become rigid. Excessive drying should be avoided because the plants become overly brittle and will tend to crumble more readily. Plants are then removed and stored in a dry location within their newsprint folders, ready for identification and mounting or storage, loose within the folders.

Mounting and Storage

To be useful as reference material for a personal collection, dried specimens need not be mounted. They can be stored simply within their newsprint folders, with the plant name and other pertinent data written on the outside, and kept in closed cardboard boxes in a dry location. Another form of simple storage and preparation of a reference collection is that of gluing specimens or portions of plants on sheets within a three-ring binder or scrap book organized in some particular manner that is useful for the collector.

For more professional results, dried specimens are mounted on a sheet of stiff, white, acid-free mounting paper, about 30 by 42 cm, having a 100% rag content. They are fastened by applying narrow beads of white (polypropylene) glue over stems and leaf stalks. Delicate structures, especially features required for identification, should not be covered with glue. Alternatively, narrow strips of gummed paper can be used. Cellophane tape is not suitable for mounting because it deteriorates rapidly with age. While the bands of glue are drying, plant parts are weighted down with metal washers of sufficient weight to hold the parts flat to the surface of the paper. Washers can be purchased in bulk at larger hardware stores. If mounted specimens are placed on cardboard ventilators and small uniform blocks of wood are placed at each corner, the mounting sheets can be stacked vertically to minimize space needed to store them overnight while the glue is drying.



The addition of a label in the bottom right hand corner of the sheet, recording such information as the name of the plant, collection locality, habitat, collector, collection number, collection date, and the name of the person having identified the plant, completes the process of preparing a specimen as a properly documented voucher. It is generally best to include only a single species from a given locality on one sheet.

Example of a specimen label. The year of the North American Datum (NAD) used in deriving the map projection and preparing the topographic maps and instructions on how to determine UTM easting and northing values are given on the National Topographic System (NTS) map sheets.

Selected References

COSEWIC. 1997. Mailing list. The Committee on the Status of Endangered Wildlife in Canada. COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa. K1A 0H3.

Brayshaw, T.C. 1996. Plant collecting for the amateur. The Royal British Columbia Museum. 44 pp.

Saville, D.B.O. 1962. Collection and care of botanical specimens. Research Branch, Canada Department of Agriculture, Ottawa. Publ. No. 1113. 124 pp.

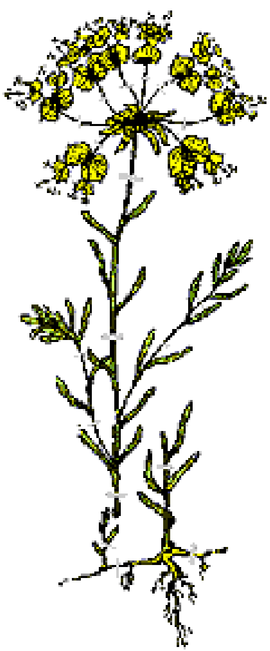
Plants of Canada

Province:
County:
Ecozone:
Map No.: Lat: Long:
Zone: UTM: __________E __________N
NAD:
Locality:

Habitat:

Collector: Date:
Coll. No.:

Example of a mounted voucher specimen with label.



Plants of Canada

Euphorbia esula L

Province: Saskatchewan

LSD 16, Sec. 7, T 24, R 03 W 3
Lat: 51° 02' 10" Long: 106° 24'

Zone: 13 UTM: 401838E 5654555N NAD: 1927
Locality:
Elbow Sand Hills; 17 km SE of Elbow, 5 km N-NE of Qu'Appelle Dam
Habitat: in cattle pasture

Collector: E.J. Brighton Date: 27 June 1994
Coll. No. 94365
Notes: abundant in the area: plants generally about 60 cm

Appendix 4

Bibliography

The following is an annotated list of selected standard reference manuals and floras for Canada, books on plant groups of special interest and popular field guides to plants. This selection of books contains information on and provides a means of identifying both native and exotic plants.

Floras and Manuals

Calder, J.A. and R.L. Taylor. 1968. Flora of the Queen Charlotte Islands. Research Branch, Canada Department of Agriculture Monograph No. 4, Parts 1, 659 pp. & 2, 148 pp. [with keys to species, distribution maps and black and white and colour illustrations of habitats].

Catling, P.M., D.S. Erskine and R.B. MacLaren. 1985. The plants of Prince Edward Island with new records, nomenclatural changes, and corrections and deletions. Research Branch, Agriculture Canada Publ. 1798. Reprint of The Plants of Prince Edward Island, D.S. Erskine, 1960. 272 pp.[no keys for identification purposes; primarily an atlas of distribution maps of the plants].

Cody, W.J. 1996. Flora of the Yukon Territory. NRC Research Press, Ottawa. 643 pp. [with line drawings and distribution maps for most species].

Dore, W.G. and J. McNeill. 1980. Grasses of Ontario. Research Branch, Agriculture Canada Monograph 26. 566 pp.[keys, maps, illustrations and descriptions].

Fernald, M.L. 1950. Gray's manual of botany. Edition 8. American Book Company, NY. 1632 pp. [keys, synoptic descriptions, etymology of scientific names, common names for many species and some line drawings].

Gleason, H.A. 1963. The new Britton and Brown illustrated flora of the northeastern United States and adjacent Canada. In 3 volumes. The New York Botanical Garden. Hafner Publishing Co., Inc., NY. 595 pp. [fully illustrated with line drawings].

Gleason, H.A. and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. Van Nostrand Company, NY. 810 pp. [keys and synoptic descriptions; a handy, portable, single volume work for the serious student].

Hinds, H. 1986. The flora of New Brunswick. Primrose Press, Fredericton. 460 pp. [with line drawings and distribution maps for most species].

Looman, J. and K.F. Best. 1979. Budd's flora of the Canadian prairie provinces. Agriculture Canada, Publ. 1662. 863 pp. [with some illustrations].

Marie-Victorin, Frère. 1964. Flore Laurentienne. Deuxième édition. E. Rouleau. Les Presses de l'Université de Montréal, Montréal. 925 pp.[with French and English common names, where available; illustrated].

Morton, J.K. and J.M. Venn. 1990. A checklist of the flora of Ontario vascular plants. Department of Biology, University of Waterloo, Waterloo, ON. 218 pp. [a useful compendium of scientific names and common synonyms of plants of Ontario].

Moss. E.H. 1983. Flora of Alberta. Second edition. J. G. Packer. University of Toronto Press, Toronto. 687 pp. [with distribution maps for most species].

Porsild, A.E. and W. J. Cody. 1980. Vascular plants of continental Northwest Territories, Canada. National Museum of Natural Sciences, National Museums of Canada. 667 pp. [with line drawings and distribution maps for most species].

Roland, A.E. and E.C. Smith. 1966. The flora of Nova Scotia. Part I. The pteridophytes, gymnosperms, and monocotyledons. Proceedings of the Nova Scotian Institute of Science 26: 4-242.

Roland, A.E. and E.C. Smith. 1969. The flora of Nova Scotia. Part II. The dicotyledons. Proceedings of the Nova Scotian Institute of Science 26: 277-743. [with some illustrations and distribution maps for most species].

Rouleau, E. 1992. Atlas of the vascular plants of the Island of Newfoundland and of the Islands of Saint-Pierre et Miquelon. 1st ed. Fleurbec, Saint-Henri-de-Lévis, Quebec. 777 pp. [contains 1197 distribution maps of the plants of the province].

Scoggan, H.J. 1957. Flora of Manitoba. National Museum of Canada, Ottawa. Bull. No. 140, Biological Series No. 47. 619 pp. [not illustrated but provides an indication of range within the province and gives the first report for each species].

Scoggan, H.J. 1978-79. The flora of Canada. In 4 volumes. Canadian Museum of Nature, Ottawa. 1711 pp. [provides an excellent descriptive overview of the flora of Canada in volume I and keys and range information for each species in the following three volumes].

Taylor, R.L. and B. MacBryde. 1977. Vascular plants of British Columbia. University of British Columbia Press, Vancouver. 754 pp. [This is not an identification manual. The authors have assembled a broad range of data on the biology and ecology of every species listed for the province.].

Books on Plants of Special Interest

Alex, J.F., R. Cayouette and G.A. Mulligan. 1980. Common and botanical names of weeds in Canada / Noms populaires et scientifiques des plantes nuisibles du Canada. Agriculture Canada, Publ. 1397. 132 pp. [provides a listing by scientific names, English common names and French common names; an informative section is also provided on the spelling of common names].

Farrar, J.L. 1995. Trees in Canada. Fitzhenry & Whiteside Ltd., Markham, ON and Canadian Forest Service, Ottawa. 502 pp. [showy reference work with line drawings and colour plates for each species together with keys to species groups; also includes a forest regions map and plant hardiness zone maps for Canada].

Frankton, C. 1963. Weeds of Canada. Botany and Plant Pathology Division, Science Service, Publ. 948, Canada Department of Agriculture. Ottawa. 196 pp. [about 100 weeds are described and illustrated with line drawings].

Kingsbury, J.M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall, Inc., New Jersey. 626 pp. [provides valuable information on the toxic properties of vascular plants].

Reader's Digest. 1986. Magic and medicine of plants. Inge N. Dobelis, project editor. Reader's Digest Association, Inc. Montreal. 464 pp. [includes a broad range of topics such as myths, people and medicine, making a plant collection, cooking with herbs; the main emphasis is on the species treatments, with each beautifully illustrated with colour photographs and paintings; many common weeds and native plants are included].

Sherk, L.C. and A.R. Buckley. 1968. Ornamental shrubs for Canada. Research Branch, Canada Department of Agriculture, Ottawa. 187 pp.[descriptions, scientific and common names, b/w and colour photographs of ornamental shrubs, and a plant hardiness map; provides a basic reference to a large group of exotic shrubs, some of which are invasive].

Soper, J.H. and M.L. Heimburger. 1982. Shrubs of Ontario. Royal Ontario Museum, Toronto. 495 pp. [each species is illustrated with a line drawing and a distribution map].

Szczawinski, A. F. and N.J. Turner. 1978. Edible Garden Weeds of Canada. National Museum of Natural Sciences, National Museums of Canada. 184 pp. [illustrated with line drawings and colour photographs; includes brief descriptions, interesting facts and recipes].

Popular Field Guides

Foster, S. and J.A. Duke. 1990. A field guide to medicinal plants: Eastern and Central North America. Houghton Mifflin Company, Boston. 366 pp.[a Peterson field guide; about 500 plants are described and illustrated in line drawings or colour photographs].

McKay, S.M. and P.M. Catling. 1979. Trees, shrubs and flowers to know in Ontario. J.M. Dent & Sons (Canada) Ltd. 208 pp. [descriptions and line drawings of about 450 species, including some of the common weeds].

Newcomb, L. 1977. Newcomb's wildflower guide. Little, Brown and Company, Toronto. 490 pp. [an illustrated guide to over 1300 plants of flowering herbs, shrubs and vines of northeastern and northcentral North America, including the southern portions of Canada; plants are grouped and identified on the basis of a combination of several vegetative and floral characteristics; a French version is also available under the name Guide des Fleurs Sauvages de l'est de l'Amérique du Nord, Marcel Broquet, La Prairie, Quebec].

Niehaus, T.F. and C.L. Ripper. 1976. A field guide to Pacific states wildflowers. Houghton Mifflin Co., Boston. 432 pp. [a Peterson field guide; includes southern British Columbia].

Niering, W. A. 1979. The Audubon Society field guide to North American wildflowers: Eastern Region. Alfred A. Knopf, NY. 887 pp. [a photographic guide with 700 pictures].

Peterson, L. 1978. A field guide to edible wild plants of eastern and central North America. Houghton Mifflin Company, Boston. 330 pp. [about 400 species are described and illustrated in line drawings and colour photographs].

Peterson, R.T. and M. McKenny. 1968. A field guide to wildflowers of northeastern and northcentral North America. Houghton Mifflin Company, Boston. 420 pp. [a Peterson field guide; over 1300 species are illustrated in line drawings, some in colour; species are segregated initially on the basis of flower colour and subsequently on form and detail of structures].

Spellenberg, R. 1979. The Audubon Society field guide to North American wildflowers: Western Region. Alfred A. Knopf, NY. 862 pp. [a photographic guide].

Exotic Plants Roadside Monitoring and Action Form

Road section identifier:____________________________

Road monitor:___________________________

Site No.	Date (y/m/d)	Species Present	Location	Habitat	No. plants or area in m²	Action Taken and Date

Location: indicate distance from an obvious road map reference point in km; detailed site information can be recorded in a form similar to the Exotic Plant Survey Record Form

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Exotic Plants Trail Monitoring and Action Form

Trail name:____________________________

Trail Monitor:___________________________

Site No.	Date (y/m/d)	Species Present	Location	Habitat	No. plants or area in m²	Action Taken and Date

Location: indicate distance from trail landmark in metres; use map coordinates; indicate colour and location of flagging tape

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Exotic Plant Survey Record Form

Scientific name:____________________ Common Name:___________________
Record date (y/m/d):________________ First Record (yes/no) Repeat record (yes/no)
Observer name and address: _____________________ Tel: ( ) ____ - _____
_____________________ Fax: ( ) ____ - _____
____

Geographical Site Data

Prov.:________________ County:________________ Twp.:________________
Locality name:___________________ Nearest city/town:_____________________
Locality description (highway/road, distance & direction to nearest town, crossroad or topo map reference point):
____
____
____

Topo map no:__________ Lat:__________ Long:__________ Elevation:__________
UTM: ____________E _____________N Zone:_________ NAD:_________

Habitat Description

Type of habitat (woodland; grassland/prairie/meadow; wetland/aquatic; roadside; pasture, croplands):
____
____
____

Degree of disturbance:____

Other significant species (other alien species present in abundance or rare plants at risk from infestation):
____
____
____

Population Information

Total number of plants/shoots:_____ or Estimated number of plants/shoots per m^2:_____

Estimated total area (m^2 or ha; one hectare = 100 m x 100 m):____________________

Condition of plants: vegetative (yes/no) flowering (yes/no) in fruit (yes/no)

Seedlings present: none (yes/no) few (yes/no) common (yes/no) abundant (yes/no)

Supplementary Field Data

Photo taken (yes/no)   Specimen collected (yes/no)

Notes:

____

____

____

Invasive plants, in particular, are to blame for much native species decline and ecosystem degradation. The invasion of native ecosystems by alien plants can lead to alterations in nutrient cycling, fire regime, hydrology, energy budgets, and native species abundance and survival. There are studies being conducted to answer ecological, environmental, management and socio-economic questions related to invasive alien plans in forested ecosystems the world over.Â Strategies to monitor and manage invasive weeds in forests and national parks in Vietnam are outlined. Full article. (This article belongs to the Special Issue Exotic and Invasive Plant Species Impacting Forests). â–ºâ–¼ Show Figures. Figure 1.