Invasive plant mapping : a standardized system
by Diana Irene Cooksey

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Resources and Environmental Sciences
Montana State University

Abstract:
Public and private land managers are becoming acutely aware of the negative impacts of invasive plant species, and efforts to minimize their effects are underway. Management of invasive plants depends on availability of accurate information about location, size and severity of infestations. Data collected by invasive plant surveys can help scientists and land managers to develop, implement, and evaluate integrated invasive plant management plans; assess the economic impacts of plant invasion and alternative management strategies; and increase public awareness. Standardized invasive plant surveying and mapping methods are critical because they provide consistently uniform information that can be compared over time and incorporated into a geographic information system (GIS) for production of regional maps for management planning.

In response to the need for a consistent protocol for surveying and mapping invasive plants, guidelines and standards were developed and a statewide invasive plant GIS was created. Educational materials were distributed and training workshops were presented to invasive plant managers throughout Montana. The system was planned, developed, implemented and evaluated by personnel at Montana State University-Bozeman, in cooperation with private, county, State and Federal land managers, using an outcome-based logic model approach. A method for gathering complete statewide data at a generalized scale to provide immediate information about invasive plant distribution was also developed, and a plan to create a self-sustaining future for the system and statewide database was devised.

This system has been adopted by invasive plant managers in Montana and throughout the U.S. The statewide invasive plant database now has a permanent home with the Bureau of Land Management and leadership is provided by the Montana Department of Agriculture, Stillwater County, and an advisory team of agency, industry, and private representatives. Its data have been used for local and statewide invasive plant management, and for public education. Future efforts should focus on developing Internet-based update and retrieval capabilities, educating users, and increasing participation in the system. Additional uses for standardized invasive plant data could include research on invasion biology and ecology, invasive plant spread, and predicting areas potentially subject to weed invasion; verification of invasive plant maps generated using modeling and remote sensing; and Internet-based multimedia public education.

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APPROVAL

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Diana Irene Cooksey

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Weeds are plants that interfere with the management objectives of a given area of land. *Noxious weeds* are those weeds that society has declared we are legally responsible to manage because of their negative impacts (Sheley et al., 1998). *Invasive plants* is a more descriptive term than *weeds* or *noxious weeds* because it reflects the tendency of certain non-native plant species to reproduce and spread rapidly, often crowding out existing vegetation. Although the term *invasive plants* is preferred, *weeds* and *noxious weeds* are used throughout the text where they are in common usage among managers involved in the activity or product being described. All three terms are intended to be synonymous.

ABSTRACT

Public and private land managers are becoming acutely aware of the negative impacts of invasive plant species, and efforts to minimize their effects are underway. Management of invasive plants depends on availability of accurate information about location, size and severity of infestations. Data collected by invasive plant surveys can help scientists and land managers to develop, implement, and evaluate integrated invasive plant management plans; assess the economic impacts of plant invasion and alternative management strategies; and increase public awareness. Standardized invasive plant surveying and mapping methods are critical because they provide consistently uniform information that can be compared over time and incorporated into a geographic information system (GIS) for production of regional maps for management planning.

In response to the need for a consistent protocol for surveying and mapping invasive plants, guidelines and standards were developed and a statewide invasive plant GIS was created. Educational materials were distributed and training workshops were presented to invasive plant managers throughout Montana. The system was planned, developed, implemented and evaluated by personnel at Montana State University-Bozeman, in cooperation with private, county, State and Federal land managers, using an outcome-based logic model approach. A method for gathering complete statewide data at a generalized scale to provide immediate information about invasive plant distribution was also developed, and a plan to create a self-sustaining future for the system and statewide database was devised.

This system has been adopted by invasive plant managers in Montana and throughout the U.S. The statewide invasive plant database now has a permanent home with the Bureau of Land Management and leadership is provided by the Montana Department of Agriculture, Stillwater County, and an advisory team of agency, industry, and private representatives. Its data have been used for local and statewide invasive plant management, and for public education. Future efforts should focus on developing Internet-based update and retrieval capabilities, educating users, and increasing participation in the system. Additional uses for standardized invasive plant data could include research on invasion biology and ecology, invasive plant spread, and predicting areas potentially subject to weed invasion; verification of invasive plant maps generated using modeling and remote sensing; and Internet-based multimedia public education.

CHAPTER 1

INTRODUCTION

Public and private land managers are becoming acutely aware of the negative impacts of invasive plant species. Invasive species have dramatic effects on the structure and function of ecosystems making them a major threat to earth's biodiversity (Binggeli, 1996; Simberloff, 2001). Invasive plants can reduce forage (Hein and Miller, 1992), increase soil erosion (Lacey et al., 1989), alter soil chemistry and nutrient cycling (Pokorny, 2002), reduce habitat for native and endangered species (Lesica and Shelly, 1996), create fire hazards (Whisenant, 1990), and interfere with recreational activities (Westbrooks, 1998). Invasive plants infest 100 million acres (40 million hectares) in the U.S., spread at about 14 percent per year, remove 4,600 acres (1,840 hectares) of wildlife habitat per day on public lands, and cause losses to crop and rangeland productivity exceeding $7 billion annually (Babbitt, 1998). Pimental et al. (2000) estimate annual economic costs associated with invasive plant species to exceed $34 billion in the U.S. alone.

The challenge now before the public is to prevent further damage to natural and managed ecosystems caused by invasive species (Pimentel et al., 2000) to all lands, public or private. Federal efforts to minimize these effects of invasive species are underway. On February 3, 1999, a Presidential Executive Order creating a new federal interagency Invasive Species Council charged with producing a broad management plan for biological invaders was signed (Clinton, 1999). The Federal Interagency Committee for the Management of Noxious and Exotic Weeds has developed a strategy for management of invasive plant species (FICMNEW, 2000a; FICMNEW, 2000b). From a land management perspective, prevention and early detection followed by eradication are the most practical methods for managing new introductions, whereas containment, control and restoration are appropriate strategies for managing large-scale invasive plant infestations (Sheley et al., 1999). Early detection and immediate control depend upon the availability of information that keeps pace with new invasion threats (Ricciardi et al., 2000). Standardized invasive plant mapping and monitoring programs can provide critical information needed to meet future challenges and evaluate progress of invasive plant programs.

Data collected by invasive plant surveys can help scientists and land managers to develop, implement, and evaluate integrated management plans; assess the economic impacts of plant invasion and alternative management strategies; and increase public awareness, education, and management efforts. Invasive plant management plans are important working documents used by land managers to guide invasive plant control and land rehabilitation. Management plans should be reviewed and updated annually (Goodall and Naude, 1998; Sheley et al., 1999). A critical component of these plans is an accurate and complete invasive plant inventory of the management area (Sheley et al., 1999). Mapping can be used to target control efforts, document activities, monitor change over time, and evaluate the plan's success. Accurate maps that are updated regularly can provide reliable area (acres, hectares) estimates, from which economic costs associated with nonindigenous plant invasions can be calculated. Documenting economic and environmental impacts of plant invasions is important for obtaining funding for management programs. In addition, documentation of these costs can help increase public awareness of the magnitude and complexity of plant infestations. Even though the negative impacts of invasive plant species are well-known among scientists and land managers, the general public remains largely unaware of the problems associated with biological invasions by plants, partly because they have not been told about their distribution and impacts. Without public support, local invasive species control efforts can be hindered because of complacence or even opposition (Colton and Alpert, 1998). Maps showing areas infested by invasive plants can be used to educate the public by illustrating the extent and severity of the problem.

Standardized weed surveying and mapping methods are important because they provide consistently uniform information that can be compared over time to document progress in management. Our previous experience with attempting to compile invasive plant maps revealed a serious lack of consistency in the way invasive plant managers were collecting and reporting data. Some mappers carefully outlined the boundaries of infestations on paper maps, while others simply marked entire sections or townships as being infested. Others reported points representing the centers of infestations rather than outlining the infested area. Some mappers collected percent cover as an attribute to denote severity, and others collected density. Several different scales and types of base maps were being used, resulting in vastly different levels of detail. These inconsistencies make it nearly impossible to combine data from site to site and year to year, and to compare changes. There is clearly a need for a standardized system for invasive plant mapping and monitoring to produce reliable data.

A standardized system would allow invasive plant survey data to be incorporated into a geographic information system (GIS) for production of regional maps showing the distribution and severity of infestations. This type of database would provide consistent and accurate information for local, statewide and regional invasive plant management plans.

In response to this need for a consistent protocol for surveying and mapping invasive plants, representatives from federal, state and county agencies, as well as industry and private individuals, developed guidelines and standards for a statewide invasive plant survey and mapping system for Montana. The system was implemented by personnel at Montana State University-Bozeman, in cooperation with private, county, state and federal land managers. In Chapter 2 we describe the processes we used to develop the standardized system. Our approach to creating a self-sustaining future for the mapping system and statewide database is discussed also. Chapter 3 describes the invasive plant mapping system in detail, including guidelines and standards for data collection, and the structure of the statewide spatial database for invasive plant management. Chapter 3 also includes a method for gathering complete statewide data at a generalized (public land survey section) scale to provide immediate information about invasive plant distribution.

CHAPTER 2

DEVELOPMENT, IMPLEMENTATION AND EVALUATION PROCESSES

Introduction

Accurate inventories of invasive plant infestations are essential for their effective management. Standardized methods are necessary to collect consistently uniform infestation data that can be compiled into a region-wide database for mapping and analysis. Analytical information provided by the database can be used for developing management plans, assessing the economic costs of plant invasion, and increasing public awareness of the negative impacts of invasive plants. In addition, assessing the effectiveness of management requires repeated collection of accurate data, and is rarely done. In Montana and throughout the western U.S., previous attempts to implement invasive plant mapping standards were unsuccessful. In response to the need for a consistent protocol for mapping invasive plants, a standardized system was developed using a process that increased the likelihood of adoption. The objective of this chapter is to discuss the process of developing a standardized system for invasive plant survey and mapping that 1) ensures its successful implementation and 2) creates a self-sustaining future for the program. The system itself is described in Chapter 3.

Critical factors for successful project management have been identified by researchers and project managers. Several of these factors were used in developing the invasive plant mapping system.

First, we knew it was important to have a clear vision of what we wanted to accomplish, and a clear strategy for achieving defined project outcomes. A systematic process for developing the program would help to define our strategy.

We also felt that a project coordinator was required to provide leadership, develop education and training materials, and communicate with our target audience--invasive plant managers throughout Montana. In order to generate support and ownership among the groups who would eventually use the system, and to benefit from their expertise, we arranged a "working group" meeting to develop a set of mapping standards that would work for everyone. The group also determined the basic format of a comprehensive statewide database. We invited representatives from all county, state and federal agencies, as well as industry and private groups, involved in invasive plant management. Individuals were chosen based on their knowledge, experience and interest in invasive plant issues.

The first meeting was held in May of 1995. Participants were asked to bring ideas and samples of mapping and monitoring systems they felt were worth considering. The meeting was led by a facilitator whose job was to manage the discussion, listen to concerns of all people involved, and build support so everyone had an active role in developing the standards. Each agency provided a description of their current mapping efforts. Issues of data collection methods, data format and scale were discussed. Decisions about standardized base maps, attribute data to be collected, and methods for collecting data were made by consensus. The group decided to adopt a set of standards that had previously been developed for the Greater Yellowstone Area (Free et al., 1991) with a few modifications.

Once the standards were implemented, we developed educational materials including publications, workshops, a web site and downloadable files to help with data collection and processing. Efforts to market the program included informing our target audience about products and services available, where they could be accessed, and how the program could benefit users. We used language familiar to county weed coordinators, including the term *noxious weeds* rather than *invasive plants*, to avoid the "ivory tower" perception that is sometimes associated with university programs. We also made it clear that the system was developed and implemented in cooperation with private, county, state and federal land managers, not by the university acting alone.

Throughout the development and implementation process, we attempted to remain flexible, responding to challenges such as lack of participation, private landowner resistance, and technology barriers. We viewed development and implementation of the invasive plant mapping system as an interactive process, constantly changing and shaping the program. We saw "stumbling blocks" as opportunities for continual formative evaluation, and attempted to be flexible in responding to problems, while remaining true to the agreed on outcomes. We tried to look ahead, anticipating user needs for specific products. For example, users needed more detail about mapping procedures and GIS data format, so we developed a weed mapping handbook (Roberts et al., 1999). It includes step-by-step procedures for mapping according to the standards. Reflection was also important: looking back, getting feedback from users, and finding ways to improve.

Various models have been developed for planning, managing and evaluating programs. For the invasive plant mapping system, a logic model approach provided an outcome-based framework to guide development and implementation of the program, as well as an avenue for its evaluation. Logic models are graphical depictions of program elements and their relationships with one another, that portray the path toward desired outcomes (Millar et al., 2001). They model or simulate real-life in such a way that the fundamental logic underlying program activities and outcomes is apparent. The logic model tool helps to identify processes and activities that determine program successes, failures, and effectiveness (McLaughlin and Jordan, 1999).

Methods

We designed a logic model (Figure 1), to guide our efforts in creating a successful mapping system that would increase the effectiveness of local and statewide invasive plant management. The model was developed by first identifying project outcomes, and then working back to determine what we needed to do to achieve those outcomes. Logic model elements will be discussed starting from the leftmost column of Figure 1.

Situation

The negative environmental impacts of invasive plant species are well known, and invasion by non-native species has become a priority issue for resource management (Babbitt, 1998; Clinton, 1999; DiTomaso, 2000; FICMNEW, 2000b; Pimentel et al., 2000). For land managers to develop effective invasive plant management plans, accurate

Figure 1. LOGIC MODEL: Montana Noxious Weed Survey and Mapping System development and implementation.

SITUATION	INPUTS	OUTPUTS		OUTCOMES-IMPACT		
		Activities	**Participation**	**Short**	**Medium**	**Long-term**
SITUATION: Lack of accurate and complete information on weed distributions to guide management → Need for standardized system for mapping weeds	MSU, BLM & MDA Staff Partners in development: County weed coordinators Federal and state agency people Time Money (NWTF, MSU-MAES, BLM) Materials (base maps, colored pencils) Equipment / technology (computers, GPS receivers, GIS)	Meetings Advisory team Standards Statewide database Information delivery - Mailings - News releases - Web site Educational materials - Publications - WWW site Training workshops Technical support	Target audience: County weed coordinators Federal and state agency land managers County weed board members Concerned citizens	**Learning** Weed managers become aware of the system, its resources, and its importance Weed managers learn how to map using the standards	**Action** Weed managers use standards to map weeds → (Better records for next coordinator) Weed managers submit data to → statewide database Increased cooperation among weed managers statewide	**Conditions** Improved local weed management Improved statewide weed management Reduced weed populations, improved environment

ASSUMPTIONS

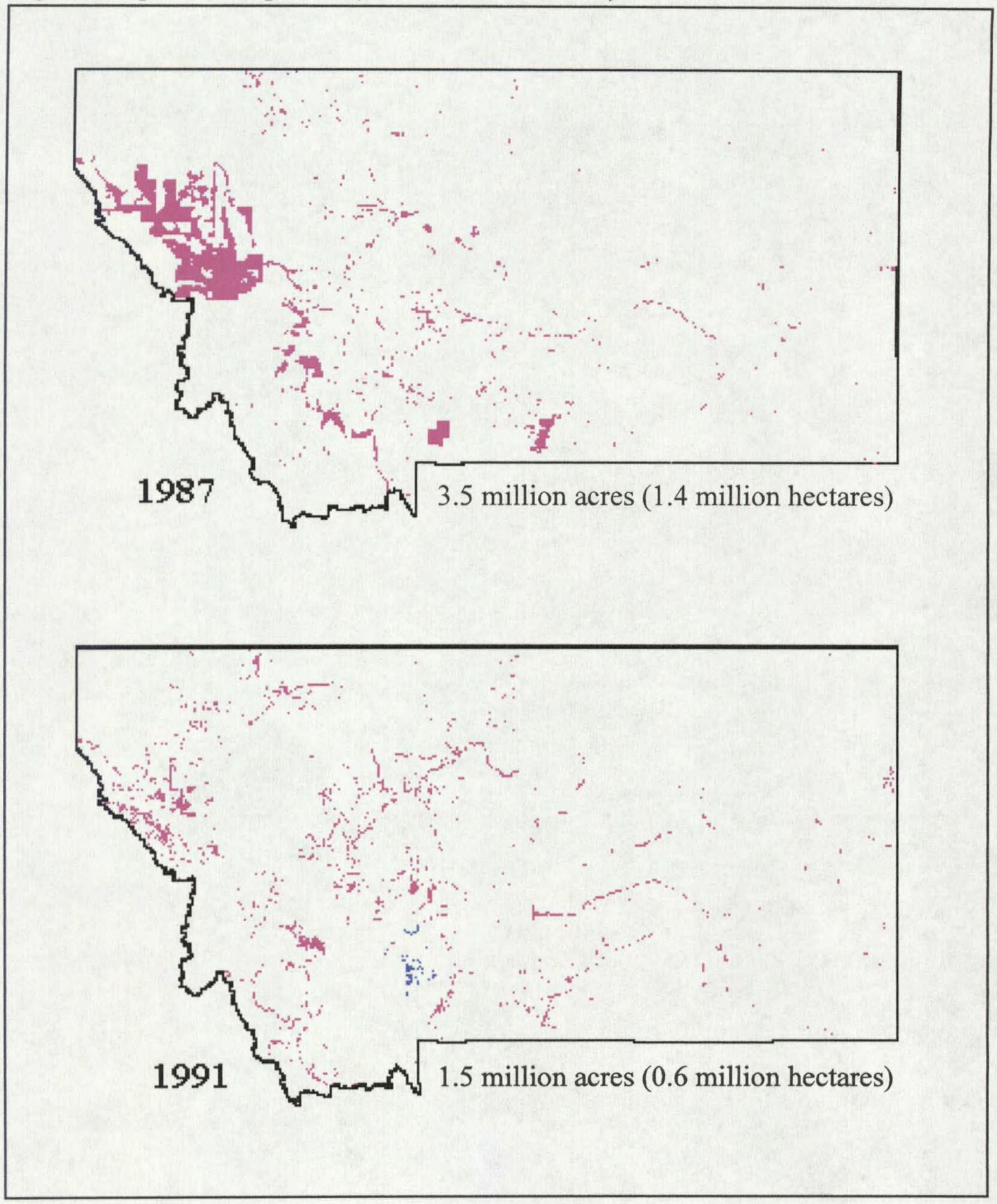
1. Communications reach intended audience
2. Managers can be trained
3. Once trained, managers will use the system to map weeds and will submit their data to the statewide database
4. Once trained, managers will teach others

ENVIRONMENT

Politics, Noxious Weed Education and Awareness Program, lack of adequate funding, demands on program staff and weed coordinator time, weed coordinator perceptions about mapping (important, costly, time-consuming, easy, too difficult, etc.), capable and dependable people to sustain the system into the future and complete information on their distribution is necessary. Land managers spend millions of dollars mapping invasive plants, but often the methods being used lack repeatability. A compilation of data from invasive plant managers in 1987 and 1991 produced statewide maps of spotted knapweed (*Centaurea maculosa*) distribution in Montana (Figure 2). Calculations from the maps showed that between 1987 and 1991, the statewide spotted knapweed infestation decreased from 3.5 million acres (1.4 million hectares) to 1.5 million acres (0.6 million hectares). Unfortunately, we know this is not true. Inconsistencies in data collection and reporting produced erroneous results. Differences in the way infestation locations were recorded, types of attribute data collected, and scale of base maps used made it difficult, if not impossible, to compare data over space and time. Tracking changes over time is important for determining the effectiveness of management activities. The data did not include severity of infestations, important information for management planning. Also, there was no way to assess the accuracy of data collected.

Standardized surveying and mapping methods provide consistently uniform information that can be compared over time and compiled into a comprehensive statewide database for use in management planning and evaluation. A set of mapping standards had previously been developed for the Greater Yellowstone Area (Free et al., 1991), but were not widely adopted in the region. A uniform set of standards used by land managers statewide should yield higher quality information, resulting in better local and statewide invasive plant management. Improved management should lead to reduced invasive plant populations and a better environment.

Figure 2. Spotted knapweed (*Centaurea maculosa*) distribution in Montana.



Inputs

Resources invested in the program included staff at Montana State University-Bozeman: the project coordinator (Diana Cooksey), her assistant (Elizabeth Roberts), several student workers, and Extension Noxious Weed Specialist and Associate Professor of Weed Ecology (Roger Sheley). Representatives from the Montana Department of Agriculture (MDA) and the Bureau of Land Management (BLM) provided input throughout the development and implementation phases of the program. Additional partners who contributed to development of the standards included county weed coordinators, private individuals, and representatives from other state and federal agencies. Countless hours of participants' time were donated. Additional funding was provided by the Montana Noxious Weed Trust Fund through the MDA, with matching funds contributed by MSU-Bozeman Montana Agricultural Experiment Station and BLM. These funds were used to hire the project coordinator and staff, purchase equipment and materials, and eventually to maintain the statewide database.

Outputs: Activities/Participation

The working group met to develop standardized mapping procedures, including type and scale of base maps to be used, how to designate infested areas on the map, symbols to use for percent cover, codes for indicating invasive plant species, and the type of drawing instruments to use when hand-drawing infestation boundaries on base maps (Chapter 3). The group had learned from earlier attempts to develop a mapping system that simple and easy-to-use standards were essential for widespread adoption. The basic data collected are the simplest possible that can still provide enough information to make management decisions. In response to a request from managers interested in biological invasive plant control, the group also developed standards to use when mapping biocontrol release and recovery sites. The working group met regularly, and eventually became the advisory team for the invasive plant mapping system, responsible for continued program development and funding.

We developed a statewide Geographic Information System (GIS) using Arc-Info software (ESRI, Inc.). Data are organized by county in an Arc-Info map library. Three separate databases store weed point, weed line and weed area data. All data are in the State Plane 83 coordinate system, and digital metadata (data documentation) are created for each dataset. Technical details of the statewide database are presented in Chapter 3.

Once the standards, data collection procedures, and database specifications were developed, we designed educational materials to provide information about the system to invasive plant managers throughout Montana. Information was disseminated through mailings, news releases, and a weed mapping system web site (www.montana.edu/places/mtweeds). A four-page Extension MontGuide describes the system and mapping standards (Cooksey and Sheley, 1996). A 20-page Extension Bulletin provides more information about mapping procedures, data recording and data management (Cooksey and Sheley, 1998, 2001). It explains how to collect standardized data using three different mapping technologies: hand-drawn maps, computer mapping systems and the Global Positioning System (GPS), and includes standards for mapping biological control agents. In order to address some of the more technical mapping issues, information about combining data collected by different methods, software compatibility considerations and digital base layers available for computer mapping is also presented. A 117-page handbook gives detailed information about how to collect invasive plant data using the three mapping technologies, and how to prepare data for submission to the statewide database (Roberts et al., 1999). The Montana Noxious Weed Survey and Mapping System WWW site (Cooksey, 2002) is a resource for information, news, technical help, downloadable publications, files, and a slide show about the system.

Hands-on training workshops were presented to invasive plant managers throughout the state (Appendix A). Most of the materials used in the workshops were incorporated into the weed mapping handbook. Our hope was that trained managers would in turn train others, eventually developing a sufficient network of knowledgeable trainers to fulfill training needs statewide. We presented five hands-on training workshops during the first three years of program implementation. The workshops included instruction on hand mapping, GPS mapping and on-screen digitizing in a GIS. We used mapping grade GPS receivers (Trimble Navigation, Ltd.) and ArcView GIS software (ESRI, Inc.) for the workshops, although the system is flexible enough to allow use of equipment and software from other manufacturers.

In addition to the training workshops, we gave approximately 15 presentations about the invasive plant mapping system at various meetings and conferences, including the Montana weed coordinator training, the Western Society of Weed Science (WSWS) Noxious Weed Short Course, the Montana GIS Conference, the Montana Weed Control

Association (MWCA) annual meeting, and BLM Integrated Pest Management (IPM) training.

We also provided technical support to invasive plant mappers throughout the state. Support covered standardized mapping procedures, equipment and software operation, and purchases of equipment and software.

Our educational materials are intended to reach county weed coordinators, federal and state agency invasive plant managers and private landowners. Others who should be aware of these materials include county weed board members and people generally concerned about invasive plant management.

Outcomes: Short-, Medium-, and Long-term

The intended outcomes, or what the program seeks to accomplish through its activities and participation, are categorized into short-, medium-, and long-term impacts. In the short-term, our intention was to make land managers throughout the state aware of the invasive plant mapping system, its resources, and importance as a result of our marketing efforts (information delivery) and the educational program (publications, WWW site, workshops and technical support). We also expected managers, especially those who attended training, to become proficient at mapping invasive plants according to the standards.

The medium-term outcomes include land managers using the standards to map invasive plants on lands under their jurisdiction, again, as a result of the marketing and educational programs. An expected benefit is that consistent mapping and reporting will produce better records for subsequent weed coordinators, which will help alleviate problems associated with weed coordinator turnover. With standardized mapping procedures, new coordinators should be better able to understand and use the results of previous work performed by others. Those who are actively mapping are expected to submit their data to the statewide database, which will eventually result in invasive plant infestation data covering the entire state.

Another expected intermediate outcome is that, as more and more land managers become familiar with the system, cooperative mapping projects will be initiated in specific areas of concern to different agencies.

In the long term, the system is expected to improve invasive plant management at the local and statewide levels, resulting in reduced invasive plant populations and improved environments. In addition, as agencies and individuals work together on invasive plant problems of mutual concern, increased cooperation among land managers will be promoted statewide.

Assumptions

Assumptions are beliefs we have about the program and the way we think it will work. The assumptions underlying our plan for developing and implementing a standardized statewide invasive plant mapping system are that 1) our communications will reach the intended audience, invasive plant managers throughout Montana, 2) invasive plant managers are capable of learning to map according to the standards,

3) once trained, managers will use the system to map invasive plants and will submit their data to the statewide database, and 4) once trained, managers will teach others.

Environment

The context in which the program exists, and external conditions which influence its success include public and political attitudes regarding invasive plants, and other programs which seek to educate the public about the negative impacts of invasive plant species such as Montana's Statewide Noxious Weed Awareness and Education Campaign (Hoopes, 2002). Financial and time constraints of project staff and participants, preconceived ideas people might have about mapping noxious invasive plants, and the availability of people to continue the program and help it become self-sustaining also affect its success.

Evaluation

Both formative (intermediate) and summative (final) evaluations were designed to assess the effectiveness of the program (Table 1). An evaluation was done at the end of each hands-on workshop (Appendix B), and a detailed questionnaire was sent out to program participants and others involved in invasive plant management in Montana (Appendix C). In addition, personal communications with program participants provided some indication of its success.

The evaluation plan covers 1) what we want to know that will help us evaluate project success, 2) how success will be measured or observed (indicators), 3) where the information will come from, 4) how it will be collected, and 5) when and where it will be

Table 1. Evaluation plan for the Montana Noxious Weed Survey and Mapping System.

What do we want to know?	**Indicators - How will we know it?**	**Source of information**	**Method to collect information**	**Schedule - When/Where**
1. Are weed managers aware of the system, its resources and its importance to weed management?	- Numbers of publications distributed - Land manager knowledge of system	Land managers and others	-Publications records - Questionnaire: familiarity index	Summative: After program implemented
2. Did workshop participants learn how to map invasive plants using the standards? Did others learn how to map using the standards?	- Level of comfort after attending workshop - Are others submitting data?	- Workshop participants - Others submitting data	- Workshop evaluations: increased knowledge, increased comfort - Database records	- Formative: After each workshop - Formative: As statewide database is developed
3. Are weed managers using the standards to map weeds? (Better records for next coordinator)	- Land manager records - Tech. support records: # requesting support	Land managers and others	Questionnaire: percent collecting data	Summative: After program implemented
4. Are weed managers submitting their data to the statewide database?	- Land manager records - Number of datasets in statewide database vs. number of weed managers trained in workshops	Land managers and others	Questionnaire: percent submitting data	Summative: After program implemented
5. Is there increased cooperation among weed managers statewide?	- Number of agencies cooperating on system development and implementation - Number of agencies participating in cooperative mapping projects	Program participants	Personal communication	Formative: During program implementation
6. Are weed managers using the information for improved local weed management?	- Land manager perceptions - Case study examples	Land managers and others	- Questionnaire: Q1A - Case studies	Summative: After program implemented
7. Has use of the system resulted in improved statewide weed management?	- Land manager perceptions	Land managers and others	Questionnaire: Q1E	Summative: After program implemented
8. Has the program been successful overall?	Land manager perceptions	Land managers and others	Questionnaire: usefulness of system, importance of continuing activities	Summative: After program implemented

collected. Indicators are the evidence or measures that will show whether or not we have achieved our short-, medium-, and long-term outcomes.

Results and Discussion

Figure 3 integrates the logic model and evaluation indicators, and provides a format for discussing how the logic model compares with actual program results. Responses to a mail questionnaire (Appendix C) conducted in 2002 are evaluation indicators for several of the outcomes. This questionnaire was sent to 255 people involved in invasive plant management in Montana. One hundred thirty seven questionnaires were returned and included in the analysis. Complete questionnaire results are presented in Appendix D.

Short-term Outcomes

Are weed managers aware of the statewide invasive plant mapping system, its resources, and its importance to weed management? The first indication that managers are familiar with the system is the number of publications requested and distributed during the implementation phase of the program. Five thousand copies of the MontGuide and 2,300 copies of the Extension Bulletin have been delivered to weed managers throughout Montana and the region. Excluding initial mailings to weed managers in the state, most of these were sent by request. The weed mapping system handbook was distributed to 259 weed managers in Montana and the Western U.S by request. In addition, since the

Figure 3. EVALUATION: Montana Noxious Weed Survey and Mapping System development and implementation.

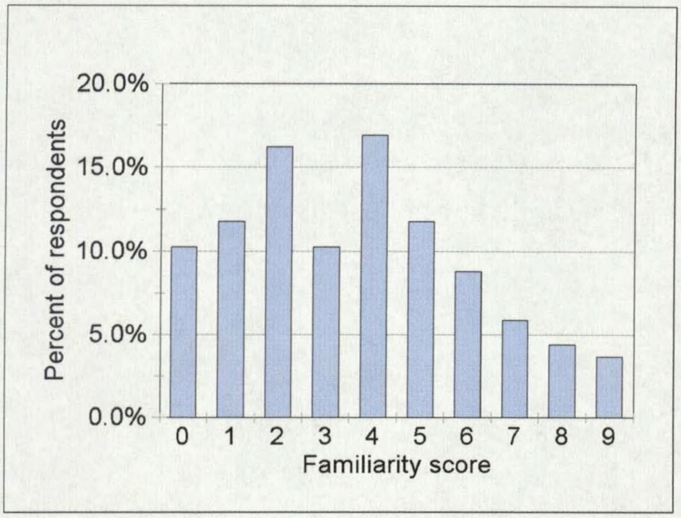
	INPUTS	OUTPUTS		OUTCOMES-IMPACT		
		Activities	**Participation**	**Short**	**Medium**	**Long-term**
SITUATION: Lack of accurate information → Need for standardized system for mapping weeds	MSU, BLM & MDA Staff Partners in development: County weed coordinators Federal and state agency managers Time Money (NWTF, MSU-MAES, BLM) Materials (base maps, colored pencils) Equipment / technology (computers, GPS receivers, GIS)	Meetings Advisory team Standards Statewide database Information delivery - Mailings - News releases - Web site Educational materials - Publications - WWW site Training workshops Technical support	Target audience: County weed coordinators Federal and state agency land managers County weed board members Concerned citizens	**Learning** Weed managers become aware of the system, its resources, and its importance Weed managers learn how to map using the standards	**Action** Weed managers use standards to map weeds (Better records for next coordinator) Weed managers submit data to statewide database Increased cooperation among weed managers statewide	**Conditions** Improved local weed management Improved statewide weed management Reduced weed populations, improved environment
INDICATORS				- # publications distributed - Questionnaire: familiarity questions & index - Level of comfort after workshop - Others submitting data	- Questionnaire - # requests for tech. support - # datasets in statewide database - # agencies doing cooperative mapping	Questionnaire Case study examples on infestations contained since they were mapped

handbook was made available on the web site in June 1999, it has been downloaded 284 times (as of February 2002) by people throughout the U.S. and around the globe. The web site has received over 5,000 hits since November 1997 from people searching for information or downloading publications and other files.

Answers to questions in section IV of the questionnaire indicate respondents' familiarity with and use of weed mapping system resources. Of the 136 respondents, 66.2% have seen the weed mapping system handbook, 47.1% own a copy of the handbook, 42.6% have seen a presentation about the project, 23.5% have attended a training workshop, 56.6% have read the MontGuide, 56.6% have read the Extension bulletin, 35.3% have browsed the website, 16.9% have downloaded files from the website and 19.1% have called the weed mapping system office for assistance.

A familiarity index summarizes responses to questions in section IV of the questionnaire. The familiarity index is the total number of "yes" answers to questions A through I in section IV. Values from 0 to 9 are possible. The higher the value, the more knowledgeable the respondent is about the weed mapping system. The overall average familiarity index including all groups (people from county, state or federal agencies, farms or ranches, businesses and others) was 3.64, showing that the average person responding to the questionnaire has done about 3 ½ of the activities listed. County agency people were most familiar with the system with an average of 3.97: they are above the average in their familiarity. All other groups were below the average. Business people, as well as farm or ranch individuals, were least familiar with an average of 3.00. We believe that a person who is fairly familiar with the system should have a score of about 5. The

Figure 4. Familiarity of respondents with WMS.



histogram (Figure 4) shows that over one-third (34.6%) of the respondents have a high level of familiarity with the system (a score of 5 or above). Ideally, we would like everyone to have a high familiarity score, but we feel that reaching one-third of our target audience is a good start. A future goal will be to increase the familiarity score for the remaining two-thirds of weed managers in Montana.

Have weed managers learned how to map weeds according to the standards? Thirty-one Montana county weed coordinators, and four from Wyoming and South Dakota attended 3-day hands-on workshops. In addition, 33 state and federal agency personnel, and three private individuals were trained. Their level of comfort with mapping methods was assessed from two questions on the workshop evaluations. In response to the question, "How much has your knowledge increased as a result of this workshop?" none of the participants answered "none," 3% answered "a little," 35% answered "a fair amount," and 62% answered "a great deal." The question "Do you feel more comfortable with the standardized weed survey and mapping system now that you've attended this workshop?" received 83% "Yes" answers. Seventeen percent of the participants did not answer the question. Even though the majority of participants felt more comfortable using the system after attending the workshop, several felt that they needed additional instruction to better understand the system, and more practice time, especially with GPS and GIS mapping methods.

Another indication that weed managers have learned to map weeds according to the standards is the number submitting data to the statewide database, which is covered below. Those who successfully submitted data obviously learned to do the mapping.

Medium-term Outcomes

Are weed managers using the standards to map weeds in their counties or management areas? Results from section II of the questionnaire regarding use of the weed mapping system showed that 81% of respondents have collected data about the location of weed infestations, and 91% expect to be collecting data in the future.

We handled a total of 282 requests for technical support between February 1996 and February 2002. Questions dealt with details of mapping and reporting methods, mapping standards, and use of new technologies for noxious weed inventory. Those requesting technical support were obviously using the standards for mapping.

Are weed managers submitting data to the statewide database? Even though 80.9% of respondents have collected data about the location of weed infestations, only 28.7% have submitted data to the statewide database. And, even though 91.2% expect to be collecting weed data in the future, only 56.6% expect to submit data to the statewide database. Why are people collecting data but not submitting them? Forty-five percent indicated that they need training in data collection and/or submission procedures. Forty percent said they needed technical assistance in using equipment for weed mapping. Additional reasons given for non-submission of data are lack of knowledge of the weed mapping system (21.3% of those who collected data, but did not submit them), incomplete data or data not up to standard (15.7%), incompatible format (14.6%), too busy (11.2%), already submitted data to county weed coordinator (7.9%), submit to a different database (6.7%), new at collecting data (5.6%), submission process too complex (4.5%), and privacy issues (2.2%).

A closer look at the results shows that of those who have collected data (80.9% of the entire sample), 35.5% have submitted them to the statewide database, 97% expect to continue collecting data, and 84.6% expect to submit them to the statewide database in the future. Although these respondents are collecting and submitting data, they still indicated a need for training (33.3%) and technical assistance (38.5%). Of those who have collected data, but have not submitted them to the statewide database, 97% expect to collect data and 47% expect to submit data in the future. 51.5% expressed a need for training and 42.4 % said they needed technical assistance. Of those who have not collected data (17.6% of the entire sample), 62.5% expect to be collecting data and 37.5% expect to submit data in the future. 37.5% said they needed training and 41.7% said they needed technical assistance.

In question II.B.B2. of the questionnaire, respondents are asked what help they needed to be able to submit their data. The following results report needs of both people who have submitted data and people who have not submitted data. Needs mentioned are information and assistance (33.7%), more funding/time/personnel (30.3%), accessibility of data after submission (10.1%), publicity for and feedback from the weed mapping system (9%), and on-line access and submission capability (2.2%). Of those who need information and assistance, specific requests include general information and assistance (15.7%), information on how to submit data (12.4%), training and technical assistance (7.9%) and a contact person for the weed mapping system.

Personal communications have confirmed that several people are having trouble mapping and preparing their data for submission to the statewide database, and some are unsure about who to contact to submit data. This, coupled with the questionnaire results, implies a need for ongoing training and support in using the standards to collect data, and procedures for submitting data to the statewide database. We believe this deficiency arose out of a temporary lag in activity and funding while we were working out issues related to private landowner data reporting. To address the need for information and support, we have planned more formal marketing and training efforts for 2002. Training workshops are being coordinated by the Stillwater County weeds/GIS specialist, and are being presented to weed managers statewide. In addition, the County hired a ½ time person to help implement increased efforts in marketing, training and technical support. Leadership from the county level is important for building trust and participation among county weed coordinators. We believe this "ground level" involvement will help to reduce some of the resistance resulting from primary involvement by a university and a federal agency. Much of Stillwater County's work involves communication and hands-on assistance to people with specific data collection and submission problems. We have also prepared a step-by-step guide for submitting data to the statewide database, which will be posted on the web site. This guide, along with other materials that answer specific data collection questions, is expected to help people get their data into the statewide database. The advisory team has planned these efforts to "jump start" the system and eventually create a self-sustaining program with active participation from weed managers statewide. We realize this cannot take place, however, without direct involvement by advisory team members for the next several years. The advisory team must continue to address issues of funding and leadership to ensure a self-sustaining future for the system.

Time and financial constraints appear to be another important factor in determining whether or not people submit their data. Many weed coordinators are overwhelmed with the amount of work they have to do, and find it difficult to take the time to learn the system and data submission procedures. The evaluation results also suggest a need for improvement in accessibility of data once they have been submitted. This could be accomplished by faster turnaround time for end products (primarily large format maps) and on-line accessibility of maps including totals of infested acres (hectares). In addition, an on-line submission process would be helpful for some people, and is being considered.

Another factor influencing whether or not people submit data to the statewide database could be that private landowners are reluctant to turn over data about invasive plants on their property for fear it would be publically accessible. Our solution to the private landowner privacy issue is discussed under "Current and Future Issues."

Our records show that approximately one-fourth of the county weed coordinators who attended training workshops have submitted data to the statewide database. In addition, several counties who did not receive training have submitted data, showing that people can learn to map weeds according to the standards, and properly prepare their data for addition to the statewide database, without having been trained. Our observations indicate that using new technologies for invasive plant mapping is difficult for some people, while others have no problem. This was one of the reasons we created procedures for mapping using three different methods. Those who are uncomfortable with new technology could continue to map invasive plants by hand, while those who are comfortable with GPS and GIS systems could take advantage of them. Problems arise when people try to use the new technologies without proper background or aptitude. This can be a frustrating experience for someone who just wants to get the job done.

Weed survey data have been submitted for all or parts of 24 counties in Montana, by county weed districts, the U.S. Forest Service, Nature Conservancy, Montana Dept. of Fish, Wildlife and Parks, and the Bureau of Land Management.

Is there increased cooperation among weed managers statewide? The National Park Service, U.S. Forest Service, Bureau of Indian Affairs, Bureau of Reclamation and the Agricultural Research Service have all cooperated in development and use of this system. Cooperation among Montana State University, Montana Department of Agriculture, Bureau of Land Management and Montana county weed districts has been crucial to its success. Agencies are also beginning to cooperate on focused weed mapping activities in Montana, such as the 2000-2001 cooperative helicopter noxious weed mapping project involving nine county weed departments, Montana Fish, Wildlife and Parks, Montana Department of Natural Resources and Conservation, United States Forest Service, Bureau of Land Management and a private enterprise. Another example of cooperation is Yellowstone National Park's partnering activities with surrounding counties and the U.S. Forest Service, helping them to digitize their invasive plant data and prepare quality output maps. Also, a few county weed coordinators who have become proficient in mapping are providing training to groups in neighboring counties. We believe the invasive plant mapping system has provided a format for cooperation among agencies involved in managing invasive plants.

Long-term Outcomes

Is there improved management at the county or weed management area level? When asked if the weed mapping system has helped local weed coordinators in weed management planning, 69.2% of respondents agreed, 18.3% were neutral, and 12.5% disagreed. Those who collected data about the location of weed infestations mentioned several ways they have used the data: mapping (mentioned by 63.6%), management (63.6%), economic analysis (15.5%), locate infestations (31.2%), control infestations (23.9%), acquire funding (10.1%) and other (22.9%).

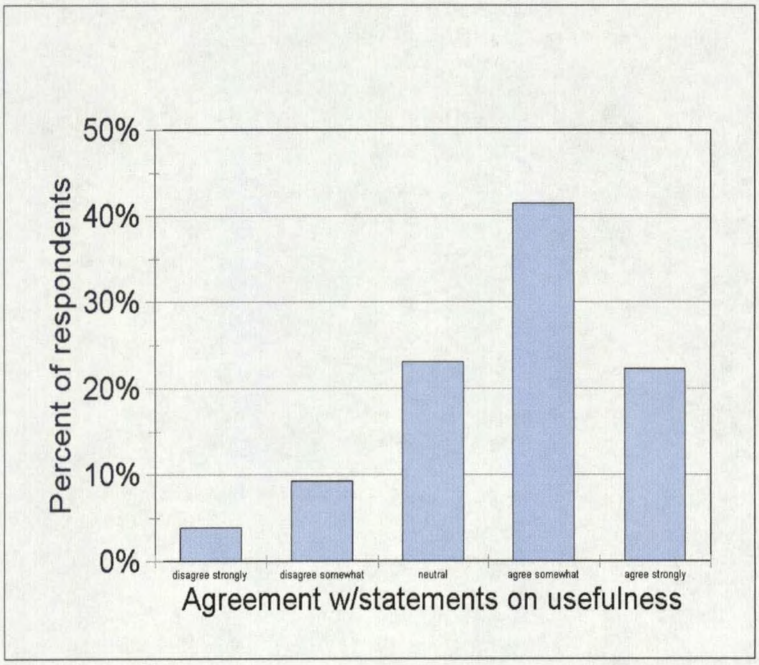
Is there improved management at the statewide level? When asked if the weed mapping system will produce beneficial data for managing weeds in Montana, 89.9% of respondents agreed, 7.8% were neutral, and 2.3% disagreed. As the statewide database is populated with data from weed managers throughout the state, eventually the entire state will be mapped, but completing the statewide database at the detailed (1:24,000) scale used by the invasive plant mapping system will take many years. We also recognize the dynamic temporal nature of the database. Information for different counties and management areas will be created and updated at different times, so that the complete statewide spatial data set will have subsets with different time spans and different update frequencies. For statewide management planning, invasive plant distribution for the entire state is needed immediately. This need led us to develop a method for gathering generalized data for the entire state. The method, described in Chapter 3, allowed us to compile a complete statewide view of invasive plants for 1998 at the public land survey section scale over a period of two years. Now that it has been done once, and everyone is familiar with the procedure, we will be able to add additional weeds to the database and update existing data much more quickly. The data were compiled at MSU-Bozeman, and the GIS database was turned over to the Montana Department of Agriculture (MDA) in January of 2000.

Have weed populations been reduced? Two case studies presented in Chapter 3 give examples of local successes in reducing invasive plant populations with mapping as a catalyst. Reductions in individual weed populations should lead to a reduction in total area infested statewide, but we do not yet have data to support this. This type of analysis will be possible when the statewide database is complete.

Has the program been successful overall? The questionnaire assessed the overall usefulness of the invasive plant mapping system to Montana weed managers. Responses to questions A and E were discussed above. 82.4% of respondents agree that the weed mapping system has made progress in setting standards for weed mapping. 64.4% agree that the system has helped many people work with technical problems related to weed mapping. 89% agree that it will help in the study of the spread of weeds. 84.6% agree that the system will add to weed managers' understanding of how to map and keep track of the spread of weeds in their areas. Figure 5 summarizes the overall usefulness of the invasive plant mapping system as perceived by questionnaire respondents.

Respondents rated the importance of continuing various activities of the invasive plant mapping system on a scale of 1 to 5, one being not important and 5 being very

Figure 5. Usefulness of WMS.



important (Figure 6). Table 2 lists the average importance of activities in their order of importance to respondents. On average, all of the activities were rated as moderately to very important.

Figure 6. Importance of WMS activities.

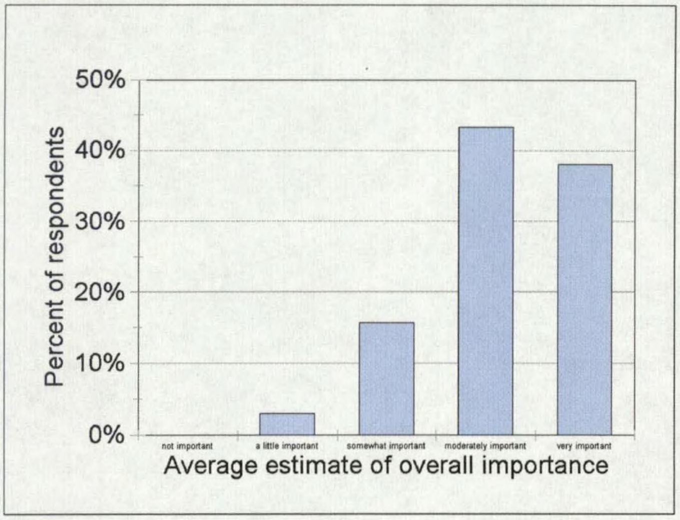


Table 2. Average importance of WMS future activities.

III. WMS FUTURE ACTIVITIES:	AVERAGE
Determination of how fast noxious weeds are spreading	4.6
Calculating number of acres infested by different weeds	4.4
Maintenance and addition of data to statewide database	4.4
Maintenance of WMS Web site	4.2
Availability of ready-made maps which show weed infestations	4.2
Availability of downloadable files– Extension Bulletin, MontGuide,	4.2
Availability of computerized weed data for creating reports and maps	4.2
Continued availability of WMS Handbook, MontGuide and	4.2
Workshops for training in use of GPS and GIS equipment	4.2
Workshops covering weed mapping, and how to prepare data for the	4.1
Technical assistance in collecting data for the statewide database	4.0
Technical assistance in setting up and using equipment for weed	4.0
Technical assistance in purchasing equipment for weed mapping	3.8

Additional Outcomes

Our target audience was Montana invasive plant managers. We did not anticipate the widespread adoption of this system throughout the Western U.S. and the globe. We continually receive requests for information from people in other states and countries who are just beginning to develop mapping programs. The invasive plant mapping system gives people something to start with, which they can adapt to their own needs.

The Noxious Weed Trust Fund council recognizes the importance of mapping, and now requires recipients of grant funding to map invasive plants and other features in areas where control projects are taking place. Maps developed using the standardized system have helped invasive plant managers receive grant funding for cooperative mapping projects (Chapter 3).

Has the mapping produced better records for the next weed coordinator? Although we did not assess this question quantitatively, personal communications indicate that standardized mapping and reporting procedures have helped to minimize the effort involved in interpreting a previous weed coordinator's mapping records. Because all weed coordinators in the state are using the same system, new weed coordinators find previously collected data more usable. Also, help is available because the weed coordinators in neighboring counties are using the same mapping methods.

Assumptions

Publications records and questionnaire results indicate that communications have reached many members of our target audience, but it is clear that others do not understand the system and how it works. Additional marketing and training efforts are needed, and a plan for achieving them is in place.

The issue of some people being uncomfortable with equipment and technology is discussed above. We believe that those who are not comfortable with GPS and GIS should continue to use the hand-mapping method. Many county weed coordinators want to use low cost recreational grade receivers for invasive plant mapping. Though these receivers do not have the capability to generate location and attribute data automatically formatted for a GIS, one can collect location coordinates for point features (not lines or areas) and link them to paper records. These data can then be formatted for GIS entry. We have created a procedure for doing this, for those who want to use recreational grade equipment. The location coordinates, however, cannot be differentially corrected for increased accuracy.

The assumption that managers will use the system and submit data to the statewide database is addressed above. There is clearly a need for increased education and training to encourage more participation in the program.

Though a few managers who were trained in workshops have made the effort to teach others, this has not occurred to the level needed to fulfill training needs statewide. Additional training being offered in 2002 by a county coordinator will hopefully result in more participation and more data submitted to the statewide database.

Current and Future Issues

In July of 1999, at the end of the development stage of the invasive plant mapping system project, an "advisory team" was formed to develop a plan for continued implementation and funding of the system. Members of the original working group were invited, and others were added to ensure representation from all agencies actively involved in invasive plant management. The first advisory team meeting was, again, led by a facilitator with the same approach used for working group meetings. All participants were involved in the process of developing a charter and a set of objectives to guide their activities. This process was intended to identify problems to be addressed and needs of the invasive plant mapping system, as well as to secure team commitment. The charter and objectives of the advisory team are presented below.

Charter for advisory team: The advisory team provides leadership and direction for the statewide weed database and mapping partnership for the greatest benefit to effective cooperative weed management programs. The advisory team objectives are:

1. Set goals and priorities - identify user requirements
2. Facilitate funding source development
3. Ensure quality data
4. Identify and solve problems
5. Promote good public relations
6. Promote and improve standardized system
7. Provide self-assessment (is it working?)
8. Assess usefulness of data

The advisory team continues to provide leadership, direction and development of funding opportunities to sustain the weed mapping system. Regular meetings are held twice per year.

In 1999, the Bureau of Land Management (BLM) became a primary partner in the system, providing housing and management of the statewide database. In 2002, the Stillwater County weeds/GIS office also assumed a major leadership role, to fulfill marketing and training needs identified by the advisory team. Internet web pages containing information about the invasive plant mapping system are still maintained by MSU-Bozeman.

One of the future goals for the program is to develop an interactive map server application on the weed mapping system web site where users can view maps and information on the status of invasive plants throughout Montana. Two years ago, an issue regarding web maps and private landowner contributions to the statewide database came to the attention of the advisory team. Some private landowners were reluctant to provide data to the system because they felt their right to privacy could potentially be violated if maps were accessible on the Internet. The advisory team addressed the issue by making it clear to users that cooperation is completely voluntary. No private landowner is required to enter data into the statewide database. However, progress is dependent on private and public sources actively taking part in contributing their data to the system. Therefore, entry of private landowner data is encouraged. In addition, managers of the statewide database devised a way for individual data to be password protected to prevent private weed location information being made available to the public. In these cases, data would only be used by the database managers in the calculation of overall acreage figures.

Summary

Development and initial implementation of the invasive plant mapping system took four years. Complete population of the statewide database will take many more years, and continued effort on the part of the advisory team and partners to inform and educate invasive plant managers throughout Montana will be needed.

Implementing a standardized mapping system had been attempted previously, but the standards were not widely adopted. We believe that the planning, development, and evaluation processes we used led to successful implementation of the invasive plant mapping system. We started with a clear vision of what we wanted to accomplish and developed a strategic, outcome-based framework to guide us. We provided a project coordinator to lead the effort, and worked to generate support for and ownership of the project among cooperators and users. We used facilitation techniques in meetings to develop consensus, and we initiated a marketing program to inform users. A flexible approach has allowed us to respond to challenges and find solutions. However, there is still much work to do.

Efforts are in place to meet the needs specifically mentioned by questionnaire respondents. These include additional training, publicity and information about the invasive plant mapping system, online data access and data submission capability, and expanded technical support. Strong and continued leadership on the part of the advisory team and our primary partners will be necessary to keep mapping efforts and database expansion going. Active participation by land managers statewide will result in readily accessible and comprehensive data for improved local and statewide invasive plant management.

CHAPTER 3

SYSTEM DESCRIPTION

Introduction

A standardized system for invasive plant mapping allows survey data to be incorporated into a geographic information system (GIS) for production of regional maps showing the distribution and severity of infestations. This type of database can provide consistent and accurate information for local, statewide and regional invasive plant management plans.

Statewide invasive plant management plans are used to guide the implementation of local programs. Current and accurate assessments of invasive plant extent and severity are central to developing effective statewide plans. Compiling a statewide spatial database is complex and requires several years to complete. We believe that useful data, coarser in scale than that needed for local management, can be efficiently collected by surveying local invasive plant specialists who have knowledge of invasive plant species locations.

Our objectives were to develop invasive plant mapping guidelines and standards and a detailed statewide spatial database for invasive plant management. In addition, we developed a method for gathering complete statewide data at a generalized (public land survey section) scale to provide immediate information about invasive plant distribution.

Representatives from federal, state and county agencies, as well as industry and private individuals, developed guidelines and standards for a statewide invasive plant survey and mapping system. In this chapter, we introduce this standardized mapping procedure, including type and scale of base maps to be used, how to designate infested areas on the map, codes and colors for indicating invasive plant species, symbols to use for percent cover, and the type of drawing instruments to use when hand-drawing weed infestations on base maps. The system also includes standards to use when mapping biological control release and recovery sites. We provide information on data recording methods including use of hand-drawn maps, computer mapping systems and GPS receivers. Methods for combining data, software compatibility considerations and digital base layers available for computer mapping are also discussed. The purpose of this chapter is to provide this system as a prototype for others interested in developing standardized invasive plant mapping systems. Two case studies are shown to emphasize the advantages and disadvantages of the system based on our experiences.

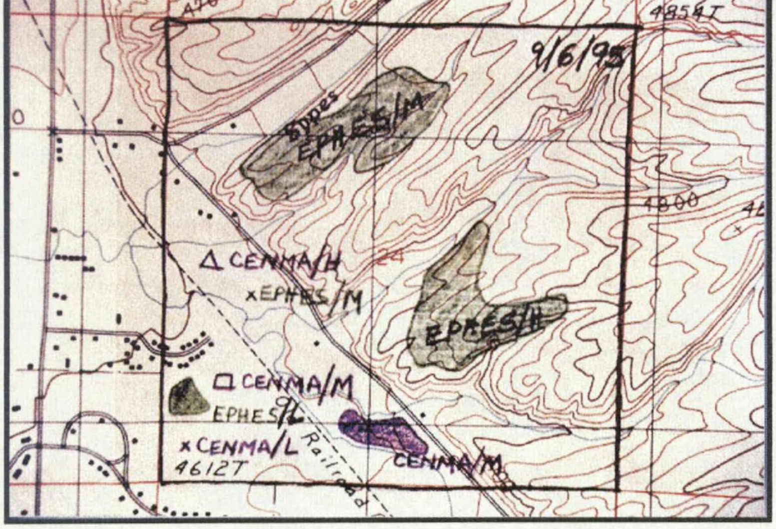
We also describe a faster method for gathering complete statewide data at a generalized scale to provide immediate information for statewide invasive plant management plans.

Guidelines and Standards for Invasive Plant Mapping

A simple and straightforward set of standards, previously used in the Greater Yellowstone area, provides the basis for this system (Free et al., 1991). We learned from earlier attempts to develop an invasive plant mapping system that simple and easy-to-use standards are necessary for widespread adoption. The basic data collected are the minimum data set that still provides enough information to make management decisions. The guidelines and standards allow for creation of weed survey maps by hand-drawing infestation boundaries on base maps, collecting coordinates of invasive plant locations using GPS technology, and drawing infestation boundaries on digital base maps in a GIS (on-screen digitizing). The same data elements are collected, regardless of the method used.

Hand mapping involves field identification of weed infestations using 1:24,000 USGS base maps or mylar overlays. With hand mapping, all required information is written on the map (Figure 7). The locations of weed infestations are later digitized and entered into a GIS (Figure 8). GPS mapping involves in-field use of GPS receivers to map weed infestations. With GPS mapping, a database is loaded into the GPS receiver, which facilitates the collection of attribute data along with location coordinates, and

Figure 7. Topographic map with hand-drawn weed inventory.

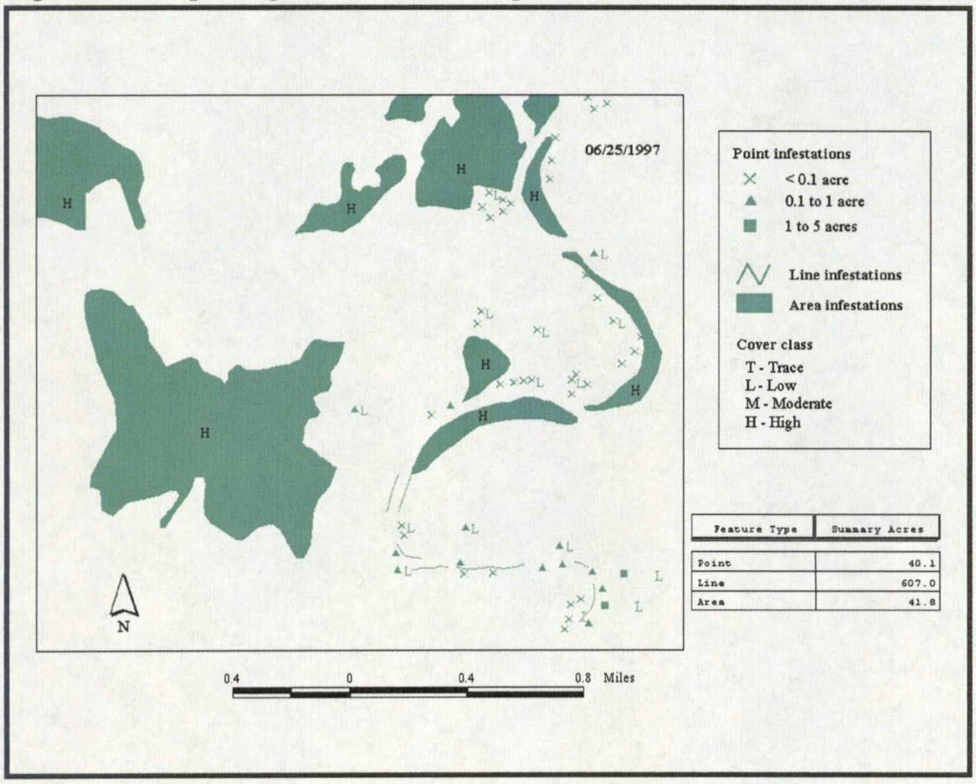


eliminates the need to write down information in the field (Figure 9). GPS data are easily exported to a GIS. With on-screen digitizing in a GIS, the database is linked to point, line and area features, which are created by clicking the mouse cursor over identifiable areas on a digital base map. Attribute data can be entered once the features are created.

Type and Scale of Base Maps to be Used

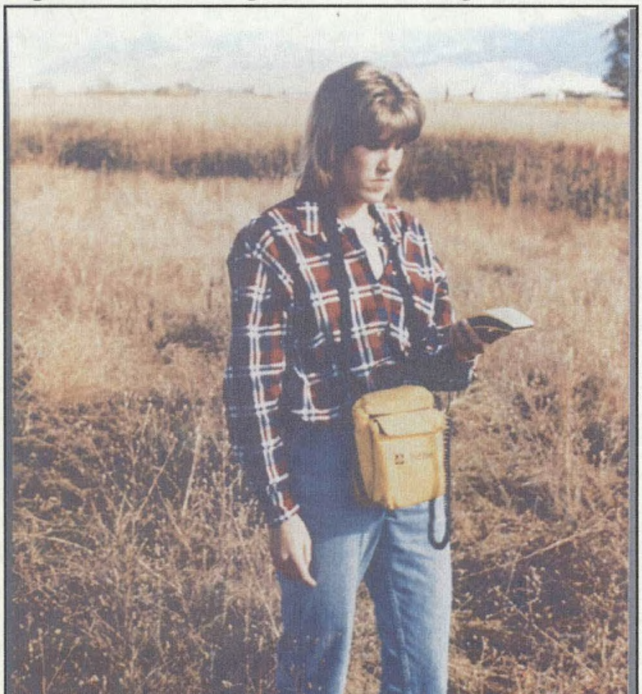
For standard base maps, United States Geological Survey (USGS) 7.5 minute series (1:24,000 scale) topographic maps are used. These maps are widely available in paper and now digital format, and are familiar to most people. This scale is appropriate for weed management planning, and the standardized scale ensures that data can be combined from site to site and year to year. Another option for base maps is 1:24,000

Figure 8. Computer-generated weed map.



scale orthophoto maps, which are geodetically corrected aerial photographs. Digital orthophotos are now available for many areas in the United States. Scientists and managers are beginning to use satellite or other remotely sensed imagery for invasive plant mapping. As spatial and spectral resolution of digital imagery improves and costs decrease, these types of products will increasingly be used for invasive plant mapping, analysis and management. The scale of these products is generally larger (more detailed) than 1:24,000. Like GPS-mapped data which are captured at a scale of 1:1, maps created using remotely sensed imagery can be incorporated into a spatial database along with 1:24,000 scale data, as long as the original scale of the data is documented. Data captured

Figure 9. Collecting weed data using GPS.



at a scale smaller (less detailed) than 1:24,000 are not acceptable for the statewide spatial database.

Designating Infested Areas on the Map

The mapped data includes an outline of the survey area and the date of the survey. Areas inside the survey boundary without size and location designations are considered free of invasive plants. The following symbols are used to designate the size and locations of the infestations. An "X" over the appropriate location is used to specify an individual plant or a weed infestation of less than 0.1 acre, a triangle specifies a weed infestation of 0.1 to 1 acre, and a square specifies a weed infestation of 1 to 5 acres in size (Figure 8). When collecting these data using GPS receivers, point features are recorded by standing in the center of the infestation. Areas larger than five acres are outlined directly on the map. GPS mapping of area features requires walking or driving around the perimeter of the infestation. Weed infestations that follow linear features such as roads and streams are designated by drawing lines on the map and recording the average width of the weed infestation. With hand-mapping, the line is drawn through the center of the linear weed infestation. With GPS mapping, the direction of weeds from the line is recorded (i.e. indicates that weed infestations are left, right or centered on the mapped line).

Codes and Colors for Indicating Weed
Species, Symbols to use for Percent Cover

In addition to marking locations and sizes of weed infestations on the map, each weed species is identified by the appropriate Weed Science Society of America (WSSA)-approved computer code (Alex et al., 1989). Weed species are also assigned unique colors (Cooksey and Sheley, 1997), so they can be easily recognized on maps produced by different mappers. Finally, infestation cover class is noted on the map or entered into the database. Cover classes are as follows: trace = less than 1 %, low = 1 to 5 %, moderate = 5 to 25 %, and high = 25 to 100%. Density, growth stage, and other information mappers may wish to collect are optional data elements. Density values represent number of plants per square yard or square meter. Growth stages include seedling (S), bolt (B), bud (Bd), flower (Fl), seed set (SS) and mature (M).

Drawing Instruments used for Hand-drawn Weed Infestation Maps

Accuracy of hand-drawn maps can be affected by the size of the drawing instrument. A line 1/32 of an inch wide (1 mm) on a 1:24,000 scale USGS map is equal to 62.5 feet on the ground. If a felt pen is used to mark the perimeter of a weed infestation, it may appear larger than if a No. 2 pencil is used. Therefore, a standardized size of drawing instrument should be used to delineate weed infestations. A specific set of color pencils is used for hand-drawn weed maps. These pencils are widely available and have long-lasting lead which is light-fast and water proof. A unique color is assigned to each noxious weed species, and the colors have been translated into digital codes for use in computer programs (Table 3). It is important to keep the pencils sharp to avoid introducing error when the maps are digitized. If the pencils are kept sharp, the line width is about 1/64 of an inch (0.5 mm). This line width represents about 30 feet on a 1:24,000 scale map.

Table 3. Color pencil names and codes and digital color codes for noxious weed species.

Common name	Scientific name	WSSA code	Prismacolor pencil name (code)	ESRI ArcView H/S/V[1] code	RGB[2] code	CMYK[3] code	HTML[4] code
CATEGORY I[5]							
leafy spurge	*Euphorbia esula*	EPHES	Peacock Green (739)	110 / 255 / 169	0 / 170 / 105	170 / 0 / 65 / 85	#00AA69
Canada thistle	*Cirsium arvense*	CIRAR	Tuscan Red (746½)	0 / 125 / 136	138 / 70 / 70	0 / 68 / 68 / 117	#8A4646
Russian knapweed	*Centaurea repens*	CENRE	Terra Cotta (745½)	14 / 135/ 167	168 / 109 / 80	0 / 59 / 88 / 87	#A86D50
spotted knapweed	*Centaurea maculosa*	CENMA	Parma Violet (742½)	194 / 130 / 254	197 / 124 / 254	57 / 130 / 0 / 1	#C57CFE
diffuse knapweed	*Centaurea diffusa*	CENDI	Warm Grey (734½)	42 / 5 / 213	215 / 215 / 211	0 / 0 / 4 / 40	#FFDCC4
field bindweed	*Convolvulus arvensis*	CONAR	Deco Pink (743)	241 / 51 / 254	255 / 204 / 219	0 / 51 / 36 / 0	#FFCCDB
whitetop (hoary cress)	*Cardaria draba*	CADDR	Peacock Blue (740½)	131 / 255 / 162	0 / 148 / 164	164 / 16 / 0 / 91	#0094A4
Dalmatian toadflax	*Linaria dalmatica*	LINDA	Canary Yellow (735)	41 / 255 / 253	255 / 245 / 0	0 / 10 / 255 / 0	#FFF500
St. Johnswort (goatweed)	*Hypericum perforatum*	HYPPE	Olive Green (739½)	57 / 219 / 132	95 / 133 / 18	38 / 0 / 115 / 122	#5F8512
sulfur cinquefoil	*Potentilla recta*	PTLRC	Orange (737)	23 / 252 / 252	255 / 137 / 2	0 / 118 / 253 / 0	#FF8902
common tansy	*Tanacetum vulgare*	CHYVU	Indigo Blue (741)	140 / 255 / 158	0 / 104 / 160	160 / 56 / 0 / 95	#0068A0
houndstongue	*Cynoglossum officinale*	CYWOF	Crimson Red (745)	235 / 255 / 221	225 / 0 / 90	0 / 225 / 135 / 30	#E1005A
oxeye daisy	*Chrysanthemum leucanthemum*	CHYLE	Black (747)	0 / 0 / 0	0 / 0 / 0	0 / 0 / 0 / 255	#000000

[1] Hue/saturation/value
[2] Red-green-blue
[3] Cyan-magenta-yellow-black
[4] Hypertext markup language

[5] Category 1 noxious weeds are weeds that are currently established and generally widespread in many counties of the State. Management criteria include awareness and education, containment and suppression of existing infestations and prevention of new infestations. These weeds are capable of rapid spread and render land unfit or greatly limit beneficial uses.

Table 3., cont. Color pencil names and codes and digital color codes for noxious weed species.

Common name	**Scientific name**	**WSSA code**	**Prismacolor pencil name (code)**	**ESRI ArcView H/S/V code**	**RGB code**	**CMYK code**	**HTML code**
CATEGORY II[6]							
dyer's woad	*Isatis tinctoria*	ISATI	Grass Green (738)	82 / 255 / 205	14 / 206 / 0	192 / 0 / 206 / 49	#0ECE00
purple loosestrife	*Lythrum salicaria* and *Lythrum virgatum*	LYTSA and LYTVI	Dahlia Purple (752)	.213 / 255 / 152	153 / 0 / 153	0 / 153 / 0 / 102	#990099
orange hawkweed	*Hieracium aurantiacum*	HIEAU	Dark Umber/Brown (756)	15 / 125 / 91	92 / 63 / 47	0 / 29 / 45 / 163	#5C3F2F
saltcedar	*Tamarix ramosissima*	TAARA	Process Red (743½)	227 / 255 / 211	212 / 0/ 134	0 / 212 / 78 / 43	#D40086
tansy ragwort	*Senecio jacobaea*	SENJA	Light Peach (757)	16 / 59 / 254	255 / 220 / 196	0 / 35 / 59 / 0	#FFDCC4
tall buttercup	*Ranunculus acris*	RANAC	Apple Green (738½)	61 / 125 / 216	167 / 217 / 110	50 / 0 / 107 / 38	#A7D96E
meadow hawkweed complex	*Hieracium pratense, H. floribumdum, H. piloselloides*	HIECA	Lemon Yellow (735 ½)	42 / 102 / 254	255 / 253 / 153	0 / 2 / 102 / 0	#FFFD99
CATEGORY III[7]							
yellow starthistle	*Centaurea solstitialis*	CENSO	Ultramarine (740)	170 / 171 / 218	72 / 72 / 220	148 / 148 / 0 / 35	#4848DC
common crupina	*Crupina vulgaris*	CJNVU	Violet (742)	196 / 255 / 208	132 / 0 / 208	76 / 208 / 0 / 47	#8400D0
rush sleletonweed	*Chondrilla junca*	CHOJU	Poppy Red (744)	8 /·255 / 254	255 / 51 / 0	0 / 204 / 255 / 0	#FF3300

[6] Category 2 noxious weeds have recently been introduced into the state or are rapidly spreading from their current infestation sites. These weeds are capable of rapid spread and invasion of lands, rendering lands unfit for beneficial uses. Management criteria include awareness and education, monitoring and containment of known infestations and eradication where possible.

[7] Category 3 noxious weeds have not been detected in the state or may be found only in small, scattered, localized infestations. Management criteria include awareness and education, early detection and immediate action to eradicate infestations. These weeds are known pests in nearby states and are capable of rapid spread and render land unfit for beneficial uses.

Most weed managers using the hand-mapping method prefer to draw weed infestation boundaries on Mylar overlays, so the topographic maps can be used repeatedly. The recommended pencils work well with both paper maps and mat acetate or Mylar overlays, and are erasable. A convenient size for overlays is 18" x 24" (45 x 60 cm). The overlay should be smaller than the topographic map so it can be taped to the map. Drafting tape should be used to avoid tearing the map. Mylar overlays should be sprayed with a map fixative to minimize pencil marking smears. Topographic maps usually have four "+" marks used to position the overlay on the map. These should be marked carefully on the overlay to position them properly on the topographic base map for digitizing.

These mapping standards and methods have been successfully applied to invasive plant survey on foot, horseback, all-terrain vehicle (ATV), and by boat, as well as aerial surveys via helicopter and fixed-wing aircraft. When using GPS with fixed-wing aerial surveys, the data dictionary must be simplified to allow the mapper to start and end line features quickly. Quick reaction time is important because of the delay problem due to higher speed of fixed-wing aircraft compared to other modes of transportation. When traveling at 80 mi/hr (128 km/hr), the true start of a line feature could be several meters ahead of the mapped feature, because of the distance traveled between sighting the infestation and pressing the appropriate keys on the GPS receiver. Line features are the easiest to map using GPS from fixed-wing aircraft. Area features are difficult, unless the areas are quite large, because the aircraft has to fly around the perimeter of the infestation. Point features are impossible, because fixed-wing aircraft cannot hover over a point.

Standards to use When Mapping Weed
Biological Control Release and Recovery Sites

Standards for mapping invasive species biological control releases and recoveries were developed by a working group of weed coordinators and scientists. Biocontrol mapping is done on USGS 1:24,000 scale topographic or orthophoto maps or mylar overlays. Symbols for designating releases and recoveries are marked using a No. 2 lead pencil as follows. The appropriate symbol is centered over the release or recovery site to designate its location: Ⓡ = biocontrol release Ⓥ = biocontrol recovery

A code used to uniquely identify the release or recovery site is written next to the symbol using the following format: *YYSSSAAA*. *YY* refers to the last two digits of a year, for example, *1997* would be coded *97*. *SSS* is a 3-digit code for site number, designated by the agency doing the release or recovery according to their own coding system. *AAA* is a 3-character code that identifies the agency or county weed district doing the release or recovery according to the codes listed in Tables 4 and 5.

This unique code is used to link the following additional information to the site: species of the biocontrol agent designated by the codes listed in Table 6, and species of the target noxious weed designated by the WSSA codes listed in Table 3. These two additional items can be written on the map or on a separate paper or form, and submitted to the statewide invasive plant mapping system along with the map.

Table 4. Three-letter agency codes.

Agency	Code
Montana Department of Natural Resources and Conservation	DNR
Montana Department of Transportation	MDT
Montana Department of Fish, Wildlife and Parks	FWP
Montana Department of Agriculture	MDA
Private agency or individual	PRI
US Department of Energy	DOE
US Army Corps of Engineers	ACE
US Department of Defense	DOD
US Department of Transportation	DOT
USDA-Agricultural Research Service	ARS
USDA-Animal and Plant Health Inspection Service (APHIS)	APH
USDA-Forest Service	UFS
USDA-National Park Service	NPS
USDA-Natural Resources Conservation Service	NRC
USDI-Bureau of Indian Affairs	BIA
USDI-Bureau of Land Management	BLM
USDI-Bureau of Reclamation	BOR
USDI-Fish and Wildlife Service	FWS

Other optional information can be collected and linked to the sites by the unique code, but may not be used by the statewide system. Examples of optional information are date of the release or recovery, number of organisms released, climatic conditions, slope, moisture, landowner, notes, and so on.

Table 5. Three-character county FIPS codes.

County	Code	County	Code	County	Code
Beaverhead	001	Granite	039	Powell	077
Big Horn	003	Hill	041	Prairie	079
Blaine	005	Jefferson	043	Ravalli	081
Broadwater	007	Judith Basin	045	Richland	083
Carbon	009	Lake	047	Roosevelt	085
Carter	011	Lewis & Clark	049	Rosebud	087
Cascade	013	Liberty	051	Sanders	089
Chouteau	015	Lincoln	053	Sheridan	091
Custer	017	McCone	055	Silver Bow	093
Daniels	019	Madison	057	Stillwater	095
Dawson	021	Meagher	059	Sweetgrass	097
Deer Lodge	023	Mineral	061	Teton	099
Fallon	025	Missoula	063	Toole	101
Fergus	027	Musselshell	065	Treasure	103
Flathead	029	Park	067	Valley	105
Gallatin	031	Petroleum	069	Wheatland	107
Garfield	033	Phillips	071	Wibaux	109
Glacier	035	Pondera	073	Yellowstone	111
Golden Valley	037	Powder River	075	Yellowstone NP	113

Table 6. Six-letter biocontrol agent codes.

Species	Code	Species	Code
Aceria centaureae	ACECE1	*Ceutorhynchus litura*	CEULI1
Aceria chordillae	ACECH1	*Chaetorellia acrolophi*	CHAAC1
Aceria malherbae	ACEMA1	*Chaetorellia australis*	CHAAU1
Agapeta zoeqana	AGAZO1	*Chamaesphecia crassiformis*	CHACR1
Agasicles hygrophilia	AGAHY1	*Chamaesphècia empiformis*	CHAEM1
Agonopterix alstroemeriana	AGOAL1	*Chamaesphecia hungarica*	CHAHU1
Agonopterix nervosa	AGONE1	*Chamaesphecia tenthrediniformis*	CHATE1
Agonopterix ulicitella	AGOUL1	*Cheilosia corydon*	CHECO1
Agrilis hyperici	AGRHY1	*Chrysolina hyperici*	CHRHY1
Altica carduorum	ALTCA1	*Chrysolina quadrigemini*	CHRQU1
Aphthona abdominalis	APHAB1	*Chrysolina varians*	CHRVA1
Aphthona chinchihi	APHCH1	*Coleophora klimeschiella*	COLKL1
Aphthona cyparissiae	APHCY1	*Coleophora parthenica*	COLPA1
Aphthona czwalinae	APHCZ1	*Cyphocleonus achates*	CYPAC1
Aphthona flava	APHFL1	*Cystiphora schmidti*	CYSSC1
Aphthona lacertosa	APHLA1	*Dasineurea sp. nr. capsulae*	DASCA1
Aphthona nigriscutis	APHNI1	*Diorhabda elongata*	DIOEL1
Aphthona ovata	APHOV1	*Eriophyes chondrellae*	ERICH1
Aphthona seriata	APHSE1	*Eteobalea intermediella*	ETEIN1
Aphthona venustula	APHVE1	*Eteobalea serratella*	ETESE1
Apion fuscirostre	APIFU1	*Eurytoma euphorbiae*	EUREU1
Aplocera plagiata	APLPL1	*Eustenopus villosus*	EUSVI1
Bagous affinis	BAGAF1	*Exapion ulicis*	EXAUL1
Bangasternus fausti	BANFA1	*Fusàrium avenaceum*	FUSAV1
Bangasternus orientalis	BANOR1	*Galerucella calmariensis*	GALCA1
Brachyperolus pulicarius	BRAPU1	*Galerucella pusilla*	GALPU1
Bruchidius villosus	BRUVI1	*Gymnetron antirrhini*	GYMAN1
Calophasia lunula	CALLU1	*Gymnetron linariae*	GYMLI1
Cassida rubiginosa	CASRU1	*Hydrellia pakistanae*	HYDPA1
Hyles euphorbiae	HYLEU1	*Pterolonche inspersa*	PTEIN1
Hylobius transversolvittatus	HYLTR1	*Puccinia carduorum*	PUCCA1
Larinus curtus	LARCU1	*Puccinia chondrillina*	PUCCH1

Species	Code	Species	Code
Larinus minutus	LARMI1	*Rhinocyllus conicus*	RHICO1
Larinus obtusus	LAROB1	*Rhizoctonia solani*	RHISO1
Larinus planus	LARPL1	*Sameodes albiguttalis*	SAMAL1
Leucoptera spartifoliella	LEUSP1	*Sclerotinia sclerotiorum*	SCLSC1
Longitarsus jacobaeae	LONJA1	*Septoria convolvuli*	SEPCO1
Mecinus janthinus	MECJA1	*Simyra dentinosa*	SIMDE1
Metzneria paucipunctella	METPA1	*Sphenoptera jugoslavica*	SPHJU1
Microlarinus larevnii	MICLA1	*Spurgia capitigena*	SPUCA1
Microlarinus lypriformis	MICLY1	*Spurgia esulae*	SPUES1
Nanophyes brevis	NANBR1	*Subanquina picridis*	SUBPI1
Nanophyes marmoratus	NANMA1	*Terellia virens*	TERVI1
Neochetina bruchi	NEOBR1	*Tetranychus lintearius*	TETLI1
Neochetina eichhorniae	NEOEI1	*Trichosirocalus horridus*	TRIHO1
Oberea erythrocephala	OBEER1	*Tyria jacobaeae*	TYRJA1
Oncochila simplex	ONCSI1	*Tyta luctuosa*	TYTLU1
Oxicesta geographica	OXIGE1	*Urophora affinis*	UROAF1
Pegohylemyia seneciella	PEGSE1	*Urophora cardui*	UROCA1
Pegomya curticornis	PEGCU1	*Urophora jaculata*	UROJA1
Pegomya euphorbiae	PEGEU1	*Urophora quadrifasciata*	UROQU1
Pelochrista medullana	PELME1	*Urophora sirunaseva*	UROSI1
Phrydiuchus spilmani	PHRSP1	*Urophora solstitialis*	UROSO1
Phrydiuchus tau	PHRTA1	*Urophora stylata*	UROST1
Prolelisia marginata	PROMA1	*Zeuxidipolis giardi*	ZEUGI1
Psylloides chalcomera	PSYCH1		

Statewide Spatial Database for Invasive Plant Management

After weed infestation data are collected according to the standards, they are prepared for addition to the statewide database, which is housed in an ArcInfo (ESRI, 2001) map library. Mapped areas are grouped by county and features are stored in the State Plane 83 coordinate system. Before being incorporated into the statewide database, each data set is organized, verified and checked for errors. Questions about the data are directed to the original mappers. Data processing includes digitizing hand-mapped data, exporting GPS-mapped data to the correct format, and converting GIS data to the correct format when necessary. Digital metadata are created for each data set from written records kept by mappers. Once these housekeeping tasks are completed, each data set is imported and incorporated into the statewide database.

When combining data from various sources into a standardized GIS database, technical issues of format, scale, accuracy, coordinate system, and data documentation must be addressed. Data captured using different methods (hand mapping, GPS mapping, and computer mapping) can be effectively integrated in a spatial database, provided these technical issues are dealt with properly.

Data Format and Mapping Methods

Three different types of features can be used to represent actual locations of objects in a spatial data format: points, lines and areas. Points are 0-dimensional features (they have no length or width) that represent locations of individual objects or events, such as wells, sample or treatment sites, individual plants, or centers of weed infestations.

Lines, or arcs, are 1-dimensional representations of linear features such as roads, waterways, or weed infestations following a linear feature. Areas, or polygons, are 2-dimensional and represent features with defined boundaries, such as lakes, soil types, or weed infestations. The invasive plant mapping standards specify when to use different feature types, depending on the infestation size. Area features are used for outlining survey boundaries. This allows calculation in the GIS of the total area surveyed for invasive plants.

In addition to collecting location data in the form of point, line or area features, information associated with those features are collected. The attribute data required by the standardized invasive plant mapping system include date survey was conducted, species, cover class, infestation size, and, for line features, buffer width (infestation width), buffer units (yards or meters) and direction from line in yards or meters. The survey area feature requires date and species surveyed. Additional attribute data such as feature ID, accuracy level, and agency performing the survey are created from metadata (data documentation) records, and are included when data are added to the statewide database.

With hand-mapping, all data are recorded on the map or on associated paper records. GPS receivers, on the other hand, act as field computers in which all data are recorded. Mapping grade GPS receivers have the ability to collect attribute data along with geographic coordinates. Less accurate recreational grade receivers can be used. However, these receivers are unable to capture attribute data, cannot be used to directly map line and area features, and data collected using these receivers cannot be differentially corrected. Differential correction removes the effects of atmospheric and other GPS errors, and involves the use of a base station operating at a known location. Several community base stations provide data to users throughout the United States.

GPS data captured with mapping grade receivers requires the use of a database or data dictionary to structure location and attribute data collection. The data dictionary used by the standardized statewide system allows for efficient collection of point, line and area features, along with their associated attribute data (Table 7). It also provides the capability to collect other point, line or area features not associated with weed infestations. The data dictionary is designed to be used with GPS receivers manufactured by Trimble Navigation, Ltd., but can be used as a pattern for structuring data collection with mapping grade receivers built by other manufacturers.

Like GPS mapping, computer mapping requires a database structure to link attribute data with point, line and area features. Attribute data can be written down in the field and then entered into the database during digitizing, scanning or on-screen drawing of weed infestations in the GIS software.

Statewide Database Structure

The statewide invasive plant inventory for Montana is maintained in ArcInfo GIS software. Currently, the data are stored in four separate databases, one for each feature type (weed point, weed line, weed area, and survey area). The data are managed, stored and updated through a sub-utility of Arc/Info called Librarian. The Arc/Info map library provides an efficient framework for storing data from several counties. In the near future,

Table 7. Weed mapping system data dictionary.

Survey Area	Area feature, if walking survey area perimeter
Date	Date, automatic generation, Year-Month-Day format
WeedsSurv	Text, 100, required, list of WSSA codes of weeds surveyed
Notes	Text, 100
Survey Point	Point feature, must collect 4 corners of survey area
Date	Date, automatic generation, Year-Month-Day format
SurvExtents	Menu, required
NE corner [NE]	
NW corner [NW]	
SE corner [SE]	
SW corner [SW]	
WeedsSurv	Text, 100, required, list of WSSA codes of weeds surveyed
Notes	Text, 100
Weed Point	Point feature
Date	Date, automatic generation, Month-Day-Year format
Species	Menu, required
leafy spurge [EPHES]	
Canada thistle [CIRAR]	
Russian knapweed [CENRE]	
spotted knapweed [CENMA]	
diffuse knapweed [CENDI]	
field bindweed [CONAR]	
whitetop/hoary cress [CADDR]	
Dalmatian toadflax [LINDA]	
St. Johnswort/goatwd [HYPPE]	
sulfur cinquefoil [PTLRC]	
dyer's woad [ISATI]	
s/purp.lythrum [LYTSA]	
v/purp.lythrum [LYTVI]	
yellow starthistle [CENSO]	
common crupina [CJNVU]	
rush skeletonweed [CHOJU]	
Other [O]	
Unknown [U]	
SizeInfest	Menu, required
< .1 acre [X]	
.1 to 1 acre [T]	
1 to 5 acres [S]	
CoverClass	Menu, required
Trace/rare [T]	
Low/occasional plts. [L]	
Moderate/scatt.plts. [M]	
High/fairly dense [H]	
Notes	Text, maximum length = 100

Table 7 (cont.), Weed mapping system data dictionary.

Weed Line	Line feature
Date	Date, automatic generation, Month-Day-Year format
Species	Menu, required
leafy spurge [EPHES]	
Canada thistle [CIRAR]	
Russian knapweed [CENRE]...rest of list is same as for weed point	
CoverClass	Menu, required
Trace/rare [T]	
Low/occasional plts. [L]	
Moderate/scatt.plts. [M]	
High/fairly dense [H]	
BufferWdth	Numeric, decimal places = 0 Minimum = 1, maximum = 999, default value = 100, required
BufferUnits	Menu, required
Meters [M]	
Yards [Y]	
DirFrmLine	Menu, required
Center [C]	
Left [L]	
Right [R]	
Notes	Text, maximum length = 100
Weed Area	Area feature
Date	Date, automatic generation, Month-Day-Year format
Species	Menu, required
leafy spurge [EPHES]	
Canada thistle [CIRAR]	
Russian knapweed [CENRE]...rest of list is same as for weed point	
CoverClass	Menu, required
Trace/rare [T]	
Low/occasional plts. [L]	
Moderate/scatt.plts. [M]	
High/fairly dense [H]	
Notes	Text, maximum length = 100
Point	Point feature, generic point feature
Descrip	Text, maximum length = 25
Notes	Text, maximum length = 100
Line	Line, generic line feature
Descrip	Text, maximum length = 25
Notes	Text, maximum length = 100
Area	Area, generic area feature
Descrip	Text, maximum length = 25
Notes	Text, maximum length = 100

the data will be moved to ArcSDE, a spatial database management system. The new State Plane coordinate system, which now has only one zone for the entire state of Montana, was chosen to match base data layers (roads, rivers, cities and towns, etc.) provided by the Natural Resource Information System (NRIS) at the Montana State Library. Table 8 lists details about the coordinate system in which the data are stored.

Table 8. Statewide weed data coordinate system and map parameters.

Coordinate System: State Plane Coordinate System (SPCS)
Datum: North American Datum of 1983 (NAD83)
Projection: Lambert Conformal Conic
Units: meters
Spheroid: GRS1980
Xshift: 0.00000
Yshift: 0.00000
Parameters:
45 0 0.000 /* 1st standard parallel
49 0 0.000 /* 2nd standard parallel
-109 30 0.000 /* central meridian
44 15 0.000 /* latitude of projection's origin
600000.00000 /* false easting (meters)
0.00000 /* false northing (meters)

Each of the four databases has a unique data file structure. Table 9 lists all the fields used in these four databases and a description of each.

Table 9. Fields in the statewide weed database.

Field Name	Contents
WEED_ID or **SURV_ID**	This field acts as a database record number.
LEVEL	This field identifies the accuracy level of the data set (either Level I, II, or III).
DATE	This field identifies the date data were collected or created, in the YYYYMMDD format (i.e. 19970217).
WDS_SURV	This field identifies the weed species surveyed within the survey area.
SOURCE	This field identifies the agency responsible for data using a 3-letter code.
SPECIES	This field identifies the weed species using the WSSA 5-letter codes.
COVERCLASS	This field identifies the infestation's cover class. Use the letters T, L, M, and H to represent Trace, Low, Moderate, and High values.
SIZEINFEST	This field identifies weed infestation size for point features. Use the letters X, T and S to represent <0 .1 acre, 0.1 to 1 acre and 1 to 5 acres, respectively.
BUFFERWDTH	This field identifies the buffer width. It contains the real-world width of weed infestations recorded as line features. Values are entered in either yards or meters.
BUFFERUNITS	This field identifies whether the buffer width was entered in yards (Y) or meters (M).
DIRFRMLINE	This field identifies the direction of the weeds from the recorded line. Use C, L, or R to identify whether the weed infestation is centered, on the left, or on the right of the mapped line.
NOTES	This field identifies any peculiarities or extra information about the infestation.

Tables 10, 11, 12 and 13 present attribute table structures for the survey area and weed point, line and area data files, along with an example record for each.

Table 10. Table structure and example record for survey area database.

Table Structure

NAME	TYPE	WIDTH	DECIMAL
SURV_ID	NUMERIC	6	0
SOURCE	CHARACTER	6	0
LEVEL	CHARACTER	10	0
DATE	CHARACTER	20	0
WDS_SURV	CHARACTER	100	0
NOTES	CHARACTER	100	0

Example record

SURV_ID	SOURCE	LEVEL	DATE	WDS_SURV	NOTES
1	BLM	II	19970217	CIRAR EPHES	N/A

Table 11. Table structure and example record for weed point database.

Table Structure

NAME	TYPE	WIDTH	DECIMAL
WEED_ID	NUMERIC	6	0
SOURCE	CHARACTER	6	0
LEVEL	CHARACTER	10	0
DATE	CHARACTER	20	0
SPECIES	CHARACTER	20	0
COVERCLASS	CHARACTER	20	0
SIZEINFEST	CHARACTER	20	0
NOTES	CHARACTER	100	0

Example record

WEED_ID	SOURCE	LEVEL	DATE	SPECIES	COVERCLASS
1	BLM	II	19970217	CIRAR	H

SIZEINFEST	NOTES
T	N/A

Table 12. Table structure and example record for weed line database.

Table Structure

NAME	TYPE	WIDTH	DECIMAL
WEED_ID	NUMERIC	6	0
SOURCE	CHARACTER	6	0
LEVEL	CHARACTER	10	0
DATE	CHARACTER	20	0
SPECIES	CHARACTER	20	0
COVERCLASS	CHARACTER	20	0
BUFFERWDTH	NUMERIC	6	0
BUFFERUNIT	CHARACTER	20	0
DIRFRMLINE	CHARACTER	20	0
NOTES	CHARACTER	100	0

Example record

WEED_ID	SOURCE	LEVEL	DATE	SPECIES	COVERCLASS	BUFFERWDTH
1	BLM	II	19970217	EPHES	L	100

BUFFERUNIT	DIRFRMLINE	NOTES
Y	C	N/A

Table 13. Table structure and example record for weed area database.

Table Structure

NAME	TYPE	WIDTH	DECIMAL
WEED_ID	NUMERIC	6	0
SOURCE	CHARACTER	6	0
LEVEL	CHARACTER	10	0
DATE	CHARACTER	20	0
SPECIES	CHARACTER	20	0
COVERCLASS	CHARACTER	20	0
NOTES	CHARACTER	100	0

Example record

WEED_ID	SOURCE	LEVEL	DATE	SPECIES	COVERCLASS	NOTES
12	BLM	II	19970217	LINDA	M	N/A

Database Maintenance Issues

Housing of a statewide invasive plant database requires a state-of-the art computer with a fast microprocessor and a substantial amount of hard drive storage. A sophisticated GIS program such as ArcInfo is required to maintain the data and produce quality output maps. One of the most important components of a successful GIS is the personnel who manage it. A GIS specialist who has been properly trained and is knowledgeable about the issues of spatial data processing and maintenance is important for its success. Technical problems continually occur, and can only be handled if the database manager is skilled in GIS methods and understands GIS mapping issues.

Submitting Data to the Statewide Database

Once invasive plant data have been collected according to the established standards, getting them into the statewide database can be a challenge. Inexperienced users of the system rarely understand the steps required. When their data reaches the database specialist, sometimes a substantial amount of work is required to prepare them for addition to the statewide system. This might be required because the standards were not followed carefully, or because the user did not understand how to prepare the collected data for submission. In any case, a metadata form (described below) is invaluable for identifying and solving submission problems. The steps that must be performed by users and database managers are outlined below.

Steps For Users. For the data to be successfully incorporated into the statewide database, users must insure that statewide standards have been followed exactly as described. For hand mapped data, the steps are

- Follow all recommendations regarding base maps, drawing instruments, symbols, codes and colors, indicating the survey area boundary, recording the survey date, using mylar overlays (mark the four internal tics, spray mylar with workable map fixative), etc.
- Roll materials in a map tube (do not fold) for mailing
- Fill out completely and submit a metadata form for each dataset

For GPS mapped data the steps are

1. Follow all recommendations regarding GPS mapping including using the appropriate data dictionary
2. Differentially correct your data (uncorrected data will not be accepted)
3. Clean up data before submitting
    a. delete unnecessary features or features collected by mistake
    b. edit lines and polygons to remove crossing lines or inaccurate vertices caused by multipath, obstructions or other errors
    c. fix incorrectly closed polygons
4. Make a backup of data in its corrected form for your own records
5. Fill out completely and submit a metadata form for each dataset
6. Submit all required data files on the requested medium (floppy disk, E-mail attachment, FTP file transfer)

For computer mapped data the steps are

1. Follow all recommendations regarding computer mapping including using the appropriate database structure
2. Clean up data before submitting
    a. delete unnecessary features or features created by mistake
    b. edit lines and polygons if necessary
    c. check to make sure attribute data are entered accurately and completely
3. Make a backup of data in its corrected form for your own records
4. Fill out completely and submit a metadata form for each dataset (make sure the metadata form includes the coordinate system and projection of the data, and the date the survey was done)
5. Submit all required data files on the requested medium (floppy disk, E-mail attachment, FTP file transfer)

Steps for Database Managers. Several tasks must be accomplished before data can be successfully added to the statewide database. They are

1. Review submitted materials and inventory datasets
2. Check data for errors
3. Clear up any problems with the data originator
4. Data processing
    a. Hand mapped data
        i. Digitize topographic maps or mylar overlays
        ii. Enter attribute data

iii. Complete any data editing/cleanup required (for example, changes to the format of the attributes may occur if data are collected for polygons that are <5 acres in size)

b. GPS mapped data

i. Convert to proper coordinate system if necessary

ii. Convert to proper GIS format

iii. Complete any data editing/cleanup required

iv. If user submits point data collected with recreational grade receivers, create point features and enter attribute data

c. Computer mapped data

i. Convert to proper coordinate system if necessary

ii. Convert to proper GIS format

iii. Complete any data editing/cleanup required

5. Create metadata for each dataset

6. Import into ArcInfo map library

Database Access

A web-based data retrieval application has been developed. Users can query the database to calculate county or statewide acreage estimates and produce quality output maps. This interactive map server application allows users to zoom in and out to view invasive plant infestations in different areas of the state or project area. To protect private landowner privacy, the data they submit are included in acreage estimates, but general users are not able to view maps of weed infestations on private land.

Map Scale and Accuracy

The scale of a map is the ratio between a distance on the map and the corresponding distance on the earth. Hand-mapped data are captured at the scale of the base map used to record the data. The 7.5 minute series USGS topographic maps used for the standardized mapping system are at a scale of 1:24,000. GPS data are captured at a scale of 1:1, because the mapper is physically visiting the real-world locations of mapped data. In a GIS, it is possible to combine data captured at different scales. However, it must be understood that the scale at which data are originally captured strongly influences their level of accuracy. For example, GPS mapped and hand mapped data can be overlaid in a GIS database and displayed on the same output map at any scale, yet their original scales and accuracy do not change. The GPS data are more accurate and detailed than the hand-mapped data, regardless of the scale at which they are displayed. Information about the original scale of the data must be documented, so erroneous assumptions are not made.

Scale is not the only determinant of accuracy. Various data capturing methods have their own inherent considerations that affect accuracy. For hand mapped data, the width of the drawing instrument affects the accuracy of features recorded. For example, if one draws a 1 cm line identifying an unmarked dirt road on a 1:24,000 scale map, the location is somewhere within 24,000 cm (240 m) in real life. If the line (more realistically) is only 1 mm wide, then it is still only accurate to within 24 meters of the road's real location. This is before taking into account the human error involved in determining the road's location on the map, and drawing it accurately. In this case, the map scale, drawing instrument, and human error all affect accuracy of the data collected. GPS data are captured at a scale of 1:1, but any GPS position will be accurate to within 1-5 meters of the true location, provided a mapping grade GPS receiver is used and the data are differentially corrected. Uncorrected data are accurate to roughly 10 meters in most cases.

When data are captured by hand mapping, quality of the base map can influence accuracy. Topographic or orthophotographic base maps are recommended. Both are geodetically correct, and therefore accurately represent true locations on the earth. Data associated with these maps can be accurately displayed in a GIS. Many mappers, however, prefer to use photocopies or enlargements of topographic or orthophoto quadrangle maps. Both processes introduce distortion. Others prefer to use aerial photographs on which to draw weed infestations. Aerial photos are inherently distorted because of the particular configuration of platform altitude, camera system alignment, and topography. If non-corrected base map sources are used, the data must be transferred to geodetically correct topographic or orthophoto maps before being digitized and entered into a GIS. If data are captured using on-screen digitizing in a GIS, the digital base map must be geodetically correct. Digital raster graphics (DRGs) and digital orthophoto quadrangles (DOQs) are now available for most of the U.S. and can be used effectively for this purpose.

Two different types of accuracy must be determined and reported with weed survey data (Table 14). The first is attribute accuracy, which has to do with how closely the values assigned to attributes (i.e. species, cover class, infestation size) match their true values. Attribute accuracies are often estimated as percentages. The second is horizontal positional accuracy, which has to do with how close the recorded locations are to their actual positions on the earth. These values are usually in linear units, such as feet or meters. Detailed instructions and examples for determining accuracy levels are given in the weed mapping handbook (Roberts et al., 1999).

Table 14. Accuracy levels for noxious weed survey.

Accuracy Level	**What determines accuracy level**
Level I (high level accuracy and detail)	○ intensive mapping techniques were used ○ survey methods often based on grid patterns ○ attribute accuracy = 80 - 100%, horizontal postional accuracy = 0 - 20 m
Level II (moderate level accuracy and detail)	○ less intensive mapping techniques were used ○ general in-the-field scanning for infestations ○ attribute accuracy = 60 - 80%, horizontal postional accuracy = 20 - 100 m
Level III (low level accuracy and detail)	○ reconnaissance mapping techniques were used ○ utilized existing information (interviews) ○ aerial inventory methods (aerial photographs) ○ "windshield surveys" ○ attribute accuracy < 60%, horizontal postional accuracy > 100+ m

Coordinate Systems

A coordinate system is a two- or three-dimensional reference frame that locates objects in space. All mapped positions are described in some coordinate system. The most common coordinate systems used for mapping invasive plant infestations include geographic (latitude/longitude), Universal Transverse Mercator (UTM), State Plane 27 and State Plane 83. Each has an associated map projection, geodetic datum, one or more standard parallels, a central meridian, and possible shifts in the x and y directions. Before data from various sources can be combined in a GIS database, they must be converted to the same coordinate system. It is possible to add data in different coordinate systems to a single GIS project, however, they will not display properly when there is a coordinate system mismatch. The mismatched data set might seem to disappear altogether because of its widely different coordinate values.

For hand mapped data, the coordinate system is determined by the base map used. Most 1:24,000 USGS topographic maps in the Western United States use the UTM coordinate system with a Lambert Conformal Conic projection and are based on the North American Datum of 1927 (NAD 27). When hand mapped data are digitized, these parameters are associated with the resulting data file. If these data are to be incorporated into an existing statewide database, they first must be converted to the proper format. Our database uses the State Plane coordinate system based on the North American Datum of 1983 (NAD 83) with a Lambert Conformal Conic projection. GPS mapped data are based on the geographic (latitude/longitude) coordinate system and the World Geodetic System of 1984 (WGS 84) datum by default. They can usually be converted to any other coordinate system for addition to existing databases. Parameters for data captured via on-screen digitizing in a GIS are determined by the base map used. For example, in Montana, available DOQs and DRGs are based on either UTM NAD 27, UTM NAD 83 or State

Plane NAD 83 coordinate systems. UTM data must be converted to State Plane 83 before addition to Montana's database.

Data Documentation

Metadata are "data about data," or data documentation. They include information such as who collected the data, when and how were they collected, how accurate they are, what editing or processing was done to the data. Without metadata, the source, accuracy and collection methods of a dataset are unknown. The standardized weed mapping system was devised to eliminate unknowns and create a comprehensive, accurate statewide database. When you know information about how data were collected, stored and transformed, you gain access to that data. It becomes information that you can understand and trust. The metadata each user provides is compiled into a larger document that describes the entire statewide database.

In addition to the standard metadata the invasive plant mapping system requires, users are also encouraged to record in the field anything unusual about the files or the data collection session. Documentation of problems or mistakes enables efficient correction during data processing.

The Federal Geographic Data Committee (FGDC) has developed a national content standard for all digital geospatial data (Federal Geographic Data Committee, 1994). The standard provides a common set of terminology and definitions for the documentation of digital geospatial data. According to the FGDC, the major uses of metadata are:

1. To maintain an organization's internal investment in geospatial data. Metadata allow an organization to keep track of the accuracy and quality of its data so that it can continue to be of value.
2. To provide information about an organization's data holdings to data catalogues, clearinghouses, and brokerages. Data can be trusted and shared if there is information explaining how it was collected, what flaws may exist, who to contact for more information, and so on.
3. To provide information needed to process and interpret data to be received through a transfer from an external source. There are many different GIS software packages and, consequently, different formats for storing geospatial data. When full metadata are available, it makes importing and using spatial data in different systems much easier. It reduces frustrating unknowns and increases the organization's ability to share data and utilize those data effectively.

Metadata play four major roles in providing information about geospatial data. These are

1. Availability: Metadata provide information about what geographic data are available for a particular area.
2. Fitness for use: Metadata provide information needed to determine if a set of geospatial data meets a specific need.
3. Access: Metadata provide information needed to acquire an identified set of geospatial data.
4. Transfer: Metadata provide the information to process and use a set of data.

Metadata for the standardized invasive plant mapping system should meet FGDC standards. This will help ensure that data in the system are well-documented, of high quality, and able to be shared with other groups or individuals. A portion of the metadata is prepared by database managers as they develop the geographic database. However, the overall quality of the invasive plant data and metadata is dependent on documentation by people who collect the data. Data collectors are required to provide a metadata form for each dataset submitted to the statewide database to insure quality (Appendix E).

Generalized (section-based) Statewide Maps

To compile a complete statewide view of invasive species status in a relatively short time frame, we developed a smaller scale (less detailed) statewide weed database for five noxious weed species[1] considered to be priority weeds in Montana. We created five maps for each county, showing public land survey section (1 sq. mi.) boundaries and features such as roads and waterways for reference. The maps were sent to county weed coordinators, who worked with federal and state agency personnel to collect the data. For each of the five weeds, coordinators reported a value of present, absent, or unknown for each section in the county. Collecting and compiling the data took about 1.5 years. In contrast to mapping using the detailed standards, completing this process required no previous training of weed managers.

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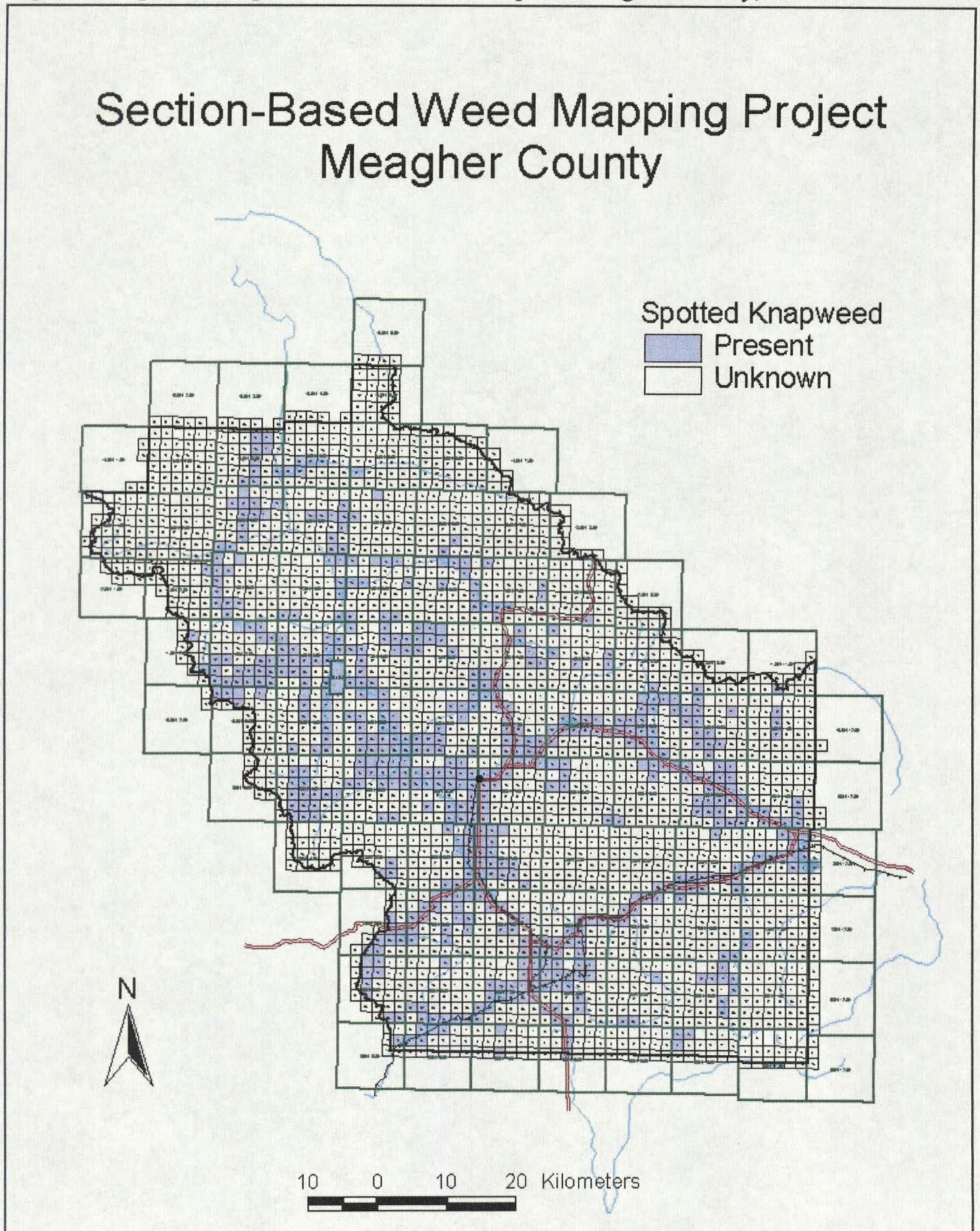
[1] Leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea maculosa)*, Russian knapweed (*Acroptilon repens*), sulfur cinquefoil (*Potentilla recta*) and Dalmatian toadflax (*Linaria dalmatica*).

The end products were complete, county-based maps (Figure 10) showing the status of each weed in each section for the entire State. It was not possible to generate exact acreage estimates from these data, but acreage ranges were calculated. For example, most public land survey sections are 640 acres (256 hectares) in size. A section could be marked "present" for an invasive species regardless of whether the infestation covered only a small portion of the section, or the entire section. Therefore, sections marked present were considered to contain anywhere from 64 to 640 acres (25.6 to 256 hectares) of the species in question. The total possible infested area for each species was determined from the GIS by calculating the total area of all sections marked "positive." This was designated as the maximum value for the range. The minimum value was determined to be 1/10th of the maximum value. For example, the total infested area of spotted knapweed (*Centaurea maculosa*) in the state of Montana is between 1,952,569 and 19,525,686 acres (781,027 to 7,810,274 hectares).

Additional maps will be prepared for the remainder of invasive species on Montana's noxious weeds list. These section-based weed maps provide general infestation and spread information, and are used in developing a priority strategy for the statewide weed management plan (Montana Weed Summit Steering Committee and Weed Management Task Force, 2001).

Figure 10. Spotted knapweed section-based map for Meagher County, Montana.



Case Studies

The invasive plant mapping system has given land managers a tool that can be used to enhance the effectiveness of weed management programs. GIS data can be used to help managers set priorities and plan management strategies. Accurate information on the extent and severity of noxious weed problems can be used for public education, to assess the economic impacts of weed invasion, and to acquire funding for management programs. Research uses of invasive plant maps include modeling invasive plant spread, predicting areas potentially subject to weed invasion, and validating alternative methods for mapping invasive plants. We present two examples of how invasive plant managers are using the standardized mapping system to develop, implement and evaluate weed management plans.

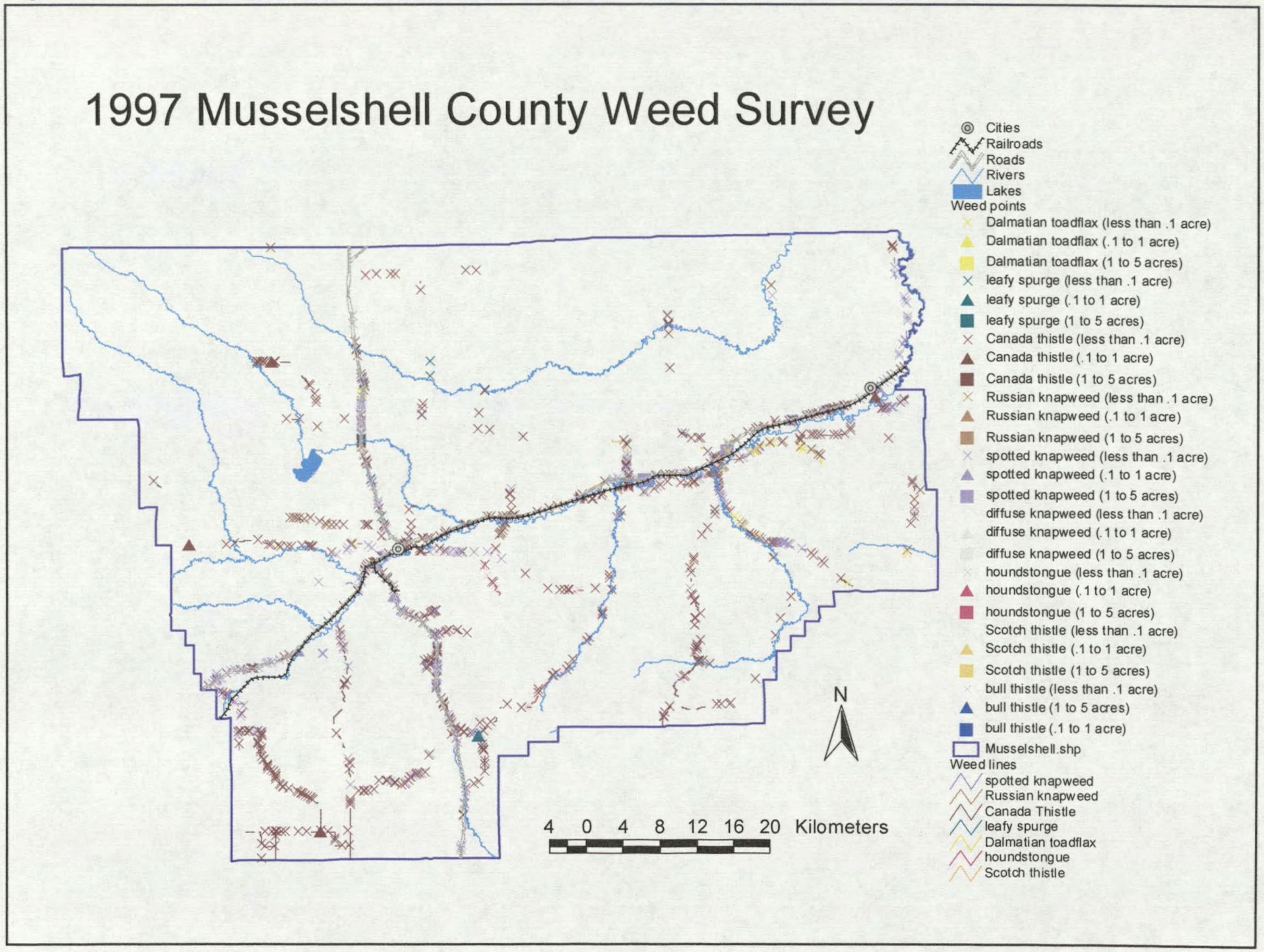
Musselshell County Noxious Weed Survey

John Pfister, Extension agent and weed coordinator for Musselshell and Golden Valley Counties in Montana, used the standardized invasive plant mapping system to complete a road right-of-way survey of noxious weeds in 1997 and 1998 (J. Pfister, personal communication, 2002). Before the mapping project was initiated, Musselshell and Golden Valley Counties did not have an accurate inventory of invasive plant species. This lack of information made it difficult to estimate and monitor spraying contractor charges. The Musselshell County project was implemented with grant support from the Montana Noxious Weed Trust Fund, which covered a training workshop for twelve participants, two GPS receivers, GPS and GIS software, and summer wages for two mappers.

The mappers traveled together on four-wheeled vehicles, each mapping one side of the road using a GPS receiver containing the invasive plant mapping system data dictionary. They collected point, line and area features for eight noxious weed species: Canada thistle (*Cirsium arvense*), Scotch thistle (*Onopordum acanthium*), bull thistle (*Cirsium lanceolatum*), leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea maculosa*), Russian knapweed (*Centaurea repens*), Dalmatian toadflax (*Linaria dalmatica*), and sulfur cinquefoil (*Potentilla recta*). Approximately 1.5 months were required for each county to map and process invasive plant data for all road rights-of-way. In Musselshell County, approximately 1,000 shoulder miles of road were mapped. Normally, it is difficult to map more than five species at once, especially in areas where invasive plant infestations are heavy. In this area of eastern Montana the weed infestations are intermittent, making it possible to map all eight species in one pass.

Survey Results and Management Decisions. GPS data collected during the survey were exported to ArcView GIS software and final maps were produced on a large-format plotter. Figure 11 shows a reduced version of the map. When viewing maps in a GIS, attributes for infestations are available by clicking on the features. Data for both counties were submitted to the statewide invasive plant mapping system. One of the major uses for the invasive plant data is to bid out spray work at road construction sites.

Figure 11. Musselshell County noxious weed survey.



The most dramatic outcome of the invasive plant survey was identification of the relationship between weed density and location with respect to roads, rivers and an old railroad. Project maps clearly showed that weed density decreases with distance from these features. Maps were used to educate landowners about invasive plant dispersal and spread. The information also caused the County to change its management practices regarding chemical control of noxious weeds. More "blanket" spraying is now done within the first mile of rivers and roads, whereas spot spraying is done in areas further away from the road and river corridors.

Project data revealed that 80% of the noxious weed problem in Musselshell County was caused by Canada thistle. This was contrary to the perception of weed managers that leafy spurge and spotted knapweed were the main weed problems in the County. This knowledge caused the County to change the nozzle configuration and type of chemicals carried on the weed control truck, allowing them to develop more efficient spraying operations.

It was found that the northern 25% of Musselshell County had significantly fewer invasive plants than the rest of the County. The County Weed Board decided that it was more efficient for the weed coordinator to spray those areas, rather than having the contractor spend valuable time driving lightly infested roads where limited spraying is required. This way, financial resources are maximized in more heavily infested areas, while still reducing the density of weeds in the northern part of the County.

Two invasive plant species that had not previously been reported in the County were detected by the survey: Russian knapweed (two sites) and sulfur cinquefoil (one site). Early detection enabled successful eradication of these two species.

Management of whitetop (*Cardaria draba*) infestations was improved as a result of the survey. Early spring mapping efforts showed that whitetop appears at least two weeks earlier than the other invasive species, and should be targeted separately. Proper timing of control measures has increased their effectiveness in reducing whitetop infestations.

In 1999, a separate noxious weed mapping project helped to settle a conflict between landowners and a federal agency. Landowners believed that invasive plants were spreading from a canal to a river. Maps of the canal inlet and outlet showed that the theory was unfounded, and were instrumental in settling the dispute.

The invasive plant survey prompted discussions among County Weed Board members on how to prioritize areas with light infestations: control these areas first with the aim of eradication, or last assuming that less serious infestations can wait to be controlled?

Now that the initial invasive plant survey has been completed, new sightings reported by weed sprayers and others are mapped individually using GPS technology and added to the County spatial database. The County weed coordinator would ideally like to map the entire County every five years, but this is not possible because of time constraints and limited financial resources. The spray contractor is working with engineers to develop a system to map as he sprays. The attribute data he is able to collect will be limited compared to data collected using the standardized invasive plant mapping system, but will still be valuable. Cover class and infestation size, both important for planning future spray operations, will not be included.

Economic Impacts of Invasive Plant Infestations. Data and maps the project generated allowed the county weed coordinator to calculate acres infested, amount of chemical needed, and control costs for various weed management areas in the County. For example, a highway department gravel pit that was seriously infested with spotted knapweed was contributing to its spread throughout the County. The highway department was storing gravel at the site, and hauling it out for road work, thereby spreading weed seed and plant parts. The spray contractor could not cover the area because the site was inaccessible by the spray truck. Funds were needed to control the infestations using a 4-wheeled vehicle and backpack spray equipment. The site was mapped and photographs were taken of knapweed infestations. Control costs were calculated based on infestation sizes and equipment required. The maps and photographs were included in a proposal submitted to the highway department, and were instrumental in illustrating the severity of the problem. Funds were subsequently awarded and the area was "cleaned up." Continued monitoring will help to ensure the success of future control efforts at this site.

The weed coordinator believes he has saved a substantial amount of money by prioritizing management activities based on invasive plant survey data. The best example of this is that control costs were reduced substantially in the northern part of the county by having the weed coordinator rather than the spray contractor perform control work there.

In addition, weed maps have been used to obtain grant funds for weed control projects from the Montana Noxious Weed Trust Fund. The maps show landowner property boundaries and invasive plant infestations. The GIS database allows calculation of infested acres and control costs to be requested from the funding agency. The goal for these projects is use the 50:50 cost share match provided by Trust Fund grants to reduce weed populations enough over four years that the 50% landowner match can cover the cost of continuing the project. The maps also help landowners plan control strategies and decide whether to spray two times per year, or spray twice as much land one time per year. Weed maps and acreage data have helped producers receive over $100,000 in cost share funding.

Public Awareness and Education. Invasive plant maps proved to be the most valuable products generated by the mapping project. It is difficult to explain the specifics of invasive plant problems in words, whereas pictures can communicate much more clearly. The maps were invaluable for describing the negative impacts of invasive plant infestations, and convincing people of the need for their management. For example, maps of the entire County were used to show landowners in the less infested Northern part of the County how fortunate they are. This allowed the group to develop a pro-active approach to managing invasive plants rather then trying to eradicate them once they are firmly established. The maps were included in newsletters alerting landowners to local problems, and in environmental assessments required for grant funding and other purposes.

Increased Cooperation. The County weed coordinator provides mapping training and technical support to coordinators in neighboring counties, and has used his expertise to gain funding and facilitate mapping of five different weed districts. Communication with maps has encouraged producers to work together in addressing invasive plant problems. The GPS equipment purchased for the County road right-of-way survey was shared with the county road crew to map culverts, cattle guards and signs. Additional features mapped by cooperating entities were a county walking path, a new sewer lagoon, additional noxious weeds in special weed management areas, and private landowner weed infestations. The weed coordinator has also helped other agencies such as the Federal Aviation Administration (FAA), BLM, Department of State Lands, the County Sheriff, and the local elementary school with some rather unique mapping projects that benefit the agencies and local citizens.

Problems/Challenges. The greatest challenges encountered in the Musselshell/Golden Valley Counties invasive plant mapping program are associated with data management. Large volumes of data and several different types of files are generated and need to be organized and documented. Different maps are created for different purposes, and their digital files must be stored in a way that can be easily understood for future retrieval and maintenance. Backups of data in GPS format are kept, as well as backups of the GIS files. Records on any editing done to the data need to be created and maintained. Sometimes it is more efficient to combine or merge certain data layers, and sometimes it makes sense to separate them. Keeping all of the spatial data files, attribute data files, output products and metadata documentation organized can be a daunting task.

Updating the spatial and attribute databases requires another level of organization. Incorporating updated and new features into the database is an ongoing task that must be done carefully. Fortunately, new technologies that make data update easier have emerged, but proper training and organization are still necessary to accomplish this successfully.

Another challenge is finding the funds to purchase and maintain expensive equipment and software, and train people to use it effectively. Most producers are unable or unwilling to spend thousands of dollars on mapping grade GPS equipment and software. They are willing, however, to purchase less expensive recreational grade GPS receivers which can provide location data, but are not designed for GIS mapping. Also, unless a real-time differential correction system is attached to or incorporated within a recreational grade receiver, accuracy of the location coordinates is limited to about 15 meters, whereas mapping grade GPS receivers are capable of one to five meter accuracy after differential correction. In response to the demand, systems are now being developed to allow limited mapping capability with recreational grade GPS receivers.

Keeping up with changing technology is perhaps the biggest challenge, as rapidly improving equipment and software continually emerge. Investing the time in staying up-to-date is important to making this type of program work.

Charles M. Russell Wildlife Refuge

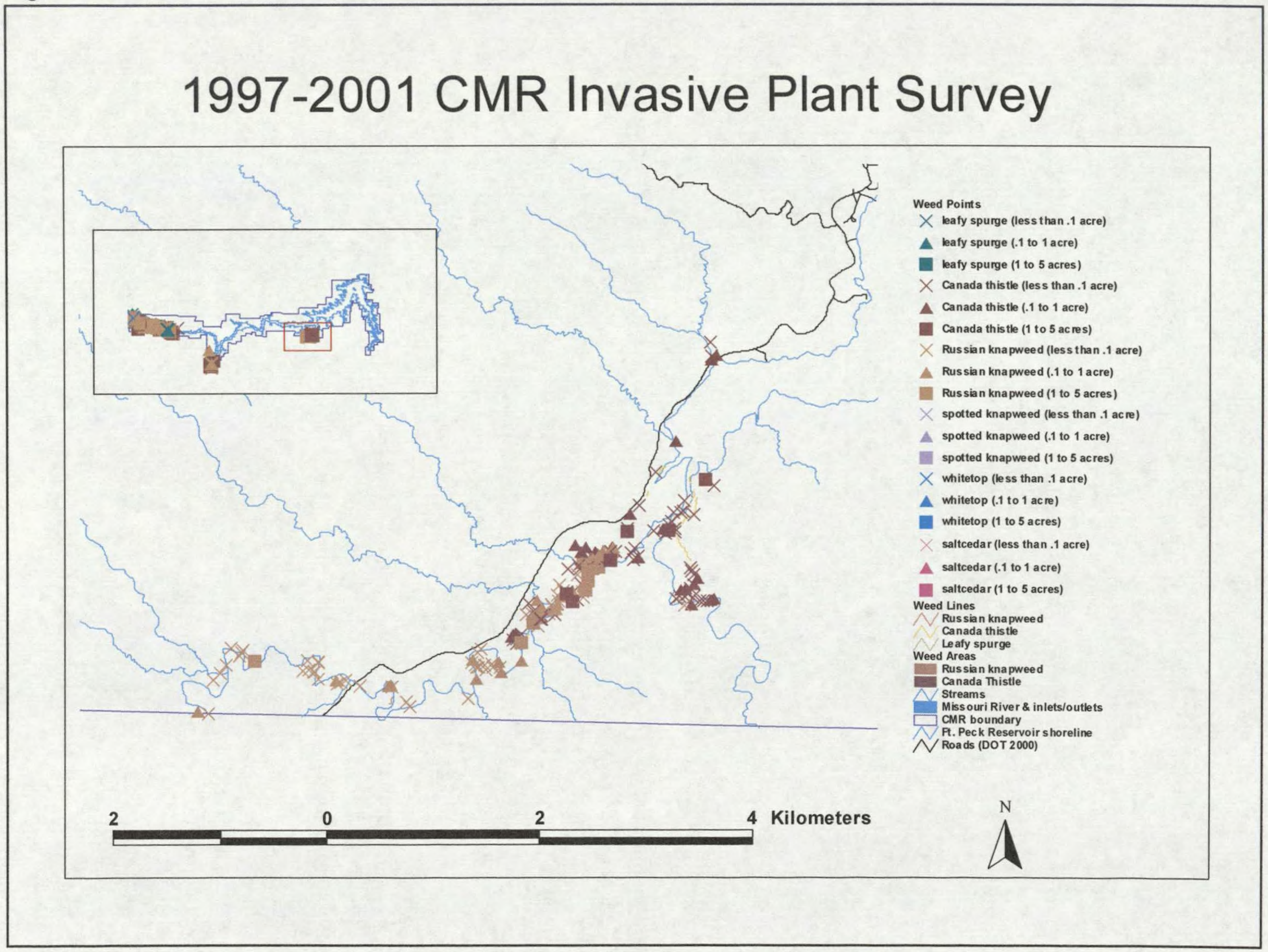
Steve Henry, ecologist and GIS specialist with the Charles M. Russell Wildlife Refuge in Northeastern Montana, conducted a coordinated mapping effort to delineate invasive plant populations and determine acres of invasive species present on the Refuge (S. Henry, personal communication, 2002). The mapping program was initiated in 1997 as the first step in an effort to develop a scientifically-based integrated pest management (IPM) plan. The refuge already had a well-developed GIS system and GPS equipment, but they lacked a scientifically valid invasive plant inventory. In addition, the refuge was under increasing pressure from surrounding counties and landowners to "get its weed problem under control." Quality baseline data were needed to determine the extent and distribution of noxious weed infestations on the refuge so management planning could begin. The statewide invasive plant mapping system provided logical and easy to use standards, and the resulting data were easily integrated into their existing GIS.

In order to accomplish the enormous task of mapping presence and absence of invasive species on 1.1 million acres of land, it was necessary to determine which areas should be mapped first. The staff biologist, managers, and technical personnel established priority areas based on threat, importance as wildlife habitat and concerns of neighbors. Three areas were selected: river bottoms in the Western end of the Refuge, the Musselshell River to its mouth, and the major drainages that flow into the Missouri River in South Phillips County. Russian knapweed, Canada thistle, leafy spurge, spotted knapweed and whitetop were mapped by teams of two people, with a "spotter" searching for and marking weed infestations, and a mapper following with GPS equipment. The drainages in South Phillips County were mapped from the air in cooperation with the Phillips County weed coordinator, using funds provided by the Montana Department of Agriculture. The mapping project spanned four years and involved about 19 staff members. In all, about 1200 hours were spent in the field, and about 120 hours in the office processing the data. Approximately 150 GPS files and 350 GIS coverages were generated, and a total of about 2500 features were mapped. Most of the infestations were small, less than 1 acre in size. Figure 12 shows the entire Refuge (inset) and a portion of the mapped area.

Survey Results and Management Decisions. Now that the baseline inventory has been completed, Refuge personnel are working on developing an IPM plan that will move them away from relying on chemicals as a sole means of invasive plant control, and toward a more effective integrated approach with fewer negative environmental consequences. Control options being investigated include chemical, mechanical, and biological methods, and establishment of resistant native and non-native plant communities. A major goal is to not only control invasive plants, but keep them from reappearing. Several research projects have been initiated to address specific invasive plant problems on the Refuge.

Spotted knapweed is the most prolific invasive plant species in river bottoms on the Western end of the Refuge. The most effective timing and application rate of herbicides have been determined, and re-seeding trials have begun. Once the results are in, refuge managers will have the tools needed to combat this tenacious invasive plant.

Figure 12. Charles M. Russell Wildlife Refuge invasive plant survey.



Another serious problem is tamarisk (*Tamarix spp.*) around the Fort Peck Reservoir. Tamarisk occurs on nearly 1600 miles of shoreline, and access to the lakeshore is possible only by boat, which precludes the use of heavy equipment. Also, spraying from the air is prohibited next to the water. Pilot work began last summer on a control project which involves cutting the tamarisk plants down and painting their stems with a herbicide, a time-consuming process, but one of the few options available.

Refuge managers have been using biological control methods for over a decade, and have had good success with leafy spurge beetles, which have virtually eliminated spurge on the Western end of the Refuge. An attempt to use nematodes to control Russian knapweed was not as successful. Current research projects include work with the Agricultural Research Service (ARS) on a mite for controlling field bindweed.

Public use restrictions have been put in place to stop the spread of invasive plant seeds. These include requiring vehicles to stay on roads, and requiring the use of weed seed free hay when packing stock on the Refuge. Spray work along high traffic roads is contracted with county weed control crews, and the Army Corps of Engineers (ACE) is doing control work in some areas.

Not only do the data collected from the invasive plant survey serve as a foundation for a long-range management plan, they also provide a baseline for monitoring. A stratified re-sampling will be done every three to five years to assess the effectiveness of control methods and determine whether infestations are decreasing or spreading. All data collected are available in the refuge GIS for advanced analysis and to complement other data layers.

Economic Impacts of Invasive Plant Infestations. The invasive plant mapping project has focused control efforts on targeted priority areas, and has helped to make them more effective, resulting in reduced control costs. In addition, the mapping project has stimulated interest in invasive plant management on the Refuge from outside sources, and has brought in both state and federal research funding. Also, with accurate invasive plant infestation data, the Refuge is in a good position to lobby for funding to develop a comprehensive management plan.

Increased Cooperation. Maps generated by the Refuge's invasive plant GIS are used in meetings with county weed board members and local officials. The maps have also helped to generate good public relations with neighboring landowners. Before the mapping project was initiated, a common perception among landowners was that weeds were spreading from the Refuge onto their land. Refuge managers, on the other hand, saw the Refuge as a sink rather than a source of invasive plant propagules, because several waterways flow into the Refuge. However, they lacked good information to counteract the landowners' claim. Project maps clearly illustrated a pattern of knapweed distribution sweeping into the Refuge along a river. When Refuge managers sat down with neighbors to look at the picture created by the maps, they were convinced. Now they understand that the Refuge is seriously making an effort to manage its invasive plants, and the atmosphere is cooperative rather than combative. As a result, the Refuge worked collaboratively with a local landowner and the Garfield County weed district to address a

Russian knapweed infestation along Hell Creek. After two seasons of treatment, the infestation was nearly eradicated.

The project has also initiated partnerships with surrounding counties and universities. Weed managers in Petroleum County were provided with training and given help with invasive plant mapping. Research projects with Montana universities have been undertaken.

Problems/Challenges. One difficulty encountered during the mapping process was determining the edge of an infestation, which in turn delineates the perimeter of the polygon being mapped. These edges are inherently fuzzy. Because some mappers tend to lump separate infestations into one, and others tend to split large infestations into separate parts, it is important to standardize as much as possible at the beginning of the survey. This can be done using example infestations during initial training to ensure consistency. A minimum level of variability in the data is acceptable for management purposes.

Another challenge in following the invasive plant mapping standards relates to infestation size. The standards map infestations greater than five acres as polygons, and infestations less than five acres as points. With irregularly shaped areas and fuzzy edges, it is sometimes hard to tell how large they are, especially when invasive species are mixed with other vegetation. As a result, several mapped polygons turned out to be less than five acres in size. These can, however, be converted to point features in the GIS to comply with the invasive plant mapping standards.

Aerial mapping using fixed wing aircraft or helicopters turned out to be difficult for some species, especially when mapping several species at once. In many cases plants were detected on the ground that would have been impossible to see from the air. Aerial mapping must be timed properly, usually when the plant is flowering, to be effective. Russian knapweed can be mapped from the air in the fall when it turns a rusty brown color and contrasts with tan colored grasses.

At the time the mapping was done, tamarisk was not included in the data dictionary used for the invasive plant mapping system. However, the system is flexible enough to be adaptable to local needs, and the data dictionary can be easily modified. Because tamarisk was important locally, it should have been added to the data dictionary and mapped.

With three or four crews mapping at the same time, GPS data file management became an issue. Because the receivers automatically create a file name based on date and time, it is important to assign a unique filename prefix to each receiver. Also, files collected on the same date in subsequent years must be stored in a separate folder on the computer, to avoid overwriting files from previous years.

Mr. Henry and others have suggested an on-line data entry system to make it easier for users to add data to the Statewide invasive plant database. Allowing users to update the database through an Internet web site interface would streamline the data submission process and encourage users to submit their data.

Summary and Conclusions

This invasive plant mapping system has been effectively used to determine and record locations of noxious weeds on private and public lands, and produce useful information for local and statewide invasive plant management. It has also served as a medium for cooperation among local, state and federal agencies, and private individuals involved in weed management. Standardized data collection procedures have made it possible to establish a statewide database that accepts data from many different sources (local, state and federal agencies, as well as private individuals) in various formats (hand-mapped, GPS-mapped and GIS-mapped). The success of this system has been largely due to its simplicity. Only the most important data attributes are required, limiting field time needed to build a useful database. However, the system is flexible enough that additional attributes can be added if desired to address unique local requirements.

Storing the statewide data in a GIS allows accurate calculations of infested acres in defined management areas, which, in turn, allows calculation of economic impacts and management costs. The defined limits can be a 500 acre ranch, a national forest, a county, an entire state or any area specified for the purpose of assessing the impact of noxious weeds and determining appropriate management strategies. For areas that have been mapped periodically, the GIS format also allows comparison of weed inventories over time. This information can be used to determine how fast noxious weeds are spreading, and to assess the success of weed management strategies. To date, analysis has been done at the local level, as Montana does not yet have a complete statewide invasive plant database. Once a complete statewide database is achieved, noxious weed acreage and economic impact calculations will be possible for the entire State. We expect that this kind of documentation will be invaluable in planning and funding noxious weed management programs.

We have demonstrated that new technologies such as GPS and GIS can be effectively used to map and manage invasive plant infestation data, and to generate products that enhance public education and awareness. In many cases, GPS receivers have increased the ability of weed mappers to collect accurate data, easily and quickly. In other situations, hand- or GIS-mapping methods have proven to be more appropriate and/or cost-effective. The GIS framework allows for effective compilation, storage and analysis of invasive plant data, and communication of survey results. GIS can also manage the spatial aspects of modeling invasive plant dynamics and spread. Accurate model predictions could be used to prioritize management strategies that optimize resource use.

Development and use of standardized mapping protocols facilitates the building of partnerships and cooperation across disciplines and agencies. Invasive plant inventories have stimulated management and research partnerships, and increased cooperation among landowners, county weed districts, and state and federal agencies. Chapter 2 addresses the process of developing cooperative relationships to ensure successful implementation of the statewide invasive plant mapping system.

As the importance of invasive plant mapping becomes clear, many states are beginning to develop coordinated mapping efforts. Most of these are adopting or basing their programs on the Montana system. In 1998, the BLM adopted the Montana invasive plant mapping standards nationwide (H. McNeel, personal communication, 2001). We continually receive inquiries from organizations around the globe about the system and its products. In addition, we have provided the impetus for development of standards for reporting and sharing invasive plant data.

In contrast to our standardized methods for invasive plant survey and mapping intended to generate data for a region-wide spatial database, the North American Weed Management Association (NAWMA) has developed standards for reporting and sharing noxious weed survey data among agencies (NAWMA, 2001). The NAWMA standards specify what information should be gathered by people mapping invasive plant infestations, rather than defining exactly how to map points, lines and areas representing invasive plant infestations. Further, the NAWMA database is tabular in format, and is not intended to create a single spatial database for a county, state or defined management area. Invasive plant infestation data and associated metadata collected according to the Montana standardized survey and mapping system together contain most of the information required by the NAWMA standards. However, reformatting is required for entry into a NAWMA tabular database. Maps can be created from point locations in a NAWMA tabular database, but a spatial database structure is not included in the NAWMA standards. Both sets of standards increase the ability to share information and can be applied at local, state, regional, national or international scales.

As more land managers participate in the effort to map invasive species using standardized methods and new technologies, a greater portion of infested lands will be accurately mapped. The ultimate goal for each defined management area is a complete inventory of all invasive plants. An accurate and complete inventory provides information that can greatly enhance management programs. It can also be used for modeling endeavors that could contribute to an understanding of invasion biology and risk assessment. Verification of weed maps generated through remote sensing and other techniques can be accomplished using these data.

An interface for populating the invasive plant database through on-line data entry should be developed, to make the data submission process easier for users and to encourage users to submit their data. The update system would have to incorporate user identification, error checking, and other processes yet to be defined.

This system has provided a format for accurate and consistent collection, communication and analysis of invasive plant infestation data. As it continues to grow, users will find new ways to use the data for improving invasive plant management and research.

CHAPTER 4

SUMMARY AND RECOMMENDATIONS

An outcome-based process was used to plan, implement and evaluate a standardized invasive plant mapping system that has been widely adopted. The system allows for mapping using three different methods: hand-mapping, computer-mapping and GPS mapping, and combines data from many different sources into a comprehensive statewide database. Users have been provided with education, training and technical support. A WWW site was established to serve as a communication device and to provide information to users, including news, publications, technical information and downloadable files. The standards are being used by land managers to map and manage invasive plants at both local and statewide levels. The system produces accurate and consistent data that are being used for management planning and evaluation, and to enhance support for invasive plant programs through public education and grant funding. It has been instrumental in increasing cooperation among land managers and has been the basis for coordinated mapping projects involving several groups and agencies. Data collected using the mapping standards have been used for developing, implementing and evaluating invasive plant management plans, assessing the economic impacts of plant invasion, increasing public awareness, and securing funding for invasive plant management programs.

This system has served as a model for managers in other areas who are developing their own invasive plant mapping programs. We continually receive calls from people in other states and countries asking for information, and people from around the globe have downloaded our weed mapping handbook from the web site. The BLM has adopted the invasive plant mapping system nationwide.

We have secured a permanent home for the statewide database, along with personnel, equipment and financial resources, being provided by the BLM. We also have leadership and financial support from Stillwater County, who are providing additional marketing, training and technical support in 2002. This leadership and support from the field is expected to increase participation among county weed coordinators, as well as state and federal agency land managers.

Future plans for the invasive plant mapping system include a map server application which will make data and maps available over the Internet, a system for on-line data entry, continued availability of information via the web site, and ongoing support from the advisory team to maintain the system into the future.

Additional Uses for the Standardized System

Nonindigenous species of plants and animals have caused major economic losses in agriculture, forestry, and several other segments of the U.S. economy, in addition to harming the environment (Pimentel et al., 2000). They are possibly the most serious threat to biodiversity, often resulting in the loss of native species (Webb, 2000). Although this system was designed for mapping invasive plant species, we suggest that the same model could be used for developing a system for other invasive species (e.g. animals, microbes). Availability of standardized, accurate and complete information could greatly benefit efforts to manage them.

Invasive Plant Maps for Research

Complete and accurate GIS data of invasive plant infestations could benefit research on the spread of invasive plants and predictions of areas potentially subject to invasion. A GIS platform can effectively handle the spatial aspects of modeling invasive plant spread, and furnish many spatial analysis tools[2] that aren't available in strictly mathematical or knowledge-based models. These types of models can, however, be linked to or operate within a GIS to take advantage of their unique contributions to understanding the whole system. A GIS can provide the framework to bring all the available knowledge and tools together. Looking at the functional interactions of invasions in a GIS setting could provide new and effective methods for predicting the potential spread of alien plants. If the predictions are accurate, the information could be used to target mapping and management activities.

Once initial colonization and establishment of an invasive species has occurred, it may spread to other locations via dispersal agents such as wind, water, animals and vehicles. Preventing the expansion of plant infestations requires understanding of the biological, genetic, and environmental factors that contribute to their establishment in

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[2] Spatial analysis tools available in a GIS include buffer operations, overlay analysis, point pattern analysis, spatial interpolation, connectivity analysis, diffusion modeling through grid analysis, focal functions (neighborhood analysis), multiple layer operations, and so on.

new areas. Survey data showing current distribution of invasive plants can be incorporated into spatial models where correlations between invasive plant occurrence and various physical and environmental factors can be identified. For example, associations between plant infestations and roads, including traffic patterns, could help explain how invasive plants arrived, and indicate where they might be likely to spread. Other factors useful for these types of models might include climate (temperature, precipitation, wind patterns), soil types, habitat or environmental types, wildlife use patterns, grazing history, human disturbances, and locations of rivers and other natural features.

Predictions of the rate and direction of spread of invasive species that have already become established are critical to any management program (Sakai et al., 2001). Associations revealed through spatial modeling efforts could provide the information needed to predict potential invasive species expansion. Accurate predictions would provide land managers with advance notice of potential problems, would permit them to implement preventive invasive plant management measures, and could help identify locations where survey efforts should be focused.

Invasive plant survey data might also be useful for understanding population biology and genetic factors that allow individuals to survive and reproduce in new ranges. Hypotheses on the importance of human-mediated introductions, changes in habitat quality, and life history traits favoring establishment could be tested through experimental manipulations of invasive species that are actively colonizing areas (Sakai et al., 2001).

Maps of existing infestations, along with spatial data documenting such experimental manipulations, could aid this type of research.

Most natural communities are susceptible to invasion by exotic species (Binggeli, 1996; Gordon, 1998). Although many biological and ecological factors most likely interact to influence the success of alien species invasions, models incorporating environmental and physical attributes, such as those described above, can help to identify areas at risk.

What are the characteristics of invaded environments, and what makes an environment invasible? The "fluctuating resource availability" theory states that a plant community becomes more susceptible to invasion whenever there is an increase in the amount of unused resources (light, nutrients and water) coinciding with the presence of invading propagules (Davis et al., 2000). Resource release could follow events such as disturbance, heavy grazing, pest or disease outbreak, or increased water supply, making the community particularly vulnerable to invasion (Davis et al., 2000). This and other theories of invasion biology could be incorporated, along with environmental factors, into spatial models predicting susceptible areas. Models incorporating the "fluctuating resource availability" theory would require, along with spatial data, temporal data representing events that affect resource availability.

Researchers are developing various types of models to determine which habitats are most vulnerable to invasion by exotic species (Chong et al., 2001; Despain et al., 2001; Zalba et al., 2000). Results of such models can be used to identify invasion susceptible environments, facilitating detection of invasions in their initial stages, and thereby optimizing monitoring and early control actions (Zalba et al., 2000). Survey data delimiting existing infestations can be used as model inputs as well as to test the validity of and refine such models. Spatial data delineating habitat types can help facilitate model implementation within a geographic information system (GIS), and can also provide a visual display of susceptible areas to be used for planning and evaluating management activities.

Many aspects of global change, such as increasing CO_2 concentration, changes in climate, atmospheric nitrogen deposition, altered disturbance regimes, and increased habitat fragmentation are expected to favor invasive alien species (Dukes and Mooney, 1999). Observing the performance of an invasive species in many different geographically isolated locations and correlating its performance with biotic and environmental variables in those areas will help test whether climate change is increasing the susceptibility of ecosystems to invasion (Dukes and Mooney, 1999). These observations will also help examine the responses of invasive species to relevant components of global change (Dukes and Mooney, 1999). Invasive plant infestation maps could be a valuable source of data for identifying and tracking the effects of global change on invasive plant infestations.

It has been suggested that many invasive non-indigenous species alter ecosystem properties at several scales, by either significantly changing resource availability or disturbance regimes or both (Gordon, 1998). The types of processes that may be modified include geomorphological processes, biogeochemical or hydrological cycling, disturbance types and regimes, stand structure, recruitment rates of natives, and resource competition

(Gordon, 1998). Invasive plant survey data and other map layers could be used to track changes in ecosystem properties resulting from invasive species infestations.

New Methods for Mapping Invasive Plants

In addition to visual surveys, other methods for mapping invasive plants are emerging. GIS modeling has been used to predict invasive plant locations from existing data. Samples gathered from GPS-based infestation maps were used to predict the presence or absence of invasive plant species using inverse distance weighting, a method for spatial interpolation (Roberts, 2001). Accurate data collected according to the invasive plant mapping standards could be used to verify and test such models.

Various types of remotely sensed imagery have been investigated for detecting and mapping plant infestations over large areas. These include satellite imagery (Anderson et al., 1993; Dewey et al., 1991; Everitt et al., 1993; Peters et al., 1992) multispectral digital imagery (Carson et al., 1995; Lass and Callihan, 1997; Lass et al., 1996), hyperspectral digital imagery (O'Neill et al., 2000), and aerial photography and videography (Anderson et al., 1996; Everitt et al., 1996; Everitt et al., 1995). Satellite imagery has also been used to identify land cover types that are suitable for particular invasive plants (Dewey et al., 1991). Invasive plant survey data collected from the ground can be used for verification of maps developed by remote sensing techniques. Combining remote sensing with other data and models in a GIS framework can provide powerful tools for spatial data analysis.

In addition to the applications of invasive plant survey data for management purposes discussed above, we believe that information from systems such as this one can be used to improve our understanding of invasion biology and ecology, help determine means by which invasive plants spread, and predict those areas potentially subject to plant invasion. A more complete understanding of these processes will in turn benefit invasive plant management, as new knowledge is applied and used to predict management outcomes.

Additional Uses for Invasive Plant Infestation Data

Invasive plant maps produced by the system could be included in an expanded Internet map server application that contains additional GIS data layers (vegetation maps, aerial photography, satellite imagery, and so on), descriptive text, photographs, digital video clips, and audio segments highlighting the characteristics of plant communities, individual species, and invasive exotics. This type of interactive multimedia approach provides a unique way to represent features in a spatial framework, and can be used to enhance understanding of the interrelationships among flora, fauna and human activities (Hu, 1999). It could be an excellent tool for public education about the impacts of invasive plant species on the environment.

The Internet map server application could also be linked to a global information system for invasive species. Such a system has been proposed to connect all independently operated databases available on the Internet. The global system would provide diagnostic information for identifying newly introduced species (including photographs and illustrations), current distribution maps of the native and invaded ranges of each listed species, basic biological information, specific modes of dispersal, impacts, control methods and contact information for pertinent studies and cooperating authorities. Such a system would help to organize the increasing volume of information on invaders and make it more accessible to users. It would clarify spatial and temporal patterns of invasion on regional, national, and global scales. It would help managers assess risk and more effectively allocate limited resources toward preventing spread and enabling early eradication, and could serve as an early warning system. It would also promote public awareness of invasion problems and human activities that contribute to them (Ricciardi et al., 2000).

We believe we have made substantial progress toward our goal of enhancing the effectiveness of invasive plant management by implementing a standardized mapping system and statewide database. As the invasive plant problem is not expected to disappear in the near or long-term future, work in this area should continue. Future efforts should focus on increasing participation in the system and finding new uses for the data that will benefit invasive plant management worldwide.

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APPENDICES

APPENDIX A

WORKSHOP OUTLINE

Day 1	
8-9:30 am	**1. Welcome and Introduction to the Weed Mapping System,** *Diana Cooksey, Elizabeth Roberts, Celestine Duncan*
	Introductions
	The Montana Noxious Weed Survey and Mapping System
	Example of Hand-mapping Using the Montana Standards
	Noxious Weed Inventory Methods
9:30-10 am	**Break**
10 am-12 pm	**2. Map Concepts and Map Reading Skills,** *Elizabeth Roberts, Diana Cooksey*
	Reading 1:24,000 USGS Topographic Maps
	Computer Mapping Issues: datums, projections, coordinate systems, scale, accuracy and precision
12 pm-1 pm	**Lunch on Your Own**
1-5 pm	**3. Hand-mapping of Weeds,** *Celestine Duncan, Bob Grubb, Elizabeth Roberts, Diana Cooksey, Jeff Copeland*
	Hand-mapping on Aerial Photos
	Weed Mapping System Standards
	Transferring Hand Mapped Data to USGS quads
	Metadata: filling out metadata forms, importance of metadata
	Short Introduction to Montana's 16 Noxious Weeds
Day 2	
8 am-12 pm	**4. Overview of GIS Technology and Software,** *Elizabeth Roberts, Diana Cooksey*
	What is a GIS?
	Overview of Digitizing Paper Maps
	On-screen Digitizing in ArcView GIS
	Editing and Creating Presentation Quality Maps
	Weed Mapping System Standards, Database Structure and Metadata
12 pm-1 pm	**Lunch on Your Own**
1-5 pm	**5. Basic GPS Theory,** *Diana Cooksey, Elizabeth Roberts*
	Design, Development & Characteristics of the Global Positioning System
	Potential Evolution of the GPS
	GPS Mapping Issues: datums, coordinate systems, height systems, precision and accuracy
	Mission Planning
	Weed Mapping System Standards, Database Structure and Metadata
	When is GPS Appropriate?

Day 3	
8 am-12 pm	**6. Hands-on GPS,** *Elizabeth Roberts, Diana Cooksey, Jeff Copeland*
	Weed Data Collection Field Exercises (Story Hills)
	Differential Correction of Field-collected GPS Data
	Working with GPS Data in Pathfinder Office Software
	Weed Mapping System Standards, Database Structure and Metadata
12 pm-1 pm	**Lunch on Your Own**
1-5 pm	**7. Exporting GPS data to ArcView,** *Diana Cooksey, Elizabeth Roberts, Jeff Copeland, Cyndi Crayton, Jay Brenenstuhl*
	GPS/GIS Mapping Issues: datums, coordinate systems, height systems, projections, scale, precision and accuracy
	Editing and Creating Presentation Quality Maps
	Weed Mapping System Standards, Database Structure and Metadata
	Exporting GPS Data
	Export File Management
	GIS Analysis
	Questions, Individual Work, etc.
Day 4	
8 am-12 pm	**8. Advanced GPS and GIS Work,** *Elizabeth Roberts, Diana Cooksey, Jeff Copeland, Cyndi Crayton*
	Advanced Work with Your Own Data
	Creating a Weed Data Dictionary & Biocontrol Data Dictionary
	Individual Help With Specific Problems or Questions

APPENDIX B

WORKSHOP EVALUATION

Weed Survey and Mapping System Workshop

(Workshop Location)

(Workshop Date)

We'd like to know how well we accomplished our objectives with the weed survey and mapping system workshop and get some ideas for improvement for future workshops. You can help by completing this questionnaire. Please be candid, we promise to take constructive criticism well!

Directions: circle the number on the following items that indicates how you would rate the instructor and program, with 5 being excellent and 1 being poor. (Indicate "NA" if not applicable).

Evaluation of Instructor - Diana Cooksey

	Poor				Excellent
1. Was well prepared and organized	1	2	3	4	5
2. Presentation was understandable	1	2	3	4	5
3. Demonstrated enthusiasm for subject	1	2	3	4	5
4. Allowed time for questions and interaction	1	2	3	4	5
5. Stimulated me to think about how to use the information	1	2	3	4	5
6. Visual aids were appropriate for presentation	1	2	3	4	5
7. Information presented was of educational value	1	2	3	4	5
8. My ability to understand subject was improved	1	2	3	4	5

Evaluation of Instructor - Elizabeth Roberts

	Poor				Excellent
1. Was well prepared and organized	1	2	3	4	5
2. Presentation was understandable	1	2	3	4	5
3. Demonstrated enthusiasm for subject	1	2	3	4	5
4. Allowed time for questions and interaction	1	2	3	4	5
5. Stimulated me to think about how to use the information	1	2	3	4	5
6. Visual aids were appropriate for presentation	1	2	3	4	5
7. Information presented was of educational value	1	2	3	4	5
8. My ability to understand subject was improved	1	2	3	4	5

(over, please)

How much has your knowledge increased as a result of this workshop?

none a little a fair amount a great deal

Were there topics or exercises that were not helpful and could have been left out? (Please list)

Were there topics or exercises that should have been included and were not? (Please list)

Do you feel more comfortable with the standardized weed survey and mapping system now that you've attended this workshop?

Additional comments or suggestions for the next workshop.

APPENDIX C

QUESTIONNAIRE

We seek your honest opinions on the usefulness of the Weed Mapping System (WMS), your use of it as a weed manager in Montana, and your ideas for the future of the system. There are no right or wrong answers to these questions. *Every question is important.* Please mark one answer for *every* question. Since you may not be familiar with all parts of the system, feel free to choose "don't know" if necessary.

I. Usefulness of the Weed Mapping System

How much has the WMS helped Montana weed managers? You may agree or disagree with the statements below. *Please indicate the level of your agreement with each statement.* The scale is from 1 to 5, where "1" means "disagree strongly" and "5" means "agree strongly." If unsure, circle DK/NA (don't know / no answer).

THE MONTANA NOXIOUS WEED MAPPING SYSTEM:	LEVEL OF AGREEMENT					
	DISAGREE STRONGLY	DISAGREE SOMEWHAT	NEUTRAL	AGREE SOMEWHAT	AGREE STRONGLY	don't know /no answer
A. has helped local weed coordinators in weed management planning	1	2	3	4	5	DK/NA
B. has made progress in setting standards for weed mapping	1	2	3	4	5	DK/NA
C. has helped many people work with technical problems related to weed mapping	1	2	3	4	5	DK/NA
D. will help in the study of the spread of weeds	1	2	3	4	5	DK/NA
E. will produce beneficial data for managing weeds in Montana	1	2	3	4	5	DK/NA
F. will add to weed managers' understanding of how to map and keep track of the spread of weeds in their areas	1	2	3	4	5	DK/NA

II. Your Use of the Weed Mapping System:

PLEASE CIRCLE ONE ANSWER FOR EACH QUESTION

A. Have you **collected data** about the location of weed infestations? . . . . YES NO NO RESPONSE

A1. If yes, how have the data you have collected been used? (e,g,: mapping, management, economic analysis, etc)

B. Have you **submitted your data** to the WMS statewide database? . . . . YES NO NO RESPONSE

B1. If you collect data, but **do not** submit it to WMS, can you tell us why not?

B2. What help **do you need** to be able to submit your data?

C. Do you **expect to be collecting data** about the location of weeds? . . . . YES NO NO RESPONSE

D. Do you **expect to submit data** to the WMS database in the future? . . . . YES NO NO RESPONSE

E. Do you **need training** in collecting and/or submitting data to the WMS? . . . . YES NO NO RESPONSE

F. Do you **need technical assistance** in using equipment for weed mapping? . . . . . . YES NO NO RESPONSE

G. Do you have **anything else** to add?

III. Future of Montana Noxious Weed Mapping System:

Please answer the following questions to the best of your ability. *Circle the number that describes how you feel about the* *__importance of ontinuing__* *each listed activity in the future*. The scale is from 1 to 5, where "1" means "NOT IMPORTANT" and "5" means "VERY IMPORTANT." If you are unsure of a response, circle DK/NA.

WMS FUTURE ACTIVITIES:	**IMPORTANCE OF CONTINUING ACTIVITY** NOT IMPORTANT	A LITTLE IMPORTANT	SOMEWHAT IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	don't know /no answer
A. Maintenance and addition of data to statewide database	1	2	3	4	5	DK/NA
B. Continued availability of WMS Handbook, MontGuide and Extension Bulletin	1	2	3	4	5	DK/NA
C. Calculating number of acres infested by different weeds	1	2	3	4	5	DK/NA
D. Determination of how fast noxious weeds are spreading	1	2	3	4	5	DK/NA
E. Maintenance of WMS Web site	1	2	3	4	5	DK/NA
F. Workshops covering weed mapping, and how to prepare data for the statewide database	1	2	3	4	5	DK/NA
G. Workshops for training in use of GPS and GIS equipment	1	2	3	4	5	DK/NA
H. Technical assistance in purchasing equipment for weed mapping	1	2	3	4	5	DK/NA
I. Technical assistance in setting up and using equipment for weed mapping	1	2	3	4	5	DK/NA
J. Technical assistance in collecting data for the statewide database	1	2	3	4	5	DK/NA
K. Availability of computerized weed data for creating reports and maps of weed infestations	1	2	3	4	5	DK/NA
L. Availability of ready-made maps which show weed infestations	1	2	3	4	5	DK/NA
M. Availability of downloadable files–Extension Bulletin, MontGuide, Handbook, data dictionaries, ArcView legend files, etc	1	2	3	4	5	DK/NA

IV. Your Familiarity with the Weed Mapping System:
Finally, we would like information on *your involvement* with the WMS.

PLEASE CIRCLE ONE ANSWER FOR EACH QUESTION

A. Have you ever seen the WMS Handbook?	YES	NO	NO RESPONSE
B. Do you own a copy of the WMS Handbook?	YES	NO	NO RESPONSE
C. Have you ever seen a presentation about the WMS project?	YES	NO	NO RESPONSE
D. Have you ever attended a WMS workshop?	YES	NO	NO RESPONSE
E. Have you read the WMS MontGuide? YES	NO		NO RESPONSE
F. Have you read the WMS Extension Bulletin?	YES	NO	NO RESPONSE
G. Have you ever browsed the WMS website?	YES	NO	NO RESPONSE
H. Have you ever downloaded files from the website?	YES	NO	NO RESPONSE
I. Have you ever called the WMS office for assistance?	YES	NO	NO RESPONSE

J. What best defines your involvement in weed mapping? (Circle one below):

COUNTY AGENCY STATE AGENCY FEDERAL AGENCY FARM/RANCH BUSINESS OTHER:______________

V. ***Please feel free to comment on any aspects of the Montana Noxious Weed Survey and Mapping System Project anywhere on the questionnaire. If you wish, you may attach another sheet of paper.***

Thank you very much for your assistance. Your responses will help decide the future of the Weed Mapping System and are very important to everyone in Montana who must deal with noxious weeds.

APPENDIX D

QUESTIONNAIRE RESULTS TABLES

I. Usefulness of the Weed Mapping System.

THE MONTANA NOXIOUS WEED MAPPING SYSTEM:	**LEVEL OF AGREEMENT** (count, percent of total)							
	DISAGREE STRONGLY	DISAGREE SOMEWHAT	NEUTRAL	AGREE SOMEWHAT	AGREE STRONGLY	DK/NA	TOTAL	OVERALL AVERAGE
Has helped local weed coordinators in weed management planning	6	7	19	49	23	32	136	3.7
	4.4%	5.1%	14.0%	36.0%	16.9%	23.5%	100.0%	
Has made progress in setting standards for weed mapping	1	6	12	46	43	28	136	4.1
	0.7%	4.4%	8.8%	33.8%	31.6%	20.6%	100.0%	
Has helped many people work with technical problems related to weed mapping	3	11	22	42	23	35	136	3.7
	2.2%	8.1%	16.2%	30.9%	16.9%	25.7%	100.0%	
Will help in the study of the spread of weeds	0	3	11	57	56	9	136	4.3
	0.0%	2.2%	8.1%	41.9%	41.2%	6.6%	100.0%	
Will produce beneficial data for managing weeds in Montana	1	2	10	61	55	7	136	4.3
	0.7%	1.5%	7.4%	44.9%	40.4%	5.1%	100.0%	
Will add to weed managers' understanding of how to map and keep track of the spread of weeds in their areas	0	5	14	55	49	13	136	4.2
	0.0%	3.7%	10.3%	40.4%	36.0%	9.6%	100.0%	

I. Usefulness of the Weed Mapping System (Collapsed into 3 categories of agreement: With DK/NR removed).

THE MONTANA NOXIOUS WEED MAPPING SYSTEM:		LEVEL OF AGREEMENT		
Collapsed into 3 categories of agreement: With DK/NR removed	DISAGREE	NEUTRAL	AGREE	TOTAL
Has helped local weed coordinators in weed management planning	13	19	72	104
	12.5%	18.3%	69.2%	100.0%
Has made progress in setting standards for weed mapping	7	12	89	108
	6.5%	11.1%	82.4%	100.0%
Has helped many people work with technical problems related to weed mapping	14	22	65	101
	13.9%	21.8%	64.4%	100.0%
Will help in the study of the spread of weeds	3	11	113	127
	2.4%	8.7%	89.0%	100.0%
Will produce beneficial data for managing weeds in Montana	3	10	116	129
	2.3%	7.8%	89.9%	100.0%
Will add to weed managers' understanding of how to map and keep track of the spread of weeds in their areas	5	14	104	123
	4.1%	11.4%	84.6%	100.0%

II. Your use of the Weed Mapping System.

	YES	NO	NO RESPONSE	TOTAL
Have you **collected data** about the location of weed infestations?	110	24	2	136
	80.88%	17.6%	1.5%	100.0%
Have you **submitted your data** to the WMS statewide database?	39	89	8	136
	28.7%	65.4%	5.9%	100.0%
Do you **expect to be collecting data** about the location of weeds?	124	10	2	136
	91.2%	7.4%	1.5%	100.0%
Do you **expect to submit data** to the WMS database in the future?	77	29	30	136
	56.6%	21.3%	22.1%	100.0%
Do you **need training** in collecting and/or submitting data to the WMS?	61	66	9	136
	44.9%	48.5%	6.6%	100.0%
Do you **need technical assistance** in using equipment for weed mapping	55	70	11	136
	40.4%	51.5%	8.1%	100.0%

II. Your use of the Weed Mapping System (cont.).

Of those who **have collected data**	yes	percent	no	percent
Have you submitted data to the WMS? (n = 110)	39	35.5%	66	60.0%

Of those who **have collected data** about the location of weed infestations **and have submitted it** to the WMS (n=39):	yes	percent
Do you expect to be collecting data about the location of weeds?	38	97.4%
Do you expect to submit data to the WMS database in the future?	33	84.6%
Unsure, may do so	3	7.7%
Do you need training in collecting and/or submitting data to the WMS?	13	33.3%
Do you need technical assistance in using equipment for weed mapping	15	38.5%
Of those who **have collected data** about the location of weed infestations **and have <u>not</u> submitted it** to the WMS (n = 66):	yes	percent
Do you expect to be collecting data about the location of weeds?	64	97.0%
Do you expect to submit data to the WMS database in the future?	31	47.0%
Unsure, may do so	20	30.3%
Do you need training in collecting and/or submitting data to the WMS?	34	51.5%
Do you need technical assistance in using equipment for weed mapping?	28	42.4%
Of those who **have <u>not</u> collected data** about the location of weed infestations (n=24).	yes	percent
Do you expect to be collecting data about the location of weeds?	15	62.5%
Do you expect to submit data to the WMS database in the future?	9	37.5%
Unsure, may do so	5	20.8%
Do you need training in collecting and/or submitting data to the WMS?	9	37.5%
Do you need technical assistance in using equipment for weed mapping?	10	41.7%

II A1. If yes, how have the data you have collected been used?

II A1. Use of data (asked of those who answered "yes" to question IIA, n=110)	Number mentioning item	Item mentioned, % n = 110
Mapping	70	63.6%
Management	70	63.6%
Economic analysis	17	15.5%
Locate infestations	34	31.2%
Control infestations	26	23.9%
Funding	11	10.1%
Other	25	22.9%

II B1. If you collect data, but do not submit it to the WMS, can you tell us why not?

II B1: Reasons given by those who have <u>not</u> submitted data:		
REASON	n	Percent of those who do *not* submit data (n = 89)
Lack of knowledge of WMS (Waiting for data *requests*–4)	19	21.3%
Incomplete/fragmented/small amount of data/ not up to standard	14	15.7%
Incompatible format/GPS system	13	14.6%
Too busy	10	11.2%
Submit to county coordinator/who else should they submit to?	7	7.9%
Submit to different database	6	6.7%
New at collecting data	5	5.6%
Submission process too complex	4	4.5%
Privacy issues	2	2.2%

II B2. What help do you need to be able to submit your data?

IIB2: Needs mentioned by respondents re: use of WMS		
NEED	n	percent of those who do *not* submit data (n = 89)
Information and assistance (see below for breakdown)	30	33.7%
More funding/time/personnel	27	30.3%
Accessibility of data after submission	9	10.1%
Publicity for and feedback from WMS	8	9.0%
On-line access and submission capability	2	2.2%

II B2. What help do you need to be able to submit your data?

IIB2, cont.: Information and assistance needs mentioned by respondents re: use of WMS		
SPECIFIC INFORMATION OR ASSISTANCE NEEDED	n*	percent of those who do *not* submit data (n = 89)
General information and assistance	14	15.7%
How to submit data	11	12.4%
Training and technical assistance	7	7.9%
Contact person/place	6	6.7%

* Some respondents mentioned more than one of these specific needs.

III. Future of Montana Noxious Weed Mapping System.

III. WMS FUTURE ACTIVITIES:	**IMPORTANCE OF CONTINUING ACTIVITY**							
	NOT IMPORTANT	A LITTLE IMPORTANT	SOMEWHAT IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	DK/NA	TOTAL	AVG IMP.
Maintenance and addition of data to statewide database	0	3	16	38	74	5	136	4.4
	0.0%	2.2%	11.8%	27.9%	54.4%	3.7%	100.0%	
Continued availability of WMS Handbook, MontGuide and Extension Bulletin	1	1	24	41	56	13	136	4.2
	0.7%	0.7%	17.6%	30.1%	41.2%	9.6%	100.0%	
Calculating number of acres infested by different weeds	0	6	13	42	73	2	136	4.4
	0.0%	4.4%	9.6%	30.9%	53.7%	1.5%	100.0%	
Determination of how fast noxious weeds are spreading	2	1	9	30	92	2	136	4.6
	1.5%	0.7%	6.6%	22.1%	67.6%	1.5%	100.0%	
Maintenance of WMS Web site	0	6	19	43	53	15	136	4.2
	0.0%	4.4%	14.0%	31.6%	39.0%	11.0%	100.0%	
Workshops covering weed mapping, and how to prepare data for the statewide database	2	7	22	42	58	5	136	4.1
	1.5%	5.1%	16.2%	30.9%	42.6%	3.7%	100.0%	
Workshops for training in use of GPS and GIS equipment	3	5	19	45	58	6	136	4.2
	2.2%	3.7%	14.0%	33.1%	42.6%	4.4%	100.0%	

III. Future of Montana Noxious Weed Mapping System, cont.

III. WMS FUTURE ACTIVITIES:	**IMPORTANCE OF CONTINUING ACTIVITY**							
	NOT IMPORTANT	A LITTLE IMPORTANT	SOMEWHAT IMPORTANT	MODERATELY IMPORTANT	VERY IMPORTANT	DK/NA	TOTAL	AVG IMP.
Technical assistance in purchasing equipment for weed mapping	3	12	31	45	38	7	136	3.8
	2.2%	8.8%	22.8%	33.1%	27.9%	5.1%	100.0%	
Technical assistance in setting up and using equipment for weed mapping	3	7	19	57	45	5	136	4.0
	2.2%	5.1%	14.0%	41.9%	33.1%	3.7%	100.0%	
Technical assistance in collecting data for the statewide database	3	5	25	58	41	4	136	4.0
	2.2%	3.7%	18.4%	42.6%	30.1%	2.9%	100.0%	
Availability of computerized weed data for creating reports and maps of weed infestations	2	9	18	41	63	3	136	4.2
	1.5%	6.6%	13.2%	30.1%	46.3%	2.2%	100.0%	
Availability of ready-made maps which show weed infestations	2	5	19	41	64	5	136	4.2
	1.5%	3.7%	14.0%	30.1%	47.1%	3.7%	100.0%	
Availability of downloadable files–Extension Bulletin, MontGuide, Hand-book, data dictionaries, ArcView legend files, etc	1	6	21	39	65	4	136	4.2
	0.7%	4.4%	15.4%	28.7%	47.8%	2.9%	100.0%	

IV. Your familiarity with the Weed Mapping System

IV. Your Familiarity with the Weed Mapping System:	YES	NO	NO RESPONSE	TOTAL
Have you ever seen the WMS Handbook?	90	40	6	136
	66.2%	29.4%	4.4%	100.0%
Do you own a copy of the WMS Handbook?	64	67	5	136
	47.1%	49.3%	3.7%	100.0%
Have you ever seen a presentation about the WMS project?	58	73	5	136
	42.6%	53.7%	3.7%	100.0%
Have you ever attended a WMS workshop?	32	100	4	136
	23.5%	73.5%	2.9%	100.0%
Have you read the WMS MontGuide?	77	55	4	136
	56.6%	40.4%	2.9%	100.0%
Have you read the WMS Extension Bulletin?	77	54	5	136
	56.6%	39.7%	3.7%	100.0%
Have you ever browsed the WMS website?	48	85	3	136
	35.3%	62.5%	2.2%	100.0%
Have you ever downloaded files from the website?	23	111	2	136
	16.9%	81.6%	1.5%	100.0%
Have you ever called the WMS office for assistance?	26	105	5	136
	19.1%	77.2%	3.7%	100.0%

IV. Familiarity index.

Average Familiarity Index for Groups and Total Sample (The Familiarity Index is the total number of "yes" answers to questions A through I in Section IV of the questionnaire. Values from 0 to 9 are possible; the higher the value, the more knowledgeable the respondent is about the WMS.)		
Group	Average	n
County Agency	3.97	64
State Agency	3.44	18
Federal Agency	3.47	34
Farm/Ranch	3.00	5
Business	3.00	5
Other	3.10	10
TOTAL	3.64	136

IV J. Your involvement in weed mapping.

IV J. What best defines your involvement in weed mapping?	Number in category	% in category: n 136
County Agency	64	47.1%
State Agency	18	13.2%
Federal Agency	34	30.9%
Farm/Ranch	5	4.6%
Business	5	4.6%
Other	10	9.2%
TOTAL	136	100.0%

APPENDIX E

METADATA FORM

Montana Noxious Weed Survey and Mapping System
Metadata Form

Record of weed data collection details

Please complete one metadata form for each data set collected

I. General Information Date(s) data collected ____________________

Name of person(s) collecting data ____

Agency ____

Address ____

City, State, Zip ____

Phone ______________ Fax ______________ E-mail ______________

II. Survey Information

Weeds surveyed ____

Survey boundary data format (circle one)

Hand-drawn on USGS map or mylar GPS file GIS File

Method used to map weed infestations (circle one)

Hand mapping GPS mapping Computer mapping (digitizing) Computer mapping (on-screen drawing)

III. Data Set Accuracy Level. Before filling out this section, *please read the* ***Guidelines to Filling out Metadata Forms*** in the **Weed Mapping System Handbook**; then check the appropriate accuracy level of the data set.

✔	**Accuracy Level**	**What determines accuracy level**
	Level I (high level accuracy and detail)	o intensive mapping techniques were used o survey methods often based on grid patterns o attribute accuracy = 80 - 100%, horizontal postional accuracy = 0 - 20 m
	Level II (moderate level accuracy and detail)	o less intensive mapping techniques were used o general in-the-field scanning for infestations o attribute accuracy = 60 - 80%, horizontal postional accuracy = 20 - 100 m
	Level III (low level accuracy and detail)	o reconnaissance mapping techniques were used o utilized existing information (interviews) o aerial inventory methods (aerial photographs) o "windshield surveys" o attribute accuracy < 60%, horizontal postional accuracy > 100+ m

Description of technique used to collect data (*see guidelines*) ____________________

____

IV. Additional Metadata. Please fill out the appropriate section, depending on the mapping method used.

A. Hand mapping. Data MUST be submitted on 1:24,000 USGS maps or mylar overlays. *Please do not fold maps or mylar: they must be sent in a mailing tube!*

Number of quad/mylar sheets ________ Names of quads ______________________________

____

If submitting hand-mapped data, please check the procedure followed.

✔	Mapping Procedure
	Data were mapped directly onto 1:24,000 USGS base maps or mylar overlays
	Data were mapped onto photocopies or enlargements of 1:24,000 USGS base map, then transferred to map or mylar
	Data were mapped on higher resolution maps (i.e. aerial photos), then transferred to map or mylar
	Other ______________________________

B. GPS mapping

Manufacturer and model of receiver used ______________________________

Are files differentially corrected? (circle one) yes no

Location of base station used for differential correction ______________________________

Number of GPS file(s) _____ File name(s) ______________________________

____

Describe any cleanup/editing done to files ______________________________

____

Name of person who did the cleanup/editing ______________________ Phone ____________

C. Computer mapping

Program and version used to record data ______________________________

File format (circle one) E00 SHP AGF DXF MIF DWG Other __________

Number of files _____ File name(s) ______________________________

____

If digitizing, was the RMS error <= .003? (check one)

____ Yes ____ No, RMS = _____ ____ N/A, mapping software does not provide an RMS error

Name of person who did the digitizing/editing ______________________ Phone ____________

If submitting computer-mapped data, please fill out the following table.

Background/ base maps used	Type:	Scale:	Coord. system/datum/projection:
	Type:	Scale:	Coord. system/datum/projection:
Technique used to draw/digitize infestations *(see guidelines)*	Methods:		