National Park Service
Natural Resource Program Center
Biological Resource Management Division
and Natural Resource Information Division

Invasive Plant Inventory and Monitoring Guidelines (DRAFT)

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Silverleaf nightshade

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The following individuals and programs are acknowledged for their contributions to the development of the Inventory and Monitoring for Invasive Plant Workshop and Framework:

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Gail Montgomery - Kodailey & Associates

Steve Fancy and Gary Williams - The Inventory and Monitoring Program

The Workshop Participants

Introduction

Invasive Plant Management

The invasion and establishment of non-native species is accelerating at an unprecedented rate due to increases in global trade and transportation. This breakdown of biogeographical barriers is having profound consequences on ecosystems worldwide and is second only to habitat destruction as a threat to wildland biodiversity. National Parks are deluged by new non-native species arriving through predictable (e.g. road, trail and riparian corridors), sudden (e.g. long-distance dispersal through cargo containers and air freight) or unexpected anthropogenic means (weed seeds in restoration planting mixes, on soles of hikers shoes). Many National Park Service areas have park resources that are threatened and/or impacted by invasive plants. Given the seeds of destruction already planted (figuratively speaking) and those yet to come, invasive species are certainly one of the greatest threats to national parks in the early decades of the 21st century. Appropriately, alien species are one of the three emphasis areas of the NPS Natural Resource Challenge.

Development of Invasive Plant Management Protocols

A workshop was held in Fort Collins, Colorado on June 4-6, 2002 to create a document that would support NPS I&M Networks, National Park Service land managers, and other land managers in the development of invasive plant inventory and monitoring protocols. The workshop provided participants with the time and resources to determine common goals, objectives and guidelines for invasive plant assessment, inventory and monitoring, as well as suggested approaches for developing these at the park or network level. Participants at the workshop included experts with experience in park-based monitoring programs, protocol design, modeling, and/or the ecology of invasive plants. They came from within NPS, other federal agencies, states, and academia. Hopefully, their work will help avoid duplication of effort and make the process of developing invasive plant management protocols more efficient, consistent and ecologically based.

Multiple methods have already been developed to monitor plant populations and communities in general. For example, principles in *Measuring and Monitoring Plant Populations* by Elzinga, Salzer and Willoughby (1998) target rare plant species but can be easily adapted for invasive plants. In addition, guidelines and protocols for plant species inventory and monitoring have been developed by agencies such as the US Forest Services, the Bureau of Land Management, and the Intermountain Region (IMR) of the National Park Service (Appendix C). Therefore, it was not the intent of the workshop group to "reinvent the wheel" but to compile, apply, and modify existing inventory and monitoring guidance and protocols as appropriate. The result of the group's efforts at the workshop is the addition of this document to the Service Wide Inventory and Monitoring Guidelines. This document's purpose is not to promote or dictate specific inventory and

monitoring methods but to provide guidelines for the selection of appropriate methods and to ensure a level of protocol compatibility between the various networks. Each network is encouraged to tailor the guidelines to the particular ecology and landscapes of the region and to use them as the foundation of their invasive plant inventory and monitoring program.

Goals for Invasive Plant Inventory and Monitoring

Effective invasive plant management begins with identified goals, measurable objectives, and protocols for inventory, mapping, and monitoring. Selection/ creation of optimal protocols by each NPS I&M network or park may vary depending upon consideration of many factors including the ecological context, management goals and objectives, priorities, and the political background. In most cases, park resources are limited so priorities will need to be determined for inventory and monitoring goals, plant species, and park areas. Tools exist to guide these decisions, such as SWEPIC, Timmons and Owen (2001), and Elzinga et al (Chapter 3) (Appendix C).

A common goal of all invasive plant management actions is not just to kill weeds but also to protect and/or restore the function, structure and composition of the systems NPS is entrusted to manage. Following this principal, four general inventory and monitoring goals for invasive plant efforts were proposed and adopted:

1. Determine the distribution and abundance of known species within parks and their surroundings. Assess which are and which have a high potential to be invasive.

2. Prevent, detect and eradicate new invasions.

3. Evaluate the effects of management actions on targeted species and the ecosystems that they have invaded and determine whether strategic plan goals have been accomplished.

4. Determine status and trends of plant invasions over time and space and develop predictive capabilities to better guide future monitoring and management efforts.

Monitoring methodology varies according to its intent, and different strategies will be necessary in addressing different goals of the inventory and monitoring program. Inventory and mapping serve as the basis for establishing measurable monitoring objectives and for prioritizing species and locations. Methods for monitoring species already in the park and its environs can be borrowed and modified from existing protocols. Methods for preventing and rapidly detecting new invasions (monitoring for rare events) may need to be developed and tested through research. The effects of management actions such as control programs should also be monitored at the species and habitat levels to measure effectiveness and to suggest modifications in goals and/or management schemes. Finally, monitoring for spatial and temporal trends can contribute to a better understanding of invasive species

dynamics and management at the park, regional and national scales.

Document Contents

The document is organized into six sections. The first four sections address the goals identified above. The final two sections address special considerations for data management and sharing and for communication and outreach. Each section identifies goals, objectives, guidelines and suggested approaches for its topic. References, copies of web addresses for key documents, and a list of workshop participants can be found in the Appendices. The majority of the text for each section was drafted during the workshop and later edited by the workshop coordinator Ron Hiebert and an independent editor.

Some very important elements of alien plant inventory and monitoring, which are not specifically covered in the document, are: setting goals and objectives, prioritizing species and places, and selecting the proper scale and intensity of monitoring. For further/additional guidance on setting management objectives, review Chapter Four of *Measuring and Monitoring Plant Populations* (1998). In this same book setting sampling objectives is addressed in Chapter Six and prioritizing species and places is addressed in Chapter Three as well as in a presentation by Hiebert (Appendix C). Selecting the proper scale and intensity of sampling is also covered in Chapter Three and in the paper by Thomas (Appendix C).

Alien Plant Inventory and Mapping

General Information

To be cost-effective and efficient in utilizing resources that are dedicated to an invasive plant management program, you must first know which plants you have and the extent of their occurrences. For the majority of park units within the NPS, however, there is very limited information available on the distribution of most invasive plant species. Without location and distribution information, park resource managers lack the critical tools required to develop a focused strategy for addressing weed management issues. Specifically, weed inventory and mapping information can:

- Increase the ability of resource managers to analyze and prioritize weed management needs and to appropriately direct work efforts and resources, enhancing the time and cost effectiveness of weed management actions.

- Serve as a baseline for long-term monitoring, and assist with the evaluation of changes in alien plant populations over time, the detection of new alien infestations and/or the effectiveness of alien management activities.

- Combine with other layers of information (e.g. soil types, depth to water table, elevations) which can assist in identifying appropriate treatment or control options as well as adding to the knowledge of ecological relationships associated with alien invasions (predictive modeling).

- Serve as a critical tool for increasing public and political awareness and education on invasive plant issues.

Inventory and mapping of invasive plant species in parks and in their other environs should be integrated with general vegetation surveys and surveys being conducted by other agencies, states, and organizations. Data organized in maps and databases provide valuable information towards the development of a network-monitoring scheme. Ancillary uses of maps and data are for public education, development of predictive models and estimations of risk from various species. Goals and objectives for inventory and mapping should ensure products can serve the above purposes.

This section identifies goals and guidelines for alien plant inventory and mapping. The guidelines are based on those identified for the National Park Service, Intermountain Region (IMR) (Appendix C). The process of alien plant inventory and monitoring is illustrated on the next page in Figure 1.

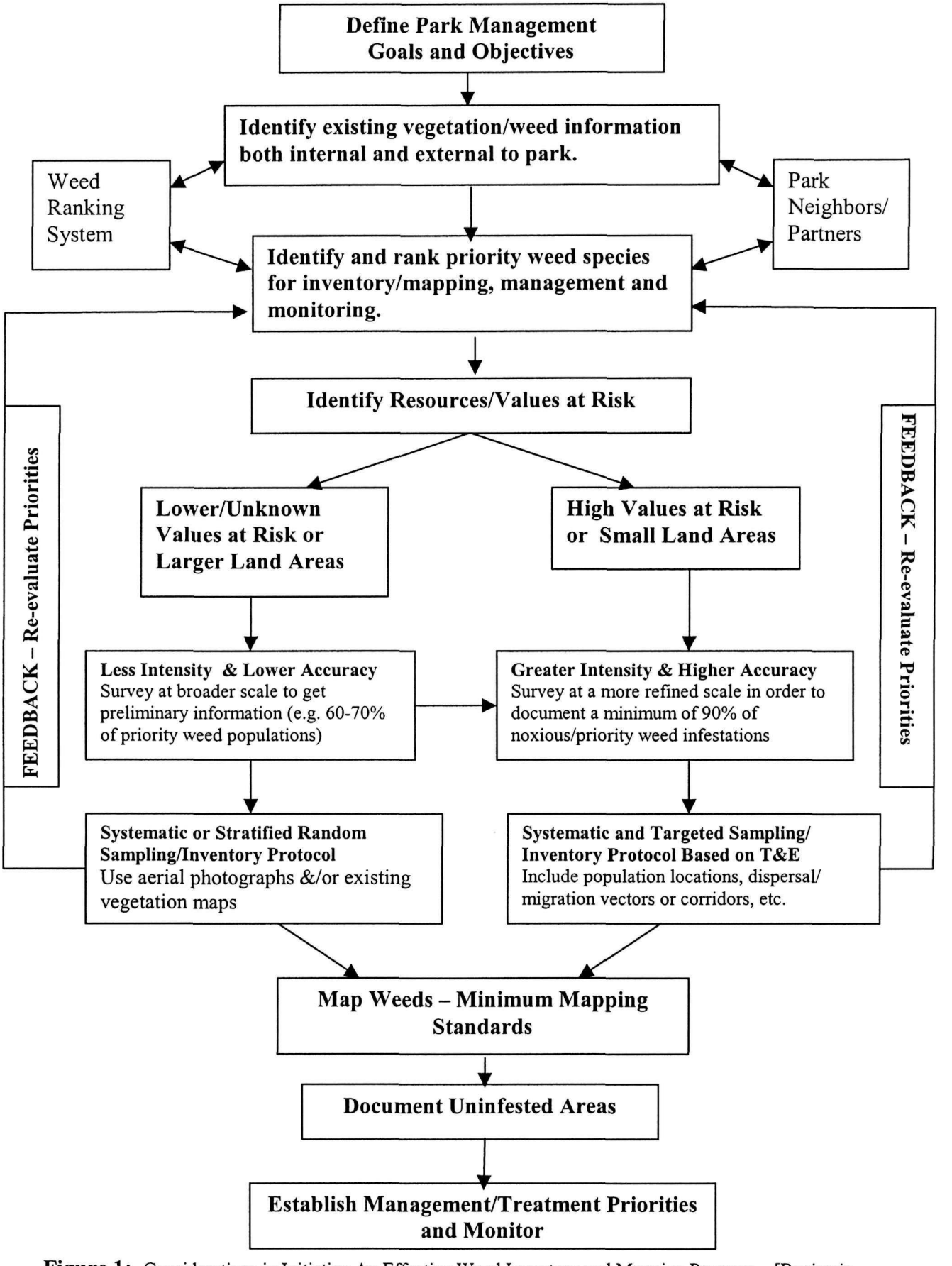

Figure 1: Considerations in Initiating An Effective Weed Inventory and Mapping Program– [Benjamin, unpublished – will be part of IMR Weed Inventory and Mapping Guidelines]

Goals and Objectives for Weed Inventory and Mapping

Goals:

1. **Determine distribution and abundance of all invasive (or potentially invasive), non-native plant species populations within and surrounding a park.**

2. **Encourage and support multi–agency dialogue and inventories across boundaries.**

Guidelines for Weed Inventory and Mapping

- **Set clear goals and objectives.** Weed inventory and/or monitoring protocols will vary depending on numerous variables (e.g. park specific management objectives, resource values, habitat type, terrain, land use). Park management objectives need to ensure that the selected inventory/mapping and monitoring protocols provide the data necessary to efficiently manage and evaluate the resource values of the park.

- **Integrate weed inventory and monitoring data collection and management efforts with other vegetation management activities to the greatest extent possible.** Integrating weed inventory and monitoring efforts with other vegetation management activities (e.g. vegetation mapping and characterization, rare plant inventory and monitoring, fire effects monitoring, weed team program) will assist in making the best use of limited people and dollar resources. This integration should focus on the *bioregion* of the park/network and should include NPS efforts as well as efforts of other agencies and entities.

- **Prior to conducting field inventories, collect all available existing information about alien species known or with potential to occur in the park or surrounding areas.** Assess all existing vegetation data for the park **and** consult with other local weed managers from county, state and federal agencies, as well as from weed councils external to the park. Remember that parks are not islands. External land managing entities can provide valuable information on existing or potential weed infestations occurring adjacent to park boundaries.

- **Prior to mapping, develop a list of known and potential weeds for your park.** Determine which species are essential to be inventoried and mapped and which are not likely to cause significant resource damage. Noxious and highly invasive weeds should always be mapped.

- **If it is not feasible or desirable to inventory for all alien species, develop a priority list of target species.** Use of an alien ranking system (such as APRS 2002) will greatly assist in identifying priority species for mapping, monitoring, and management. But remember, invasive plants can often undergo a lag phase and priorities can change over time. Species rankings should be re-evaluated on a routine basis (e.g. every 2-3 years).

Guidelines for Weed Inventory and Mapping (Continued)

- **Base the scale and intensity of the inventory on the level of accuracy needed.** Accuracy requirements will change with scale and sampling intensity. Units of a park with significant resources at risk should be inventoried and mapped at a higher level of accuracy (e.g. greater mapping intensity) than units with less significant resource value(s). For example, for park areas with high resource values at risk (T&E habitat), it may be desirable to identify and map a minimum of 90% of all invasive plant populations within a survey unit (high intensity – high accuracy). For large parks where it may not be practical to perform high intensity surveys for the entire landscape or that have little or no information on invasive plant locations, the baseline inventory is then likely be at a much rougher scale (e.g. less accurate – 60% of noxious weed populations). This information would then be used to target or identify areas that may require more intensive surveys. Consider how much time and effort you can devote and who will be responsible for collecting the data – these factors will also help in defining the scale, intensity, and accuracy of the inventory and mapping process.

- **Focus inventory efforts on new invaders and/or species that will be the most difficult to control if not managed early.** Remember that complete eradication of a alien population is usually only possible when the alien population is relatively small.

- **Make areas of the park with high natural/cultural resource values a high priority for inventory and mapping.** It may not be possible to inventory all park lands at once; therefore, weed inventory and mapping will need to be performed in multiple phases. Units or areas of the park that support significant resources of management concern or interest (e.g. T&E species, riparian habitat, wetlands) and/or areas with the highest potential to support weed infestations (e.g. along road corridors, disturbed sites, old home sites, riparian corridors) should be inventoried first (see Timmons and Owen 2001 for guidance on ranking places).

- **Plan a systematic survey to include as much of the land area as is possible.** There are pros and cons to both random sample surveys and delineated (targeted) surveys. Sample surveys are time repeatable and cost effective, but are less efficient at locating rarer species (e.g. new/small infestations). Delineated (targeted) mapping is more intensive and usually more costly in terms of time and dollars, but results in higher levels of accuracy and provides an increased ability for early detection of new infestations. Remember, the type of inventory and/or monitoring protocol used will be driven by specific management objectives for a given unit and/or the values at risk. Both survey categories, random sample and delineated, can be applied in a systematic fashion to increase efficiencies in locating potential weed "hot spots."

Guidelines for Weed Mapping and Inventory (Continued)

- **Park units that are 1,000 acres or less in size should be inventoried with a high level of accuracy.**

- **Park units that are greater than 1,000 acres can be inventoried less intensively.** However, intensive efforts should be undertaken in areas that can serve as weed vector/migration corridors (e.g. human and animal trails, frontcountry campgrounds and picnic areas, roadways, ditches, streams, and in areas with significant resource value(s) such as T&E species or high quality natural areas).

- **When possible, structure inventory protocols to ensure they are applicable/appropriate for future monitoring efforts or repeated measures.**

- **Develop a system for documenting areas surveyed that do not support target species as well as those that do.** As critical as it may be to know where weeds are, it is even more critical to know where weeds are not. Protecting non-infested land areas is of highest priority and is the basis for proactive management. Ensure that your weed inventory efforts include a means to document/record areas of land that are not infested. These areas should also be considered as high priorities for establishing routine and long-term monitoring (e.g. ensure early detection).

- **Design inventory efforts to be adaptive.** When patterns of invasion are identified in certain sites/areas, adapt surveys to target those types of sites/areas.

- **Expand inventory efforts outside of park boundaries.** The extent of these expanded efforts will vary based on target species life history attributes, regional distributions, vectors, the values of the park relative to surrounding lands (e.g. if a river runs through the park), the ability to survey private lands, and other characteristics of the surrounding social landscape.

Monitoring for Prevention and Early Detection

General Information

Exotic invasions often follow a typical pattern. Seeds or plant fragments arrive by various mechanisms and become established; however, the persistence of these new individuals is tenuous because of unsuitable habitat or low population levels. If the exotic invaders persist it takes some time (the lag phase) for the population to increase in size. Only after some time specific to species and habitat has elapsed does the population suddenly expand. Control efforts are most cost effective and likely to succeed during this lag phase.

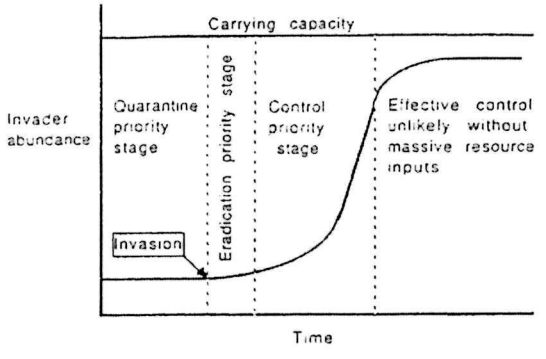

Figure 2: Phases of weed invsion and priorities for action at each phase. Ease of treatment of an invasion problem declines from left to right (after Chippendale 1991).

Thus the early detection of newly arriving exotic species is an important component of a control program. Unfortunately, these newly establishing populations are rare and consequently difficult to detect.

This section identifies goals, objectives and guidelines to prevent new introductions and detect new populations early in the establishment phase. When applying the information presented in this section, it is important to:

- Work outside of park boundaries to manage at a landscape scale. Identify a buffer zone which, when adequately managed in cooperation with partners, will more effectively accomplish invasive species management goals.

- Integrate efforts with ongoing projects in the park/network/area and with other agencies (fire effects monitoring, vegetation mapping, weed management areas). Data from these efforts broaden a surveillance system.

- Where possible, standardize prevention and detection programs across parks within a network or ecoregion.

- Keep abreast of newly emerging surveillance and sampling design strategies to make programs more effective and efficient. This may involve stepping outside of the mainstream land management and conservation disciplines (e.g. novel sampling designs from oil and mineral exploration literature).

- Consider that integrated monitoring can be developed across multiple scales: park subunit, park, buffer zone around park, and region.

- One role of inventory and monitoring is to provide relevant information to determine appropriate management action along a continuum (e.g. prevention, detection, eradication, containment, suppression, or no action) for an invasive, vascular plant species or conservation value (e.g. site, native species, assemblage or ecosystem function).

- Integrate monitoring for prevention and early detection goals and guidelines with ongoing inventory, monitoring and research efforts.

- Develop a sound information base for invasive aliens; control can only be achieved by acting at multiple spatial scales and in regional partnerships. This information can be used by park managers acting in concert with multiple agencies to develop new strategies for stemming the tide of alien invasions.

- The strengths and weaknesses of various survey and mapping methods for prevention and early detection need to be investigated (e.g. grid-based, probabilistic, species or patch-focal mapping, adaptive sampling).

- Spatially explicit non-occurrence information is essential for predictive monitoring.

Goals and Objectives for Prevention and Early Detection Monitoring

Goals:

1. **Prevent new invasions through best management practices and awareness of invasive species that have a high potential to invade a park.**

2. **Detect the early establishment of invasive alien species and provide timely monitoring feedback to target control efforts toward the most severe threats.**

Objectives:

1. **Identify new and emerging threats.**

2. **Develop and implement a surveillance system.**

3. **Target limited management resources toward highest priority risks.**

Guidelines for Prevention and Early Detection Monitoring

The following guidelines presume that the park or network has completed a vascular plant inventory and identified, prioritized, and mapped the distribution of exotic species within the park(s).

Guidelines for Objective 1: Identify new and emerging threats.

- **Determine which species are not present in park/area, but threaten the area.**
  - Develop a communication network beyond the park (state and federal agencies, private land managers, literature and academic contacts, websites such as TNC exotic plants, Southwest Exotic Plant Information Clearinghouse, etc.).
  - Develop a regional understanding of preeminent threats.
  - Identify direct human activities serving as dispersal vectors (e.g. construction equipment, park animal hay, horticultural use, etc.)

Guidelines for Objective 2: Develop and implement a surveillance system.

- **Concentrate sampling or searching effort for highest information return.**
  - Gather information on ecology of high priority species (dispersal mechanisms, limiting factors, etc.).
  - Identify invasion corridors and vectors of spread.
  - Identify areas of high invasibility (high nitrogen sinks like riparian corridors, cultural sites).
  - Identify areas of high conservation value (T&E species, wetlands, uninvaded areas, wildflower meadows, etc.).

- **Develop and implement a sampling design that fits the rarity and distribution of the species/new arrivals** (e.g. adaptive sampling designs). Special sampling designs may need to be developed which are designed to be able to detect rare events or very sparse distributions of new invaders. Research may also be needed to help predict corridors for invasion and habitats which are most vulnerable to invasion.

- **Collect relevant biotic and abiotic ancillary data that allow you to understand why species are located where they are and to predict where they may spread.**

- **Create information-gathering capacity for opportunistic data** (visiting botanists, tourists, rangers, federal and state employees, etc.).

- **Develop predictive tools and models to improve surveillance system** (e.g. spatially explicit models of likely invasion patterns and vectors of spread, life history and disturbance models overlain on landscape habitat mosaic, spatial interpolation, etc.).

Guidelines for Prevention and Early Detection Monitoring (continued)

Guidelines for Objective 3: Target limited management resources toward highest priority risks.

Monitoring well established populations presents different sampling issues than detecting newly establishing populations. The management goal shifts from searching for and destroying small populations to one of containment or exclusion. The objective of monitoring is to identify invasion fronts or defensible boundaries.

- Create sampling designs that are flexible and adaptive to avoid over- or under-sampling (probability of occurrence ranges from moderately frequent to common event). For example, the Prairie Cluster parks have successfully used an adaptive sampling strategy that increases sampling intensity in areas where invasive plant populations have been found (Appendix C).

- Consider the dispersal modes of target species. Is there a single front of plants advancing towards or through the park? Are there small spot infestations that occur far away from the main plant population?

- Include a modeling component that is a synthesis of accumulated data and experience and can help explain or predict the spread of invasive plants. Computer and GIS models are useful tools, but even a written summary may lead to a better understanding of invasion dynamics and appropriate management strategies.

Monitoring the Effects of Management on System Recovery

General Information

It is assumed that each park will have management goals including, for example, desired future conditions of plant communities. Where invasive species are currently or potentially a problem, you will likely take management action. Effects monitoring is imperative to determine whether management goals are being reached.

There is a continuum between research and monitoring. Monitoring is used to tell whether a change has occurred (or not). If it has become necessary to determine if a specific factor is responsible for a change, research is indicated. No single protocol can answer all these questions on every site. Nonetheless, a well-designed monitoring program can give an indication of the success of a management strategy.

This section identifies the goals, objectives and guidelines for monitoring the effect of management on recovery of systems impacted by invasive plants. When applying the information in this section, it is important to:

- Utilize consistent protocols for both monitoring and for the databases that record, share and analyze data. The work of different parks within networks should be complementary. For example, if monitoring at one park is applicable for other parks or agencies (BLM, USFWS), little or no intensive monitoring may be required.

- Identify common questions that could be answered by monitoring and used in the design of network-wide monitoring.

- Identify unique ecological settings for which there is little or no data and develop appropriate monitoring schemes to collect that information. For example, there are few data on weed management strategies for altitudes over 5,000 feet in the West.

- Include the three phases of monitoring in your program:
    1. Implementation monitoring--did you do what you said you were going to do?
    2. Effectiveness monitoring--what was the effect of the treatment on the target species, and how much was eradicated?
    3. Environmental effects monitoring--what was the effect on soils, native vegetation composition and structure, and ecological processes?

Goals and Objectives for Monitoring the Effects of Management on System Recovery

Goal:

Measure the effects of invasive species management on the recovery of the desired plant community.

Objectives:

1. **Have a strategic plan that includes an invasive plant component.**

   Develop a specific plan to address invasives that are deemed to be a problem. A component of this plan is a protocol for monitoring, treatment, and evaluation of changes in the native plant community within which the invasive plants were found.

2. **Describe existing, desired and potential plant communities in terms of floristic components and/or functional group diversity.**

   The potential plant community will guide management actions, with the realization that resources or changes in the ecosystem may not permit desired results. A decision must be made regarding the desired plant community, given these considerations. The condition of the existing plant community will determine whether or not management actions can feasibly restore the desired condition or if the system is not restorable.

3. **Because management actions may influence ecological processes, monitoring should also include factors that indicate change in those processes.**

   In most cases you will monitor changes in abundance and distribution of invasive species, but keep in mind that the real goal of management is to bring about positive changes in the desired native plant community and the processes upon which they depend. Monitor variables that indicate those changes in processes and components of desired community where appropriate. Examples of such variables include soil and water data, nutrient cycling information, fire frequency and intensity, etc.

4. **Define thresholds and trends that will trigger management (e.g. disturbance, colonization).** One might set a threshold abundance of an invasive plant; once the threshold is reached, current management is evaluated and enhanced or modified as indicated.

Guidelines for Monitoring the Effects of Management on System Recovery

- **Identify desired plant community.**
- **Identify management goals.**
- **Determine the existing community.** Identify dominant life forms.
- **Determine the invasive species' current distribution and abundance.**
- **Determine potential plant communities.** Hypotheses are ok.
- **Determine the management actions that may result in the desired community.**
- **Develop a management plan.**
- **Take management action.**
- **Develop monitoring framework based on management goals and objectives.** For example, if your management goal is to maintain a certain native plant community, your objectives may include maintaining at least 70% cover of native species and no more than 30% cover of invasive species, you could monitor for those levels. (*Measuring and Monitoring Plant Populations*, Elzinga, Salzer and Willoughby (1998) provides excellent guidance on creating a monitoring program.)
    - Ensure that protocols meet the network standards.
    - Stratify monitoring based on pre-existing information and attribute data to maximize efficiency.
    - Determine desired plant community (i.e. literature search, herbarium records, vegetation maps, historic information).
    - Develop appropriate sampling strategies (should be consistent with inventory methods when possible).
    - Characterize/document management strategy.
    - Include money and time for monitoring and data analysis in your invasive species management program.
    - Analyze and synthesize monitoring data every year (or every year that data are collected).
    - Use results of monitoring data analysis to guide management decisions.
- **Ensure that monitoring is consistent and repeatable.**

Monitoring Status and Trends of Invasive Plants

General Information

Ecosystem processes operate over multiple spatial and temporal scales, from microbial dynamics to global nutrient and weather systems, over the span of seconds to geologic timescales. The traditional model of land management has focused on only the narrow strata of vegetation stands and political units. As organisms are typically not constrained by arbitrary political boundaries, effective resource monitoring and management must likewise be extended to biogeographical units. This can best be achieved through collaboration with other park units, land management agencies, scientists, non-government entities, as well as direct outreach and education of the public. Inherent to this effort is partnering to achieve shared goals, quality science, and feedbacks to management.

This section identifies goals, objectives and guidelines to monitor for invasive species status and trends.

Goals and Objectives for Monitoring Status and Trends of Invasive Plants

Goal:

Identify patterns and evaluate trends of invasive and potentially invasive alien plant species on multiple temporal and spatial scales, compatible and appropriate to the bioregion.

Objectives:

1. **Develop scientifically credible, repeatable sampling techniques to detect patterns and trends of alien plants within parks, surrounding areas and in the bioregion.**

2. **Utilize monitoring data to provide reliable predictions of probability of spread and potential distributions of invasive species.**

Guidelines for Monitoring Status and Trends

Guidelines for Objective 1: Develop scientifically credible, repeatable sampling techniques to detect patterns and trends of non-native plants within parks, surrounding areas and in the bioregion.

- **Clearly define goals and set measurable objectives.**

- **Define the area of interest (e.g. network environs, bioregion, etc.).**

- **Aggregate existing ecological data and knowledge for the species of interest and the ecosystem, such as:**
  - Known distribution and abundance of invasive species
  - Condition and composition of native vegetation
  - Life history strategy of invasive species
  - Natural and anthropogenic disturbance regimes
  - Ecosystem functional attributes – nutrient/water/energy cycles, species interactions
  - Landscape arrangement/ topographic and edaphic heterogeneity
  - Patterns of land use
  - Areas of special concern – e.g., rare habitats, T&E species
  - Paleoecology

- **Select parameter(s) of interest based on goals and objectives.**
  - **Explanation/examples**

- **Consult with a statistician on design and define method of analysis.**
  Careful design of a sampling strategy is critical for documenting and predicting non-native plant encroachment of natural systems in park units. Sampling strategies must evolve directly from specific goals and objectives developed with partners. There are a few guiding principles to which any sampling strategy should adhere:

  - Strategies must be appropriate to the bioregion and species of concern.
  - Methods should be quantitative and repeatable.
  - Scope of the effort must be scaled to the problem but constrained by practical realities.
  - Partners must make a long-term commitment to the effort.
  - Roles of all partners must be clearly defined.
  - Results of monitoring must be linked to management actions.
  - Data products must be disseminated widely.
  - Data must be spatially explicit.

Guidelines for Monitoring Status and Trends of Invasive Plants (continued)

- **Create pilot studies to test and refine methodology and sampling framework (temporal and spatial considerations).**
- **Define data management and archiving protocols.**
- **Arrange peer review of sampling strategy.**
- **Finalize strategy and implement.**

Guidelines for Objective 2: Utilize monitoring data to provide reliable predictions of probability of spread and potential distributions of invasive species.

As monitoring and research data accumulate, a better understanding of patterns and processes of invasive species will allow for the development of predictive models. These predictive models can be used to (1) identify areas to concentrate control efforts, (2) highlight knowledge gaps that must be addressed, and (3) conduct "what if" simulations to test control efforts. These models would be developed in an iterative process in which additional data is incorporated to refine the predictive power of the model. Models will therefore move from conceptual models based on known or hypothesized mechanisms of encroachment (e.g. reproductive strategy, interaction with disturbance, etc.) towards empirical models that include spatial predictions of spread and, ideally, the effects of control efforts. Empirical modeling is beyond the scope of most monitoring programs, and should be approached through collaboration with academia.

Developing and Sharing Data Collaboratively

General Information

Weed management (including inventory and monitoring) in a vacuum (independent from the efforts, knowledge, and experience of others beyond the immediate park boundaries) is grossly inefficient. Without minimal collaboration and information sharing, it is extremely difficult to set alien plant management priorities accurately, allocate resources in a cost-efficient manner, ensure the long-term preservation and protection of park values (natural and cultural), and develop internal and external constituencies that support weed management programs.

Although a park's primary responsibility is to itself and to upholding the mission for which it was established, parks have a role and responsibility in promoting and supporting collaborative information exchange among local weed and natural resource management professionals. It is in the self-interest of the park (in fulfilling its mission) and the agency (as a cooperating federal land management agency) to do more than simply share data passively or opportunistically.

To the extent that a park can place the distribution and abundance of its invasive species in the context of a larger landscape, the park's efforts to identify management objectives and allocate resources efficiently will be improved as the scale of that landscape grows in size. Determining accurate and achievable management objectives (e.g. eradication, containment, suppression) based upon a myopic perspective of only one individual's jurisdiction is nearly always flawed and leads to an inefficient allocation of limited financial and personnel resources. However, determining such objectives becomes more accurate and cost-effective as this view of the species' distribution and abundance broadens. It then encompasses a larger landscape that is more cognizant of vectors such as roads and rivers, the relative abundance of target species, and the propagule pressure impacting existing populations and metapopulations. In addition, engaging partners to develop a shared, landscape level perspective of the distribution of target species and valued resources may lead to a shared solution that directs partner resources in a direction complementary to those allocated by NPS. (Perhaps this solution is devised through some consensus-building process.)

Goals and Objectives for Developing and Sharing Data Collaboratively

Goal:

Identify and opportunistically gather--from internal as well as external sources--information and data that enhance immediate park needs and alien plant management objectives.

Objectives:

1. **Query local weed managers, neighboring landowners and managers, and experienced botanists to determine the presence/absence and location of targeted species and relative abundance within and adjacent to the park. DETERMINE:**
    a. Species of NPS concern as well as those of concern to landowners within the buffer zone.
    b. Location and abundance, especially relative to vectors, and affinity for specific habitat types.
    c. Suspected or known sources and dates of introductions.

Goal:

Facilitate the exchange of inventory, mapping, and monitoring information among partners primarily within the buffer zone that will enhance the success of management efforts to protect identified natural and cultural values within the park and the natural functions and cultural landscapes that support them.

Objectives:

1. **Identify common management objectives and the information necessary to support group or complementary data gathering and analysis.**
    a. Develop a communication network among natural resource and weed management professionals within the buffer zone to identify and detect the spread of known and potential species within buffer zone.
    b. Identify pertinent and knowledgeable participants.
    c. Implement passive systems such as listserves, newsletters, websites, etc.

Goals and Objectives for Developing and Sharing Data Collaboratively (continued)

Objectives (continued):

2. **Develop active communication strategies to ensure timely transfer of new and emerging information.**

3. **Establish a regular means to communicate findings of monitoring efforts that measure the success of management/restoration efforts to partners and seek out ideas for improved weed management/restoration techniques.**

Goal:

Promote efforts to standardize data collection and reporting and/or contribute to the development of a process for acquiring and sharing data in compatible formats at the local, watershed, and state levels.

Objectives:

1. **In cooperation with partners, create or adopt minimum inventory, mapping, and monitoring standards (e.g. North American Weed Management Association (NAWMA) standards) that will facilitate the sharing of data among neighboring jurisdictions regarding the distribution and abundance of target species.**

2. **Work with partners to devise a system for viewing landscape scale invasions that relies upon existing data (GIS data from NAWMA standards that can be uploaded into a landscape perspective that utilizes consistent units of acreage such as townships, quadrangles, etc) as well as the acquisition of knowledge presently locked in the brains of weed management and natural resource professionals.** Examples of such products include the PLANTS database maps and the Invaders Database (although these use counties which are not a consistent unit of acreage) or the Southwest Exotic Plant Mapping Program (SWEMP) (Appendix C).

3. **Ensure that internal NPS data collection and management is coordinated across parks, networks and Exotic Plant Management Teams.**

Goals and Objectives for Developing and Sharing Data Collaboratively (continued)

Goal:

Manage and contribute data that can be used by researchers and others investigating landscape level trends and patterns.

Objectives:

1. **Respond to data requests in a timely manner and solicit final products from researchers.**

2. **Endeavor to adopt data and database standards (including metadata) that can be easily utilized by outside researchers.**

Communication and Outreach

General Information

The purposes of communication and outreach are to facilitate data exchange, improve efficiency, educate and be educated, create opportunities for cooperative work, increase political support, build a holistic understanding of the ecosystems and land management outside parks, and profit from the synergy of multiple perspectives and expertise. The following communication and outreach guiding principles should be understood:

- Building relationships takes time
- Be honest (and real)
- Share knowledge and data freely (except where exempted by law)
- Reach out first; go to them
- Other people are just as busy as you are

Goals and Objectives for Communication and Outreach

Goal:

Foster communication between federal and state agencies, private landowners and other involved parties to:

- **Facilitate data exchange.**
- **Improve efficiency.**
- **Educate and be educated.**
- **Create opportunities for cooperative work.**
- **Increase political support.**
- **Build a holistic understanding of the ecosystems and land management strategies outside parks.**
- **Profit from the synergy of multiple perspectives and expertise.**

Guidelines for Communication and Outreach

- **Provide Interpretation to the Public**

  An interested and informed public can greatly assist with early detection and monitoring, and facilitate prevention of additional infestations. Programs can be established with volunteers who help with treatment and control of exotics. For example, at Denali NP volunteers can dig out dandelions for a week along the park road in exchange for camping space and transportation at the far (best) end of the park road. An active and educated public can also bring pressure to bear on the political process, ranging from additions to various weed lists to the budget process.

  Networks or NPS regions can develop common interpretative materials that are applicable throughout a bioregion. Such materials could be used to present programs to park visitors, schools and special interest groups. Common training could be held for park and concessionaire interpreters about identification of weeds, their impacts on park ecosystems and prevention measures. If park control programs are occurring near popular access routes, interpretative signs could be erected. Written materials such as brochures can be available for programs and trade fairs, various open house days at parks or other events. Such brochures may be useful in large areas of the country.

  One facet of the public that is key to non-native plant "control" is the gardening industry. Special efforts need to be made to reach out to the nursery industry and Master Gardner groups to elicit their expertise in selection of native or non-invasive plants for gardens, and to help locate and document species which are escaping from human cultivation. This may be worthy of a national level effort to contact seed catalog and Internet companies. Monitoring which invasive plants are marketed by local nurseries is essential to the prevention of new park invasions.

- **Interact With and Educate Other NPS Divisions**

  The spread of non-native plants is an issue that cuts across many park divisions. Interpretation, as discussed in outreach, is vital for spreading the information in a format easily grasped by the general visiting public.

Guidelines for Communication and Outreach Activities (continued)

Special attention needs to go to any division that plans for, contracts, oversees or drives heavy equipment on park lands. Ideally, resource specialists knowledgeable about invasive species and their ecological constraints would help review construction plans, include siting and landscape design, for all construction disturbances on park lands. Contract specifications should be reviewed by resource personnel, especially with regard to plant material sources for landscaping, fill, topsoil and gravel sources, cleaning of equipment BEFORE it is brought to park lands, and compliance with these specifications should be reviewed after construction is finished. After all, seeds move with dirt—not on paper.

Additionally, resource staff need to work closely with maintenance/construction personnel during work that involves moving dirt or disturbing natural vegetation. Native plant materials and topsoil can be stockpiled for use in reclamation. Trail construction can be crafted to encourage native plants and discourage exotics. (For example: trail hardening with sterile or recycled plastic matting on wetland areas, rather than letting social trails develop in the mud.)

Often backcountry rangers have a resource background or interest. A few minutes during ranger orientation about non-native plant identification can yield information about early infestations or spread of species. Fire crews and other personnel with backcountry duties can also be useful resources.

- **Exchange Information and Data with Other Land Managers**

Effective communication with surrounding and inholding landowners and managers is necessary to elicit actions on lands where NPS has little or no direct control. It may take many incremental steps to establish relationships with people who have different interests or mandates than the NPS. Ideally, all levels of park management would build these relationships. An open and cooperative attitude on the part of individual NPS "bureaucrats" can go a long way, not only for exotic vegetation, but also with other resource or park management programs.

Frequently, another place for NPS to lend expertise would be with highway construction and maintenance projects. Roadside seeding for stabilization brings persistent and/or highly invasive species right to the edge of parks, where they are easily transported onto parklands by vehicles and pedestrians. Effective and ongoing communication with transportation personnel and their contractors can help prevent introductions of non-native species.

Guidelines for Communication and Outreach (continued)

- **Participate in Cooperative Projects**

  Effective communication and information exchange will often lead to cooperative projects with other groups. These projects can involve data collection for inventory, early detection and monitoring, projects for treatment and control of non-natives, and restoration of native ecosystems. There is often economy of scale and greater efficiency by planning coordinated projects, personnel and logistics on NPS and neighboring lands. Limited NPS funds can frequently be leveraged through cost sharing programs or contribution of in-kind services and equipment. There is great teambuilding value in sharing work. The common goal of controlling an infestation of invasives can supercede conflicting philosophies in other land management arenas (e.g. off-road vehicle users, etc.).

- **Participate in Cooperative Research**

  When data from many sources are available in one place, resource scientists can analyze and interpret a much larger and holistic view of the ecosystem than is available with limited park data. Patterns and trends over a large landscape place park data in perspective and can guide monitoring protocols. Often academic institutions have historic data sources that can be mined (by graduate students!) for earlier conditions or successional trajectories. Scientists in other disciplines, or people with long history in a place can give different perspectives that trigger new interpretations or theories.

  NPS lands can provide unique opportunities to research scientists to conduct descriptive or inventory projects, study life history of selected species and generally add to the overall ecological knowledge base of an area. Facilitating appropriate research projects is an excellent way to stretch resource funding and avail the park of specialized scientists. They often bring money and students from other funding sources, and parks may be in a position to assist with background information, data and logistics.

Guidelines for Communication and Outreach (continued)

- **Conduct Outreach to Legislative Staffs at Local, State and National Levels**

  The general public and their elected officials are just becoming aware of the magnitude and impacts of the non-native species. Often elected bodies make decisions, which greatly affect the importation, establishment and spread of invasive species. Often these effects are spin offs of well-intentioned legislation. Seek out officials of local governments, and contact staffs of state and national level legislators. Have briefing papers and numbers ready (especially about financial costs and benefits). Be prepared to speak knowledgably beyond the borders and purview of NPS. Local media such as newspapers, newsletters, radio and television are useful vehicles to get the word out beyond NPS interests. There may be occasions to give tours of control or reclamation projects. Use them and praise your cooperators.

Appendix A: Characteristics of a Good Monitoring Protocol

Characteristics of a Good Monitoring Protocol

Steven G. Fancy, National Monitoring Coordinator

What should be included in a good Monitoring Protocol?

A well-developed, field-tested and reviewed Monitoring Protocol is a critical component of Quality Assurance for any monitoring program. Quality Assurance can be defined as "the policy, procedures, and systematic actions established for the purpose of providing and maintaining a specified degree of confidence in data integrity and accuracy throughout the lifecycle of the data, which includes input, update, manipulation, and output". The whole purpose of monitoring is to detect and document change over time. When attempting to scientifically detect and document change based on resource sampling, we must use a very consistent and exactly repetitive method of collecting and recording data. Otherwise, it is not possible to determine if the changes observed within the sample data are a result of the method by which the samples were obtained or of actual changes in the resource being monitored. This requires that very detailed and exacting monitoring protocols be established at the start of any long-term monitoring project. Monitoring protocols are:

- A key component of Quality Assurance of a monitoring program to ensure that data meet defined standards of quality with a stated level of confidence;
- Necessary for the program to be credible, so that data stand up to external review;
- Necessary to detect changes over time and for the program to survive turnovers in personnel;
- Necessary to allow comparisons of data among places/agencies.

Why do we need Monitoring: Protocols?

If a protocol is to meet the objectives listed above, it needs to be much more than a detailed description of field methodology. A good monitoring program will be well thought out and have a high probability of detecting change in the resource being monitored. It is important to make a large up-front investment in the development of the monitoring program and to clearly represent this investment in the protocol document. It has been said that designing a monitoring project is a lot like getting a tattoo-you want to get it right the first time, because making major changes later can get messy and will be painful. Careful documentation of the questions being asked; the sampling framework; step-by-step procedures for collecting, managing and analyzing the data; and expectations on how the data will be presented and used are all part of "getting it right the first time". A good monitoring protocol will include extensive testing and evaluation of the effectiveness of the procedures up front, before they are accepted for long-term monitoring.

No matter how much advanced planning goes into protocol development, minor changes and improvements in such things as methodology and approaches to data analysis and reporting are to be expected, and periodic reviews and improvements to protocols should be a part of the program. For this reason, it is recommended that a Monitoring Protocol consist of three parts:

1. The **Protocol Narrative:** an overview of the various components of the protocol, including there source issue being addressed, measurable objectives, sampling design, field methodology, data analysis and reporting, personnel requirements, training procedures, and operational requirements. Details for the various components should be provided in the SOPs.
2. A series of **Standard Operating Procedures (SOPs)** that are periodically updated and that present the details on how all aspects of the components described in the narrative will be carried out. The SOPs should be written in the form of instructions, with step-by-step details of how to carry out the procedure. One of the SOPs should explain the procedure for making revisions to the protocol and archiving previous versions, and each SOP should include its revision history. Data sets should also indicate which version of the protocol was being used when the data were collected. The number and content of the SOPs are collected. The number and content of the SOPs are determined by the Principal Investigators who develop them.

3. **Supplementary Materials** such as example databases, maps and photographs.

Recommended Format for the Protocol Narrative:

Background and Objectives
- Program background and objectives
- Park natural resource issues of concern and rationale for selecting this resource to monitor
- Summary of current and historic monitoring activities related to the resource being monitored
- Summary of relevant laws and regulations relative to the resource being monitored Measurable objectives -what are the specific questions being addressed?

Sampling Design
- Rationale for selecting this sampling design over others.
- Site selection
  - Criteria for site selection; define the boundaries or "population" being sampled
  - Procedures for selecting sampling locations; stratification, spatial design

Sampling Frequency and Replication
- Recommended number and location of sampling sites
- Recommended frequency and timing of sampling
- Level of change that can be detected for the amount/type of sampling being instituted.

Field Methods
- Field season preparations and equipment setup (including pennitting/compliance procedures)
- Sequence of events during field season
- Safety precautions
- Details of taking measurements, with example field forms
- Voucher collection, preservation and storage procedures if applicable
- Post-collection processing of samples (e.g., lab analysis, preparing voucher specimens) End-of-season procedures

Data Management
- Overview of database design
- Data entry, verification and editing
- Metadata procedures
- Data archival procedures

Analysis and Reporting
- Recommendations for routine data summaries and statistical analyses to detect change
- Recommended annual report format with examples of summary tables and figures
- Recommended methods for long-term trend analysis (e.g., every 5 or 10 years)

Personnel Requirements and Training
- Roles and responsibilities
- Qualifications
- Training procedures

Operational Requirements
- Annual workload and field schedule
- Facility and equipment needs
- Startup costs and budget considerations

References

Acknowledgments: The content of these guidelines is based largely on work by Lisa Thomas of the Great Plains Prairie Cluster LTEM program of the NPS and Karen Oakley of the USGS/BRD working with the Denali NPP LTEM program. Their contributions are appreciated.

Appendix B: Information/Data to Collect While Performing Weed Inventory and Mapping Activities

A broad range of information is needed for effective management of invasive plants, including data on ranges of species, their abundance, habitat preference, rate of spread, impacts to wildlife and other species, use of natural control agents, and measurements of response to control actions. Once accurate baseline data is obtained, maps in association with long-term monitoring become invaluable tools for addressing the broad range of information identified above and are required to effectively and efficiently address weed management issues.

The careful and consistent recording of data in a standardized format is a critical step in ensuring proper data organization, especially for long-term monitoring efforts. The standardized format also maximizes the analytical ability of the resource manager at multiple scales – the individual unit or park, network of parks, and at the regional level. There is additionally an enhanced ability to exchange data with other external agencies and organizations that utilize similar data standards with minimal manipulation of the data.

Modern database and spreadsheet software are very powerful tools for organizing and sharing data. The primary consideration in the development of either a park-specific, regional, or national database is deciding what data fields of information **must** be put into standard format to maximize both the information sharing and analytical abilities of resource managers at multiple scales.

Five primary categories of data variables have been identified to assist in the increasing the NPS's abilities in addressing weed management issues. These categories include: (1) Agency Specific Metadata, (2) Location Data (for Survey Units and for individual weed populations), (3) Invasive Plant Species Data, (4) "Changes Over Time" Data, and (5) Site Environmental Information (Abiotic and Biotic). Specific data elements were identified under each of these categories and were identified as either "required" or "optional" for collection. Table 1 below provides an overview of the categories and their associated data elements.

The "required" data elements will be considered as the "minimum mapping standards" for weed mapping or sightings information in the NPS and parallel those identified by the North American Weed Mapping Association (NAWMA) (Beard, *et. al.* 2001). The decision to use the NAWMA mapping standards as requirements within the NPS was based on the following:

- **Use of the standardized NAWMA standards will enhance regional and service-wide analytical abilities related to invasive plants. This will, in turn, allow for an enhanced ability to identify and communicate regional & service-wide weed management strategies and/or needs.**

- **The standards ensure a consistent definition of "acre of infestation" across all park units within the region. The mapping standards allow for the reporting of infestations down to 1/100 of an acre. Although this may overestimate reporting**

of a single weed plant or small infestation, it will still provide much more accurate data than our current reporting abilities.

- **Other federal agencies, such as the U.S. Forest Service and Bureau of Land Management, have already formally adopted the NAWMA mapping standards. These standards have also been adopted for use by most of the states within the western United States. This substantially increases our data/information sharing abilities across the greater landscape.**

- **Most existing formal weed mapping/reporting programs (e.g. Montana Weed Inventory and Mapping Program, Southwest Exotic Mapping Program, {ADD IN NAMES OF PROGRAMS IN ADDITION TO THOSE IN THE IMR} already collect or will be incorporating data that encompasses the NAWMA minimum mapping standards. Similarly, most existing individual park weed mapping programs already include information related to the "required" data elements or can incorporate them with little or no difficulty.**

Because the NPS has a strong preservation mandate there is a benefit from collecting additional information related to the ecological and environmental parameters associated with weed occurrences. *Many of these data elements have been identified as "optional" within these guidelines, but are highly recommended for inclusion in any weed mapping effort.* These additional data elements are not meant to discourage the recording of casual observations by park staff or visitors, but could be collected separately by natural resource management staff during a follow-up visit to confirm a casual sighting. Similarly, the required and optional data elements do not prohibit the parks from collecting any additional data that they feel are important to a park's weed management program.

The following data elements have been identified by the North American Weed Management Association (Beard et.al, 2001) and the Intermountain Region of the NPS (Benjamin, 2001) as critical or effective invasive weed documentation and for inter-agency communications. These data elements have been adopted for servicewide use by the National Park Service.

GENERAL INFORMATION

***PARK WEED CONTACT** (Name and Phone):* This is a **required** character field and contains the contact information for the individual responsible for managing the parks' weed management program/database.

As the NPS begins to coordinate a regional and national weed management programs, it will be especially important that each park identify an individual to serve as a primary contact for obtaining weed management data and for communicating weed management needs to regional personnel.

REGION: This is a **required** 3-letter character field based on the appropriate 3-letter acronym as identified in the table below.

NER	Northeast Region
SER	Southeast Region
NCR	National Capital Region
MWR	Midwest Region
IMR	**Intermountain Region**
PWR	Pacific West Region
AAR	Alaska Area Region

I&M NETWORK: This is a **required** 3-4 letter character field identifying the appropriate 3-letter acronym for one of the 9 I&M networks found within the Intermountain Region.

RMN	Rocky Mountain Network
GYN	Greater Yellowstone Network
GPN	Great Plains Network
NCPN	Northern Colorado Plateau Network
SCPN	Southern Colorado Plateau Network
SDN	Sonoran Desert Network
SPN	Southern Plains Network
CDN	Chihuahuan Desert Network
SEN	Southeast Network
MDN	Mojave Desert Network

PARK UNIT: This is a **required** 4-letter character field representing the appropriate park unit code. *Example: Organ Pipe Cactus National Monument* – ORPI.

STATE: This is a **required** 2-letter character field that identifies the state code in which the survey unit lies.

CODE	*STATE*	*CODE*	*STATE*
AZ	*Arizona*	*OK*	*Oklahoma*
CO	*Colorado*	*TX*	*Texas*
MT	*Montana*	*UT*	*Utah*
NM	*New Mexico*	*WY*	*Wyoming*

COUNTY: This is a **required** 3-digit numeric field that identifies an assigned county code for each county in every state of the Intermountain west. These codes can be obtained by accessing the NAWMA website (www.nawma.org) and printing out APPENDIX D under "Mapping Standards".

SURVEY UNIT or PARK SUBUNIT NAME: This is a **required** character field that allows the park to specify a specific survey unit or park subunit name. This field refers to the entire land area surveyed for weeds, whether weeds were found or not. *Example: Yellowtail Wildlife Unit.*

OWNERSHIP: This is a **required** 3-4 letter character field that identifies the ownership of the land where the infestation is located. The table below identifies a listing of ownership acronyms.

ALOT	Native American Allotments
ARS	Agricultural Research Station
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
CGOV	County Government Ownership
DOD	Department of Defense
EPA	Environmental Protection Agency
FHW	Federal Highways
FSR	USDA Forest Service/Research Station
NOAA	National Oceanic and Atmosphere Association
NPS	National Park Service
NRCS	Natural Resources Conservation Services
PRV	Private Land Ownership
SGOV	State Government Ownership (includes state DOT/parks)

RECORDERS NAME(S): This is a **required** character field that should identify the name(s) of the individual(s) that are actually performing the field work/survey or that is reporting a casual sighting. The name(s) identified may or may not be the same as the park weed contact. This data element provides a contact(s) for the collected data in case any questions arise.

SURVEY DATES: This is a **required** numeric field that should identify the "start" and "completion" dates for a survey activity. Dates should be reported as YYYYMMDD. *Example: A survey start date of May 25, 2002 would be recorded as **20020525**.*

This data element tells you when the inventory was conducted and provides information on the time of year that weed species were noted. Additionally, this data field tells you how old the information is and can consequently provide insight into the reliability of the information.

TYPE OF SURVEY: This is a **required** character field that identifies the nature or method of a survey or weed population documentation. There are three types of surveys that can be identified:

(1) ***Observed (casual sighting)*** – this type of survey would typically be marked if there were a report made by non-resource management staff (e.g. other park employees or park visitors). If a weed occurrence is based on a casual sighting, this sighting needs to be confirmed and documented by the appropriate resource management staff.
(2) ***Observed (mapped)*** – this type of survey would be marked if either hand or GPS mapping has formally documented the weed occurrence.
(3) ***Remote Sensing*** – this type of survey would be marked if a weed occurrence has been documented through the use of aerial photography or by other remote sensing techniques (e.g. satellite imagery).

The type of survey should also identify if a survey was conducted for a single or multiple weed species.

UNIT OF MEASURE FOR SURVEY: This is a **required** character field that simply identifies if survey information is being provided in acres or in hectares.

TOTAL NUMBER OF ACRES/HECTARES IN THE SURVEY UNIT: This is a **required** numeric field that provides a total measurement (infested and uninfested land area) of the size of the complete area surveyed, whether weeds were found or not.

LOCATION INFORMATION – SURVEY UNIT

QUAD NUMBER: This is an **optional** numeric field that contains the identification number (which appears on the corner of the quad map). USGS 7.5 quad maps are often available at the 1:24,000 scale and are most often used to reference weed survey or management activities.

QUAD NAME: This is an **optional** character field that contains the name of the specific USGS 7.5 quad map in which the survey unit lies.

SURVEY LOCATION: This is an **optional** field that will describe the site location through one (or more if desired) of the following methods: (1) Section , Township, and Range, (2) Latitude/Longitude, or (3) UTM's. Location information is essential to identify where the survey has occurred. It allows the survey unit to be located on a map, be plotted across landscapes and allows users to relocate the survey unit.

LOCATION INFORMATION – WEED POPULATION(S)

QUAD NUMBER: This is an **optional** numeric field that contains the identification number (which appears on the corner of the quad map). USGS 7.5 quad maps are often available at the 1:24,000 scale and are most often used to reference weed survey or management activities.

QUAD NAME: This is an **optional** character field that contains the name of the specific USGS 7.5 quad map in which the survey unit lies.

SURVEY LOCATION: This is an **optional** field that will describe the site location through one (or more if desired) of the following methods: (1) Section , Township, and Range, (2) Latitude/Longitude, or (3) UTM's. Location information is essential to identify where the survey has occurred. It allows the survey unit to be located on a map, be plotted across landscapes, and allows users to relocate the survey unit.

HYDROLOGICAL UNIT CODE (HUC#): This is a **required** 2-8 digit numeric field **for aquatic species only** (those found in streams and rivers). It is an **optional** field for all **terrestrial weed infestations** and for **aquatic infestations found in lakes, ponds, or wetland habitats**. The HUC number is a unique number assigned to over 2,000 major watersheds in the United States.

The United States Geological Survey (USGS) has divided all the water systems in the U.S. into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units. For more information on Hydrologic Unit Maps see *http://water.usgs.gov/GIS/huc.html.*

PLANT INFORMATION

SITE NUMBER: This is an **optional** numeric field and can be used by park units to assign specific numbers to survey units or weed populations. Site numbers may be important to identify, especially for areas that are or have undergone weed management actions. This will assist in providing continuity of information/records should an individual leave and a new individual come into a park unit.

GENUS/SPECIES: These are **required** character fields that contain the scientific (Latin) name of the weed species identified. The use of Latin names provides a distinct advantage over common names, since common names can vary from region to region and over time.

INTRASPECIFIC NAME: This is an **optional** character field that contains the scientific (Latin) name for species that are further classified into subspecies or varieties.

AUTHORITY: This is a **required** character field that identifies what source was used to obtain the scientific name. For the IMR Kartez will serve as the formal authority for placing species names into the database.

COMMON NAME: This is an **optional** character field that contains the name of a weed species as it is usually identified in casual conversation. Although the database will always require the use of scientific names, common names can be beneficial. These names are easy to pronounce and to remember and are typically preferred for use by non-resource management staff or visitors.

PLANT CODE: This is a **required** 4-5 space combined character and numeric field that follows the coding system used by the NRCS PLANTS database. This database can be found at ***http://plants.usda.gov/plants/index.html***. Plant codes are useful tools for recording plant names in the field and for use in databases. Since there are several types of plant codes, those identified in the PLANTS database will be used to standardize the entry of codes region-wide. Appendix 3 identifies noxious weeds by state and their associated PLANTS database code.

An appropriate code as identified by the Integrated Taxonomic Information System (**ITIS**) can also be created as an **optional** 5-6 digit numeric field. The ITIS code is also linkable to the NPspecies database.

INFESTED AREA: This is a **required** data element that refers to the actual or estimated area of land (acres or hectares) occupied by a single weed species. An **infested area** is defined by drawing a line around the actual perimeter of the canopy cover of the weed plants, excluding areas that are not infested or through an estimation of an individual species occupancy within a gross area (see below). This data element is divided into two data fields. The first field is a numeric value reflecting a conversion of the percent canopy cover into infested area (see canopy cover definition below) and the second field is a character field that identifies the unit of measure used (e.g. acres or hectares). Infested area can be reported as low as 0.01 acre or 0.004 hectares.

A value for infested area is required regardless of whether the perimeter of an infestation for a species is an actual measurement or an estimated value from the gross area. Areas of land containing only occasional weed plants do not equal an acre of infestation. By measuring or more closely estimating the actual area infested by a weed species, individual parks, networks, and the IMR will become much better equipped to define a truer picture of "acres of infestation" by weeds. This will greatly enhance the efficacy of

setting weed management priorities and in communicating appropriate resource needs. Examples 1 and 2 below the explanation of "canopy cover" help to illustrate the use of Infested area, gross area, and canopy cover.

This is the data element that will be used to sum and report weed acres occurring within parks in the IMR. Figures 1 and 2 depict situations that display "infested area" based on actual measurements.

GROSS AREA: This is an **optional** data element that is intended to reflect general location and weed population information. Similar to "infested area", the gross area reflects an area of land occupied by a weed species. Unlike "infested area", however, the gross area is defined by drawing a line around the general perimeter of the infestation (an estimate) and is not based on an actual measurement of canopy cover. Gross areas may also contain significant parcels of land that are not occupied by weeds.

Gross area should be used whenever actual measurements of "infested area" cannot be made. Although **gross area** is not an actual measurement, it can be used to calculate an estimated value for "infested area" for each weed species. Situations in which use of gross area will prove beneficial include: (1) areas of large infestations that contain multiple weed species (especially if they are intermixed) and (2) areas with large discontinuous infestations. Figures 3 and 4 depict situations where gross area may be most beneficial for use.

Example of use of Gross Area: A LARGE, BUT DISCONTINUOUS INFESTATION OF SPOTTED KNAPWEED OCCUPIES A DRAINAGE. After walking the drainage (survey unit) and using the assistance of aerial photographs, it is approximated that the "gross area" of infestation is 600 acres. However, there are significant portions of this gross area (600 acres) that are not infested and it is further estimated that only ~60% of the total area is actually occupied by the knapweed. Thus, the estimated value that would be entered into the required "Infested Area" field would be 360 acres or 60% of the 600 acre gross area.

CANOPY COVER: This is a **required** 1-3 digit numeric field that is defined as the *percent of the ground covered by foliage of a specified weed species within the perimeter of the area identified for measurement.* Canopy cover can be an actual measurement (e.g. recorded foliage perimeter with a GPS unit) or can be an estimated value (e.g. actual ocular estimate of cover or an identified cover class) in situations where an actual measurement is not feasible. **Actual measurements are preferred** (e.g. GPS perimeter of weed population), however, in cases where a park may already be using cover classes to estimate cover by a weed species, then either the mid-point of the chosen cover class should be entered into this data field or an actual ocular estimate. Examples of three separate cover class systems are presented in Appendix 3. A second character data field that identifies whether the data value entered is either actual or estimated should be established with this data element.

Example 1: The actual perimeter of a population of yellow sweetclover was mapped using a GPS unit and equaled 1.5 acres in size. Several uninfested patches of vegetation occur within the measured 1.5 acres with the canopy cover of yellow sweetclover only equaling 75% of the total measured area. The total infested acreage for yellow sweetclover in this example would be 75% of the 1.5 acres, or 1.125 acres. 1.12 acres would be the value to be entered into the "Infested Area" data field.

Example 2: A 50 acre riparian unit of Black Canyon National Recreation Area is occupied by multiple weed species including, Tamarisk, Russian Olive, and Russian Knapweed. Because these species are so heavily intermixed it is extremely difficult to obtain actual measurements for each species. In this case, the park uses the 50 acre unit as a gross area and then approximates the area of canopy cover for each species as follows: Tamarisk 45% canopy cover; Russian Olive 35% canopy cover; Russian Knapweed 38% canopy cover. [NOTE: Total canopy cover by all three species can be more than 100% if there is overlap in the area of ground covered by the foliage of more than one species]

The estimated area of infestation within the 50 acre gross area is then calculated and entered into the "Infested Area" data field as a separate entry for each species: Tamarisk = 45% of 50 acres or 22.5 acres of infestation; Russian Olive = 35% of 50 acres or 17.5 acres infestation; Russian Knapweed = 38% of 50 acres or 19 acres of infestation.

DENSITY OF STEMS – within each polygon it is important to document some type of stem density assessment in addition to canopy cover. This assessment can be qualitative **(required)** and simply note if stem density is **low (1-3 stems/sq meter), moderate (4-7 stems/sq. meter), or high (>7 stems/sq. meter) or can reflect an actual quantitative measurement (optional)**

LIFE FORM: This is an **optional** character field that simply identifies the weed species as a tree, shrub, grass, or forb.

SPECIES STATUS: This is an **optional** character field that identifies if a weed species is a state listed noxious weed or if it is an unlisted weed, but of special concern to an

individual park. (e.g. Yellow and White Sweet Clovers are not typically listed as noxious weeds by most states, but they are species of great concern to many NPS park units.)

PRIORITY SPECIES FOR MANAGEMENT: This is an **optional** character field that allows the investigator to document if a weed species is a priority species for management. This data field will additionally assist the networks of parks and the region in gaining a better perspective of which weed species are priority management issues across the larger landscape.

ECOLOGICAL STATUS OF SITE/SURVEY UNIT: This is a **required** character field that provides a qualitative description of the level of infestation by weed species and that identifies the ability to recover an area to a natural state once the weeds have been removed.

WEED DISTRIBUTION THROUGHOUT SURVEY UNIT: This is an **optional** character field that provides a qualitative assessment of the total level of weed infestation by species throughout the entire unit included in a survey.

WEED PHENOLOGY: This is an **optional** character field that identifies the phenological state of a weed species at the time that the survey/inventory was conducted.

MANAGEMENT ACTION(S) TAKEN: This is an **optional** character field that will allow the investigator to identify if any management action(s) were taken either at the time of the survey or as part of a longer-term management strategy. If this data element is used, then the park should also create two additional data fields: one that identifies the **dates of any management actions** and the **% of the weed population that has been treated**.

ACTIVE or INACTIVE MANAGEMENT: This is an **optional** character field that defines if the weed population is undergoing active or inactive management.

DISTANCE OF WEED POPULATION TO WATER: This is an **optional** data element that is recommended for use whenever a weed population is located within close proximity to water. This element consists of two numeric data fields that define the distance, both horizontally and vertically, of a weed population to a water source.

VALUES AT RISK: This is a **required** 3-4 letter character field that identifies specific resource values that are threatened by the presence of a weed population(s) within the survey unit.

T&E	Threatened or Endangered Species	SCS	Rare or Special Concern Species
PNH	Prime or Unique Natural Habitat	WILD	Designated Wilderness
WRH	Wetland or Riparian Habitat	RNA	Research Natural Area
WLH	Wildlife Habitat	ACEC	Area of Critical Environmental Concern
DRS	Developed Recreation Site	ADM	Administrative
CRCL	Cultural Resources/Landscape	OTH	Other (Specify)

NOTES/COMMENTS: This is an **optional** multi-character field that allows the investigator to document any additional information not covered by the forms for a specific weed population.

SITE ENVIRONMENTAL DATA (Optional)

BIOTIC

VEGETATION CLASSIFICATION: This is an **optional** character field that identifies the appropriate class of plant community as defined by the USGS Vegetation Mapping Program.

DOMINANT ASSOCIATED VEGETATION: This is an **optional** character field that allows the investigator to identify additional native or non-native vascular species associated with a given weed population. Associated vegetation should be entered by their appropriate plant code as identified in the NRCS PLANTS Database.

HABITAT TYPE: This is an **optional** 2-3 letter character field that allows the investigator to provide information on the general habitat type in which a weed population is located.

DS	Desert Grassland	HR	Herbaceous Riparian
TG	Tall Grassland	SW	Savanna/Sparse Woodland
MG	Mixed Grassland	DF	Deciduous Forest
SG	Short Grassland	EF	Evergreen Forest
AG	Alpine/Sub-alpine Grassland	MED	Mixed Evergreen – Deciduous Forest
ESH	Evergreen Shrubland	WM	Wet Meadow/Grassland
DSH	Deciduous Shrubland	TF	Tall Forb Dominated
ASH	Alpine/sub-alpine Shrubland	LF	Low Forb Dominated
SDS	Sparse (Desert) Shrubland	SV	Sparsely Vegetated/Non-vascular
WR	Wooded Riparian	BG	Bare Ground (sand, rock)

SEREL STAGE: This is an **optional** character field that allows the investigator to identify the general successional stage of the plant community containing the weed infestation.

ES	Early - Succession
MS	Mid - Succession
LS	Late - Succession
CL	Climax

DISTURBANCE (HISTORIC & CURRENT): This is an **optional** 4-7 letter character field that allows the investigator to identify up to 5 primary causes of historic and/or current disturbance factors that may be affecting the current vegetation composition of a site.

AG/GRAZ	Agriculture/Livestock Grazing	IRRGAT	Irrigation/Ditching
CON/DEV	Construction/Development	MINING	Mining/Quarries
OIL/GAS	Oil/Gas Development/Production	WLDFIRE	Wildfire
FLOOD	Flooding	FIRESUP	Fire Suppression
REC/VIS	Recreation/Visitor Use	WIND	Wind Disturbance/Erosion
GEOTHRM	Geothermal	RGHTWAY	Right-of-Way
ANMLDIS	Animal Disturbance	UTILITY	Utility Corridor
HABPROJ	Habitat Improvement Project	RD/ORV	Unmaintained road/ORV use

ABIOTIC

ELEVATION: This is an **optional** numeric field that identifies the average elevation for an identified weed population. If specific elevation data is not known then this value can be estimated as a single value or as the minimum or maximum elevation for the population. This data element contains a second character field that identifies the unit of measure used to record elevation (e.g. feet or meters).

ASPECT: This is an **optional** character field that allows the investigator to identify the direction of a slope or land area in which a weed population is located.

N	North	SW	Southwest
NW	Northwest	SE	Southeast
NE	Northeast	E	East
S	South	W	West

SLOPE POSITION of WEED POPULATION: This is an **optional** character field that identifies the general position of a weed population on a sloped area. If no slope exist then the position is reported as "flat".

PERCENT SLOPE: This is an **optional** numeric data field that identifies either the estimated or actual percent of slope occurring within a given weed population.

SOIL TYPE: This is an **optional** combination letter and numeric data field that allows an investigator to enter the mapping symbol as identified by the appropriate NRCS Soil Survey for the soil type in which a weed population is located.

Examples: *Yahola fine sandy loam MAP SYMBOL =* ***Ya***
Quinlan soils, severely eroded MAP SYMBOL = ***Qu3***

LANDFORM: This is an **optional** character field that identifies the general landform in which a weed population occurs.

STEP	Steep Talus	RIPA	Riparian/Bottomland
BRSL	Broken Slope	WTLD	Wetland
BNCH	Bench	SAND	Sand Dune
ALBN	Alluvial Bench	UPLD	Upland
TERR	Terrace	GSLP	Gentle/Rolling Slope
MESA	Mesa	LVEL	Level/Flatland
CANY	Canyon	DIST	Disturbed/Developed

GEOLOGIC SUBSTRATE: This is an **optional** data element that consists of two character data fields. The first data field allows the investigator to enter the general classification of the geologic substrate as identified in the table below. The second data field allows the investigator to specify a specific rock type if this information is known (e.g. granite, basalt, lava).

Abbreviation	General Geologic Substrate	Examples of Specific Rock Types
SED	Sedimentary	Limestone, halite, gypsum, sandstone
IGN	Igneous	Granite, lava, basalt, quartz, obsidian
MET	Metamorphic	Gneiss, micaschist, quartzite, marble

CLIMATE: This is an **optional** data element that consists of three numeric data fields: (1) Average Summer Temperature (°F), (2) Average Winter Temperature (°F), and (3) Average Annual Precipitation (inches). Climate data is most beneficial when collected as close to the weed population being documented as possible. However, if data is only available from a single park source, these values should be used. If a park does not collect climate data, then the closest external source of data can be used.

References for Appendix D

(*The references listed on this page are for appendix D only. References for the entire document are in Appendix C: References.*)

Beard, Rita, Craig Searle, Danielle Bruno, Jonathon Rife, Dean Cline, Barbara Mullen. 2001. North American Weed Management Association – Weed Mapping Standards.

Benjamin, Pamela K. 2001. Weed Mapping and Database Development Guidelines for the National Park Service – Intermountain Region (DRAFT).

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U.S. Department of the Interior, Bureau of Land Management. 2000.

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Dewey, Steven A. 1985. Noxious Weeds – A Biological Wildfire: Applying Fundamentals of Wildfire Management to Improve Noxious Weed Control. Cooperative Extension Service, Utah State University, publication 10M/8-95.

Appendix C: References

The reference materials listed in this section are a compilation of all papers, PowerPoint files, web sites, and handouts that were presented, referenced, or distributed during the workshop. Each item listed in this reference section (except Elizinga, etc) is available as a PDF file at the end of this document.

General References

Carpenter, Alan T., Thomas A. Murray, and Jeremy Buxbaum. 2002. Inventorying and mapping invasive plants. *Natural Areas Journal* 22(2): 163-165.

Daniels, Judy and Aaron Kogan. 2002. Alien plant control and monitoring database (APCAM) Version 4.0.

_____ Field Guide -- Invasive Plant Inventory, Monitoring and Mapping Protocol, US Forest Service.

Elzinga, C.L., P.W. Salzer and J.W. Willoughby. 1998. *Measuring and Monitoring Plant Populations*. BLM/RS/ST-98/005+1730.

Hobbs, Richard J. and Stella E. Humphries. 19945 An integrated approach to the ecology and management of plant invasions. *Conservation Biology* 9(4): 761-770.

Larson, Diane L., Patrick J. Anderson, and Wesley Newton. 2001. Alien plant invasion in mixed-grass prairie: effects of vegetation type and anthropogenic disturbance. *Ecological Applications* 11(1): 128-141.

Loope, Lloyd L. and Francis G. Howarth. 2002. Globalization and pest invasion: where will we be in five year's time? In: R. Van Driesche (ed.), *Proceedings, First International Symposium on Biological Control of Arthropods*, 13-18 January 2002, Honolulu, Hawaii, U.S.A. to be published by U.S. Forest Service (In press).

Loope, Lloyd L. and Donald W. Reeser. 2001. Crossing boundaries at Haleakala: addressing invasive species through partnerships. In: David Harmon (ed.), *Crossing Boundaries in Park Management: Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands*. The George Wright Society, Inc.

Peitz, David G., Steven G. Fancy, Lisa P. Thomas, and Brian Witcher. 2002. *Bird monitoring protocols for Agate Fossil Beds National Monument, Nebraska and Tallgrass Prairie National Preserve, Kansas*. U.S. Department of the Interior, National Park Service.

Sheley, R. L., T. J. Svejcar and B. D. Maxwell. 1996. A theoretical framework for developing successional weed management strategies on rangeland. *Weed Technology* 10:766-773.

Stohlgren, Thomas J., David T. Barnett, and Sara E. Simonson. 2002. Beyond North American Weed Management Association Standards.

Thomas, Lisa P., Michael D. DeBacker, and John R. Boetsch, 2002. Considerations for Developing Invasive Exotic Plant Monitoring, Prairie Cluster Prototype Monitoring Program.

Timmons, Susan M. and Susan-Jane Owen. 2001. Scary species, superlative sites: assessing weed risk in New Zealand's protected natural areas. In *Weed Risk Assessment*, R.H. Grove, F.D. Panetta, and J.G. Virtue, Eds. CSIRO: Collingwood, Australia. Pp. 217-227.

Papers in Review or Draft

Benjamin, Pamela K. 2001. Weed mapping and database development guidelines for the National Park Service, Intermountain Region (IMR). (Draft Manuscript).

Randall, J., N. Benton, L. Morris and R. Hiebert. 2002. Prioritizing alien plants and invaded sites for inventory and monitoring. (in prep).

Handouts

The Exotic Vegetation Ranking System Used at Acadia National Park. Modified from Hiebert and Stubbendiek

MS Access Natural Resource Database Template: Data Dictionary for Phase 2 Example

Invasive Plant Field Form

Rangeland General Form – For Interim Invasive Tool

Bird Monitoring Protocol for Agate Fossil Beds National Monument, Nebraska and Tallgrass Prairie National Preserve, Kansas: Standard Operating Procedure (SOP) #5, Conducting the Variable Circular Plot Count, Version 0.1 (May 2002)

Disturbed Lands Inventory and Assessment Protocol

Web Sites of Interest

PLANTS National Database -- http://plants.usda.gov/

Southwest Exotic Plant Information Clearinghouse (SWEPIC) – http://www.usgs.nau.edu
Includes the Alien Plant Ranking System (APRS) and the Southwest Exotic Mapping Program (SWEMP)

The Nature Conservancy invasive plants page– http://www.tncweeds.ucdavis.edu

Invaders database – http://invader.dbs.umt.edu
Includes distribution maps for invasive species in WA, OR, MT, ID, WY

Presentations

Presenter: Pamela Benjamin
Subject: NAWMA and Intermountain Region Weed Mapping and Database Development Guidelines

Presenter: Steve Fancy
Subject: Where do Invasive Plant Monitoring Guidelines Fit Into Overall Inventory and Monitoring Programs? and Data Management

Presenters: Ron Hiebert and John Randall
Subject: Prioritization of Invasive Plants and Places

Presenter: Lisa Jameson
Subject: APCAM The Alien Plant Control & Monitoring Database
Download at: ftp://ftp.nps.gov/incoming/APCAM3.0

Presenter: Lloyd Loope
Subject: The Challenge of Effectively Addressing the Threat of Invasive Species to the Nation Park System: is the National Park Service Doing Enough?

Presenter: Tom Stohlgren
Subject: Current Status of Inventory and Monitoring of Non-native Plants
http://www.nrel.colostate.edu/projects/stohlgren

Presenter: Lisa Thomas
Subject: Prairie Cluster Prototype Monitoring Program

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