



Invasive Exotic Plant Monitoring Protocol Narrative for Northern Colorado Plateau Network Parks

Version 1.02

Natural Resource Report NPS/NCPN/NRR—2016/1340



ON THE COVER

Top: Field crew member with woolly mullein (*Verbascum thapsus*).

Bottom: Invasive exotic plant monitoring at Golden Spike National Historic Site. NPS photos.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Protocol Narrative

Revision History Log

Previous version #	Revision date	Author	Changes made	Reason for change	New version #
1.00	09/2013	D. Perkins	Editorial changes based on peer review comments	Clarity	1.01
1.01	3/7/2016	A.W. Biel H. Thomas D. Perkins	Minor editorial changes Updates to Section 4 Additional information	Preparation for publication To reflect current practices Clarity	1.02

1 Introduction

This sampling protocol consists of this protocol narrative and the following standard operating procedures (SOPs), available at <https://irma.nps.gov/DataStore/Reference/Profile/2236957>:

SOP 1: Field Work Preparation
SOP 2: Training Observers
SOP 3: Monitoring Route Methods
SOP 4: Extra-Area Search Methods
SOP 5: Monitoring Lite
SOP 6: Using Global Positioning System (GPS) Units
SOP 7: Data Management
SOP 8: Data Analysis and Reporting
SOP 9: Developing a Priority Invasive Exotic Plant List
SOP 10: Revising the Protocol Narrative and SOPs

1.1 Background

Invasive exotic species fragment native ecosystems, displace native plants and animals, and alter ecosystem function. Invasive species are second only to habitat loss from human development as threats to global biodiversity (Scott and Wilcove 1998) and represent one of the most serious threats to natural ecosystem integrity (NRC 2002). Biological invasions are occurring at accelerated rates in nearly every major ecosystem globally (Mooney and Hobbs 2000).

National Park Service (NPS) Management Policies (NPS 2006) state that “high priority will be given to managing exotic species that have, or potentially could have, a substantial impact on park resources, and that can

reasonably be expected to be successfully controllable.” Exotic plants negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, and increasing trail maintenance needs. Recognizing these challenges, Northern Colorado Plateau Network (NCPN) parks identified invasive exotic plants as a high-priority vital sign.

Invasive exotic plants (IEPs) are a subset of exotic plants “whose introduction does or is likely to cause economic or environmental harm or harm to human health” (Executive Order 13112). In order to manage IEPs effectively, strategic control methods are essential, and are predicated on early detection. With the need for strategic control approaches in mind, this monitoring protocol detects early invasions, identifies existing invasions, and, to the extent possible, tracks changes in the abundance and distribution of IEPs in parks.

This protocol is adaptable, allowing approximately 25% of the annual effort to be directed toward “extra-area” searches (i.e., searches occurring beyond standardized methods) in places where parks need a rapid and possibly unexpected inventory. Examples could be on the occasion of a new burn, a change in land management within a park or adjacent to a park, or an anecdotal report of a threatening new invasive plant. In some years, there may not be any extra-area searches conducted; in other years, multiple surveys may be needed.

National parks are being deluged by a whole host of new IEPs, arriving through a variety

of pathways and presenting significant challenges to the agency's ability to maintain natural resources "unimpaired for the enjoyment of future generations." Predictable pathways include roads, trails, and riparian corridors. Sudden pathways include long-distance dispersal through cargo containers and air freight. Anthropogenic pathways include horticultural escapes and seeds carried on shoes, in restoration seed mixes, and many more.

IEPs infest an estimated 2.6 million (1,052,183 ha) acres of the 83 million acres (33,588,908 ha) managed by the NPS. National Park Service lands are infested daily despite diligent efforts to curtail the spread of IEPs. Impacts from IEP species have been realized in most parks, resulting in an expressed need to control existing infestations and restore affected ecosystems. There is a growing urgency to be proactive—to protect resources not yet impacted by current and future IEPs (Marler 1998). IEPs are currently, and certainly will continue to be, a management priority for NPS well into the future.

Prevention of plant invasions is the most effective, economical, and ecologically sound approach to managing invasive species. When preventive measures are not successful, early detection of new invasions is the next critical step. To do this, three approaches are employed: first, early detection methods should be employed to find and subsequently eradicate incipient populations of IEPs while these measures are still feasible and cost effective. Second, control strategies should be applied to existing populations that require a more substantial resource investment to mitigate associated impacts. Third, containment measures should be used when populations have become so entrenched that removal and effective control are impractical.

Detecting invasive species before they become established has been a longstanding practice in agriculture, with point-of-entry and distribution inspections, insect traps, and nursery certification, but has not been widely used by other resource land managers in invasive species monitoring and management programs. Early detection, followed by rapid response, is cost-effective in that it removes a species before it establishes within a park—where once established, it can spread quickly (OTA 1993; Myers et al. 2000; Tim-

mins and Braithwaite 2002; Harris et al. 2001; Rejmanek and Pitcairn 2002). Hobbs and Humphries (1995) identified a significant time lag between the initial establishment of an invasive exotic plant and its rapid expansion toward local carrying capacity. Control efforts initiated during this lag phase are likely to cost less and achieve higher success rates than efforts begun later in the invasion cycle (Hobbs and Humphries 1995). In addition to saving money, early detection and rapid response efforts minimize ecological damage by preventing habitat fragmentation and ecosystem degradation associated with large or widespread invasive species populations.

Strategic control of IEPs requires a large-scale, comprehensive approach to effectively maintain and manage ecosystem landscapes in their natural state. In their review of the status of biotic invasions, Mack and others (2000) stated, in no uncertain terms, that "control of biotic invasions is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders." Therefore, effective control of IEPs requires managers to match management strategies with individual tasks at hand.

Comprehensive monitoring for exotic plants across all areas of all NCPN parks would be impractical and beyond the fiscal capabilities of the network and the parks. Therefore, strategies to maximize the effectiveness and usefulness of exotic plant surveys are essential. Through individual park base funding, natural resource projects, and NCPN inventory efforts, some parks have completed inventories to initially describe the distribution and abundance of IEPs (Dewey and Anderson 2005 a, b, c, and more). However, while useful, these inventories become quickly outdated, as exotic plant invasions are quite dynamic. Therefore, the NCPN is concentrating surveys on the most likely infestation areas where a suite of invasive exotic plants may occur: riparian corridors, roads, trails, areas of high visitor impact (campgrounds), and park boundaries. While this approach can miss IEPs dispersed by wind and animals to the interior areas of large parks, it is the most cost-effective approach available at this time and is outlined in this protocol.

1.2 Protocol objectives

The objectives of NCPN IEP monitoring are to:

1. Detect incipient populations and new introductions of invasive exotic plant species before they become established in areas of management significance, and
2. Determine status and trends of selected populations of invasive plants of management significance.

2 Sampling Design

2.1 Sampling design overview

NCPN monitoring of IEPs in parks follows three methodologies. First, IEPs are mapped along monitoring routes that follow invasive pathways. Transects, each with three quadrats, are placed every 500–1,000 meters along the monitoring routes to provide consistent interannual surveys of selected park areas that can assess long-term changes in IEP distributions and densities. Monitoring routes are surveyed every 3–5 years, depending on the number of routes to be monitored and the extent of infestations. Second, extra-area searches are conducted in locations of likely invasion that lie beyond the distribution of the monitoring routes. Third, the NCPN has developed a “monitoring lite” version of the monitoring routes. The “lite” methods are a simpler version of the formal route surveys, without the transects and with fewer target species. They are designed to be performed by park employees or volunteers able to identify a few IEP species.

2.2 Rationale for selecting sampling design

Given mapping, sampling, and modeling challenges, the sampling design for this protocol was selected to balance multiple goals, including identifying high-priority IEPs, ensuring maximum spatial coverage, detecting new plant invasions, monitoring multiple species simultaneously, tracking changes in abundance and distribution of existing invasions, and providing the ability to adaptively react to and address management priorities (e.g., recent fires, changes in land use on an adjacent property, site disturbance), while working within program capacity. The primary focus of this protocol is to conduct routine monitoring along areas where invasives are most likely to invade—specifically, roads, trails, and riparian corridors.

The protocol emphasizes the quick collection of IEP location and abundance data to maximize the amount of area searched. Maximizing the search area provides the greatest opportunity to find new invasions and established IEPs in parks. Roads, trails, and waterways are major vectors for invasive

plants, which tend to clump along these corridors. Searching these areas will capture the greatest amount of information for relatively low effort.

Unlike many other monitoring programs, where the threshold at which a manager might need to take management action is often unknown, the management threshold for IEPs is known and clear. Because of the rapid-invasion population dynamics of these types of plants, if there is even one IEP present, then there is a management problem to consider.

Numerous weed mapping efforts have been initiated in many countries and by local, state, federal, and non-governmental agencies in the United States. The North American Weed Management Association (NAWMA) has issued guidelines to bring a minimum level of standardization to mapping efforts in North America (NAWMA 2002). The National Park Service has signed on as a participating member.

A perfect map showing all IEPs in each national park unit would fully meet most basic inventory and monitoring needs. As an inventory product, maps comprehensively identify and locate IEPs, allowing resource managers to assess the scope of the problem, strategically plan management, and prescribe actions for exact locations.

From a monitoring standpoint, maps with reasonably small minimum mapping units (i.e., mapping infestations of less than 0.1 hectare) reproduced accurately over time would clearly detect changes in the abundance and distribution (i.e., spread) of IEPs. These maps, combined with information on the locations of treatments applied to IEPs, could also assess management effectiveness of particular treatments over time. Widespread interest among park staff in weed mapping reflects the potential benefit of such maps and the availability of GPS technology.

Given that complete mapping of all IEPs is generally not possible to accomplish in a comprehensive fashion—nor often enough, a few alternatives are available:

1. ***Develop statistically rigorous measures of IEP cover and frequency.*** A precise measurement of IEP cover or frequency would provide a strong indicator of spread over time or increasing density in a given location. However, the spatiotemporal variability in IEP populations—especially small, widely scattered populations—results in numerous non-detects when sampling, and eradication of detected infestations makes permanent quadrats infeasible, precluding precise and powerful estimation. Additionally, a lack of spatial referencing prevents managers from determining which plants may impact areas that protect particularly valuable resources.
2. ***Limit mapping or sampling to suitable habitat or likely points of invasion.*** Targeting monitoring to invasion pathways or suitable habitat may greatly increase sampling efficiency and the precision of abundance and frequency estimates. However, this approach depends on the availability of an accurate habitat model for each IEP species. As with all models, sample size and methods affect model accuracy. Given the tendency of IEPs to expand their range, even accurate maps may not reflect the invasion potential of a given plant. The need to monitor multiple IEP species simultaneously can also diminish the practicality of this approach. In short, by the time enough is known about an IEP to develop a statistically rigorous model, the IEP is already a problem in a park or area.
3. ***Combine sampling with a landscape modeling approach to determine likelihood of occurrence.*** Combined with spatially referenced habitat data, sampling may be used to map the probability of IEP occurrences on the landscape. These maps show a generalized area where the species may be located and can estimate the percentage of potential habitat occupied. In this regard, the maps can provide a powerful assessment tool for management planning and for improving search or sampling efficiency (see #2). Once man-

agement decisions are made, managers must still survey high-probability areas for exact IEP locations. Limited data can compromise the reliability of these habitat maps, because small invasions provide little site-based habitat information, requiring extrapolation from other invaded sites or from the native range. The ability of such designs to determine change in IEP abundance or frequency may suffer from the same problems mentioned above (see #1).

4. ***Map changes in IEP distribution and abundance using remotely sensed imagery.*** Successful identification of IEPs from remotely sensed imagery offers the potential to track changes in distribution and abundance over extremely large areas. This has been accomplished for a number of species in rangelands where interference from tree canopies is limited. Developing reliable reflectance signatures used for remote sensing for IEPs may depend on distinct phenological or habitat characteristics, as well as relatively large patch sizes (Young and Schrader 2007). Signatures can only feasibly be developed for a relatively small number of species.

When developing this protocol, network staff evaluated these possible approaches, as well as the relative costs and park needs for IEP information. This protocol focuses on the areas most likely to have the broadest range of IEPs and covers the maximum extent possible. Monitoring routes (see §§ 2.3 and 3.1) cover large areas of ground, allowing focus on the most threatening invasive species. Data that are useful for controlling IEPs can be quickly collected using this method. For example, information on the size and number of infestations might tell a manager how much herbicide or how many garbage bags will be needed to perform control in a given area. Similarly, knowing the growth stage of tree species will help managers to know whether hand-loppers or chainsaws would be the most appropriate tool for removing them.

Monitoring transects (see §§ 2.3 and 3.1) are more quantitative and will likely only provide information on species that are more

collected from plots according to a systematic design, the results are more statistically sound than the mapping on routes.

Extra areas (see § 3.2) are incorporated because IEP monitoring needs to account for new drivers that can rapidly alter IEP presence and abundance. If a fire or other major disturbance that could result in the spread of IEPs occurred, the network would not want to potentially wait 4–5 years until that area came up again in the monitoring rotation before collecting additional data—and managers may want more extensive spatial information than can be collected by just following a road, trail, or riparian area through the burn.

2.3 Monitoring routes

Approximately 75% of NCPN IEP monitoring efforts each year are focused on surveys associated with transects along monitoring routes. Transects are more statistically sound than simple mapping of IEPs, and increase the power of the data collected. Collecting transect data also makes the samples comparable to other monitoring programs and standards (e.g., Forest Health Monitoring, Forest Inventory and Analysis, U.S. Geologi-

cal Survey Modified-Whittaker technique, and others).

Along monitoring routes, monitoring transects with quadrats are established to collect data for trend estimates. These transects provide an estimate of actual cover, a method to calibrate ocular and other cover estimates, a way to model the patches of missed and less-sampled non-native species, and a method for understanding which habitats and sites are being invaded. Within a park, NCPN and park staff identify monitoring routes of management importance, with re-visit frequency ranging from 1 to 5 years, depending on the number of routes that a park wants covered and the severity of IEP infestations along a given route.

2.4 Prioritization of invasive species

NCPN staff work with a variety of sources in order to prioritize which invasive species to monitor and be aware of new species that could soon invade a park. With park staff and county and state weed managers, NCPN personnel run all potential invasive species through a prioritization process (see SOP #11).

3 Field Methods

3.1 Monitoring route methods

Monitoring routes follow roads, trails, and riparian areas in a park. As monitoring routes are traversed, locations of all target species are documented. Once a plant or patch/infestation has been discovered, a mapping crew records (1) the monitoring route and monitoring segment, (2) GPS location and size of infestation, (3) whether the plant was pulled, and (4) an estimate of canopy cover. Each new observation is notated using a sequential survey number.

Non-native species that are found are mapped during these surveys. For example, when cheatgrass (*Bromus tectorum*) is dominant across a park or a portion of the park, it will not be individually mapped; however, it will be recorded in the quantitative transects. Such species are identified prior to surveying any individual monitoring route.

Transects with three 1-m² vegetation quadrats are established every 500–1,000 m along each monitoring segment. Along each transect, quadrats are centered at 0.5, 5, and 10 meters away from the route. Invasive plant and habitat cover measurements are taken within the 1-m² quadrat.

In general, IEPs at a particular park are monitored at the same time of year, to maintain consistency in detection probabilities and cover estimates for most species. For many species, sampling any time during May through September is not expected to drastically alter monitoring results. However, sampling after May could prevent detection or identification of spring-blooming exotic plants and exotic cool-season grasses. Field crews usually cover no more than 5–10 kilometers of the project area per day, depending on target invasive plant densities, vegetation, and terrain.

3.2 Extra-area searches

Invasive plants expand rapidly and can quickly colonize new areas that may not be part of routine monitoring routes. Therefore, NCPN staff allocate up to 25% of effort each year to conducting inventories in areas of highest management concern or other corridors of likely invasion. Extra-area searches

generally take place during the growing season (April–October).

3.3 “Monitoring lite”

“Monitoring lite,” also known as opportunistic sampling, is a term the network uses to describe a supplemental approach to gathering information about IEPs in parks. This approach uses observations by personnel who may not have comprehensive knowledge of the local flora but can reliably detect a few high-priority species. Opportunistic sampling makes use of park staff, researchers, visitors, and volunteers who travel in and around a park regularly. This sampling operates on the principle that with proper and consistent training, each person represents a potential set of eyes able to correctly identify new high-priority weed infestations and record the location(s) with the highest level of accuracy possible. The technique is a simplification of the monitoring methods outlined above. This efficient, practical inventory technique has been used nationwide to increase the chances of early detection of invasive species and has the side benefit of being used to maximize detection opportunities through education and awareness. Monitoring lite sampling can take place at any time of year.

3.4 Control of invasives

For all of the methods outlined above, qualified observers may remove small populations if under a certain threshold size (i.e., if it would take less time to remove the plants during the survey than it would for someone to return and remove them later). Larger populations require rapid response commitments from parks in order to be effective. When invasive plants are removed by surveyors, site location are still documented.

3.5 Limitations

Prior to officially adopting this monitoring protocol, network staff assessed its limitations. Substantial inter-observer error associated with visual cover-class estimates applied at a broad scale would reduce our ability to detect changes in cover over time. Because locations are not precisely documented, the amenability of these data to spatial analysis is

limited. Finally, the design is not necessarily suited to assess the effectiveness of management treatments applied at local scales or to compare the effectiveness of control treatments. For example, a replicated study would be required to determine whether glyphosate

or mowing provided more effective treatment of smooth brome (*Bromus inermis*). As the spatial scale of control increases with cumulative management actions, however, assessment of management effectiveness becomes increasingly feasible with this design.

4 Data Management

4.1 Data processing overview

IEP monitoring data are stored in a Microsoft Access database that conforms to the Natural Resource Database Template standards established by the Inventory and Monitoring Program. The database is populated by both data import and data entry. Data collected on GPS units are imported, while data collected on field data sheets are entered via a data-entry interface. Data verification immediately follows data entry and involves checking the accuracy of the computerized records against the original source. Data validation is then performed, which involves reviewing the data for range and logic errors.

4.2 Metadata procedures

Each table and field in the database is defined and documented in a data dictionary and/or in Section 5 of a Federal Geographic Data Committee (FGDC)-compliant metadata file. FGDC-compliant metadata are created for all spatial data. In addition, information

on data manipulations and the status of data verification and validation is recorded in a data management log.

4.3 Data archival procedures

Digital data are archived in their native database format at the end of each field season after all data have been verified and validated. A complete copy of the database in its native database format is also archived whenever the database version changes. These version archives are supplemented by a platform-independent copy of the database tables in ASCII format. All archived files are designated as read-only. All files, both active and archival, are stored on a secure server with regular backup routines that include an off-site storage rotation. All final IEP monitoring data and data products, both digital and hard-copy formats, are archived at the Western Archeological and Conservation Center after each field season.

5 Data Analysis and Reporting

Data of invasive exotic plant distributions acquired from surveys are time-sensitive. Because these plants reproduce quickly, acting upon new detections of highly invasive species is critical. Therefore, a feedback loop between monitoring and treatment programs must be established. In any surveys in which exotic invasive plants are detected, the park weed manager is notified of particularly important or significant new invasions (e.g., a species with high invasive potential found in a canyon that was formerly weed-free) within 30 days of monitoring.

In addition to 30-day notification, annual monitoring reports are submitted to the park that identify newly discovered species and provide the locations of newly discovered infestations. These reports identify the locations and cover of species during the most recent survey and the amount of change since the previous survey. Reports will also include the time spent surveying and kilometers covered, as well as maps of locations and presence/absence of species by monitoring route. Reports are prepared and distributed by May of the next calendar year following data collection.

Approximately every five years, the network will produce a report focusing on trends in species distributions. IEP spread rates will be analyzed/summarized by habitat type and

trends will be assessed using changes in the number of detections per species per year. Regression analyses could be employed to estimate rates of change or the trajectory of change (i.e., linear or nonlinear). A repeated-measures ANOVA could also be used to statistically test pre- versus post- differences relative to events that could change the amount and distribution of IEPs (e.g., fires, release of tamarisk beetle, changes in grazing practices). Because some portions of parks will only be sampled infrequently (e.g., every five years), statistical analyses in which sample size is equivalent to number of years (e.g., regression) should only be done after enough data points are obtained to allow sufficient statistical power.

The primary intent of surveying for IEPs is to identify their locations in parks in order to enhance control prior to spread. As such, classical statistical analyses are of lesser concern, as managers may act to reduce the densities of a number of the invasive species. These actions are likely to vary both spatially and temporally within and among parks. Unless the histories of such management actions are documented and made available to the analyst, interpretation of observed long-term patterns may prove difficult, even as the value of the program remains high.

6 Personnel Requirements

A network ecologist serves as the project manager for IEP monitoring. Data management is the shared responsibility of the project manager and the data manager. Typically, the project manager oversees data collection, data entry, and data verification and validation, as well as data summary, analysis, and reporting. The data manager designs the database and oversees data security, archiving, and dissemination. The data manager, in collaboration with the project manager, also develops data-entry forms and other database features to assure data quality and automate report generation. The data manager and project manager are responsible for building adequate quality assurance/quality control procedures into the database management system and for following appropriate data-handling procedures.

For routine monitoring, a competent, detail-oriented observer is essential for collecting credible, high-quality IEP data. Misidentification of species decreases capacity to detect trends in IEP abundance and distribution through time. Field observers must be able to accurately identify target IEPs. Field observers must also be skilled with GPS navigation and data collection. Observers should be well organized, work well as part of a team, be comfortable in the field, and able to work methodically under difficult conditions.

For the “lite” monitoring to be effective, observers can come from a variety of sources, and each park unit must take responsibility for creatively recruiting help. Observers can be from any skill level, as long as they have completed minimal training in the identification of top-priority species. Observers consist of (but are not limited to) the following types of individuals:

1. Interpreters leading hikes and disseminating information
2. Rangers patrolling the backcountry
3. Maintenance staff working at remote sites, road edges, and along trails
4. Resource managers, research permittees, and scientists working in the backcountry
5. Park contractors
6. Park lessees
7. Special Use permittees
8. Volunteer groups (especially Native Plant Societies)
9. Educational groups
10. Park partners

7 Operational Requirements

7.1 Field season preparations and equipment set-up

Sampling trips are scheduled and organized prior to the start of each field season. Prior to working in the field, observers must review the network safety plan and the entire protocol. Observers review IEP identification using herbarium specimens, keys, and photographs. The crew leader provides a refresher on plant identification, GPS navigation, compass use, and foliar cover estimation. All equipment and supplies, especially GPS units, are organized and prepared for the field season. All files needed for navigation are loaded onto a GPS unit for transport to the park.

7.2 Training procedures

Training is essential for developing competent observers (see SOP #2). Observers will review exotic plant identification using herbarium specimens, keys, and photographs. The crew leader will provide a refresher on exotic plant identification, GPS navigation (see SOP #6), compass use, and foliar cover estimation. Observers will be tested frequently on their ability to identify exotic plant species.

7.3 Sequence of events during field season

Prior to visiting the field sites, the park is contacted according to park procedure. All equipment required for sampling will be assembled and checked (see SOP #1). Each day, the crew leader provides a briefing regarding safety, plant identification, and park navigation. All observers must be properly trained (see SOP #2). The crew leader assigns crew members to the search areas for the day. Prior to beginning work in the field, observers collectively estimate IEP cover over a given area and compare observations in order to calibrate cover-class estimates.

7.4 Post-collection processing of samples

Research specimens may be collected to confirm identification of IEPs, especially those that are likely to be identified incorrectly (see SOP #10). In some cases, small or partial samples may be quickly collected and stored in a field notebook. Location, description, and habitat information are recorded using an unknown specimen data sheet. Research specimens are only for confirmation of taxonomy and will not be stored in a collection. Photographs may also be used to document unknown specimens.

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