National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Problematic Plant Monitoring Protocol for the Heartland Inventory and Monitoring Network

Narrative, Version 2.0

Natural Resource Report NPS/HTLN/NRR—2022/2376

ON THE COVER
Herbert Hoover birthplace cottage at Herbert Hoover NHS, prescribed fire at Tallgrass Prairie National Preserve, aquatic invertebrate monitoring at George Washington Carver NM, the Missiissippi River at Effigy Mounds NM.
Photography by NPS/Heartland I&M Network

Problematic Plant Monitoring Protocol for the Heartland Inventory and Monitoring Network

Narrative, Version 2.0

Natural Resource Report NPS/HTLN/NRR—2022/2376

Kathleen A. Kull, Craig C. Young, Jennifer L. Haack-Gaynor, Lloyd W. Morrison, and Michael D. DeBacker

National Park Service
Heartland I&M Network
Wilson's Creek National Battlefield
6424 West Farm Road 182
Republic, Missouri 65738

Editing and Design by
Tani Hubbard

National Park Service &
Northern Rockies Conservation Cooperative
12661 E. Broadway Blvd.
Tucson, AZ 85748

April 2022

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from Heartland Inventory and Monitoring Network website, and the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Kull, K. A., C. C. Young, J. L. Haack-Gaynor, L. W. Morrison, and M. D. DeBacker. 2022. Problematic plant monitoring protocol for the Heartland Inventory and Monitoring Network: Narrative, version 2.0. Natural Resource Report NPS/HTLN/NRR—2022/2376. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/nrr-2293355.

NPS 920/180322, April 2022

Contents

Contents (continued)

Page

Figures

Page

Tables

Page

Protocol Revision History

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.0	2020	K.A. Kull, C.C. Young	Update revisit design and search list prioritization, readdress EFMO and HOSP sampling, clarify analyses used.	More accurately depict network capacity and operations, improve clarity and accuracy overall	2.0

Standard Operating Procedures

The following standard operating procedures (SOPs) for problematic plant monitoring are published as separate documents in the Integrated Resource Management Applications (IRMA).

SOP 1. Reference Frame Development and Sample Selection

SOP 2. Field Work Preparation

SOP 3. Observer Training

SOP 4. Field Survey Methods

SOP 5. Collecting and Processing Unknown Specimens

SOP 6. Problematic Plant Prioritization Database (PriorityDB)

SOP 7. Field Database and Data Management

SOP 8. Data Analysis and Reporting

SOP 9. Revising the Protocol

Executive Summary

Problematic species, which include invasive, exotic, and harmful species, fragment native ecosystems, displace native plants and animals, and alter ecosystem function. In National Parks, such species 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, Heartland Inventory and Monitoring (I&M) Network parks identified problematic plants as the highest-ranking vital sign across the network.

Given the need to provide early detection of potential problematic plants (ProPs) and the size of network parks, the Heartland I&M Network opted to allocate available sampling effort to maximize the area searched. With this approach and the available sampling effort in mind, we developed realistic objectives for the ProP monitoring protocol. The monitoring objectives are:

1. Create a watch list of ProPs known to occur in network parks and a watch list of potential ProPs that may invade network parks in the future, and occasionally update these two lists as new information is made available.
2. Provide early detection monitoring for all ProPs on the watch lists.
3. Search at least 0.75% and up to 40% of the reference frame for ProP occurrences in each park.
4. Estimate/calculate and report the abundance and frequency of ProPs in each park.
5. To the extent possible, identify temporal changes in the distribution and abundance of ProPs known to occur in network parks.

ProP watch lists are developed using the best available and most relevant state, regional, and national exotic plant lists. The lists are generated using the PriorityDB database. We designed the park reference frames (i.e., the area to be monitored) to focus on accessible natural and restored areas. The field methods vary for small parks and large parks, defined as parks with reference frames less than and greater than 350 acres (142 ha), respectively. For small parks, surveyors make three equidistant passes through polygon search units that are approximately 2-acres (0.8 ha) in size. For large parks, surveyors record each ProP encountered along 200-m or 400-m line search units. The cover of each ProP taxa encountered in search units is estimated using the following cover scale: 0 = 0, 1 = 0.1-0.9 m^2, 2 = 1-9.9 m^2, 3 = 10-49.9 m^2, 4 = 50-99.9 m^2, 5 = 100-499.9 m^2, 6 = 499.9-999.9 m^2, and 7 = 1,000-4,999.9 m^2. The field data are managed in the FieldDB database. Monitoring is scheduled to revisit most parks every four years. The network will report the results to park managers and superintendents after completing ProP monitoring.

Acknowledgments

The National Park Service's Inventory and Monitoring Program provides funding for the problematic plant monitoring protocol and monitoring implementation. We gratefully acknowledge helpful reviews from Dr. Penny Latham, Susan O'Neil, Dr. Dennis Odion, Dr. Lisa Rew, and Dr. Bradley Welch. The protocol conforms to WASO guidelines for NPS Inventory and Monitoring Program protocols (Oakley et al. 2003). This protocol uses sections of text without citation, but with permission from a draft document: *Vegetation Community Monitoring Protocol for the Heartland Inventory and Monitoring Network, Version 5.0*, Sherry A. Leis et al. We thank Kevin James, Mike Williams, and Gareth Rowell for assistance with database development.

Background and Objectives

Background, history, and rationale for selecting this resource to monitor

The National Park Service's management policies distinguish between native and exotic (i.e., nonnative) plant species (NPS 2006), with native species defined as those currently or historically present within a specified geographic range without human intervention (Morse 2004). Exotic plant species, then, are typically characterized as introduced by human actions, whether intentional or not. Invasive plants, following the definition used in Executive Order 13751, are those plants that are both exotic and cause ecological or economic harm. Another classification, pest plant species, is defined less by species biology and more by context, similar to the way that the term "weed" is defined (NPS 2006). Pest plants, which include native and nonnative species, interfere with a specific management objective, including protecting human health. We suggest thinking of this collection of exotic, invasive, and pest plants as *potentially problematic* species.

Problematic plants (ProPs) fragment native ecosystems, displace native plants and animals, and alter ecosystem function. In National Parks, such taxa negatively affect park resources and visitor enjoyment by altering landscapes and fire regimes, reducing native plant and animal habitat, increasing trail maintenance needs, and threatening historic viewsheds and park buildings. However, park managers are only required to control ProPs that lead to *resource impairment* at a definable level. For PRoP populations causing effects that fall short of the impairment threshold, park managers wield a high level of discretion in judging whether the population should be controlled or not. The standard for making this decision rests on five criteria: the origin of the species, prudence, feasibility, the harm (i.e., impact) that the plant causes to park resources, and the harm that removal causes (NPS 2006). As with impairment determinations, these decisions are based on professional judgment, environmental assessment, consultation with regulating agencies, evidence-based scholarship, subject matter expertise, and civic engagement with the public (NPS 2006). This monitoring protocol contains procedures for collecting information on the location and abundance of ProPs to assist managers in developing effective management strategies.

The parks in the Heartland Inventory and Monitoring (I&M) Network recognized ProP management and monitoring as a network priority. During the vital signs selection process in 2003, eight parks (CUVA, EFMO, GWCA, HEHO, HOCU, HOME, LIBO, PERI) identified ProPs as their most important management issue, two parks (TAPR, WICR) identified ProPs as their second most important management issue, and one park (PIPE) identified ProPs as its third most important management issue (DeBacker et al. 2004; see Table 1 for park codes). Overall, ProP monitoring was recognized across all network parks as the most important shared monitoring need. An overview of park species lists and planning documents highlights three points: (1) network parks support vegetation resources of tremendous cultural and natural significance, (2) these vegetation resources are susceptible to numerous plant invasions, and (3) network parks already contain some of the most recalcitrant ProPs found in forests, grasslands, and wetlands. The need to both detect new invasions and track existing invasions necessitated the development of the ProP monitoring protocol for the Heartland I&M Network.

Measurable objectives

Given the need for early detection of potential ProPs and the combined size of network parks, the Heartland I&M Network opted to allocate available sampling effort to maximize the area searched. With this approach and the available sampling effort in mind, we developed the following realistic objectives for the ProP monitoring protocol:

1. Create a watch list of ProPs known to occur in network parks and a watch list of potential ProPs that may invade network parks in the future, and occasionally update these two lists as new information is made available.
2. Provide early detection monitoring for all ProPs on the watch list.
3. Search at least 0.75% and up to 40% of the reference frame for ProP occurrences on each park.

4. Estimate/calculate and report the abundance and frequency of ProPs in each park.
5. To the extent possible, identify temporal changes in the distribution and abundance of ProPs known to occur on network parks.

The objectives are specifically designed to assist managers with identifying high priority problematic plants, planning problematic plant management, and assessing management in an adaptive sampling framework.

Table 1. Ecoregions of Heartland Inventory and Monitoring Network problematic plant monitoring parks.

Ecological Group	Park Units	Code	Acres (Ha)
Eastern Deciduous Forest	Cuyahoga Valley National Park	CUVA	32,571 (13,181)
	Effigy Mounds National Monument	EFMO	2,526 (1,022)
	Hopewell Culture National Historical Park	HOCU	1,776 (719)
	Lincoln Boyhood National Memorial	LIBO	200 (81)
Mississippi Embayment	Arkansas Post National Memorial	ARPO	758 (307)
Ouachita Mountains	Hot Springs National Park	HOSP	5,554 (2,248)
Ozark Plateau	George Washington Carver National Monument	GWCA	240 (97)
	Pea Ridge National Military Park	PERI	4,300 (1,740)
	Wilson's Creek National Battlefield	WICR	2,408 (974)
Tallgrass Prairie	Homestead National Historical Park	HOME	210 (85)
	Herbert Hoover National Historic Site	HEHO	187 (76)
	Pipestone National Monument	PIPE	282 (114)
	Tallgrass Prairie National Preserve	TAPR	10,883 (4,404)

Sampling Design

Rationale for selecting species for monitoring

A great number of problematic plant prioritization and risk assessment protocols have been developed, often designed for particular purposes or specific geographic regions. Examples are the Alien Plant Ranking System that evaluates plant life-history, ecological effects, and management feasibility to prioritize control efforts in parks (Hiebert and Stubbendieck 1993); NatureServe's I-ranks system that uses extensive biogeographical information as criteria to rank plant invasiveness at local, regional, national, and global scales (Morse et al. 2004); the California Exotic Pest Plant Council list that relies heavily on expert opinion to assess ecosystem effects and plant invasion potential (Warner et al. 2003); and the Invasive Plants Association of Wisconsin's Working List of the Invasive Plants of Wisconsin that was developed through a systematic survey of plant experts in the state (IPAW 2003). While each of these systems provides a well-conceived model for ranking problematic plants, other less formal lists draw on experience across a range of resource management disciplines for prioritization. Such lists, which include state and federal noxious weed lists, have historically targeted agricultural pest plants to address the concerns of farmers and ranchers.

Development of the Heartland I&M Network problematic plant prioritization database (PriorityDB) occurred in two stages. During the initial phase, numerous state and national lists of exotic, invasive, and otherwise harmful plant taxa were consulted (see Young et al. 2007) to create a priority ranking. This priority ranking was an attempt to distinguish problematic plants that are likely to invade natural areas from those that are either naturalized or disturbance dependent. In addition, the first iteration of the database contained a list of problematic plants found in each state within the network (based on the USDA Plants database and state lists) and a list of problematic plants found in each network park (based on the NPSpecies database). Collectively, these state, park, and priority lists were utilized to generate two watch lists for each park: an "early detection watch list" contained high-priority ProPs that occur within the state but are not yet known to occur on the park and a "park-established watch list" contained high-priority ProPs that are known to occur on the park. As their names suggest, these two lists were developed to detect new invasions and to monitor established invasions, respectively. A third list, the "park-based watch list" contained taxa that park managers or network staff identified for monitoring and that did not occur on either of the other two lists. Inclusion of this third list allows us to prioritize park concerns and include species that are missing in USDA Plants and/or NPSpecies.

The second phase (Figure 1), which occurred during protocol version 2.0 revisions, called for streamlining of the PriorityDB and a more dynamic approach to updating search lists while remaining grounded in original methodology. Full routine updates of state and park occurrence lists (from USDA Plants and NPSpecies, respectively) were found to be outside the capacity of the Heartland I&M Network and introduced potential errors through taxonomic serial number (TSN) and accepted symbol mismatches. The network also makes use of sub-genera classifications for closely related species (such as *Poa compressa*/*P. pratensis*) which have no direct way to relate to the USDA Plants database. Concerns over the accumulation of non-priority taxa on park search lists in some years were also present. For these reasons, a new systematic approach to prioritization lists was created, along with a fresh database.

Under this second system, the base search list for each park becomes the list of all high-priority problematic plants that occur in a state (based on USDA Plants); thus, parks in the same state (such as GWCA and WICR) begin with the same base list. All taxa from this list are tagged with an "Original" designation to denote that their inclusion was based on the consultation of many state and national species lists (Young et al. 2007), but the specific lists from which each taxon was drawn are not maintained in the new database. To the base search list are added taxa previously included on the "park-based watch list" and those deemed important under the discretion of network staff. Such additions are tagged with either "From Park" or "From Network" designations based on their origin, to both distinguish them from the originally prioritized taxa and to document the history of their inclusion on the

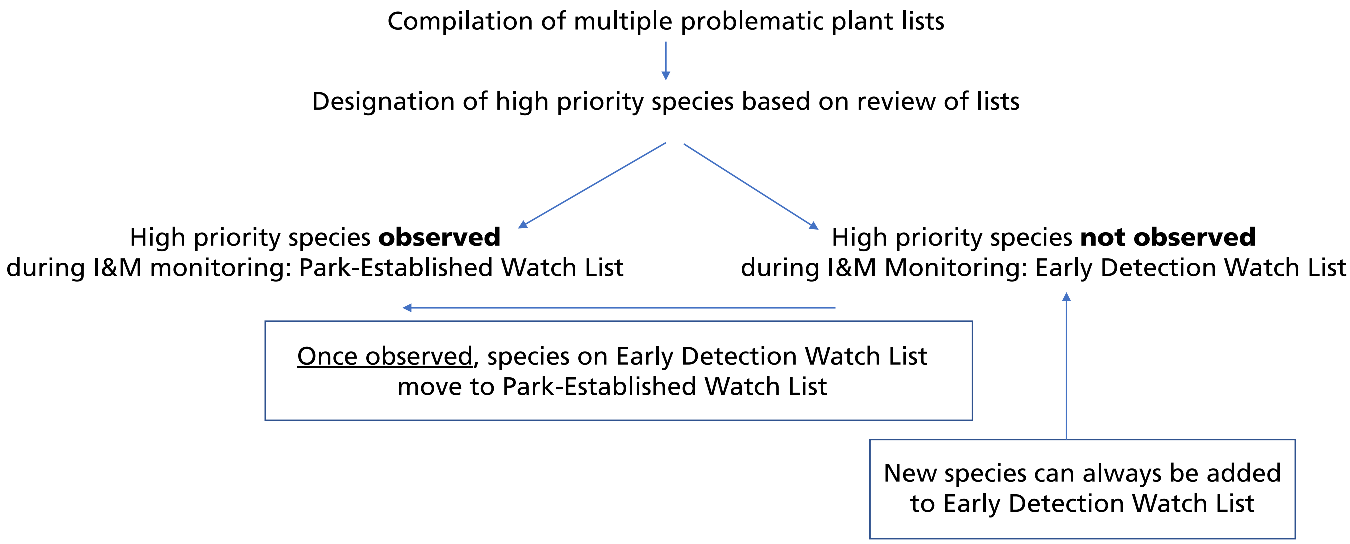

Figure 1. Second phase process for developing and updating early detection and park-established watch lists.

list. Documentation in this way allows for dynamic updates to park search lists with traceable justification; additional tags supported by the database include "New Information" (for regional bulletins, studies improving understanding of the invasiveness of certain species, etc.) and "Other."

The search list for each park is now a combination of the three search lists described by Young et al. (2007)—early detection, park-established, and park-based. While "park-based" terminology can largely be retired in the new system, classification of species as either "early detection" or "park-established" may still be of use to managers. Now that we have monitored ProPs for several years at each network park, "park-established" taxa can be defined as those detected in any previous monitoring year while "early detection" taxa are those being searched for but not yet found. It is important to note that this is a shift in definition from the first system of search lists, and technical reports should be interpreted carefully to understand which definitions were/are in use.

Reduction in systematic updates improves sustainability for the network while still maintaining the modular structure and expert consensus that were advantages to the first phase of the PriorityDB (Young et al. 2007). Updates to taxonomy, based on the authority of the USDA Plants database and the Integrated Taxonomic Information System (ITIS), may be made on an ad hoc basis as network workloads allow. Taxa may be added to or removed from lists as seen fit by the experience and expertise of managers and network staff and/or the consensus of the scientific community.

While strong arguments can be made that monitoring should focus only on taxa that will be actively managed in a park, management priorities are likely to shift over time based on invasion spread, resources threatened, and feasibility of control. With these factors in flux, long-term monitoring that focuses on a narrow list of species of immediate concern may fail to provide critical information on distribution and abundance. On the other hand, while more detailed prioritization is possible, this basic approach eliminates the need for more exhaustive, time-consuming, and often redundant assessments of each ProP taxa. As other organizations prioritize problematic plants based on life-history and management feasibility, the PriorityDB will incorporate this information. However, managers should be aware that these lists are inevitably imperfect, requiring managers or volunteers to watch for other unlisted ProPs during routine management activities.

Rationale for selecting this sampling design over others

Taking a holistic approach to ProP management, national park managers work to prevent the introduction of ProPs (usually via propagules), detect and respond rapidly to new ProP invasions, and control or at least contain established invasions. The probability of successful control decreases at each stage on this invasion continuum (Naylor

2000; McNeely 2001). Early detection and rapid response generally require far fewer resources than managing established ProP populations (OTA 1993). Eradication efforts are most successful for invasions less than 2.5 acre (1 ha) and typically not successful for invasions exceeding 250 acres (100 ha; Rejmanek and Pitcairn 2002). While early detection usually implies the establishment of plants not previously occurring on the park, the scale should clearly be specified. For example, early detection in previously non-infested sections of a national park may also warrant immediate control at a more localized scale.

A three-stage approach applies to the management of ProPs regardless of invasion status: inventory/survey, monitor, and manage (Rew et al. 2006). Inventories document the presence and, in some instances, the abundance or extent of ProPs in a natural area. Monitoring, on the other hand, provides unbiased, statistically powerful, and cost-effective approaches to detect change in ProP abundance or distribution (Gibbs et al. 1998). At the risk of oversimplification, inventories often focus on extensive spatial scales, while monitoring focuses only as broadly as necessary to provide reasonably precise estimation given the expected spatiotemporal variability. The line between inventory and monitoring begins to blur if the inventory is designed to be repeated over time and to allow detection of changes in ProP abundance or distribution.

A perfect map of ProPs on a national park would fully meet most basic inventory and monitoring needs. As an inventory product, maps comprehensively identify and locate ProPs, allowing natural areas 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 reproduced accurately over time would clearly detect changes in the abundance and spread of ProPs. Combined with information on the treatments applied to ProPs, maps could also assess management effectiveness. Wide-spread interest in problematic plant mapping reflects the potential benefit of such maps and the availability of GNSS technology. Numerous ProP mapping efforts have been initiated in many countries and by local, state, federal, and non-governmental agencies in the United States. For example, the North American Invasive Species Management Association (NAISMA, formerly NAWMA) has issued guidelines to bring a minimum level of standardization to mapping efforts in North America (NAISMA 2018).

Despite numerous advantages, comprehensive mapping of ProPs in national parks faces several challenges. To accurately track change using mapped perimeters, replicable mapping rules must be carefully observed. For example, a minimum mapping unit must be designated and followed. Mapping using small minimum units can often only be accomplished over small areas. As map unit size increases, mapping becomes more efficient, but the difficulty of detecting change in infestation perimeters increases and errors are introduced in estimates of ProP abundance within the perimeter. Furthermore, comprehensively mapping ProPs on a large landscape, even using large map units, is generally cost-prohibitive.

Given the limitations of mapping, a few alternatives are available: (1) develop statistically rigorous measures of ProP cover and frequency (Elzinga et al. 2001), (2) limit mapping or sampling to suitable habitat or likely points of invasion (Despain et al. 2001; Poon and Margules 2004; Rew et al. 2006), (3) combine sampling with a landscape modeling approach to determine likelihood of occurrence (Chong et al. 2001; Campell et al. 2002; Shafii et al. 2003; Rew et al. 2005; Chong et al. 2006; Barnett et al. 2007), and (4) map changes in ProP distribution and abundance using remotely sensed imagery (Anderson et al. 1996; Everitt et al. 1996; Lass et al. 1996; Lass et al. 2002; Lawrence et al. 2006). The strengths and weaknesses of each approach should be evaluated relative to the monitoring objectives.

1. A precise measurement of ProP cover or frequency would provide a strong indicator of spread over time. However, the spatiotemporal variability in ProP populations, especially small populations, may preclude precise and powerful estimation. Additionally, a lack of spatial referencing prevents managers from determining if the plant may impact areas that protect particularly valuable resources.
2. 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. As with all models, sample size and methods affect model accuracy. Given the

tendency of ProPs to expand their range, even accurate maps may not reflect the invasion potential of a plant. The need to monitor multiple ProP species simultaneously can also diminish the practicality of this approach.

3. Combined with spatially referenced habitat data, sampling may be used to map the probability of ProP occurrences on the landscape. These maps show a generalized area where the taxa 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 management decisions are made, managers must still survey high probability areas for exact ProP locations. Limited data can compromise the reliability of these habitat maps since 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 ProP abundance or frequency may suffer from the same problems mentioned above (see #1)
4. Successful identification of ProPs 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 for ProPs 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.

Given these mapping, sampling, and modeling challenges, the sampling design for this protocol was selected to balance multiple objectives. These objectives are to identify high priority problematic plants, focus on natural and restored areas, ensure good spatial coverage, detect new plant invasions, monitor multiple species simultaneously, track changes in abundance and distribution of existing invasions, and address management priorities, while working within program capacity. The protocol emphasizes the quick collection of ProP location and abundance data to maximize the area searched. Maximizing the search area provides the greatest opportunity to find new invasions in parks, while also maximizing encounter rate of established ProPs. For small parks (reference frame <350 acres/142 ha), a relatively high percentage of the park area is covered to create a map of the plant locations on the park. For large parks (reference frame >350 acres/142 ha), the selected method covers a greater portion of the park than is typically covered using plot-based sampling approaches. At the same time, the sampling units (search units consisting of either polygons or lines) are semi-permanent, which should reduce sample variance to improve detection of change in ProP abundance and distribution over time. By default, absence data (i.e., negative data) are collected as ProP search routes are known. Taken together, the maps and estimates of cover and frequency provide critical information for designing ProP control strategies.

Prior to adopting this monitoring protocol, we also assessed its weaknesses. As with any sampling or mapping approach, plants may be overlooked due to incomplete coverage of the sample area, as well as differences in observer's taxonomic expertise and plant detectability due to growth-form or surrounding vegetation. Changes in the distribution (i.e., frequency) of ProPs must be interpreted with this in mind. Substantial interobserver error associated with visual cover class estimates applied at such a broad scale will also reduce resolution to detect change in cover over time. Because locations are not documented precisely, 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. As the spatial scale of control increases with cumulative management actions, however, assessment of management effectiveness becomes progressively more feasible with this design.

Site selection

The reference frames directing monitoring were designed to focus on accessible natural and restored areas. Areas requiring special equipment or permission for access were excluded from the reference frame, as were developed areas. In some cases, reference frames were much smaller than the park acreage; for example, much of the acreage at ARPO was flooded following downstream construction of a dam and thus was excluded. The decision to focus on natural and restored areas was based on several lines of reasoning. First, because managers are generally aware that disturbed and developed areas support numerous ProPs, we determined that the limited resources available for monitoring would be best allocated towards intact natural areas. Second, some ProPs are well established on Heartland I&M Network parks but do not readily invade intact natural areas, particularly forests. Early detection in these natural areas ensures a rapid response as needed, while taking a wait-and-see approach in the extensively invaded areas where successful control is unlikely (e.g., battlefields). Third, ProPs are known to be established (and presumably will continue to establish) throughout natural areas on network parks, possibly due to the disturbance history or relatively small size of many of the parks. Finally, as a logistical consideration, some highly disturbed areas in network parks, especially early successional forests, are virtually impenetrable. The reference frame for each park was created in a geographic information system (GIS) to define the area of interest (i.e., statistical population). Reference frames were developed following field reconnaissance, consultation with park resource managers, and review of vegetation maps and remotely sensed images. Operational considerations during the first fifteen years of monitoring provided additional insights and edits to the reference frames of several parks moving forward. Details on reference frame design and sample selection are presented in SOP 1.

Sampling frequency and replication

ProP monitoring in each park will occur on a four-year basis with one exception; CUVA, due to its large size, will be monitored annually by staff stationed at the park. Parks were divided into sampling groups based on geographic location, habitat type, and survey schedule for other Heartland I&M Network monitoring protocols (primarily bird communities and vegetation; Table 2).

A description of start-up monitoring in Heartland I&M Network parks can be found in Young et al. (2007). Any variations that have occurred or may occur to the monitoring design will be documented in the protocol traceability Excel spreadsheet (SOP 7) which is attached to the FieldDB (see below); for specifics please consult the database or the project manager.

Recommended number of sampling sites

Two types of sampling units were developed for parks of different sizes: (1) polygon search units for small parks (reference frame <350 acres/142 ha) and (2) line search units on large parks with high to moderate accessibility (reference frame >350 acres/142 ha). Small parks include ARPO, GWCA,

Table 2. Revisit schedule for problematic plant monitoring. X denotes a revisit.

Park	Group A	Group B	Group C	Group D
ARPO	–	–	–	X
CUVA	X*	X*	X*	X*
EFMO	–	X	–	–
GWCA	X	–	–	–
HEHO	–	X	–	–
HOCU	–	–	–	X
HOME	–	X	–	–
HOSP	X	–	–	–
LIBO	–	–	–	X
PERI	X	–	–	–
PIPE	–	X	–	–
TAPR	–	–	X	–
WICR	X	–	–	–

* Annual surveys conducted by Heartland Inventory and Monitoring Network staff stationed at the park rather than inclusion in any particular group.

HEHO, HOCU, HOME, LIBO, and PIPE. Large parks include CUVA, EFMO, HOSP, PERI, TAPR, and WICR. Sampling units were created by dividing existing park management units into polygons that were generally 1 to 3 acres (0.4 to 1.2 ha) in size with 2 acres as the target size (see SOP 1 for examples). For large parks (reference frame >350 acres/142 ha), systematically located line search units were established in a GIS using a random start (see SOP 1 for examples). This process created contiguous lines across the entire park, which increases sampling efficiency. The length of line search units as well as the distance between adjacent contiguous lines is 200 m on EFMO and WICR and 400 m on CUVA, HOSP, PERI, and TAPR. The number of sampling units and the estimated number of person-days required to complete sampling are shown in Tables 3 and 4 for small and large parks, respectively. Sampling units at several parks (GWCA, PIPE, WICR) have experienced updates during the first fifteen years of protocol implementation, while two other parks (EFMO, HOSP) have not yet been sampled under this protocol. Full details on reference frame design and sample selection for each park are presented in SOP 1.

Timing of sampling

In general, ProPs at a particular park will be monitored at the same time of year. Consistency in timing should generally maintain consistency in detection probabilities and cover estimates. For many species, sampling any time during June–September is not expected to drastically alter monitoring results. However, sampling after May could prevent detection or identification of spring-blooming ProPs such as dame's rocket (*Hesperis matronalis*), plants in the families Brassicaceae and Caryophyllaceae, and exotic cool season grasses such as Kentucky bluegrass (*Poa pratensis*), brome grasses (*Bromus* spp.), and fescues (*Schedonorus* spp.). The semi-evergreen nature of some species, such as Japanese honeysuckle, allows monitoring to continue through autumn, and garlic mustard may only be effectively

Table 3. Overview of polygon search units on small parks (reference frame <350 acres/142 ha). GWCA and PIPE have experienced updates since ProP monitoring initiated.

Park	Reference Frame Acres (ha)	Number of Polygon Search Units	Estimated Person-Days
ARPO	339 (137)	169	9
GWCA	218 (88)	114	6
HEHO	82 (33)	50	6
HOCU	223 (90)	107	12
HOME	168 (68)	82	6
LIBO	153 (62)	77	6
PIPE	287 (116)	122	9

Table 4. Overview of line search units for large parks (reference frame >350 acres/142 ha). WICR has experienced updates since ProP monitoring initiated, while EFMO and HOSP have not yet been monitored under this protocol; estimated person-days required for HOSP is yet to be determined (tbd)

Park (search unit line length and distance to adjacent lines)	Reference Frame Acres (ha)	Number of Line Search Units	Search Miles (km)	Estimated Person-Days
CUVA (400 m)	26,241 (10,619)	822	161.6 (260.1)	80
EFMO (200 m)	2,305 (933)	245	26.8 (43.1)	15
HOSP (400 m)	5,446 (2,210)	144	32.7 (52.6)	tbd
PERI (400 m)	3,124 (1,264)	101	19.8 (31.8)	9
TAPR (400 m)	10,735 (4,344)	301	71.5 (115.1)	12
WICR (200 m)	1,350 (546)	157	17.1 (27.6)	9

detected prior to leaf-out or following leaf-fall. With these limitations in mind, sampling during the first fifteen years of protocol implementation occurred from May to September, with most sampling periods from June to August.

Levels of change that can be detected for the amount/type of sampling being instituted

Differences in search effort, plant detection probabilities, global navigation satellite system (GNSS) error associated with navigation, and unavoidable navigator discretion pose several problems for analyzing changes in ProP abundance and distribution. The coarse scale of cover measurement and the difficulty in visually integrating cover across large areas may contribute to substantial interobserver differences. However, the use of semi-permanent search units should still partially reduce sample variance. Using non-overlapping cover ranges as the criteria for detecting change in ProP abundance on six smaller parks, ProPs of low abundance could have to increase over five doubling periods before a change in abundnce would be detected, while ProPs of high abundance could have to increase over three or four doubling periods to notice a change.

Field Methods

Field season preparations and equipment set-up

Sampling trips will be scheduled and organized prior to the start of each field season. Prior to working in the field, observers must review the Heartland I&M Network safety plan and the entire protocol. Observers will review ProP identification using herbarium specimens, keys, and photographs (SOP 3). The crew leader will provide a refresher on plant identification, GNSS navigation, compass use, and foliar cover estimation. All equipment and supplies, especially GNSS units, should be organized and prepared for the field season. All files needed for navigation will be loaded onto GNSS units for transport to the park.

Sequence of events during field season

After arrival to each park, all equipment required for sampling is assembled and checked (SOP 2).

Each day the crew leader provides a briefing regarding safety, plant identification, and park navigation. All observers must be properly trained (SOP 3). The crew leader assigns crew members to the search units for the day. Prior to beginning daily work in the field, observers collectively estimate ProP cover over a given area and compare observations in order to recalibrate cover class estimates and maintain data quality.

For small parks (reference frame <350 acres/142 ha), surveyors make three equidistant passes through each polygon search unit in an east-west direction, focusing on an approximately 3- to 12-m-wide belt (1.5 to 6 m on either side of the surveyor). Cover estimates for each ProP encountered are recorded using a cover scale: 0 = 0, 1 = 0.1–0.9 m^2, 2 = 1–9.9 m^2, 3 = 10–49.9 m^2, 4 = 50–99.9 m^2, 5 = 100–499.9 m^2, 6 = 499.9–999.9 m^2, and 7 = 1,000–4,999.9 m^2 (SOP 4). Observations are made in the widest possible belt given site conditions. Passes through the search unit are made using GNSS navigation and relative location to other surveyors. Assuming a perfectly square 2-acre plot (0.8 ha), surveyors cover approximately 10 to 40% of the park reference frame. The time required to complete monitoring depends on park size and access logistics (Table 3).

For large parks (reference frame >350 acres/142 ha), surveyors record and estimate the cover of each ProP encountered along line search units in an approximately 3- to 12-m belt (1.5 to 6 m on either side of the surveyor) using the same cover scale as above (SOP 4). Observations are made in the widest possible belt given site conditions. Line search units are followed using GNSS navigation. Assuming that surveyors estimate plant cover in a 12-m belt, 1.5 to 6% and 0.75 to 3% of the park reference frame will be surveyed using 200-m and 400-m line search units, respectively. The time required to complete monitoring depends on park size and access logistics (Table 4).

It should be noted that during the first round of samples in 2006, constraints on search belt width were not in place. Surveyors had discretion to search a larger belt if feasible, to search additional areas up to 200 m in perpendicular distance from a search unit, and to target additional locations likely to support problematic plants (e.g. field edges, roads). In most cases, surveyors remained close to the established line or pass through the polygon, and in subsequent years observations were specifically limited to the 3- to 12-m belts (1.5 to 6 m on either side of the surveyor).

Details of taking measurements

Measurements require the use of a foliar cover class scale. Foliar cover is the area of ground covered by the vertical projection of the leaf surface area of the plants. Field forms are of two types: the first was used in earlier survey rounds. In this case, plant taxon and a cover class were assigned without any information on prior observations. The more recent field forms listed previous taxa found, but not the cover class. Blank space was also provided for recording species not encountered during previous surveys. Full details on field methods are presented in SOP 4.

Post-collection processing of samples

Research specimens may be collected to confirm identification of ProPs, especially those that are likely to be identified incorrectly (SOP 5). In some cases, small or partial samples may be quickly collected and stored in a field notebook; alternatively, photographs of key features may be used to document unknown specimens. Location, description, and habitat information are recorded using an unknown specimen data sheet (SOP 5). Research specimens are only for confirmation of taxonomy and will not be stored in a collection.

Data Handling, Analysis, and Reporting

Metadata procedures

The Federal Geographic Data Committee (FGDC) now provides a range of options as guidance for metadata of spatial and non-spatial federal agency data. Most recommendations are variations of the ISO191xx standard, which is typically used for natural resource datasets. Creation of ISO metadata has been greatly facilitated by ESRI ArcGIS utilities that automatically generate spatial metadata. Once metadata has been created, it should be saved in XML format following ISO metadata standards. Metadata is archived in the geodatabase and by the WASO Inventory and Monitoring Division (IMD) in IRMA. Metadata is archived by WASO with the submission of the monitoring protocol. It should be updated with each protocol revision. New Guidance for monitoring datasets will soon be available from the IMD IT Governance Board Metadata Working Group and SOP 7 will be updated accordingly.

Overview of database design

There are three databases utilized in the ProP monitoring project. Two are tabular Microsoft Access databases—the ProP Prioritization Database (PriorityDB; SOP 6) and the ProP Monitoring Field Database (FieldDB; SOP 7)—and one is an ESRI ArcGIS file geodatabase, hereafter referred to as the geodatabase (SOP 7). PriorityDB and FieldDB are maintained on the Heartland I&M Network server in the 'Databases' folder as 'HTLN_ProP_EPPDb' and 'HTLN_ProP_Access', respectively, while the geodatabase is maintained on the spatial server in the 'Geodatabases' folder as 'INP_FileGDB'.

PriorityDB provides three key data elements: a search list of priority ProPs for each park; a record of previous search lists by event period for monitoring from 2006 to the present; and a list of reference information about all priority ProP taxa, including scientific and common names, family, and NatureServe Invasive Rank (I-Rank). FieldDB houses the non-spatial core data for the monitoring project in six tables including sampling period, search unit name/location, and ProP taxa abundance. The geodatabase houses all the spatial data associated with the monitoring project, including search units; reference frame and park boundaries; starting points, end points, and midpoints of lines; and grid cells associated with those lines. A separate feature dataset contains feature classes for each Universal Transverse Mercator (UTM) coordinate zone. All data in FieldDB and the geodatabase can be linked together by using the key fields InpID and LocationID.

Data entry, verification, and validation

Data processing typically involves the following steps: data entry, data verification, data validation, and backups/storage (see SOP 7). Data entry consists of transferring data from field sheets into a database using a data entry interface. Data verification immediately follows data entry and involves checking the accuracy of computerized records against the original source. Validation procedures seek to identify generic errors (e.g., missing, mismatched, or duplicate records) as well as logical errors specific to particular projects.

Routine data summaries and statistical analyses

Most routine data summaries will focus on reporting the locations and cover of species during the most recent survey and the amount of change since the previous survey (usually four years before). Our main objectives are to provide managers with the information needed to eradicate new invasions and control existing invasions, while providing feedback for ongoing control efforts. Full data summary and analysis procedures are explored in SOP 8.

Reporting schedule and format

Problematic plant monitoring reports will be prepared and distributed the next calendar year following data collection (SOP 8). These reports were previously published under the Natural Resource Technical Report (NRTR) series, which was combined with the Natural Resource Report (NRR) series in 2014. Report templates for the NRR series, as well as the Natural Resource Data (NRD) series, are available at https://www.nps.gov/im/publication-series.htm. A fresh template should be used with each report, as templates change periodically and old templates can become corrupt. An example NRR for Arkansas Post National Memorial is available at https://irma.nps.gov/DataStore/DownloadFile/596226.

Long-term trend analyses

Statistical analyses will be used to evaluate changes in the cover and frequency of ProPs (SOP 8). Trends in cover will be evaluated based on the differences detected by non-overlapping cover ranges, an approach similar to an analysis of variance (ANOVA). A 10-acre threshold will be used to indicate levels at which successful control of ProPs becomes less likely. Trends in frequency will be evaluated using regression analysis. The following frequency thresholds will be used to categorize ProPs: very low frequency (≤ 2%), low frequency (> 2–10%), medium frequency (> 10–40%) and high frequency (> 40%).

Data archival procedures

The Heartland I&M Network backs up all spatial and non-spatial data (including tabular documents) regularly. Weekly and monthly backups are incremental while quarterly and annual backups are mirrored copies of the server. Quarterly and annual copies of the server are stored off-site in a bank safe-box.

Like other monitoring databases/geodatabases, the problematic plant monitoring databases and geodatabase are secured by file archives stored on the server. The databases are maintained under a directory called InvasiveNonnativePlants under the HeartlandCommon and Spatial production drives. The geodatabase immediately below this directory in the Spatial drive is the in-use copy of the geodatabase, while all backups and earlier versions are stored under the "dev" directory (short for "development").

Annually, in fulfillment of the Data Analysis and Reporting Requirements (Gallo, K. memorandum dated 4/23/2018), the dataset will be uploaded to IRMA DataStore. The dataset is currently flagged as "read only" for all users except the project manager and data manager.

Personnel Requirements and Training

Roles and responsibilities

A HTLN staff member serves as the project manager and normally as the crew leader for ProP monitoring. Data management is the shared responsibility of the project manager and the data manager. Typically, the project manager oversees data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The data manager designs the databases 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 to automate report generation. The data manager is responsible for building adequate QA-QC procedures into the database management system and for following appropriate data handling procedures.

Qualifications

A competent, detail-oriented observer is essential for collecting credible, high-quality ProP data. Misidentification of species decreases capacity to detect trends in ProP abundance and distribution through time. Field observers must be able to quickly scan extensive swaths of vegetation to accurately identify target ProPs. Field observers must also be skilled with GNSS navigation and data collection. Observers should be well-organized, work well as a team member, be comfortable in the field, and work methodically under difficult conditions.

Training procedures

Training is essential for developing competent observers (see SOP 3). Observers will review problematic plant identification using herbarium specimens, keys, and photographs. The crew leader will provide a refresher on problematic plant identification, GNSS navigation, compass use, and foliar cover estimation. Observers will be tested frequently on their ability to identify problematic plant taxa.

Operational Requirements

Annual workload

Monitoring will require at least one and up to three crew members each year to sample ProPs. Additional crew members may also be useful as available to focus on navigation while observers focus on detections. Depending on the year, 30 to 60 person-days in the field will be required annually to complete monitoring (Tables 3 and 4). The number of person-days may change depending on the parks sampled, logistics, weather, and crew skill level.

Facility and equipment needs

Problematic plant monitoring does not require special facilities beyond normal office space and equipment and herbarium storage. A list of field equipment needs for field sampling can be found in SOP 2. As number of observers on the crew increases, equipment requirements will also increase accordingly.

Procedures for Revising the Protocol

Over time, revisions to the protocol narrative and to SOPs are to be expected. Careful documentation of changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis. Mitchell et.al. (2018) describe the types of documentation and review that are needed for modifying a protocol (SOP 9).

Literature Cited

Anderson, G. L., J. H. Everitt, D. E. Escobar, N. R. Spencer, and R. J. Andrascik. 1996. Mapping leafy spurge (*Euphorbia esula*) infestations using aerial photography and geographic information systems. Geocarto International 11:81–89.

Barnett, D. T., T. J. Stohlgren, C. S. Jarnevich, G. W. Chong, J. A. Ericson, T. R. Davern and S. E. Simonson. 2007. The art and science of weed mapping. Environmental Monitoring and Assessment 132:235–252.

Campell, G. S., P. G. Blackwell, and F. I. Woodward. 2002. Can landscape-scale characteristics be used to predict plant invasions along rivers? Journal of Biogeography 29:535–543.

Chong, G. W., R. M. Reich, M. A. Kalkhan, and T. J. Stohlgren. 2001. New approaches for sampling and modeling native and exotic plant richness. Western North American Naturalist 61:328–335.

Chong, G. W., Y. Otsuki, T. J. Stohlgren, D. Guenther, P. Evangelista, C. Villa, and A. Waters. 2006. Evaluating plant invasions from both habitat and species perspectives. Western North American Naturalist 66:92–105.

DeBacker, M. D., C. C. Young (editor), P. Adams, L. Morrison, D. Peitz, G. A. Rowell, M. Williams, and D. Bowles. 2004. Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program vital signs monitoring plan: phase III report. National Park Service, Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program, Wilson's Creek National Battlefield, Republic, Missouri.

Despain, D. G., T. Weaver, and R. J. Aspinall. 2001. A rule-based model for mapping potential exotic plant distribution. Western North American Naturalist 61:428–433.

Elzinga, C. L., D. W. Salzer, J. W. Willoughby, and J. P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Malden, MA.

Everitt, J. H., D. E. Escobar, M. A. Aleniz, M. R. Davis, and J. V. Richerson. 1996. Using spatial information technologies to map Chinese tamarisk (*Tamarix chinensis*) infestations. Weed Science 44:194–201.

Gibbs, J. P., S. Droege, and P. Eagle. 1998. Monitoring populations of plants and animals. BioScience 48:935–940.

Hiebert, R. D., and J. Stubbendieck. 1993. Handbook for ranking exotic plants for management and control. U. S. Department of the Interior, Natural Resources Report NPS/NRMWRO/NRR-93/08. National Park Service, Natural Resources Publication Office, Denver, CO.

Invasive Plants Association of Wisconsin (IPAW). 2003. IPAW working list of the invasive plants of Wisconsin. Newsletter of IPAW. Issue 4. Available at http://www.ipaw.org/ (accessed 2006 Dec 1).

Lass, L. W., H. W. Carson, and R. H.Callihan. 1996. Detection of yellow starthistle (*Centaurea solstitialis*) and common St. Johnswort (*Hypericum perforatum*) with multispectral digital imagery. Weed Technology 10:466–474.

Lass, L. W., D. C. Thill, B. Shafii, and T. S. Prather. 2002. Detecting spotted knapweed (*Centaurea maculosa*) with hyperspectral remote sensing technology. Weed Technology 16:426–432.

Lawrence, R. L., S. D. Wood, and R. L. Sheley. 2006. Mapping invasive plants using hyperspectral imagery and Breiman Cutler classifications (RandomForest). Remote Sensing of Environment 100:356–362.

McNeely, J. A. Invasive species: A costly catastrophe for native biodiverity. Land Use and Water Resources Research 2:1–10.

Mitchell, B., A. Chung-MacCoubrey, J. Comiskey, L. Garrett, M. MacCluskie, B. Moore, T. Philippi, G. Sanders and J. P. Schmit. 2018. Inventory and Monitoring Division protocol review guidance. Natural Resource Report NPS/NRSS/IMD/NRR—2018/1644. National Park Service, Fort Collins, Colorado.

Morse, L. E., J. M. Randall, N. Benton, R. D. Hiebert, S. Lu, and NatureServe. 2004. An invasive species assessment protocol: evaluating non-native plants for their impact on biodiversity, version 1. Available at https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1536&context=govdocs (accessed 2020 Apr 6).

National Park Service (NPS). 2006. Management policies 200. US Department of the Interior, National Park Service, Washington, D.C., USA.

Naylor, R. L. 2000. The economics of alien species invasions. Pages 241–259 in H. A. Mooney and R. J. Hobbs, editors. Invasive Species in a Changing World. Island Press, Washington, D.C., USA.

North American Invasive Species Management Association (NAISMA). 2018. Mapping standards for program managers. Report. Available at https://www.naisma.org/wp-content/uploads/2019/06/NAISMA_Mapping_Standards.pdf (accessed 2020 Feb 11).

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin 31(4):1000–1003.

Office of Technology Assessment (OTA). 1993. Harmful non-indigenous species in the United States. OTA-F-565. U.S. Congress, Government Printing Office, Washington, D.C., USA.

Poon, E. L., and C. R. Margules 2004. Searching for new populations of rare plant species in remote locations. Pages 189–210 *in* W. L. Thompson, editor, Sampling Rare or Elusive Species: Concepts, Designs, and Techniques for Estimating Population Parameters. Island Press, Covelo, California.

Rejmanek, M., and M. J. Pitcairn. 2002. When is eradication of exotic pest plants a realistic goal? Pages 249–253 *in* C. R. Veitch and M. N. Clout, editors, Turning the Tide: the Eradication of Invasive Species. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Rew, L. J., B. D. Maxwell, R. Aspinall. 2005. Predicting occurrence of non-indigenous species using environmental and remotely sensed data. Weed Science 53:236–241.

Rew, L. J., B. D. Maxwell, F. L. Dougher, R. Aspinall. 2006. Searching for a needle in a haystack: evaluating survey methods for non-indigenous plants. Biological Invasions 8:523–539.

Shafii, B., W. J. Price, T. S. Prather, L L.W. Lass, and D. C. Thill. 2003. Predicting the likelihood of yellow starthistle (*Centaurea solstitialis*) occurrence using landscape characteristics. Weed Science 51:748–751.

Warner, P. J., C. C. Bossard, M. L. Brooks, J. M. DiTomaso, J. A. Hall, A. M. Howald, D. W. Johnson, J. M. Randall, C. L. Roye, and A. E. Stanton. 2003. Criteria for categorizing invasive non-native plants that threaten wildlands. California Exotic Pest Plant Council and Southwest Vegetation Management Association. Available at https://www.cal-ipc.org/docs/ip/inventory/pdf/Criteria.pdf.

Young, C. C., J. L. Haack, L. W. Morrison, and M. D. DeBacker. 2007. Problematic plant monitoring protocol for the Heartland Network Inventory and Monitoring Program. Natural Resource Report NPS/HTLN/NRR-2007/018. National Park Service, Fort Collins, Colorado.

Young, K. E., and T. S. Schrader. 2007. Predicting risks of invasive species occurrence: remote-sensing strategies. Chapter 7 in P.H. Geissler and B.A. Welch, editors. Early Detection of Invasive Plants: A Handbook. Draft Report. Unites States Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland.

NPS 920/180322, April 2022

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525