Research Reports

A rapid, invasive plant survey method for national park units with a cultural resource focus

By Craig C. Young and Jennifer L. Haack

INVASIVE PLANT MANAGEMENT PLANNING IN NATIONAL parks can be categorized in three stages: inventory/survey, monitoring, and management (Rew et al. 2006). Inventories or surveys document the presence and may roughly describe the relative abundance of invasive plants in natural areas. The flexibility and broad spatial extent associated with inventories are often required for effective early detection of small invasive plant populations (Carpenter et al. 2002). Monitoring, by contrast, provides unbiased, statistically powerful, and cost-effective approaches to detect change in invasive plant abundance or distribution (Gibbs et al. 1998). While inventories often focus on extensive spatial scales, monitoring focuses only as broadly as necessary to provide reasonably precise variable estimates given the expected spatio-temporal variability. Inventories and monitoring are intended to plan or assess invasive plant management.

A comprehensive map of invasive plants occupying a national park would fully meet inventory and monitoring needs. From a monitoring standpoint, maps with reasonably small minimum mapping units reproduced accurately over time would detect changes in the abundance and spread of invasive plants. Combined with information on the controls applied to specific groups of invasive plants, maps could also be used to assess management effectiveness. Widespread interest in weed mapping reflects the potential benefit of such maps and the availability of global positioning system (GPS) technology (NAWMA 2002).

Despite notable advantages, comprehensive mapping of invasive plants in national parks poses several challenges. Mapping with small minimum units can often be accomplished only over small areas. As map unit size increases, mapping becomes more efficient, but increases the difficulty of detecting change in perimeters and presumably increases error in plant detection and estimation of abundance within the perimeter. Furthermore, comprehensively mapping invasive plants on a large landscape is generally cost-prohibitive (Stohlgren 2007). With this challenge in mind, we developed and tested a simple, rapid survey method intended to simultaneously inventory, monitor, and map invasive plants in national parks with a cultural resource focus (Young et al. 2007).

Figure 1. Pipestone National Monument, Minnesota, is one of six national park units in the Midwest that was the subject of surveys to establish a protocol for monitoring high-priority invasive plants.

Survey methods

Six national park units served as the sites for this study in 2006 (figs. 1 and 2, and table 1). Each park, administered by the NPS Midwest Regional Office and located in the Heartland Inventory and Monitoring Network in the central United States, was established for the interpretation of American history and encompasses 750 acres (304 ha) or less. The park landscapes consist of forests or prairies in three ecoregional provinces (Bailey 1998; table 1). With the exception of some native prairie remnants at Pipestone National Monument (Minnesota), most prairies in these parks have been restored from abandoned agricultural lands. The forests in the six parks reflect succession following agricultural clearing, logging, and planting.

We developed lists of target invasive plants for each park based on our review of 15 available lists (appendix A). During review, we designated a subset of high-priority invasive plants as the focus of our sampling based on one of three criteria. Each plant given a high invasive rank ("H" in Morse et al. 2004) and all plants on the New Invasive Plants in the Midwest list (MIPN 2006) were marked as a high priority. Finally, invasive plants repeatedly identified on multiple lists were subjectively designated as high priorities. The ranking resulted in a list of 126 high-priority invasive plants (referred to collectively as HPIPs) that the USDA Plants database (2007) designated as occurring in that park's respective state (see appendix A).

We limited the invasive plant survey in each park to terrestrial habitat in a relatively natural condition; this area constituted the reference frame. We divided reference frames into sampling units termed "search units," with 2 acres (0.8 ha) as the target size (fig. 3A, next page; table 1). Search units varied in size, however, because of each park's shape and management unit boundaries.

Using a GPS unit, observers made three equidistant passes in an east-to-west direction through search units in the parks (fig. 4, next page). On each pass, we identified HPIPs in each search unit within a 3 to 12 m (9.8 to 39.4 ft) belt. Observers visually documented plants in the widest belt possible given site conditions (e.g., height of grass, density of woody species). We introduced variation in belt width to maximize capture of plant occurrences, while allowing adjustment for conditions where surveying wider transects was not feasible. We assigned a cover class category to each HPIP in each search unit using the following foliar cover scale:

0 = 0
1 = 0.1–0.9 m^2 (1.1–9.7 ft^2)
2 = 1.0–9.9 m^2 (10.8–106.6 ft^2)
3 = 10.0–49.9 m^2 (107.6–537.1 ft^2)
4 = 50.0–99.9 m^2 (538.2–1,075.3 ft^2)
5 = 100.0–499.9 m^2 (1,076.4–5,380.9 ft^2)
6 = 500.0–999.9 m^2 (5,382.0–10,762.8 ft^2)
7 = 1,000.0–4,999.9 m^2 (10,763.9–53,818.5 ft^2)

Figure 2. The Heartland Inventory and Monitoring Network tested the efficacy of the invasive exotic plant survey method for cultural resource–focused parks in six national park units in the central United States: Arkansas Post National Memorial, George Washington Carver National Monument, Herbert Hoover National Historic Site, Homestead National Monument of America, Lincoln Boyhood National Memorial, and Pipestone National Monument.

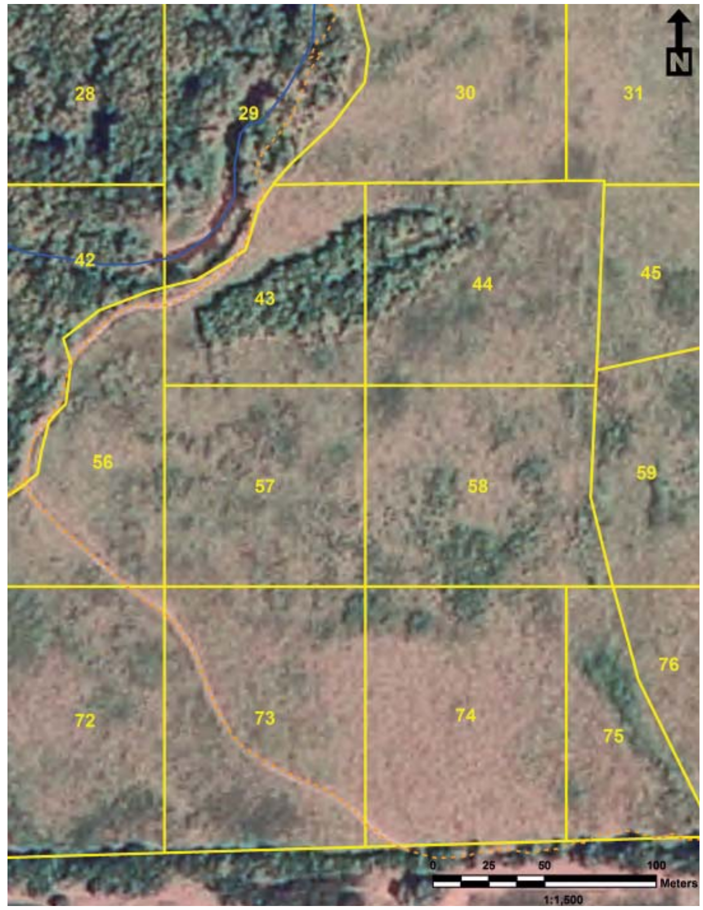
Table 1. Midwestern cultural resource–focused national parks sampled for invasive plants, 2007

National park unit	State	Ecoregion (Bailey 1998)	Park size (acres/ha)	Reference frame size (acres/ha)	Number of search units	Mean search unit size (acres/ha)	Percentage of park sampled (min./max.)
Arkansas Post National Memorial	Ark.	Lower Riverine Mississippi Forest Province	758 (307)	339.3 (137.3)	169	2.01 (0.81)	10.0 39.9
George Washington Carver National Monument	Mo.	Eastern Broadleaf Forest (Continental) Province	210 (85)	188.4 (76.2)	97	1.94 (0.79)	10.2 40.6
Herbert Hoover National Historic Site	Iowa	Prairie Parkland (Temperate) Province	187 (76)	83.7 (33.9)	50	1.67 (0.68)	10.9 43.7
Homestead National Monument of America	Neb.	Prairie Parkland (Temperate) Province	195 (79)	163.9 (66.3)	82	2.00 (0.81)	10.0 40.1
Lincoln Boyhood National Memorial	Ind.	Eastern Broadleaf Forest (Continental) Province	200 (81)	153.6 (62.2)	77	2.00 (0.81)	10.0 40.1
Pipestone National Monument	Minn.	Prairie Parkland (Temperate) Province	282 (114)	270.3 (109.4)	114	2.37 (0.96)	9.2 36.8

Note: The minimum and maximum park percentage sampled indicates the potential range of the park that was surveyed given the variability in transect belt widths.

NPS/JENNIFER HAACK

Figure 3. (A) Exotic plant search units at Herbert Hoover National Historic Site, Iowa. Numbers identify individual units. (B) Cover of *Bromus inermis* Leyss. (smooth brome) at Hoover. Numbers represent plant cover: 1 = 0.1–0.9 m^2 (1.1–9.7 ft^2), 2 = 1.0–9.9 m^2 (10.8–106.6 ft^2), 3 = 10.0–49.9 m^2 (107.6–537.1 ft^2), 4 = 50.0–99.9 m^2 (538.2–1,075.3 ft^2), 5 = 100.0–499.9 m^2 (1,076.4–5,380.9 ft^2), 6 = 500.0–999.9 m^2 (5,382.0–10,762.8 ft^2).



NPS GRAPHIC/JENNIFER HAACK

Figure 4. Orthorectified image of invasive plant search units at Homestead National Monument of America, Nebraska. The image is used for navigation with the GeoXT global positioning system.

To summarize HPIP abundance, we calculated a cover range for each HPIP in each park (see appendix B for an example calculation). To calculate the minimum end of the range, we summed the lower endpoints associated with the cover class values assigned to an HPIP (Kelrick 2001) and then divided by the reference frame fraction observed assuming the widest possible survey belt, 12 m (39.4 ft). We calculated the observed reference frame fraction as follows:

$$\text{fraction of reference frame observed} = \frac{\text{transect length} \times \text{number of transects} \times \text{belt width}}{\text{reference frame area}}$$

We calculated transect lengths for each park using the mean sample unit size and assuming square search units. Maximum cover was calculated similarly, using the upper endpoints of the cover values in each search unit, and assumed that a 3 m (9.8 ft) belt was surveyed. We then summed high and low estimates across species, respectively, to estimate the range of total HPIP cover for each park, as well as across all six parks.

Survey results

In the six parks encompassing approximately 1,832 acres (741.4 ha), observers surveyed 589 search units in reference frames covering 1,199.2 acres (485.3 ha) (table 1). Based on the reference frame fractions observed, observers surveyed at least 9.2–10.9% and no more than 36.8–43.7% of park reference frames (table 1). Surveys at the six parks required approximately 29 person-days.

During the surveys, we identified 53 HPIPs and estimated total HPIP cover at between 165.1 acres (66.8 ha) and 1,988.8 acres (804.8 ha) in the six parks. From this estimate, the best-case scenario indicated that HPIPs cover at least 13.8% of the reference frames in these parks. The worst-case scenario suggested that HPIPs cover up to 165.8% of the reference frames. This clear overestimate (in excess of 100%) is a weakness of the survey method that resulted from the wide cover classes and variable belt widths used to estimate plant cover. This overestimation problem is exacerbated in parks with one or more frequently encountered, abundant HPIPs. For example, the maximum cover estimate for Lincoln Boyhood National Memorial (Indiana), which generally hosts HPIPs with low cover, accounted for 31.5% of the reference frame area (table 2). However, the extensive cover of smooth brome (*Bromus inermis*) (fig. 5) and reed canarygrass (*Phalaris* *arundinacea*) in Pipestone National Monument led to an estimate of maximum HPIP cover as 455.9% of the reference frame.

A relatively small number of highly abundant species accounted for the majority of HPIP cover within and among parks (table 2). Observers identified as few as 9 HPIPs in Homestead National Monument of America (Nebraska) and as many as 29 HPIPs in Lincoln Boyhood National Memorial (table 2). In each park, most HPIPs (55.6–82.8%) occupied less than 2 acres (0.8 ha) (table 2). On the other hand, relatively few species (0.0–27.8%) in each park covered more than a maximum of 25 acres (10.1 ha). Across all six parks, the combined cover of 58.5% of HPIPs was less than 2 acres (0.8 ha), and 75.5% of species occupied a maximum of 10 acres (4.0 ha). Maximum cover estimates indicated that only 11.3% of HPIPs potentially occupy more than 100 acres (40.5 ha or 8.3% of reference frame) across all six parks. Of these six species, Japanese honeysuckle (*Lonicera japonica*), sweetclover (*Melilotus officinalis*), reed canarygrass, and trifoliate orange (*Poncirus trifoliata*) occupy at least 10 acres (4.0 ha), while smooth brome and bluegrass (*Poa compressa/pratensis*) occupy at least 43 acres (17.4 ha).


COPYRIGHT MIKE HADDOCK, UNIVERSITY OF KANSAS

Figure 5. Smooth brome (*Bromus inermis*) is one of the two most abundant invasive plants found in the six national parks included in the study.

Table 2. Invasive plant cover in six midwestern cultural resource–focused national parks, 2007

Abundance categories		Percentage of high-priority invasive plants in each park[‡]					
Minimum cover* acres (ha)	Maximum cover* acres (ha)	ARPO[†] (15 plants)	GWCA[†] (21 plants)	HEHO[†] (21 plants)	HOME[†] (9 plants)	LIBO[†] (29 plants)	PIPE[†] (18 plants)
> 0.1 (> 0.04)	< 2.0 (< 0.8)	66.7	57.1	71.4	55.6	82.8	55.6
0.1 – 0.4 (0.04 – 0.2)	1.0 – 5.0 (0.4 – 2.0)	6.7	14.3	14.3	11.1	6.9	5.6
0.3 – 0.8 (0.1 – 0.3)	5.0 – 10.0 (2.0 – 4.1)	13.3	9.5	4.8	0.0	3.4	5.6
0.5 – 2.0 (0.2 – 0.8)	10.0 – 25.0 (4.1 – 10.1)	6.7	9.5	0.0	22.2	6.9	5.6
1.5 – 4.0 (0.6 – 1.6)	25.0 – 50.0 (10.1 – 20.2)	0.0	4.8	4.8	0.0	0.0	11.1
4.0 – 10.0 (1.6 – 4.1)	50.0 – 100.0 (20.2 – 40.5)	0.0	4.8	0.0	11.1	0.0	5.6
10.0 – 25.0 (4.1 – 10.1)	100.0 – 250.0 (40.5 – 101.2)	6.7	0.0	4.8	0.0	0.0	0.0
35.0 – 45.0 (14.2 – 18.2)	400.0 – 650.0 (161.9 – 263.1)	0.0	0.0	0.0	0.0	0.0	11.1
Parkwide cover range		**Acres (ha)**					
Minimum cover estimate		20.5 (8.3)	15.6 (6.3)	23.7 (9.6)	8.3 (3.4)	3.4 (1.4)	93.6 (37.9)
Maximum cover estimate		182.0 (73.7)	177.4 (71.8)	246.2 (99.6)	102.4 (41.4)	48.4 (19.6)	1,232.2 (498.7)

*The minimum and maximum cover values are each presented as ranges that constitute the low and high ends of abundance categories.

[†]The percentage of high-priority invasive plant species in the national park unit falling within the abundance category ranges (min. and max. values) is presented.

[‡]ARPO = Arkansas Post National Memorial, GWCA = George Washington Carver National Monument, HEHO = Herbert Hoover National Historic Site, HOME = Homestead National Monument of America, LIBO = Lincoln Boyhood National Memorial, and PIPE = Pipestone National Monument.

A relatively small number of highly abundant species accounted for the majority of high-priority invasive plant cover within and among parks.

Evaluation of the survey method

The survey method covered a relatively high proportion of park reference frames and identified 42% of the invasive plant species of management concern. Though the probability of HPIP detection and accuracy of cover estimates in smaller quadrats (i.e., rectangular plots) is likely higher than in the long belt transects sampled here, sampling just 10% of park reference frames would require sampling 4,850 100 m^2 (1,076.4 ft^2) quadrats. The variable belt widths also increased plant detection by adapting to site conditions. In instances where the sampling area needs to be maximized to detect incipient HPIP populations, the survey method presumably requires substantially less sampling effort per unit area than quadrat-based methods.

In addition to identifying HPIPs, the survey method mapped plant locations within search units. In this respect, the method essentially predetermined the minimum mapping unit and delineation rules. Assuming that each species encountered in a search unit in this study represents only a single mapped cluster of plants (or polygon), a mapping approach would require delineating 2,365 polygons. The 2-acre (0.8 ha) search units appeared to be sufficient for planning invasive plant management actions and finding invasive plants for treatment. Managers must keep in mind that search units are not completely searched and may contain invasive plants not found during surveys. Search units, however, also provided a way to document locations where HPIPs were not found. Such areas may constitute park tracts free from invasive plants. More exhaustive follow-up surveys may be conducted in these search units as needed.

The abundance estimates can be evaluated from two perspectives: (1) suitability as a point-in-time estimate and (2) ability to detect change over time. As point-in-time estimates, the cover estimates appeared sufficiently precise to guide invasive plant management planning despite wide range variations. For example, sow thistle (*Sonchus arvensis*) occupies between 6.7×10^{-5} and 2.4×10^{-3} acres (2.7×10^{-5} and 9.7×10^{-4} ha, respectively), while smooth brome occupies between 37.7 and 469.0 acres (15.3 and 189.8 ha, respectively) at Pipestone National Monument. Despite these wide ranges, smooth brome has clearly invaded the park much more extensively than sow thistle. The wide abundance ranges posed some limitations on the survey's effectiveness in detecting change in abundance over time. Under the most extreme scenario (all actual cover values at the low end of the assigned cover class), change would be detected for 4.4%, 33.6%, 24.8%, and 37.2% of HPIPs following three, four, five, and six doubling periods (i.e., the time required for a population to increase by 100%), respectively. Without comparisons from plot sampling data, however, it is difficult to know if the ability of the method to detect change is reduced compared with plot sampling approaches. We note that we did not convert cover classes to midpoint values, which artificially reduces the sample variance. Rather, assuming a high ability to detect HPIPs and to accurately estimate plant cover visually, sources of sample variation due to imprecision of cover classes and variation in belt width are completely accounted for in the HPIP cover ranges. As an alternative, the semipermanent transects support analysis of the survey data as a paired-sample design. The average change in cover class may be calculated as an indicator of change in HPIP abundance in each park.

Invasive plant management planning

Based on minimum cover estimates alone, the extent of HPIP invasion at multiple and individual park scales suggests the need for a strategic management approach in culturally focused national parks. Though invasive plant management plans are inevitably site-specific, the survey provided several criteria that have already assisted National Park Service resource managers in developing management plans for Arkansas Post National Memorial (Arkansas), Pipestone National Monument, and Wilson's Creek National Battlefield (Missouri). The assessment method provides a parkwide estimate of invasive plant cover, as well as a map of the observed cover within occupied search units (fig. 3B, page 72). Assuming that success of control is more probable for small HPIP populations (Rejmanek and Pitcairn 2002), the relatively low abundance of the majority of HPIPs may give managers the opportunity to control a large number of plant species within and across these parks. Managers may also view HPIP distribution maps in relation to high-priority management areas (e.g., rare plant populations) and strategically focus on controlling only particular HPIPs in specific locations. These planning criteria may be augmented with available information on invasive plant impacts, management feasibility, and nontarget effects (Hiebert and Stubbendieck 1993; Morse et al. 2004) to improve site-based decisions.

Summary

In our opinion, this survey approach represents the simplest solution to invasive plant monitoring for many cultural resource parks. The approach can provide a starting point for more complex designs that focus on a set of more specific objectives. As designed, this method appears best suited for national parks of limited size where observers must balance multiple objectives that include identifying high-priority invasive exotic plants, focusing on natural and restored areas, ensuring good spatial coverage, detecting new plant invasions, monitoring multiple species simultaneously, and tracking changes in abundance and distribution of existing invasions.

Acknowledgments

This project was funded and completed under the auspices of the NPS Inventory and Monitoring Program. Dan Tenaglia conducted fieldwork in four of the six study sites. Dan died on 13 February 2007 following a collision two days earlier while riding his bike near his home in Opelika, Alabama. Dan's botanical photography can be found at his Missouri Plants Web site: http://www.missouriplants.com/. The introduction benefited from Brad Welch's summary of invasive plant literature in the first three chapters of the *Early detection of invasive plant species handbook* (http://www.pwrc.usgs.gov/brd/invasiveHandbook.cfm). Tyler Cribbs, Karola Mlekush, and Brittany Hummel assisted with fieldwork. Mike DeBacker and Melanie Weber provided helpful editorial comments.

Appendixes A and B

Appendixes A and B are published online at http://science.nature.nps.gov/im/units/htln/library/monitoring/JournalArticles/InvasivePlants_SupplementaryInformation.doc.

Literature cited

Bailey, R. G. 1998. Ecoregion map of North America, scale 1:15,000,000: Explanatory note. USDA Forest Service Miscellaneous Publication 1548:1–10. Washington, D.C., USA.

Carpenter, A. T., T. A. Murray, and J. Buxbaum. 2002. Inventorying and mapping invasive plants. Natural Areas Journal 22:163–165.

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. Natural Resources Report NPS/NRMWRO/NRR-93/08. U.S. Department of the Interior, National Park Service, Natural Resources Publication Office, Denver, Colorado, USA.

Kelrick, M. I. 2001. Missouri bladderpod monitoring protocol for Wilson's Creek National Battlefield. U.S. Geological Survey Unpublished Report. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Midwest Invasive Plant Network (MIPN). 2006. New invasive plants in the Midwest. Available at http://www.mipn.org/New%20Invasives%20Flyer.pdf (accessed 18 September 2007).

Morse, L. E., J. M. Randall, N. Benton, R. D. Hiebert, and S. Lu. 2004. An invasive species assessment protocol: Evaluating non-native plants for their impact on biodiversity. Version 1. Document available from http://www.natureserve.org/getData/plantData.jsp#InvasivesProtocol. (accessed 1 December 2006).

North American Weed Management Association (NAWMA). 2002. North American invasive plant mapping standards. Available from http://www.nawma.org/ (accessed 28 February 2007).

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, F. L. Dougher, and R. Aspinall. 2006. Searching for a needle in a haystack: Evaluating survey methods for non-indigenous plants. Biological Invasions 8:523–539.

Stohlgren, T. J. 2007. Measuring plant diversity. Oxford University Press, Oxford, UK.

United States Department of Agriculture (USDA). 2007. The PLANTS Database. Available at http://plants.usda.gov (accessed 18 September 2007).

Young, C. C., J. L. Haack, L. W. Morrison, and M. D. DeBacker. 2007. Invasive exotic 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, USA. Available at http://science.nature.nps.gov/im/units/htln/library/monitoring/protocols/ExoticPlantProtocol.pdf.

About the authors

Craig C. Young *(e-mail: craig_young@nps.gov) and* ***Jennifer L. Haack*** *work with the National Park Service's Heartland Inventory and Monitoring Network in Republic, Missouri. Craig conducts rare plant and invasive plant monitoring. Jennifer's responsibilities include network GIS management and land use change monitoring.*