



Invasive Non-native Plant Inventory for Tonto National Monument, 2005

Natural Resource Technical Report NPS/SODN/NRTR—2011/478



ON THE COVER

Clockwise from top left: *Avena fatua* (wild oat), *Eragrostis lehmanniana* (Lehmann lovegrass), *Brassica tournefortii* (Sahara mustard), *Pennisetum ciliare* (buffelgrass). All photos ©Patrick J. Alexander.

Invasive Non-native Plant Inventory for Tonto National Monument, 2005

Natural Resource Technical Report NPS/SODN/NRTR—2011/478

Authors

Sarah E. Studd
Jason Welborn
Sonoran Institute
7650 E. Broadway Blvd., #203
Tucson, AZ 85710

Theresa Mau-Crimmins
Sonoran Desert Network
National Park Service
7660 E. Broadway Blvd., #303
Tucson, AZ 85710

Editing and Design

Alice Wondrak Biel
Sonoran Desert Network
National Park Service
7660 E. Broadway Blvd., #303
Tucson, AZ 85710

August 2011

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

The National Park Service's Natural Resource Stewardship and Science office, in Fort Collins, Colorado, publishes a range of reports that address natural resource topics 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 Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

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.

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 the Sonoran Desert Network website, <http://www.nature.nps.gov/im/units/sodn/>, as well as at the Natural Resource Publications Management web site, <http://www.nature.nps.gov/publications/nrpm/>.

Please cite this publication as:

Studd, S. E., T. M. Mau-Crimmins, and J. Welborn. 2011. Invasive plant mapping inventory for Tonto National Monument, 2005. Natural Resource Technical Report NPS/SODN/NRTR—2011/478. National Park Service, Fort Collins, Colorado.

Contents

Figures v

Tables v

Executive Summary vii

Acronyms ix

Acknowledgements xi

1 Introduction 1

 1.1 Project goals 1

 1.2 Study area..... 1

2 Methods..... 3

 2.1 Roaming surveys 3

 2.2 Beyond NAWMA sampling 3

 2.3 Comparison with previous studies.....6

 2.4 Alien Plants Ranking System 6

3 Results..... 7

 3.1 Beyond NAWMA sampling 7

 3.2 Comparison of roaming surveys and circular plots 7

 3.3 Alien Plants Ranking System 9

 3.4 Locations and species..... 12

4 Discussion 19

 4.1 Parkwide observations..... 19

 4.1 Differences between this and other studies 19

 4.2 Management recommendations 20

5 Literature Cited 21

Appendix A. Species Maps..... 23

Figures

Figure 1-1. Location of Tonto National Monument, Arizona 2

Figure 2-1. Locations of circular-plot surveys at Tonto National Monument, 2005..... 5

Figure 2-2. Circular-plot diagram showing locations of 1-m² quadrats..... 5

Figure 3-1. Relative abundance of target species collected via roaming surveys and circular plots at Tonto NM..... 8

Figure 3-2. Plot of species ranked using APRS, showing ease of control versus level of impact 9

Figure 3-3. Plot of species ranked using the APRS, ability to become a pest versus ease of control..... 11

Figure 3-4. Monument areas as described within this report. 12

Figure 3-5. Diagram showing proposed entrance roadway design and position..... 15

Tables

Table 2-1. Arizona Wildlands Invasive Plants Working Group target exotic plant species 4

Table 3-1. Total area affected and total area infested by target species within Tonto NM 7

Table 3-2. Target species occurrences and relative abundances within circular plots..... 8

Table 3-3. Ranks of target species for significance of impact (Impact), innate ability to become a pest (Pest), and difficulty to control or manage (Control). 10

Executive Summary

The Sonoran Desert Network Inventory & Monitoring Program has targeted early detection and trends of exotic plant species for long-term vital signs monitoring. Baseline information on the presence, location, and abundance of exotic plant species is necessary to accomplish two goals: (1) to identify which exotic species are not yet present on the monument and will therefore be monitored for appearance (early detection monitoring); and (2) to map the spatial location, distribution, and abundance of exotic species that already occur on the monument, to serve as the basis for future trend assessment.

The goals of this project at Tonto National Monument were (1) to map the spatial location, abundance, and distribution of 74 invasive plants on the Arizona Wildlands Invasive Plant Working Group (AZ-WIPWG) list, (AZ-WIPWG 2005a), plus five additional species known by the park's natural resource manager to be or have recently been present at Tonto NM; (2) to compare findings from this study to data collected in previous studies (1992 and 2002); and (3) to rank the recorded exotic species based on ease of control, invasibility, and current extent using the Alien Plant Ranking System (Hiebert 1999).

Of the 79 target species, 16 were observed during roaming surveys at Tonto NM in 2005. Four species, all grasses, were recorded both in high densities and over large areas at Tonto NM: *Avena fatua* (wild oats), *Bromus rubens* (red brome), *Bromus rigidus* (ripgut brome), and *Eragrostis lehmanniana* (Lehmann lovegrass). These were the most problematic species within the monument, due not only to their relative abundance but also to the difficulty of controlling them and their level of impact on the surrounding ecosystem. The steep slopes beneath the Upper Ruin and the Cave Canyon riparian corridor are the two most affected areas in the monument.

Additional species of concern were *Brassica tournefortii* (Sahara mustard) and *Pennisetum ciliare* (buffelgrass). While neither of these species is widespread within the monument, they are both of great concern, as they are aggressive invaders that “crowd out native Sonoran Desert species by creating monocultures that consume scarce water and nutrient resources” (Siegel 2002). *B. tournefortii* has been documented to increase fuel loads and fire hazard in desert scrub environments. *P. ciliare* also poses significant threats of spreading fire. In the early stages of invasion, when plants are still sparse, control of both *B. tournefortii* and *P. ciliare* is possible, and efforts toward eradication should be made. Currently, both of these species are growing only along the sides of Highway 88, but care should be taken to eliminate the threat of spread by vehicles, animals, and foot traffic by removing these plants on a regular basis.

Pennisetum ciliare and *Brassica tournefortii* should be pursued with vigilance. Both of these species were observed within the monument in small numbers of individual plants. At this stage, control of both of these species is possible through mechanical means (e.g., hand-pulling). However, if allowed to spread, both plants can severely impact native vegetation. Additionally, because *Avena fatua*, *Brassica tournefortii*, *Bromus rigidus*, *Bromus rubens*, and *Eragrostis lehmanniana* have all been associated with increasing fire risk and respond positively to the effects of fire, efforts should be made to control their abundance and spread. Persistence of these species has the potential to significantly alter the landscape at Tonto NM, as repeated fires have adverse impacts to native vegetation, including the characteristic cactus species.

Acknowledgements

Many thanks to Tonto NM Superintendent Brad Traver for his support of and interest in this project. Thanks also to Chief of Resources Shirley Hoh, whose help and knowledge of the park areas was invaluable. We would also like to thank Patty Guertin, of the University of Arizona, for sharing data from her recent mapping effort, which enabled us to track changes in exotic plant location and abundance at Tonto NM over time. The University of Arizona herbarium staff was, as always, gracious in assisting with identification of plant specimens. Kristen Beaupré, Sonoran Desert Network Cartographic Technician, and Cheryl McIntyre, Project Manager for the Adaptive Management Program, Sonoran Institute, were instrumental in data management and manipulation.

1 Introduction

Non-indigenous invasive species are a major threat to native species diversity and ecosystem function, causing economic impacts within the U.S. estimated at more than \$100 billion annually (Pimentel et al. 1999). In addition to competing with and displacing native species, these introduced species can hybridize with natives and alter conditions to promote the establishment and spread of other non-native species. Invasive species have been called the “single most formidable threat of natural disaster of the twenty-first century” (Schnase et al. 2002).

“Exotic species” are those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities (USDI 2001). Exotic species are also commonly referred to as non-native, alien, or invasive species. Because exotic species did not evolve in concert with native species, exotic species are not natural ecosystem components. According to the *NPS Management Policies* (NPS 2006), “(e)xotic species will not be allowed to displace native species if displacement can be prevented.” In addition, these policies 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.”

The Sonoran Desert Network Inventory & Monitoring Program has targeted early detection and trends of exotic plant species for long-term vital signs monitoring. Baseline information on the presence, location, and abundance of exotic plant species is necessary to accomplish two goals: (1) to identify which exotic species are not yet present on the monument and will therefore be monitored for appearance (early detection monitoring); and (2) to map the spatial location, distribution, and abundance of exotic species that already occur on the monument, to serve as the basis for future trend assessment.

1.1 Project goals

The goals of this project were:

- 1) To map the spatial location, abundance, and distribution of 74 invasive plants on the Arizona Wildlands Invasive Plant Working Group (AZ-WIPWG) list, (AZ-WIPWG 2005a) list, plus five additional species known by the park’s natural resource manager to be or have recently been present at Tonto NM.
- 2) To perform comparative analyses between data collected in this study and mapping data collected in 1992 (Philips 1992), and 2002 (Guertin and Halvorson 2002).
- 3) To rank the recorded exotic species based on ease of control, invasibility, and current extent using the Alien Plant Ranking System (Hiebert 1999). The results of this ranking will help park managers to prioritize control efforts.

1.2 Study area

Tonto National Monument is located 30 miles northwest of Globe, in central Arizona (Figure 1-1). The monument was established in 1907 to preserve fourteenth-century masonry cliff dwellings and other archeological sites of the prehistoric Salado culture. Tonto NM is situated near the northeastern boundary of the Sonoran Desert and comprises 453 ha (1,120 acres). The monument has one main entrance road leading to the visitor center and two trails that lead to two cave dwellings that are open to the public. The remainder of the monument is without trails, and the entire unit is fenced to exclude cattle.

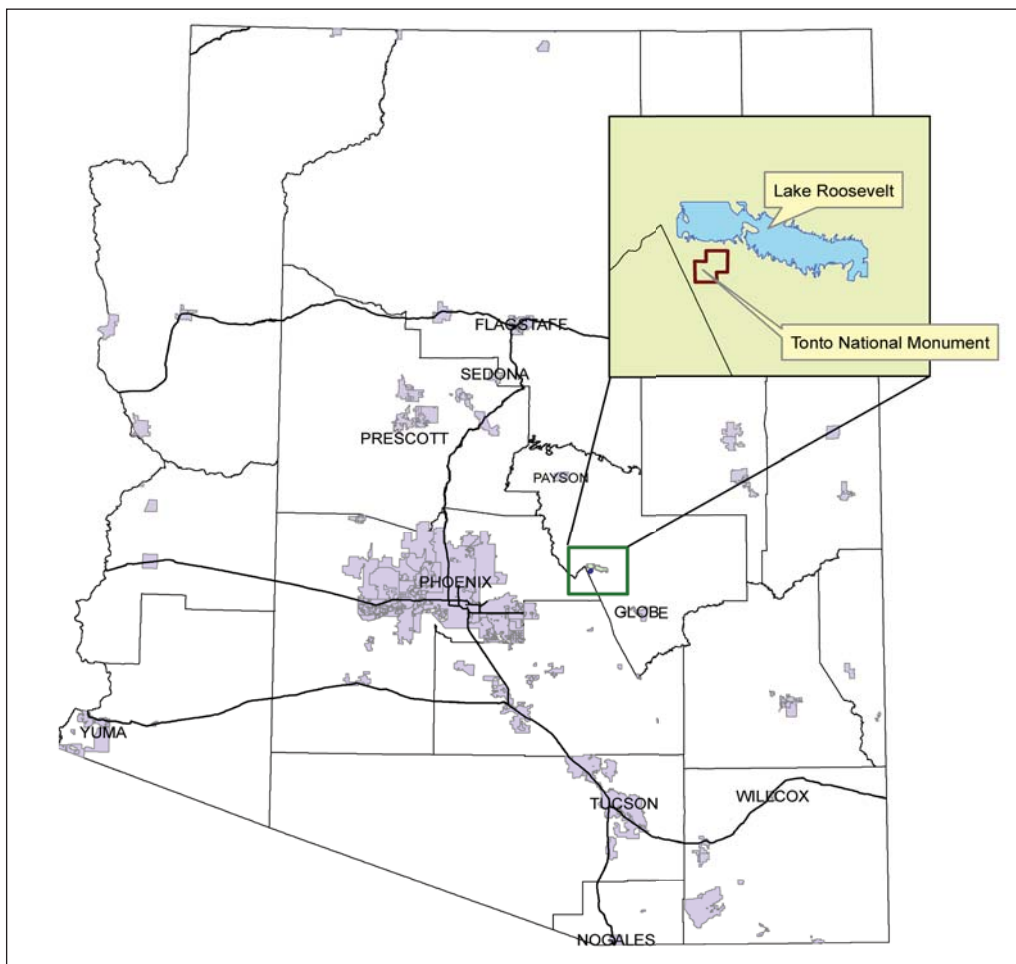


Figure 1-1. Location of Tonto National Monument, Arizona.

2 Methods

The abundance and location of 79 exotic plant species were mapped at Tonto NM following the North American Invasive Plant Mapping Standards (NAWMA 2002) and the “Beyond NAWMA” guidelines suggested by researchers at the U.S. Geological Survey and Colorado State University, National Institute of Invasive Species Science (Stohlgren et al. 2003). Because Tonto NM is small (less than 500 ha), an intensive mapping method was undertaken. Individual target plants were mapped as points and invaded regions were mapped as polygons using handheld computers and global positioning system (GPS) units.

2.1 Roaming surveys

Roaming surveys were performed with the intent of covering the majority of the park unit. As the unit is relatively small, an intensive survey was both practical and desirable. Target species for this effort included the 74 species currently on the AZ-WIPWG list (<http://www.usgs.nau.edu/swepic>) and five other plants known to be problematic at Tonto NM (Table 2-1).

Spatial location, distribution, and abundance of the species were recorded as ArcMap shapefiles (.shp). Two researchers identified and mapped species via walking surveys. Individual target plants were mapped as points, and areas over 3 m in diameter were mapped as polygons. Up to five species could be recorded in each polygon, and a percent cover class was assigned for each species. The cover classes were:

- <1%
- 1–5%
- 6–25%
- 26–50%
- 51–75%
- 76–95%
- 96–100%

Data collection took place on July 25–28, August 8–9, August 29–September 1, and September 20–21, 2005. Approximately 240 person hours were required for data collection over 15 days. Data were collected following the NAWMA 2002 standards and included the following fields:

- collection date
- collection time

- plant name; genus and species
- aerial percent cover
- location (in Universal Transverse Mercator coordinates)

Data files were merged and then split to generate individual ArcMap shapefiles by species, with point and polygon files separated. Metadata were written for each shapefile.

Due to the steep, rocky terrain, polygons were often delineated by the mappers’ ability to climb and circumvent certain areas. At times, the polygon was described as slightly larger than the densest part of the infestation, thereby resulting in a polygon with a lower percent cover than if the polygon had been described more precisely around the main infestation. However, any area included within a polygon exhibited some level of infestation.

Based on observations made during scoping hikes of the park, it was decided that the back-country area surrounding Dead Man’s Canyon (toward the western park boundary), did not have sufficient infestation of any species to warrant the extensive climbing and traversing that polygon description would require. These areas were evaluated by sight from high vantage points and from Dead Man’s Canyon. Small areas and occasional *Avena fatua* (wild oats) and *Bromus rubens* (red brome) individuals were encountered and mapped as points.

2.2 Beyond NAWMA sampling

In the “Beyond NAWMA” guidelines, Stohlgren et al. (2003) recommended supplementing roaming surveys with randomly located circular-plot sampling to estimate spatial bias and accuracy. Approximately one-quarter of our field resources were used to perform circular-plot sampling.

Twenty-five circular plots were sampled within Tonto NM (Figure 2-1). The circular plots were 7.32 m (24 ft.) in diameter, encompassing three 1-m² quadrats (Figure 2-2). The percent aerial cover of all species was recorded within the 1-m² quadrats to the nearest 1%. All additional species observed within the entire circular plot were also recorded. Data were recorded directly into an Excel spreadsheet on the handheld PC. Excel spreadsheets were downloaded onto a laptop computer each day and subsequently imported into an Access database for further analysis.

Table 2-1. Arizona Wildlands Invasive Plants Working Group target exotic plant species.

Scientific name	Common name	Scientific name	Common name
<i>Acroptilon repens</i> (L.) DC	Russian knapweed	<i>Lolium perenne</i> L.	perennial ryegrass
<i>Aegilops cylindrical</i> Host	jointed goatgrass	<i>Malva parviflora</i> L.	cheeseweed ¹
<i>Alhagia maurorum</i> Medik.	camelthorn	<i>Marrubium vulgare</i> L.	horehound ¹
<i>Arundo donax</i> L.	giant reed	<i>Melilotus alba</i> Medikus	white sweetclover
<i>Asphodelus fistulosus</i> L.	onionweed	<i>Melilotus officinalis</i> (L.) Lam.	yellow sweetclover
<i>Avena fatua</i> L.	wild oat	<i>Mesembryanthemum crystallinum</i> L.	common iceplant
<i>Brassica tournefortii</i> Gouan	Sahara mustard	<i>Mesembryanthemum nodiflorum</i> L.	slenderleaf iceplant
<i>Bromus diandrus</i> Roth	ripgut brome	<i>Myriophyllum aquaticum</i> (Vell.) Verdc.	parrot's feather
<i>Bromus inermis</i> Leyss.	smooth brome	<i>Myriophyllum spicatum</i> L.	Eurasian watermilfoil
<i>Bromus rubens</i> L.	red brome	<i>Onopordum acanthium</i> L.	Scotch thistle
<i>Bromus tectorum</i> L.	cheatgrass	<i>Panicum antidotale</i> Retz.	blue panicum
<i>Cardaria chalapensis</i> (L.) Hand.-Maz.	lenspod whitetop	<i>Pennisetum ciliare</i> (L.) Link	buffelgrass
<i>Cardaria draba</i> (L.) Desv.	whitetop	<i>Pennisetum setaceum</i> (Forssk.) Chiov.	fountain grass
<i>Cardaria pubescens</i> (C.A. May) Jamo- lenko	hairy whitetop	<i>Phalaris minor</i> Retz.	littleseed canarygrass ¹
<i>Carduus nutans</i> L.	musk thistle	<i>Rhus lanceae</i> L.f.	African sumac
<i>Centaurea biebersteinii</i> DC.	spotted knapweed	<i>Rubus armeniacus</i> Focke	Himalayan blackberry
<i>Centaurea diffusa</i> Lam.	diffuse knapweed	<i>Rubus discolor</i> Weihe & Nees	Himalayan blackberry
<i>Centaurea melitensis</i> L.	Malta starthistle	<i>Saccharum ravennae</i> (L.) L.	Ravennagrass
<i>Centaurea solstitialis</i> L.	yellow starthistle	<i>Salsola collina</i> Pallas	slender Russian thistle
<i>Chondrilla juncea</i> L.	rush skeletonweed	<i>Salsola pausenii</i> Litv.	barbwire Russian thistle
<i>Cirsium arvense</i> (L.) Scop.	Canada thistle	<i>Salsola tragus</i> L.	prickly Russian thistle
<i>Cirsium vulgare</i> (Savi) Ten.	bull thistle	<i>Salvina molesta</i> Mitchell	giant salvinia
<i>Conium maculatum</i> L.	poison hemlock	<i>Schismus arabicus</i> Nees	Arabian schismus
<i>Convolvulus arvensis</i> L.	field bindweed	<i>Schismus barbatus</i> (Loefl. ex L.) Thellung	common Mediterranean grass
<i>Cortaderia selloana</i> (J.A. & J.H. Schul- tes) Aschers. & Graebn.	Pampasgrass	<i>Sisymbrium irio</i> L.	London rocket ¹
<i>Cynodon dactylon</i> (L.) Pers	Bermudagrass	<i>Sonchus asper</i> (L.) Hill	spiny sowthistle
<i>Cynoglossum officinale</i> L.	houndstongue	<i>Sonchus oleraceus</i> L.	annual sowthistle
<i>Echinochloa crus-galli</i> (L.) Beauv.	barnyardgrass	<i>Sorghum halepense</i> (L.) Pers.	Johnsongrass
<i>Eichhornia crassipes</i> (Mart) Solms	water hyacinth	<i>Tamarix aphylla</i> (L.) Karst	Athel tamarisk
<i>Elaeagnus angustifolia</i> L.	Russian olive	<i>Tamarix chinensis</i> Lour.	five-stamen tamarisk
<i>Elymus repens</i> (L.) Gould	quackgrass	<i>Tamarix parviflora</i> DC.	smallflower tamarisk
<i>Eragrostis curvula</i> (Schrad.) Nees	weeping lovegrass	<i>Tamarix ramosissima</i> Ledeb.	saltcedar
<i>Eragrostis lehmanniana</i> Nees	Lehmann lovegrass	<i>Tribulus terrestris</i> L.	puncturevine
<i>Erodium cicutarium</i> (L.) L'Her ex Ait.	redstem filaree	<i>Ulmus pumila</i> L.	Siberian elm
<i>Euphorbia esula</i> L.	leafy spurge	<i>Verbascum thapsus</i> L.	common mullein
<i>Euryops multifidus</i> (Thunb.) DC.	sweet resinbush	<i>Vinca major</i> L.	bigleaf periwinkle
<i>Galium aparine</i> L.	stickywilly ¹		
<i>Hordeum murinum</i> L.	mouse barley		
<i>Hydrilla verticillata</i> (L.f.) Royle	hydrilla		
<i>Lepidium latifolium</i> L.	perennial pepperweed		
<i>Leucanthemum vulgare</i> Lam.	oxeye daisy		
<i>Linaria dalmatica</i> (L.) P. Mill.	Dalmatian toadflax		
<i>Linaria vulgaris</i> P. Mill.	yellow toadflax		

¹Indicates plant not on AZ-WIPWG list; added to survey by Tonto NM staff.

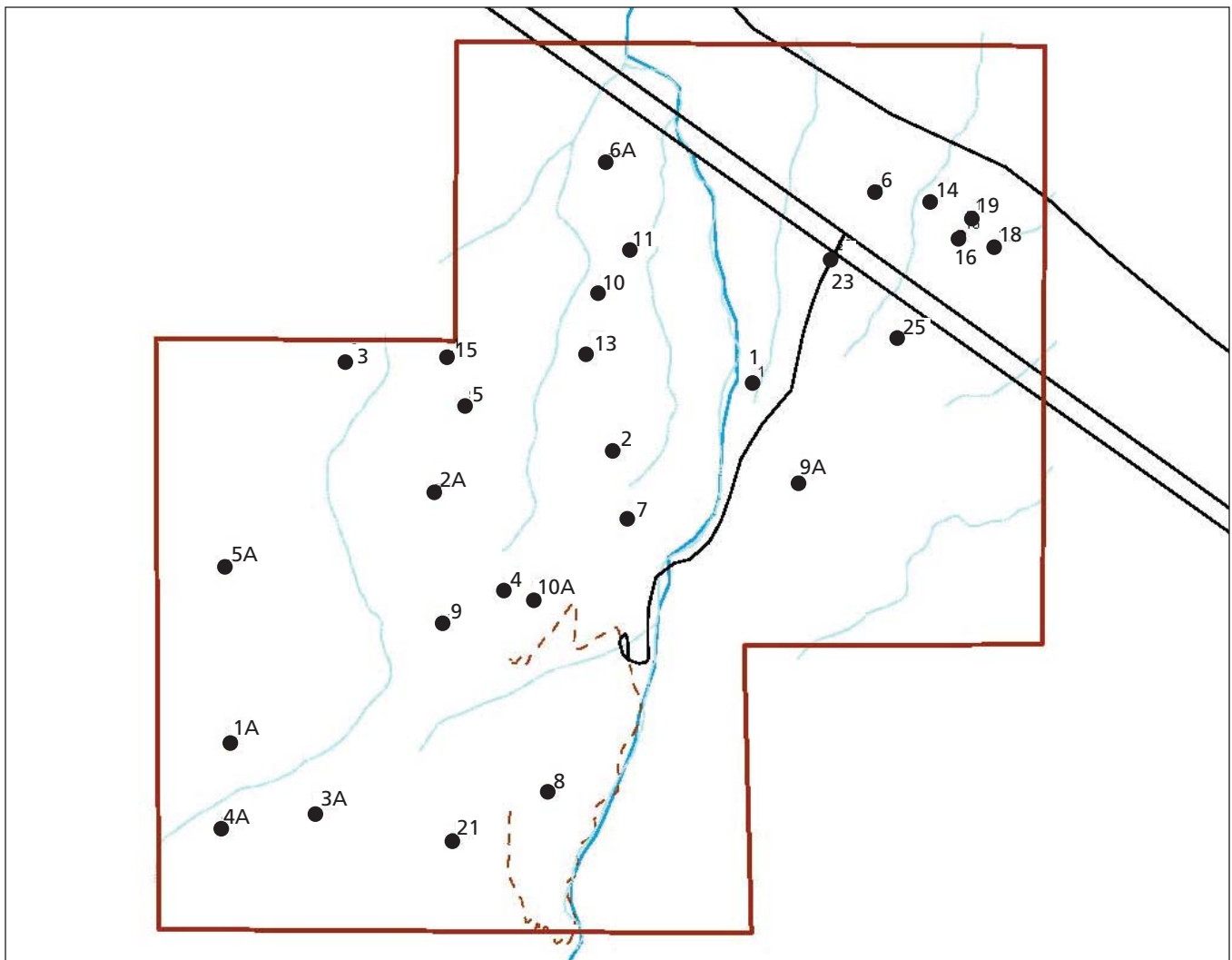


Figure 2-1. Locations of circular-plot surveys at Tonto National Monument, 2005.

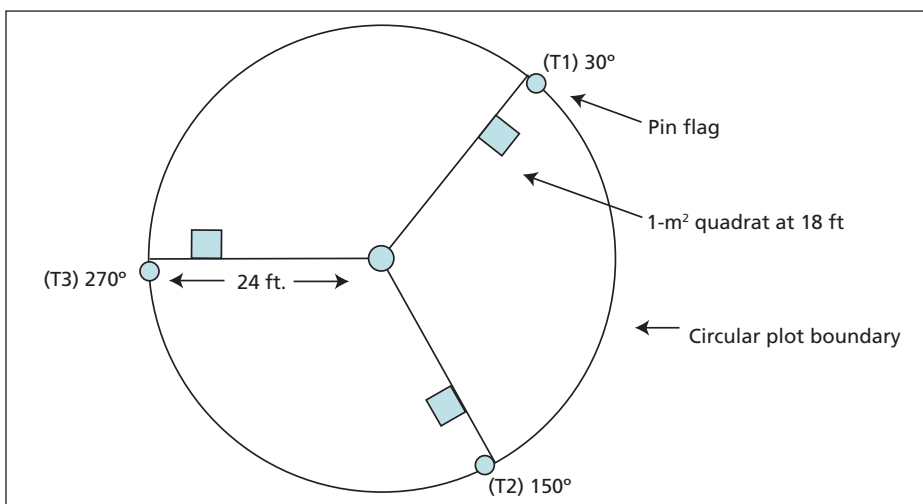


Figure 2-2. Circular-plot diagram showing locations of 1-m² quadrats.

2.3 Comparison with previous studies

Several previous studies at Tonto NM focused on exotic plants or general park vegetation. In one study (Phillips 1992), transects were walked and marked on topographic maps. In that study, efforts were concentrated on areas where disturbance had been intense, either due to fire or human activity. Additional hikes were made in backcountry areas to look for other areas where introduction may have occurred due to livestock or other means. The general location and relative abundance of 13 non-native species were marked on topographic maps. These data allowed us to visually compare the general location of plants recorded in 1992 to those collected in 2005.

P. Guertin (2003) completed a multi-season, multi-year study documenting the status of introduced plants at Tonto NM. Efforts were made to cover 100% of the grounds and to document any observations of 50 target species. Individual plants or groups of plants were recorded as point shapefiles using GPS equipment in the field. In Guertin's study, 21 species were documented. GIS layers were created for each species and made available to us for direct comparison with our data in ArcMap. Additional information about the extent and condition of each plant represented by a point was available in associated attribute tables. Using this data, we were able to estimate approximate coverage by area recorded in 2003 and compare that to coverage recorded during this census.

Jenkins and others (1995) reported on the status of both native and non-native flora at Tonto NM. Their study detailed the general location and gen-

eral abundance of non-native flora. This information was used to identify the presence or absence of a species in certain areas at that time and, to some degree, enabled us to gauge whether a substantial increase or decrease had occurred since then. The "Biological Inventory and Hydrological Assessment of the Cave Springs Riparian Area" (Albrecht et al. 2003) recorded the presence of both native and non-native flora in the Cave Canyon riparian area. We used this information to establish the presence of a species in that area during that time and thereby assess its continued presence or absence from that area.

2.4 Alien Plants Ranking System

Target species were prioritized for treatment using the Alien Plants Ranking System (APRS) v7.1 (APRSIT 2001). Information regarding each species's distribution and abundance, phenology, and morphology were collected through the fieldwork and extensive literature review. This information was then entered into the APRS database for ranking.

The APRS is divided into two main sections: significance of impact and feasibility of control or management. The impact category is further divided into two subcategories: significance of impact and innate ability to become a pest. Each plant is ranked based on criteria that fit into three categories: impact, pest, and control, on a scale of 100 points. The resulting ranks can be used to help managers make decisions on the urgency of action. The information gained through this ranking system will enable prioritization of exotic plant management efforts within Tonto NM.

3 Results

Of the 79 target species, 16 were observed during roaming surveys at Tonto NM in 2005 (Table 3-1). Maps of each species by park unit appear in Appendix A. Table 3-1 also provides measures of area affected and infested within the park unit by species. Area affected is a measure of plant distribution calculated directly from mapped polygon boundaries; this measure does not reflect the intensity of invasion. For example, a polygon 1.5 ha in area estimated at 25–50% cover would represent 1.5 ha affected.

Area infested is a measurement of the actual land area infested by each target species. Infested area was calculated using polygon data by multiplying the cover class midpoint by the polygon’s area. For example, a polygon 1.5 ha in area estimated at 25–50% cover would represent 0.5625 ha ($1.5 \times 0.375 = 0.5625$) infested. In both calculations, points were estimated to represent 0.5 m².

3.1 Beyond NAWMA sampling

Of the 79 target species, six species were recorded within the circular plots (Table 3-2). Three 1-m² quadrats were located within each circular plot,

in which percent cover of all species was recorded to the nearest 1%. Using these data, the relative abundance of the target species was calculated (Table 3-2).

3.2 Comparison of roaming surveys and circular plots

The circular plots were implemented to estimate spatial bias and accuracy of the roaming surveys. Stohlgren and others (2003) suggested randomly locating these plots and comparing the foliar cover of target species within the circular plots to the foliar cover of target species collected during the roaming surveys. This comparison identifies observer bias to particular regions of the study area (i.e., near roads or riparian areas).

Figure 3-1 depicts foliar cover of target species collected via circular plots plotted against foliar cover of target species collected via roaming surveys. Both datasets were transformed using the cube-root transformation. The relative abundance of target species is relatively consistent between the two methods ($R^2 = 0.71$), indicating that roaming surveys perform well at estimating abundance of target species.

Table 3-1. Total area affected and total area infested by target species within Tonto NM.

Scientific name	Common name	Hectares affected	Percent of park affected	Hectares infested	Percent of park infested
<i>Avena fatua</i>	wild oat	241.3	53%	23.1	5%
<i>Brassica tournefortii</i>	Sahara mustard	9.6	2%	0.2	T
<i>Bromus rigidus</i>	ripgut brome	87.8	19%	5.0	1%
<i>Bromus rubens</i>	red brome	291.5	64%	59.7	13%
<i>Eragrostis curvula</i>	weeping lovegrass	0.3	T	T	T
<i>Eragrostis lehmanniana</i>	Lehmann lovegrass	29.6	6%	2.2	T
<i>Galium aparine</i>	stickywilly	0.01	T	T	T
<i>Hordeum</i> sp.	barley	T	T	T	T
<i>Marrubium vulgare</i>	horehound	T	T	T	T
<i>Melilotus indicus</i>	Indian sweetclover	T	T	T	T
<i>Pennisetum ciliare</i>	buffelgrass	T	T	T	T
<i>Phalaris</i> sp.	canarygrass	0.2	T	T	T
<i>Salsola kali</i>	prickly lettuce	T	T	T	T
<i>Sisymbrium irio</i>	London rocket	5.9	1%	0.02	T
<i>Sorghum halepense</i>	Johnsongrass	T	T	T	T
<i>Tribulus terrestris</i>	puncturevine	0.3	T	T	T

T denotes area <0.1 ha or <0.1 %

Table 3-2. Target species occurrences and relative abundances within circular plots.

Scientific name	Common name	Circular-plot occurrences	Circular plot foliar cover
<i>Avena fatua</i>	wild oat	10	1.6%
<i>Bromus rubens</i>	red brome	54	33.8%
<i>Eragrostis curvula</i>	weeping lovegrass	1	0.04%
<i>Eragrostis lehmanniana</i>	Lehmann lovegrass	1	0.04%
<i>Hordeum</i> spp.	barley	2	0.2%
<i>Phalaris minor</i>	littleseed canarygrass	1	0.04%

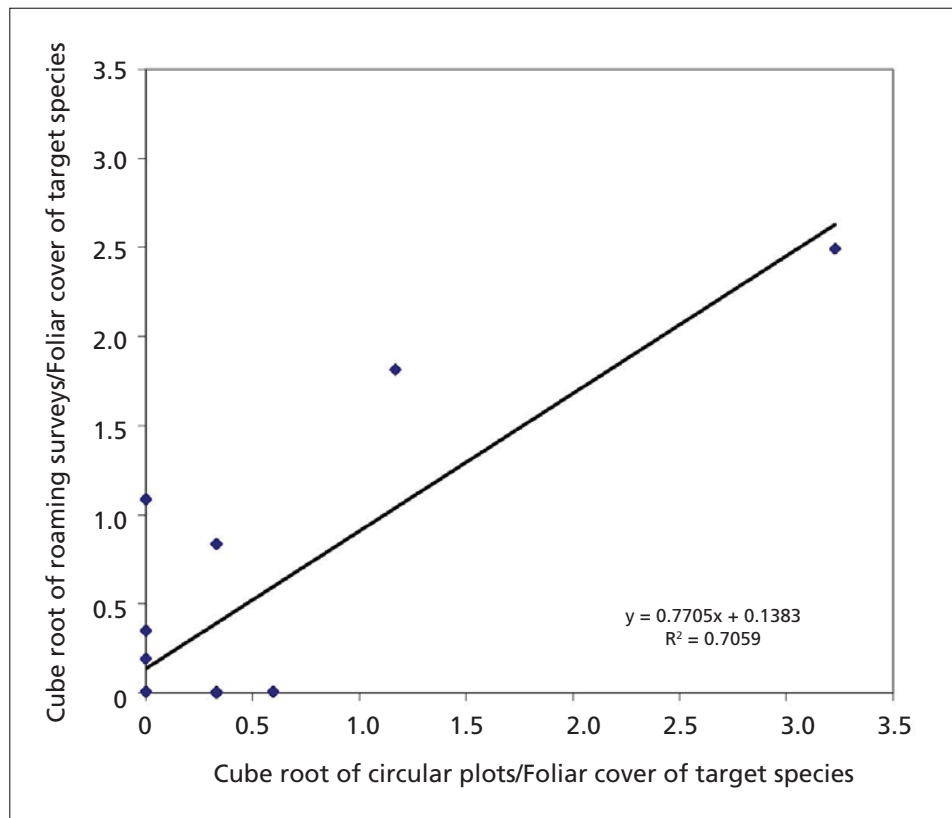


Figure 3-1. Relative abundance of target species collected via roaming surveys and circular plots at Tonto NM.

As a whole, the circular plots detected fewer target species; six target species were captured in circular plots, whereas 16 target species were identified through roaming surveys. In part, this could be because some of the species were found in very small quantities; only one or a few individuals of *Marrubium vulgare* (horehound) and *Pennisetum ciliare* (buffelgrass) were recorded on the park.

3.3 Alien Plants Ranking System

Insufficient information was available for *Phalaris* spp. (canarygrass) to be included in the APRS. Very few individuals of this species were recorded during this census. All were contained within a small area, and they were not considered to pose a significant threat. For these reasons, we have omitted *Phalaris* spp. from the APRS. Of the 15

species ranked using the APRS system, most fell within the low- and medium-impact categories; *Bromus rubens* was the only species to fall within the high-impact portion of the graph (Figure 3-2). Species ranged from easy to control to difficult to control (Figure 3-2). On the 100-point scale, plants ranged from 33 to 84 for significance of impact; 4–69 for innate ability to become a pest; and 28–71 for feasibility of control or management (Table 3-3).

Figure 3-3 displays the ease of control and ability to become a pest for the target species. The target species were rather evenly distributed along the x-axis, ability to become a pest. Several of the target species are very problematic; others appear to have less direct impact on the ecosystems they invade.

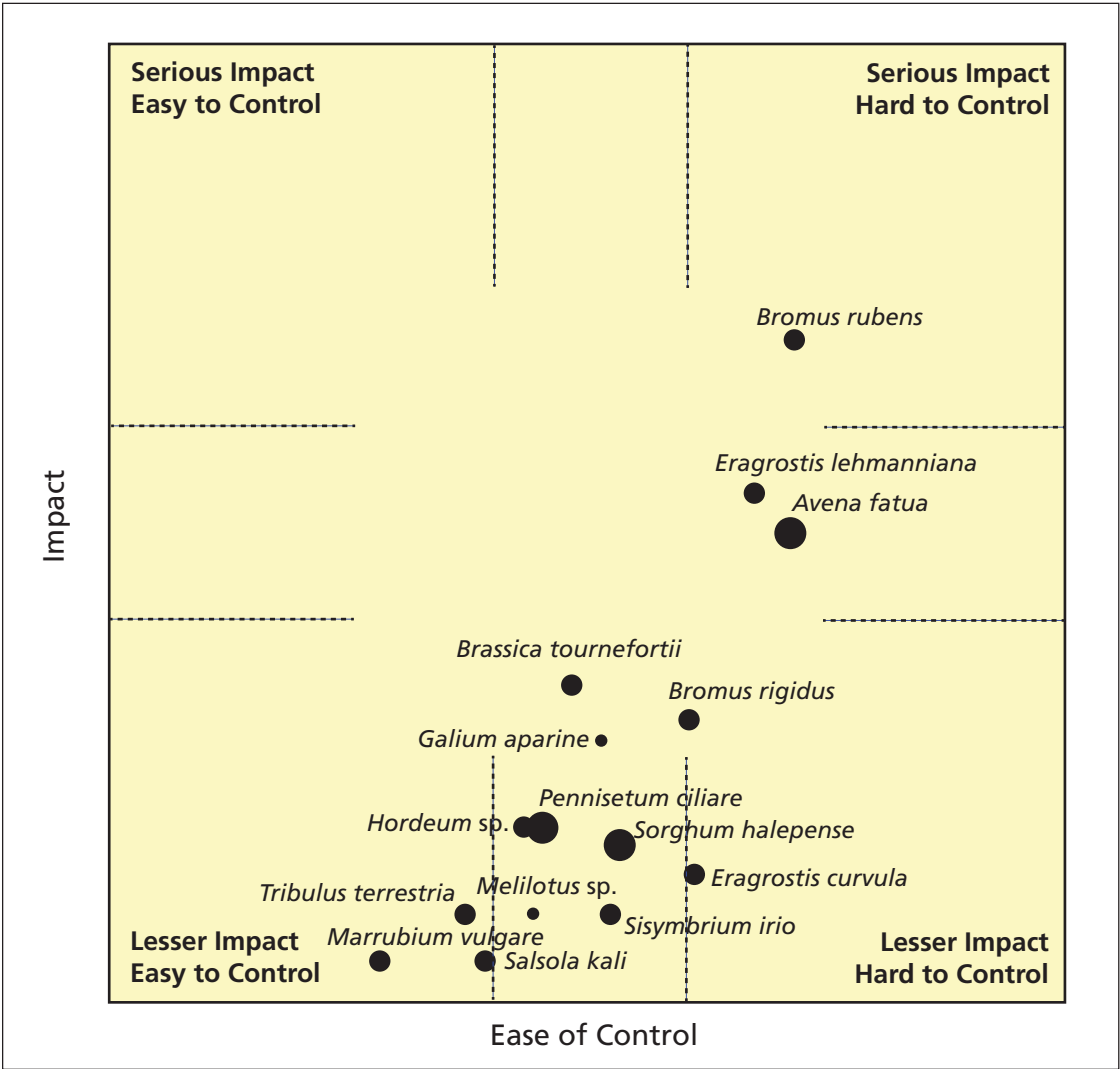


Figure 3-2. Plot of species ranked using APRS, showing ease of control versus level of impact. Size of dot represents the pest score derived using the APRS.

Table 3-3. Ranks of target species for significance of impact (Impact), innate ability to become a pest (Pest), and difficulty to control or manage (Control).

Scientific name	Common name	Impact	Pest	Control
<i>Bromus rubens</i>	red brome	59	69	71
<i>Avena fatua</i>	wild oat	65	49	71
<i>Eragrostis lehmanniana</i>	Lehmann lovegrass	41	53	67
<i>Sorghum halepense</i>	Johnsongrass	84	16	53
<i>Bromus rigidus</i>	ripgut brome	59	29	60
<i>Pennisetum ciliare</i>	buffelgrass	78	18	45
<i>Brassica tournefortii</i>	Sahara mustard	60	33	48
<i>Eragrostis curvula</i>	weeping lovegrass	48	13	61
<i>Sisymbrium irio</i>	London rocket	56	9	52
<i>Galium aparine</i>	stickywilly	33	27	51
<i>Hordeum</i> sp.	barley	48	18	43
<i>Salsola kali</i>	prickly lettuce	56	4	39
<i>Tribulus terrestris</i>	puncturevine	52	9	37
<i>Melilotus</i> spp.	sweetclover	35	9	44
<i>Marrubium vulgare</i>	horehound	46	4	28

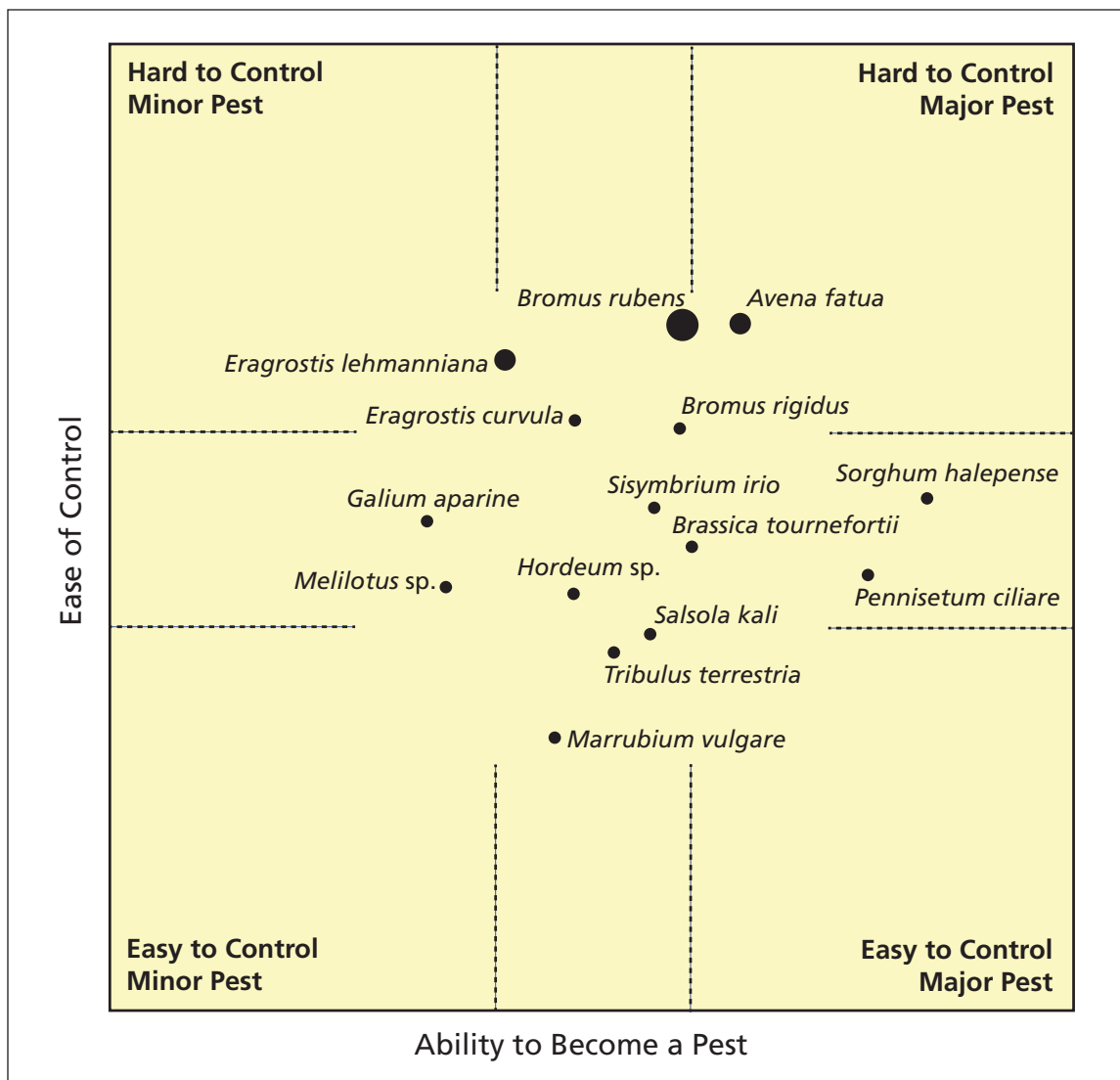


Figure 3-3. Plot of species ranked using the APRS, ability to become a pest versus ease of control. Size of dot represents the impact score derived using the APRS.

3.4 Locations and species

Distribution and abundance of target species varied by topography, soils, and disturbance history. Descriptions are provided for patterns of target species based on natural breaks within the park landscape (Figure 3-4).

3.4.1 Northeast corner

To the northeast of Highway 88 is a completely fenced area containing two old roads (Figure 3-4). Old Highway 88, which runs parallel to the current Highway 88, is now used as a utility access road (herein referred to as the utility road). There is also a short, abandoned road connecting old Highway 88 and the current Highway 88. Vegetation debris and tree branches are piled here. We observed and mapped six species in this portion of the park: *Avena fatua*, *Bromus rubens*, *Brassica tournefortii* (Sahara mustard), *Salsola kali* (prickly lettuce), and *Sisymbrium irio* (London rocket).

3.4.1.1 *Avena fatua*

All locations of *A. fatua* were recorded between the current Highway 88 and the utility road (Ap-

pendix A, Map A-1). No individuals were observed to the northeast of the utility road. Much of the area between the two roads was only sparsely covered by *A. fatua*. The majority of these plants was found closer to Highway 88, often within meters of the roadside fenceline. When observed, *A. fatua* had not spread far into this area nor developed any large stands. The Highway 88 corridor was, in contrast, heavily infested with, on average, 50% cover and up to 95% cover for its entire length.

In 1992, *Avena fatua* was reported along the drainages of the utility road, by the culvert at milepost 246, and along Highway 88 (Phillips 1992). Only six *A. fatua* points were mapped between 1999 and 2001: four along Highway 88 and two along the utility road (Guertin 2003). These were described as being small patches. It seems clear that since that time, *A. fatua* increased its range along the highway roadsides quite dramatically and has become the dominant species. It also spread across the fenceline a short distance away from the road.

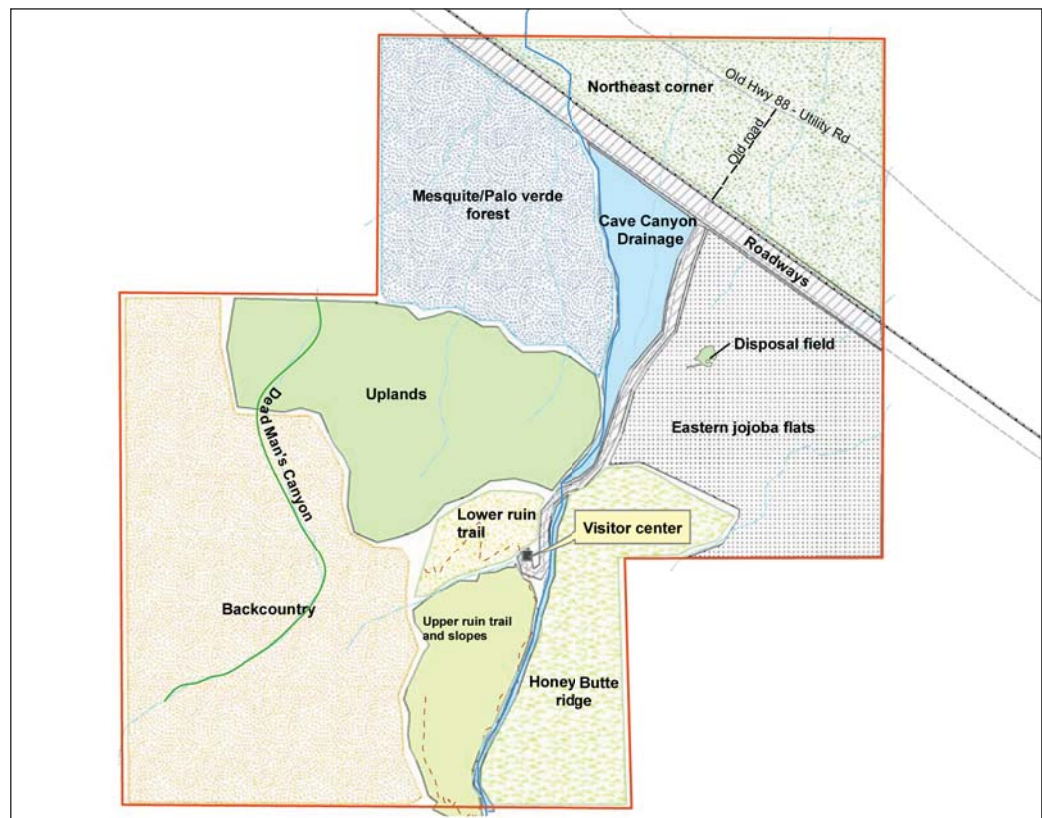


Figure 3-4. Monument areas as described within this report.

3.4.1.2 *Brassica tournefortii*

Eight points representing individual plants or a small cluster of 2–3 plants were mapped for the entire park. All but one was located either along the highway or in this northeastern portion (Appendix A, Map A-2). On the south side of the highway, a large, dense, monotypic stand was present. Additionally, two large areas were delineated with *B. tournefortii* estimated at less than 1% cover; only a small number of individuals was present within these areas.

B. tournefortii is a big problem locally (S. Hoh, pers. comm. 2005). Road corridors leading to recreation sites at nearby Roosevelt Lake are extremely infested. Park staff has seen this plant in other locations in the monument for the past few years, and has been actively removing it before it sets seed. *B. tournefortii* was observed in the park in the early 2000s (Albrecht et al. 2005); however, this report did not offer location or geographic extent. No other records of *Brassica tournefortii* exist for Tonto NM. It is likely that the spread of this species has been facilitated by recreational traffic and construction vehicles along Highway 88.

3.4.1.3 *Bromus rubens*

Cover of *B. rubens* was between 6 and 50% over this entire area (Appendix A, Map A-4). As in other locations in the park, *B. rubens* was most often observed growing beneath shrubs and trees. This grass takes advantage of the increased soil moisture offered by the shade of shrubs and is not typically found in the same densities in more open areas. Cave and Patten (1984) found that “in microhabitats of open shrub versus shade, densities approximately doubled for the shady areas.” The northern portion of this area, adjacent to the large deep drainage culvert that runs under Highway 88, was more affected (26–50% cover) than the southern portion (6–25% cover; Appendix A, Map A-4). This could be the result of increased water supply from the drainage or due to increased traffic and disturbance from foot travel, car travel, and recent construction.

Ninety-two *B. rubens* points were reported in this area between 1999 and 2001 (Guertin 2003). All points represented extensive coverage, and it was noted that the species was apparent for as far as could be seen in either direction from the utility roads (Guertin 2003). In 1995, *B. rubens* was noted to be “abundant in nearly every situation on the monument” (Jenkins et al. 1995).

3.4.1.4 *Salsola kali*

We recorded one individual plant in the large culvert under Highway 88 (Appendix A, Map A-13). This plant was removed by park staff following mapping. Three *Salsola* sp. points were reported in 2003 (Guertin 2003), each representing a few individuals. These points were mapped approximately halfway up the entrance road. This plant was also reported in the riparian area of Cave Canyon in a separate 2003 report, but no geographic extent was recorded (Albrecht et al. 2005). It seems likely that this plant was not observed in greater abundance because park personnel have been vigilant about its control.

3.4.1.5 *Sisymbrium irio*

A small number of plants was mapped in the eastern portion of this area. These were all dead at the time of the survey. It is likely that this species may be found in other areas, especially the Cave Canyon drainage, if surveyed in the spring. *Sisymbrium irio* was not recorded in this part of the park in previous studies (Jenkins et al. 1995; Guertin 2003).

3.4.2 Highway 88 and monument entrance road

From July 2002 to May 2003, State Highway 88 underwent major construction to widen, repave, and reinforce the road (ADOT 2001). All of the areas where drainages traverse underneath the roadbed were disturbed, and erosion control efforts and run-off gullies were installed. These areas still appeared freshly disturbed, and weedy species were dominant at the time of this survey. As part of the construction project, the monument’s entrance road was moved a few hundred meters to the east, repaved, and curved for safety reasons. Both sides of Highway 88 were heavily infested with *A. fatua* and *B. rubens*. Other species present in small patches or as individuals included *Brassica tournefortii*, *Pennisetum ciliare*, *Melilotus* spp. (sweetclover), *Eragrostis lehmanniana* (Lehmann lovegrass), *Eragrostis curvula* (weeping lovegrass), and *Sorghum halepense* (Johnsongrass).

3.4.2.1 *Eragrostis curvula*

One individual *E. curvula* plant was recorded along Highway 88 (Appendix A, Map A-5). Only three points were mapped in 1999–2001 (Guertin 2003), all located close to the monument

entrance along Highway 88. Ten years prior, Jenkins and others (1995) noted *Eragrostis curvula* to be abundant in the riparian areas and scattered elsewhere. *E. curvula* often does not actively colonize adjacent non-planted sites (Cox et al. 1988). This plant does not seem to pose a major threat to the park's resources.

3.4.2.2 *Eragrostis lehmanniana*

The majority of *Eragrostis lehmanniana* plants observed in this area were concentrated toward the northeastern edge of the monument and on the north side of Highway 88 (Appendix A, Map A-6). The plants were not found here in dense stands, but rather interspersed amid *A. fatua*, *B. rubens*, and some native grasses and forbs. Four locations mapped in 1999–2001 were also located along the highway corridor (Guertin 2003). Other reports noted its extent in the areas below upper canyon but not in the vicinity of the roads (Jenkins et al. 1995).

3.4.2.3 *Melilotus* spp.

Melilotus species were mapped, though identification to the species level was difficult due to the lack of flowers and identifying characteristics. In this survey, nine individual *Melilotus* spp. plants were observed (Appendix A, Map A-10). Previous inventories have noted the presence of *Melilotus indicus* (Indian sweetclover) (Philips 1992; Jenkins et al. 1995; Albrecht et al. 2003; Guertin 2003). *M. indicus* was not one of our target species; *M. alba* (white sweetclover) and *M. officinalis* (yellow sweetclover) were the two species of interest, due to their inclusion on the AZ-WIPWG list. We included *Melilotus* spp. here because definitive identification could not be made to rule out any of the above target species.

3.4.2.4 *Pennisetum ciliare*

Ten points representing 1–3 plants were mapped (Appendix A, Map A-11). This is the first record of *P. ciliare* at Tonto NM. A related species, *Pennisetum setaceum*, was recorded in 1999 and 2000 in the vicinity of the park staff housing area and maintenance yard (Guertin 2003). These individuals have since been removed. All of the plants recorded during this survey were removed, and new individuals are sought out on a regular basis by park natural resource staff (S. Hoh, pers. comm. 2005). *P. ciliare* is a problematic species in Arizona, known to greatly alter desert communities by reducing native plant recruitment. It has the potential to dramatically alter fire regimes

by initiating positive feedback grass/fire cycles in ecotypes historically without large, frequent fires (D'Antonio and Vitousek 1992). It is possible that seed was brought in on vehicles or in soil during construction, as these plants were all located along the road.

3.4.2.5 *Sorghum halepense*

This grass was recorded adjacent to Highway 88 (Appendix A, Map A-15) in one small area above the large drainage gully of Cave Canyon. Several plants were seen within a 10-meter radius. This area was extensively disturbed during the recent road construction, probably enhancing conditions for this grass to become established. This grass's extensive, quick-growing rhizomes and large size give it a competitive edge over native plants and, once established, it can be difficult to manage or remove. *Sorghum halepense* is considered to be one of the ten worst weeds in the world (Holm et al. 1977). Nearby populations (outside park boundaries) of *S. halepense* were observed by researchers during this mapping effort, the majority of which were growing in drainages and culverts. It was recorded as occasional on roadsides in 1995 (Jenkins et al. 1995), but only one individual was recorded during the 1999–2001 mapping effort. This was located within the Tonto NM maintenance yard (Guerin 2003). Due to this grass's large size and distinct form, recognition is easy and individuals should be treated quickly when observed to prevent establishment.

3.4.3 Entrance road: Old and new

Construction in 2002 and 2003 removed the lower portion of the visitor entrance road and moved the remaining road to increase safety (Figure 3-5). After the old entrance road pavement was broken up and removed, the upper (southern) end was planted with saguaro (*Carnegie gigantea*), ocotillo (*Fouquieria splendens*), and barrel cactus (*Ferocactus wislizeni*; B. Traver, pers. comm. 2005). No other reseeding occurred here.

There are now several weedy species where the road was previously located, and no shrubs or trees have established. Three exotic plants were recorded here: *Phalaris* spp. (<1% cover), *Avena fatua* (6–25% cover) and *Bromus rubens* (26–50% cover). The roadsides leading up to the visitor center were not infested to any greater extent than the adjacent areas as a whole.

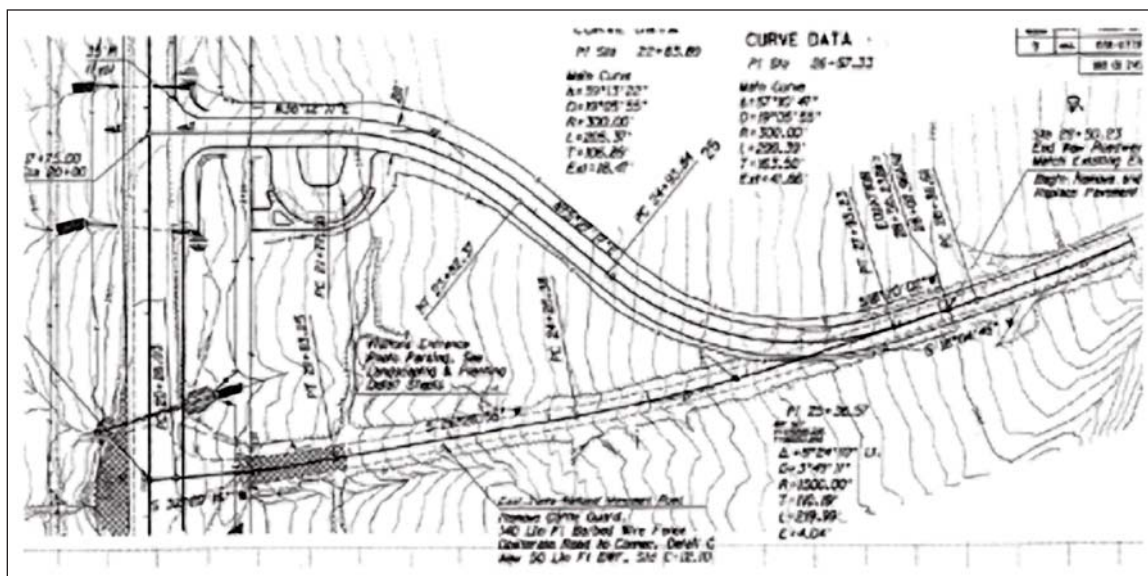


Figure 3-5. Diagram showing proposed entrance roadway design and position. Highway 88 is shown on the left side of the diagram; the original entrance road is toward the bottom (ADOT 2001).

3.4.4 Disposal field

Utility improvements were conducted at Tonto NM from February 2002 through May 2002. This work included the replacement of water pipes and septic pipes spanning from the visitor center to the picnic area. It also included the development of a new, larger septic disposal field to replace the existing two, smaller disposal fields. Construction of the new septic field involved excavating 1,200 feet of trench within approximately one-half acre to bury the pipe. This area is located to the east of the entrance road and to the northeast of the staff housing area (Figure 3-4). The results of this disturbance were still apparent during this study in 2005. *Tribulus terrestris* (puncturevine), an exotic species not found elsewhere in the monument, nor previously recorded at Tonto NM, was found in this area at less than one percent cover (Appendix A, Map A-16). Additionally, *Bromus rigidus*, *Bromus rubens* (both 1–5% cover) and *Eragrostis curvula* (<1%) were recorded here (Appendix A, Maps A-3, A-4, A-5).

3.4.5 Cave Canyon main drainage

We traversed Cave Canyon several times along the streambed and mapped target plants as points in an effort to increase accuracy. This area was known by park staff to have historically been infested by several of our target species, including *Marrubium vulgare*, *Brassica tournefortii*, and *Eragrostis* spp. Some of these species were actively removed over the past several years by the

park's natural resource manager. Therefore, we did not expect to find them in any great abundance—if at all, especially as we surveyed in the late summer. However, a number of target species were mapped, and are described as follows.

3.4.5.1 *Avena fatua*

Occasional single plants lined the Cave Canyon drainage; they were mostly present on the banks and surrounding areas (Appendix A, Map A-1). Along the southern end of Cave Canyon beneath the Upper Ruin slopes, *Avena fatua* was far more abundant than in the northern reaches. It was noted as abundant in this area at least since 1992 (Philips 1992). Twenty points were mapped in 2003 (Guertin 2003), with the majority of those points representing a few individuals.

3.4.5.2 *Brassica tournefortii*

A single individual, encountered in Cave Canyon close to the Upper Ruin trailhead, was desiccated and had already gone to seed, so it was not removed (Appendix A, Map A-2). This species is actively monitored by park staff in the spring and early summer and typically removed before seed sets. Cave Canyon is known to have recurring infestations of a few to many individuals and is watched carefully (S. Hoh, pers. comm. 2005). The effect of continuing hand-pulling before seed sets will be to reduce the seed bank and thus prevent large stands from becoming established in the drainage.

3.4.5.3 *Bromus rigidus*

B. rigidus was found growing predominantly in and around Cave Canyon and along both the Upper Ruin and Lower Ruin trails in 2005 (Appendix A, Map A-3). This species appeared to favor the shelter of trees and shrubs and was rarely seen in open areas. Isolated patches were common, with the highest density reported at 6–25% cover. Prior reports showed similar locations and extents (Jenkins et al. 1995). Fifty-three points, ranging from extensive patches to remnants of single individuals, were recorded in 2003 (Guertin 2003). All of these points were within the same general area of those mapped in this effort; it appeared that this population was stable and not spreading significantly.

3.4.5.4 *Bromus rubens*

B. rubens was observed on average at 25% cover within Cave Canyon, mostly along the stream bank (Appendix A, Map A-4). Within the wash, only sparse, scattered individuals were noted. In 2003, *B. rubens* was recorded here in much the same areas; more individuals were seen along the banks of the wash under trees and relatively few patches within the wash (Guertin 2003). It was described as locally abundant in Cave Canyon in 1992 (Philips 1992).

3.4.5.5 *Eragrostis curvula*

Nine *Eragrostis curvula* occurrences were recorded in the Cave Canyon riparian corridor (Appendix A, Map A-5). *E. curvula* was not found in any dense patches and appeared to be outcompeted by other grasses. In 1995, it was seen to be abundant in the Cave Canyon riparian area (Jenkins et al. 1995). To our knowledge, removal of this grass has not been implemented in the park at any level. It seems to have maintained its historical range, but it is hard to determine if abundance and density have increased or decreased.

3.4.5.6 *Eragrostis lehmanniana*

Lehmann lovegrass was recorded along the Cave Canyon drainage from the south boundary fence to Highway 88 (Appendix A, Map A-6). Most of the plants recorded were small bunches; none was seen in dense stands. The area directly above the southern portion of Cave Canyon (see Figure 3-4, Upper Ruin trail and slopes) was seeded with a mix containing *E. lehmanniana* in the 1960s (Philips 1992). It was co-dominant on these slopes with *A. fatua*, *B. rubens*, and *E. curvula*.

Across the south boundary fence into the Tonto National Forest, *E. lehmanniana* was dominant in large stands. Seeds could easily reach Cave Canyon from there and spread downstream, and be supplied back across the slopes.

3.4.5.7 *Galium aparine*

Although not included on the AZ-WIPWG list of invasive plant species used to guide this inventory, *G. aparine* (stickywilly) is one of the five additional species known by park staff to be problematic in the monument and was thus included in this effort. While identification was possible at this time of year, the plants were hard to see and required extra attention to detect. Due to the detection difficulty, *G. aparine* abundance may be underestimated in this study. Only seven locations were mapped this season within the riparian area of Cave Canyon (Appendix A, Map A-7), but more could be expected if mapped in the spring. *G. aparine* was previously reported below the Lower Ruin by Jenkins and others (1995). During 2003, it was noted at 18 locations in small to large patches, all but two occurring within Cave Canyon.

3.4.5.8 *Marrubium vulgare*

One plant was recorded during this survey (Appendix A, Map A-9). It was located in the Cave Canyon streambed close to the gate on the Upper Ruin trail. This plant was removed after being recorded by park natural resource staff. *M. vulgare* has been very abundant in the park and, at times, quite dense, especially in the southern reaches of Cave Canyon (Jenkins et al. 1995). Twenty-one locations were recorded between 1999 and 2001 (Guertin 2003), representing one to many individuals. These were all either within the Cave Canyon drainage or within a few meters of the streambed. Active removal of these plants has occurred since 1999, and has clearly impacted the level of infestation to the point where only isolated individuals are reappearing. Natural resource staff noted large, dense patches near the southern boundary fence in the last two years and removed them mechanically (S. Hoh, pers. comm. 2005). This species has repeatedly invaded the southern park boundary following intensive removal efforts by park staff, suggesting that seeds are possibly being introduced from U.S. Forest Service lands upstream and south of the park. Recurring invasions can likely be expected unless the upstream populations are eradicated.

3.4.6 Mesquite/Paloverde forest

During this survey, *Bromus rubens* was recorded at 6–25% cover in the Mesquite/Paloverde portion of the park, growing under trees and shrubs (Appendix A, Map A-4). *Avena fatua* was scarce in this area, observed at less than 1%; only occasional plants were encountered (Appendix A, Map A-1). These were typically seen close to the highway, along the northwestern boundary fence and at the entrance to Dead Man's wash. No other species were seen. In general, this area was thick with *Acacia greggii* (catclaw acacia), *Acacia constricta* (whitethorn acacia), *Parkinsonia* spp. (paloverde) and *Prosopis* spp. (mesquite). Many dead native annual species were apparent. To the south of this area, *Bromus rubens* persisted across the alluvial fans and was dense on many easterly slopes (Appendix A, Map A-4).

In 2003, twenty-eight *B. rubens* points were mapped in this area (Guertin 2003). Points located under trees and shrubs were described as extensive patches; points located in open areas represented lower cover. These observations were consistent with our observations throughout the monument. Philips (1998) noted dense patches of both *A. fatua* and *B. rubens* in Cave Canyon wash, as well as some northeast of Highway 88 and along the park entrance road.

3.4.7 Eastern Jojoba Flats

Most of this area was observed to exhibit 1–5% cover of *Bromus rubens* (Appendix A, Map A-4), less than 1% cover of *Bromus rigidus* (Appendix A, Map A-3), and less than 1% cover of *Avena fatua* (Appendix A, Map A-1), with the latter two species observed in proximity of the northern fenceline. Most *B. rubens* plants were observed growing beneath trees and shrubs. Seventy-seven *B. rubens* points were mapped here in 2003, dispersed throughout the area, suggesting that this species was well established at that time (Guertin 2003). *A. fatua* appeared to be creeping slowly across the fenceline into the monument from the roadways; efforts should be made to curb this advance. Three *Avena fatua* points were recorded within this area over a three-year period between 1999 and 2001, each representing a few individuals (Guertin 2003). One was located adjacent to the monument entrance road, one close to the northeastern fenceline, and the last was located in the middle of this area. No other records of *Avena fatua* are known for this area.

3.4.8 Honey Butte Ridge

The area described here contained *Avena fatua* at about 1–5% cover in 2005, but as high as 50% cover in some small portions (Appendix A, Map A-1). Overall, *A. fatua* seemed to occur more frequently on the slopes with loose rock debris and open spaces, and less frequently in areas with dense native plant cover. *Bromus rubens* was more common throughout the area, at 6–25% cover (Appendix A, Map A-4). *Bromus rigidus* was again scarce, occurring in only a few locations (Appendix A, Map A-3).

During the 2003 inventory, *B. rubens* was described as extensive in this area, while *A. fatua* was recorded in just one spot near the saddle summit. *Eragrostis lehmanniana* was observed to be growing in large patches over the flatter areas. In 1992, *B. rubens* was noted as the co-dominant species on the north-facing hillside (Philips 1992). Without management intervention, it is unlikely that these species will decrease in abundance. Fluctuations in their cover may be explained by their sensitivity to moisture; both species respond positively to winter precipitation (Wu and Jain 1979; AZ-WIPWG 2005b).

3.4.9 Upper Ruin Trail and surrounding slopes

In “History of Fire and Fire Impacts at Tonto National Monument, Arizona,” Philips (1997) noted that the U.S. Forest Service seeded *Eragrostis lehmanniana*, among other grasses, in the 1960s and 1970s as a post-fire revegetation effort. The area seeded was predominantly in the southeast portion of the park, near the Upper Ruin and beyond the south boundary in the Tonto National Forest. This area burned severely in the Schultz Fire of 1964, which damaged many *Carnegia gigantea*, *Opuntia* spp. (pricklypear), and *Cercidium* spp. (paloverde). Additional fires in 1970, 1976, and 1980 re-burned portions of the Schultz Fire area. Currently, few cacti and shrubs dot these hills.

This area was by far the most infested portion of the monument, with high levels of several non-native grasses. The slopes and trail were predominantly covered with *Avena fatua* (approximately 51–75% cover), *Bromus rubens* (approximately 26–50% cover) and *Eragrostis lehmanniana* (approximately 6–25% cover). It appears, from the data we collected, that seed from this area travels down into Cave Canyon wash, making Cave

Canyon an additional vector for the spread of these grasses. With heavy flow during storms, it is possible that seed could travel from the southern to the northern end of the monument.

Earlier reports (Philips 1992; Jenkins et al. 1995) noted *A. fatua* as being abundant in Cave Canyon, but no mention was made of extensive patches on the hillsides. Guertin (2003) mapped 22 points along the trail and across the slopes, representing moderate to extensive areas of *A. fatua*. This area is visible from the road, and the dried stems of wild oats were obvious due to the distinct coloration of the large, dense patches. Based on information from this inventory effort and previous studies, *A. fatua* seems to have increased in both range and density across these slopes. Seeds from this species are known to remain dormant in the soil for up to 10 years and, moreover, the plants exhibit allelopathic qualities that inhibit the growth of other species (Tinnin et al. 1972).

Bromus rigidus was also recorded in this area at 6–25% cover, which represents individual plants or small patches predominantly closer to the riparian portion of the trail. Philips (1992) found *B. rigidus* in the riparian portion of Cave Canyon and some at the Upper Ruin. No occurrence was noted on the slopes of the Upper Ruin trail. Jenkins and others (1995) also noted its presence in Cave Canyon wash, growing under trees. This species is most effective at spreading to new sites following disturbance, such as fire, grazing, or land-clearing (AZ-WIPWG 2005d).

3.4.10 Lower Ruin Trail and visitor center

The same species were problematic along the slopes to the Lower Ruin. *Avena fatua*, *Bromus rigidus*, and *Bromus rubens* were all present, but to a lesser degree than at the Upper Ruin (Maps A-1, A-3, A-4). On average, the cover was between 6 and 25%, with *B. rigidus* less abundant, at 1–5% cover. This area has a much higher density of cacti and shrubs and higher native species richness. One large drainage here, to the far northeast of the trail, was heavily infested (75–100% cover) with *B. rubens* and *A. fatua*. The trail edges did not appear to be more affected than the surrounding areas. Above the Lower Ruin, we noted that *Selaginella arizonica* (Arizona spikemoss) was the dominant ground cover, and the spread of the grasses tended to be to the south and northeast.

The area around the visitor center and parking lot were, in some places, quite overrun with these

grasses; *Bromus rubens* and *Avena fatua* were especially apparent beyond the low walls of the parking area. The lower reaches of the trail were more infested than locations further up, with drainages having the highest density due, in part, to increased water catchment.

3.4.11 Uplands and backcountry

The uplands area consists of rolling hills leading to the entrance of Dead Man's Canyon on the northwest side of the park unit. At the tops of these hills and ridges, exotic species were less dense, and the native vegetation more diverse, than on the slopes. Several cacti and native grasses not seen elsewhere in the monument were seen here. *Avena fatua*, *Bromus rubens*, and *Bromus rigidus* were observed. On some northeast-facing slopes, *Bromus rubens* was observed at 50–75% cover, and on south-facing slopes as low as 5–25% cover. In general, the whole area exhibited *B. rubens* at 25–50% cover and *A. fatua* at 6–25% cover.

During 1999–2001, *A. fatua* was observed in many of the same areas as during this census, but at slightly lower densities (Guertin 2003). Both the 1992 and 2003 reports found some plants growing at the entrance to Dead Man's Canyon and reported the surrounding slopes as infested (Philips 1992; Guertin 2003). In 2003, *A. fatua* was reported as “extensive on the slopes;” we often observed it in monotypic stands on some slopes or co-dominant with *Bromus rubens*. *Avena fatua* had taken advantage of small areas where it could establish easily, such as disturbed rock sites. However, where native shrubs and grasses were still present, the grass was spotty and scarce.

The backcountry area was accessed from Dead Man's Canyon twice, and also from the high ridges at the southern end of the monument. In general, this area had diverse, abundant native species. Occasional *Bromus rubens* and *Avena fatua* plants were seen close to the entrance to Dead Man's Canyon, in the wash and on the adjacent slopes. Further up the canyon, none was seen.

B. rubens, *E. lehmanniana*, and *A. fatua* were mapped here in 2001, with all but one point occurring on the east side of the canyon and many falling at the saddle of Cholla Canyon and Dead Man's Canyon (Guertin 2003). This saddle is the lowest point of entry into Dead Man's Canyon and appeared to be a vector of dispersal from the east side of the unit.

4 Discussion

4.1 Parkwide observations

The steep slopes beneath the Upper Ruin and the Cave Canyon riparian corridor were the two areas in the monument most affected by exotic plants. The Upper Ruin slopes have been badly burned four times in the last 40 years (Philips 1992), severely damaging cacti and shrubs. Following the first of these fires, these slopes were seeded with grass mix, including *Eragrostis lehmanniana* (Philips 1992). It appears that seeds of these plants are carried downhill via water and wind toward the north end of the monument, facilitating the spread of these species.

Four species, all grasses, were recorded both in high densities and over large areas at Tonto NM: *Avena fatua* (wild oats), *Bromus rubens* (red brome), *Bromus rigidus* (ripgut brome), and *Eragrostis lehmanniana* (Lehmann lovegrass). These are the most problematic species within the monument, due not only to their relative abundance but also to their difficulty to control and level of impact on the surrounding ecosystem.

The presence of *Bromus rubens*, *Bromus rigidus*, and *Eragrostis lehmanniana* in the park is cause for concern due to their ability to impact the frequency, intensity, and rate of spread of wildfires (Cable 1971; Brown and Smith 2000; AZ-WIPWG 2005d). Additionally, all three species can displace native plants, especially following disturbances, such as fire (Anable et al. 1992; Brooks 1999; AZ-WIPWG 2005d). AZ-WIPWG (2005e, 2005f) has given both *B. rubens* and *E. lehmanniana* an overall score of “high” for level of impact and invasiveness, in part because of their association with increases in fire frequency. *B. rigidus* was rated “medium” and given an “alert” due to its ability to rapidly invade unexploited natural communities (AZ-WIPWG 2005d).

Based on observations from this and previous studies, *Avena fatua*, which responds favorably in wet years (P. Guertin pers. comm. 2004), appears to be spreading within the park unit. The winter of 2005 was remarkably wet for Tonto NM; precipitation totals from December 2004 through March 2005 were 16.46" at the nearby Roosevelt 1WNW National Weather Service cooperative observer station, which was dramatically higher than the long-term average of 7.48" for this pe-

riod (WRCC 2005). The additional precipitation may explain the apparent increase in *A. fatua* at the park. AZ-WIPWG (2005b) has given *A. fatua* an overall score of “medium,” as it has been associated with increases in fire frequency.

Additional species of concern are *Brassica tournefortii* and *Pennisetum ciliare*. While neither of these species is widespread within the monument, they are of great concern as they are both aggressive invaders that “crowd out native Sonoran Desert species by creating monocultures that consume scarce water and nutrient resources” (Siegel 2002). *B. tournefortii* has been documented to increase fuel loads and fire hazard in desert scrub environments (AZ-WIPWG 2005c). *P. ciliare* also poses significant threats of spreading fire (Esque and Schwalbe 2000; Burquez-Montijo et al. 2002). In the early stages of invasion, when plants are still sparse, control of both *B. tournefortii* and *P. ciliare* is possible, and efforts toward eradication should be made. Currently, both of these species are growing only along the sides of Highway 88. However, care should be taken to eliminate the threat of spread by vehicles, animals, and foot traffic by removing these plants on a regular basis.

4.1 Differences between this and other studies

Several of our target species may not have been seen during this census (or seen in less abundance) because they were winter and spring annuals, and the census occurred during the summer. These species were *Erodium cicutarium* (red-stem storksbill), *Malva parviflora* (little mallow), *Melilotus* spp., (sweetclover) *Sisymbrium irio*, and *Galium aparine*. A previous study (Guertin 2003) mapped these species during spring 1999, 2000, and 2001. *E. cicutarium*, in particular, was noted in every area of the monument and, as this is a difficult species to treat, this range will probably persist. Following up this effort with a spring survey (March–April) would help to address this inconsistency in study findings.

Some other species not seen during this survey were thought to have been absent due to a strict removal program. *Sonchus asper* (spiny sowthistle), *Sonchus oleraceus* (common sowthistle), and *Centaurea melitensis* (Maltese star-thistle) are three species of which individual plants were previously seen and removed. *Marrubium vulgare* has essentially been tempered, when compared to previous extents in the Cave Canyon drainage.

Again, this was achieved by manual removal. *Cynodon dactylon* (Bermudagrass), while recorded in 2001 and 2003, was not seen over the course of this inventory. It seems likely that it is still present; to our knowledge, no removal efforts have been undertaken for this species.

4.2 Management recommendations

Because *Avena fatua*, *Brassica tournefortii*, *Bromus rigidus*, *Bromus rubens*, and *Eragrostis lehmanniana* have all been associated with increasing fire risk and respond positively to the effects of fire (Cable 1971; Brown and Smith 2000; Esque and Schwalbe 2000; Burquez-Montijo et al. 2002; AZ-WIPWG 2005b, 2005c, 2005d), efforts should be made to control their abundance and spread. Persistence of these species has the potential to significantly alter the landscape at Tonto NM, as repeated fires have adverse impacts to native vegetation, including the characteristic cactus species.

Pennisetum ciliare and *Brassica tournefortii* should be pursued with vigilance. Both of these species were observed within the monument in small numbers of individual plants. At this stage, control of both species is possible through mechanical means (e.g., hand-pulling). However, if allowed to spread, both plants can have severe impacts on native vegetation.

The other target species observed on the monument also warrant attention, but pose lesser threats than those mentioned above. Efforts to control these species should be made after the more problematic species are addressed.

5 Literature Cited

- Albrecht, E. W., W. L. Halvorson, P. P. Guertin, B. F. Powell, and C. A. Schmidt. 2005. A biological inventory and hydrological assessment of the Cave Springs riparian area, Tonto National Monument, Arizona. Unpublished report.
- APRS Implementation Team (APRSIT). 2001. Alien plants ranking system version 7.1. Flagstaff, Az. <http://www.usgs.nau.edu/swepic/>. Accessed 15 Apr 2004.
- Anable, M. E., M. P. McClaran, and G. B. Ruyle. 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees in southern Arizona. *Biological Conservation* 61:181–188.
- Arber R. P. 2001. Engineering report and maintenance plan. Tonto National Monument Utility Improvements. Where can this be found?
- Arizona Department of Transportation (ADOT). 2001. Claypool-Jakes corner Highway (SR-188) and Tonto National Monument-Resort road; Construct new roadway. Where can this be found?
- Arizona Wildlands Invasive Plant Working Group (AZ-WIPWG). 2005a. Invasive non-native plants that threaten wildlands in Arizona. <http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/InvasiveNon-NativePlantsThatThreatenWildlandsInArizona.pdf>
- . 2005b. *Avena fatua* plant assessment form, version 1. http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/PLANTPDF/Avena_fatua_AZ_PAF.pdf.
- . 2005c. *Brassica tournefortii* plant assessment form, version 1. http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/PLANTPDF/Brassica_tournefortii_AZ_PAF.pdf.
- . 2005d. *Bromus rigidus* plant assessment form, version 1. http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/PLANTPDF/Bromus_diandrus_AZ_PAF.pdf.
- . 2005e. *Bromus diandrus* plant assessment form, version 1. http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/PLANTPDF/Bromus_diandrus_AZ_PAF.pdf.
- . 2005f. *Eragrostis lehmanniana* plant assessment form, version 1. http://sbsc.wr.usgs.gov/research/projects/swepic/SWVMA/PLANTPDF/Eragrostis_lehmanniana_AZ_PAF.pdf.
- Brooks, M. L. 1999. Alien annual grasses and fire in the Mojave Desert. *Madrono* 46:13–19.
- Brown, J. K., and J. K. Smith, eds. 2000. Wildland fire in Ecosystems: Effects of fire on flora. Gen. Tech. Rep. RMRS-GRT-42, vol. 2, USDA Forest Service Rocky Mountain Research Station, Ogden, Ut.
- Burquez-Montijo, A., M. E. Miller, and A. Martinez-Yrizar. 2002. Mexican grasslands, thornscrub, and the transformation of the Sonoran Desert by invasive exotic buffelgrass (*Pennisetum ciliare*). Pages 126–146 in B. Tellman, ed., *Invasive exotic species in the Sonoran region*. Tucson: University of Arizona Press and the Arizona-Sonoran Desert Museum.
- Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937–1968. *Journal of Range Management* 24:17–21.
- Cave, G. H., and D. T. Patten. 1984. Short-term vegetation responses to fire in the upper Sonoran Desert. *Journal of Range Management* 37(6):491–496.
- Cox, J. R., M. H. Martin-R., F. A. Ibarra-F., J. H. Fourie, N. F. G. Rethman, and D. G. Wilcox. 1988. The influence of climate and soils on the distribution of four African grasses. *Journal of Range Management* 41:127–139.
- D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses: The grass/fire cycle and global change. *Annual Review of Ecology and Systematics* 23:63–87.
- Esque, T. C., and C. Schwalbe. 2000. Non-native grasses and fire create double jeopardy. *People, Land, and Water*. U.S. Department of the Interior. http://www.usgs.gov/invasive_species/plw/grassfire.html. Accessed 21 Jun 2004.
- Guertin, P. 2003. Weeds in the West project: Status of introduced plants in southern Arizona parks. <http://sdfsnet.srn.arizona.edu/index.php?page=datamenu&lib=2&sublib=13>.

- Holm, L. G., P. Donald, J. V. Pancho, and J. P. Herberger. 1977. *The world's worst weeds: Distribution and biology*. Honolulu: University Press of Hawaii.
- Jenkins, P. D., F. W. Reichenbacher, K. Johnson, and A. E. Gondor. 1995. Vegetation inventory, classification and monitoring for Tonto National Monument, Arizona. <http://sdrsnet.srn.arizona.edu/index.php?page=reports>.
- Mau-Crimmins, T., M. Mauzy, S. Studd, and G. R. McPherson. 2004. Continuation of a non-native plant mapping project at Montezuma Castle and Tuzigoot national monuments. Where can this be found? Can we cite the MOCA-TUZI combined report?
- National Park Service (NPS). 2006. Management Policies 2006. <http://www.nps.gov/policy/MP2006.pdf>.
- Phillips, B. 1992. Status of non-native plant species, Tonto National Monument, Arizona. Technical report NPS/WRUA/NRTR-92/46. <http://sdrsnet.srn.arizona.edu/index.php?page=reports>
- Phillips, B. 1997. History of fire and fire impacts at Tonto National Monument, Arizona. Technical report No. 59. <http://sdrsnet.srn.arizona.edu/index.php?page=reports>
- Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 1999. Environmental and economic costs associated with non-indigenous species in the United States. *BioScience* 50:53–65.
- Schnase, J. L., J. A. Smith, T. J. Stohlgren, S. Graves, and C. Trees. 2002. Biological invasions: A challenge in ecological forecasting. IEEE International Geoscience and Remote Sensing Symposium, 24th Canadian Symposium on Remote Sensing: 122–124.
- Siegel, B.S. 2002. Community responds to invasive plant threat. The Arizona Native Plant Society. http://aznps.org/html/exotics_weed-wackers.html Accessed 24 Sep 2005.
- Stohlgren, T.J., T.D. Barnett, and S.S. Simonson. 2003. Beyond North American weed management standards. http://science.nature.nps.gov/im/monitor/meetings/FtCollins_02/StohlgrenBeyondNAW_MA.pdf Accessed June 7, 2003.
- Tinnin, R. O., and C.H. Muller. 1972. The allelopathic influence of *Avena fatua*: The allelopathic mechanism. *Bulletin of the Torrey Botanical Club* 99:287–292.
- U.S. Department of the Interior (USDI). 2001. Management policies 2001. Accessed online: <http://www.nps.gov/policy/mp/policies.pdf>. Accessed January 15, 2004.
- Western Regional Climate Center (WRCC). 2005. Arizona climate summary for Roosevelt 1 WNW, Arizona. <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?azroos>. Accessed January 11, 2006.
- Wu, K. K., and S. K. Jain. 1979. Population regulation in *Bromus rubens* and *B. mollis*: Life cycle components and competition. *Oecologia* 39:337–357.

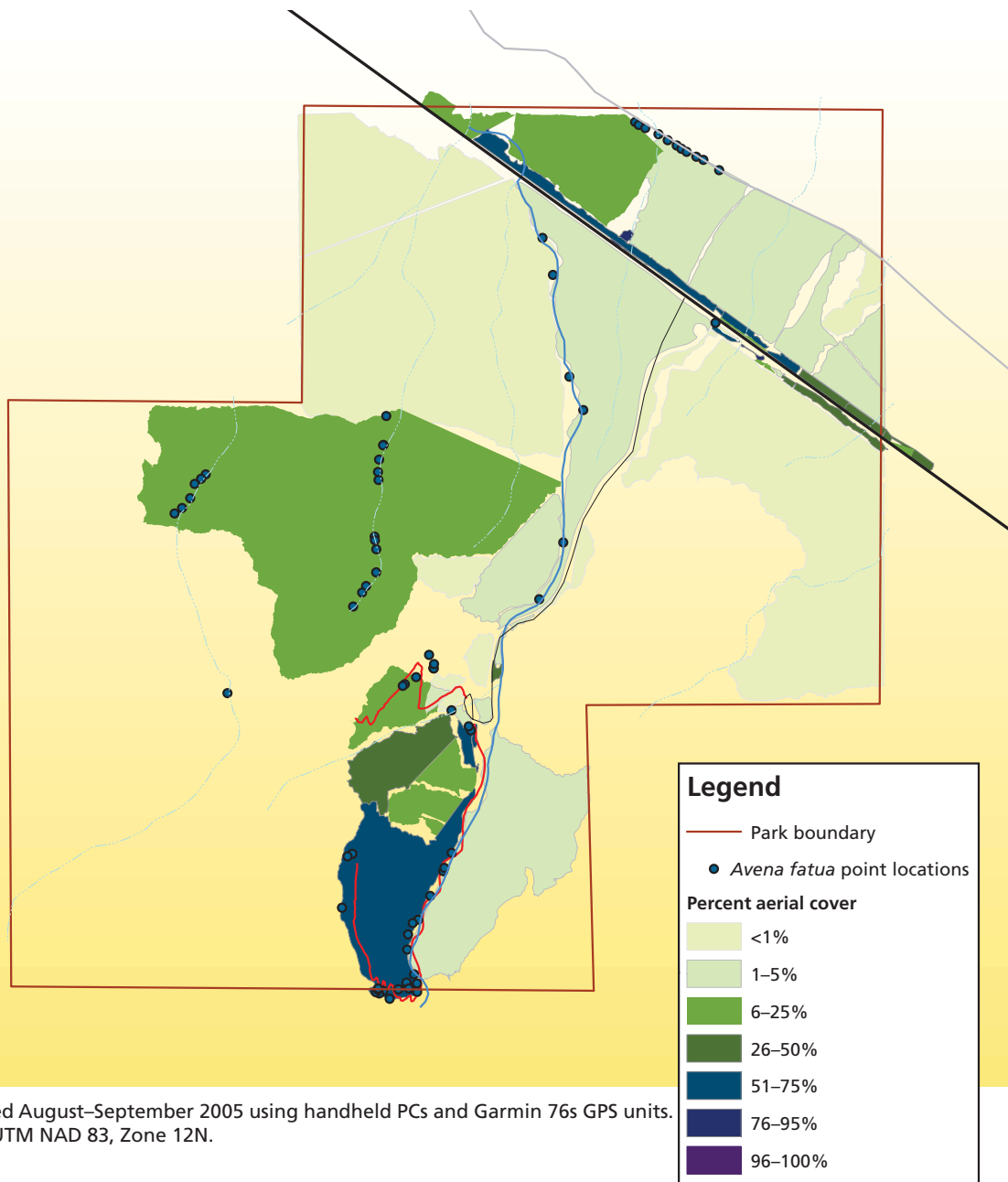
Appendix A. Species Maps

Tonto National Monument
Arizona

National Park Service
U.S. Department of the Interior



Avena fatua (wild oats) Map A-1



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units.
Data are in UTM NAD 83, Zone 12N.

0 0.050.1 0.2 0.3 0.4
Miles

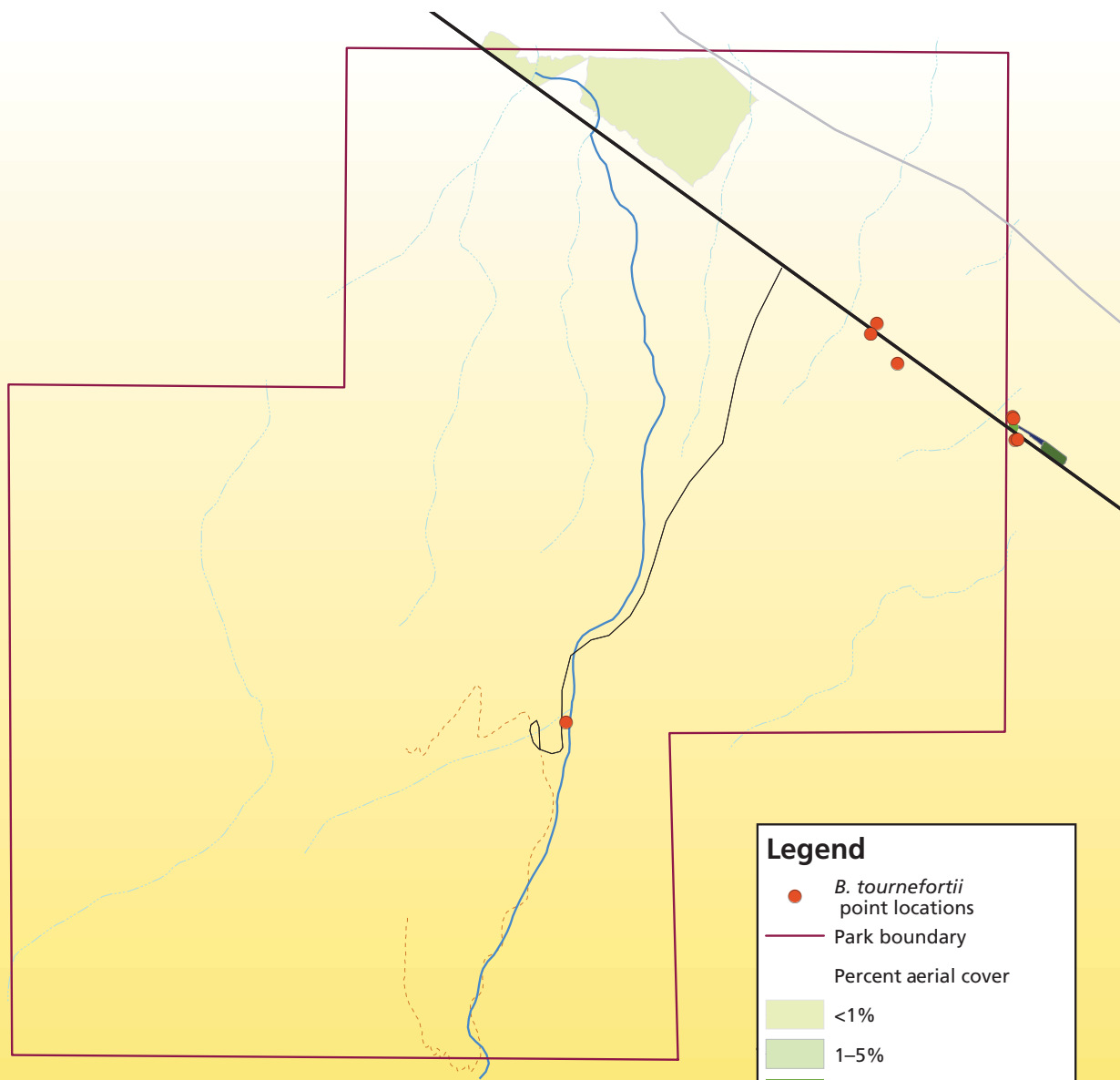
Produced by Sarah Studd & Jason Welborn

October 2005



Brassica tournefortii (Sahara mustard)

Map A-2



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4 Miles

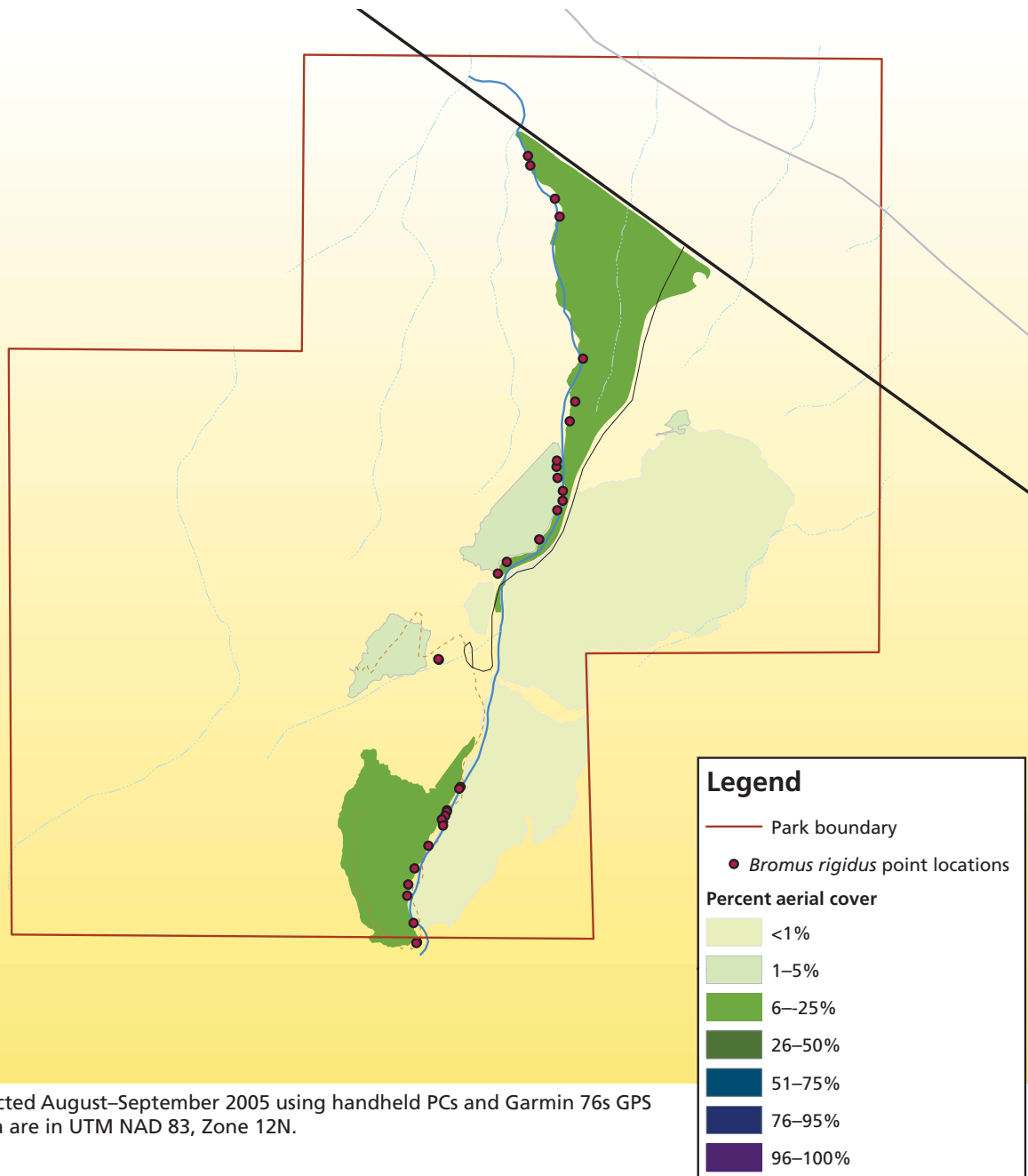
Produced by Sarah Studd and Jason Welborn

October 2005



Bromus rigidus (ripgut brome)

Map A-3



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

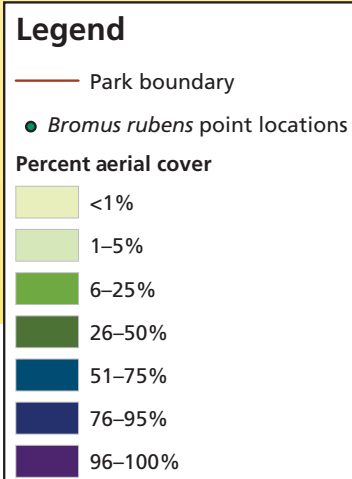
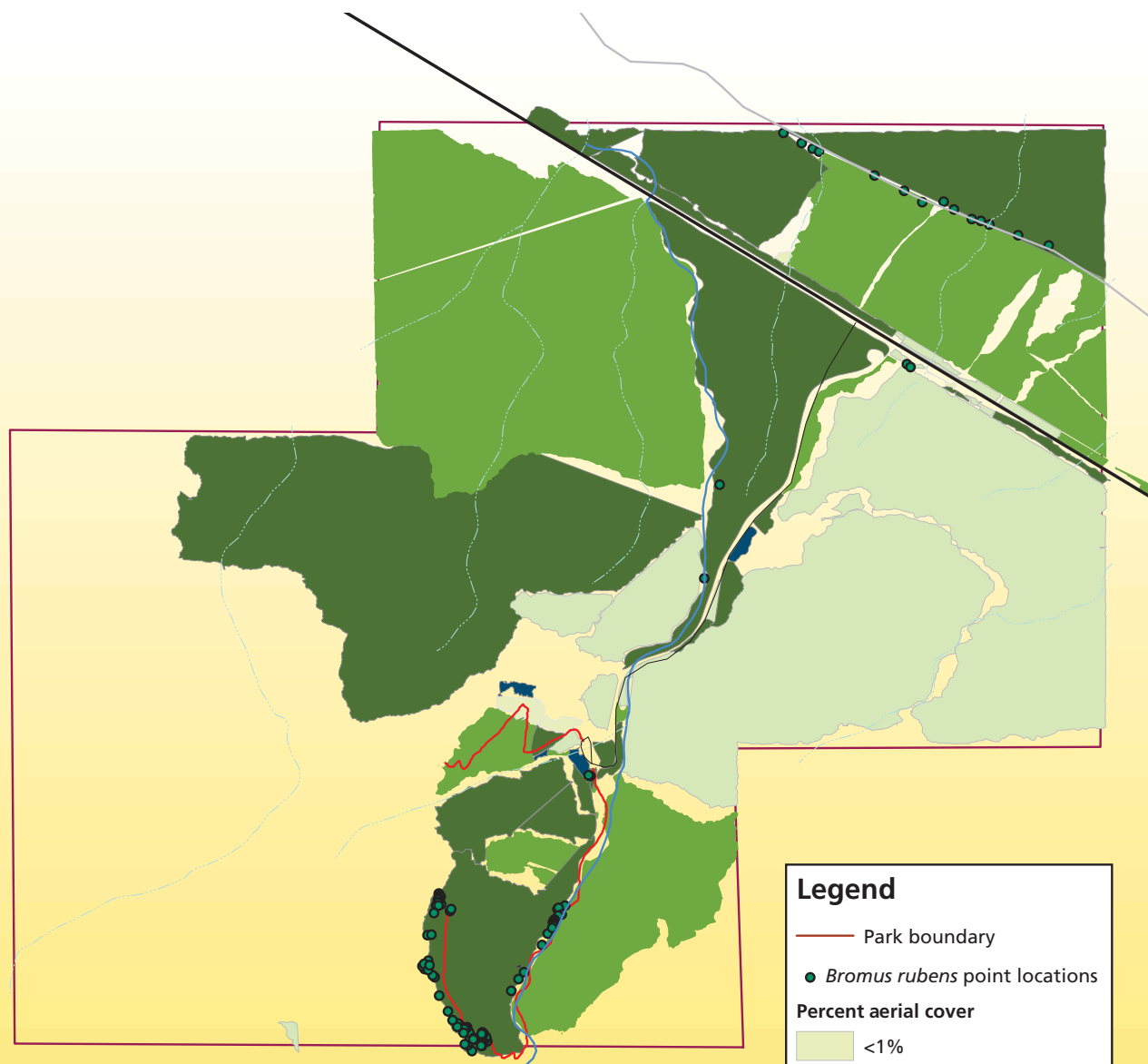
Produced by Sarah Studd & Jason Welborn

October 2005



Bromus rubens (red brome)

Map A-4



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

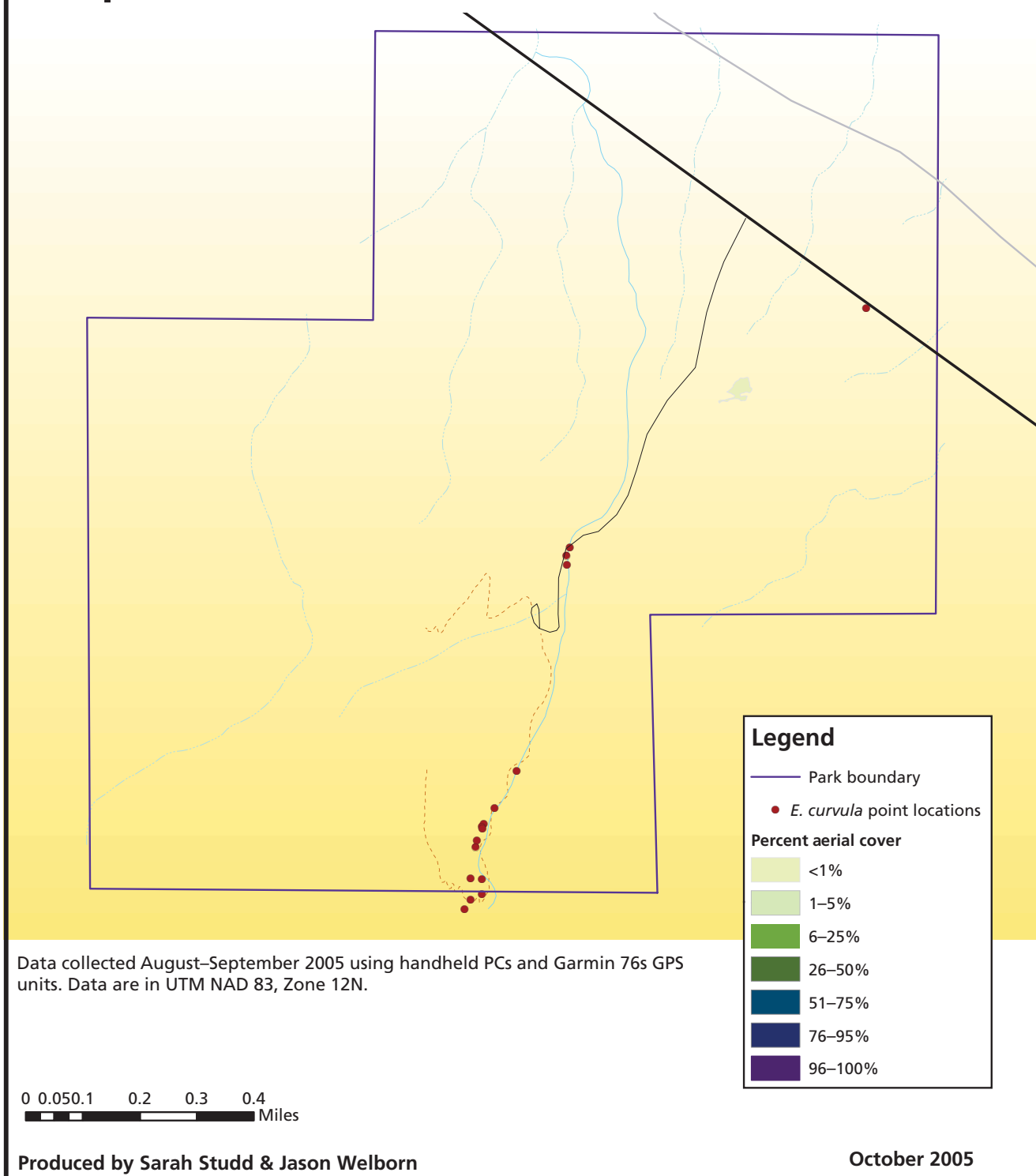
0 0.05 0.1 0.2 0.3 0.4
Miles

Produced by Sarah Studd & Jason Welborn

October 2005



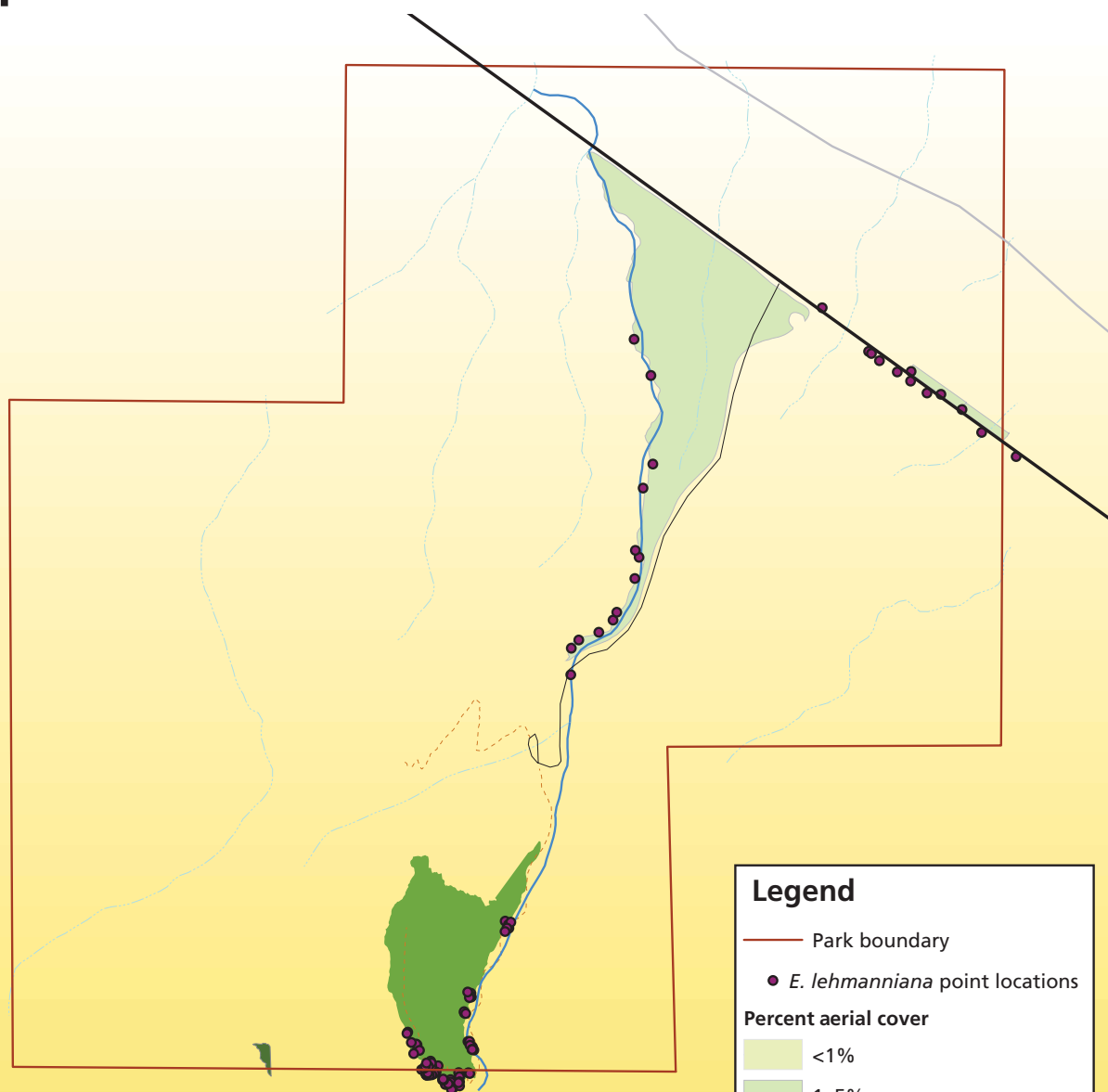
Eragrostis curvula (weeping lovegrass) Map A-5





Eragrostis lehmanniana (Lehmann lovegrass)

Map A-6



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

Legend

- Park boundary
- *E. lehmanniana* point locations
- Percent aerial cover**
 - <1%
 - 1–5%
 - 6–25%
 - 26–50%
 - 51–75%
 - 76–95%
 - 96–100%

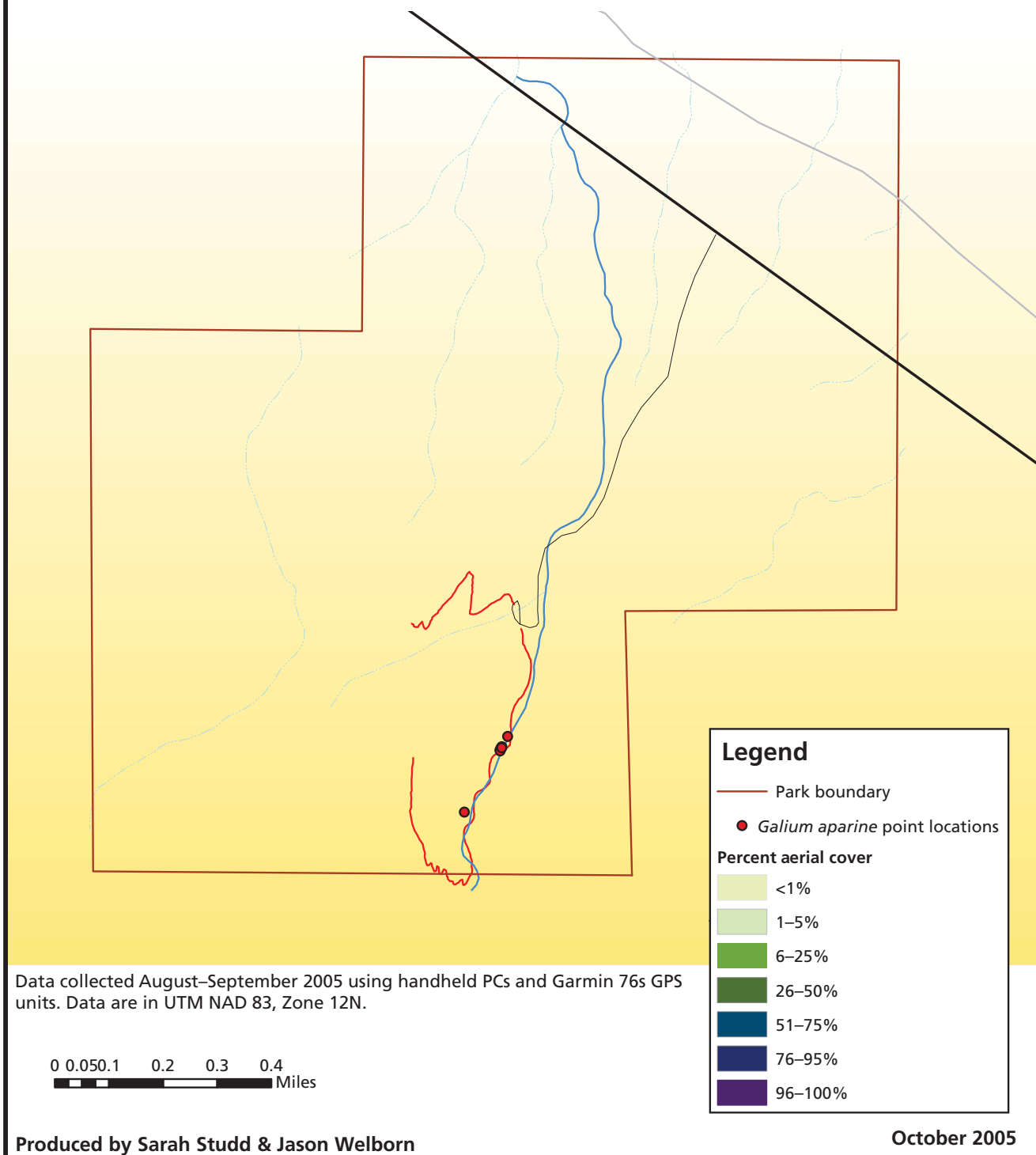
Produced by Sarah Studd & Jason Welborn

October 2005



Galium aparine (stickywilly)

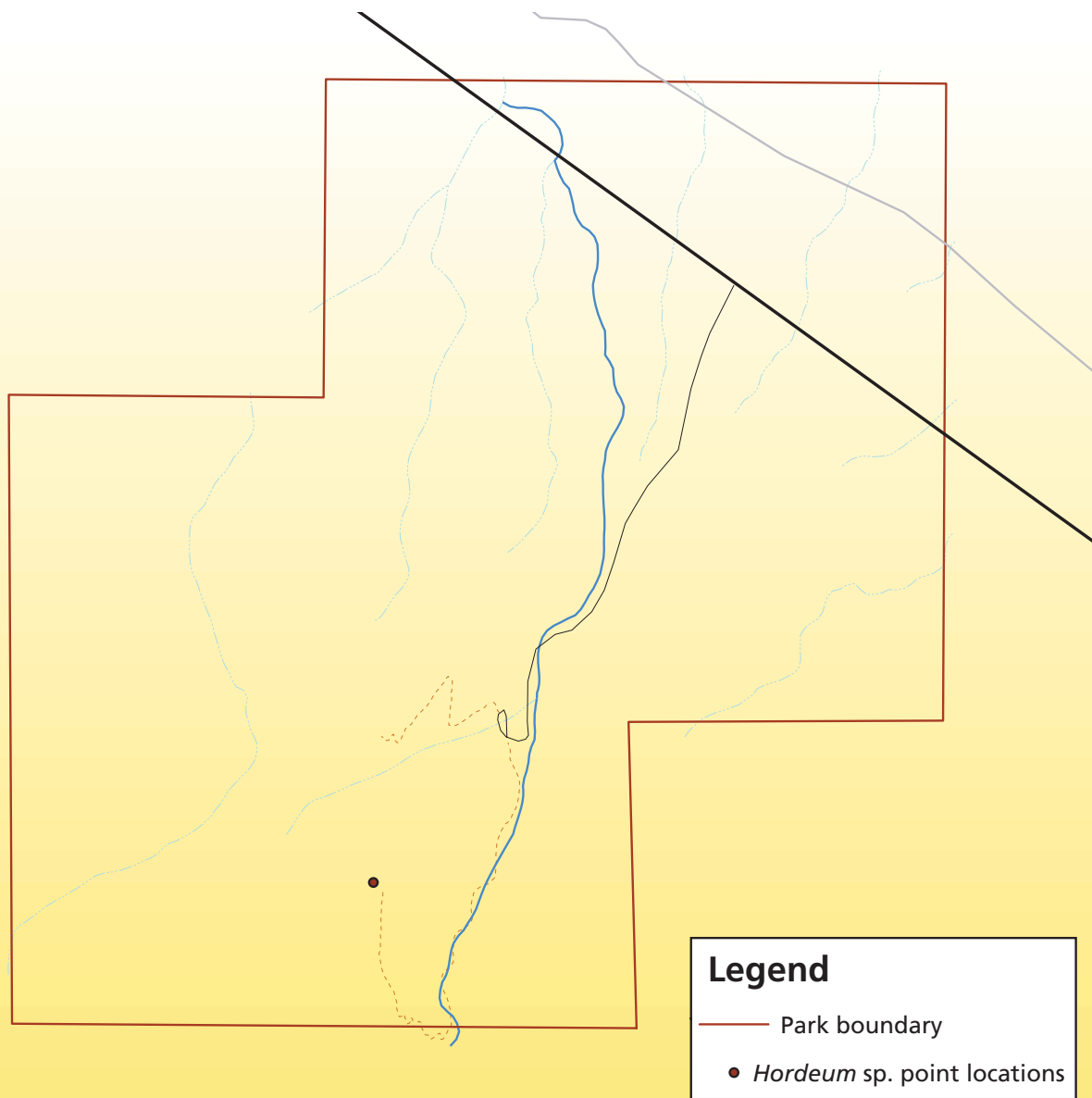
Map A-7





Hordeum sp. (barley)

Map A-8



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.050.1 0.2 0.3 0.4
Miles

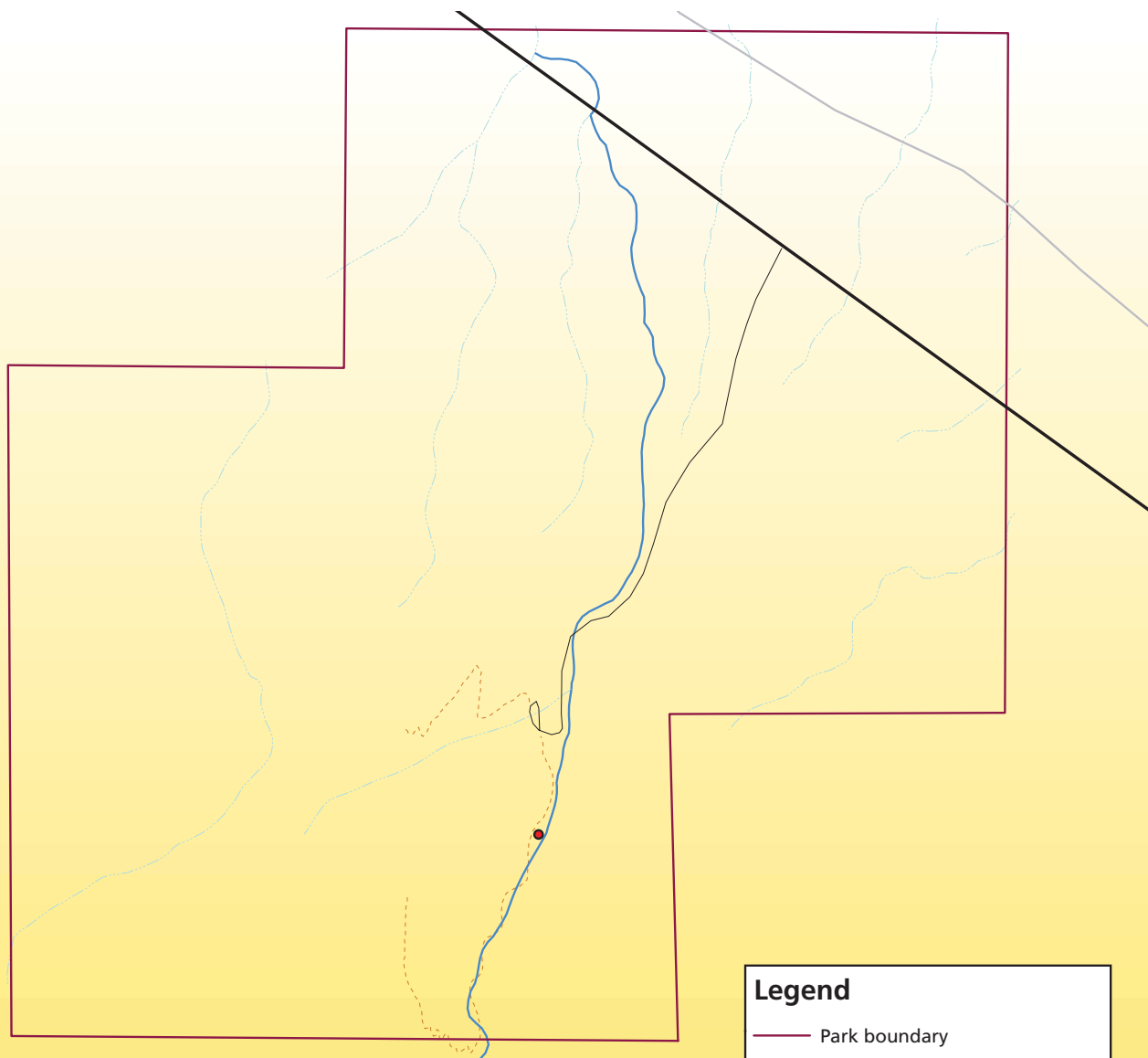
Produced by Sarah Studd & Jason Welborn

October 2005



Marrubium vulgare (horehound)

Map A-9



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

Note: Individuals on this map have been removed by park staff.

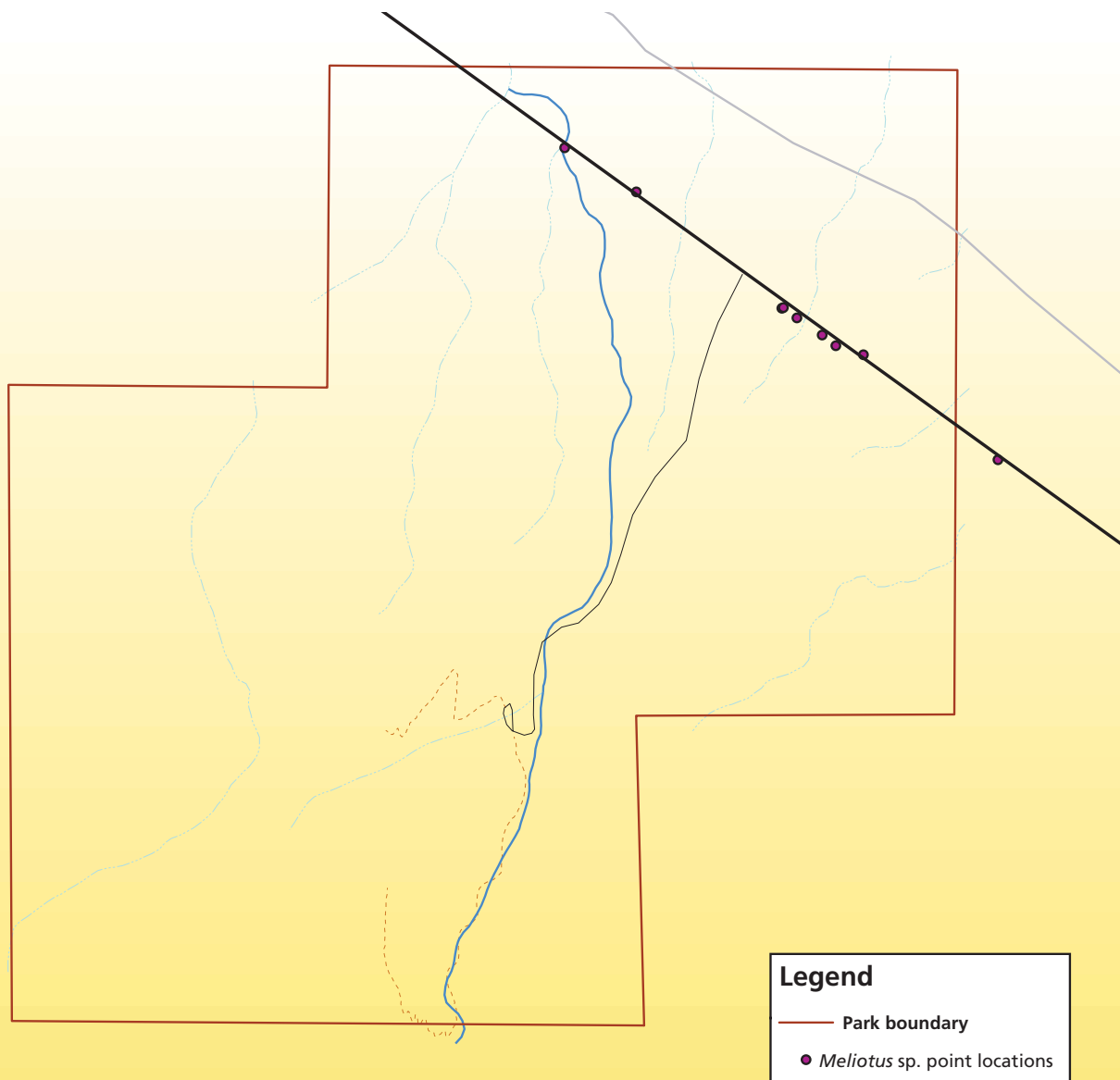
October 2005

Produced by Sarah Studd and Jason Welborn



Melilotus sp. (sweetclover)

Map A-10



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

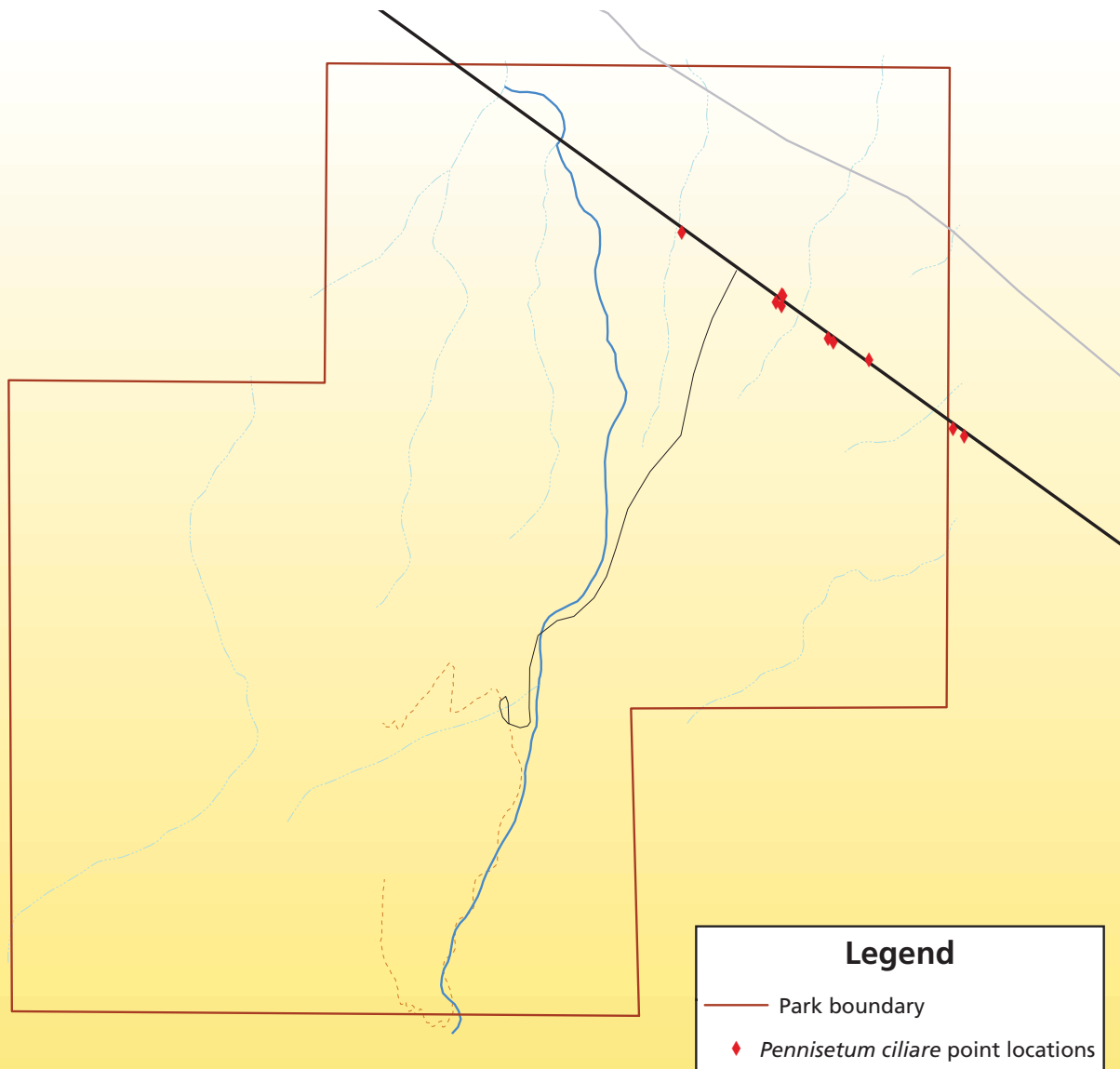
Produced by Sarah Studd & Jason Welborn

October 2005



Pennisetum ciliare (buffelgrass)

Map A-11



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.050.1 0.2 0.3 0.4
Miles

NOTE: Individuals on this map have been removed by park staff.

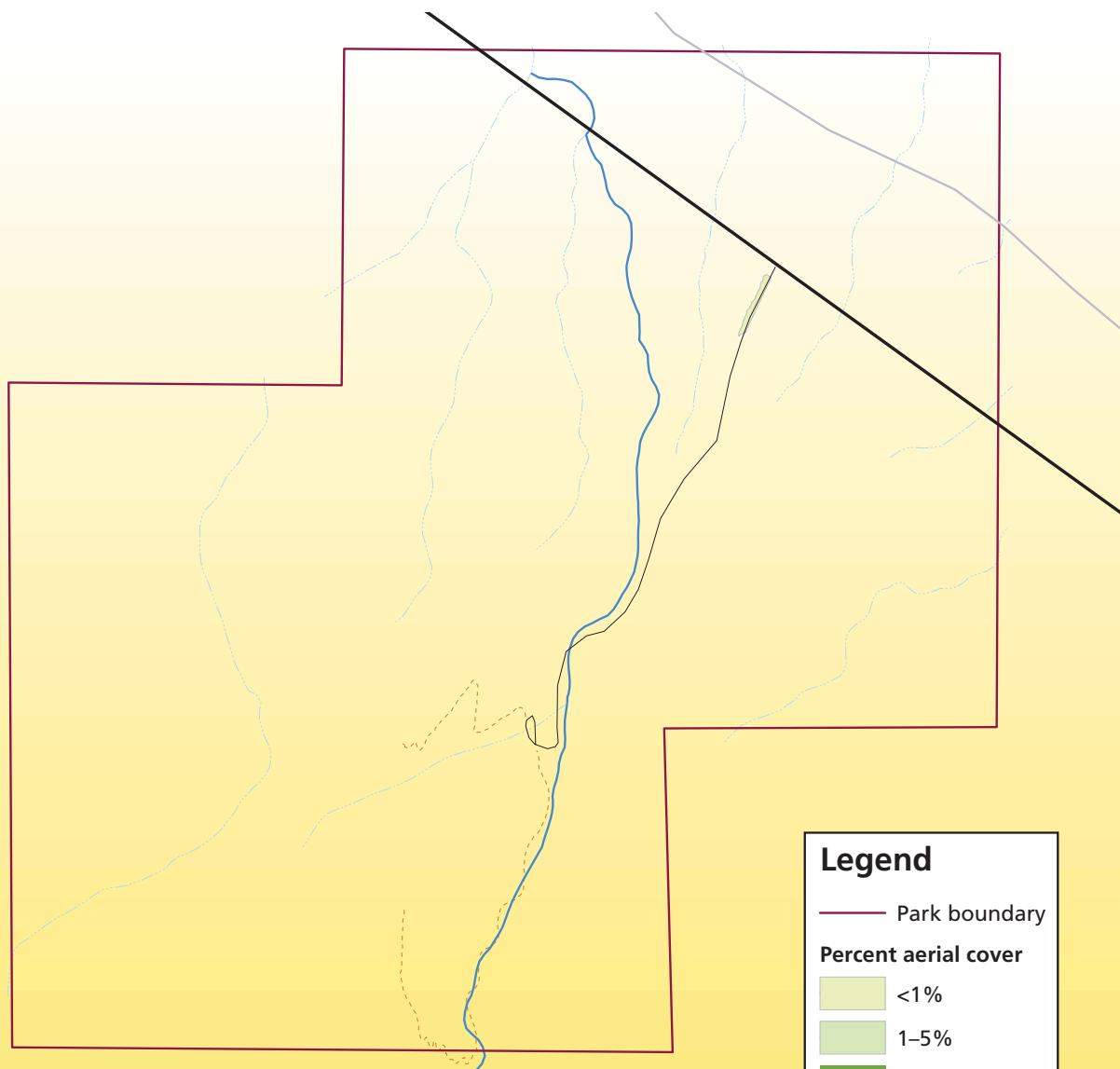
Produced by Sarah Studd & Jason Welborn

October 2005



Phalaris sp. (canarygrass)

Map A-12



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

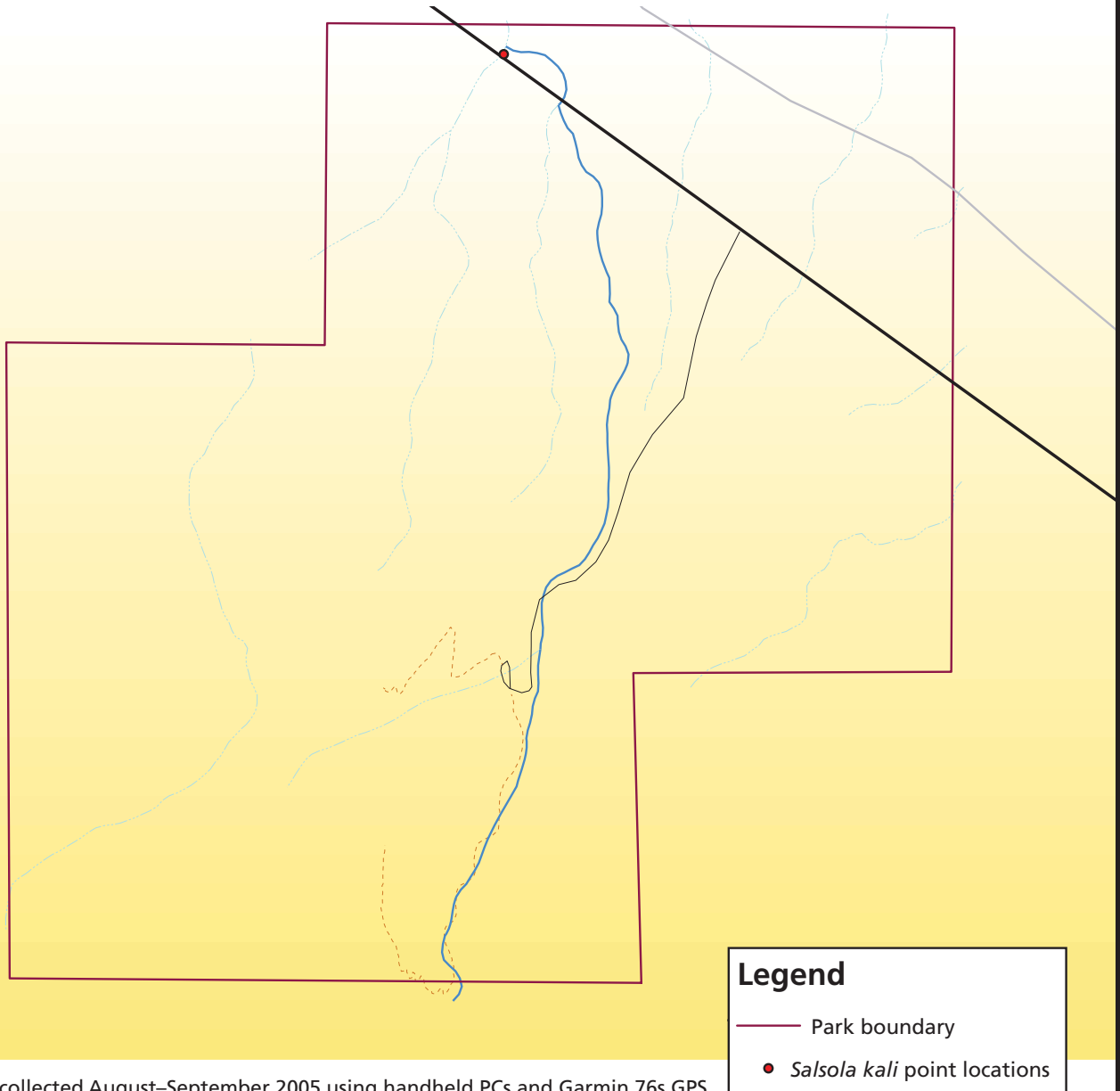
Produced by Sarah Studd and Jason Welborn

October 2005



Salsola kali (Russian thistle)

Map A-13



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

NOTE: Individuals on this map have been removed by park staff.

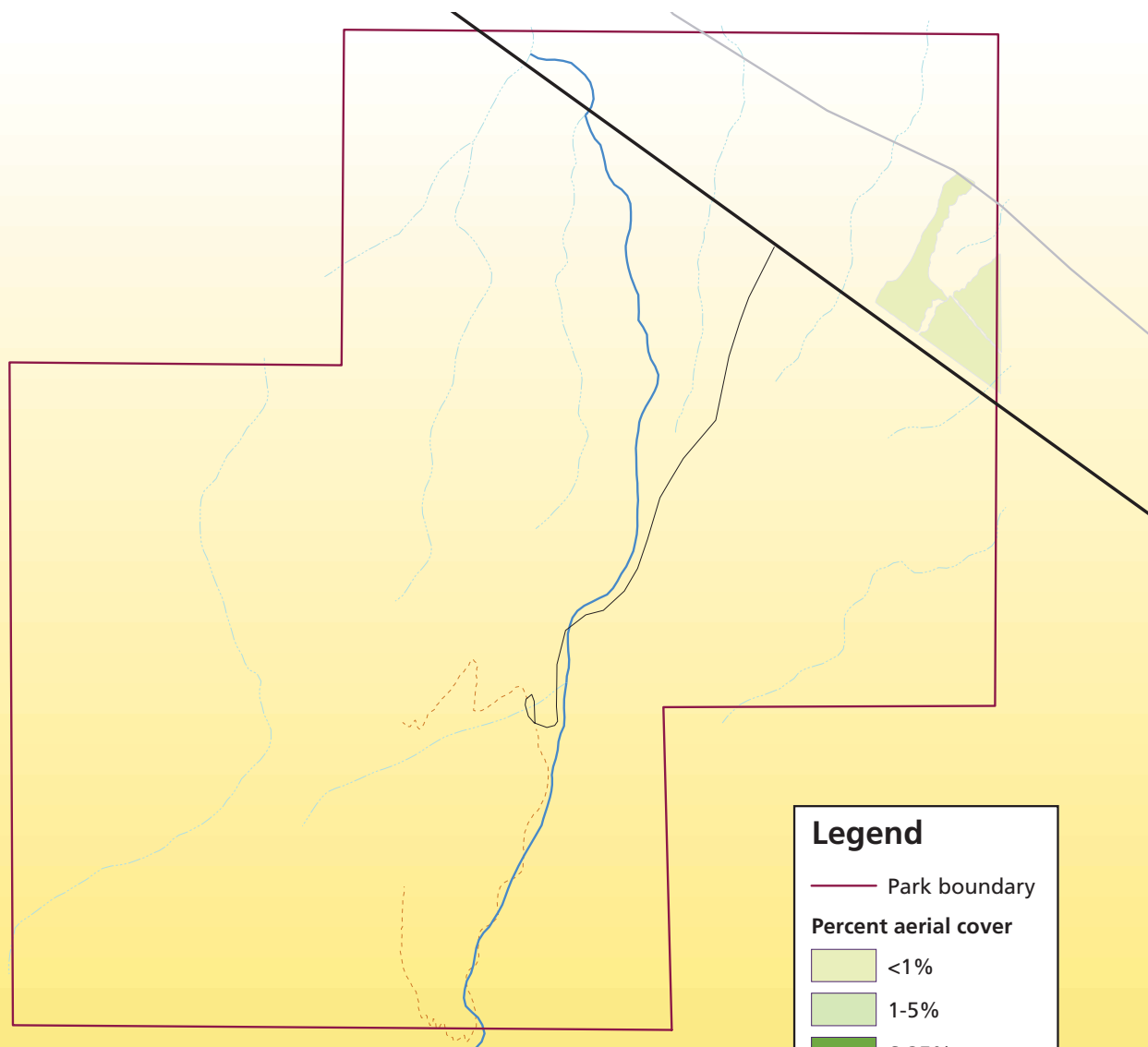
Produced by Sarah Studd and Jason Welborn

October 2005



Sisymbrium irio (London rocket)

Map A-14



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.050.1 0.2 0.3 0.4
Miles

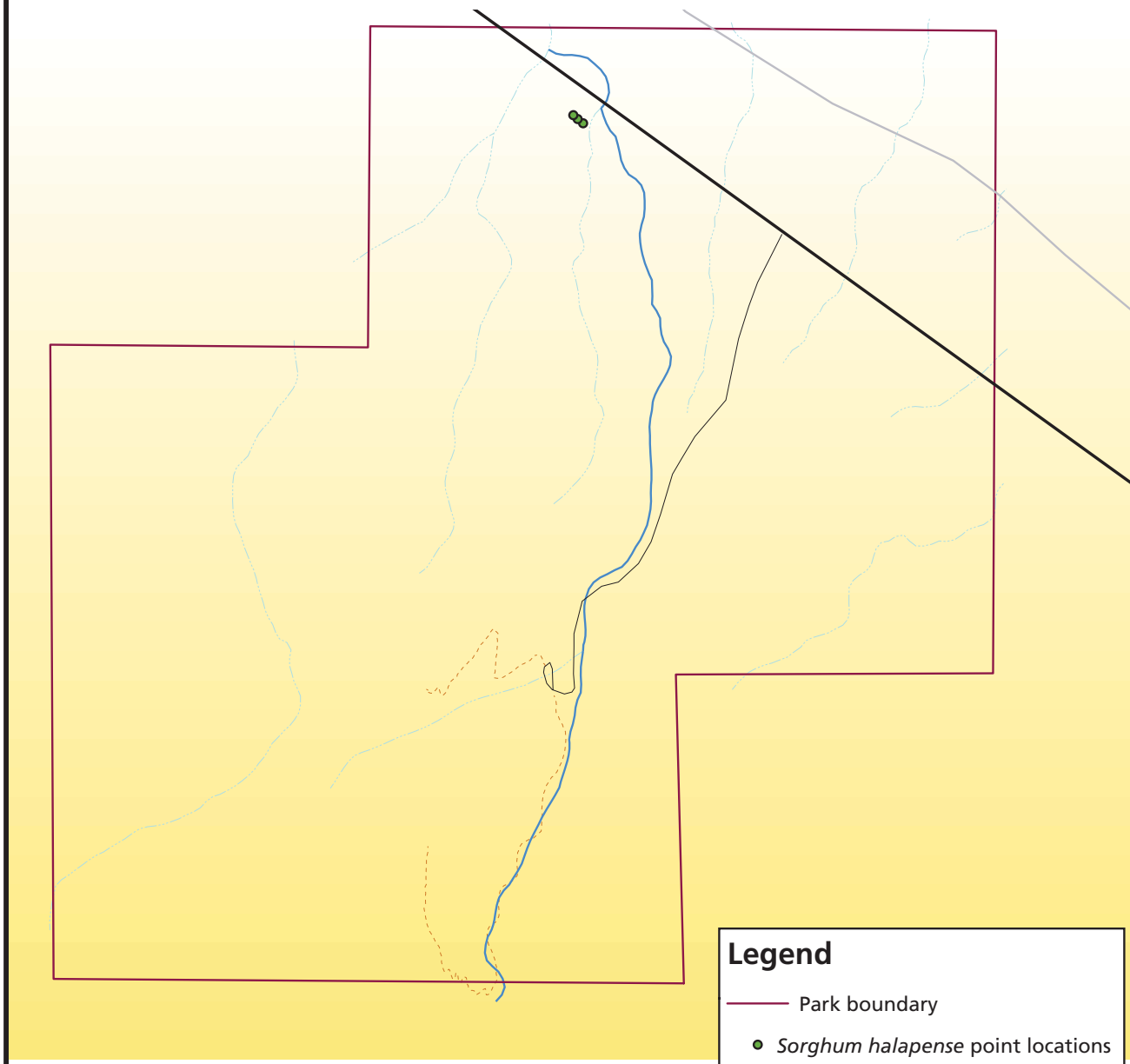
Produced by Sarah Studd and Jason Welborn

October 2005



Sorghum halapense (Johnsongrass)

Map A-15



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

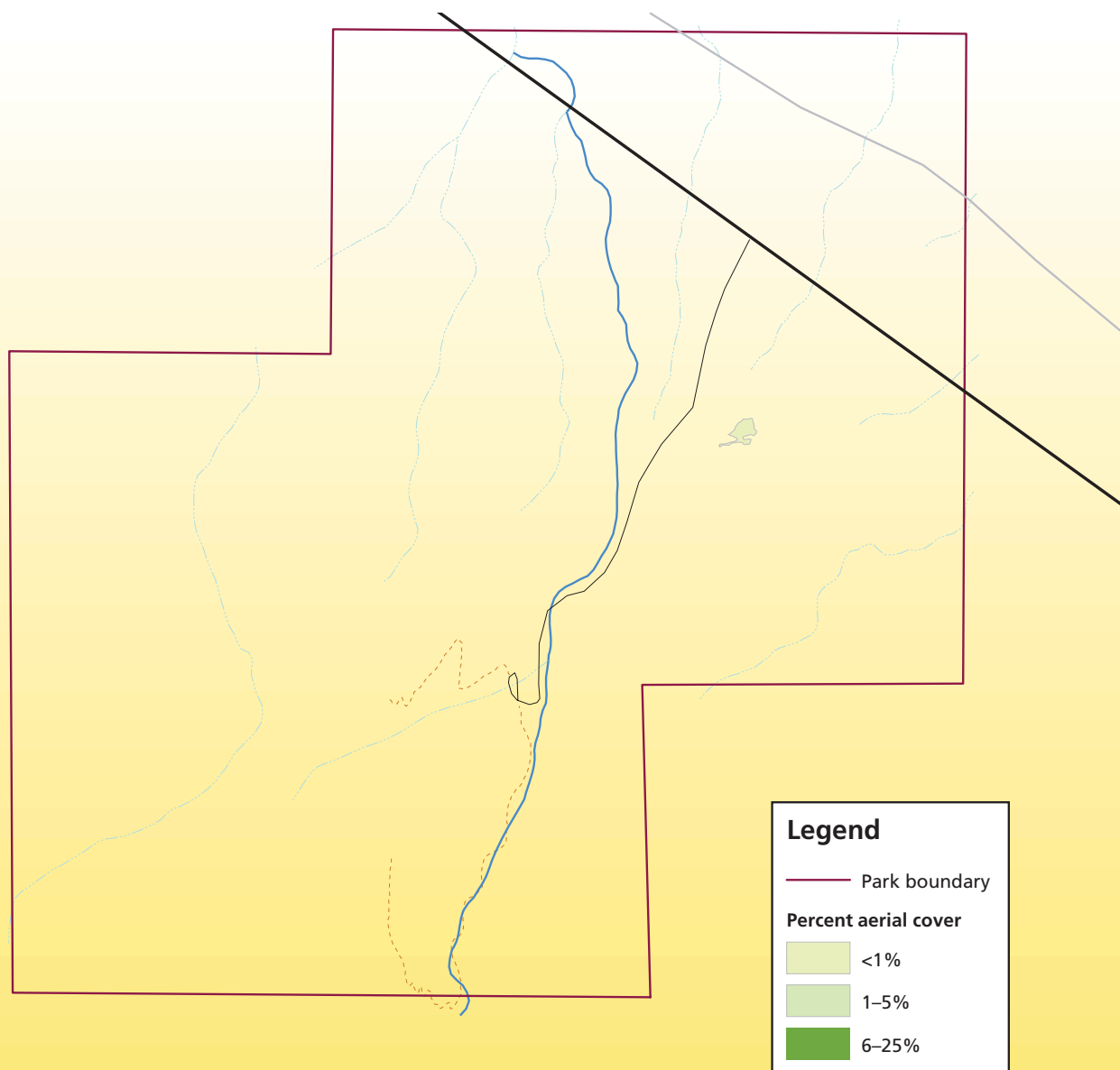
Produced by Sarah Studd and Jason Welborn

October 2005



Tribulus terrestris (puncturevine)

Map A-16



Data collected August–September 2005 using handheld PCs and Garmin 76s GPS units. Data are in UTM NAD 83, Zone 12N.

0 0.05 0.1 0.2 0.3 0.4
Miles

Produced by Sarah Studd and Jason Welborn

October 2005

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 358/109183, August 2011

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov