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Inventory of Exotic Plant Species in the Resource Preservation Zone of Walnut Canyon National Monument, Arizona

Natural Resource Technical Report NPS/SCPN/NRTR—2010/314

ON THE COVER

Old growth ponderosa forest, Walnut Canyon National Monument
Photo by Ron Hiebert

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Executive Summary

A survey of exotic plant species found within the Resource Preservation Zone of Walnut Canyon National Monument was conducted in September and October, 2008. The purpose of the study was to identify patterns and distribution of individual exotic plant species and to identify areas that were "exotic free", so efforts could be made to keep them that way. A method developed by Young et al. (2007) was employed. The method is tapeless and uses GIS techniques to generate a grid of the study area and then randomly select the number of grid cells that will result in a predetermined percent of the area one wants covered. For Walnut Canyon, developed areas, private in-holdings and areas with slopes greater than 25° were eliminated from consideration. Thirty-three percent of the available area, or 106 of 321 grid cells, was randomly selected for sampling. Exotic plant presence/absence data were collected for each 150 m x 150 m grid cell. In addition, cover was estimated for exotic plants by species within a 6 m x 50 m belt transect within each grid cell.

One hundred and five of 106 grid cells sampled contained at least one exotic plant species. Thus, we concluded that no area of any size within the monument is devoid of exotic plant species. However, native vegetation remains dominant throughout the park, with the average cover of exotic plants at 1.75%. We observed 20 exotic plant species in our sampling grids. *Linaria dalmatica* (87,74) and *Verbascum thapsus* (83.02) were the species with the highest frequencies of occurrence. *Chenopodium* spp. had a frequency of 62.26. Three other species had a frequency greater than 20.00 (*Bromus tectorum, Portulaca oleracea* and *Tragopogon dubius*). Three species were encountered only once. Average cover of all exotic species observed was below 4%.

We compared species frequencies and cover between lands within the original 1915 boundary, lands added in 1938, and those added in 1996. We observed 18 exotic plant species in grid cells on lands added in 1996, compared to 15 for lands added in 1938 and the original monument lands. Five species were found only in grid cells located on lands added in 1996 (*Agropyron desertorum, Amaranthus blitoides, Circium vulgare, Kochia scoparia*, and *Salsola tragus*). Contrary to expectations, the highest average frequency of exotic species occurrence was within the boundaries of the original monument.

We also compared exotic species frequencies and cover among four vegetation types: Riparian, Ponderosa Forest, Pinyon-Juniper Woodland, and Sparse Vegetation. Two species were observed only in Riparian grid cells (*Cirsium vulgare* and *Leonurus cardiaca)*. *Chenopodium* spp. and *Portulaca oleracea* had their highest frequencies in Pinyon-Juniper Woodlands.

We also compared exotic species frequencies and cover on the north versus the south side of Walnut Canyon. Five species were found only on one side or the other of the canyon, but these were species that were observed only in 1-2 grid cells. Therefore, we see little significant pattern here.

The study provides fine-scale information on the distribution and abundance of exotic plant species in the Resource Preservation Zone of Walnut Canyon National Monument. Unfortunately, we found no area of the monument to be free of exotic plants. At least one exotic plant was found within 105 of the 106 grid cells. However, the average exotic plant cover was 1.75%—native vegetation dominates the park. In our opinion, the monument contains some of the most pristine Ponderosa Forest and Pinyon-Juniper Woodlands in the region. We feel the restriction of visitor activities to areas around the Visitor Center is a major contributor to the high quality of the landscape.

As Schelz et al. (2008) did in their inventory of exotic plants in high-use areas, we recommend that the park keep soil disturbance to a minimum and encourage neighbors to do the same. Prevention of new invasions and containment of existing infestations should be a top priority. Several species which are recognized as invasive plants that cause negative impacts were found in low frequencies in the park: *Bromus tectorum*, *Onopordum acanthium, Salsola tragus* and *S. collina* and *Sisymbrium altissimum*. These species should be targeted for control and monitoring. Monitoring should also be concentrated on areas of known disturbance within or adjacent to the monument boundary.

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We would like to acknowledge funding by Walnut Canyon National Monument and the National Park Service's Southern Colorado Plateau Inventory and Monitoring Network. The project was processed through the Colorado Plateau Cooperative Ecosystem Studies Unit.

More specifically, we wish to acknowledge project planning work by Steve Mitchelson and John Canella, and field support from Charles Schelz, Flagstaff Monuments. The field work went quite smoothly , due, in large part, to the loading of all the GIS information in the GPS and generation of new grid sites by Jodi Norris. We acknowledge development of the database and the queries by Allison Snyder. Special thanks goes to Kristen Straka for assistance with queries and creation of the tables found within the report.

We further acknowledge funding by the National Park Service, Colorado Plateau Cooperative Ecosystem Studies Unit (CPCESU) to support Hillary Hudson's use of the data to develop an efficient monitoring program for early detection of invasive plant species.

1 Introduction and Background

The escalating rate of the transfer of exotic species beyond their natural geographical range is having major negative impacts on biodiversity around the world (Mooney and Hobbs, 2000). Exotic plants are estimated to be invading 70,000 ha of U.S. habitats per year (Pimental 2004). Although not explicitly stated in the Organic Act, which created the National Park Service (NPS), the preservation of biodiversity is one of the NPS's major missions: "Given the seeds of catastrophic loss already planted and those yet to come, invasive species pose a highly significant threat to biodiversity in the National Park System in the early 21st Century" (Loope 2004).

Invasive species, ranging from forest pathogens and vascular plants to reptiles, are one of the three major causes of biodiversity loss, along with climate change and habitat loss and fragmentation (Keane and Crawley 2002). Invasive species have been shown to act as disease vectors, and to alter ecosystem function and cycles and species composition (Simberloff 1996, Blumenthal 2003).

The NPS has formed Exotic Plant Management Teams (EPMT) in an effort to control invasive plants on NPS lands (Drees 2003). However, the Colorado Plateau EPMT has been constrained by the lack of good inventory information on exotic plants in the parks they serve. The Southern Colorado Plateau Network (SCPN) of the NPS has been evaluating monitoring approaches aimed at the early detection of exotic plant invasions on NPS lands (Thomas et al. 2006). The SCPN, the Colorado Plateau EPMT, and Flagstaff Monuments have pooled their resources to fund an inventory of exotic plants in the Resource Preservation Zones of Walnut Canyon National Monument (WACA). This inventory complements an inventory and mapping of exotic plants conducted by Schelz et al. (2008) in the most heavily used areas of the park, which were assumed to have the highest concentration of exotic plants.

1.1 Study Area

Walnut Canyon is located about 15 km east of Flagstaff on the Colorado Plateau in north-central Arizona. It was designated a monument in 1915 to protect ancient cliff dwellings and associated cultural and natural resources of great historic, scientific and educational value (Presidential Proclamation 1318, 39 Stat, 1761). The boundary has been expanded twice since then (1938 and 1996) , and the area now includes 1,452 ha immediately adjacent to the city limits of Flagstaff and Coconino National Forest (USDI 2007). The 1938 boundary was fenced around 1973, and the new boundary of the park was fenced in 2004 and 2005. Visitor access to the park is restricted to areas along the entrance road and developed trails originating near the visitor center.

WACA and its environs contain hundreds of archeological sites dating to the 11th- 13th century. These sites contain artifacts related to a prehistoric Sinagua culture that flourished in the region AD 600 to 1400, including cliff dwellings, mesa top dwellings, pottery, and stone tools. The high density of sites reflects the diversity of plant and animals resources that were available to the inhabitants. The area remains important to contemporary tribes in addition to being a popular destination for visitors to the Flagstaff area.

The range in elevation, exposure, substrate, and seasonably available water contribute to the high biological diversity of WACA. The monument contains large predators, including the black bear and mountain lion; large ungulates, such as deer and elk; 120 species of birds; 4 amphibian and 14 reptile species; and over 400 species of vascular plants. Only 43 of these are exotic (11%). The entire monument has been designated critical habitat for the Mexican spotted owl. In addition, north facing canyon slopes support Douglas fir-dominated (*Pseudotsuga menzisii*) forests. WACA also contains riparian areas supporting a deciduous forest of Arizona walnut (*Juglans major*) and cottonwood (*Populus* spp.), and old growth

ponderosa pine and pinyon-juniper woodlands.

Currently, the pools within Cherry Canyon (a side canyon of Walnut Canyon) provide the only perennial sources of water in the park (Thomas et al. 2006). Historically, perennial water may have existed in Walnut Canyon prior to the construction of the Lake Mary Dam in the upper reaches of Walnut Creek.

Lands adjacent to the park are managed for multiple use by Coconino National Forest. Forest lands are currently grazed by cattle, with some adjacent lands having been "managed" for range improvement. Other major uses include firewood cutting, hunting, camping, and ATV use. Most U.S. Forest Service (USFS) roads are at least several hundred meters from the park boundary. The entrance road to the park is accessed from I-40, has a narrow buffer on each side, and experiences high vehicular use. This area was surveyed for exotic plants by Schelz et al. (2008).

1.2 Project Overview

The purpose of this study was to conduct an inventory of exotic plants in the Resource Preservation Zone of Walnut Canyon National Monument, identifying exotic plant locations as well as locations where exotic plants were absent. Using this information, we examined patterns of distribution in relation to level of disturbance, the time the area was added to the park, and plant community type. Based upon the results, we discuss management implications and make some recommendations.

2 Methods

2.1 Sampling Design

Our sampling followed a systematic grid approach that was developed by Young et al. (2007) to provide for rapid, but repeatable data collection. The Flagstaff Monuments GIS staff created a gridded map of the Resource Preservation Zone of WACA, dividing the park into 150 m X 150 m (2.25 ha or 5.56 ac) grid cells (fig. 1). Grid cells falling on private in-holdings and those with a slope greater than 25° at the grid centroid were eliminated. We randomly selected 106 grids to be inventoried from the remaining 321 grid cells. At the center of each grid cell, we established a 50 m x 6 m belt transect from which we would collect quantitative information on exotic species cover. Surveys of these transects were conducted in September and October, 2008.

The GIS Digital Elevation Model (DEM) data did not always correspond with field conditions, and so, approximately 20 plots were rejected in the field because a significant portion of the grid cell was located on extremely steep slopes. Other plots were rejected if more than 50% of the plot was outside the park boundary. The SCPN spatial analyst generated 30 additional grids from which additional plots could be selected, if necessary, to ensure the 106 grid cell minimum. In order to comply with random grid selection protocols, replacement plots were inventoried or rejected in chronological order.

2.2 Field Methods

Field methods were entirely tapeless. Grid cell and transect locations were predetermined and entered into a GPS unit. The field crew normally consisted of two people, either Ron Hiebert and graduate assistant, Hillary Hudson, or Hillary Hudson and field technician, Shannon Sellers. Park ecologist Charles Schelz joined the crew on the first day to test field methods, and later to assist in inventorying the floor of Walnut Canyon. All have experience with Colorado Plateau vegetation, and exotic species in particular. Hillary Hudson served as the GPS technician, locating the beginning of the transect within a grid, as well as the grid cell boundaries. Ron Hiebert or Hillary Hudson would walk the 50 m transect, identifying all exotic plants within 3 m on either side of the belt transect center. Where field identification was not possible, voucher specimens were collected. Identification of the specimens was verified by the SCPN botanist. Some

spring ephemerals, such as *Erysimum repandum,* may have been missed, but we feel most exotic plant species were obvious and identifiable to species.

Foliar cover was estimated in the belt transect for each exotic species using the following cover class scale:

1. <0.1%
2. 0.1 to 1%
3. 1 to 5%
4. 5 to 10%
5. 10 to 25%
6. 25 to 50%
7. > 50%

In order to search the entire grid cell, a GPS and compass were used to locate the north or south edge of the grid cell. Two people made four passes through the grid cell, recording all exotic plant species seen. Figure 1 identifies grid cells where exotic species were present. We recorded GPS coordinates for centroids in areas with high concentrations of exotic species. These locations are listed in Appendix E. The USDA Plants Database was used as the reference for nomenclature and nativity.

2.3 Data Entry and Analysis

Hillary Hudson entered all data into an Access database created by SCPN data manager, Allison Snyder. Ron Hiebert checked accuracy by comparing all entries to the field data sheets. Queries were created to estimate mean cover (using cover class midpoints) and frequency from the belt transect data. Frequency was also calculated for the grid cells (including species encountered in the belt transects). For analysis, the data were stratified by the 3 boundary dates of 1915, 1938, and 1996; by the gross vegetation types of Ponderosa Forest, Pinyon-Juniper Woodland, Sparse

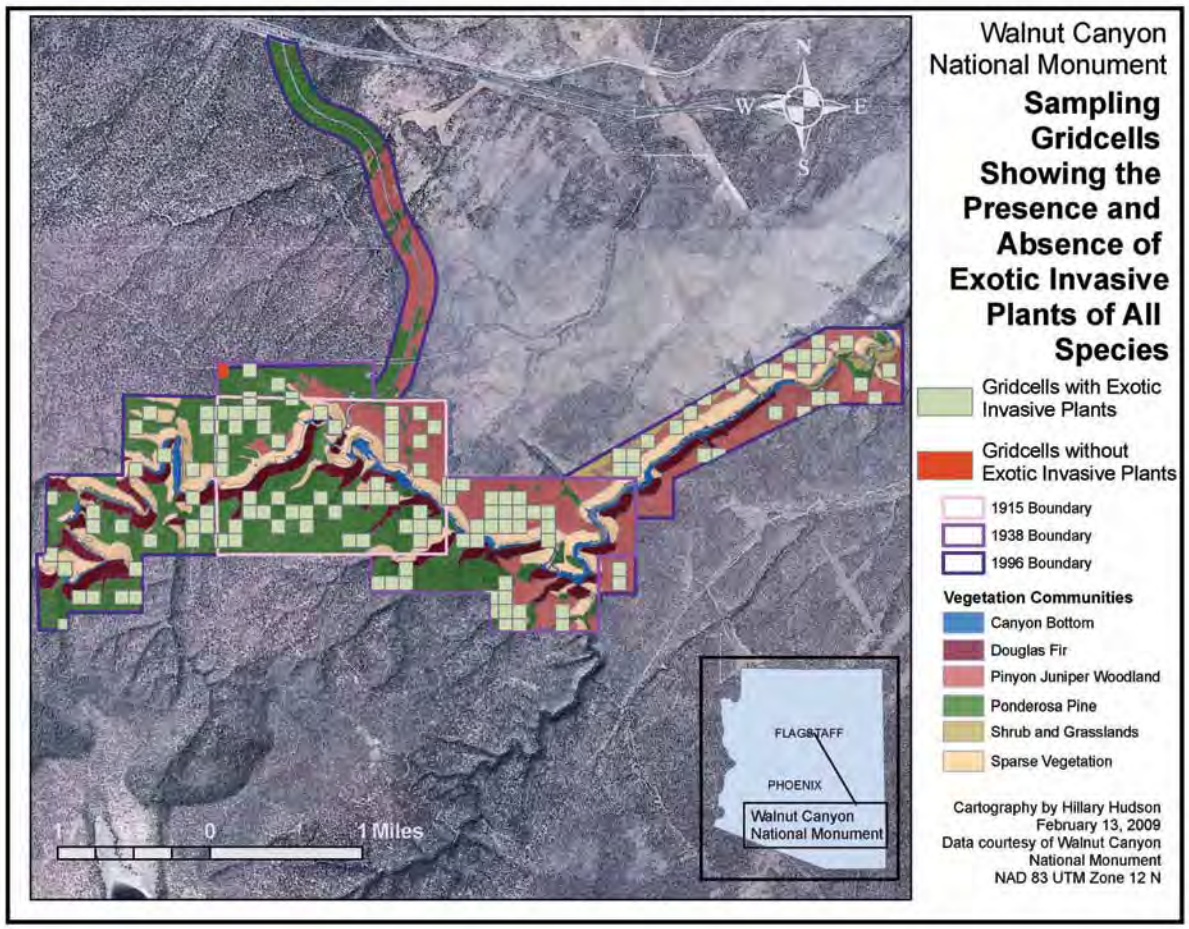

Figure 1. Map of Walnut Canyon National Monument showing location of all sampling grids and those grids that had exotic plant species present

Vegetation (usually canyon edge), and Riparian (canyon bottom); and by side of the canyon. We assigned grids to a vegetation type based on a vegetation map overlay of the grid cells . We also calculated the average number of exotic species per grid cell.

3 Results

In this report, we present data for grid cells and for transects within grid cells. Grid cell data includes qualitative walk-through encounters for grids scattered over an area of 22,500 m^2. The transects within the grids were 6 m x 50 m (300 m^2). Cover estimates were made for the individual species found within the belt transect. The median value for the cover classes was used to calculate cover, and, therefore, the values should be interpreted as rough estimates.

3.1 Overall Patterns For Resource Protection Zone

We encountered 20 exotic plant species, including three species that had not been previously reported for Walnut Canyon (table 1). Of the three new records, only *Descurainia sophia* (tansy mustard) is con-

Table 1. Exotic plant species encountered in the survey of exotic plants in the Resource Preservation Zone of Walnut Canyon National Monument.

Scientific Name	Common Name
Agropyron desertorum	desert wheatgrass
Amaranthus blitoides	mat amaranth
Bromus tectorum	cheat graminoid
Chenopodium spp.[1]	lambs quarters
Circium vulgare	bull thistle
Descurainia sophia[2]	tansy mustard
Kochia scoparia	burning bush
Lactuca serriola	prickly lettuce
Leonrus cardiaca	common motherwort
Linaria dalmatica	Dalmatian toadflax
Marrubium vulgare	horehound
Medicago lupulina	alfalfa
Melilotus officinalis	yellow sweetclover
Onopordum acanthium	Scotch cottonthistle
Portulaca oleracea	little hogweed
Salsola tragus	Russian thistle
S. collina[3]	
Sisymbrium altissimum	tall tumblemustard
Taraxacum officinale	common dandelion
Tragopogon dubius	western salsify
Verbascum thapsus	common mullein

[1]Not able to distinguish the exotic *Chenopodium album* from the native *Chenopodium berlandieri* without microscopic analysis of seed characteristics. Thus, we report as *Chenopodium* spp.

[2] Species in bold are new records.

[3]*Salsola collina*, a newly identified species for the monument, was confirmed by the SCPN botanist. This plant may be under-documented in many of the plots in the northeastern section where all *Salsola* observations were recorded as *Salsola tragus*.

Table 2. Frequency of exotic plant species in grid cells sampled in the Resource Preservation Zone of Walnut Canyon National Monument. N=106 150 m x 150 m grid cells.

Species	Parkwide
Linaria dalmatica	87.74
Verbascum thapsus	83.02
Chenopodium spp.	62.26
Tragopogon dubius	29.25
Portulaca oleracea	24.53
Bromus tectorum	20.75
Marrubium vulgare	17.92
Descurainia sophia	13.21
Lactuca serriola	12.26
Taraxacum officinale	12.26
Sisymbrium altissimum	10.38
Salsola tragus	6.60
Leonurus cardiaca	5.66
Melilotus officinalis	2.83
Cirsium vulgare	1.89
Kochia scoparia	1.89
Agropyron desertorum	0.94
Amaranthus blitoides	0.94
Medicago lupulina	0.94
Onopordum acanthium	0.94

sidered a recent invader.

One hundred five of the one hundred and-six grid cells had at least one non-native species present (fig. 1). However, the average cover for all exotic species encountered was 1.75 %. Species with the highest frequencies in grid cells were *Linaria dalmatica* (87.74%), *Verbascum thapsus* (83.02%) and *Chenopodium* spp. (62.26%) (table 2). Four species were only encountered once. Only 3 additional species had a grid frequency of 20 or higher—*Bromus tectorum*, *Portulaca oleracea* and *Tragopogon dubius*.

Transect data showed similar, but reduced, frequency patterns (table 3). *L. dalmatica* (50.00%), *V. thapsus* (33.02%), and *Chenopodium* spp. (20.75%) had the highest frequencies. Frequency of all other species encountered in transects was below 9. The highest cover of an exotic species along a transect was 7.50% for *Leonurus cardiaca*, which occurred only along one transect. Other species with a mean percent cover over 1.5 % were *Linaria dalmatica*, *Portulaca oleracea*, and *Verbascum thapsus*.

3.2 Patterns of Exotic Species in the Orginal Area and in Later Additions to the Monument

The original designation of the park occurred in 1915. The boundary was increased in 1938, and then again in 1996. A new boundary fence was completed in 2005. Before these areas were designated and fenced they were subject to trespass livestock grazing, wood cutting, and off-road vehicle (ORV) use. We thought this might result in different levels and patterns of exotic plant cover across the original park boundary area and the expansion areas, therefore, we compared transects within the original boundary of the park with transects within the 1938 and 1996 boundaries. Five species occurred only in grid cells on land added to the park in 1996—*Agropyron desertorum*, *Amaranthus blitoides*, *Circium vulgare*, *Kochia scoparia*, and *Salsola tragus* (table 4.). *Kochia scoparia* and *Salsola tragus* are considered

Table 3. Transect frequency and mean % cover of exotic plant species for Walnut Canyon NM. N=106 6m x 50m transects.

Species	Frequency	Mean Cover (%)
Linaria dalmatica	50.00	2.01
Verbascum thapsus	33.02	3.18
Chenopodium spp.	20.75	0.45
Portulaca oleracea	8.49	3.51
Bromus tectorum	6.60	0.05
Salsola tragus	3.77	0.16
Taraxacum officinale	3.77	0.05
Tragopogon dubius	3.77	0.05
Lactuca serriola	2.83	0.05
Descurainia sophia	1.89	0.05
Kochia scoparia	1.89	0.50
Melilotus officinalis	1.89	0.05
Agropyron desertorum	0.94	0.05
Leonurus cardiaca	0.94	7.50
Marrubium vulgare	0.94	0.05
Sisymbrium altissimum	0.94	0.05

Table 4. Frequency of exotic plant species encountered in the original boundary, the 1938 expansion, and the 1996 expansion in 150 m x 150 m grid cells sampled in Walnut Canyon National Monument.

	Grid Frequency by Boundary Year		
Species	1915 N=40	1938 N=28	1996 N=38
Agropyron desertorum	0.00	0.00	2.63
Amaranthus blitoides	0.00	0.00	2.63
Bromus tectorum	17.50	25.00	21.05
Chenopodium spp.	60.00	64.29	63.16
Cirsium vulgare	0.00	0.00	5.26
Descurainia sophia	17.50	14.29	7.89
Kochia scoparia	0.00	0.00	5.26
Lactuca serriola	15.00	17.86	5.26
Leonurus cardiaca	5.00	7.14	5.26
Linaria dalmatica	97.50	85.71	78.95
Marrubium vulgare	12.50	14.29	26.32
Medicago lupulina	2.50	0.00	0.00
Melilotus officinalis	0.00	3.57	5.26
Onopordum acanthium	0.00	3.57	0.00
Portulaca oleracea	10.00	32.14	34.21
Salsola tragus	0.00	0.00	18.42
Sisymbrium altissimum	5.00	3.57	21.05
Taraxacum officinale	15.00	14.29	7.89
Tragopogon dubius	27.50	28.57	31.58
Verbascum thapsus	97.50	75.00	73.68

ephemeral weeds. Four species have their highest frequency in grids found within the original boundary—*Descurainia sophia*, *Linaria dalmatica*, *Taraxacum officinale*, and *Verbascum thapsus*.

A comparison of the data from belt transects within the three boundaries yielded results similar to the grid data, but with some exceptions (table 5). As in the grid cells, *A. desertorum*, *Kochia scoparia* and *Salsola tragus* were observed only in transects on lands added in 1996. In addition, *Melilotus officinalis* and *Sisymbrium altissimum* were found only in grid cells in the 1996 boundary expansion. *Bromus tectorum*, *Chenopodium* spp., *Portulaca oleracea*, and *Taraxacum officinale* had much higher frequencies in 1996 transects compared to 1915 and 1938 transects. Of note is that the mean cover never exceeded 2.00%. For many species, the cover was below 0.01 and thus appears as zero in Table 5.

3.3 Patterns Among Vegetation Types

Some exotic species have affinities for certain vegetation types. We therefore decided to compare grid cell and transect frequencies, and cover estimates among four general vegetation types: Riparian (canyon bottom), Pinyon-Juniper Woodland, Ponderosa Pine Forest, and Sparse Vegetation (usually canyon wall).

Two species were encountered only in Riparian grid cells—*Cirsium vulgare and Leonurus cardiaca* (table 6). This is true even with the small sample size in the riparian zone (N=7) compared to 99 grid cells above the canyon. Five other species had their highest frequencies in the riparian zone. *Agropyron desertorum* and *Amaranthus blitoides* were observed

Table 5. Frequency and mean percent cover of exotic plant species found in the original 1915 boundary, the 1938 expansion, and the 1996 expansion in 106 6 m x 50 m belt transects at Walnut Canyon National Monument.

	1915 Boundary N=40		1938 Boundary N=28		1996 Boundary N=38	
Species	**Frequency**	**Mean Cover (%)**	**Frequency**	**Mean Cover (%)**	**Frequency**	**Mean Cover (%)**
Agropyron desertorum					2.63	0.00
Bromus tectorum	2.50	0.00	3.57	0.00	13.16	0.01
Chenopodium spp.	7.50	0.02	21.43	0.11	34.21	0.16
Descurainia sophia	2.50	0.00	3.57	0.00	–	–
Kochia scoparia	–	–	–	–	5.26	0.03
Lactuca serriola	2.50	0.00	3.57	0.00	2.63	0.00
Leonurus cardiaca			3.57	0.27	–	–
Linaria dalmatica	60.00	1.89	50.00	0.31	39.47	0.59
Marrubium vulgare	–	–	3.57	0.00	–	–
Melilotus officinalis	–	–	–	–	5.26	0.00
Portulaca oleracea	–	–	7.14	0.09	18.42	0.76
Salsola tragus	–	–	–	–	10.53	0.02
Sisymbrium altissimum	–	–	–	–	2.63	0.00
Taraxacum officinale	2.50	0.00	3.57	0.00	5.26	0.00
Tragopogon dubius	5.00	0.00	–	–	5.26	0.00
Verbascum thapsus	42.50	1.33	21.43	0.50	31.58	1.16

Table 6. Frequency of exotic plant species by Vegetation Type in 106 150 m x 150 m transects at Walnut Canyon National Monument.

	Grid Frequency by Vegetation Type			
Species	**Riparian N=7**	**Pinyon-Juniper Woodland N=20**	**Ponderosa Pine N=54**	**Sparse Vegetation N=25**
Agropyron desertorum	0.00	5.00	0.00	0.00
Amaranthus blitoides	0.00	5.00	0.00	0.00
Bromus tectorum	57.14	20.00	11.11	32.00
Chenopodium spp.	71.43	90.00	42.59	80.00
Cirsium vulgare	28.57	0.00	0.00	0.00
Descurainia sophia	0.00	15.00	7.41	28.00
Kochia scoparia	0.00	5.00	0.00	4.00
Lactuca serriola	28.57	5.00	3.70	32.00
Leonurus cardiaca	85.71	0.00	0.00	0.00
Linaria dalmatica	100.00	70.00	96.30	80.00
Marrubium vulgare	57.14	40.00	7.41	12.00
Medicago lupulina	0.00	0.00	1.85	0.00
Melilotus officinalis	14.29	0.00	0.00	8.00
Onopordum acanthium	0.00	0.00	0.00	4.00
Portulaca oleracea	0.00	60.00	7.41	40.00
Salsola tragus	0.00	10.00	1.85	16.00
Sisymbrium altissimum	42.86	25.00	1.85	8.00
Taraxacum officinale	85.71	0.00	11.11	4.00
Tragopogon dubius	85.71	30.00	27.78	16.00
Verbascum thapsus	100.00	55.00	88.89	88.00

only in one Pinyon-Juniper grid cell. *Bromus tectorum*, *Marrubium vulgare*, and *Portulaca oleracea* were found in multiple vegetation types, but at a much higher frequency in Pinyon-Juniper Woodland. *Medicago lupulina* was found in one Ponderosa Pine Forest grid cell. The two most frequent species, *Linaria dalmatica,* and *Verbascum thapsus*, had very high frequencies in Ponderosa Pine Forest, compared to the other vegetation types. *Onopordum acanthium* was found only in sparse vegetation. It should be noted that the number of grids in each vegetation type was not equal, as grid cells were not stratified by vegetation type but were randomly selected across the park.

Transect data revealed frequency patterns similar to the grid cell frequencies. *Leonurus cardiaca* was found only in the riparian zone. *Taraxacum officinale* and *Tragopogon dubius* had their highest frequencies in the riparian zone. *Linaria dalmatica* had its highest frequency in Ponderosa Pine Forest transects.

Mean cover for all exotic species was very low. The highest, by far, was *Verbascum thapsus* (3.58%) in the riparian zone. Exotic species with a mean percent cover of less than 0.01 show a zero value in Table 7.

3.4 Comparison of Canyon Sides

Because the north side of the canyon differs from the south side in environmental characteristics, such as aspect, distance to roads and land use, we compared the fre-

Table 7. Frequency and mean cover of exotic plant species in transects, by vegetation type in Walnut Canyon National Monument.

	Riparian N=7		Pinyon-Juniper Woodland N=20		Ponderosa Pine N=54		Sparse Vegetation N=25	
Species	**Frequency**	**Mean Cover (%)**	**Frequency**	**Mean Cover (%)**	**Frequency**	**Mean Cover (%)**	**Frequency**	**Mean Cover (%)**
Agropyron desertorum	–	–	5.00	0.00	–	–	–	–
Bromus tectorum	14.29	0.01	5.00	0.00	1.85	0.00	16.00	0.01
Chenopodium spp.	28.57	0.01	35.00	0.16	5.56	0.00	40.00	0.25
Descurainia sophia	–	–	–	–	3.70	0.00	–	–
Kochia scoparia	–	–	5.00	0.03	–	–	4.00	0.02
Lactuca serriola	28.57	0.01	–	–	–	–	4.00	0.00
Leonurus cardiaca	14.29	1.07	–	–	–	–	–	–
Linaria dalmatica	28.57	0.08	40.00	0.14	62.96	1.84	36.00	0.15
Marrubium vulgare	–	–	–	–	–	–	4.00	0.00
Melilotus officinalis	14.29	0.01	–	–	–	–	4.00	0.00
Portulaca oleracea	–	–	35.00	1.43	–	–	8.00	0.12
Salsola tragus	–	–	5.00	0.03	1.85	0.00	8.00	0.00
Sisymbrium altissimum	–	–	5.00	0.00	–	–	–	–
Taraxacum officinale	28.57	0.01	–	–	1.85	0.00	4.00	0.00
Tragopogon dubius	28.57	0.01	5.00	0.00	1.85	0.00	–	–
Verbascum thapsus	100.00	3.58	–	–	42.59	1.08	20.00	1.12

quency and cover of exotic species in grid cells located on the north side with grid cells located on the south side. Grid cell data revealed that five species were present only on one side of the canyon: *Agropyron desertorum*, *Kochia scoparia* and *Onopordum acanthium* were found only on the north side; and *Amaranthus blitoides* and *Medicago lupilina* were found only on the south side (table 8). Four of the above were single occurrences and one species occurred in two grid cells. Transect data indicate six species tallied only on the north side and two only on the south side (table 9). All of these species were observed in 2 transects or less. Transect data also shows *Chenopodium* spp. to have a relatively high frequency on the north side.

4 Discussion

4.1 Park-wide Patterns

The information gathered in this study provides a fine-scaled representation of the current distribution and abundance of exotic plant species in the Resource Preservation Zone of Walnut Canyon National Monument (WACA). The data collected in this study is more descriptive than analytical and was not intended for statistical analysis to determine significant correlations, nor to identify causative factors. For example, one of our objectives was to identify areas where exotic plants weren't present, so that these areas could be managed to remain weed-free. Unfortunately, our results indicate that no sizeable piece of land within the monument was free of exotic plants. That's the bad news. The good news is that the average percent cover of exotic species is only 1.75 % in the Resource Preservation Zone. This can be compared to the high use areas of the park surveyed by Schelz et al. (2008), where the average cover was 9.3% (It should be noted, however, that differ-

ent methods were employed to estimate cover in the two studies).

We did not detect any sizable area where impacts from exotic plants were obvious, nor did we encounter any woody exotic species. We observed only two Arizona Noxious Weeds: *Bromus tectorum* and *Linaria dalmatica*, of which only *B. tectorum* is included in the high risk category in the list of species that threaten wildlands in Arizona (www.swvma.org). Three species that we encountered are on the medium risk list (*L. dalmatica, Melilotus officinale*, and *Salsola tragus*). The native vegetation is basically intact.

The distribution of some exotic plants across the park is not that surprising. WACA is a relatively small linear area, and thus has a high boundary to area ratio. Propagules in multiple use areas and along roads adjacent to the park are vulnerable to being dispersed to most areas of the park by birds or other animals and wind, or stepwise from passive dispersal over a few years. The lack of anthropogenic disturbance in the majority of the park has kept invasion sites at a minimum. However, natural events, such as fire, blow downs, and the pinyon die-off experienced in parts of the park, do open sites for invasion.

4.2 Patterns Between Boundary Years, Vegetation Types, and Side of Canyon

Observations of exotic plants in the grid cells and transects indicated a non-random distribution of exotic plant species at Walnut Canyon. The new areas added to the park in 1996, and fenced in 2004-2005, had much higher frequencies of ephemeral weeds or species that require recent and/or frequent land disturbance for their establishment (e.g. *Kochia scoparia, Salsola tragus, Melilotus officinalis, Bromus tectorum* and *Portulaca oleracea)*. These patterns held true, both for the presence/absence data collected in the grid cells and for the transect data.

Table 8. Frequency of exotic plant species in 150 m x 150 m grid cells on opposite sides of Walnut Canyon.

Species	North Side	South Side
Agropyron desertorum	2.04	0.00
Amaranthus blitoides	0.00	2.00
Bromus tectorum	22.45	14.00
Chenopodium spp.	67.35	56.00
Cirsium vulgare	0.00	0.00
Descurainia sophia	12.24	16.00
Kochia scoparia	4.08	0.00
Lactuca serriola	12.24	10.00
Leonurus cardiaca	0.00	0.00
Linaria dalmatica	85.71	88.00
Marrubium vulgare	22.45	8.00
Medicago lupulina	0.00	2.00
Melilotus officinalis	2.04	2.00
Onopordum acanthium	2.04	0.00
Portulaca oleracea	28.57	24.00
Salsola tragus	8.16	6.00
Sisymbrium altissimum	12.24	4.00
Taraxacum officinale	4.08	10.00
Tragopogon dubius	24.49	26.00
Verbascum thapsus	79.59	84.00

Table 9. Frequency and mean percent cover of exotic plant species in 6 m x 50 m belt transects on opposite sides of the canyon at Walnut Canyon National Monument.

	North Side		South Side	
Species	Frequency	Mean cover (%)	Frequency	Mean cover (%)
Agropyron desertorum	2.04	<0.01	–	–
Bromus tectorum	8.16	<0.01	4.00	<0.01
Chenopodium spp.	26.53	0.17	14.00	0.03
Descurainia sophia	–	–	4.00	<0.01
Kochia scoparia	4.08	0.02	–	–
Lactuca serriola	2.04	<0.01	–	–
Linaria dalmatica	57.14	1.02	46.00	1.12
Marrubium vulgare	2.04	<0.01	–	–
Melilotus officinalis	2.04	<0.01	–	–
Portulaca oleracea	10.20	0.52	8.00	0.12
Salsola tragus	4.08	<0.01	4.00	0.01
Sisymbrium altissimum	2.04	<0.01	–	–
Taraxacum officinale	–	–	4.00	<0.01
Tragopogon dubius	2.04	<0.01	2.00	<0.01
Verbascum thapsus	24.49	0.84	32.00	0.91

The new boundary was posted at some regular intervals, but newly added lands continued to be subjected to livestock grazing, wood cutting, and ORV use until the fence was completed. Although the fence was constructed with minimal land disturbance, the fencing itself was a significant disturbance. The number of exotic species observed was highest in samples in the lands added in 1996 (20 in grid cells and 15 in transects for 1996, compared to 16 and 10 respectively for both sites in the original boundary and those on lands added in 1938). Despite the recent disturbances, the vegetation is dominated by native plant species and exotic plant cover is lower than 2 percent. We have no explanation why the average frequency of exotic plants was highest within the original boundary of 1913.

Due to the disparity in sample sizes (e.g. Riparian: N=7, Ponderosa: N=54), one must be conservative in attributing affinities of exotic species to certain vegetation types. The data suggest, however, that the exotic species we observed are not randomly distributed among vegetation types. We do not consider it a coincidence that four exotic species occurred only in the riparian zone. As is the case throughout the Colorado Plateau, the riparian zone at Walnut Canyon has experienced severe alteration of the hydrologic regime, precipitated by dam construction in the upper reaches of Walnut Creek.

The two most frequent exotic plant species, *Linaria dalmatica* and *Verbascum thapsus,* had their highest frequency in the riparian zone, followed by Ponderosa Forest. The high frequency of *Bromus tectorum, Marrubium vulgare,* and *Portulaca oleracea* in Pinyon-Juniper may be due to a true affinity of these species for this vegetation type, or at least partially due to the fact that most of the 1996 land additions to the monument were Pinyon-Juniper Woodlands.

Five exotic species were found on only one side of the canyon. However, we feel interpretation of this data is difficult in that the five species are based upon one or two observations.

4.3 Critique of Sampling Method

The sampling scheme employed for this project was developed primarily for application in small park areas (50-2,000 ha) of the Heartland Inventory and Monitoring Network (Young et al. 2007), but it has been used for inventory of exotic plants both at WACA and Aztec Ruins National Monument (AZRU)(Korb et al. 2010). AZRU is similar to WACA in that it was designated to preserve structures and artifacts of the Ancestral Puebloans. It differs in that most of the park encompasses old fields and orchards, and is much smaller (129 ha).

The protocol was designed to provide a systematic, yet random sampling scheme for the area of interest. Field sampling is completely "tapeless" and depends solely on using recreational grade GPS units to determine the location of grid cells and their centroids. It combines presence/absence data gathered in 150 x 150 m grid cells, with more quantitative data, including cover estimates along belt transects within each grid cell. Grid cells are generated following some site stratification (to avoid developed areas and slopes greater than 25% at grid centroid). Sampling can be further stratified as appropriate. The percentage of the study area to be sampled is determined a priori, and plots are selected using random number generators.

Since we preloaded hard copy maps and the grid cell boundaries and centroids into the GPS unit, planning an efficient work day and finding the grid cells was easy. One person navigated and the other observed and recorded. Grid cells and the accompanying transect could be sampled in an hour or less, depending on topography and density of vegetation. Much of the field time involved getting to and from grid cells, as WACA is dominated by roadless backcountry and it was necessary to hike moderate distances between grid cell

locations.

If we had only collected presence/absence data for the grid cells, this study would have been misleading. The data would have depicted the monument as being overrun with exotic plants. While 105 of the 106 grid cells had at least one exotic plant species present, the transect data showed that exotic species cover was very low—an average of 1.75 % for the park. While exotic species were widespread, their abundance was very low. In addition, if only the transect data had been gathered, many exotic species present in grid cells would have been missed. Thus, the combination of the grid cells and transects provided excellent coverage, plus supplied an estimate of abundance in the form of cover classes.

4.4 Comparison of High Use Areas to the Resource Preservation Zone

In the summer of 2008, WACA staff inventoried and mapped exotic plants in the high use areas of the monument. The Schelz project differed in that one of the objectives was to remove as many exotic plants as possible. The goal of our study was to randomly sample the remaining parts of the park. We did record GPS centroids for areas with high concentrations of exotic plants to guide the park or the EPMT to areas needing control (Appendix E).

Although the methods of survey employed by Schelz et al. (2008) were different from those employed in this study, the two inventories should be complementary. Schelz et al. found 17 exotic plant species (9 for which they collected data) which we did not observe. Most of these are known as species which are found in recently or frequently disturbed sites (e.g. *Conyza canadensis*, *Convolvulus arvensis*, *Erodium cicutarium*, and *Melilotus alba)*. Their top 10 in total counts or total density have seven species in common with our 10 most frequent species observations in grids. We found one species (*Leonurus cardiaca*) that they did not find. Both inventories detected *Onopordum acanthium*, which had not previously been recorded for the monument. One of the most significant differences between exotic plants in high use areas and those in the Resource Preservation Zone was the difference in cover. As would be expected, cover of exotic plants-for the high use areas was higher (9.75%) than that of the Resource Preservation Zone (1.75%).

5 Management Implications and Recommendations

Walnut Canyon National Monument has some outstanding examples of old growth Ponderosa Forest and Pinyon-Juniper woodlands. Some areas of the park did not experience historic timber harvesting and they preserve remnants of “virgin” forest. Several species of exotic plants are widespread throughout the park, yet the native vegetation dominates.Maintaining or improving the current condition should be the goal of the Flagstaff Area Monuments. As per Schelz et al. (2008), preventing soil disturbance within and adjacent to the park is most important. Monitoring the sites with a high probability for new invasions is the next most important task.

Control or eradication of the two most prominent and wide-spread exotics (*Linaria dalmatica* and *Verbascum thapsus*) will be difficult at best. *L. dalmatica* can produce up to 500,000 seeds per plant and seed viability can be as high as 75%, remaining viable in the soil for up to 10 years. Though it has no special adaptations for seed dispersal, the seeds are slightly winged and can be carried short distances by wind and long distances by monsoon rains. In addition, *L. dalmatica* also reproduces vegetatively (Erskine et al. 2005). The only promising solution for control or eradication is biological control, a venture which would benefit from cooperation with the Coconino National Forest. Eight insects have been approved for release

by the USDA-APHIS-PPQ. A shoot and flower feeding beetle (*Brachypterolus pulicarius*) has been shown to reduce seed production by up to 74% (McClay 1992).

Verbascum thapsus is believed to require bare ground to become established. Our observations would suggest disturbances to the soil and opening of the forest canopy are the only requirements for establishment. The plant produces large numbers of small seeds which can remain viable in the soil for up to 100 years. Two biological control agents have been tested, but none approved (AZ-WPWG 2005). Existing plants can be controlled by pulling and/or the use of a glyphosate herbicide. Again, prevention of soil disturbance is the most effective way to prevent new infestations.

The next most frequent species was *Chenopodium* spp., a species which is a common weed of gardens and agricultural areas. However, we do not know if what we were observing was *C. album* or *C. berlandieri,* which is native and cannot be distinguished from *C. album* without microscopic observation of the seeds. To our knowledge, *C. album* is not on any federal or state list of invasive plants. It may be worthwhile to collect multiple specimens across the monument to determine if the species is *C. album* or *C. berlandieri,* or a mix of the two.

Another frequent species, *Tragopogon dubius* had a grid frequency of almost 30%. However, cover was always low. To our knowledge, no negative ecological impacts due to this species have been documented.

Frequencies of *Portulaca oleracea* were-highest in areas added to the park in 1996 and in Pinyon-Juniper Woodlands. An annual weed normally found in cultivated lands and gardens, *Portulaca oleracea* should be monitored. However, we predict it will decrease as the time from last disturbance increases.

The number one priority for natural area managers should always be prevention and early detection of known aggressive invaders of wildlands. Of the species observed, but at low numbers, *Bromus tectorum, Onopordum acanthium*, *Salsola tragus and S. collina*, and *Sisymbrium altissimum* deserve special attention. *B. tectorum* is a known bad player in rangelands throughout the west where it can become a dominant understory species. Our observation is that it is limited in distribution above 2,000 m elevation. Climate warming could change that (Bradley et al. 2009). We recommend regular monitoring of this species.

Schelz et al. (2008) observed *Onopordium acanthium* in the monument for the first time. We also had one observation. It is abundant in the area along roadsides and in areas that are or have been overgrazed in the past. Colonies of this species can become impenetrable and eliminate competing plant species. We urge the monument to eradicate all observed plants and to work cooperatively with Coconino National Forest to halt the spread of this species. Practical suggestions on integrated control strategies can be found at the Douglas County, Colorado web site (Rife no date).

S. tragus has also been considered a weed of frequent and highly disturbed areas, such as roadsides and construction sites, but it is being found more frequently in wildlands with minimal disturbance. It has been found to be widespread at Petrified Forest NP (Thomas et al. 2009). A different looking *Salsola* was collected from grid cell 98. It was identified as *S. collina* by Megan Swan, SCPN botanist. Further research is warranted to determine if these two species are hybridizing and creating a more invasive form.

We have no strong literature to support our view that *Sisymbrium altissimum* can increase rapidly at the monument except for its special adaptation for seed dispersal. The top part of the plant, which contains the ripe seeds, breaks off and is carried long distances by the wind, dropping seeds as it goes.

The species we recommend for close at-

tention do not include all of the species recommended by Schelz et al. (2008). Our recommendations are based upon our inventory which did not include all the species on their list.

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Appendix A. List of exotic plant species known to occur at Walnut Canyon National Monument

Family	Species	Common Name	Growth form
Amaranthaceae	*Amaranthus blitoides*	mat amaranth	forb
Apiaceae	*Torilis arvensis*	spreading hedge parsley	forb
Asteraceae	*Circium vulgare*	bull thistle	forb
	Lactuca serriola	prickly lettuce	forb
	Taraxacum laevigatum	rock dandelion	forb
	T. officinale	common dandelion	forb
Brassicaceae	*Erysimum repandum*	spreading wallflower	forb
	Sisymbrium altissimum	tall tumble mustard	forb
Chenopodiaceae	*Chenopodium album*	lambs quarters	forb
	Kochia scoparia	burning bush	forb
	Salsola tragus	Russian thistle	forb
Convolvulaceae	*Commelina dianthifolia*	field bindweed	forb
	C. equitans	Texas bindweed	forb
Fabiaceae	*Melilotus officinalis*	yellow sweetclover	forb
Geraniaceae	*Erodium cicutarium*	redstem stork's bill	forb
Lamiaceae	*Leonrus cardiaca*	common motherwort	forb
	Marrubium vulgare	horehound	forb
Plantaginaceae	*Plantago lanceolata*	narrowleaf plantain	forb
Poaceae	*Agropyron desertorum*	desert wheat graminoid	graminoid
	Agrostis gigantea	redtop	graminoid
	Bromus diandrus	ripgut brome	graminoid
	B. rididus	ripgut brome	graminoid
	B. tectorum	cheatgraminoid	graminoid
	Dactylis glomerata	orchard graminoid	graminoid
	Festuca ovina	sheep fescue	graminoid
	F. trachyphylia	hard fescue	graminoid
	Poa pratensi	Kentucky bluegraminoid	graminoid
	Secale cereale	cereal rye	graminoid
Polyginaceae	*Polygonum aviculare*	prostrate knotweed	forb
	Rumex crispus	curly dock	forb
	Portulaca oleracea	little hogweed	forb
Rosaceae	*Malus pumila*	paradise apple	shrub
	Potentilla norvegica	Norwegian cinquefoil	shrub
	Rosa odorata	tea rose	shrub
	Sanguisorba minor	small burnet	forb
Rubiaceae	*Galium aparine*	stickywilly	forb
Scrophulariaceae	*Linaria dalmatica*	Dalmatian toadflax	forb
	Verbascum Thapsus	common mullein	forb
Tamaricaceae	*Tamarix chinensis*	five-stamen tamarisk	shrub

Appendix B. Figures identifying grids where exotic species were observed

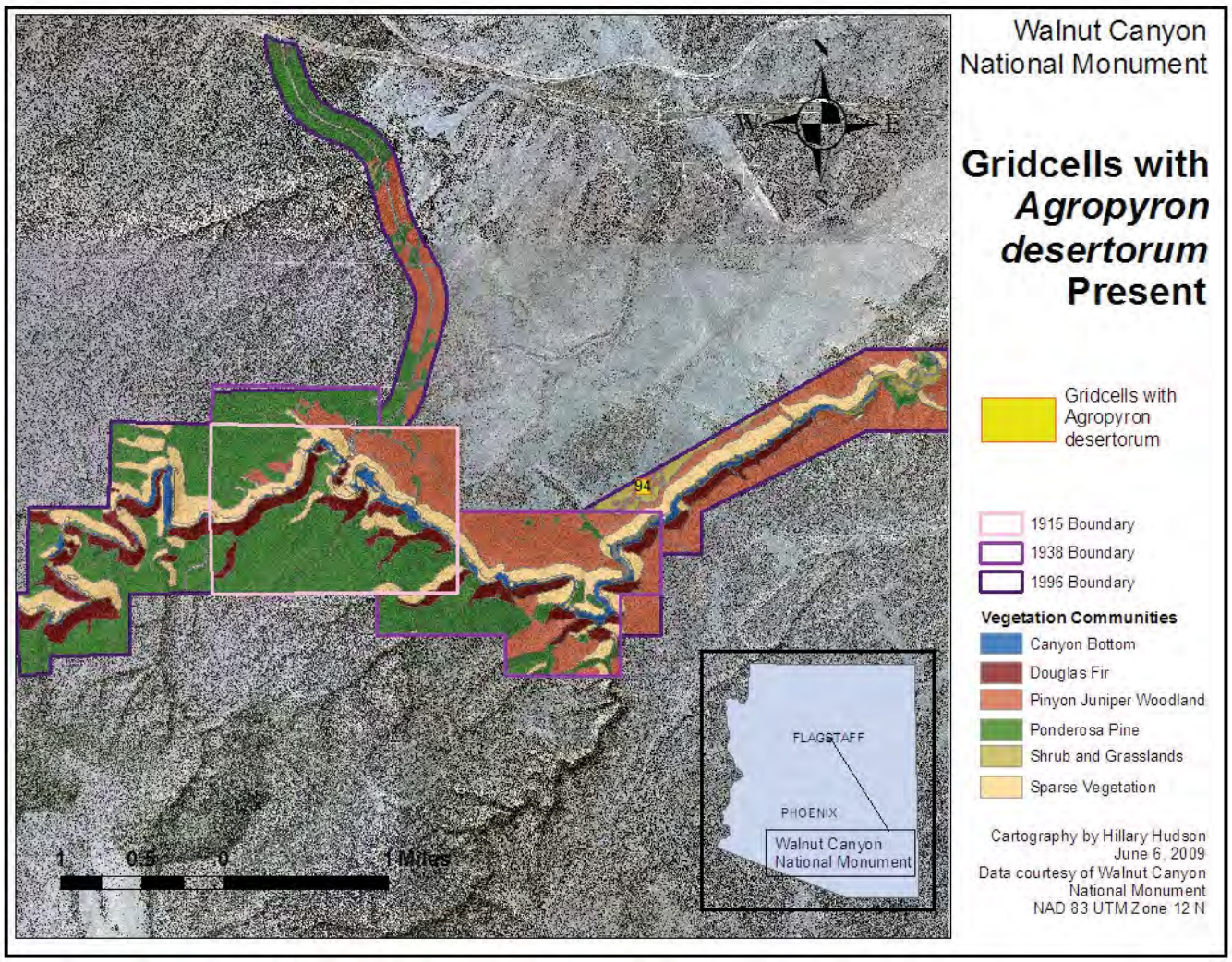


Figure B-1. Gridcells with *Agropyron desertorum* present

Appendix B continued

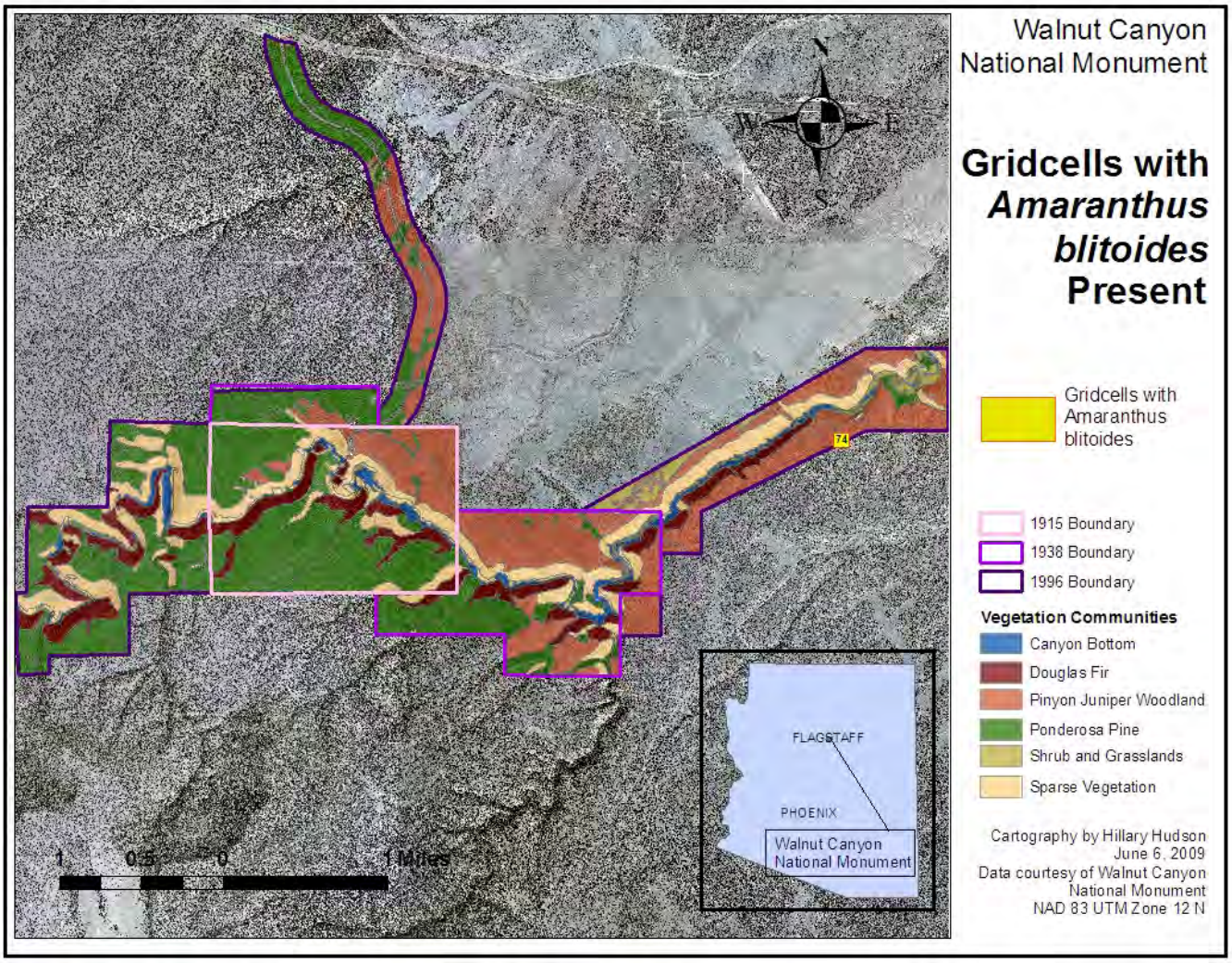


Figure B-2. Gridcells with *Agropyron blitoides* present

Appendix B continued

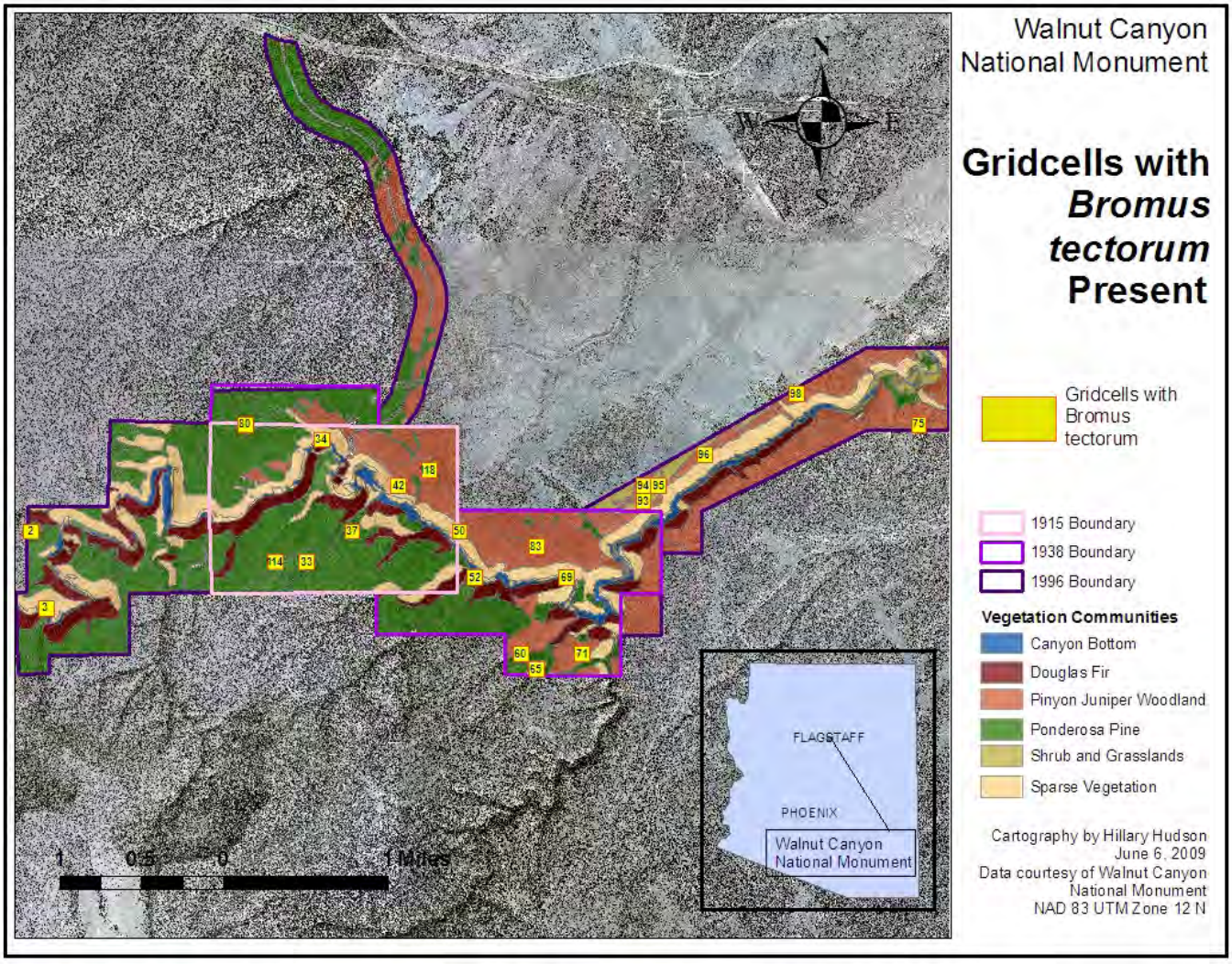


Figure B-3. Gridcells with *Bromus tectorum* present

Appendix B continued

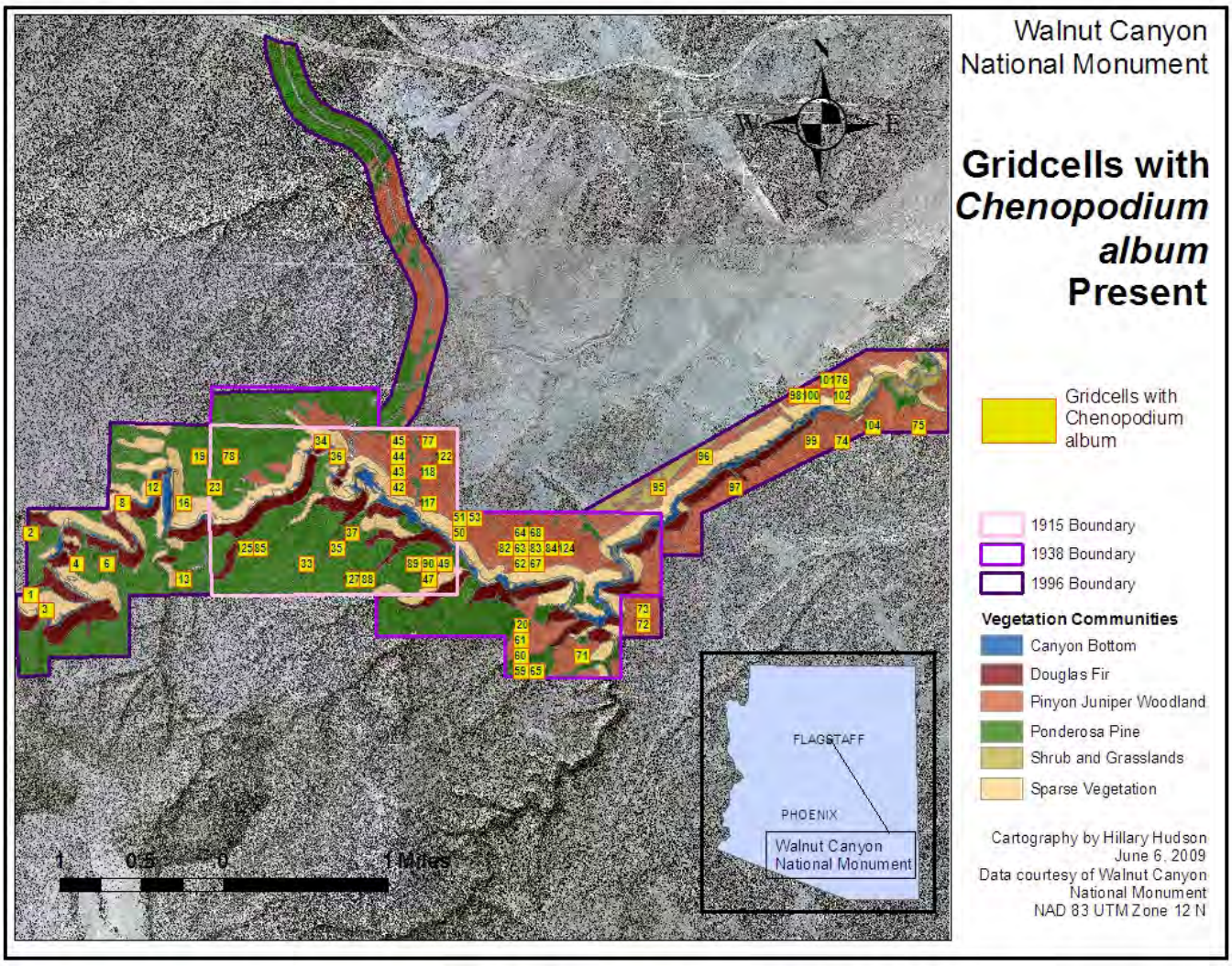


Figure B-4. Gridcells with *Chenopodium album* present

Appendix B continued

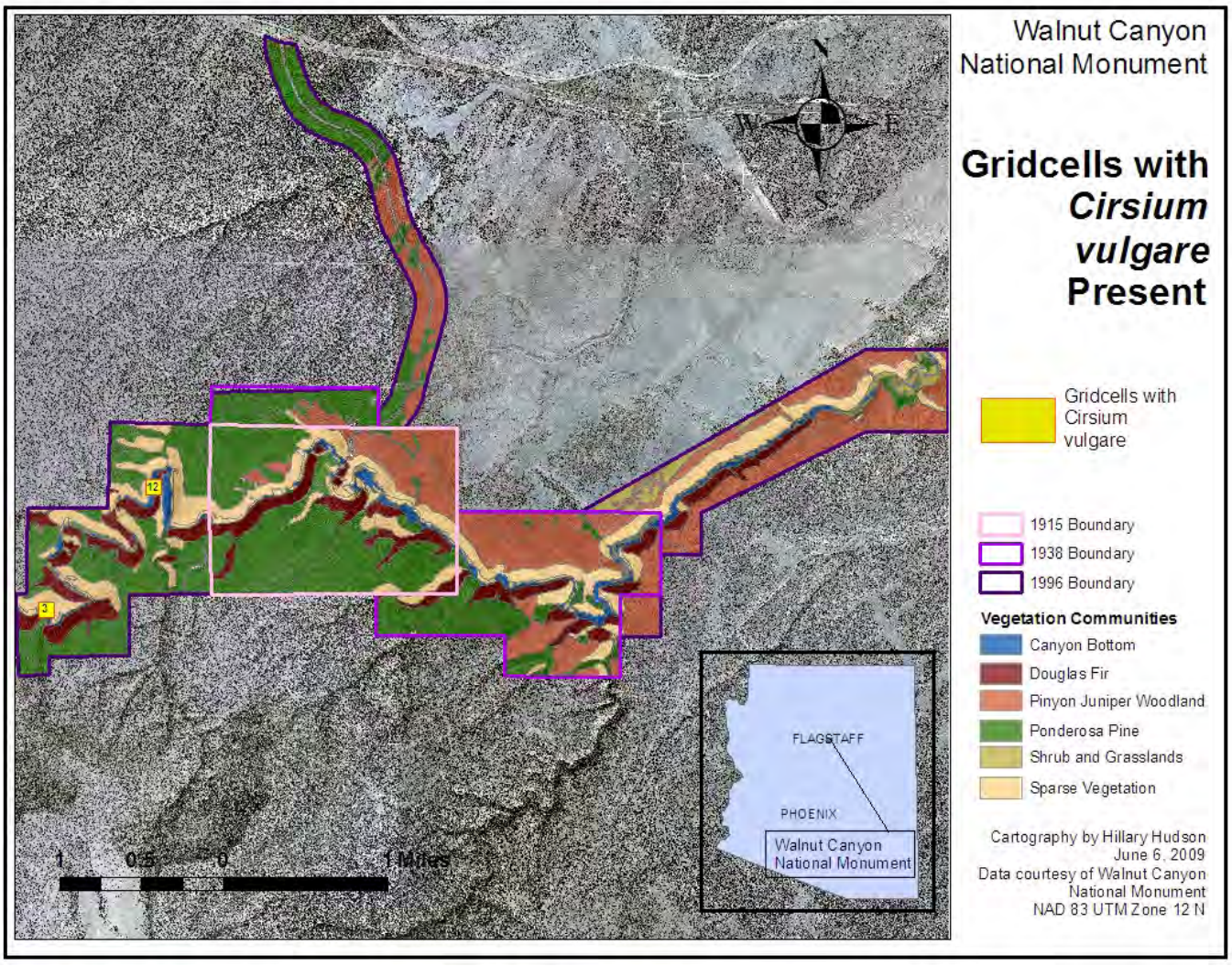


Figure B-5. Gridcells with *Cirsium vulgare* present

Appendix B continued

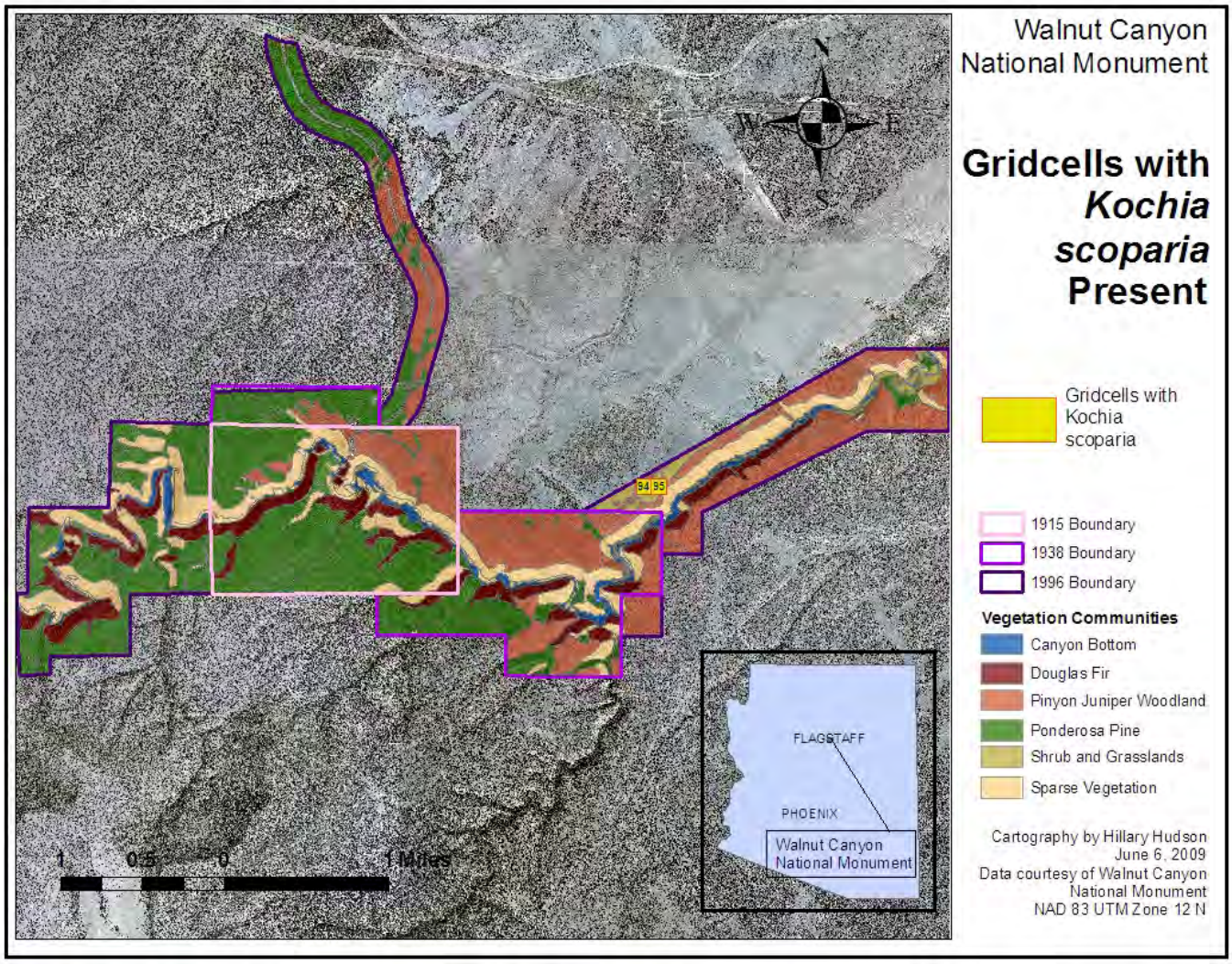


Figure B-6. Gridcells with *Kochia scoparia* present

Appendix B continued

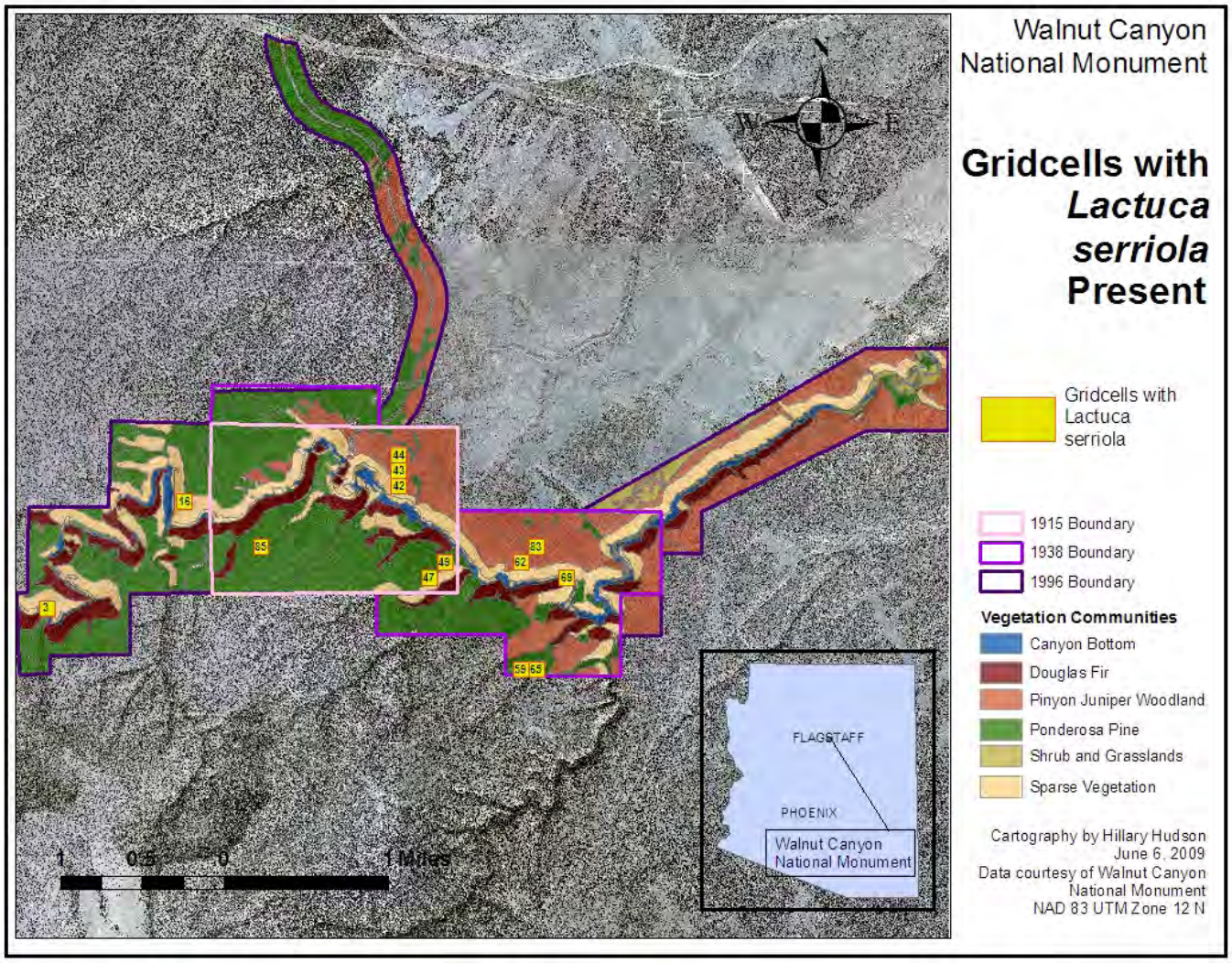


Figure B-7. Gridcells with *Latuca serriola* present

Appendix B continued

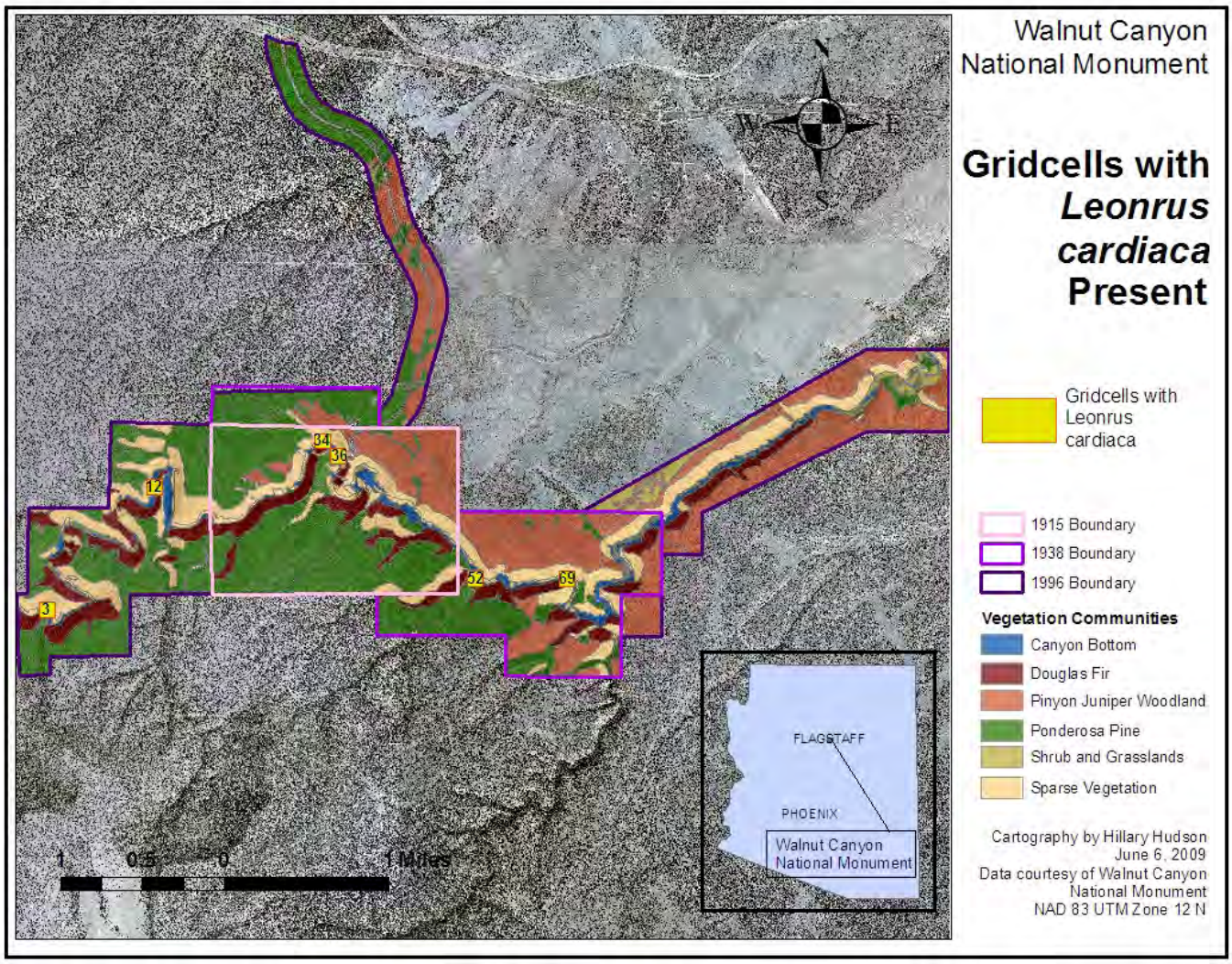


Figure B-8. Gridcells with *Leonrus cardiaca* present

Appendix B continued

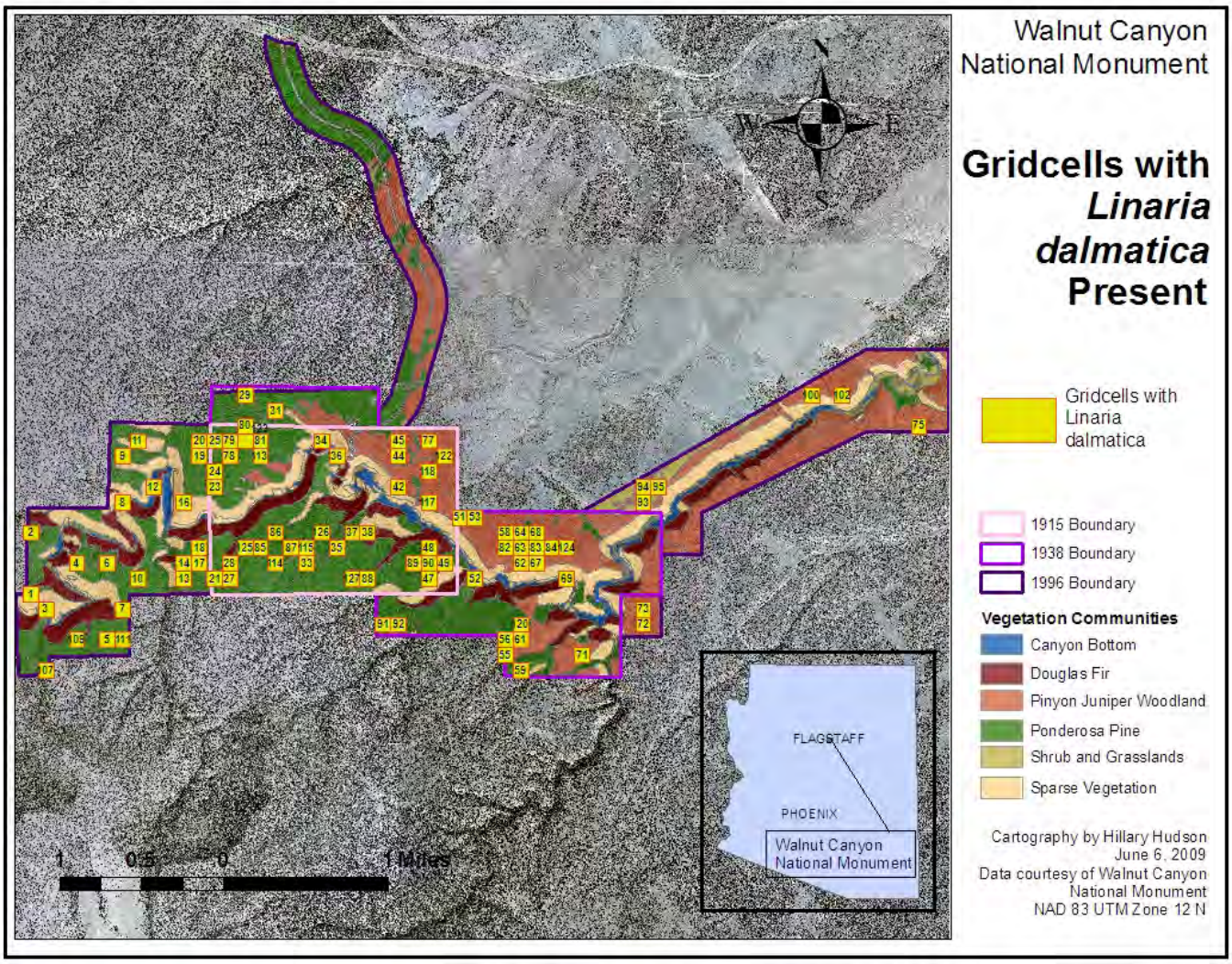


Figure B-9. Gridcells with *Linaria dalmatica* present

Appendix B continued

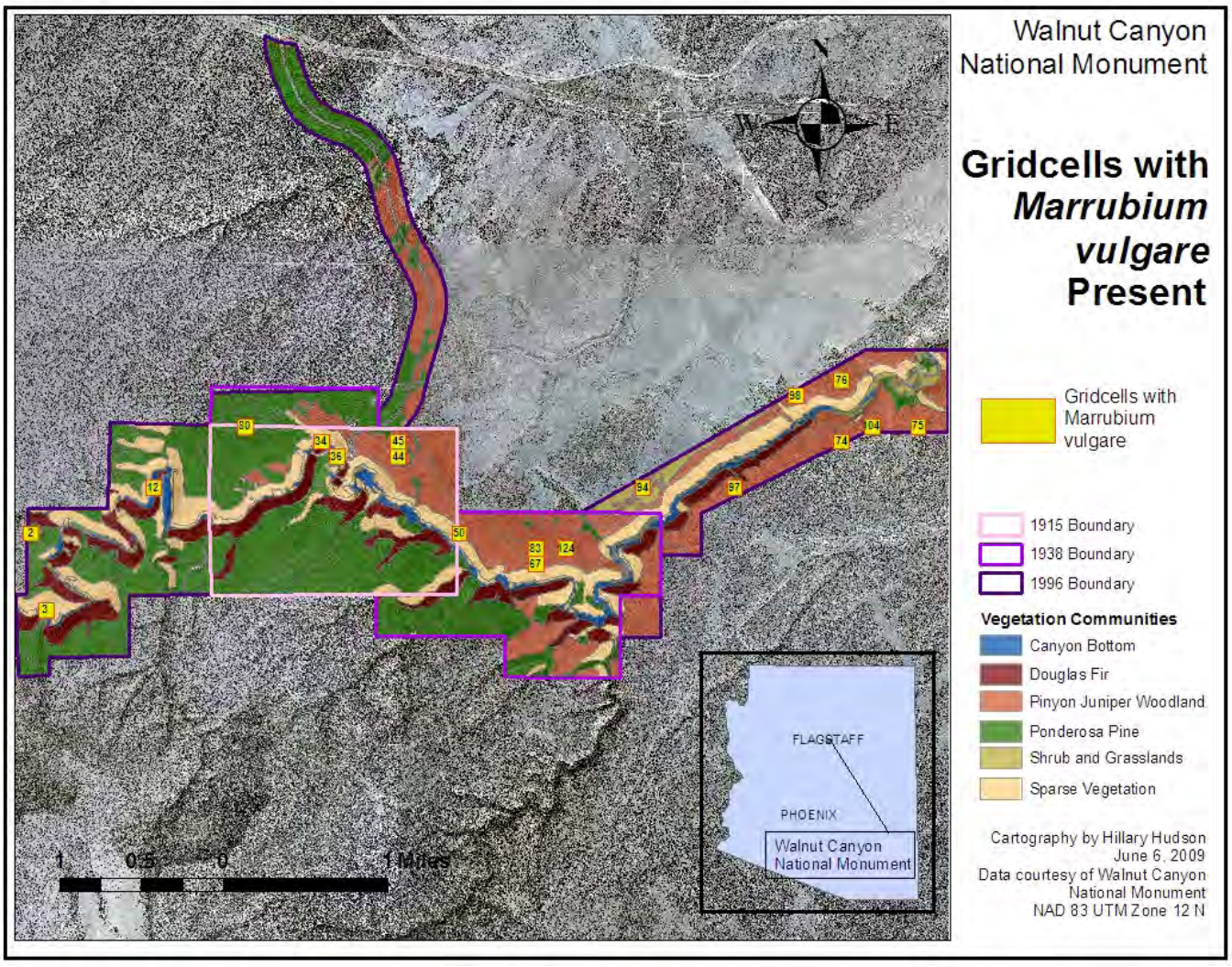


Figure B-10. Gridcells with *Marrublum vulgare* present

Appendix B continued

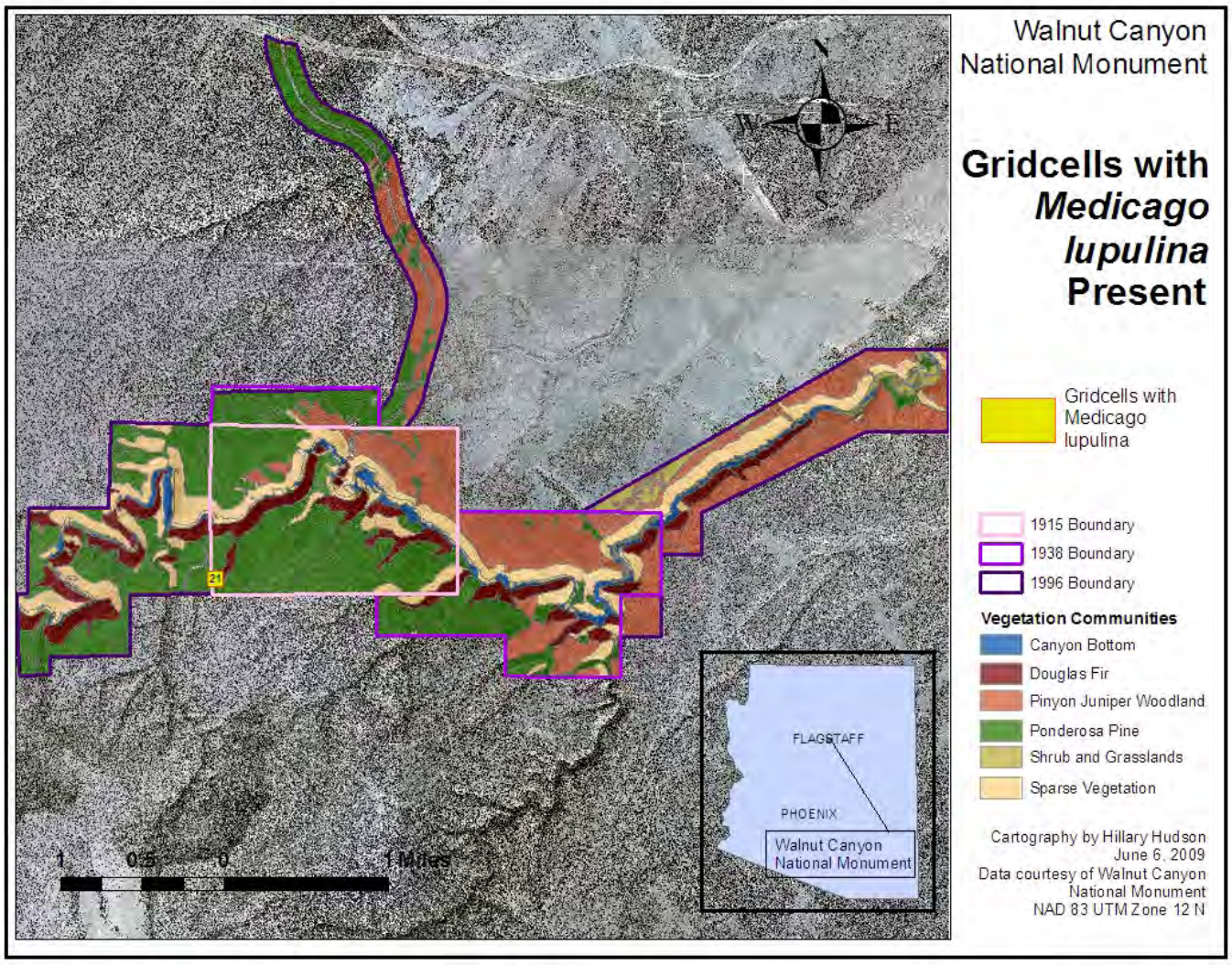


Figure B-11. Gridcells with *Medicago lupulina* present

Appendix B continued

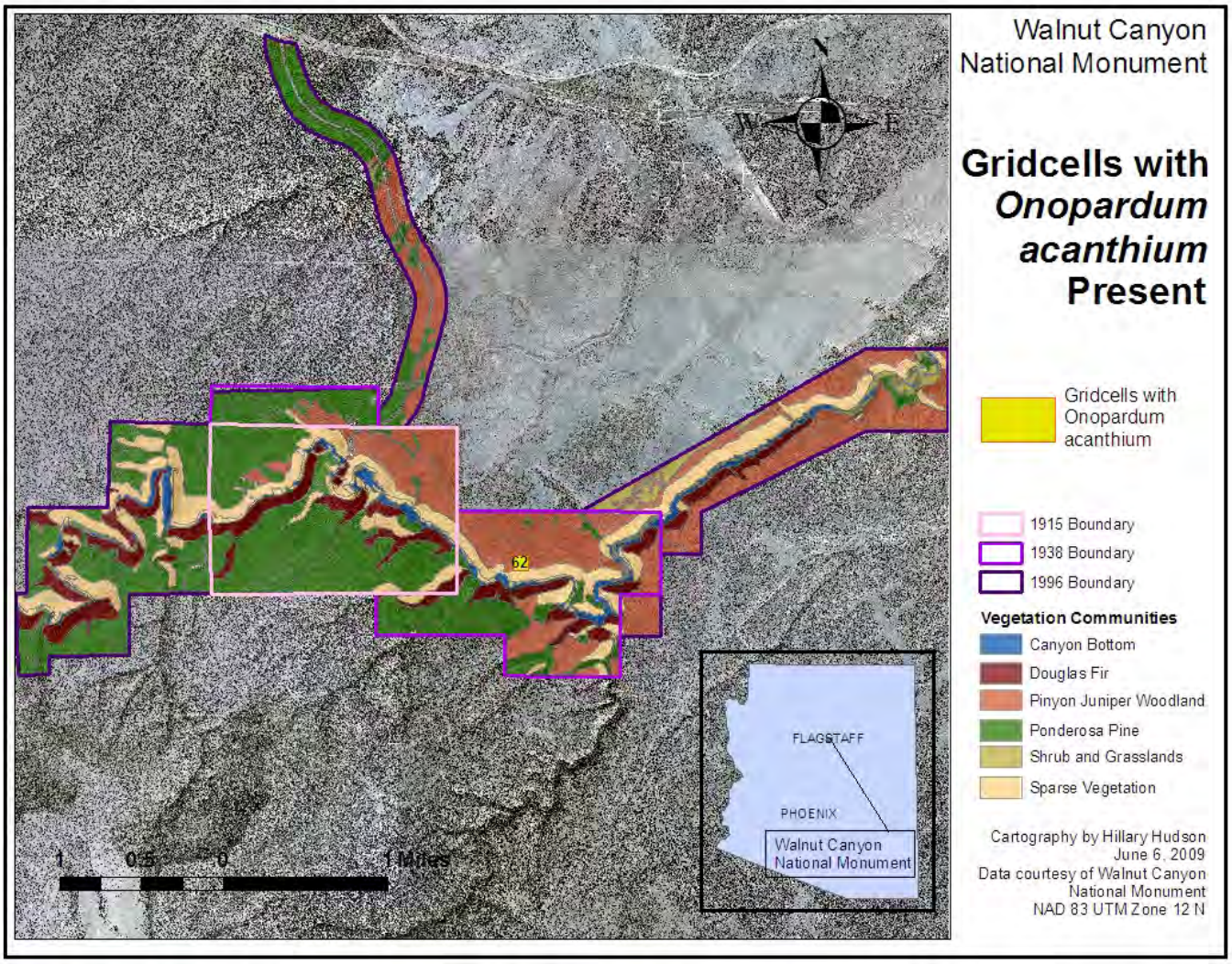


Figure B-12. Gridcells with *Onopardum acanthium* present

Appendix B continued

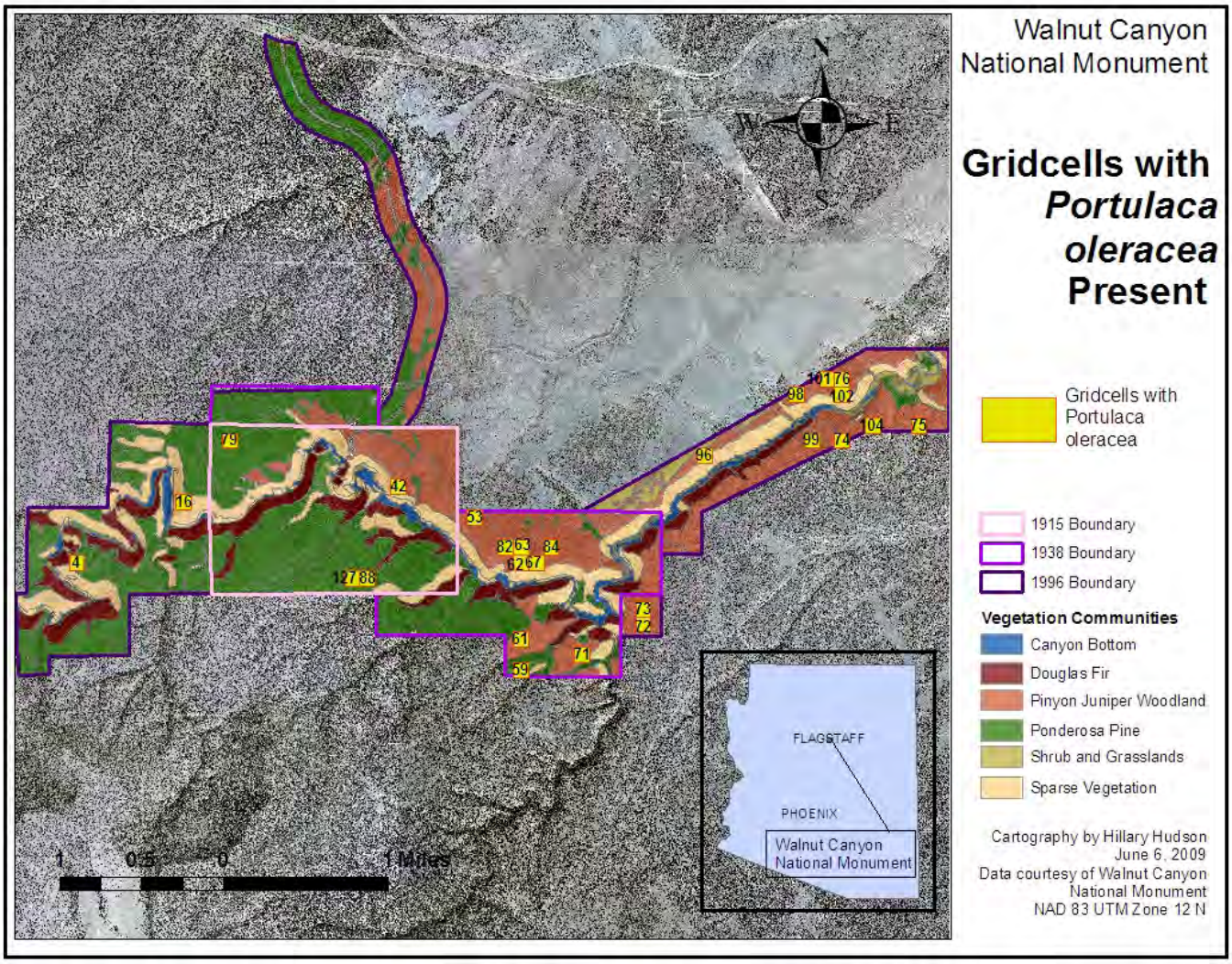


Figure B-13. Gridcells with *Portulaca oleracea* present

Appendix B continued

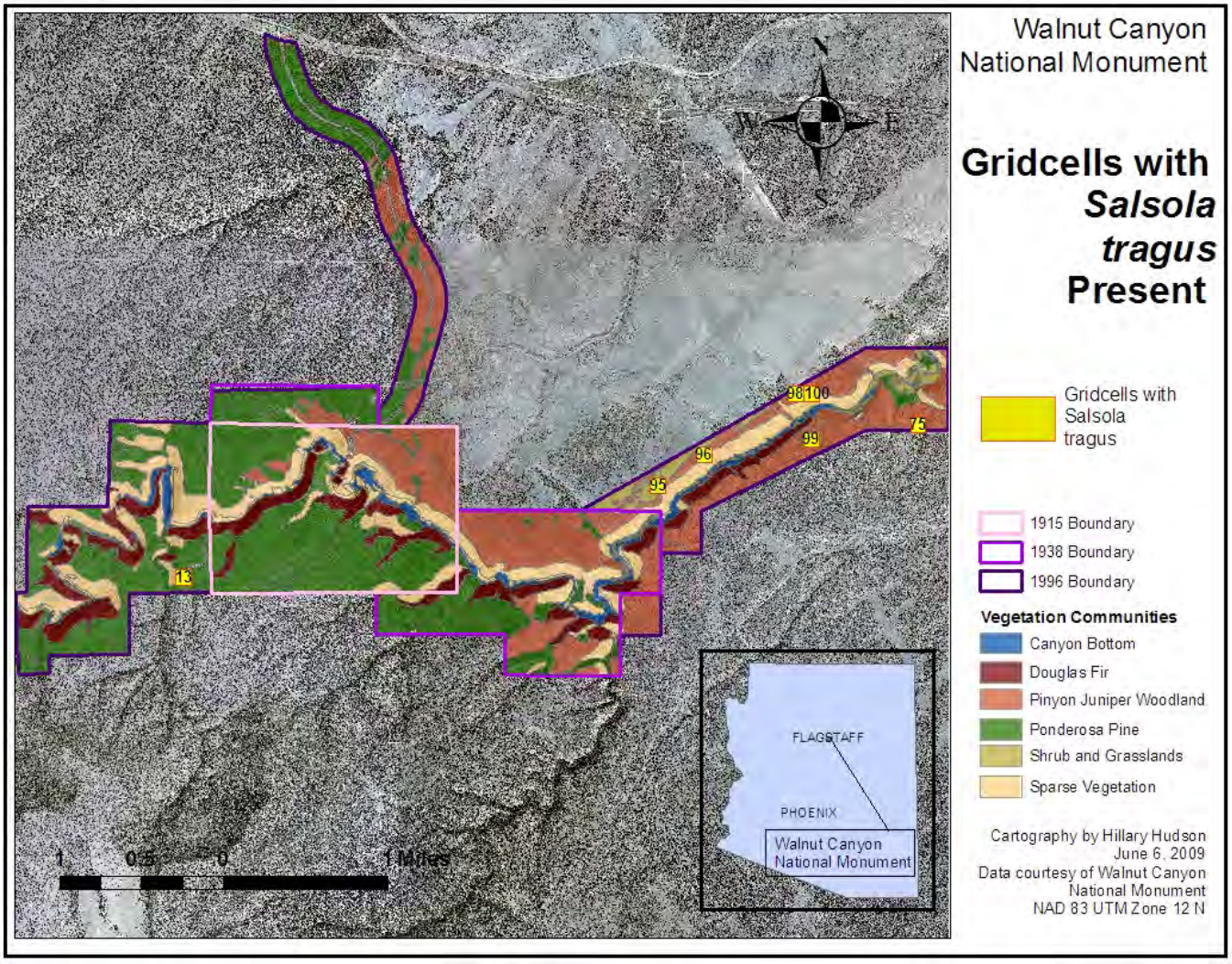


Figure B-14. Gridcells with *Salsola tragus* present

Appendix B continued

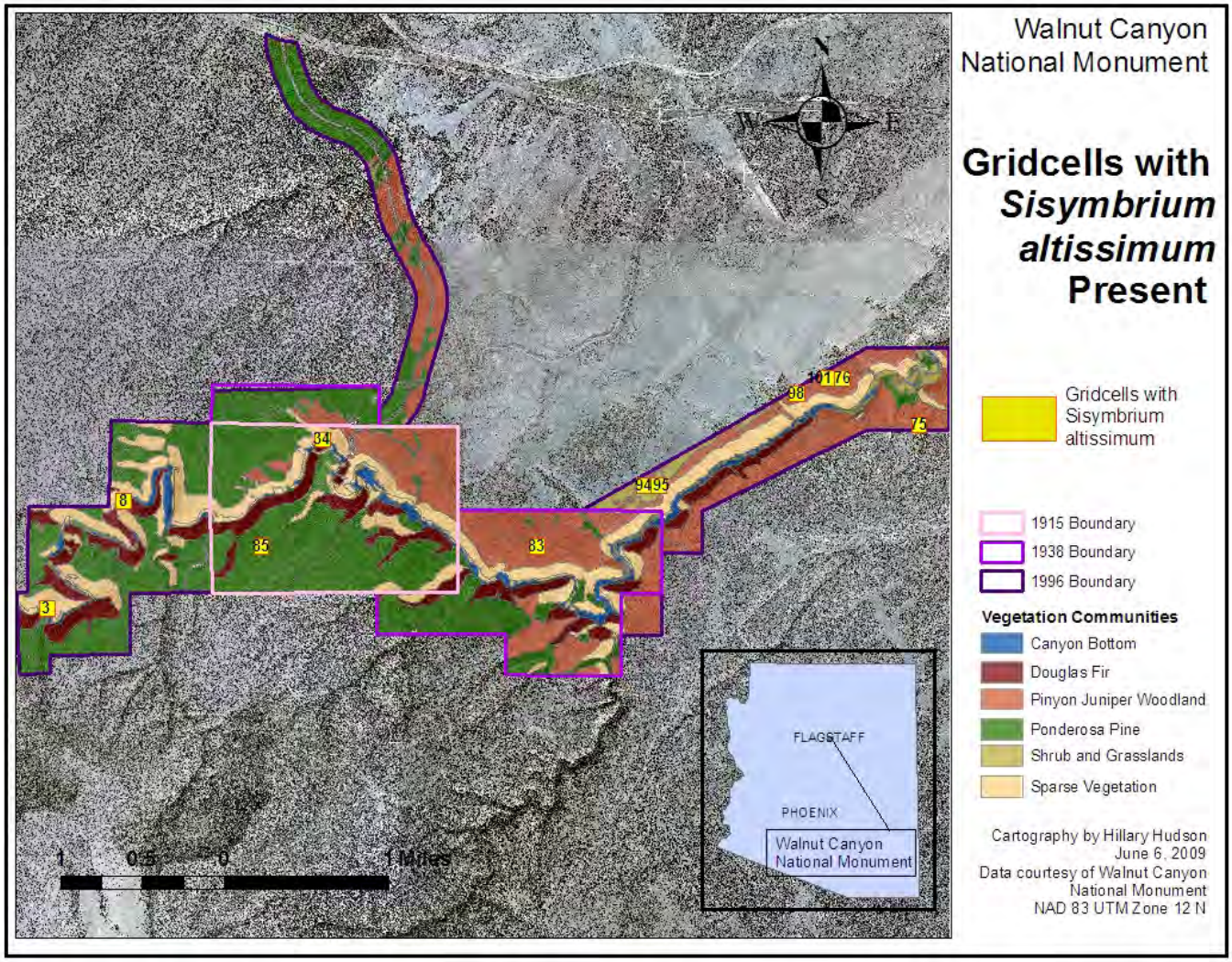


Figure B-15. Gridcells with *Sisymbrium altissimum* present

Appendix B continued

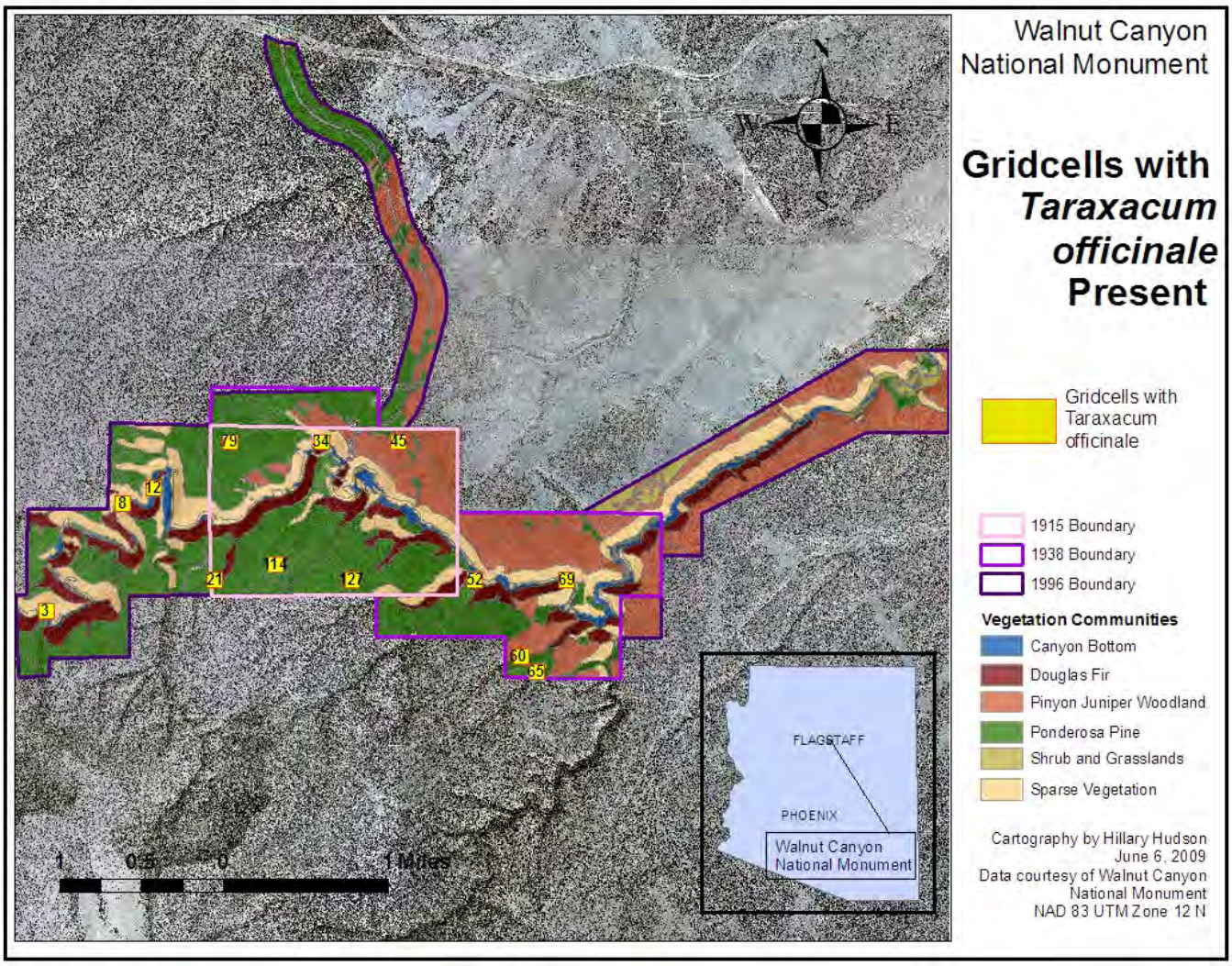


Figure B-16. Gridcells with *Taraxacum officinale* present

Appendix B continued

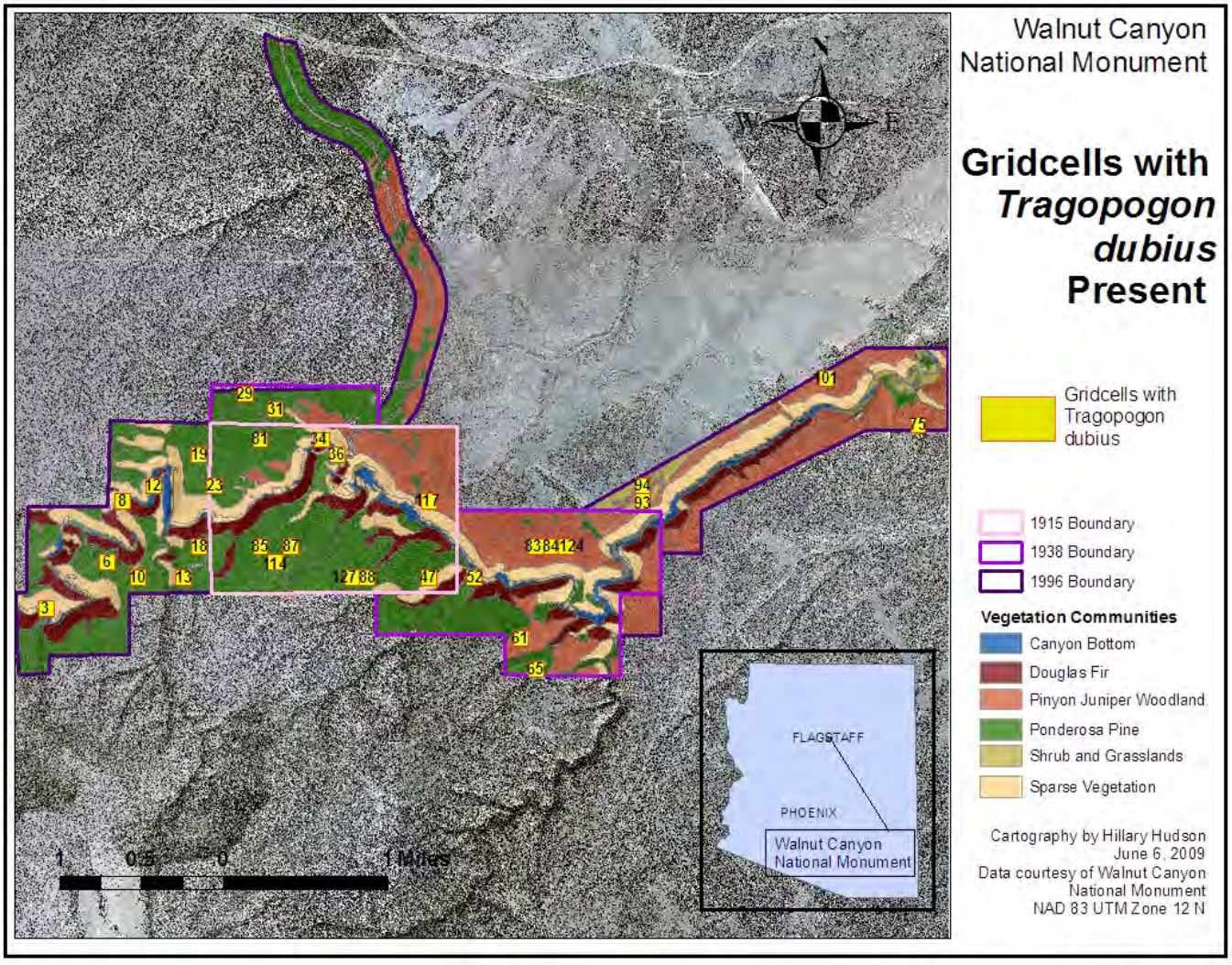


Figure B-17. Gridcells with *Tragopogon dubius* present

Appendix B continued

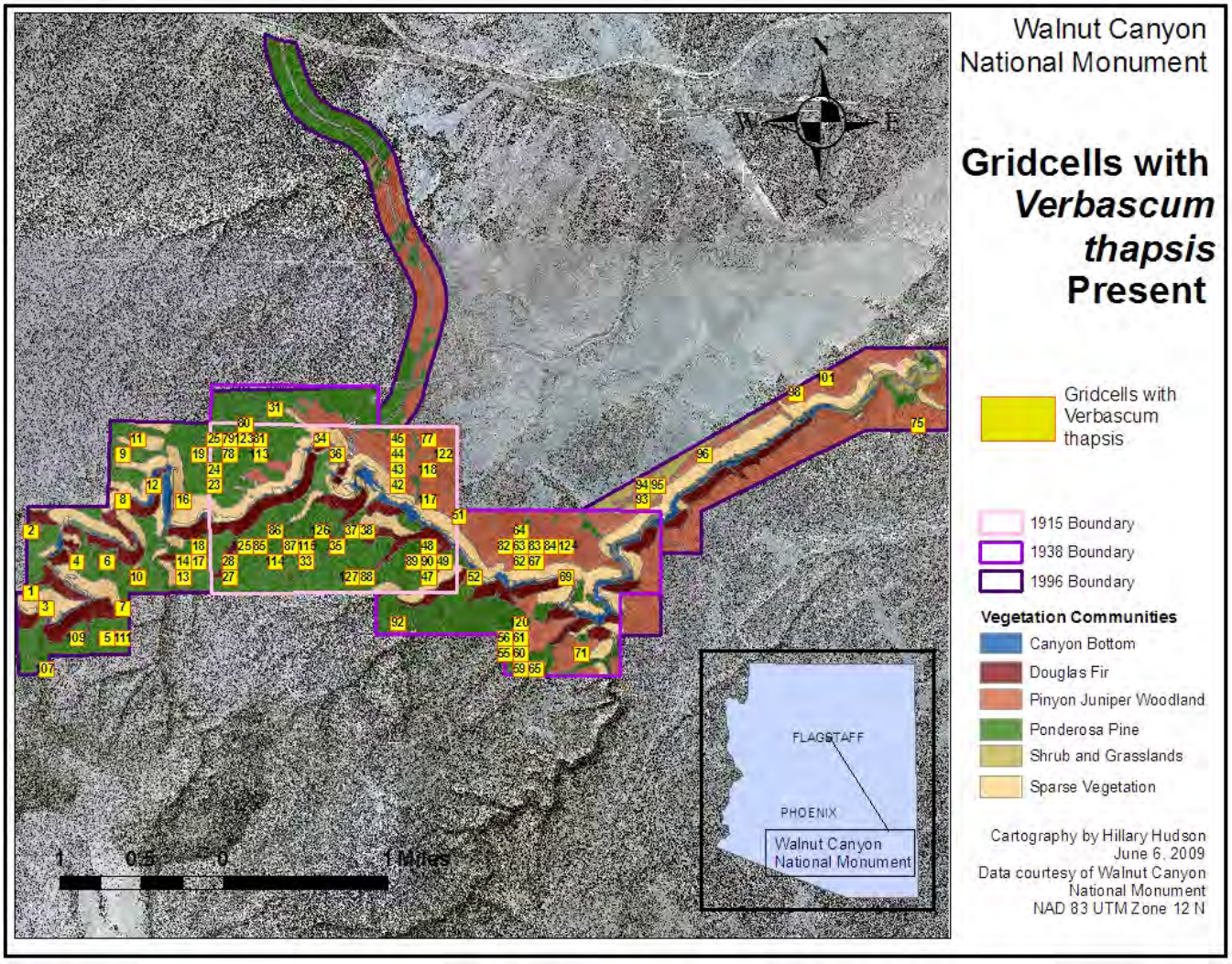


Figure B-18. Gridcells with *Verbascum thapsis* present

Appendix C. List of exotic species occurring in each grid cell sampled in the Resource Preservation Zone of Walnut Canyon National Monument

Grid 1	**2**	**3**	**4**	**5**
Chenopodium spp. *Linaria dalmatica* *Verbascum thapsus*	*Bromus tectorum* *Chenopodium* spp. *Linaria dalmatica* *Marrubium vulgare* *Verbascum thapsus*	*Bromus tectorum* *Chenopodium* spp. *Cirsium vulgare* *Lactuca serriola* *Leonurus cardiaca* *Linaria dalmatica* *Marrubium vulgare* *Tragopogon dubius* *Verbascum thapsus*	*Chenopodium* spp. *Descurainia sophia* *Linaria dalmatica* *Portulaca oleracea* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*
Grid 6	**7**	**8**	**9**	**10**
Chenopodium spp. *Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Sisymbrium altissimum* *Taraxacum officinale* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*	*Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*
Grid 11	**12**	**13**	**14**	**16**
Linaria dalmatica *Verbascum thapsus*	*Chenopodium* spp. *Cirsium vulgare* *Leonurus cardiaca* *Linaria dalmatica* *Marrubium vulgare* *Taraxacum officinale* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica* *Salsola tragus* *Tragopogon dubius* *Verbascum thapsus*	*Verbascum thapsus*	*Lactuca serriola* *Linaria dalmatica* *Portulaca oleracea* *Verbascum thapsus*
Grid 17	**18**	**19**	**20**	**21**
Verbascum thapsus	*Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica*	*Linaria dalmatica* *Medicago lupulina*
Grid 23	**24**	**25**	**26**	**27**
Chenopodium spp. *Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica*	*Linaria dalmatica* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica*	*Linaria dalmatica* *Verbascum thapsus*
Grid 28	**29**	**31**	**33**	
Linaria dalmatica	*Linaria dalmatica* *Tragopogon dubius*	*Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*	*Bromus tectorum* *Chenopodium* spp. *Linaria dalmatica* *Verbascum thapsus*	

Appendix C *continued*

Grid 34	**35**	**36**	**37**	**38**
Bromus tectorum *Chenopodium* spp. *Leonurus cardiaca* *Linaria dalmatica* *Marrubium vulgare* *Sisymbrium altissimum* *Taraxacum officinale* *Tragopogon dubius* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*	*Leonurus cardiaca* *Linaria dalmatica* *Marrubium vulgare* *Tragopogon dubius* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Verbascum thapsus*	*Verbascum thapsus*
Grid 42	**43**	**44**	**45**	**47**
Bromus tectorum *Chenopodium* spp. *Descurainia sophia* *Lactuca serriola* *Linaria dalmatica* *Portulaca oleracea* *Verbascum thapsus*	*Chenopodium* spp. *Lactuca serriola* *Verbascum thapsus*	*Lactuca serriola* *Linaria dalmatica* *Marrubium vulgare* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Marrubium vulgare* *Taraxacum officinale* *Verbascum thapsus*	*Chenopodium* spp. *Descurainia sophia* *Lactuca serriola* *Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*
Grid 48	**49**	**50**	**51**	**52**
Linaria dalmatica *Verbascum thapsus*	*Chenopodium* spp. *Lactuca serriola* *Linaria dalmatica* *Verbascum thapsus*	*Bromus tectorum* *Chenopodium* spp. *Marrubium vulgare*	*Chenopodium* spp. *Linaria dalmatica* *Verbascum thapsus*	*Bromus tectorum* *Leonurus cardiaca* *Linaria dalmatica* *Taraxacum officinale* *Tragopogon dubius* *Verbascum thapsus*
Grid 53	**55**	**56**	**58**	**59**
Bromus tectorum *Leonurus cardiaca*	*Linaria dalmatica* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*	*Linaria dalmatica*	*Lactuca serriola* *Linaria dalmatica* *Portulaca oleracea* *Verbascum thapsus*
Grid 67	**69**	**71**	**72**	**73**
Chenopodium spp. *Linaria dalmatica* *Marrubium vulgare* *Portulaca oleracea* *Verbascum thapsus*	*Bromus tectorum* *Lactuca serriola* *Leonurus cardiaca* *Linaria dalmatica* *Taraxacum officinale* *Verbascum thapsus*	*Bromus tectorum* *Chenopodium* spp. *Descurainia sophia* *Linaria dalmatica* *Portulaca oleracea* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Portulaca oleracea*	*Chenopodium* spp. *Linaria dalmatica* *Portulaca oleracea*
Grid 74	**75**	**76**	**77**	**78**
Portulaca oleracea	*Linaria dalmatica* *Portulaca oleracea* *Salsola tragus* *Sisymbrium altissimum* *Tragopogon dubius*	*Marrubium vulgare* *Sisymbrium altissimum*	*Linaria dalmatica*	*Linaria dalmatica*
Grid 79	**80**	**87**	**88**	**89**
Linaria dalmatica *Portulaca oleracea* *Taraxacum officinale* *Verbascum thapsus*	*Linaria dalmatica* *Marrubium vulgare*	*Tragopogon dubius* *Verbascum thapsu*	*Descurainia sophia* *Linaria dalmatica* *Tragopogon dubius*	*Linaria dalmatica*

Appendix C *continued*

Grid 90	**91**	**93**	**94**	**95**
Chenopodium spp. *Linaria dalmatica* *Verbascum thapsus*	*Linaria dalmatica*	*Melilotus officinalis* *Tragopogon dubius*	*Linaria dalmatica* *Marrubium vulgare* *Tragopogon dubius* *Verbascum thapsus*	*Kochia scoparia* *Linaria dalmatica* *Salsola tragus* *Sisymbrium altissimum* *Verbascum thapsus*
Grid 96	**97**	**98**	**99**	**100**
Chenopodium spp. *Portulaca oleracea* *Salsola tragus* *Verbascum thapsus*	*Marrubium vulgare*	*Bromus tectorum* *Chenopodium* spp. *Marrubium vulgare* *Portulaca oleracea* *Salsola tragus* *Sisymbrium altissimum* *Verbascum thapsus*	*Salsola tragus*	*Linaria dalmatica* *Salsola tragus*
Grid 101	**102**	**104**	**107**	**109**
Chenopodium spp. *Descurainia sophia* *Portulaca oleracea* *Sisymbrium altissimum* *Tragopogon dubius* *Verbascum thapsus*	*Chenopodium* spp. *Descurainia sophia* *Linaria dalmatica* *Portulaca oleracea*	*Chenopodium* spp. *Marrubium vulgare* *Portulaca oleracea*	*Linaria dalmatica* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*
Grid 111	**113**	**114**	**117**	**118**
Linaria dalmatica *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*	*Bromus tectorum* *Linaria dalmatica* *Taraxacum officinale* *Tragopogon dubius* *Verbascum thapsus*	*Chenopodium* spp. *Descurainia sophia* *Linaria dalmatica* *Tragopogon dubius* *Verbascum thapsus*	*Bromus tectorum* *Chenopodium* spp. *Descurainia sophia* *Linaria dalmatica* *Verbascum thapsus*
Grid 120	**122**	**123**	**124**	**125**
Chenopodium spp. *Linaria dalmatica* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Verbascum thapsus*	*Linaria dalmatica* *Verbascum thapsus*	*Chenopodium* spp. *Descurainia sophia* *Linaria dalmatica* *Marrubium vulgare* *Tragopogon dubius* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Verbascum thapsus*
Grid 126	**127**			
Descurainia sophia *Linaria dalmatica* *Verbascum thapsus*	*Chenopodium* spp. *Linaria dalmatica* *Portulaca oleracea* *Verbascum thapsus*			

Appendix D. Data Sheet

Exotic Plant Inventory Data Sheet

Park: ____________________ Date:____________________ Observers:______________________

Grid Cell Number:_________ Belt Width (m):___________ Waypoint Numbers: ____________

Species	**Cover Class**	**Present in Grid Cell** (check)

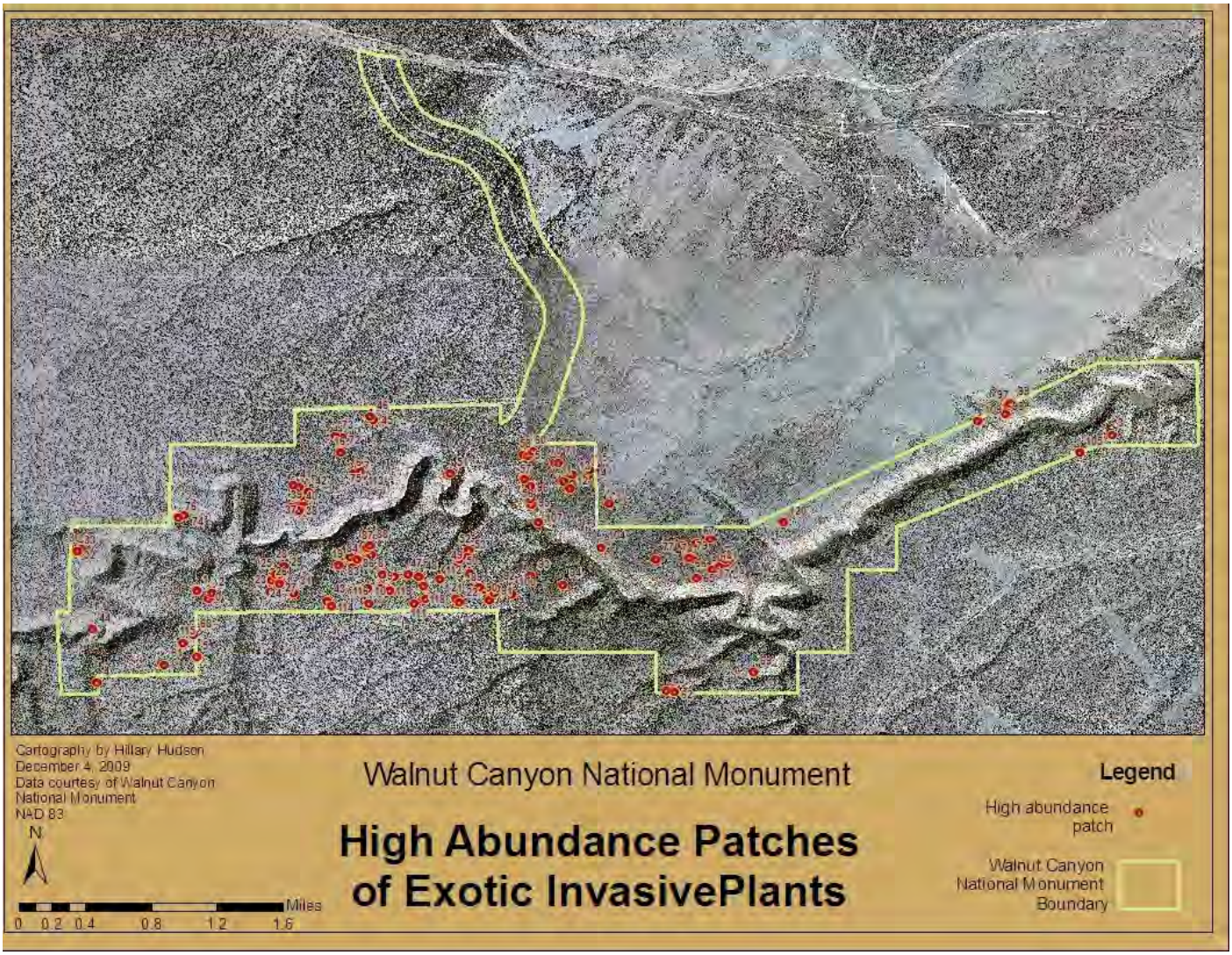
Appendix D Data Sheet, side 2

Cover Class Scale for Foliar Cover Estimation:

Cover range	<0.01%	0.1-1%	1-5%	5-10%	10-25%	25-50%	50-100%
Code	1	2	3	4	5	6	7
Belt Width	Upper Cutpoint	Upper Cutpoint	Upper Cutpoint	Upper Cutpoint	Upper Cutpoint	Upper Cutpoint	
3 m belt	0.39 X 0.39	1.22 X 1.22	2.74 X 2.74	3.87 X 3.87	6.12 X 6.12	8.66 X 8.66	
4 m belt	0.45 X 0.45	1.41 X 1.41	3.16 X 3.16	4.47 X 4.47	7.07 X 7.07	10 X 10	
5 m belt	0.5 X 0.5	1.58 X 1.58	3.54 X 3.54	5 X 5	7.91 X 7.91	11.18 X 11.18	
6 m belt	0.55 X 0.55	1.73 X 1.73	3.87 X 3.87	5.48 X 5.48	8.66 X 8.66	12.25 X 12.25	
7 m belt	0.59 X 0.59	1.87 X 1.87	4.18 X 4.18	5.92 X 5.92	9.35 X 9.35	13.23 X 13.23	

Comments:

Appendix E. Patches with high abundance of invasive exotic plants at Walnut Canyon National Monument (WACA)



Appendix E-1. Map showing patches with high abundance of invasive exotic plants at Walnut Canyon National Monument

Appendix E-2 Geographical Positioning System Coordinates for High Density Exotic Plant Species at Walnut Canyon National Monument. Locations are listed by grid cell if they occurred within a grid cell sampled in this study. If outside a grid cell, locations are listed by the dominant exotic species.

FID	IDENT	Y_PROJ	X_PROJ	Species1	Species2	Species3	Species4	Species5	Comments
0	10-1	3890958.33	451547.09	*Linaria dalmatica*					Large patch
1	10-2	3891031.42	451450.58	*Verbascum thapsis*					
2	10-3	3891007.61	451577.03	*Linaria dalmatica*					Large patch
3	104-1	3892518.90	458779.98	*Marrubium vulgare*					Large patch
4	107-1	3890141.63	450649.71	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
5	111-1	3890385.40	451447.46	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
6	113-1	3892165.41	452710.79	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
7	113-2	3892128.72	452749.18	*Verbascum thapsis*	*Linaria dalmatica*				Several lg patches within 150 ft of point
8	114-1	3891181.55	452940.60	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
9	114-2	3891053.27	452921.58	*Linaria dalmatica*	*Verbascum thapsis*				Several large patches within 150 ft of pt & @ pt
10	114-3	3891053.13	452816.98	*Linaria dalmatica*					Large patch
11	118-1	3892083.38	454390.04	*Linaria dalmatica*					Large patch
12	118-2	3892017.90	454438.46	*Linaria dalmatica*					Large patch
13	122-1	3892147.15	454455.21	*Linaria dalmatica*					Large patch
14	122-2	3892141.30	454591.39	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
15	122-3	3892196.06	454603.59	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
16	123-1	3892370.83	452611.19	*Verbascum thapsis*					Large patch
17	124-1	3891317.66	455716.09	*Linaria dalmatica*	*Verbascum thapsis*				Large patch, 50 ft radius
18	124-2	3891284.87	455690.35	*Linaria dalmatica*	*Verbascum thapsis*				Large patch, 50 ft diameter
19	125-1	3891271.48	452590.70	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
20	127-1	3891006.41	453659.22	*Linaria dalmatica*	*Verbascum thapsis*				Lg patch w/Lindal all over surrounding area.

Appendix E-2 Geographical Positioning System Coordinates for High Density Exotic Plant Species at Walnut Canyon National Monument. continued

FID	IDENT	Y_PROJ	X_PROJ	Species1	Species2	Species3	Species4	Species5	Comments
21	127-2	3890939.77	453526.41	*Linaria dalmatica*					Large patch
22	127-3	3890905.33	453549.58	*Linaria dalmatica*	*Verbascum thapsis*				Large patch w/ whole area to the west very weedy.
23	13-1	3891024.93	452033.01	*Verbascum thapsis*	*Linaria dalmatica*				Large patch, mostly Lindal
24	14-1	3891136.31	452048.51	*Verbascum thapsis*	*Linaria dalmatica*				Large patch, mostly linaria
25	17-1	3891184.71	452081.91	*Verbascum thapsis*					Large patch
26	17-2	3891100.47	452113.49	*Linaria dalmatica*					Large patch
27	17-3	3891193.02	452121.62	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
28	18-1	3891269.41	452146.91	*Verbascum thapsis*	*Linaria dalmatica*				Large patch, Ron's camera photo 100-0034, 100-0033
29	18-2	3891198.54	452146.83	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
30	2-1	3891445.58	450537.87	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
31	21-1	3891012.33	452226.29	*Linaria dalmatica*					Large patch
32	2-2	3891413.97	450493.27	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
33	2-3	3891423.31	450495.68	*Verbascum thapsis*	*Linaria dalmatica*	*Marrubium vulgare*			Large patch
34	23-1	3891913.86	452311.45	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
35	23-2	3891870.35	452266.95	*Linaria dalmatica*					Large patch
36	23-3	3891853.71	452252.46	*Linaria dalmatica*					Large patch
37	23-4	3891854.30	452307.28	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
38	23-5	3891812.91	452276.16	*Linaria dalmatica*					Large patch
39	23-6	3891850.51	452214.66	*Linaria dalmatica*					Large patch
40	24-1	3892033.82	452277.15	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
41	24-2	3892054.19	452231.78	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
42	24-3	3891987.71	452346.45	*Linaria dalmatica*					Large patch
43	27-1	3890928.98	452491.44	*Linaria dalmatica*					Large patch
44	3-1	3890664.89	450609.88	*Marrubium vulgare*					Large patch
45	31-1	3892693.41	452877.83	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
46	31-2	3892719.31	452845.13	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
47	33-1	3891179.46	453142.74	*Linaria dalmatica*	*Verbascum thapsis*				Large patches with others in the area
48	33-2	3891155.39	453227.99	*Linaria dalmatica*	*Verbascum thapsis*				Large patches with others in the area
49	35-1	3891251.95	453523.22	*Verbascum thapsis*	*Linaria dalmatica*				Large patch

Appendix E-2 Geographical Positioning System Coordinates for High Density Exotic Plant Species at Walnut Canyon National Monument. continued

FID	IDENT	Y_PROJ	X_PROJ	Species1	Species2	Species3	Species4	Species5	Comments
50	35-2	3891326.08	453557.29	*Linaria dalmatica*					Large patch
51	36-1	3892165.53	453485.17	*Marrubium vulgare*					Several large patches in the vicinity.
52	37-1	3891414.54	453624.49	*Linaria dalmatica*					Large patch
53	37-2	3891350.99	453621.87	*Linaria dalmatica*					Large patch
54	43-1	3892040.64	454125.98	*Verbascum thapsis*					Large patch
55	44-1	3892195.13	454094.79	*Verbascum thapsis*					Large patch
56	44-2	3892103.96	454078.81	*Marrubium vulgare*					A few Marvul
57	45-1	3892345.35	454103.18	*Marrubium vulgare*					A few plants
58	45-2	3892344.30	454069.46	*Linaria dalmatica*					Large patch
59	45-3	3892333.83	454103.94	*Marrubium vulgare*					Large patch
60	45-4	3892374.34	454142.30	*Verbascum thapsis*					Large patch
61	5-1	3890316.12	451188.54	*Linaria dalmatica*					Large patch, seems whole drainage is Lindal
62	59-1	3890034.41	455266.25	*Linaria dalmatica*					Medium sized patch
63	59-2	3890040.27	455204.99	*Verbascum thapsis*					Large patch
64	64-1	3891453.94	455338.44	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
65	67-1	3891143.10	455445.35	*Marrubium vulgare*	*Linaria dalmatica*				A few Marvul & a large patch of Lindal nearby
66	68-1	3891344.37	455388.94	*Linaria dalmatica*					Large patch
67	68-2	3891482.77	455451.53	*Linaria dalmatica*					Large patch
68	7-1	3890600.49	451422.93	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
69	71-1	3890216.17	455899.15	*Linaria dalmatica*	*Bromus tectorum*				Highest amount of Brotec pop. seen yet.
70	77-1	3892266.96	454324.97	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
71	77-2	3892269.57	454346.57	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
72	80-1	3892520.97	452620.33	*Verbascum thapsis*	*Marribium vulgare*	*Bromus tectorum*			Large patch
73	80-2	3892530.35	452561.70	*Verbascum thapsis*					Large patch
74	8-1	3891768.76	451358.19	*Marrubium vulgare*					Large patch
75	81-1	3892257.66	452799.90	*Verbascum thapsis*	*Linaria dalmatica*				Large patch

Appendix E-2 Geographical Positioning System Coordinates for High Density Exotic Plant Species at Walnut Canyon National Monument. continued

FID	IDENT	Y_PROJ	X_PROJ	Species1	Species2	Species3	Species4	Species5	Comments
76	8-2	3891746.76	451309.53	*Verbascum thapsis*					Large patch
77	82-1	3891321.45	455126.22	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
78	83-1	3891314.68	455420.93	*Linaria dalmatica*	*Marrubium vulgare*	*Verbascum thapsis*	*Lactuca serriola*	*Bromus tectorum*	Large patch
79	83-2	3891334.97	455390.62	*Linaria dalmatica*					Large patch
80	84-1	3891216.65	455575.98	*Linaria dalmatica*					Large patch
81	84-2	3891246.69	455638.71	*Linaria dalmatica*					Large patch
82	85-1	3891250.78	452699.71	*Verbascum thapsis*					Photo # 0039, Ron's camera
83	85-2	3891350.28	452684.03	*Linaria dalmatica*					Large patch
84	85-3	3891328.23	452735.94	*Verbascum thapsis*					Large patch
85	86-1	3891373.01	452849.55	*Linaria dalmatica*					Large patch
86	86-2	3891435.29	452811.48	*Linaria dalmatica*					Large patch
87	86-3	3891447.20	452822.99	*Linaria dalmatica*					Large patch
88	86-4	3891465.04	452842.70	*Linaria dalmatica*					Large patch
89	88-1	3891038.13	453757.16	*Linaria dalmatica*					Large patch
90	88-2	3890932.58	453796.44	*Linaria dalmatica*					Large patch
91	88-3	3891003.79	453829.73	*Linaria dalmatica*					Large patch
92	88-4	3891048.11	453853.23	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
93	89-1	3891165.55	454124.68	*Linaria dalmatica*					Many lg patches of Lindal w/in 100 ft of point.
94	90-1	3891076.11	454378.12	*Verbascum thapsis*					Large patch
95	92-1	3891856.86	454132.63	*Verbascum thapis*					Large patch
96	93-2	3891912.82	454124.70	*Linaria dalmatica*					Large patch
97	98-1	3892799.61	457950.98	*Marrubium vulgare*					Large patch
98	98-2	3892720.73	457925.44	*Marrubium vulgare*					Large patch
99	98-3	3892825.64	457970.72	*Marrubium vulgare*					Large patch
100	LINDAL101	3890987.06	453974.82	*Linaria dalmatica*					Lg patch with many weed patches within 100 ft.
101	LINDAL103	3890899.57	453192.52	*Verbascum thapsis*	*Linaria dalmatica*				Many large patches w/in 200 ft of point.
102	LINDAL1032	3891186.79	453640.11	*Linaria dalmatica*					Large patch
103	LINDAL1033	3891055.22	453706.92	*Linaria dalmatica*					Large patch

Appendix E-2 Geographical Positioning System Coordinates for High Density Exotic Plant Species at Walnut Canyon National Monument. continued

FID	IDENT	Y_PROJ	X_PROJ	Species1	Species2	Species3	Species4	Species5	Comments
104	MARVUL50	3891438.64	454688.60	*Marrubium vulgare*					Large patch
105	MARVUL923	3892345.39	458518.02	*Marrubium vulgare*					Beginning of patch, runs 100 ft from the point.
106	MAVU10-15	3891517.25	455561.57	*Marrubium vulgare*					Large patch
107	MAVU10-17	3891684.27	454190.65	*Marrubium vulgare*					Large patch
108	MAVU-124	3891312.36	455680.64	*Marrubium vulgare*					Small patch
109	ONAC106	3892652.19	457705.28	*Onopardum acanthium*					Large patch
110	SCOTCH62	3891864.11	454751.61	*Onopardum acanthium*					Patch
111	VERTHA103	3890940.68	453280.42	*Verbascum thapsis*					6 different patches w/in 100 ft.
112	VERTHA1032	3891133.42	453390.87	*Verbascum thapsis*					Large patch
113	VERTHA917	3892198.24	452772.70	*Verbascum thapsis*	*Linaria dalmatica*				Lg patch of Vertha, 150 ft with Lindal
114	VERTHA922	3890877.21	452527.76	*Verbascum thapsis*					Large patch
115	VERTHA924	3890529.50	451334.68	*Verbascum thapsis*					Large patch
116	VERTHA925	3890902.98	452827.80	*Linaria dalmatica*	*Verbascum thapsis*				5 acres of scattered dense patches.
117	VERTHA9252	3891164.66	453028.01	*Verbascum thapsis*					Large patch
118	VERTHA9253	3891074.52	453265.61	*Linaria dalmatica*	*Verbascum thapsis*				Large patch
119	VERTHA9254	3891029.49	452991.83	*Verbascum thapsis*	*Linaria dalmatica*				Large patch
120	WEEDY1	3891674.43	456144.59	*Linaria dalmatica*	*Onopardum acanthium*				Large patch

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