DISTRIBUTION AND STATUS OF ENDEMIC AND NON-NATIVE PLANT SPECIES AT THE PAINTED HILLS UNIT OF JOHN DAY FOSSIL BEDS NATIONAL MONUMENT

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ABSTRACT

Populations of rare and selected non-native plant species were quantitatively surveyed throughout the Painted Hills unit of John Day Fossil Beds National Monument in 2007 and 2008. A total of 5 endemic plant species were mapped including *Castilleja xanthotricha*, *Chaenactis nevii*, *Juncus torreyi*, *Pediocactus nigrispinus*, and *Penstemon eriantherus* var. *argillosus*. A total of 1125 associated occurrences were identified and surveyed. Populations are generally stable with large plant numbers and few apparent threats affecting their persistence.

A total of 15 non-native plants with 1364 associated occurrences were also surveyed and mapped. Populations of exotic species are extensive, but predominantly restricted to low elevation disturbed habitats in the vicinity of roads and creeks or to burned sites at high elevations. More than 80% of all detected weed occurrences were located within 400 m of a road, trail, or stream channel.

Continued quantitative monitoring using standardized protocols is recommended in order to assess future population trajectories, evaluate the efficacy of management prescriptions, and to facilitate the early detection of additional introductions of potentially invasive non-native species.

INTRODUCTION

The vegetation of the Painted Hills unit of John Day Fossil Beds National Monument is shaped in part by extreme climatic aridity and the presence of unstable clay-rich paleosols exposed by long-term weathering processes. Plant communities comprising Painted Hills' environments include *Juniperus occidentalis* woodlands, *Artemisia tridentata* ssp. *wyomingensis* and *Atriplex confertifolia* shrub steppe associations, and *Festuca idahoensis* and *Pseudoroegneria spicata* savannas and grasslands. Some of these vegetation types are recognized as critically endangered due to habitat losses and reductions in biodiversity associated with agricultural conversion, excessive livestock grazing, proliferation of non-native invasive plant species, and the associated alteration of natural fire regimes (Miller et al. 1994; Noss et al. 1995; Christensen et al. 1996; Knick 1999; Mack et al. 2000). Portions of the Painted Hills are currently occupied by relatively unmodified native plant communities with sparse non-native plant cover that may potentially serve as reference sites to guide restoration goals in similar but degraded landscapes in the intermountain west (Shinneman et al. 2007). Painted Hills vegetation is also characterized by the presence of several globally rare endemic plant species including *Castilleja xanthotricha*, *Chaenactis nevii*, *Juncus torreyi*, and *Pediocactus nigrispinus*.

The establishment and proliferation of non-native species is widely recognized as a major threat to ecosystem integrity and function (Lonsdale 1999; D'Antonio and Vitousek 1992) and the preservation of biodiversity (Schmitz et al. 1997). The expansion of non-native species contributes to the decline of almost half of all imperiled species in the Unites States (Wilcove et al. 1998). Invasive plant species potentially alter ecosystem properties such as water and nutrient availability, influence disturbance processes and community succession, and sometimes cause the complete replacement of native shrub and bunchgrass communities (Booth et al. 2003). Some of the most prolific and widespread species in semiarid environments causing the greatest threats to ecosystem integrity include *Acroptilon repens*, *Centaurea solstitialis*, *Bromus tectorum*, and *Taeniatherum caput-medusae* (DiTomaso 2000).

Despite an awareness of the ecological impacts associated with non-native species expansions and a growing research focus on the susceptibility or resistance of particular habitats to colonization (Belote et al. 2008), a paucity of quantitative, standardized monitoring data is available that describes long-term changes in the structure and function of plant communities impacted by invasive species (Lonsdale 1999; West 2003; Clark et al. 2005). The primary objective of this study was to compile a comprehensive inventory of both rare and non-native plant species occurring in the Painted Hills and to quantify corresponding occurrence locations and population sizes.

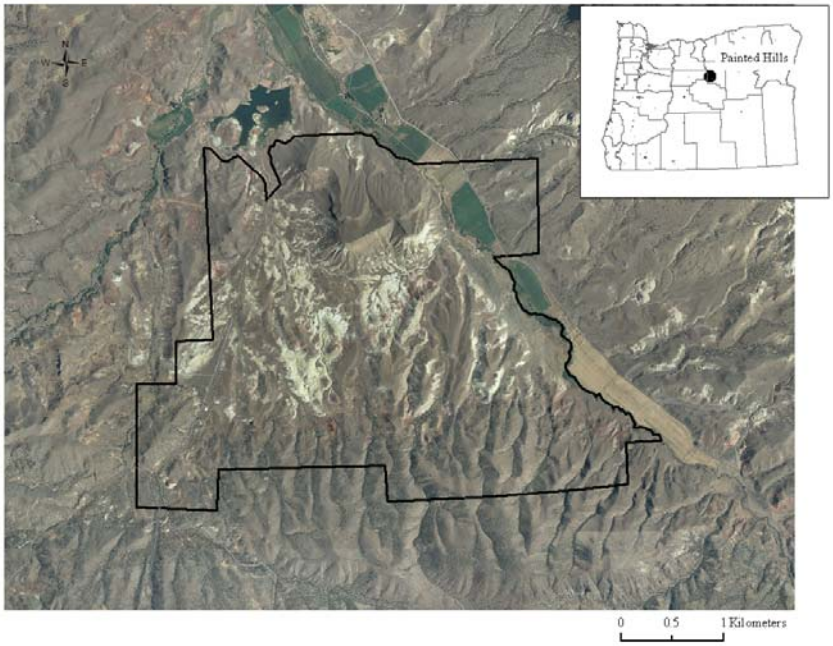
The resulting inventory will provide managers with baseline data for evaluating future changes in vegetation patterns, emerging potential threats to native species viability, and the effectiveness of weed management prescriptions. In order to facilitate a standardized approach to field data collection, future vegetation monitoring, and potential data exchange between agencies, The Nature Conservancy's (TNC) Weed Information Management System (WIMS; http://tncweeds.ucdavis.edu/wims.html) was used for field recording of inventory data, spatial mapping of plant polygons, and subsequent data processing and management efforts.

METHODS

Study area

The Painted Hills is one of three spatially disjunct units comprising John Day Fossil Beds National Monument in eastern Oregon (Figure 1). The Painted Hills unit is located 9 miles northwest of Mitchell, Oregon and 75 miles east of Bend. The areal extent of the unit is 3,132 acres (1267.5 ha). Vegetation patterns and plant community composition are determined in part by climatic aridity and unstable, moisture-limiting soils. Steep-sided, sparsely vegetated clay hills heavily dissected by gullies and seasonally dry washes comprise major portions of the unit. Annual precipitation ranges from 9 to 12 inches (23-30 cm).

Figure 1: Painted Hills study area



Preliminary meeting and target plant list

A preliminary meeting was conducted with project partners at the Painted Hills unit in early March 2007 and a partial reconnaissance was conducted to assess terrain characteristics and vegetation patterns. Project objectives and appropriate field survey methods were reviewed in consultation with NPS staff. Target lists of rare (Table 1) and invasive non-native (Table 2) plant species potentially present at the Painted Hills were developed based on data from previous surveys, local knowledge, and expert opinion.

Table 1: Target rare plant species

Rare/sensitive Plants	**Common name**	**Rarity status** (ORNHIC 2007)	**Habit**	**Habitat**	**Phenology**
Achnatherum hendersonii	Henderson's needlegrass	G4 / S2	perennial graminoid	Scablands	May to early June
Asclepias cryptoceras	pallid milkweed	G4 (not tracked)	perennial forb	Heavy clay to gravelly soil at low elevation	April to June
Astragalus diaphanus	transparent milkvetch	G3G4 / S2	annual forb	Sandy washes over basalt	Early June
Carex hystericina	porcupine sedge	G5 / S3	perennial graminoid	Riparian and wetland habitat with hydric soils	July
Castilleja xanthotricha	yellowhair Indian paintbrush	G4 / S4	perennial forb	Dry sagebrush slopes	Late April to early July

Rare/sensitive Plants	Common name	Rarity status (ORNHIC 2007)	Habit	Habitat	Phenology
Chaenactis nevii	John Day's pincushion	G4 / S4	annual forb	Barren hillsides in heavy clay	early May through June
Juncus torreyi	Torrey's rush	G5 / S2	perennial forb	Riparian zone; ephemeral and perennial channels	July and August
Mimulus jungermannioides	liverwort monkeyflower	G3 / S3	perennial forb	Fractures in basalt cliffs; rocky slopes with seepage	Late May to early August
Pediocactus nigrispinus	snowball cactus	G4 / S4	shrub	Ridgetops and gravelly washes	May to June
Penstemon eriantherus var. *argillosus*	fuzzytongue penstemon	G3 / S2	subshrub / forb	Open dry thin soils over basalt	June to July
Silene scaposa var. *scaposa*	Blue Mountain catchfly	G4 (not tracked)	perennial forb	Mountain slopes with sagebrush	May to July
Thelypodium eucosmum	arrow-leaf thelypody	G2 / S2	perennial forb	Lower canyons; seasonally wet steep drainages	May to June

Table 2: Target invasive non-native plant species

Species	Common name	Survey priority
Acroptilon repens	Russian Knapweed	1
Cardaria draba	Whitetop	1
Carduus nutans	Musk Thistle	1
Centaurea diffusa	Diffuse knapweed	1
Centaurea maculosa	Spotted knapweed	1
Centaurea solstitialis	Yellow starthistle	1
Chondrilla juncea	Rush skeleton weed	1
Cirsium arvense	Canada thistle	1
Conium maculatum	Poison hemlock	1
Cynoglosssum officinale	Houndstongue	1
Euphorbia esula	Leafy spurge	1

Species	Common name	Survey priority
Lepidium latifolium	Perennial pepperweed	1
Onopordum acanthium	Scotch Thistle	1
Phalaris arundinacea	Reed canary grass	1
Salvia aethiopis	Mediterranean sage	1
Saponaria officinalis	Bouncing bet	1
Taeniatherum caput-medusae	Medusahead rye	1
Dipsacus fullonum	Teasel	2
Linaria dalmatica	Dalmatian toadflax	2
Linaria vulgaris	Yellow toadflax	2
Melilotus officinalis	Yellow sweetclover	2
Salsola kali	Russian thistle	2
Tribulus terrestris	Puncturevine	2
Verbascum thapsus	Common mullein	2

Survey design

Field data collection was standardized according to NPS protocols for rare plant and weed monitoring. Minimum patch size for field sampling and mapping was identified as 0.01 ha. A systematic survey design was implemented to ensure complete areal coverage of the study area with an associated detection confidence level of 90 percent. Survey transect lines were generated in a GIS to guide field sampling. A preliminary transect spacing or swath width of 40 m was determined from a field reconnaissance of the study area and estimated maximum ocular detection distances based on terrain heterogeneity and vegetation structure. A total of 176 parallel transects were generated ranging from 250 m to 3.0 km on a 360 degree azimuth.

Field methods

Handheld pocket PC units (HP iPAQ) equipped with Globalsat bluetooth GPS receivers were used for both field navigation and data recording. ESRI's Arcpad and TNC's Weed Information Management System (WIMS) software were used to facilitate and streamline data collection. Several GIS layers including road locations, terrain contours, NPS boundaries, creeks, and transect lines were displayed in Arcpad and enabled surveyors to accurately locate transect lines, navigate around inaccessible terrain, and survey or digitize the extent of target plant occurrences.

WIMS is a Microsoft Access based relational database application that standardizes data collection and subsequent data management procedures. WIMS provides a windows interface with various data entry forms for field recording of spatial and associated attribute information describing the target plant occurrences. Spatial information includes GIS point data corresponding to plant occurrence centroids and GIS polygon data delineating the areal extent or boundaries of the associated weed or rare plant patches. To ensure spatial accuracy, occurrence centroids were determined from a minimum of 20 GPS-captured satellite coordinates. Maximum PDOP for data capture was set to 8. To increase field survey efficiency, polygons were generally digitized in Arcpad with vertices located subjectively according to the estimated size and orientation of the target plant occurrence or metapopulation. Polygons with limited areal extent were quantitatively surveyed with GPS positional data captured while walking plant occurrence boundaries. Discrete polygons were generated for all plant occurrences spatially disjunct by a distance equal to half the swath width (40 m). A WGS84 datum and a Universal Transverse Mercator (UTM) projection were used for all GPS data capture.

Additional attribute data collected included survey date, species name, plant abundance represented by both foliar cover and number of stems, plant phenology, apparent population trends or viability in the case of rare plants, and additional observations of disturbance or threats. The number of stems was not estimated for graminoids. WIMS subsequently calculated gross and infested areas for each occurrence based on the areal extent of surveyed patches and associated estimates of foliar cover. General plant community types were also identified from observations of dominant vegetation patterns (Table 3).

Table 3: Major vegetation types in the Painted Hills based on field observations

Plant community name	Physiognomic class	Association no.
Achnatherum thurberianum - *Poa secunda*	Herbaceous – Grassland	a14
Annual grassland (*Bromus tectorum* or *Taeniatherum caput-medusae*)	Herbaceous - Grassland	a9
Non-native dominated herbaceous and graminoid vegetation	Herbaceous - Grassland	a10
Pseudoroegneria spicata - *Achnatherum thurberianum*	Herbaceous - Grassland	a6
Pseudoroegneria spicata - *Festuca idahoensis*	Herbaceous - Grassland	a5
Pseudoroegneria spicata - *Poa secunda*	Herbaceous - Grassland	a7
Sporobolus cryptandrus - (*Pseudoroegneria spicata*)	Herbaceous - Grassland	a8
Sporobolus cryptandrus - *Hesperostipa comata*	Herbaceous - Grassland	a18
Thinopyrum intermedium	Herbaceous - Grassland	a15
Barren clay formation	Non-vegetated	a11
Rock outcrop	Non-vegetated	a12

Plant community name	Physiognomic class	Association no.
Juniperus occidentalis / *Pseudoroegneria spicata* - *Festuca idahoensis*	Savanna	a2
Artemisia rigida / *Poa secunda*	Shrubland	a19
Artemisia tridentata ssp. *wyomingensis*	Shrubland	a3
Artemisia tridentata ssp. *wyomingensis* - *Salvia dorrii*	Shrubland	a20
Atriplex confertifolia / *Poa secunda*	Shrubland	a4
Riparian permanent vegetation (*Salix exigua*)	Shrubland	a17
Sarcobatus vermiculatus	Shrubland	a13
Riparian ephemeral vegetation	Herbaceous	a16
Juniperus occidentalis / *Pseudoroegneria spicata* - *Festuca idahoensis*	Woodland	a1

Data processing and verification

Field collected data was transferred from handheld PCs to a WIMS Access database for quality control and management. Occurrence records were reviewed in Access for consistency, missing values, outliers, and data entry error. Occurrence data and associated polygons were subsequently exported from the WIMS database into a GIS environment for mapping and spatial analyses. Occurrence records with potential errors were revisited in May and June of 2008 for data validation.

RESULTS

Field surveys

Field surveys conducted in the spring and summer of 2007 provided complete coverage of the area of the Painted Hills unit of John Day Fossil Beds National Monument. A preliminary transect width of 40 m was increased to 80 m to compensate for reduced survey rates associated with high weed densities and enable project completion within budget constraints and the temporal flowering window of the target plants. A total of 88 transects ranging in length from 250 m to 3.0 km were completed over 18 days of field data collection conducted between April 23 and May 14. Two additional days of field surveys were conducted in mid August to sample occurrences of *Juncus torreyi* in the riparian zone of Bridge Creek. Three one person crews completed all surveys. A total of 1125 occurrences of rare plants and 1364 occurrences of non-native species were observed and quantified.

Rare plant summary

A total of 5 rare plant species were identified in the 2007 field surveys (Tables 4 and 5). Several species including *Castilleja xanthotricha*, *Chaenactis nevii*, *Juncus torreyi*, and *Pediocactus nigrispinus*

are endemic to the region. A total of 1125 occurrences were identified and quantified in 2007. Collectively, rare plant occurrences occupied a total area of 44.4 ha with a mean patch size of 0.03 ha. Generally, these populations appear to be stable with large plant numbers and few apparent threats affecting their continued viability.

Follow-up data verification surveys conducted in the spring of 2008 generally corroborated mapping results from 2007. An *Achnatherum hendersonii* occurrence was misidentified in 2007, or incorrectly recorded, and revised to *Acroptilon repens* following a revisit in 2008.

Table 4: Biotic parameters of observed rare plant occurrences

Species	**No of occurrences**	**Patch size** (mean # of plants/ occurrence)	**Cover** (mean %)	**Areal extent of patches** (ha/occurrence)			**Plant height** (cm)	**Veg Type** (see Table 3)
				Mean	**Range**	**Total** (ha)		
Castilleja xanthotricha	307	15	<1	0.04	0.0004-0.79	11.9	5-20	a7; a6; a4
Chaenactis nevii	374	380	<1	0.1	0.002-1.3	25.3	0-10	a4; a11
Juncus torreyi	244	18	<1	0.008	0.0004-0.03	2.0	20-40	a17
Pediocactus nigrispinus	191	6	<1	0.03	0.0001-0.6	5.2	5-15	a2, a7
Penstemon eriantherus var. *argillosus*	8	3	<1	0.002	0.0004-0.006	0.01	25-30	a1; a5; a16
Total	**1124**	**84**	**<1**	**0.04**	**0.0001-1.3**	**44.4**		

Table 5: Abiotic environment of rare plant populations

Species	**Elevation (m)**		**Slope (deg)**		**Aspect (deg)**	**Habitat**
	mean	**range**	**mean**	**range**	**range**	
Castilleja xanthotricha	2271	1919 -2897	12	1-36	1-359	ridge tops and upper hill slopes
Chaenactis nevii	2073	1910 -2389	8	0-38	1-358	lower slopes of clay hills

Species	Elevation (m)		Slope (deg)		Aspect (deg)	Habitat
	mean	range	mean	range	range	
Juncus torreyi	1957	1916 -2038	2	0-11	1-358	stream terraces
Pediocactus nigrispinus	2505	1946 -2966	14	1-36	230-116	rocky ridges
Penstemon eriantherus var. *argillosus*	2353	2077 -2658	13	6-40	40-61; 225-338	steep ridges; rocky drainages

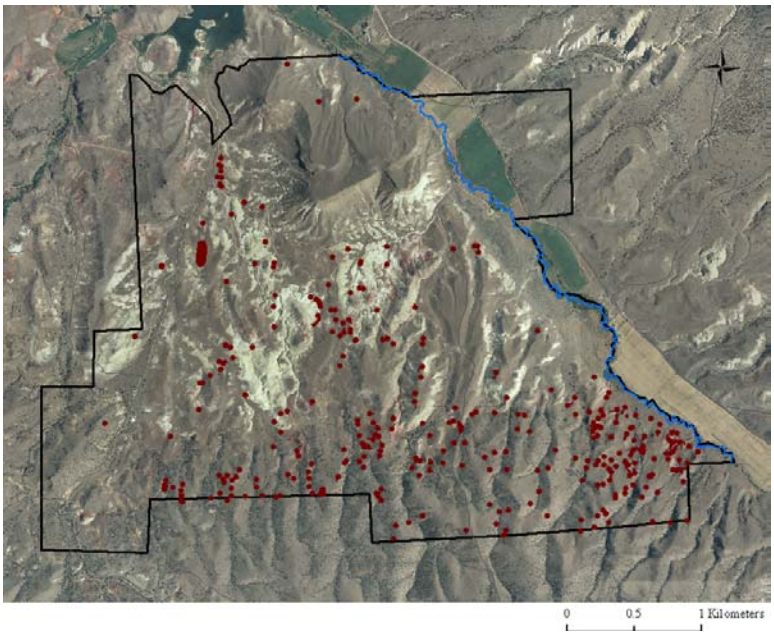
Castilleja xanthotricha

Figure 2: *Castilleja xanthotricha* in a sparse *Atriplex confertifolia - Chrysothamnus viscidiflorus* shrubland on the perimeter of a clay hillside.

Castilleja xanthotricha is widespread at the Painted Hills with a total of 307 spatially distinct occurrences observed in 2007 (Table 4). The highest plant densities occurred on hill slopes and ridges in the southern reaches of the unit (Figure 3). Occurrences were comprised of an average of 15 plants and occupied an average areal extent of 0.04 ha. Elevations ranged from 1919 m on lower toe slopes to 2897 m on the upper ridges at the southern Painted Hills boundary (Table 5). Aspects were variable.

Castilleja xanthotricha occurrences were generally associated with *Pseudoroegneria spicata - Achnatherum thurberianum* and *Pseudoroegneria spicata - Poa secunda* grasslands or savannas. Scattered occurrences occupied the perimeter of barren clay hillsides, which were often characterized by *Atriplex confertifolia* shrublands. *Bromus tectorum* (cheat grass) was the principal non-native species present. The large *C. xanthotricha* population is currently stable at the Painted Hills.

Figure 3: Distribution of *Castilleja xanthotricha* occurrences at the Painted Hills.



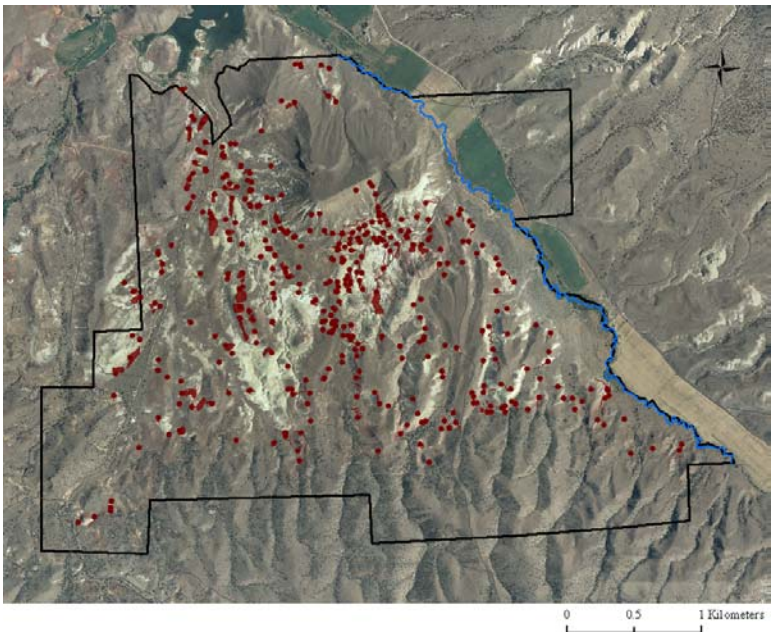
Chaenactis nevii

Figure 4: A large C*haenactis nevii* occurrence on a barren clay hillside with *Cleome platycarpa* (golden spiderflower).

C*haenactis nevii* is an annual forb with a short lifecycle constrained by extreme summer temperatures and aridity. This species is endemic to the region, and widespread and abundant at the Painted Hills (Figure 5). Surveys conducted in the spring of 2007 preceded peak germination times for C*haenactis nevii*. Maximum areal extent and population size were therefore underestimated. A total of 374 occurrences were identified and comprised, on average, of an estimated 380 individuals. The mean areal extent of each occurrence was 0.1 ha (Table 4). Occurrences were associated with exposed clay paleosols and generally restricted to the margins of barren hillsides. Scattered occurrences also occupied rocky substrates on steep slopes. *Chaenactis nevii* apparently tolerates the shrink/swell tendencies of associated clay substrates, which limits the establishment of competing plant species. Elevations ranged from 1910 to 2389 m (Table 5).

Chaenactis nevii is primarily associated with sparsely vegetated *Atriplex confertifolia* / *Poa secunda* shrublands. The most common non-native plant components in these communities include the graminoids *Bromus tectorum* and *Taeniatherum caput-medusae*. The C*haenactis nevii* population is large and apparently stable at the Painted Hills.

Figure 5: Distribution of *Chaenactis nevii* occurrences at the Painted Hills.



Juncus torreyi

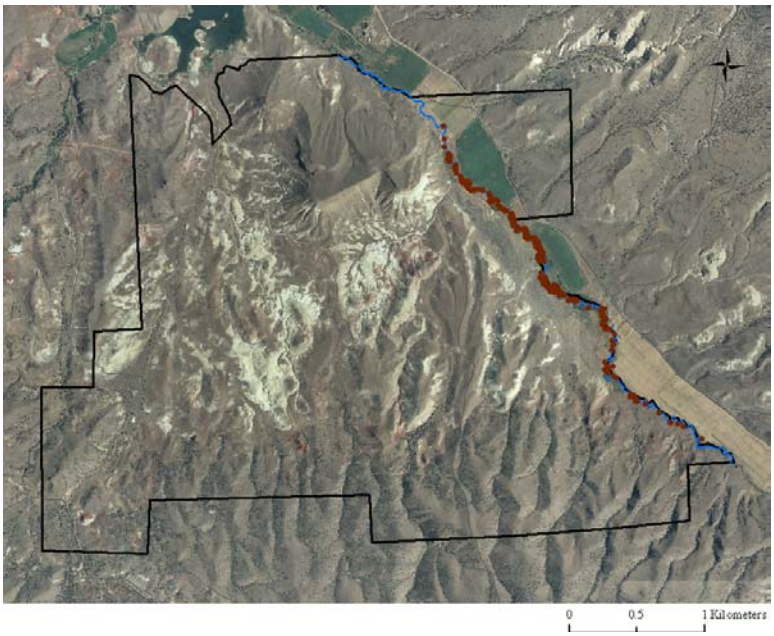
Figure 6: *Juncus torreyi* on Bridge Creek with *Melilotus officinalis* in a plant community characterized by *Salix exigua.*

Juncus torreyi is associated with perennial stream flow and is abundant on terraces adjacent to Bridge Creek on the northeastern boundary of the Painted Hills (Figure 7). A total of 244 distinct occurrences were identified comprised of an average of 18 plants per occurrence (Table 4). The mean area occupied by each occurrence was less than 0.01 ha. Elevations within the drainage range from 1916 to 2038 m (Table 5).

The most extensive plant community occupying the riparian zone of Bridge Creek is a tall shrubland dominated by *Salix exigua* (Coyote willow). Non-native species proliferate with adjacent agricultural fields providing large source populations. The most common invasive species include *Melilotus officinalis*, *Cirsium arvense*, *Cardaria draba*, and *Elaeagnus angustifolia*. The non-native graminoids *Phalaris arundinacea* and *Arrhenatherum elatius* (tall oatgrass) are also abundant.

Field surveys and observations of downstream reaches of Bridge Creek indicate that cattle grazing has extirpated *J. torreyi* from riparian habitat outside the fenced northern park boundary. The population within the park boundary remains large, however, and is apparently tolerating shading and competition from abundant non-native plants.

Figure 7: Distribution of *Juncus torreyi* occurrences at the Painted Hills.



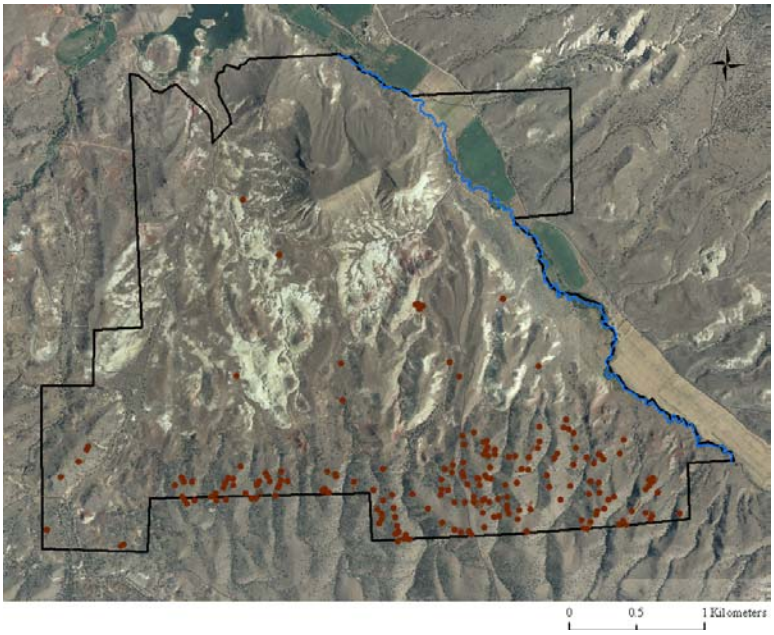
Pediocactus nigrispinus

Figure 8: *Pediocactus nigrispinus* in flower on a high elevation rocky ridge with *Achnatherum thurberianum* (Thurber's needlegrass).

Pediocactus nigrispinus is abundant on upper hill slopes and ridges in the southern regions of the Painted Hills (Figure 9). A few scattered plants were observed on shallowly sloping valley bottom sites. All occurrences were strongly associated with rocky microsites. A total of 191 occurrences were identified in 2007. An average colony consisted of 6 plants. The mean areal extent of an occurrence was 0.03 ha (Table 4). Elevations ranged from 1946 m for valley bottom plants to 2966 m on the highest ridges at the southern boundary (Table 5). Aspects were variable.

The most common plant communities associated with *Pediocactus nigrispinus* were *Juniperus occidentalis* / *Pseudoroegneria spicata* - *Poa secunda* woodlands. Scattered ridge-top occurrences were also associated with *Juniperus occidentalis* / *Artemisia rigida* associations. Few non-native species were present in upland habitats. In contrast, valley bottom sites were often dominated by non-native plants including *Taeniatherum caput-medusae*, *Cardaria draba*, and *Acroptilon repens*. The overall population of *P. nigrispinus* is large and stable and no apparent threats to its future viability were observed.

Figure 9: Distribution of *Pediocactus nigrispinus* occurrences at the Painted Hills.



Penstemon eriantherus* var. *argillosus

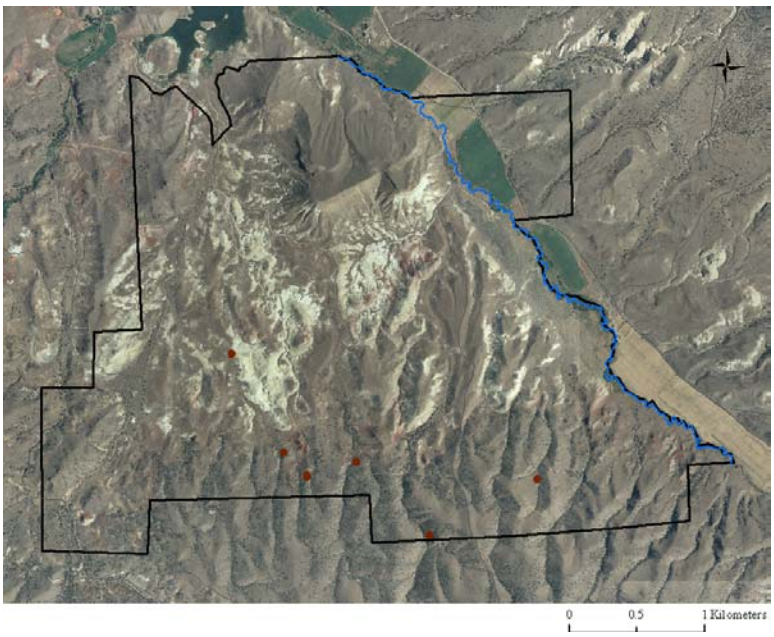
Figure 10: *Penstemon eriantherus* var. *argillosus* in a burned shallow drainage dominated by invasive non-native species.

Penstemon eriantherus var. *argillosus* occurs infrequently at the Painted Hills. A total of eight occurrences were observed in 2007 (Figure 11). Patches were relatively small with an average of 6 plants per occurrence occupying an average area of 0.002 ha (Table 4). Plants were generally associated with rocky substrates on ridges or in drainage areas with elevated seasonal moisture availability. Elevations ranged from 2077 to 2658 m (Table 5).

Penstemon eriantherus var. *argillosus* is most commonly associated with *Juniperus occidentalis* / *Artemisia tridentata* spp. *wyomingensis* woodlands. No significant population viability threats were observed.

Field surveys conducted in 2007 preceded the peak flowering interval of P. *eriantherus* var. *argillosus*. However, subsequent surveys conducted in the late spring of 2008 did not identify additional occurrences.

Figure 11: Distribution of *Penstemon eriantherus* var. *argillosus* occurrences at the Painted Hills



Non-native plant summary

Non-native invasive plant species are ubiquitous and abundant in all low elevation habitats of the Painted Hills. A total of 15 non-native plant species were sampled in the 2007 field surveys and an associated 1364 occurrences were quantified and mapped (Tables 6 and 7). Collectively, invasive weed species occupied a total area of 94.5 ha with a mean patch size of 0.07 ha. Roads and creeks appear to function as dispersal vectors. More than 80 % of all weed patches occur within 400 m of roads, trails, and stream channels. In contrast, relatively isolated high elevation hillslope and ridge-top habitats in southern regions of the unit currently support relatively few weed populations.

Follow-up data verification surveys conducted in 2008 generally corroborated mapping results from 2007. A single occurrence of *Carduus nutans* recorded in 2007 was revised to *Cirsium arvense* following a 2008 revisit.

Table 6: Biotic parameters of observed non-native plant occurrences

Species	**No of occurrences**	**Population size** (mean # of plants/ occurrence)	**Cover** (mean %)	**Areal extent of patches** (ha/occurrence)			**Plant height** (cm)	**Veg Type**
				Mean	**Range**	**Total** (ha)		
Acroptilon repens	181	122	4	0.04	0.0004-2.1	6.1	10-20	a13; a10; a15; a3; a17
Cardaria draba	257	154	6	0.03	0.0004-0.7	8.4	10-20	a13; a10; a15; a3; a17
Centaurea solstitialis	8	45	6	0.7	0.0009-4.9	5.0	20-30	a17; a9
Cirsium arvense	33	40	3	0.006	0.001-0.02	0.2	15-30	a17; a16
Cirsium vulgare	4	7	<1	0.002	0.0006-002	0.005	20-30	a1
Crataegus monogyna	1	2	<1	0.002	-	0.002	300	a17
Cynoglossum officinale	7	5	2	0.007	0.0002-0.02	0.05	10-20	a17
Dipsacus fullonum	16	59	2	0.02	0.0002-0.03	0.3	50-200	a16; a1

Species	No of occurrences	Population size (mean # of plants/ occurrence)	Cover (mean %)	Areal extent of patches (ha/occurrence)			Plant height (cm)	Veg Type
				Mean	Range	Total (ha)		
Elaeagnus angustifolia	43	4	4	0.008	0.0002-0.04	0.3	10-500	a16; a17
Melilotus officinalis	262	133	7	0.02	0.0003-0.2	3.5	30-180	a17; a16; a18; a10; a13
Onopordum acanthium	33	13	3	0.002	0.0001-0.01	0.4	20-70	a1; a16; a18
Phalaris arundinacea	61	-	22	0.01	0.002-0.04	0.2	100-150	a16; a17
Polypogon monspeliensis	2	-	2	0.004	0.002-0.006	0.004	5-15	a17; a3
Taeniatherum caput-edusae	445	-	14	0.2	0.0001-0.5	69.8	5-15	a10; a4; a3; a13; a9; a2
Verbascum thapsus	10	71	7	0.02	0.002-0.05	0.2	15-150	a18; a16
TOTAL	**1364**			**0.07**		**94.5**		

Table 7: Abiotic environment of non-native plant populations

Species	Elevation (m)		Slope (deg)		Aspect (deg)	% of occurrences adjacent to roads, creeks, or trails			Ave road dist (m)	Ave creek dist (m)
	mean	range	mean	range		100m	200m	400m		
Acroptilon repens	2036	1893-2435	5	0-20	0-354	33	65	93	275	575
Cardaria draba	2071	1893-2398	6	0-27	1-356	43	61	87	260	900
Centaurea solstitialis	1950	1916-2047	4	0-11	4-90	88	100	100	166	8
Cirsium arvense	1977	1933-2238	3	0-24	0-341	97	100	100	187	153
Cirsium vulgare	2327	2185-2402	13	5-21	17-315	0	0	25	581	684
Crataegus monogyna	1936	-	4	-	14	100	100	100	56	56
Cynoglossum officinale	1971	1939-2024	2	0-8	1-225	100	100	100	140	7
Dipsacus fullonum	2366	2166-2644	14	3-31	5-354	6	6	31	585	1361
Elaeagnus angustifolia	2029	1910-2536	5	0-23	320-60	77	81	91	251	164
Melilotus officinalis	2000	1896-2238	3	0-18	1-358	88	97	99	105	780
Onopordum acanthium	1983	1916-2238	3	0-24	0-350	85	91	100	161	242
Phalaris arundinacea	1967	1936-2244	3	0-14	1-353	98	98	100	219	11

Species	Elevation (m)		Slope (deg)		Aspect (deg)	% of occurrences adjacent to roads, creeks, or trails			Ave road dist (m)	Ave creek dist (m)
	mean	range	mean	range		100m	200m	400m		
Polypogon monspeliensis	2126	1982-2270	9	6-12	264-332	100	100	100	39	713
Taeniatherum caput-medusae	2143	1900-2451	8	0-30	-357	0	43	75	336	1686
Verbascum thapsus	2064	1959-2129	5	2-10	0-126	100	100	100	31	2603
TOTAL						**63**	**71**	**81**	**242**	**652**

Acroptilon repens

Figure 12: *Acroptilon repens* on a recently burned hilltop at intermediate elevations co-occurring with *Bromus tectorum*.

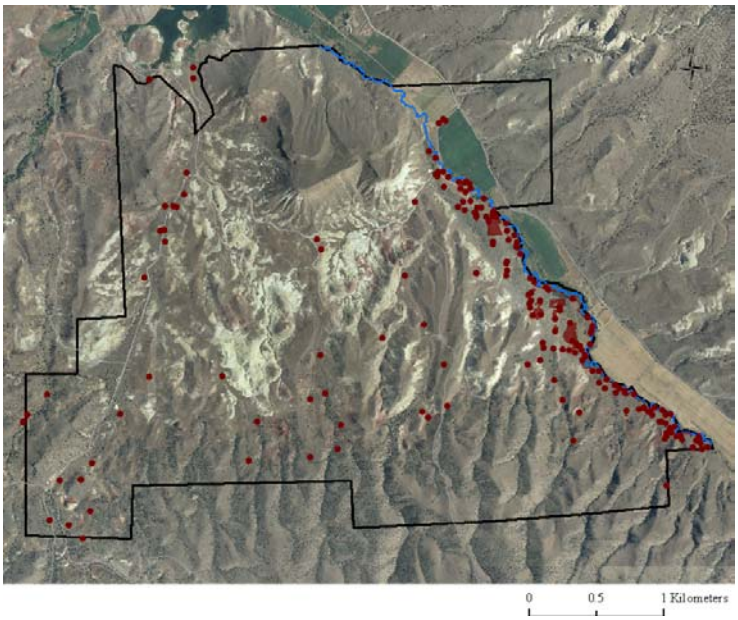
Acroptilon repens is abundant and widespread at low elevations in the Painted Hills (Figure 13). A total of 181 occurrences were observed in 2007. The total areal extent of all occurrences was 6.1 ha (Table 6) and an estimated average of 122 plants comprised each occurrence. Mean foliar cover was 4%.

Elevations ranged from 1893 to 2435 m and aspects were variable (Table 7). The average distance of an *Acroptilon repens* occurrence to the nearest road or trail was 275 m and 93% of all occurrences were located within 400 m of a road, trail, or Bridge Creek. Upland occurrences were few, limited in areal extent, and primarily associated with scattered burned sites and fire-killed juniper trees.

A majority of occurrences and the highest densities of plants were associated with plant communities occupying the lower flats and terraces of Bridge Creek including non-native *Thinopyrum intermedium* grassland, *Sarcobatus vermiculatus* vegetation, and *Salix exigua* shrubland.

Extensive, dense populations of *Acroptilon repens* were observed outside the park boundaries in riparian areas and in cultivated fields. Seed dispersal from these large source populations may result in the recolonization of habitats managed for weed removal within the Painted Hills unit.

Figure 13: Distribution of *Acroptilon repens* at the Painted Hills.



Cardaria draba

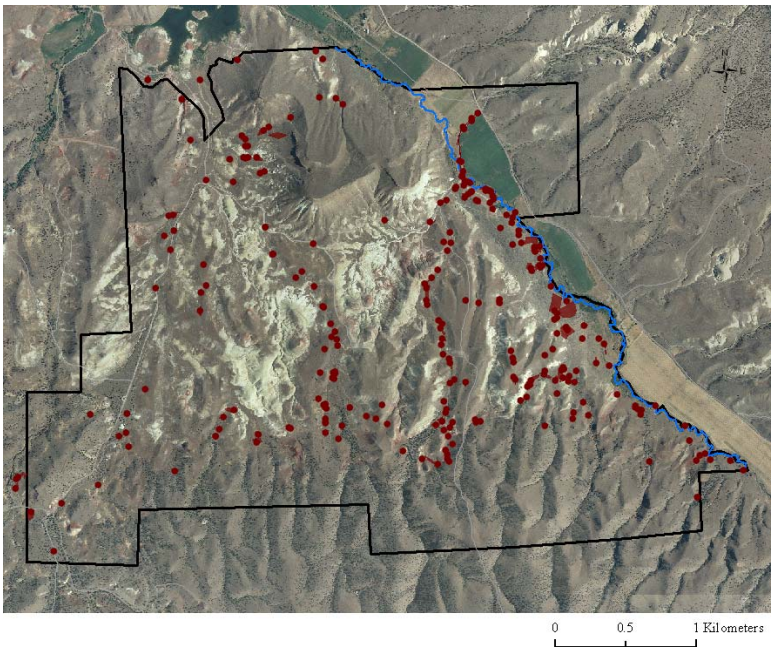
Figure 14: *Cardaria draba* on a terrace of Bridge Creek adjacent to a dense stand of *Typha latifolia* (broadleaf cattail).

Cardaria draba is abundant and widespread at low elevations in the Painted Hills (Figure 15). A total of 257 occurrences were observed in 2007 with an estimated 154 plants comprising each occurrence. The total areal extent of all occurrences was 8.4 ha (Table 6). Mean foliar cover was 6%.

Elevations ranged from 1893 to 2398 m and aspects were variable (Table 7). A majority of plants occupied valley bottom habitats and were strongly correlated with anthropogenic disturbance. The average distance from an occurrence to the nearest road was 260 m and 87 % of all occurrences were located within 400 m of a road, trail, or Bridge Creek (Table 7). Scattered high elevation occurrences were associated with seepage areas or recently burned sites.

Plant communities with significant *Cardaria draba* cover include *Thinopyrum intermedium* vegetation, *Sarcobatus vermiculatus* shrubland, and riparian communities adjacent to Bridge Creek. Large, dense populations of *Cardaria draba* were observed outside park boundaries in riparian areas and in cultivated fields. Continued seed dispersal from these large source populations may result in the recolonization of habitats managed for weed removal within the Painted Hills.

Figure 15: Distribution of *Cardaria draba* occurrences at the Painted Hills.



Centaurea solstitialis

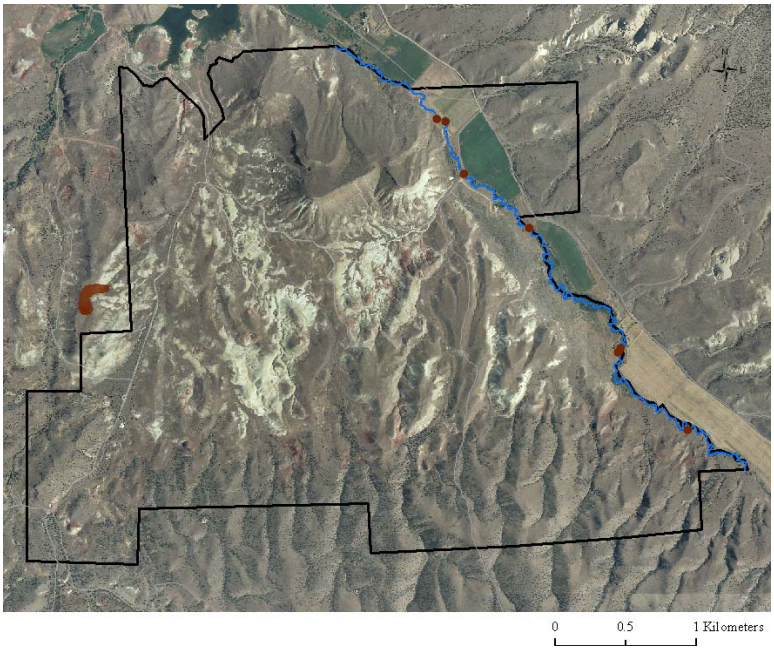
Figure 16: *Centaurea solstitialis* in flower.

Centaurea solstitialis is presently a relatively minor non-native component of the Painted Hills flora in terms of overall distribution and total population size. A total of 8 occurrences were observed in 2007 (Figure 9) occupying an aggregate area of 5.0 ha (Table 6). Occurrences were comprised of 45 plants on average with an estimated foliar cover of 6%. Almost 90% of all occurrences were located within 100 m of Bridge Creek (Table 7). The average distance to Bridge Creek was 8 m. Elevations ranged from 1916 m at Bridge Creek to 2047 m at the western boundary (Table 7).

A large *Centaurea solstitialis* occurrence occupying 4.9 ha and co-occurring with *Taeniatherum caput-medusae* was identified outside the western Painted Hills boundary on BLM land (Figure 17). Additional dense occurrences were observed but not quantified in riparian habitats grazed by livestock along Bridge Creek north of the Painted Hill boundary.

Centaurea solstitialis was primarily associated with mesic sites and stream terraces characterized by *Salix exigua* or *Artemisia tridentata* spp. *wyomingensis* shrubland vegetation.

Figure 17: Distribution of *Centaurea solstitialis* occurrences at the Painted Hills

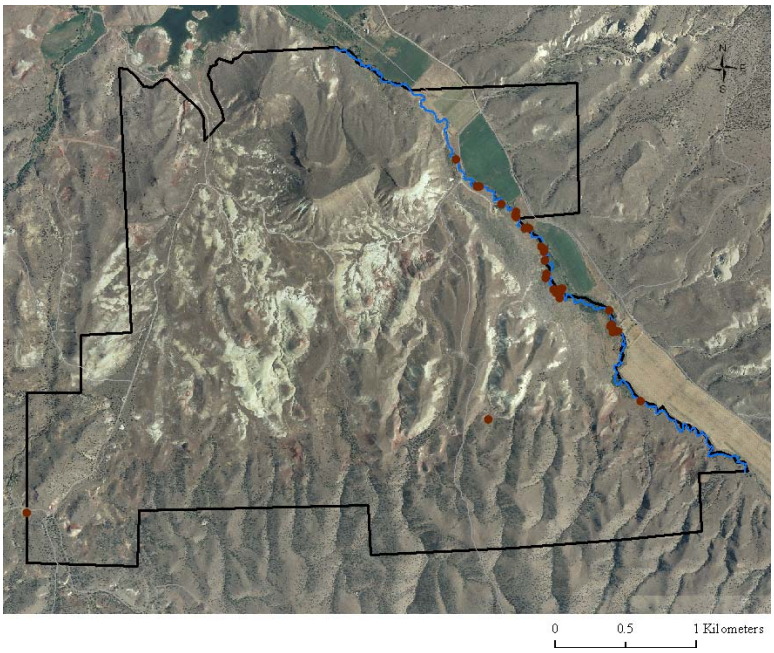


Cirsium arvense

Figure 18: *Cirsium arvense* In flower on a terrace of Bridge Creek.

Cirsium arvense is common on stream terraces adjacent to Bridge Creek and in mesic seeps and draws in upland areas (Figure 19). Surveys conducted in 2007 under-represent its actual distribution. A total of 33 occurrences comprised of an estimated 40 plants per occurrence was surveyed. The combined areal extent of all patches was 0.2 ha. A majority (97%) of occurrences were located within 100 m of Bridge Creek (Table 7). Elevations range from 1933 m at Bridge Creek to 2238 m at an upland occurrence in a seepage area. The predominant associated plant community is *Salix exigua* shrubland.

Figure 19: Distribution of *Cirsium arvense* occurrences at the Painted Hills.



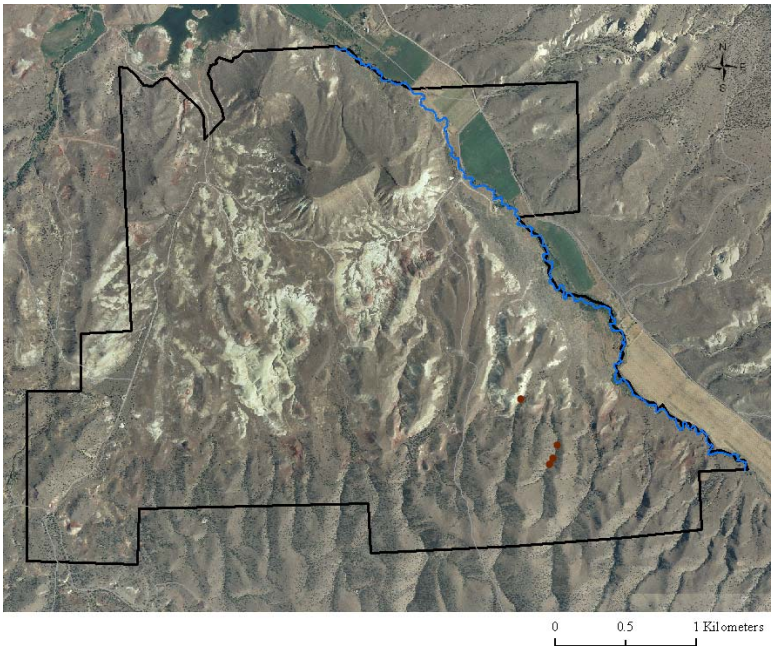
Cirsium vulgare

Figure 20: *Cirsium vulgare* on a terrace of Bridge Creek.

Cirsium vulgare is a relatively minor weed component at the Painted Hills in terms of its impacts to native vegetation and was not prioritized for survey in 2007 due to logistical constraints. Its actual distribution and population size are therefore underrepresented by the survey data. A total of 4 occurrences were quantified (Figure 21) with an average of 7 plants comprising each occurrence. The total areal extent for all occurrences was 0.005 ha (Table 6). Elevations ranged from 2185 to 2402 m and aspects were variable (Table 7).

Qualitative surveys conducted in 2008 indicate that *Cirsium vulgare* is widely distributed in upland seasonally mesic drainages and along stream terraces adjacent to Bridge Creek. Scattered occurrences are also present along roads. Occurrences are generally minor in terms of plant numbers, however. Associated vegetation includes *Juniperus occidentalis* / *Artemisia tridentata* ssp. *wyomingensis* woodlands and *Salix exigua* shrublands.

Figure 21: Location of surveyed *Cirsium vulgare* occurrences at the Painted Hills.

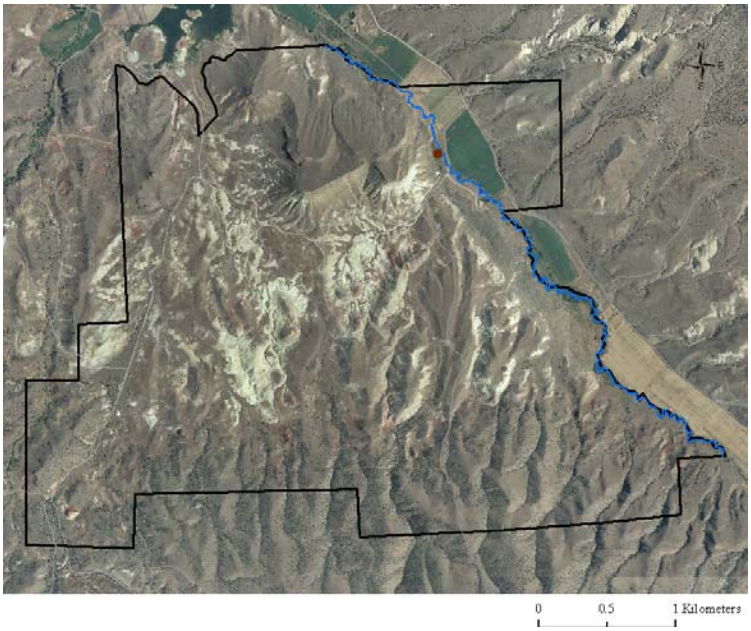


Crataegus monogyna

Figure 22: *Crataegus monogyna*

A single occurrence of *Crataegus monogyna* was observed in 2007. This was not a priority species and is predominantly known from western Oregon, where it frequently forms dense stands in valley bottom habitats. Two stems were identified in the Painted Hills on a stream terrace approximately 56 m from both the main unit access road and Bridge Creek (Figure 23). The elevation was 1936 m.

Figure 23: Distribution of *Crataegus monogyna* occurrences at the Painted Hills.

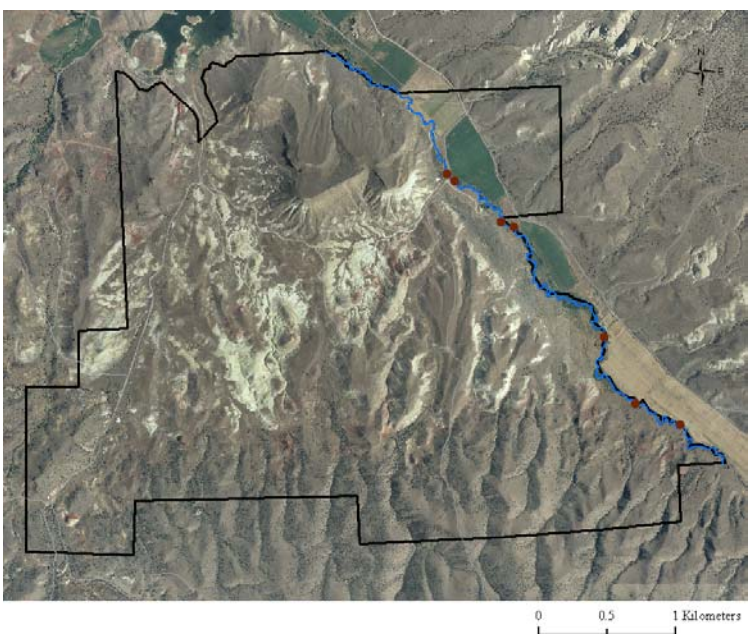


Cynoglossum officinale

Figure 24: *Cynoglossum officinale*

A total of 7 occurrences of *Cynoglossum officinale* were observed and quantified in 2007 (Table 6). Patches were small with an average of 2 plants per occurrence. The mean occurrence extent was 0.007 ha. All occurrences were associated with mesic riparian habitat and were in close proximity to Bridge Creek (Figure 25; Table 7). Elevations ranged from 1939 to 2024 m.

Figure 25: Distribution of *Cynoglossum officinale* occurrences at the Painted Hills.



Dipsacus fullonum

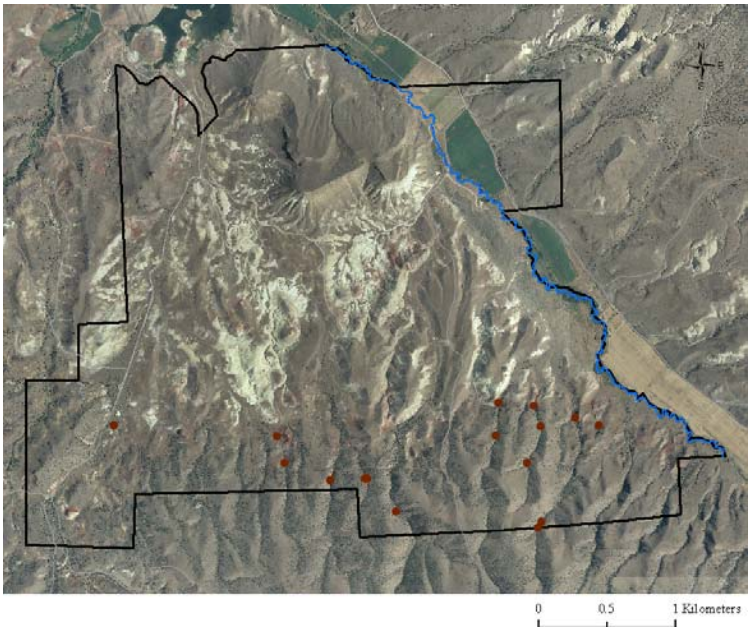
Figure 26: *Dipsacus fullonum* with *Salix exigua* on a floodplain of Bridge Creek.

Dipsacus fullonum was not originally prioritized for mapping and not comprehensively quantified in the 2007 field survey. A total of 16 occurrences were surveyed (Table 6) with an estimated average of 59 plants comprising each occurrence and a total areal extent of 0.3 ha. Elevations ranged from 2166 to 2644 m and aspects were variable (Table 7).

Surveyed occurrences were mainly restricted to high elevation drainages in the southern reaches of the Painted Hills (Figure 27). However, plants were common in all upland seasonally mesic washes and draws as well as in valley bottom riparian habitat adjacent to Bridge Creek (Figure 26).

Dipsacus fullonum plants generally co-occurred with other non-native species including *Melilotus officinalis* and *Verbascum thapsus*. The most common associated plant communities included *Juniperus occidentalis* / *Artemisia tridentata* ssp. *wyomingensis* woodlands on upland slopes, and *Salix exigua* shrubland in valley bottom riparian areas.

Figure 27: Distribution of *Dipsacus fullonum* at the Painted Hills



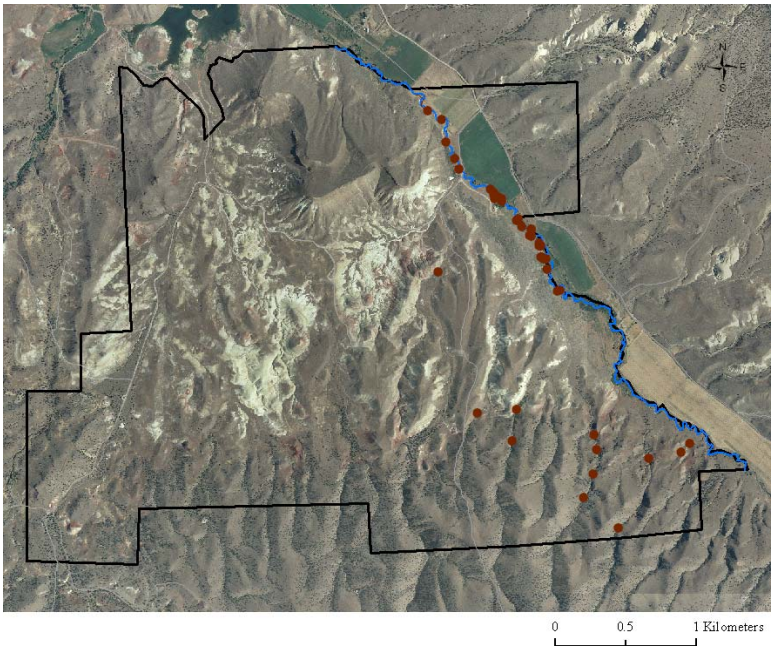
Elaeagnus angustifolia

Figure 28: Dense stand of *Elaeagnus angustifolia* on Bridge Creek adjacent to and just north of the Painted Hills boundary.

Elaeagnus angustifolia occurrences are distributed throughout mesic habitats in the Painted Hills including riparian sites adjacent to Bridge Creek and higher elevation draws in the southeastern hills (Figure 29). A total of 43 occurrences were identified in 2007 with an average of 4 stems per occurrence (Table 6). The estimated total area occupied by all occurrences was 0.3 ha. Elevations ranged from 1910 m at Bridge Creek to 2536 m at the southern unit boundary. Aspects generally ranged from northwest to northeast (Table 7).

Scattered resprouting *E. angustifolia* seedlings were observed on stream terraces adjacent to Bridge Creek where trees had been previously mechanically or chemically treated. Extensive *E. angustifolia* stands comprised of trees with heights exceeding 6 m occur on private land along Bridge Creek just north of the Painted Hills boundary (Figure 28).

Figure 29: Distribution of *Elaeagnus angustifolia* occurrences at the Painted Hills.



Kochia scoparia

Figure 30: *Kochia scoparia* on a terrace of Bridge Creek in June 2008.

Kochia scoparia was not prioritized for field surveys and was not quantitatively sampled in surveys. Its lifecycle does not overlap the spring timing of the data collection. However, qualitative observations from a reconnaissance of the Painted Hills in 2008 indicate that *Kochia scoparia* is widespread with high plant densities on seasonally mesic valley bottom flats and Bridge Creek terraces (Figure 30). It was not observed on hillsides or upland habitats.

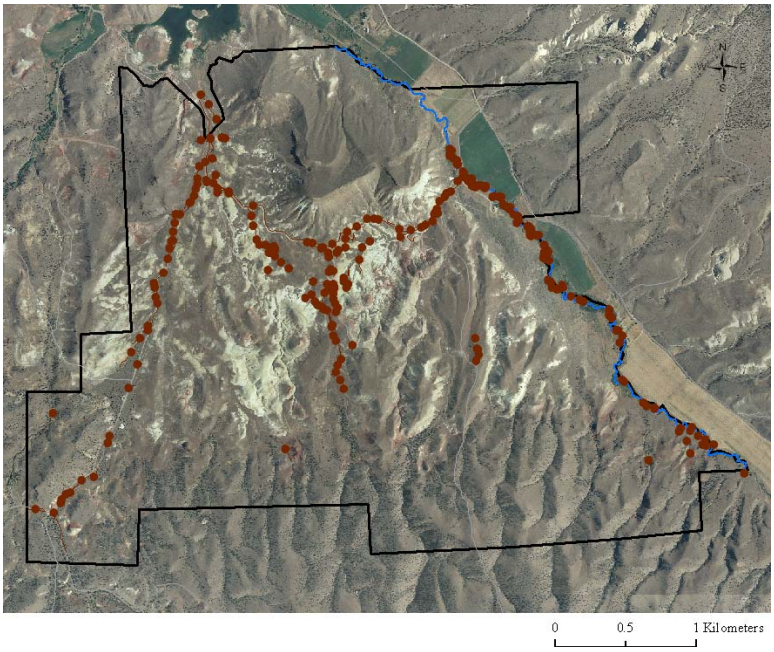
Melilotus officinalis

Figure 31: *Melilotus officinalis* in a shallow draw at low elevation. Surrounding habitat was recently burned and dominated by non-native vegetation.

Melilotus officinalis is ubiquitous in mesic drainages, riparian habitats, and roadside areas at mainly low elevations in the Painted Hills (Figure 32). A total of 262 occurrences were surveyed in 2007 with an estimated population size of 133 plants per occurrence. The total areal extent of all occurrences was 3.5 ha and mean foliar cover was 7% (Table 6). Elevations ranged from 1896 to 2238 m and aspects were variable (Table 7).

The average distance to the nearest road or trail was 105 m and 99% of all occurrences were located within 400 m of a road, trail, or Bridge Creek.

Figure 32: Distribution of *Melilotus officinalis* occurrences at the Painted Hills.



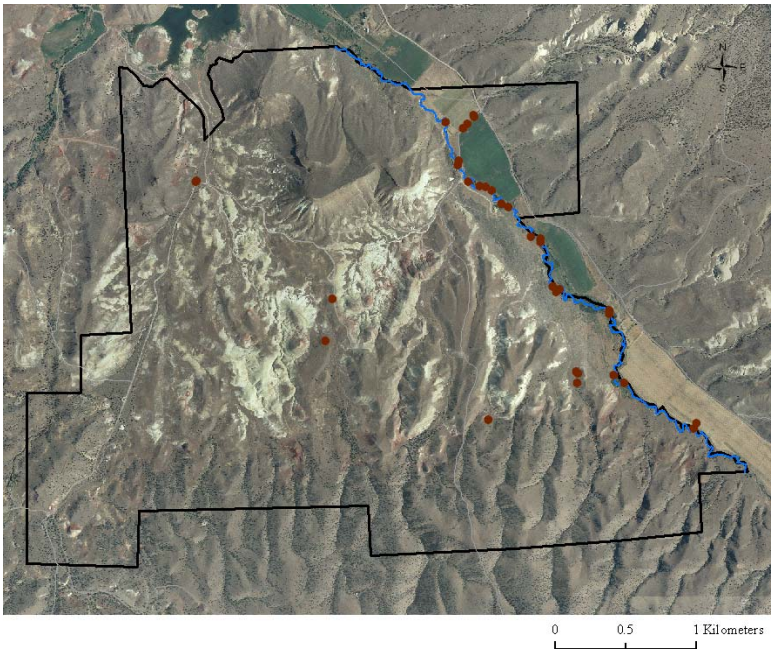
Onopordum acanthium

Figure 33: *Onopordum acanthium* adjacent to a road.

A total of 33 occurrences of *Onopordum acanthium* were identified in 2007 with an estimated population size of 13 plants per occurrence. Mean foliar cover was 3% and the total areal extent of all occurrences was 0.4 ha (Table 6). Elevations ranged from 1916 to 2238 m and aspects were variable (Table 7). The average distance to the nearest road or trail was 161 m and 100% of all occurrences were located within 400 m of a road, trail, or Bridge Creek (Figure 34).

Occurrences were generally associated with mesic or burned habitat adjacent to roads, trails, draws, and Bridge Creek. Associated vegetation included riparian *Salix exigua* shrublands and upland *Juniperus occidentalis* / *Artemisia tridentata* ssp. *wyomingensis* woodlands. Large, dense populations of *Onopordum acanthium* were observed in agricultural fields north of the Painted Hills boundary.

Figure 34: Distribution of *Onopordum acanthium* occurrences at the Painted Hills.

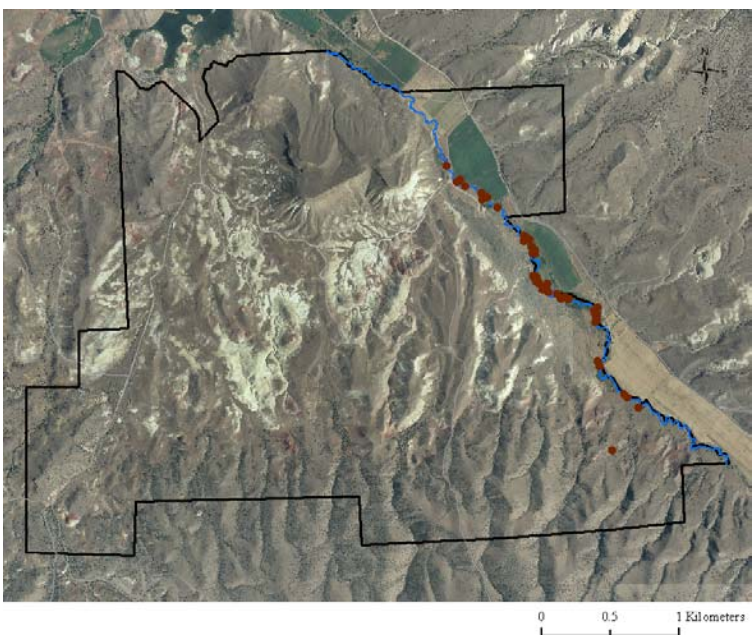


Phalaris arundinacea

Figure 35: *Phalaris arundinacea* colonizing a *Salix exigua* shrubland adjacent to Bridge Creek.

Dense patches of *Phalaris arundinacea* occupy riparian areas adjacent to Bridge Creek (Figure 36). A single occurrence was also observed in a mesic draw at intermediate elevations. A total of 61 occurrences were surveyed in 2007 with a mean foliar cover of 7%. Plant number was not estimated for this species. The total areal extent of all occurrences was 0.2 ha (Table 6). Elevations ranged from 1936 to 2244 m and aspects were variable (Table 7). The average distance to the nearest creek was 11 m and 98% of all occurrences were located within 100 m of a drainage.

Figure 36: Distribution of *Phalaris arundinacea* occurrences at the Painted Hills.

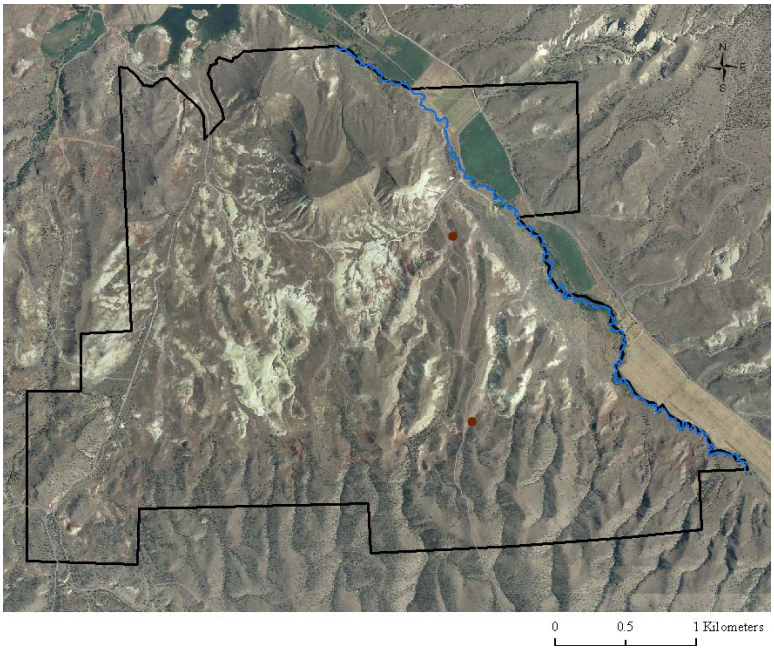


Polypogon monspeliensis

Figure 37: *Polypogon monspeliensis*

Polypogon monspeliensis is uncommon in the Painted Hills. This species was not prioritized for mapping in 2007, but two occurrences were observed in seepage areas at intermediate elevations (Figure 38). Mean foliar cover was 2%. Plant number was not estimated. The total areal extent of all occurrences was 0.004 ha (Table 6). Elevations ranged from 1982 to 2270 m and aspects were west to northwest (Table 7).

Figure 38: Distribution of *Polypogon monspeliensis* occurrences at the Painted Hills



Taeniatherum caput-medusae

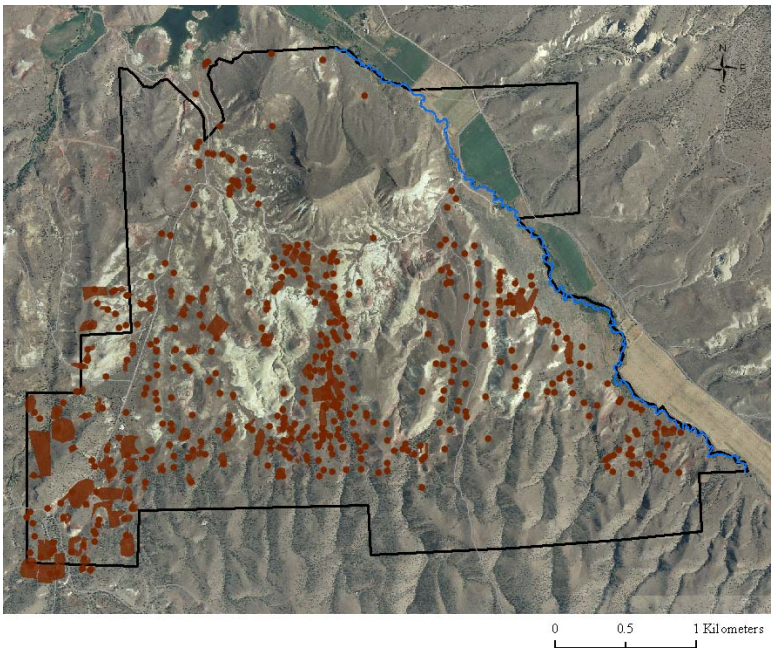
Figure 39: *Taeniatherum caput-medusae* occupying a recently burned patch on a hillside at intermediate elevation. Surrounded by *Pseudoroegneria spicata* herbaceous vegetation.

Taeniatherum caput-medusae is abundant and widespread at the Painted Hills forming dense stands at mainly low elevations (Figure 40). A total of 445 occurrences were surveyed in 2007 with a mean foliar cover of 14%. Plant number was not estimated. The total areal extent of all occurrences was 69.8 ha (Table 6). Elevations ranged from 1936 to 2244 m and aspects were variable (Table 7).

Taeniatherum caput-medusae occupies hillsides, flats, and valley bottom habitats. Occurrence locations were strongly correlated with recent burns (Figure 39). *Taeniatherum caput-medusae* has not established on high elevation hillsides in the southeastern portions of the Painted Hills (Figure 40).

Taeniatherum caput-medusae is present in most vegetation types at the Painted Hills, but reaches maximum densities in *Sarcobatus vermiculatus* shrublands, *Thinopyrum intermedium* grasslands, and some lower elevation *Juniperus occidentalis* woodlands.

Figure 40: Distribution of *Taeniatherum caput-medusae* occurrences at the Painted Hills.



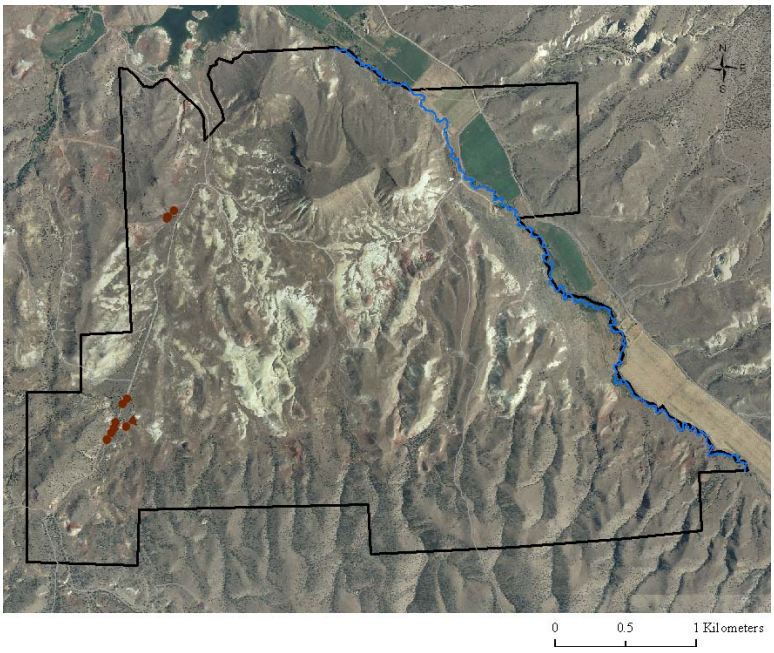
Verbascum thapsus

Figure 41: *Verbascum thapsus* on a rocky hillside with *Artemisia tridentata* spp. *wyomingensis* and *Purshia tridentata*.

Verbascum thapsus was not prioritized for field survey in 2007. Its distribution and population size are therefore not comprehensively quantified (Figure 42). A total of 10 occurrences were mapped from survey data with an estimated patch size of 71 plants per occurrence. The total areal extent of all occurrences was 0.2 ha. Estimated mean foliar cover was 7% (Table 6). Elevations ranged from 1959 to 2129 m (Table 7). All surveyed plants occurred with 100 m of a road.

Supplementary qualitative surveys conducted in the spring of 2008 identified significant additional occurrences at low elevation in the Painted Hills. *Verbascum thapsus* is relatively widely distributed at low elevations in disturbed, burned, or mesic habitats. *Verbascum thapsus* is also scattered in seasonally mesic drainages at intermediate to high elevations. Associated vegetation types include *Artemisia tridentata* spp. *wyomingensis* and *Salix exigua* shrublands at low elevations, and *Juniperus occidentalis* woodlands at high elevations.

Figure 42: Distribution of *Verbascum thapsus* occurrences at the Painted Hills surveyed in 2007.



DISCUSSION

Limitations of data

Accurate quantification of endemic plant population size was constrained by high species abundances and a lack of congruence between the phenologies of the target plants. For example, occurrences with extremely high plant densities were semi-quantitatively surveyed using ocular estimates of total plant number. Field surveys also occurred prior to the peak germination period for *Chaenactis nevii* and *Penstemon eriantherus* var. *argillosus* and therefore underestimated actual population sizes.

Future viability of rare plants and potential threats

A majority of the rare plant species mapped at the Painted Hills are widespread and currently stable within the park. *Castilleja xanthotricha*, *Chaenactis nevii*, and *Pediocactus nigrispinus* are abundant with several hundred spatially distinct occurrences. Associated habitats occur primarily at high elevations and have been insulated from anthropogenic-related disturbance by physical isolation.

Two rare species, *Penstemon eriantherus* var. *argillosus* and *Juncus torreyi*, may require additional future monitoring. *Penstemon eriantherus* var. *argillosus* is uncommon and sometimes associated with disturbed habitats dominated by exotic species. *Juncus torreyi* occupies highly disturbed riparian areas adjacent to Bridge Creek and co-occurs with dense populations of competing non-native invasive species, such as *Melilotus officinalis* and *Phalaris arundinacea*. However, high current *Juncus torreyi* plant densities suggest species persistence. The interspersion of *Juncus torreyi* and non-native species, and the proximity to Bridge Creek limits the potential for targeted herbicide treatment.

Potential future threats to the persistence of endemic plant species and associated plant communities may include alterations in disturbance regimes related to vegetation management or climate change. Plant communities occupying high elevation sites in the southeastern portions of the Painted Hills are currently dominated by native graminoids including *Achnatherum thurberianum*, *Festuca idahoensis*, and *Pseudoroegneria spicata*. Non-native forbs such as *Acroptilon repens* and *Cardaria draba* and weedy grasses including *Taeniatherum caput-medusae* and *Bromus tectorum* are sparse and generally associated with scattered burned sites and juniper snags killed by recent fire. Invasive non-native species colonizations have been previously associated with disturbance events including fire (Hobbs and Huenneke 1992; DiTomaso 2000), suggesting that management prescriptions involving fire may have the potential to promote weed expansion in these areas. Associated increases in non-native species may subsequently promote future fire occurrence, reduce natural fire intervals (Mack and D'Antonio 1998), and potentially further alter native plant community composition by, for example, causing fire-related decreases in *Artemisia tridentata* cover (Booth et al. 2003).

Hot spots for weeds

The most abundant weed species currently occupying the Painted Hills include *Acroptilon repens*, *Cardaria draba*, *Melilotus officinalis*, *Phalaris arundinacea*, and *Taeniatherum caput-medusae*. The highest weed densities occur in low elevation habitats along road corridors, in seasonally mesic valley bottom draws, and on stream terraces associated with Bridge Creek. Over 80 percent of all non-native species occurrences are located with 400 meters of a road or creek suggesting that these features function as dispersal vectors for weed propagules. Roads may also facilitate non-native species establishment and spread by concentrating runoff and enhancing adjacent soil moisture reservoirs (Gelbard and Belnap 2003).

Large dense populations of *Acroptilon repens*, *Cardaria draba*, and *Onopordum acanthium* were observed in riparian areas and agricultural fields to the east and north of the Painted Hills boundary.

Elaeagnus angustifolia and *Centaurea solstitialis* were also abundant in the heavily degraded Bridge Creek channel north of the Painted Hills unit. Any weed management activity restricted to the interior of the unit will be hampered by continued seed dispersal from these large source populations.

Recommendations

Continued monitoring using standardized methods is recommended in order to quantitatively measure temporal changes in both rare and non-native plant distributions and to also assess the efficacy of treatment prescriptions. A complementary inventory of rare and weed plant populations in the Clarno and Sheep Rocks units of John Day Fossil Beds would provide the NPS with comprehensive baseline data to support future monitoring and early detection of additional non-native plant species introductions or emerging threats to native plant communities.

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