

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



Report to the National Park Service

Task Agreement No. J8W07060015

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February 2008

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INTRODUCTION

The vegetation of the Painted Hills unit of John Day National Monument is shaped in part by extreme climatic aridity and the presence of unstable clay-rich soils or 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 pristine native plant communities with sparse non-native plant cover and 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 considered 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 United 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 describing long-term changes in the structure and function of plant communities impacted by invasive species (Lonsdale 1999; West 2003; Clark et al. 2005). The objective of this study was to conduct 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. This report summarizes data collected during the 2007 field season.

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 management.

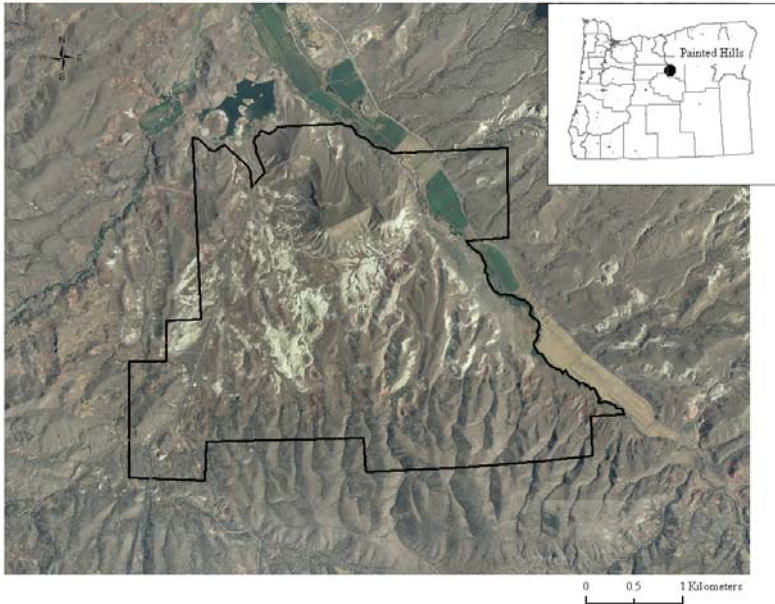
METHODS

Study area

The Painted Hills is one of three spatially disjunct units comprising John Day 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 or 1267.5 ha. Vegetation patterns and plant community composition are determined in part by climatic aridity and unstable, moisture limiting soils exposed by long term weathering processes. Steep-sided clay hills comprise major portions of the unit and are heavily dissected by gullies and seasonally dry washes. Annual precipitation ranges from 9 to 12 inches.

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. The study area, terrain, and vegetation were assessed during a partial reconnaissance to assist subsequent field survey planning and design. Project objectives and appropriate field survey methods required to achieve objectives 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
<i>Achnatherum hendersonii</i>	Henderson's needlegrass	G4 / S2	perennial graminoid	Dry, rocky soil in sagebrush and juniper woodland	July to August
<i>Asclepias cryptoceras</i>	pallid milkweed	G4 (not tracked)	perennial forb	Heavy clay to gravelly soil at low elevation	April to June
<i>Astragalus diaphanus</i>	transparent milkvetch	G3G4 / S2	annual forb	Sandy washes over basalt	Early June
<i>Carex hystericina</i>	porcupine sedge	G5 / S3	perennial graminoid	Riparian and wetland habitat with hydric soils	July

Rare/sensitive Plants	Common name	Rarity status (ORNHIC 2007)	Habit	Habitat	Phenology
<i>Castilleja xanthotricha</i>	yellowhair Indian paintbrush	G4 / S4	perennial forb	Dry sagebrush slopes	Late April to early July
<i>Chaenactis nevii</i>	John Day's pincushion	G4 / S4	annual forb	Barren hillsides in heavy clay	early May through June
<i>Juncus torreyi</i>	Torrey's rush	G5 / S2	perennial forb	Riparian zone; ephemeral and perennial channels	July and August
<i>Mimulus jungermanniioides</i>	liverwort monkeyflower	G3 / S3	perennial forb	Fractures in basalt cliffs; rocky slopes with seepage	Late May to early August
<i>Pediocactus nigrispinus</i>	snowball cactus	G4 / S4	shrub	Ridgetops and gravelly washes	May to June
<i>Penstemon eriantherus</i> var. <i>argillosus</i>	fuzzytongue penstemon	G3 / S2	subshrub / forb	Open dry thin soils over basalt	June to July
<i>Silene scaposa</i> var. <i>scaposa</i>	Blue Mountain catchfly	G4 (not tracked)	perennial forb	Mountain slopes with sagebrush	May to July
<i>Thelypodium eucosmum</i>	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
<i>Acroptilon repens</i>	Russian Knapweed	1
<i>Cardaria draba</i>	Whitetop	1
<i>Carduus nutans</i>	Musk Thistle	1
<i>Centaurea diffusa</i>	Diffuse knapweed	1
<i>Centaurea maculosa</i>	Spotted knapweed	1
<i>Centaurea solstitialis</i>	Yellow starthistle	1
<i>Chondrilla juncea</i>	Rush skeleton weed	1
<i>Cirsium arvense</i>	Canada thistle	1
<i>Conium maculatum</i>	Poison hemlock	1
<i>Cynoglossum officinale</i>	Houndstongue	1

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

Survey design

Field data collection procedures were designed to meet NPS inventory and monitoring objectives for identifying both rare and non-native invasive plant species occurrences with areal extents of 0.01 ha and larger. A systematic survey design was therefore implemented to ensure complete areal coverage of the study area with a detection confidence level of 90 percent. Survey transects were generated in a GIS with a preliminary spacing of 40 m between adjacent transect lines to guide field surveys. The initial transect or swath width was determined from a field reconnaissance of the study area and estimated average maximum 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

Field data collection was standardized according to NPS protocols for rare plant and weed monitoring. 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 population 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 population or metapopulation. Polygons with limited areal extent were quantitatively surveyed with GPS data captured while walking plant occurrence boundaries. Discrete polygons were generated for all plant occurrences spatially separated 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 species name, date, 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 estimates of foliar cover. Coarse plant community types were also identified according to the dominant vegetation patterns observed during field surveys (Table 3).

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

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

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

Data processing

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 and field data entry accuracy. Occurrence data and associated polygons were subsequently exported from the WIMS database as GIS shapefiles for mapping and spatial analyses in a GIS environment.

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 National Monument. A preliminary transect width of 40 m was expanded 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 identify 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 6 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 numbers of plants and few apparent threats affecting their continued viability.

Table 4: Biotic parameters of observed rare 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 (see Table 3)
				Mean	Range	Total		
<i>Achnatherum hendersonii</i>	1	50	5	0.01		0.01	50	a17
<i>Castilleja xanthotricha</i>	307	15	<1	0.04	0.0004-0.79	11.9	5-20	a7; a6; a4
<i>Chaenactis nevii</i>	374	380	<1	0.1	0.002-1.3	25.3	0-10	a4; a11
<i>Juncus torreyi</i>	244	18	<1	0.008	0.0004-0.03	2.0	20-40	a17
<i>Pediocactus nigrispinus</i>	191	6	<1	0.03	0.0001-0.6	5.2	5-15	a2, a7
<i>Penstemon eriantherus</i> var. <i>argillosus</i>	8	3	<1	0.002	0.0004-0.006	0.01	25-30	a1; a5; a16
Total	1125	79	<1	0.03	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	
<i>Achnatherum hendersonii</i>	1952	-	3	-	56	stream terrace
<i>Castilleja xanthotricha</i>	2271	1919-2897	12	1-36	1-359	ridge tops and upper hill slopes
<i>Chaenactis nevii</i>	2073	1910-2389	8	0-38	1-358	lower slopes of clay hills

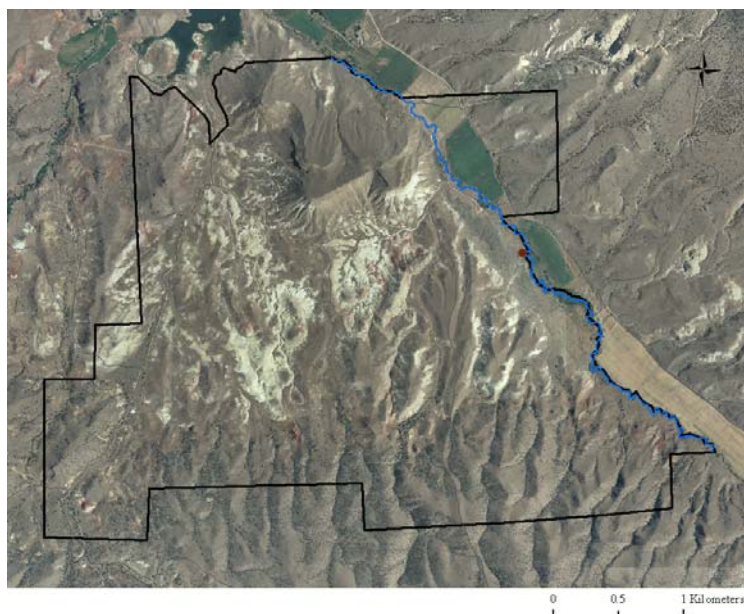
Species	Elevation (m)		Slope (deg)		Aspect (deg)	Habitat
	mean	range	mean	range	range	
<i>Juncus torreyi</i>	1957	1916-2038	2	0-11	1-358	stream terraces
<i>Pediocactus nigrispinus</i>	2505	1946-2966	14	1-36	230-116	rocky ridges
<i>Penstemon eriantherus</i> var. <i>argillosus</i>	2353	2077-2658	13	6-40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

Achnatherum hendersonii

A single of occurrence of *Achnatherum hendersonii* was observed on the periphery of riparian vegetation associated with Bridge Creek on the eastern boundary of the Painted Hills (Figure 2). Approximately 50 plants provided an estimated foliar cover of 5% and occupied an area of 0.01 ha (Table 4). This population occurred at an elevation of 1952 m on flat terrain (Table 5).

Adjacent upland plant communities were dominated by a matrix of cultivated *Thinopyrum intermedium* grassland and *Sarcobatus vermiculatus* shrubland. Associated riparian vegetation included *Salix exigua* shrubland with dense patches of *Phalaris arundinacea*. Large, dense non-native populations of *Acroptilon repens* and *Cardaria draba* occupy and dominate both upland and riparian plant communities. The species is susceptible to local extinction due to its extremely limited extent at the Painted Hills, highly degraded habitat conditions, and proximity to sites managed intensively for weed control.

Figure 2: Distribution of *Achnatherum hendersonii* occurrences at the Painted Hills

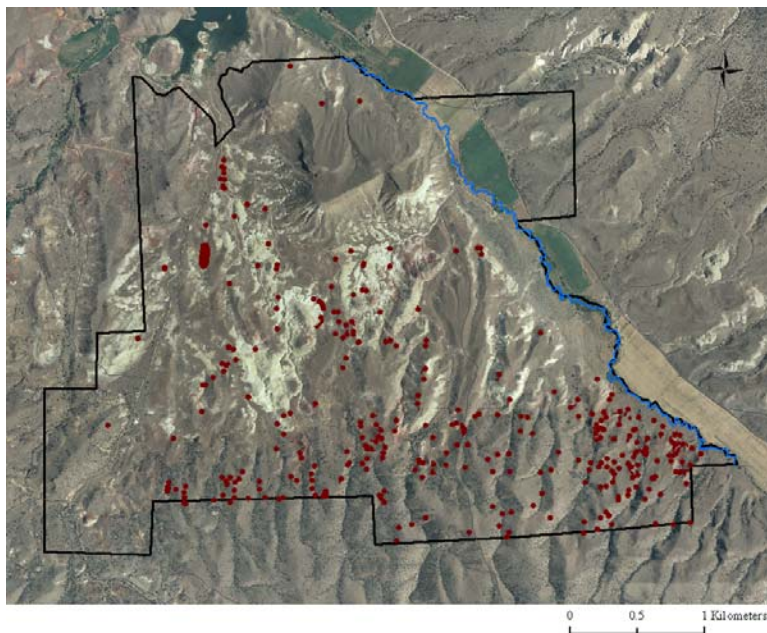


Castilleja xanthotricha

Castilleja xanthotricha is abundant 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). The average areal extent of an occurrence was 0.04 ha and consisted of 15 plants. 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. Some plants occupied barren clay hillsides or the perimeter of clay hills which were often characterized by *Atriplex confertifolia* shrubland. *Bromus tectorum* was the principal non-native species. The *C. xanthotricha* population is apparently stable and no immediate threats were identified.

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



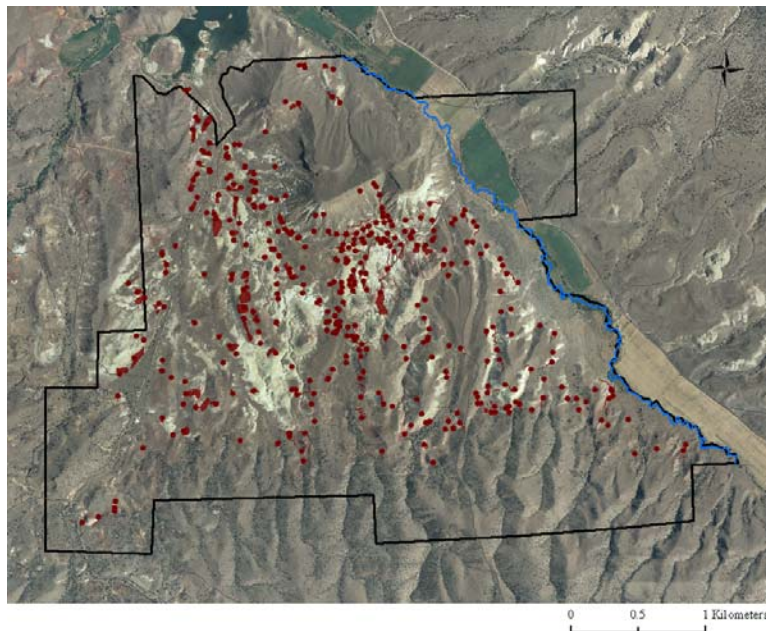
Chaenactis nevii

Chaenactis nevii is an endemic annual forb with a short flowering interval and lifecycle constrained by extreme summer temperatures and aridity. This species is widespread and abundant at the Painted Hills (Figure 4). Surveys conducted in the spring of 2007 occurred early in the life cycle of *C. nevii* and preceded peak germination for the species. Maximum areal extent and population size was therefore underestimated. A total of 374 occurrences were identified with an average estimated population size of 380 individuals per occurrence and a mean patch area of 0.1 ha (Table 4). Most patches assumed a linear configuration aligned with the lower slopes or periphery of barren clay hillsides and were closely associated with exposed clay paleosols. Scattered occurrences also occupied rocky substrates on steep slopes. Elevations ranged from 1910 to 2389 m. Corresponding terrain angles ranged from almost level toe slopes to steep hillsides of 30 degrees or more (Table 5).

The primary plant community associated with *C. nevii* is an *Atriplex confertifolia* / *Poa secunda* shrubland that dominates the lower margins of the exposed paleosol hillsides. *Bromus tectorum* and *Taeniatherum caput-medusae* were the most common and abundant non-native species, but do not appear to be directly competing with or threatening the persistence of *C. nevii*. *C. nevii* also appears to

tolerate minor levels of disturbance associated with soil erosion and processes of soil expansion and contraction.

Figure 4: Distribution of *Chaenactis nevii* occurrences at the Painted Hills

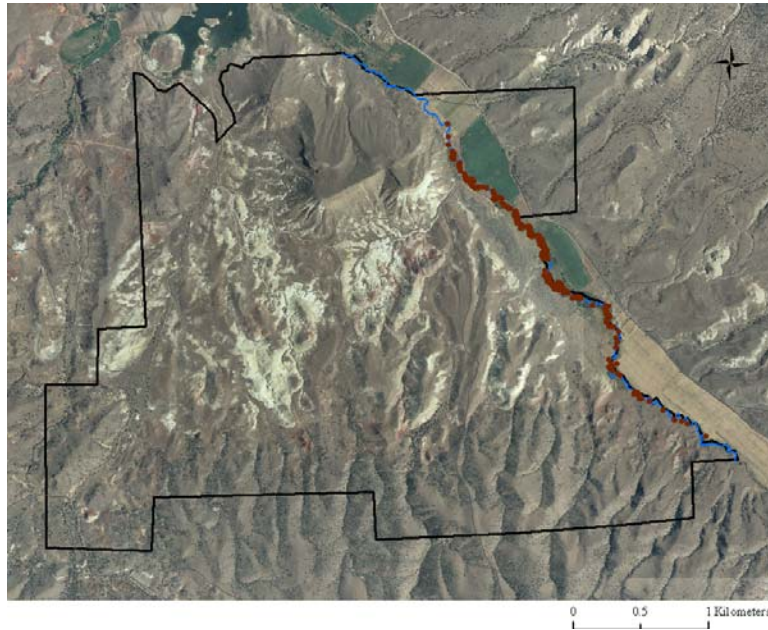


Juncus torreyi

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

The primary plant community is a *Salix exigua* shrubland. Non-native species proliferate in this environment with adjacent agricultural fields providing abundant seed production and stream flow functioning as a probable vector. Invasive species co-occurring with *Juncus torreyi* include *Phalaris arundinacea*, *Melilotus officinalis*, *Cirsium arvense*, *Cardaria draba*, and *Elaeagnus angustifolia*. However, the overall population of *J. torreyi* is sufficiently large and potentially able to persist despite dense populations of non-natives at this site. Treatments such as targeted herbicide applications are constrained by the close proximity of weed and *J. torreyi* occurrences with each other and the presence of perennial stream flow. Surveys indicate that grazing pressure associated with cattle has extirpated *J. torreyi* from downstream reaches of Bridge Creek outside the fenced northern park boundary.

Figure 5: Distribution of *Juncus torreyi* occurrences at the Painted Hills

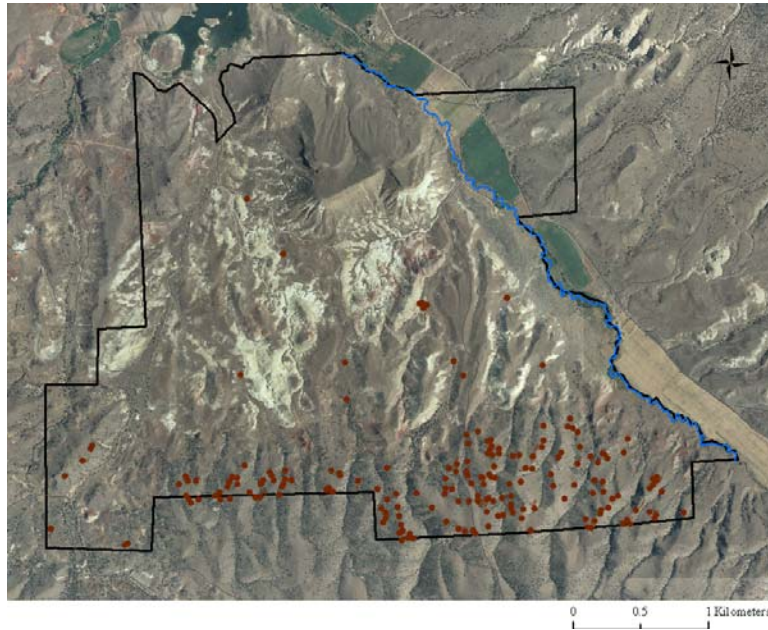


Pediocactus nigrispinus

Pediocactus nigrispinus is abundant on upper hill slopes and ridges in the southern regions of the Painted Hills (Figure 6). A few scattered plants were observed in flat valley bottom areas. All occurrences are strongly associated with shallow, rocky microsites. A total of 191 occurrences were identified averaging 6 plants per occurrence. The average 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 on the southern boundary (Table 5). Aspects were variable.

The most common associated plant communities were *Juniperus occidentalis* / *Pseudoroegneria spicata* - *Poa secunda* woodlands and savannas. Scattered ridge top occurrences were also associated with *Juniperus occidentalis* / *Purshia tridentata* and *Juniperus occidentalis* / *Artemisia rigida* associations. Few non-native species occurred in upland habitats occupied by *P. nigrispinus*. Valley bottom plants co-occurred with *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 6: Distribution of *Pediocactus nigrispinus* occurrences at the Painted Hills

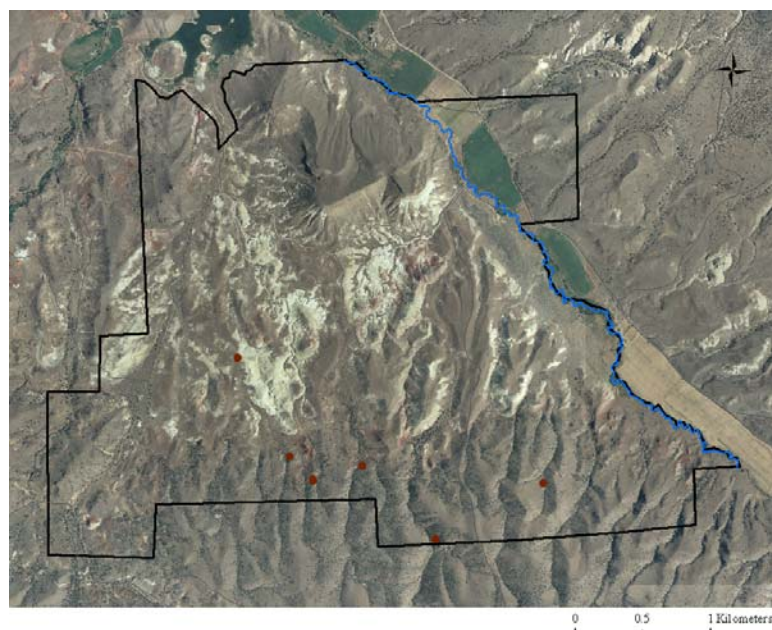


Penstemon eriantherus* var. *argillosus

Penstemon eriantherus var. *argillosus* occurs infrequently at the Painted Hills and only eight occurrences were observed in 2007 (Figure 7). 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 and appear to depend on seasonal moisture availability or mesic aspects. Elevations ranged from 2077 to 2658 m (Table 5).

Associated plant communities include *Juniperus occidentalis* / *Artemisia tridentata* spp. *wyomingensis* woodlands. No significant non-native populations occurred at these sites and no apparent threats were observed. Field surveys conducted in 2007 preceded the optimal flowering interval of *P. eriantherus* var. *argillosus* and future surveys are recommended to identify possible additional occurrences.

Figure 7: Distribution of *Penstemon eriantherus* var. *argillosus* occurrences at the Painted Hills



Weed summary

Non-native invasive plant species are ubiquitous and abundant in all lower elevation habitats of the Painted Hills. A total of 16 non-native plant species were identified 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 higher elevation hill slope and ridge top habitats in southern regions of the unit currently support relatively few weed populations.

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		
<i>Acroptilon repens</i>	181	122	4	0.04	0.0004-2.1	6.1	10-20	a13; a10; a15; a3; a17
<i>Cardaria draba</i>	257	154	6	0.03	0.0004-0.7	8.4	10-20	a13; a10; a15; a3; a17
<i>Carduus nutans</i>	1	50	18	0.03	-	0.03	30	a1
<i>Centaurea solstitialis</i>	8	45	6	0.7	0.0009-4.9	5.0	20-30	a17; a9

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		
<i>Cirsium arvense</i>	33	40	3	0.006	0.001-0.02	0.2	15-30	a17; a16
<i>Cirsium vulgare</i>	4	7	<1	0.002	0.0006-0.002	0.005	20-30	a1
<i>Crataegus monogyna</i>	1	2	<1	0.002	-	0.002	300	a17
<i>Cynoglossum officinale</i>	7	5	2	0.007	0.0002-0.02	0.05	10-20	a17
<i>Dipsacus fullonum</i>	16	59	2	0.02	0.0002-0.03	0.3	50-200	a16; a1
<i>Elaeagnus angustifolia</i>	43	4	4	0.008	0.0002-0.04	0.3	10-500	a16; a17
<i>Melilotus officinalis</i>	262	133	7	0.02	0.0003-0.2	3.5	30-180	a17; a16; a18; a10; a13
<i>Onopordum acanthium</i>	33	13	3	0.002	0.0001-0.01	0.4	20-70	a1; a16; a18
<i>Phalaris arundinacea</i>	61	-	22	0.01	0.002-0.04	0.2	100-150	a16; a17
<i>Polypogon monspeliensis</i>	2	-	2	0.004	0.002-0.006	0.004	5-15	a17; a3
<i>Taeniatherum caput-medusae</i>	445	-	14	0.2	0.0001-0.5	69.8	5-15	a10; a4; a3; a13; a9; a2

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		
<i>Verbascum thapsus</i>	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		
<i>Acroptilon repens</i>	2036	1893-2435	5	0-20	0-354	33	65	93	275	575
<i>Cardaria draba</i>	2071	1893-2398	6	0-27	1-356	43	61	87	260	900
<i>Carduus nutans</i>	2093	-	11	-	52	0	0	0	483	491
<i>Centaurea solstitialis</i>	1950	1916-2047	4	0-11	4-90	88	100	100	166	8
<i>Cirsium arvense</i>	1977	1933-2238	3	0-24	0-341	97	100	100	187	153
<i>Cirsium vulgare</i>	2327	2185-2402	13	5-21	17-315	0	0	25	581	684
<i>Crataegus monogyna</i>	1936	-	4	-	14	100	100	100	56	56
<i>Cynoglossum officinale</i>	1971	1939-2024	2	0-8	1-225	100	100	100	140	7

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		
<i>Dipsacus fullonum</i>	2366	2166-2644	14	3-31	5-354	6	6	31	585	1361
<i>Elaeagnus angustifolia</i>	2029	1910-2536	5	0-23	320-60	77	81	91	251	164
<i>Melilotus officinalis</i>	2000	1896-2238	3	0-18	1-358	88	97	99	105	780
<i>Onopordum acanthium</i>	1983	1916-2238	3	0-24	0-350	85	91	100	161	242
<i>Phalaris arundinacea</i>	1967	1936-2244	3	0-14	1-353	98	98	100	219	11
<i>Polypogon monspeliensis</i>	2126	1982-2270	9	6-12	264-332	100	100	100	39	713
<i>Taeniatherum caput-medusae</i>	2143	1900-2451	8	0-30	1-357	0	43	75	336	1686
<i>Verbascum thapsus</i>	2064	1959-2129	5	2-10	0-126	100	100	100	31	2603
TOTAL						63	71	81	242	652

Acroptilon repens

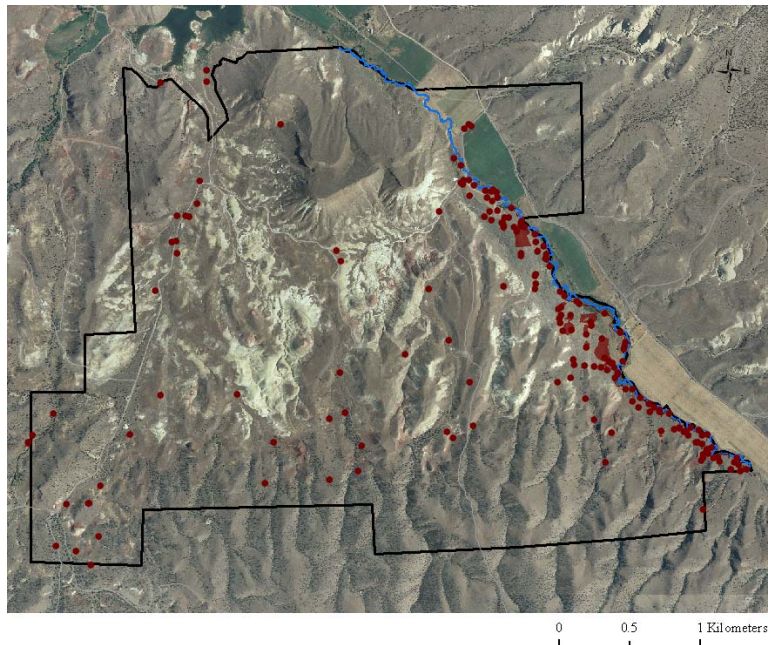
Acroptilon repens is abundant and widespread at lower elevations in the Painted Hills (Figure 8). A total of 181 occurrences were observed in 2007 with an estimated population size of 122 plants per occurrence. Mean foliar cover was 4% and the total areal extent of all occurrences was 6.1 ha (Table 6). Elevations ranged from 1893 to 2435 m and aspects were variable (Table 7). The average distance 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. Scattered upland occurrences were limited in areal extent and mainly associated with small burn areas and fire killed juniper trees.

Associated vegetation types included *Thinopyrum intermedium* grassland, *Sarcobatus vermiculatus* shrubland, and riparian vegetation adjacent to Bridge Creek. *Juniperus occidentalis* woodlands also supported scattered populations of *Acroptilon repens*.

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

Figure 8: Distribution of *Acroptilon repens* occurrences at the Painted Hills

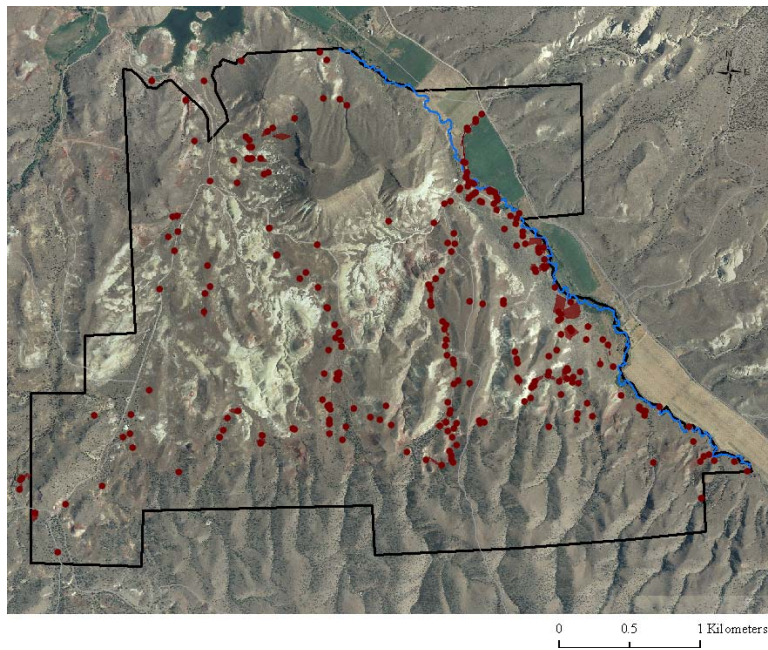


Cardaria draba

Cardaria draba is also abundant and widespread at lower elevations in the Painted Hills (Figure 9). A total of 257 occurrences were observed in 2007 with an estimated population size of 154 plants per occurrence. Mean foliar cover was 6% and the total areal extent of all occurrences was 8.4 ha (Table 6). Elevations ranged from 1893 to 2398 m and aspects were variable (Table 7). A majority of plants occupied valley bottom habitats with 87 % of all occurrences located within 400 m of roads, trails, or Bridge Creek (Table 7). The average distance from an occurrence to the closest road was 260 m indicating the significance of roads for seed dispersal and plant establishment. Scattered higher elevation occurrences were associated with seepage areas or small burns.

The most common plant communities occupied by *Cardaria draba* include *Thinopyrum intermedium* grassland, *Sarcobatus vermiculatus* shrubland, and riparian vegetation 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 areas may result in the recolonization of habitats managed for weed removal within the Painted Hills.

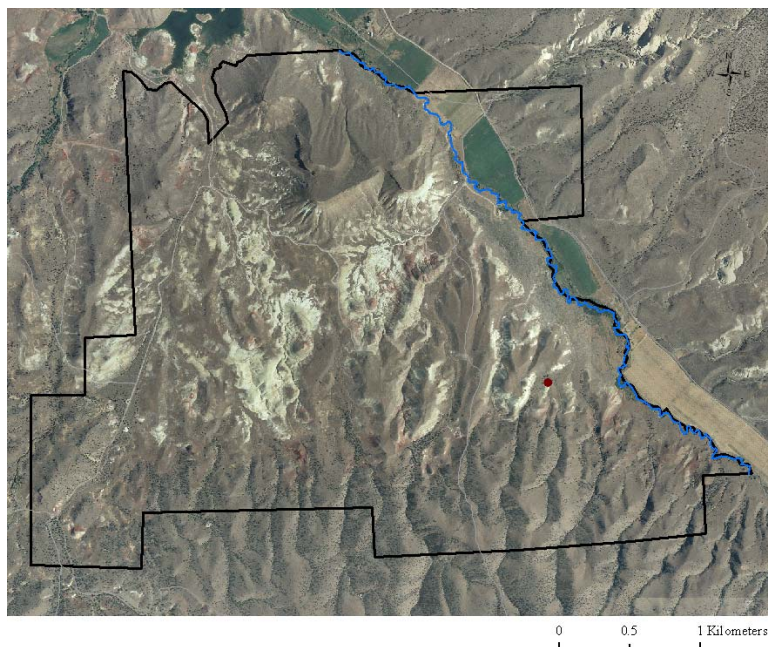
Figure 9: Distribution of *Cardaria draba* occurrences at the Painted Hills



Carduus nutans

A single occurrence of *Carduus nutans* was observed and quantified in the 2007 survey (Figure 10). An estimated 50 plants covered an area of 0.03 ha (Table 6). This single occurrence was associated with seepage from an upland site. The elevation was 2093 m and the aspect was approximately northeast (Table 7). The associated plant community was a *Juniperus occidentalis* / *Artemisia tridentata* spp. *wyomingensis* woodland.

Figure 10: Distribution of *Carduus nutans* at the Painted Hills

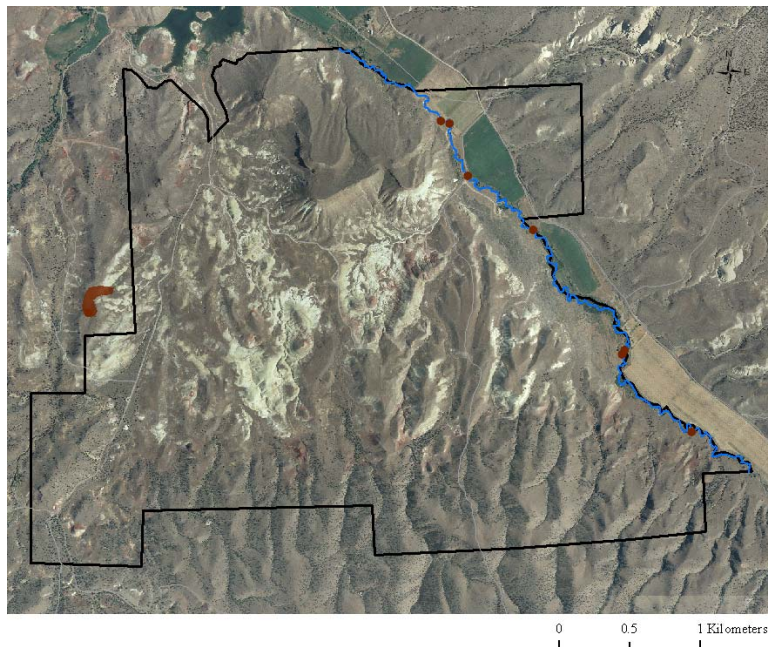


Centaurea solstitialis

Centaurea solstitialis is presently a relatively minor non-native component of the Painted Hills. A total of 8 occurrences were observed in 2007 (Figure 11) 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. A single large patch was identified just outside the western unit boundary that occupied 4.9 ha and co-occurred with *Taeniatherum caput-medusae*. Elevations ranged from 1916 m at Bridge Creek to 2047 m at the western boundary (Table 7).

Associated vegetation was comprised predominantly of riparian plant communities characterized by *Salix exigua* and some *Artemisia tridentata* spp. *wyomingensis* shrublands. The western upland patch was associated with a non-native annual grassland.

Figure 11: Distribution of *Centaurea solstitialis* occurrences at the Painted Hills

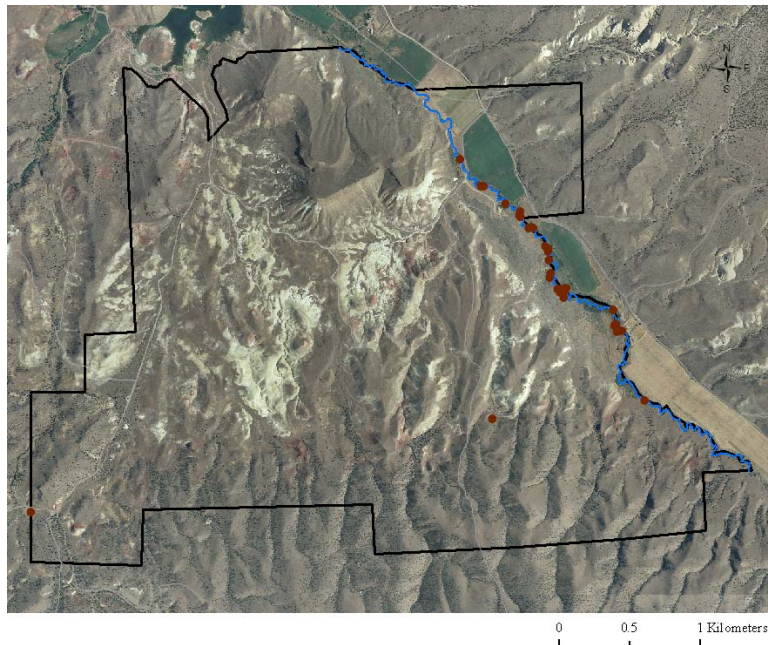


Cirsium arvense

Cirsium arvense is a relatively minor weed component at the Painted Hills occurring primarily in mesic riparian habitat (Figure 12). A total of 33 occurrences were surveyed in 2007 with an estimated 40 plants associated with each occurrence. The total areal extent of all patches was 0.2 ha. The average distance to water was 153 m and 97% of all occurrences were located within 100 m of Bridge Creek. Elevations ranged from 1933 m at Bridge Creek to 2238 m at an upland occurrence in a seepage area.

Associated vegetation consists mainly of riparian plant communities adjacent to Bridge Creek. A single occurrence with 10 plants is located on the western boundary of the Painted Hills in a seasonally mesic depression and co-occurs with an annual non-native grassland dominated by *Taeniatherum caput-medusae*.

Figure 12: Distribution of *Cirsium arvense* occurrences at the Painted Hills



Cirsium vulgare

Cirsium vulgare is also a minor weed component at the Painted Hills. A total of 4 occurrences were inventoried although this was not a priority species in the 2007 surveys (Figure 13). An average of 7 plants was observed at 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).

Plants were mainly associated with narrow, ephemeral drainage bottoms. Associated vegetation included *Juniperus occidentalis* / *Artemisia tridentata* ssp. *wyomingensis* / *Pseudoroegneria spicata* - *Poa secunda* woodlands, which dominated adjacent slopes.

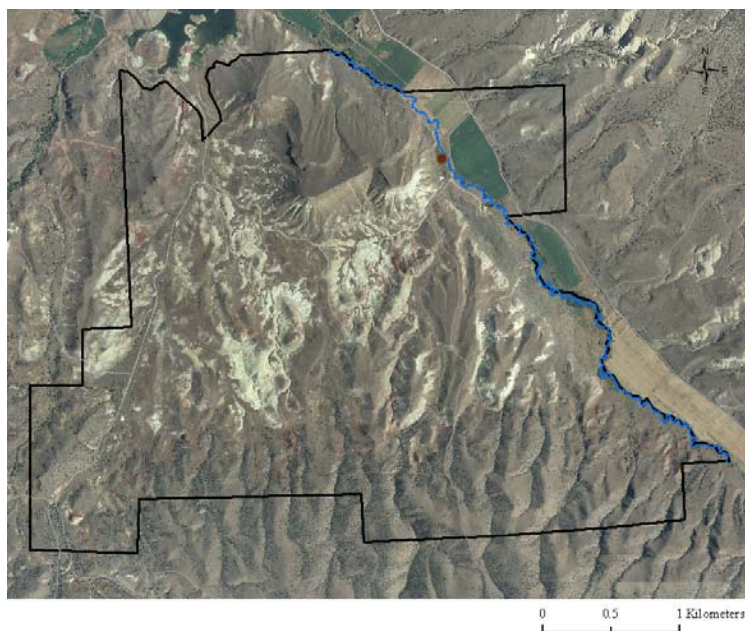
Figure 13: Distribution of *Cirsium vulgare* occurrences at the Painted Hills



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 14). The elevation was 1936 m.

Figure 14: Distribution of *Crataegus monogyna* occurrences at the Painted Hills

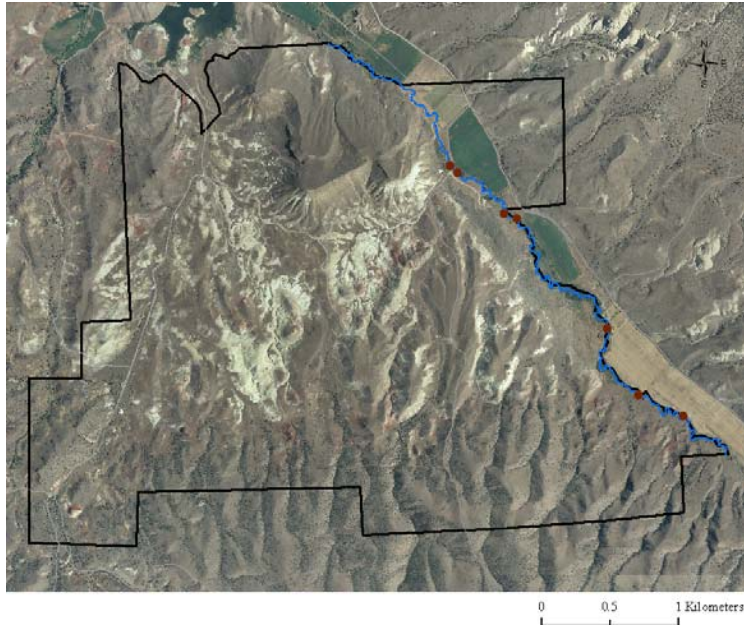


Cynoglossum officinale

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 average patch size was 0.007 ha. All occurrences were associated with mesic riparian habitat and were in close proximity to Bridge Creek (Figure 15; Table 7). Elevations ranged from 1939 to 2024 m.

Associated riparian vegetation was dominated by non-native species including *Cirsium arvense* and *Acroptilon repens*.

Figure 15: Distribution of *Cynoglossum officinale* occurrences at the Painted Hills

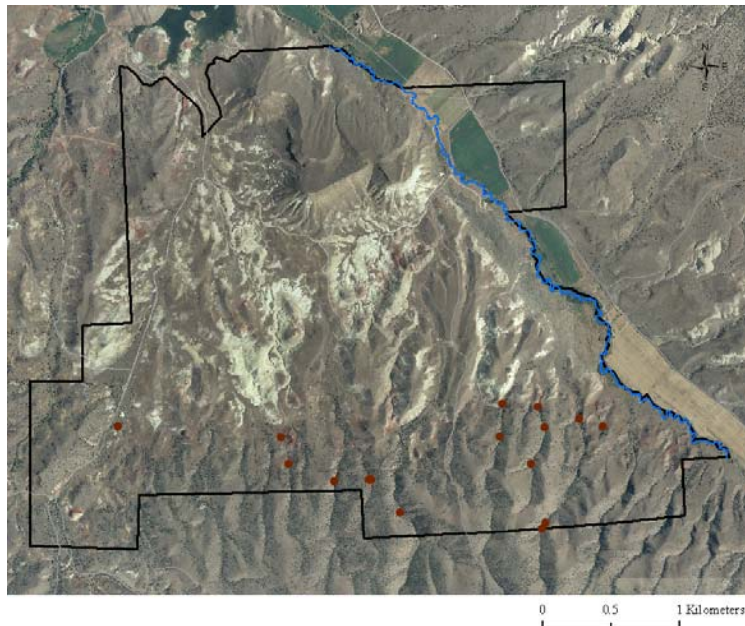


Dipsacus fullonum

Dipsacus fullonum was mainly observed in seasonally mesic drainage bottom areas in the higher elevations of the Painted Hills (Figure 16). A total of 16 occurrences were identified in 2007 (Table 6). Since *Dipsacus fullonum* was not prioritized for survey (Table 2), additional populations may be present. Mapped occurrences were comprised of 59 plants on average. Occurrences occupied a total area of 0.3 ha. Elevations ranged from 2166 to 2644 m and aspects were variable (Table 7).

Plants generally co-occurred with other invasive species including *Melilotus officinalis* and *Verbascum thapsus*. The most common associated plant community was *Juniperus occidentalis* / *Artemisia tridentata* ssp. *wyomingensis* woodland, which dominated surrounding slopes.

Figure 16: Distribution of *Dipsacus fullonum* at the Painted Hills

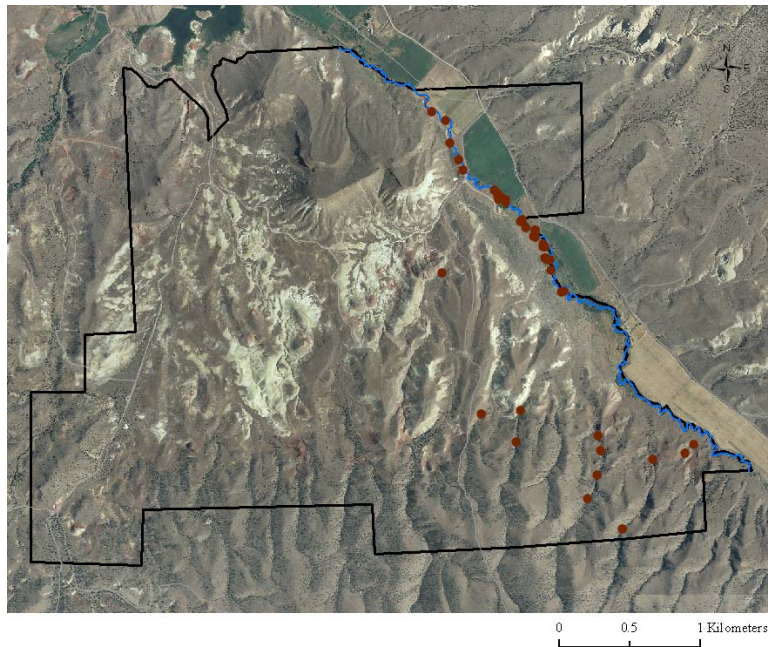


Elaeagnus angustifolia

Elaeagnus angustifolia occurrences are distributed throughout mesic habitats in the Painted Hills including riparian sites adjacent to Bridge Creek and higher elevation drainage bottoms in the southeastern hills (Figure 17). 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 *E. angustifolia* was 0.3 ha. Most plants are linearly distributed along drainage bottoms or washes. 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).

Resprouting *E. angustifolia* seedlings were observed adjacent to Bridge Creek where previous stems had been previously mechanically or chemically treated. Large *E. angustifolia* trees with heights exceeding 6 m occur on Bridge Creek just outside the northern Painted Hills boundary in riparian areas denuded by grazing cattle.

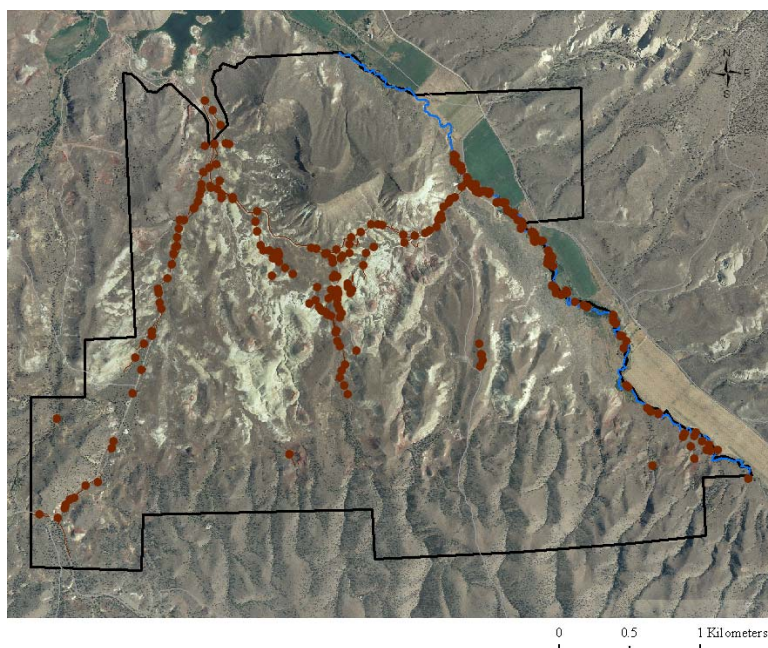
Figure 17: Distribution of *Elaeagnus angustifolia* occurrences at the Painted Hills



Melilotus officinalis

Melilotus officinalis is ubiquitous in riparian and roadside areas of the Painted Hills (Figure 18). A total of 262 occurrences were surveyed in 2007 with an estimated population size of 133 plants per occurrence. Mean foliar cover was 7% and the total areal extent of all occurrences was 3.5 ha (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 18: Distribution of *Melilotus officinalis* occurrences at the Painted Hills

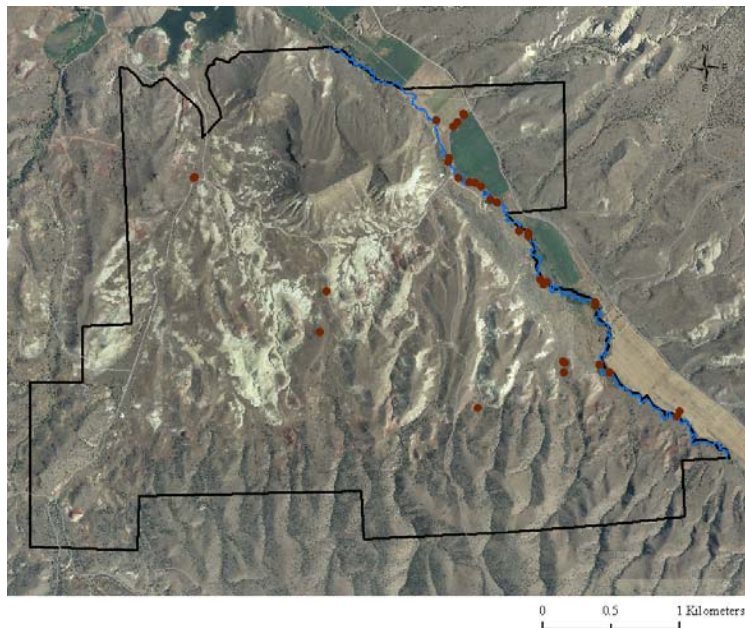


Onopordum acanthium

Scattered occurrences of *Onopordum acanthium* are associated with mesic habitats adjacent to roads, draws, or Bridge Creek (Figure 19). A total of 33 occurrences of *Onopordum acanthium* were observed 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.

Associated vegetation included riparian plant communities characterized by *Salix exigua* and *Juniperus occidentalis* / *Artemisia tridentata* ssp. *wyomingensis* woodlands. Large, dense populations of *Onopordum acanthium* were observed in agricultural fields north of the Painted Hills boundary which may provide an abundant and continuous seed source for recolonization of any treated areas within the unit.

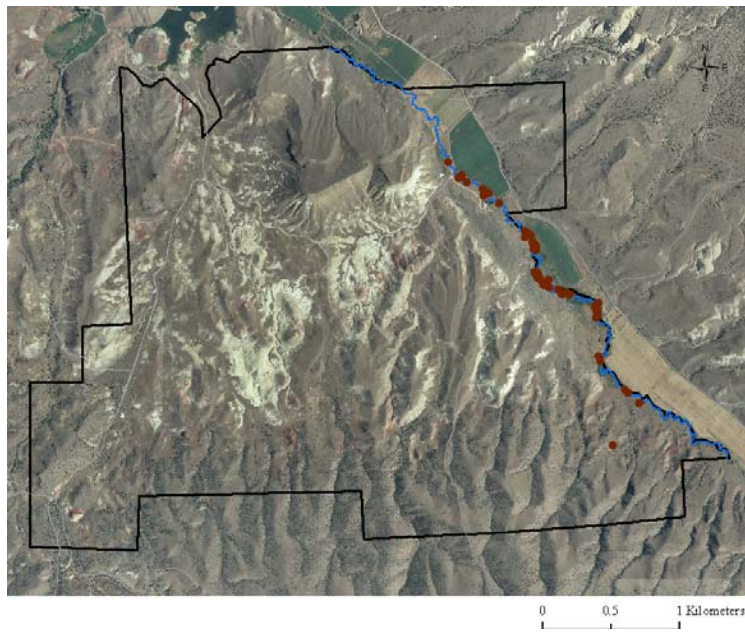
Figure 19: Distribution of *Onopordum acanthium* occurrences at the Painted Hills



Phalaris arundinacea

Dense patches of *Phalaris arundinacea* occupy riparian areas adjacent to Bridge Creek (Figure 20). A single occurrence was also observed in a mesic draw in the southeastern hills. A total of 61 occurrences were surveyed in 2007 with a mean foliar cover of 7%. The number of individual plants 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.

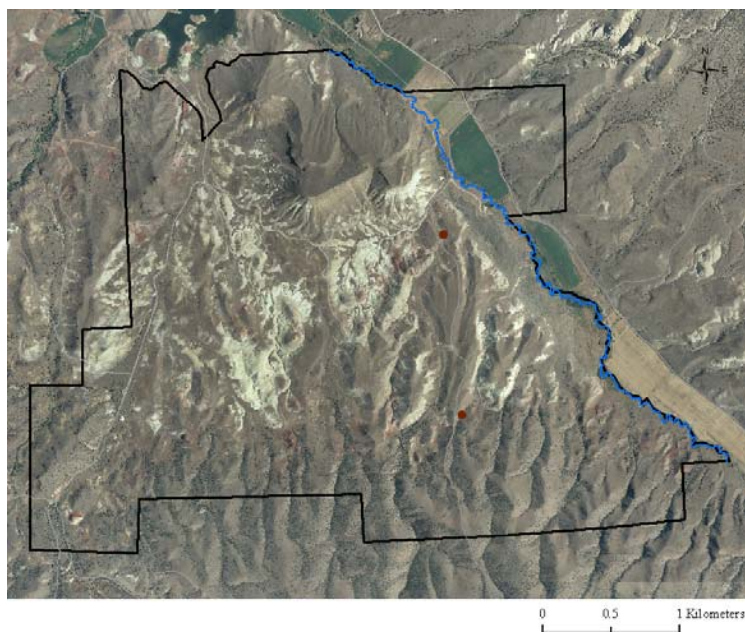
Figure 20: Distribution of *Phalaris arundinacea* occurrences at the Painted Hills



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 (Figure 21). Mean foliar cover was 2%. The number of individual plants was not estimated for this species. 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 21: Distribution of *Polypogon monspeliensis* occurrences at the Painted Hills

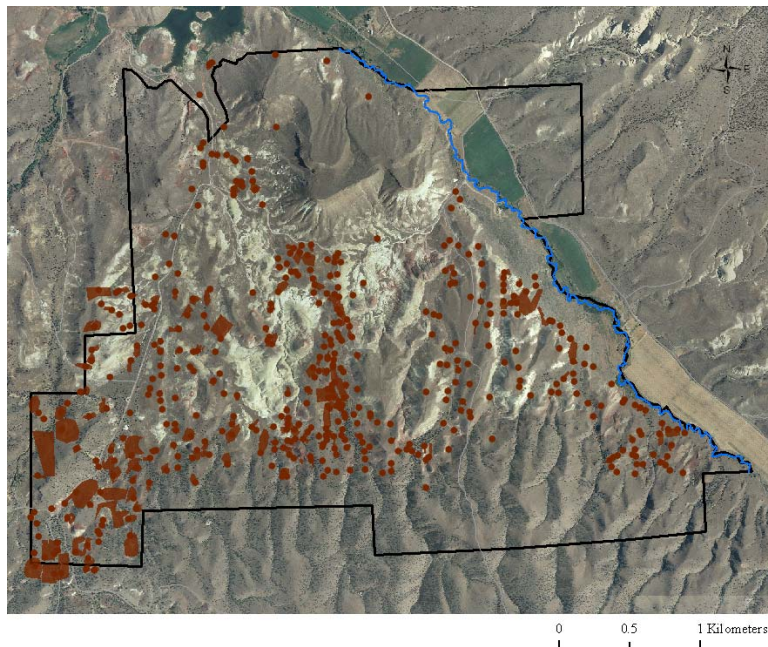


Taeniatherum caput-medusae

Taeniatherum caput-medusae is abundant and widespread forming dense patches at lower elevations in the Painted Hills (Figure 22). A total of 445 occurrences were surveyed in 2007 with a mean foliar cover of 14%. The number of individual plants 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). Habitats occupied by this species were generally shallowly sloping although scattered patches occurred on slopes reaching 30 degrees. Occurrences were not obviously correlated with road or creek locations. Recent fire appears to have promoted this species, but unlike *Bromus tectorum*, *Taeniatherum caput-medusae* has not established at higher elevations in the southeastern hills.

Taeniatherum caput-medusae is present in most vegetation types at the Painted Hills, but dominates the graminoid layer of *Sarcobatus vermiculatus* and *Atriplex confertifolia* shrublands, *Thinopyrum intermedium* stands, and some lower elevation *Juniperus occidentalis* woodlands.

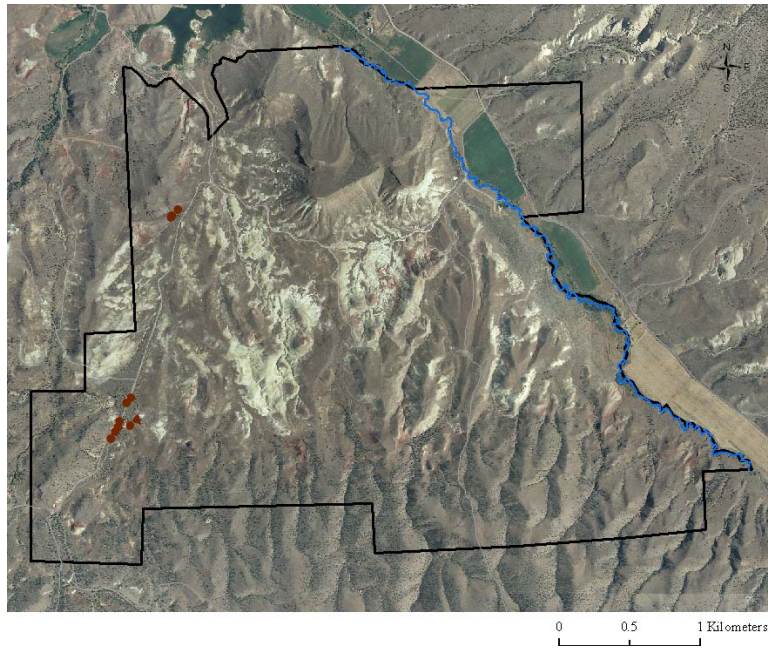
Figure 22: Distribution of *Taeniatherum caput-medusae* occurrences at the Painted Hills



Verbascum thapsus

Verbascum thapsus is presently relatively uncommon in the Painted Hills with a few scattered occurrences adjacent to roads near the western boundary of the unit (Figure 23). A total of 10 occurrences were mapped with an estimated population size of 71 plants per occurrence. Mean foliar cover was 7% and the total areal extent of all occurrences was 0.2 ha (Table 6). Elevations ranged from 1959 to 2129 m (Table 7). All plants occurred within 100 m of a road.

Figure 23: Distribution of *Verbascum thapsus* occurrences at the Painted Hills



DISCUSSION

Large populations of four endemic species were identified in the 2007 field survey for rare plants at the Painted Hills including *Castilleja xanthotricha*, *Chaenactis nevii*, *Juncus torreyi*, and *Pediocactus nigrispinus*. Two additional species, *Achnatherum hendersonii* and *Penstemon eriantherus* var. *argillosus* were also observed, but occurrences were infrequent. Accurate quantification of population sizes were constrained by the large areal extent, number of plants, and frequency of occurrence for the 4 most abundant endemic species. A lack of congruence between the phenologies of the target rare plants also limited data collection. For example, field surveys conducted in the early spring of 2007 preceded the peak germination of *Chaenactis nevii* and therefore underestimated its actual population size. The early timing of the spring survey also preceded the flowering period of *Penstemon eriantherus* var. *argillosus* and *Mimulus jungermannioides* and the midsummer inventory concentrated on riparian areas adjacent to Bridge Creek. Future surveys may focus on habitats potentially suitable *Penstemon eriantherus* var. *argillosus* and *Mimulus jungermannioides*.

Populations of *Castilleja xanthotricha*, *Chaenactis nevii*, *Juncus torreyi*, and *Pediocactus nigrispinus* are not currently endangered by any apparent threats. A majority of *Castilleja xanthotricha*, *Chaenactis nevii*, and *Pediocactus nigrispinus* occurrences are associated with upland, higher elevation habitats dominated by native species. In contrast, *Juncus torreyi* occupies degraded riparian areas adjacent to Bridge Creek and co-occurs with dense populations of competing non-native species, but large plant numbers and subjective observations of species interactions suggest that this species will persist among with non-native species. The interspersions of *J. torreyi* and weeds, and the proximity to Bridge Creek limits the potential for a targeted herbicide treatment.

Potential future threats may include alterations in disturbance regimes related to vegetation management or climate change. The herbaceous layer of plant communities occupying higher elevation sites predominantly located in the southeastern portions of the Painted Hills are currently dominated by native graminoids including *Achnatherum thurberianum*, *Festuca idahoensis*, *Poa secunda*, and *Pseudoroegneria spicata*. Non-native forbs such as *Acroptilon repens* and *Cardaria draba* and weedy grasses including *Taeniatherum caput-medusae* and *Bromus tectorum* are currently sparse and generally associated with scattered burned sites and juniper snags killed by recent fire. Invasive weed

expansions have been associated with disturbance events including fire (Hobbs and Huenneke 1992; DiTomaso 2000) suggesting that management prescriptions involving fire may have the potential to promote the colonization of sites by exotic species currently dominated by natives. The establishment of non-natives may initiate a feedback effect in which an altered biota increases the frequency and intensity of fire (Mack and D'Antonio 1998). Increases in fire occurrence may further affect community composition and structure by, in part, decreasing cover of *Artemisia tridentata*, which does not resprout following fire (Booth et al. 2003).

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 lower elevation habitats particularly along road corridors, on relatively or seasonally mesic valley bottoms and flats, and on stream terraces associated with Bridge Creek. Over 80 percent of all non-native species occurrences are located within 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 enhancing adjacent soil moisture reservoirs by concentrating runoff to roadside margins (Gelbard and Belnap 2003).

The southeastern hills support relatively few weed occurrences. Scattered, sparse populations of *Acroptilon repens*, *Cardaria draba*, and *Bromus tectorum* were associated with burned sites and scattered *Elaeagnus angustifolia* trees were observed in some drainages. *Elaeagnus angustifolia* was also observed in riparian areas adjacent to Bridge Creek resprouting from previously treated stems.

Large dense populations of *Cardaria draba*, *Acroptilon repens*, and *Onopordum acanthium* were observed in riparian areas and agricultural fields to the east and north of the Painted Hills boundary. *Centaurea solstitialis* was also abundant in the heavily degraded Bridge Creek channel north of the Painted Hills. Any weed management activity restricted to the interior of the unit will be hampered by continued seed dispersal from these large source populations.

RECOMMENDATIONS

Subsequent surveys are recommended for June or July of 2008 to target habitats and flowering phenologies associated with rare plant species potentially missed during the 2007 field inventory including *Penstemon eriantherus* var. *argillosus* and *Mimulus jungermannioides*.

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 new introductions or emerging threats to native plant viability. Continued monitoring using standardized methods is recommended in order to quantitatively measure temporal changes and assess treatment prescriptions.

ACKNOWLEDGEMENTS

Funding was provided by the National Park Service under Cooperative Agreement Number H8W07060001. Field surveys in 2007 were conducted by Berta Youtie, Erin Riggs, Lindsey Koepke, Sonja Ralph, and David Schuhwerk.

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