Noxious Weed Monitoring at the U.S. Air Force Academy- Year 5 Results

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On the cover: Canada thistle plot 2, photo point 2 (2005) and (2009)

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EXECUTIVE SUMMARY

This report includes a summary of the results of the past five years of population monitoring of targeted noxious weeds at the US Air Force Academy ("the Academy"), emphasizing changes that were observed between 2008 and 2009.

In 2009 the sampling methodology of this project was adjusted based on analyses of the past four years' data, and the fieldwork was streamlined to focus resources on the most urgent weed management challenges. These changes included decreased emphasis on species that are of lesser management concern such as yellow toadflax, which have already occupied most available niches at the Academy and are beyond our ability to eradicate. Where necessary, methodological changes resulting from this shift in emphasis are also presented in this report. Management of all noxious weed species at the Academy is important and all are integrated into weed monitoring efforts at the Academy, but the periodicity of sampling for some species has been shifted from every year to every two to five years depending on the species.

Increased emphasis has been given to species for which relatively inexpensive management efforts have a high probability of success. The primary species in this category are myrtle spurge (*Euphorbia myrsinites*), tamarisk (*Tamarix ramossisima*), Russian Olive (*Eleagnus angustifolia*) Russian knapweed (*Acroptilon repens*), Scotch thistle (*Onopordum acanthium*), and common St. Johnswort (*Hypericum perforatum*). These species are still relatively uncommon at the Academy and can still reasonably be eradicated or controlled, and also pose a significant risk to the natural resource values of Academy if they continue to spread. A complete census and GIS mapping of all infestations of these species has been conducted annually. Others, including leafy spurge and spotted knapweed, pose an equal threat to the natural resource values of the Academy but their current high abundance precludes an annual census; nonetheless these species continue to be a high priority for management and monitoring. In 2009 we developed a suitable habitat model and predicted pace of spread for spotted knapweed.

The highlights of 2009 monitoring are listed below.

- **Russian knapweed:** aggressive spraying has extirpated the few known populations, however, continued monitoring is necessary to assure that this species is permanently eliminated from the Academy.
- **Musk thistle:** number of individuals significantly declined in plots that were treated while significant increases occurred in untreated plots.
- **Canada thistle:** cover increased in areas where untreated.
- **Leafy spurge:** a very similar pattern to 2008.
- **Myrtle spurge:** the permanent plots reacted positively to herbicide spraying and direct pulling, however the species remains present at these sites. The Academy-wide population and locations continues to increase, however we are hopeful that on-going management will keep this weed at a minimum.

- **St Johnswort:** Number of individuals increased in **all** the permanent plots; most striking was the observation that two of these plots had been weed free for several years prior to 2009. One of these plots exploded, with over 17,000 individuals cropping up in 2009. This species continues to spread in spite of an active beetle population that preys on this species. Occupied area nearly doubled from 2008, from 4300 m^2 to 8200 m^2. We recommend a concerted effort is needed to control this species as we believe it is still at the stage that will respond to aggressive treatment. Most of the occurrences are within the Kettle Creek floodplain thus careful attention is needed when applying herbicides.
- **Scotch thistle:** occupied area tripled over 2008, from 1 to 3.5 acres. Number of individuals were nearly 12 times higher in 2009 than 2008 (1710 vs. 144). In addition, the number of mapped features nearly doubled from 27 in 2008 to 50 in 2009. On-going weed management is critical for this species.
- **Diffuse knapweed:** mixed results were observed from the three permanent plots including an increase, a decrease, and stable density counts. One plot doubled in density while another plot decreased by 25%. The decrease may have been associated with the repeated mowing.
- **Spotted knapweed:** this species has reached high numbers; thus we developed two models. One model predicts the areas with suitable habitat and the other model predicts the pace of spread between 2007-2015.
- **Tamarisk:** continued management and monitoring is necessary, but as of 2009, treatments appear to be keeping this species under control.
- **Houndstongue and Dalmatian toadflax:** these two species are new to the list and were mapped and censused in 2009. Both have the potential for complete elimination.

INTRODUCTION

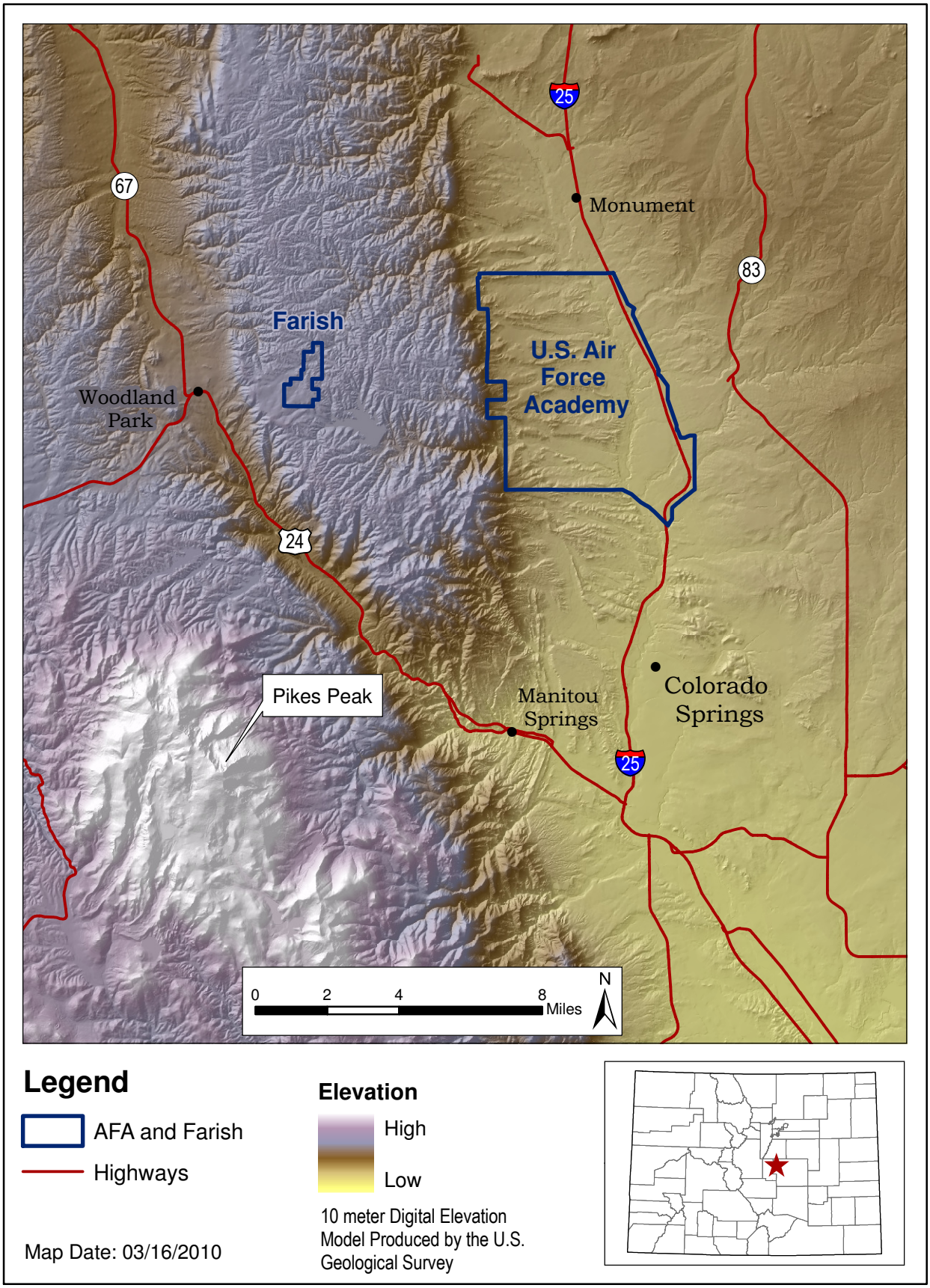
Weeds are known to alter ecosystem processes, degrade wildlife habitat, reduce biological diversity, reduce the quality of recreational sites, reduce the production of crops and rangeland forage plants, and poison livestock (Sheley and Petroff 1999). All of these impacts are occurring in Colorado (Colorado Department of Agriculture 2001). In recognition of their enormous detriments to our society and environment, many local governments now require public and private landowners to manage noxious weeds. The U.S. Air Force Academy (referred to herein as "the Academy") must conform to state (Colorado Department of Agriculture Plant Industry Division 2005) and county (El Paso County 2007) weed control regulations for noxious weeds. The Academy has also established management objectives for weed control in order to remain compliant with local weed regulations.

The Academy and the Farish Outdoor Recreation Area ("Farish") are near Colorado Springs, Colorado (Map 1) and are important for local and global biodiversity conservation. The Academy has become increasingly insular and, like many military installations, increasingly important for conservation as natural landscapes elsewhere in the area are developed and altered. In total, at least 30 plants, animals, and plant communities of conservation concern are found at the Academy and Farish, including Porter's feathergrass (*Ptilagrostis porteri*), a globally imperiled endemic of Colorado, and silkyleaf cinquefoil (*Potentilla ambigens*), found only in Colorado and New Mexico (Spackman Panjabi and Decker 2007, Colorado Natural Heritage Program 2008). The Academy is critically important for the conservation of the listed threatened Preble's meadow jumping mouse (*Zapus hudsonius preblei*) (Colorado Natural Heritage Program 2008). Noxious weeds threaten the viability of conservation targets by competing for resources and altering the structure and function of the ecosystems they invade. They also increase the cost while diminishing the likelihood of success of restoration efforts.

History of Weed Mapping and Monitoring at the Academy

In 2002 and 2003, the Colorado Natural Heritage Program (CNHP) mapped selected noxious weeds found at the Academy and Farish (Anderson et al. 2003). The project was undertaken to provide the U.S. Air Force Academy Department of Natural Resources with information on noxious weeds to serve as the basis for development of a formal Integrated Weed Management Plan, and to meet the requirements of a comprehensive management plan. In 2002, 3,936 infestations were mapped for 14 target species at the Academy and Farish, and additional infestations were mapped in 2003 (Anderson et al. 2003).

In 2004, an integrated noxious weed management plan was developed based largely on the results of the weed mapping exercise (Carpenter et al. 2004). The purpose of this plan is to guide the management of noxious weeds at the Academy and Farish in the most efficient and effective manner. This plan supports the 2003-2008 *Integrated Natural Resources Management Plan* for the Academy. The plan set weed management objectives and recommended weed management protocols for the



Map 1. Vicinity map for the U.S. Air Force Academy and the Farish Memorial Recreation Area.

The plan also underscored the importance of monitoring weed infestations as a means of measuring the effectiveness of management practices, and recommended monitoring protocols.

Weed management priorities have been set for the Academy and Farish that are based primarily on four factors: 1) current status on State and County noxious weed lists, 2) current prevalence at the Academy or Farish and cost effectiveness of management, 3) potential invasiveness, and 4) the threat posed to significant natural resources (Anderson et al. 2003, Carpenter et al. 2004, Spackman Panjabi and Decker 2007). For example, myrtle spurge is given a high priority for management due to its status as a List A species, for which eradication is required by State Law. However, common St. Johnswort is also given a high priority for management; although State and County weed management statutes do not require eradication of this species, its distribution at the Academy is localized and eradication is feasible at present. This species is also a threat to significant natural resources at the Academy.

In 2005, a monitoring program for 13 species of noxious weeds (Russian knapweed (*Acroptilon repens*), hoary cress (*Cardaria draba*), musk thistle (*Carduus nutans*), diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*Centaurea maculosa*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), Fuller's teasel (*Dipsacus fullonum*), Russian olive (*Elaeagnus angustifolia*), leafy spurge (*Euphorbia esula*), common St. Johnswort (*Hypericum perforatum*), yellow toadflax (*Linaria vulgaris*), and Scotch thistle (*Onopordum acanthium*)) was established at the Academy. Of the 13 species targeted for monitoring in this study, 12 are species that had been mapped in 2002 and 2003. A total of 14 species were mapped in 2002 and 2003, but two species (Tamarisk, *Tamarix ramosissima,* and field bindweed, *Convolvulus arvensis*) were not targeted for monitoring. Tamarisk was not targeted for monitoring because the single plant discovered in 2002 had been destroyed and there had been no new reports of this species at the Academy. Field bindweed was not targeted for monitoring because it occurs sporadically in relatively small infestations in a limited area of the Academy, mostly near infrastructure. Russian knapweed was discovered at the Academy in 2004, so it was not mapped in 2002 and 2003 but is included as a monitoring target because of its legal status and invasiveness.

In 2006, all permanent monitoring plots established in 2005 were resampled. A fourteenth species, myrtle spurge (*Euphorbia myrsinites*) was added to this study because it is listed on Colorado's A List of noxious weeds, and eradication of this species is required under state law (Colorado Department of Agriculture 2005). It was discovered at the Academy in 2005 by Natural Resources staff. In 2007, the monitoring plots were sampled a third time. The first three years of data from this project were analyzed and presented in the 2009 report (Anderson et al. 2009).

In 2007 CNHP completed a weed map of the Academy and Farish, completely revising the baseline weed survey completed in 2002 and 2003 for most target species (Anderson and Lavender 2008a). Data from this study were complementary to the ongoing monitoring project.

Weed monitoring also continued in 2007. The first three years of monitoring data were analyzed and the results were used to adjust the monitoring protocols and

priorities in subsequent years of monitoring. The report for 2007 (Anderson and Lavender 2008b) includes specific recommendations for continued weed monitoring that were followed in 2008. The results of 2008's field work were summarized and presented in the year-4 report, and modifications and additions to previous methods were detailed (Anderson et al. 2009).

In 2009, we applied the recommendations from the year-4 results which are detailed in this report. Two additional species were mapped in 2009: Houndstongue (*Cynoglossum officinale)* and Dalmatian toadflax (*Linaria genistifolia* ssp. *Dalmatica).* A total of 46,468 m^2 of infestations were mapped for 14 target species in 2009 (see Appendix A).

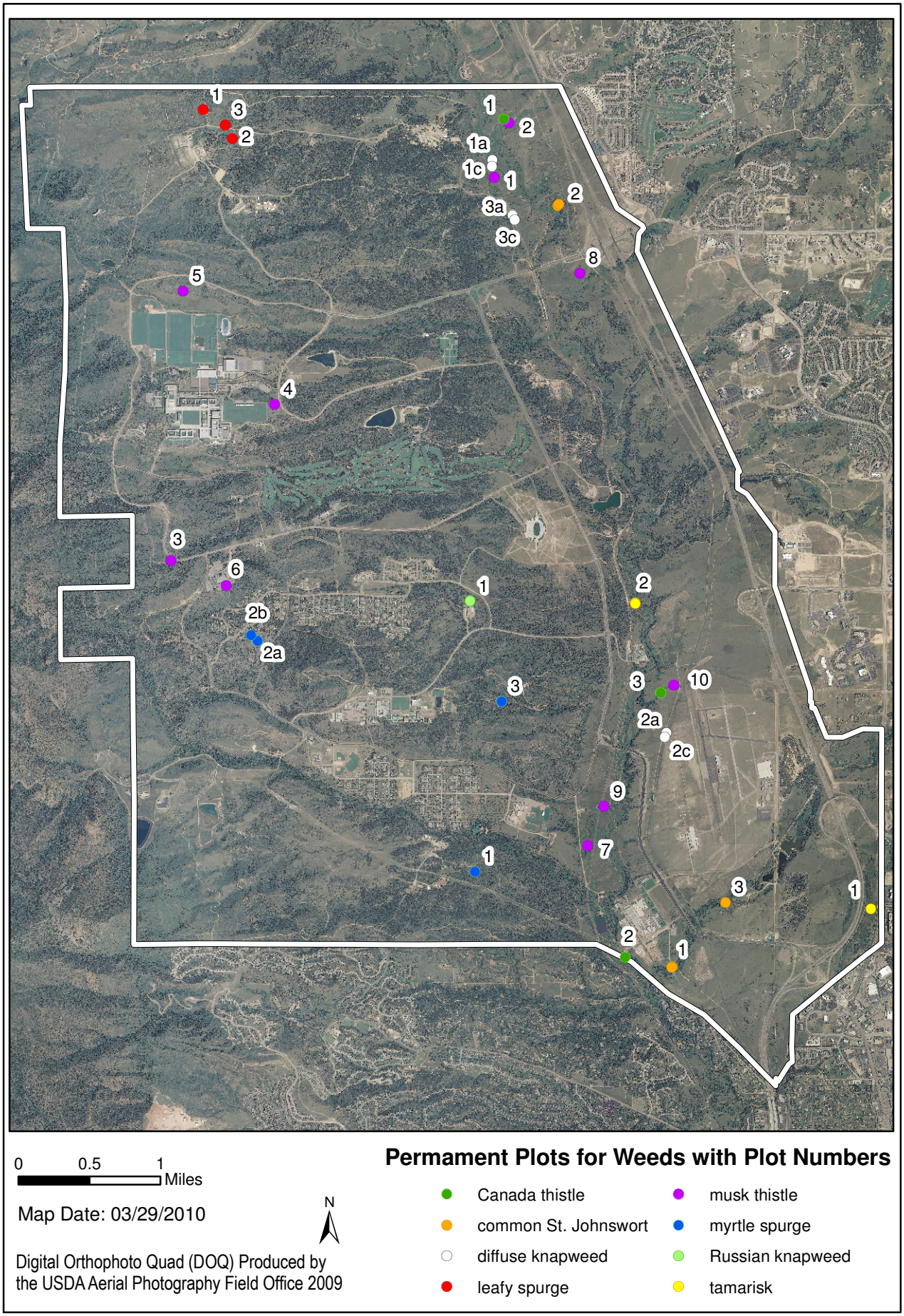
METHODS

This project was undertaken to evaluate the effectiveness of ongoing management of noxious weeds at the Academy, and to determine whether weed management objectives are being met. The recommendations for the design and deployment of monitoring plots offered by Carpenter et al. (2004) were adhered to closely in this study. The monitoring program at the Academy has utilized a combination of permanent plots and census techniques, as recommended by Carpenter et al. (2004). Adjustments were made to these methods in 2009 as indicated by analysis of the first four years of monitoring data (Anderson et al. 2009).

In 2009, combinations of transect sampling, photoplots, photopoints, survey transects, perimeter mapping, and census were utilized in monitoring the target noxious weed species. These methods have been described in detail in Anderson and Lavender (2006) and Anderson and Lavender (2007). Details on which methods were utilized for each target species are presented in Table 1. Permanent plot locations are presented in Map 2.

Table 1. Summary of methods used for sampling, mapping, and modeling in 2008 and 2009.

Species	2008 Sampling Methods	2009 Sampling Methods
Russian Knapweed	*perimeter mapping/ census*	*perimeter mapping/ census*
Spotted Knapweed	*Not sampled in 2008*	Produced a predicted occurrence model
Whitetop	*Not a target in 2008*	*Not a target in 2009*
Musk Thistle	*10 Photopoints /estimated size*	*9 Photopoints / estimated size*
Diffuse knapweed	*Not a target in 2008*	*Belt transects/photopoints*
Canada Thistle	*Transect/ photopoint/ photoplot*	*Transect/ photopoints/ photoplot*
Bull Thistle	*Not a target in 2008*	*Not a target in 2009*
Fuller's Teasel	*Not a target in 2008*	*Not a target in 2009*
Leafy Spurge	*Perimeter mapping/ survey transects/ photopoint*	*Perimeter mapping/ survey transects/ photopoint*
Common St. Johnswort	*Photopoints and perimeter mapping*	*Photopoints/ quadrats and perimeter mapping*
Yellow Toadflax	*Not a target in 2008*	*Perimeter mapping/census*
Houndstongue	*Not a target in 2008*	*Perimeter mapping/census*
Myrtle Spurge	*Perimeter mapping/ census/ photopoint*	*Perimeter mapping/ census/ photopoints*
Tamarisk	*Perimeter mapping/ census/ photopoint if plants are found*	*Perimeter mapping/ census/*



Map 2. Locations of all permanent monitoring plots sampled in 2009.

RESULTS AND RECOMMENDATIONS

As in previous years, climate continued to have a considerable influence over the cover and density of the target species. The 2009 growing season was characterized by an average precipitation in all growing months except for August, which was below average (Table 2). The non-growing months had below average precipitation.

Results specific to each target noxious weed species and for the natural resource based monitoring plots are summarized in the following sections. See Appendix A for additional information.

Table 2. Summary data for monthly precipitation (inches) at Colorado Springs for water years. (Colorado Climate Center 2009). The growing months (summer) are shaded in green. Summary data form monthly precipitation (inches) at Colorado Springs, Colorado for water years.

Water Yr.	Data	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Summer Total
2004-2005	**Monthly Precip.**	**0.18**	**0.65**	**0.24**	**0.78**	**0.04**	**1.03**	**1.08**	**0.73**	**2.10**	**1.91**	**2.65**	**0.68**	**8.07**
	Average	0.86	0.52	0.42	0.28	0.35	1.06	1.62	2.39	2.34	2.85	3.48	1.23	12.29
	% of Ave.	21	125	57	279	11	97	67	31	90	67	76	55	64
	Accumulated	0.18	0.83	1.07	1.85	1.89	2.92	4.00	4.73	6.83	8.74	11.39	12.07	
	Average Accum.	0.86	1.38	1.80	2.08	2.43	3.49	5.11	7.50	9.84	12.69	16.17	17.40	
	% Ave. Accum.	21	60	59	89	78	84	78	63	69	69	70	69	
2005-2006	**Monthly Precip.**	**0.48**	**0.08**	**0.30**	**0.24**	**0.04**	**0.24**	**0.09**	**0.81**	**0.82**	**4.42**	**3.52**	**1.51**	**11.08**
	Average	0.86	0.52	0.42	0.28	0.35	1.06	1.62	2.39	2.34	2.85	3.48	1.23	12.29
	% of Ave.	56	15	71	86	11	23	6	34	35	155	101	123	0
	Accumulated	0.48	0.56	0.86	1.10	1.14	1.38	1.47	2.28	3.10	7.52	11.04	12.55	
	Average Accum.	0.86	1.38	1.80	2.08	2.43	3.49	5.11	7.50	9.84	12.69	16.17	17.40	
	% Ave. Accum.	56	41	48	53	47	40	29	30	32	59	68	72	
2006-2007	**Monthly Precip.**	**1.57**	**0.19**	**0.39**	**0.31**	**0.17**	**0.66**	**1.85**	**2.35**	**0.94**	**1.74**	**2.69**	**0.34**	**8.06**
	Average	0.86	0.52	0.42	0.28	0.35	1.06	1.62	2.39	2.34	2.85	3.48	1.23	12.29
	% of Ave.	183	37	93	111	49	62	114	98	40	61	77	28	61
	Accumulated	1.57	1.76	2.15	2.46	2.63	3.29	5.14	7.49	8.43	10.17	12.86	13.20	
	Average Accum.	0.86	1.38	1.80	2.08	2.43	3.49	5.11	7.50	9.84	12.69	16.17	17.40	
	% Ave. Accum.	183	128	119	118	108	94	101	100	86	80	80	76	
2007-2008	**Monthly Precip.**	**0.25**	**0.10**	**0.39**	**0.46**	**0.19**	**0.96**	**0.39**	**0.34**	**0.52**	**0.29**	**4.31**	**4.97**	**10.43**
	Average	0.86	0.52	0.42	0.28	0.35	1.06	1.62	2.39	2.34	2.85	3.48	1.23	12.29
	% of Ave.	29	19	93	164	54	91	24	14	22	10	124	404	114.8
	Accumulated	0.25	0.35	0.74	1.20	1.39	2.35	2.74	3.08	3.60	3.89	8.20	13.17	
	Average Accum.	0.86	1.38	1.80	2.08	2.43	3.49	5.11	7.50	9.84	12.69	16.17	17.40	
	% Ave. Accum.	29	25	41	58	57	67	54	41	37	31	51	76	
2008-2009	**Monthly Precip.**	**0.14**	**0.25**	**0.15**	**0.09**	**0.04**	**0.45**	**1.52**	**2.39**	**2.91**	**3.82**	**1.84**	**1.2**	**12.16**
	Average	0.86	0.52	0.42	0.28	0.35	1.06	1.62	2.39	2.34	2.85	3.48	1.23	**12.29**
	% of Ave.	16	48	36	32	11	42	94	100	124	134	53	98	102
	Accumulated	0.14	0.39	0.54	0.63	0.67	1.12	2.64	5.03	7.94	11.76	13.6	14.8	
	Average Accum.	0.86	1.38	1.8	2.08	2.43	3.49	5.11	7.5	9.84	12.69	16.17	17.4	
	% Ave. Accum.	16	28	30	30	28	32	52	67	81	93	84	85	

Acroptilon repens (Russian Knapweed)

Species	Sampling Methods
Russian knapweed	*perimeter mapping and census at all locations*

Russian knapweed decreased in 2009 (potentially eliminated)

In 2009 Russian knapweed was treated with herbicide in the eastern portion of the large infestation near the Skills Development Center, it appears that the treatment was successful as we did not locate any individuals in early July, however these sites should be visited in subsequent years as the seed bank is most likely still viable.

Russian knapweed was observed along Douglass Drive in 2005 and 2006 but not 2008. On July 7th, 2009, no plants were observed in this area during 20 minutes of searching along the ¼ mile stretch of Douglass Drive where they were previously documented.

Carduus nutans (Musk Thistle)

Species	Sampling Methods	Plots 1-10
Musk thistle	*Photopoint*	1 photopoint per plot

Treated

Number of individuals declined in treated plots.

Untreated

Number of individuals increased in untreated plots.

Nine of the ten established plots were revisited in 2009 (see Map 2 for locations). Photos were repeated from the permanent rebar and plants that occur within the frame of the photo were counted (Tables 3 and 4). Number of individuals declined in the three of the four plots that were treated (Table 4), while number of individuals went up in all five of the untreated plots (Table 4). This suggests that musk thistle is killed when treated with herbicide. Recommendations for musk thistle include continuation of herbicide treatment of large infestations in 2011, and manual destruction of plants in smaller infestations and bag inflorescences if they contain ripe seed. All 10 plots should be revisited in 2011.

Table 3. Summary of treatment at the ten musk thistle plots. Tx is shorthand for "treatment."

Plot	2005	2006	2007	2008	2009
1	no Tx	herbicide	no Tx	no Tx	No Tx
2	no Tx	herbicide	no Tx	herbicide	No Tx
3	herbicide	no Tx	herbicide	herbicide	herbicide
4				no Tx	No tx
5				no Tx	No tx
6				herbicide	No tx
7				herbicide	herbicide
8				no Tx	herbicide
9				no Tx	herbicide
10				no Tx	Not visited

Table 4. Population size at each of the 10 plots for musk thistle in 2005-2009. Bolded numbers were treated plots. A positive sign indicates it increased while a negative sign indicates it decreased from the previous year.

Plot	2005	2006	2007	2008	2009
1	13	**-0**	+12	11	+ 134
2	116	**-0**	+19	**-6**	+ 80
3	**25**	-0	**-8**	**-1**	**2**
4				1	+ 63
5				1	+ 27
6				**10**	+ 45
7				**102**	**- 90**
8				212	**-31**
9				160	**-1**
10				500	Not visited

Cirsium arvense (Canada Thistle)

Plot 1 was stable in 09

Plot 2 **(treated)** decreased in 09

Plot 3 (**untreated**) increased in 09

Species	Sampling Methods	Plot 1	Plot 2	Plot 3
Canada thistle	*Transect/ photopoint/ photoplot*	50 m transect, 20 quadrats, 5 photoplots, 2 photopoints	50 m transect, 20 quadrats, 5 photoplots, 2 photopoints	50 m transect, 20 quadrats, 5 photoplots, 2 photopoints

Canada thistle is one of the most abundant noxious weeds at the Academy, second only to yellow toadflax in occupied area (Anderson and Lavender 2008a). Along with yellow toadflax, it is one of two species that is only targeted for management within high priority conservation areas.

Plot 3 has never been treated, whereas, Plots 1 and 2 have been treated (Table 5). In 2009 a decline was observed at plots 1 and 2 while plot 3 increased (Table 6 and Figures 1 and 2). The decline of Canada thistle in plot 3 in 2007 and 2008 was probably due to climate variation. In 2008, most if not all of plot 1 had been treated with herbicide while no treatments had been applied in plots 2 and 3. Plot 1 was observed to be even wetter than it was in 2007, almost certainly due to the rising water table resulting from the upstream restoration of Black Forest Creek.

It appears that the current hydrologic regime at most of plot 1 is now too wet for Canada thistle to thrive, although areas adjacent to this plot that were formerly drier may now become infested. Plot 2 and 3 are still vulnerable to a resurgence of this species in favorable years for this species.

At plot 3, two probable silkyleaf cinquefoil plants were found in 2008 and 2009, just north of the transect. Previously this site has been searched for silkyleaf cinquefoil due to the abundance of wooly cinquefoil (*Potentilla hippiana*) and beautiful cinquefoil (*P. pulcherrima*). Silky cinquefoil is often found with these species and may actually be a hybrid involving these species in its parentage. The silkyleaf cinquefoil at this site has somewhat uncharacteristic leaves which have been seen in other occurrences at the Academy but apparently nowhere else, with decurrent blades on the leaflets.

Table 5. Summary of treatment applications at the three permanent plots for Canada thistle. Tx is shorthand for "treatment."

Plot	2005	2006	2007	2008	2009
1	no Tx	herbicide	no Tx	herbicide	no Tx
2	no Tx	herbicide	no Tx	no Tx	herbicide
3	no Tx	no Tx	no Tx	no Tx	no Tx

Table 6. Summary data from the three permanent monitoring plots for Canada thistle. P-values are for paired T-tests. Bolded numbers indicated that it was treated.

		2005	2006	2007	2008	2009
Plot1	**% Cover**	33.5	**17.1**	0.3	**0.1**	0.5
	SD	19.27	14.17	0.62	0.15	1.14
	p		0.003	<0.001	0.09	0.1
Plot 2	**% Cover**	24.7	**5.4**	2.2	2.6	1.5
	SD	8.6	8.2	6.95	7.26	4.72
	P		<0.001	0.05	0.57	0.31
Plot 3	**% Cover**	33.5	14	8.2	8.2	13.7
	SD	25.46	9.21	8.72	12.08	16.12
	P		0.004	0.06	0.98	0.05

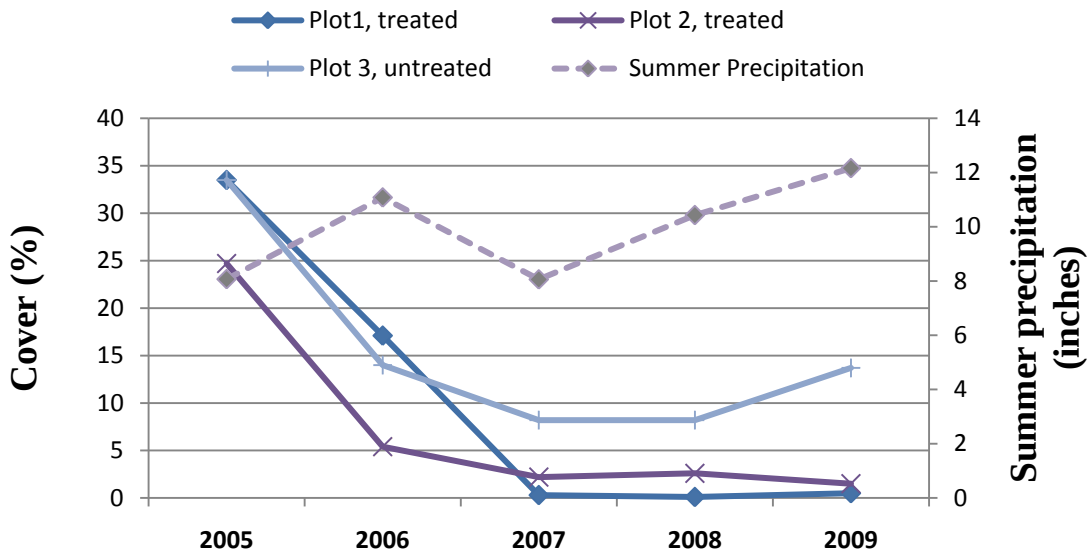
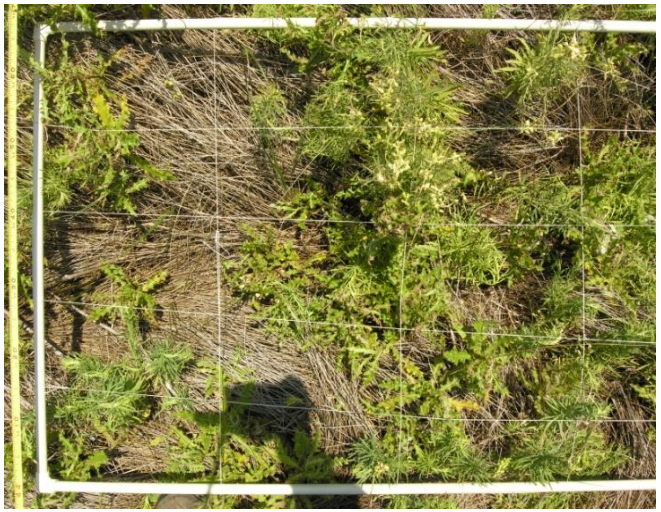


Figure 1. Canada thistle cover (%) for three permanent plots from 2005-2009 and the associated summer precipitation.

Monitoring these sites will still be worthwhile for informing management decisions, particularly at plot 1 due to its proximity to the Black Forest Creek restoration project, and at plot 3 due to its proximity to silkyleaf cinquefoil, a rare plant.

Figure 2. Photo quadtat of *Cirsium arvense*; Plot 1, quadrat 5 from years 2005-2009. Treated with herbicide in 2006 and 2008; stream restoration in 2008 increased water table and it is now too wet for *Cirsium arvense.*

2005



2006

2007

2008

2009

Euphorbia esula (Leafy Spurge)

Plot 1. Occupied area decreased by 1/3 of 2008. **Not treated.**

Plot 2. Occupied area was nearly identical to 2008. **Treated.**

Plot 3. Occupied area was nearly identical to 2008. **Treated.**

Species	Sampling Methods	Plot 1	Plot 2	Plot 3
Leafy spurge	*Perimeter mapping/ survey transects*	Perimeters mapped, 5 E-W survey transects spaced 20m apart	Perimeters mapped, 4 E-W survey transects spaced 20m apart	Perimeters mapped, 4 E-W survey transects spaced 20m apart

Plot 2 has the largest population of the three plots (Table 8 and Figure 2). At plot 2, herbicide has been applied aggressively every year to control leafy spurge (Table 8). From 2005 to 2008, leafy spurge spread rapidly into uninfested areas at this site. Efforts to spray it were locally effective here, but in any given year many stems evaded herbicide treatment and these became nodes from which the species spread in subsequent years. Overall, the area occupied and number of stems increased continuously from 2005 through 2008 despite treatment efforts, and was stable in 2009 (Tables 7 and 8). Previously cleared areas are becoming infested once again at this site (Map 3).

Herbicide was probably applied to the largest infestation at plot 3 in 2008 although the poor condition of the plants in this plot due to drought made it difficult to tell. No plants were seen at the small founder infestation on the west side of this plot. An infestation of white top was observed at this site in 2008 that is the first known infestation of this species in Jack's Valley.

The small infestation at plot 1 was not treated in 2005-2009, and no new infestations were detected at this plot in 2009, better yet, the occupied area decreased from 313 m^2 to 100 m^2.

Plot 3 remained nearly identical to 2008.

Table 7. Summary of treatment applications for the three leafy spurge plots from 2005-2009. Tx is shorthands for "treatment".

Plot	2005	2006	2007	2008	2009
1	no Tx	no Tx	no Tx	no Tx	no Tx
2	Herbicide	no Tx	Herbicide	Herbicide (in part)	Herbicide
3	no Tx	no Tx	Herbicide (in part)	Herbicide (in part)	Herbicide

Table 8. Summary data from the three permanent plots for leafy spurge. Bolded numbers indicate that the plot was treated in that year.

		Occupied Area (m^2)	N (ramets)	# patches	Summer Precipitation (in)
Plot 1	**2005**	78	234	1	8
	2006	146	5840	1	11
	2007	129	5149	1	8
	2008	313	40	1	10
	2009	100	200	1	12
Plot 2	**2005**	**2340**	**6097**	**6**	8
	2006	3193	11130	7	11
	2007	**4214**	**18156**	**4***	8
	2008	**5533**	**1076**	**5**	10
	2009	5373	295	4	12
Plot 3	**2005**	79	393	1	8
	2006	97	970	2	11
	2007	**108**	**545**	**3**	**8**
	2008	**144**	**13**	**2**	**10**
	2009	185	11	3	12

* In 2007, several smaller patches grew and amalgamated into four larger patches at plot 2.

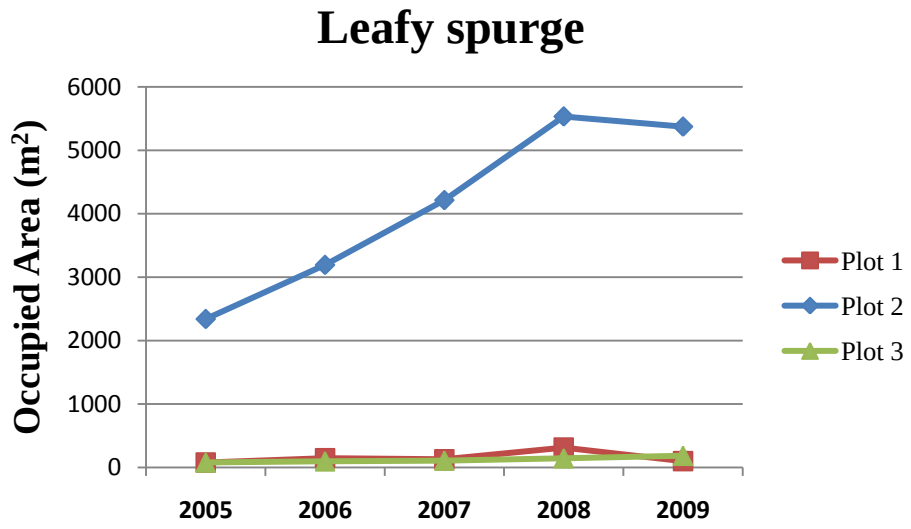
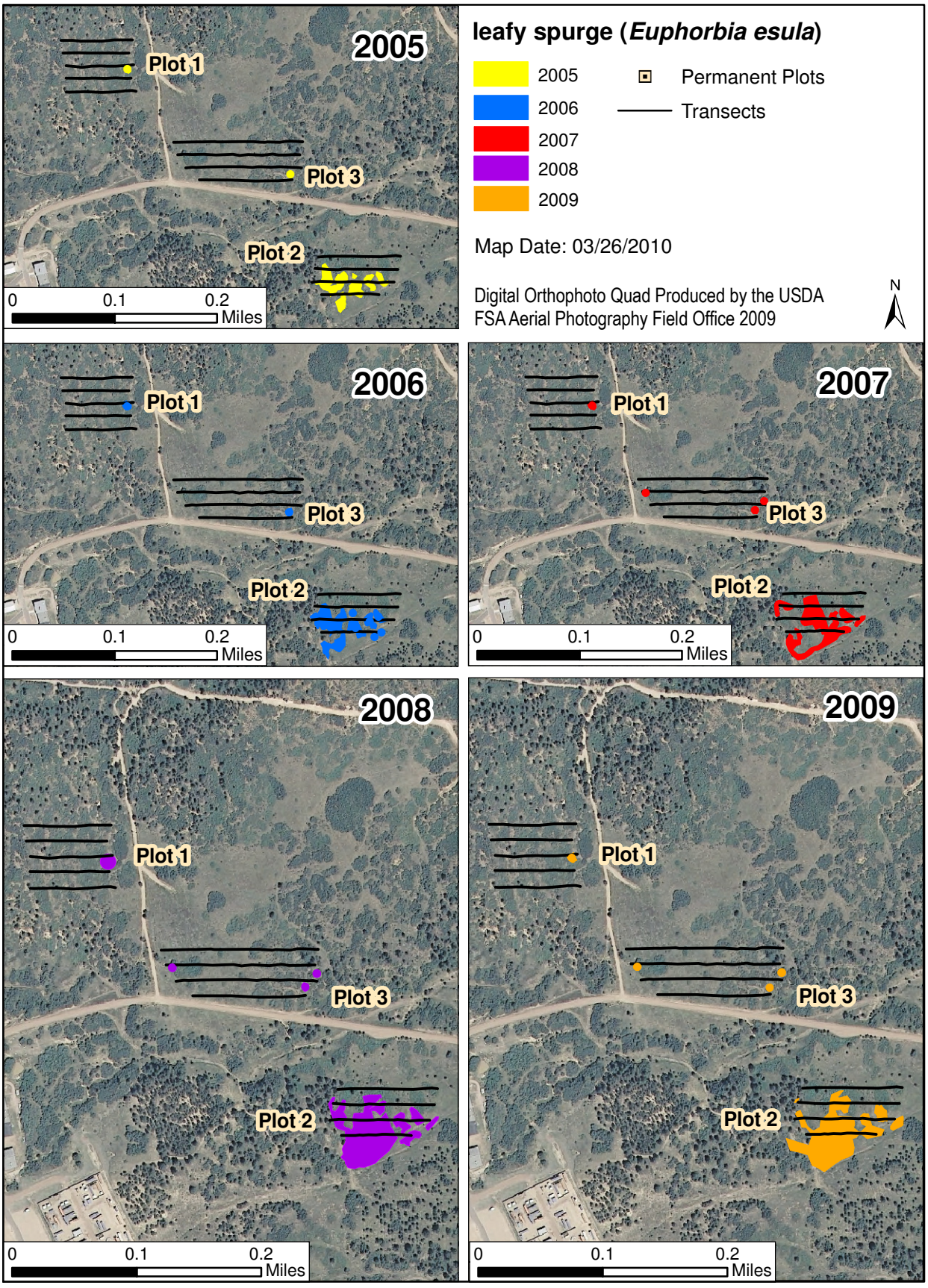
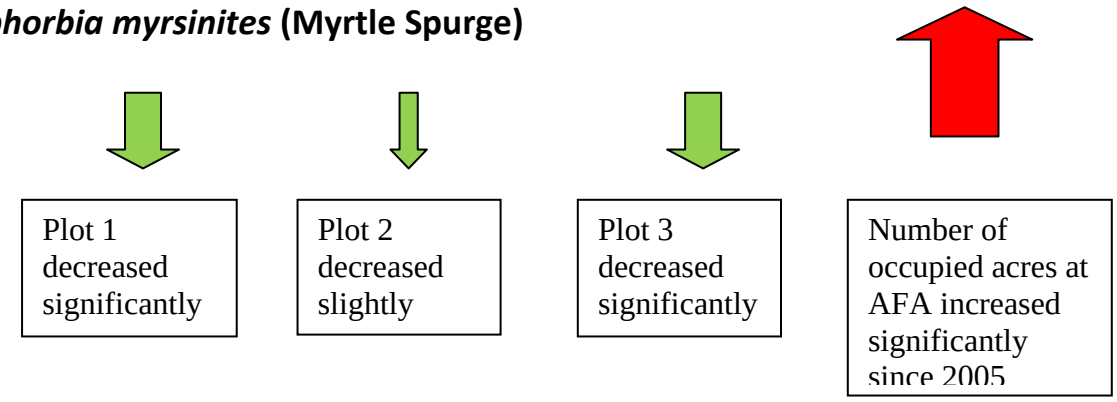


Figure 2. Occupied area of leafy spurge at three plots 2005-2009.



Map 3. Distribution of leafy spurge at the three permanent plots in 2005-2009.

Euphorbia myrsinites (Myrtle Spurge)



Species	Sampling Methods	Plot 1	Plot 2	Plot 3	Additional locations
Myrtle spurge	*Perimeter mapping/ census/ photopoint*	Perimeter mapping, census, 1 photopoint	Perimeter mapping, census, 2 photopoints	Perimeter mapping, census, 1 photopoint	Perimeter mapping, census, photos

Myrtle spurge is on the noxious weed list, A status, mandating the eradication of this species wherever it is found (Colorado Department of Agriculture, Plant Industry Division 2005). Fortunately, Natural Resources Staff at the Academy identified the presence of myrtle spurge at an early stage of its invasion, and some progress is being made towards its eradication, however new locations and number of individuals continues to increase (Table 9, Figure 3, and Map 4). See Appendix A for information about each location depicted on the map. The three permanent plots for this species were established at the only known extant infestations in 2006, but there are now 9 additional infestations that are also being mapped (Map 4). The total area infested by myrtle spurge at the Academy in 2009 was approximately 9634 m^2 with 464 individuals counted (Table 9 and Figure 3).

Table 9. Number of individuals, occupied area, extant and eradicated locations for myrtle spurge.

	2005	2006	2007	2008	2009
No. of individuals	25	243	261	419	464
Area (m^2)				2678	9643
Extant locations				13	12
Eradicated locations				1	6

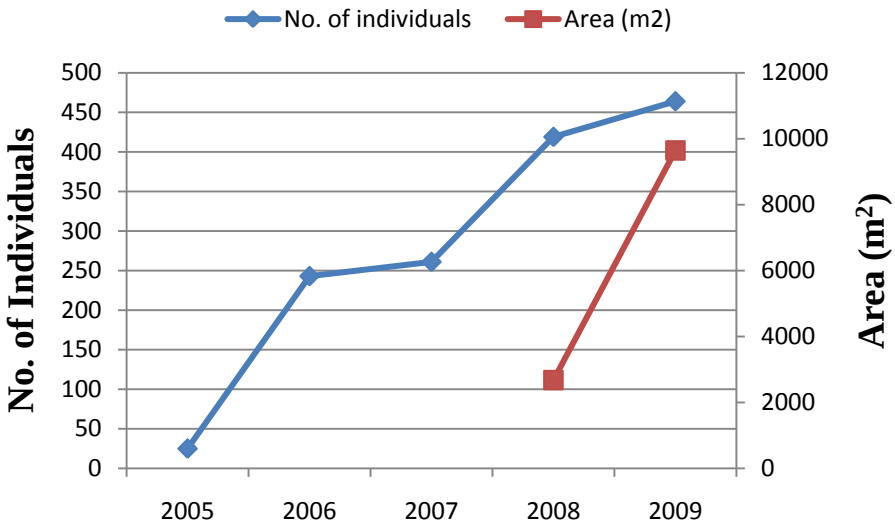
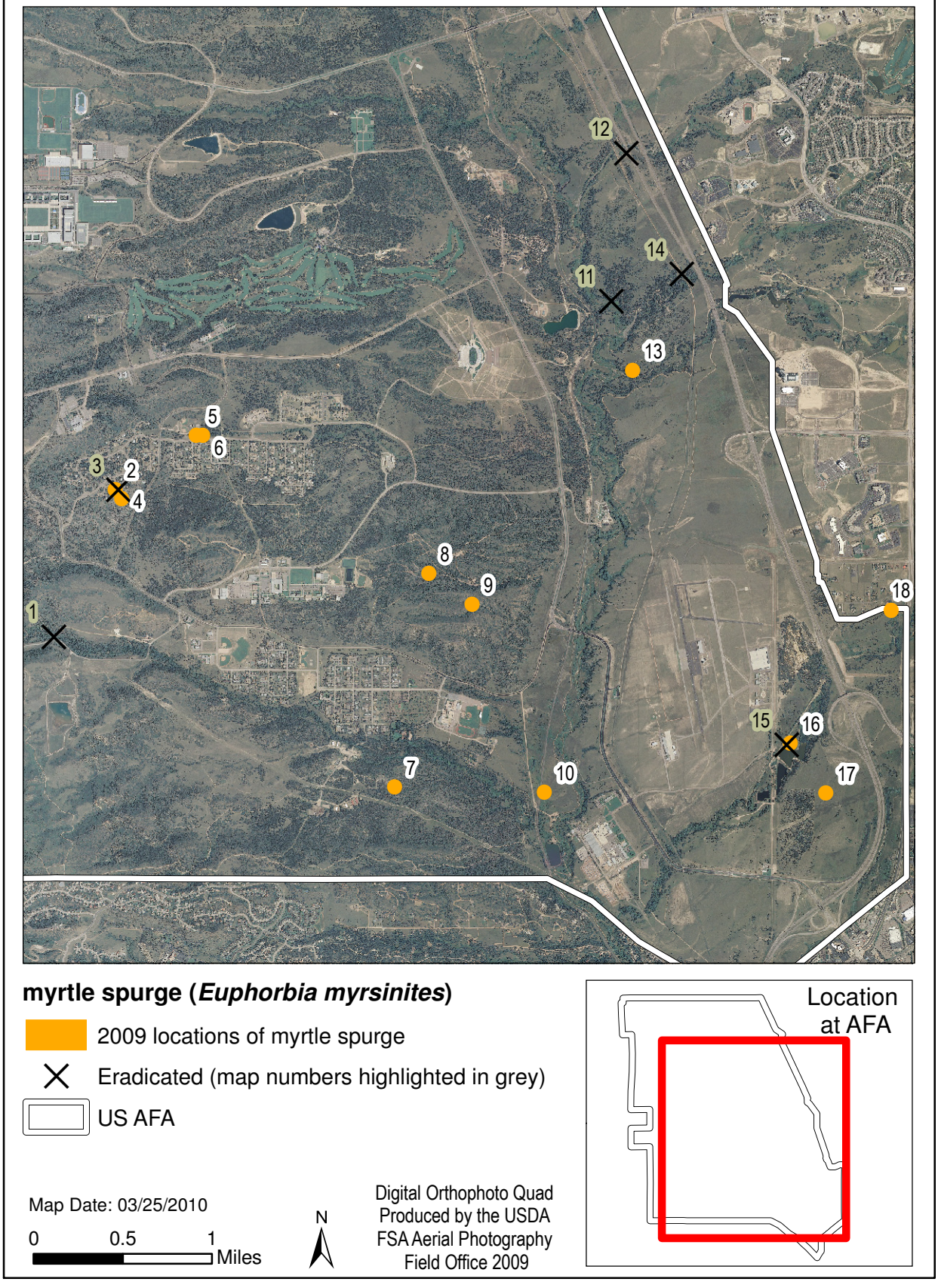


Figure 3. Number of individuals and occupied area for myrtle spurge



Map 4. All known sites where myrtle spurge has been found at the Academy between 2005 and 2009. Numbers correspond to locations described in the Appendix.

Plot 1 is located east of the stables in a dense stand of ponderosa pines that is being thinned. Aggressive measures were taken in 2005 and 2006 to eradicate this infestation by pulling and excavating plants. This reduced the density but many small plants were found in 2007 that may be sprouting from seeds or from rootstock that remained underground after the 2006 treatment. In 2008 myrtle spurge was once again abundant at this site (N=146) and the site had not been treated. No flowering individuals were observed in 2008 but some flowering stalks were present. A beetle tree was felled upslope and dragged through the N edge of the infestation. In 2009, plants were pulled, however 10 plants were still present when we monitored this site in August.

Plot 2 is located at the southwestern edge of the housing in Douglass Valley behind 4176 Douglass Way, where two large patches are present. There was no evidence of treatment at this plot in 2006 or 2007. In 2006, myrtle spurge was found in a rockgarden adjacent to the two large patches where the resident said they had dug up four plants from behind their house and planted it; the resident voluntarily removed the plants after realizing it is a noxious weed. In 2007, another lone individual was found between two houses just east of the northernmost patch; the plant was pulled. The number of individuals at this plot increased considerably from 2006 to 2007 (Table 10). In 2008 large, reproductive plants remained at this location and no treatment was evident. In 2009 restoration occurred in part of this site, with drill seedling of *Lolium* and *Avena*; 21 seedlings were visible. The other area at this site did not have any treatment and had 70 individuals (See Appendix A).

Plot 3 is located in the Archery Range area near Sumac Drive. It was treated with herbicide in 2006. This was somewhat successful, but again there were numerous small plants sprouting from seed or rootstock in 2007. In 2008 this site was partially treated. Many senescent plants as well as withered native dicots were observed but many individuals remained untreated here. In 2009, seven plants were pulled on July 10.

Table 10. Number of individuals at sampled plots 2006-2009. Bolded numbers indicate that it was treated.

Plots	***2006***	***2007***	***2008***	***2009***
Plot 1- East of Stables	**142**	**97**	146	**10**
Plot 2- Douglass Valley Housing	72	122	120	**91**
Plot 3- Archery Range	**25**	41	**24**	**7**

Hypericum perforatum (Common St. Johnswort)

Plot 1
Increased from 0 individuals in 2008 to over 17,000 in 2009

Plot 2
Increased from 0 individuals in 2008 to 3 individuals in 09

Plot 3
A 20% increase in number of individuals: 56,000 to 68.000

All locations
Occupied area nearly doubled from 2008: 4300 to 8200 m^2

Species	2009 Sampling Methods	Plot 1	Plot 2	Plot 3	Other sites
Common St. Johnswort	*photopoint/ census/ perimeter mapping*	2 photopoints, perimeter mapping	3 photopoints, perimeter mapping	2 photopoints, perimeter mapping	Perimeter mapping and census

What appeared to be effective management for St. Johnswort in the past several years was reversed in 2009. There was an increase in number of individuals and occupied area for all plots as well as all mapped locations throughout the AFA (Tables 11 and 12; Figure 4 and Map 5). Plot 1 along south Kettle Creek (Map 2 and Figure 5) was the most dramatic as it appeared to be eradicated for the last several years after beetles were introduced by Michels et al. (2004), but in 2009 over 17,000 individuals were estimated, occupying some 230 m^2. Beetles were, once again, on the plants.

At plot 2, the furthest north occurrence, (Map 2), a broadleaf herbicide was applied sometime in the summer or fall of 2005 after the baseline data were obtained at this site. No evidence of common St. Johnswort was found at this site in 2006 and 2007. In 2008 a small patch was detected along the road adjacent to the large infestation, however the original site was still free of St. Johnswort. In 2009 another small location approx. 0.1 miles southwest was detected and the original site had 3 plants in 2009 (Table 11).

At plot 3, middle Kettle Creek, (Map 2), biocontrol insects introduced by Michels et al. (2004) had considerable local impacts on the density of common St. Johnswort in previous years but not so in 2009; both number of individuals and area increased (Table 11).

Additional infestations of common St. Johnswort were discovered along Kettle Creek in 2009, illustrating that this species is continuing to spread at the Academy (Table 12, Map 5 and Figure 4). Based on these observations, it appears timely now to use herbicide to eradicate small founder infestations along Kettle Creek and on the roadside infestation at plot 2. It will be necessary to continue perimeter mapping and census of

the entire population of this species in 2010 to inform eradication efforts for this species.

Table 11. Plot summary for St. Johnswort 2005-2009.

		2005	2006	2007	2008	2009
plot 1	no. of ind	?	?	?	0	17,261
	area (sq m)	?	?	?	0	230
	cover					
plot 2	no. of ind		0	0	0	3
	area (sq m)					
	cover	27	0	0	0	?
plot 3	no. of ind	?	?	?	56,439	68,368
	area (sq m)	?	?	?	1128	1709
	cover	21.3	11.8	17.7	?	?

Table 12. Occupied area, number of individuals and patches for St. Johnswort 2007-2009.

Year	Occupied Area (m^2)	# of individuals	# of patches
2007	3,491	44,647	8
2008	4,341	130,371	13
2009	8,199	95,883	21

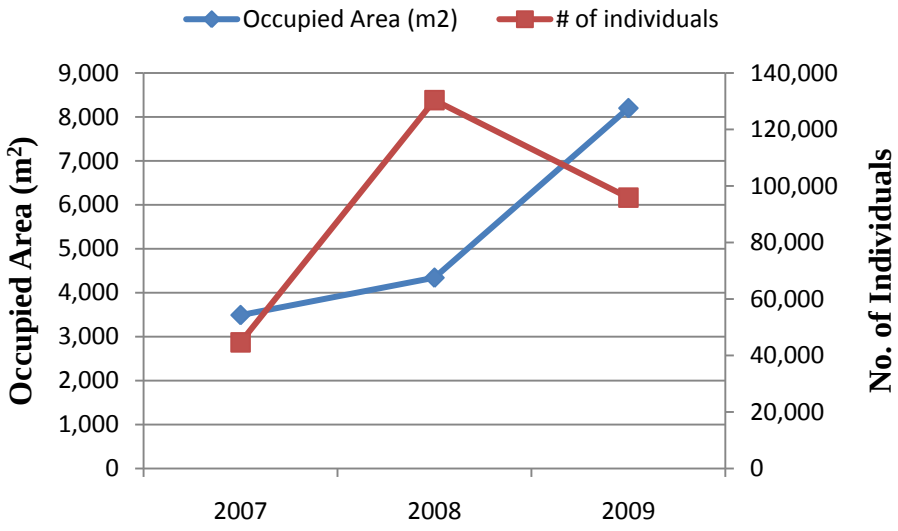
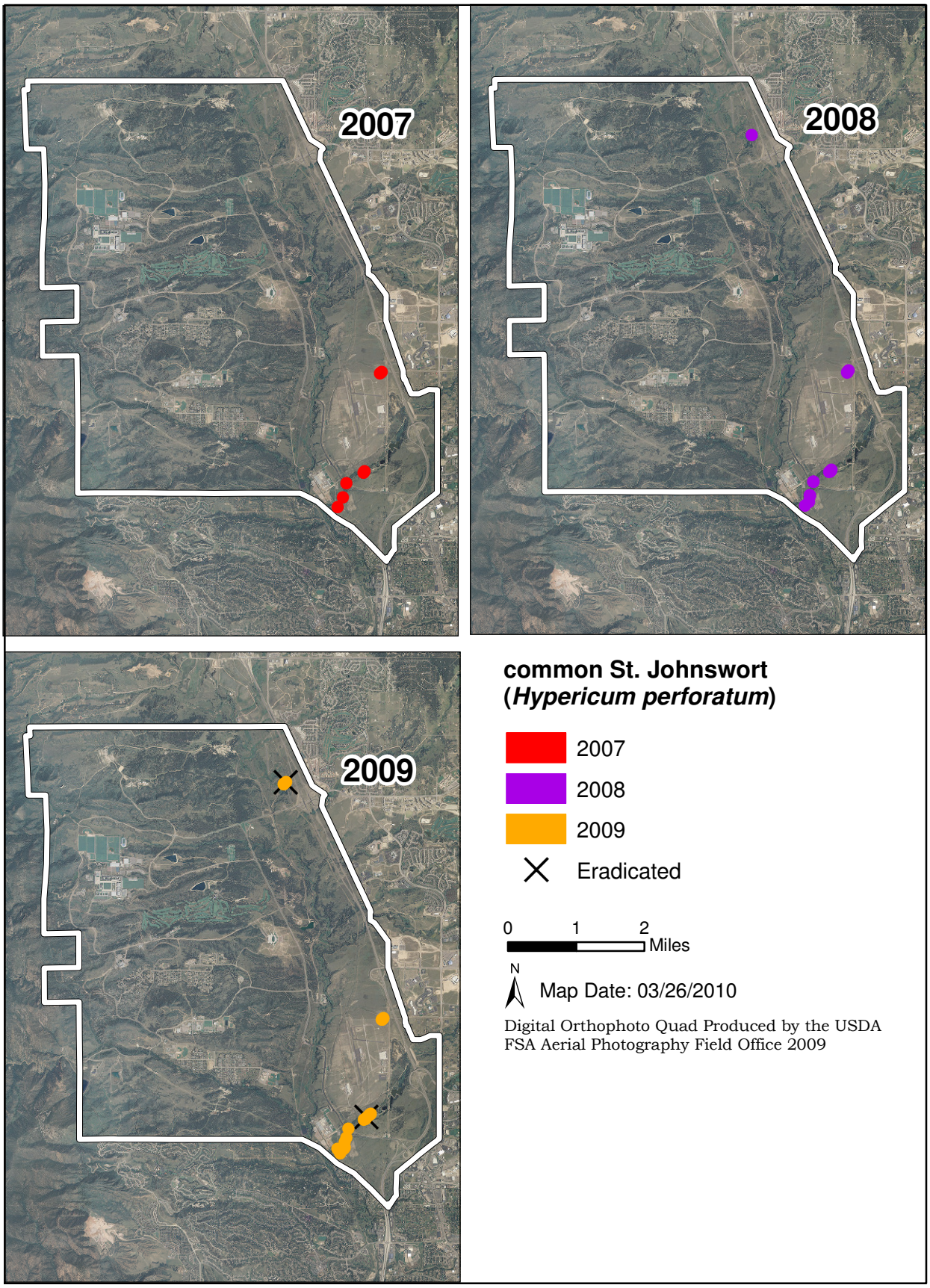


Figure 4. Occupied area and number of individuals for St. Johnswort for all mapped locations on AFA (2007-2009).

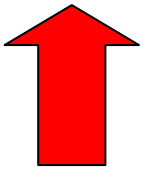


Map 5. Distribution of common St. Johnswort at the Academy in 2007, 2008 and 2009.

Figure 5. Photopint 1a, showing progress in managing common St. Johnswort with bicontrol insects from 2005-2008 and a re-occurrence in 2009. In 2009 over 17,000 individuals were estimated for the area, mostly behind the shrub in the foreground (black polygon).

Onopordum acanthium (Scotch Thistle)

Occupied acres **tripled** over 2008, increasing from 1.1 to 3.5.



Number of individuals increased from 144 in 2008 to 1710 in 2009

Number of mapped features doubled over 2008, from 27 to 50

The population of Scotch thistle has increased from 2002 through 2009 at the Academy (Table 13, Map 6, Figure 6). Compared with 2008, occupied acres doubled and number of individuals greatly increased from 144 to over 1700 (Table 13). Although 34 locations were mapped as eradicated in 2009 the overall trend is upward. It may still be possible to eradicate this species through a coordinated and consistent program of treatment. Where treatments have been carefully applied, reproductive success is limited. However, most infestations observed at the Academy have remained viable over several years whether they were treated or not so it remains important to revisit and assess infestations after they have seemingly been eradicated.

Table 13. Summary data for Scotch thistle at the Academy form 2002-2008.

	Occupied Acres	Number of Individuals	Number of Mapped Features
2002	0.17	52	7
2005	0.42	137	12
2007	1.30	1,307	36
2008	1.14	144	27
2009	3.47	1710	50

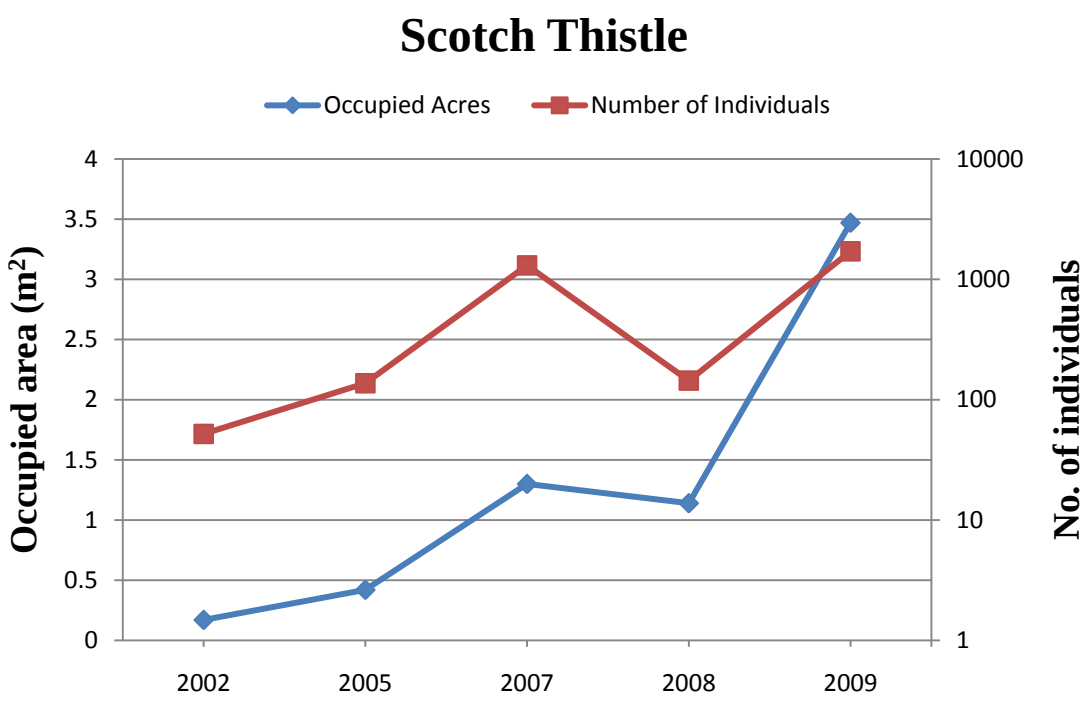
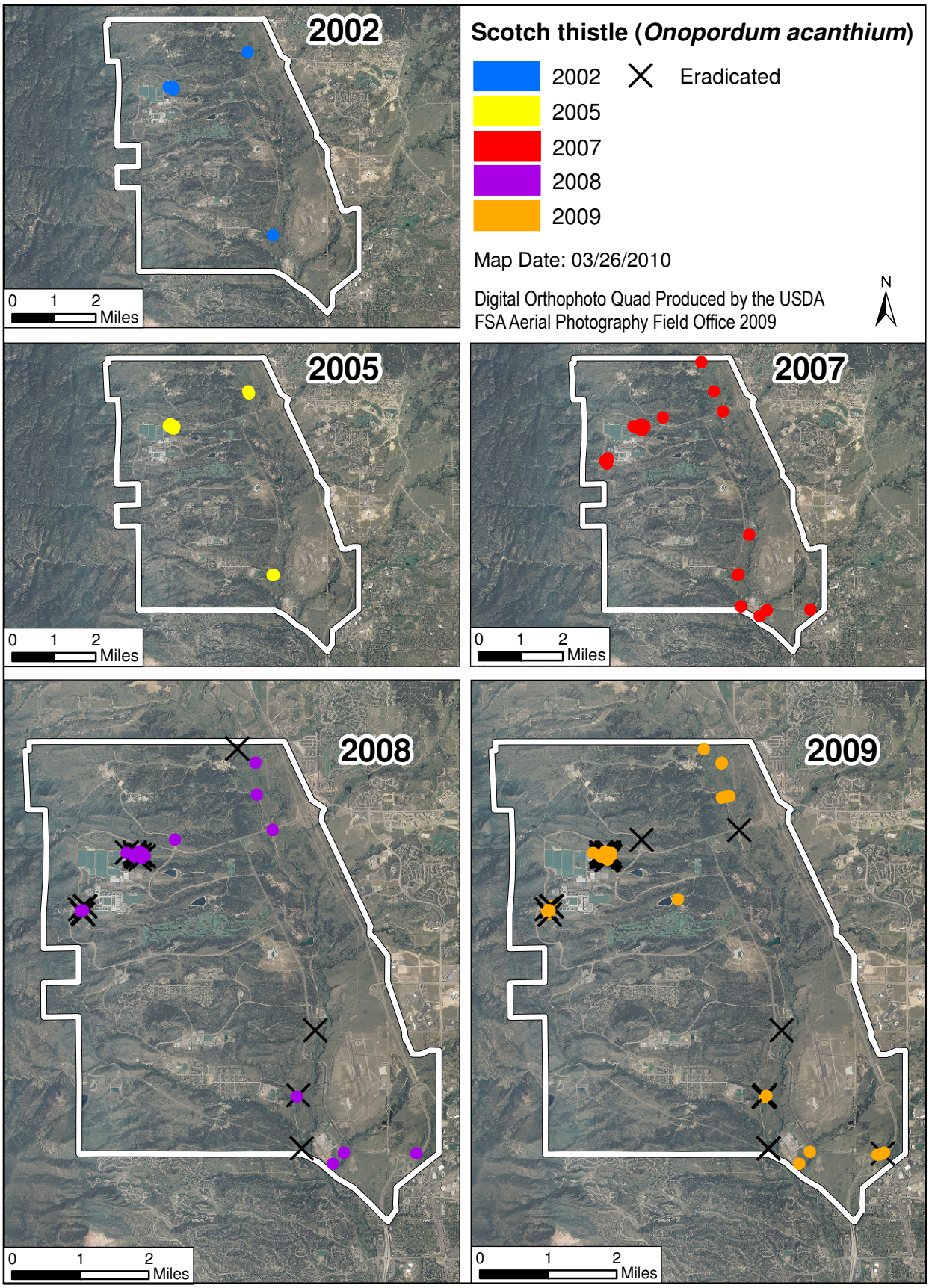
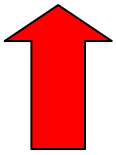


Figure 6. Scotch thistle, Academy-wide, occupied area and number of individuals from 2002-2009.



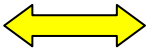
Map 6. Extent of Scotch thistle in 2002-2009 at the Academy.

Centaurea diffusa (Diffuse Knapweed)



Plot 1 plant density doubled from 2007

Plot 2 plant density decreased by 25% from 2007



Plot 3 plant density was unchanged from 2007

Species	Sampling Methods	Plot 1	Plot 2	Plot 3
Diffuse knapweed	*Belt Transects/ photopoints*	4 25 m belt transects, each divided into five segments, 2 photopoints	4 25 m belt transects, each divided into five segments, 2 photopoints	4 25 m belt transects, each divided into five segments, 2 photopoints

In 2009 density (plants/m^2) of diffuse knapweed increased in plot 1, decreased in plot 2 and was stable in plot 3. Plot 1 has seen the most drastic change in density, steadily increasing since 2006 (Table 14 and Figure 7). Plot 2, near the runway, was repeatedly mowed and decreased by nearly 25%. In 2006 a strip along the west side of plot 3 was mowed prior to sampling in 2007, which evidently resulted in a considerable reduction of density at this location compared with 2006 (Figure 7). Mowing, though impractical for most knapweed infestations, may be an effective means of managing this species at the Academy along the railroad right-of-way and roadsides. The railroad appears to be a major corridor for the dispersal of diffuse knapweed throughout the Academy, so intensive management of infestations there may provide benefits base-wide.

Table 14. Summary data from permanent monitoring plots for diffuse knapweed.

		2005	2006	2007	2009
Plot 1	**Average density (plants/m^2)**	1.02	0.92	9.83	19.67
	SD	0.29	1.41	9.59	9.89
	N (*C. diffusa*)	153	138	1475	2950
	N (hybrids)	0	19	24	73
Plot 2	**Average density (plants/m^2)**	6.85	6.44	12.73	8.3
	SD	8.32	5.98	12.16	7.50
	N (*C. diffusa*)	771	966	1909	1237
	N (hybrids)	0	92	160	8
Plot 3	**Average density (plants/m^2)**	2.68	5.68	2.05	2.08
	SD	0.89	4.35	2.77	2.69
	N (*C. diffusa*)	302	809	292	300
	N (hybrids)	0	27	1	8

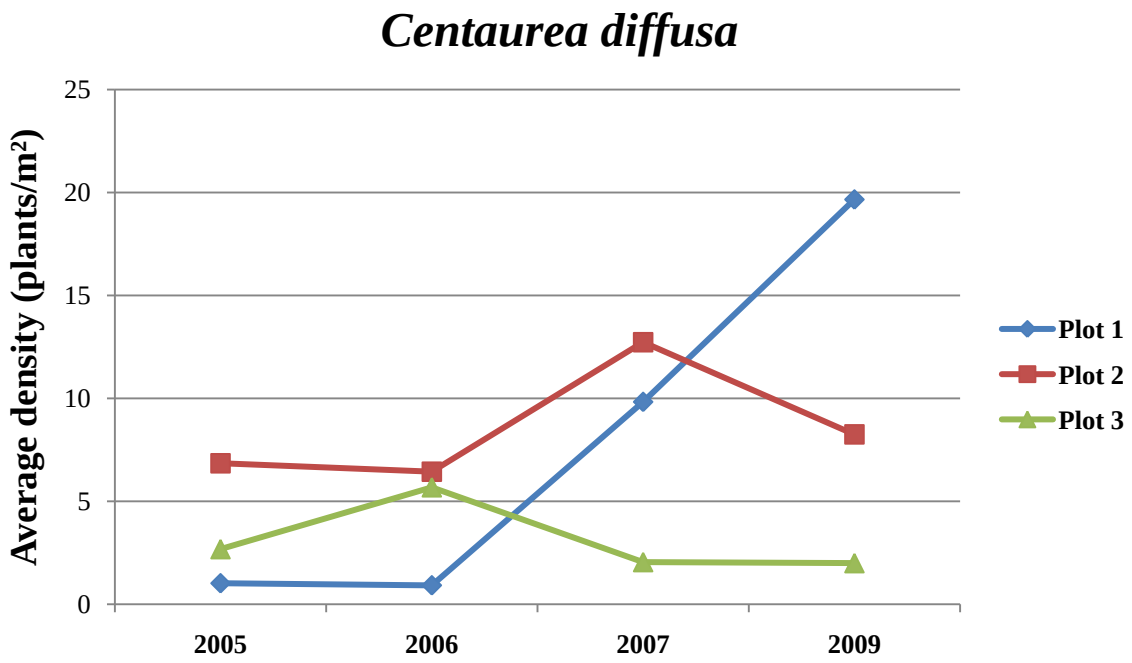


Figure 7. Diffuse knapweed average density for three permanent plots from 2005-2009.

Centaurea maculosa (Spotted Knapweed)

Spotted knapweed was mapped in 2002, 2005, 2006, and 2007 at the Academy, dramatically illustrating its rapid spread (Table 15). The population size of spotted knapweed was 36 times greater in 2007 than it was in 2002. Although it was relatively uncommon at the Academy in 2002, it occupied a total of 57.89 acres in 2007 and had the fourth largest footprint of all the targeted noxious weeds at the Academy, superseded only by diffuse knapweed, yellow toadflax, and Canada thistle (Anderson and Lavender 2008). The eruption of this species at the Academy is centered at the water treatment plant and stables, and the Parade Loop area, suggesting that founder populations may have been located in these areas. The I-25 corridor and Monument Creek have also become infested.

Table 15. Summary data for spotted knapweed at the Academy from 2002-2007.

	Occupied Acres	N	Number of Mapped Features
2002	4.68	3,485	54
2005	14.19	86,392	71
2006	40.61	116,455	91
2007	57.89	127,803	323

Aggressive management of this species is needed to prevent further spread. Because most infestations are small and scattered, herbicide treatment is likely to be a more effective means of controlling this species base-wide than biocontrols. However, continuing the ongoing biocontrol program in conjunction with herbicide treatment is advisable given the rapid rate of spread of this species.

Due to the rapid spread of this species we decided that rather than mapping this species we would model the potential habitat and pace of infestation. The methods and results of this model are below.

Modeling methods and results

Nine hundred and fifteen presence data points were produced from mapped polygons of 2007. Instead of making a centroid for each polygon, a point was created at the center of each grid cell intersected by a polygon. The grid was registered with the 30 m raster extent used for all other inputs. This procedure insured that all values of each raster data where the species had been mapped as occurring would be included. This procedure does introduce spatial bias in that a large number of sample points are clustered in a small geographic area that is relatively homogenous for the various environmental factors, resulting in a low omission rate (the number of test locations that do not fall in an area predicted by the model as suitable habitat) that may not truly reflect the accuracy of the model.

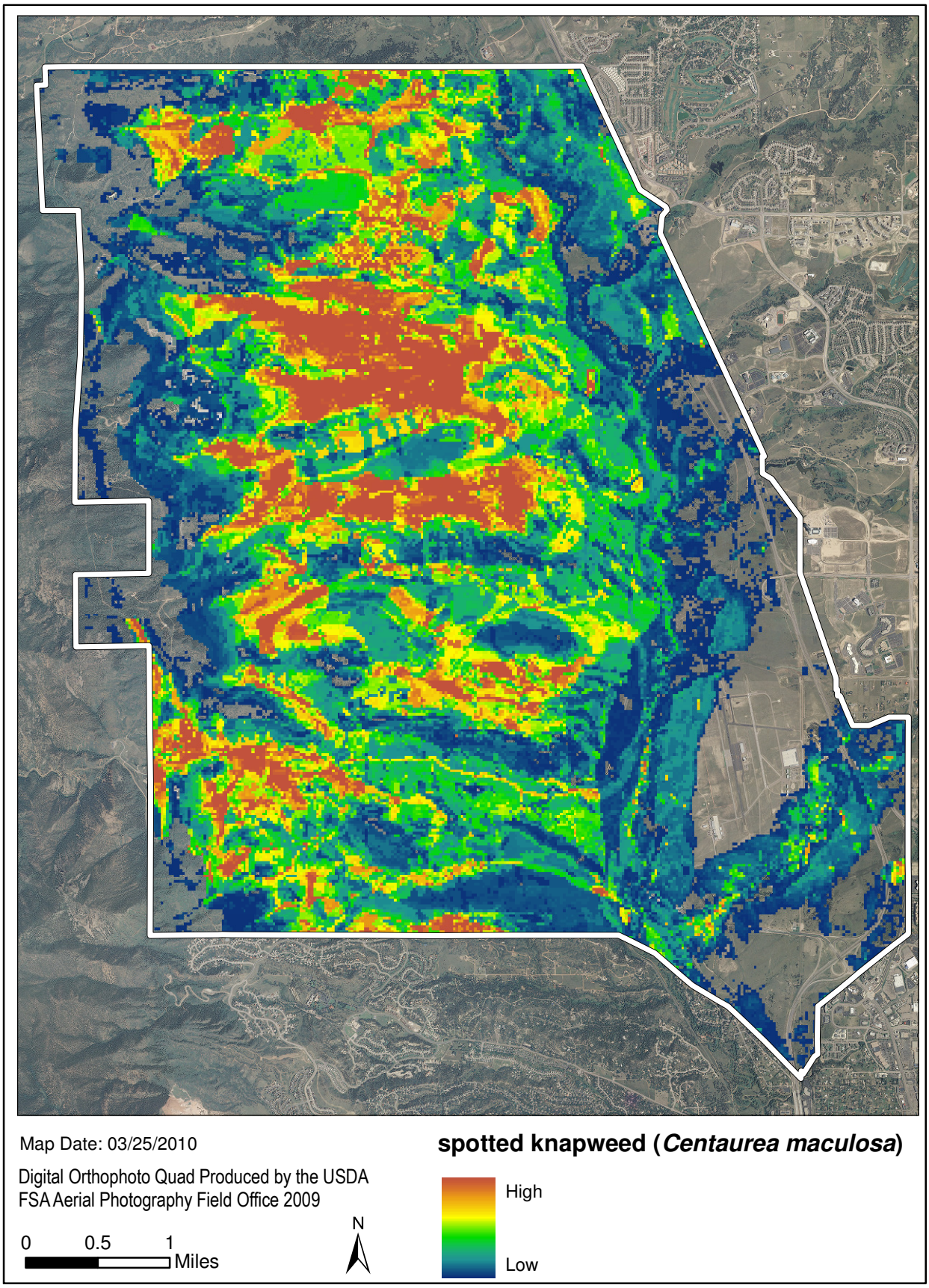
Environmental factors available for the analysis included: aspect (categorical), slope, elevation, local relief, soils (categorical), vegetation type (categorical), precipitation, and temperature. The final selected model incorporated only (in order of contribution), elevation, relief, soils, aspect, vegetation type and slope. The resulting probability surface map (Map 7) is intended to represent areas of potentially suitable habitat for *Centaurea maculosa* (spotted knapweed) within the boundaries of the US Air Force Academy.

The PathDistance model (cema_dist) represents the predicted spread over time of *Centaurea maculosa* (CEMA) within the boundaries of the U.S. Air Force Academy (USAFA) in Colorado Springs, Colorado, and is used in conjunction with the predicted distribution model of *Centaurea maculosa* within the USAFA (Figure 8). The values of the cema_dist dataset represent a weighted distance from source areas (2007 CNHP field surveys mapping CEMA on the USAFA). Based on past years of mapping and the resolution of this dataset, CEMA is assumed to expand its range by 30 weighted meters every two years. Because this model is based on 2007 mapped areas, the dataset should be classed as the following raster values representing the potential spread of the distribution of CEMA by the following year:

Year	Value (weighted meters)
2009	30
2011	60
2013	90
2015	120
2017	150

Distances are weighted by landscape permeability - i.e., areas of high habitat and dispersal suitability are more permeable and therefore have a lower weight. Distances are cumulative from source areas.

The entire bounding rectangle around the USAFA was modeled. The highest value in the dataset is over 204,500 weighted meters away from source areas, which roughly translates to CEMA reaching that particular area in the year 15642. Obviously this is not meaningful, and as a general rule of thumb, the farther out into the future this prediction is taken, the less reliable it becomes. We do not recommend using this model to predict CEMA dispersal beyond 20-30 years from when the source data was mapped (2007). Also, this model is unable to take into account the effect of dispersers on the spread of knapweed (i.e., the model cannot predict new infestations). Humans and their vehicles are among the most effective dispersers of weed seeds, especially along roadsides and other areas of frequent vehicle traffic. A population of CEMA could be easily established far from existing source areas through unintentional human dispersal, but would not be predicted by the model.



Map 7. Habitat suitability model (Maxent) for spotted knapweed at the Academy.

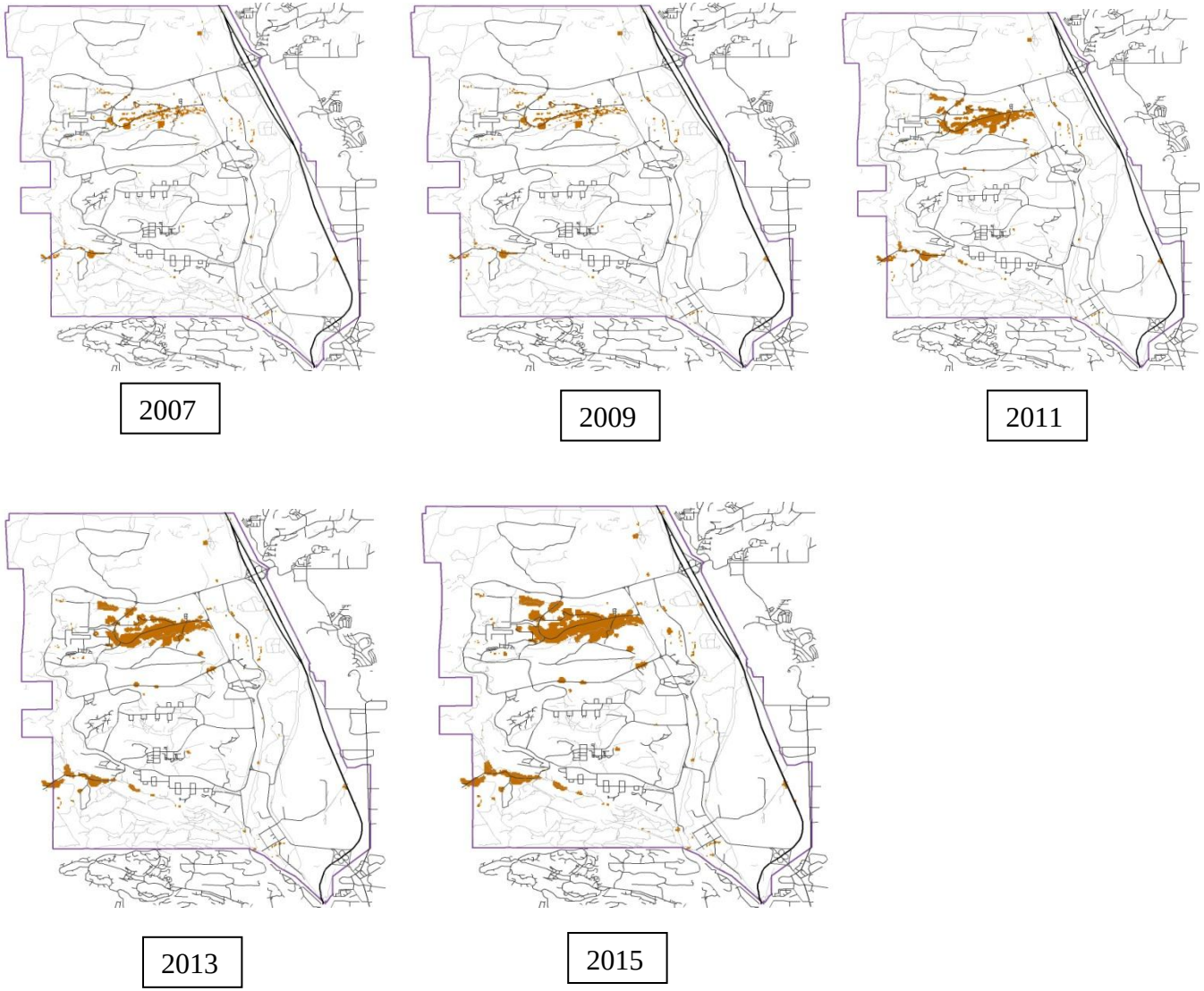


Figure 8. Predicted spread of spotted knapweed between years 2007-2015.

Tamarix ramossisima (Tamarisk)

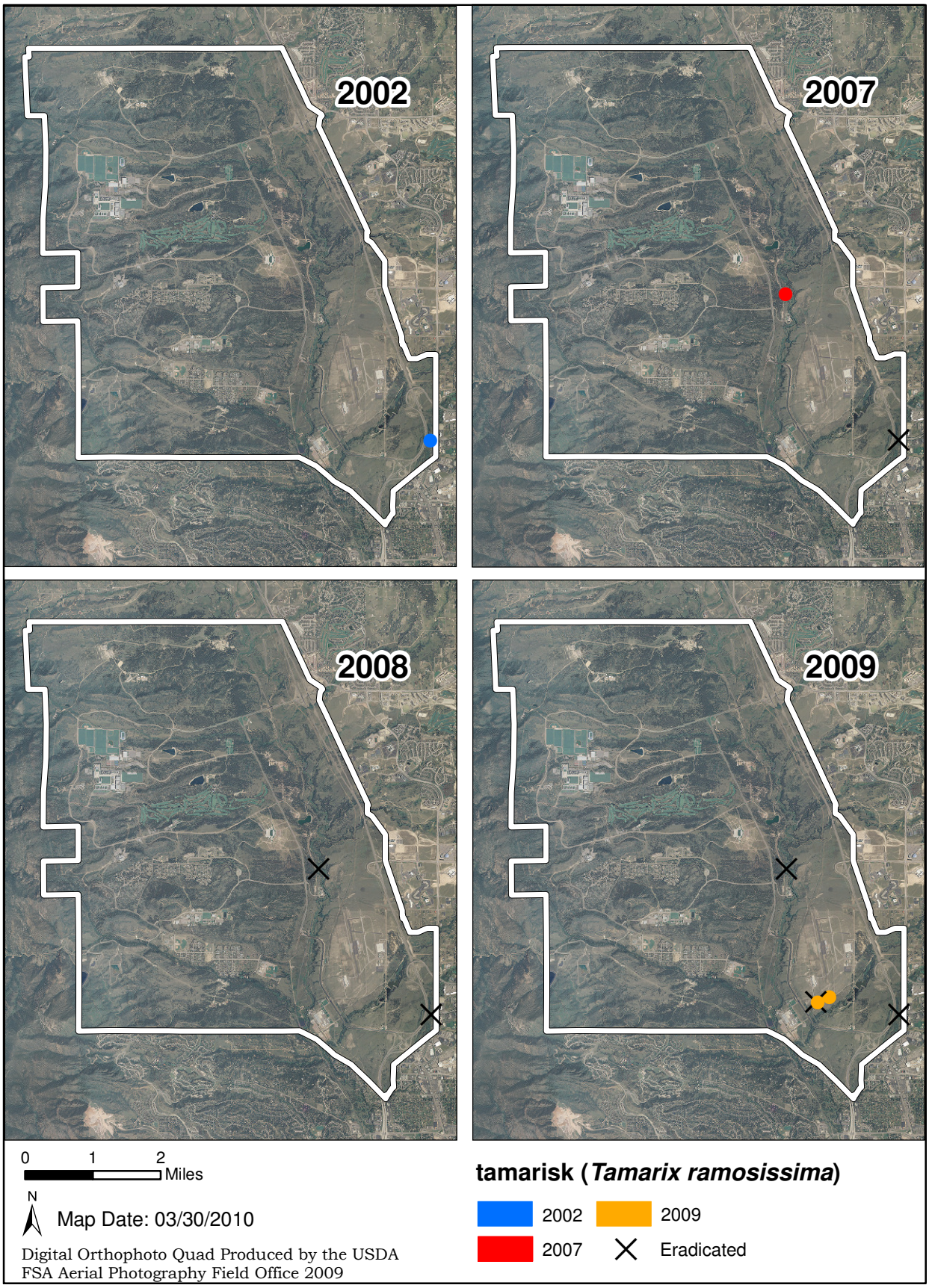
Tamarisk was located at two extant locations in 2009 and was eradicated from two other sites (Map 8).

*Cynoglossum officinale (*Houndstongue*)*

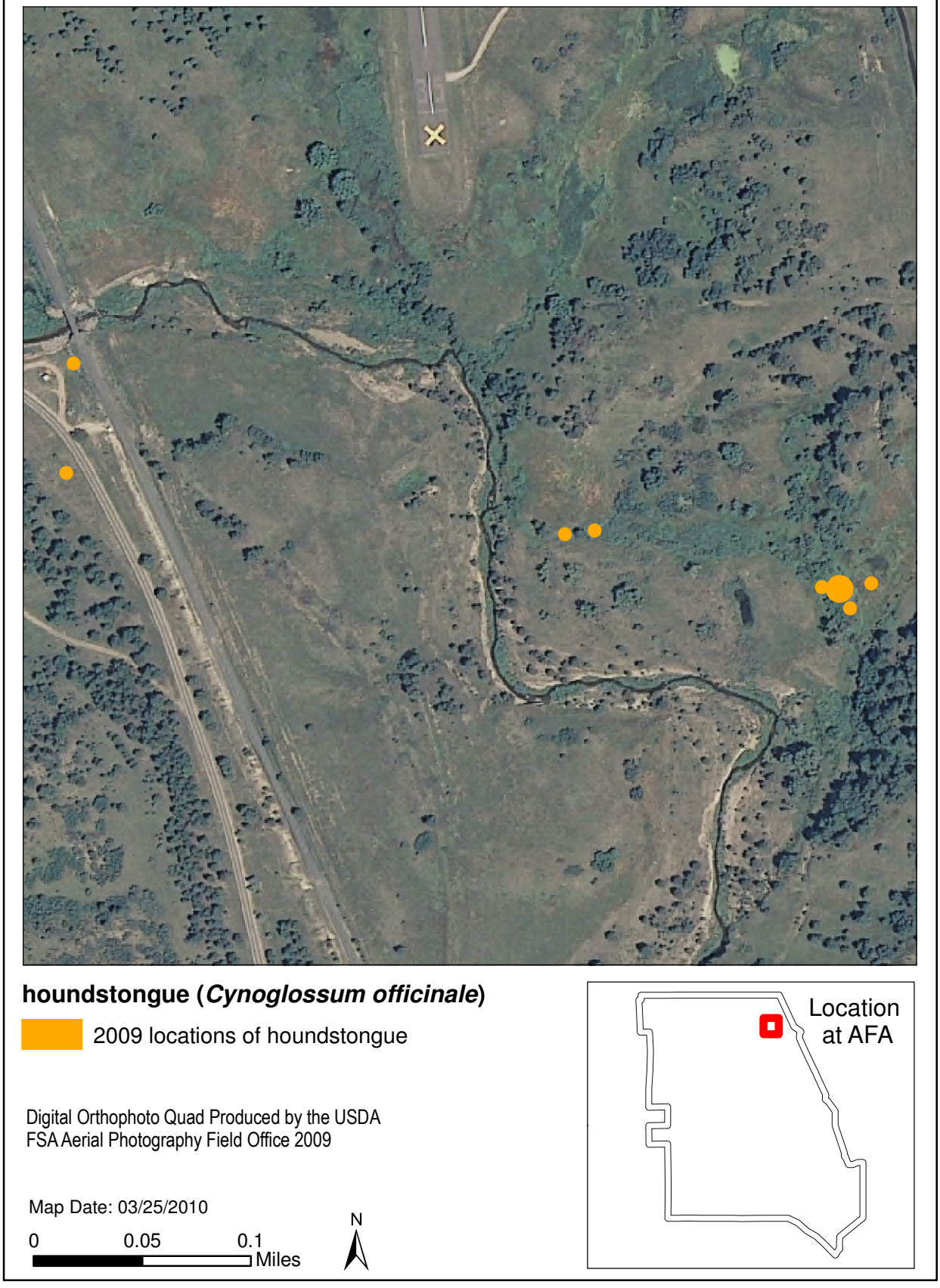
*Linaria genistifolia ssp. Dalmatica (*Dalmatian Toadflax*)*

These two species were recently discovered at the Academy. Eight locations of houndstongue were mapped and one occurrence of Dalmatian toadflax was found near Kettle Lake #1 near the boat ramp in 2009. The occurrence consisted of a small number of plants.

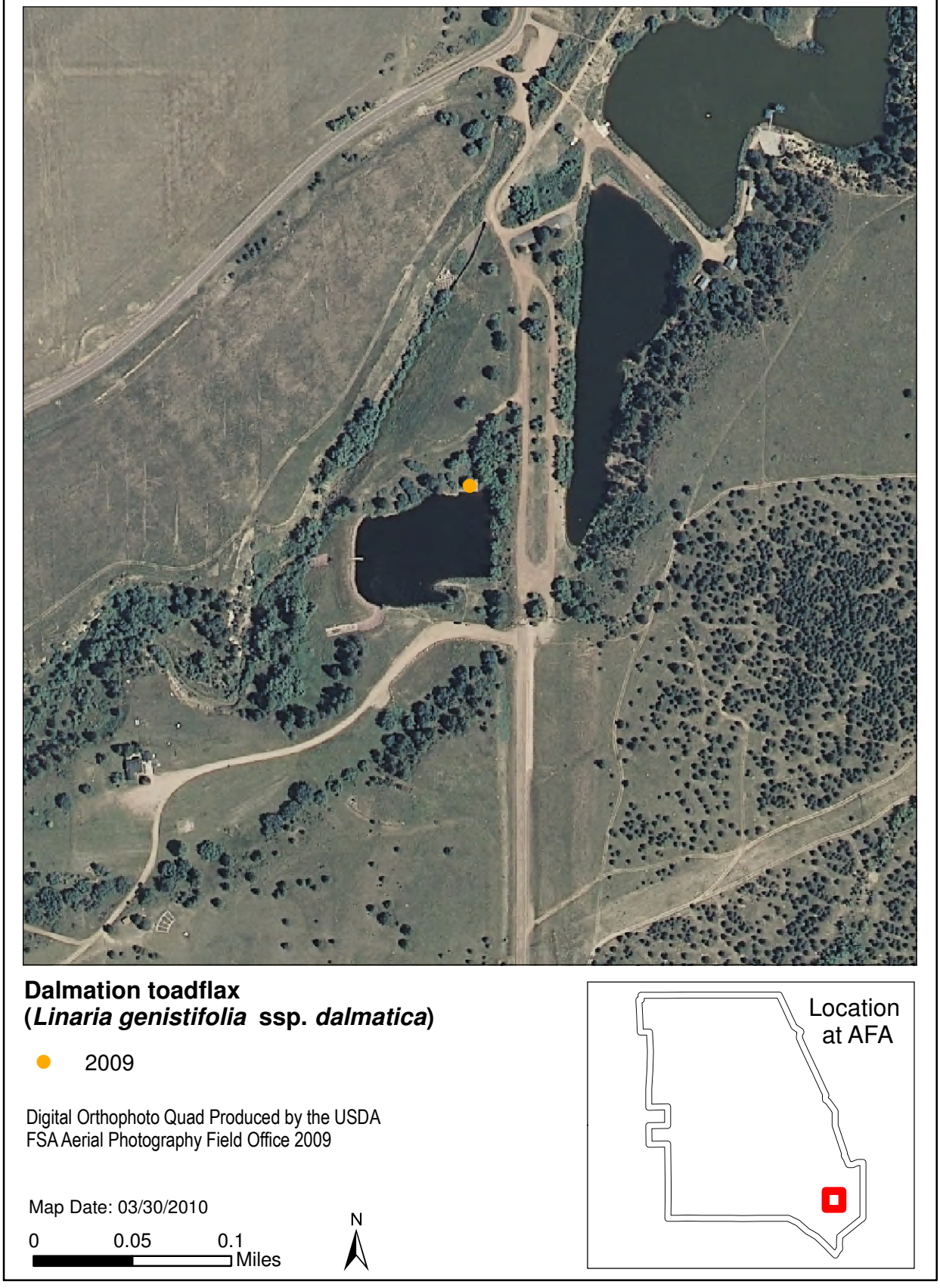
Map 9 and 10 map depicts the location of houndstongue and toadflax locations.



Map 8. Distribution of tamarisk at the Academy in 2002, 2007, 2008 and 2009.



Map 9. All known sites where houndstongue has been found at the Academy.



Map 10. Distribution of Dalmation toadflax at the Academy in 2010.

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Appendix A.

Myrtle Spurge Table

Bolded rows refer to the permanent plots. Map number refers to Map 4 within this document.

Map_Num	No. of Individuals	Area (m^2)	Date	Comment
1	0	3	8/20/2009	Not in 2008 report
2	**21**	**272**	**7/10/2009**	**Plot 2**
3	0	3	7/10/2009	Not in 2008 report
4	**70**	**205**	**7/10/2009**	**Plot 2**
5	4	3	5/6/2008	Not in 2008 report
6	3	3	9/1/2008	
7	**10**	**136**	**8/25/2009**	**Plot 1**
8	**7**	**19**	**7/10/2009**	**Plot 3**
9	20	102	8/24/2009	
10	5	1792	7/15/2009	
11	0	3	8/20/2009	
12	0	3	5/12/2009	Not in 2008 report
13	3	68	8/20/2009	
14	0	12	8/20/2009	
15	0	3	7/8/2009	
16	1	3	5/6/2008	Not in 2008 report
17	300	6548	6/10/2009	Not in 2008 report
18	20	465	5/12/2009	Not in 2008 report
TOTAL	**464**	**9643**		

St. Johnswort 2009 information. Bolded rows are where permanent photoplots are.

OBJECT ID	Date	No. of individuals	DENSITY	RADIUS	COVERCLASS	PATTERN	EXAMINER	BUFFER WIDTH	TREAT STATUS	T. SUCCESS	TREATCOMME	Area (sq m)	Acres
458	7/9/2009	8	0	0	Low, 1-5%	Patchy	Renee Rondeau	2	Extant	Not treated		153	0.04
5290	7/8/2009	600	0	10	Moderate, 5-25%	Continuous	Renee Rondeau	0	Extant	Poor	beetles present	313	0.08
5291	7/9/2009	5	0	6	Low, 1-5%	Patchy	Renee Rondeau	0	Extant	Poor	beetles present	113	0.03
5292	7/8/2009	100	0	3	Moderate, 5-25%	Continuous	David G. Anderson	0	Extant	Not treated		28	0.01
5293	7/8/2009	200	0	4	High, 25-75%	Continuous	David G. Anderson	0	Extant	Not treated	new in 07?	50	0.01
5294	7/9/2009	10	0	1	Low, 1-5%	Continuous	David G. Anderson	0	Extant	Fair	not sprayed 7/10/08	3	0.00
5295	7/8/2009	0	0	1	Trace, 0-1%	Continuous	David G. Anderson	0	Eradicated	Good		3	0.00
5296	7/9/2009	120	0	3	Moderate, 5-25%	Continuous	David G. Anderson	0	Extant	Not treated	no beetles seen	28	0.01
5297	7/8/2009	500	0	5	High, 25-75%	Continuous	Renee Rondeau	0	Extant	Poor	beetles present	78	0.02
5298	7/8/2009	20	0	3	Low, 1-5%	Continuous	Renee Rondeau	0	Extant	Not treated	no beetles	20	0.00
5299	7/8/2009	50	0	1	Low, 1-5%	Continuous	Renee Rondeau	0	Extant	Not treated	no beetles	3	0.00
5300	**7/9/2009**	**3**	**0**	**1**	**Trace, 0-1%**	**Continuous**	**Renee Rondeau**	**0**	**Extant**	**Not treated**	**2005 spraying eradicated**	**3**	**0.00**
5301	7/9/2009	6	0	2	Low, 1-5%	Patchy	Renee Rondeau	0	Extant	Poor	beetles present	7	0.00
5302	7/9/2009	0	0	1	Trace, 0-1%	Patchy	Renee Rondeau	0	Eradicated	Good	Brian pulled 3 individuals	3	0.00
5303	7/9/2009	120	0	4	Low, 1-5%	Patchy	Renee Rondeau	0	Extant	Not treated	no beetles, 2 clumps beetles	50	0.01
5304	7/9/2009	12	0	2	Low, 1-5%	Patchy	Renee Rondeau	0	Extant	Poor	present	13	0.00
5305	7/9/2009	50	0	1	High, 25-75%	Continuous	Renee Rondeau	0	Extant	Poor	beetles present	3	0.00

OBJECT ID	Date	No. of individuals	DENSITY	RADIUS	COVERCLASS	PATTERN	EXAMINER	BUFFER WIDTH	TREAT STATUS	T. SUCCESS	TREATCOMME	Area (sq m)	Acres
72	7/9/2009	500	0	0	Low, 1-5%	Patchy	David G. Anderson	0	Extant	Not treated	no beetles seen	1329	0.33
73	7/10/2008	50	0	0	Moderate, 5-25%	Continuous	David G. Anderson	0	Extant	Poor	beetles are present	9	0.00
74	**7/8/2009**	**68368**	**40**	**0**	**Moderate, 5-25%**	**Patchy**	**Renee Rondeau**	**0**	**Extant**	**Not treated**		**1709**	**0.42**
75	**7/9/2009**	**17261**	**75**	**0**	**Moderate, 5-25%**	**Patchy**	**Renee Rondeau**	**0**	**Extant**	**Poor**	**beetles present**	**230**	**0.06**
76	7/9/2009	7000	0	0	Moderate, 5-25%	Patchy	Renee Rondeau	0	Extant	Poor	beetles present	3514	0.87
77	7/9/2009	900	0	0	Moderate, 5-25%	Patchy	Renee Rondeau	0	Extant	Poor	beetles present	537	0.13
TOTAL		**95883**										**8199**	**2.03**

All mapped weeds in 2009 (does not include 2008 unvisited extant locations)

SPECIES	Extant	Eradicated	Area of extant infestations in sq m (removed overlap between infestations of the same species)
Acroptilon repens	2	0	103.73
Cardaria draba	1	0	4.65
Carduus nutans	2	0	297.64
Centaurea diffusa	2	0	987.31
Cirsium arvense	1	0	464.61
Cynoglossum officinale	8	0	378.21
Elaeagnus angustifolia	17	0	2,771.64
Euphorbia esula	15	0	6,130.33
Euphorbia myrsinites	9	6	9,606.88
Hypericum perforatum	20	2	8,183.49
Linaria genistifolia ssp. dalmatica	2	0	3.28
Linaria vulgaris	5	0	3,494.05
Onopordum acanthium	49	32	14,036.76
Tamarix ramosissima	2	2	6.25
Total	**135**	**42**	**46,468.83**
Total area (removed overlap for co-occuring species)			**46,365.12**