Noxious Weed Monitoring at the U.S. Air Force Academy- Year 6 Results

April, 2011

Prepared For:
U.S. Air Force Academy Department of Natural Resources

Prepared By:
Renée Rondeau, David G. Anderson, and Amy Lavender

Colorado Natural Heritage Program
College of Natural Resources, CSU
1474 Campus Delivery
Fort Collins, CO 80523-1474
http://www.cnhp.colostate.edu

On the cover: Canada thistle plot 2, photo point at (2005) and (2010).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

EXECUTIVE SUMMARY

This report includes a summary of the results of the past six years of population monitoring of targeted noxious weeds at the US Air Force Academy ("the Academy"), emphasizing changes that were observed between 2009 and 2010.

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. In 2010 our sampling methodology was nearly identical to 2009. 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 knapweed (*Acroptilon repens*), Scotch thistle (*Onopordum acanthium*), common St. Johnswort (*Hypericum perforatum*), houndstongue (Cynoglossum officinale), Dalmation toadflax (*Linaria genistifolia* ssp. *Dalmatica*), and yellow bedstraw (*Galium verum*). 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, spotted knapweed, and whitetop, 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 and 2010 we field verified some 20 points.

The highlights of 2010 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:** all ten plots were treated and the number of individuals significantly declined.
- **Canada thistle:** cover increased in areas where untreated.
- **Leafy spurge:** regardless of herbicide or biocontrol treatment this species continues to expand, while the untreated plot remained stable.
- **Myrtle spurge:** the aggressive treatment, including herbicide treatment and direct pulling, is having a positive impact. The Academy-wide population and locations decreased from 2.4 acres to 0.5 acres; however it has not been eradicated.
- **St Johnswort:** Overall, the 2010 occupied area decreased by 25% since 2009, from 2 acres to 1.5 acres. Number of individuals slightly decreased

EXECUTIVE SUMMARY

This report includes a summary of the results of the past six years of population monitoring of targeted noxious weeds at the US Air Force Academy ("the Academy"), emphasizing changes that were observed between 2009 and 2010.

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. In 2010 our sampling methodology was nearly identical to 2009. 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 knapweed (*Acroptilon repens*), Scotch thistle (*Onopordum acanthium*), common St. Johnswort (*Hypericum perforatum*), houndstongue (Cynoglossum officinale), Dalmation toadflax (*Linaria genistifolia* ssp. *Dalmatica*), and yellow bedstraw (*Galium verum*). 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, spotted knapweed, and whitetop, 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 and 2010 we field verified some 20 points.

The highlights of 2010 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:** all ten plots were treated and the number of individuals significantly declined.
- **Canada thistle:** cover increased in areas where untreated.
- **Leafy spurge:** regardless of herbicide or biocontrol treatment this species continues to expand, while the untreated plot remained stable.
- **Myrtle spurge:** the aggressive treatment, including herbicide treatment and direct pulling, is having a positive impact. The Academy-wide population and locations decreased from 2.4 acres to 0.5 acres; however it has not been eradicated.
- **St Johnswort:** Overall, the 2010 occupied area decreased by 25% since 2009, from 2 acres to 1.5 acres. Number of individuals slightly decreased

as well; the plot that has a biocontrol but no herbicide remains nearly identical to 2009. 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 acres decreased by over 80% since 2009, form 3.5 acres to 0.66 acres and number of individuals also decreased from 1710 to 669. On-going weed management is critical for this species.
- **Spotted knapweed:** this species has reached high numbers; thus we developed two models in 2009. One model predicted the areas with suitable habitat and the other model predicted the pace of spread between 2007-2015. We tested the suitable habitat model in 2010 by visiting 20 sites; 8 points were positive while 12 were negative; however most of the 12 negative hits were in areas that aren't predicted to have spotted knapweed until 2015 or later.
- **Tamarisk:** continued management and monitoring is necessary, but as of 2010, treatments appear to be keeping this species under control as no plants were found.
- **Houndstongue and Dalmatian toadflax:** these two species were new to the list and mapped and censused in 2009. An aggressive treatment in 2010 had positive impacts however both species are still present but still have the potential for complete elimination.
- **Yellow bedstraw:** This is a new weed at AFA and was discovered at one area in 2010. The population was treated however this site and species should be monitored every year and treated aggressively.

INTRODUCTION

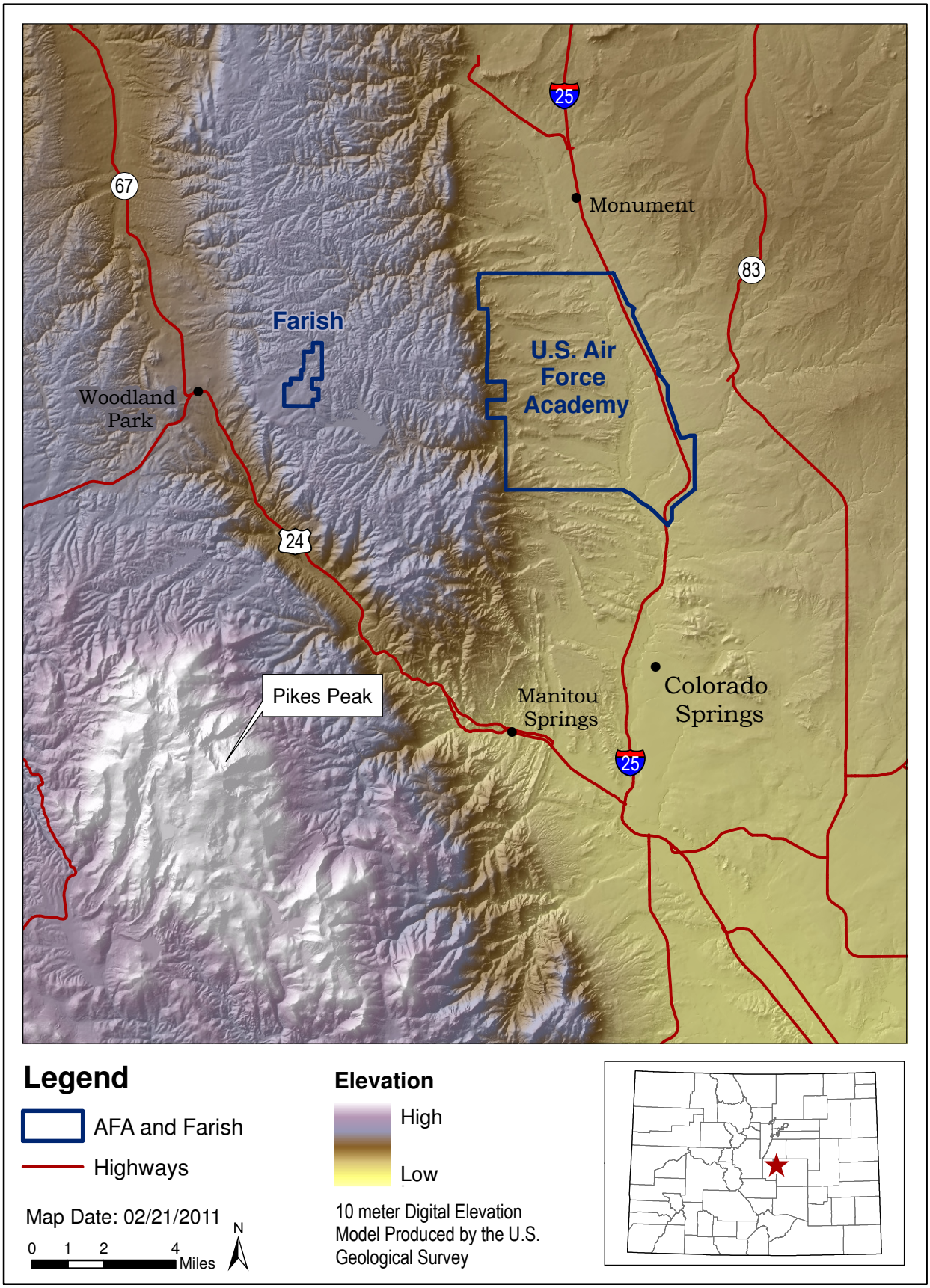
Weeds are known to alter ecosystem processes, degrade wildlife habitat, reduce biological diversity, reduce the quality of recreational sites, reduce the production of crops and rangeland forage plants, and poison livestock (Sheley and Petroff 1999). All of these impacts are occurring in Colorado (Colorado 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 Southern Rocky Mountain 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.

Academy and Farish. 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 (Rondeau et al. 2010). 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.

In 2010, we primarily mirrored 2009 methods, however we did not monitor diffuse knapweed but we did monitor whitetop. A new species, yellow bedstraw (*Gallium verum*) was discovered, mapped, and counted in 2010. A total of 23,238 m^2 of infestations were mapped for 11 target species in 2010.

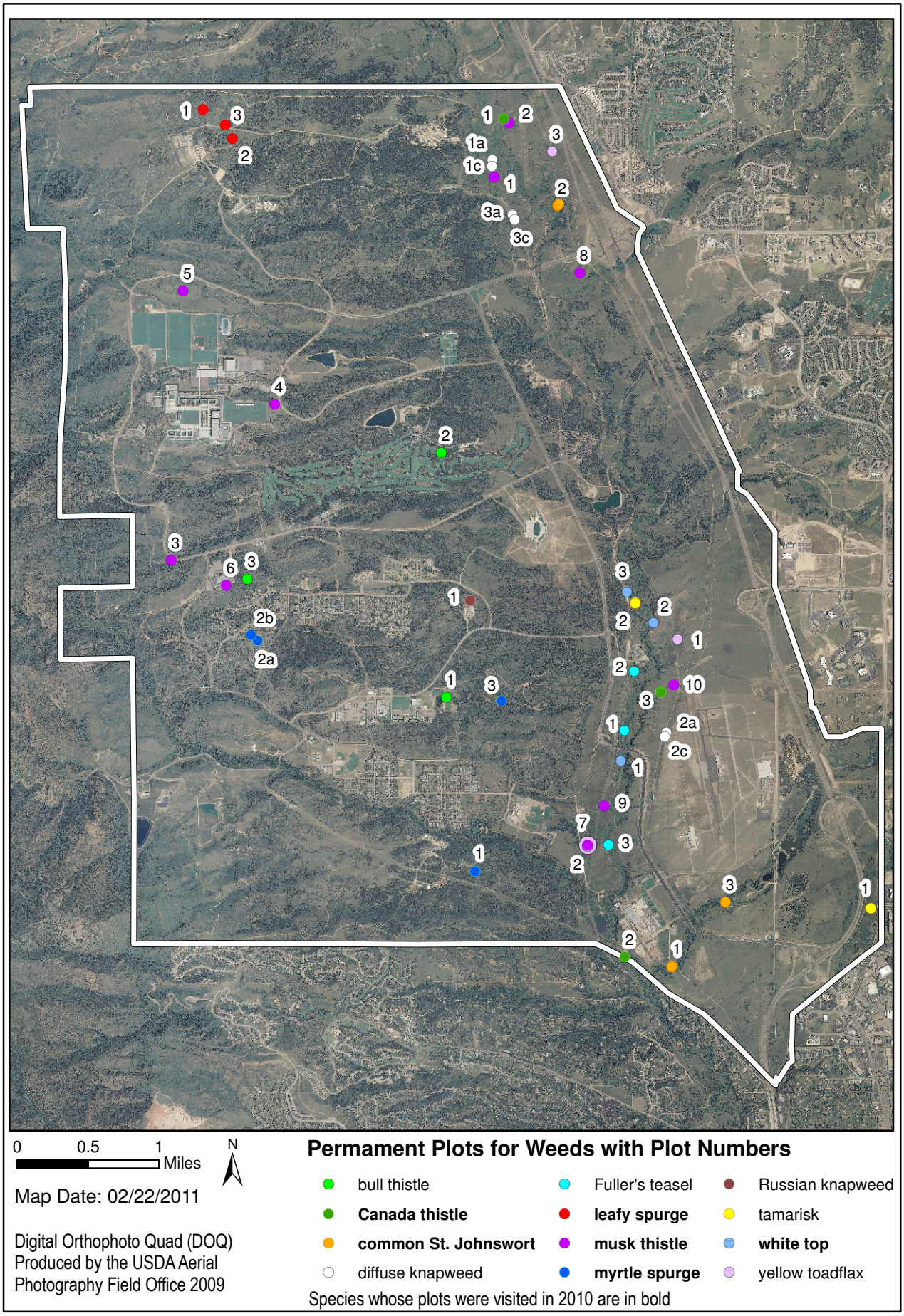
METHODS

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 2010, 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 2009 and 2010.

Species	2009 Sampling Methods	2010 Sampling Methods
Russian Knapweed	*perimeter mapping/ census*	*Perimeter mapping/ census*
Spotted Knapweed	Produced a predicted occurrence model	*Ground-truthed predicted occurrence model*
Whitetop	*Not a target in 2009*	*Belt transects/photopoints*
Musk Thistle	*9 Photopoints / estimated size*	*10 Photopoints/ estimated size*
Diffuse knapweed	*Belt transects/photopoints*	*Not a target in 2010*
Canada Thistle	*Transect/ photopoints/ photoplot*	*Transect/photopoints/photoplot*
Bull Thistle	*Not a target in 2009*	*Not a target in 2010*
Fuller's Teasel	*Not a target in 2009*	*Not a target in 2010*
Leafy Spurge	*Perimeter mapping/ survey transects/ photopoint*	*Perimeter mapping/survey transects/photopoint*
Common St. Johnswort	*Photopoints/ quadrats and perimeter mapping*	*Photopoints/quadrats and perimeter mapping*
Yellow Toadflax	*Perimeter mapping/census*	*Perimeter mapping/census*
Houndstongue	*Perimeter mapping/census*	*Perimeter mapping/census*
Myrtle Spurge	*Perimeter mapping/ census/ photopoints*	*Perimeter mapping/census/photopoints*
Tamarisk	*Perimeter mapping/ census*	*Perimeter mapping/ census*
Yellow Bedstraw	*Not observed*	*1st observation in 2010; perimeter mapping/census*



Map 2. Locations of all permanent monitoring plots for weeds.

RESULTS AND RECOMMENDATIONS

The 2010 growing season was relatively dry with only 52% of the average precipitation (Table 2). The non-growing months were 40% drier than average at just 10.3 inches vs. the normal 17.4 inches (Table 2).

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 WSO station 51778 for water year. Average precipitation is for 1949-2010 (http://ccc.atmos.colostate.edu).The growing months (summer) are shaded.

Water Yr.	Data	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Summer Total	Annual 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	9.15	12.07
	Average	0.78	0.45	0.32	0.29	0.31	0.88	1.36	2.12	2.27	2.87	2.93	1.24	12.79	15.82
	% of Ave.	0.23	1.44	0.75	2.69	0.13	1.17	0.79	0.34	0.93	0.67	0.90	0.55	72%	76%
	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.	0.78	1.23	1.55	1.84	2.15	3.03	4.39	6.51	8.78	11.65	14.58	15.82		
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	11.17	12.55
	Average	0.78	0.45	0.32	0.29	0.31	0.88	1.36	2.12	2.27	2.87	2.93	1.24	12.79	15.82
	% of Ave.	0.62	0.18	0.94	0.83	0.13	0.27	0.07	0.38	0.36	1.54	1.20	1.22	87%	79%
	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.	0.78	1.23	1.55	1.84	2.15	3.03	4.39	6.51	8.78	11.65	14.58	15.82		
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	9.91	13.20
	Average	0.78	0.45	0.32	0.29	0.31	0.88	1.36	2.12	2.27	2.87	2.93	1.24	12.79	15.82
	% of Ave.	2.01	0.42	1.22	1.07	0.55	0.75	1.36	1.11	0.41	0.61	0.92	0.27	77%	83%
	Accumulated	0.51	1.76	2.15	2.46	2.63	3.29	5.14	7.49	8.43	10.17	12.86	13.20		
	Average Accum.	0.78	1.23	1.55	1.84	2.15	3.03	4.39	6.51	8.78	11.65	14.58	15.82		
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	10.82	13.17
	Average	0.78	0.45	0.32	0.29	0.31	0.88	1.36	2.12	2.27	2.87	2.93	1.24	12.79	15.82
	% of Ave.	0.32	0.22	1.22	1.59	0.61	1.091	0.29	0.16	0.23	0.101	1.471	4.008	85%	83%
	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.	0.78	1.23	1.55	1.84	2.15	3.03	4.39	6.51	8.78	11.65	14.58	15.82		
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	13.68	14.80
	Average	0.78	0.45	0.32	0.29	0.31	0.88	1.36	2.12	2.27	2.87	2.93	1.24	12.79	15.82
	% of Ave.	0	0.56	0.47	0.31	0.13	0.511	1.12	1.13	1.28	1.331	0.628	0.968	107%	94%
	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.	0.78	1.23	1.55	1.84	2.15	3.03	4.39	6.51	8.78	11.65	14.58	15.82		
2009-2010	Monthly Precip.	0.36	0.45	0.67	0.12	0.49	0.55	1.25	0.82	0.34	2.67	2.47	0.09	7.64	10.28
	Average	0.78	0.45	0.32	0.29	0.31	0.88	1.36	2.12	2.27	2.87	2.93	1.24	12.79	15.82
	% of Ave.	0.46	1	2.09	0.41	1.58	0.625	0.92	0.39	0.15	0.93	0.843	0.073	60%	65%
	Accumulated	0.36	0.81	1.48	1.6	2.09	2.64	3.89	4.71	5.05	7.72	10.19	10.28		
	Average Accum.	0.78	1.23	1.55	1.84	2.15	3.03	4.39	6.51	8.78	11.65	14.58	15.82		

Acroptilon repens (Russian Knapweed)

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

Russian knapweed has not been observed for two years (2009 and 2010). SUCCESS

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 July 2010.

Russian knapweed was observed along Douglass Drive in 2005 and 2006 but not 2008, 2009, or 2010.

We recommend annual visits to these sites by AFA weed contractors and a follow up site visit by CNHP.

Cardaria draba (Whitetop)

Whitetop has remained stable since 2005.

Species	Sampling Methods	Plot 1	Plot 2	Plot 3
Whitetop	*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

Whitetop, a.k.a. hoary cress, has remained fairly stable since 2005, regardless of treatment, with the exception of 2006 when cover declined in all plots, probably due to low precipitation (Figure 1).

None of the plots were treated between 2005-2007; plots 2 and 3 were treated in 2009 and 2010. Plot 1 is in the riparian area of Monument Creek and is a diverse site that is also habitat for the Hops Azure butterfly, a species of concern. Plots 2 and 3 are in a more disturbed area and are dominated by smooth brome. Plot 3 is beside the railroad and maintenance in 2009 covered part of the plot with rock. If the herbicide treatment is working it is only doing so by keeping the cover at a low level in plots 2 and 3. We ran a GLM model to determine if the herbicide treatment has worked. Herbicide treatment had no significant effect on whitetop cover as shown by a GLM incorporating rain, plot, and treatment over 4 years 2005-2007, 2010 (Table 3 and 4).

We recommend that treatment continues on plots 2 and 3 and that monitoring also continues.

Table 3. Whitetop cover (%) and treatment, 2005-2007, 2010.

	plot 1	Treatment	plot 2	Treated	plot 3	Treatment	Precip (April-June)
2005	59.5	no tx	14.3	no tx	8.2	no tx	3.9
2006	27.3	no tx	1.3	no tx	1.37	no tx	1.4
2007	49.9	no tx	8.5	tx	7.8	tx	7.8
2010	62	no tx	8	tx	10	tx	2.6

Table 4. Whitetop GLM model, from SAS (rain = Apri-June).

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Rain	1	219.265706	219.265706	1.03	0.3399
Plot	1	3344.891371	3344.891371	15.71	0.0042
trt	1	0.001629	0.001629	0.00	0.9979

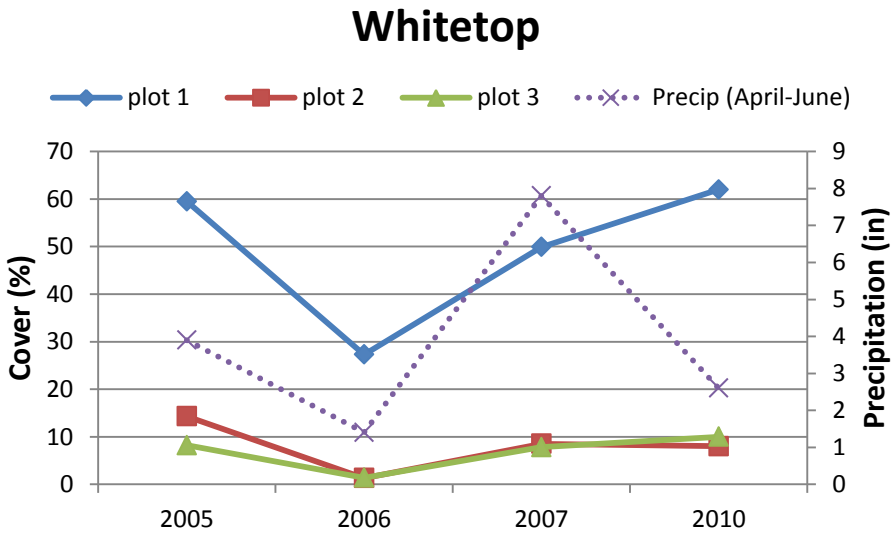


Figure 1. Whitetop cover (%) in Plots 1-3 at AFA in years 2005-2007 and 2010.

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

All plots were treated in 2011.

Ten of the ten established plots were revisited in 2010 (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 5 and 6). All plots were treated with herbicide however plots 3 and 5 were treated in the early spring while the other plots were treated during the summer. Number of individuals declined in all of the plots (Table 6). This suggests that musk thistle is killed when treated with herbicide and that the spraying has successfully reduced the population size of musk thistle at AFA. Recommendations for musk thistle include continuation of herbicide treatment of large infestations in 2012, and manual destruction of plants in smaller infestations and bag inflorescences if they contain ripe seed. All 10 plots should be revisited in 2012.

Table 5. Musk thistle plot and associated treatment. Tx is shorthand for "treatment."

Plot	2005	2006	2007	2008	2009	2010
1	no Tx	herbicide	no Tx	no Tx	No Tx	herbicide
2	no Tx	herbicide	no Tx	herbicide	No Tx	herbicide
3	herbicide	no Tx	herbicide	herbicide	herbicide	herbicide
4				no Tx	No tx	herbicide
5				no Tx	No tx	herbicide
6				herbicide	No tx	herbicide
7				herbicide	herbicide	herbicide
8				no Tx	herbicide	herbicide
9				no Tx	herbicide	herbicide
10				no Tx	Not visited	herbicide

Table 6. Musk thistle population size at 10 plots, 2005-2010. Bolded numbers were treated plots. * = treated in early spring; all other treatment times were during the summer.

Plot	2005	2006	2007	2008	2009	2010
1	13	**0**	12	11	134	**9**
2	116	**0**	19	**6**	80	**5**
3	**25**	0	**8**	**1**	**2**	**1***
4				1	63	**0**
5				1	27	**10***
6				**10**	45	**33**
7				**102**	**90**	**25**
8				212	**31**	**10**
9				160	**1**	**1**
10				500	Not visited	**40+**

Cirsium arvense (Canada Thistle)

Plot 1(**treated)** was stable in y10

Plot 2 **(treated)** was stable in y10

Plot 3 (**untreated**) increased in y10

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.

Canada thistle percent cover and related precipitation for all three plots over all sampled years are graphed in Figure 2.

Plot 1 is in the Black Forest stream restoration project that began in 2008 and the combination of herbicide treatment (Table 7) with an increase in water table has drastically reduced Canada thistle cover from 33% in 2005 to just 2% in 2010 (Table 8).

Plot 2 is in a Monument Creek meadow below the RV parking lot and Civil Engineering Picnic Area. This plot was treated in multiple years and the Canada thistle went from 25% cover in 2005 to 0% in 2010 (Tables 7 and 8). It appears that while the herbicide successfully decreased Canada thistle it allowed the exotic monocot, smooth

brome, to drastically increase from 22% cover in 2005 to 64% cover in 2010 (Table 9, Figure 3). In 2010, a new power line was erected near plot 2 (cover photo).

Plot 3 has never been treated and Canada thistle has varied from a high of 33% in 2005 to a low of 8% in 2007 and 2008, perhaps due to precipitation variation. In 2010 Canada thistle had 18% cover (Tables 7 and 8).

At plot 3, two probable Southern Rocky Mountain cinquefoil plants were found in 2008 and 2009, just north of the transect. Previously this site has been searched for Southern Rocky Mountain cinquefoil due to the abundance of wooly cinquefoil (*Potentilla hippiana*) and beautiful cinquefoil (*P. pulcherrima*). Southern Rocky Mountain cinquefoil is often found with these species and may actually be a hybrid involving these species in its parentage. The Rocky Mountain 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.

We suggest that in 2011, Plot 3 remain as is, that is, not treated, while Plot 1 and 2 remain under treatment. This is a small sample size and because Plot 1 underwent a drastic restoration project the sample size is even smaller than it appears. If time and funding in 2011 permits, we suggest adding two or three more permanent plots.

Table 7. Canada thistle treatment applications at the three permanent plots, 2005-2010. Tx is shorthand for "treatment."

Plot	2005	2006	2007	2008	2009	2010
1	no Tx	herbicide	no Tx	herbicide	no Tx	herbicide
2	no Tx	herbicide	no Tx	no Tx	herbicide	herbicide
3	no Tx	no Tx	no Tx	no Tx	no Tx	No Tx

Table 8. Canada thistle cover (%) from the three permanent monitoring plots, 2005-2010. Summer precipitation is for May-September.

	Plot 1	Plot 2	Plot 3	Summner Precipitation (in)
2005	33.5	24.7	33.5	8.07
2006	17.1	5.4	14	11.08
2007	0.3	2.2	8.2	8.06
2008	0.1	2.6	8.2	10.43
2009	0.5	1.5	13.7	12.16
2010	2	0	18	6.39

Table 9. Canada thistle, smooth brome and snowberry cover (%) for Plot 2.

	2005	2006	2007	2008	2009	2010
Canada Thistle	25	5	2	3	2	0
Smooth Brome	22	12	24	11	40	64
Snowberry	16	11	11	10	14	12

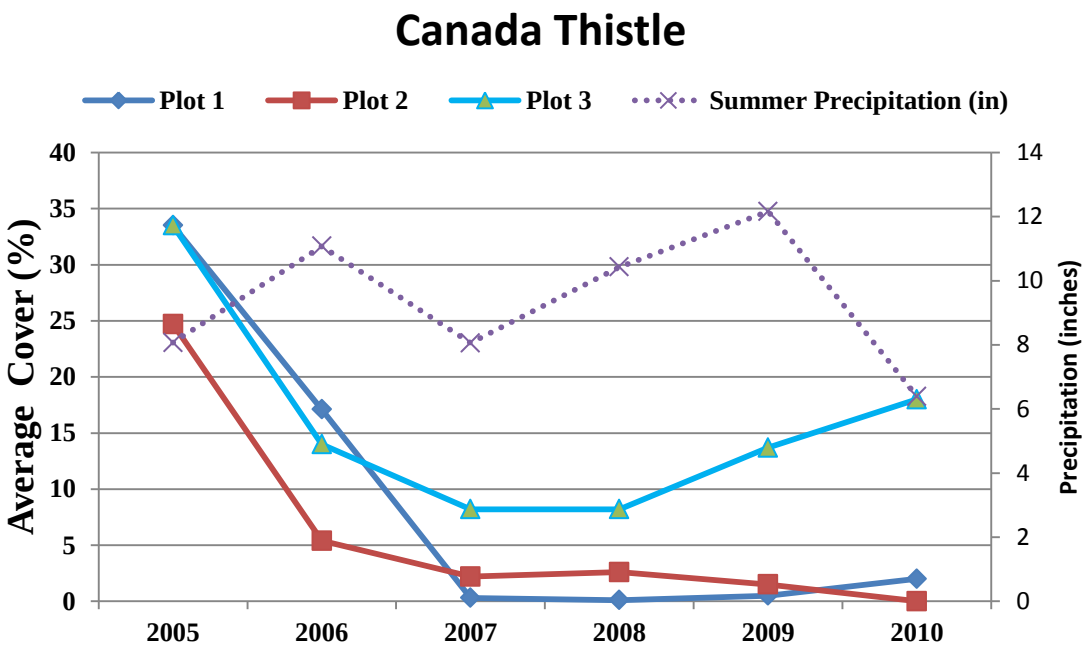


Figure 2. Canada thistle cover (%) for three permanent plots from 2005-2010 and the associated summer precipitation (May-September).

Figure 3 . Photo quadrat of *Canada thistle*; Plot 2, quadrat 1 from years 2005-2010. Herbicide treatment has successfully eliminated Canada thistle however it has also eliminated other dicots, e.g., snowberry. Smooth brome has replaced the dicots.






Euphorbia esula (Leafy Spurge)

Plot 1. Occupied area remained nearly the same as 2009. **No treatment.**

Plot 2. Occupied area increased by 378 m^2 in 2009; *no. of ramets also increased.* **Biocontrol treatment.**

Plot 3. Occupied area was nearly identical to 2009; no. of ramets increased. **Herbicide treatment**

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

Over the course of this study 2005-2010, leafy spurge plots have experienced herbicide and biocontrol treatments as well as no treatment. The plot that has never been treated is the only plot that has not expanded while the other two treated plots have increased, regardless of treatment type.

Plot 2 has the largest population of the three plots (Table 11, Figure 4, Map 3). At plot 2, a biocontrol agent was released in 2005 and herbicide treatment only occurs outside of the plot (personal communication with Brian Milbachler, 2010). From 2005 to 2010, leafy spurge has spread into uninfested areas at this site. In 2010, the occupied area grew by another 378 m^2 and the number of ramets drastically increased from 295 in 2009 to 27,653 in 2010. The increase in number of ramets may be misleading as it is an estimated density per m^2 for the entire area and thus the occupied area is probably a better indicator. This site has become challenging to monitor because it continues to grow. Overall, the area occupied and number of stems increased continuously from 2005 through 2008 despite treatment efforts, and was stable in 2009 but increased again in 2010 (Tables 10 and 11). Previously cleared areas are becoming infested once again at this site (Map 3).

Herbicide was applied to the largest infestation at plot 3 in 2007-2010, although the poor condition of the plants in this plot in 2008, 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. This plot has been fairly stable in 2009 and 2010.

The small infestation at plot 1 was not treated in 2005-2010, and no new infestations were detected at this plot in 2010, better yet, the occupied area remained stablen at 100 m^2 and the number of ramets slightly declined from 200 to 150 (Table 11).

Table 10. Leafy spurge treatment applications for the plots from 2005-2010. Tx is shorthands for "treatment".

Plot	2005	2006	2007	2008	2009	2010
1	no Tx	no Tx	no Tx	no Tx	no Tx	No tx
2	biocontrol	biocontrol	biocontrol	biocontrol	biocontrol	biocontrol
3	no Tx	no Tx	Herbicide (in part)	Herbicide (in part)	Herbicide	Herbicide

Table 11. Leafy spurge summary data from the three permanent plots. Summer precipitation is May-September. Bolded numbers indicate that the plot was treated with herbicide in that year. Plot 2 had a biocontrol treatment started in 2005. Summer precipitation is for May-September.

		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
	2010	100	150	1	6
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
	2010	5751	27,653	4	6
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**
	2010	**185**	**23**	**3**	**6**

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

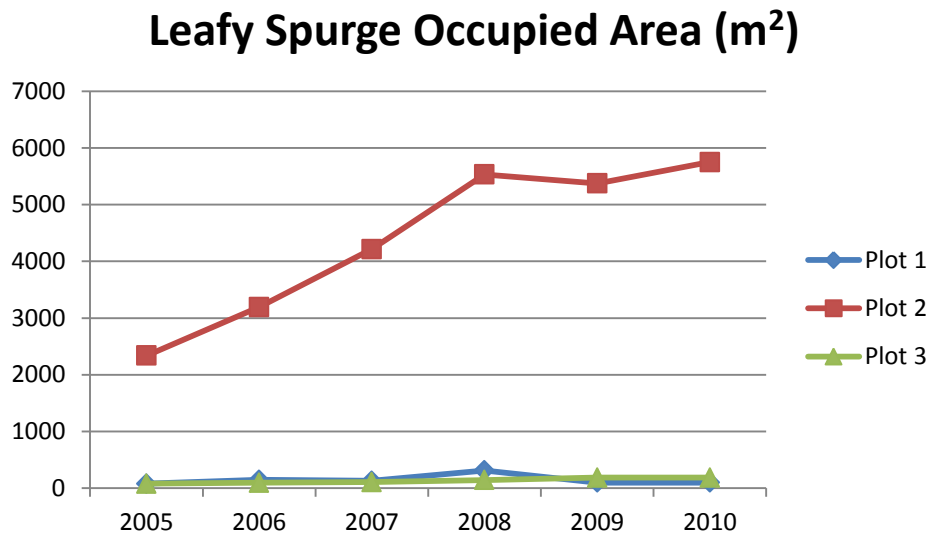
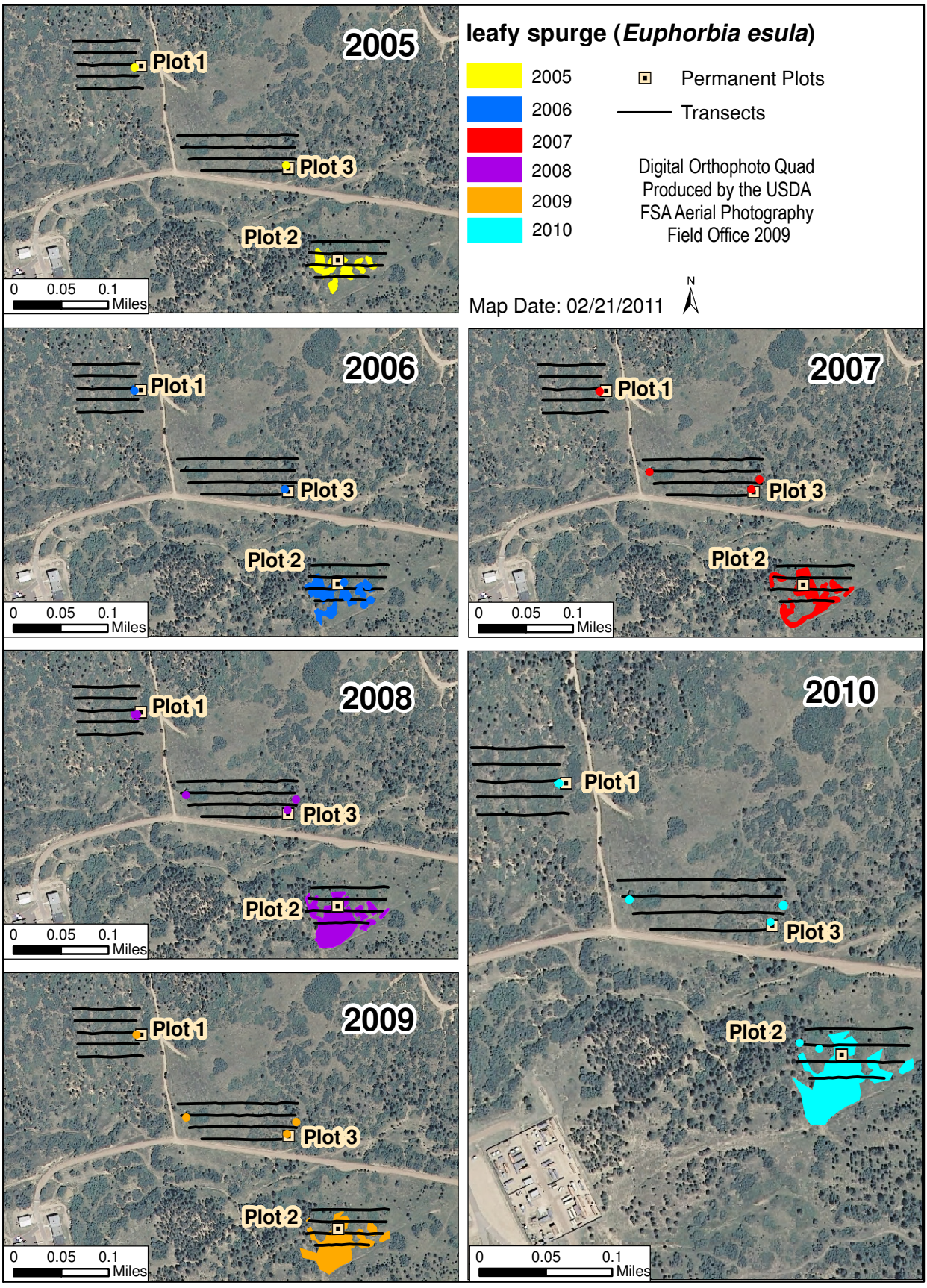
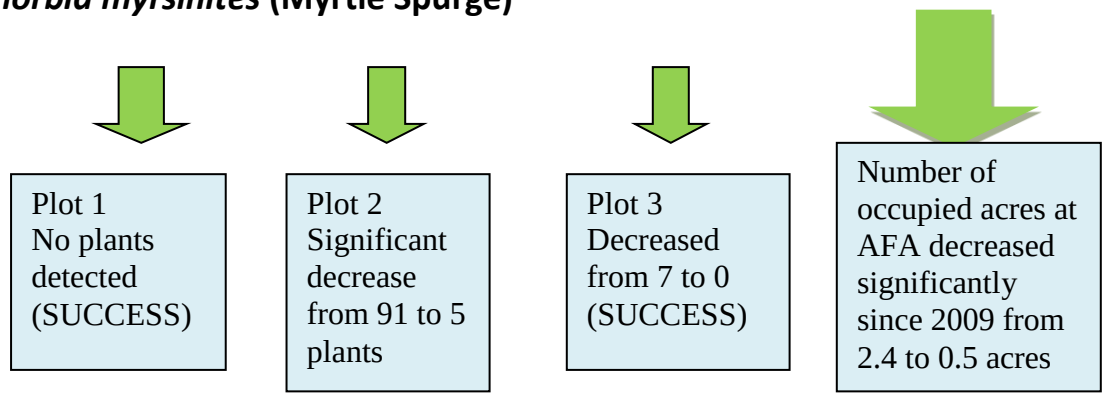


Figure 4. Occupied area of leafy spurge at three plots 2005-2010.



Map 3. Distribution of leafy spurge at the three permanent plots in 2005-2010.

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 (Table 12, Figure 5, 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 7 additional infestations that are also being mapped (Map 4). The total area infested by myrtle spurge at the Academy in 2010 was 2,203 m2 with a total of 56 individuals, a significant decrease over the 2009 area and population: 9634 m^2 with 464 individuals; however the number of locations in 2010 is just slightly lower than 2009 (Table 12 and Figure 5).

AFA's efforts at eradicating this species is keeping this species in check and this kind of effort (spraying and pulling) needs to continue in future years.

Table 12. Myrtle spurge summary data.

	2005	2006	2007	2008	2009	2010
No. of individuals	25	243	261	419	464	56
Area (m^2)				2678	9643	2203
Area (acres)				0.66	2.4	0.5
Extant locations				13	12	10
Eradicated locations				1	6	12

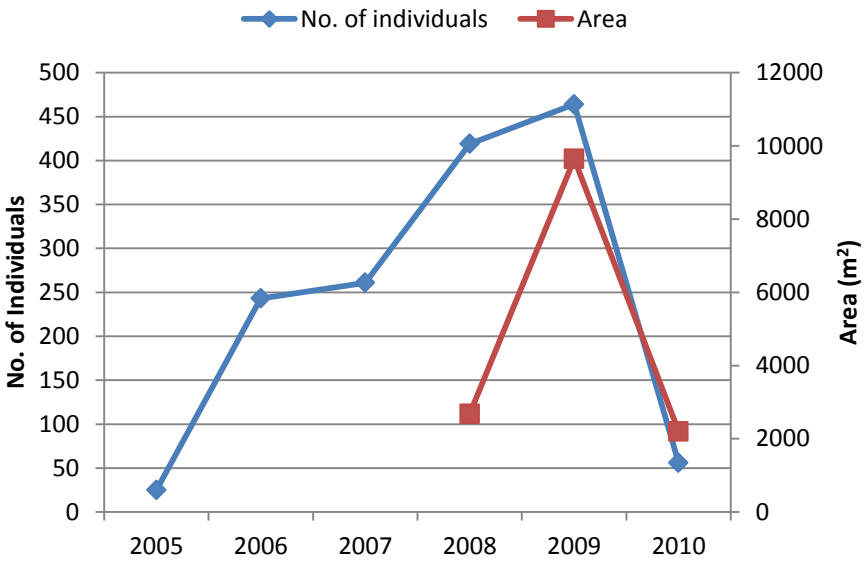
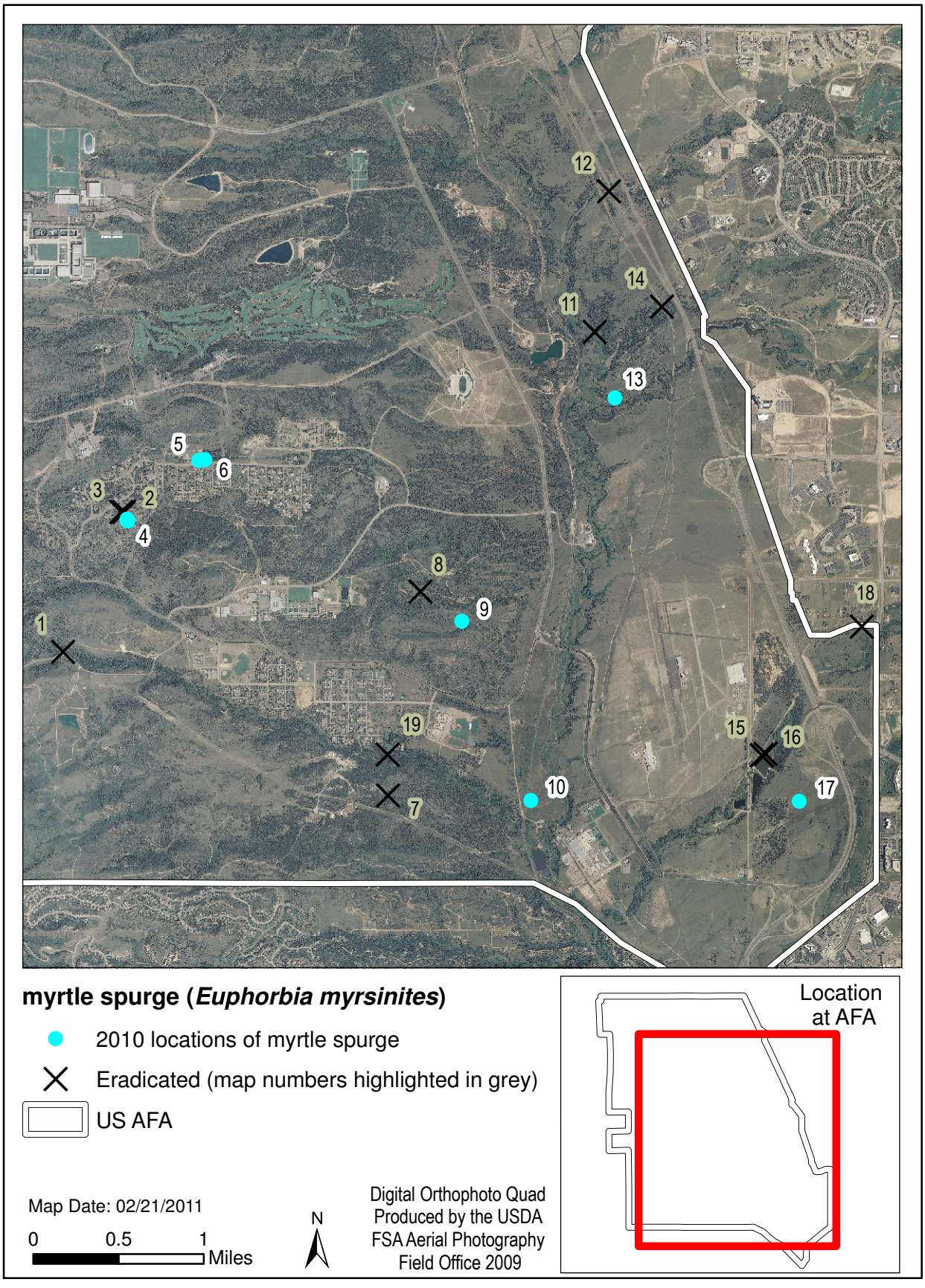


Figure 5. Number of individuals and occupied area for myrtle spurge 2005-2010.



Map 4. All known sites where myrtle spurge has been found at the Academy between 2005 and 2010. Numbers correspond to locations described in the Appendix.

The following paragraphs summarize the permanent plot data depicted in Table 13. 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 have sprouted 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. In 2010 no plants were observed, however we recommend continued monitoring of this site as seeds may survive in the soil bank for years.

Plot 2 is located at the southwestern edge of the housing in Douglass Valley behind 4176 Douglass Way, where two large patches were documented in past years. 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). The AFA continues to treat this site and by August of 2010 only 5 small plants were noted. Continued diligence is necessary to completely eradicate this species from the site.

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. In August of 2010 no plants were observed.

Table 13. Myrtle spurge population size at sampled plots 2006-2010. Bolded numbers indicate that it was treated.

Plots	***2006***	***2007***	***2008***	***2009***	***2010***
Plot 1- East of Stables	**142**	**97**	146	**10**	**0**
Plot 2- Douglass Valley Housing	72	122	120	**91**	**5**
Plot 3- Archery Range	**25**	41	**24**	**7**	**0**

Hypericum perforatum (Common St. Johnswort)

Plot 1
Decreased from 17,261 individuals in 2009 to less than 3550 in 2010 (herbicide)

Plot 2
Increased from 3 individuals in 2009 to 5 individuals in 2010

Plot 3
Remained nearly the same as 2009 (no tx except beetles)

All locations
Occupied area decreased by approx. 25% from 2009: from 2 acres to 1.5 acres

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

In 2010, compared to 2009, there was a decrease in number of individuals and occupied area for all plots however mapped locations remained stable (Tables 14 and 15; Figure 6 and Map 5). What appeared to be effective management for St. Johnswort in 2007 and 2008 was reversed in 2009 when number of individuals and occupied area increased, however in 2010 this species was knocked back probably due to a more aggressive herbicide treatment. Number of individuals and occupied area somewhat decreased in 2010 compared to 2009 from 95,883 to 82,724 individuals and 2 acres (8199 m^2) to 1. 5 acres (5945 m^2). This decrease is a positive sign but since the number of patches is nearly the same in 2010 as 2009 we believe this species could easily get out of control if due diligence is not maintained.

Plot 1 along south Kettle Creek (Map 2 and Figure 6) was sprayed in 2010 and this significantly reduced the number of individuals and occupied area. No beetles were present in 2010 (Table 14). A nearby occurrence adjacent to old road bed apparently wasn't sprayed in 2010 and it was doing quite well.

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 14). In 2010 this site remained nearly identical as 2009 (Table 14).

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 or 2010; both number of individuals and area increased in 2009 and the area was nearly identical in size and number of individuals in 2010 (Table 14).

Additional infestations of common St. Johnswort were discovered along Kettle Creek in 2010 however some patches were eradicated, illustrating that this species still has the potential to spread at the Academy (Table 15, Map 5 and Figure 6). 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 2011 to inform eradication efforts for this species.

Table 14. St. Johnswort summary for permanent plots, 2005-2010.

		2005	2006	2007	2008	2009	2010
plot 1	no. of ind	?	?	?	0	17,261	3550
	area (sq m)	?	?	?	0	230	71
	Cover (%)						
plot 2	no. of ind		0	0	0	3	5
	area (sq m)						
	Cover (%)	27	0	0	0	?	
plot 3	no. of ind	?	?	?	56,439	68,368	69,559
	area (sq m)	?	?	?	1128	1709	1739
	Cover (%)	21.3	11.8	17.7	?	?	8

Table 15. St. Johnswort summary data for AFA, 2007-2010.

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
2010	5,945	82,724	20

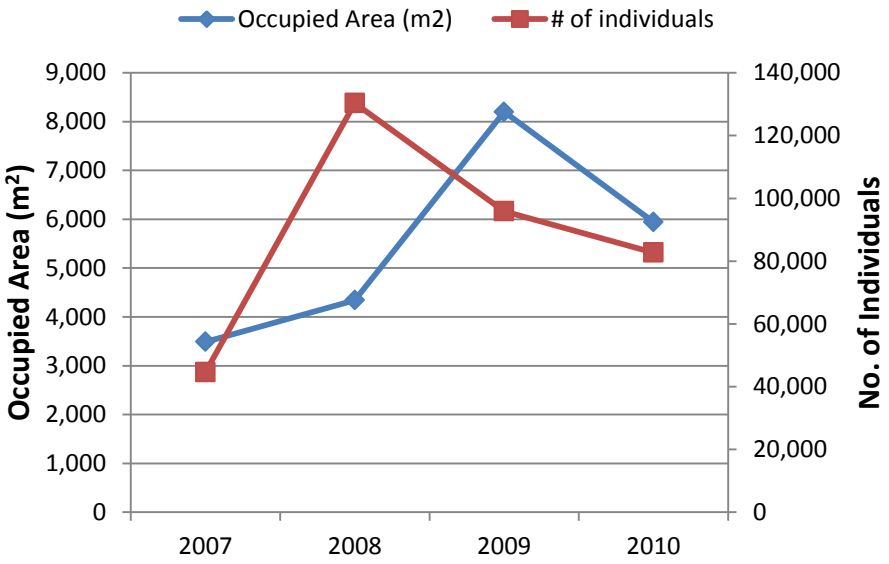
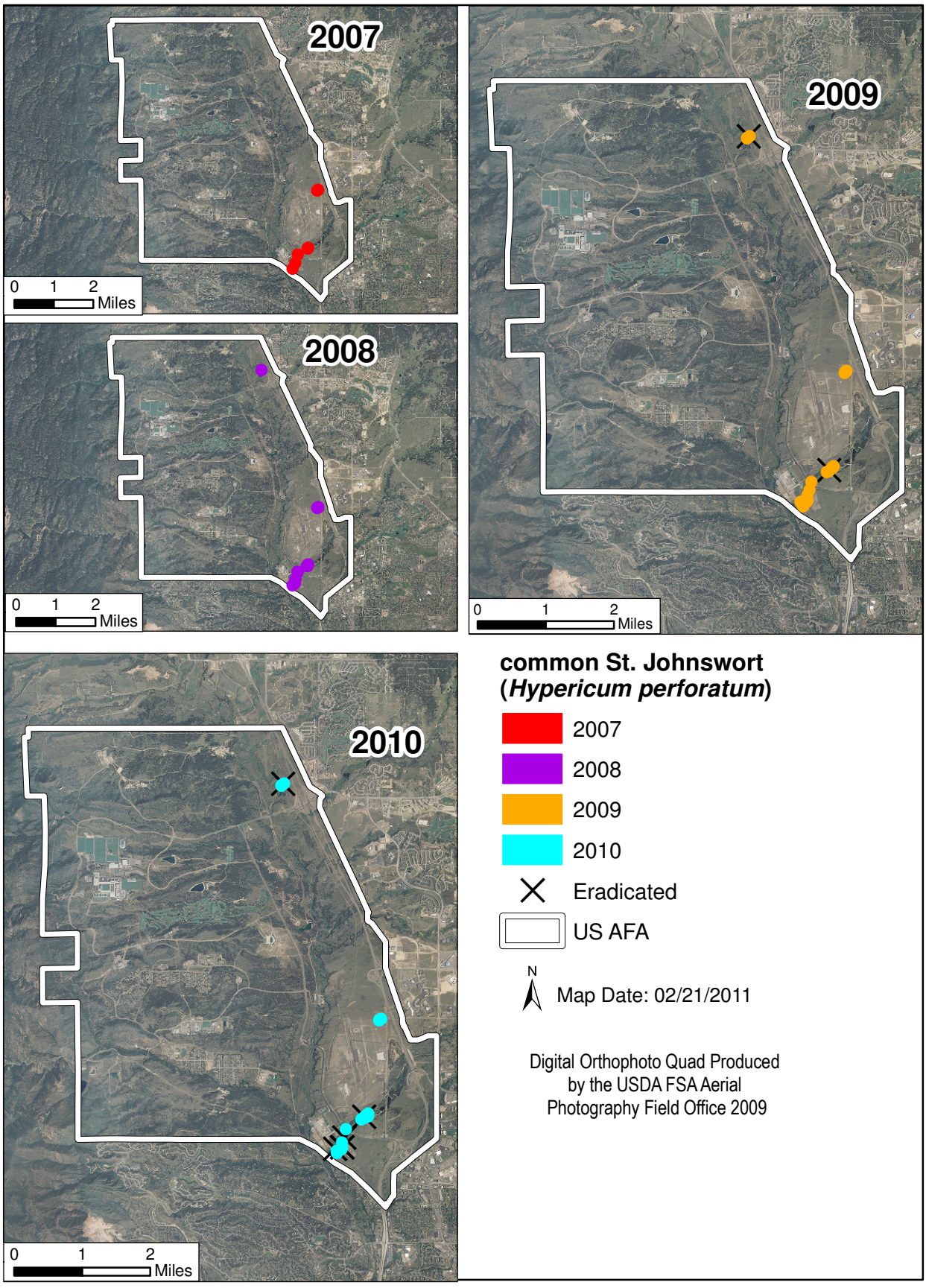


Figure 6. St Johnswort occupied area and number of individuals for all mapped locations on AFA, 2007-2010.



Map 5. Distribution of common St. Johnswort at the Academy in 2007, 2008, 2009 and 2010.

Onopordum acanthium (Scotch Thistle)

Occupied acres **decreased** over 80% since 2009, 3.5 acres to 0.66 acres.

Number of individuals **decreased** from 1710 in 2009 to 669 in 2010

The population of Scotch thistle had increased from 2002 through 2009 at the Academy (Table 16, Map 6, Figure 7), however in 2010 there was a significant decrease in occupied acres and number of individuals, most likely due to an active herbicide treatment. Compared with 2009, occupied acres drastically decreased by over 80% from 3.5 acres to 0.66 acres (Table 16). The number of individuals also decreased since 2009 from 1710 to 669 (Table 16). 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, even if reduced, over several years whether they were treated or not so it remains important to revisit and assess infestations after they have seemingly been eradicated.

We recommend a continuation of the aggressive herbicide treatment for this species in 2011.

Table 16. Scotch thistle summary data at the Academy, 2002-2010.

	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
2010	0.66	669	61

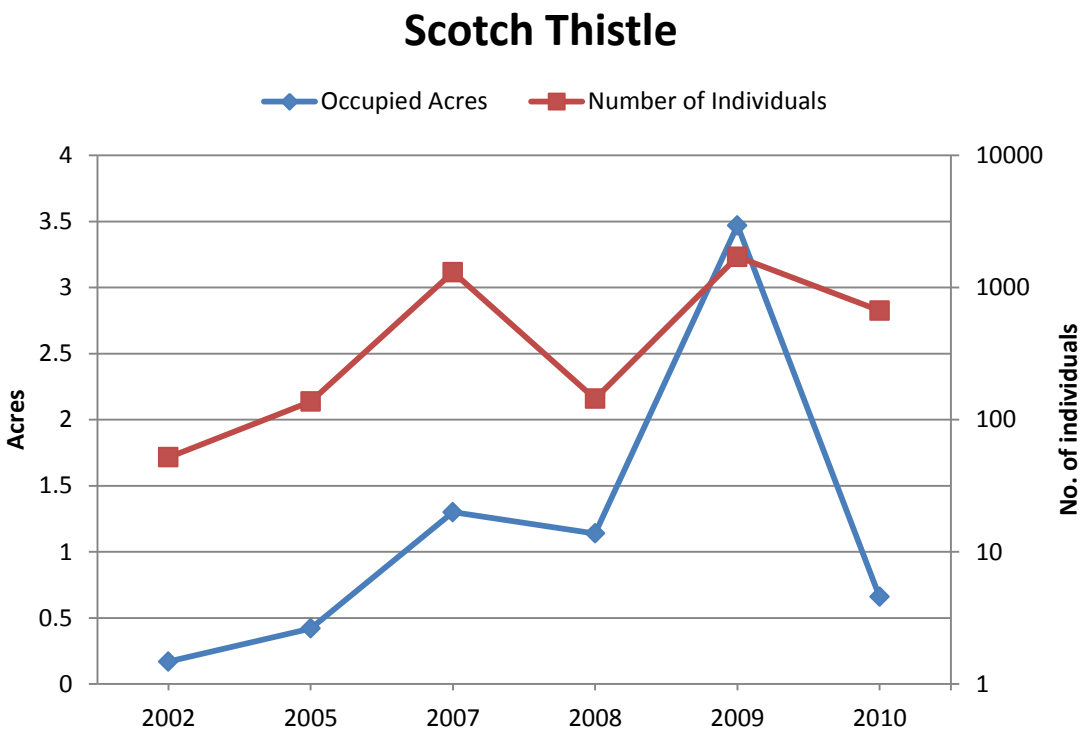
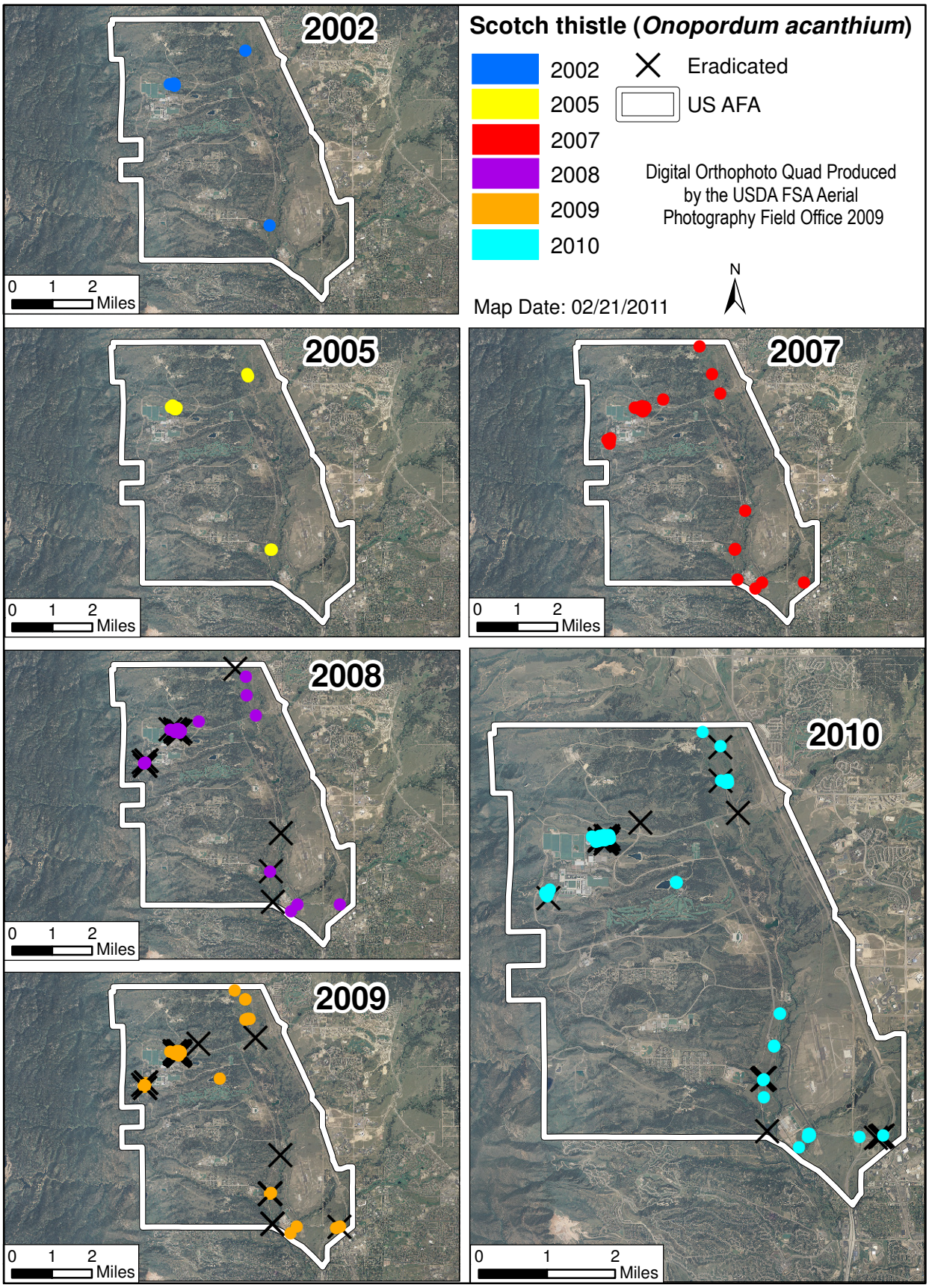
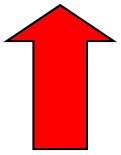


Figure 7. Scotch thistle, Academy-wide, occupied area and number of individuals from 2002-2010.



Map 6. Extent of Scotch thistle in 2002-2010 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

NOT SAMPLED IN 2010. 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 17 and Figure 8). 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 8). 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 17. 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

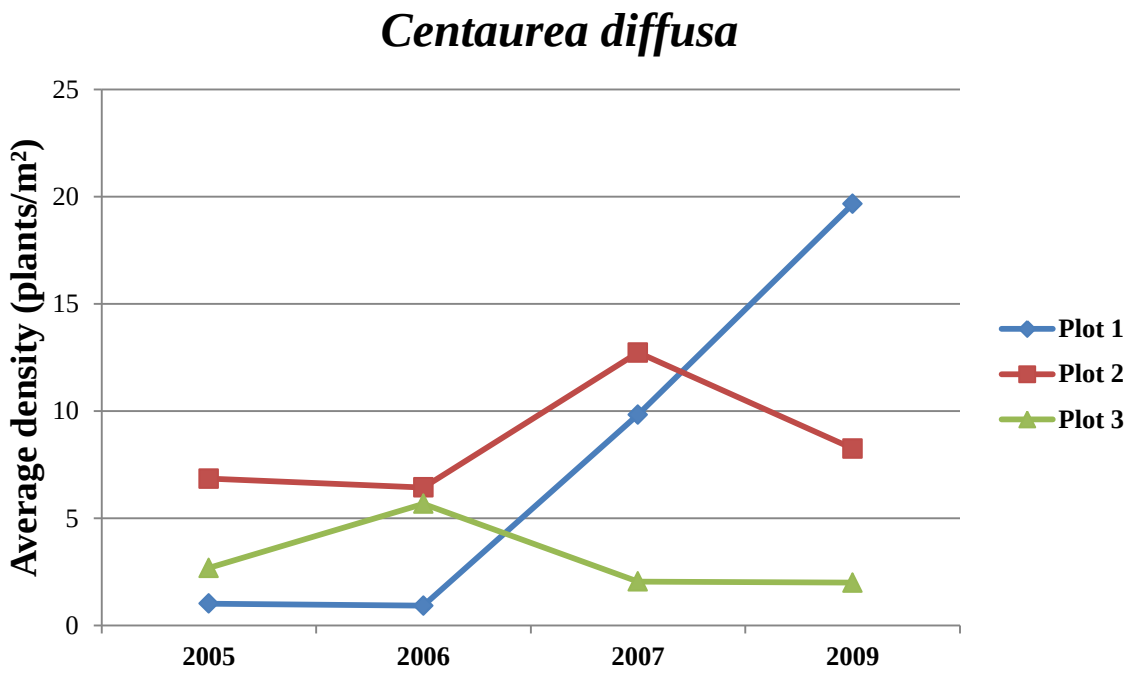


Figure 8. **Diffuse knapweed average density for three permanent plots from 2005-2009.**

Centaurea maculosa (Spotted Knapweed)

Spotted knapweed was mapped in 2002, 2005, 2006, and 2007 at the Academy, dramatically illustrating its rapid spread (Table 18). 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 18. Spotted knapweed summary data at the Academy, 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:

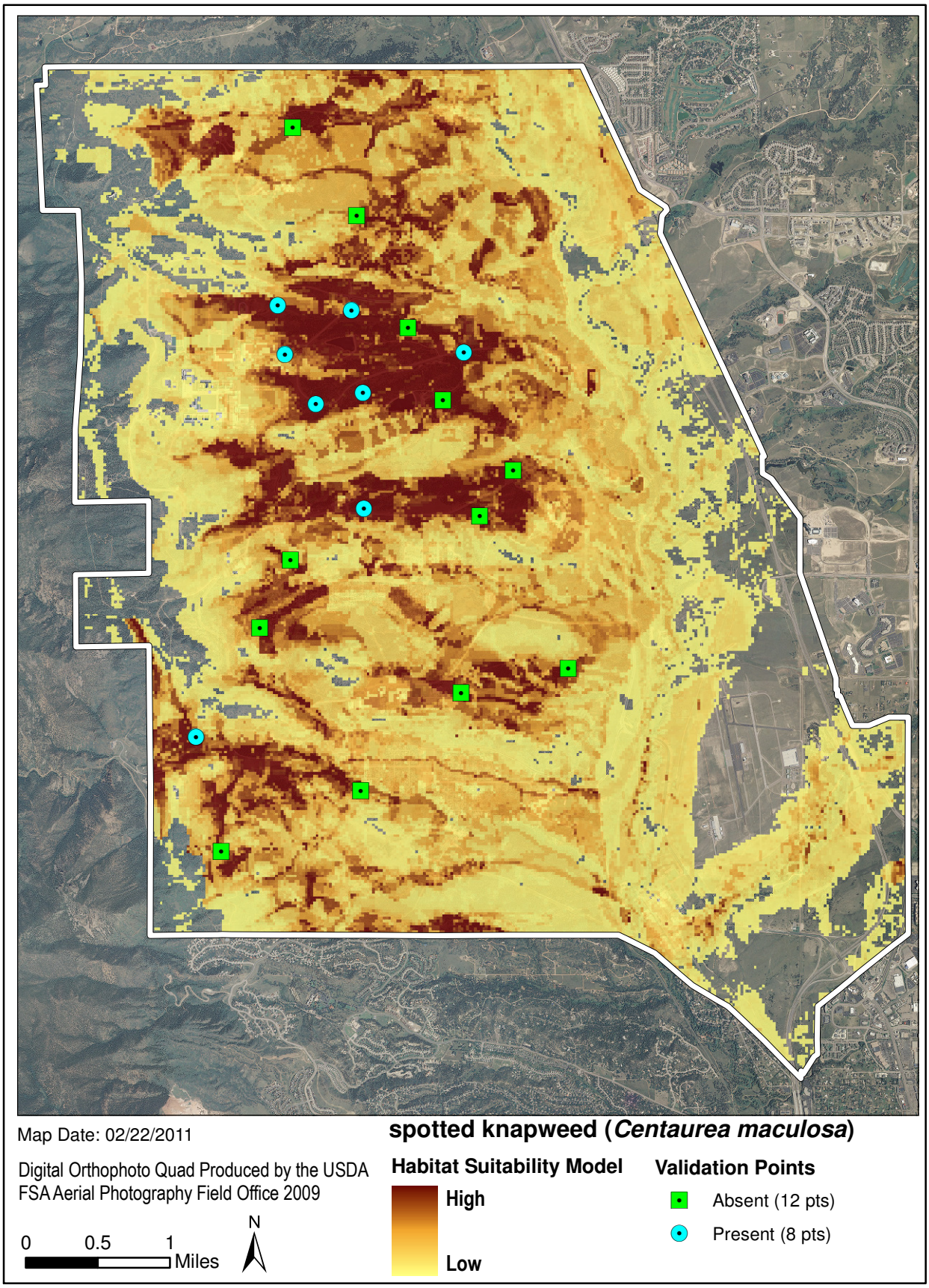
Year	Value (weighted meters)
2009	30
2011	60
2013	90
2015	120
2017	150

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.

In 2010, we randomly chose 20 points from the suitable habitat model to verify if spotted knapweed was present. Eight out of the 20 points had spotted knapweed while 12 did not (Map 7). It is worth noting that many of the 12 points that did not have spotted knapweed are in areas that we predicted would not have spotted knapweed until the years 2015.

We recommend that in 2011 we choose another 20 random points to validate the model.



Map 7. Habitat suitability model (Maxent) for spotted knapweed at the Academy and validation points collected in 2010.

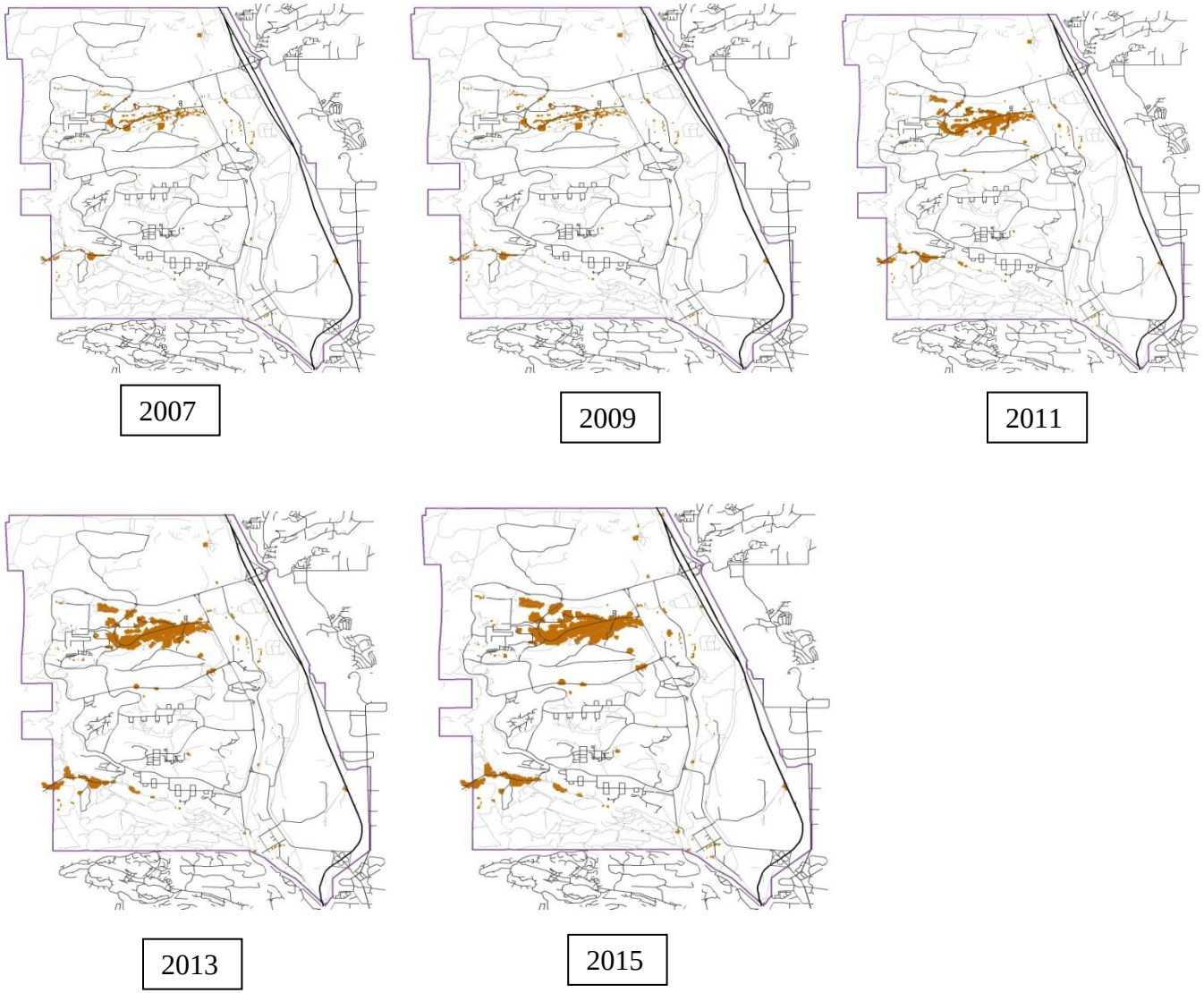
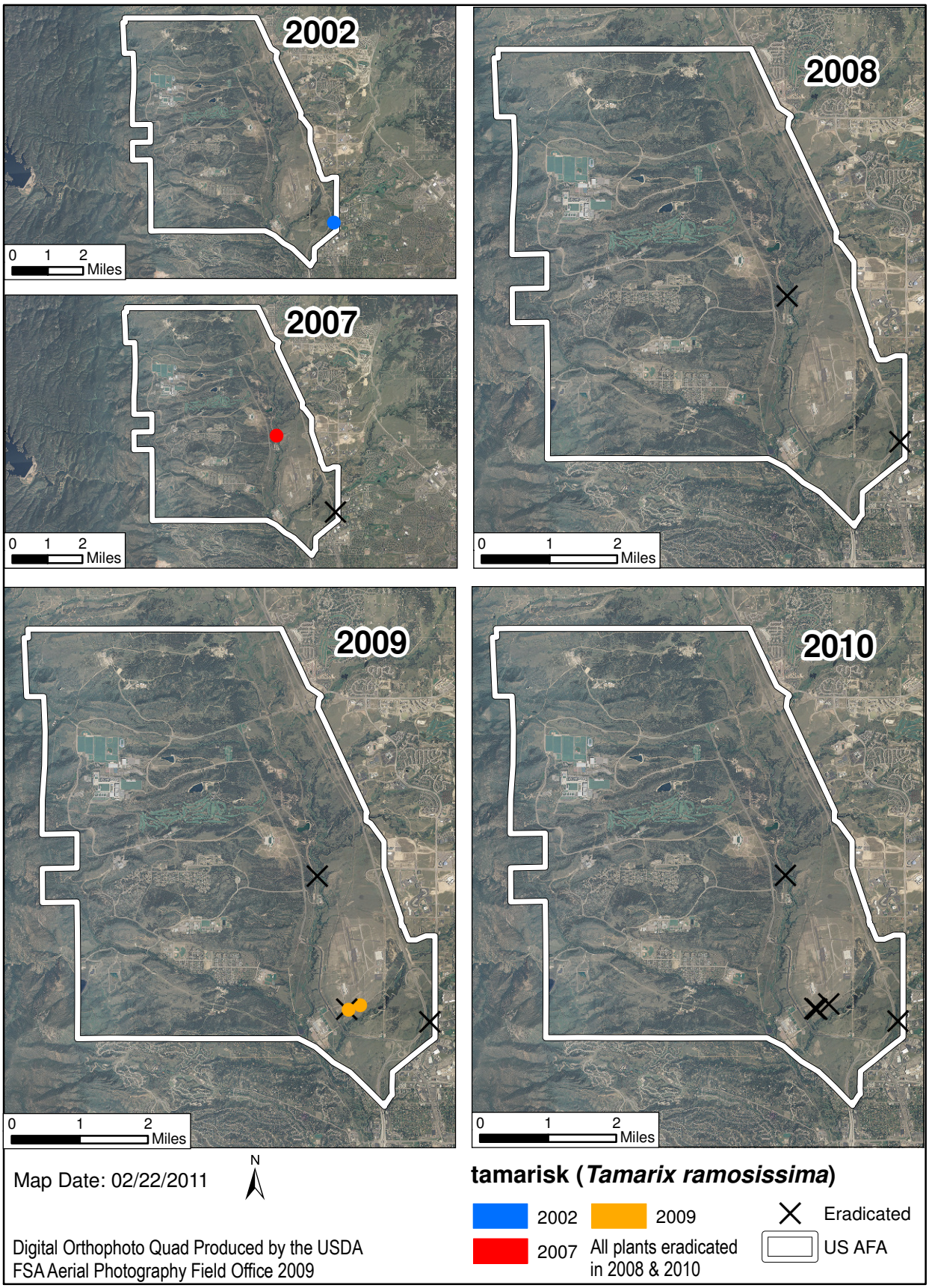


Figure 9. Predicted spread of spotted knapweed between years 2007-2015.

Tamarix ramossisima (Tamarisk)

Tamarisk was not present at any of the visited sites therefore the eradication efforts have been successful. Continued monitoring is worthwhile. (Map 8).



Map 8. Distribution of tamarisk at the Academy in 2002, 2007, 2008, 2009 and 2010.

*Cynoglossum officinale (*Houndstongue*)*

Occupied acres **decreased** over 80% since 2009; 378 m^2 to 78 m^2.

Number of individuals **decreased** from 95 in 2009 to 11 in 2010

Houndstongue was treated with herbicide in 2010 and the success was notable with only one remaining patch that had 11 individuals (Table 19, Map 9). These plants had fruits on them thus it is likely that the seed bank has been populated. We recommend continued monitoring and rapid response to any new populations.

Table 19. Houndstongue summary data, 2009-2010.

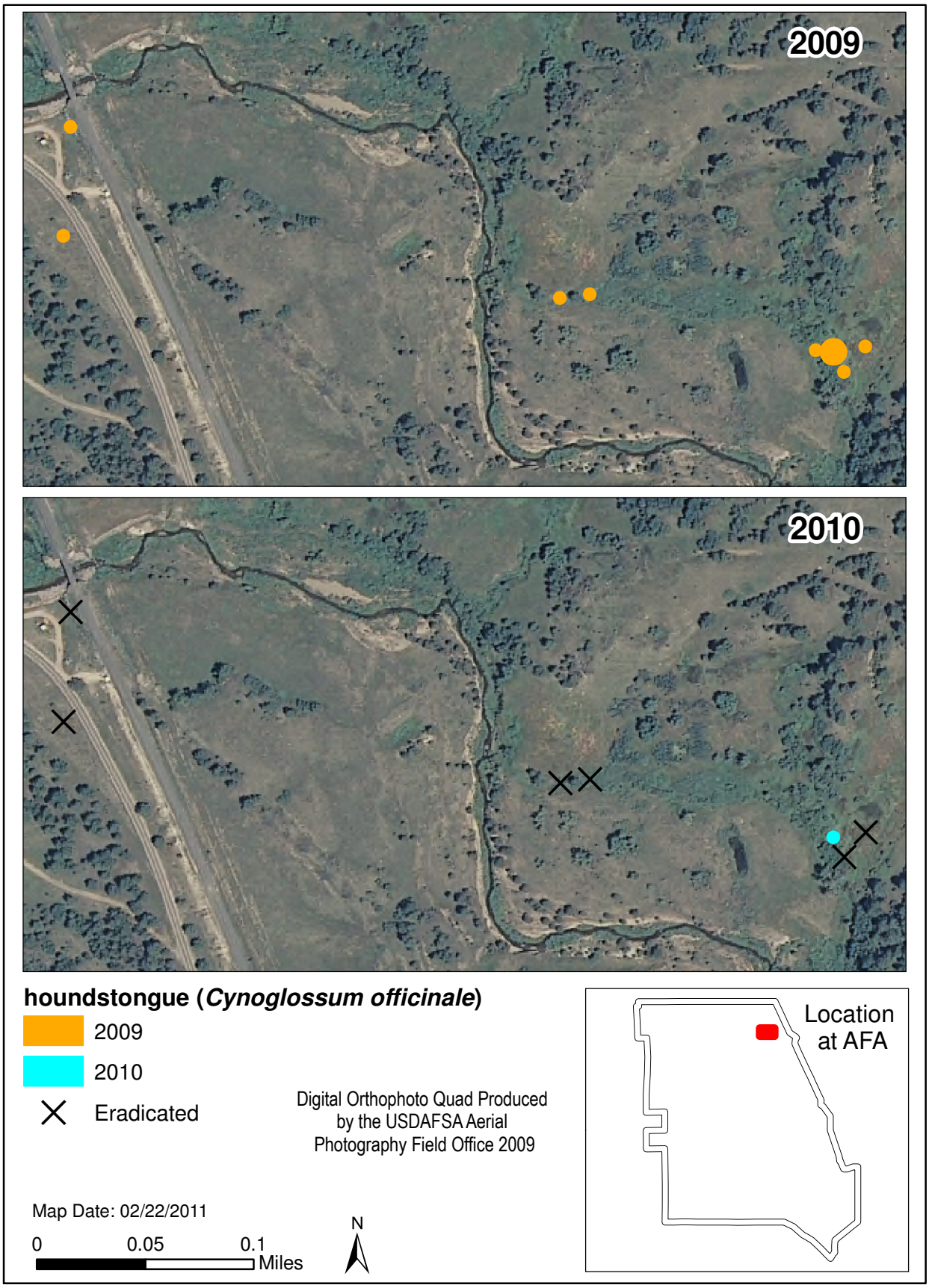
	Occupied Acres (m^2)	Number of Individuals	Number of Mapped Features
2009	378	95	8
2010	78	11	1

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

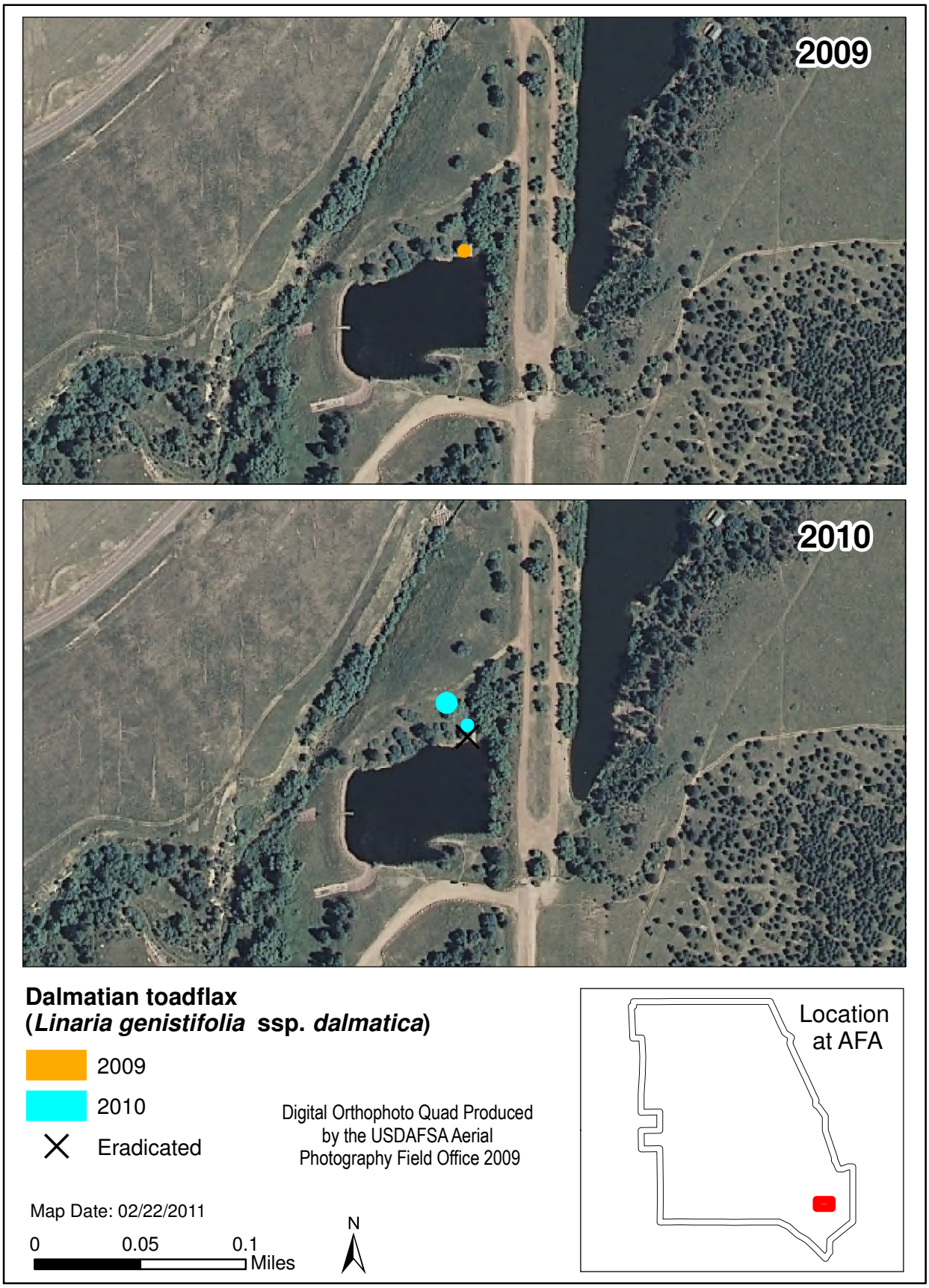
This species was discovered at the Academy in 2009 with one occurrence found near Kettle Lake #1 near the boat ramp. The occurrence consisted of a small number of plants. In 2010 we mapped two patches (Map 10), counted 107 individuals that covered approximately 203 m^2. The AFA was going to spray herbicide on it after our 2010 visit thus we recommend visiting these sites in 2011 and any patches should be treated early.

Gallium verum (Yellow Spring Bedstraw)

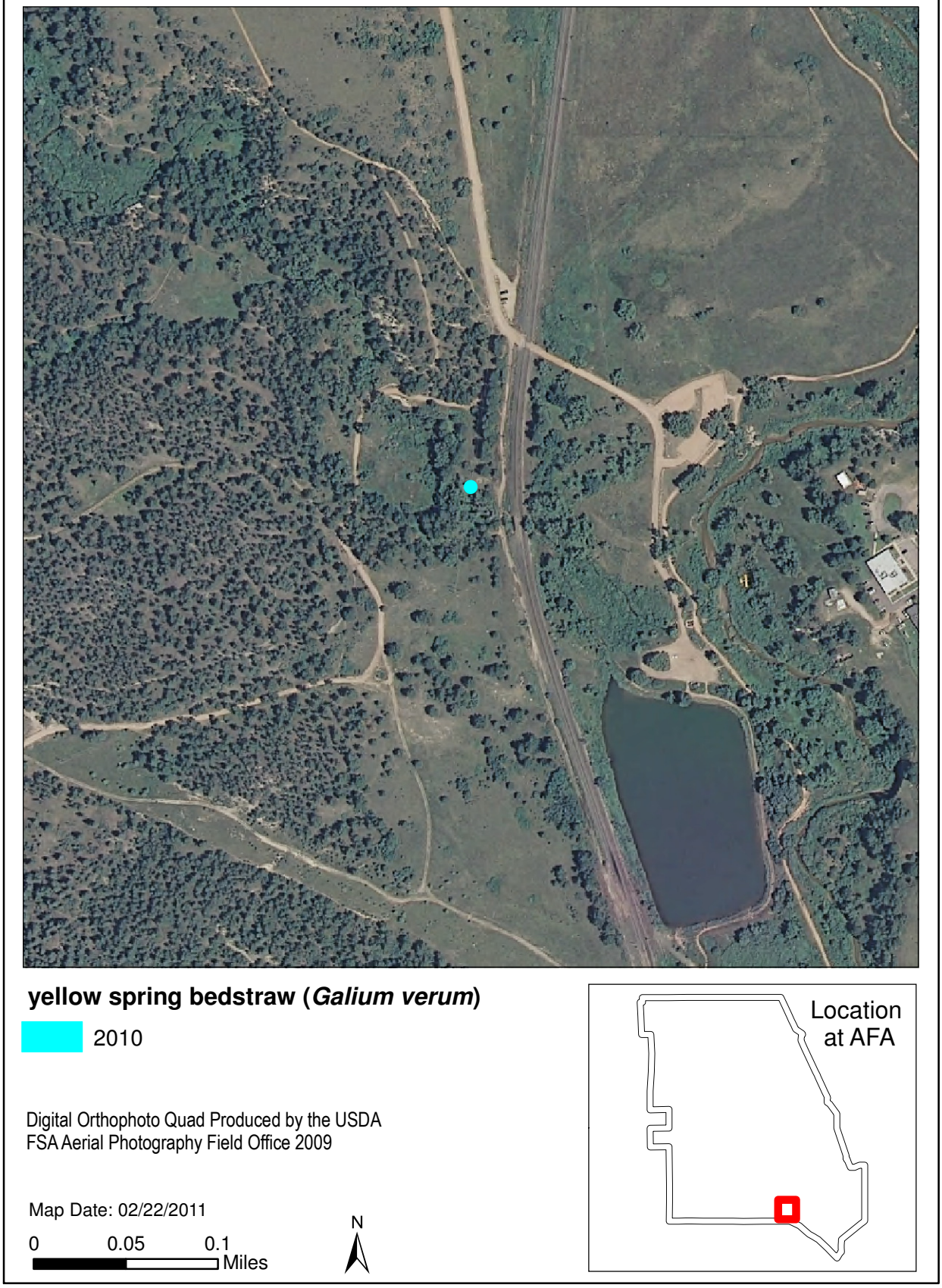
This species was discovered at the Academy in 2010 with one occurrence found near Ice Lake (Map 11). The occurrence consisted of 700 individuals in 28 m^2. The AFA immediately eradicated it however this species can be very aggressive and warrants multiple visits and rapid responses.



Map 9. All known sites where houndstongue has been found at the Academy in 2009 and 2010.



Map 10. Distribution of Dalmatian toadflax at the Academy in 2009 and 2010.



Map 11. Distribution of yellow spring bedstraw at the Academy in 2010.

ACKNOWLEDGEMENTS

The help and generosity of many experts is gratefully acknowledged. Brian Mihlbachler (USFWS), our primary contact at the Academy, played a critical role in this project. His assistance with project logistics and with identifying study sites was extremely valuable, as was his time orienting CNHP personnel. Greg Speights, Steve Wallace, and Diane Strohm (all USFWS) also provided crucial logistical support and advice. Janet Coles, Alan Carpenter, George Beck, and James R. ZumBrunnen provided advice on sampling design and statistical considerations for establishing the weed monitoring program. Rob Schorr and Karin Decker provided valuable background information for this project. The work of Gerry Michels (Texas A&M) and his colleagues has also been valuable for this project. Bruce Rosenlund (USFWS) assisted with project management and support.

REFERENCES

Anderson, D.G. 2006. *Potentilla ambigens* Greene (silky leaf cinquefoil): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region. Available via the internet at: http://www.fs.fed.us/r2/projects/scp/assessments/.

Anderson, D.G., and A. Lavender. 2008a. Noxious Weed Survey of the U.S. Air Force Academy and Farish Outdoor Recreation Area. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Anderson, D.G. and A. Lavender. 2008b. Noxious Weed Monitoring at the U.S. Air Force Academy- Year 3 Results. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Anderson, D.G., and A. Lavender. 2007. Noxious Weed Monitoring at the U.S. Air Force Academy- Year 2 Results. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Anderson, D.G., and A. Lavender. 2006. Noxious Weed Monitoring at the U.S. Air Force Academy- Year 1 Results. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Anderson, D.G., A. Lavender, and S. Neid. 2009. Noxious Weed Monitoring at the U.S. Air Force Academy – Year 4 Results. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Anderson, D.G., A. Lavender, and R. Abbott. 2003. Noxious Weed Survey of the U.S. Air Force Academy and Farish Outdoor Recreation Area. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Carpenter, A.T., S.G. Perce, M. Schmidt, and N. Lovell. 2004. Integrated Noxious Weed Management Plan- U.S. Air Force Academy and Farish Outdoor Recreation Area. El Paso County, Colorado. Produced for the U.S. Air Force Academy by Land Stewardship Consulting Company in collaboration with URS, Inc.

Colorado Climate Center. 2009. Water Year Data- Colorado. Available via the Internet at: http://ccc.atmos.colostate.edu/coloradowater.php.

Colorado Department of Agriculture. 2001. Colorado's Strategic Plan to Stop the Spread of Noxious Weeds: a Framework for State-wide Coordinated and Cost Effective Action to Protect Agriculture and the Environment. Colorado Department of Agriculture. Lakewood, CO: Prepared by Eric Lane.

Colorado Department of Agriculture, Plant Industry Division. 2005. 8 CCR 1203-19- Rules Pertaining to the Administration and Enforcement of the Colorado Noxious Weed Act.

Colorado Natural Heritage Program. 2008. Biodiversity Tracking and Conservation System. Fort Collins, CO: Colorado State University.

El Paso County. 2007. Noxious Weeds Subject to Control. El Paso County Forestry and Noxious Weed Division of the Environmental Services Department. Available via the Internet at: http://adm.elpasoco.com/ForNoxWd/default.asp.

Levine, J.M., M. Vila, C.M. D'Antonio, J.S. Dukes, K. Grigulis, and S. Lavorel. 2003. Mechanisms underlying the impacts of exotic plant invasions. Proceedings of the Royal Society of London B 270: 775–781.

Michels, G.J., V. Carney, M. Mirik, J. Bible, S. Bruno, C. Evers, T. Vick, B. Villarreal, D. Jimenez, J. Newton, and S. Kassymzhanova-Mirik. 2004. Biological Control of Noxious Weeds on Federal Installations in Colorado and Wyoming- Consolidated 2004 Report. Bushland, TX: Texas Agricultural Experiment Station.

Oostermeijer, J.G.B. 2003. Threats to rare plant persistence. In: Brigham, C.A. and M.W. Schwartz (eds) Population Viability in Plants, pp 17–43. Springer, New York.

Rondeau, R.J., D.G. Anderson, A. Lavender, K. Decker, and M. Fink. Noxious Weed Monitoring at the U.S. Air Force Academy- Year 5 Results. Produced for the U.S. Air Force Academy by the Colorado Natural Heritage Program.

Sheley, R. L. and J. K. Petroff (eds.). 1999. Biology and Management of Noxious Rangeland Weeds. Corvallis, OR: Oregon State University Press.

Spackman Panjabi, S. and K. Decker. 2007. Front Range Eco-regional Partnership Invasive Plant Species Strategic Plan. Unpublished report prepared for the United States Department of Defense by the Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO.

Thomson, D. 2005. Measuring the effects of invasive species on the demography of a rare endemic plant. Biological Invasions 7:615-624.

USDA, NRCS. 2009. The PLANTS Database (http://plants.usda.gov, 9 August 2009). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. Bioscience 48: 607–615.

Wisconsin Department of Natural Resources. 2004. Tartarian Honeysuckle (Lonicera tatarica). Available via the internet at: http://www.dnr.state.wi.us/invasives/fact/honeysuckle_tart.htm.

Appendix A.

Myrtle Spurge Table

Map number refers to Map 4 within this document.

Map Number	No. of Individuals	Area (m^2)	Date
1	0	0	8/4/2010
2	0	0	8/4/2010
3	0	0	8/4/2010
4	19	215	8/4/2010
5	4	3	5/20/2010
6	4	3	5/12/2010
7	0	0	8/4/2010
8	0	0	8/4/2010
9	12	102	7/7/2010
10	1	1792	7/6/2010
11	0	0	7/14/2010
12	0	0	7/14/2010
13	1	68	7/14/2010
14	0	0	8/14/2010
15	0	0	7/12/2010
16	0	0	7/12/2010
17	15	28	7/12/2010
18	0	0	7/13/2010
19	0	0	8/30/2010
Total	**56**	**2211**	

All mapped weeds in 2010.

SPECIES	Extant	Eradicated	# of individuals	Area in sq m (with overlap removed)
Acroptilon repens	0	4	0	0
Cynoglossum officinale	1	6	11	78
Euphorbia esula*	8	0	27826	6037
Euphorbia myrsinites	10	12	56	2203
Hypericum perforatum	20	6	82733	5945
Linaria genistifolia spp. dalmatica	2	1	107	203
Onopordum acanthium	61	30	669	2706
Tamarix ramosissima	0	5	0	0
Galium verum	1	0	700	28
*Only includes data near transects				
Euphorbia esula Plot 1	1	0	150	100
Euphorbia esula Plot 2	4	0	27653	5751
Euphorbia esula Plot 3	3	0	23	186