Noxious Weed Monitoring at the U.S. Air Force Academy - Year 9 Results

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On the cover: Leafy spurge plot 2, 2012 and 2013. Herbicide treatment reduced leafy spurge from 35%cover to 3% cover. Max Canestorp is in the 2013 photo.

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EXECUTIVE SUMMARY

This report includes a summary of the results of the past nine years of population monitoring of targeted noxious weeds at the U.S. Air Force Academy ("the Academy"), emphasizing changes that were observed between 2012 and 2013.

In 2013 we monitored 16 species utilizing two methods, depending on species: a complete census (areal mapping) or permanent plots. The areal mapping was conducted on 11 species that have a high probability of suppression or eradication while the species monitored with permanent plots have a low probability of suppression; however they are still being selectively managed. The mapped species were Russian knapweed (*Acroptilon repens*), houndstongue (*Cynoglossum officinale*), myrtle spurge (*Euphorbia myrsinites*), yellow spring bedstraw (*Galium verum*), dames rocket (*Hesperis matronalis;* not updated in 2013), common St. Johnswort (*Hypericum perforatum*), Dalmatian toadflax (*Linaria genistifolia* ssp. *dalmatica*), tatarian honeysuckle (*Lonicera tatarica*), Scotch thistle (*Onopordum acanthium*), bouncingbet (*Saponaria officinalis*), and tamarisk (*Tamarix ramosissima*). These species pose a significant risk to the natural resource values of Academy if they continue to spread. Species with permanent plots included whitetop (*Cardaria draba*), musk thistle (*Carduus nutans*), diffuse and spotted knapweeds (*Centaurea diffusa* and *C. maculosa*), and leafy spurge (*Euphorbia esula*). Canada thistle (*Cirsium arvense*) was not monitored in 2013; however, permanent plots were established for this species in 2012.

Summary data for all of the above species are provided under each species account. We did not conduct any monitoring at Farish in 2013.

The highlights of 2013 monitoring are listed below.

- **Russian knapweed (*Acroptilon repens*):** The 2012 weed mapping project located 10 new sites totaling over 500 plants and an aggressive herbicide treatment ensued with excellent results. By 2013, none of the sites had any live plants however at least three sites had dead standing plants with seed heads. This species is a high priority for complete eradication and annual herbicide treatment and monitoring is recommended.
- **Whitetop (*Cardaria draba*):** We monitored 7 permanent plots along Monument Creek and found that density and cover significantly increased in spite of the drought; however, frequency remained stable indicating that whitetop spread was negligible. Six outlier populations are a high priority for weed management and we recommend increasing the number of permanent plots to at least 10.
- **Musk thistle (*Carduus nutans*):** Although musk thistle is widespread, there is ample evidence that herbicide treatment reduces the number of individuals. In 2013, our photo monitoring plots recorded the lowest count since 2008.

- **Diffuse and spotted knapweeds (*Centaurea diffusa* and *C. maculosa*):** We monitored 10 non-biocontrol and 2 biocontrol permanent plots in 2013. Knapweed significantly decreased in density, cover, and frequency, regardless of treatment type. The most significant decrease was in a biocontrol plot. Eradication is not feasible; therefore, selecting targeted areas for treatment is suggested.
- **Canada thistle (*Cirsium arvense):*** We did not monitor this species in 2013. Biocontrol and selected sites for herbicide treatment may be the best solution, especially for sites with high cover. Monitoring is recommended in 2014.
- **Houndstongue (*Cynoglossum officinale*):** Early detection and rapid response is still controlling this species and eradication is still possible. The number of individuals dropped from 70 to 48, 2012-2013. Annual pulling coupled with herbicide, especially prior to seed development, should control this species since seeds are short lived (3 years).
- **Leafy spurge (*Euphorbia esula*):** We monitored 10 permanent plots in 2012-2013. Density significantly decreased in the herbicide treated plots, while cover and frequency were not significantly different between years. The 2012 weed map recorded that this species continues to spread south. Areas treated with herbicide appear to be controlling the cover but it is challenging to treat all infestations. Southern populations should be a high priority for 2014 herbicide treatment.
- **Myrtle spurge (*Euphorbia myrsinites*):** The number of individuals and mapped sites were slightly higher in 2013 compared to 2012. Management efforts are able to keep this species from rapidly expanding however eradication appears to be difficult. Continued annual treatment at each site and annual monitoring is recommended.
- **Yellow spring bedstraw (*Galium verum*):** One site was discovered in 2010. A rapid response successfully eradicated this species. No plants have been observed during the last two years. Continued monitoring is recommended.
- **Dames rocket (*Hesperis matronalis*):** Newly discovered in 2012. This species is primarily located close to I-25; it probably escaped from nearby gardens. Eradication may be possible. It was not remapped in 2013.
- **Common St. Johnswort (*Hypericum perforatum*):** Number of individuals, occupied area, and number of patches decreased, documenting the strongest downward trend since 2009, primarily due to an aggressive herbicide treatment. Continued herbicide treatment and monitoring should continue. This is still a high priority species for potential eradication.
- **Dalmatian toadflax (*Linaria genistifolia* spp. *dalmatica*):** It appeared to be eradicated for two years but a new site was discovered in 2013. Continued monitoring of extirpated sites is warranted.

- **Tatarian honeysuckle (*Lonicera tatarica*):** The number of locations increased from one to five and number of individuals increased from 30 to 38 between 2012 and 2013. One site is also the location for the rare American currant (*Ribes americanum*); therefore, care should be taken when trying to eradicate this species. Hand digging is recommended.
- **Scotch thistle (*Onopordum acanthium*):** Occupied acres probably remained stable while number of mapped locations decreased and number of individuals slightly increased between 2012 and 2013; thus relatively stable. Aggressive herbicide and pulling treatment should continue and annual monitoring is essential.
- **Bouncingbet (*Saponaria officinalis*):** This species was only mapped in two years: 2002 and 2013. It does not appear to be an aggressive spreader and eradication may be possible.
- **Tamarisk (*Tamarix ramosissima*):** Only one individual was located in 2013; however, this species is moving around the Academy and has a high probability of spreading if unchecked.

INTRODUCTION

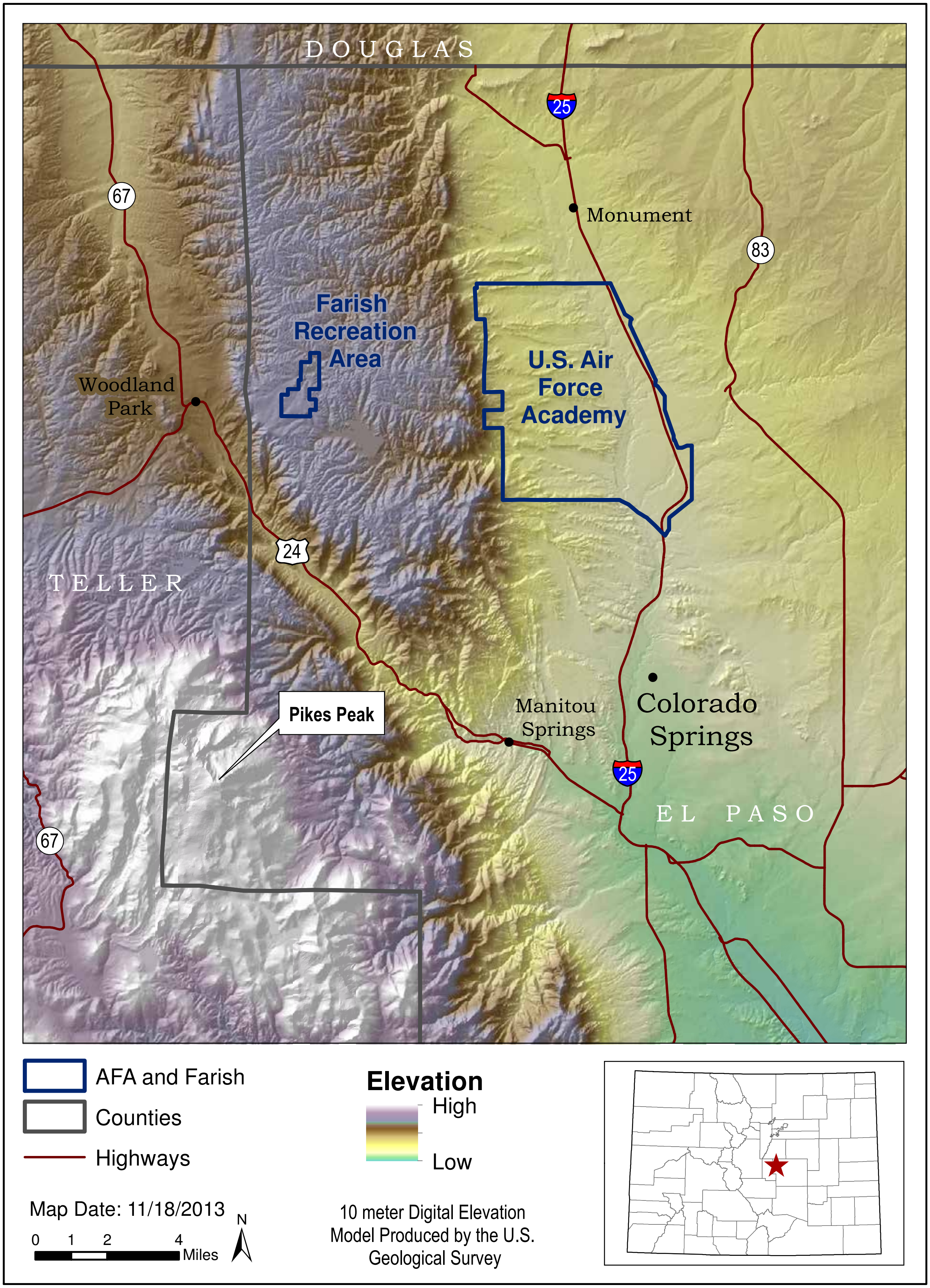
Weeds are known to alter ecosystem processes, degrade wildlife habitat, reduce biological diversity, reduce the quality of recreational sites, reduce the production of crops and rangeland forage plants, and poison livestock (Sheley and Petroff 1999). All of these impacts are occurring in Colorado (Colorado Department of Agriculture 2013). 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 (Carpenter et. al 2004).

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 (Siemers et al. 2012). 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 (Siemers et al. 2012). The Academy is critically important for the conservation of the listed threatened Preble's meadow jumping mouse (*Zapus hudsonius preblei*) (Siemers et al. 2012, 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 natural resources management plan. In 2002, almost 4,000 infestations were mapped for 14 target species at the Academy and Farish, and additional infestations were mapped in 2003 for whitetop and Russian olive (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 was to guide the management of noxious weeds at the Academy and Farish in the most efficient and effective manner. This plan also supports the *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 Farish Outdoor 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 were set for the Academy and Farish that were 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 (Spackman-Panjabi and Decker 2007, Carpenter et al. 2004, Anderson et al. 2003). For example, myrtle spurge was 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 was 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*), whitetop (*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 were 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 removed and there were 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 Plant Industry Division 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 second weed map of the Academy and Farish, completely revising the baseline weed survey completed in 2002 and 2003 for most target species; three additional weed species were discovered for a total of 17 mapped 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 (11.48 acres) of infestations were mapped for 14 target species in 2009.

In 2010 and 2011, we primarily mirrored 2009 methods; however, we did not monitor diffuse knapweed (*Centaurea diffusa*) or whitetop (*Cardaria draba*). A total of 16,102 m^2 (3.98 acres) of infestations were mapped for 10 target species in 2011.

In 2012, we coordinated with United States Fish and Wildlife Service (USFWS) and the Texas A&M AgriLife Research biocontrol program to address future weed monitoring and management of several weed species. We primarily discussed the management of leafy spurge and common St. Johnswort. CNHP inherited the monitoring and management responsibilities for all these sites; thus, they were removed from the Texas A&M AgriLife Research biocontrol program. Texas A&M will no longer pursue biocontrol efforts on these weed species. The decision was made for all common St. Johnswort on the Air Force Academy to be eradicated immediately using chemical treatments. As of 2012, both CNHP and Texas A&M AgriLife Research are using the same vegetation collection methods for monitoring transects (see Methods below).

The biocontrol plots from Texas A&M are compared to the non-biocontrol plots for Canada thistle and diffuse knapweed. Whitetop and leafy spurge do not have any biocontrol plots; however, we set up permanent transects for these species as well.

In 2012 CNHP conducted the third weed mapping effort at AFA and Farish, documenting and mapping 22 weed species and a 39% increase of area occupied by weeds (Lavender-Greenwell and Rondeau 2013).

In 2013 CNHP continued to monitor using the same methods as 2012: mapping/census and permanent plots and only conducted field work at the Academy (Farish was not visited). Diffuse and spotted knapweed hybridization had become so widespread that we had to lump these two species into a hybrid swarm, "knapweeds".

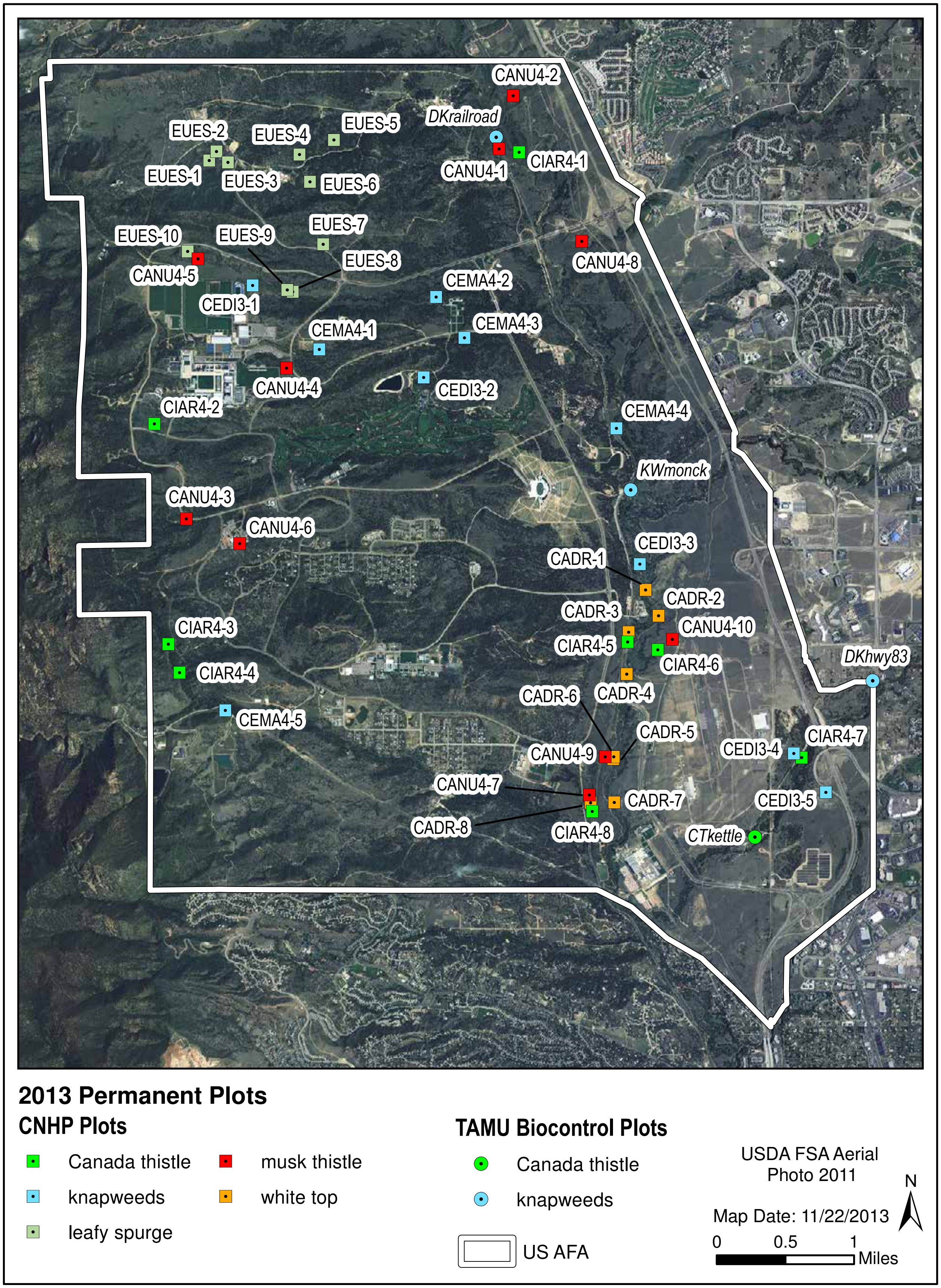
See Appendix A for a history of all CNHP-related weed mapping and monitoring projects from 2002 to the present, organized by species.

METHODS

This project was undertaken to evaluate the effectiveness of ongoing management of noxious weeds at the Academy in order to determine whether weed management objectives are being met and to determine trend. The recommendations for the design and deployment of monitoring plots offered by Carpenter et al. (2004) were originally adhered to and subsequently modified as new information was collected. In 2013, combinations of transect sampling, photoplots, and perimeter mapping and census were utilized in monitoring the 16 target noxious weed species (Table 1). Permanent plot locations are presented in Map 2. In order to closely align with the Texas A&M AgriLife biocontrol, we established 36 permanent plots utilizing the same methods as Michels et al. (2013) for: *Cardaria draba* (7), *Centaurea diffusa* (5), *C. maculosa* (5), *Cirsium arvense* (8) and *Euphorbia esula* (10). We randomly selected the plots, utilizing 2007 weed mapping data (Anderson and Lavender 2008a). Details for the methods used for collecting density, cover, height, reproductive stage, number of flowers, and flower width at each of the permanent plots are in Appendix B. In 2013 we resampled all but *Cirsium arvense*. Collecting data in subsequent years will allow us to analyze trend and treatment data.

Table 1. Summary of methods used for monitoring in 2013.

Latin name	Common name	2013 Sampling Methods
Acroptilon repens	Russian knapweed	*Mapping/ census*
Cardaria draba	Whitetop	*7 permanent plots*
Carduus nutans	Musk thistle	*10 permanent photo plots*
Centaurea diffusa, *Centaurea maculosa* and hybrid	Diffuse and spotted knapweed	*10 permanent plots*
Cirsium arvense	Canada thistle	*Not monitored*
Cynoglossum officinale	Houndstongue	*Mapping/census*
Euphorbia esula	Leafy spurge	*10 permanent plots*
Euphorbia myrsinites	Myrtle spurge	*Mapping/ census*
Galium verum	Yellow spring bedstraw	*Mapping/census*
Hesperis matronalis	Dames rocket	*Not monitored*
Hypericum perforatum	Common St. Johnswort	*Mapping/Census*
Linaria genistifolia spp *dalmatica*	Dalmatian toadflax	*Mapping/census*
Lonicera tatarica	Tatarian honeysuckle	*Mapping/census*
Onopordum acanthium	Scotch thistle	*Mapping/census*
Saponaria officinalis	bouncingbet	*Mapping/census*
Tamarix ramosissima	Tamarisk	*Mapping/ census*



Map 2. Locations of permanent monitoring plots for weeds at the Academy.

RESULTS AND RECOMMENDATIONS

The 2011-2012 drought continued into the winter and spring of 2013 (Fig. 1) and the dry patters was broken in mid-July 2013. The monsoons brought exceptionally violent storms and a record amount of precipitation, the highest since we began monitoring in 2002 with 8 inches above average (Fig. 1). Since most of the 2013 monitoring data was collected prior to, or shortly after, the monsoons we considered 2013 weed data as representing drought conditions (Fig. 1). The annual average precipitation for the area is 17.4 inches.

Results specific to each target noxious weed species are summarized in the following sections. See Appendix A-D for additional information on methods and results.

Recent treatment areas at the Academy (2013) are depicted in Map 3 along with the location of the biocontrol plots. We hope to have more detailed spatial data of treated (sprayed, pulled, biocontrol, etc.) areas in the future.

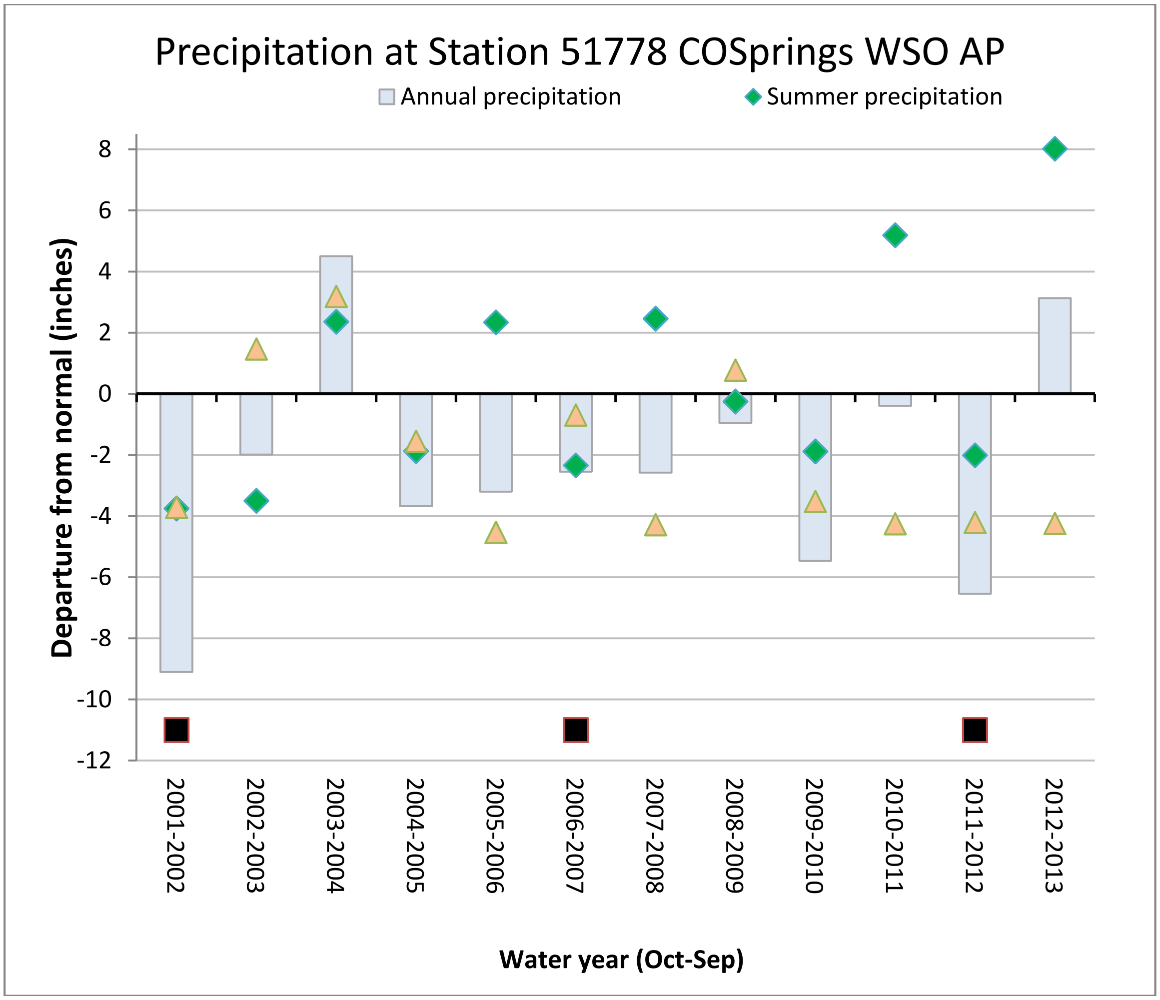
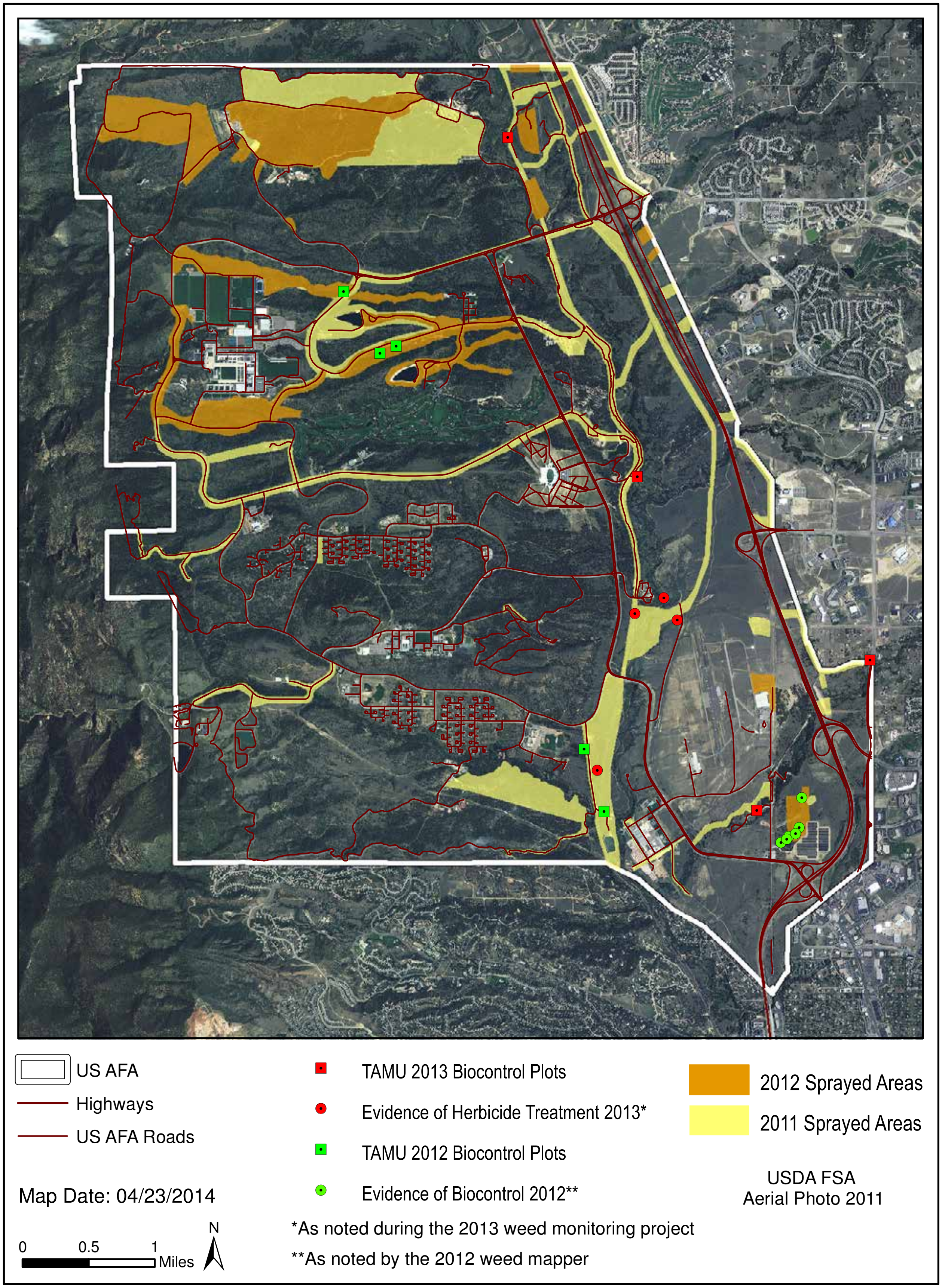


Figure 1. Summary data for annual precipitation by water year (October-September) at Colorado Springs, Colorado from 2002 through 2013 (Western Regional Climate Center 2014). Average annual precipitation is 17.4 inches. Spring = March-June, Summer = July-September.



Map 3. Recent treatment areas at the Academy.

Russian Knapweed (*Acroptilon repens*)

Russian knapweed was considered eradicated until the 2012 weed mapping project discovered 10 new sites. All sites were successfully treated in 2013.

Photo by David Anderson

Species	Sampling Methods
Russian knapweed	mapping and census at all locations

Russian knapweed occupied 0.05 acres in 2012, a 69% increase over 2007. In 2012, 10 new locations were mapped (Map 4), totaling 543 shoots (Table 2 and Figure 2). This represented a 172% increase in number of shoots and a 400% increase in number of extant mapped features since 2007 (Table 2). In 2013 all locations were treated and no live plants were observed (Table 2 and Figure 2).

The first appearance of Russian knapweed was in 2004 and by 2007 there were two extant occurrences and 2 eradicated occurrences, all near Douglass Way (Map 4). By 2009, all of these occurrences were eradicated (Rondeau and Lavender 2012). In 2005, herbicide treatment was applied to part of the Skills Development Center and Douglass Way occurrences and the Skills Development Center was treated again in 2009. Specific details about the first two locations can be found in Anderson and Lavender (2008b).

The 2012 weed mapping project found 10 new locations of Russian knapweed and a rapid response will likely control suppress or eradicate this weed. Roots from a recently established plant expand rapidly and may cover up to 12 square yards in two growing seasons and stands may survive 75 years or longer (Beck 2008). This species has the ability to greatly expand at the AFA, especially around disturbed areas; therefore we place a high priority on controlling this species.

In 2013 all of the known Russian knapweeds were effectively treated with herbicide, although at least three sites still had dead standing stalks with visible seed heads. Therefore we recommend annual visits to these sites by AFA weed controllers and a follow-up site visit by CNHP.

Table 2. Russian knapweed summary data, 2004-2013.

	Occupied Acres	Number of Individuals	Number of Extant Mapped Features
2004			3
2005			2
2007	0.03	200	2
2008	0.025	157	2
2009	0	0	2
2010	0	0	0
2011	0	0	0
2012	0.05	543	10
2013	0	0	0

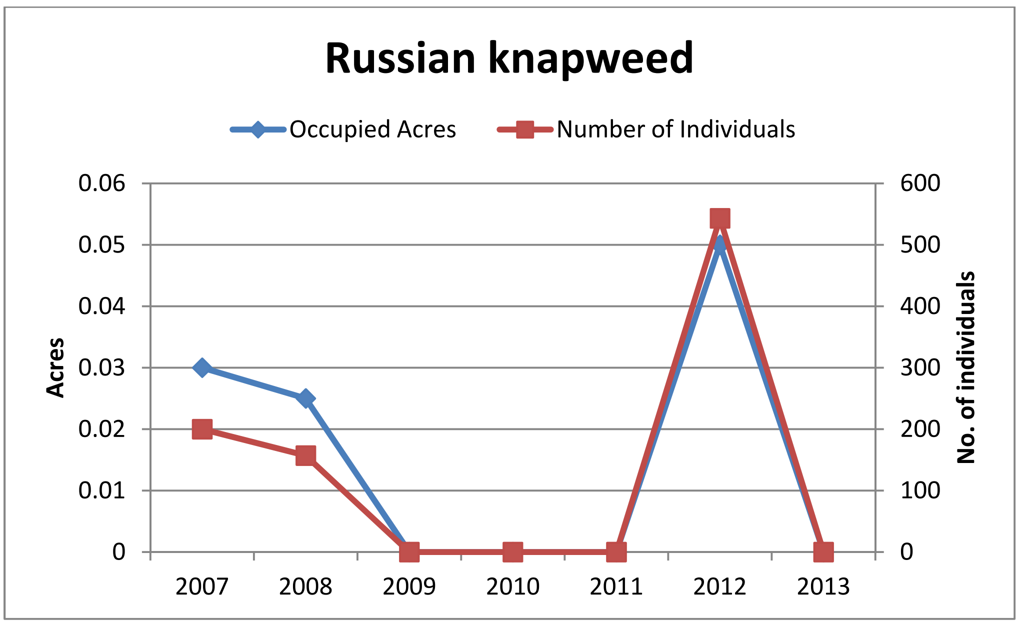
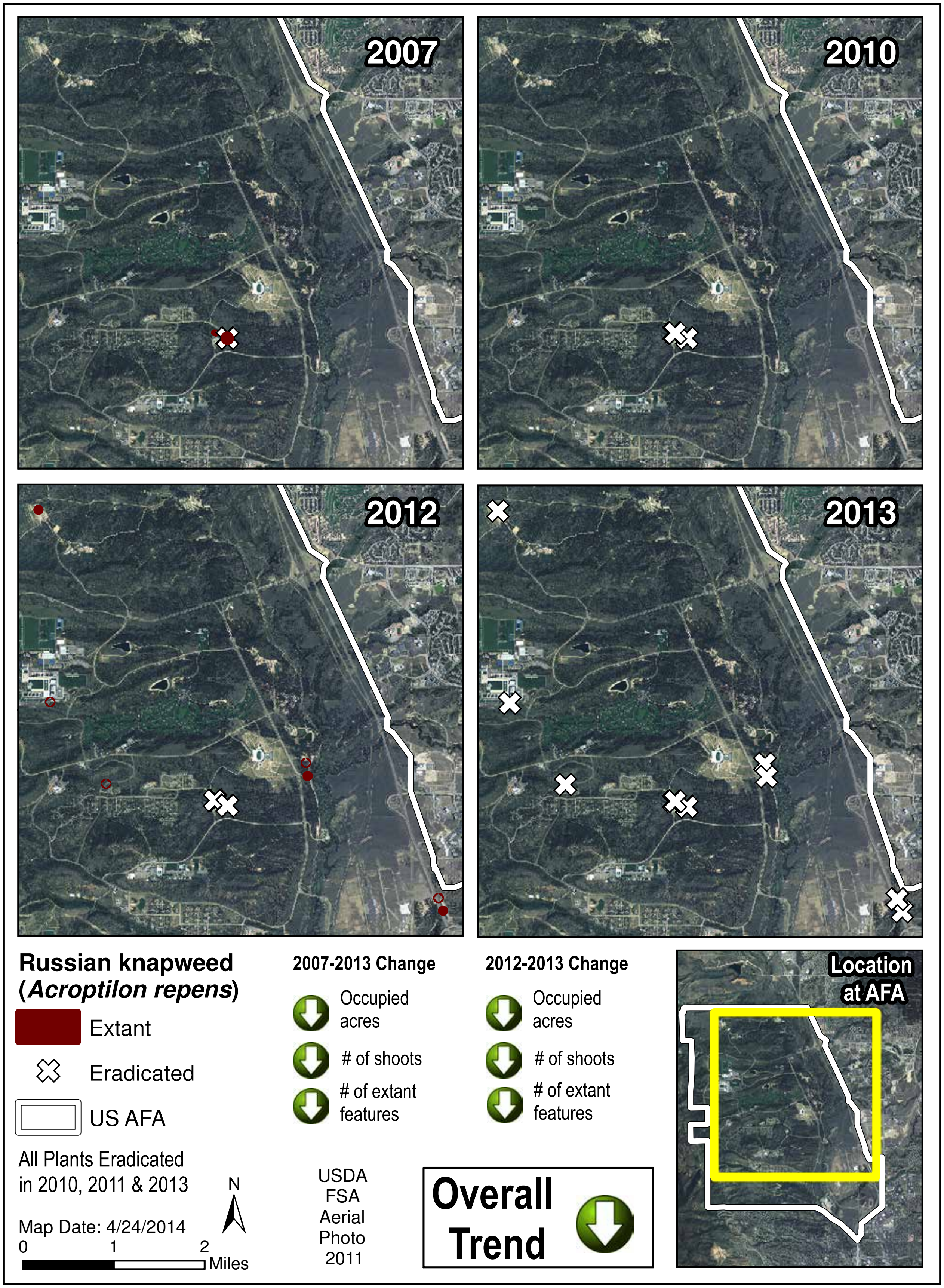


Figure 2. Russian knapweed trend, 2007-2013.



Map 4. Distribution of Russian knapweed at the Academy between 2007 and 2013.

Whitetop (*Cardaria draba*)

While frequency remained stable between 2012-2013, density and cover significantly increased

Species	Sampling Methods	Data Collected
Whitetop	7 Permanent transects	Frequency, density, cover

Photo by Michelle Washebek

Due to the large number of mapped locations at AFA (Lavender and Rondeau 2013) we chose to monitor whitetop by randomly selecting sites from the 2007 dataset. In 2012, we randomly chose 8 sites that were known to have whitetop in 2007, and established 8 permanent plots (Map 5). We recorded density, cover, frequency, and height. In 2013 we re-sampled 7 of the 8 plots as one of the 2012 plots was not adequately marked and re-sampling was not possible. See Table 3 for summary data from each plot.

Frequency: The number of quadrats/plot that had whitetop present was stable between 2012 and 2013, with the overall average at 31 and 30, respectively (50% frequency; Table 3). We can infer that whitetop distribution remained steady and did not significantly spread into new areas.

Density: The average number of shoots/quadrat significantly increased from 2012 to 2013 from 12 to 15 shoots respectively (P= 0.007, one-tailed paired t-test). CADR-4 and CADR-6 were basically stable while all of the other plots increased. CADR-7 and CADR-2 had the largest increases (Table 3).

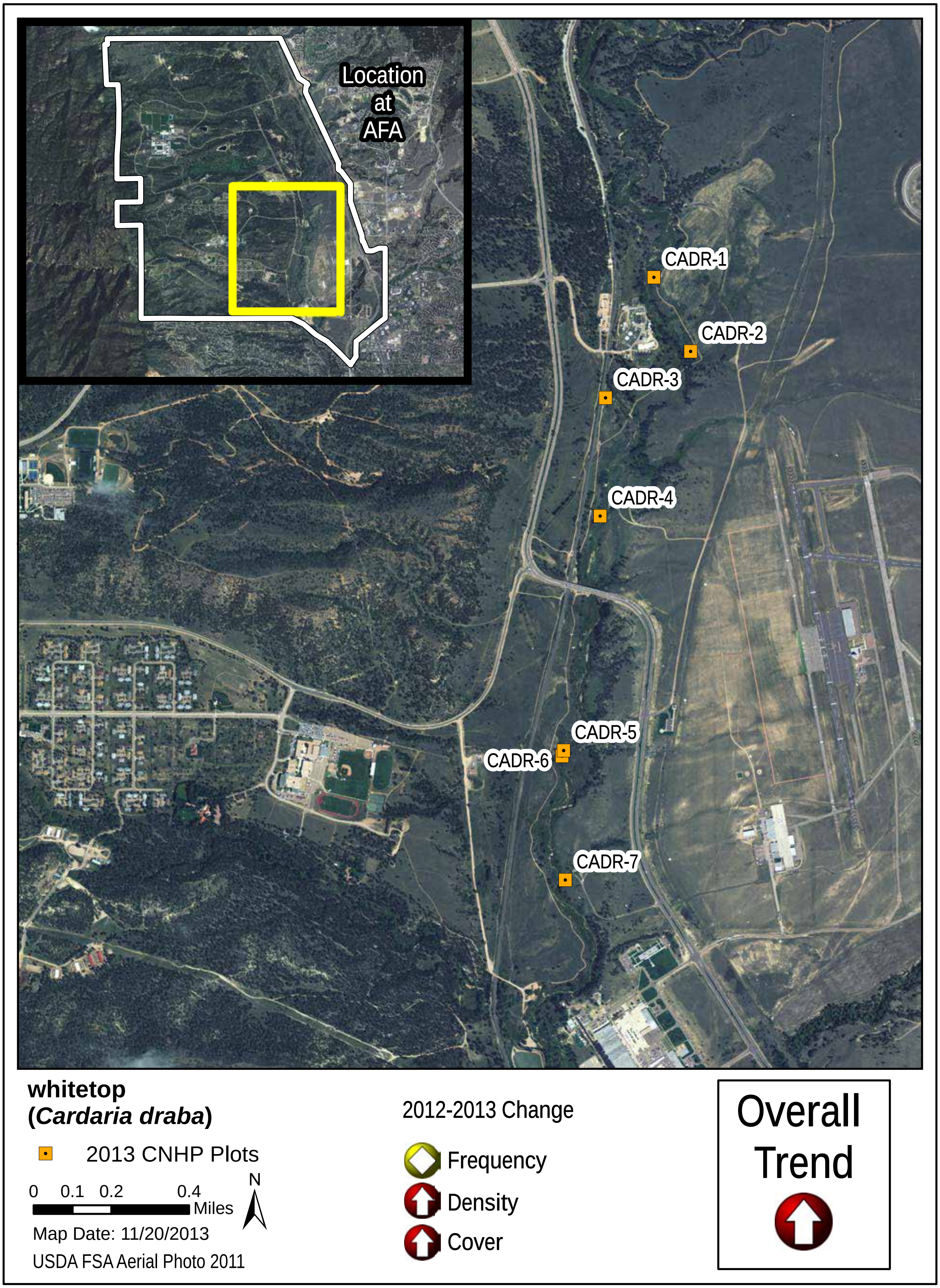
Cover: The average cover of whitetop significantly increased from 2012 to 2013 from 4.8% to 7.5% respectively (P=0.037; one-tailed paired t-test). CADR-6 was the only plot that effectively remained stable. As with the density measure, CADR-7 increased more than any other plot, from 10.5% to 20% (Table 3).

Summary and Discussion: In 2013, we sampled whitetop from June 5-7 within 4 days of the 2012 sample date. While whitetop did not spread within the plots the density and cover significantly increased in 2013. CADR-2 and CADR-3 were treated with herbicide in 2013 just prior to data collection. The effects of this treatment will be more evident in 2014. Two of the 2012 plots were not resampled: CADR-8 did not have any whitetop in either year while CADR-9 was not repeatable due to all but 2 stakes missing. It may be necessary to establish additional plots. In 2014, we should check CADR-8 to see if whitetop has moved in, otherwise we may want to establish two new plots.

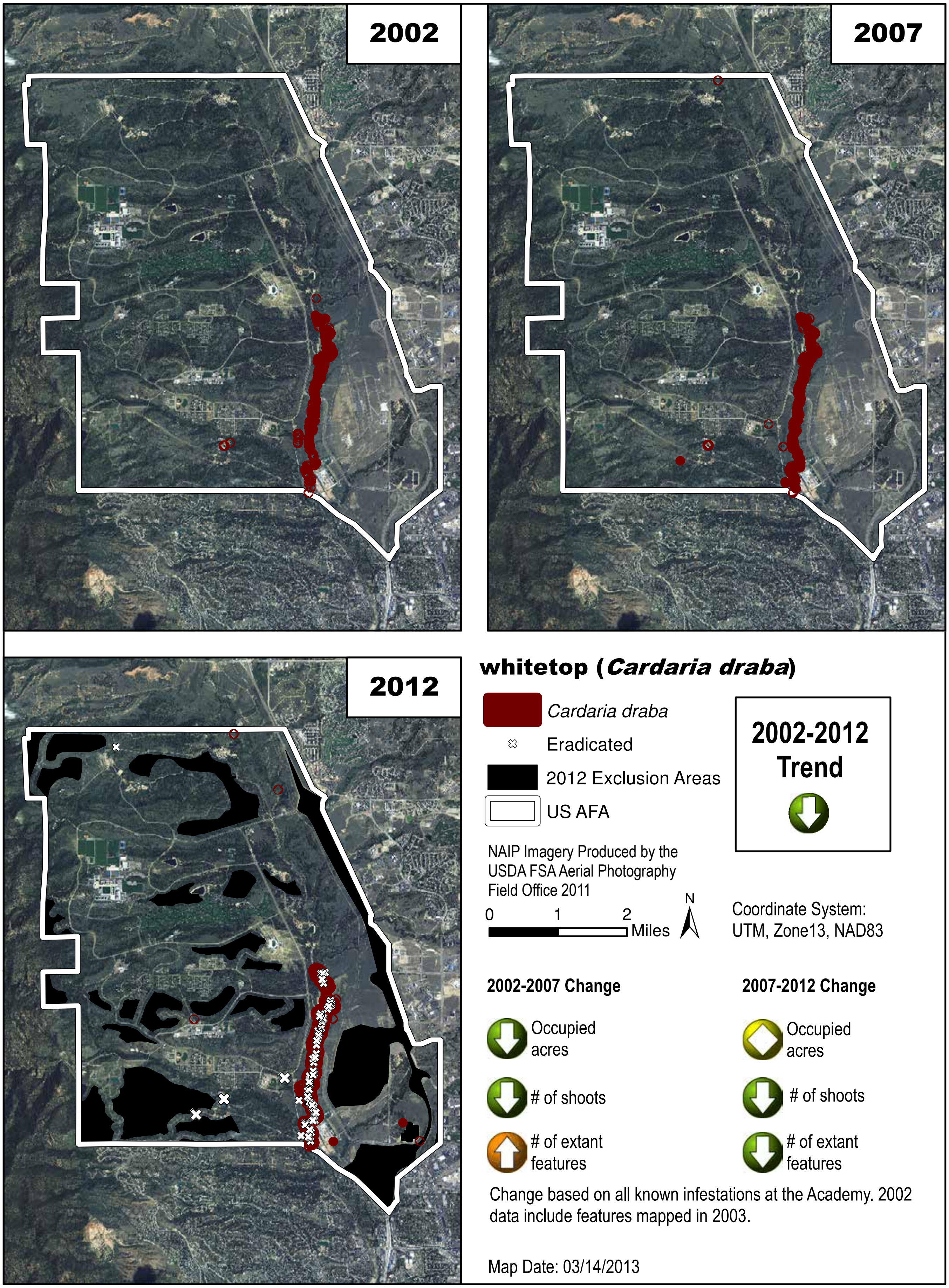
Although we are only monitoring permanent plots there is still a need for all outlier infestations mapped in 2012 (Map 6) to be considered a high priority for eradication especially the northern locations because they could easily disperse seeds downstream and infest the upper reaches of Monument Creek (Greenwell and Rondeau 2013).

Table 3. Whitetop permanent plot data, 2012-2013. *Treatment in 2013 had little impact on data collection as it was applied just prior to sampling.

Plot Name	Treatment 2012	Treatment 2013*	Avg Density 2012	Avg Density 2013	Avg Cover (%) 2012	Avg Cover (%) 2013	Quadrats with plants (%) 2012	Quadrats with plants (%) 2013
CADR-1	none	none	27	30	12	13	0.81	0.82
CADR-2	none	Yes	7	11	6	9	0.65	0.67
CADR-3	none	Yes	1	3	0	1	0.21	0.26
CADR-4	none	none	7	8	2	5	0.52	0.50
CADR-5	none	none	9	12	2	3	0.37	0.39
CADR-6	none	none	5	4	1	1	0.26	0.26
CADR-7	none	none	31	37	11	20	0.65	0.61
		Avg	**12**	**15**	**5**	**7**	**0.49**	**0.50**
		SD	**12**	**13**	**5**	**7**	**0.22**	**0.21**



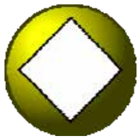
Map 5. 2013 whitetop plots at the Academy.



Map 6. Distribution of whitetop at the Academy in 2002, 2007, and 2012.

Musk Thistle (*Carduus nutans*)

Treated



Number of individuals remained similar in treated plots.

Untreated

Number of individuals decreased in untreated plots.

Photo by Michelle Washebek

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

All ten of the established plots were revisited in 2013. We believe that three of the plots were treated in 2013 or late in 2012 (plots 1, 7, and 10, Table 5). Plot 10 had never been treated in the previous years but we believe that it was treated in either fall of 2012 or spring of 2013, which means that all plots have been treated at least once if not multiple times. The overall population in 2013 was reduced to a total of 28 individuals, the lowest since we began monitoring (Table 4). Spring precipitation has been below average every monitoring year except for 2009 (Table 4), while summer precipitation has varied from below average to above average (Figure 1) thus precipitation patterns may not be the reason for a decrease in number. The most likely explanation for a decrease in numbers is the herbicide treatment. There seems to be a good response to herbicide treatment that may last several years, however most plots appear to become re-infested over time. Therefore, continued monitoring and spraying is necessary.

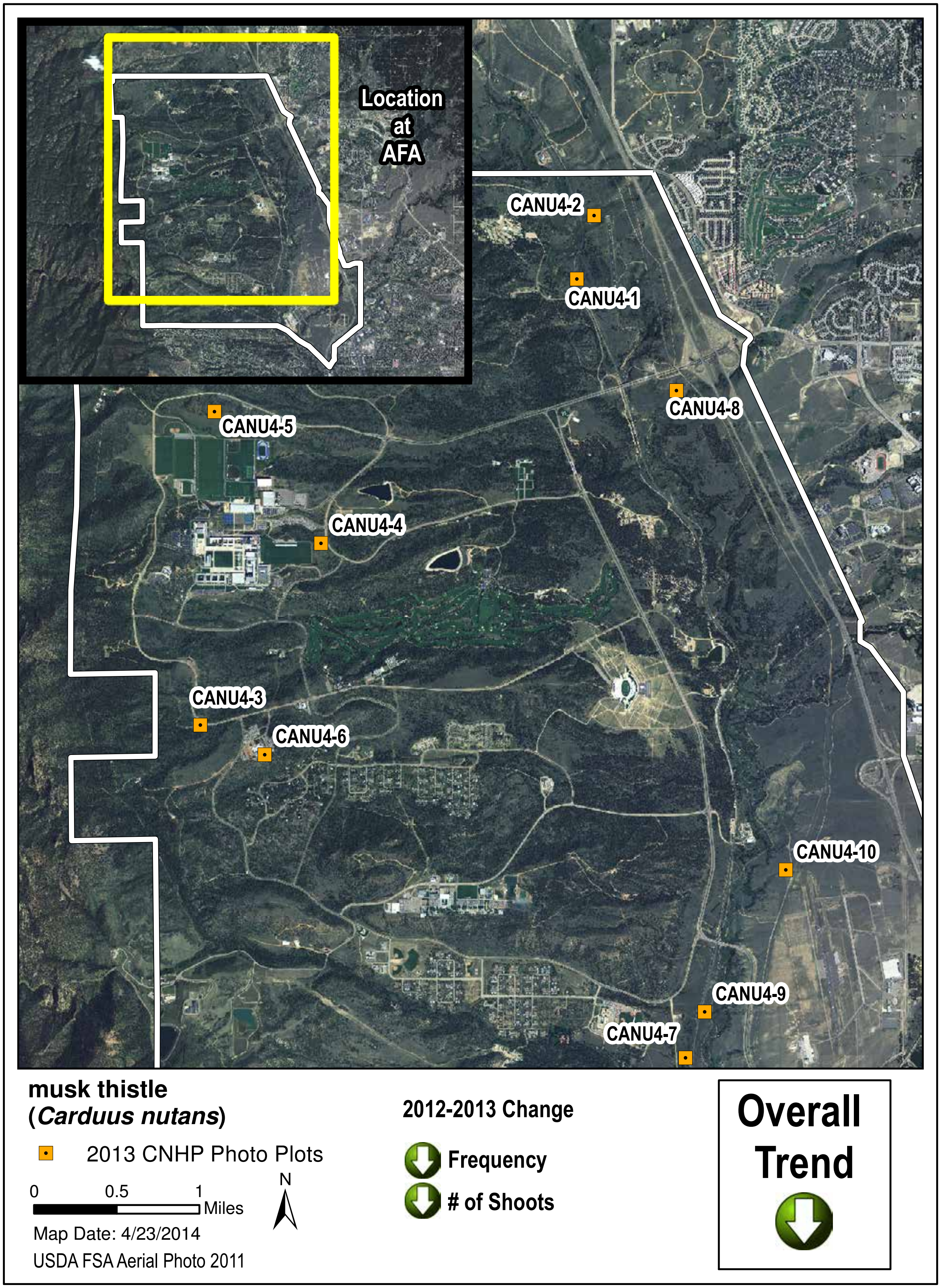
Musk thistle is a biennial weed that reproduces only from seed. The key to successful musk thistle control is to prevent seed production. Applying herbicide in the spring or fall is most effective or when it is in early flower. This is an aggressive weed that establishes easily where there is bare ground however without adequate surface soil moisture, musk thistle will not germinate and, therefore, deep soil moisture has no effect on establishment. In drought years, musk thistle may germinate, but will probably fail to survive due to lack of soil moisture in the 0-30 cm layer of the soil (Beck 1999 and Han 2012). Once the plant has bolted it is more resistant to herbicide treatment. Most seed is dispersed within the immediate vicinity of the parent plant. This leads to a clumped pattern of seedling development. High quality (i.e., good condition) native plant communities are more resistant than degraded sites. The musk thistle seed head weevil, *Rhinocyllus conicus*, can reduce seed production by 50 percent on average. This weevil is no longer being redistributed because it attacks native thistles as well (Beck 2008). The *Trichosirocalus horridus* weevil attacks the crown area of musk thistle rosettes and kills or weakens the plant before it bolts. Michels et al. (2013) have successfully employed this biocontrol at select AFA sites.

Musk thistle appears to be spreading at Academy and Farish (Lavender-Greenwell and Rondeau 2013) even though the annual and spring precipitation, since 2001, has generally been below average. Potentially the rate of spread would be even greater if treatment was not being applied. In 2013, July-September precipitation was exceptionally high and may be ideal for germination, thus 2014 may be a year of expansion for musk thistle.

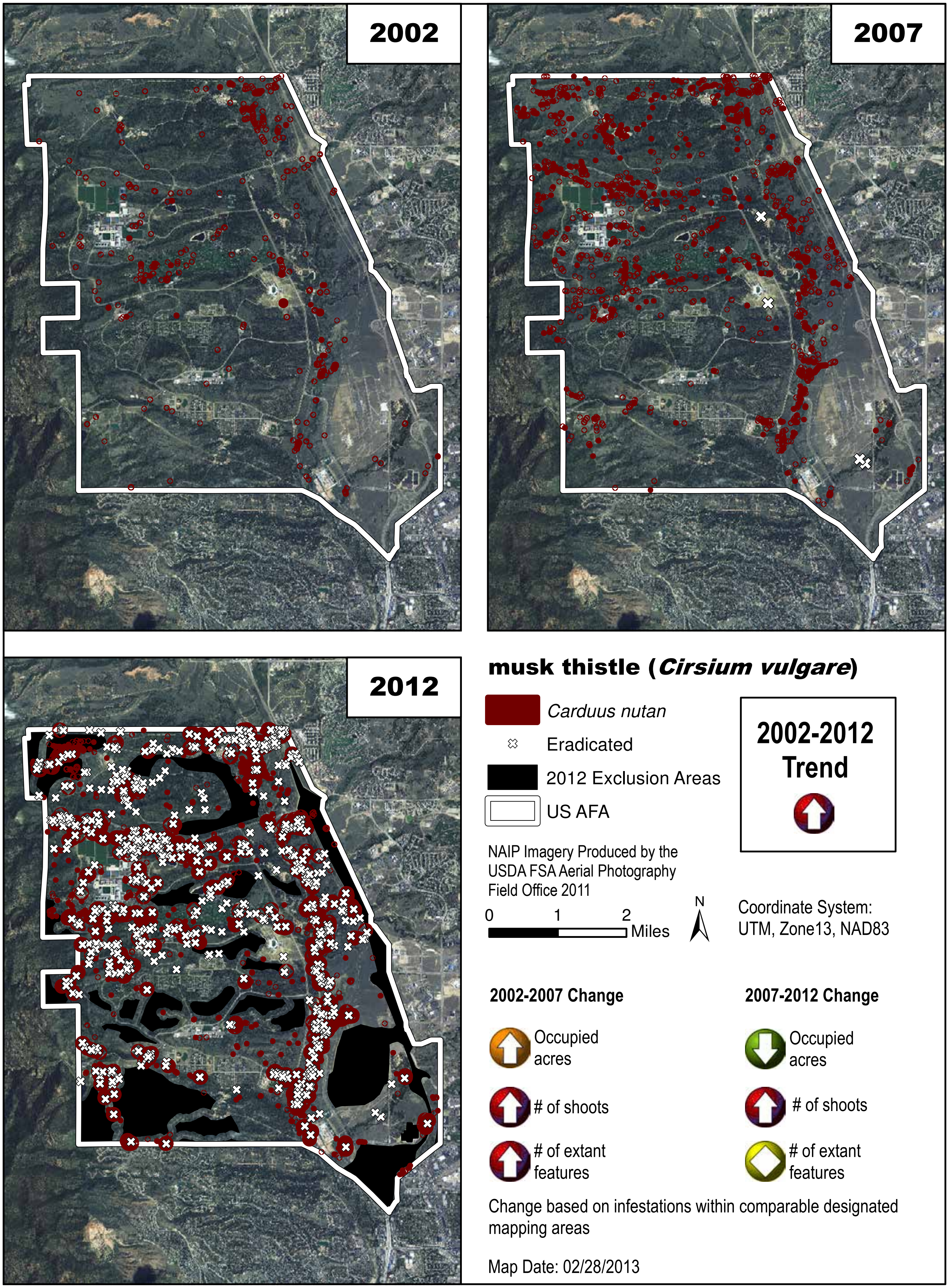
Recommendations for musk thistle include continuation of herbicide treatment of large infestations, especially near biologically important areas, and manual destruction of plants in smaller infestations and all inflorescences should be bagged if they contain ripe seed. All 10 plots should be revisited in 2014 and all treated areas should be mapped.

Table 4. Musk thistle population size at photo plots, 2008-2013. Bolded numbers were treated plots.

Plot	2008	2009	2010	2011	2013
1	11	134	**9**	**7**	**7**
2	**6**	80	**5**	**160**	0
3	**1**	**2**	**1***	**8**	1
4	1	63	**0**	**0**	0
5	1	27	**10***	0	6
6	**10**	45	**33**	3	2
7	**102**	**90**	**25**	**0**	**5**
8	212	**31**	**10**	**7**	7
9	160	**1**	**1**	**0**	0
10	500	Not visited	**40+**	400	**28**
SUM	1004	473	123	585	56
Mar-June precip, inches (departure from average)	-4.28	0.78	-3.52	-4.25	-4.24



Map 7. 2013 musk thistle plots at the Academy.



Map 8. Distribution of musk thistle at the Academy in 2002, 2007, and 2012.

Diffuse and Spotted Knapweeds (Centaurea diffusa, Centaurea maculosa and hybrid)

In 2013, knapweed significantly decreased in frequency, density, and cover, regardless of treatment type. The most significant decrease was in the DKrailroad plot, a biocontrol plot.

Photo by Michelle Washebek

Species	Sampling Methods
Diffuse knapweed	10 non-biocontrol plots established in 2012; 2 biocontrol plots established in 2011 (Michels et al. 2013). Map 9.

Diffuse and Spotted knapweeds have been hybridizing over the last few years and nearly all monitoring sites have a hybrid swarm, therefore we have combined all the spotted and diffuse knapweed plots into “knapweeds”. In 2013 we collected plot data from July 15-17. The following description and data are from the 2012-2013 monitoring plots (Map 9).

Frequency: Eight knapweed plots were untreated in both 2012 and 2013 yet the average frequency (number of quadrats/plot with knapweed present) significantly declined from an average of 9 quadrats/plot (15%) to 4 quadrats/plot (8% (P=0.09, t-test, paired two sample, 2-tailed)). Five of the eight plots experienced a decline while three of the eight plots were stable or increased (Table 5 and Fig. 3). In other words, knapweed distribution within a plot decreased between 2012 and 2013 even though they were not treated. There were four knapweed plots that were treated with either herbicide or biocontrol of which three declined in frequency and one increased (Table 5 and Fig. 3). The average frequency of treated plots was 16 quadrats/plot in 2012 and declining to 8 quadrats/plot in 2013 (P=0.16, t-test, paired two sample, one-tailed). One of the biocontrol plots, DKrailroad decreased, while the other biocontrol plot, KWmonck increased. Both of the herbicide treated plots (CEDI3-1 and CEDI3-2 decreased (Table 5 and Fig. 3).

Density: The mean density in the untreated plots declined from 0.8 shoots/quadrat to 0.4 shoots/quadrat between 2012 and 2013, respectively (P=0.12, t-test, paired sample, two-tailed). As with the frequency measure, knapweed declined even though there was no treatment. Five of the eight plots decreased, while three of the plots were either stable or increased). For the treated plots the density also declined from an average of 1.1 shoots/quadrat to 0.4 shoots/quadrat between 2012 and 2013, respectively (P=0.14, t-test, paired sample, one-tailed). Three of the four plots decreased while one of the plots remained stable (Table 5 and Fig. 3).

Cover: The mean cover in untreated plots dropped from 2.1% to 0.8% between 2012 and 2013, respectively (P=0.06, t-test, paired two sample, two-tailed). Six out of the eight plots experienced a decline in cover while two plots were either stable or had a slight increase (Table 5 and Fig. 3). The mean cover in treated plots dropped from 6.2% to 1.3% between 2012 and 2013, respectively (P=0.11, t-test, paired two sample, one-tailed). All of the treated plots experienced a decrease in cover (Table 5 and Fig. 3).

Summary and Discussion: Knapweeds, regardless of treatment, experienced a decrease in frequency, density, and cover, most likely due to the drought. (All of the 2013 plots were measured before the drought broke). Additional years for both the treated and untreated plots should help tease apart the effectiveness of treatment. TAMU established a new biocontrol plot, DKhighway in 2013; not shown in this report. Therefore, in 2014 we will have 5 treated plots. If we were to randomly choose one of the non-treated plots and treat it with herbicide we would have a more balanced design that could help detect efficacies in treating knapweed. Another option would be to randomly treat two of the non-treated plots and establish a new untreated plot, which would balance it out so that we would have 7 treated and 7 non-treated (preferred).

Although 2013 plot data trends were downward it is worth noting that in 2012 we conducted weed mapping of diffuse knapweed (Map 10) and the number of extant mapped areas increased 37% from 2007-2012 (Lavender-Greenwell and Rondeau 2013).

Table 5. Diffuse and spotted knapweed summary of permanent plots, 2012-2013. *Herbicide Treatment in 2012; **Biocontrol treatment in 2012 and 2013.

Plot Name	Frequency 2012	Frequency 2013	Avg Density 2012	Avg Density 2013	Avg Cover (%) 2012	Avg Cover (%) 2013	Quadrats with plants (%) 2012	Quadrats with plants (%) 2013
Not Treated								
CEDI3-3	8	4	0.2	0.3	1.4	0.5	0.14	0.07
CEDI3-4	4	8	0.1	0.4	1.3	1.6	0.11	0.21
CEDI3-5	9	9	0.7	0.6	3.3	2.3	0.14	0.15
CEMA4-1	14	4	1.6	0.1	1.7	0.3	0.23	0.07
CEMA4-2	17	0	1.5	0.0	2.2	0.0	0.27	0.00
CEMA4-3	2	1	0.1	0.0	0.1	0.0	0.03	0.02
CEMA4-4	14	4	2.2	1.3	6.2	1.3	0.26	0.08
CEMA4-5	1	1	0.2	0.2	0.6	0.6	0.02	0.02
Avg	**9**	**4**	**0.8**	**0.4**	**2**	**1**	**0.15**	**0.08**
SD	**6.0**	**3.3**	**0.8**	**0.4**	**1.9**	**0.8**	**0.10**	**0.07**
Treated								
CEDI3-1*	5	0	0.1	0.0	0.3	0.0	0.09	0.00
CEDI3-2*	13	2	0.8	0.3	2.7	0.1	0.21	0.03
KWmonck**	10	18	1.0	1.0	5.9	3.5	0.24	0.43
DKrailroad**	34	13	2.7	0.4	16.0	1.7	0.56	0.21
Avg	**16**	**8**	**1**	**0**	**6**	**1**	**0.27**	**0.17**
SD	**12.8**	**8.7**	**1.1**	**0.4**	**6.9**	**1.7**	**0.2**	**0.20**

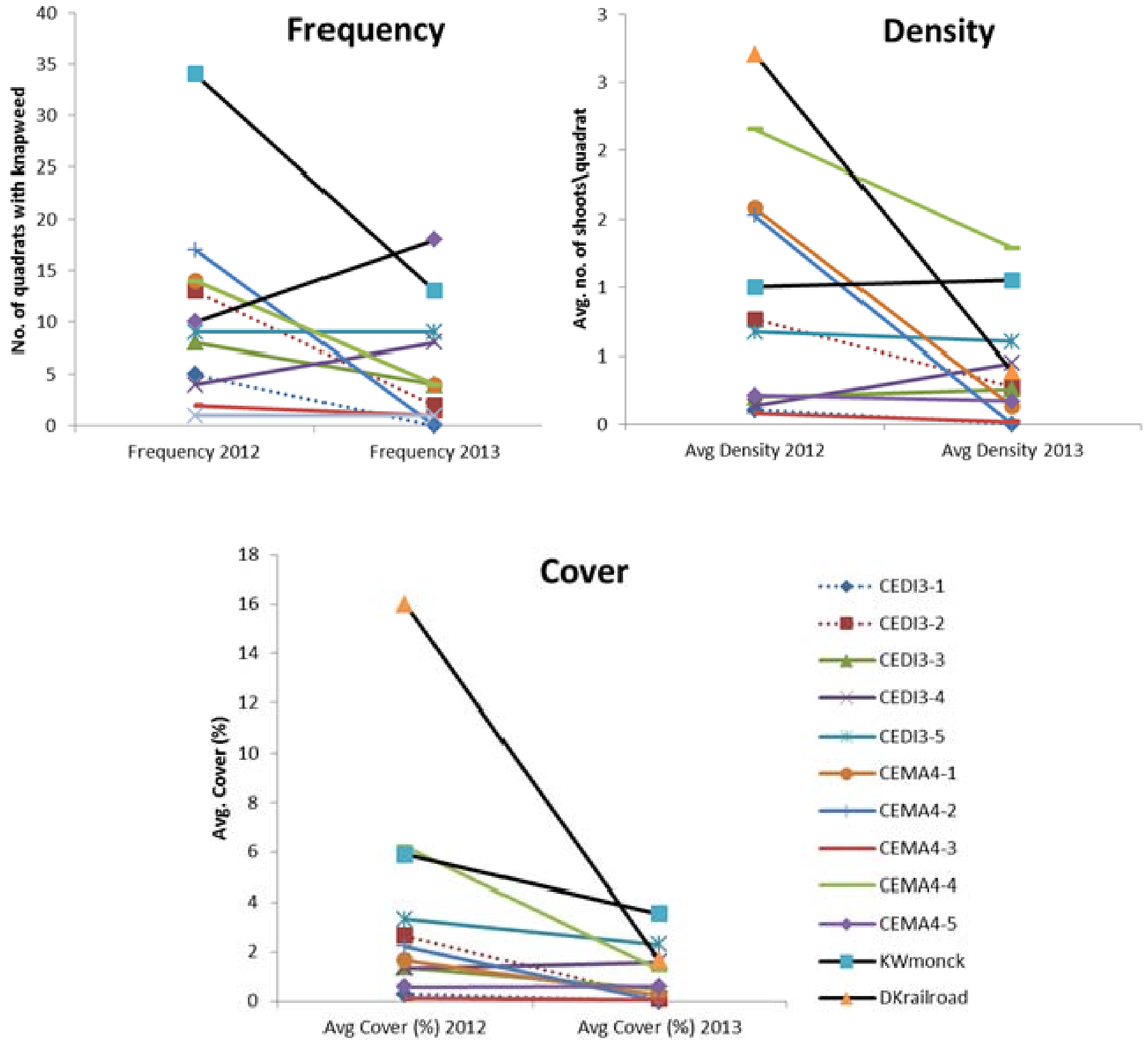
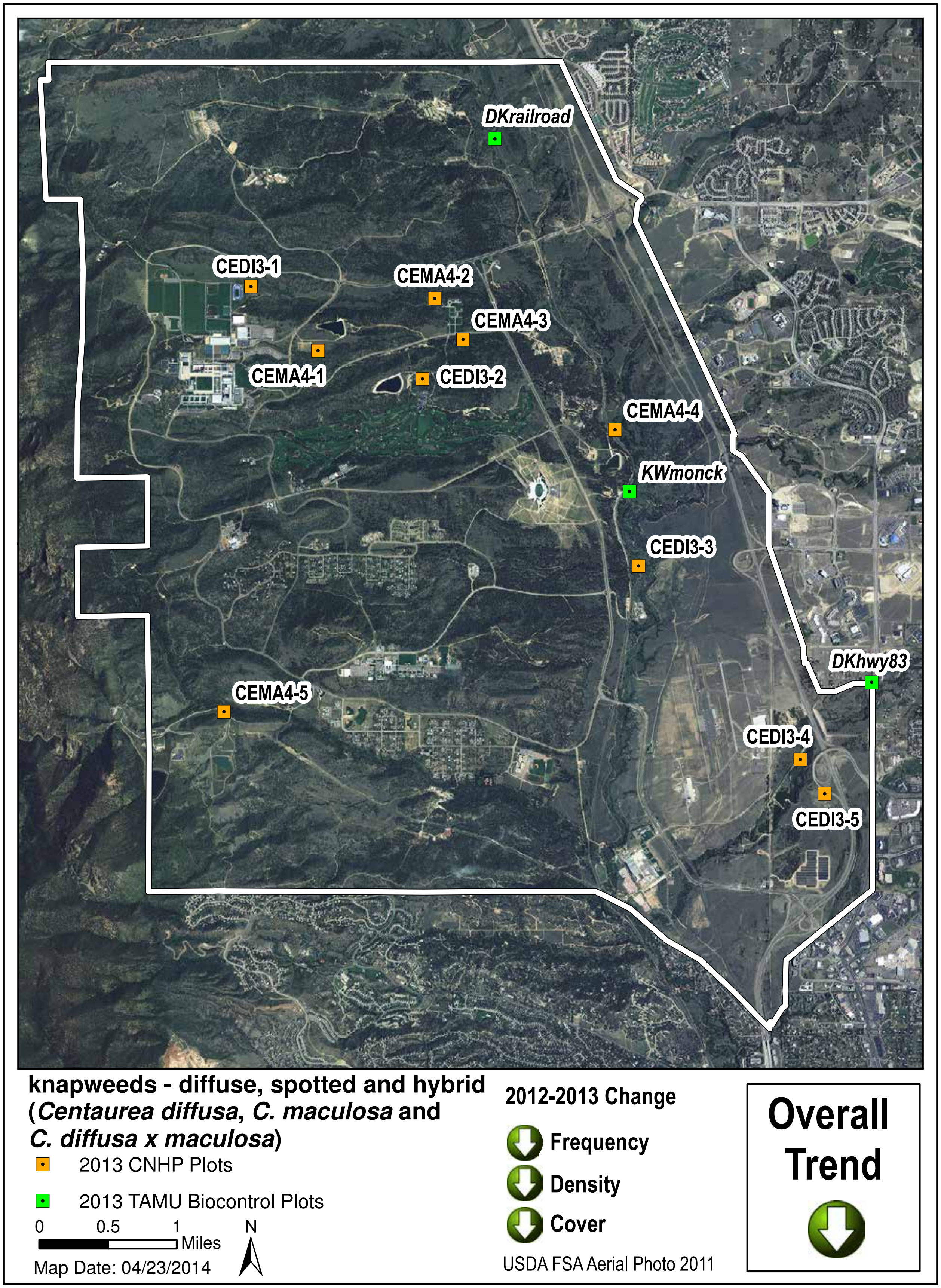
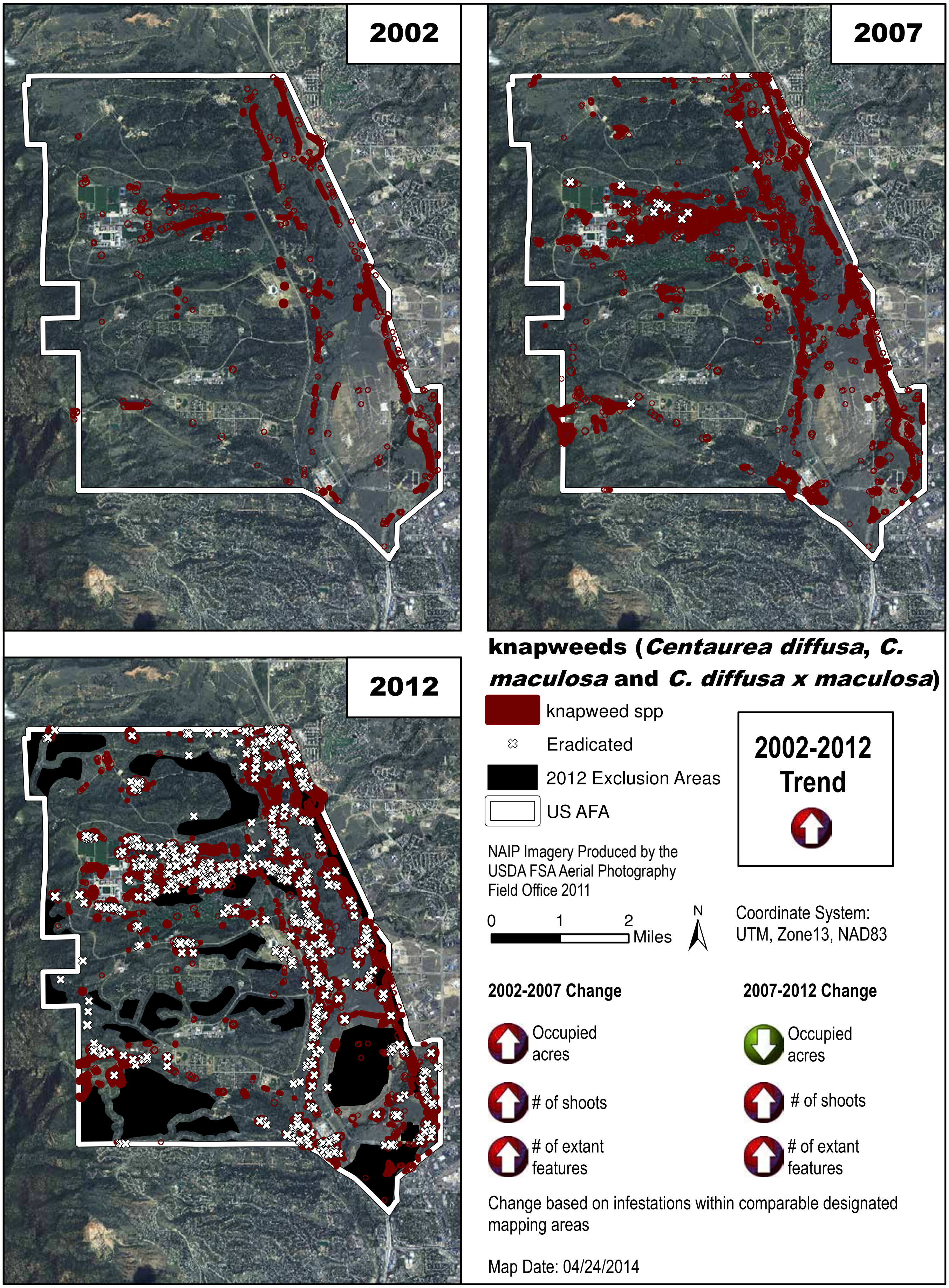


Figure 3. Diffuse and spotted knapweed trend, 2012-2013. Knapweed density, frequency, and cover declined in 2013, regardless of treatment type. The solid black lines and dashed lines represent treated plots; all other lines represent non-treated plots.



Map 9. 2013 knapweed (diffuse, spotted and hybrid) plots at the Academy.



Map 10. Distribution of knapweeds (diffuse, spotted and hybrid) at the Academy in 2002, 2007, and 2012.

Canada Thistle (*Cirsium arvense*)

Continues to spread and invade wet areas. Biocontrol may be the best solution, but so far insects are not widespread.

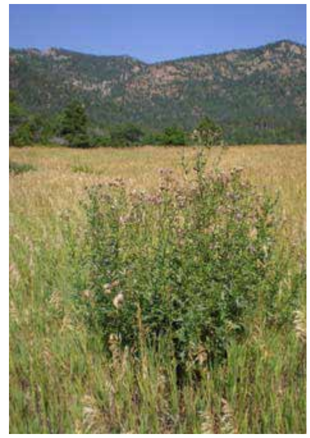


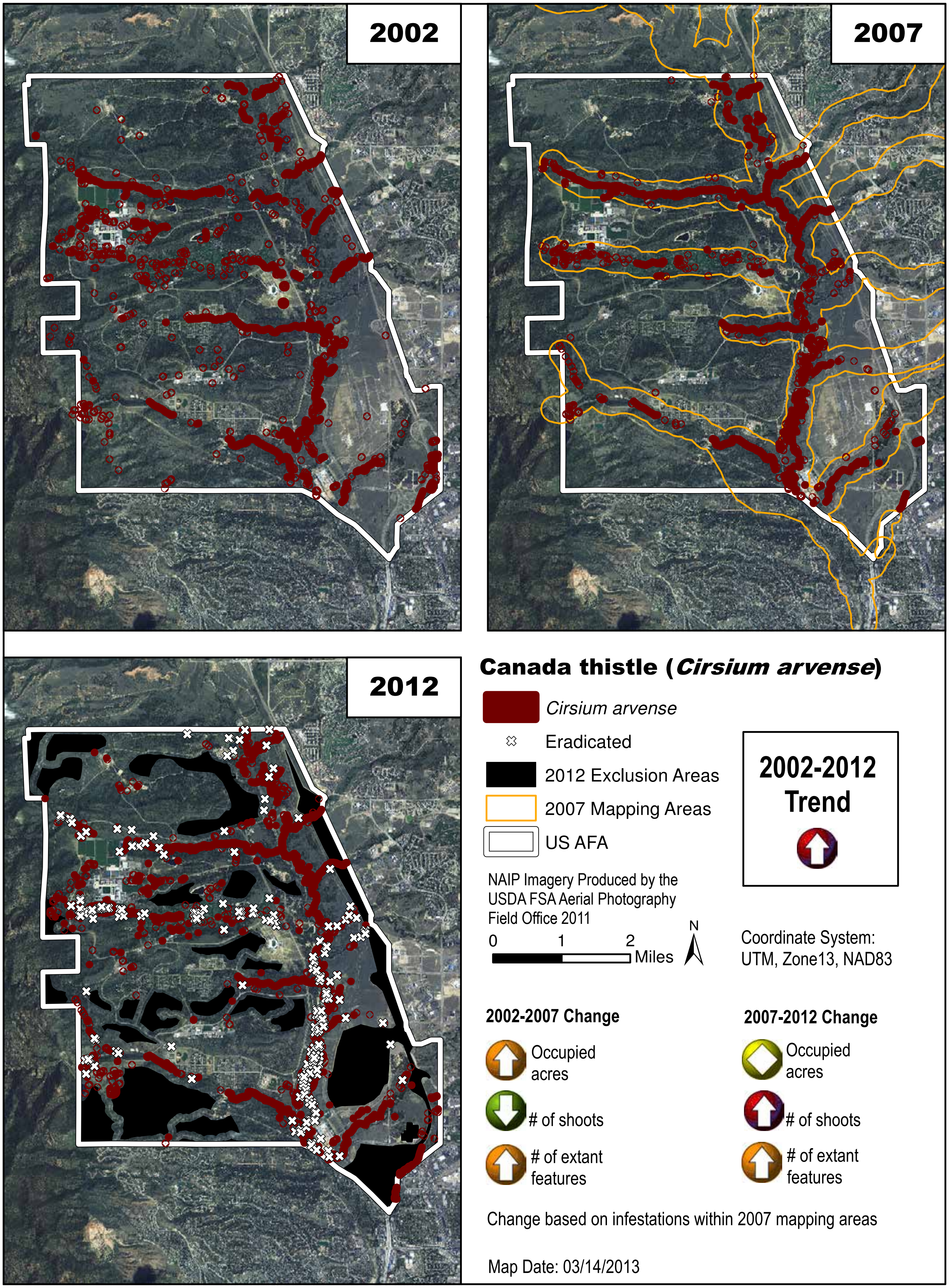
Photo by Michelle Washebek

	Sampling Methods	Plots
Canada thistle	Transect/ quadrats	8 plots—untreated 4 plots--biocontrol

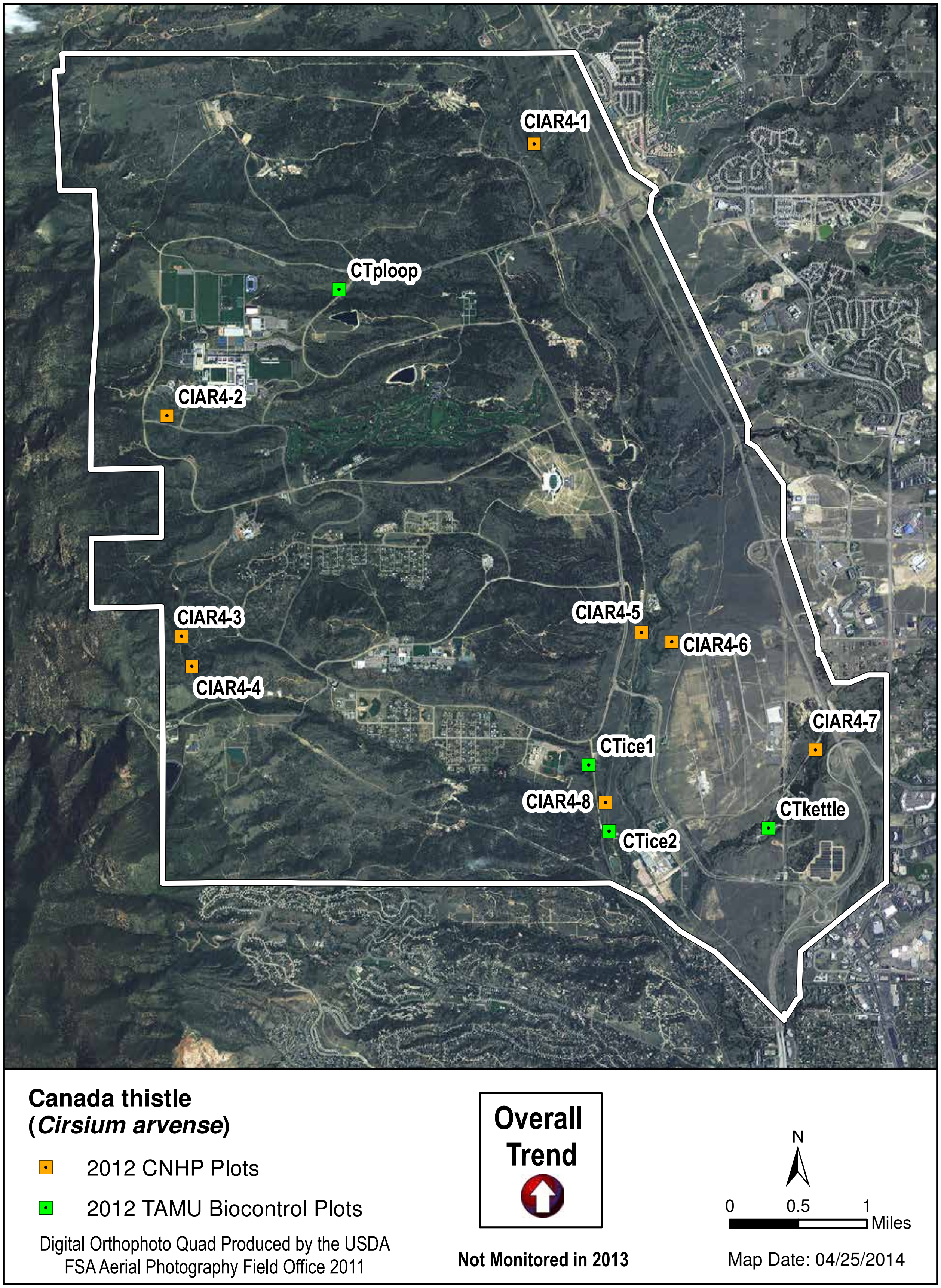
In 2012, we established 8 permanent plots and Michels et al. (2013) collected data from four established plots (Map 12). Table 6 summarizes the plot data; Map 11 depicts weed distribution at the Academy. We did not revisit any of these plots in 2013. In addition to establishing permanent plots, we mapped Canada thistle during the weed mapping project (Lavender-Greenwell and Rondeau 2013). It was the second most numerous weed mapped in our 2012 mapping project, occupying nearly 90 acres, which is 30% of all weed acres and second only to knapweeds. Each of the weed sampling years saw an increase in the estimated number of shoots and extant mapped features.

Table 6. Canada thistle summary of permanent plot data, 2012.

Plot Number	Date	Frequency	No_Quadrats	Ave_Density	Average Percent Cover	Average Height	% quadrats with plant
CIAR4-1	8/22/2012	13	62	1	2	10	21%
CIAR4-2	7/18/2012	4	40	1	2	5	10%
CIAR4-3	7/25/2012	13	52	0	2	12	25%
CIAR4-4	7/24/2012	6	48	0	1	4	13%
CIAR4-5	8/21/2012	22	52	2	7	15	42%
CIAR4-6	8/15/2012	41	62	4	14	36	66%
CIAR4-7	8/22/2012	6	38	0	1	5	16%
CIAR4-8	7/25/2012	12	62	1	3	8	19%
Average		**15**	**52**	**1**	**4**	**12**	**27%**
SD		**12**	**10**	**1**	**4**	**10**	**19%**
Biocontrol							
CTice1	7/19/2012	22	38	2	7	23	58%
CTice2	6/21/2012	15	15	9	26	47	100%
CTkettle	6/21/2012	14	58	1	2	5	24%
CTploop	7/12/2012	15	29	3	8	16	52%
Average		**17**	**35**	**4**	**11**	**23**	**47%**
SD		**4**	**18**	**4**	**11**	**18**	**31%**

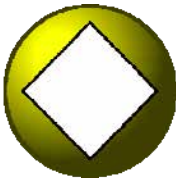


Map 11. Distribution of Canada thistle at the Academy in 2002, 2007, and 2012.



Map 12. 2012 Canada thistle plots at the Academy.

Houndstongue (*Cynoglossum officinale*)



Increasing but aggressive management is controlling this species. Eradication is still possible especially if plants are killed prior to seeding.

Photo by M. DiTomaso, University of California - Davis

Houndstongue was treated with herbicide and manual pulling at all known sites since the first population was discovered in 2009. In 2010 and 2011 there was a notable decrease in the number of acres occupied. However, the plants did reproduce from seeds and the number of individuals were high in 2012 and 2013 (Table 7, Fig. 4, and Map 13). In 2012, a new site was located south of the existing known sites and the number of individuals also increased. In 2013 no new sites were found and all sites were treated however this species is persistent and plants survived pulling and herbicide treatment.

This species is still at a level where eradication is possible. Houndstongue is a short lived perennial or biennial forb. It produces rosettes in the first year, and bolts a stout, erect stem that is 1-4 feet tall. Reproduction is solely by seeds. Seeds are 4 prickly teardrop-shaped nutlets. Most seeds fall close to the parent plant, but can travel great distances due to the Velcro-like barbs that clings to animals, clothing and machinery. A mature plant can produce 2,000 seeds and each seed is viable for 1 to 3 years (Colorado Department of Agriculture 2013). **The key to effective control is preventing seed production**. Chemical and mechanical control should be used on all of the AFA occurrences followed by annual monitoring of all sites.

Table 7. Houndstongue summary data, 2009-2013.

	Occupied Area (m^2)	Number of Individuals	Number of Extant Mapped Features
2009	378	95	8
2010	78	11	1
2011	10	21	2
2012	40	70	3
2013	218	48	7

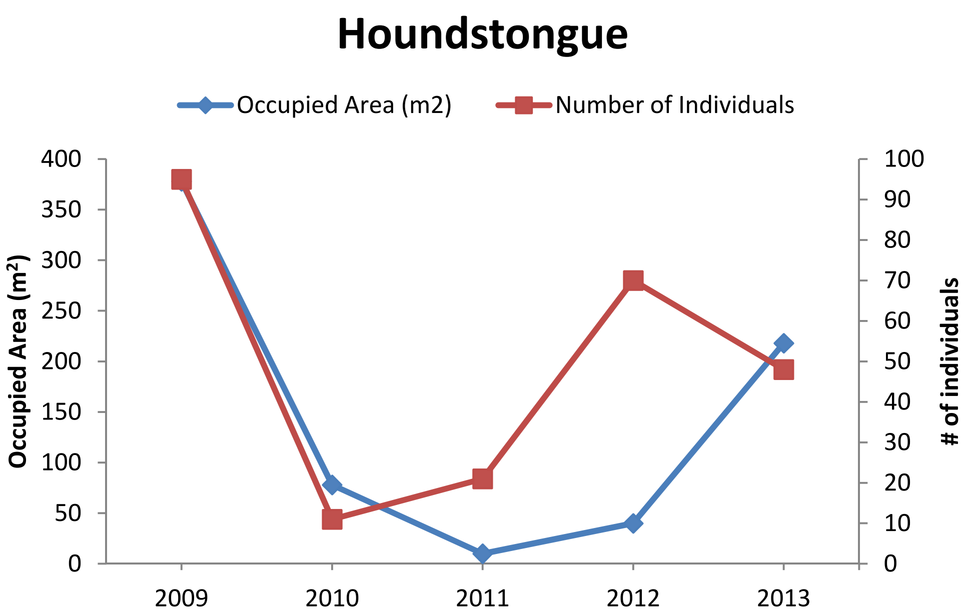
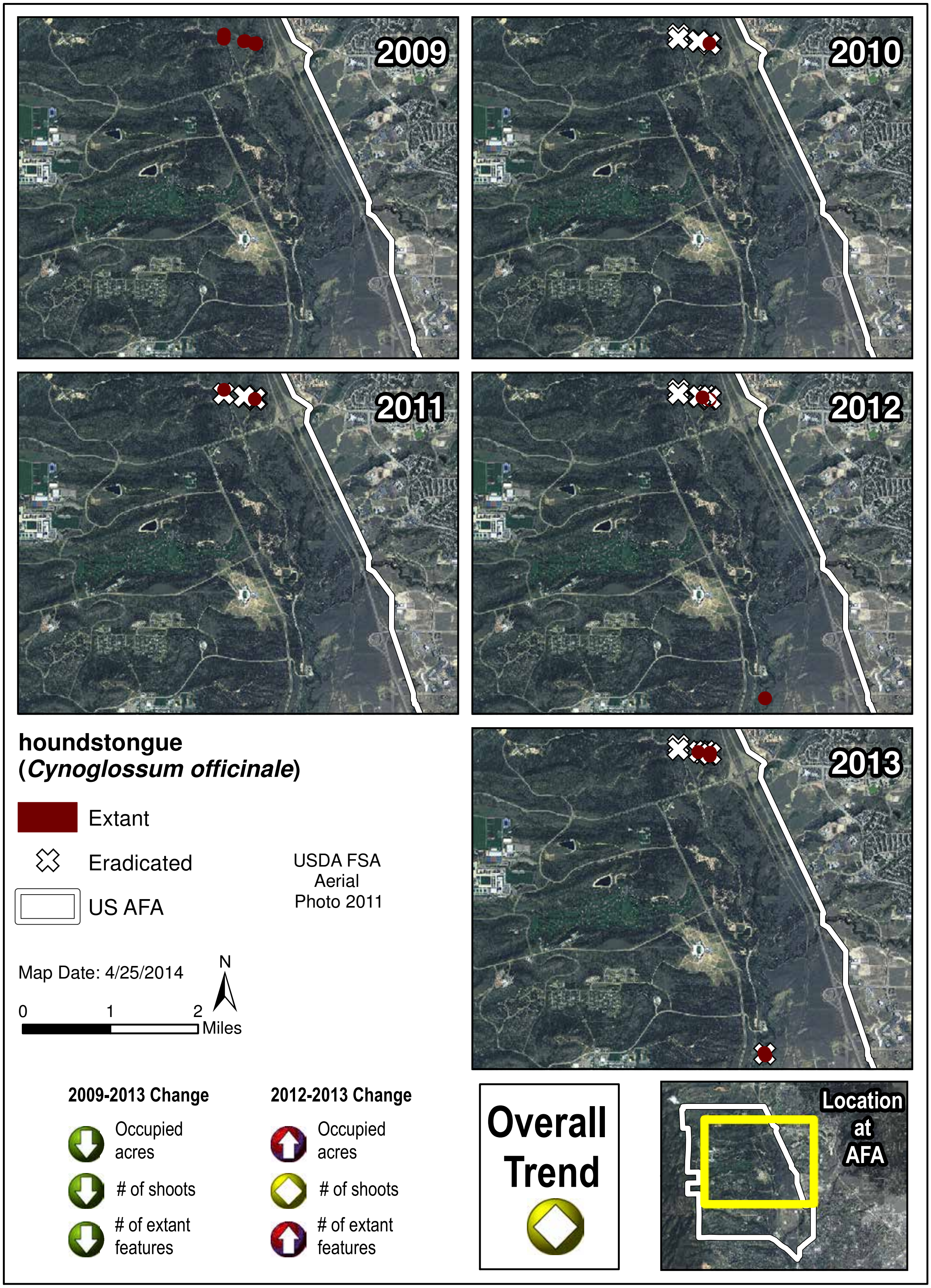


Figure 4. Houndstongue trend, 2009-2013.



Map 13. Distribution of houndstongue at the Academy between 2009 and 2013.

Leafy Spurge *(Euphorbia esula)*

Increasing and spreading south. Focus on outlier populations as eradication is not likely feasible.

Species	Sampling Methods
Leafy spurge	Mapping 2002, 2007, 2012 10 monitoring plots

Photo by Michelle Washebek

We established 10 permanent plots in 2012 (Map 14). Michels et al. (2013) terminated their biocontrol efforts of this species and herbicide treatment became the primary control measure. The 2013 plot data was collected June 8-27. Table 8 summarizes the permanent plot information. In addition to establishing the permanent plots, we mapped this species during the weed mapping project (Lavender-Greenwell and Rondeau 2013). In summary, leafy spurge occupied 11 acres in 2012, an increase of 3 acres since 2007; and the number of extant mapped areas increased by 34% in the same time period, with over a dozen new populations mapped in the southeastern portion of the Academy (Map 15). The following information summarizes the plot data.

Frequency: There was no significant difference in overall leafy spurge frequency (a measure of occupancy or distribution) between 2012 and 2013 within the treated plots (19% and 17% respectively); three plots had a decrease and 5 plots had an increase (Table 8, Fig. 5). Regardless of the lack of statistical significance, plots EUES-2 and EUES-9 were notable in that they had large declines in frequency between 2012 and 2013. In 2012, EUES-2 had leafy spurge present in 25 quadrats (40% of all quadrats) and by 2013 only 2 quadrats (3%) had leafy spurge. This plot was sprayed with Chaparral after we collected data in 2012 and the herbicide treatment had a significant impact to all of the forbs (Fig 6), including leafy spurge. This site was previously disturbed and is in an early seral stage. EUES-9 decreased in frequency from 21 quadrats (32%) in 2012 to 10 quadrats (21%) in 2013. This plot was also treated with herbicide in 2012. EUES- 3 had a slight decrease; otherwise all other plots stayed the same or increased in 2013, including the two plots that were reportedly not treated (Table 8 and Fig. 5).

Average Density: Density significantly decreased between 2012 and 2013 in the treated plots, declining from an average of 2.6 to 1.5 plants/quadrat (P=0.08, one-tailed paired t-test for treated plots). EUES-2 had the largest change declining from an average of 6 plants/quadrat to 0.03 plants/quadrat (Table 8 and Fig 5). EUES-9 had the next greatest decline dropping from 3.5 plants/quadrat to 2 plants/quadrat (Table 8 and Fig. 5).

Average Cover: Cover remained low in 2013, regardless of treatment type with the average of treated plots slightly dropping from 1.9% in 2012 to 1.7% in 2013. (Detecting an increase will be easier than detecting significant decreases due to the low cover). There was no significant difference in cover between years within the plots that were treated (P=0.3; paired two sample t-test, one-tailed), however EUES-2 was a notable exception as it went from 4% cover in 2012 to 0.1% cover in 2013. EUES-8 (treated) increased from 2.1% in 2012 to 3.5% in 2013, in spite of the fact that it was supposedly treated with herbicide in 2012. The two non-treated plots had mixed results with one plot decreasing in cover and one plot increasing in cover, however neither one of these plots had very much leafy spurge to begin with (Table 8 and Fig. 5).

Summary and Discussion: Data collection in 2012 and 2013 occurred in June during drought conditions which most likely depressed growth. The herbicide treatment at EUES-2 was quite effective; however, there was photographic evidence that the treatment impacted more than just leafy spurge. We did not observe any negative impact to non-target forbs in EUES-9. The 2012 treatment map is a course representation of treatment areas and therefore our confidence in treatment type is low. This may account for why some of the plots classified as “treated” increased or had little change in the measured variables. It would be beneficial to have more precise treatment data, including actual area sprayed, date sprayed, and herbicide type and concentration.

Table 8. Leafy spurge summary of permanent plot data, 2012-2013.

Plot Name	Treatment 2012	Treatment 2013	Avg Density 2012	Avg Density 2013	Avg Cover (%) 2012	Avg Cover (%) 2013	Quadrats with plants (%) 2012	Quadrats with plants (%) 2013
EUES-1	Yes	none	2.0	2.2	1.9	2.0	0.29	0.35
EUES-2	Yes	none	5.6	0.0	4.1	0.1	0.40	0.03
EUES-3	Yes	none	0.8	0.6	1.1	0.4	0.25	0.15
EUES-4	Yes	none	1.3	1.4	1.3	1.3	0.27	0.36
EUES-5	Yes	none	2.8	1.8	0.8	2.3	0.31	0.32
EUES-6	Yes	none	2.4	1.9	2.0	2.3	0.35	0.42
EUES-8	Yes	none	2.0	2.1	2.1	3.5	0.27	0.32
EUES-9	Yes	none	3.6	1.9	2.1	1.4	0.43	0.21
EUES-10	none	none	2.2	1.1	1.1	0.5	0.18	0.18
EUES-7	none	none	0.2	0.4	0.2	0.7	0.11	0.13

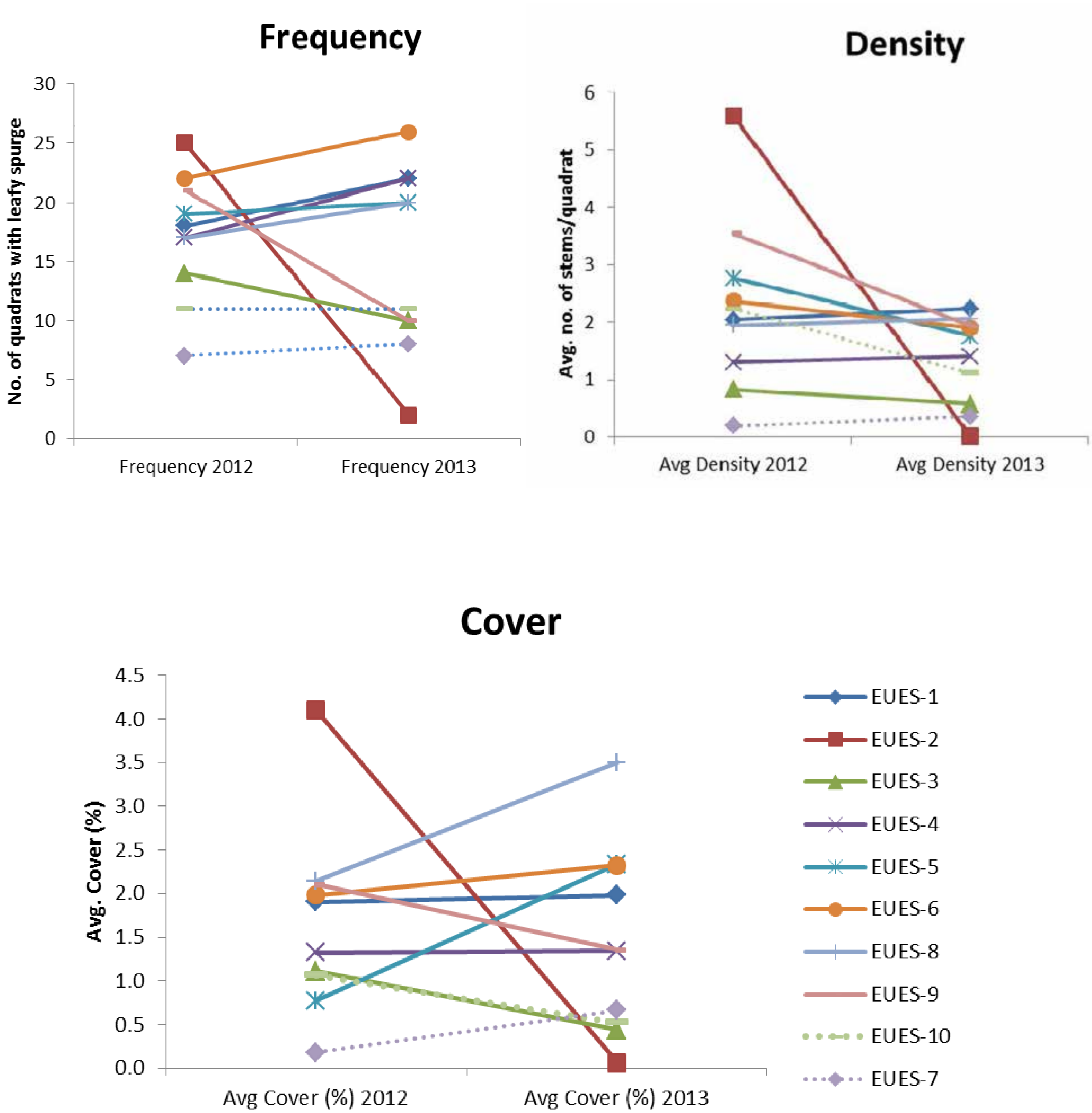
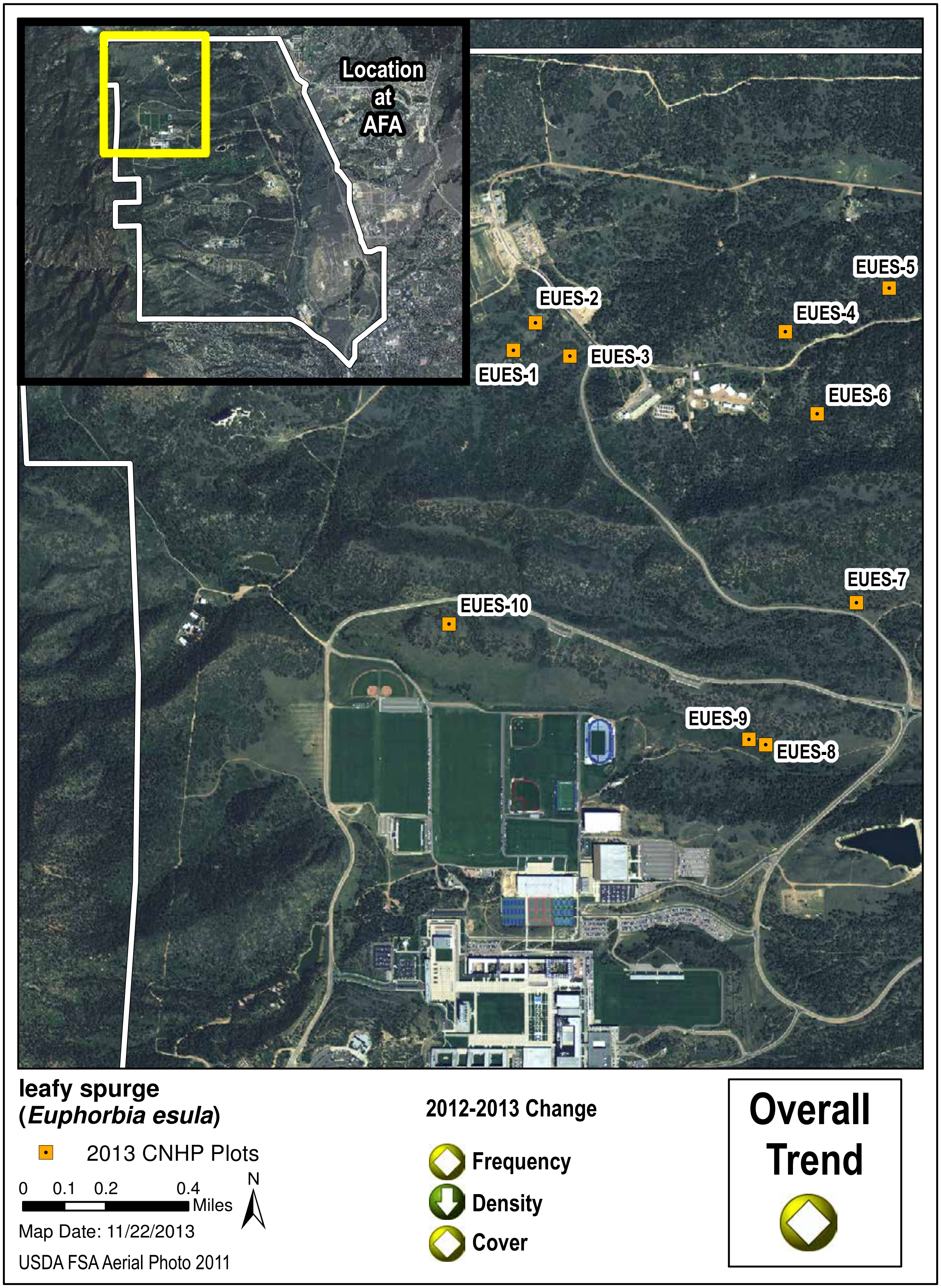
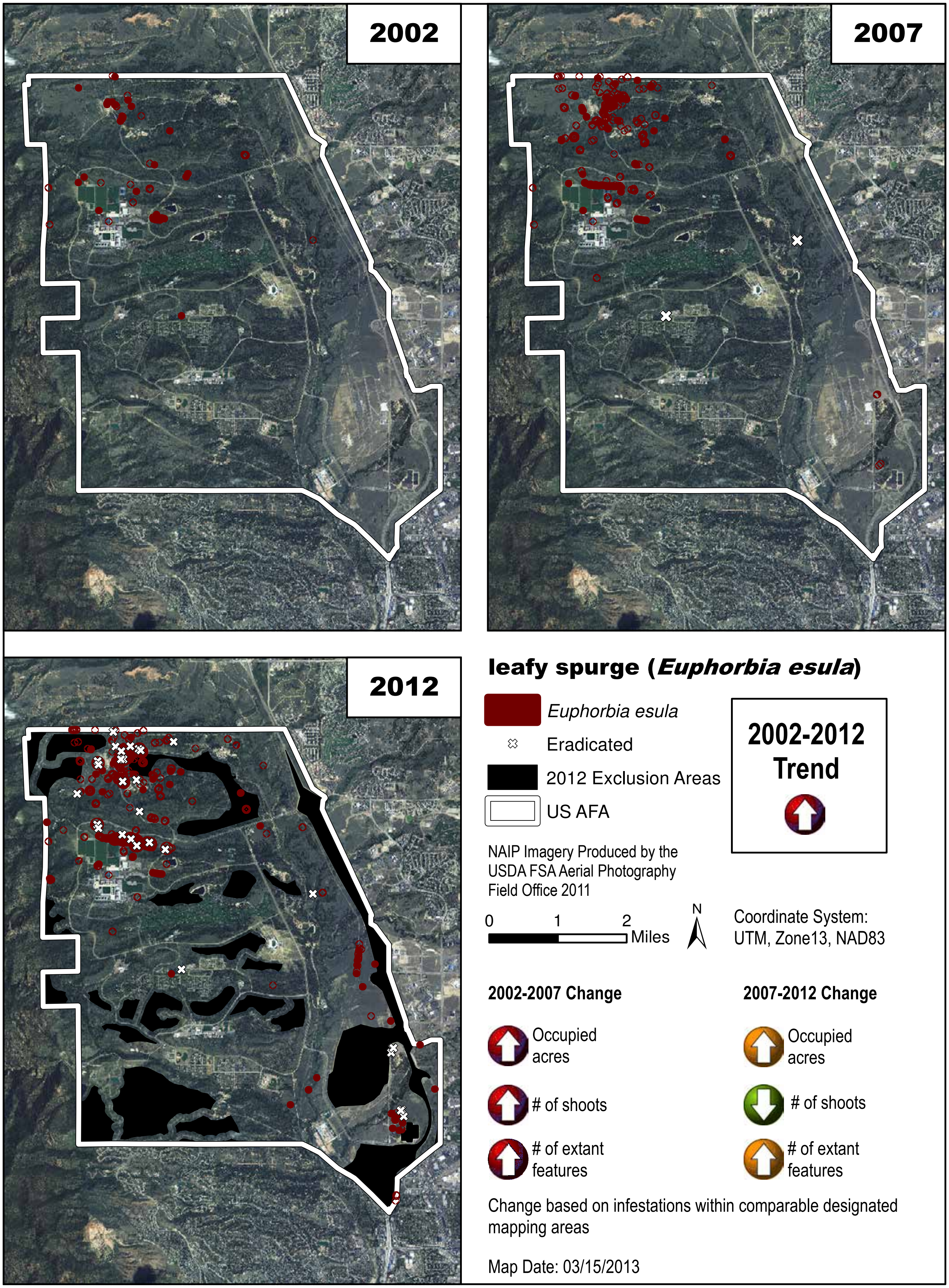


Figure 5. Leafy spurge frequency, density, and cover 2012-2013. Dashed lines represent untreated plots; solid lines represent treated plots. The overall density in treated plots significantly declined (P=0.08), yet the frequency and cover was not significantly different.

Figure 6. Repeat photos of EUES-2, 2012-2013. Top photo taken 06/05/2012 and bottom photo taken 06/10/2013. Herbicide was sprayed after the 2012 photo was taken. The brown vegetation in the bottom photo is mostly dead leafy spurge.



Map 14. 2013 leafy spurge plots at the Academy.



Map 15. Distribution of leafy spurge at the Academy in 2002, 2007, and 2012.

Myrtle Spurge (*Euphorbia myrsinites*)

Number of individuals and locations increased but occupied area remained stable. Eradication is unlikely but possible. Monitoring is essential.

Photo by David Anderson

Species	Sampling Methods
Myrtle spurge	mapping/ census

Myrtle spurge is on the state 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 in 2005, at an early stage of its invasion, and some progress is being made towards its eradication yet this species continues to spread (Table 9, Figure 7, Map 16). The total area infested by myrtle spurge at the Academy in 2013 was not measured however there was a total of 129 individuals at 19 locations; this was slightly higher than 2012. The number of known extant locations significantly increased from 10 to 19, indicating that control methods are moderately effective. The number of individual's slightly increased from 113 to 129, continuing the upward trend over the last 4 years, however much below the high number of approximately 1,000 individuals in 2007 (Table 9, Figure 7).

AFA's efforts at controlling this species have been considerable yet eradication appears to be unlikely. Due diligence at each site is warranted as well as continued monitoring.

Table 9. Myrtle spurge summary data, 2005-2012.

	Occupied Area (acres)	Number of Individuals	Number of Extant Mapped Features
2005	?	25	7
2006	?	243	10
2007	0.18	1021	7
2008	0.66	419	13
2009	2.4	464	12
2010	0.5	56	10
2011	0.25	57	12
2012	0.23	113	10
2013	?	129	19

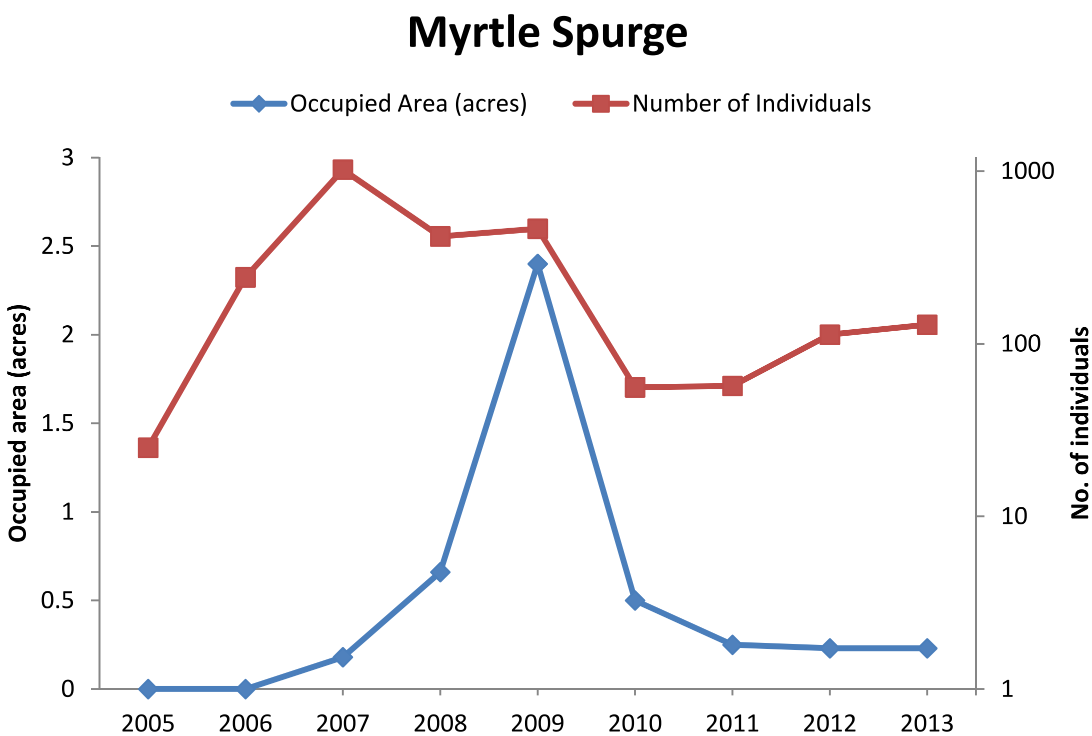
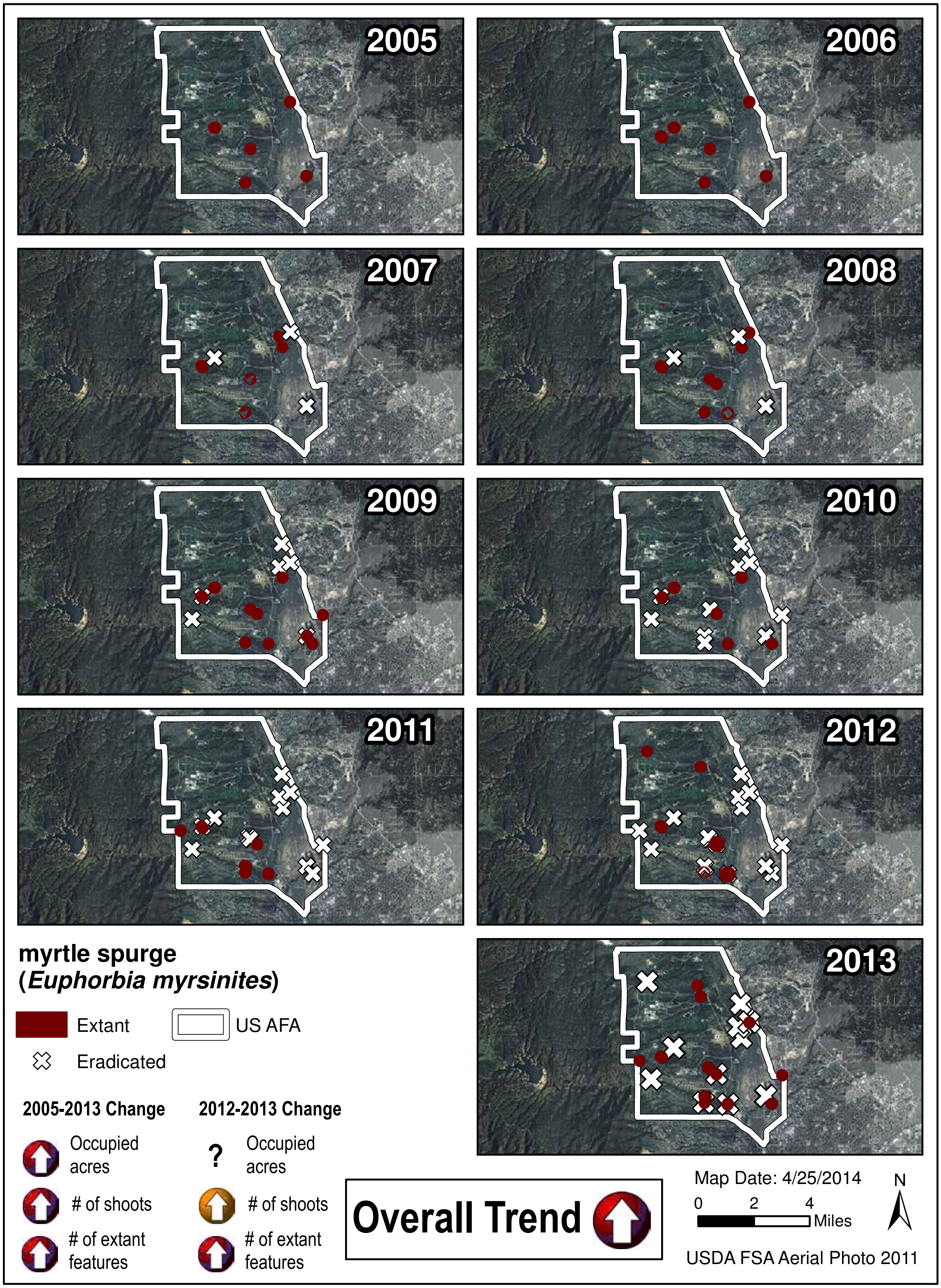
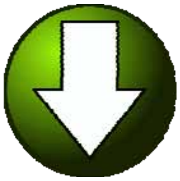


Figure 7. Myrtle spurge trend, 2005-2013.



Map 16. Distribution of myrtle spurge at the Academy between 2005 and 2013.

Yellow Spring Bedstraw (*Gallium verum*)



SUCCESS. No plants have been observed during the last two years.

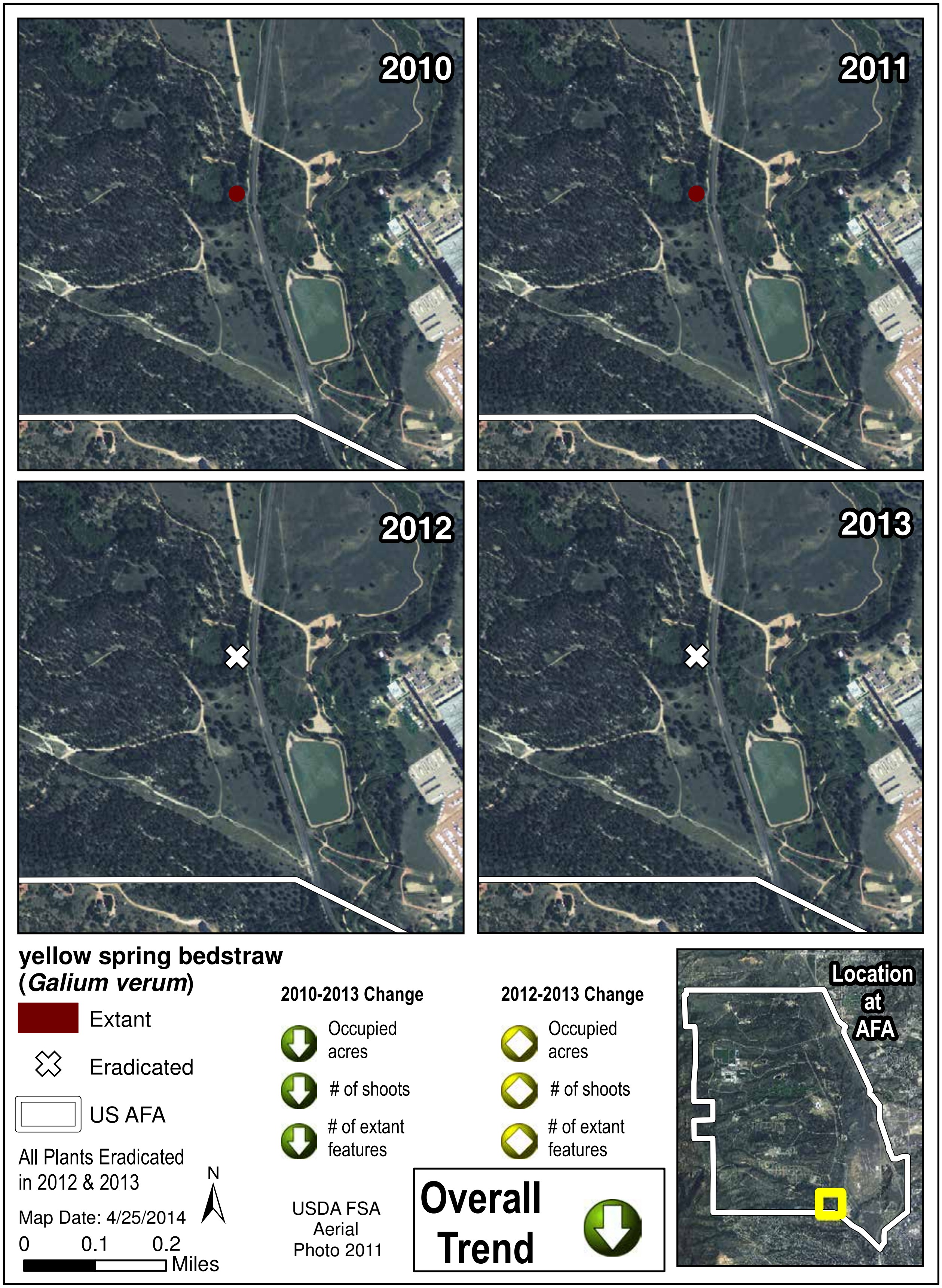
Wikipedia photo

This species was discovered at the Academy in 2010 with one occurrence found near Ice Lake (Table 10, Map 17). The occurrence consisted of 700 individuals in 28 m^2 (0.01 acres). The AFA immediately eradicated it; however, this species can be very aggressive and warrants multiple visits and rapid responses. We visited this site in 2011 and located and pulled one individual. The 2012 mapping project misidentified two additional sites while the original site was still free of this weed. No plants were observed in 2013. A high priority should be placed on eradicating any new sites and revisiting the original site.

At Farish, it was determined that one point mapped in 2012 was misidentified. This was confirmed by Natural Resources staff in 2013.

Table 10. Yellow spring bedstraw summary data, 2010-2013.

	Occupied Area (m^2)	Number of Individuals	Number of Mapped Features
2010	28	700	1
2011	0	1	1
2012	0	0	0
2013	0	0	0



Map 17. Distribution of yellow spring bedstraw at the Academy between 2010 and 2013.

Dames Rocket (*Hesperis matronalis*)

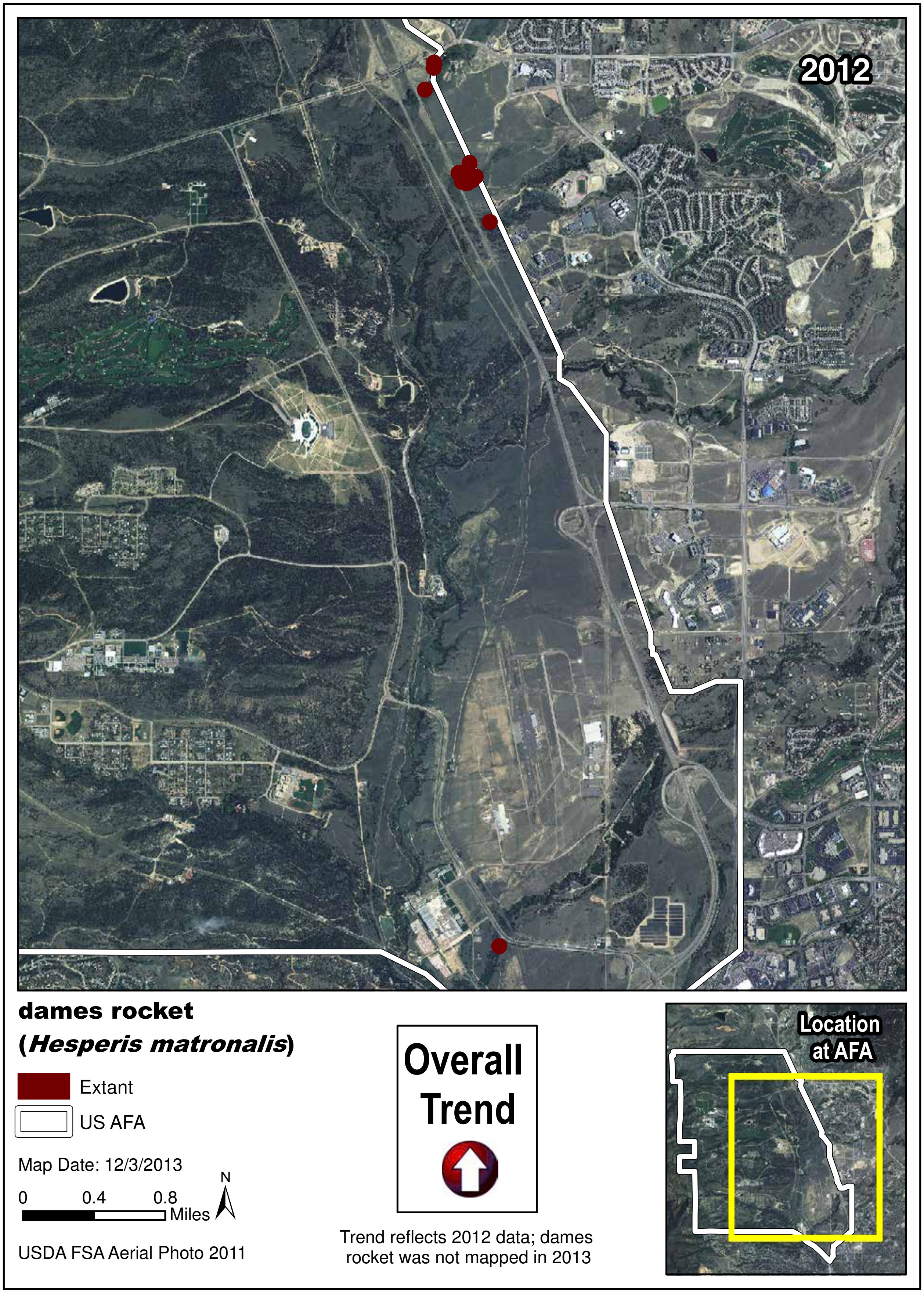
Newly discovered in 2012. Eradication is possible. Note outlier population in the south.

Photo by Brian Mihlbachler

Dames rocket was first mapped at the Academy during the 2012 mapping project (Lavender-Greenwell and Rondeau 2013) and occupied 0.18 acres with 16,871 shoots in 14 distinct locations (Map 18). Most of these occurrences are very close to I-25. Eradication should be possible and therefore this species is a high priority for control. We were not able to monitor this species in 2013 nor did the Natural Resources department spend any effort on managing however we should add this to our 2014 monitoring list.

This species is a hardy perennial escaped horticulture plant, native to Europe. It is a prolific seed-producer. First year plants develop into a low rosette and stay green all winter. By early spring, they send up an erect, 2-4 foot tall flower stem. Each plant is capable of producing hundreds of seedpods, each with abundant seeds. Seeds remain viable in the soil for many years (http://www.na.fs.fed.us/spfo/invasiveplants/). Preferred habitats include lowland forests, moist meadows, woodland edges and openings, banks of ditches and roadsides. The seeds are still available in the horticulture market.

Both mechanical and chemical control methods should work. Foliar application of glyphosate, triclopyr in early spring or late fall is suggested. Hand-pulling or digging can also be effective, but if the plants are flowering at the time of pulling then these should be bagged, as seed production can still happen after the plant is pulled.



Map 18. Distribution of dames rocket at the Academy in 2012.

Common St. Johnswort (*Hypericum perforatum*)

Number of individuals, occupied area and number of patches decreased, documenting the strongest downward trend since 2009. Continued aggressive herbicide treatment and annual monitoring is essential.

Photo by Renée Rondeau

Species	**2013 Sampling Methods**
Common St. Johnswort	census/ mapping

Common St. Johnswort peaked in 2008-2009 and the trend has been downwards since 2010 (Table 11, Fig. 8, Map 19). Intensive herbicide treatment continued and resulted in a significant decline in number of individuals from 2012-2013 from 83,115 to 2,621, respectively. The number of sites also decreased however there were still 22 distinct patches with live plants in 2013. One area in the north had been eradicated for many years yet in 2013 several individuals were observed. This event emphasizes the longevity of the seed bank and the need for yearly visits to extirpated sites.

Beginning in 2010, management decided to discontinue the biocontrol treatments and rely entirely on herbicide treatment. In 2011, 8 out of the 26 known locations were sprayed with good results; the number of individuals decreased at most of the treated patches (Table 12). Although complete eradication has not been achieved, the trend is in the right direction.

In 2013 a large flood occurred after we mapped this species and there is potential for new satellite populations. It will be necessary to continue perimeter mapping and census of the entire population to inform suppression efforts for this species.

Table 11. Common St. Johnswort summary data, 2007-2013.

	Occupied Area (acres)	**Number of Individuals**	**Number of Extant Mapped Features**
2007	0.86	44,647	8
2008	1.07	130,371	13
2009	2.02	95,883	21
2010	1.47	82732	20
2011	1.44	87128	26
2012	1.16	83115	29
2013	0.85	2621	22

Table 12. Common St. Johnswort herbicide treatment results from 2011.

	2010	2011	Difference
1	10	60	10
2	600	30	-570
3	8	0	-8
4	300	20	-280
5	4,270	3,559	-711
6	800	400	-400
7	7,370	6,330	-1,040
8	69,559	76,090	6,531

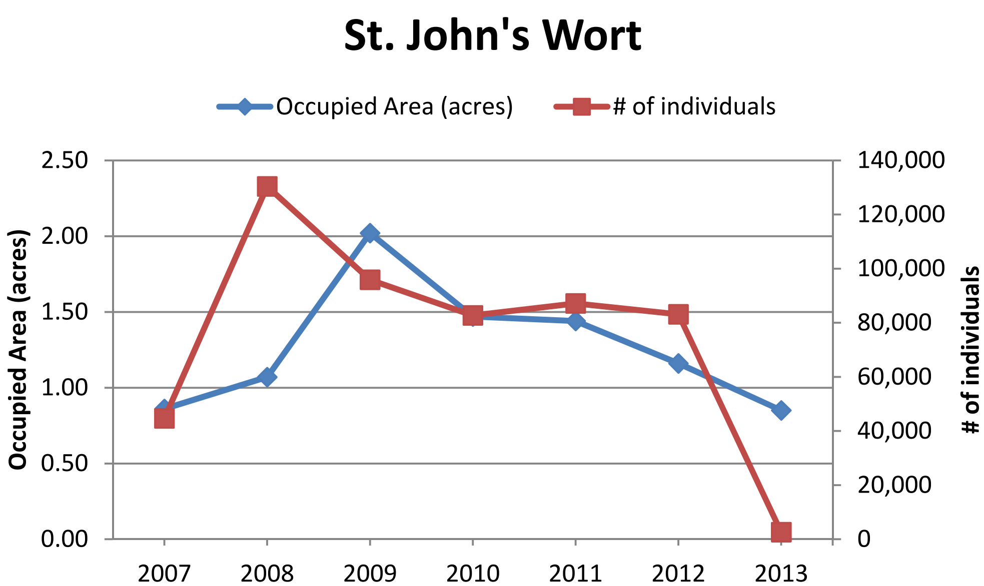
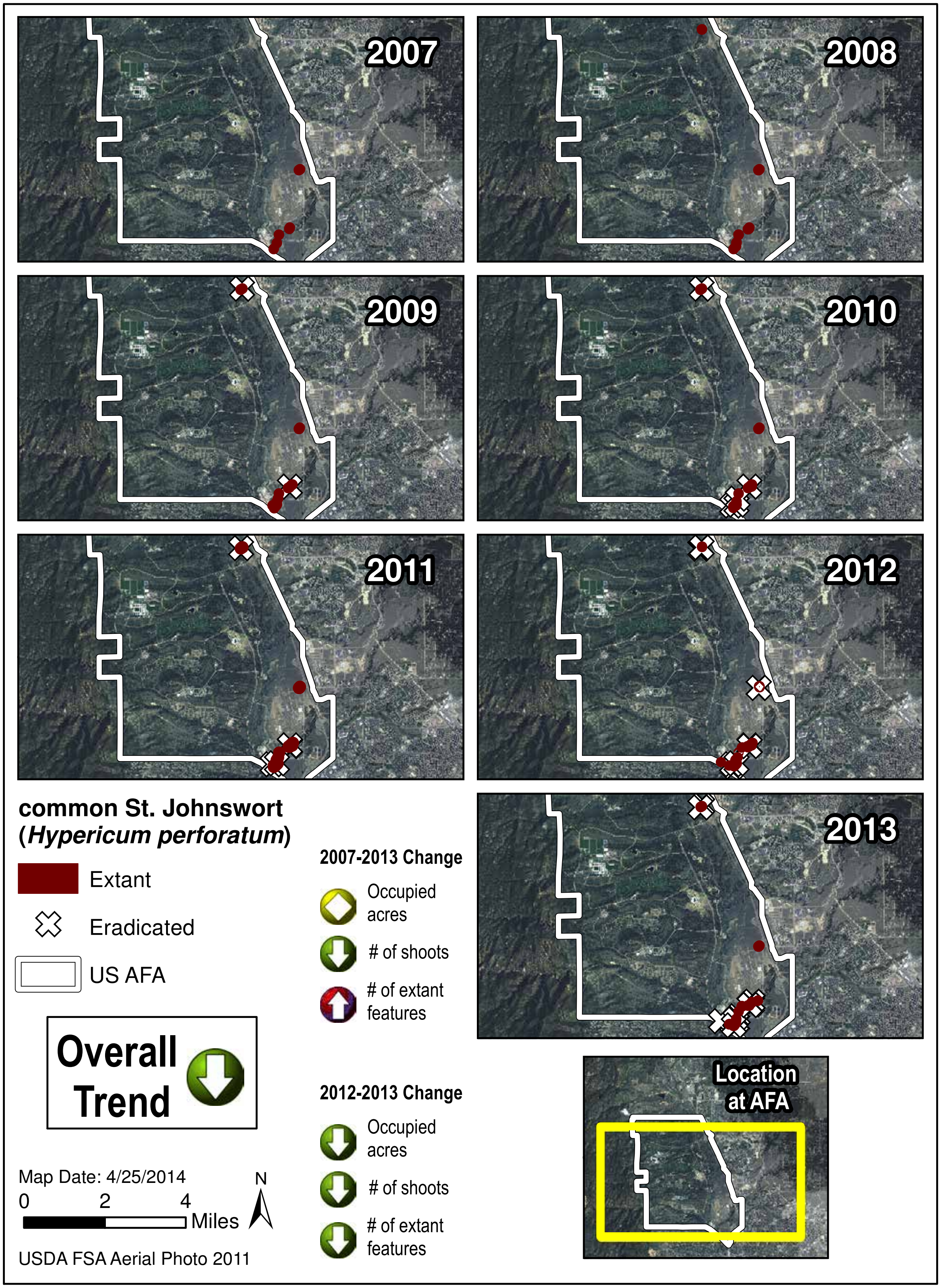


Figure 8. Common St. Johnswort trend, 2007-2013.



Map 19. Distribution of common St. Johnswort at the Academy between 2007 and 2013.

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

Appeared to be eradicated for two years but a new site was discovered in 2013.

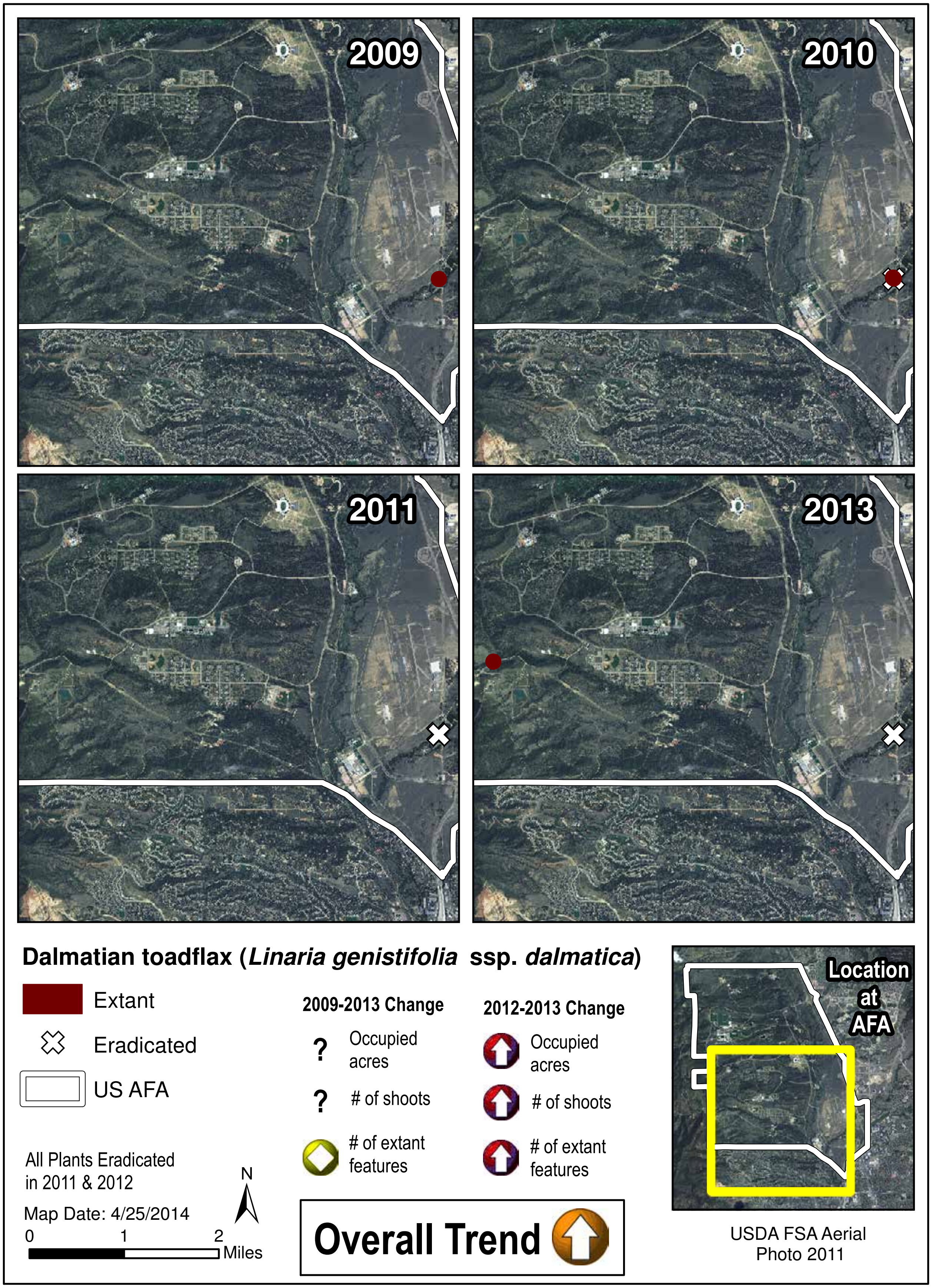
Wikipedia photo

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 20) and counted 107 individuals that covered approximately 203 m^2 (0.05 acres) (Table 19). The AFA sprayed the plants in 2010 and in 2011 -2013 no plants were observed at these known locations; however, a new site was discovered in 2013 and eradication efforts were immediately embarked on. This is an excellent example of early detection and treatment leads to success.

CNHP will continue to visit these sites during their annual weed monitoring.

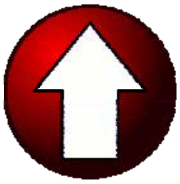
Table 13. Dalmatian toadflax summary data, 2009-2013.

	Occupied Area (m^2)	Number of Individuals	Number of Extant Mapped Features
2009		10	1
2010	203	107	2
2011	0	0	0
2012	0	0	0
2013	?	?	1



Map 20. Distribution of Dalmatian toadflax at the Academy between 2009 and 2013.

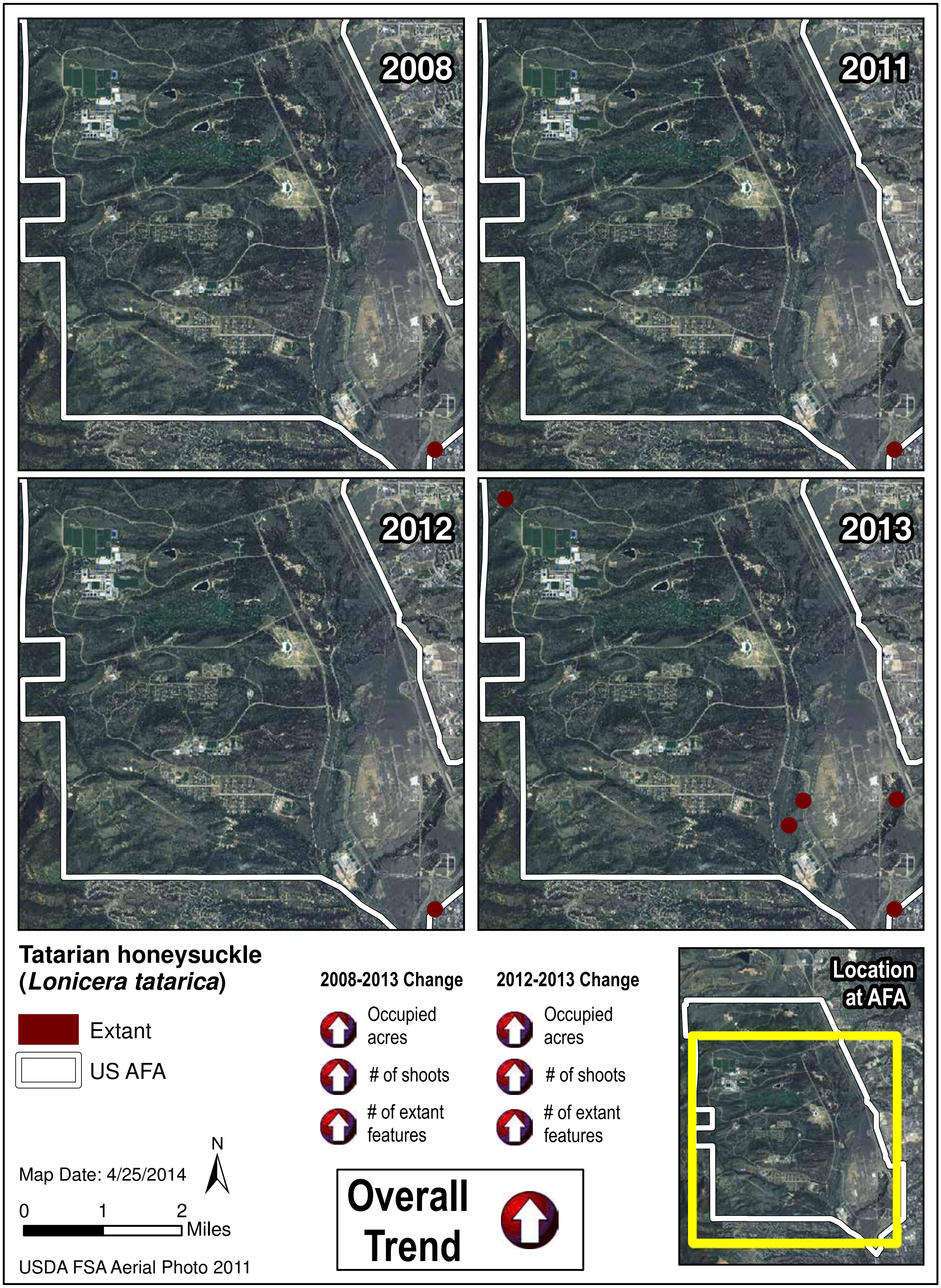
Tatarian Honeysuckle (*Lonicera tatarica*)



Number of mapped locations increased from 1 to 5, and individuals increased from 30 to 38. Eradication is possible. Pulling is recommended due to nearby rare plant.

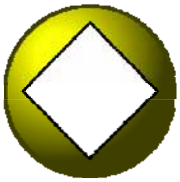
Wikipedia photo

Tatarian honeysuckle occupied 0.015 acres with approximately 30 individuals at one site in 2012 however in 2013 4 new locations were discovered with an additional 8 individuals (Map 21). This species was first discovered at the Academy in 2008, embedded with the state rare plant, *Ribes americanum*. The invasion of *Lonicera tatarica* is a concern due to its potential to dominate the site at the exclusion of the rare currant. Since this site is sensitive to herbicide spraying, pulling plants is likely the best way to control this infestation. Weed technicians should be informed of the presence of the rare plant prior to pulling weeds. Plants may need to be pulled for three to five years to fully eradicate the honeysuckle, but success is high if the weed is targeted early on in its establishment and the site is monitored annually for resprouting (Batcher and Stiles 2000).



Map 21. Distribution of Tatarian honeysuckle at the Academy between 2008 and 2013.

Scotch Thistle (*Onopordum acanthium*)



Occupied acres probably remained stable, while number of mapped features decreased and number of individuals slightly increased. Aggressive herbicide and pulling treatment should continue and annual monitoring is essential.

Photo by David Anderson

The overall number of mapped areas decreased between 2012 and 2013 however the number of individuals increased (Table 14, Fig. 9, and Map 22). Continued annual pulling and herbicide treatment is warranted.

The population of Scotch thistle peaked in 2009 and then declined in 2010 and has remained more or less stable over the last four years, largely due to the annual herbicide and pulling treatment at the Academy. 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 and mechanical treatments coupled with monitoring.

Table 14. Scotch thistle summary, 2002-2013.

	Occupied Acres	Number of Individuals	Number of Extant 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	1,710	50
2010	0.66	669	61
2011	0.64	293	39
2012	0.3	889	66
2013	0.3?	970	48

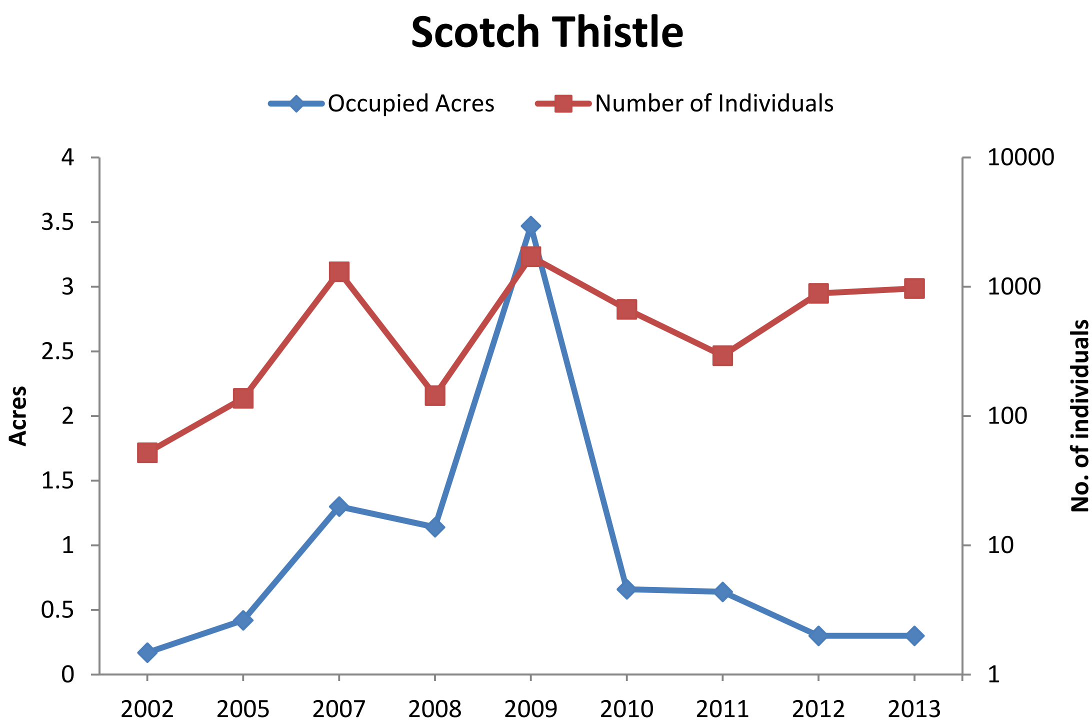
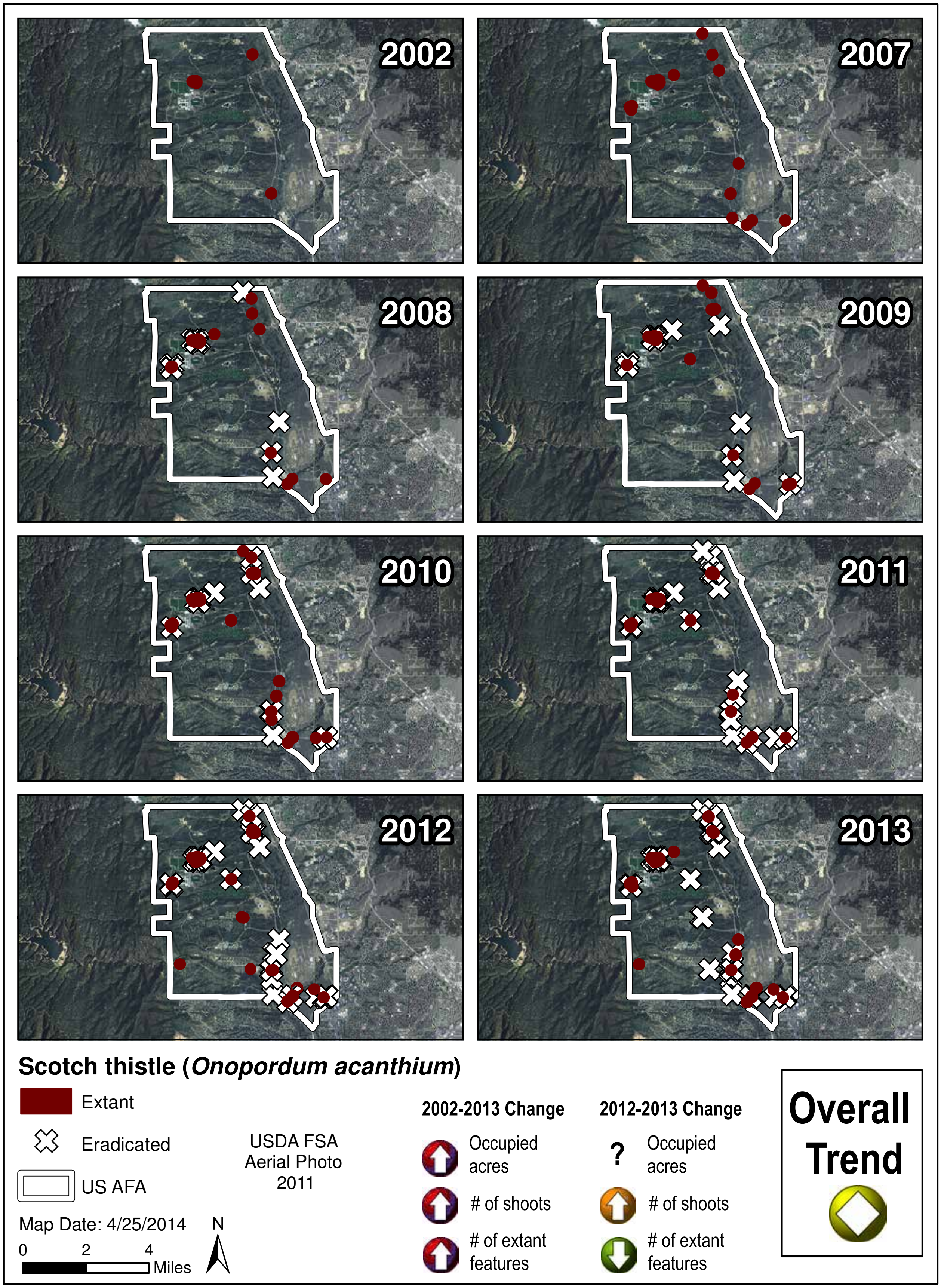
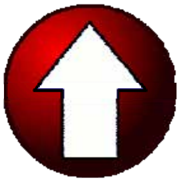


Figure 9. Scotch thistle trend, 2002-2013.



Map 22. Distribution of Scotch thistle at the Academy between 2002 and 2013.

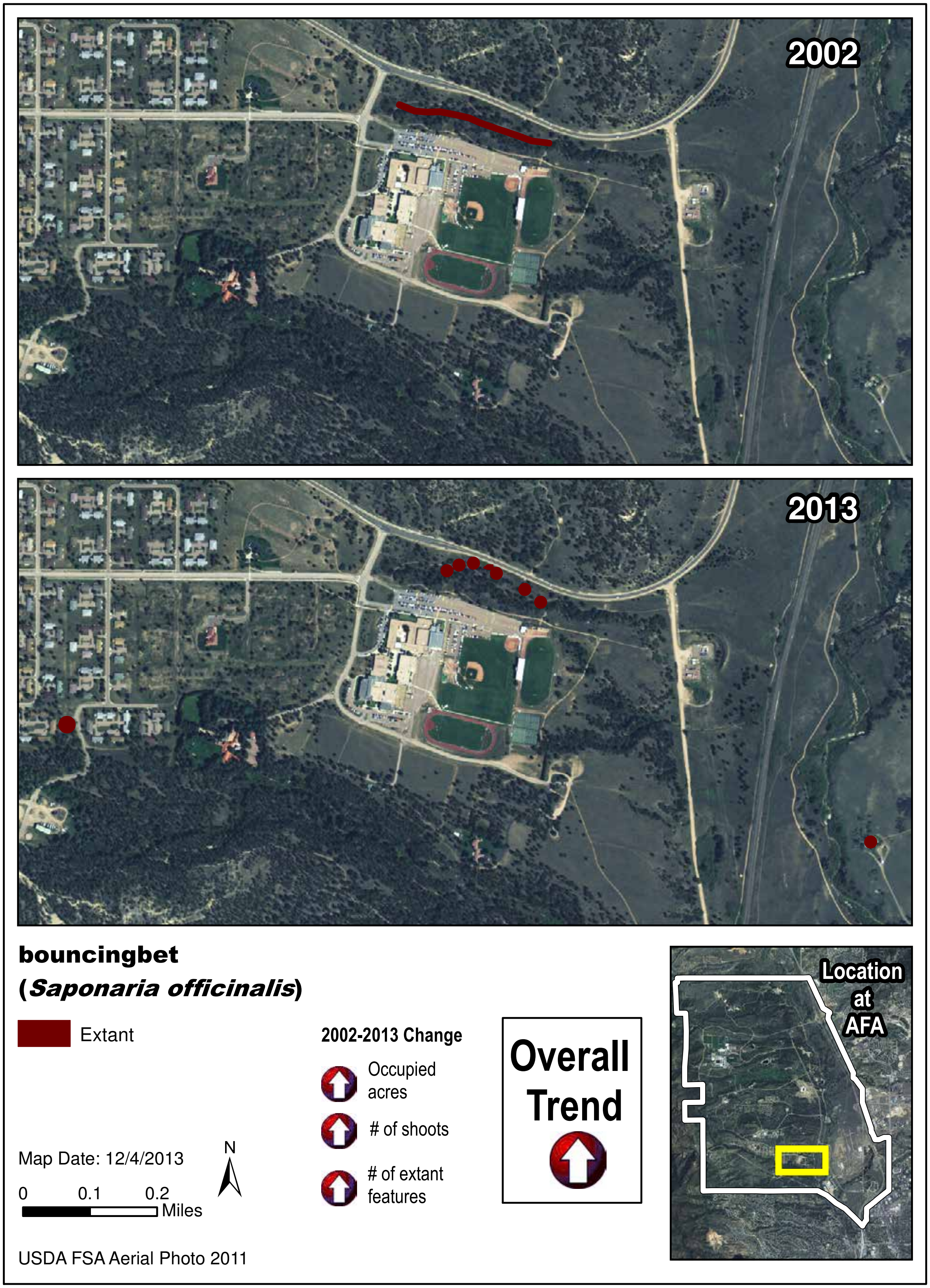
Bouncingbet (*Saponaria officinalis*)



An increase in number of locations between the years 2002-2013. This species does not appear aggressive at this time.

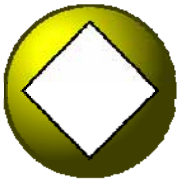
www.donaldhyatt.com

Bouncingbet was mapped at one location in 2002 and remapped in 2013 with three distinct areas noted (Map 23). In spite of no intervening management, bouncingbet did not increase at the 2002 mapped location and potentially decreased (Map 23). After mapping the 2013 locations, the AFA did treat the three areas.



Map 23. Distribution of bouncingbet at the Academy between 2002 and 2013.

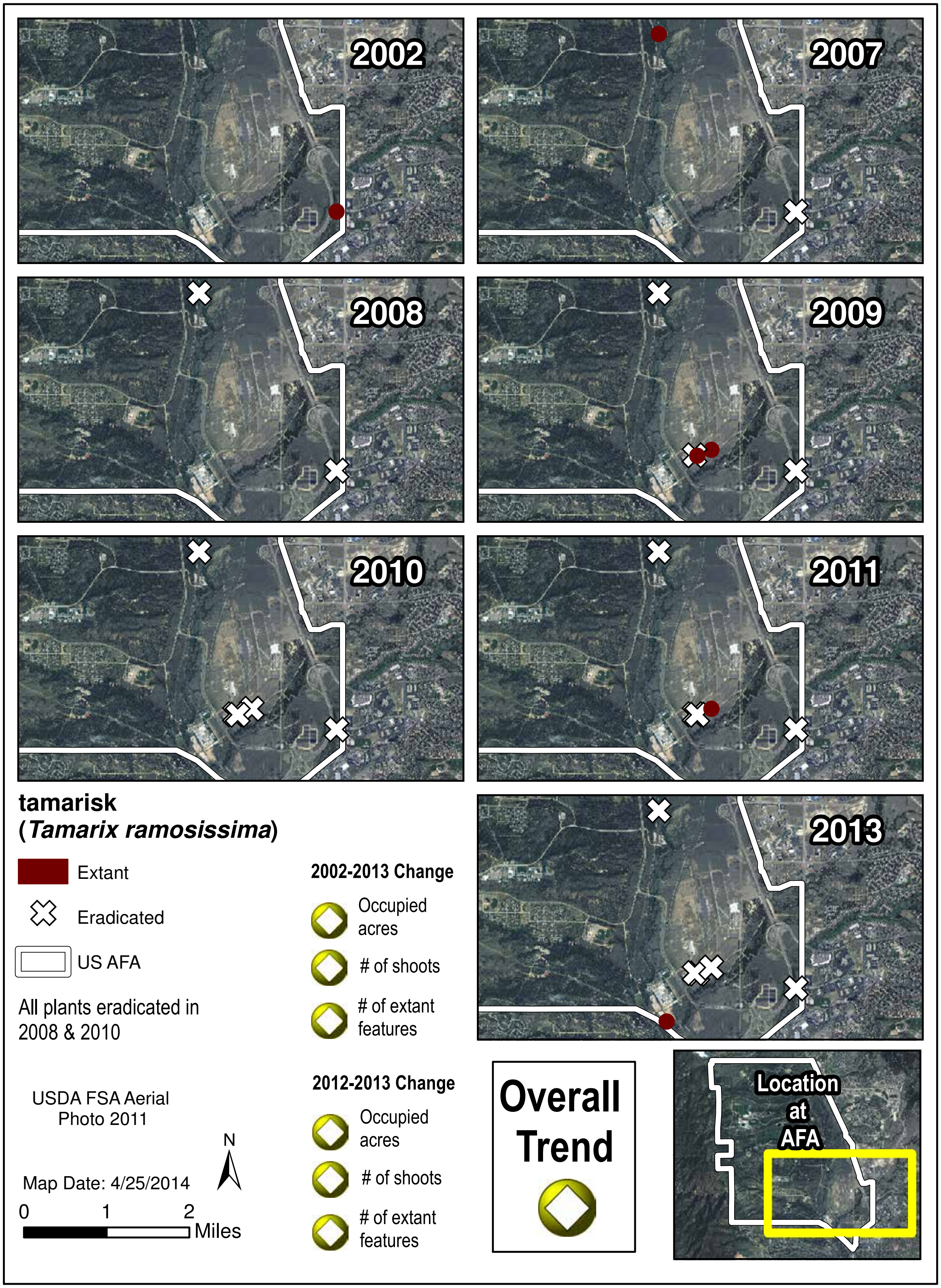
Tamarisk (*Tamarix ramosissima*)



Only one mapped occurrence with one plant.

Photo by Renée Rondeau

There is currently one mapped occurrence with one plant on the Academy (Map 24). The Natural Resources team at the Academy has been diligent and successful with the removal of any tamarisk. While number of individuals as remained stable over the years, tamarisk has increased its range at the Academy, having shown up at 5 separate sites between 2002 and 2013 (Map 24). We will continue to monitor this species on an annual basis as it can become extremely invasive.



Map 24. Distribution of tamarisk at the Academy between 2002 and 2013.

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APPENDIX A. Summary of mapping and monitoring activities by species at the Academy since 2002. Monitoring activities (not necessarily mapping) are indicated by brown shading.

Common Name	Scientific Name	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Russian knapweed	***Acroptilon repens***			M*	M	M	M	M	M	M	M	M	M
Siberian peashrub	***Caragana arborescens***											M	
whitetop	***Cardaria draba***	M	M				M					M	
musk thistle	***Carduus nutans***	M					M					M	
diffuse knapweed	***Centaurea diffusa***	M					M					M	
diffuse / spotted knapweed hybrid	***C. diffusa x maculosa***				M*		M					M	
spotted knapweed	***Centaurea maculosa***	M			M	M	M					M	
Canada thistle	***Cirsium arvense***	M					PM					M	
bull thistle	***Cirsium vulgare***	M					M					M	
field bindweed	***Convolvulus arvensis***	M					M						
houndstongue	***Cynoglossum officinale***								M*	M	M	M	M
Fuller's teasel	***Dipsacus fullonum***	M					M					M	
Russian olive	***Elaeagnus angustifolia***	M	PM		PM		M					M	
leafy spurge	***Euphorbia esula***	M					M					M	
myrtle spurge	***Euphorbia myrsinites***				M*	M	M		M	M	M	M	M
yellow spring bedstraw	***Gallium verum***									M*	M	M	M
dames rocket	***Hesperis matronalis***											M*	
common St. Johnswort	***Hypericum perforatum***	M			M	M	M	M	M	M	M	M	M
Dalmatian toadflax	***Linaria genistifolia ssp. dalmatica***								M*	M	M	M	M
yellow toadflax	***Linaria vulgaris***	M					PM					PM	

Common Name	Scientific Name	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Tatarian honeysuckle	***Lonicera tatarica***							M*			M	M	M
Scotch thistle	***Onopordum acanthium***	M			M	M	M	M	M	M	M	M	M
Bouncingbet	***Saponaria officinalis***	M*											M
tamarisk	***Tamarix ramosissima***	M					M	M	M	M	M	M	M

M = mapped, PM = partially mapped, * indicates year discovered

Appendix B. Transect Survey Protocols for AFA utilized for biocontrol and non-biocontrol plots for whitetop, Canada thistle, knapweeds, and leafy spurge.

The following methods were implemented in 2011 by TAMU and in 2012 by CNHP.

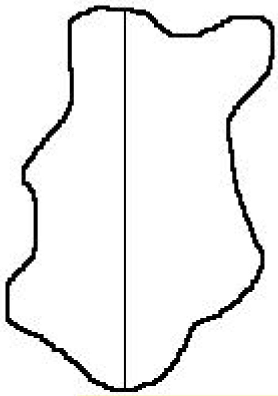
Materials needed for transect establishment:
Compass
50 m survey tape (2 or 3)
GPS unit, with the needed background file(s) for site(s) being surveyed
Wooden stakes
Orange marking paint
Dead blow hammer (2)

Materials for SURVEY ONLY:
Quadrat 50 x 50 cm (2)
50 m survey tape (minimum of 2, however 3 can also work well.
GPS unit, with the current year's shapefile for data entry

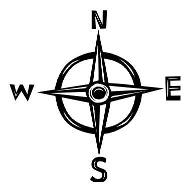
Standard survey procedure:

- The technique outlined here will apply to the majority of sites
- The general concept is to aim for a 50 m transect through the center of weed infestation. Sometimes it may be necessary to do a shorter transect in order to stay within the habitat. Ideally, the 25 m long bisecting transects have the 12.5 m mark crossing the main 50 m long transect. These secondary transects can be shortened if habitat does not extend the entire 25 m length.
- Identify a line which bisects the weed infestation along the longest axis, for a maximum of 50m. (Fig. 1)
- Five transects will be created, intersecting the bisecting line (Fig. 1) at points that are 5%, 25%, 50%, 75% and 95% of the line's length. These will span the width of the infestation, or a maximum of 25m. (Fig. 2)
    - If this is the first establishment of transects, mark beginning and end points with survey stakes and orange marking paint.
- Conduct weed and agent surveys at 3 m intervals, starting at the 0 m mark along each 50m and 25 m transect, recording survey data using ArcPad
    - In general, the 0 m mark for primary and lateral transects are either South or West.
    - Vegetation surveys will be conducted along these transects, following the appropriate methods outlined for the weed at the site.
    - Quadrats will be placed with the lower left corner of the quadrat placed at the 3 m interval point along the transect, always on the right side as looking from up the transect from the 0 m mark

Fig. 1



0 m mark is south or west



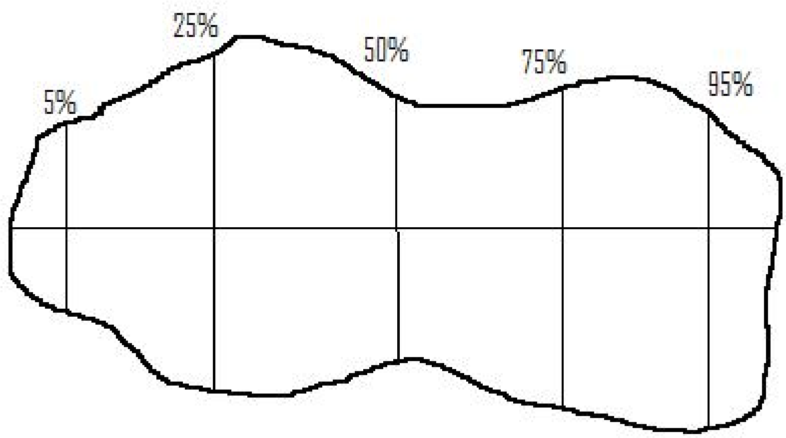


Fig. 2

0 m mark is south or west

Survey strategy for "unmappable" sites (never used in 2012)

- For sites deemed unmappable because of vas size and/or excessively rough topography.
- Should comprise a minimal proportion of total sites
- Two variations
    - Variation 1: An unmappable site having a linear pattern of weed infestation
        - Identify the largest reach of the site that is accessible; perhaps defined by access points from roads.
        - Consider the first accessible point along the infestation the "beginning" of the area and the last accessible point the "end" of the area. (Fig. 3)

- Use the 5%-25%-50%-75%-95% method outlined above (in standard methods) to partition the infestation into roughly equal sections (the division of the infestation into these sections may be approximate). (Fig. 4)
- At the midpoint of each of these dividing lines, create a 25 m long transect, that will lie along the longest axis of the infestation. (Fig. 5)
    - If this is the first establishment of transects, mark beginning and end points with survey stakes and orange marking paint.
- Conduct weed and agent surveys at 3 m intervals along each 50 m and 25 m transect, recording survey data using ArcPad
    - Vegetation and agent surveys will be conducted along these transects, following the appropriate methods outlined for the weed and agent(s) at the site.
    - Quadrats will be placed with the lower left corner of the quadrat placed at the 3 m interval point along the transect.

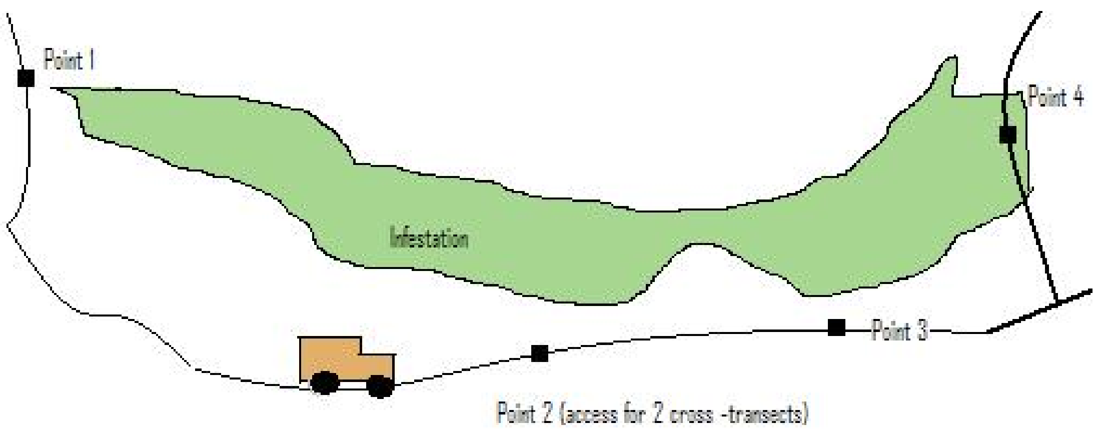
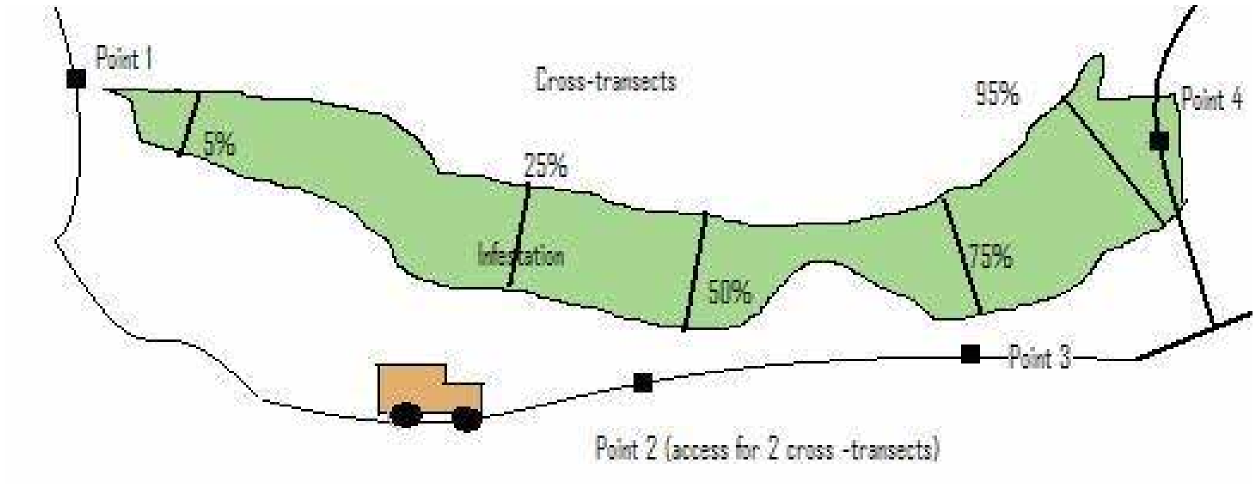
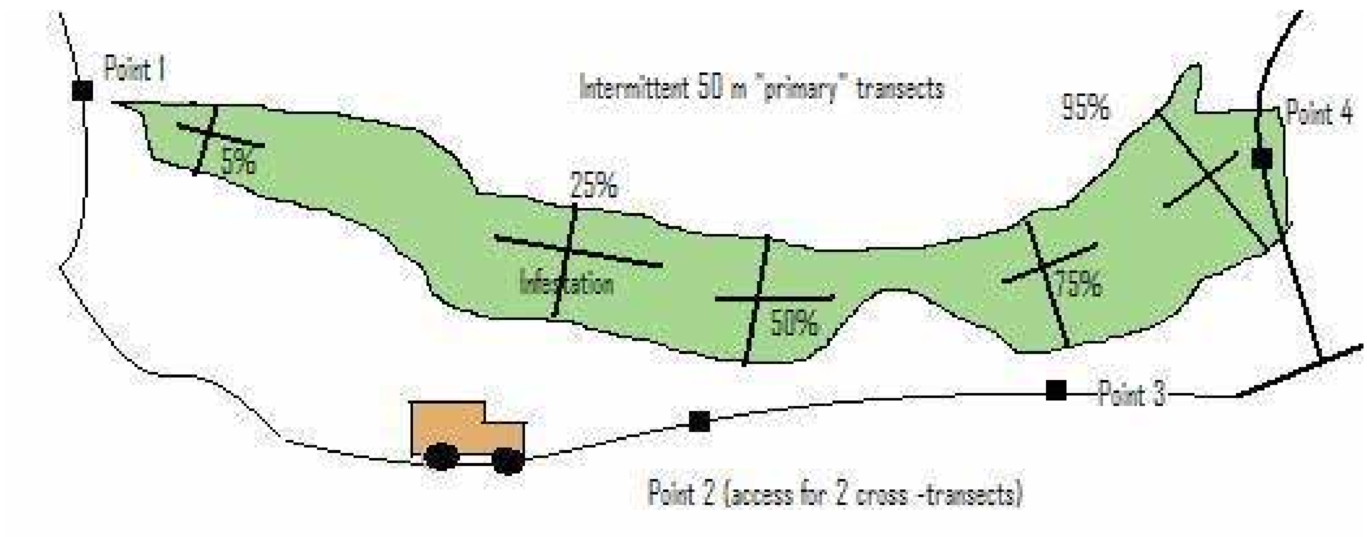


Fig. 3



Point 1
Cross-transects
95%
Point 4
5%
25%
Infestation
75%
50%
Point 3
Point 2 (access for 2 cross -transects)

Fig. 4



Point 1
Intermittent 50 m "primary" transects
95%
Point 4
5%
25%
Infestation
75%
50%
Point 3
Point 2 (access for 2 cross -transects)

Fig. 5

Collecting data at each50 x 50 cm quadrat, (every 3 m, starting at 0 m mark):

- **Reproductive stage**: chosen for the most mature stage in the quadrat.
  - Seedling, bud, flowering, seed, post seed
- **Density**
  - Number of shoots/stems arising from ground within the quadrat
- **Cover, use the following categories:**
  - 0, 1, 3, 5, 7, 10, 15, 20, 25, 30, 35, etc.
- **Height (cm)**
  - Measure tallest stem in quadrat
- For knapweeds and Canada thistle only:
  - Count the number of **flower heads** on the tallest stem
  - **Measure flower diameter, including phyllaries, (mm)**
- **Comments: general comments about the transect should be placed in the first quadrat at the 0 m mark.**

Photos: Take a photo from the 0 m and 50 m mark of the primary transect, looking down the transect.

Appendix C. Mapping Protocol.

All weed infestations were mapped in the field using ArcPad version 10.0.3 (ESRI 1995-2011), a portable version of GIS software that allows the user to create and edit spatial data remotely using a tablet computer. ArcPad was installed on a Trimble Yuma rugged tablet with a Windows 7 operating system and a built-in GPS receiver module. The Yuma tablet has improved display capabilities, a rugged exterior to withstand adverse weather conditions, a stable operating system and hard drive, and a larger screen to help with navigation and data collection. The configuration of a built-in GPS receiver module prevented reoccurring loose connections that were problematic during previous weed mapping efforts. According to Trimble specifications (http://www.trimble.com/mappingGIS/yuma_rugged_tablet.aspx?dtID=technical_specs) the GPS is generally accurate to within 2-5m using SBAS (Satellite-Based Augmentation System). To ensure data accuracy during the collection process, SBAS was activated and warning systems were enabled in ArcPad to notify the user when the PDOP (Positional Dilution of Precision) exceeded 6 and the EPE (Estimated Probable Error) exceeded 8. Twenty points were averaged at each location, and 10 vertices were averaged for lines and polygons.

Weeds were mapped as points, lines or polygons. Linear features were mapped as lines and assigned a buffer width to estimate area. Irregularly shaped features greater than approximately 600 square meters (30m x 30m) were mapped as polygons. All other features were mapped as points and assigned a radius. Since weeds are mobile from year to year, and the GPS has inherent inaccuracies, infestations within 5 meters of each other were mapped as one feature. If previously mapped infestations were not located, they were marked as eradicated, as opposed to deleted, in order to keep track of the soil seed bank and ensure future visits to historically infested areas. Weeds tend to fluctuate based on annual weather patterns and have been found to be absent one year, only to crop up in the same location or nearby during the next growing season. All features were collected using the GPS unless otherwise noted in the attribute table. Features that were inaccessible due to natural barriers or exclosures were digitized "heads-up" using the 2011 NAIP digital orthophoto quad for reference. Attributes were collected using customized field forms, designed to minimize user error by maximizing domain tables and field auto-population techniques. One free text field was maintained to document any observations deemed important, such as nearby significant species or difficulties incurred in a specific area (e.g., dense oak thickets affecting the ability to map features or estimate individuals). The field technician had the option to document number of individuals or density as number of individuals per square meter. If density was noted, the number of individuals was calculated in the office based on the assigned density and the size of the infestation.

Weed data were stored in a master geodatabase in ArcGIS v10 (ESRI 1999-2010). The following attributes were captured:

COLLECTDAT – Collection date
PLANSCODE – USDA plants code
SPECIES – Scientific name
COMMONNAME - Common name
NUMINDIV – Number of individuals
DENSITY – Density per square meter
BUFFDIST - Radius for point features; buffer width for line features; not applicable to polygon features
COVERCLASS – 0-1%, Trace; 1-5%, Low; 5-25%, Moderate; 25-75%, High; 75-100%, Very High
PATTERN – Continuous, Patchy, NA (for eradicated infestations)

COMMENT – Free text field
DATUM – Datum
FEATTYPE – Point, line or polygon
USOWNER – Federal land ownership
LOCALOWNER – Local land ownership
US_STATE – U.S. state
COUNTRY - Country
EXAMINER –Field observer
MAPAGENCY – Mapping agency
STATUS – Extant, Eradicated, Dead Standing, Sprouting, Other

Appendix D. All mapped weeds in 2013 in comparison to 2009-2012.

Metric	Year	*Acroptilon repens*	*Cynoglossum officinale*	*Euphorbia myrsinites*	*Galium verum*	*Hesperis matronalis*	*Hypericum perforatum*	*Linaria genistifolia spp. dalmatica*	*Lonicera tatarica*	*Onopordum acanthium*	*Saponaria officinalis*	*Tamarix ramosissima*
# of Extant Features	2009	2	8	12	NA	NA	21	1	NA	50	?	2
	2010	0	1	10	1	NA	20	2	NA	61	?	0
	2011	0	2	12	1	NA	26	0	1	39	?	1
	2012	10	3	10	0	14	29	0	1	66	?	1
	2013	0	7	19	0	?	22	1	5	48	8	1
# of Erad. Features	2009	2	0	6	NA	NA	2	0	NA	34	?	3
	2010	4	6	12	0	NA	6	1	NA	30	?	5
	2011	4	6	16	0	NA	5	3	0	56	?	4
	2012	4	9	25	1	0	10	3	0	73	?	4
	2013	12	8	12	1	?	21	3	0	85	0	5
# of Shoots	2009	?	95	464	NA	NA	95,883	10	NA	1,710	?	2
	2010	0	11	56	700	NA	82,733	107	NA	669	?	0
	2011	0	21	57	1	NA	87,128	0	30	293	?	1
	2012	543	70	113	0	16,871	83,115	0	30	889	?	1
	2013	0	48	129	0	?	2,621	12	38	970	42,092	1
Occ. Acres	2009	?	0.09	2.4	NA	NA	2.02	?	NA	3.47	?	<0.01
	2010	0	0.02	0.5	0.01	NA	1.47	0.50	NA	0.66	?	0
	2011	0	< 0.01	0.25	<0.01	NA	1.44	0	0.15	0.64	?	<0.01
	2012	0.05	0.01	0.23	0	0.83	1.16	0	0.15	0.3	?	<0.01
	2013	0	0.05	?	0	?	0.85	?	0.18	?	0.50	<0.01