Noxious Weed Monitoring at the U.S. Air Force Academy - Year 8 Results

April, 2013

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

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On the cover: Sophie Recca at knapweed plot, Aug 10, 2012.

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EXECUTIVE SUMMARY

This report includes a summary of the results of the past eight years of population monitoring of targeted noxious weeds at the U.S. Air Force Academy ("the Academy"), emphasizing changes that were observed during 2012, especially from the 2012 weed mapping project (Lavender-Greenwell and Rondeau 2013).

In order to closely align CNHP's monitoring protocol with the Texas A&M AgriLife biocontrol project, we established 36 non-biocontrol permanent plots utilizing the same methods as Michels et al. (2013) for: *Cardaria draba* (8), *Centaurea diffusa* (5), *C. maculosa* (5), *Cirsium arvense* (8) and *Euphorbia esula* (10). Summary data from the biocontrol and non-biocontrol plots are provided under each species account.

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 ramosissima*), Russian knapweed (*Acroptilon repens*), Scotch thistle (*Onopordum acanthium*), common St. Johnswort (*Hypericum perforatum*), houndstongue (*Cynoglossum officinale*), Dalmatian toadflax (*Linaria genistifolia* ssp. *dalmatica*), dames rocket (*Hesperis matronalis*), and yellow spring bedstraw (*Galium verum*). These species are relatively uncommon at the Academy and can still reasonably be eradicated or controlled. They 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. Yellow toadflax (*Linaria vulgaris*) is widespread and abundant on the Academy and poses a serious threat to the integrity of various habitats and natural resource values. However, limited monitoring and management of this species is conducted due to scale of the infestation and the lack of effective control techniques.

We did not conduct any monitoring at Farish; however, the weed mapping project mapped musk thistle, Canada thistle, yellow spring bedstraw, and a sample of yellow toadflax sites (see Lavender-Greenwell and Rondeau 2013 for results).

The highlights of 2012 monitoring are listed below.

- **Russian knapweed:** Aggressive spraying had *extirpated* the few known populations; however, the 2012 weed mapping project located 10 new sites. This species is a high priority for complete eradication and annual herbicide treatment and monitoring is recommended.
- **Whitetop:** It is primarily contained along Monument Creek with stable to diminishing population estimates. Six outlier populations are a high priority for weed management.

- **Musk thistle:** While it continues to spread into new areas, there is ample evidence that herbicide treatment reduces the number of individuals.
- **Diffuse and spotted knapweeds:** Continue to spread into new areas; however, overall cover is still low. Eradication is not feasible therefore selecting targeted areas for treatment is suggested.
- **Canada thistle:** Continues to spread and invade wet areas. Biocontrol may be the best solution, especially for sites with high cover.
- **Houndstongue:** Early detection and rapid response is still working for this species. There are only three known sites with less than a total of 70 individuals. Annual pulling treatments, especially prior to seed development, should control this species as seeds are short lived (3 years).
- **Leafy spurge:** 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 2013 herbicide treatment.
- **Myrtle spurge:** While the number of individuals doubled between 2011 to 2012, the number of locations was reduced from 12 to 10. Eradication efforts have been successful at 25 locations. Continued annual treatment at each site is recommended.
- **Yellow spring bedstraw:** This weed was discovered and eradicated at one area in 2010; however, the 2012 weed mapping project located two new small populations. This species is a high priority for complete eradication in 2013.
- **Dames rocket:** Newly discovered in 2012. This species is primarily located close to I-25; it probably escaped from nearby gardens. Eradication may be possible.
- **Common St. Johnswort:** Herbicide treatment appears to be keeping the species from erupting as number of individuals and occupied acres decreased in 2012. This is still a high priority species for potential eradication.
- **Dalmatian toadflax:** All known sites have been eradicated.
- **Tatarian honeysuckle:** Only one site near the eastern boundary is known. This 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:** Remains fairly stable however new populations were discovered during the 2012 weed mapping project. Herbicide treatment and hand pulling are keeping this species from erupting.
- **Tamarisk:** Only one individual was located in 2013.

INTRODUCTION

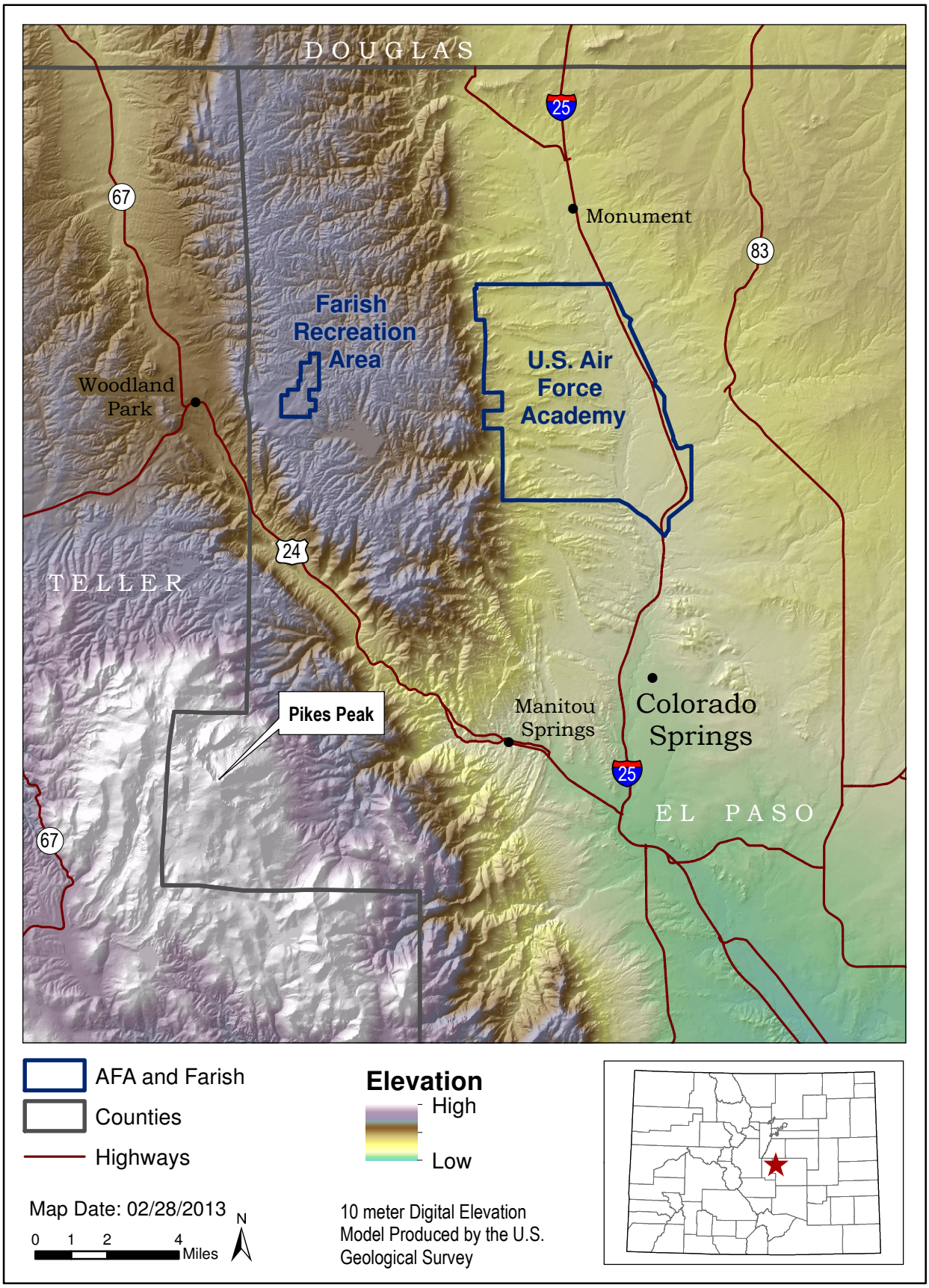
Weeds are known to alter ecosystem processes, degrade wildlife habitat, reduce biological diversity, reduce the quality of recreational sites, reduce the production of crops and rangeland forage plants, and poison livestock (Sheley and Petroff 1999). All of these impacts are occurring in Colorado (Colorado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

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 is to guide the management of noxious weeds at the Academy and Farish in the most efficient and effective manner. This plan supports the 2008-2013 *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 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 (Spackman-Panjabi and Decker 2007, Carpenter et al. 2004, Anderson et al. 2003). 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*), 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 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 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 (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*) nor 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. In May, we combined efforts and conducted a "Field Day" to sample the LSferl (leafy spurge) site and discuss weed mapping protocols. 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 will be 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.

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

METHODS

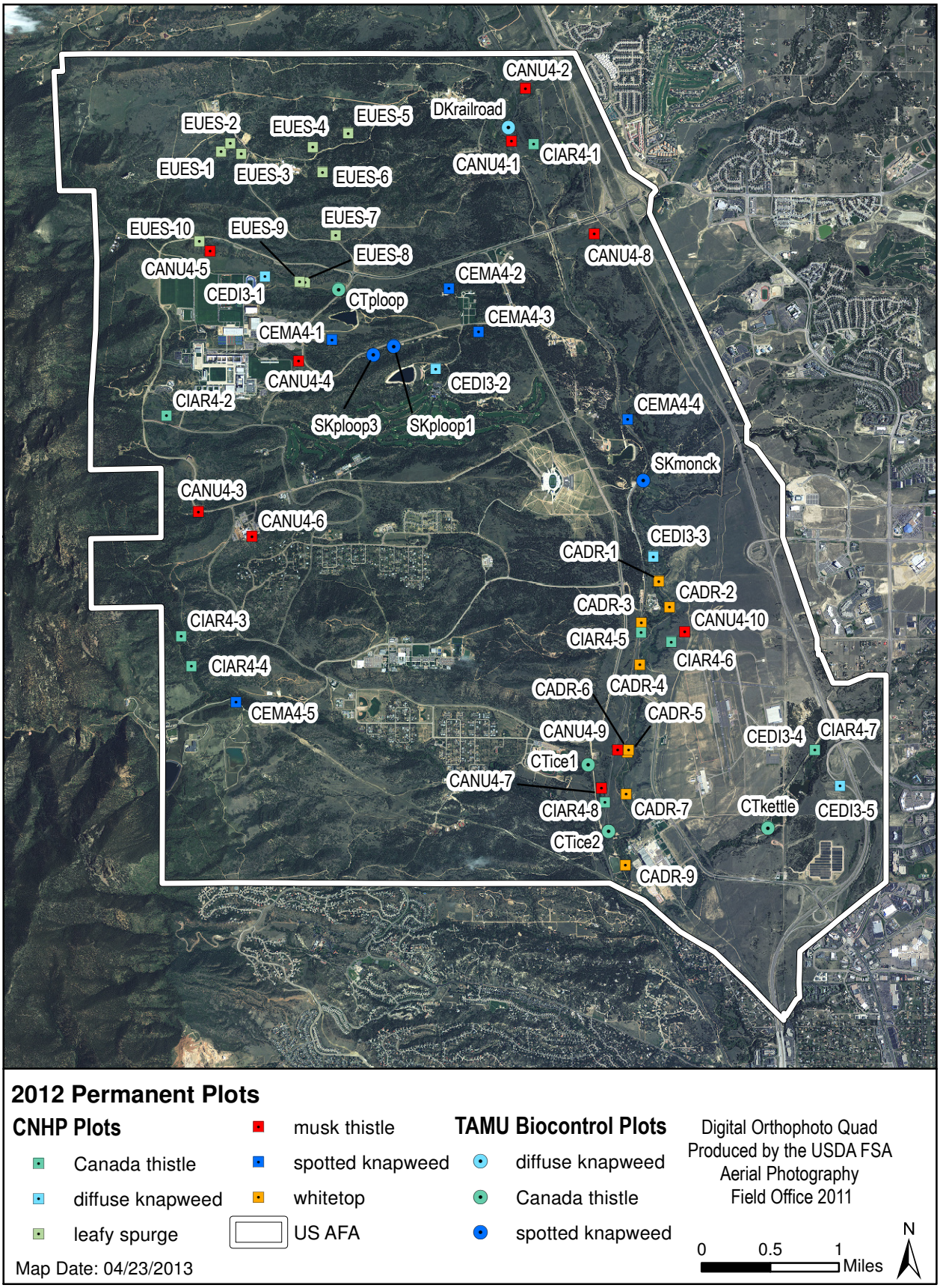
This project was undertaken to evaluate the effectiveness of ongoing management of noxious weeds at the Academy in order to determine whether weed management objectives are being met and to determine trend. The recommendations for the design and deployment of monitoring plots offered by Carpenter et al. (2004) were adhered to closely in this study. In 2012, 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* (8), *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. Collecting data in subsequent years will allow us to analyze trend and treatment data.

In addition to monitoring, CNHP conducts a weed mapping survey every five years and 2012 was the third sampling year (Lavender-Greenwell and Rondeau 2013). Weed mapping is a form of monitoring and summaries from the weed mapping report, for species included in this report, are provided under the species account section. The combination of weed mapping and monitoring provides the most complete picture of weed status, trends, and management effectiveness.

Table 1. Summary of methods used for sampling and mapping in 2011 and 2012.

Latin name	Common name	2011 Sampling Methods	2012 Sampling Methods
Acroptilon repens	Russian knapweed	*Mapping/ census*	*Mapping/ census*
Cardaria draba	Whitetop	*Not sampled*	*8 plots*
Carduus nutans	Musk thistle	*10 Photopoints/ estimated size*	*Weed mapping (Lavender-Greenwell and Rondeau,2013)*
Centaurea diffusa	Diffuse knapweed	*Not sampled*	*5 untreated plots, 1 biocontrol plot (Michels et al. 2013)*
Centaurea maculosa	Spotted knapweed	*Not sampled*	*5 untreated plots, 3 biocontrol plots (Michels et al. 2013)*
Cirsium arvense	Canada thistle	*Transect/ photopoints/ photoplot*	*8 untreated plots, 4 biocontrol plots (Michels et al. 2013).*
Cynoglossum officinale	Houndstongue	*Mapping/census*	*Mapping/census*
Euphorbia myrsinites	Myrtle spurge	*Mapping/ census/ photopoints*	*Mapping/ census*
Euphorbia esula	Leafy spurge	*Mapping/ survey transects/photopoint*	*10 plots*
Galium verum	Yellow spring bedstraw	*Not observed*	*Mapping/census*
Hesperis matronalis	Dames rocket	*Not sampled*	*Mapping/census*
Hypericum perforatum	Common St. Johnswort	*Photopoints/ quadrats and mapping*	*Mapping/Census*
Linaria genistifolia spp. dalmatica	Dalmatian toadflax	*Mapping/census*	*Mapping/census*
Lonicera tatarica	Tatarian honeysuckle	*Not sampled*	*Mapping/census*
Onopordum acanthium	Scotch thistle	*Mapping/census*	*Mapping/census*
Tamarix ramosissima	Tamarisk	*Mapping/ census*	*Mapping/ census*



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

RESULTS AND RECOMMENDATIONS

The 2012 water year was relatively dry for both the growing season and total precipitation, with approximately six inches below average (Figure 1). The annual average precipitation is 17.4 inches.

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

Recent treatment areas at the Academy (2011 and 2012) are depicted in Map 3 along with the location of the biocontrol plots. Evidence of additional biocontrol insects were noted by the 2012 weed mapper (Map 3). We hope to have more detailed spatial data of treated (sprayed, pulled, biocontrol, etc.) areas in the future.

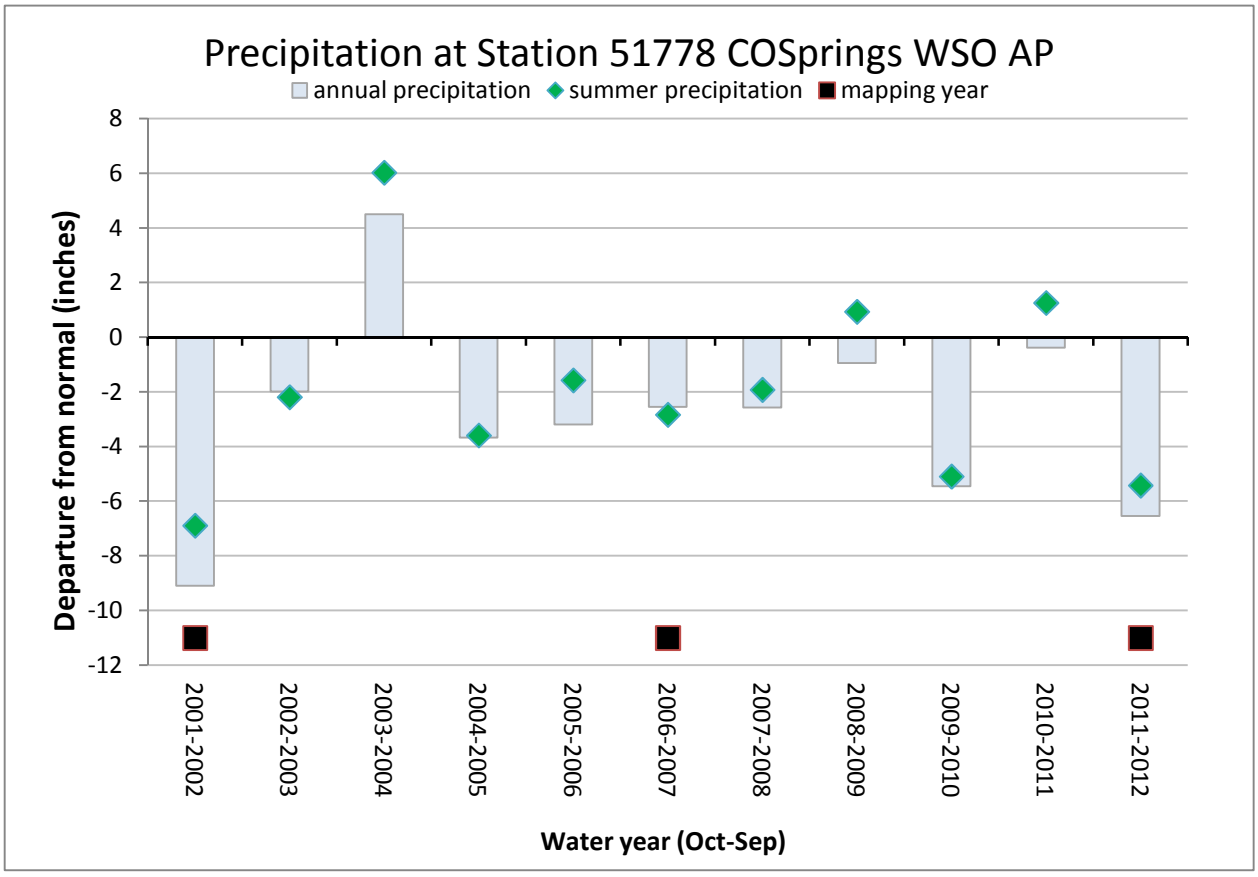
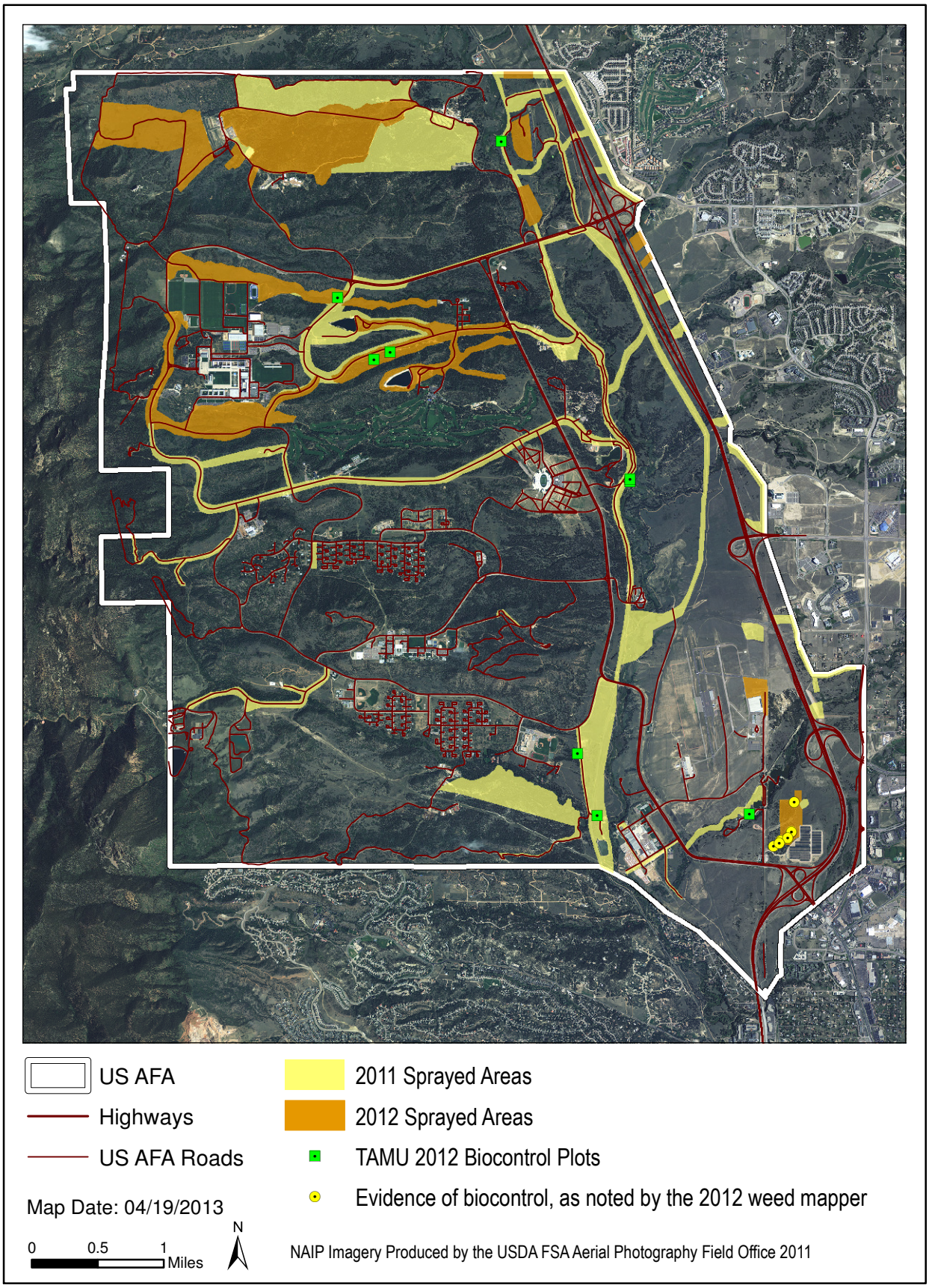


Figure 1. Summary data for monthly precipitation (in inches) at Colorado Springs, Colorado from 2002 through 2012 (Western Regional Climate Center 2013). Average annual precipitation is 17.4 inches.



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. It is still possible to eradicate.

Species	Sampling Methods
Russian knapweed	mapping and census at all locations

Photo by David Anderson

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 represents a 172% increase in number of shoots and a 400% increase in number of extant mapped features since 2007 (Table 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 was critical to finding new locations of Russian knapweed since an early response will probably control 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.

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

Table 2. All infestations of Russian knapweed at the U.S. Air Force Academy.

	2002	2007	2012
Occupied Acres	**NA**	**0.03**	**0.05**
Estimated Number of Shoots	**NA**	**200**	**543**
Number of Extant Features	**NA**	**2**	**10**
Number of Eradicated Features	NA	2	4

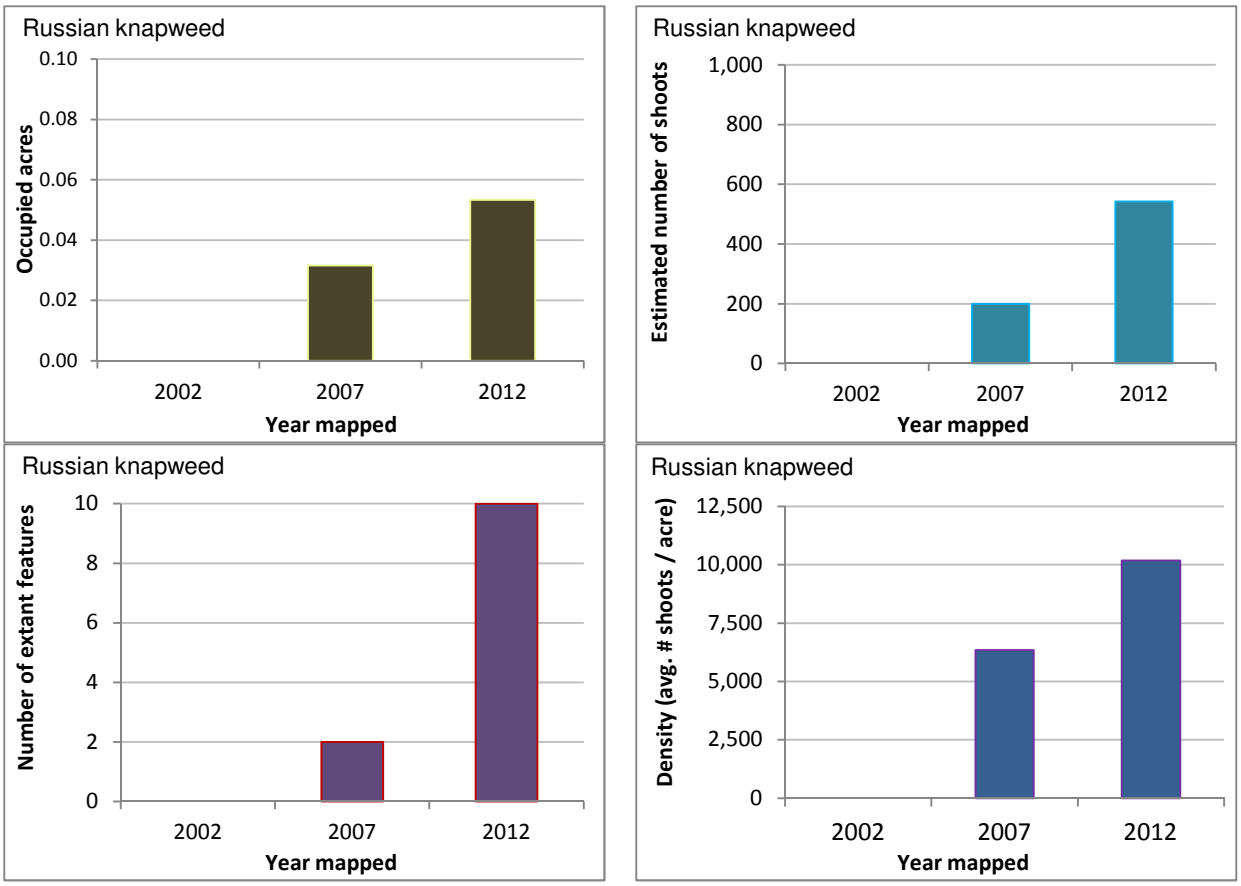
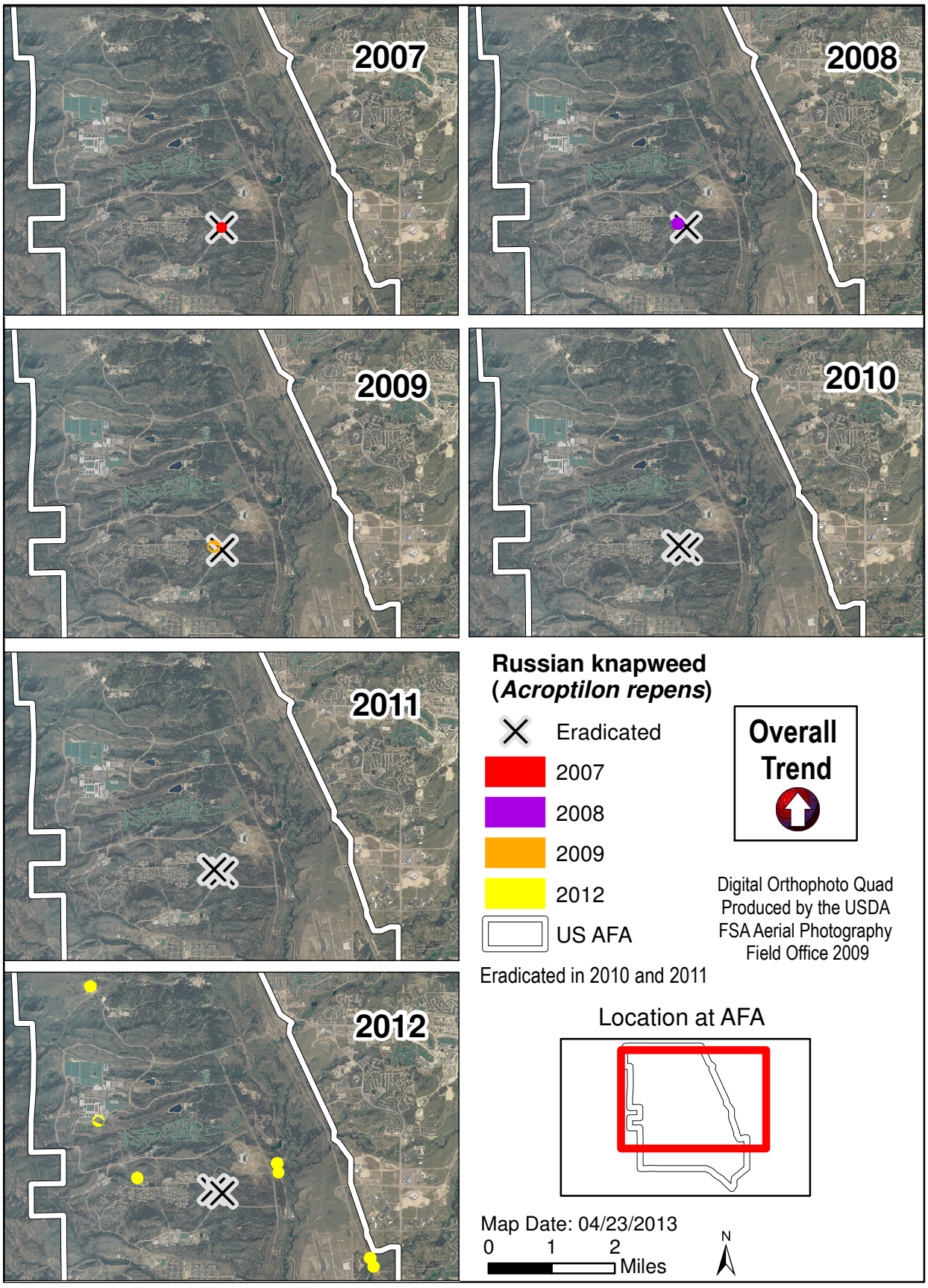


Figure 2. Russian knapweed trend, 2002-2012.



Map 4. Distribution of Russian knapweed at the Academy between 2007 and 2012.

Whitetop (*Cardaria draba*)

Decreasing but outliers are a concern as they have the potential to greatly expand the distribution of this weed.

Photo by Michelle Washebek

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. See Table 3 for summary data from each plot. In addition, the 2012 weed mapping project mapped all known infestations and those are summarized below in Table 4 (Lavender-Greenwell and Rondeau 2013).

Whitetop occupied 13 acres in 2012, more or less unchanged from 2007 (Table 4). The number of extant mapped features and number of shoots also decreased (16% and 20% respectively) in the same time period (Table 4 and Figure 3).

Whitetop appears to be fairly well contained along the southern portion of Monument Creek at the Air Force Academy (Map 6) and may also be fairly stable. Whitetop is more responsive to drought conditions than many other noxious weed species at the Academy. In 2002 it was very difficult to detect during the extreme drought conditions of that year, and additional mapping was needed in 2003 to establish the extent of the infestation at the Academy. In 2003, growing conditions were more favorable and a much better understanding of the status of whitetop was gained. All of the 2007 outliers were eradicated, except possibly the northernmost one, however additional outliers were located in 2012 (Map 6). In 2012, only two outliers were found near the northern boundary. All outlier infestations are a high priority for eradication efforts, especially the northern locations because they could easily disperse seeds downstream and infest the upper reaches of Monument Creek.

Whitetop is not yet known from Farish; if any infestations are found there they will warrant aggressive management efforts.

Table 3. Summary of 2012 permanent plot data for whitetop.

PlotNo_Txt	Date	Frequency	No_Quadrats	Ave_Density	Average Percent Cover	Average Height
CADR-1	6/2/2012	50	62	27	12	29
CADR-2	6/2/2012	40	62	7	6	20
CADR-3	6/2/2012	13	62	1	0	7
CADR-4	6/4/2012	32	62	7	2	14
CADR-5	6/3/2012	23	62	9	2	10

PlotNo_Txt	Date	Frequency	No_Quadrats	Ave_Density	Average Percent Cover	Average Height
CADR-6	6/3/2012	16	62	5	1	5
CADR-7	6/4/2012	40	62	31	11	20
CADR-9	6/4/2012	29	62	6	1	11
Average		**30**	**62**	**12**	**4**	**14**
SD		**12.7**	**0.0**	**11.0**	**4.5**	**7.9**

Table 4. All infestations of whitetop at the U.S. Air Force Academy.

	2002	2007	2012
Occupied Acres	**20.47**	**12.76**	**13.08**
Estimated Number of Shoots	**1,671,728**	**1,035,489**	**828,036**
Number of Extant Features	**164**	**241**	**203**
Number of Eradicated Features	NA	0	77

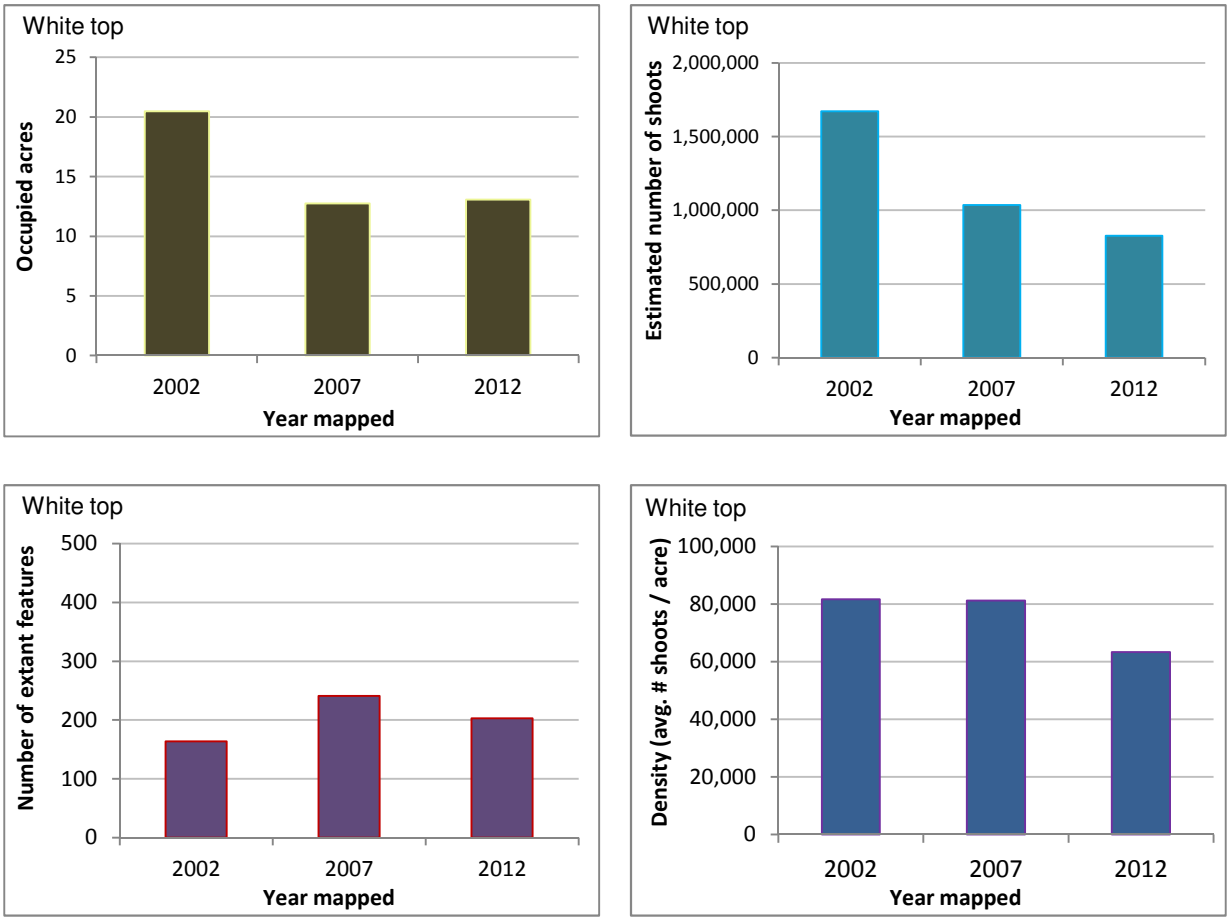
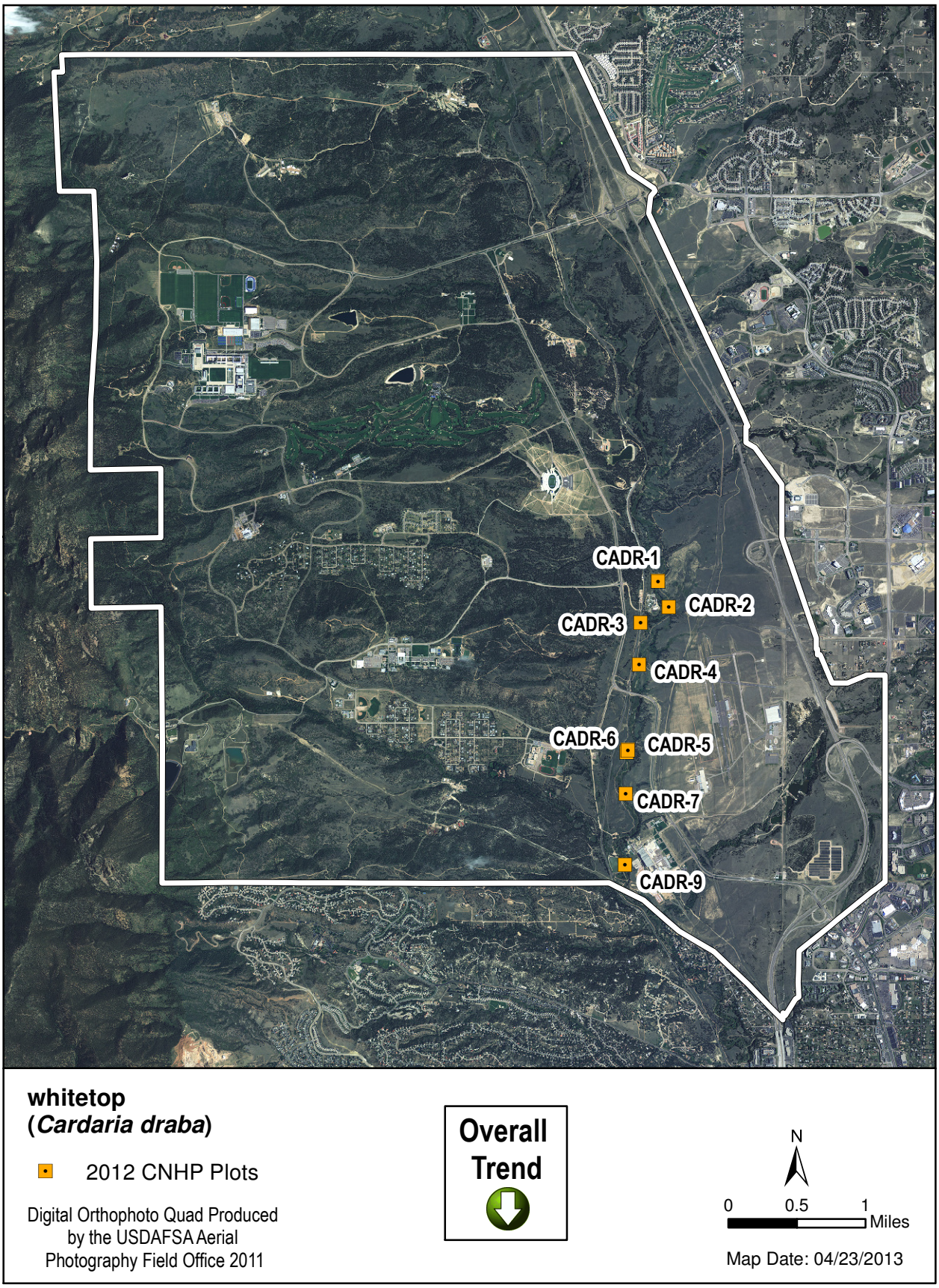
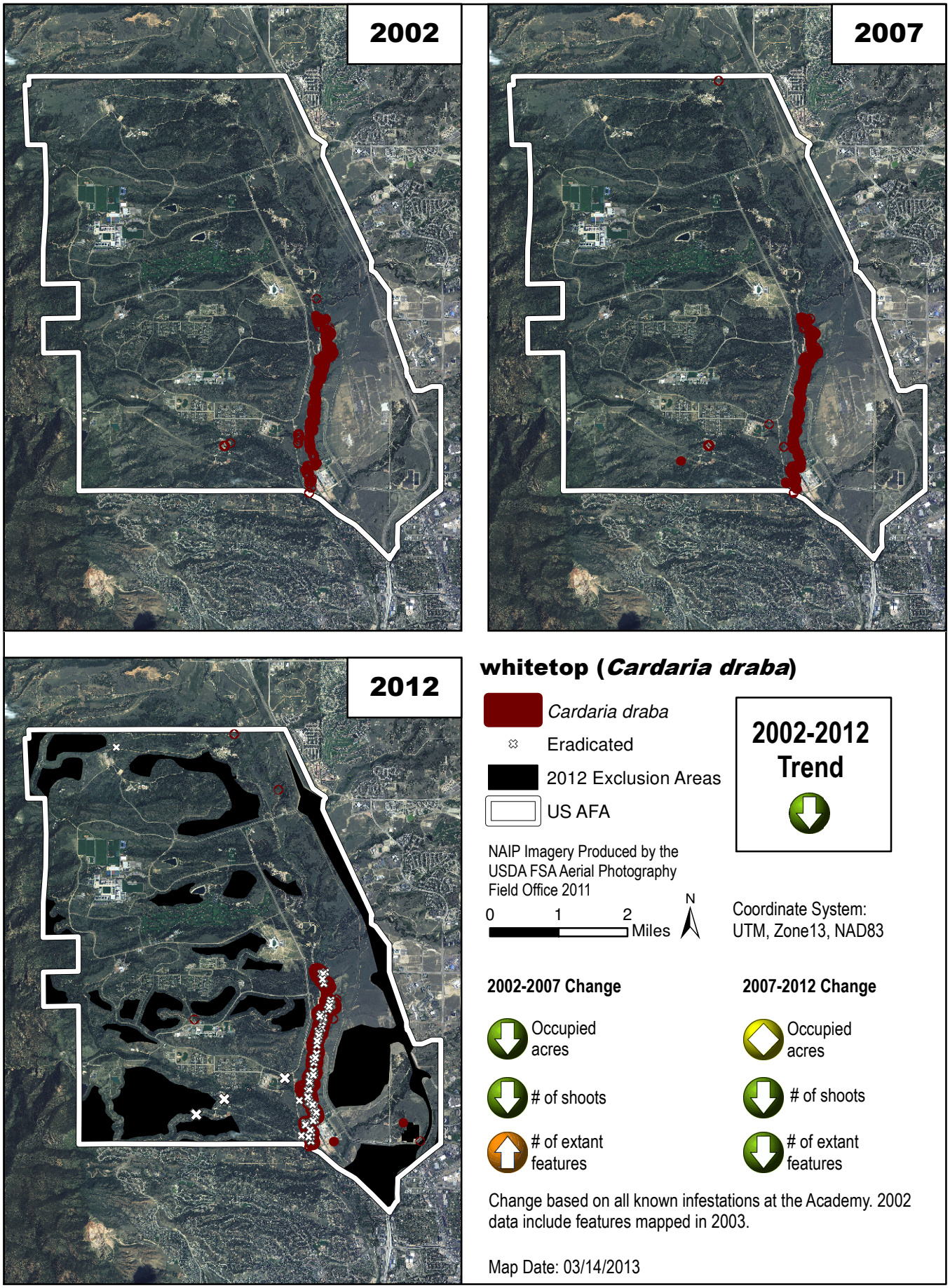


Figure 3. Whitetop trend, 2002-2012.



Map 5. 2012 whitetop plots at the Academy.



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

Musk Thistle (*Carduus nutans*)

Photo by Michelle Washebek

Treated	Untreated
	
Number of individuals declined in treated plots.	**Number of individuals generally increased in untreated plots.**

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

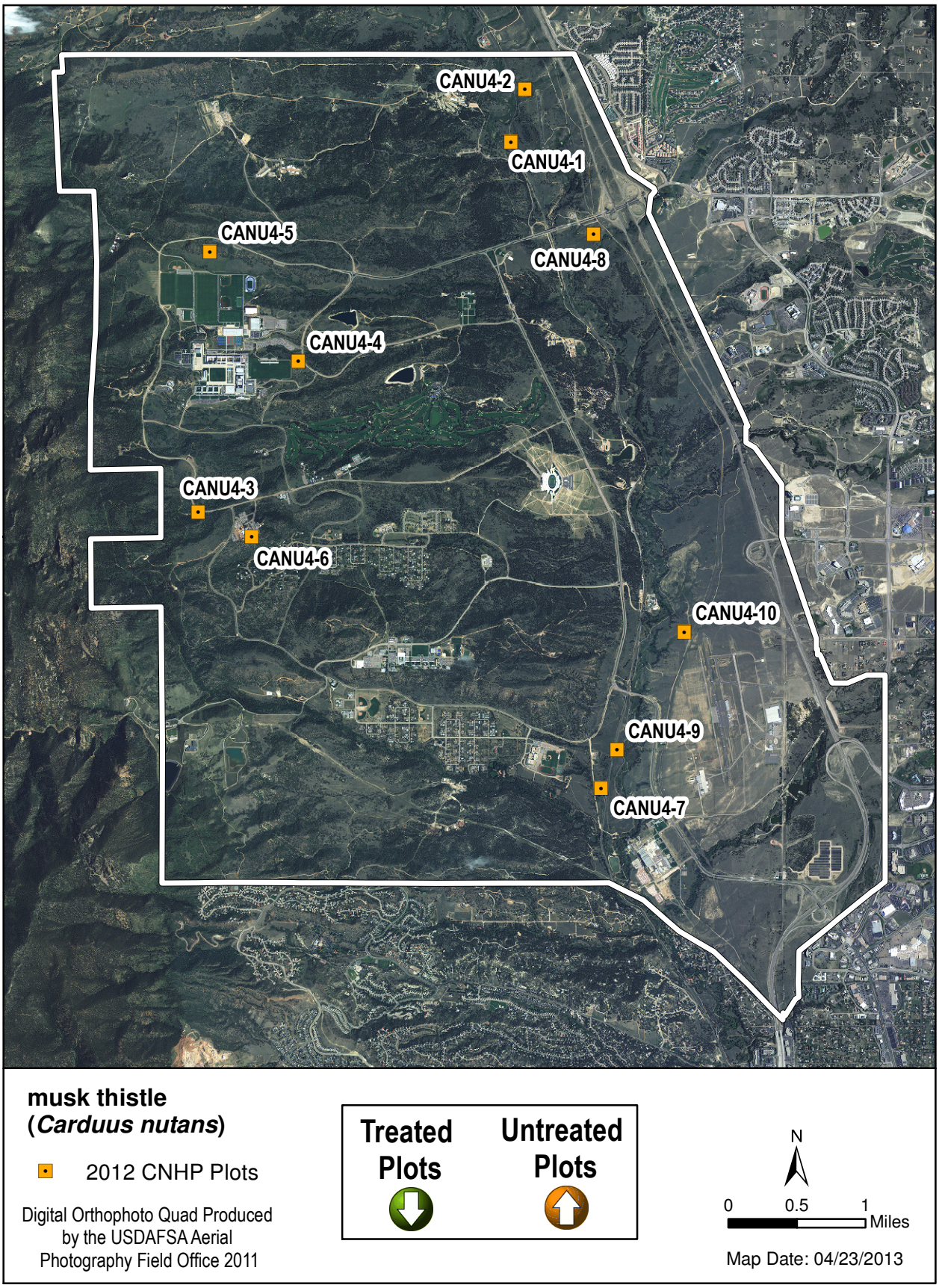
All ten of the established plots were revisited in 2012 by the weed mapper (see Map 7 for plot locations). In 2012, photos were not repeated from the permanent rebar and plants that occur within the frame of the photo were not counted (Table 5); however, density and cover for each infestation was collected. Plots 1 and 10 were the only plots where we had to extrapolate the population size as the occurrence is much larger than the photopoint. None of the plots were treated in 2012, but six of them were treated in 2011 (Table 5). Only one plot, plot 10, has never been treated and the population size remains high. All of the other plots have been treated at least twice. There seems to be a good control rate when this species is treated and it often lasts multiple years, but 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. 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 bicontrol at select AFA sites.

Musk thistle appears to be spreading at Academy and Farish (Lavender-Greenwell and Rondeau 2013); however, the rate of spread would probably be even greater if treatment was not being applied. Recommendations for musk thistle include continuation of herbicide treatment of large infestations in 2013, and manual destruction of plants in smaller infestations and bag inflorescences if they contain ripe seed. All 10 plots should be revisited in 2013.

Table 5. Musk thistle population size at 10 plots, 2008-2012. Bolded numbers were treated plots.

Plot	2008	2009	2010	2011	2012
1	11	134	**9**	**7**	600
2	**6**	80	**5**	**160**	1
3	**1**	**2**	**1***	**8**	1
4	1	63	**0**	**0**	0
5	1	27	**10***	0	225
6	**10**	45	**33**	3	21
7	**102**	**90**	**25**	**0**	0
8	212	**31**	**10**	**7**	36
9	160	**1**	**1**	**0**	0
10	500	Not visited	**40+**	400	600



Map 7. 2012 musk thistle plots at the Academy.

Diffuse Knapweed (*Centaurea diffusa*)

Increasing and widespread. Select control may be most feasible option.

Photo by Michelle Washebek

Species	Sampling Methods
Diffuse knapweed	5 non-biocontrol plots established in 2012; 1 biocontrol plot established in 2011 (Michels et al. 2013)

In 2012 we established 5 permanent plots and Michels et al. (2013) had one biocontrol plot (Map 8). The following table provides a summary of the 6 permanent plots.

Table 6. Summary of 2012 permanent plot data for diffuse knapweed.

Plot Number	Date	Frequency	No_Quadrats	Ave_Density	Average Percent Cover	Average Height	% quadrats with plant
CEDI3-1	7/18/2012	5	58	0	0	2	9%
CEDI3-2	8/22/2012	13	62	1	3	7	21%
CEDI3-3	8/21/2012	8	56	0	1	5	14%
CEDI3-4	8/22/2012	4	38	0	1	4	11%
CEDI3-5	8/15/2012	9	63	1	3	4	14%
Average		**8**	**55**	**0**	**2**	**4**	**14%**
SD		**4**	**10**	**0**	**1**	**2**	**5%**
Biocontrol							
DKrailroad	8/13/2012	34	61	3	16	21	56%

In addition to establishing permanent plots in 2012, we conducted weed mapping of diffuse knapweed (Lavender-Greenwell and Rondeau 2013). The following summarizes the results. Diffuse knapweed occupied 101 acres in 2012, 19 acres fewer than 2007, and 56 acres more than in 2002 (Table 7, Figure 4). All other indicators significantly increased in each sampling year. There was a 238% increase in number of shoots from 2007 to 2012. The number of extant mapped areas also increased (37%) in the same time period (Table 7, Map 9).

Diffuse and spotted knapweeds occupy the same areas in Colorado and are hybridizing at AFA; it is common to find hybrid swarms.

Table 7. Infestations of diffuse knapweed within comparable designated mapping areas at the U.S. Air Force Academy.

	2002	2007	2012
Occupied Acres	45.42	119.86	100.58
Estimated Number of Shoots	130,589	394,197	1,334,253
Number of Extant Features	251	913	1,255
Number of Eradicated Features	NA	0	406

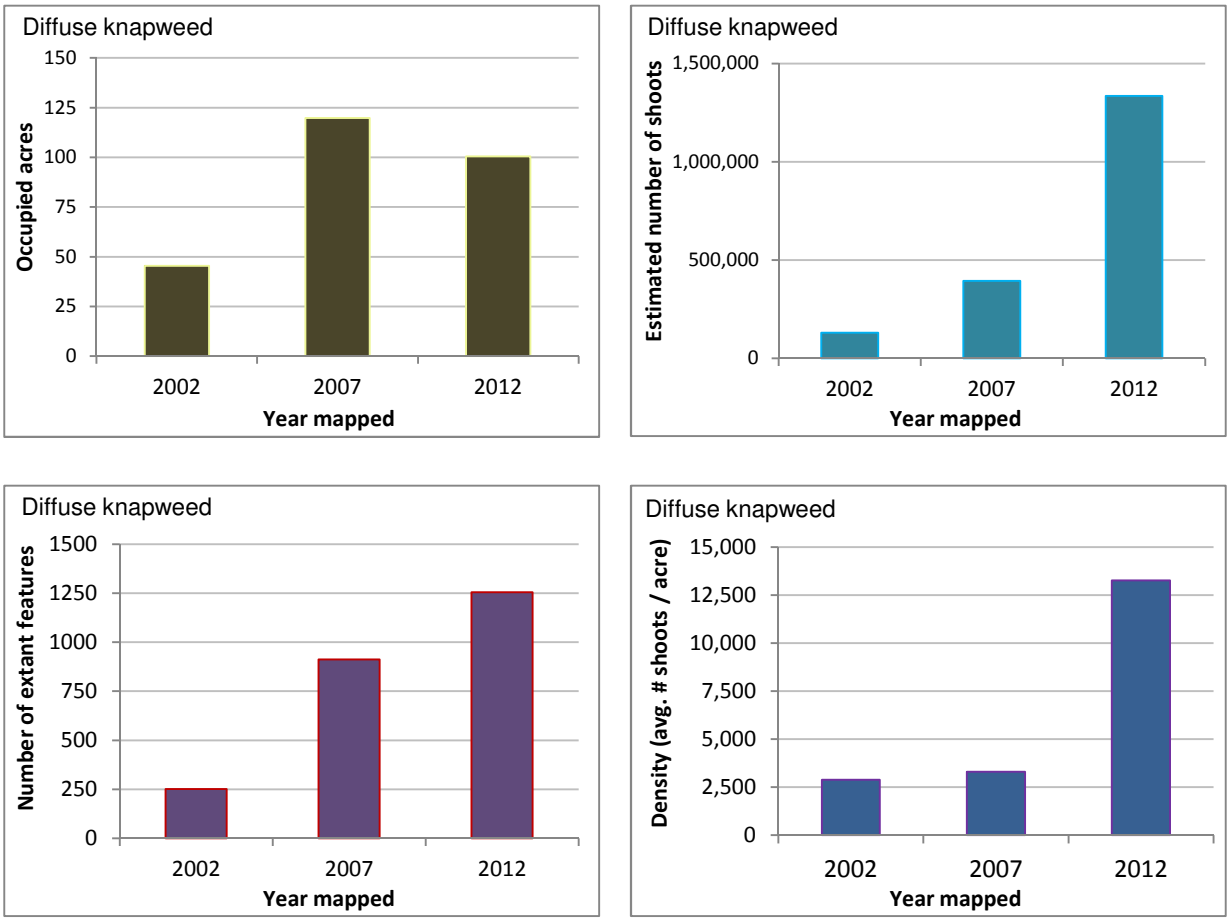
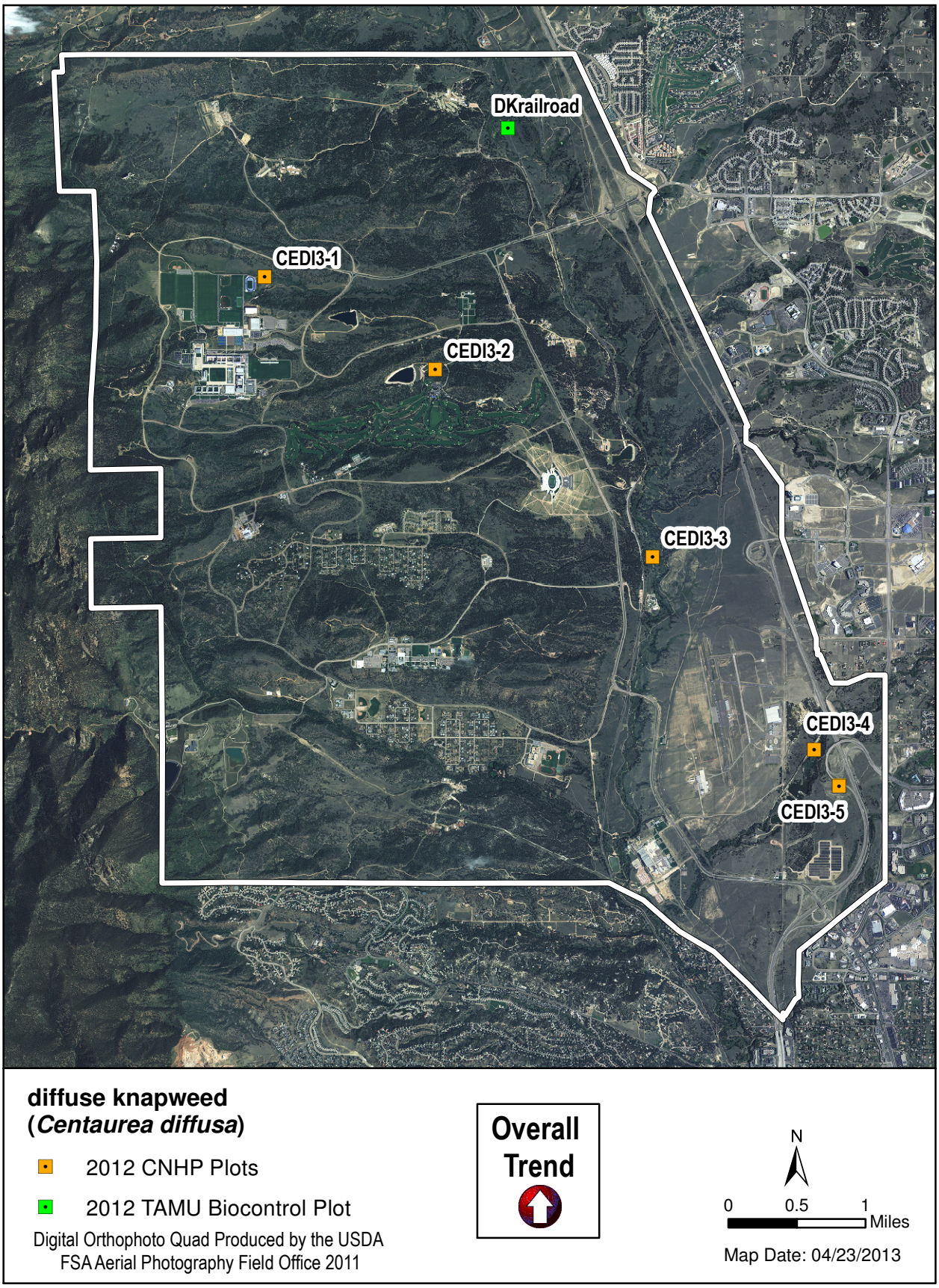
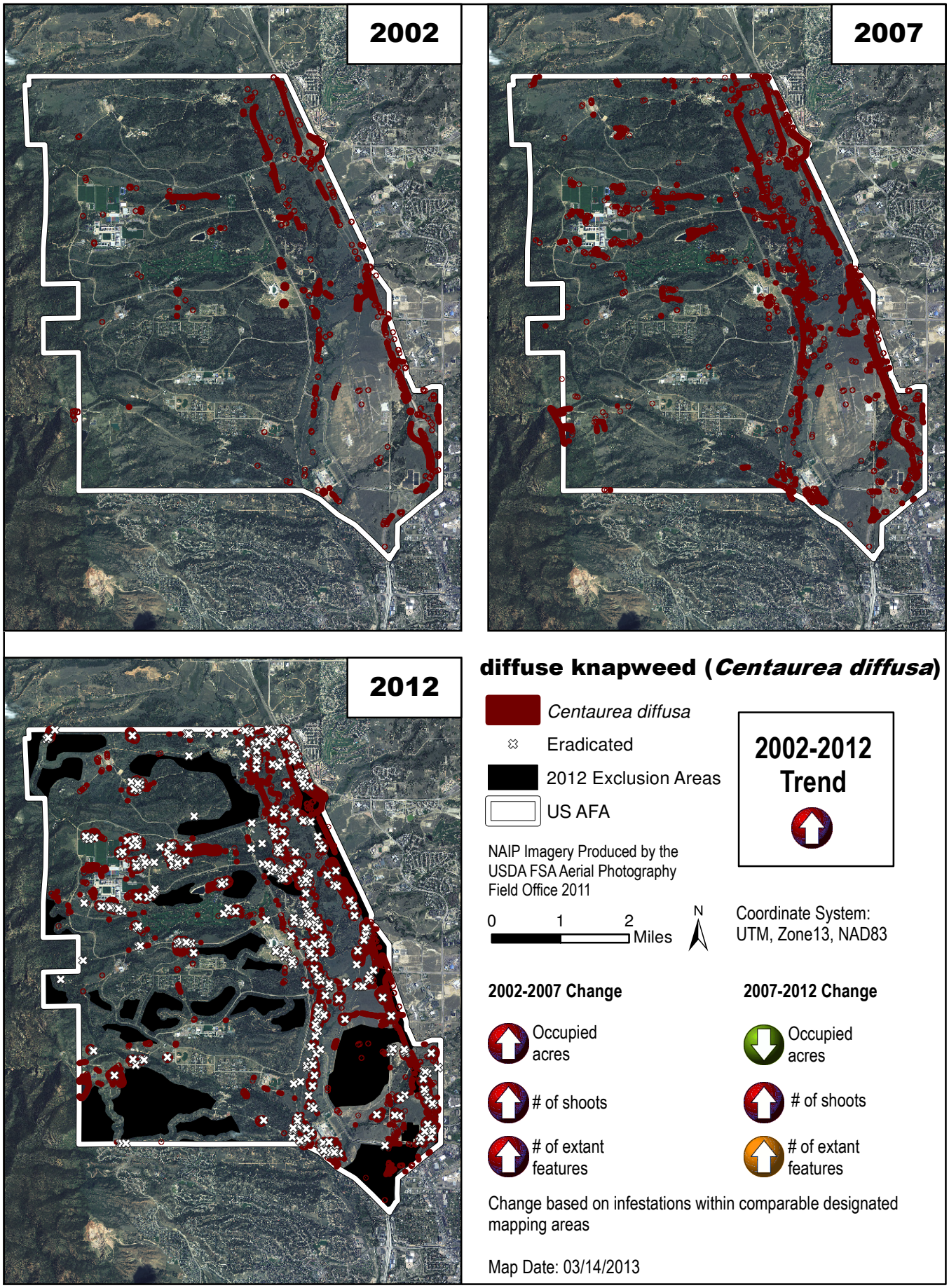


Figure 4. Diffuse knapweed trend, 2002-2012.

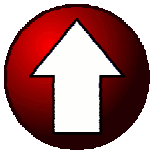


Map 8. 2012 diffuse knapweed plots at the Academy.



Map 9. Distribution of diffuse knapweed at the Academy in 2002, 2007, and 2012.

Spotted Knapweed (*Centaurea maculosa*)



Rapidly spreading and too common now for eradication.

Photo by Michelle Washebek

We established 5 permanent plots in 2012 and Michaels et al. (2013) had 3 permanent biocontrol plots in 2011 (Table 8, Map 10). See the following table for a summary of cover, density, frequency, etc. We will continue to monitor these plots to assist managers with effectiveness of treatments.

Table 8. Summary of 2012 permanent plot data for spotted knapweed.

Plot Number	Date	Frequency	No_Quadrats	Ave_Density	Average Percent Cover	Average Height	% quadrats with plant
CEMA4-1	7/24/2012	14	62	2	2	8	23%
CEMA4-2	7/24/2012	17	63	2	2	9	27%
CEMA4-3	7/18/2012	2	62	0	0	1	3%
CEMA4-4	8/15/2012	14	53	2	6	14	26%
CEMA4-5	7/25/2012	1	43	0	1	1	2%
Average		**10**	**57**	**1**	**2**	**7**	**16%**
SD		**8**	**9**	**1**	**2**	**6**	**12%**
Biocontrol							
SKmonck	8/10/2012	0	10	0	0	0	0%
SKploop3	8/10/2012	19	61	1	4	10	31%
SKploop1	8/10/2012	22	60	1	4	12	37%
Average		**14**	**44**	**1**	**3**	**7**	**23%**
SD		**12**	**29**	**1**	**2**	**6**	**20%**

In addition to establishing permanent plots in 2012, we conducted weed mapping of spotted knapweed (Lavender-Greenwell and Rondeau 2013). The following summarizes the results. Spotted knapweed occupied 53 acres in 2012, just slightly less than 2007 (Table 9, Figure 5). The number of shoots had a three-fold increase and the number of extant mapped areas increased 77%, from 319 to 565.

It continues to spread at a rapid rate, an average of 5 acres/year and is now prevalent in Monument Creek (Map 11). It was relatively uncommon at the Academy in 2002, occupying

only 4.7 acres. Unfortunately, this species has now become too common for eradication to be feasible without considerable effort.

Table 9. Infestations of spotted knapweed within comparable designated mapping areas at the U.S. Air Force Academy.

	2002	2007	2012
Occupied Acres	**4.67**	**57.52**	**53.02**
Estimated Number of Shoots	**3,485**	**127,627**	**543,144**
Number of Extant Features	**54**	**319**	**565**
Number of Eradicated Features	NA	16	156

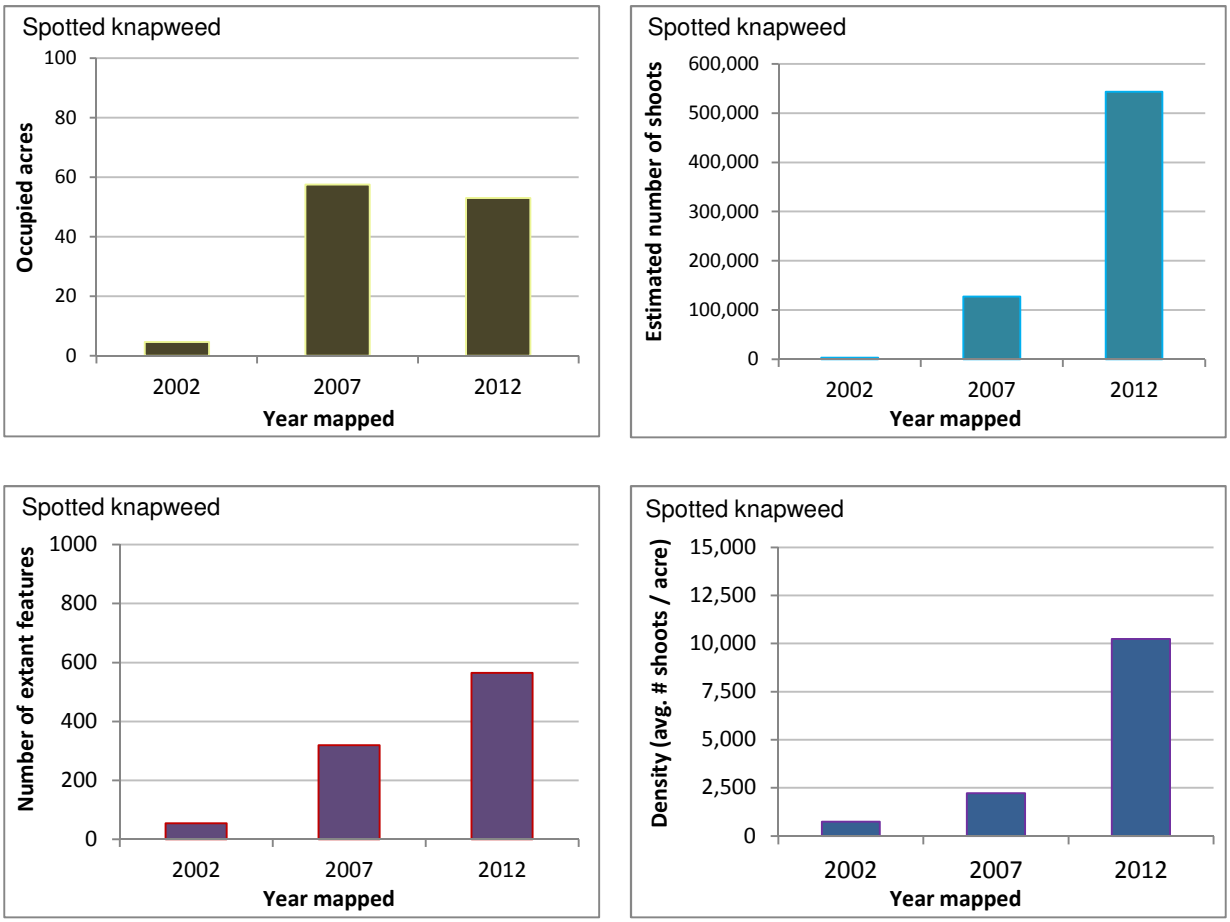
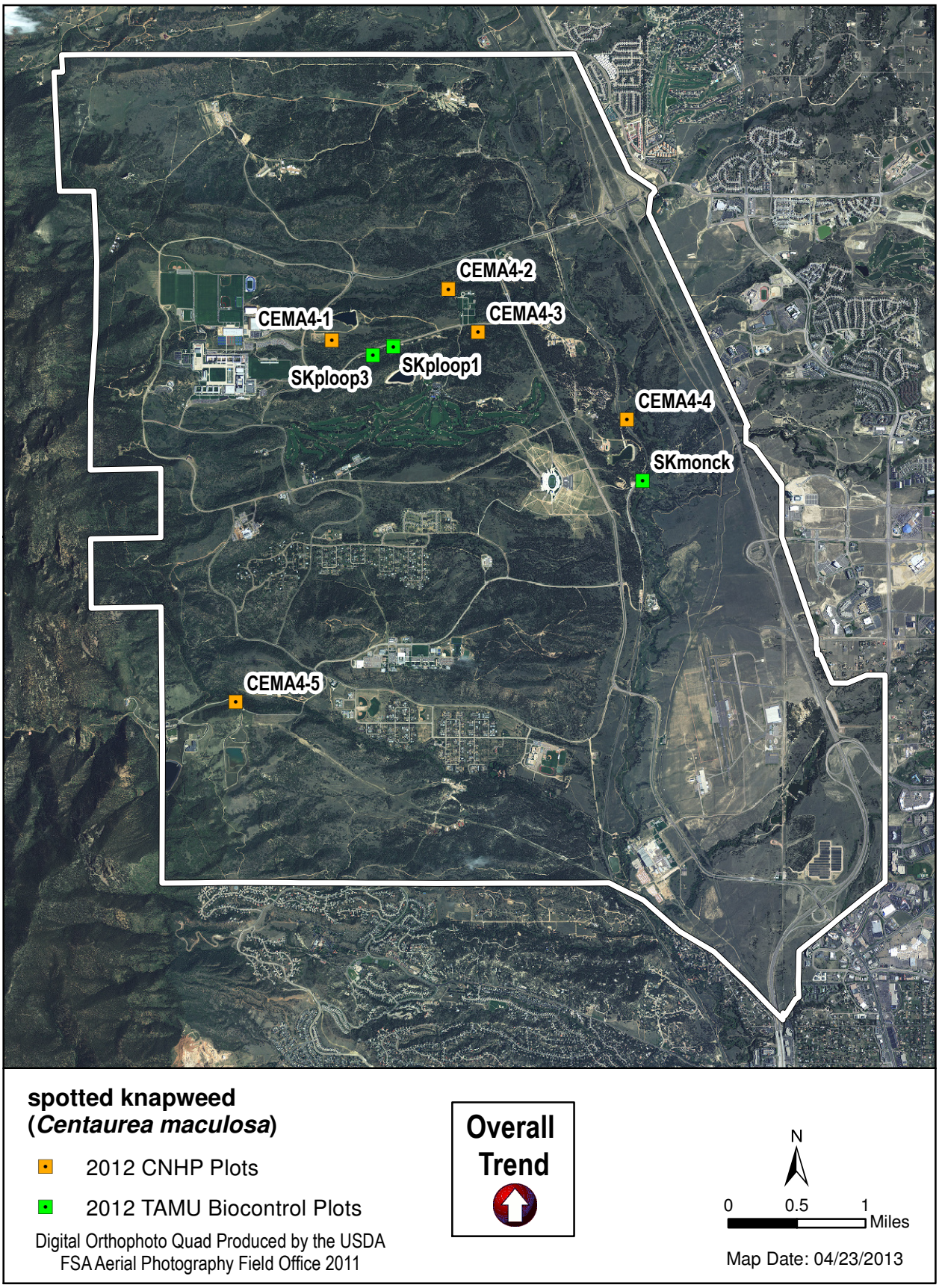
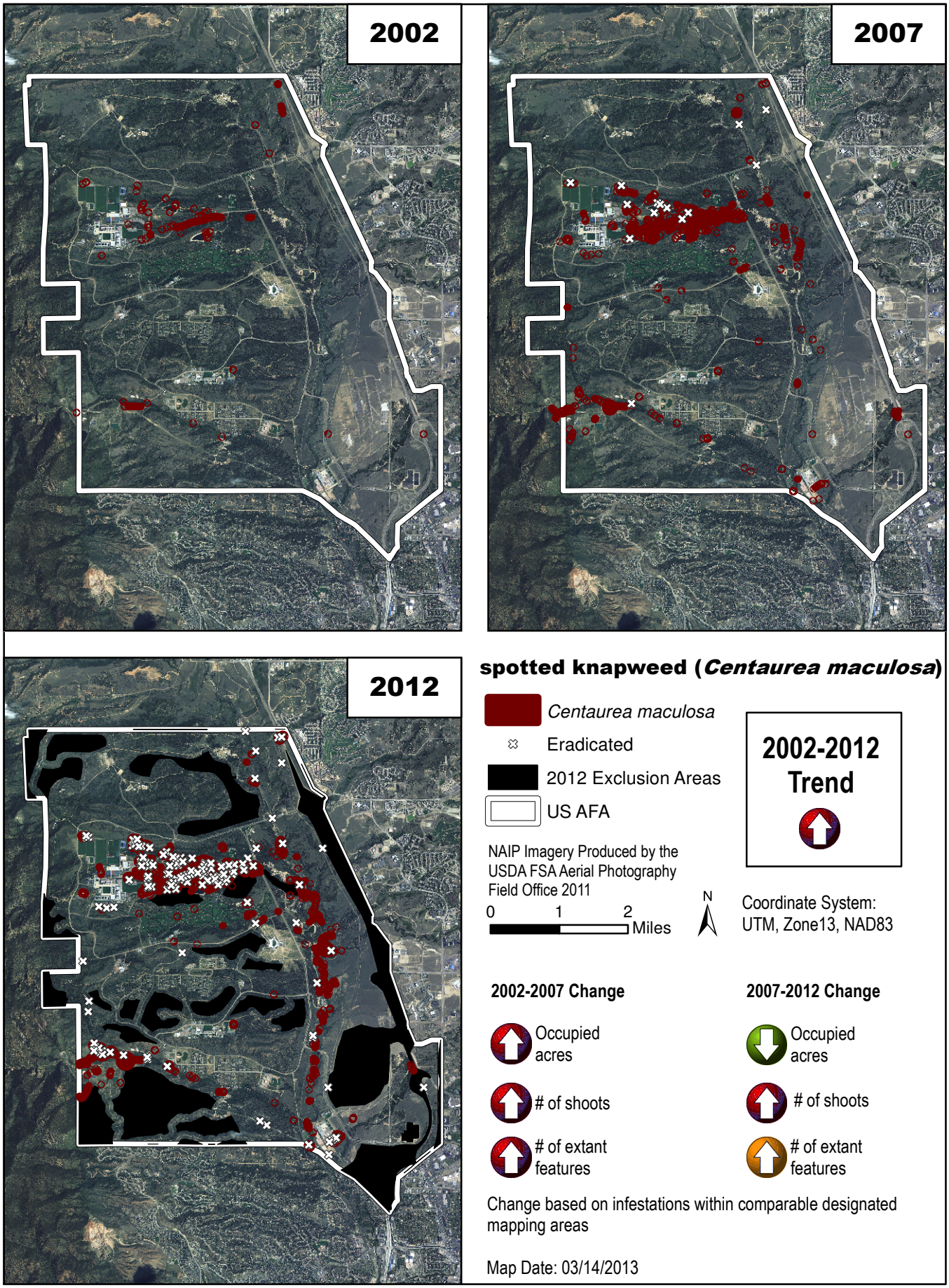


Figure 5. Spotted knapweed trend, 2002-2012.



Map 10. 2012 spotted knapweed plots at the Academy.



Map 11. Distribution of spotted knapweed 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. Table 10 summarizes the plot data; Map 12 depicts its distribution and Map 13 depicts plot locations.

Table 10. Summary of 2012 permanent plot data for Canada thistle.

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%**

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 11).

Table 11. Infestations of Canada thistle within comparable designated mapping areas at the U.S. Air Force Academy.

	2002	2007	2012
Occupied Acres	***79.27**	***90.68**	***90.17**
Estimated Number of Shoots	***408,121**	***379,992**	***1,079,070**
Number of Extant Features	***358**	***543**	***776**
Number of Eradicated Features	NA	0	*232

* Canada thistle numbers derived from 2007 designated mapping areas

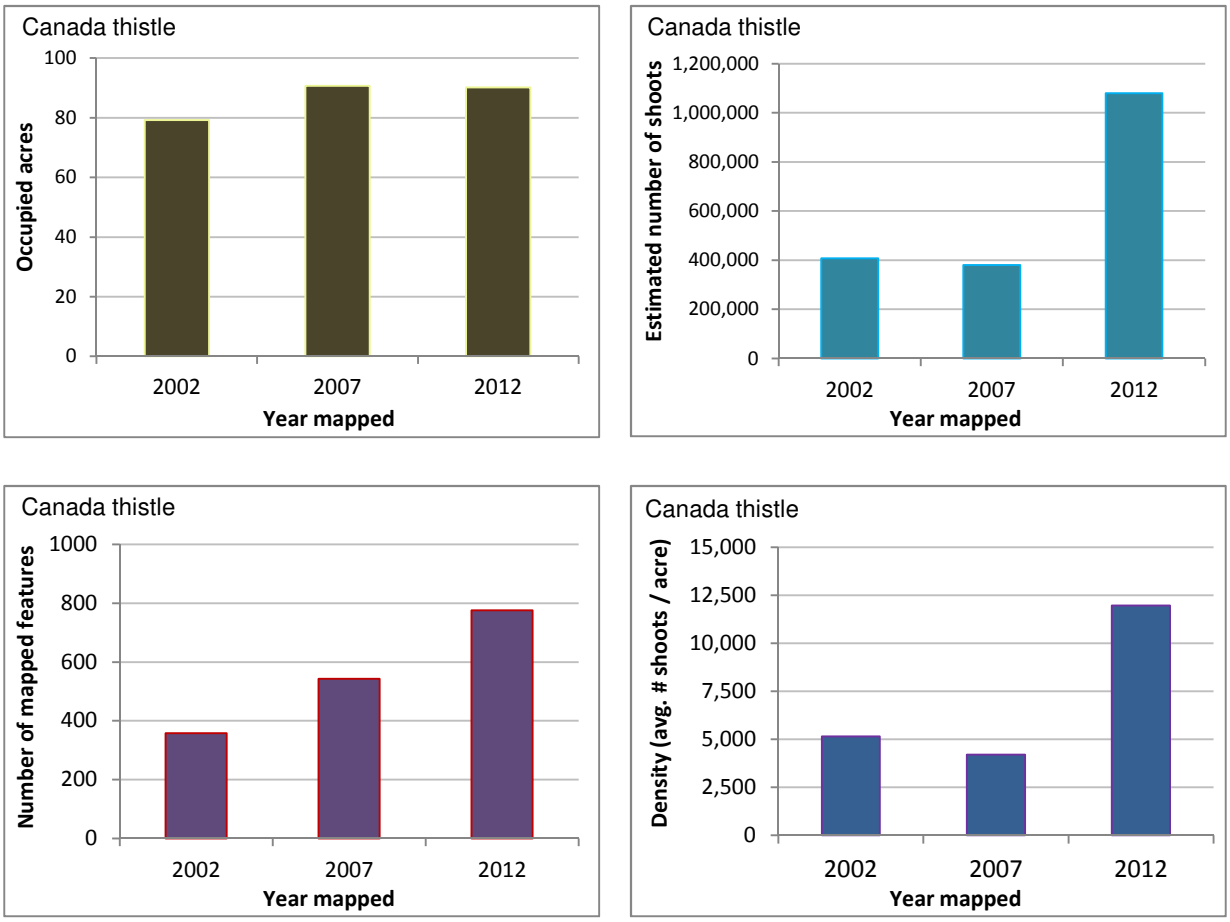
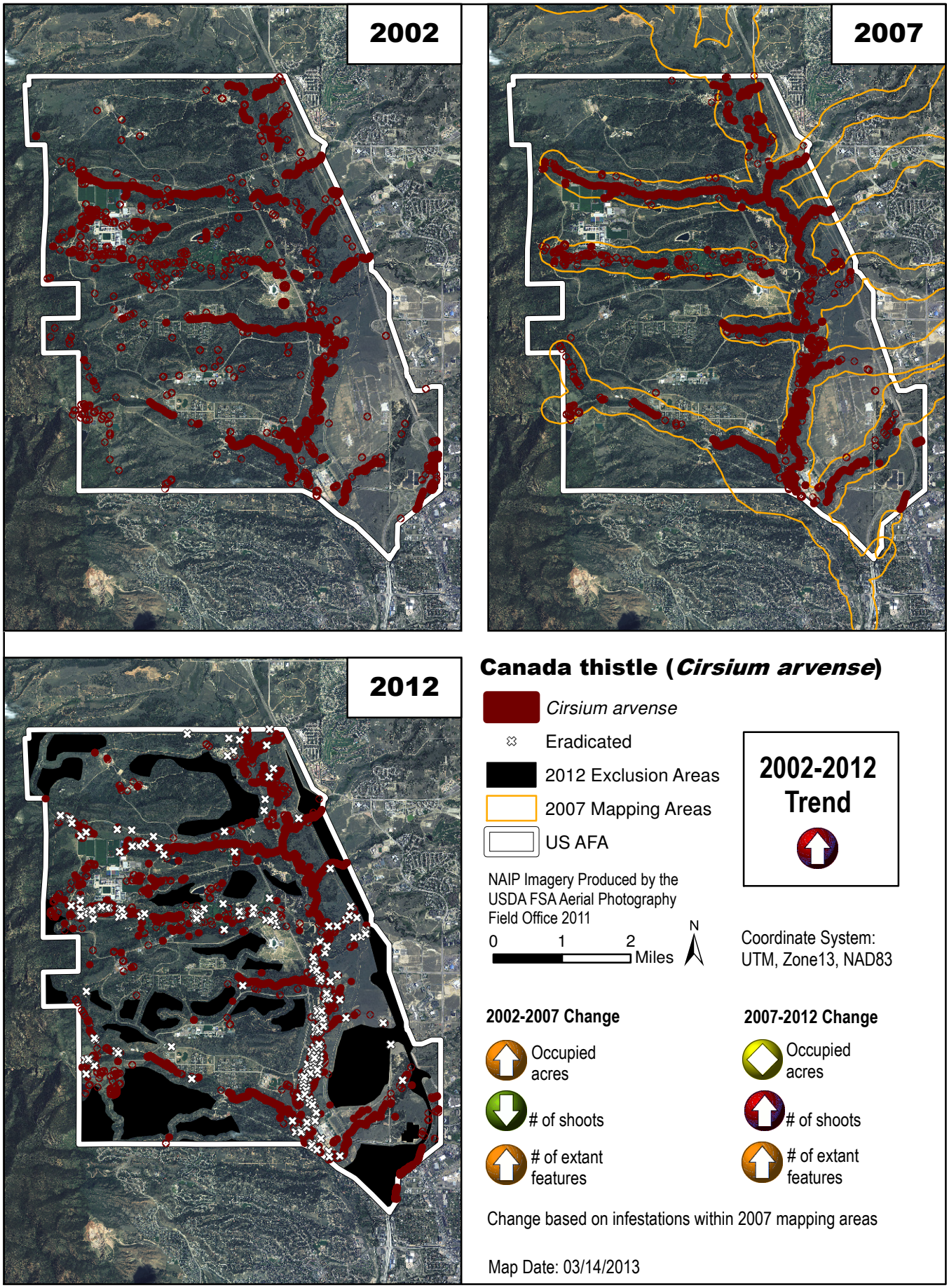
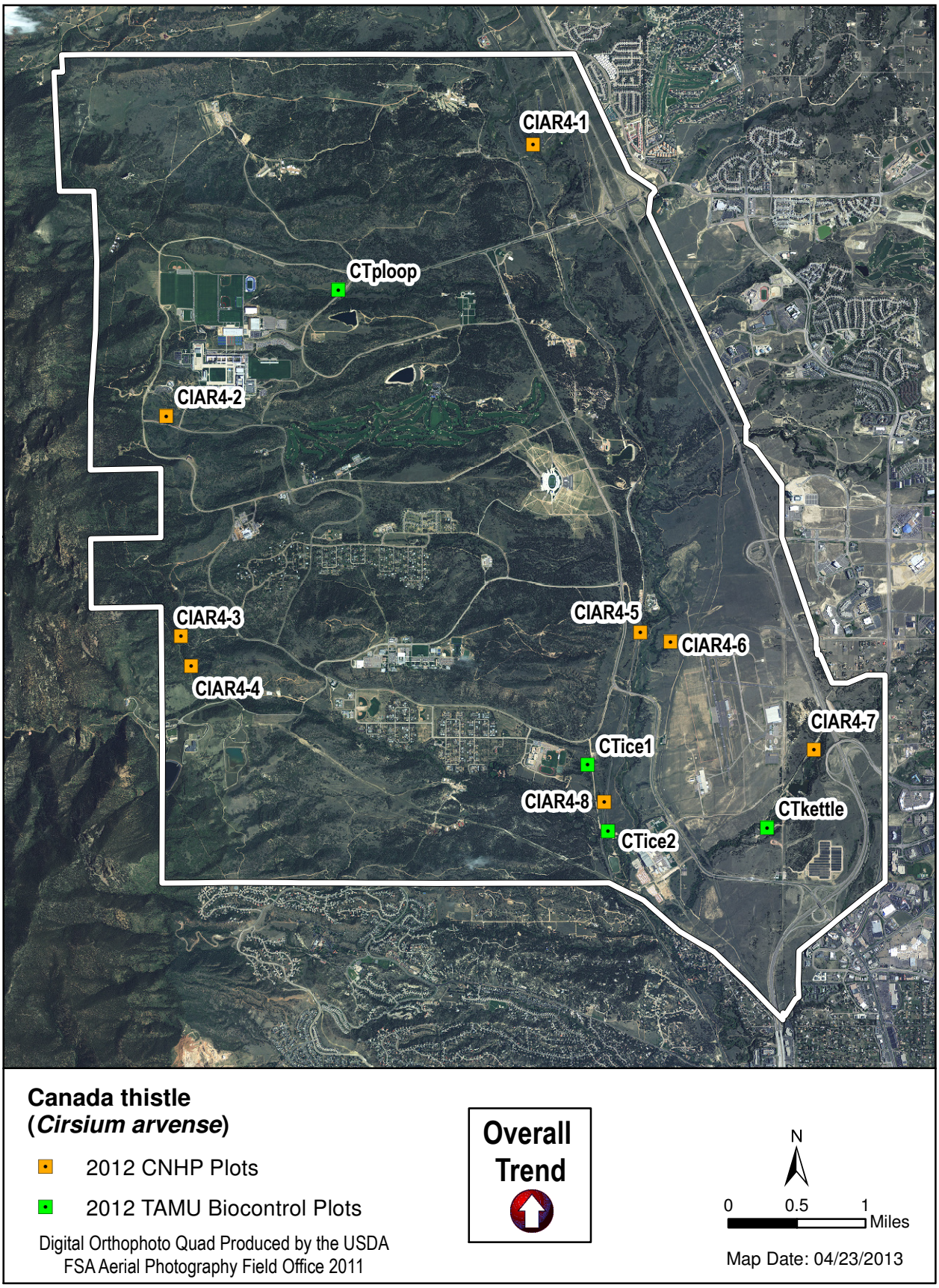


Figure 6. Canada thistle trend at the U.S. Air Force Academy, 2002-2012.



Map 12. Distribution of Canada thistle at the Academy in 2002, 2007, and 2012.



Map 13. 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.

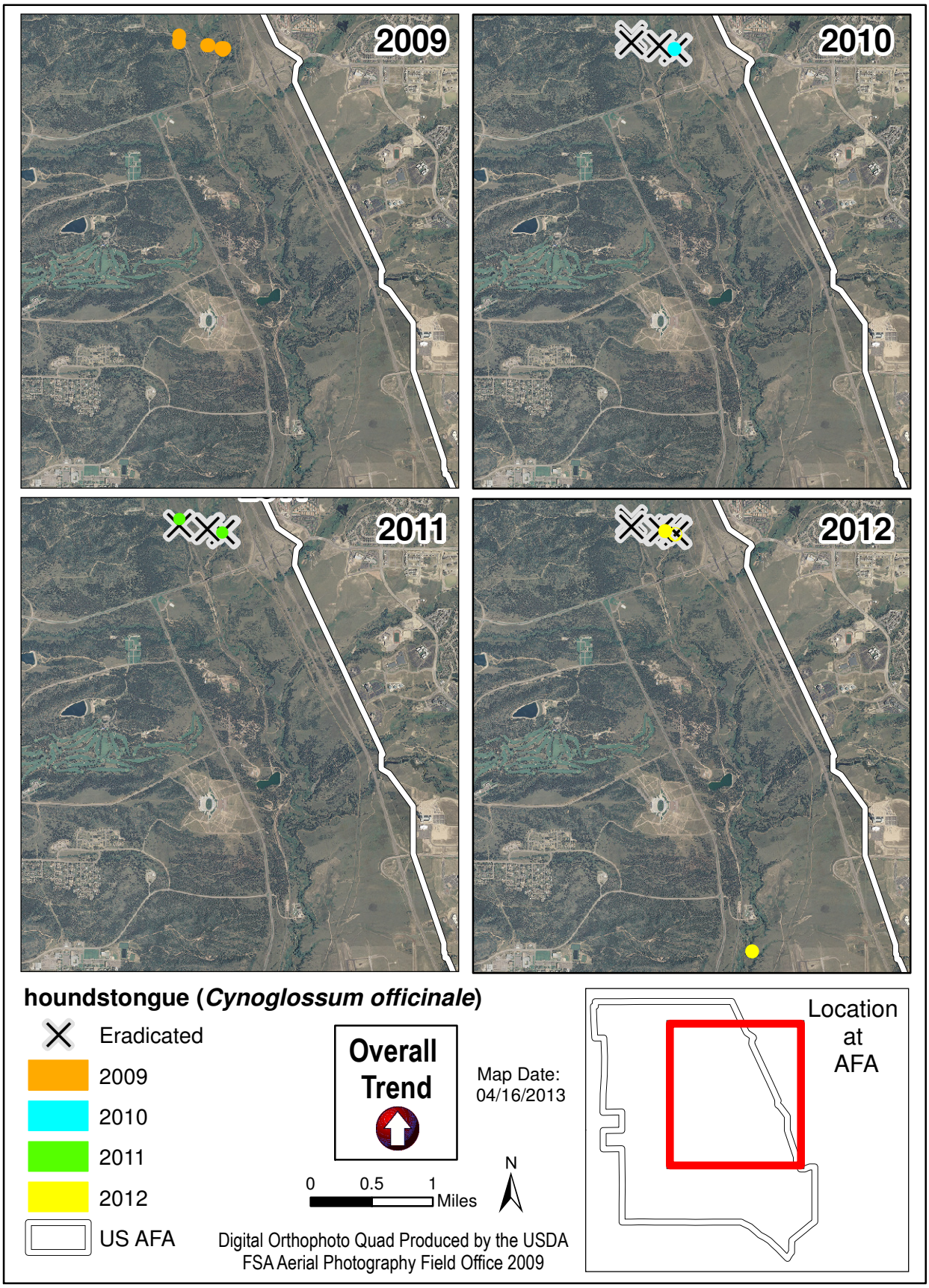
Photo by M. DiTomaso, University of California - Davis

Houndstongue was treated with herbicide in 2010 and 2011 and there was a notable decrease in the number of acres occupied. However, the plants did reproduce from seeds and the number of individuals increased in 2011 and 2012 as did the number of mapped features (Table 12, Map 14). In 2012, a new site was located south of the existing known sites and number of individuals also increased.

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 the seeds 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.

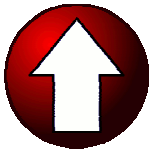
Table 12. Houndstongue summary data, 2009-2012.

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



Map 14. Distribution of houndstongue at the Academy between 2009 and 2012.

Leafy Spurge (*Euphorbia esula*)



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

Photo by Michelle Washebek

Species	Sampling Methods
Leafy spurge	Mapping 2002, 2007, 2012 8 non-biocontrol plots 4 biocontrol plots (Michels et al. 2013)

We established 10 permanent plots in 2012 (Table 13, Maps 15 and 16). Michels et al. (2013) terminated their biocontrol efforts of this species and herbicide treatment will be the primary control measure. The table below 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.

Table 13. Summary of 2012 permanent plot data for leafy spurge.

Plot Number	Date	Frequency	No_Quadrats	Ave_Density	Average Percent Cover	Average Height	Percent quadrats with plant
EUES-01	6/1/2012	18	62	2	2	9	29%
EUES-10	5/31/2012	11	62	2	1	6	18%
EUES-02	6/5/2012	25	62	8	3	15	40%
EUES-03	7/17/2012	14	55	1	1	7	25%
EUES-04	6/1/2012	17	62	1	1	10	27%
EUES-05	6/1/2012	19	62	3	1	11	31%
EUES-06	6/1/2012	22	62	2	2	14	35%
EUES-07	5/30/2012	7	62	0	0	2	11%
EUES-08	5/31/2012	17	62	2	2	12	27%
EUES-09	7/17/2012	21	49	4	2	10	43%
Average		**17.1**	**60.0**	**2.6**	**1.6**	**9.4**	**29%**
SD		**5.3**	**4.4**	**2.2**	**0.9**	**3.8**	**10%**

Table 14. Infestations of leafy spurge within comparable designated mapping areas at the U.S. Air Force Academy.

	2002	2007	2012
Occupied Acres	**0.91**	**7.58**	**10.64**
Estimated Number of Shoots	**28,338**	**336,337**	**275,713**
Number of Extant Features	**32**	**152**	**204**
Number of Eradicated Features	NA	2	30

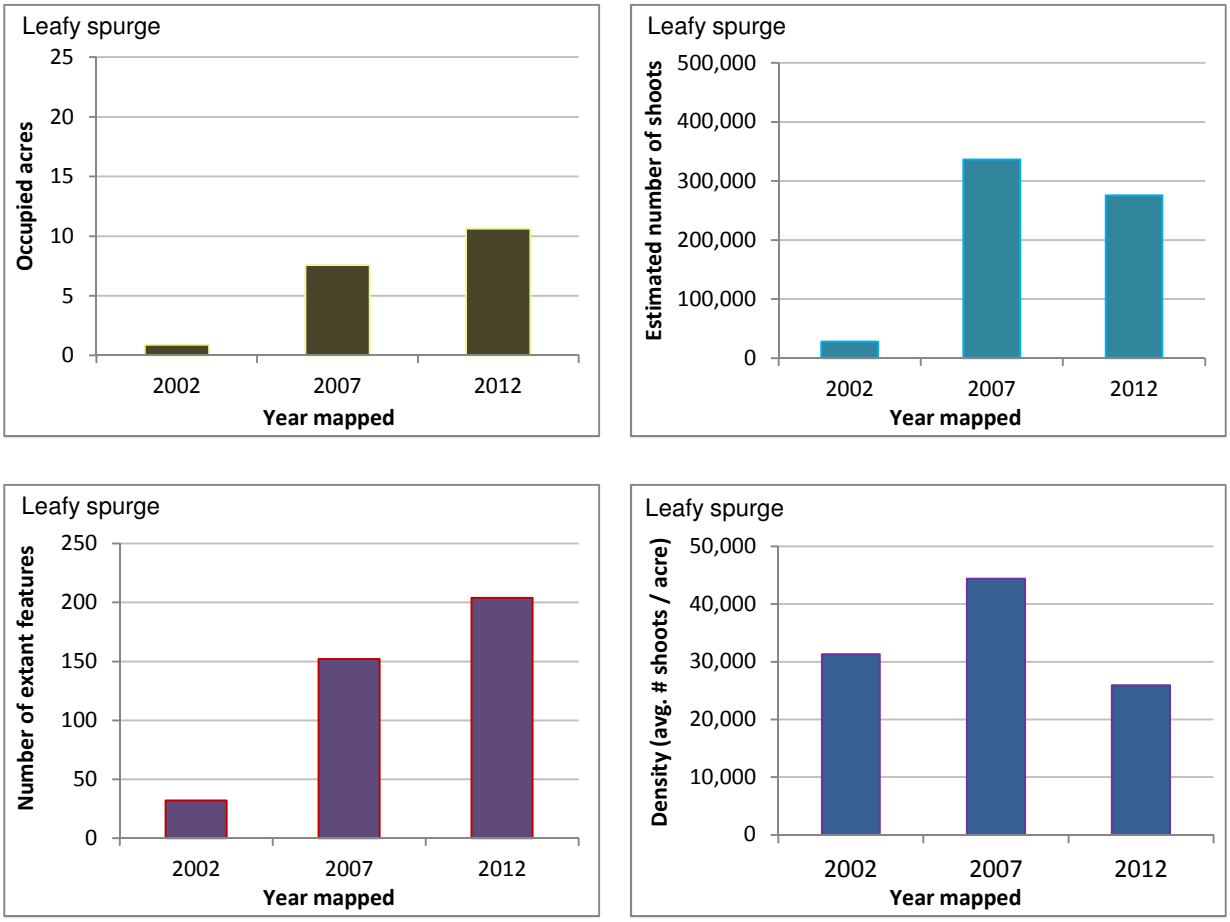
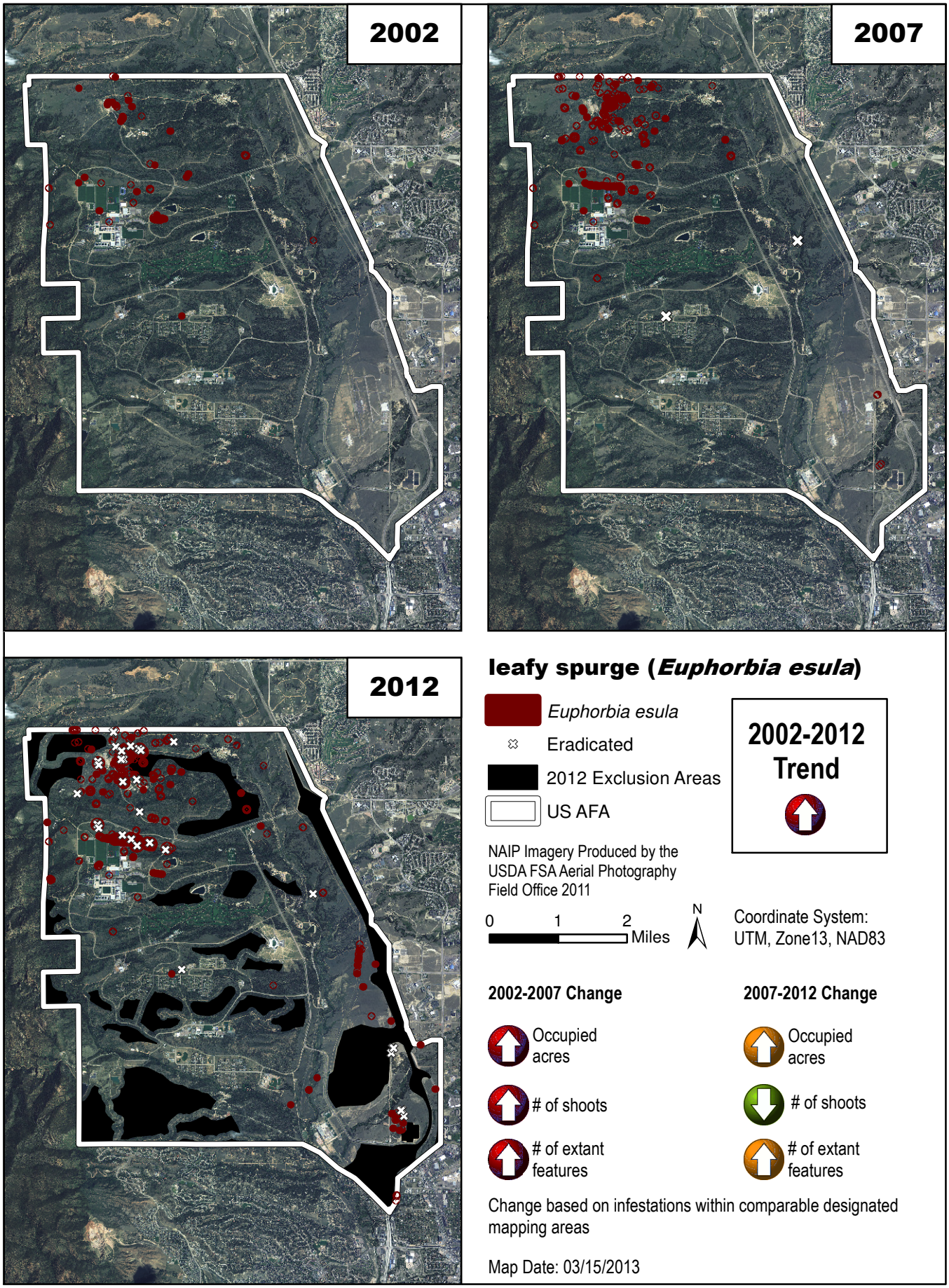
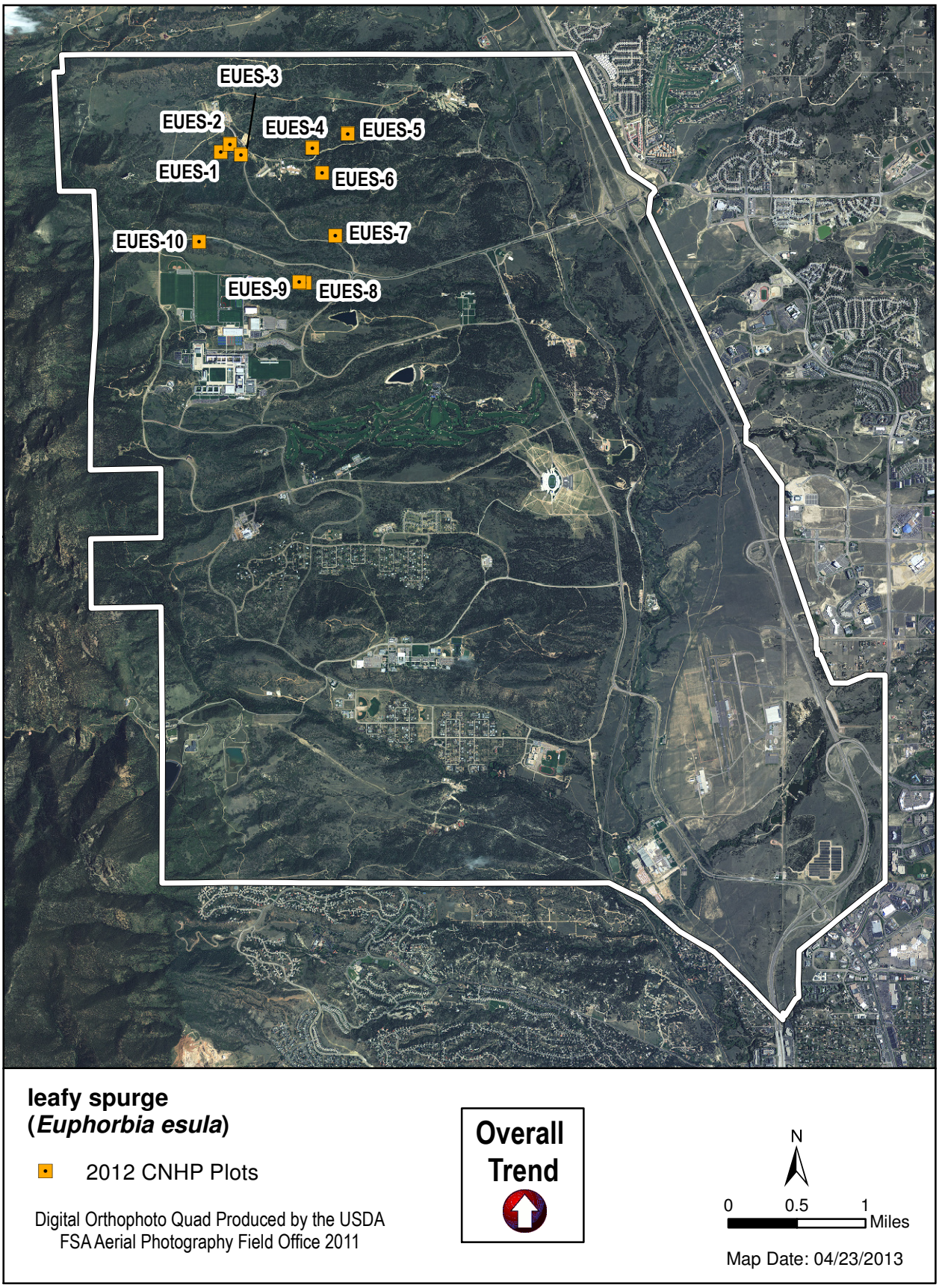


Figure 7. Leafy spurge trend at the U.S. Air Force Academy, 2002-2012.

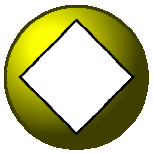


Map 15. Distribution of leafy spurge at the Academy in 2002, 2007, and 2012.



Map 16. 2012 leafy spurge plots at the Academy.

Myrtle Spurge (*Euphorbia myrsinites*)



Number of individuals increased but area and locations remained stable. Monitoring is essential.

Photo by David Anderson

Species	Sampling Methods
Myrtle spurge	mapping/ census

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 in 2005, at an early stage of its invasion, and some progress is being made towards its eradication (Table 15, Figure 8, Map 17). See Appendix C for information about each location depicted on the map. The total area infested by myrtle spurge at the Academy in 2012 was 0.23 acres with a total of 113 individuals at 10 locations; this is a slight reduction in overall area from 2011. The number of known extant locations slightly decreased from 12 to 10, indicating that control methods are working. The number of individual's increased approximately 2-fold from 57 to 113 (Table 15, Figure 8).

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 15. Myrtle spurge summary data, 2005-2012.

	2005	2006	2007	2008	2009	2010	2011	2012
No. of individuals	25	243	1,021	419	464	56	57	113
Area (acres)			0.18	0.66	2.4	0.5	0.25	0.23
Extant locations			7	13	12	10	12	10
Eradicated locations			0	1	6	12	16	25

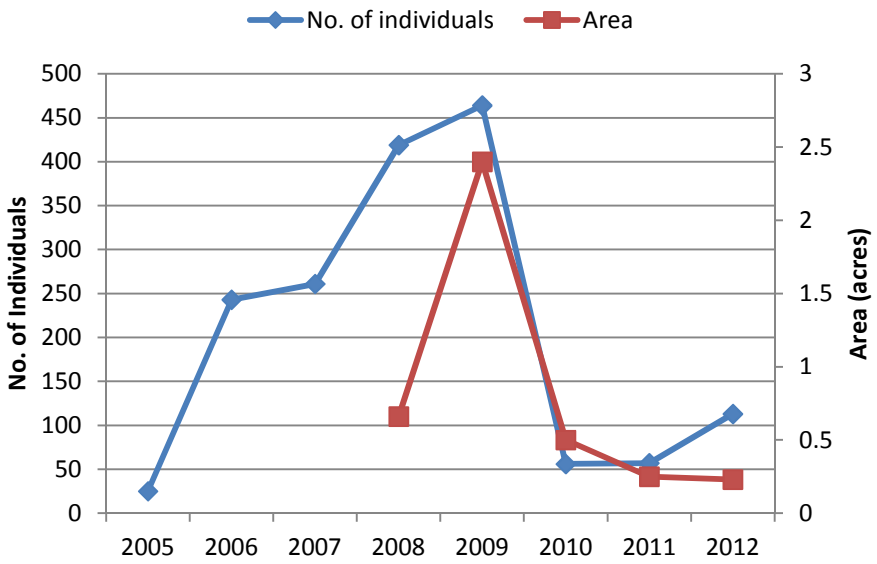
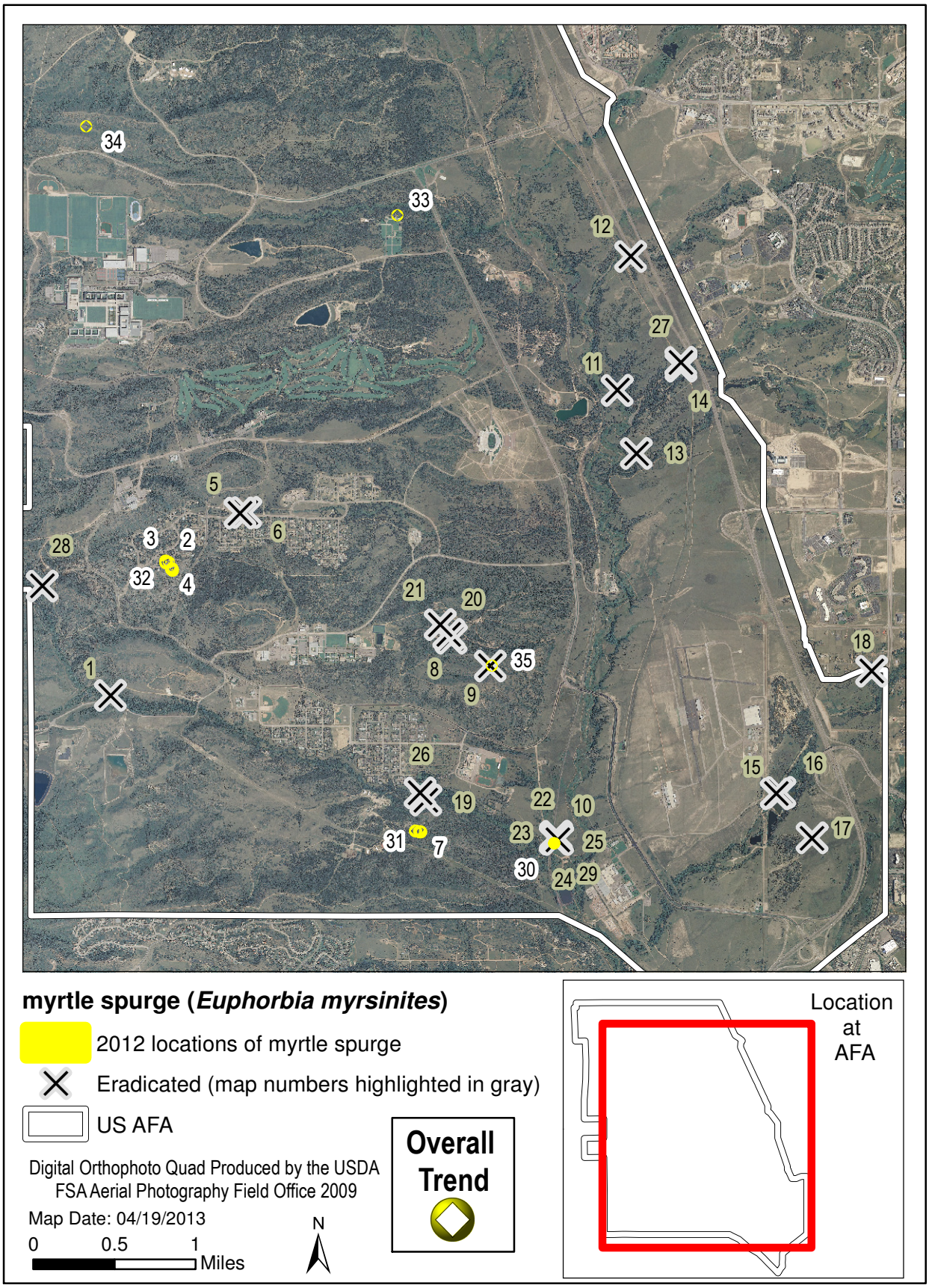


Figure 8. Number of individuals and occupied area for myrtle spurge 2005-2012.



Map 17. All known sites where myrtle spurge has been found at the Academy between 2005 and 2012. Numbers correspond to the locations described in Appendix C.

Yellow Spring Bedstraw (*Gallium verum*)

Wikipedia photo

Low cover from two known sites. Eradication is possible with aggressive treatment.

This species was discovered at the Academy in 2010 with one occurrence found near Ice Lake (Table 16, Map 18). 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 discovered two new and extant sites while the original site was still free of this weed. A high priority should be placed on eradicating this species as it is still in a responsive stage.

At Farish, one point was potentially documented. This should be checked in 2013 and if it is present, then eradication is critical.

Table 16. Yellow spring bedstraw summary data, 2010-2012.

	Occupied Area (m^2)	Number of Individuals	Number of Mapped Features
2010	28	700	1
2011	0	1	1
2012	40	566	2

Map 18. Distribution of yellow spring bedstraw at the Academy between 2010 and 2012.

Dames Rocket (*Hesperis matronalis*)

Photo by Brian Mihlbachler

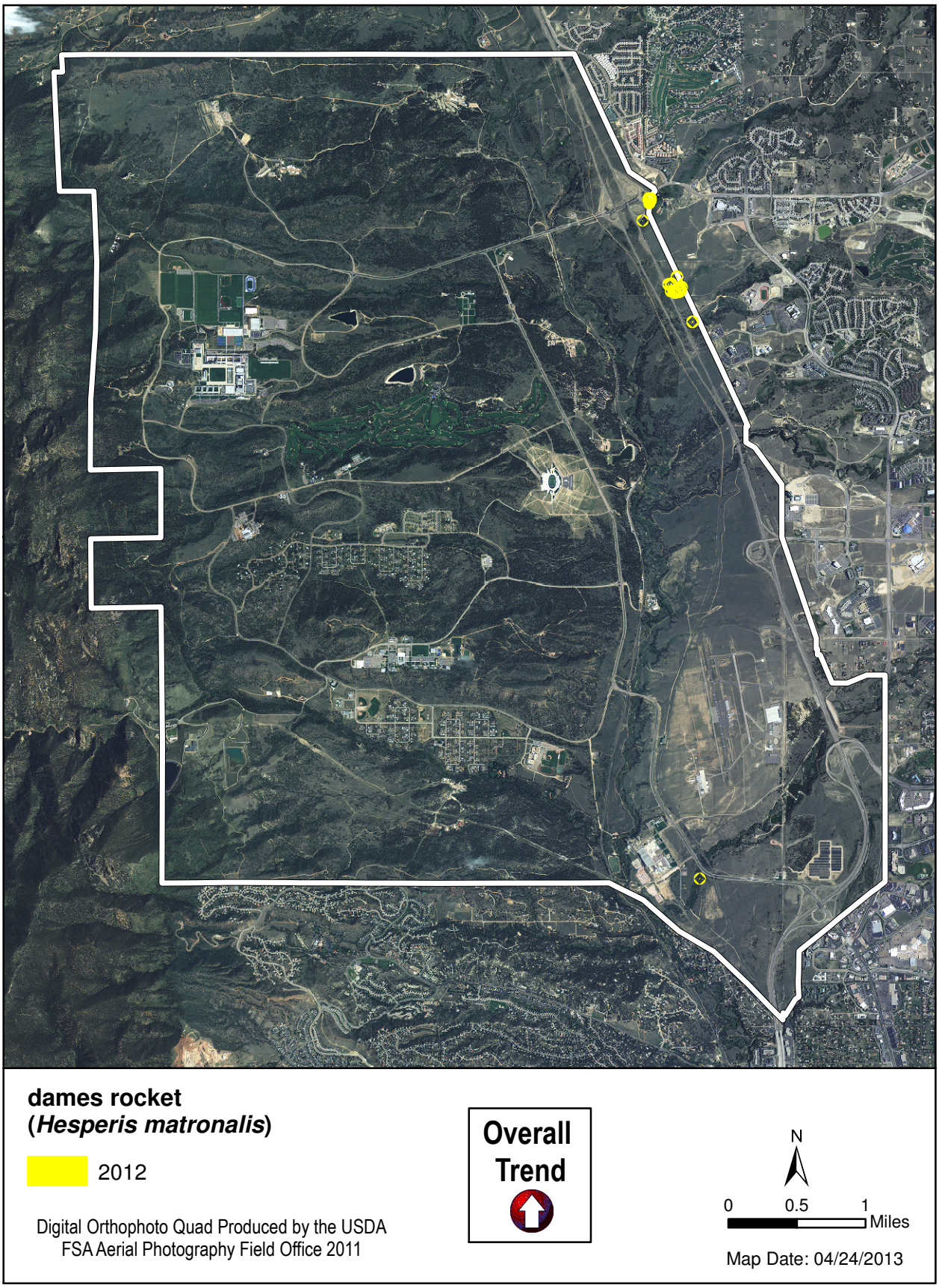
Newly discovered in 2012 and eradication is possible. Note outlier population in the south.

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 19). 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 will add this species to the yearly 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/)

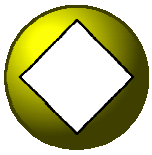
Preferred habitats include lowland forests, moist meadows, woodland edges and openings, banks of ditches and roadsides. The seeds are still available in the horticulture market.

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 19. Distribution of dames rocket at the Academy in 2012.

Common St. Johnswort (*Hypericum perforatum*)



Number of individuals and occupied area decreased and number of patches slightly increased. Continued aggressive herbicide treatment should continue and annual monitoring is essential.

Photo by Renée Rondeau

Species	2012 Sampling Methods
Common St. Johnswort	census/ mapping

Common St. Johnswort peaked in 2008-2009 and the trend has remained stable to slightly downwards over the last three years now (2010-2012) after the 2008-2009 peak (Table17, Figure 9). Although complete eradication is the goal, the stability over the last three years allows the managers to keep this species in check. Starting in 2010, management decided to treat this species more aggressively and to discontinue the biocontrol treatments. In 2011 many of the occurrences were treated with herbicide and in 2012, at least the patches north of the airfield and along Kettle Creek, were treated.

In 2011, 8 out of the 26 known locations were sprayed. The herbicide treatment negatively impacted the number of individuals in most cases (Table 18).

Additional infestations of common St. Johnswort were discovered along Kettle Creek in 2011; however, some patches were eradicated, illustrating that this species still has the potential to spread at the Academy (Table 18, Figure 9, Map 20). Based on these observations, it appears timely to use herbicide to eradicate small, founder infestations along Kettle Creek and on the roadsides. It will be necessary to continue perimeter mapping and census of the entire population of this species in 2013 to inform eradication efforts for this species.

Table 17. Common St. Johnswort summary data, 2007-2012.

	Occupied Area (m^2)	Number of Individuals	Number of 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

Table 18. Number of individuals in areas treated with herbicide. Herbicide treatment occurred in 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

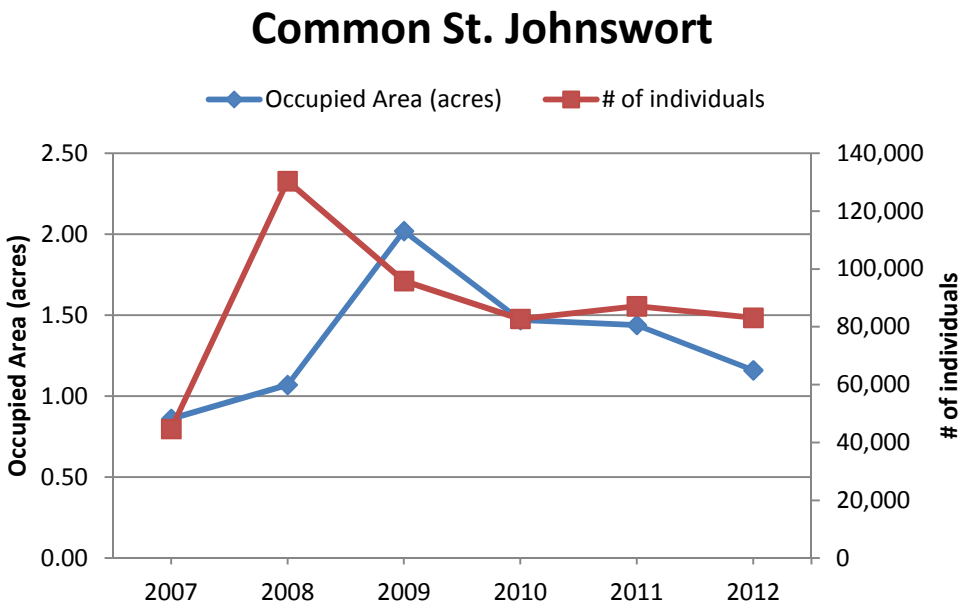
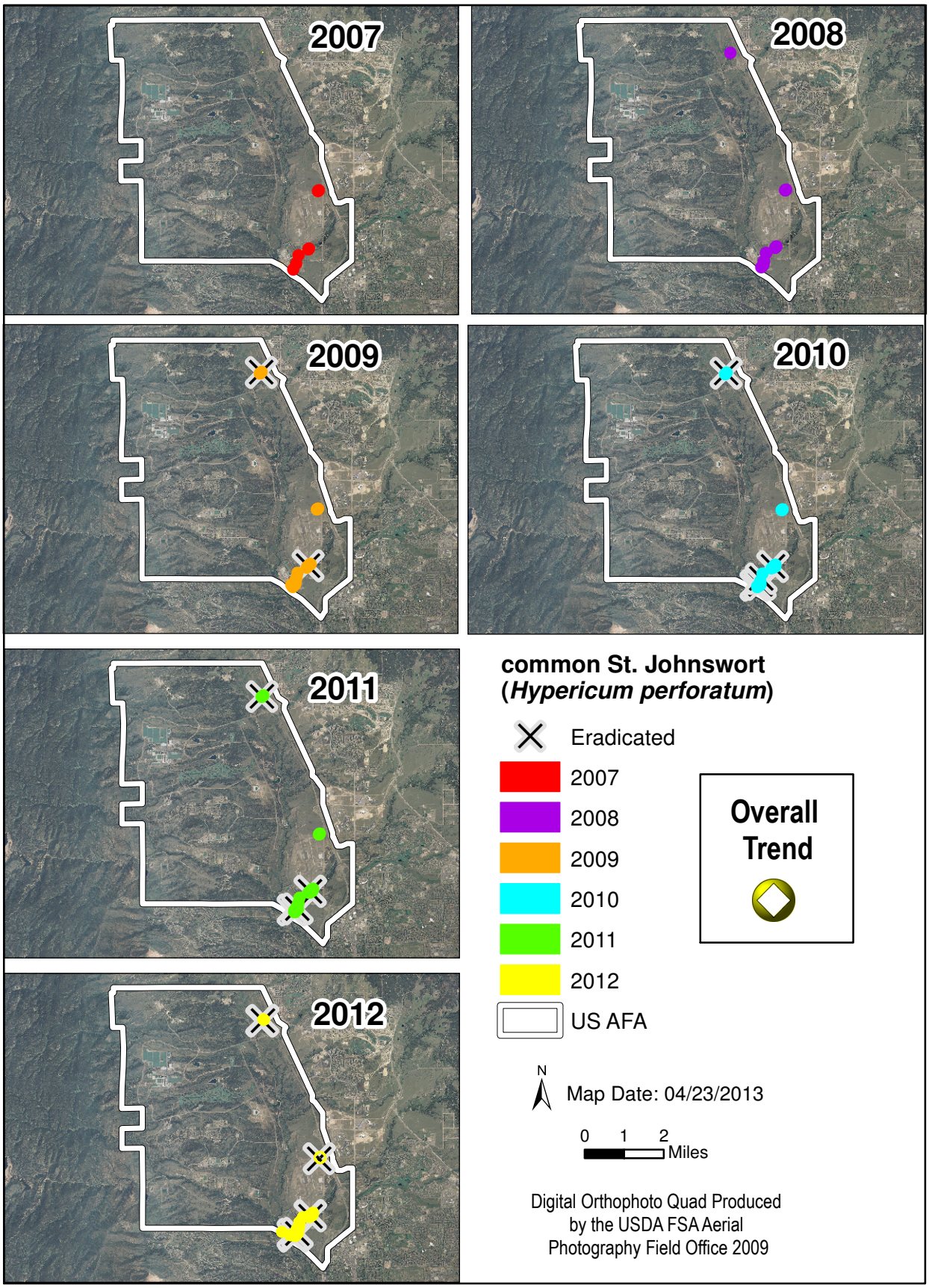


Figure 9. Common St. Johnswort occupied area and number of individuals for all mapped locations on AFA, 2007-2012.



Map 20. Distribution of common St. Johnswort at the Academy between 2007 and 2012.

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

Wikipedia photo

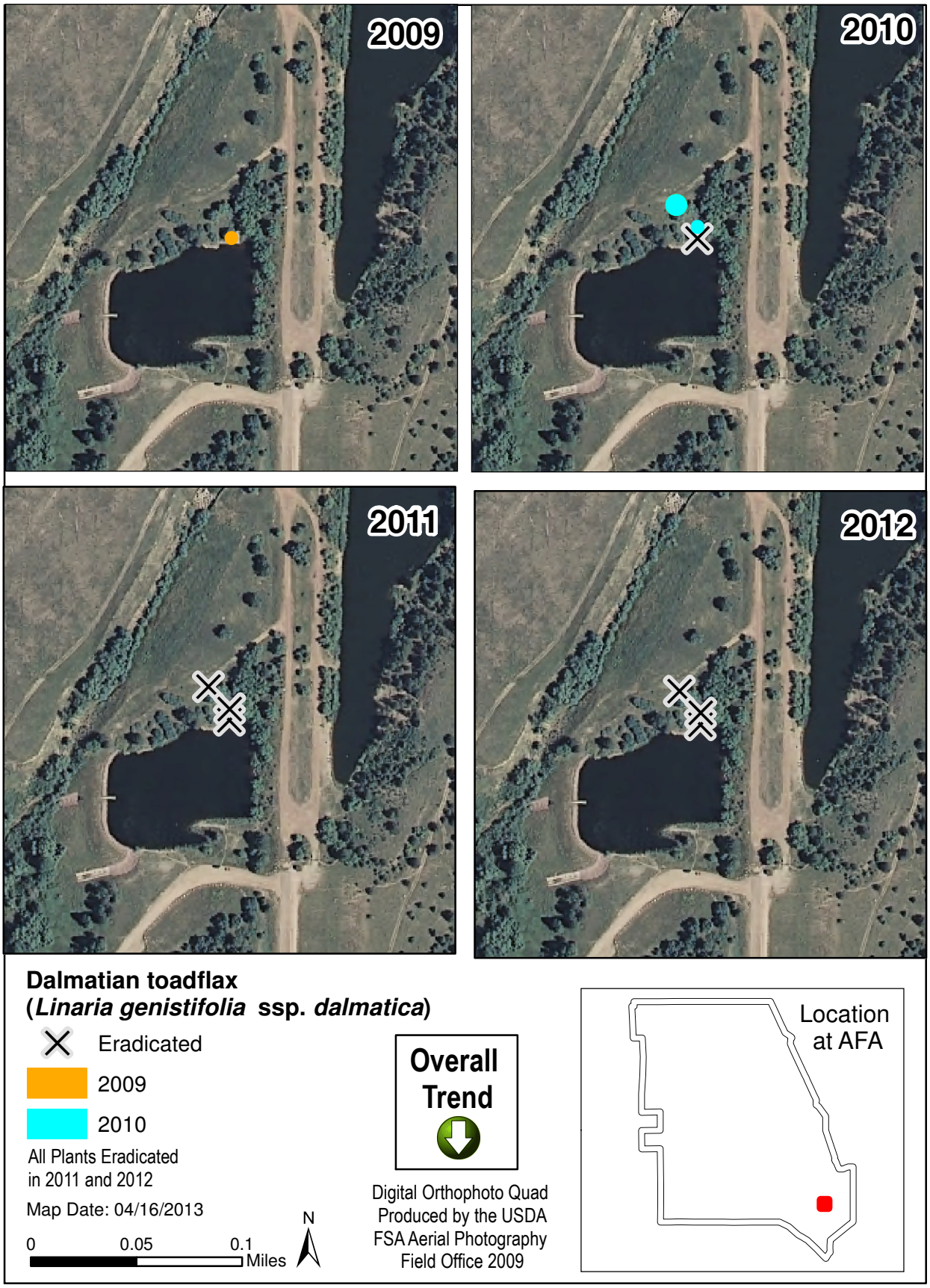
Appears to be eradicated but vigilant monitoring is required.

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 21), counted 107 individuals that covered approximately 203 m^2 (0.05 acres) (Table 19). The AFA sprayed the plants in 2010 and in 2011 and 2012 no plants were observed. 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 19. Dalmatian toadflax summary data, 2009-2012.

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



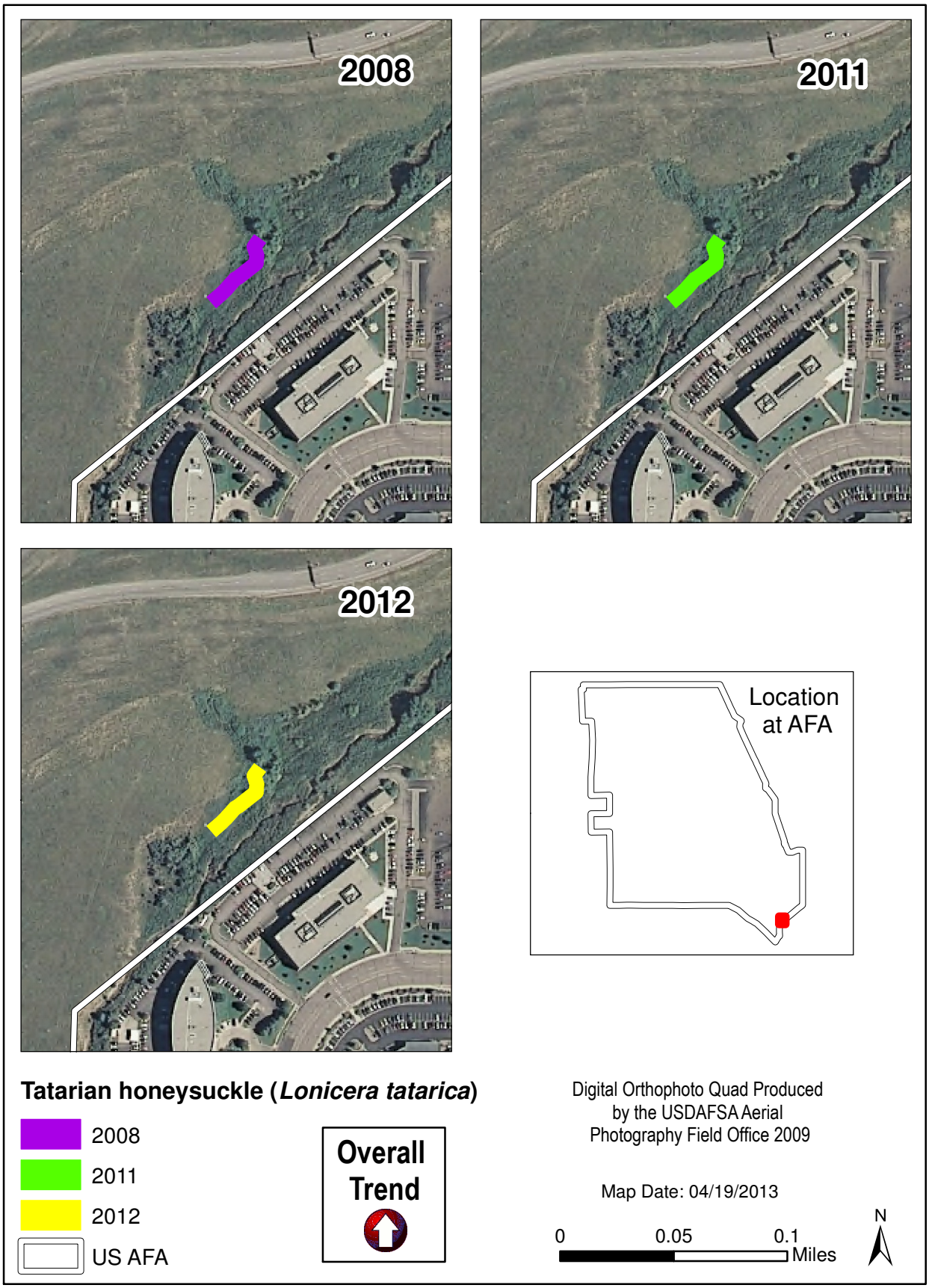
Map 21. Distribution of Dalmatian toadflax at the Academy between 2009 and 2012.

Tatarian Honeysuckle (*Lonicera tatarica*)

Only present at one location so eradication is possible. Pulling is recommended due to nearby rare plant.

Wikipedia photo

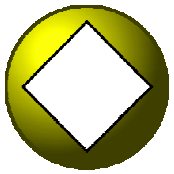
Tatarian honeysuckle occupied 0.015 acres with approximately 30 individuals at one site in 2012. This species was first discovered at the Academy in 2008, embedded with the state rare plant, *Ribes americanum*. The invasion of *Lonicera tatarica* is a concern due to its potential to dominate the site 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 22. Distribution of Tatarian honeysuckle at the Academy in 2008, 2011 and 2012.

Scotch Thistle (*Onopordum acanthium*)

Photo by David Anderson



Occupied acres continued a downward trend, however number of individuals increased as did number of mapped features. Aggressive herbicide treatment should continue and annual monitoring is essential.

Several new areas were mapped in 2012 (Lavender-Greenwell and Rondeau 2013) and while occupied acres continues to decrease, we have reason to believe that Scotch thistle is poised to expand if annual treatment of all sites wanes.

The population of Scotch thistle had increased from 2002 through 2009 at the Academy (Table 20, Figure 10, Map 23); 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 20). The number of individuals also decreased since 2009 from 1,710 to 669 and then back up to 889 (Table 21). The 2012 mapping project identified several new areas and will these will need to be monitored annually. 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 2013.

Table 20. Scotch thistle summary data at the Academy, 2002-2012.

	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	1,710	50
2010	0.66	669	61
2011	0.64	293	39
2012	0.3	889	66

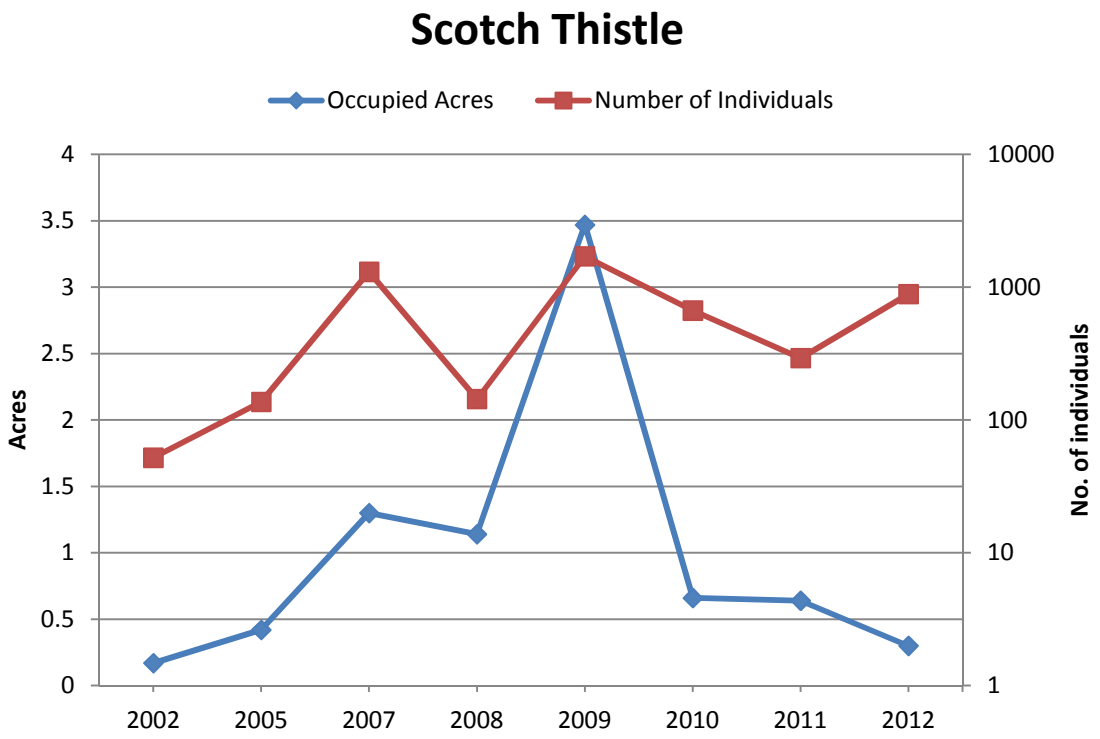
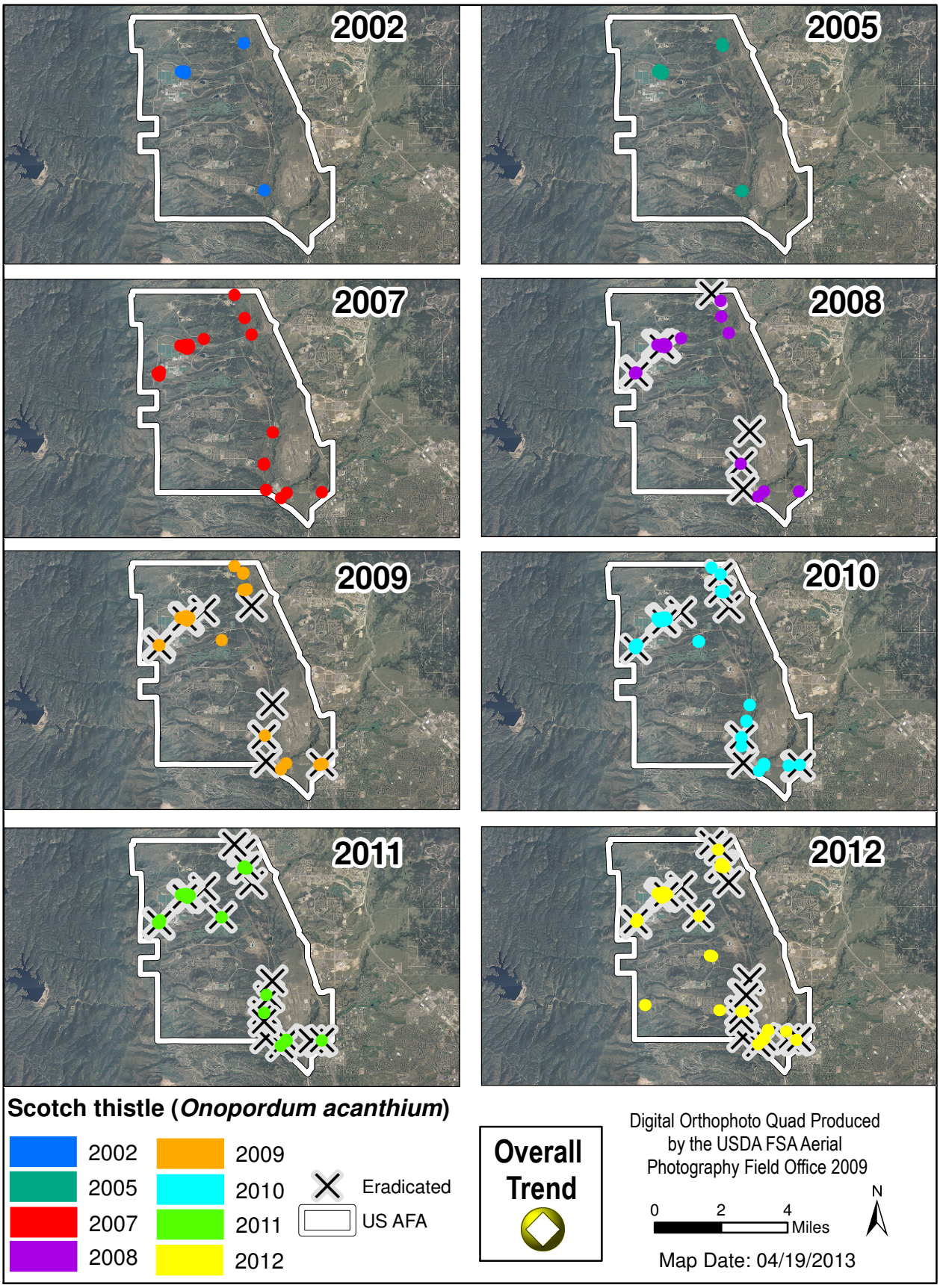


Figure 10. Scotch thistle, Academy-wide, occupied area and number of individuals from 2002-2012.



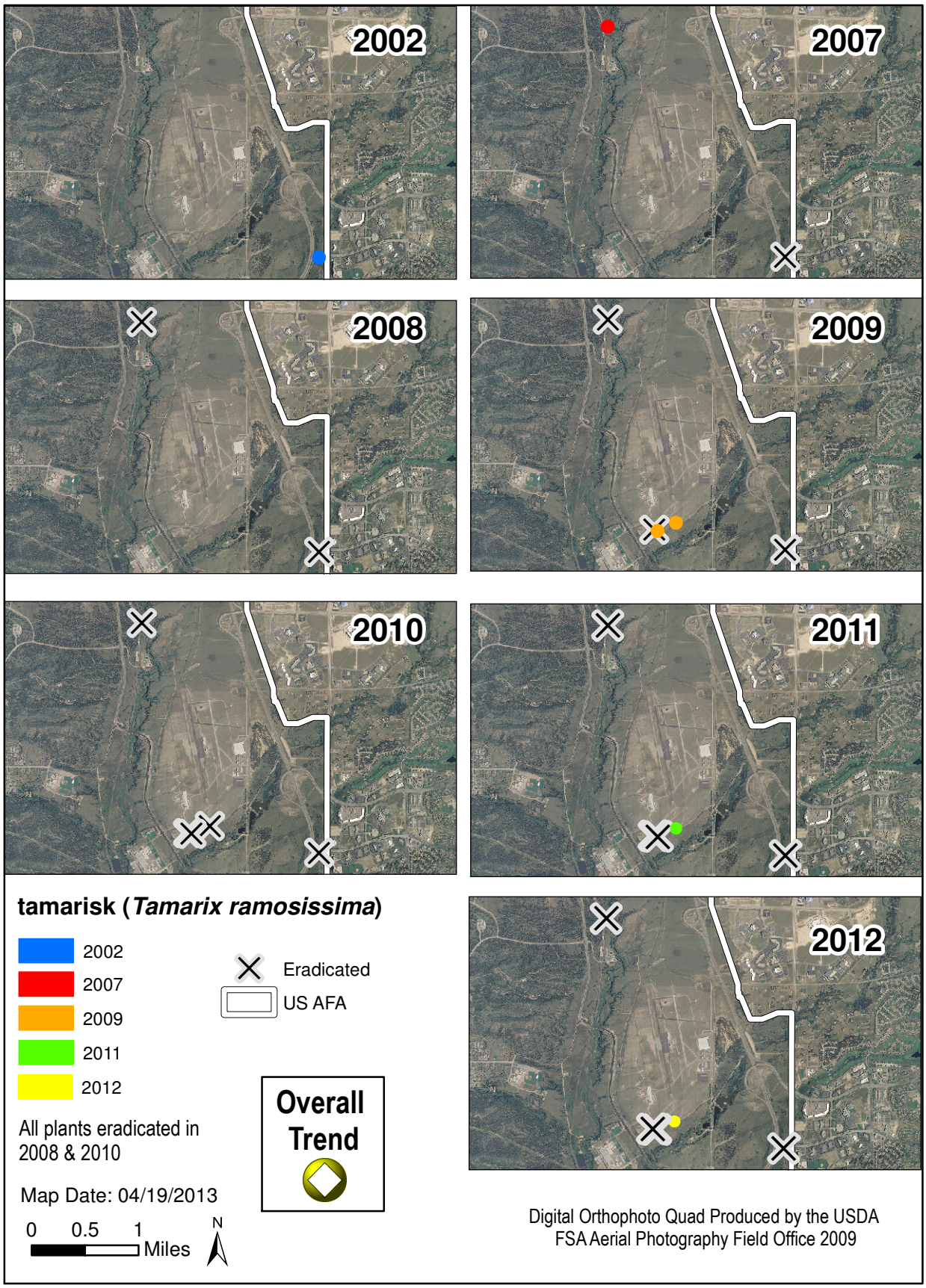
Map 23. Distribution of Scotch thistle at the Academy between 2002 and 2012.

Tamarisk (*Tamarix ramossisima*)

Photo by Renée Rondeau

Only one mapped occurrence with one plant.

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. 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 2012.

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. The work of Gerry Michels (Texas A&M) and his colleagues, especially Erin Parks, has also been valuable for this project. Tass Kelso generously provided her student, Sophie Recca, to assist with collecting monitoring data.

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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
Russian knapweed	*Acroptilon repens*			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
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
yellow spring bedstraw	*Gallium verum*									M*	M	M
dames rocket	*Hesperis matronalis*											M*
common St. Johnswort	*Hypericum perforatum*	M			M	M	M	M	M	M	M	M
Dalmatian toadflax	*Linaria genistifolia ssp. dalmatica*								M*	M	M	M
yellow toadflax	*Linaria vulgaris*	M					PM					PM
Tatarian honeysuckle	*Lonicera tatarica*							M*			M	M

Common Name	Scientific Name	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Scotch thistle	*Onopordum acanthium*	M			M	M	M	M	M	M	M	M
tamarisk	*Tamarix ramosissima*	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.

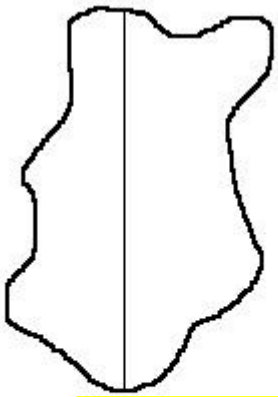
Materials needed for transect establishment:
Compass
50 m survey tape (2 or 3)
GPS unit, with the needed background file(s) for site(s) being surveyed
Wooden stakes
Orange marking paint
Dead blow hammer (2)

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

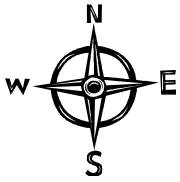
Standard survey procedure:

- 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. 7)

Fig. 1



0 m mark is south or west



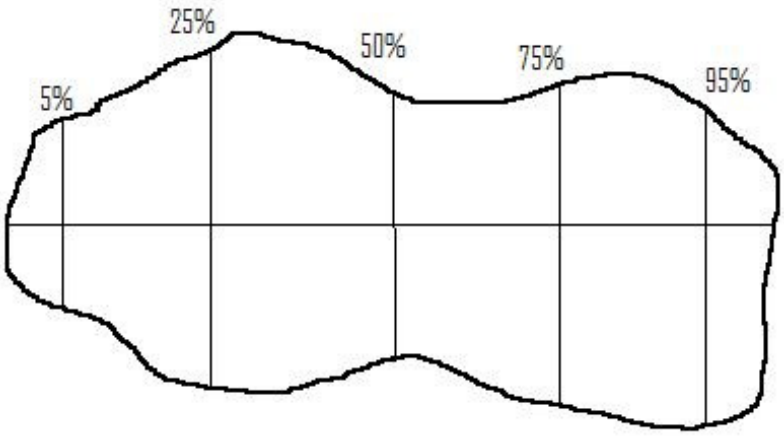


Fig. 2

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. 7)

Fig. 3

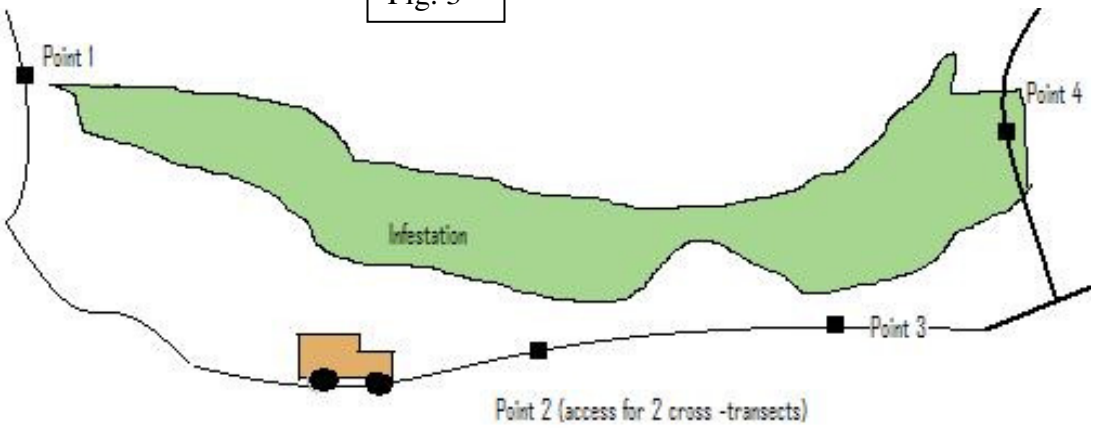
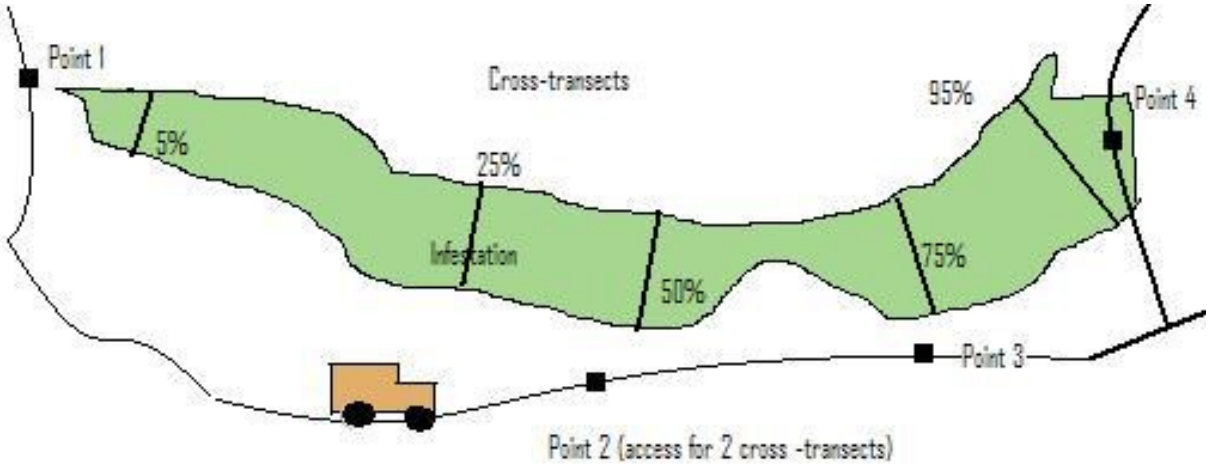


Fig. 4


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

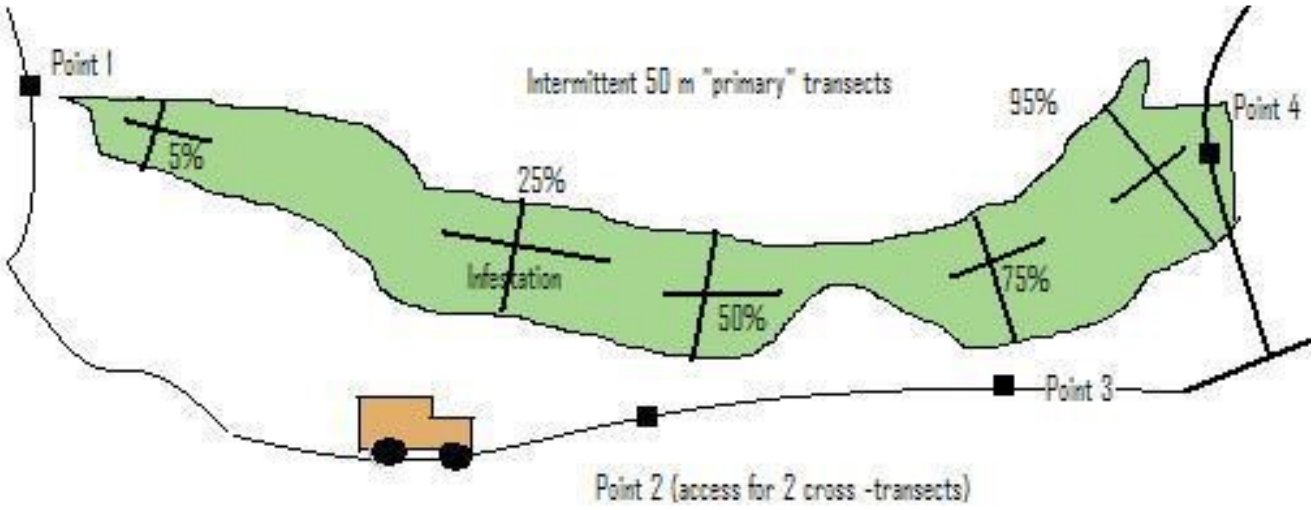

Point 1
Intermittent 50 m "primary" transects
95%
Point 4
5%
25%
Infestation
50%
75%
Point 3
Point 2 (access for 2 cross -transects)

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. Myrtle Spurge Table

Map number refers to Map 17 within this document.

Map Number	Date	Number of Individuals	Area (sq m)
1	9/16/2012	0	0.00
2	6/18/2012	1	3.13
3	8/25/2012	11	307.99
4	8/25/2012	14	242.00
5	8/25/2012	0	0.00
6	8/25/2012	0	0.00
7	8/3/2011	6	215.54
8	9/8/2011	0	0.00
9	6/15/2012	0	0.00
10	7/12/2012	0	0.00
11	8/16/2012	0	0.00
12	8/15/2012	0	0.00
13	7/18/2012	0	0.00
14	9/7/2011	0	0.00
15	6/14/2012	0	0.00
16	6/14/2012	0	0.00
17	6/9/2012	0	0.00
18	6/18/2012	0	0.00
19	9/1/2012	0	0.00
20	9/7/2012	0	0.00
21	9/7/2012	0	0.00
22	7/12/2012	0	0.00
23	7/12/2012	0	0.00
24	7/12/2012	0	0.00
25	7/12/2012	0	0.00
26	9/1/2012	0	0.00
27	8/15/2012	0	0.00
28	8/24/2012	0	0.00
29	7/12/2012	0	0.00
30	7/12/2012	1	3.13
31	6/5/2012	5	78.14
32	6/6/2012	14	78.14
33	8/8/2012	57	12.50
34	7/3/2012	1	3.13
35	6/15/2012	3	3.13
TOTALS		**113**	**946.82**

Appendix D. All mapped weeds in 2012 in comparison to 2009, 2010 and 2011.

SPECIES	Extant				Eradicated				# of individuals			
	2009	2010	2011	2012	2009	2010	2011	2012	2009	2010	2011	2012
Acroptilon repens	2	0	0	10	2	4	4	4	Unknown	0	0	543
Cynoglossum officinale	8	1	2	3	0	6	6	9	95	11	21	70
Euphorbia myrsinites	12	10	12	10	6	12	16	25	464	56	57	113
Galium verum	NA	1	1	2	NA	0	0	1	NA	700	1	566
Hesperis matronalis	NA	NA	NA	14	NA	NA	NA	NA	NA	NA	NA	16,871
Hypericum perforatum	21	20	26	29	2	6	5	10	95,883	82,733	87,128	83,115
Linaria genistifolia spp. *dalmatica*	1	2	0	0	0	1	3	3	10	107	0	0
Lonicera tatarica	NA	NA	1	1	NA	NA	0	0	NA	NA	30	30
Onopordum acanthium	50	61	39	66	34	30	56	73	1,710	669	293	889
Tamarix ramosissima	2	0	1	1	3	5	4	4	2	0	1	1