Noxious Weed Monitoring at the U.S. Air Force Academy

Year 13

May 2018

COLORADO NATURAL HERITAGE PROGRAM

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Year 13

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CNHP's mission is to advance the conservation of Colorado's native species and ecosystems through science, planning, and education for the benefit of current and future generations.

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Front Cover: Salsify in field; native butterfly on musk thistle; landscape at AFA, native dragonfly, native bee on musk thistle, photo plot CANU 10_1. Photos: Alyssa Meier 2017.

EXECUTIVE SUMMARY

This report summarizes the results of the past thirteen years of population monitoring of targeted noxious weeds at the U.S. Air Force Academy ("the Academy"), emphasizing changes that were observed from 2012 to 2017. Currently, 17 species are included on the noxious weed monitoring list for the Academy. Weed species were monitored utilizing two methods, a complete census (areal mapping) or permanent plots, depending on the species. In 2017, six species were found to be on the decline, three species were stable, six were increasing, and two were not monitored due to federal project review delays.

Summary of Findings

Areal monitoring was conducted on 12 species considered to have a high probability of suppression or eradication. Areal species were mapped as points, lines or polygons depending on the shape and size of the populations. Areal mapping species include:

- Russian knapweed (*Acroptilon repens*)
- houndstongue (*Cynoglossum officinale*)
- myrtle spurge (*Euphorbia myrsinites*)
- yellow spring bedstraw (*Galium verum*)
- Dame's rocket (*Hesperis matronalis*) – not monitored in 2017
- common St. Johnswort (*Hypericum perforatum*)
- Dalmatian toadflax (*Linaria dalmatica*)
- Tatarian honeysuckle (*Lonicera tatarica*)
- Scotch thistle (*Onopordum acanthium*)
- bouncingbet (*Saponaria officinalis*)
- salt cedar (*Tamarix ramosissima*)
- scentless chamomile (*Tripleurospermum perforatum*)

Six of the 12 species monitored using the areal method are on the rise overall. Houndstongue, myrtle spurge, and Dalmatian toadflax increased in numbers of individuals. The number of individuals for Tatarian honeysuckle has decreased overall but the number of sites where it is found has increased since it was first mapped 2008. Scotch thistle has been increasing since it was monitored in 2002 but was stable to decreasing from 2016 to 2017. Scentless chamomile was found in a new location in 2017 and is on a rapid response watch list. Salt cedar has remained stable. Four species monitored using the areal method are showing overall declines. Common St. Johnswort and bouncingbet showed decreases in numbers of individuals, while yellow spring bedstraw and Russian knapweed had no extant sites in 2017. Dame's rocket was not monitored due to the late start for the 2017 field season.

Findings – Areal Monitoring Sites 2017	Recommendations
228 of 468 weed areal locations (49%) visited had weeds present in 2017.	Continue to monitor all extant and eradicated sites in conjunction with weed mapping for 2018
Houndstongue, Scotch thistle, myrtle spurge and Dalmatian toadflax are showing increases in cover and/or the number of extant sites.	Improve real-time communications with AFA staff and weed treatment contractor. CNHP will set up two site plans for areas where weeds are increasing despite treatments to evaluate treatments and results. In addition, the weed applicator will provide monthly updates on treatment areas for weed monitoring and mapping crews in 2018.
Musk thistle and Scotch thistle appear to be treated at a fully bolted stage, with excess overspray on soils in 2017.	Make sure weed contractor understands proper use of herbicides for biennial species – typically in rosette stage or pre-flower. Spot applications are important to avoid collateral soil damage and an increase in weeds.
Bouncingbet is being actively controlled by browsing animals at the AFA. All flower tops have been grazed at all areal sites in 2016 and 2017.	Do not treat bouncingbet for the 2018 season. Monitor all known sites for browse in 2018. The natural browsers are more efficient and less stressful on the natural systems.
Myrtle spurge is increasing despite aggressive treatments.	CNHP will provide data to the Academy on a regular basis for this species and any other rapid response species. Use mechanical or precise herbicide application methods.
Wetlands and intermittently flooded areas may not always be easy to detect in the summer months. Certain herbicides can contaminate groundwater in these areas.	CNHP will provide a polygon of areas to be considered as wetlands for the staff and contractor to protect groundwater contamination.
A new weed species, scentless chamomile (*Tripleurospermum* (*Matricaria) perforatum*), that was first documented at the Air Force Academy in 2016 was also observed in 2017.	Add this species to the watch list for the weed treatment contractor and for the weed mapper. A list of potential noxious weeds that are likely to be found at the Academy are provided in the general recommendations.
Russian knapweed and yellow spring bedstraw are potentially eradicated at the Academy.	Add these species to the watch list. Monitor areal sites for at least two more years.

Permanent plots are used for the remaining five species on the monitoring list. Species monitored with permanent plots are considered to have a low probability for containment due to their widespread nature but are being selectively managed. Species with permanent plots include:

- hoary cress (*Cardaria draba*) – not monitored in 2017
- Canada thistle (*Cirsium arvense*)
- musk thistle (*Carduus nutans*; photo monitoring)
- diffuse and spotted knapweeds (*Centaurea diffusa* and *C. maculosa*)
- leafy spurge (*Euphorbia esula*)

A total of 42 plots (100x50m) were monitored in 2017: 10 plots for leafy spurge, Canada thistle, and musk thistle; and 12 plots for the knapweeds. All monitoring plots showed either stable or decreasing trends in 2017. Although musk thistle has decreased overall since 2008, it has been increasing from 2014-2017. Hoary cress was not monitored due to the late start for the 2017 field season.

Findings – Permanent Monitoring Plots 2017	**Recommendations**
All of the weed monitoring plots show stable to decreasing trends (Table 1).	Continue to avoid treating these species in plots or in natural areas where natural stability or decreases are being observed.
Active biocontrol organisms may be increasing in leafy spurge and Canada thistle populations at the Academy.	Continue to avoid treating these species in natural areas where natural stability or decreases are being observed.
Rare plants, animals and plant communities exist within the plots and the special weed management areas (natural areas).	In 2018, CNHP biologists will be revisiting known locations of element occurrences. This information will be used to update the special weed management areas. New boundaries will be available for 2019 season.

Table 1. Summary of findings for weed species monitored at the Air Force Academy in 2017. Shading indicates monitoring plot data.

Status	Name	Common Name	Comment
	Acroptilon repens	Russian knapweed	Potentially eradicated, no extant features.
	Cardaria draba	Hoary cress	Plots not monitored in 2017.
	Carduus nutans	Musk thistle	Photo plots reveal overall decrease since 2008, increases from 2013-2017. Ten plots monitored.
	Centaurea maculosa, C diffusa, & hybrids	Spotted and diffuse knapweeds	Permanent plot data show overall stable trend 2012-2017 with slight increases 2016-2017. Twelve plots surveyed (9 + 3 biocontrol plots).
	Cirsium arvense	Canada thistle	Permanent plots show an overall decreasing trend 2012-2017. Ten plots monitored. Evidence of biocontrol and rare plants/animals in plots.
	Cynoglossum officinale	Houndstongue	40% increase in # of individuals since 2016 at 26 locations.
	Euphorbia esula	Leafy spurge	Permanent plot data show stable frequency and cover and slight decrease in density. Ten plots monitored. Rare plants & evidence of biocontrol.
	Euphorbia myrsinites	Myrtle spurge	64% increase since 2017. 501 individuals at 25 sites.
	Gallium verum	Yellow spring bedstraw	Ten plants in 2015; 0 plants in 2016 &2017. Area has been landscaped since 2015 visit.
	Hesperis matronalis	Dame's rocket	Areal mapping was not conducted in 2017.
	Hypericum perforatum	Common St. Johnswort	37% decrease in individual plants since 2016. However, there was the largest number of extant sites (47) since 2007.
	Linaria dalmatica	Dalmatian toadflax	Dramatic increase 2016-2017 with 450 individuals at one site.
	Lonicera tatarica	Tatarian honeysuckle	Overall trend is slight increase since 2008. Ten sites visited with 7 extant features in 2017.
	Onopordum acanthium	Scotch thistle	Overall increase since 2008; 2016-2017 a decrease in shoots, stable # extant sites and slight increase in cover and 120 extant features.
	Saponaria officinalis	Bouncingbet	Overall downward trend 2002-2017. In 2016-2017, all flowering tops grazed; 25% reduction in individuals and 6 instead of 8 extant sites
	Tamarix ramosissima	Salt cedar	One extant occurrence out of eight sites visited in 2017. The site not visited had 9 individuals in 2015.
	Tripleurospermum perforatum	Scentless chamomile	New in 2016 to AFA. One plant observed in 2017.

General Recommendations

- Continue to coordinate treatment activities with resource management staff, contractor and CNHP to target areas of concern (rapid response). Providing the applicator with maps and polygons of the known locations of rare species helped avoid impacts to rare plant species during the 2017 season.
- Discontinue herbicide treatments on bouncingbet in 2018 and monitor all populations to determine if natural declines are continuing to reduce populations.
- CNHP will track any observations of List A or B species in need of rapid response actions and supply pertinent information to Natural Resources. List A noxious weed species that could potentially be at the Academy include:
    - Garlic mustard
    - Hairy willowherb
    - Mediterranean sage
    - Perennial pepperweed
    - Purple loosestrife
- Create site plans for two small areas in the northern section of the Academy within Special Weed Management Areas to measure success and document treatments in 2018. One site is proposed for a small but fairly dense population of Scotch thistle. The second site is a sensitive wetland area with known occurrences of both noxious weeds and rare species. (Site Plan worksheet provided in Appendix E).
- Continue to avoid weed treatments in or close to monitoring plots and away from sensitive areas with rare plants and diverse native species. Weed treatments in sensitive areas should include minimal and precise herbicide application and immediate follow-up replanting of native species if bare soil areas are created (Smith et al. 2015).
- Continue to host a yearly workshop in winter or early spring to enhance communication and information sharing to improve treatment success and reduce impacts to native species and wetlands. Updates on the locations of rare species or new weeds can be reviewed.

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 in 2017.

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INTRODUCTION

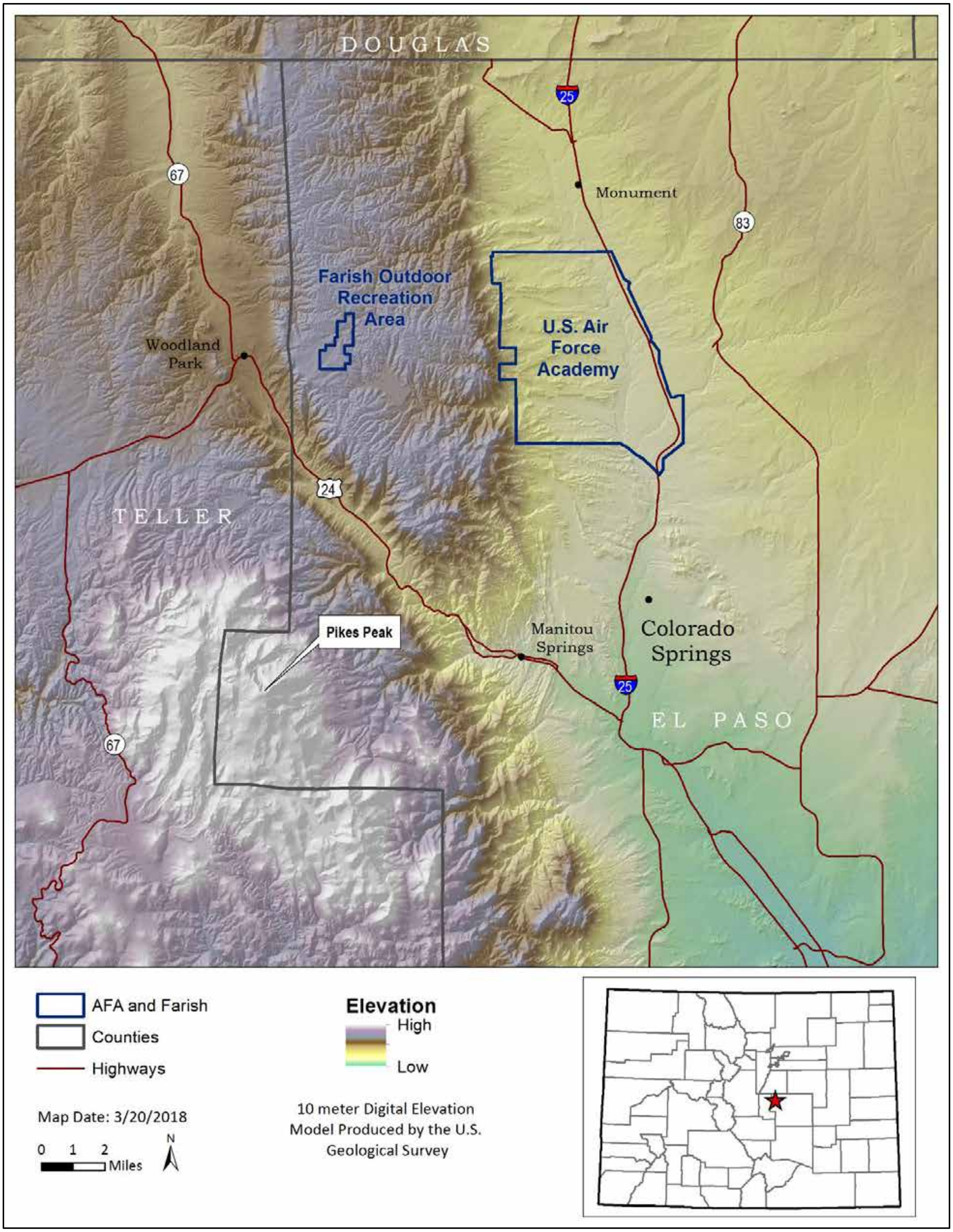
Many local governments now require public and private landowners to manage noxious weeds. The U.S. Air Force Academy (referred to herein as "the Academy") follows state (Department of Agriculture) and County (El Paso County) weed control regulations for noxious weeds (Code of Colorado Regulations 2014). The Academy is located near Colorado Springs, Colorado (Map 1).

The Academy has also established management objectives for weed control in order to remain consistent with local weed regulations (Carpenter et. al 2004, Smith et al. 2015). The management objectives are defined as specific, desired results of integrated management efforts and include the following definitions:

- **Eradication**: Reducing the reproductive success of a noxious weed species in a largely uninfested region to zero and permanently eliminating the species or population within a specified period of time (until the existing seed bank is exhausted).
- **Containment:** Maintaining an intensively managed buffer zone that separates infested regions, where suppression activities prevail, from largely uninfested regions, where eradication activities prevail.
- **Suppression**: Reducing the vigor of noxious weed populations within an infested region, decreasing the propensity of noxious weed species to spread to surrounding lands, and mitigating the negative effects of noxious weed populations on infested lands.

Many of the guidelines for controlling noxious weeds (including herbicide label instructions) are often based on agricultural landscapes and not natural areas. There is a large distinction between these two land uses, especially for weed management, which was addressed in the 2015 update to the Noxious Weed Management Plan (Smith et al. 2015). Natural areas can be defined as non-crop areas that support native vegetation, and where management includes the protection of these areas as well as the generation of ecosystem services (Pearson & Ortega 2009). To successfully manage weeds in natural areas with high biodiversity is much more complex than in an agricultural area. Successful weed management in natural areas must also consider the management of the entire community and not just removal of individual weeds. A significant portion of the landscape at the Academy falls into the "natural areas" category and includes important wetland features. The Academy and Farish Outdoor Recreation Area are important for local and global biodiversity conservation (Siemers et al. 2012). At least 31 plants, animals, and plant communities of conservation concern have been documented at the Academy. For example, 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), have been documented on-site. In addition, 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 2017).

The Colorado Natural Heritage Program first mapped noxious weeds at the Academy in 2002 and has monitored noxious weeds at the Academy for the past 13 years. The following section summarizes the results of mapping activities and the monitoring program to date.



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

Timeline of Weed Mapping and Monitoring at the Academy

Below is a summary of weed mapping and monitoring by year since the surveys began in 2002. Refer to Appendix A for monitoring and mapping activities by species.

- **2002:** Approximately 3,900 weed locations were mapped at the Academy and Farish, with 14 species on the target list (Anderson et al. 2003).
- **2003:** Hoary cress (*Cardaria draba*) and Russian olive (*Elaeagnus angustifolia*) were remapped in 2003. In 2002, severe drought conditions suppressed the distribution of these two species. In 2003, populations increased due to ample spring moisture which necessitated a second year of mapping.
- **2004:** Based on data from the weed mapping conducted in 2002-2003, an integrated noxious weed management plan was developed (Carpenter et al. 2004) which supports the *Integrated Natural Resources Management Plan* for the Academy. The first report of Russian knapweed (*Acroptilon repens*) was submitted.
- **2005:** A monitoring program was established for 13 species of noxious weeds using a combination of permanent monitoring plots and areal mapping. Natural Resource staff at the Academy reported occurrences of myrtle spurge (*Euphorbia myrsinites*), a List A noxious weed. It was also noted that diffuse and spotted knapweeds were hybridizing at the Academy.
- **2006:** Permanent monitoring plots established in 2005 were re-sampled. All infestations of spotted knapweed and Russian knapweed were revisited and mapped. Myrtle spurge was added to the target weed list for mapping and assessment.
- **2007:** The second weed map of the Academy and Farish was completed, with a total of 17 mapped species at approximately 5,500 locations (Anderson and Lavender 2008a).
- **2008:** Based on previous year's data, protocols were adjusted for the 2008 surveys. Tatarian honeysuckle (*Lonicera tatarica*) was discovered at the Academy.
- **2009:** A total of 14 species were targeted for monitoring. Two additional species were mapped: houndstongue (*Cynoglossum officinale*) and Dalmatian toadflax (*Linaria dalmatica*). Yellow toadflax was removed from monitoring due to its abundance. A habitat suitability model for spotted knapweed was produced.
- **2010:** Yellow spring bedstraw (*Gallium verum*) was discovered at the Academy and mapped. We did not monitor diffuse knapweed (*Centaurea diffusa*).
- **2011:** Updated monitoring protocols were employed. The annual mapping of Tatarian honeysuckle began. Diffuse knapweed and hoary cress (*Cardaria draba*) were not monitored.
- **2012:** Collaboration with United States Fish & Wildlife Service (USFWS) and Texas A&M AgriLife Research Biocontrol Program resulted in the following modifications: 1) CNHP and Texas A&M began using the same monitoring program for the plot surveys; 2) CNHP took over responsibility for the leafy spurge (*Euphorbia esula*) and common St. Johnswort (*Hypericum perforatum*) monitoring sites; 3) biocontrol plots (Texas A&M) for Canada thistle (*Cirsium arvense*) and diffuse knapweed (*Centaurea diffusa*) were compared to non-biocontrol plots (CNHP); 4) permanent plots were established for hoary cress (*Cardaria*

draba) and leafy spurge (*Euphorbia esula*); and 5) the third weed mapping effort for the Academy and Farish was completed, mapping 22 weed species and an estimated 39% increase in area occupied (Rondeau and Lavender 2013).

- **2013:** Monitoring was the same as in 2012, except that Farish was not visited, and Canada thistle and Dame's rocket were not monitored. Diffuse knapweed and spotted knapweed hybridization was widespread. The two knapweed species (*Centaurea maculosa, C. diffusa* and hybrid forms) were lumped together for plot results.
- **2014:** Monitoring was the same as in 2013, except that hoary cress (*Cardaria draba*) plots were not visited and Canada thistle plots were visited. Dame's rocket was mapped too late in the season to report trends. Hoary cress and Dame's rocket were prioritized for 2015.
- **2015:** Monitoring was the same as in 2014, except that hoary cress (*Cardaria draba*) plots were monitored and three new plots were established. In addition, five biocontrol plots were re-visited (and re-established) for knapweeds and a new Canada thistle plot was established. One Canada thistle monitoring plot was not visited because it was under water for most of the summer. One diffuse knapweed plot was removed from monitoring because it has been incorporated into a golf course. Five plots had rare plant or animal species located within them. A large population of a globally vulnerable, state imperiled species, the Rocky Mountain cinquefoil (*Potentilla ambigens*) was destroyed by recent flooding.
- **2016:** Monitoring at all permanent monitoring plots at the Academy (41) and Farish (30 plots) with a minimum of 10 plots for each species for 2016. Census monitoring was conducted at 412 out of 464 known sites. A List B noxious weed was collected in Kettle Creek (Scentless chamomile – *Tripleurospermum perforatum*) that was new for the Academy and a new record for El Paso County. A specimen was deposited at the Colorado State University Herbarium (CSU).
- **2017:** Monitoring at 42 plots (all plots except hoary cress), all stable to decreasing trends; 236 out of a total of 468 areal weed sites visited (49%) had weeds present in 2017. Scentless chamomile was found in Kettle Creek for a second year.

METHODS

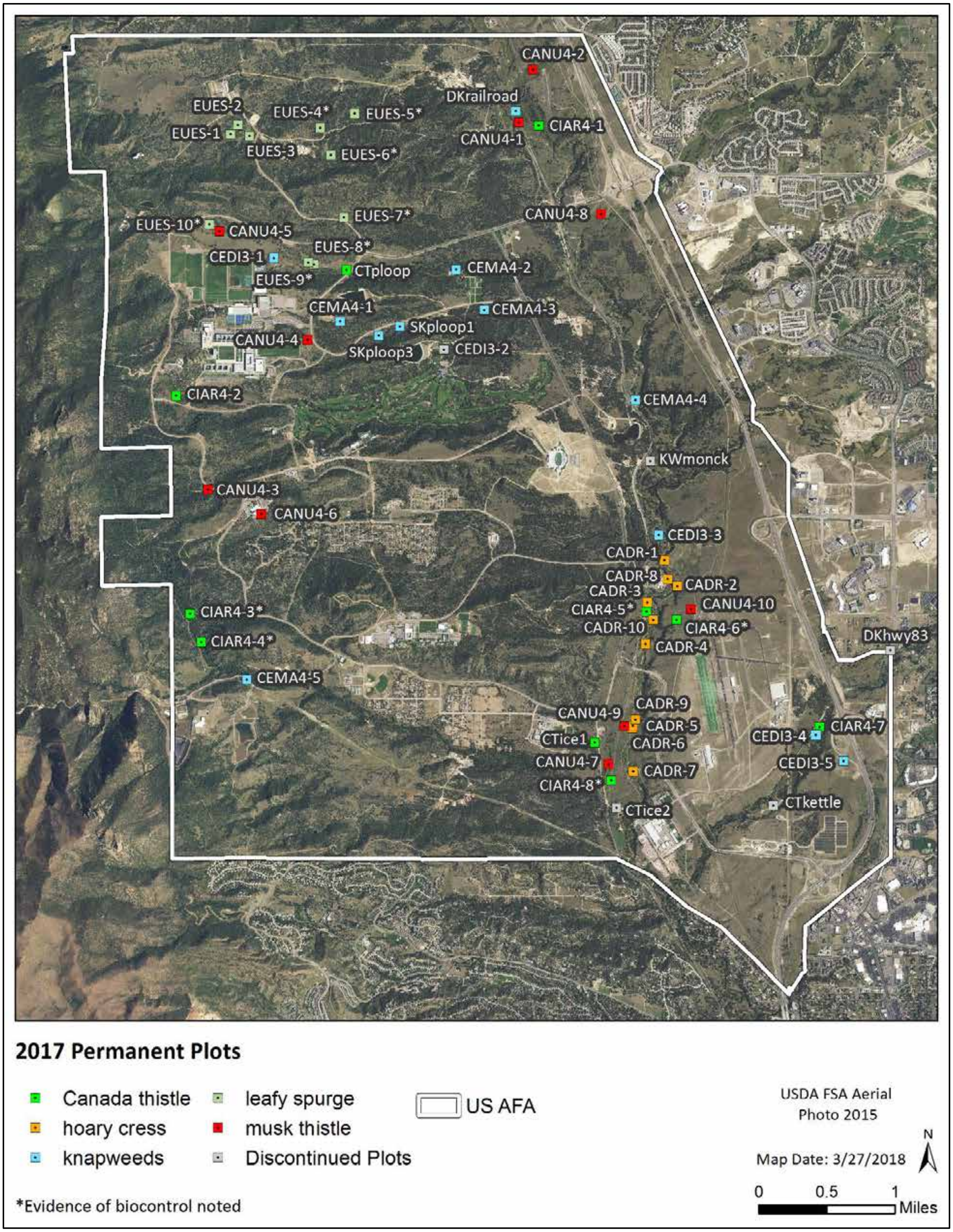
The objective of this project is to identify trends and evaluate the effectiveness of ongoing management of noxious weeds at the Academy to determine whether weed management objectives are being met. The original recommendations for the design and deployment of monitoring plots offered by Carpenter et al. (2004) were used, and subsequently modified as new information was collected. In 2012-2017, combinations of transect sampling, photo plots, and areal mapping and census were used to monitor the target noxious weed species (Table 2). Permanent plot locations are shown in Map 2. In order to closely align CNHP data collection with the Texas A&M (TAMU) AgriLife biocontrol, we established 36 permanent plots in 2015 using the methods of Michels et al. (2014). Plot numbers were hoary cress (7), diffuse knapweed (5), spotted knapweed (5), Canada thistle (8), and leafy spurge (10). Plots were randomly selected, utilizing 2007 weed mapping data (Anderson and Lavender 2008a). Details of the methods used to collect density, cover, height, reproductive stage, number of flowers, and flower width at each are in Appendix B. For all plots we calculated average density, average cover, and frequency (% quadrats with plants). The sampling in 2015 included all permanent plots listed above with the addition of 3 plots for hoary cress added in 2015 following methods in Anderson and Lavender (2008b). In 2016 a total of 41 permanent plots were surveyed: hoary cress (10), knapweeds (12), Canada thistle (9), and leafy spurge (10). Ten photo plots were visited for musk thistle. To make the statistics more robust, a total of 10 plots for each species has been a goal for monitoring. Census mapping was conducted on 12 species (Table 2) at 468 total sites at the Academy in 2017 following procedures outlined in Appendix C.

Biocontrol introductions by Texas A&M AgriLife were discontinued in 2015 since most of the populations of weeds at the Academy were determined to be too small to support biocontrol agents at this time. However, some of the noxious weed populations have the potential to grow to the point of being able to support biocontrol agents, so monitoring for these agents should continue to be a part of the survey. Weed surveyors photographed and took notes on any biocontrol or potential biocontrol agents observed at survey sites. In addition, grazing by insects and animals was noted when observed.

Table 2. Summary of methods used for monitoring by CNHP in 2012-2017.

Latin Name	*Common Name*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
Acroptilon repens	Russian knapweed	M	M	M	M	M	M
Cardaria draba	Hoary cress	PP	PP	---	PP	PP	---
Carduus nutans	Musk thistle	M	PP	PP	PP	PP	PP
Centaurea diffusa, C. maculosa and hybrid	Diffuse, spotted knapweeds	PP	PP	PP	PP	PP	PP
Cirsium arvense	Canada thistle	PP	---	PP	PP	PP	PP
Cynoglossum officinale	Houndstongue	M	M	M	M	M	M
Euphorbia esula	Leafy spurge	PP	PP	PP	PP	PP	PP
Euphorbia myrsinites	Myrtle spurge	M	M	M	M	M	M
Galium verum	Yellow spring bedstraw	M	M	M	M	M	M
Hesperis matronalis	Dame's rocket	M	---	PM	M	PM	---
Hypericum perforatum	Common St. Johnswort	M	M	M	M	M	M
Linaria dalmatica	Dalmatian toadflax	M	M	M	M	M	M
Lonicera tatarica	Tatarian honeysuckle	M	M	M	M	M	M
Onopordum acanthium	Scotch thistle	M	M	M	M	M	M
Saponaria officinalis	Bouncingbet	M	M	M	M	M	M
Tamarix ramosissima	Salt cedar	M	M	M	M	M	M
Tripleurospermum perforatum	Scentless chamomile	---	---	---	---	M	M

*Shading indicates monitoring activities: PP = permanent plots, M = mapped, PM = partially mapped



Map 2. Locations of noxious weed permanent monitoring plots at the Academy.

RESULTS AND RECOMMENDATIONS

<u>Precipitation</u>

Annual precipitation can be a helpful indicator for interpreting weed monitoring data. Higher precipitation years often result in increased weed numbers for that year. The yearly total for 2017 was 14.78 inches for spring and summer, which represents the third highest value since 2001. The highest spring and summer precipitation was recorded in 2015 with 25.25 inches which is over 60% above the average annual precipitation (1961-1990) of 12.33 inches. In 2015, the annual precipitation was the second highest recorded since record-keeping began in 1948; the high of 27.58 inches was recorded in 1999 (Western Regional Climate Center 2015). A summary of the average spring and summer precipitation (March – August) shows that 2004, 2015 and 2017 were above average for spring and summer precipitation, while 2002, 2008 and 2012 were very dry years (Figure 1).

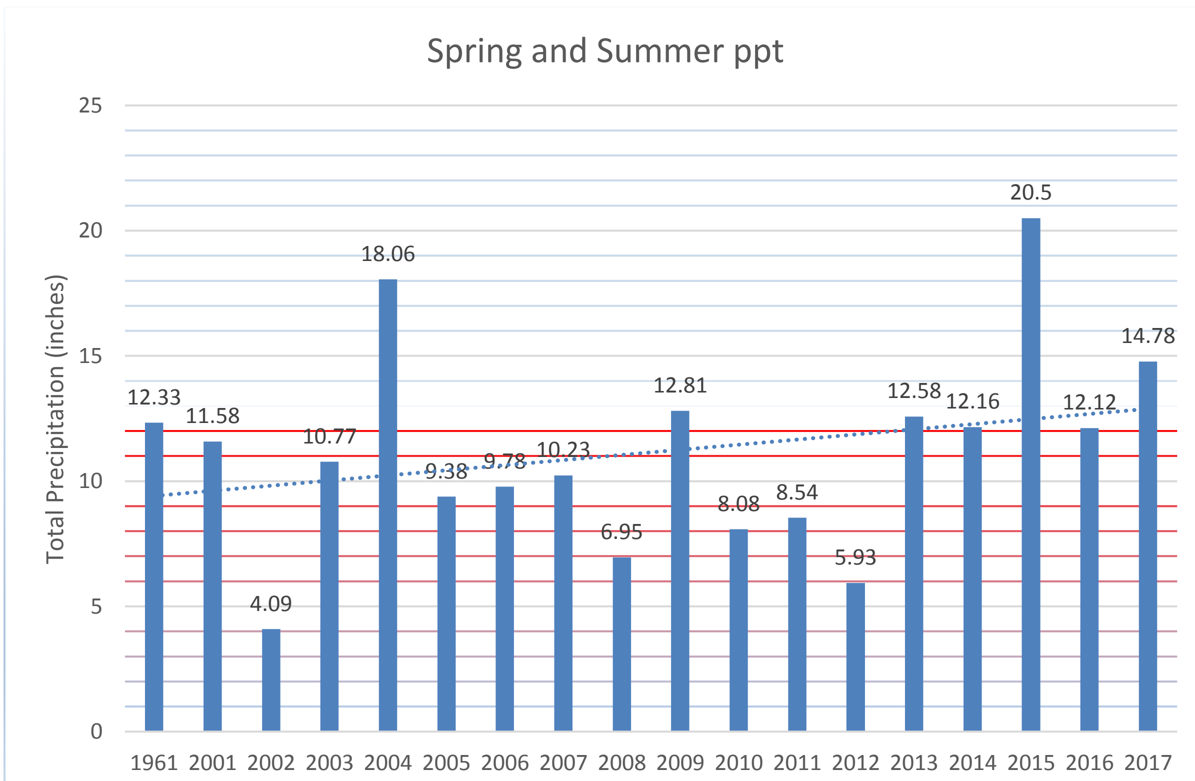


Figure 1. Average spring and summer precipitation. Spring = March-May, Summer = June-August. Blue dotted line is trend line, red line is 1961-1990 average (WU 2018).

This data may be helpful in future monitoring years determine if there is any correlation with spring and summer precipitation. Musk thistle, Scotch thistle and houndstongue seem to have population increases that follow spring and summer precipitation patterns.

Permanent Plot Monitoring Results

In 2017, 42 permanent monitoring plots were surveyed at the Academy including: 10 plots each for leafy spurge, musk thistle and Canada thistle; and 12 plots for the knapweeds. None of these plots were treated by the herbicide applicator since 2015. **Leafy spurge, Canada thistle and knapweed plots all show stable to decreasing trends.** Biocontrol organisms may be contributing to these results as evidenced by direct observations of biocontrol organisms or the resulting impacts to plants in the form of galls and flower damage. Hoary cress was not monitored in 2017 due to late start of fieldwork for the project. Musk thistle photo plots also show an overall decrease since 2008, however, increasing trends have been observed between 2012 and 2017. Details are provided in the sections below on individual species.

Areal monitoring results

Areal monitoring (complete census) was conducted on 12 species considered to have a high probability of suppression or eradication. Areal species were mapped as points, lines or polygons depending on the size of the populations and included complete stem counts or density estimates for large dense populations. Areal mapping species include:

- Russian knapweed (*Acroptilon repens*)
- houndstongue (*Cynoglossum officinale*)
- myrtle spurge (*Euphorbia myrsinites*)
- yellow spring bedstraw (*Galium verum*)
- Dame's rocket (*Hesperis matronalis*) – not monitored in 2017
- common St. Johnswort (*Hypericum perforatum*)
- Dalmatian toadflax (*Linaria dalmatica*)
- Tatarian honeysuckle (*Lonicera tatarica*)
- Scotch thistle (*Onopordum acanthium*)
- bouncingbet (*Saponaria officinalis*)
- salt cedar (*Tamarix ramosissima*)
- scentless chamomile (*Tripleurospermum perforatum*)

Areal monitoring was conducted at 468 sites in 2017. About half of the sites visited (49%) had weeds present. Russian knapweed and yellow spring bedstraw appear to be eradicated at this time. Russian knapweed has not been detected at all known locations since 2012. The shoreline area where the yellow spring bedstraw was reported has been landscaped with very large boulders, one of which lies directly on top of the known location.

Houndstongue, musk thistle and myrtle spurge all showed increases that may be correlated with the spring/summer precipitation patterns. Houndstongue showed a 61% increase in plants at a similar number of extant features from 2016-2017. The number of musk thistle plants increased by 70% between 2016 and 2017. The number of myrtle spurge plants also increased over 60% since 2016, although there is an overall decrease since a peak population of over 1,000 in 2007. The number of extant sites increased by eight since 2016. Common St. Johnswort populations have fluctuated over the years with biological controls and flooding having the largest impact on reducing the number of individuals. Since 2012, there has been a large reduction in the number of plants, but the number of extant features has remained relatively stable until 2017 with 15 more extant sites visited. However, the number of individuals actually decreased from 6,717 in 2016 to 4,202 in 2017. Dalmatian toadflax has been monitored at four sites with only one or two plants observed since 2014. However, one of the extant sites had 450 individuals in 2017, representing a dramatic increase at a single site demonstrating the importance of post-treatment monitoring. Over the past few years Tatarian honeysuckle shrubs appear to be on the decline. The number of Scotch thistle individuals has been declining since 2015 with a stable number of extant features. However, the overall trend since 2002 is increasing. All extant populations of bouncingbet monitored for this project have had the flower tops grazed by wildlife in 2016 and 2017. Salt cedar has remained stable with one site extant since 2015. Scentless chamomile was again located at one site in Kettle Creek. A summary of the results of the 2009-2017 areal mapping is provided in Appendix D.

CNHP Elements of Conservation Concern and Treatments

The Academy is home to a number of noxious weed species as well as elements of conservation concern including rare plants, animals and plant communities. Protecting these resources while controlling noxious weeds is a tall order. The weed mapping survey and biological surveys that will take place in 2018 will provide updated information for the Academy.

As has been discussed previously in reports and at meetings with AFA staff, a number of weed species that have been monitored as part of the areal surveys are not showing declines despite treatment efforts. Much of the literature that has been available since 2000, has been trying to address this particular issue with noxious weed control. Many of the studies have demonstrated that the results from weed treatment efforts result in a re-invasion by either the same weed or different noxious weed or non-native species. Replanting and restoration efforts with native species may also be met with unsatisfactory results. In areas where natural resources need protection, it is most difficult to have a successful weed treatment.

The main reason why many treatments do not work is because the original or underlying disturbance(s) that allowed noxious weeds to exist in an area have not been addressed or are not understood. They may be very difficult to even discern. Some disturbances that invite weeds into a natural area include the removal of native vegetation and changes to the overlying soils but it may also be combined with hydrological changes, climate impacts and nutrient additions from precipitation or flooding events. These disturbances may be beyond any efforts to control by a land manager. Targeting the weed for removal does not change the disturbance regime and is a major reason for the failure of many weed treatment efforts which may open the door for more weeds as treatments themselves are a disturbance. Certain species cannot be successfully controlled after they have become established, especially species with deep root systems that can spread by underground root buds (Canada thistle, hoary cress (whitetop), leafy spurge, Dalmatian toadflax and Russian thistle). To prevent the spread, recommendations are to control the satellite populations which is much easier said than done in practice because you cannot tell new sprouts from those coming up from the established root systems.

We are recommending no herbicide treatments for bouncingbet in 2018. The treated landscape, while it did reduce the numbers of plants dramatically resulted in bare ground, which is promoting noxious weed growth including cheatgrass and the return of bouncingbet (Photo 9 p. 97). Since deer or another ungulate appears to removing all of the flowers in both 2016 and 2017 surveys, it seems prudent to see if this is still occurring in 2018.

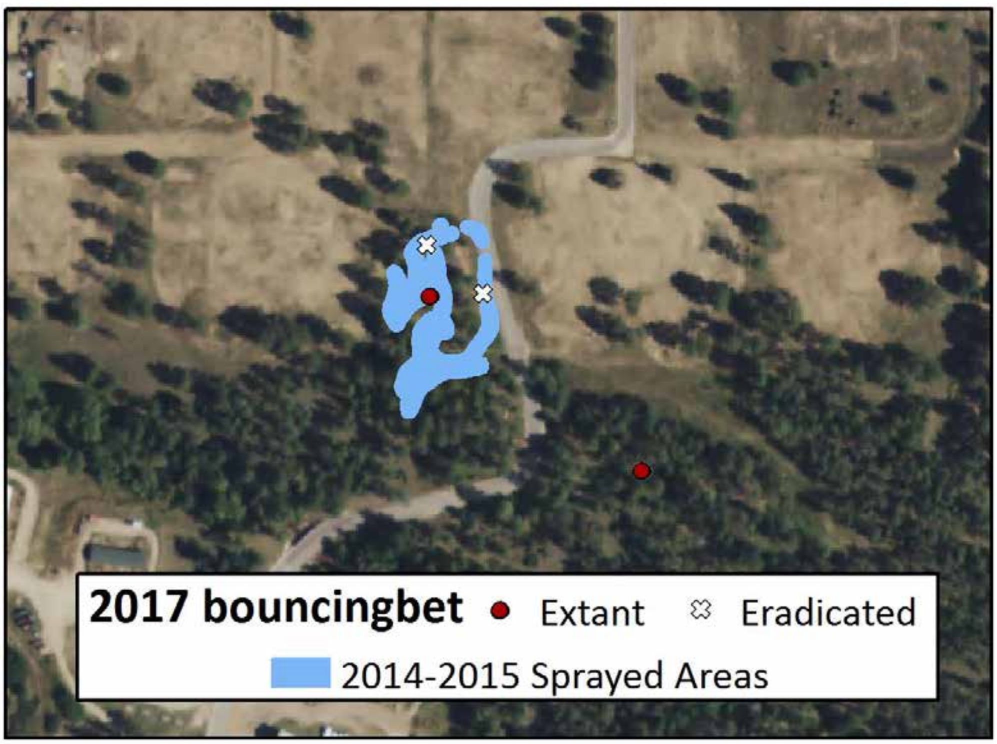


Figure 2. Herbicide area treated between 2014 and 2015 with extant populations of bouncingbet.

Scotch thistle has been treated at the Academy for over five years and yet the numbers of sites and individuals are increasing at treated sites. For example, at one heavily infested site, in 2013 there were 216 individuals at 18 extant sites; in 2016 there were 556 individuals at 75 sites and in 2017, there 357 individuals at 57 extant sites (Figure 3). These fluctuations are typical because this is a biennial species. Treatment areas showed both soil damage and non-target herbicide application across the site. Scotch thistle or new species of non-native plants and noxious weeds are filling in the bare soils resulting from overspray. At this time treatments appear to be exacerbating the Scotch thistle infestation and it would be prudent to revisit management techniques. It should be noted that the chemicals recommended by CSU for herbicide treatment for Scotch thistle are only for pastures and rangeland (CDA 2016). In addition, partial treatments may result in herbicide resistance, making treatments even more challenging. This is an ideal location for a site plan. A site plan worksheet can help guide adaptive management strategies that may lead to a more successful outcome (Worksheet provided in Appendix E). The protection of intact habitats and reduction of the seed source is a high priority for successful treatment results. This is supported by current information and articles on weed management (Pearson et al. 2016, CDA 2016, Pritekel et al. 2006).

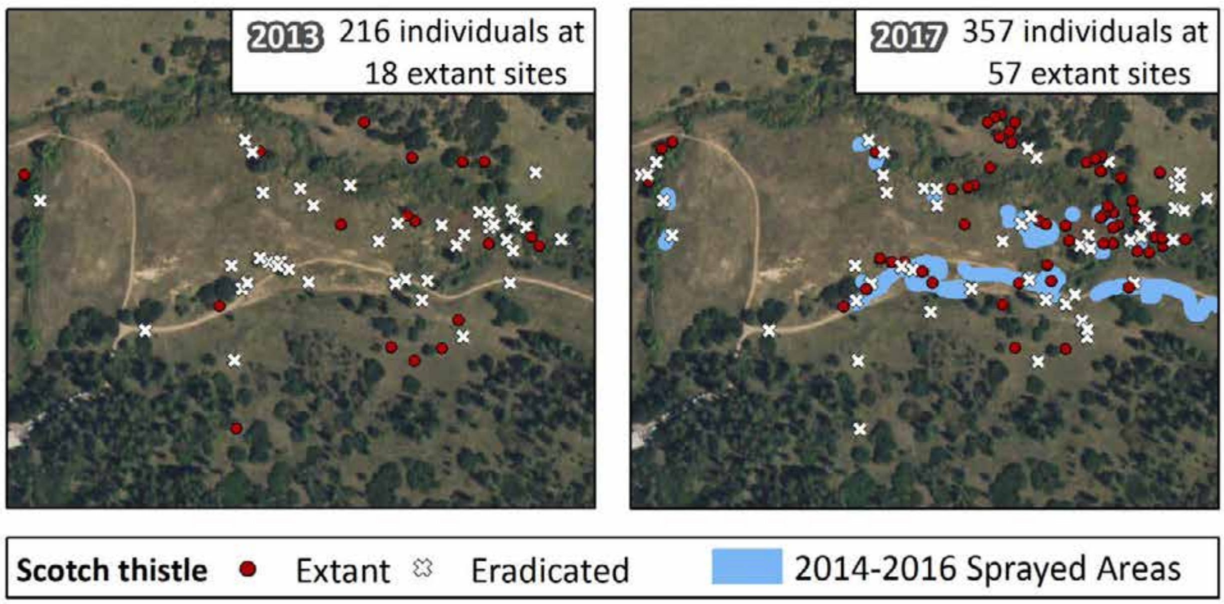


Figure 3. Comparison of 2013 and 2017 results for Scotch thistle treatment area.

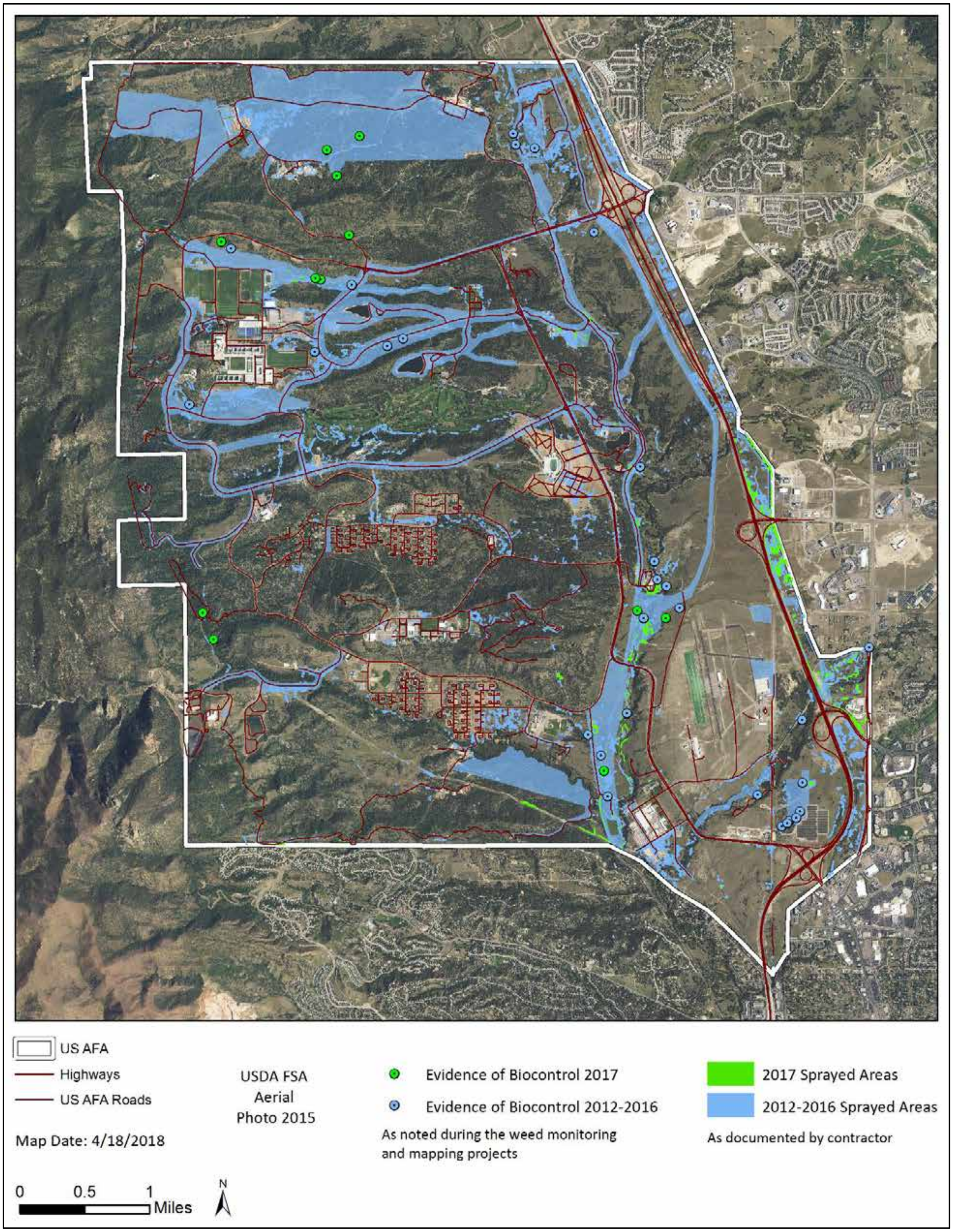
The spatial data provided by the herbicide applicator show that a number of rare plant and animal habitats were sprayed with herbicides, some directly in the heart of the main populations in 2016. At Farish, a rare plant that was sprayed in the heart of the occurrence, Porter feathergrass, was not found in 2016. Porter feathergrass (*Ptilagrostis porteri*) is a G2 species that is globally imperiled meaning there are less than 20 known locations left in the world. It is impossible to conclude for certain the absence of this plant at Farish in 2016 is linked to the herbicide spray, but it is possible. Herbicides were also sprayed in polygons where Preble's Meadow Jumping Mice, a federally threatened species, have been documented. This problematic for several reasons. The mice need the plants for food and shelter. Bugs and other organisms may be either killed or coated with herbicide that are then used by wildlife. Additionally, a large area known to contain Rocky Mountain cinquefoil (*Potentilla ambigens*) was sprayed covering 30% of the known occurrence.

Recommendations as weed management at the Academy moves forward include a new approach for weed treatment other than, or in addition to, herbicides. This is especially important for species which appear to be increasing despite aggressive and continuous herbicide treatments. Soil damage and increased footprint for weeds in treatment areas was observed in 2015-2016 in designated special weed management areas (SWMAs). Herbicides are typically not recommended as the sole source of treatment and it has been documented by numerous studies that herbicides alone do not work for species that have deep root systems (Colorado State University Extension 2016, CSU 2013, 2013b, Pritekel et al. 2006 and USFS-USDA 2014a, b). Herbicides have a residence time in soils that should be considered and applications to the same sites year after year are not recommended. Long term monitoring photo plots for musk thistle are documenting vegetation changes that include reduction in woody vegetation, forbs, biodiversity, and an increase in non-native grasses, especially cheatgrass and smooth brome in sites that have been treated with herbicides (Photo 1). This has been observed by Pearson et al. (2016) at chemically treated sites. Broadcast herbicide treatments are damaging to the natural systems at the Academy.

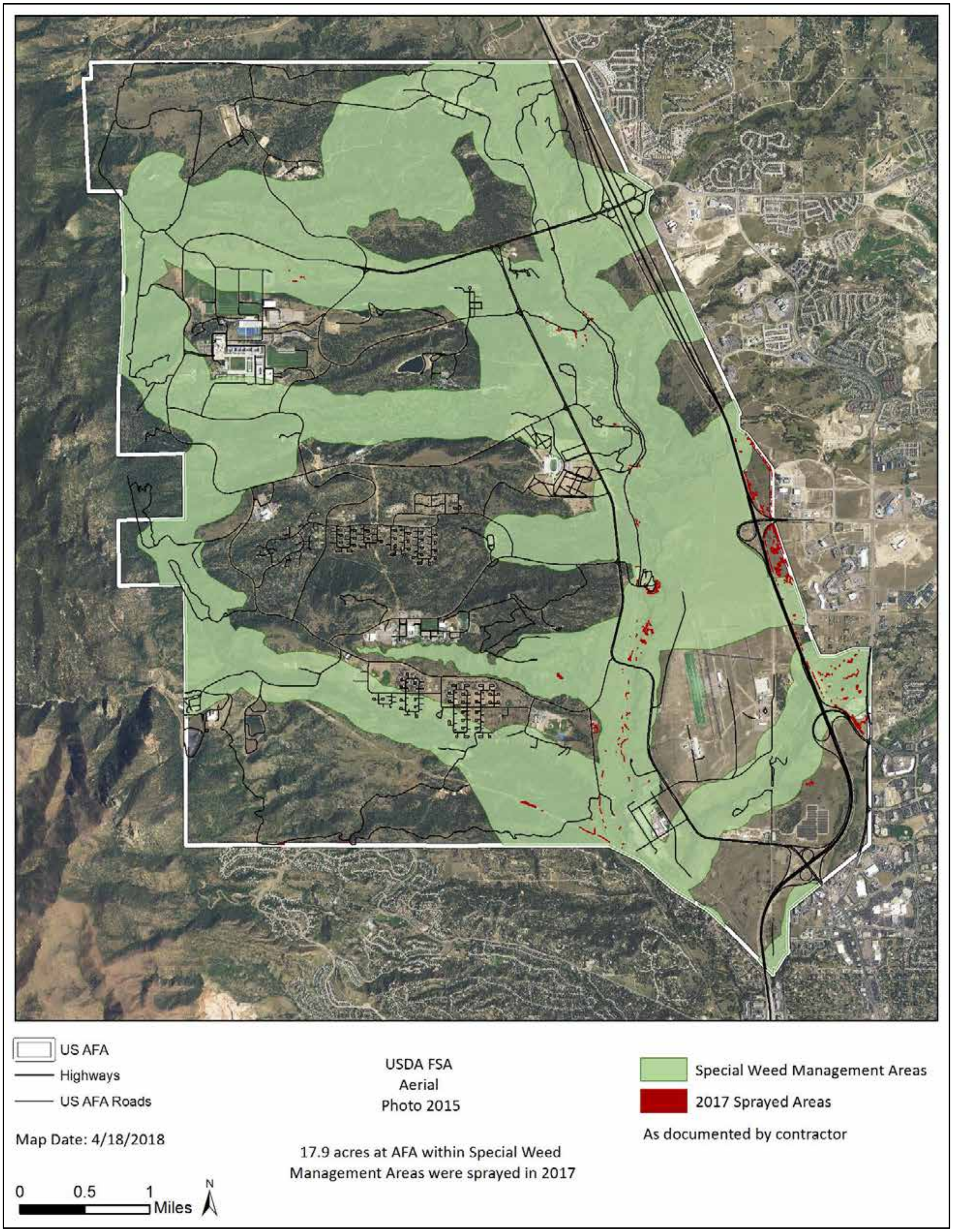
A fairly significant landscape at the Academy (Maps 3 & 4) and Farish has been treated with herbicides that contains rare plants, plant communities and animals. The Preble's Meadow Jumping Mouse territory needs to be considered as do the rare butterflies and plants that have been documented. The non-target damage was high in many sprayed areas (as has been noted over several years). This is unfortunate for the areas containing rare species and a new strategy needs to be incorporated if rare species are to be protected. To shield rare species from herbicides, the weed applicator must use a precise spot application method in areas that contain rare species (Mui and Panjabi 2016). Without a site plan, herbicide application near rare species is not recommended. The pattern of mapping weeds and spraying those areas year after year is not encouraging to native species. Areas that have been heavily treated may no longer have the target weed but contain a new weed or a non-native aggressive grass species.

Photo 1. Herbicide application area in 2017 showing significant impact and off-target damage to the surrounding vegetation and soils and creating more habitat for noxious weeds.

Securing baseline control monitoring plots that are not subjected to weed treatments has been very helpful since 2015. Control plots are necessary to interpret the weed data that is being collected and will help give an understanding of natural declines or increases that may be occurring.



Map 3. Herbicide treatment areas at the Academy in 2017.



Map 4. Special Weed Management Areas with herbicide treatment areas in 2017.

Biocontrol organisms are still active at the Academy. These plots are showing that the noxious weeds are actually stabilizing and/or decreasing in cover and frequency. Evidence of biocontrol organisms is being observed in the leafy spurge and Canada thistle plots. In 2017, the herbicide applications appear to be mainly in the eastern side of the property and away from most of the Special Weed Management Areas. However, the applications in the creek drainages may need to be re-evaluated.

CNHP and the Academy continue to improve communications between staff and contractors to ensure proper identification of target weed species, identification of wetland habitats and rare plant species known to occur within a number of the study plots and other areas at the Academy, and to interpret the monitoring results. A yearly meeting with CNHP and weed treatment staff and contractors has been a good way to open lines of communication and share information. Ongoing communication is critical because in some instances, the disturbances caused by weed treatments appear to encourage the growth of noxious weeds and smooth brome. In addition, some of the weed management occurring at the Academy is in natural areas where the native vegetation needs to be protected and/or in the vicinity of rare plants, native plant communities, and animals of conservation concern. For some species biocontrol is considered the best way to bring non-native species into balance (USFS-USDA 2014b). Therefore, protecting areas with biocontrol organisms needs to be included in the assessments before further treatments to species such as Canada thistle, leafy spurge and yellow toadflax, as these can impair the success of the biocontrol organisms (Michels et al. 2014).

Protocols for treating weeds in the vicinity of rare plants has recently been developed by the State of Colorado and CNHP (Mui and Panjabi 2016). It is important to note that weed management is a science still considered to be in its infancy. Newly published research should be considered in future weed management and this information is best shared in a yearly workshop with resource management personnel and on-the-ground applicators. This year we have provided a site assessment worksheet to help create a site plan for treatment (Appendix E). Site plans are recommended by multiple agencies and weed treatment guides (USFS Fire Effects Information System (FEIS) 2016, Interagency Workgroup 2016, Pearson et al. 2016, Mui and Panjabi 2016, CPW 2013, UC Davis Weed Research and Information Center 2013, CSU 2010, Sher et al. 2010, and Tu et al. 2001). This will not only document treatments but assess success and help develop adaptive management strategies to help reduce the use of herbicides, ineffective or harmful treatments and the success of weed management at the Academy.

Summary of Recommendations

- Continue rapid response activities for myrtle spurge, scentless chamomile, salt cedar and Russian knapweed.
- Keep Academy staff and contractor on the lookout for new occurrences of weeds that may be found on the Academy.
- Avoid herbicide application to natural areas without a site plan in place or use only spot application method. (Worksheet provided in Appendix E).
- Continue to avoid application of herbicides to permanent monitoring plots. An updated GIS shapefile will be provided to the weed contractor(s) and technicians to avoid plots. Baseline plots are needed as part of the monitoring surveys. The monitoring plots were not treated in 2016-2017. This data will now help to determine if the widespread weed species are stable without treatments and serve as useful baseline information. This will provide robust monitoring data for statistical analyses.
- Utilize only spot herbicide applications in Special Weed Management Areas (Smith et al. 2015) if herbicides are used. Herbicide applications should be targeted to roadsides and away from sensitive areas with rare plants and diverse native species unless a site specific treatment plan is in place for proposed treatment areas where natural resources need protection.
- For 2017, CNHP will create site plans for two sites in a natural area that include a site description with a species list, the proposed method of treatment(s) and a description of the follow-up monitoring and restoration activities (see worksheet in Appendix E).
- Continue to host a yearly weed workshop for updates and improved communication for contractors and staff. Native species are being directly impacted by weed management activities and information can be discussed to create site plans for proposed treatment areas with natural resources. Recognizing some of the rare species that are on the base as well as some of the target weeds in different growth stages, and newly identified species can be reviewed.
- Revisit methods used to treat weed species where the treatments do not seem to be reducing weeds: houndstongue, Scotch thistle, musk thistle, bouncingbet, myrtle spurge.
- Avoid utilizing herbicides for multiple years in the same location. The coverage of smooth brome into the natural areas seems to be increasing in areas where herbicides have been repeatedly utilized at the same locations.
- Use the details in the following sections on individual weeds for information on plant biology and treatment strategies.
- Add the following species to a watch list and provide this list to field technicians and weed sprayer: Garlic mustard
    - Hairy willowherb
    - Mediterranean sage
    - Perennial pepperweed
    - Purple loosestrife

Russian Knapweed (*Acroptilon repens*)

Potentially eradicated; no extant features observed at all sites from 2013-2017.

AFA Management Goals: Eradication through continued monitoring and rapid response with mechanical and chemical treatments

State List: B

- Perennial, spreading by lateral roots and from seeds.
- Root buds active winter and spring
- Roots of newly established plants can expand rapidly and can be 8 ft deep (Beck 2008).
- Emerges early spring, bolts May – June, flowers into fall (CSU 2013).
- Rapid Response is still a viable treatment at the AFA.
- Seed longevity: 5 years (Code of Colorado Regulations 2014).

Photo: Russian knapweed flower, note papery non-spiny phyllaries (left) and lobed leaves with hairy stems (Photo CSU Extension JK Web).

2017 Results

During the 2017 survey, seven of the twelve known sites were surveyed and no Russian knapweed plants were observed (Map 5). Russian knapweed has not been observed at the Academy for at least five years (Table 3, Figure 4). Monitoring of the known sites should continue for at least one-two more years based on herbicide residue time and seed longevity of this species which is thought to be around five years. Rapid response and early detection combined with yearly monitoring has been successful at the Academy and Russian knapweed now has a “potentially eradicated” status at the Air Force Academy. All 12 sites will be visited in 2018.

Table 3. Russian knapweed summary data, 2004-2017.

Census Mapping Method					
Year	*# Shoots*	*Total # Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2004	---	3	3	0	---
2005	---	3	2	1	---
2007	200	4	2	2	0.03
2008	157	4	2	2	0.025
2009	---	4	2	2	---
2010	0	4	0	4	0
2011	0	4	0	4	0
2012	543	12	10	2	0.05
2013	0	12	0	12	0
2014	0	12	0	12	0
2015	0	12	0	12	0
2016	0	12	0	12	0
2017	0	7	0	12	0

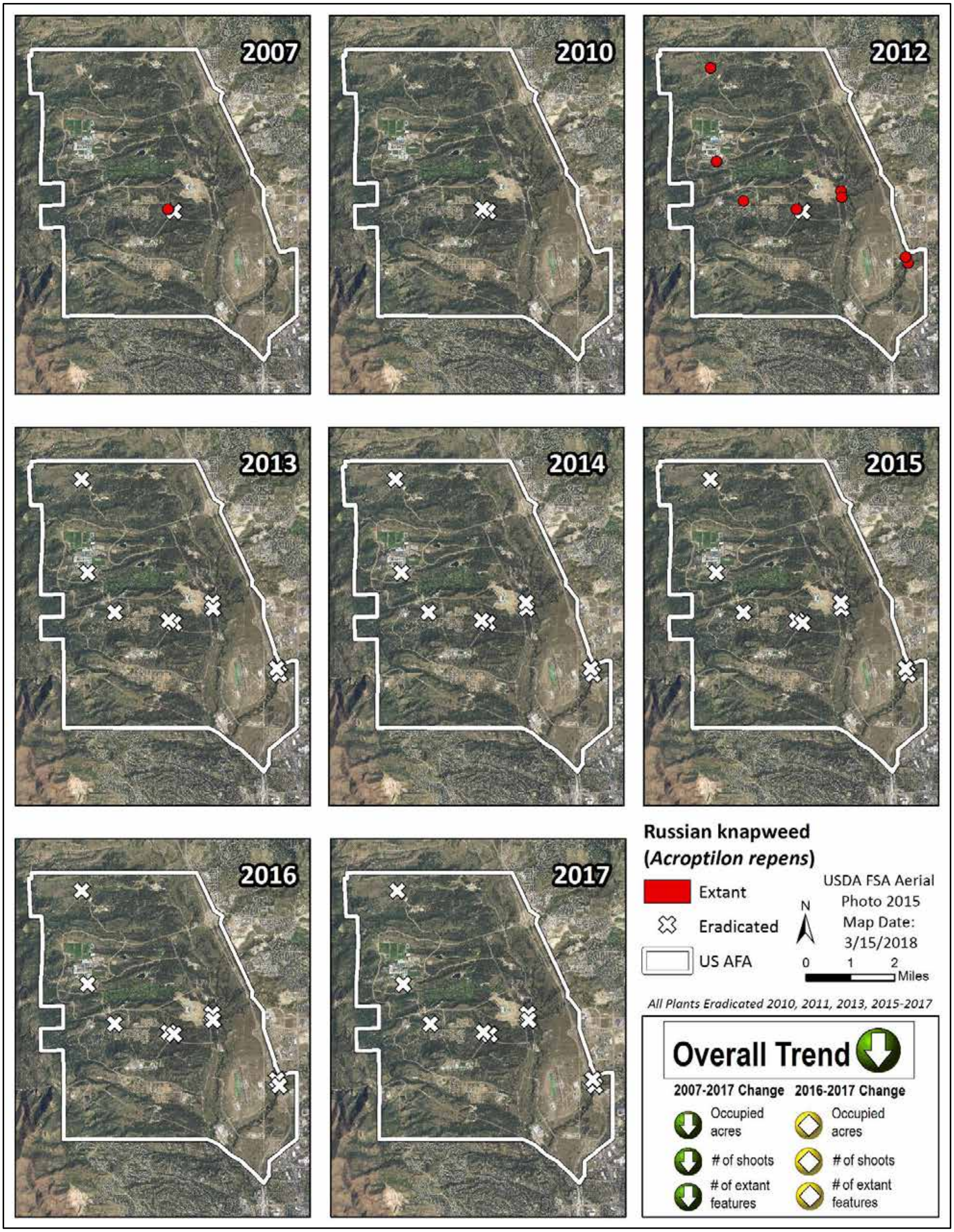
Figure 4. Number of Russian knapweed individuals and mapped features, 2007-2017 **(Seven out of 12 sites visited in 2017).**

Recommendations

Visit the 12 known sites for at least one to two more years for the census surveys (seed longevity is thought to be around five years). Weed technicians may need training to identify Russian knapweed in pre-flowering stages. It should remain on the rapid response search list for the Academy.

History of Sampling and Treatments:

- The first appearance of Russian knapweed was in 2004 and by 2007 there were two extant occurrences and two eradicated occurrences, all near Douglass Way (Map 5). By 2009, two occurrences were eradicated and two were sprayed that year (Rondeau and Lavender 2012). None of these infestations have re-established in subsequent years.
- 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).
- In 2012, when 10 new locations were mapped, Russian knapweed occupied 0.05 acres with 543 shoots. This represented a 172% increase in number of shoots and a 400% increase in number of extant features since 2007 (Figure 4).
- In 2013, all extant locations were treated (0.05 acres), and no live plants were observed in 2013 or in 2014. In 2014, a rosette was tentatively identified as Russian knapweed and was later identified as spotted knapweed.
- In 2015, no new populations were identified and no extant features were observed at eleven of the twelve known sites.
- In 2016, all twelve known sites were visited and no Russian knapweed plants were found.
- In 2017, seven of the twelve known sites were visited and no Russian knapweed plants were found.



Map 5. Distribution of Russian knapweed at the Academy between 2007 and 2017.

Hoary Cress (*Cardaria draba*)

Monitoring 2012 - 2016 populations stable to slightly decreasing.

AFA Management Goals: Containment through chemical and mechanical treatments of large infestations as necessary and monitoring for new satellite populations and changes in untreated existing populations.

State List: B

Plants not monitored in 2017

Photo by Michelle Washebek, CNHP

- Perennial that reproduces by seeds and lateral roots.
- Flowers May-June.
- Grows to 2 feet tall with root depths to 32 inches.
- Prefers disturbed alkaline soils.
- Seed longevity is 3 years (Code of Colorado Regulations 2014).

2016 Results

A total of 10 permanent plots were surveyed in 2016; seven plots were established in 2012 and three plots in 2015 (Map 6). The hoary cress plots show similar frequencies from 2012–2016 with 44-50% of quadrats containing plants, while the number of shoots in each plot have decreased since 2013 (Table 4). The average heights measured in 2016 are almost double what they were in 2012 and 2013. This is probably related to sampling 1-2 weeks later in 2016 compared to 2012-2015 and may also be related to higher precipitation levels since 2012 (Figure 1). Herbicide treatments were conducted in plots CADR-2 and CADR-3 in 2013 and in CADR-10 in 2015. Only CADR-2 showed a decrease in percent cover in the herbicide treated plots. CADR-1, CAD4-3 and CADR-10 were stable (Tables 4-6). Herbicide treatments are difficult to interpret in 2016 as they were not applied uniformly across plots.

Table 4. Summary of hoary cress permanent plot data, 2012-2016.

Permanent Plot Sampling Method							
Year	*# Plots Sampled*	*# Quads Sampled*	*# Quads with Plants*	*Frequency (%)*	*Total # Shoots*	*AVG Height (cm)*	*AVG# shoots/plot*
2012	7	434	212	49	5,350	25	764
2013	7	428	213	50	6,446*	22	920*
2014	Not Sampled						
2015	10	618	273	44	5,615	37	562
2016	10	617	278	45	3,649	46	365

*Herbicide was applied to parts of CADR-2 and CADR-3 after 2013 sampling.

Hoary cress frequency (% of quadrats within a plot containing hoary cress) ranged from 16-82% across all years, with an overall average frequency of 47% (Table 4). Standard deviation (SD) is a measure of variance from the mean. The Average Standard Deviations (ASDs) from 2012-2016 were similar, ranging from 18-22%. A change greater than the average SD for all four years within the same plot (e.g. plus or minus 20) was considered to be an overall increase or a decrease. CADR-2 showed a decrease from 2013 to 2015 (*) as well as an overall decrease from 2012-2016, while all other hoary cress plots have remained stable (Table 5, Figure 5).

Table 5. Frequency of hoary cress in permanent plots, 2012-2016. Frequency = % of quadrats with hoary cress. Bolded and shaded numbers indicate herbicide treatment. Colors indicate overall trend: yellow is stable or <1 average standard deviation ASD (20%), and green represents a decrease of >1 ASD. * indicates a change of >1 ASD for that year.

Plot Name	FREQUENCY 2012 (%)	FREQUENCY 2013 (%)	FREQUENCY 2015 (%)	FREQUENCY 2016 (%)	AVG FREQUENCY 2012-2016
CADR-1	81	82	82	77	81
CADR-2	65*	**67***	16*	26	44
CADR-3	21	**26**	24	16	22
CADR-4	52	50	40	50	48
CADR-5	37	39	41	40	39
CADR-6	26	26	29	39	30
CADR-7	65	61	68	70	66
CADR-8	---	---	43	46	45
CADR-9	---	---	45	52	49
CADR-10	---	---	**53**	50	52
AVG FREQ	**49**	**50**	**44**	**45**	**47**
ASD	**22**	**21**	**19**	**18**	**20**

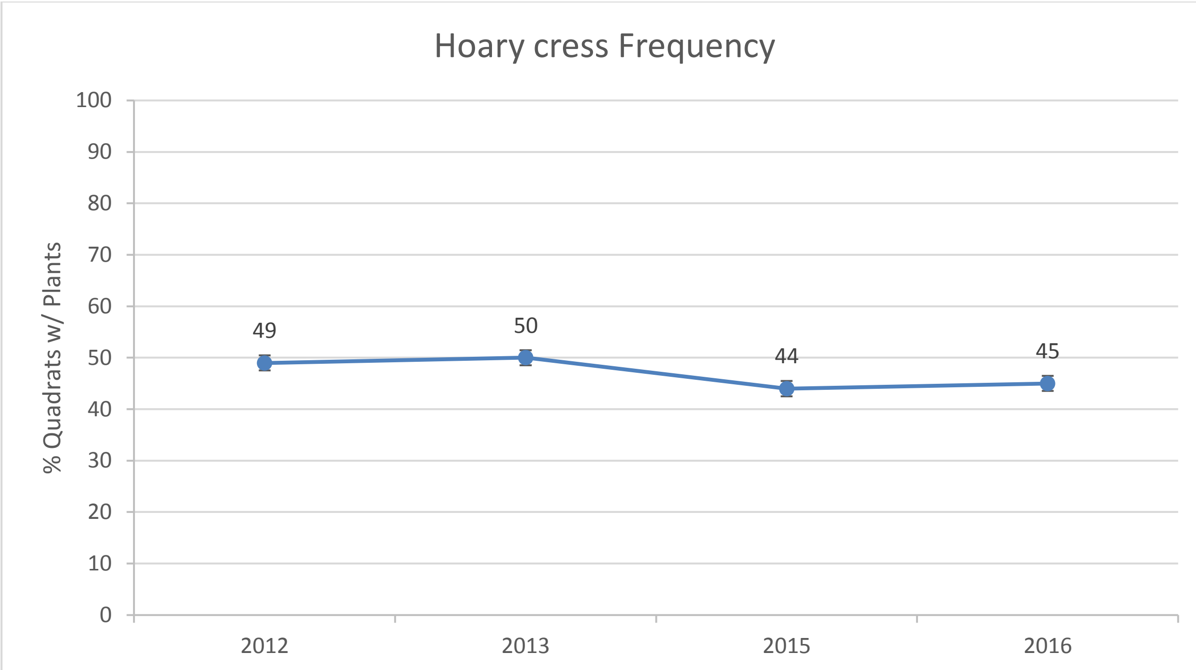


Figure 5. Hoary cress frequency at 10 permanent plots, 2012-2016.

Density is calculated from the average number of stems arising from the ground in half meter quadrats and averaged for each plot; percent cover is an estimate of how much area is occupied within the half meter quadrats and averaged for the plot. In 2016, all of the monitoring plots showed no increases or decreases greater than the ASD (plus or minus 9) and overall the density is relatively stable from 2012-2015 (Table 6). CADR-4 and CADR-7 showed decreases of > 1 ASD between 2015 -2016 but not between 2012 and 2016.

Table 6. Average density of hoary cress in permanent plots, 2012-2016. **Bolded and shaded** numbers indicate that the site was treated with herbicide. Color indicates overall trend: yellow is stable with less than one standard deviation. * indicates a change of >1 ASD for that year.

Plot Name	*AVG Density 2012*	*AVG Density 2013*	*AVG Density 2015*	*AVG Density 2016*	*AVE Density 2012-2016*
CADR-1	27	30*	12	10*	20 (11-29)
CADR-2	7	**11**	1	1	5
CADR-3	1	**3**	1	1	2
CADR-4	7	8	24*	6	12 (3-21)
CADR-5	9	12	8	8	12
CADR-6	5	4	3	2	4
CADR-7	31	37*	20	15*	26 (17-35)
CADR-8	---	---	10	6	8
CADR-9	---	---	5	6	6
CADR-10	---	---	**7**	5	6
AVG	**12**	**15**	**9**	**6**	**11**
SD	**12**	**13**	**8**	**4**	**9**

The average percent cover of hoary cress in the plots was also calculated showing an overall decrease in one plot (CADR-7), while the remaining nine plots were stable (Table 7).

Table 7. Average % cover of hoary cress in permanent plots, 2012-2016. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate overall trend: yellow is stable with less one average standard deviation (ASD); green indicates a decrease of at least one ASD. * indicates a change of >1 ASD for that year.

Plot Name	*AVG Cover (%) 2012*	*AVG Cover (%) 2013*	*AVG Cover (%) 2015*	*AVG Cover (%) 2016*	*AVG Cover 2012-2016*
CADR-1	12	13	11	5	10 (5-15)
CADR-2	6	**9**	1	1	4 (0-9)
CADR-3	0	**1**	1	<1	1
CADR-4	2	5	3	2	3 (0-8)
CADR-5	2	3	6	3	4 (0-9)
CADR-6	1	1	3	1	2
CADR-7	11	20	18	8*	14 (9-19)
CADR-8	---	---	11	3	7 (2-12)
CADR-9	---	---	5	2	4 (0-9)
CADR-10	---	---	**6**	2	4 (0-9)
AVG	**5**	**7**	**7**	**3**	**6**
SD	**5**	**7**	**5**	**2**	**5**

Recommendations

Continue to monitor 10 permanent plots yearly, if possible. Trends from that data will confirm if a natural decrease is occurring which currently appears to be the case. Herbicide should not be applied to permanent plots (unless it is added to the study design) to determine if the trend continues to be stable to decreasing naturally.

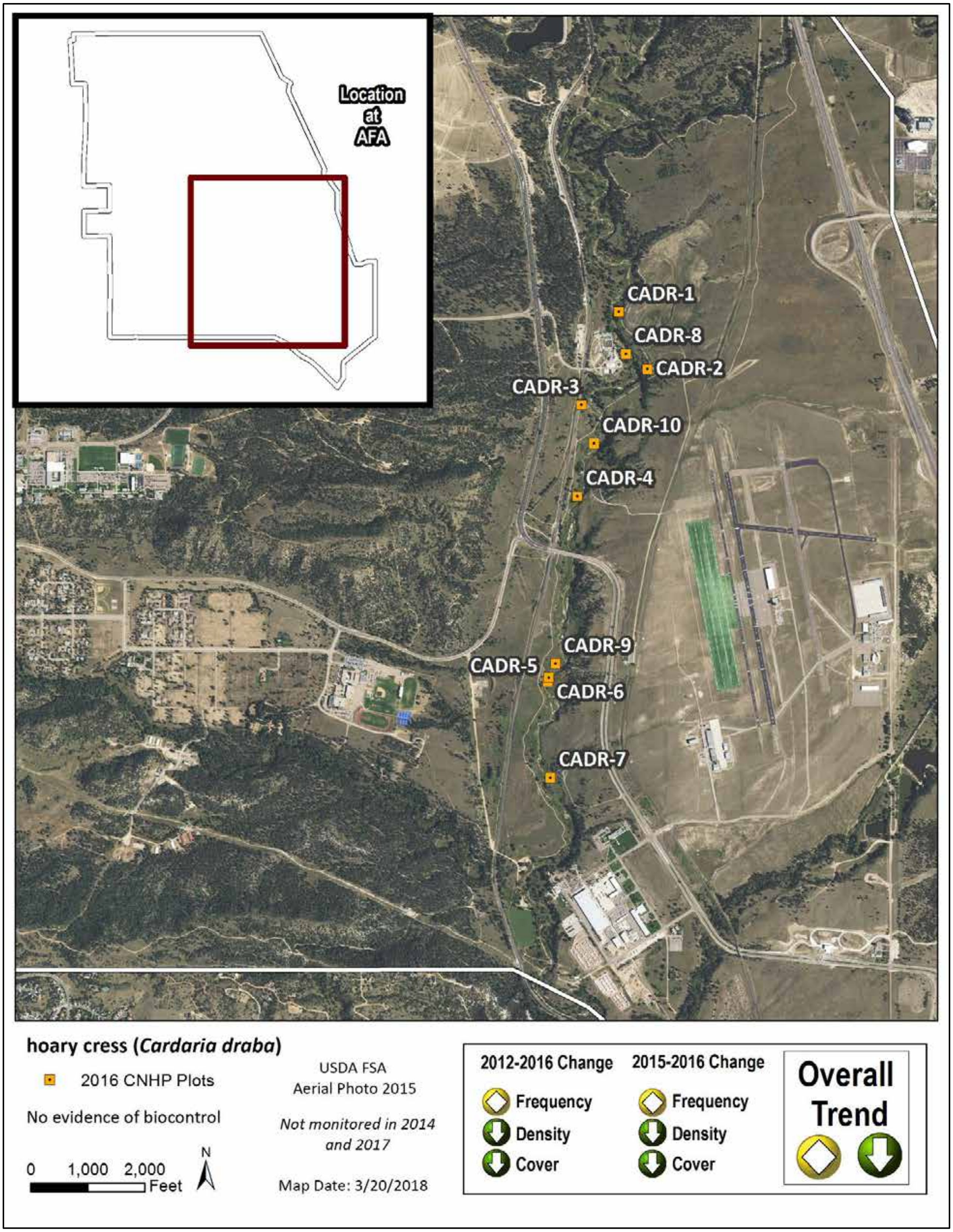
Target newly established satellite populations for control efforts. Hoary cress, like many deep-rooted perennial species, is difficult if not impossible to control once it has become established. It is thought that targeting newly established satellite populations is more effective for control, while the established populations should be monitored for expansion (USFS-USDA 2014a).

There are no state-approved biocontrol organisms currently available for hoary cress. However, insect damage was observed in half of the plots in 2015 (Map 6). This is an important consideration in the management of this difficult to control species as weed species can naturally decline over time (Norris 1999). Continued monitoring can help determine if this is occurring at the Academy.

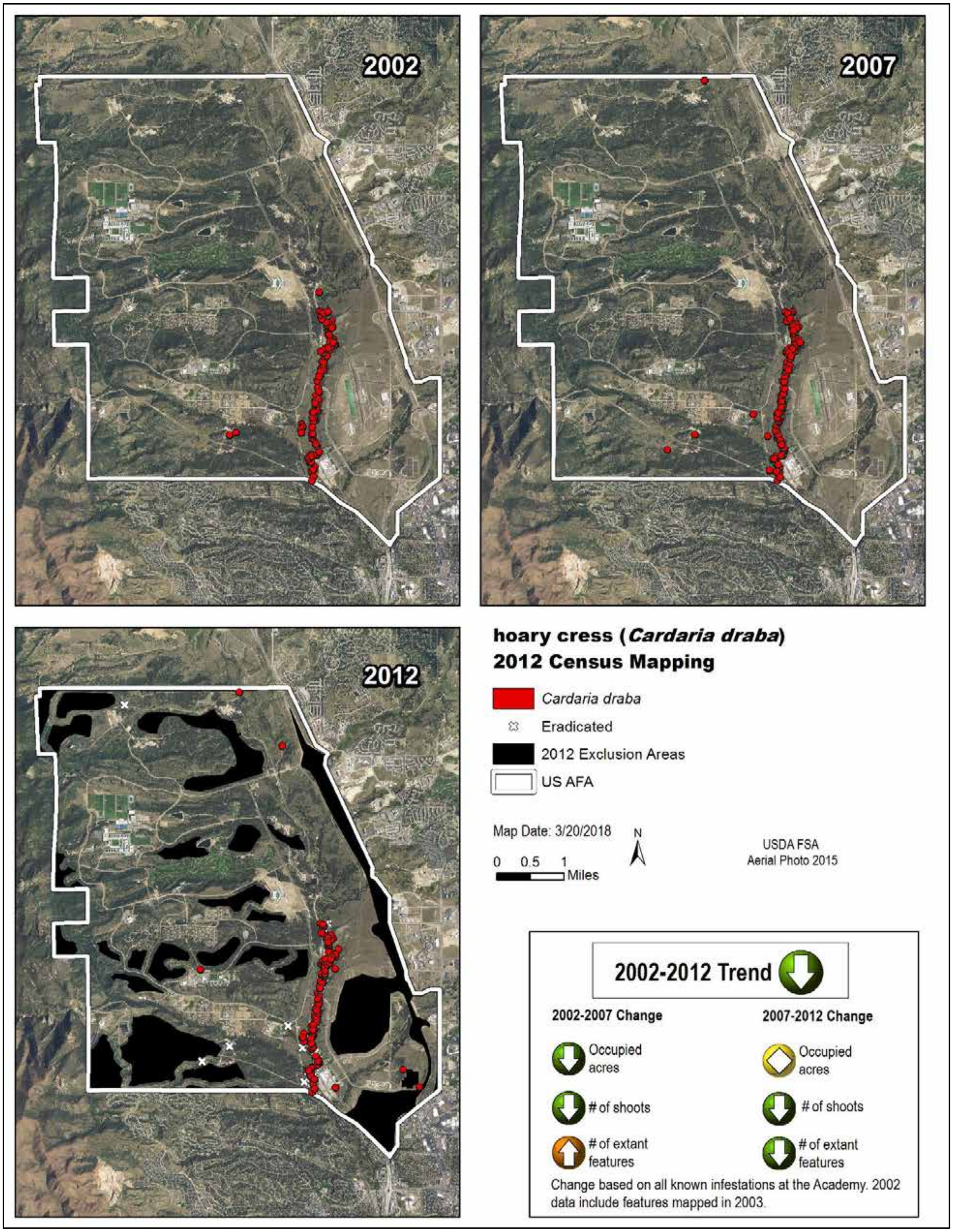
A backpack hand-held sprayer or wick method are recommended for natural areas if chemical treatments are used (only recommended for satellite populations), especially in areas known to contain resources of conservation concern and where the native vegetation needs to be protected or where smooth brome is in the vicinity (Smith et al. 2015). The most important consideration for this species at the Academy is to determine if populations are expanding, stable or naturally decreasing. Census mapping for hoary cress was conducted in 2002, 2007, and 2012, and showed a decreasing trend, although its range expanded (Map 7). Treatments have the potential to increase smooth brome coverage or that of other invasive species, if they are not carried out with care to protect surrounding native vegetation and intact soils.

History of Sampling and Treatment:

- In 2002, hoary cress was mostly concentrated along Monument Creek in the south half of the Academy (Anderson et. al. 2003).
- In 2007, a lone occurrence was identified along Monument Creek on the north end of the Academy (Anderson and Lavender 2008b).
- In 2012, eight random sites known to have hoary cress in 2007 were used to establish eight permanent plots (Map 6).
- Census mapping for hoary cress distribution across the Academy property was conducted in 2002, 2007, and 2012 (Map 7).
- In 2013, seven of the eight plots were monitored (Table 4). Frequency was stable between 2012 and 2013 (Table 5, Figure 5), density increased from 2012 to 2013 (Table 6). The average cover of hoary cress increased from 2012 to 2013 (Table 7). Herbicide was partially applied to CADR-2 and CADR-3 after 2013 field site visit.
- No plots were monitored in 2014.
- Seven of the plots sampled in 2013 were resampled in 2015. Three new additional plots were established to bring the total number of plots to 10 (Map 6). The average frequency and average density were both lower than 2012-2013; the percent average cover was the same as 2013 (Table 7).
- 10 plots were sampled in 2015. The frequency decreased in CADR-2, average density decreased in CADR-1 and CADR-7 and the percent cover decreased in CADR-1, CADR-2, CADR-7 and CADR-8. Everything else remained stable with no increases detected.
- 10 plots were sampled in 2016. The overall trend was stable for nearly all plots for frequency, average density and percent cover. There was an overall decrease in frequency in CADR-2 and a decrease in percent cover for CADR-7.
- No plots were monitored in 2017 due to late start date for field work.



Map 6. 2016 hoary cress plots at the Academy.



Map 7. Distribution of hoary cress at the Academy in 2002, 2007 and 2012.

Musk Thistle (*Carduus nutans*)

Overall a decrease since 2008, with slight increases observed from 2013-2017.

AFA Management Goal: Suppression through mechanical, chemical, and biological treatments with continued monitoring.

State List: B

Photo by Michelle Washebek

- Biennial (winter annual) with a taproot.
- Reproduction only by seed.
- Rosettes form early spring, bolts in March to May.
- Plants die after seed set (CSU 2013a).
- Plants are impacted by drought.
- Seed longevity: 10 years (Code of Colorado Regulations 2014).

2017 Results

The overall trend since 2008 is decreasing. However, between 2015 and 2017, the populations at the Academy increased from 61 to 358 individuals. There has been an increase over the last five years; the overall numbers of individuals are still lower than those observed in 2008 (Table 8, Figure 6). Spring and early summer precipitation was significantly higher than the average for Colorado Springs in 2015 (Figure 1) and could have contributed to the increases since the low of 2013 (2012 with very low spring/summer precipitation). However, field observations show that it is also very likely the actual weed treatments themselves are contributing to the increases. For example, herbicides being applied to bolted plants, which is not recommended. These plants die after they flower since they are biennial and the remaining seed heads and/or flowers are still viable on the treated plants (Photo 2). In addition, rosettes are missed at many of the treatment sites and rosettes are the most effective stage to treat with herbicides. This not only contributes to herbicide resistance but will increase the weeds at the site. The spray band also may be too wide and overspray appears to be impacting soils thereby allowing more weeds to establish, especially cheatgrass and musk thistle. The time of year the plants are sprayed, the growth stage of the plants (bolted), the amount of herbicide and overspray, as well as the incomplete treatments need to be addressed to improve treatment success.

Table 8. Musk thistle population size at photo plots, 2008-2016. Bolded and shaded indicates plots that appear to have been treated.

Plot	*2008*	*2009*	*2010*	*2011*	*2013*	*2014*	*2015*	*2016*	*2017*	*Avg #/plot (+/-ASD 54)*
CANU-1	11	134*	**9**	**7**	**7**	**40**	34	52	58	39 (0-93)
CANU-2	**6**	80	**5**	**160***	0*	0*	10	5	17	31 (0-85)
CANU-3	**1**	**2**	**1**	**8**	1	0	2	0	0	2 (0-56)
CANU-4	1	63	**0**	**0**	0	0	3	23	9	11 (0-65)
CANU-5	1	27	**10**	0	6	**17**	**7**	5	0	8 (0-62)
CANU-6	**10**	45	**33**	3	2	4	0	12	50	18 (0-72)
CANU-7	**102***	**90***	**25**	**0***	**5**	0*	6	17	0	27 (0-81)
CANU-8	212*	**31**	**10**	**7**	7	0*	0*	6	0*	30 (0-84)
CANU-9	160*	**1**	**1**	**0***	0*	0*	4	0*	0	18 (0-72)
CANU-10	500*	--	**40+***	400*	**28***	0*	32*	130	224*	169 (115-223)
SUM	**1004**	**473**	**134**	**585**	**56**	**61**	**98**	**250**	**358**	**335**
AVG	**100***	**47**	**13**	**59**	**6**	**6**	**10**	**25**	**36**	**34 (0-88)**
Ave Standard Deviation	160	44	14	130	8	13	13	40	66	**54**
Avg Spring/Summer Precipitation	**6.95**	**12.81**	**8.08**	**8.54**	**12.58**	**12.16**	**20.5**	**12.12**	**14.78**	**12.33****

**30 year average (1961-1990)

*More than 1 SD difference

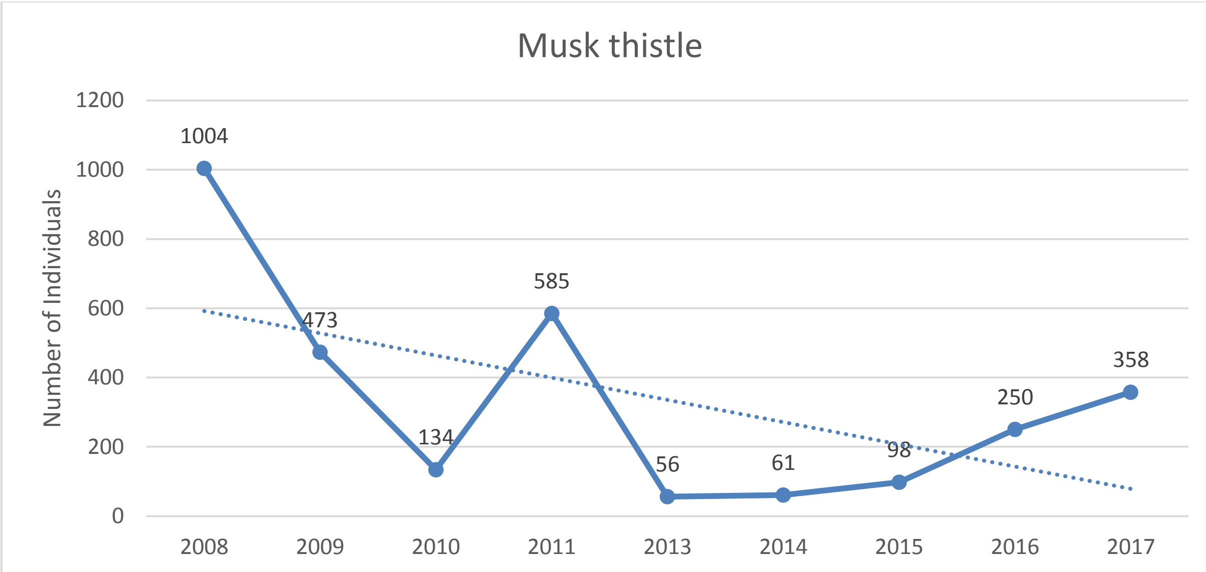


Figure 6. Musk thistle counts at 10 photo plots, 2008-2017.

Recommendations

Future treatments should not include broadcast herbicide applications in areas with native vegetation. Spot treatments at the rosette stage may be helpful. Treatments on bolted plants are likely ineffective for this biennial species (Photo 2).

Photo 2. Bolted musk thistle heads treated with herbicide which is not recommended. Cheatgrass at base indicates potential over spray damage to nearby plants and soil. P. Smith 2016.

Before herbicides are used, a site plan should be prepared because many areas where the plots have been treated are seeing a reduction in the biodiversity of plants and increasing weeds. A non-native and very aggressive perennial grass, *Bromus inermis* (smooth brome), which is harder to treat (although it is not on the State Noxious Weed List in Colorado) is becoming dominant. This grass is less beneficial to wildlife and is no longer recommended for use in restorations and plantings because of its aggressive nature (USDA-NRCS 2002). Plot CANU-7 has been treated several consecutive years with herbicides. While there has been a reduction in musk thistle plants, smooth brome is now dominant (Photo 3). The result of the herbicide treatment is a decrease in biodiversity at this site even though the weed goals are being met. Once smooth brome dominates it remains in this condition for many years. Repeated herbicide applications over multiple consecutive years are not recommended for this reason.

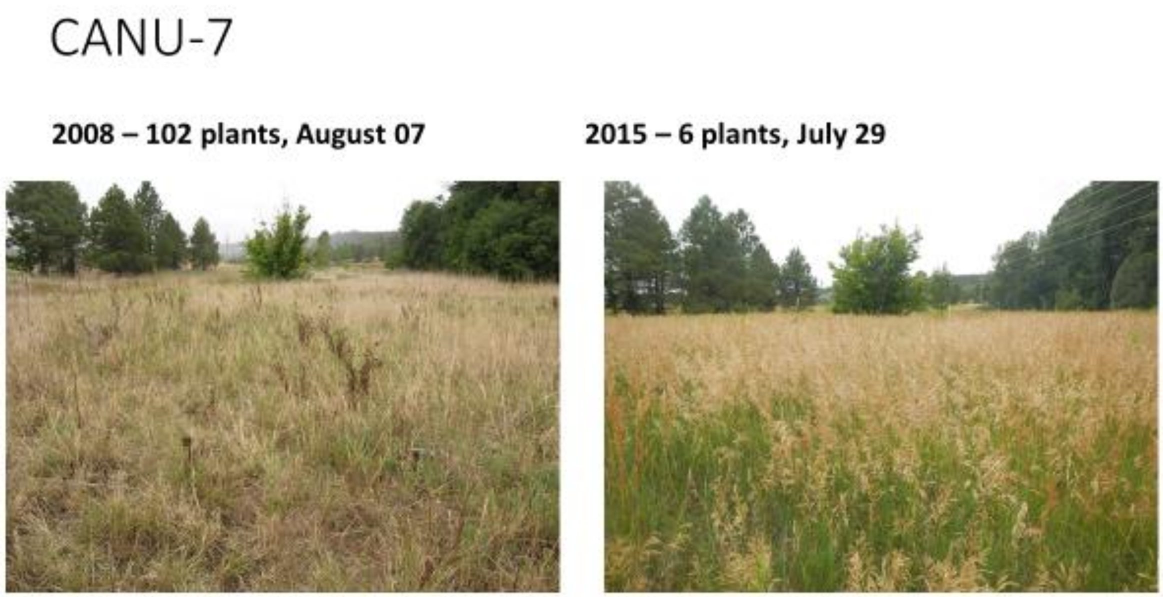


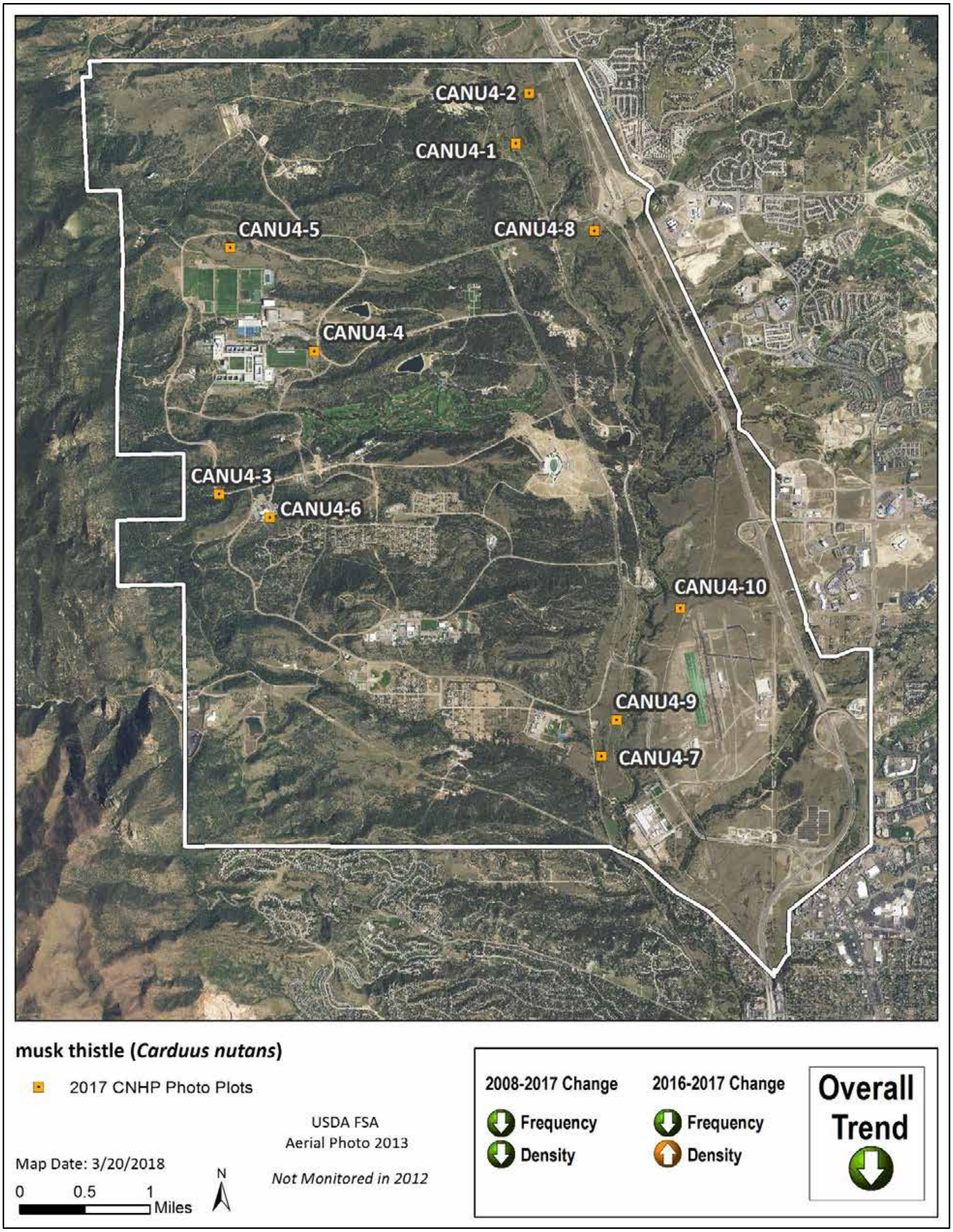
Photo 3. CANU-7 plot was treated with herbicide five years in a row. There was a reduction from 120 musk thistle to 6 plants in 2015 (17 in 2016). However, the native grasses and forbs present in 2008 have been replaced with a non-native aggressive grass – smooth brome (CNHP 2008, 2015).

History of Sampling and Treatment:

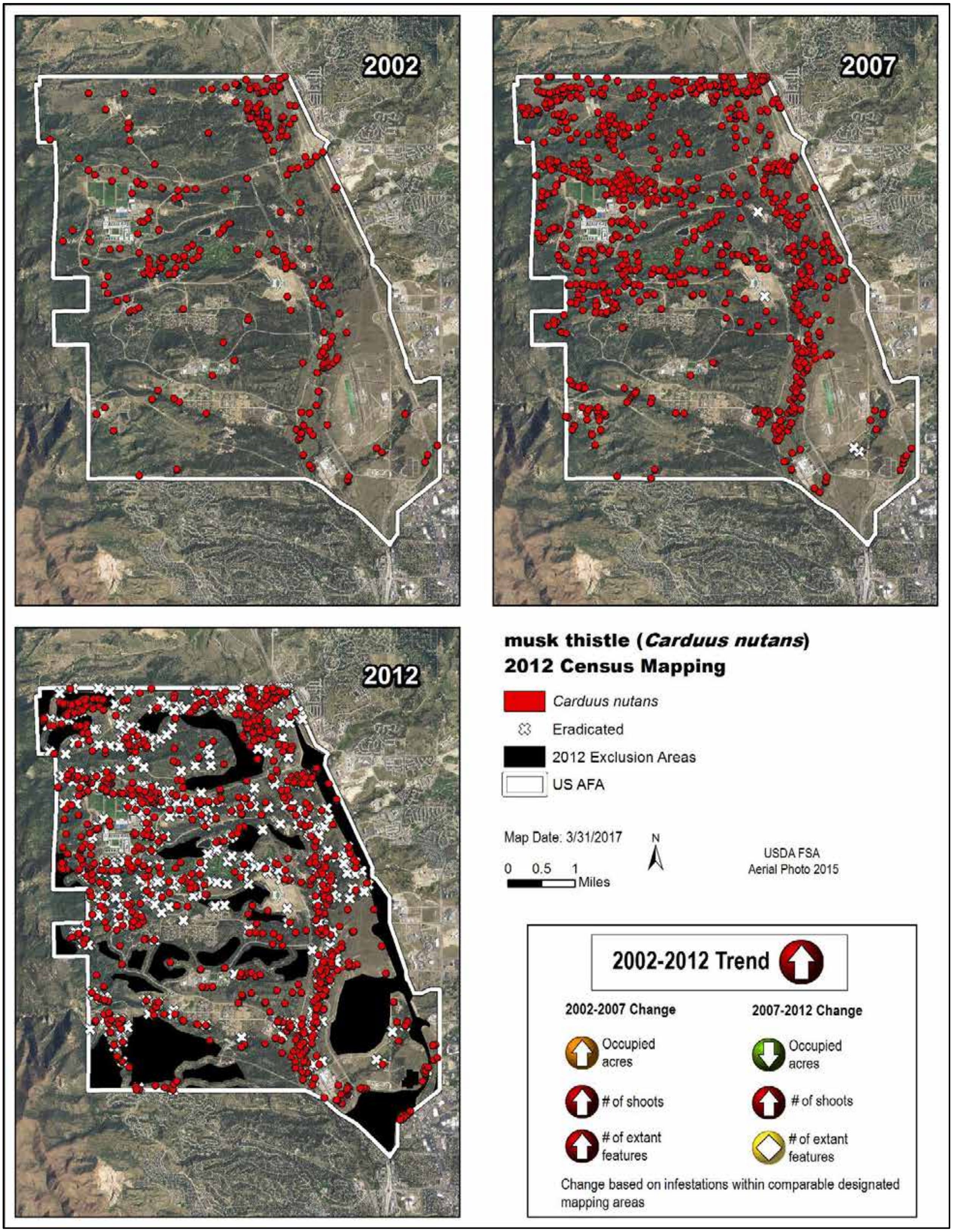
- All ten plots were visited in 2008-2015 with the exception of 2012 (Map 8).
- All plots have been treated at least once if not multiple times with herbicides based on our field observations (Table 8).
- Census mapping for musk thistle distribution across the Academy property was conducted in 2002, 2007, and 2012 (Map 9).
- The numbers of individuals recorded in the plots in 2015 were significantly lower than when the plots were initiated in 2008. Precipitation patterns may explain the increase in

plants noted in 2015. Two years in a row at CANU 2 a native plant (*Scrophularia lanceolata*) appeared to be treated with herbicides.

- In 2016-2017, there was an increase in the number of plants. The overall trend is decreasing but musk thistle has been increasing since 2013 and could be related to precipitation and inappropriate herbicide applications.



Map 8. 2017 musk thistle plots at the Academy.



Map 9. Distribution of musk thistle at the Academy in 2002, 2007, and 2012.

Spotted and Diffuse Knapweeds (*Centaurea maculosa, C. diffusa,* & hybrids)

Permanent plots show plant populations are stable in 2017. Rare plant species were located in two monitoring plots.

AFA Management Goal: Containment through monitoring and mechanical, chemical, and biological treatments.

State List: B

Left photo: Diffuse Knapweed, Michelle Washebek, right photo: Spotted Knapweed (*Centaurea maculosa*) Wiki Commons 2015

- Short-lived non-creeping perennial, biennial, occasionally annual that spreads only by seeds.
- Seeds germinate in the spring or fall and anytime during the growing season with disturbance (CSU 2013b).
- Environmental disturbance promotes invasion (CSU 2013b).
- Seed longevity: 8-10 years (Colorado Code of Regulations 2014).

2017 Results

Twelve permanent plots were surveyed in 2017 for knapweeds. All of the data indicate an overall stable trend from 2012 -2017 with slight increases for 2016-2017; the 2012-2017 data shows decreases in frequency and density with stable cover. Herbicide treatments were not applied directly to plots in 2016 or 2017. Continued monitoring will reveal trends for increases and decreases for untreated sites as long as herbicide is not applied to the knapweed monitoring plots.

The total number of shoots in the sampling plots decreased across all plots from 2012-2016 with an increase in 2017 for the non-biocontrol sampling plots. The biocontrol plots showed a decrease in shoots from 2012-2013 and have remained stable since 2013 (Table 9). The average knapweed height has ranged from 25-49 cm across all plots. The frequency has ranged from 6 to 36% across all plots in a non-linear fashion.

Table 9. Summary of knapweed permanent plot data, 2012-2017.

Non-Biocontrol Permanent Plot Sampling Method							
Year	*# Plots Sampled*	*# Quads Sampled*	*# quads with plants*	*Frequency (%)*	*Total # Shoots*	*AVG Height (cm)*	*AVG# Shoots/Plot*
2012	10	560	87	16	431	26	43
2013	10	551	33	6	168	30	17
2014	10	559	59	11	256	37	26
2015	9	496	71	14	296	45	33
2016	9	494	81	16	315	25	35
2017	9	499	112	21	483	38	54
Biocontrol Permanent Plot Sampling Method							
2012	4	163	51	31	353	34	17
2013	3	114	41	36	116	34	39
2014	0	Herbicide applied to biocontrol plots					
2015	5	247	46	19	127	49	25
2016	3	185	35	19	127	26	42
2017	3	183	46	19	139	25	46

Frequency (percent of quadrats with plants present) is the best indicator of an expanding or contracting population. The overall average frequency of the nine non-biocontrol plots was 21% for 2017. Biocontrol plots which were selected in areas with higher frequencies (because dense populations are necessary for good biocontrol results) showed an average frequency of 25% in 2017.

Table 10. Frequency of knapweeds in permanent plots, 2012-2017. Frequency = % of quadrats with knapweeds. Bolded and shaded numbers indicate herbicide treatment. Colors indicate overall trend: yellow is stable or a change of <1 average standard deviation ASD; green represents a decrease of >1 ASD, and orange indicates an increase of >1 ASD.

Plot Name	FREQ 2012 (%)	FREQ 2013 (%)	FREQ 2014 (%)	FREQ 2015 (%)	FREQ 2016 (%)	FREQ 2017 (%)	Average Frequency 2012-2017
CEDI3-1	**9**	0	**2**	7	7	5	5 (0-18)
CEDI3-2	**21**	3	6	Discontinued			
CEDI3-3	14	7	13	18	21	36*	18 (5-31)
CEDI3-4	11	21	15	15	13	20	16 (3-29)
CEDI3-5	14*	15*	**31**	42	47*	50*	33 (20-46)
CEMA4-1	23	7*	27	31	41	53*	30 (17-43)
CEMA4-2	27*	0*	2	5	3	13	8 (0-21)
CEMA4-3	3	2	2	0	0	5	2 (0-15)
CEMA4-4	26*	8	6	6	8	11	11 (0-24)
CEMA4-5	2	2	0	0	0	0	1 (0-14)
AVG	**15**	**7**	**10**	**14**	**16**	**21**	**14**
SD	**9**	**7**	**10**	**14**	**18**	**19**	**13**
Biocontrol Plots							
SK ploop3	**31**	---	---	0	7	5	11 (0-31)
SK ploop1	**37**	---	---	5	11	23	19 (0-39)
DK railroad	**56**	**21***	---	48	39	48	42 (22-62)
DK hwy83	---	**100**	---	44	Discontinued		
KW monck	24	**43**	---	16	Discontinued		
AVG	**37**	**55**	**---**	**23**	**19**	**25**	**32**
SD	**12**	**33**	**---**	**20**	**17**	**18**	**20**

*Plots discontinued in 2016: KWmonck used as a wood deposit area; DKhwy construction activities.

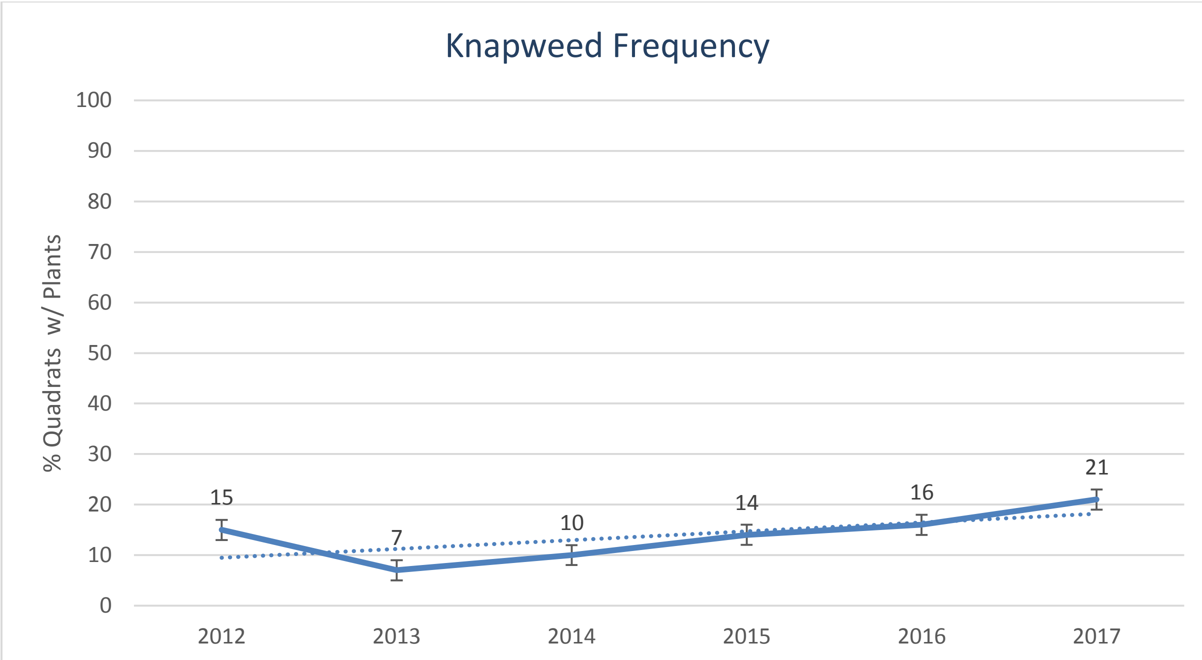


Figure 7. Knapweed frequency at 9 permanent plots, 2012-2017.

Density is calculated from the average number of stems arising from the ground in half meter quadrats and averaged for each plot; percent cover is an estimate of how much area is occupied within the half meter quadrats and averaged for the plot. Density and average cover are likely to be strongly correlated with annual precipitation values. The only plot to show an increase of greater than one average standard deviation (ASD) for average density was the partially treated plot CEDI3-5 which also showed a decrease in percent cover (Tables 10 &11). The majority of the plots were stable with less than 1 ASD difference.

Table 11. Average density of knapweeds in permanent plots, 2012-2017. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: orange is an increase >1 average standard deviation (ASD), and yellow is stable).

Plot Name	Density 2012	Density 2013	Density 2014	Density 2015	Density 2016	Density 2017	Average Density 2012-2016
CEDI3-1	**0.0**	0.0	**0.0**	0.10*	0.2	0.1	0.1 (0-0.8)
CEDI3-2	**1.0**	0.3	0.5		Discontinued		
CEDI3-3	0.0	0.3	0.5	0.5	0.6	1.1	0.5 (0-1.2)
CEDI3-4	0.0	0.4	0.5	0.6	0.7	0.5	0.5 (0-1.2)
CEDI3-5	1.0	0.6	**1.4**	2.4	2.4	3.3*	1.9 (1.2-2.6)
CEMA4-1	2.0	0.1*	1.0	1.2	1.4	2.4*	1.4 (0.7-2.1)
CEMA4-2	2.0*	0.0*	0.1	0.1	0.1	0.4	0.5 (0-1.2)
CEMA4-3	0.0	0.0	0.0	0.0	0.0	0.1	0 (0-0.7)
CEMA4-4	2.0*	1.3	0.4	0.2	0.2	0.3	0.7 (0-1.4)
CEMA4-5	0.0	0.2	0.0	0.0	0.0	0.0	0 (0-0.7)
AVG	**0.8**	**0.3**	**0.4**	**0.6**	**0.6**	**0.9**	**0.6**
SD	**0.9**	**0.4**	**0.4**	**0.7**	**0.8**	**1.1**	**0.7**
	Biocontrol Plots						
SKploop3	1.0	---	---	0.0	0.1	0.1	0.3 (0-1.3)
SKploop1	1.0	---	---	0.1	0.2	0.6	0.5 (0-1.8)
DKrailroad	3.0*	**0.4**	---	1.5	1.7	1.7	1.7 (0.7-2.7)
DKhwy83	---	**4.8**	---	0.6		Discontinued	
KWmonck	1.0	**1.0**	---	0.4		Discontinued	
AVG	**1.5**	**2.1**	**---**	**0.5**	**0.7**	**0.8**	**1.1**
SD	**0.9**	**1.9**	**---**	**0.5**	**0.9**	**0.7**	**1.0**

Table 12. Average % cover of knapweeds in permanent plots, 2012-2017. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: green represents a decrease of (>1 average standard deviation and yellow is stable.

Plot Name	Cover (%) 2012	Cover (%) 2013	Cover (%) 2014	Cover (%) 2015	Cover (%) 2016	Cover (%) 2017	Average % Cover 2012-2017
CEDI3-1	0.3	0.0	**0.4***	0.9	0.1	0.1	0.3 (0-2.6)
CEDI3-2	2.7	0.1	0.7	Discontinued			
CEDI3-3	1.4	0.5	3.8	2.8	0.4	1.2	1.7 (0-4.0)
CEDI3-4	1.3	1.6	3.1	3.3	0.2	0.2	1.6 (0-3.9)
CEDI3-5	3.3*	2.3*	**16.5***	15.5	1.0*	5.26	7.3 (5.0-9.6)
CEMA4-1	1.7	0.3	5.3*	3.4	0.5	0.9	2.0 (0-4.3)
CEMA4-2	2.2	0.0	0.4	0.3	0.1	0.1	0.5 (0- 2.8)
CEMA4-3	0.1	0.0	0.2	0.0	0.0	0.1	0.1 (0-2.4)
CEMA4-4	6.2*	1.3	1.1	0.5	0.1	0.3	1.8 (0-4.1)
CEMA4-5	0.6	0.6	0.0	0.0	0.0	0.0	0.2 (0-2.5)
AVG	**2.0**	**0.7**	**3.1**	**3.0**	**0.2**	**0.9**	**1.7**
SD	**1.7**	**0.8**	**4.8**	**4.6**	**0.3**	**1.6**	**2.3**
	Biocontrol Plots						
SKploop3	**4.4**	---	---	0.0	1.0	0.1	1.4 (0-8.5)
SKploop1	**4.1**	---	---	1.5	0.2	0.5	1.6 (0-8.7)
DKrailroad	**16.0***	**1.7**	---	7.8	0.1	0.8	5.3 (0-12.4)
DKhwy83	---	**54.5**	---	15.0	Discontinued		
KWmonck	**5.9**	**3.5**	---	5.6	Discontinued		
AVG	**7.6**	**19.9**	**---**	**6.0**	**0.4**	**0.5**	**6.9**
SD	**4.9**	**24.5**	**---**	**5.3**	**0.5**	**0.3**	**7.1**

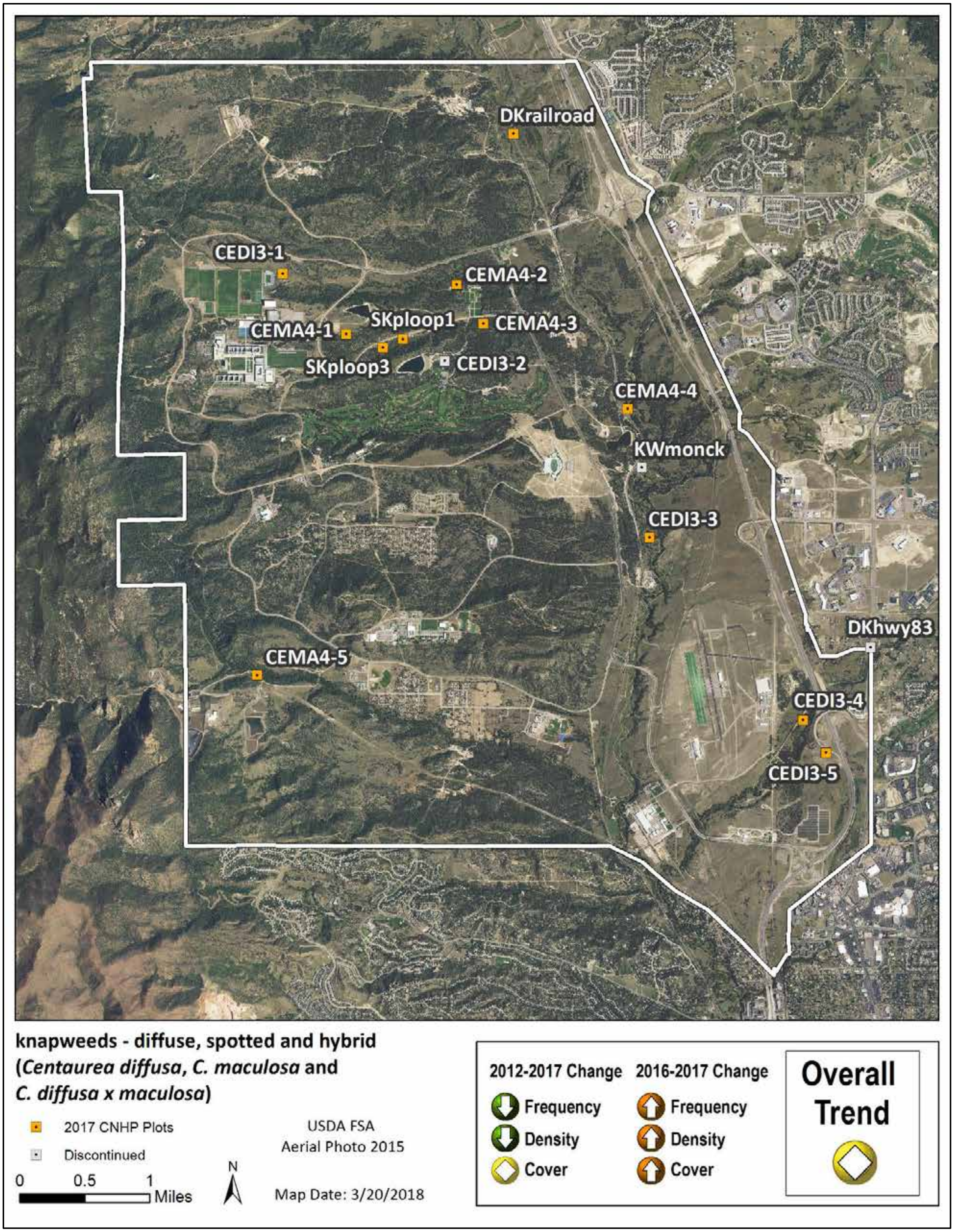
Recommendations

Continue to leave all monitoring plots untreated. Partial treatments of plots and disturbance of monitoring plots are confounding the interpretation of the plot data and also appear to increase knapweeds.

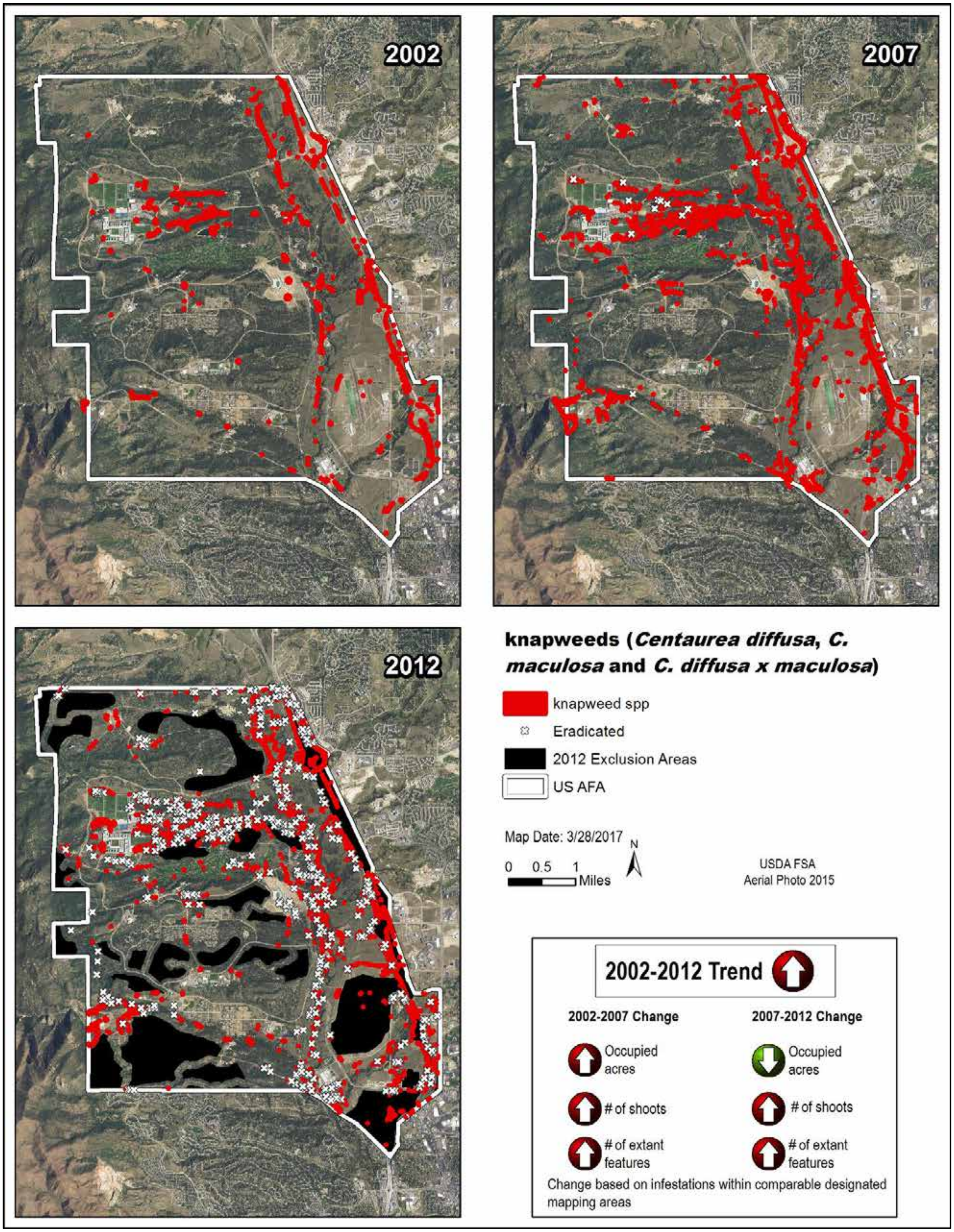
Consideration of a new treatment strategy for knapweeds that includes a site plan stating the goal of the treatment is suggested. Recent research indicates herbicide treatments alone will not eliminate knapweeds (CSU 2013b). In addition, treatments have been shown to cause an increase in other weeds or knapweeds themselves over time (Pearson and Ortega 2009). To be most effective, treatments must not affect nearby native species or cause soil disturbances. Herbicides can cause soil disturbance by increasing bare ground, changing the pH and the balance of soil organisms, and impacting nearby native forbs and woody species (Nicholas et al. 2008). Partial treatments appear to be inevitable under current practices. If there is no plan to restore the chemically or mechanically treated areas with native plantings, it may be prudent to discontinue herbicide applications in natural areas where native plants need to be protected (Smith et al. 2015). In addition the presence of native and rare (Colorado Natural Heritage Program tracked) plant species frostweed (*Crocanthemum bicknellii*) in monitoring plots needs to be considered. Frostweed is considered to be critically imperiled in Colorado with only a few known populations in the state.

History of Sampling and Treatment:

- Ten CNHP permanent plots were established in 2012 (Map 10).
- Census mapping for knapweed distribution across the Academy property was conducted in 2002, 2007, and 2012 (Map 11).
- In 2013, the diffuse and spotted knapweeds were combined into a hybrid swarm "knapweeds".
- In 2013, 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 ended).
- TAMU established a new biocontrol plot, DK kwy83 in 2013.
- 2014 plot data show a decreasing overall trend, with the density showing a significant increase (Rondeau and Lavender-Greenwell 2013). All biocontrol plots were treated with herbicide and were not monitored by TAMU in 2014.
- In 2015, the plots were stable with a slight overall decrease. Only nine of the 10 plots were monitored (plot CEDI4-2 was incorporated into the nearby golf course). One plot (CEDI3-5) showed an increase despite being treated with herbicide. The biocontrol plots were all treated with herbicides and 2015 results show stable to slightly decreasing trends. One plot showed an overall decrease (DK hwy83) and KWmonck showed a slight decrease; this plot was impacted by wood dumping that buried about five percent of the plot and included six of the monitoring points for the plot in 2015.
- Frostweed (*Crocanthemum bicknellii*) was observed in monitoring plots in 2015 -2017. This species is considered to be critically imperiled in Colorado with only a few known populations in the state.
- In 2016, KWmonck and DK hwy83 were discontinued. The total number of plots surveyed was 12. The overall trend across all plots between 2012-2106 was stable to decreasing.
- In 2017, 12 total plots were surveyed with on overall stable trend. The biocontrol plot data will be kept separate for a couple of years because of the herbicide application observed in 2014.



Map 10. 2017 knapweed (diffuse, spotted and hybrid) plots at the Academy.



Map 11. Distribution of knapweeds (diffuse, spotted and hybrid) at the Academy in 2002, 2007, and 2012.

Canada Thistle (*Cirsium arvense*)

All plot metrics indicate an overall decreasing trend in 2017. Biocontrol organisms are present and increasing in permanent plots. A rare amphibian species was noted in the monitoring plots in 2015.

AFA Management Goals: Suppression through monitoring, chemical and biological treatments.

State List: B

Photos: Left: Canada thistle plant at the Academy, CNHP. Upper right: Canada thistle in flower, CSU 2013c). Lower right: Canada thistle in seed by Jill Handwerk 2014.

- Perennial.
- Horizontal and vertical root system.
- Reproduction from root buds and seeds.
- Seed longevity 22 years with deep burial promoting longevity (CSU 2013c).
- Susceptible to shading and inundation.

2017 Results

Ten permanent plots were surveyed in 2017 for Canada thistle (two are biocontrol plots). The data from the 8 non-biocontrol plots indicate an overall decrease from 2012-2017 with slight increases in frequency and density and an increase in cover from 2016-2017 (Tables 13-15, Figure 8, Map 12).

Biocontrol agents have been observed in almost all the Canada thistle plots (not just the biocontrol plots). Biocontrol agents that form galls, necrotic leaf spots and browse by insects and animals has been observed consistently since 2015 when CNHP started making observations. In 2017, five of ten plots showed evidence of biocontrol (Map 12).

Table 13. Summary of Canada thistle permanent plot data, 2012-2017.

Non-Biocontrol Permanent Plot Sampling Method							
Year	*# Plots Sampled*	*# Quads Sampled*	*#Quads w/plants*	*Frequency (%)*	*Total # Shoots*	*AVG Height (cm)*	*AVG# shoots/plot*
2012	8	416	117	28	502	43	63/plot
2013	Not Sampled						
2014	8	411	56	14	121	36	15/plot
2015	7	348	51	15	158	38	23/plot
2016	7	348	37	11	64	52	9/plot
2017	8	422	79	18	244	43	53/plot
Biocontrol Permanent Plot Sampling Method							
2012	4	140	66	47	329	35	17/plot
2013	1	62	16	26	44	30	16/plot
2014	Discontinued – herbicide application						
2015	1	50	6	12	12	19	12/plot
2016	2	91	4	4	12	39	6/plot
2017	2	97	5	5	6	10	3/plot

Table 14. Frequency of Canada thistle in permanent plots, 2012-2017: Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: green represents a decrease >1 average standard deviation and yellow is stable.

Plot Name	FREQ 2012 (%)	FREQ 2013 (%)	FREQ 2014 (%)	FREQ 2015 (%)	FREQ 2016 (%)	FREQ 2017 (%)	Average FREQUENCY2012-2017
CIAR4-1	**21**	---	**13**	**8**	7	11	12 (2-22)
CIAR4-2	10	---	9	10	13	14	11 (1-21)
CIAR4-3	25	---	19	27	23	31	25 (15-35)
CIAR4-4	13	---	**15**	16	12	17	15 (5-25)
CIAR4-5	42*	---	**10**	6*	15	19	18 (8-28)
CIAR4-6	66*	---	21*	**	**	42	43 (33-53)
CIAR4-7	16	---	18	13	3*	5	11 (1-21)
CIAR4-8	19	---	**6***	**24***	5*	8	12 (2-22)
AVG	**27**	**---**	**14**	**15**	**11**	**18**	**17**
SD	**18**	**---**	**5**	**7**	**7**	**12**	**10**
Biocontrol Plots							
CTice1	**58***	---	---	---	0*	0*	19 (14-24)
CTploop	**52***	---	---	12*	8*	9*	20 (15-25)
CTice2	**100**	---	---	---	---	---	---
CTkettle	**24**	26	---	---	---	---	---
AVG	**55**	**---**	---	**12**	**4**	**5**	**19**
SD	**3**	---	---	---	**6**	**5**	**5**

*Greater than 1 ASD change ** Plot was flooded in 2015 and 2016. (GRAY = discontinued)

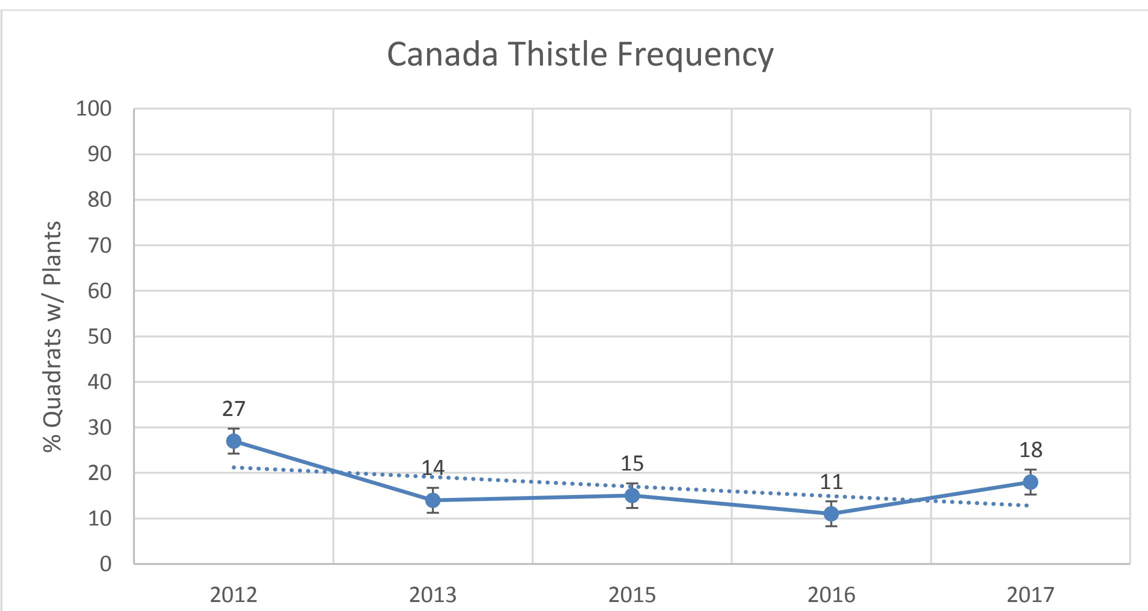


Figure 8. Canada thistle frequency at permanent plots 2012-2017.

Density is calculated from the average number of stems arising from the ground in half meter quadrats and averaged for each plot; percent cover is an estimate of how much area is occupied within the half meter quadrats and averaged for the plot (Tables 15 & 16).

Table 15. Average density of Canada thistle in permanent plots, 2012-2017. **Bolded and shaded** numbers indicate that the site was treated with herbicide. Colors indicate trend: yellow is stable with less than 1 average standard deviation (ASD), and green is a decrease indicating >1 ASD.

Plot Name	Density 2012	Density 2013	Density 2014	Density 2015	Density 2016	Density 2017	Average Density 2012-2016
CIAR4-1	**1.1**	---	**0.4**	**0.3***	0.2*	0.2*	0.4 (0-0.9)
CIAR4-2	0.5	---	0.1	0.1	0.1	0.2	0.2 (0-0.7)
CIAR4-3	0.4	---	0.3	0.4	0.4	0.4	0.4 (0-0.9)
CIAR4-4	0.2	---	**0.3**	0.5	0.2	**0.3**	0.3 (0-0.8)
CIAR4-5	1.8	---	**0.1**	0.1	0.2*	0.5	0.5 (0-1.0)
CIAR4-6	3.9	---	0.5*	---	---	2.4	2.3 (1.8-2.8)
CIAR4-7	0.4	---	0.4	0.3	0.1	0.1	0.3 (0-0.8)
CIAR4-8	0.6	---	**0.1**	**1.2***	0.1*	0.2	0.5 (0-1.0)
AVG	**1.1**	**---**	**0.3**	**0.4**	**0.1**	**0.5**	**0.5**
SD	**1.2**	**---**	**0.2**	**0.4**	**0.1**	**0.7**	**0.5**
BioControl							
CTice1	**1.7**	---	---	---	0*	0*	0.6 (0-1.4)
CTploop	**3.1***	---	---	0.2	0.2	0.1	0.9 (0.1-1.7)
CTice2	**8.8**	---	---	---	---		discontinue
CTkettle	**0.7**	0.7	---	---	---		discontinue
AVG	**2.4**	---	**---**	**0.2**	**0.1**	**0.1**	**0.7**
SD	**0.7**	**---**	**---**	**---**	**0.1**	**0.1**	**0.8**

CIAR-6 underwater in 2015-2016.

Table 16. Average % cover of Canada thistle in permanent plots, 2012-2017. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: yellow is stable with <1 average standard deviation (ASD), and green is a decrease indicating >1 ASD.

Plot Name	Cover (%) 2012	Cover (%) 2013	Cover (%) 2014	Cover (%) 2015	Cover (%) 2016	Cover (%) 2017	Average Cover (%) 2012-2017
CIAR4-1	**2.2**	---	**1.3**	**1.1**	0.1*	0.2*	1.0 (0-2.5)
CIAR4-2	1.6	---	1.2	0.6	0.1	0.1	0.7 (0-2.2)
CIAR4-3	1.7	---	1.7	2.2	0.5	0.3	1.3 (0-2.8)
CIAR4-4	0.7	---	**1.7**	1.2	0.3	0.2	0.8 (0-2.3)
CIAR4-5	7.4*	---	**0.3**	0.3	0.2	0.2	1.7 (0.2-3.2)
CIAR4-6	13.6*	---	3.4	**	**	5.3*	7.4 (5.9-8.9)
CIAR4-7	1.0	---	1.2	1.1	0.0	0.1	0.7 (0-2.2)
CIAR4-8	3.0*	---	**1.3**	**0.6**	0.1	0.1	1.0 (0-2.5)
AVG	**3.9**	**---**	**1.5**	**1.0**	**0.2**	**0.8**	**1.5**
SD	**4.2**	**---**	**0.8**	**0.5**	**0.2**	**1.7**	**1.5**
Biocontrol Plots							
CTice1	**7.1***	---	---	---	0.2	0	2.4 (0-5.8)
CTploop	**8.5***	---	---	2.3	0	0.1	2.7 (0-6.1)
CTice2	**26.3**	---	---	---	---	discontinue	
CTkettle	**1.7**	2.4	---	---	---	discontinue	
AVG	**10.9**	**---**	**---**	**---**	**0.2**	**0.1**	**3.7**
SD	**10**	**---**	**---**	**---**	**0.1**	**0.1**	**3.4**

*greater or less than one ASD, **plot underwater 2015-2016.

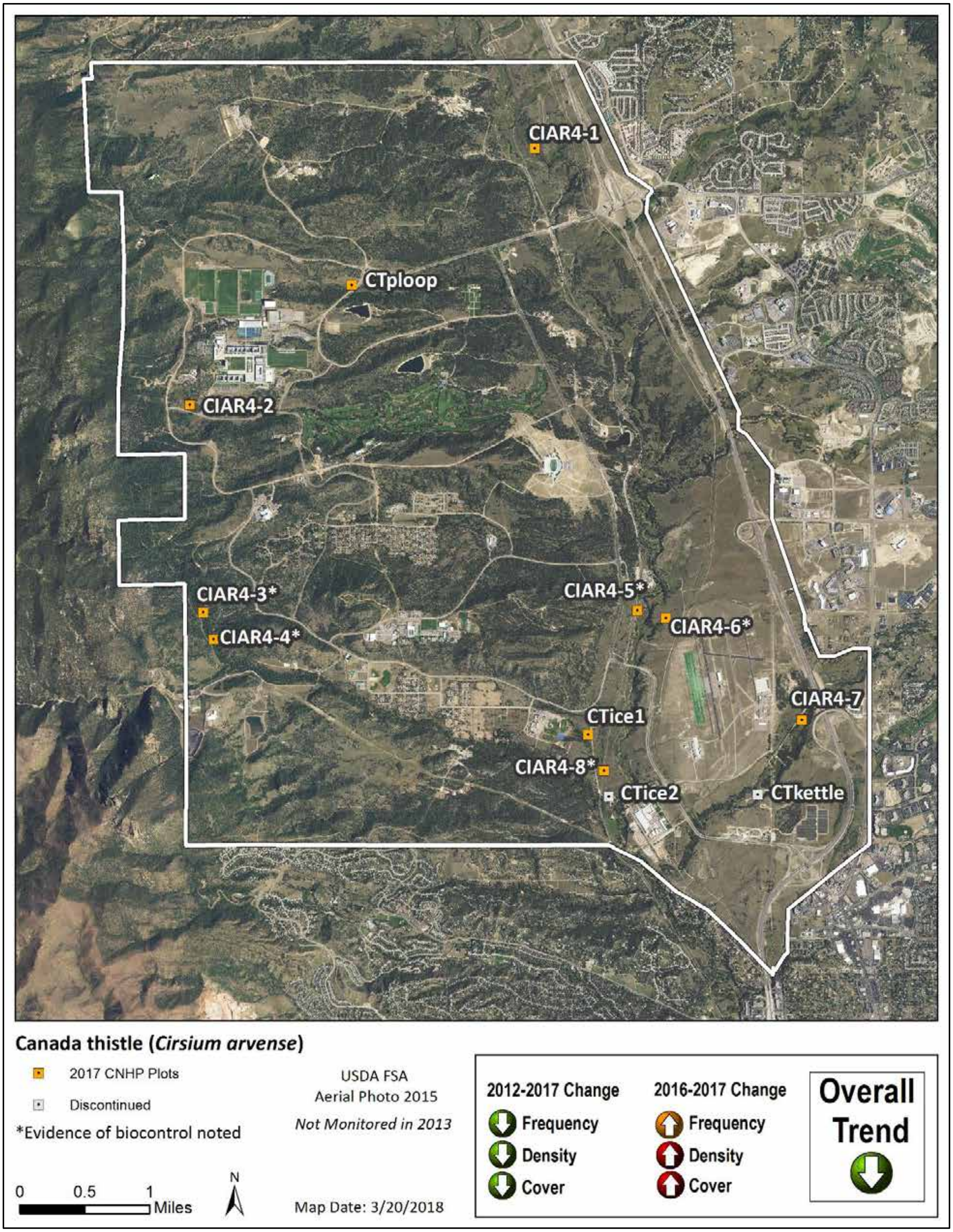
Recommendations

Continued monitoring will be important at the Academy because the untreated plots are showing stable to downward trends without herbicide application and biocontrol organisms are present, active, and appear to be increasing at a rapid rate. The protection of the rare amphibian species and uncommon plant species present should also be considered in future management since both were documented in the Canada thistle weed plots in previous years. A state vulnerable, Colorado species of concern, USFS and BLM sensitive amphibian species, Northern Leopard Frog (*Lithobates pipiens*), was noted in one of the Canada thistle monitoring plots (CIAR4-7) in 2015. An uncommon plant species (CNHP watchlist) carrion-flower (*Smilax lasioneura*) was also observed in this plot in 2015.

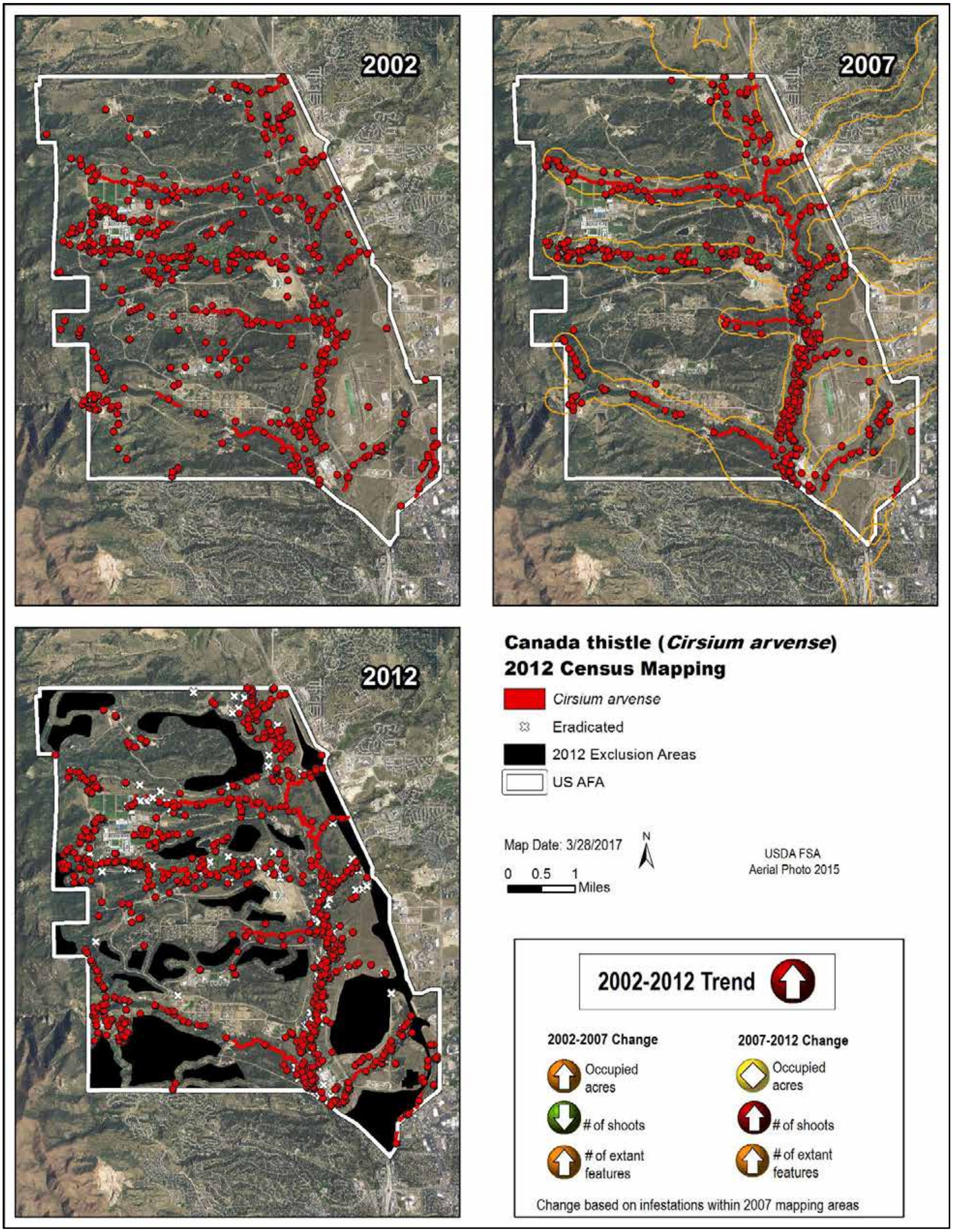
It should be noted when considering future treatments of Canada thistle that a study in Rocky Mountain National Park demonstrated that weed management practices including both chemical and mechanical treatments resulted in impacts to soils, soil biota and native plant species that were as damaging as the impacts from the Canada thistle (Pritekel et al. 2006). This calls into question the use of herbicides or any treatments that damage soils in systems where the protection of native vegetation is critical. Encouraging the biocontrol activities and protecting the surrounding landscape from disturbances while monitoring for expansion combined with a site plan for any active management are highly recommended for areas with SWMAs. This will help document what is working to decrease weeds.

History of Sampling and Treatments:

- In 2012, eight permanent plots were set up by CNHP.
- Census mapping for Canada thistle distribution across the Academy property was conducted in 2002, 2007, and 2012 (Map 13).
- Plots were monitored in 2012 and 2014.
- Although 2014 plot data trends are decreasing, it is worth noting that in 2012 we conducted weed mapping of Canada thistle. The number of extant features significantly increased between 2007 and 2012 (Lavender-Greenwell and Rondeau 2013).
- All plot metrics indicated a stable to decreasing trend from 2012-2015. Seven of eight permanent plots were monitored with the exception of CIAR4-6 (flooded); one biocontrol plot (CTploop) was added by CNHP in 2015 (Map 12). Biocontrol and insect and animal browse were noted on Canada thistle in six plots. A tracked amphibian species (Northern Leopard Frog) and a CNHP watchlisted plant species (carrion-flower) were both observed in Canada thistle monitoring plots in 2015. Plots were partially treated with herbicide.
- All metrics indicated a decreasing to stable trend for 2016. Seven of eight plots were sampled with CIAR4-6 flooded for the second year in a row. CTploop biomonitoring plot was monitored and a new plot CTice1 was added to bring the total plot number to 10 to strengthen statistics. CTice2 and CTkettle are discontinued. Both biomonitoring plots showed a decrease for all metrics greater than one average standard deviation from 2012-2016. Biocontrol organisms were noted in 7 plots in 2016 compared to only three in 2015. No plots were treated with herbicide in 2016.
- In 2017, 10 plots were monitored and show an overall decreasing trend compared to 2012. Five plots showed evidence of biocontrol organisms.



Map 12. 2017 Canada thistle plots at the Academy.



Map 13. Distribution of Canada thistle at the Academy in 2002, 2007, and 2012.

Houndstongue (*Cynoglossum officinale*)

Overall trend is increasing 2009-2017.

Rare plant species are located near or within populations of houndstongue.

AFA Management Goals: Eradication through continued monitoring and rapid response with integrated mechanical and chemical treatments. Re-evaluate treatment areas where continued treatments are not responding.

State List: B

- Biennial.
- Reproduction only by seed.
- Flowers May-July.
- Thick, black, woody taproot.
- Forms rosette first year.
- Seeds fall close to plant but Velcro©-like seeds allow transport by animals.
- Seed longevity 3 years (Colorado Code of Regulations 2014).

Houndstongue seeds, photo BLM

Photo by M. DiTomaso, University of California - Davis

2017 Results

A total of 37 locations were mapped in 2017 (36 points with 627 plants and 1 polygon with 120 plants) by CNHP (Table 17, Map 14). The number of plants (shoots) counted in 2017 has increased from 480 in 2016 to 787, a 61% increase while the number of features visited was similar, 36 in 2016 and 37 in 2017, as were the number of eradicated features with 14 sites in 2016 and 13 in 2017 (Figure 9). Precipitation correlates well with increases and decreases in numbers of individuals from 2012 to 2017 (Figure 1). Houndstongue was found in wetland areas that also contain a number of rare plant species. In addition, all features were mapped within the boundaries of the Special Weed Management Areas (SWMAs) delineated in the weed management plan (Smith et al. 2015).

Table 17. Houndstongue summary data, 2009-2017. Bolded and shaded indicates treatment.

Census Mapping Method					
Year	# Shoots	Total # Features Visited	# Extant Features	# Eradicated Features	Occupied Acres
2009	95	8	8	0	0.09
2010	11	7	1	6	0.02
2011	21	8	2	6	<0.01 (10 m^2)
2012	**70**	**12**	**3**	9	**0.01**
2013	**48**	**15**	**7**	8	**0.05**
2014	102	16	8	8	0.04
2015	534	31	22	11	0.20
2016	480	36	22	14	0.20
2017	787	37	26	13	0.41

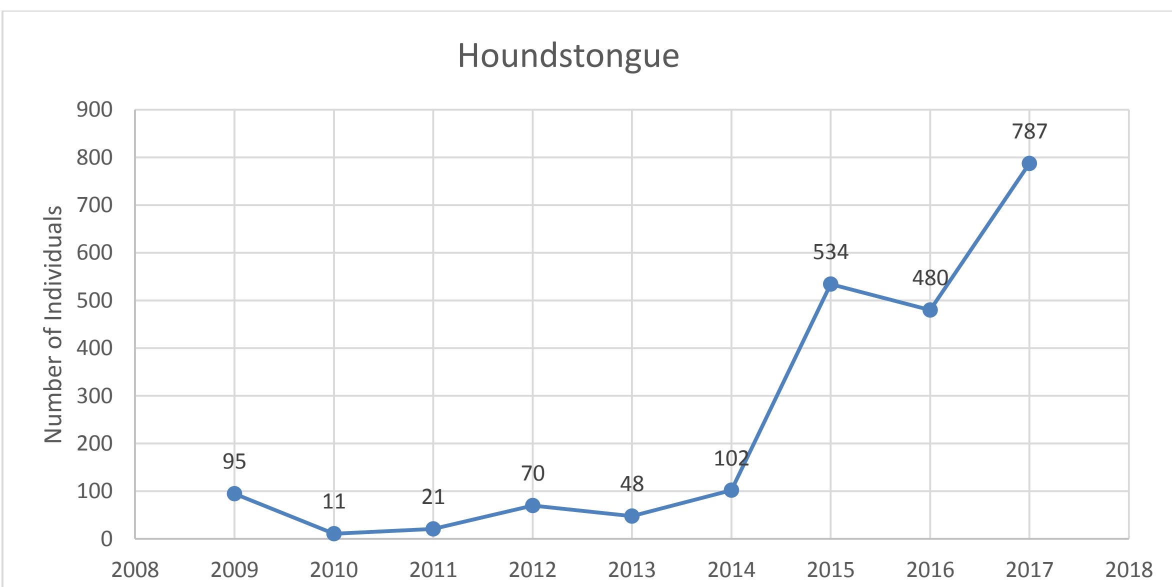


Figure 9. Number of houndstongue individuals, 2009-2017.

Recommendations

The majority of the houndstongue sites have been treated with either mechanical or chemical treatments at the Academy. However, the number of individuals at features mapped in 2009 have actually increased from 95 to 155 in 2016; including sites with multiple herbicide treatments. Overall, the numbers of individuals continue to climb despite treatments. Therefore, the first recommendation is to look as some individual sites to see if we can figure out what treatments are working or are not working (mechanical vs. herbicide) and look at the disturbance regime.

According to a number of studies (Nicholas et al. 2008, Norris 1999, Pritekel et al. 2006), if the focus is solely on the removal of a target weed species without consideration of impacts of the treatment on the surrounding vegetation, soils and fauna, the treatments will likely be unsuccessful and could create more problems. Herbicide treatments may also be contributing to the increases in numbers we are seeing. One of the problems previously identified at the Academy has been overkill at treated sites, where adjacent plants are being injured and/or killed and surrounding soils are being left in a disturbed state post treatment. In addition, when bare soil is exposed in the treatment areas noxious weed species start to occupy the area. The soil damage and an increase in weeds, likely due to herbicide treatment in a wet meadow containing rare plants at the Academy, is shown in Photo 4. The disturbance of intact native species increases the likelihood of increasing the weed species footprint in this wetland. The first rule in weed treatment is to protect intact surrounding areas from disturbance.

Photo 4. Area treated in a wet meadow for houndstongue. Treated area left bare soils and has new sprouts of houndstongue and other non-native species and noxious weeds including Canada thistle and common mullein. P. Smith 2015.

Observations at the treated sites also reveal that many plants, especially rosettes, were overlooked at treatment sites perhaps because they were not recognized and/or because they are tucked underneath nearby dense vegetation. The rosettes are hard to recognize and can be different sizes throughout the summer. Treatments at the inappropriate time of year when the plants are in fruit or flower will also lead to ineffective control if the plants are not handled properly.

Since all the known houndstongue sites are within the designated Special Weed Management Area (SWMA) delineated in the 2014 Weed Management Plan (Smith et al. 2015) herbicide applications are recommended to be done as a spot application. Site plans for known locations should be created before any more chemical or mechanical treatments occur to track what is occurring at these sites to more effectively control the weeds and prevent more weeds.

Summary of Recommendations

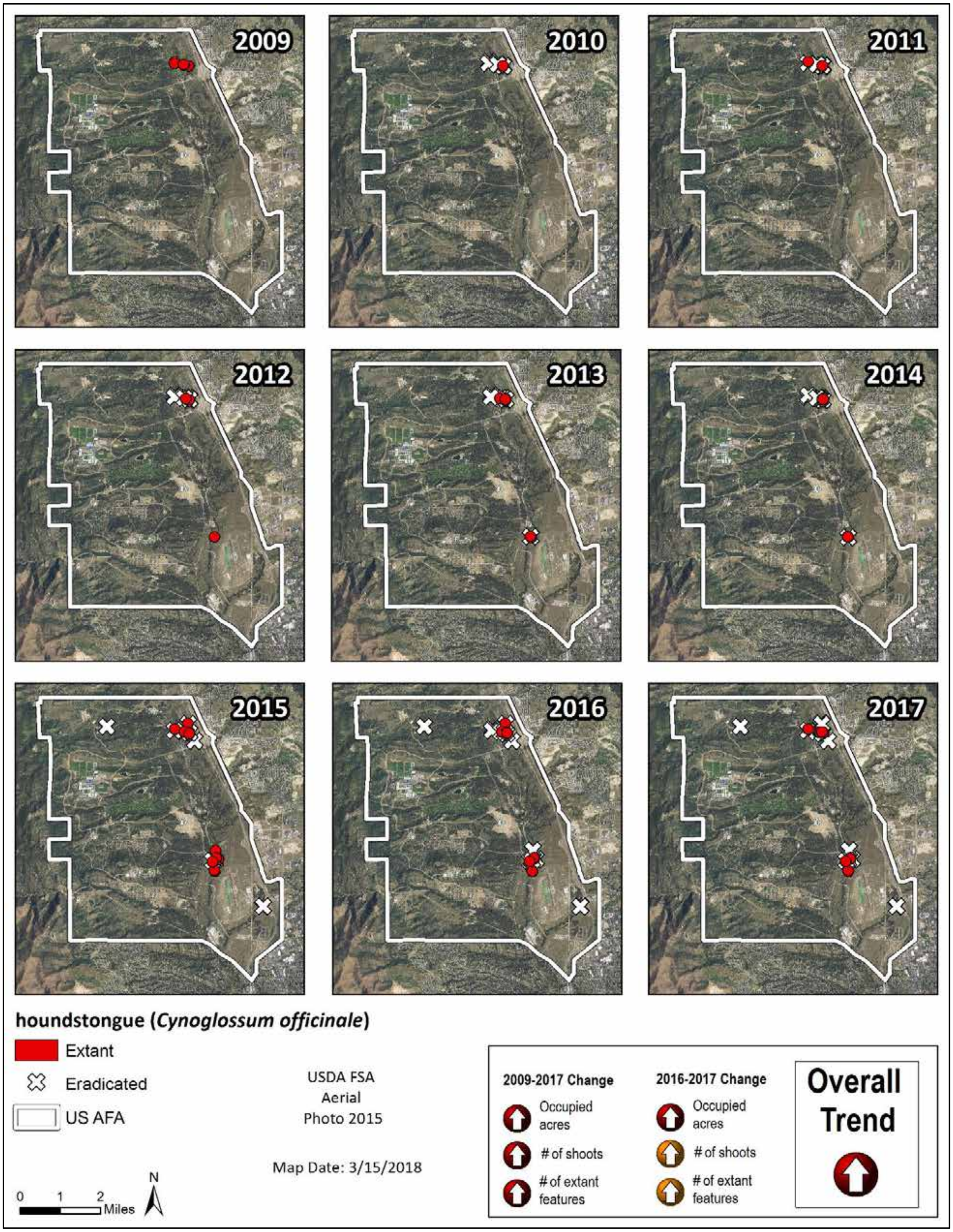
1. Mechanical removal is recommended. The root can be severed about an inch below the soil surface at the rosette stage before the plant bolts and produces flowers and/or seeds. If flowers or seed heads are present, remove the top portion of the plant. These tops should be placed in a black plastic bag and removed from the site. The black plastic bags should be left in the sun for a month to make sure the seeds are killed before discarding in the trash. Since this plant is a biennial, it dies after it produces flowers/fruits. Removal of the top portion causes less soil disturbance than digging the taproots.
2. Areas where soil area greater than a square foot is left bare should be planted with a native seed mix at the appropriate time.
3. Sites should be carefully surveyed under dense vegetation at the known sites for rosettes.
4. Follow-up monitoring should be conducted yearly. Seed longevity is relatively short compared to other species (five years) and should continue for at least five years after no plants were found. Observations should be made on the condition of the treatment site: notes on whether noxious weeds moving into the site or smooth brome, is biodiversity increasing or decreasing, bare soil presence etc.
5. Herbicide use is not recommended. If it is the manager's choice, only utilize precise spot application to rosettes making sure that wetland applications are made with wetland appropriate herbicide and that floodplains and intermittently inundated areas are considered to be wetlands. Make sure all applicators can recognize rare plants and the rosette stage of houndstongue.

History of Sampling and Treatment

- First populations discovered in 2009 at the Academy.
- In 2012 a new site was located south of the existing known sites.
- In 2013 no new sites were found and all known sites were treated.
- In 2014 two locations that had not been mapped as part of the weed monitoring project were sprayed for houndstongue by weed contractors.
- In 2015, there was an increase in the number of sites from 16 to 33 between 2014 and 2015 with a corresponding increase in the number of individuals observed (109 to 534

individuals, respectively). Many of the new plants were new rosettes and sprouts and some of them were in previously treated areas (Map 14).

- In 2016, three new points were added. There was a slight decrease in the number of individuals between 2015 and 2016 from 585 to 480, respectively.
- In 2017, there was an increase from 480 to 787 plants at a total of 26 extant features.



Map 14. Distribution of houndstongue at the Academy between 2009 and 2017.

Leafy Spurge (*Euphorbia esula*)

Frequency and density are stable with a decrease in cover. Two species of rare plants observed in 2017. Biocontrol organisms are present.

AFA Management Goals: Containment through continued monitoring, precise chemical, or biological treatments. Re-evaluate treatment methods to include integrated management and avoid harm to biocontrol organisms.

- Perennial with extensive root system that can reach 15 feet in depth.
- Reproduction from seed and root buds, seeds ejected 15' from plant.
- Plant has white milky sap.
- Seed longevity 8+ years, peak production in May.
- Young plants easily mistaken for yellow toadflax and they grow together at the Academy.
- Grows very early in the spring.
- Extremely difficult to control (CWMA 2017).

Photo by Michelle Washebek

2017 Results

Ten permanent monitoring plots were surveyed in 2017 for leafy spurge. The data shows a stable trend for both frequency and cover, and a decrease for density for 2012-2017 (Figure 10, Tables 18 -21). The overall results continue to indicate a natural decline may be occurring which is further supported by the presence of biocontrol organisms at 70% of the plots.

Table 18. Summary of leafy spurge permanent plot data, 2012-2017.

Non-Biocontrol Permanent Plot Sampling Method							
Year	*# Plots Sampled*	*# Quads Sampled*	*# quads with plants*	*Frequency (%)*	*Total # Shoots*	*AVG Height (cm)*	*AVG# shoots/plot*
2012	10	600	171	29	1,234	32.0	123/plot
2013	10	609	151	25	676	26.8	68/plot
2014	10	593	139	23	664	30.0	66/ plot
2015	10	595	120	20	534	38.2	53/plot
2016	10	573	159	28	679	33.4	68/plot
2017	10	563	172	31	644	33.4	64/plot

Frequency (percent of quadrats with the plant present) is the best indicator of an expanding or contracting population and is the least sensitive to precipitation patterns. The frequency has remained stable from 2012-2017. Eight of the plots showed no differences greater or less than one average standard deviation over five sampling years and one plot decreased and one increased (Table 18 and Figure 10).

Table 19. Frequency of leafy spurge in permanent plots, 2012-2017: % quadrats/plot with leafy spurge. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: yellow is stable <1 average standard deviation (ASD) and green is a decrease (>1 ASD).

Plot Name	FREQ 2012 (%)	FREQ 2013 (%)	FREQ 2014 (%)	FREQ 2015 (%)	FREQ 2016 (%)	FREQ 2017 (%)	Average FREQUENCY 2012-2017
EUES-1	**29**	35	38	30	39	58*	38 (27-49)
EUES-2	**40***	3	3	2	8	19	13 (2-24)
EUES-3	**25**	15	**34**	13	30	30	25 (14-36)
EUES-4	**27**	36	29	19	26	30	28(17-39)
EUES-5	**31**	32	27	32	30	24	29 (18-40)
EUES-6	**35**	42	45	40	45	47	42 (31-53)
EUES-7	11	13	15	15	29	29	19 (8-30)
EUES-8	**27**	32	**15**	24	24	29	25 (14-36)
EUES-9	**43***	21	13*	22	34	35	28 (17-39)
EUES-10	18	18	15	5	17	15	15 (4-26)
AVG	**29**	**25**	**23**	**19**	**28**	**32**	**26**
SD	**9**	**12**	**13**	**11**	**11**	**12**	**11**

*>1 average standard deviation.

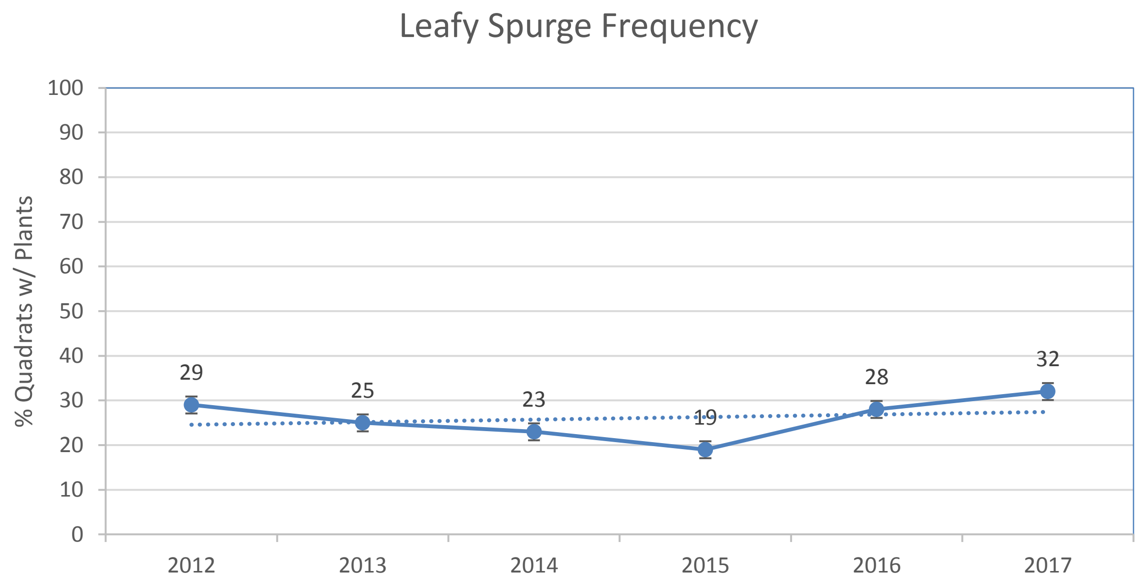


Figure 10. Leafy spurge frequency at 10 permanent plots, 2012-2017.

The overall trend was stable for density with seven plots stable for overall average density 2012-2017 and three plots showing decreases (Table 20). Density is calculated from the average number of stems arising from the ground in half meter quadrats and averaged for each plot. The percent cover is an estimate of how much area is occupied within the half meter quadrats and averaged for the plot. The average percent cover shows an overall decrease for 2012-2017 with eight plots showing a decrease and two plots remaining stable (Table 21).

Table 20. Average density of leafy spurge in permanent plots, 2012-2017. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: yellow is stable (less than 1 standard deviation) and green is a decrease (>1 standard deviation).

Plot Name	Density 2012	Density 2013	Density 2014	Density 2015	Density 2016	Density 2017	Average Density 2012-2016
EUES-1	**2**	2.2	1.9	2.4	1.4	2.6	2.1 (1.3-2.9)
EUES-2	**6***	0.0*	0.0*	0.1*	0.1*	0.7	1.2 (0.4-2.0)
EUES-3	**1**	0.6	**1.6**	0.8	1.2	1.3	1.1 (0.3-1.9)
EUES-4	**1**	1.4	1.5	0.4	0.8	1.0	1.0 (0.2-1.8)
EUES-5	**3***	1.8	1.0	1.1	1.0	0.7	1.4 (0.6-2.2)
EUES-6	**2**	1.9	2.1	1.2	2.1	1.8	1.9 (1.0-2.8)
EUES-7	0*	0.4	0.7	0.4	1.1	1.1	0.6 (0-1.4)
EUES-8	**2**	2.1	**0.5**	1.7	1.7	1.2	1.5 (0.7-2.6)
EUES-9	**4***	1.9	0.3*	0.6*	1.6	1.1	1.6 (0.8-2.5)
EUES-10	2*	1.1	0.6	0.3	1.0	0.6	0.9 (0.1-1.9)
AVG	**2.3**	**1.3**	**1.0**	**0.9**	**1.2**	**1.2**	**1.3**
SD	**1.6**	**0.7**	**0.7**	**0.7**	**0.6**	**0.6**	**0.8**

*>1 average standard deviation.

Table 21. Average % cover of leafy spurge in permanent plots, 2012-2017. Bolded and shaded numbers indicate that the site was treated with herbicide. Colors indicate trend: yellow is stable (less than 1 standard deviation) and green is a decrease (>1 standard deviation).

Plot Name	Cover (%) 2012	Cover (%) 2013	Cover (%) 2014	Cover (%) 2015	Cover (%) 2016	Cover (%) 2017	Average % Cover (2012-2017)
EUES-1	**1.9**	2.0	7.3*	1.6	0.7*	0.8*	2.4 (1.5-3.3)
EUES-2	**4.1***	0.1	0.1	0.1	0.1	0.3	0.8 (0-1.7)
EUES-3	**1.1**	0.4	**0.8**	0.3	0.6	0.5	0.6 (0-1.5)
EUES-4	**1.3**	1.3	4.0*	0.5	0.3*	0.4	1.3 (0.4-2.2)
EUES-5	**0.8**	2.3*	2.8*	1.5	0.4	0.2*	1.3 (0.4-2.2)
EUES-6	**2.0**	2.3	5.2*	1.6	0.7*	0.5*	2.1 (1.2-3.0)
EUES-7	0.2	0.7	3.3*	0.9	0.4	0.5	1.0 (0.1-1.9)
EUES-8	**2.1**	3.5*	**1.1**	2.5	0.8	0.4*	1.7 (0.8-2.6)
EUES-9	**2.1***	1.4	0.7	0.8	0.3	0.7	1.0 (0.1-1.9)
EUES-10	1.1	0.5	0.6	0.2	0.3	0.2	0.5 (0-1.4)
AVG	**1.7**	**1.5**	**2.6**	**1.0**	**0.5**	**0.5**	**1.3**
SD	**1.0**	**1.0**	**2.3**	**0.7**	**0.2**	**0.2**	**0.9**

*>1 average standard deviation.

Rare Plants

Two CNHP tracked rare plant species were documented in the plots in 2016-2017, the Rocky Mountain phacelia (*Phacelia denticulata)* was documented in (EUES-10) and the plains frostweed (*Crocanthemum bicknelli*) was observed in EUES 4 and 5 (Photo 5). The Rocky Mountain phacelia is considered to be globally vulnerable and is a regional endemic species (G3/S3) and is fully tracked by the Colorado Natural Heritage Program. This plant is only known from three states in the western U.S. The plains frostweed is a state critically imperiled (G5/S1) species known from only a few locations in the state.


Photo 5. Plains frostweed (left) and Rocky Mountain phacelia (right).

Recommendations

1) Herbicide should not be applied to leafy spurge plots. The two plots that were not treated in 2012 do not appear to be different from treated plots.
2) Consider monitoring for other leafy spurge locations for the presence of biocontrol agents. Populations appear to be declining naturally, monitoring is recommended to prevent disturbance.
3) Herbicide application is not recommended for leafy spurge populations, not only in the monitoring plots, but in the vicinity as the biocontrol organisms are present and active (Photo 6). In addition, the monitoring data shows the biocontrol organisms are working as the six year monitoring trend is showing stable to decreasing trends. Evidence of biocontrol was noted in eleven quadrats at six different plot locations in 2016 and at seven plots in 2017 (Map 15). The biocontrol organisms were frequently noted by Michels and the TAMU crew who were specifically seeking them out at appropriate emergence times. These organisms are likely contributing to observed decreases and perhaps the reason the populations are stable to decreasing.

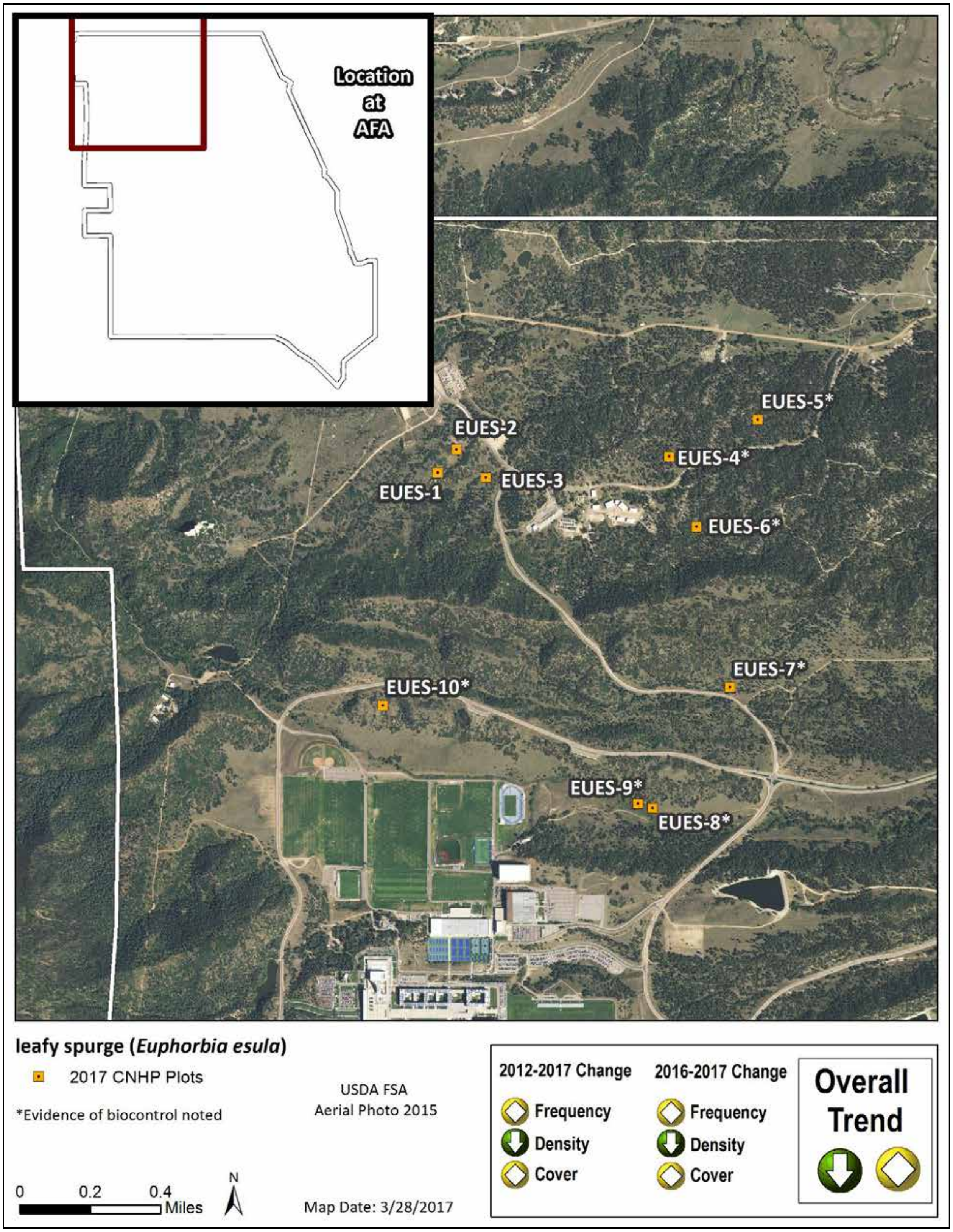
A study in Rocky Mountain National Park demonstrated that leafy spurge management practices including both chemical and mechanical treatments resulted in impacts to soils, soil biota and native plant species that were as damaging as the impacts from the leafy spurge itself (Pritekel et al. 2006). This calls into question the efficacy of treating these plants in systems where you need to protect native vegetation. Continued monitoring of these plots will be important for looking at treatment effects at the Air Force Academy since the untreated plots are showing stable to downward trends but census mapping in 2012 showed an increasing trend (Map 16). A greenhouse study conducted in 2008 (Nicholas et al.) showed that leafy spurge seedling growth was lower in spots that had native species compared to soils that had smooth brome. This further brings home the point that disturbance of the soils will encourage the growth of leafy spurge or other non-native species. Protecting areas with native plant cover from disturbance (including herbicides) should be a priority to protect soil chemistry and to prevent leaving bare spots where smooth brome often moves in.

Photo 6. Leafy spurge plants with damage to apical parts of plants in 2016. Photo: Pam Smith.

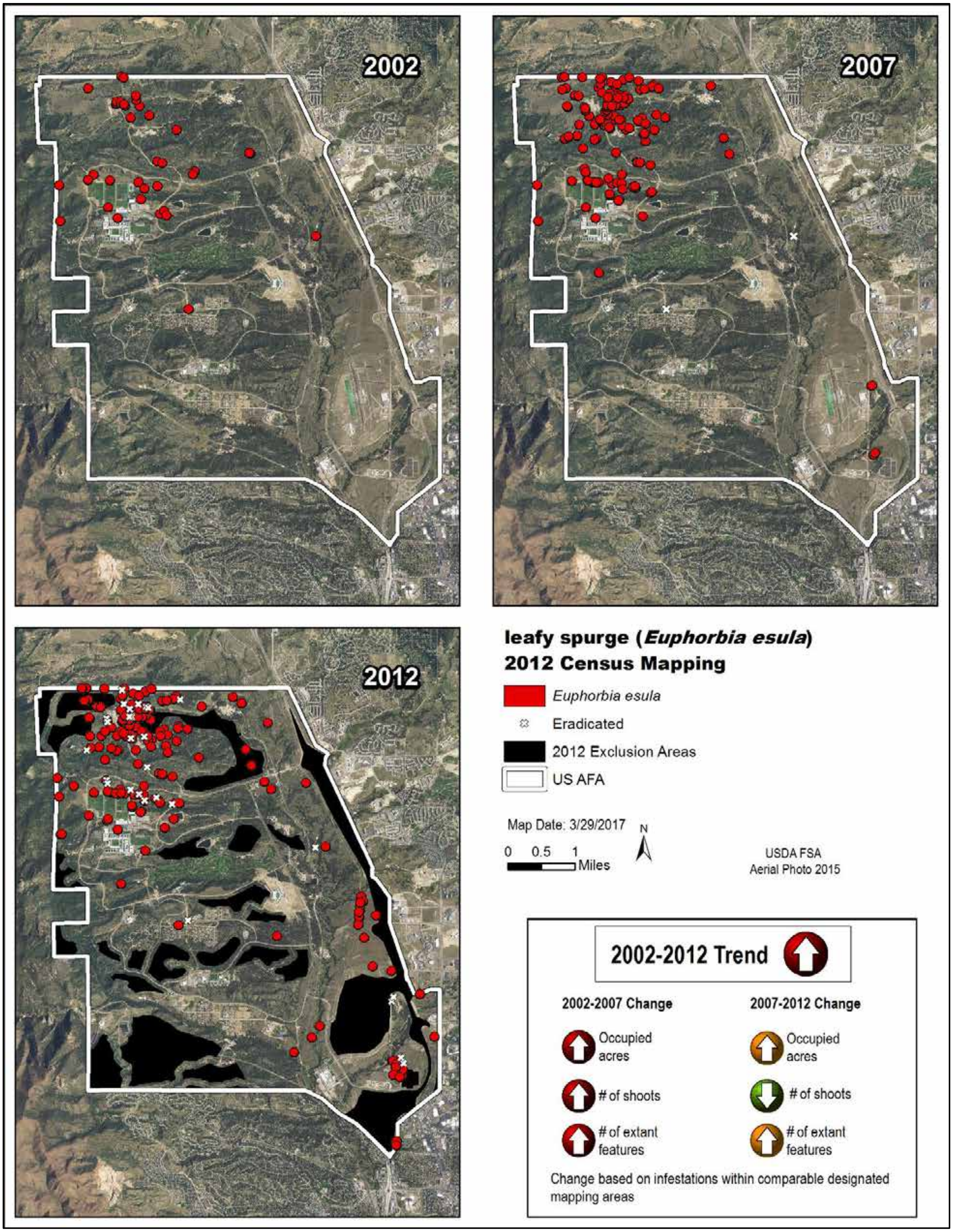
Protocols for treating weeds in the vicinity of rare plants has been developed by the State of Colorado (Mui and Panjabi, 2016), and should be considered for management activities in the areas designated by Smith et al. (2015) as SWMAs. These areas should be considered for site plans in 2018.

History of Sampling and Treatment

- Ten permanent plots were established in 2012 (Map 15).
- Census mapping for leafy spurge distribution across the Academy property was conducted in 2002, 2007, and 2012 (Map 16).
- Michaels et al. terminated biocontrol treatments in 2013.
- In 2013, a need was recognized for more accurate treatment application data that includes area treated, date, and type of treatment.
- In 2015, all non-biocontrol treatment plots were visited. Rare plants (*Phacelia denticulata*) were noted in EUES 10.
- In 2016, all ten plots were visited. There was a decrease in the percent cover of leafy spurge while the frequency and density were stable 2012-2016. No plots were treated with herbicide. Rare plants (*Phacelia denticulata*) were again noted in plot EUES 10. Evidence of biocontrol organisms causing impacts to flowering plants was noted in six plots at a total of eleven quadrats.
- In 2017, all ten plots were visited. Gambel's oak are continuing to encroach on the plots. Leafy spurge seems to be declining without treatments. Another rare plant species was located in EUES 4 & 5 (*Crocanthemum bicknellii*). Evidence of biocontrol is common and found in the majority of plots over multiple years, animal browse has also been frequently observed.



Map 15. 2017 leafy spurge plots at the Academy.



Map 16. Distribution of leafy spurge at the Academy in 2002, 2007, and 2012.

Myrtle Spurge (*Euphorbia myrsinites*)

Myrtle spurge populations show an overall decrease since 2005 but an increase from 2010-2017.

AFA Management Goals: Eradication through continued monitoring and rapid response with mechanical and chemical treatments

State List: A

- Evergreen perennial.
- Reproduction by seeds which are projected 15 feet from plant by seed pods.
- Plant is allelopathic.
- Milky sap is an irritant.
- Planted in gardens and readily escapes.
- Possibly spread by birds at AFA due to random widely spread small occurrences.
- Seed longevity 8 years.
- Easily removed by hand (CWMA 2017a)

Photo: Dave Anderson

Photo: Wikimedia Commons

2017 Results

In 2017, 501 individuals were observed at 25 extant features representing a 64% increase since 2016 (Table 22, Map 17). The number of individuals has fluctuated from 25 to 1,021 since 2005, with the highest number of individuals reported in 2007 (Table 22). The trend for the last five years shows a range of 7-25 extant features and individuals ranging from 129-501. However, the overall trend is decreasing with a large increase since 2016 (Figure 11). The new features mapped in 2017 were all in the vicinity (within 11 meters) of known locations of myrtle spurge (Map 17).

Table 22. Myrtle spurge summary data, 2005-2017.

Areal Mapping Method					
Year	# shoots	Total # of Features Visited	# Extant Features	# Eradicated Features	Occupied Acres
2005	25	7	7	0	---
2006	243	10	10	0	---
2007	1,021	13	7	6	0.18
2008	419	18	13	5	0.66
2009	464	18	12	6	2.4
2010	56	22	10	12	0.5
2011	57	28	12	16	0.25
2012	113	35	10	25	0.23
2013	129	31	19	12	---
2014	179	34	7	27	0.7
2015	173	40	14	26	1.04
2016	185	42	17	26	0.70
2017	501	45	25	23	1.15

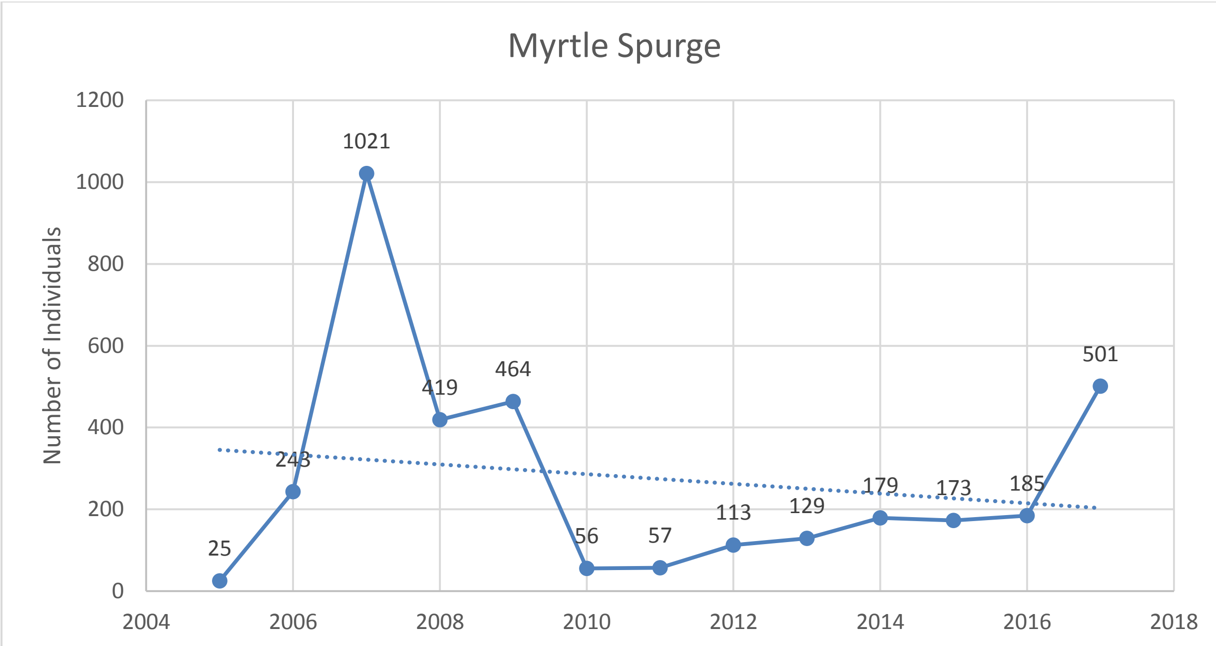


Figure 11. Myrtle spurge trend, 2005-2017.

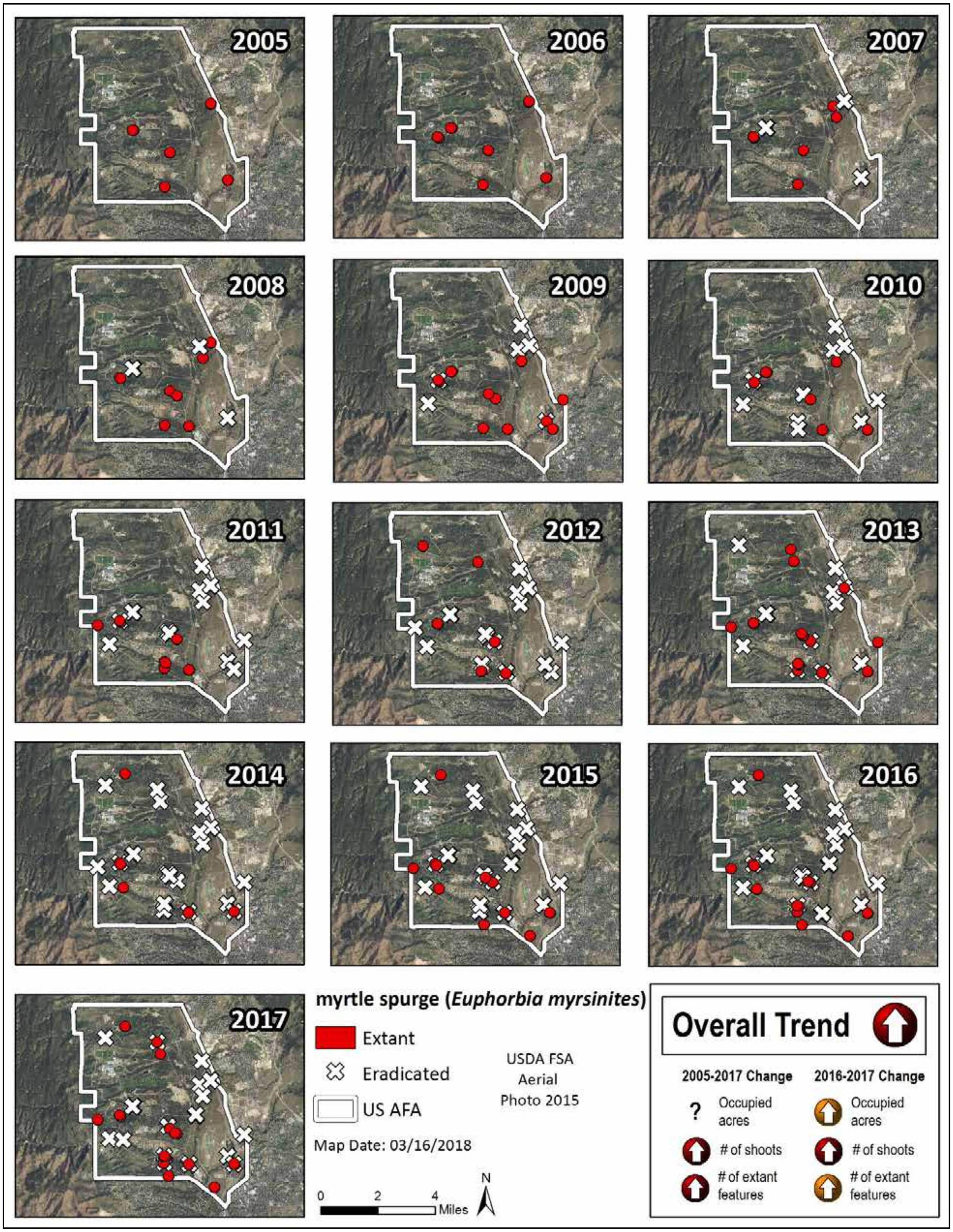
Recommendations

Continue to monitor all known mapped or reported features for sprouts annually. Pull small plants and monitor for re-growth. All of the plants were removed manually in 2017. In 2016 the applications at herbicide treated sites showed excessive off-target damage. Smooth brome is moving into chemically disturbed soils (Photo 7).

Photo 7. Treated myrtle spurge site with myrtle spurge returning; right side: smooth brome tillers moving into treated area (P. Smith 2016).

History of Sampling and Treatment:

- Natural Resources Staff at the Academy identified the presence of myrtle spurge in 2005 at an early stage of its invasion with seven sites and 25 individuals (Map 17).
- In 2007, the highest number of plants (1,021) was documented for myrtle spurge.
- 2008-2016 yearly increases in the number of individuals.
- In 2016, 185 individuals were observed at 17 extant features. (Table 22, Figure 11).
- In 2017, we saw an increase in plants at or near known sites from 185 individuals in 2016 to 501 in 2017.



Map 17. Distribution of myrtle spurge at the Academy between 2005 and 2017.

Yellow Spring Bedstraw (*Gallium verum*)

No plants observed in 2016-2017

AFA Management Goals: Eradication through continued monitoring and rapid response.

State List: Not listed

- Perennial forb (can be vine-like).
- Has the potential to be invasive once it becomes established.
- Blooms June-September.
- Dry disturbed sites.
- Escaped garden plant.
- Seed longevity – no data found.

Wikimedia photo

Results 2017

For the first time since 2011, plants were found in 2015 at the single monitoring point (Table 23, Map 18). All plants and root parts were removed by CNHP staff in 2015 and no plants were found in 2016 or in 2017. The seed longevity of this plant is not known. Large boulders and some landscaping and flooding have changed the area dramatically. Although this plant is not on the State of Colorado noxious weed list, it is a garden escape that has been shown to be aggressive at the Air Force Academy and throughout southern Canada and the northern U.S. It is a rhizomatous perennial plant that does well in dry soils. It is found on the edge of a disturbed riparian area with many native shrubs and herbs at the Academy.

Table 23. Yellow spring bedstraw summary data, 2010-2017.

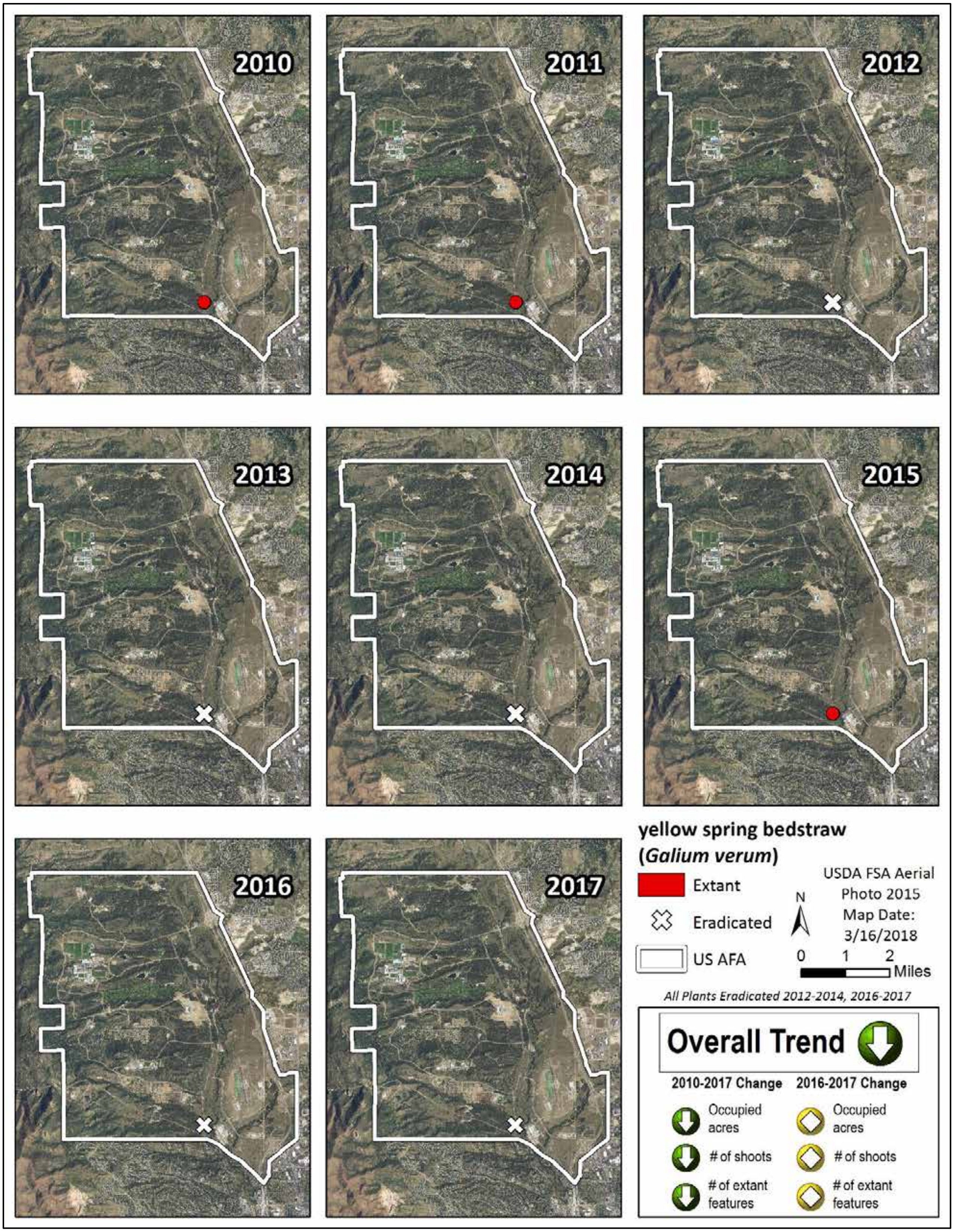
Census Mapping Method				
Year	*# Shoots*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2010	700	1	0	<0.01 (28 m^2)
2011	1	1	0	<0.01 (3.1 m^2)
2012	0	0	1	0
2013	0	0	1	0
2014	0	0	1	0
2015	10	1	0	<0.01 (3.1 m^2)
2016	0	0	1	0
2017	0	0	1	0

Recommendations

Continue to monitor the area for yellow spring bedstraw and remove when detected. Put this species on a watch list for future weed mapping efforts.

History of Sampling and Treatment:

- This species was discovered at the Academy in 2010 with one occurrence found near Ice Lake (Map 18). The occurrence consisted of 700 individuals in 28 m^2 (0.01 acres). All plants were treated by the Academy.
- CNHP 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 2012 - 2014.
- In 2015, 10 new plants were discovered at the known site and manually removed by CNHP.
- In 2016 and 2017, no plants were found. The area has been changed by flooding and landscape changes that included the addition of large boulders along the stream where the yellow spring bedstraw had been previously observed.



Map 18. Distribution of yellow spring bedstraw at the Academy between 2010 and 2017.

Dame's Rocket (*Hesperis matronalis*)

Overall trend for Dame's Rocket is decreasing.

A rare plant occurrence was documented in the vicinity of a treatment area.

AFA Management Goals: Eradication through continued monitoring and rapid response with mechanical and chemical treatments.

Sites not monitored in 2017

State List: B

- Tall, showy short-lived perennial forb.
- Garden escape.
- Taproot and spreading secondary roots.
- Reproduction only by seed.
- Seeding late summer and fall with high number of seeds.
- First year rosettes are green all winter and ready to grow early in the spring.
- Seeds available to the public for horticulture.
- Seed longevity is not known, can remain dormant for years. (CWMA 2017b).

Top photo: Colostate.edu, Bottom photo rosette by Leslie J. Mehrhoft Univ. Connecticut Bugwood.org

2016 Results (not monitored in 2017)

Three out of 17 known populations were visited in 2016 and one new population was documented with 14 plants (Map 19). Of the 16 known populations, 14 were considered eradicated features in 2015 and were not visited in 2016. One of the extant populations was reported by AFA personnel in the south part of the base with 130 individuals. That site was not visited in 2016. The overall data shows a dramatic decrease since 2012, when the number of plants reached almost 17,000 (Table 24).

Table 24. Dame's rocket summary data, 2010-2015.

Census Mapping Method				
Year	*# Shoots*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2012	16,871	14	0	0.83
2013*	---	---	---	---
2014*	---	---	---	---
2015	280	2**	14	0.08
2016	294	3	14	0.08
2017	---	---	---	---

*Base personnel found a new location with 130 individuals in June 2014 on the south boundary of the Academy far from the original infestation site near I-25. This site was not accessible in 2015-2016 (gated road) and assumed extant.

Recommendations

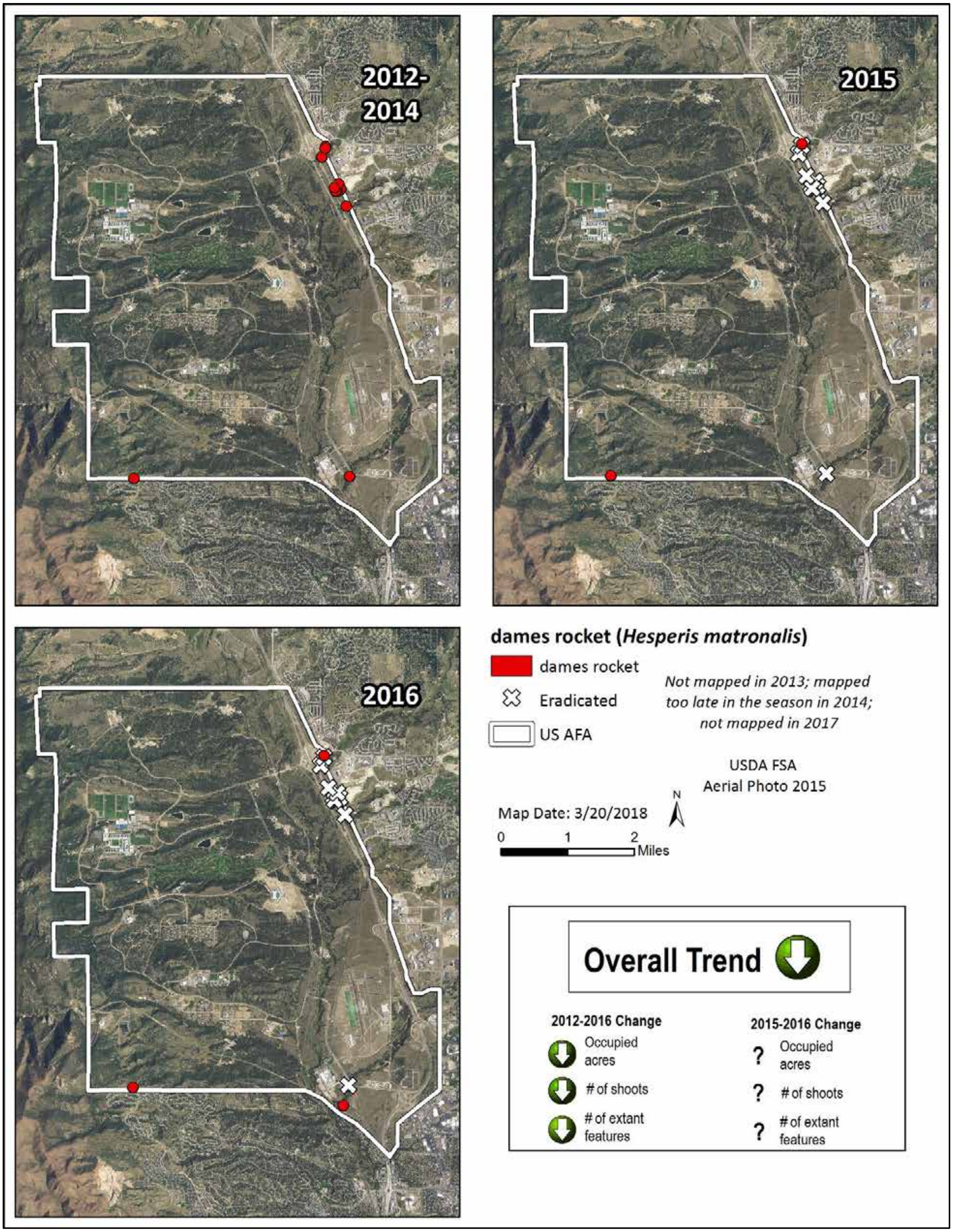
Herbicides need to be wetland compatible and a more precise method should be used to apply chemicals. For small infestations of 20 or fewer plants, consider manual removal of plants. The potential to exacerbate weed invasions is much greater in areas where native plants were impacted by herbicides or mechanical removal of plants. Rare plants, wetlands, and intact prairie uplands were located within the areas being treated. Because the seed longevity is quite long, all of the sites should be monitored for multiple years.

History of Sampling and Treatment:

- Dame's rocket was first discovered in 2012, near I-25. The 2012 mapping project (Rondeau and Greenwell 2013) documented 0.18 occupied acres with 16,871 shoots in 14 locations.
- Dame's rocket was not monitored in 2013 and visited too late in the season in 2014.
- In 2015, there were two extant locations out of a total of 15 known locations (Map 19). One of the locations was not visited in 2015 (south boundary location discovered in 2014 by base personnel) and presumed extant. Although plants have been impacted by herbicide application, excess overspray in the application of herbicides may be contributing to large areas of damage to adjacent native species in the natural areas.
- In 2016, two of the three known extant populations were visited by CNHP and one by Academy staff. One did not change and still contained 150 plants. The location in the south

west part of the Academy was behind a locked gate and was not visited in 2016. A new location was documented in the south east part of the AFA in 2016 with 14 individuals.

- In 2017, no sites were visited due to a late field start date.



Map 19. Mapped locations of Dame's rocket at the Academy between 2012 and 2016.

Common St. Johnswort (*Hypericum perforatum*)

Significant downward trend since 2007; slight decreases 2013-2017.

AFA Management Goals: Containment through continued monitoring and treatment with biological, mechanical and chemical control methods.

State List: C

- Perennial forb.
- Early successional stage.
- Invades disturbed areas.
- Can produce fertile seeds without pollination.
- Reproduction by seed and sprouts from lateral roots and crowns.
- Grows in dry and wet areas in PMJM habitat.
- Seeds viable in seed bank 20+ years.

Photo by Renee Rondeau

2017 Results

In 2017, there were 47 extant features which is an increase of 15 more sites than 2016 and the highest number recorded since 2007. However, the number of individuals is lower (Table 25). Since 2012, there has been a large reduction in the number of plants, but the number of extant features has remained relatively stable between 22-33 sites until 2017 (Table 25 & Figure 12). Flooding and biocontrol appears to have contributed to the declines in the number of shoots in some areas over the years.

Table 25. Common St. Johnswort summary data, 2007-2017.

Census Mapping Method					
Year	*# Shoots*	*Total # Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2007	44,647	8	8	0	0.86
2008	130,371	13	13	0	1.07
2009	95,883	23	21	2	2.02
2010	82,733	26	20	6	1.47
2011	87,128	31	26	5	1.44
2012	83,115	39	29	10	1.16
2013	2,621	43	22	21	0.85
2014	3,604	52	33	19	1.12
2015	3,102	56	27	29	1.27
2016	6,717	60	32	27	1.02
2017	4,202	70	47	23	1.31

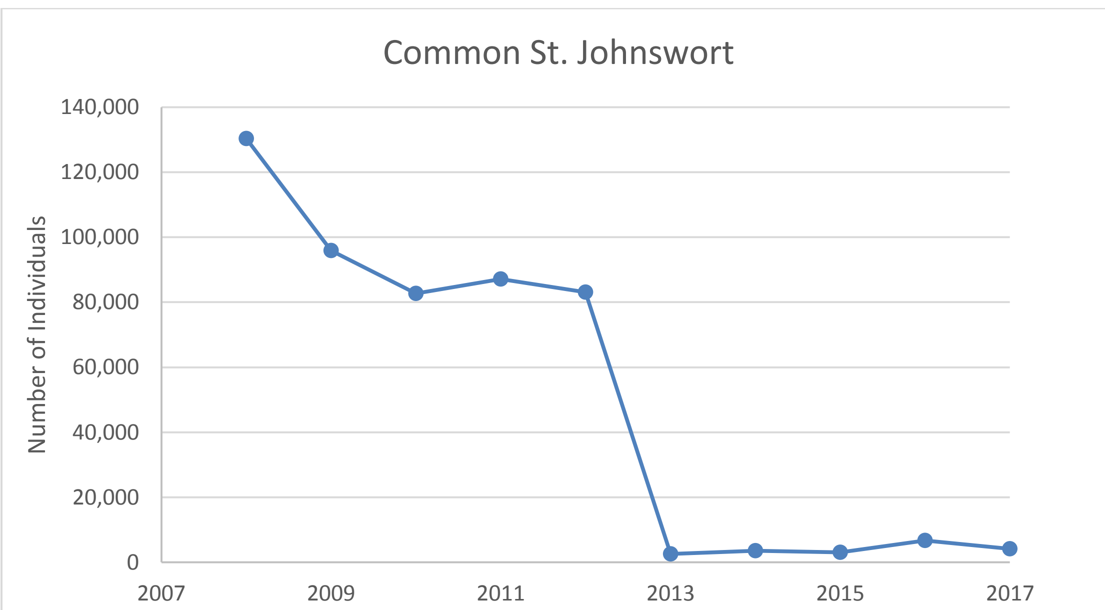
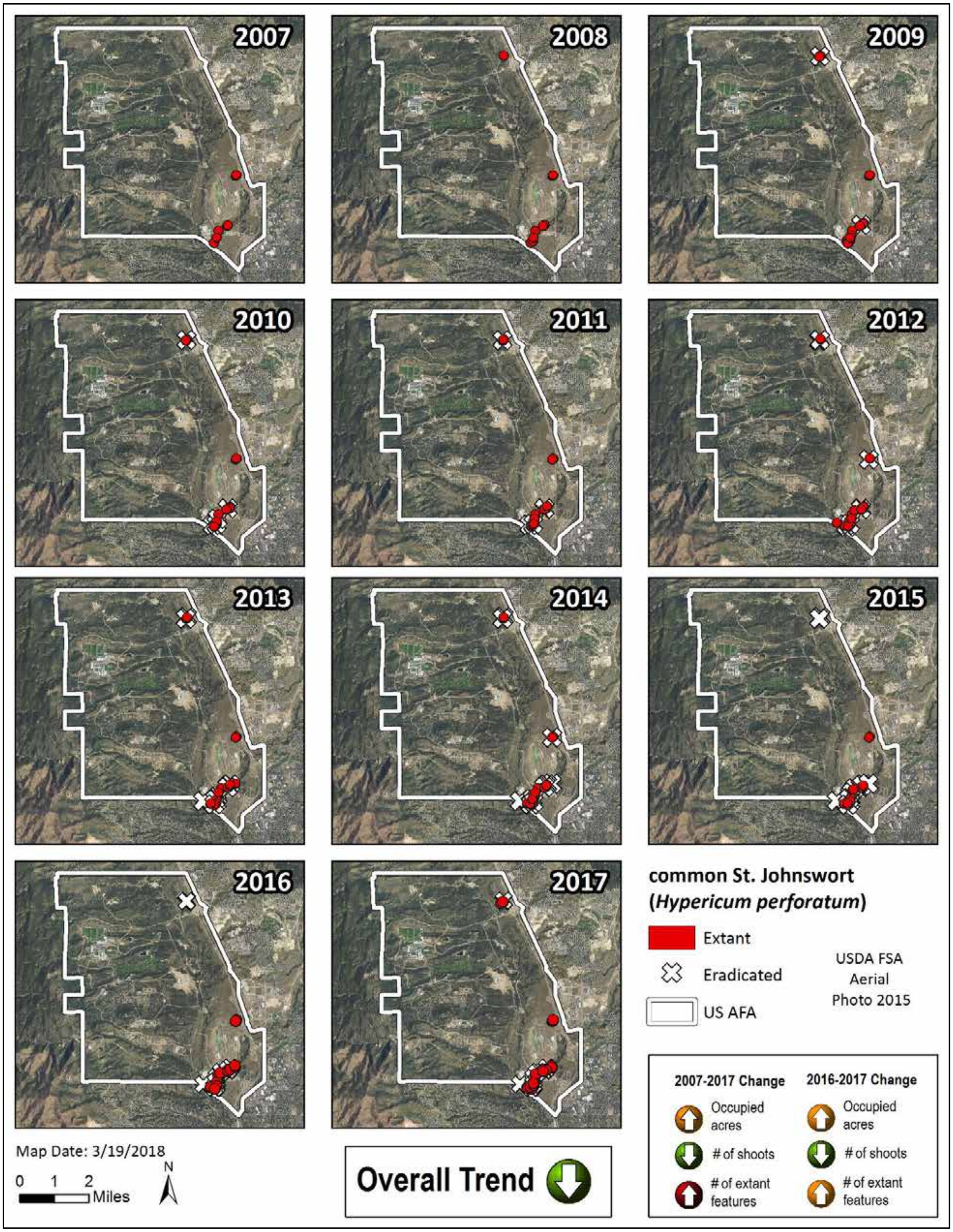


Figure 12. Number of individuals and extant features of common St. Johnswort, 2009-2017.

History of Sampling and Treatment:

- Common St. Johnswort was first monitored in 2007.
- The populations peaked in 2008-2009 (Table 25, Figure 12, and Map 20).
- Biocontrol efforts were discontinued in 2010.
- A significant decline occurred in 2012-2013, with a small spike in 2016.
- In 2017, the numbers of individuals declined while the number of extant sites increased.



Map 20. Distribution of common St. Johnswort at the Academy between 2007 and 2017.

Dalmatian Toadflax (*Linaria dalmatica*)

No new sites were documented in 2017, one site went from 1 to 480 individuals in one year.

AFA Management Goals: Eradication through continued monitoring and rapid response.

State List: B

Photos: Colorado State University

- Perennial forb.
- Prefers disturbed areas.
- Escaped garden plant.
- Emergence early spring, flowers May-June.
- Reproduction by seeds and root buds.
- Extensive root systems in established populations.
- Difficult to control. (USFS-USDA 2014b)

Results

In 2017, at Kettle Pond # 1 there were 480 plants pulled. In 2016, only one plant was observed which shows the need for yearly monitoring for the rapid response species at the Academy. The other three locations visited had no plants (Table 26, Figure 13, and Map 21).

Table 26. Dalmatian toadflax summary data, 2007-2017. Bolded and shaded indicates treatment.

Census Mapping Method					
Year	*# Shoots*	*Total # Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2009	10	1	1	0	---
2010	**107**	**3**	**2**	1	**0.50**
2011	0	3	0	3	0
2012	0	3	0	3	0
2013	**12**	**4**	**1**	3	**---**
2014	7	4	1	3	<0.01 (12.5 m^2)
2015	0	4	0	4	0
2016	1	4	1	3	<0.01
2017	480	4	1	3	<0.01

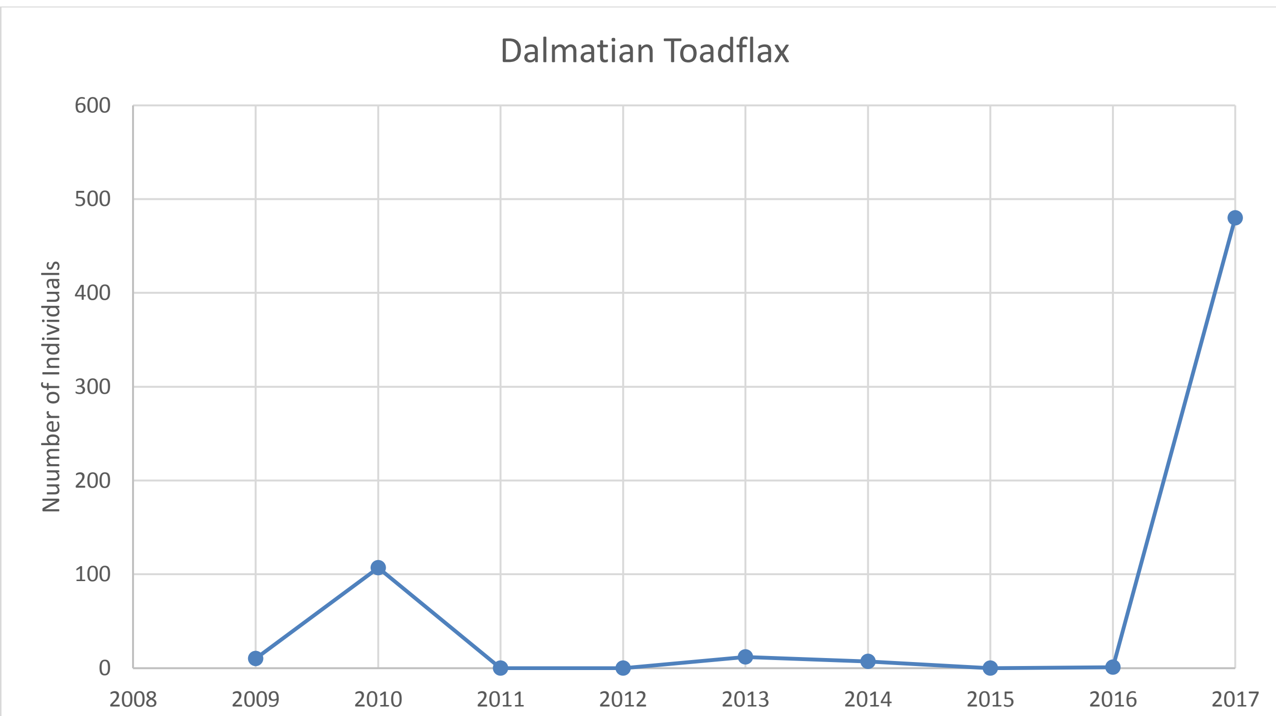


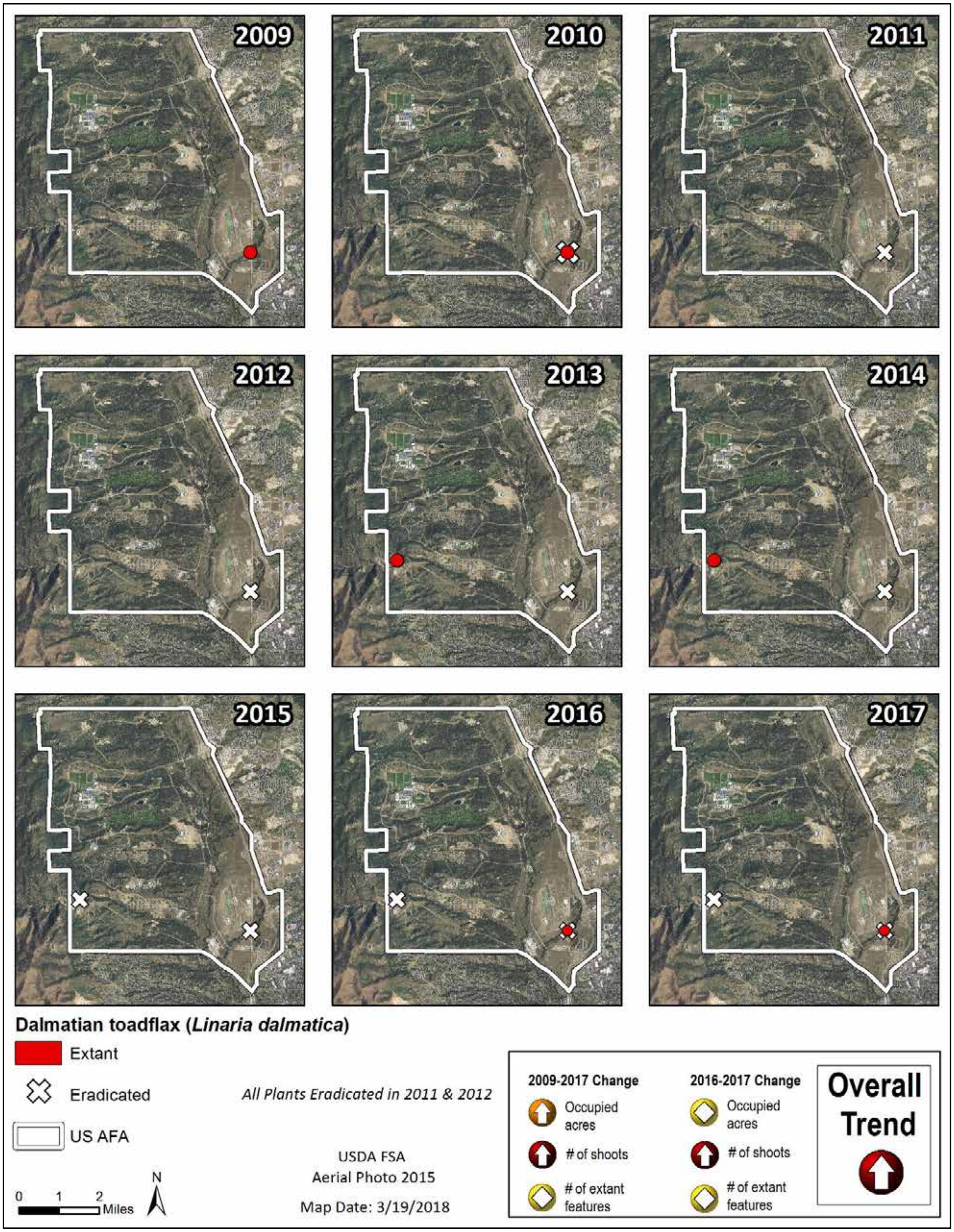
Figure 13. Number of individuals and extant features of Dalmatian toadflax, 2009-2017.

Recommendations

Continue to monitor known sites and remove new shoots as they are found, especially the site at Kettle Pond #1.

History of Sampling and Treatment:

- Dalmatian toadflax 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, two patches were mapped by CNHP (Map 21) with 107 shoots that covered approximately 203 m^2 (0.05 acres -Table 25). The original infestation was eradicated, but two new infestations were found very close by, just north of the original occurrence.
- The Academy treated the 2010 sites and no plants were observed in 2011-2012.
- A new site on the western side of the Academy was discovered in 2013 which was treated immediately. This was far away from the previous infestations on the east side of the Academy near Kettle Lake #1.
- In 2014, seven plants were observed at the western known site, they were hand pulled and have not returned as of 2016 survey.
- In 2015, no plants were observed at the four known sites and no new infestations were found.
- In 2016, one individual was found (and pulled) at the original site at Kettle Lake #1 near the boat ramp (Map 21).
- In 2017, there was a significant increase in a single year in the number of individuals the Kettle Lake #1 site where one plant was observed in 2016. All plants were removed by CNHP.



Map 21. Distribution of Dalmatian toadflax at the Academy between 2009 and 2017.

Tatarian Honeysuckle (*Lonicera tatarica*)

Population trend from 2008-2017 shows a decrease in individuals and an increase in number of known sites.

A rare plant is known to occur at one site.

AFA Management Goals: Containment through continued monitoring, mechanical and chemical treatments

State List: Not listed

- Tall shrub.
- Commonly planted and escaping to disturbed sites.
- Seeds are spread widely by animals.
- At the AFA one population is growing with a rare plant species, American currant.

Photos: Wikimedia Commons

2017 Results

In 2017, there were six extant features with a total of 8 individuals observed (Table 27). The treatment data supplied by the contractor did not show any activity in the area in either 2015 or 2016, and the trees may have died as a result of natural causes or landscape disturbances that may have altered the hydrology of the site. The number of extant features has increased since 2008; some of these features are mature trees that were missed in previous surveys and do not necessarily indicate an expansion.

Table 27. Tatarian honeysuckle summary data, 2008-2017.

Areal Mapping Method					
Year	*# Shoots*	*Total # of Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2008	20*	1	1	0	0.15
2012	20*	1	1	0	0.15
2013	28	5	5	0	0.18
2014	31	7	5	2	0.21
2015	48	10	9	1	0.40
2016	22	12	8	4	0.24
2017	8	9	6	3	0.24

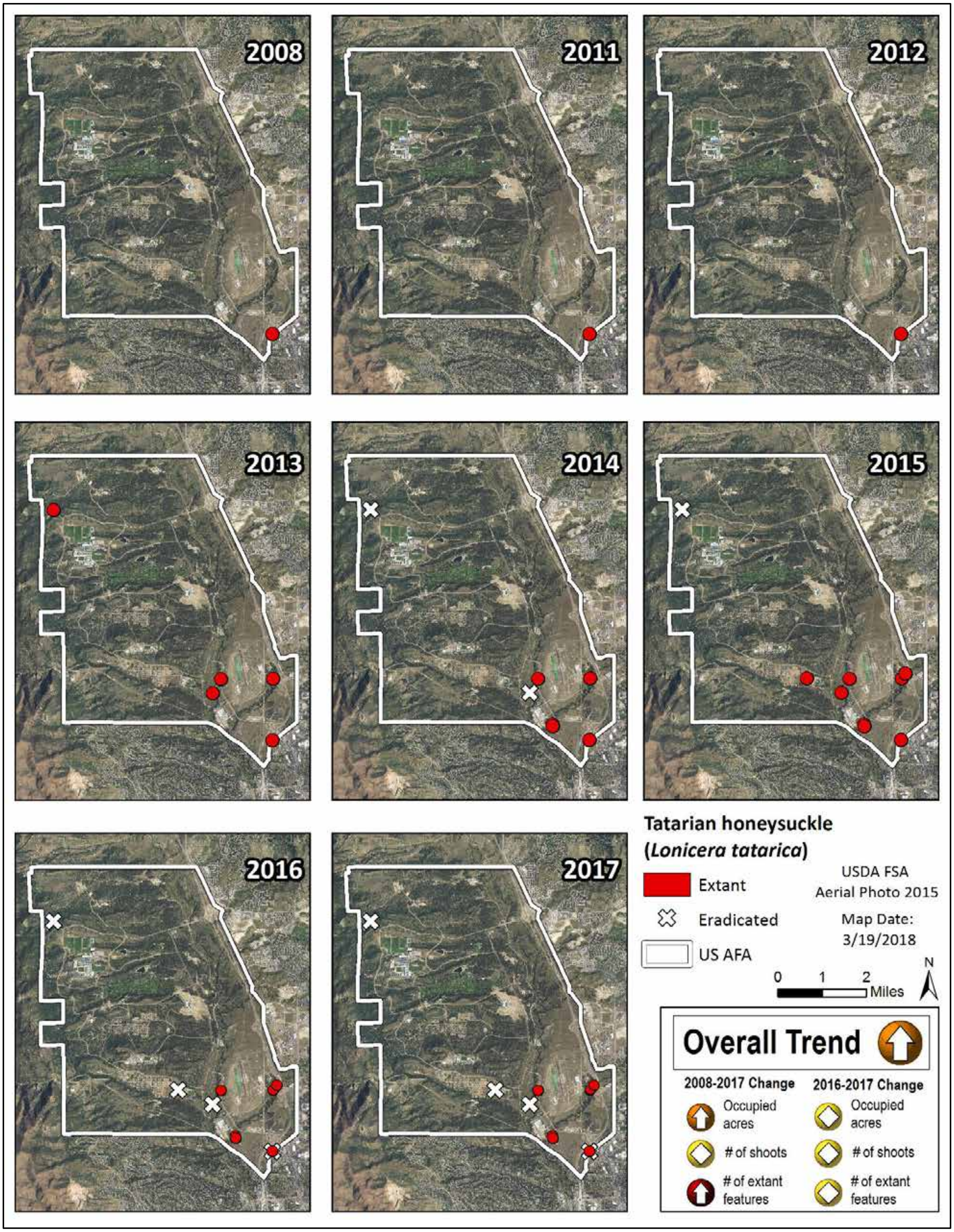
*Number of shoots at the original site documented in 2008 was previously reported to be 30 individuals, an estimate from a distance. This site was visited in 2014 for an actual count of 20.

Recommendations

Continue to monitor known sites as sprouting is common after treatment.

History of Sampling and Treatment:

- Tatarian honeysuckle was first discovered at the Academy in 2008 with American currant (*Ribes americanum*), a State rare plant species tracked by CNHP.
- Tatarian honeysuckle occupied 0.15 acres with approximately 30 individuals at one site in 2012.
- In 2013, four new locations were documented with eight individuals (Map 22). The original site was not revisited, but was assumed extant.
- In 2014, the original site documented in 2008 was visited for an actual count and found to have 20 individuals. The original number of 30 individuals was an estimate. This site is difficult to access due to dense growth and steep terrain.
- In 2015, there was an increase from 31 to 48 individuals and from 5 to 9 extant mapped features. Sprouting trees at treatment contributed to this increase.
- In 2016, all known sites were visited and 2 new sites were added. At the site on the SE side of the AFA there were 20 individuals in 2014. There was a substantial decline at this site in 2016, with only one living individual and 19 standing dead trees, apparently of natural or man-made hydrological influences.
- In 2017, one site which had 13 individuals last year appears to be defoliated and accounts for a drop from 2016. If these trees don't re-sprout, it will represent a true decline.



Map 22. Distribution of Tatarian honeysuckle at the Academy between 2008 and 2017.

Scotch Thistle (*Onopordum acanthium*)

Overall the trend is increasing 2002-2017. There was a decline in the number of individuals with a slight decrease in the number of mapped features from 2016.

AFA Management Goals: Containment through continued monitoring, mechanical and biological treatments. Re-evaluate current management methods by incorporating site plans and adaptive management strategies.

State List: B

- Biennial with a taproot that grows to 30 cm.
- Germination is in the fall.
- Rosettes form first year.
- Temperature and moisture content of soil are more important than nutrient content of soil for this species.
- Reproduction is only by seed.
- Drought resistant.
- Seed longevity is 7-20 years. (CDA 2016)

Photo: Scotch thistle rosettes, www.canadaplants.ca (left); www.readthis.tk (right).

2017 Results

In 2017, there were a total of 275 features visited with 120 extant features including 791 individuals (Table 28). This represents a decrease in individuals and a stable to decreasing number of extant features from 2015. However, the overall trend since 2002 is increasing (Figure 14 & Map 23). In some areas, treatments were impacting the surrounding areas leaving bare open soils and cheatgrass was filling in the chemically disturbed sites. Rosettes of Scotch thistle were often missed in the treatments and other noxious weeds were observed growing in treated areas, replacing one weed with another weed species (Photo 9). Cheatgrass is indicative of severe soil disturbance.

Table 28. Scotch thistle summary data, 2002-2017.

Census Mapping Method					
Year	*# Shoots*	*# Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2002	52	7	7	0	0.17
2005	137	12	12	0	0.42
2007	1307	36	36	0	1.30
2008	144	44	27	17	1.14
2009	1,710	84	50	34	3.47
2010	669	91	61	30	0.66
2011	293	95	39	56	0.64
2012	889	139	66	73	0.30
2013	970	133	48	85	---
2014	1,224	155	74	81	0.84
2015	1,629	233	157	76	1.60
2016	1,331	255	128	127	1.13
2017	791	275	120	155	1.35

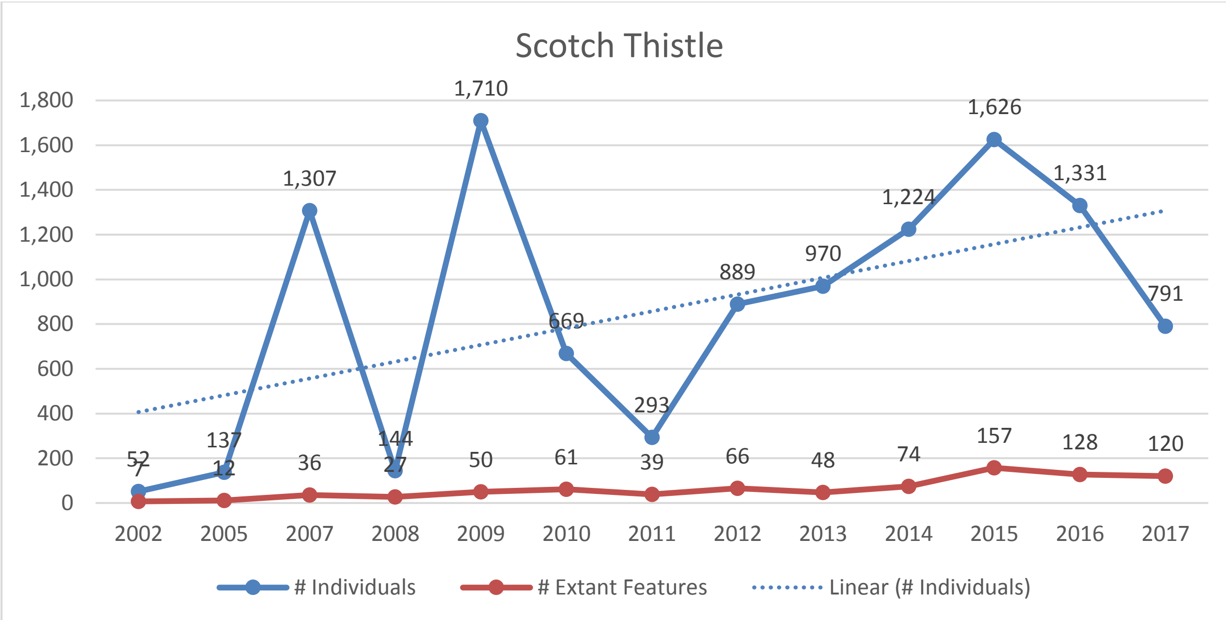


Figure 14. Number individuals and extant features of Scotch thistle, 2002-2017.

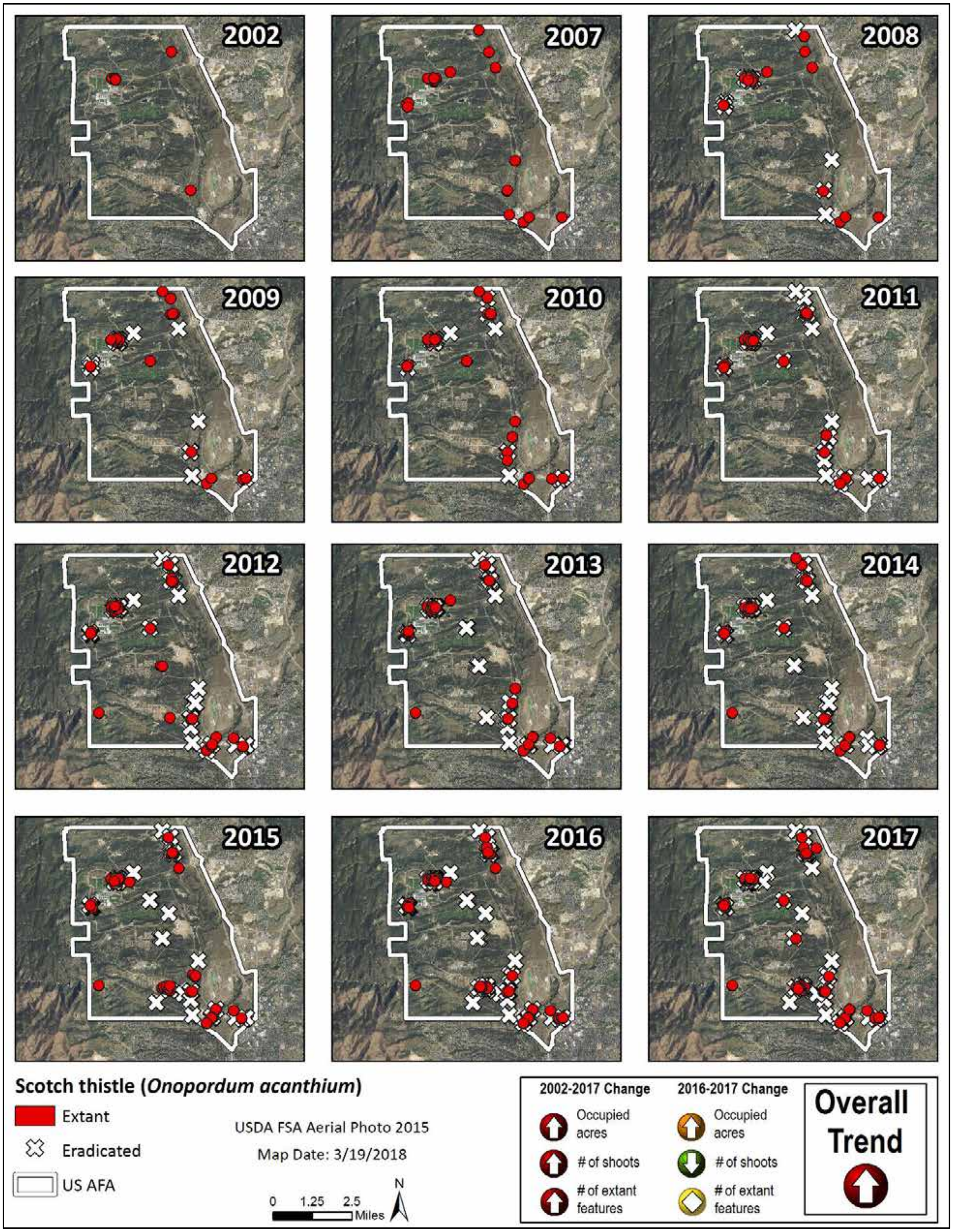
Photo 9. Photo of herbicide treated Scotch thistles showing overspray areas with bare soil and repopulation with other noxious weeds including houndstongue and cheatgrass. Photo: P. Smith 2015.

Recommendations

Despite years of active management, both the number of mapped features and the number of individuals are increasing, even in areas with multiple years of treatment at a single location. It is time to re-evaluate the treatment method as it does not appear to be providing successful results. A site plan for each of the treatment sites is recommended to help document what is occurring and what methods are helping or harming the removal of this species. The site assessments will take into consideration a variety of aspects of treatment that may be impairing success including: partial treatments, treating the proper growth stage and avoiding chemical overspray that leaves bare soil which impacts the native plants that could potentially help to provide competition. Herbicide resistance is a serious consequence to partial treatments. The effects to local flora and fauna, water quality and soil microorganisms that result from excessive use of chemicals is also problematic. The site plan could include alternate options for treatments. Removing the seed source is considered a key aspect of treating this species. Herbicides are only one tool and should not be used exclusively for control of this species.

History of Sampling and Treatment:

- The occupied areas, number of individuals and the occupied acres at the Academy have fluctuated since Scotch thistle was first monitored in 2002 (Table 28, Figure 14, and Map 23).
- The population of Scotch thistle peaked in 2007 and 2009 with a decline in 2010.
- In 2014 and 2015 it was evident that many treated areas had sprouting individuals. Bare ground left behind in both successfully controlled and unsuccessfully controlled sites provided more habitat for noxious weeds.
- In 2015, the number of extant features was higher due to the addition of new survey areas that were not part of the previous year's survey. The overall trend since 2002 is increasing.
- In 2016, there were fewer extant sites compared to 2015 because the populations added in 2015 located west of Pine Valley High School were treated. However, the number of extant features are still the third highest recorded since monitoring began in 2002.
- In 2017, there were 120 extant sites (similar to the 128 in 2016) but there fewer individuals counted.



Map 23. Distribution of Scotch thistle at the Academy between 2002 and 2017.

Bouncingbet (*Saponaria officinalis*)

Overall trend is decreasing 2013-2017.

All flower heads were grazed in 2016 and 2017.

AFA Management Goals: Eradication through continued monitoring and allow browsers to continue to remove flower tops.
State List: B

- Perennial.
- Self-fertile.
- Reproduction from seeds.
- Colony former.
- Blooms summer-fall.
- Seed longevity is unknown.
  (CDA 2016)

Photo: ct.botanicalsociety.org

Photo: Leaves of mature plant, missouristate.edu

2017 Results

One of the most interesting observations for 2016 and 2017 is that every single mature plant that was in the flower stage had the flowers browsed (Photo 8.). Since 2013, there has been a dramatic reduction in the number of bouncingbet shoots. All eight mapped features were treated with herbicides in 2013 and five additional features were mapped in 2014 (Table 29, Figure 15, & Map

24). Herbicides appear to be suppressing this species for a few years. However, most of the treated areas have smooth brome (a rhizomatous non-native grass) and/or cheatgrass and bare ground replacing the bouncingbet. Smooth brome is difficult to control once it becomes established. Cheatgrass indicates newly disturbed soils in treatment areas.

Photo 8: Browsed bouncingbet flower tops in 2016. Photo: P. Smith

The overall number of shoots has declined between 2013 and 2017 (Figure 15). In 2013, 42,092 plants were counted at 8 features, with one location containing 37,699 individuals (estimate based on density). A dramatic decline occurred in 2014 with only 42 plants at two sites; by 2015, 608 plants were mapped at eight features (Map 24).

Table 29. Bouncingbet summary data, 2002-2017. (Bolded and shaded indicates treatment.)

Census Mapping Method					
Year	*# Shoots*	*# Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2002	---	1	1	0	---
2013	42,092	**8**	**8**	0	**0.50**
2014	42	8	2	6	0.14
2015	608	13	8	5	0.09
2016	535	13	8	6	0.05
2017	401	14	6	8	0.05

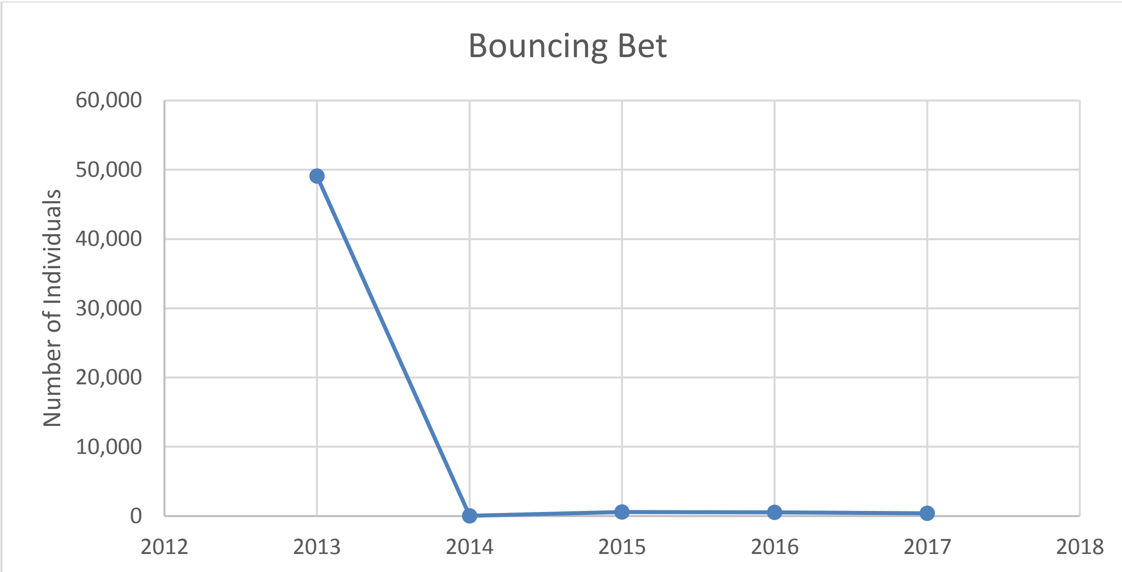


Figure 15. Number of individuals for bouncingbet, 2013-2017.

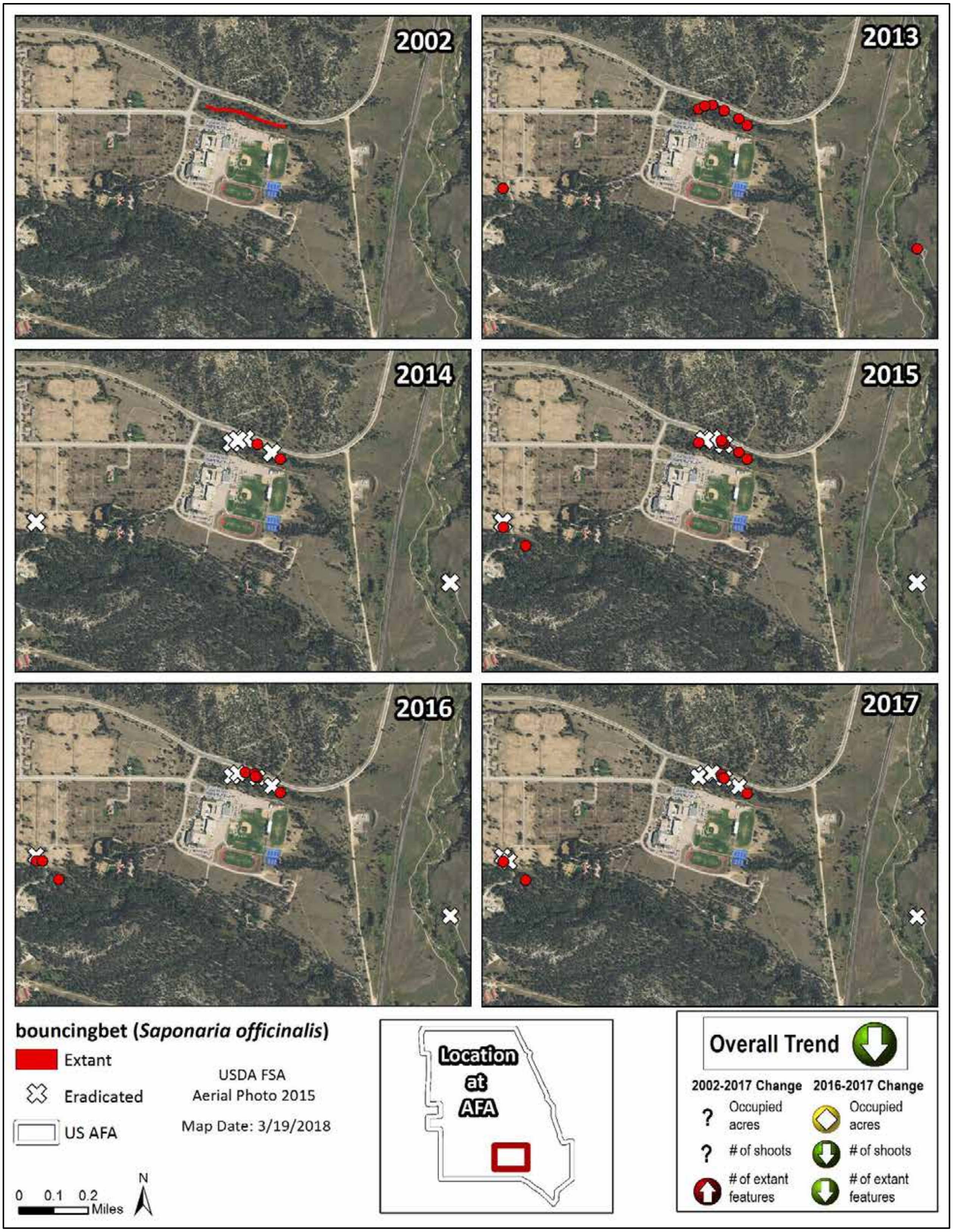
Recommendations

Discontinue herbicide treatments and allow animals to graze the flower tops. Monitor all known sites for the next few years to determine if a reduction in plant production is occurring naturally. Always be on the lookout for new populations. Herbicide treatments are reducing the number of plants that return but the plants do return and overspray is causing damage to surrounding plants which is evidenced by bare soil and thick cheatgrass (Photo 9). If the treatments result in new or different non-native species becoming dominant it is not successful from an ecological perspective. We recommend a new strategy to address damage to surrounding areas due to chemical treatment. A site plan would help focus treatments and results for a successful outcome.

Photo 9. Bouncingbet herbicide treatment area with bouncingbet returning and cheatgrass filling in bare soils left by overspray in drainage area.

History of Sampling and Treatment:

- Bouncingbet was mapped at one location in 2002 and not surveyed again until 2013.
- In 2013, three distinct areas were mapped (Map 24), but distribution was still localized.
- The westernmost infestation was huge, representing almost 40,000 individuals.
- The 2013 locations were treated by the Academy.
- In 2014, there was a decrease in the number of extant features.
- In 2015, the number of extant features was identical to those in 2013. A small population has resurfaced near the huge infestation that was discovered and thought to be eradicated in 2013. Some new locations were mapped in 2015 but several previously treated sites are repopulating.
- In 2016-2017 all known bouncing bet sites with extant plants that had flower tops were grazed by wildlife. Previously treated sites showed damage from overspray and the return of bouncingbet to the chemically treated sites.



Map 24. Distribution of bouncingbet at the Academy between 2002 and 2017.

Salt Cedar (*Tamarix ramosissima*)

Overall trend is stable 2002-2017

AFA Management Goals: Eradication through continued monitoring and rapid response with mechanical and chemical treatments

State List: B

- Reproduction by roots, submerged stems and seeds.
- Seed longevity <1 year (CDA 2016).

Photos: Renee Rondeau (left), Calphotos.berkely.edu (right)

Results 2017

In 2017, eight of nine known sites were visited, with one extant site (Jacks Valley) and seven extirpated sites (Table 30, Map 25). The Jacks Valley site appeared to have been browsed by wildlife.

Table 30. Salt cedar summary data, 2002-2017.

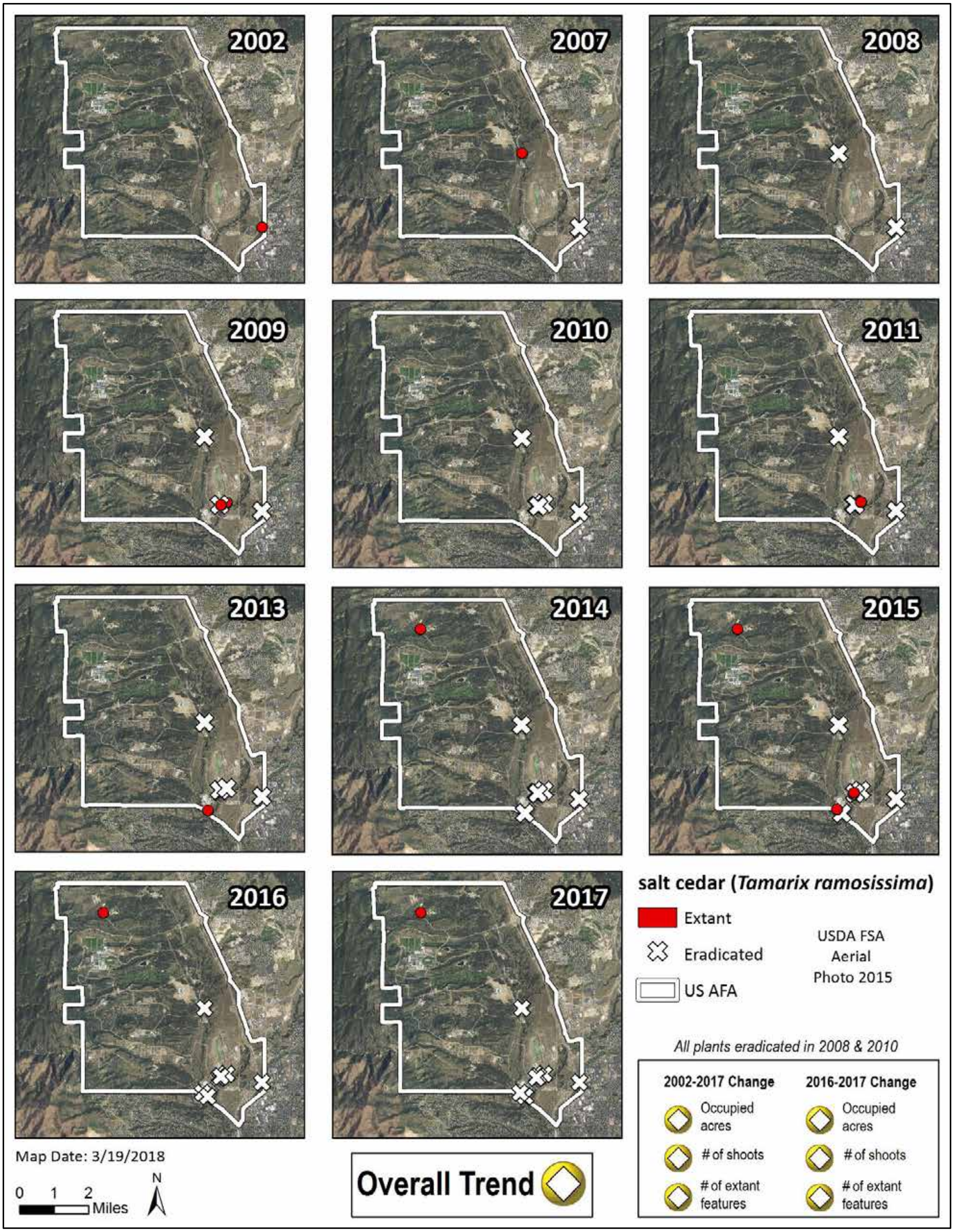
Census Mapping Method				
Year	*# Shoots*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2002	1	1	0	<0.01 (3.14 m^2)
2007	1	1	1	<0.01 (3.14 m^2)
2008	0	0	1	0
2009	2	2	3	<0.01 (6.28 m^2)
2010	0	0	5	0
2011	1	1	4	<0.01 (3.14 m^2)
2012	1	1	4	<0.01 (3.14 m^2)
2013	1	1	5	<0.01 (3.14 m^2)
2014	1	1	6	<0.01 (12.6 m^2)
2015	6	4	5	.03
2016	1	1	8	<0.01 (12.6 m^2)
2017	1	1	8	<0.01 (12.6 m^2)

Recommendations

Since the known population includes less than 10 individuals (one individual with 7 sprouts), we recommend a cut-stump method for treatment. For this method to be effective, plants are cut as close to the ground as possible (within 5 cm). According to Colorado Natural Areas BMPs for salt cedar, herbicide should be applied immediately (within one minute) to the cut since the wound will heal quickly and decrease the amount of herbicide that will be translocated into the stump (CPW 2013). Herbicide should be applied around the perimeter of the cut stump or stems. The two herbicides recommended by Colorado State Parks for this method are triclopyr and imazapyr. Follow-up monitoring is recommended. If bare soil or soil disturbance occurs, new plantings of native shrubs and forbs are recommended. Follow-up monitoring for sprouts within a year is recommended (CPW 2013). Salt cedar can spread both by seed and vegetatively. Continued monitoring at the Academy is recommended at the known and throughout the Academy, especially in ditches and riparian areas.

History of Sampling and Treatment:

- Salt cedar was known from five separate sites between 2002 and 2013 (Map 2).
- In 2008 and 2010, no plants were observed at the Academy.
- Between 2011 and 2014, the number of individuals remained stable with one plant documented each year.
- In 2015, two new sites included four individuals; one previously known extant site had been manually cut and was re-sprouting. This year's survey represented an increase in the number of extant features monitored from one to four. Five monitoring sites were found to have no living salt cedar plants in 2015.
- In 2016, six out of nine sites visited had no salt cedar present, two sites were not visited in 2016 (one near the airport and one across I-25, both of which were not found in 2015). One site had seven sprouts at Jacks Valley in 2016.
- In 2017, eight of nine sites with salt cedar were visited; the only site with salt cedar present was in Jacks Valley. The sprouts appear to have been browsed by wildlife.



Map 25. Distribution of salt cedar at the Academy between 2002 and 2017.

Scentless Chamomile (*Tripleurospermum perforatum*)

High priority watchlist for rapid response 2016-2017.

AFA Management Goals: Rapid response

State List: B

Photo: Pam Smith, Kettle Creek, July 2016

- Annual, biennial to short-lived perennial.
- Seedlings emerge in the spring.
- Seedlings can produce a dense mat, out competing other species.
- Seeds and flowers are continually formed.
- Each flower head can produce 300,000 seeds.
- Habitats roadsides, streambanks and drainages. (CWMA 2017c)

2017 Results

A new species of a list B noxious weed, scentless chamomile (*Tripleurospermum perforatum*) was mapped in 2016 in the Kettle Creek drainage (Map 26). Only a single plant was observed (and immediately removed) and appears to have come in with recent flooding. This is a new species for AFA and El Paso County, CO. In 2017, another individual was noted about 250 meters to the north of the original observation in 2016 (Table 31).

Table 31. Scentless chamomile summary data, 2016-2017.

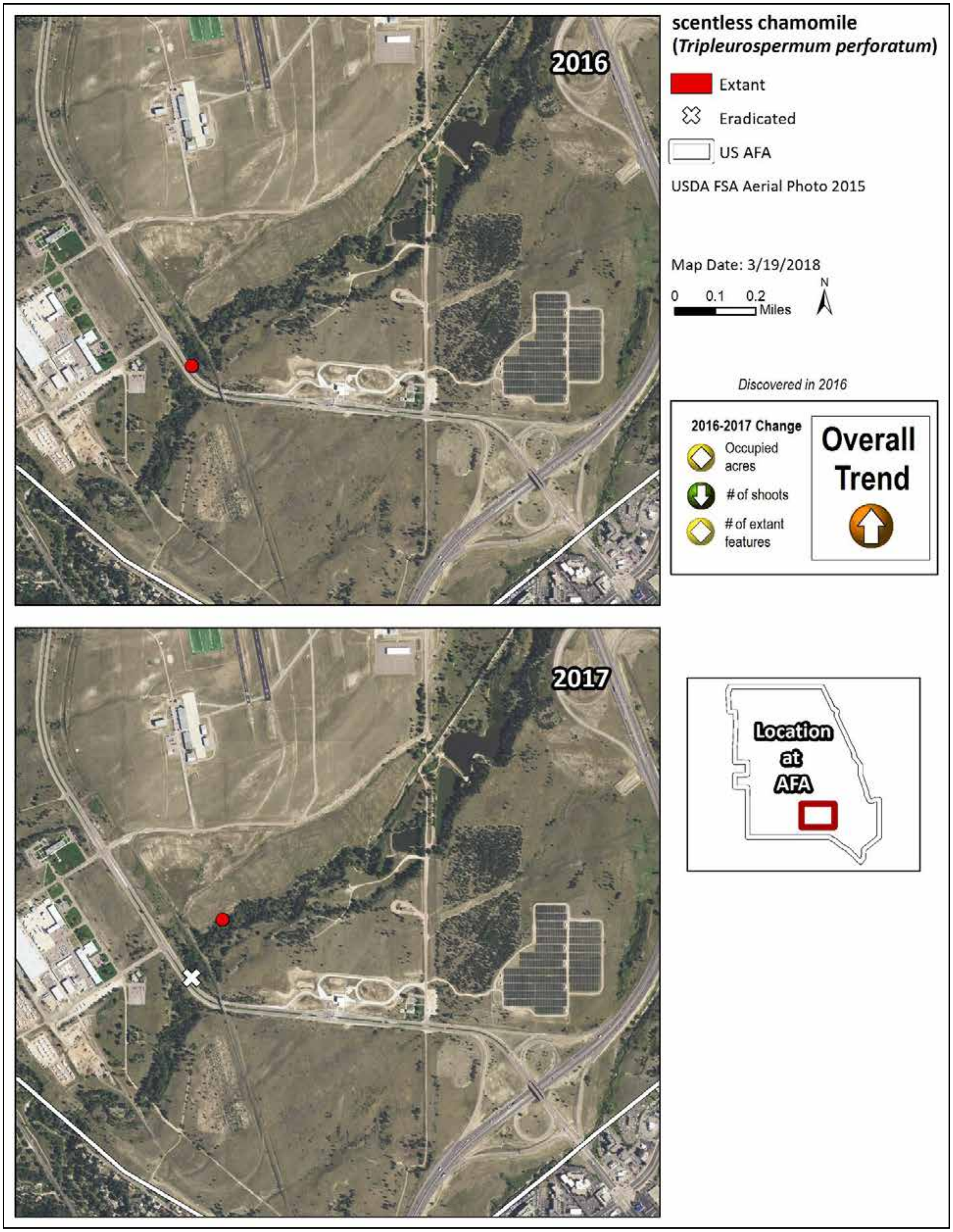
Census Mapping Method					
Year	*# Shoots*	*Total # of Features Visited*	*# Extant Features*	*# Eradicated Features*	*Occupied Acres*
2016	2	1	1	0	<0.01 acres ($3.14\ m^2$)
2017	1	2	1	1	<0.01 acres ($3.14\ m^2$)

Recommendations

Rapid response actions recommended are to survey the Kettle Creek drainage where the scentless chamomile appears to be entering the Academy on the east side. Prevention is recognized as the best known method for successful weed treatments. A diligent attempt to find plants while the invasion is new are worthwhile as this plant is known to be very invasive in other nearby counties. Rapid response efforts might include sending people to pull plants before July when these plants go to seed. The plant was found in very sandy sediment and was easy to remove with the root systems intact. Recently flooded areas should be surveyed and are only accessible on foot. The plants are likely to turn up in the other drainages at the Academy. Spending time training technicians and staff to recognize scentless chamomile and to pull plants as they are found is recommended.

History of Sampling and Treatment:

- First observation in 2016 for El Paso County and the Academy. Two individuals were found along the Kettle Creek drainage. An herbarium specimen was deposited at Colorado State University to document the county record.
- In 2017, a new location with a single individual was observed (and pulled) about 250 meters from the original site. The original site was also visited and no plants were found.



Map 26. Distribution of scentless chamomile at the Academy between 2016 and 2017.

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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.

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Russian knapweed (*Acroptilon repens*)			M*	M	M	M	M	M	M	M	M	M	M	M	M	M
Siberian peashrub (*Caragana arborescens*)											M					
hoary cress (*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					

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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	M	M	M	M
Common 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	M	M	M	M
yellow spring bedstraw (*Gallium verum*)									M*	M	M	M	M	M	M	M
Dame's rocket (*Hesperis matronalis*)											M*		PM	M	PM	

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
common St. Johnswort (*Hypericum perforatum*)	M			M	M	M	M	M	M	M	M	M	M	M	M	M
Dalmatian toadflax (*Linaria dalmatica*)								M*	M	M	M	M	M	M	M	M
yellow toadflax (*Linaria vulgaris*)	M					PM					PM					
Tatarian honeysuckle (*Lonicera tatarica*)							M*			M	M	M	M	M	M	M
Scotch thistle (*Onopordum acanthium*)	M			M	M	M	M	M	M	M	M	M	M	M	M	M
Bouncingbet (*Saponaria officinalis*)	M*											M	M	M	M	M
Salt cedar (*Tamarix ramosissima*)	M					M	M	M	M	M	M	M	M	M	M	M
scentless chamomile (*Tripleurospermum perforatum*)															M*	M

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

APPENDIX B. TRANSECT SURVEY PROTOCOLS FOR THE ACADEMY UTILIZED FOR BIOCONTROL AND NON-BIOCONTROL PLOTS FOR HOARY CRESS, 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)

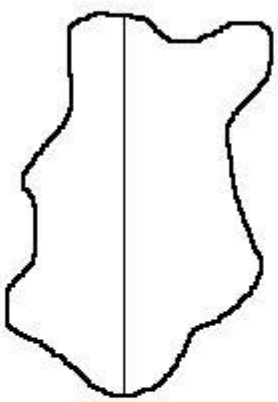
Materials for SURVEY ONLY:
Quadrat 50 x 50 cm (2)
50 m survey tape (minimum of 2, however 3 can also work well.
GPS unit, with the current year's shapefile for data entry

Standard survey procedure:

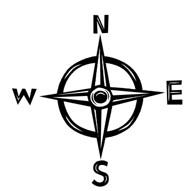
- The technique outlined here will apply to the majority of sites
- The general concept is to aim for a 50 m transect through the center of weed infestation. Sometimes it may be necessary to do a shorter transect in order to stay within the habitat. Ideally, the 25 m long bisecting transects have the 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



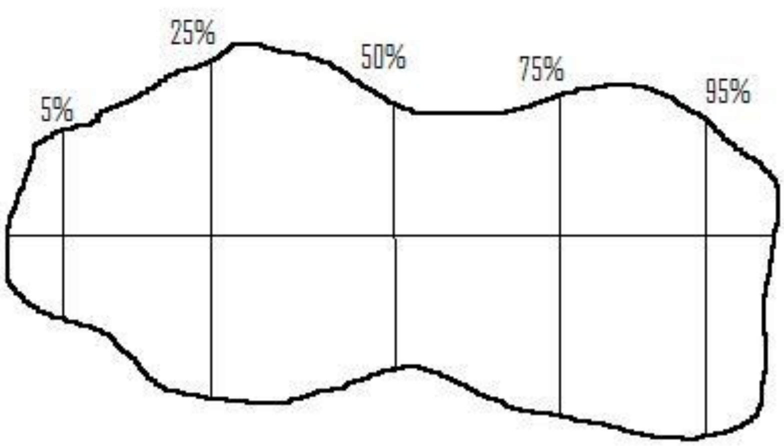


Fig. 2

0 m mark is south or west

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

- For sites deemed unmappable because of 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.

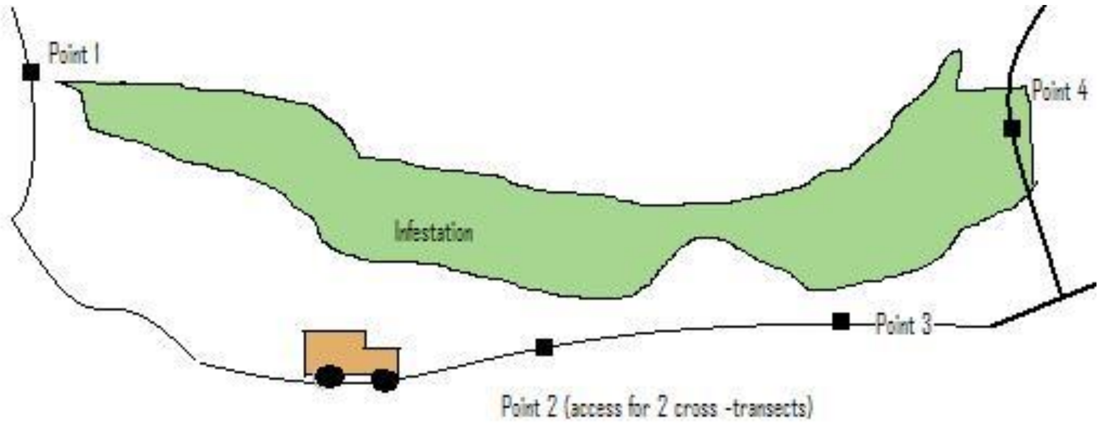

Point 1
Point 4
Infestation
Point 3
Point 2 (access for 2 cross -transects)

Fig. 3

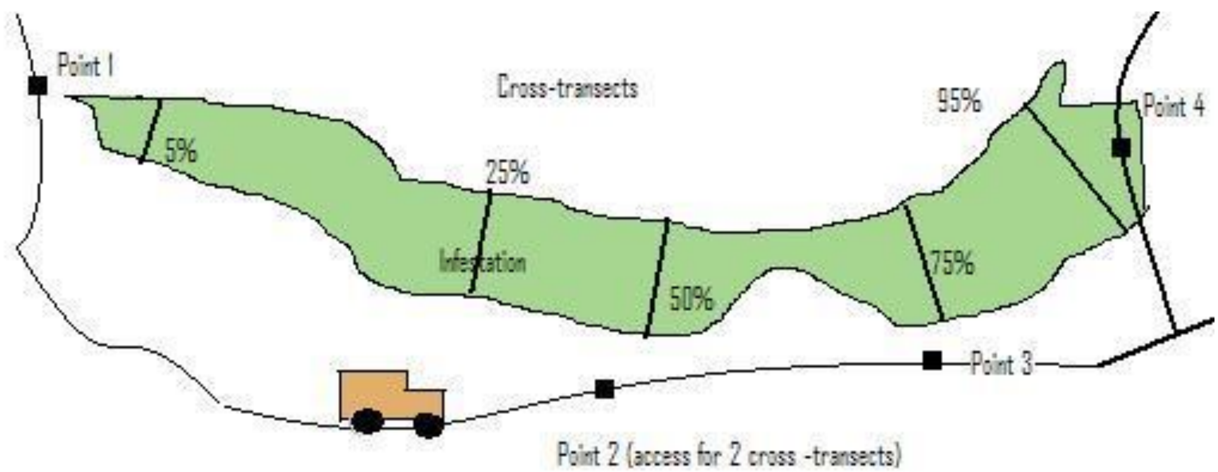

Point 1
Cross-transects
95%
Point 4
5%
25%
Infestation
75%
50%
Point 3
Point 2 (access for 2 cross -transects)

Fig. 4

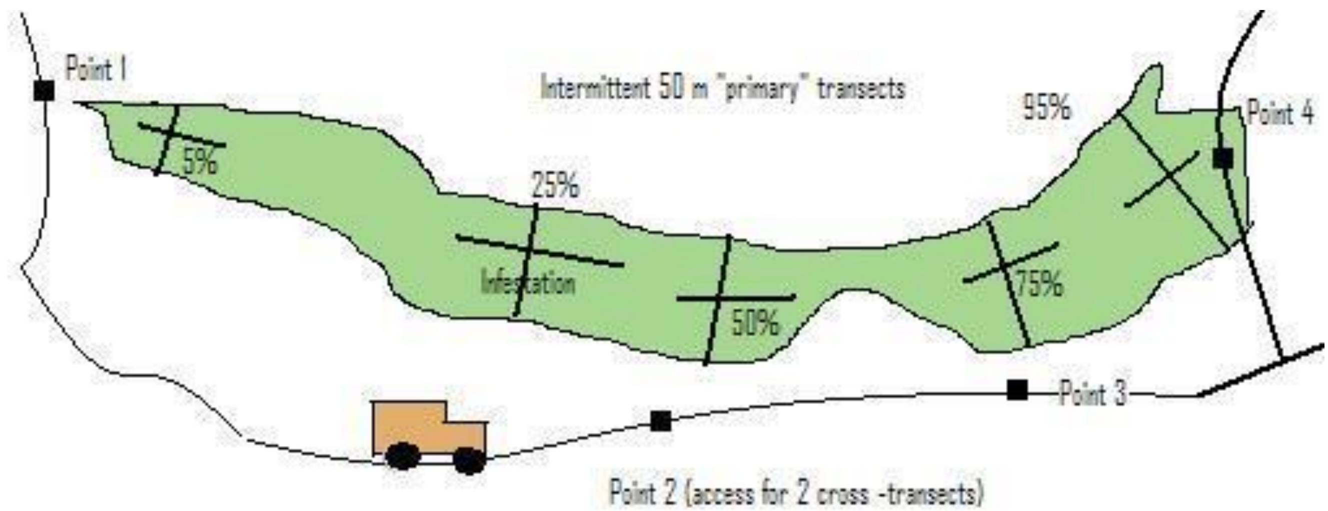


Fig. 5

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 10.2 (ESRI 1995-2015), a portable version of GIS software that allows users to efficiently create and attribute 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 large screen to help with navigation and data collection. According to Trimble specifications, the GPS is 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 30 meters in any direction 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, weeds of the same species 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.

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 2015 NAIP digital orthophoto for reference. Attributes were collected using customized field forms, designed to minimize user error by maximizing look-up tables and field auto-population techniques. One free text field was maintained to document any observations deemed important, such as nearby significant species (e.g. rare plants) or difficulties incurred in a specific area (e.g., dense oak thickets affecting the ability to map location or estimate individuals). The botany 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 by multiplying density by the size of the infestation in square meters.

Weed data were stored in an ESRI file geodatabase and 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

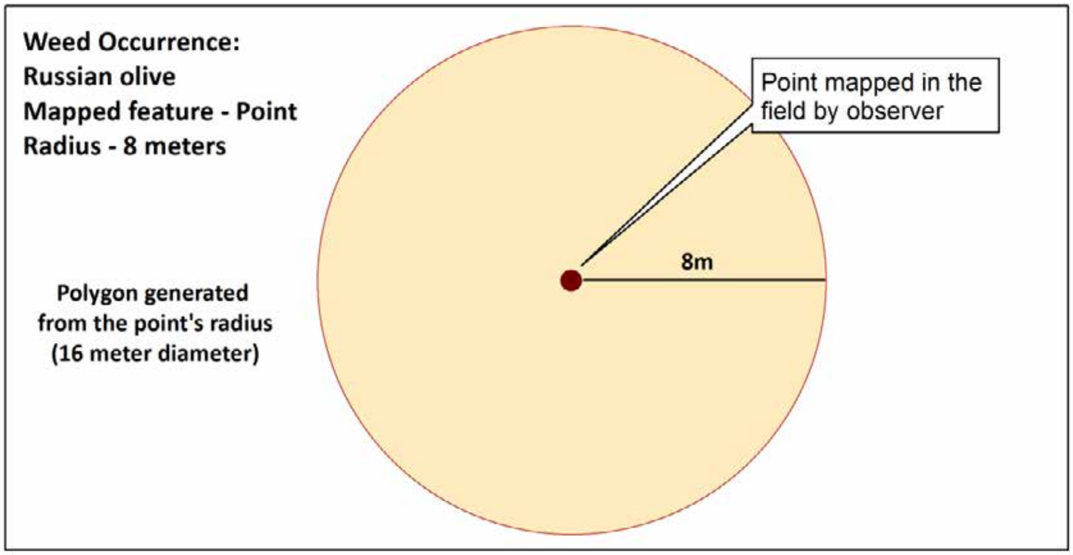
COUNTRY - Country

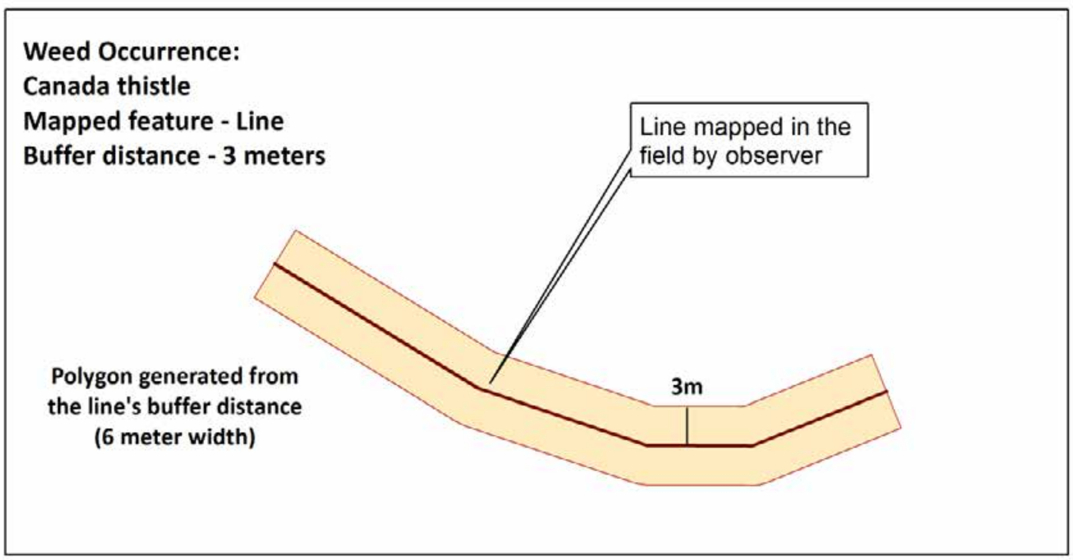
EXAMINER –Field observer

MAPAGENCY – Mapping agency

STATUS – Extant, Eradicated, Dead Standing, Sprouting, Other

Points and lines were buffered and combined with mapped polygons to generate a final weed map depicting our best representation of the distribution of noxious weeds at the Academy. See buffering examples below.





APPENDIX D. ALL MAPPED WEEDS IN 2017 IN COMPARISON TO 2009-2016

Number of Extant Features

Year	*Acroptilon repens*	*Cynoglossum officinale*	*Euphorbia myrsinites*	*Galium verum*	*Hesperis matronalis*	*Hypericum perforatum*	*Linaria dalmatica*	*Lonicera tatarica*	*Onopordum acanthium*	*Saponaria officinalis*	*Tamarix ramosissima*	*Tripleurospermum perforatum*
2009	2	8	12	NA	NA	21	1	?	50	?	2	---
2010	0	1	10	1	NA	20	2	?	61	?	0	---
2011	0	2	12	1	NA	26	0	?	39	?	1	---
2012	10	3	10	0	14	29	0	1	66	?	1	---
2013	0	7	19	0	?	22	1	5	48	8	1	---
2014	0	8	7	0	?	33	1	5	74	2	1	---
2015	0	22	14	1	2	27	0	9	157	8	4	---
2016	0	22	17	0	3	32	1	8	128	8	1	1
2017	0	26	25	0	---	47	1	8	120	6	1	1

Number of Eradicated Features

Year	*Acroptilon repens*	*Cynoglossum officinale*	*Euphorbia myrsinites*	*Galium verum*	*Hesperis matronalis*	*Hypericum perforatum*	*Linaria dalmatica*	*Lonicera tatarica*	*Onopordum acanthium*	*Saponaria officinalis*	*Tamarix ramosissima*	*Tripleurospermum perforatum*
2009	2	0	6	NA	NA	2	0	?	34	?	3	---
2010	4	6	12	0	NA	6	1	?	30	?	5	---
2011	4	6	16	0	NA	5	3	?	56	?	4	---
2012	4	9	25	1	0	10	3	0	73	?	4	---
2013	12	8	12	1	?	21	3	0	85	0	5	---
2014	12	8	27	1	?	19	3	2	81	6	6	---
2015	12	11	26	0	14	29	4	1	76	5	5	---
2016	12	14	26	1	14	27	3	4	127	6	8	0
2017	12	13	23	1	---	23	3	4	155	8	8	1

Number of Shoots

Year	*Acroptilon repens*	*Cynoglossum officinale*	*Euphorbia myrsinites*	*Galium verum*	*Hesperis matronalis*	*Hypericum perforatum*	*Linaria dalmatica*	*Lonicera tatarica*	*Onopordum acanthium*	*Saponaria officinalis*	*Tamarix ramosissima*	*Tripleurospermum perforatum*
2009	?	95	464	NA	NA	95,883	10	?	1,710	?	2	---
2010	0	11	56	700	NA	82,733	107	?	669	?	0	---
2011	0	21	57	1	NA	87,128	0	?	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	---
2014	0	102	179	0	?	3,604	7	31	1,224	42	1	---
2015	0	534	173	10	280	3,102	0	48	1,629	608	6	---
2016	0	480	185	0	294	6,717	1	22	1,331	535	1	2
2017	0	787	501	0	----	4,202	480	22	791	401	1	1

Occupied Acres

Year	*Acroptilon repens*	*Cynoglossum officinale*	*Euphorbia myrsinites*	*Galium verum*	*Hesperis matronalis*	*Hypericum perforatum*	*Linaria dalmatica*	*Lonicera tatarica*	*Onopordum acanthium*	*Saponaria officinalis*	*Tamarix ramosissima*	*Tripleurospermum perforatum*
2009	?	0.09	2.4	NA	NA	2.02	?	?	3.47	?	<0.01	---
2010	0	0.02	0.5	0.01	NA	1.47	0.50	?	0.66	?	0	---
2011	0	< 0.01	0.25	<0.01	NA	1.44	0	?	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	---
2014	0	0.04	0.7	0	?	1.12	<0.01	0.21	0.84	0.14	<0.01	---
2015	0	0.20	1.04	<0.01	0.08	1.27	0	0.40	1.60	0.09	0.03	---
2016	0	0.20	0.70	0	0.08	1.02	<.01	0.24	1.13	0.05	<0.01	<0.01
2017	0	0.41	1.15	0	---	1.31	<0.1	0.24	1.35	0.05	<0.01	<0.01

APPENDIX E. ASSESSMENT WORKSHEET FOR WEED MANAGEMENT SITE PLAN

1. Site location:____

2. Size of area with target species:______________________________________

3. Target species of concern at site:______________________________________

   a. Describe the biological characteristics that will be important for management:
      □ Annual with a shallow root system (puncturevine)
      □ Biennial species that dies after it flowers (musk thistle, knapweeds, bull thistle, teasel, Scotch thistle, houndstongue)
      □ Perennial broad-leaved plant with deep root system (hoary cress, Canada thistle, field bindweed, knapweeds, bouncingbet, St. Johnswort, Dame's rocket, scentless chamomile, toadflaxes)
      □ Woody plant (salt cedar, Russian olive, honeysuckle, Siberian peashrub)
      □ Other ____

   b. Seed longevity: ________________________ (how long to monitor site)

   c. Length of time species of concern has been present at site: ____________________

   d. % cover of target species at site: ________

   e. % cover native species: __________

   Describe other species present: ______________________________________

   ____

   ____

4. Site Description (include wildlife use):

   ____

   ____

   ____

   a. How is the target species distributed?
      a. □ solid stand
      b. □ patchy
      c. □ linear

d. □ in a depression
e. □ other____

b. Is the area a wetland? (herbicides should be wetland approved)
a. □ wet or moist soil year round
b. □ periodically flooded
c. □ upland inclusions
d. □ wetland adjacent or part of site

c. Has the site been previously treated? YES/NO. If yes,
how? ______________________________when? ____________________

d. Are there ongoing disturbances to the site? (natural and anthropogenic)
a. □ near a road
b. □ trails
c. □ culverts, drains
d. □ grazing (native or livestock)
e. □ off road use by tractors, mowers, four wheelers
f. □ soil disturbed by berm building, digging, ditching
g. □ other ____

5. Surrounding land use description: ______________________________________

____

____

6. Are there rare plants or rare plant communities either adjacent to or in the site? YES/NO.
If yes, do you know where they are located and how to identify them? __________
Is the site within a delineated natural area or sensitive natural area? YES/NO If so, follow BMPs for treating weeds in the vicinity of Rare Plants (https://www.colorado.gov/)
Is the site located near (<10 m) of a rare plant or within a rare plant community? YES/NO

7. Describe actions that are being considered for this site*:________________________

____

____

8. What are the expected results of proposed action(s)? __________________________

____

____

9. What are the potential negative impacts of proposed actions? ____________________

____

____

10. Describe the goal for the proposed action(s):
    □ **Eradication** (only for small populations; puncturevine, bull thistle, salt cedar)
    □ **Control or suppression** targeting satellite populations (Canada thistle, knapweed) (this is typically used if restoration is planned in the future or the area will be developed and removal of seed source is the goal).
    □ **Monitor** – get baseline to see if population is expanding – set up permanent monitoring plots

11. Describe the damage being caused by the presence of the target weed? (Is it clear the population is expanding? Should you monitor first?) ________________________________

    ____

    ____

12. Will removal of the target species damage the system? And will that damage have the potential to make the system more disturbed than the existing situation (i.e. produce bare soil, impacts from equipment, herbicide residue, introduction of outside seeds, change drainage pattern, etc.)?

13. Will the removal of the target species have a high likelihood of being successful?
    a. Is there potential for re-establishment of nearby native species? YES/NO
    b. Is there on-going disturbances that may make removal of targets result in secondary invasion by non-native species? YES/NO (Is smooth brome present?, herbicide residue time)
    c. Can monitoring and follow-up activities occur after treatment? YES/NO)
    d. Is the size of the treatment area workable and easily monitored for sprouts and effectiveness of treatments?
    e. Proposed schedule for follow-up monitoring (within a year) _______________________
    f. Funding available for multiple follow-up YES – NO (if No follow-up consider no treatment)
    g. Describe how you will document success? ______________________________________

    ____

    ____

14. Set up photo plot or photo monitoring plot:

INITIAL BASELINE PHOTO PLOT: (set rebar and take photo that captures the site, try to return to photograph at least once a year at or near the same date (or spring and fall).

PLOT ID:______________________________ UTM:____

DATE OF PHOTO: ____TIME________________________________

DATE PLOT INITIATED: ______________# of individuals____________est. cover %__________________

ASPECT/COMPASS HEADING FOR PHOTO: ____

***HERBICIDE**:

If herbicides are planned for SWMAs, a spot application technique for satellite populations may be appropriate. Follow-up monitoring and detailed information on the area treated with follow-up visits are necessary to observe whether treatments are working and plants are not spreading. Most populations experience some sort of runoff or flooding, and many herbicides are not appropriate for natural areas (even if the species is listed on the label). Replanting may be required. If smooth brome is in the area, there is a very high probability the area will fill in with this non-native grass and reduce forb cover.

***MOWING**: Protect native landscape from mowing machinery. Mowing will likely need to occur multiple times in a growing season. Mowing is best during droughts.

Follow-up Monitoring

Year 2 ______________________

PLOT ID: ______________________________UTM:____

DATE OF PHOTO: ______________________________TIME: ____

DATE PLOT INITIATED: ______________# of individuals: _________________ est. cover %:__________

ASPECT/COMPASS HEADING FOR PHOTO: ____

List actions taken in year 1 with observations:

□ monitor only____

□ satellite treatment only____

□ full site treatment ____

Describe in detail results (population increasing/decreasing). (photo comparison – size of polygon)

Are additional treatments necessary?

Change in treatment plan for year 2?

Next Scheduled Monitoring Date: