Noxious Weed Monitoring and Treatment at the U.S. Air Force Academy Year 17

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COLORADO NATURAL HERITAGE PROGRAM

Noxious Weed Monitoring and Treatment
Year 17 at the U.S. Air Force Academy

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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 top to bottom: beaver lodge on Monument Creek, myrtle spurge (*Euphorbia myrsinites*) sprout in September, Dr. Noyd at beaver dam on Monument Creek and Kettle Creek floodplain.

EXECUTIVE SUMMARY

This report summarizes the results of the past seventeen years of population monitoring of noxious weeds at the U.S. Air Force Academy ("the Academy") and at Farish Recreation Area ("Farish"). Basewide monitoring has been conducted at the Academy at five year intervals: 2002, 2007, 2012 and 2018 and at Farish: 2002, 2007, 2012 and 2017. In between years, areal mapping at known sites was conducted at the Academy for species with low cover, and permanent plots were monitored for widespread species. In 2021, areal mapping was conducted for 17 species (six species partially mapped). Many sites were treated manually to remove plants following specific manual weed treatment protocols. These treated sites received follow-up visits for monitoring and additional treatments as necessary. Sites were visited from 1-4 times depending on the species threat level and monitoring results.

Fifteen of the 17 noxious weeds species at the Academy were prioritized for manual treatments by CNHP for 2021 (Tatarian honeysuckle and salt cedar are treated by Academy). The results of the basewide survey in 2018 showed increases in weeds despite treatments and a new strategy was developed to reduce species that have a reasonable chance to be eradicated or reduced significantly in cover. One of the strategies to make treatments more successful was to conduct multiple visits to sites with extant occurrences throughout the same growing season for species considered to have low cover and high potential for control or eradication across the Academy. The majority of treated sites (with herbicides or manual) had sprouting individuals later in the season. In past years, these sprouts would not have been treated and would have gone on to flower and produce seeds. Removing the sprouts later in the season has yielded notable reductions for Russian knapweed, yellow spring bedstraw, dame's rocket, orange hawkweed, perennial pepperweed and common tansy in 2021.

Summary of Findings

As part of the manual treatments in 2021, there were a total of 1,158 site visits with 71,341 individuals mapped and 18,180 shoots removed (Table 1). Six species of noxious weeds at the Academy are showing decreasing trends since 2020 (green arrows): Russian knapweed, yellow spring bedstraw, dame's rocket, orange hawkweed, perennial pepperweed, and common tansy; three species (common St. Johnswort, bouncingbet and tamarisk) are stable with less than 10% change (yellow diamonds); five species (houndstongue, myrtle spurge, oxeye daisy, Dalmatian toadflax and Scotch thistle) are showing moderate increases of less than 100% change (orange arrows), and one species (garlic mustard) is increasing (>100% change red arrow). Tatarian honeysuckle and scentless chamomile have trends that are not clear due to lack of data as all sites were not visited in 2021 (question marks) (Table 1). For more details, see individual species sections.

Table 1. Summary of treatments for noxious weeds monitored at the Academy in 2021.					
Trend 2020-2021	Scientific Name	Common Name	#CNHP Site Visits	Total # Shoots	# Shoots Treated
↓	*Acroptilon repens*	Russian knapweed	15	254	254
↑	*Alliaria petiolata*	Garlic mustard	44	51,400	1,112
↑	*Cynoglossum officinale*	Houndstongue	128	5,330	3,840
↑	*Euphorbia myrsinites*	Myrtle spurge	159	1,355	1,355
↓	*Galium verum*	Yellow spring bedstraw	4	327	327
↓	*Hesperis matronalis*	Dame's rocket	4	3	3
↓	*Hieracium aurantiacum*	Orange hawkweed	2	67	67
◇	*Hypericum perforatum*	Common St. Johnswort	64	2,630	1,803
↓	*Lepidium latifolium*	Perennial pepperweed	8	179	179
↑	*Leucanthemum vulgare*	Oxeye daisy	24	1,422	1,422
↑	*Linaria dalmatica*	Dalmatian toadflax	14	2	2
?	*Lonicera tatarica*	Tatarian honeysuckle	14	83	0
↑	*Onopordum acanthium*	Scotch thistle	623	7,134	6,662
◇	*Saponaria officinalis*	Bouncingbet	29	898	898
◇	*Tamarix ramosissima*	Salt cedar	2	1	0
↓	*Tanacetum vulgare*	Common tansy	3	5	5
?	*Tripleurospermum perforatum*	Scentless chamomile	18	251	251
TOTALS			**1,158**	**71,341**	**18,180**

Summary of Recommendations

- Begin transition to a new data collection methodology.
- Monitor and treat all known sites of Russian knapweed, myrtle spurge, yellow spring bedstraw, dame's rocket, orange hawkweed, perennial pepperweed, oxeye daisy, Dalmatian toadflax, and common Tansy, multiple times during the growing season.

- Continue to monitor and treat high priority sites of Scotch thistle and houndstongue in the spring and summer. Sites in dense vegetation are low priorities for treatment for biennials, based on data that suggests leaving them in situ can result in natural reductions.
- Identify sites that should be avoided for treatments that have the potential to recover over time (Scotch thistle, houndstongue).
- Mapping and treatments for garlic mustard, Tatarian honeysuckle, scentless chamomile and large populations of Scotch thistle should be discussed in the spring meeting for 2021.
- Continue to coordinate treatment activities with resource management staff, herbicide contractor and CNHP to target areas of concern (rapid response). Provide the applicator with maps of rare species and wetland areas to help avoid impacts to rare plant and animal species during the season, as needed.
- Treat sprouts throughout the growing season at treatment sites, as this stage is the easiest, least destructive to the soils, and most effective way to provide control and prevent seed production.
- Continue to monitor populations of bouncingbet and remove flowering stems.
- Recommendations for the use of monitoring plots at the Academy and Farish is under discussion for future monitoring efforts.
- List A, B or watch list, or noxious weed species of management concern in need of rapid response actions include:
    - Myrtle spurge (List A)
    - Orange hawkweed (List A)
    - Perennial pepperweed (List B)
    - Russian knapweed (List B)
    - Oxeye daisy (List B)
    - Scotch thistle (List B)
    - Houndstongue (List B)
    - Salt cedar (List B)
    - Dalmatian toadflax (List B)
    - Dame's rocket (List B)
    - Common tansy (List B)
    - Scentless chamomile (List B)
    - Bouncingbet (List B)
    - Common St. Johnswort (List C)
    - Garlic mustard (State Watch List)
    - Yellow spring bedstraw (not listed, garden escape)
    - Tatarian honeysuckle (not listed, garden escape)

  Watch list for noxious weeds with potential to be found at the Academy and Farish include:

    - Purple loosestrife – potentially present at the Academy (List A)
    - Hairy willowherb – not found (List A - known from nearby county)
    - Mediterranean sage- not found (List A - known from nearby county)
    - Dyers woad – not found (List A – documented in the vicinity)

Acknowledgements

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INTRODUCTION

An Integrated Natural Resources Management Plan (INRMP 2015) has been developed for the U.S. Air Force Academy (the Academy) and the Air Force Civil Engineer Center (AFCEC) in accordance with Air Force Manual AFMAN 32-7003, Environmental Conservation; Air Force Policy Directive (AFPD) 32-70, Environmental Quality; and the provisions of the Sikes Act, as amended (16 United States Code [U.S.C.] 670a et seq.). AFMAN 32-7003 requires the control of noxious, exotic, and invasive species. The INRMP was updated in 2018 (Air Force Academy INRMP 2018 -2022). The Academy issued a Finding of No Significant Impact for the INRMP's Environmental Assessment, which included an analysis of noxious weed control objectives and actions. Noxious weed control is also a conservation strategy identified in the Preble's meadow jumping mouse Conservation Plan, which is supported by a USFWS Biological Opinion (ES/GJ-6-CO-00-F-009, April 2000).

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 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 Academy is located near Colorado Springs, Colorado (Map 1).

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.

A significant portion of the landscape at the Academy and Farish falls into the "natural areas" category and includes important wetland features. The Academy and Farish 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, Schorr et al. 2019).

Herbicide Use in Natural Communities

Guidelines for controlling noxious weeds (including herbicide label instructions) are often based on agricultural landscapes instead of natural plant communities or wildlands. 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). These areas were delineated at the Academy as Special Weed Management Areas (Smith et al. 2015, Figure 1). 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. The presence of rare plants, pollinators, and wildlife, including a threatened mammal species (Preble's Meadow Jumping Mouse) that lives in riparian areas at the Academy, needs consideration. Although many herbicides are tested for toxicity to animals to some degree, the adjuvants often added to herbicides and the mixtures of herbicides used by contractors are not (Wagner et al. 2017).

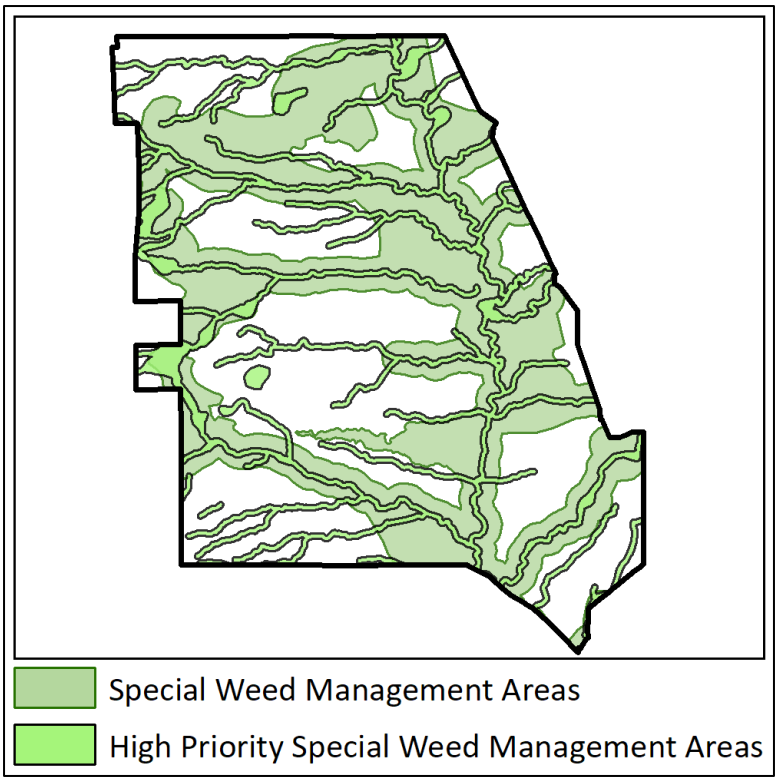


Figure 1. Special Weed Management Areas at the Academy.

Weed infestations are most often the result of previous land disturbances, therefore, the primary goal in weed management in natural communities is to prevent or minimize disturbances to soil and native plants. Herbicides can cause soil disturbances by harming soil organisms, changing soil chemistry and killing surrounding plant species and are considered a last resort by numerous wildland managers (Sources A-D, Appendix E).

The efficacy of herbicide treatments has not been well-documented in North America. There is scientific literature on the efficacy of herbicides for controlling target weeds but most of this research focuses exclusively on the target plant with no information on the desirable natives, and the outcomes are only monitored over a short period of time, neglecting the economic impacts of management actions (Wagner et al. 2017). The research suggests herbicides alone are not effective in the long-term and typically result in re-infestations of the same or different noxious weeds species (Pearson et al. 2016). Careful consideration needs to be made by land managers to consider

if an herbicide will do more conservation good than harm in each situation (Source A in Appendix E). This is the basis for the following herbicide application guidelines in natural communities at the Academy.

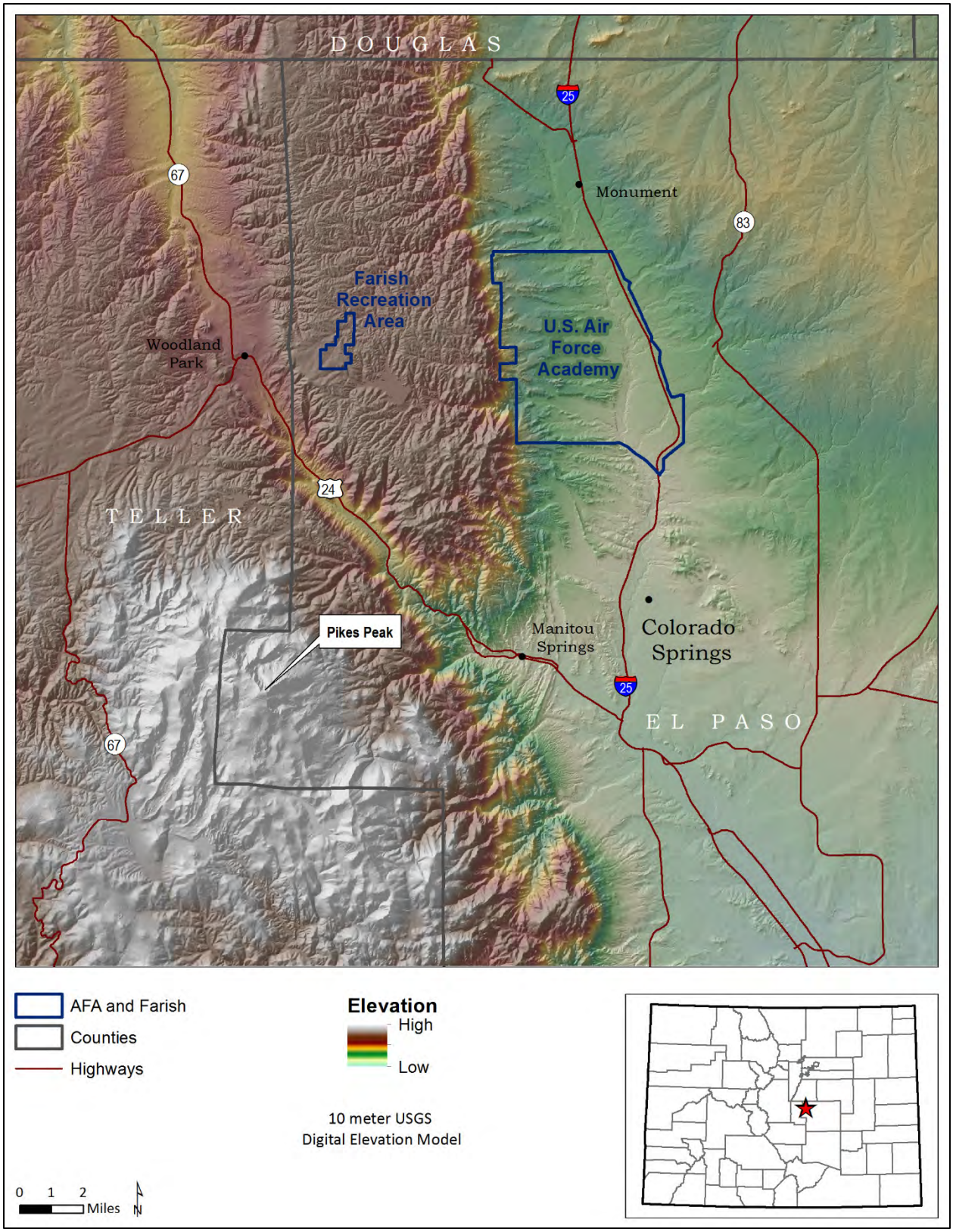
Guidelines for Herbicide Use in Natural Areas

1) If other methods (manual removal, biocontrol) are available, those should be used first. Herbicides should be used as a last resort and when all other reasonable alternatives have been ruled out in natural plant communities (Sources A-D in Appendix E).
2) Consider potential impacts of treatment to determine if there will be more impacts from treating than not treating (Sources A-D in Appendix E).
3) Spot applications of herbicide that target individual plants by either wiping herbicide with a wicking cloth or a precise spray that is aimed at the target plant minimizing harm to adjacent plants and soils is highly recommended by numerous land conservation agencies (GPMCT 2019, Sources A-D in Appendix E).
4) Consider herbicides that are selective for broadleaf weed species to protect native grasses, that are effective against the target species (Source B). The Special Management Areas are not rangelands. Recommended dosing and application methods for rangelands can damage natural resources and harm wildlife. Follow label instructions for wildlands and wetlands. Using herbicides in areas with Preble's Meadow Jumping Mice and rare plant species is not recommended.
5) Time herbicide application to the susceptible life stage and to minimize seed production. Avoid spraying bolted thistles in late stages and mid-summer application of herbicides which are less effective, require larger amounts of herbicide and result in greater off-target damage.
6) Consider not treating species with active biocontrol.
7) Document all herbicide applications.
8) Follow-up monitoring of treated sites to measure effectiveness and to catch late season sprouts.
9) Adaptive management flexibility to change a course of action if a certain method is unsuccessful or needs adjustment.
10) Use an integrated approach to treatments. Chemical treatments alone are almost never successful and are used as a part of an integrated control program when necessary in wildlands.

Reasonable Goals to Reduce Weed Cover at the Academy

1) All activities that prevent the spread of noxious weeds across the Academy, including avoiding disturbance of natural lands, cleaning equipment are considered most effective (prevention). (Wagner et al. 2017)
2) Focus on mapping, monitoring and treatments for rapid response species that have less widespread cover (Wagner et al. 2017).
3) Utilize biocontrol for species that have widespread cover.
4) Staff and contractors can be on the lookout for new infestations as weed monitoring and management activities occur in between five-year basewide monitoring efforts.

5) Avoid treating large areas with dense infestations of widespread weed species without a restoration plan. Treating satellite populations or edges may help contain some noxious weeds.
6) See individual species recommendations for specific details.



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

Timeline of Weed Mapping and Monitoring at the Academy

The Colorado Natural Heritage Program first mapped noxious weeds at the Academy and Farish in 2002 and has monitored noxious weeds at the Academy for the past 15 years. 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 basewide noxious weed survey 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 (*Galium verum*) was discovered at the Academy and mapped. Diffuse knapweed (*Centaurea diffusa*) was not monitored.
- **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 the monitoring and management responsibilities for leafy spurge (*Euphorbia esula*)

and common St. Johnswort (*Hypericum perforatum*); 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 basewide weed survey for the Academy and Farish was completed, mapping 22 weed species and an estimated 39% increase in area occupied (Lavender-Greenwell and Rondeau 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 stoebe, C. diffusa*) and the hybrid knapweed 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. Fourth comprehensive weed map for Farish with a total of four mapped species at approximately 477 extant locations.
- **2018:** The fourth basewide noxious weed survey of the Academy was completed, with a total of 25 mapped species at over 9,300 extant locations at the Academy. Forty-five permanent plots were monitored for five species: Canada thistle (8 plots), hoary cress (10 plots), leafy spurge (10 plots), knapweeds (7 plots) and musk thistle (10 photo plots). Three detailed site plans were written for weed treatments in areas with plants and animals of conservation concern. A new List A noxious weed species, orange hawkweed (*Hieracium aurantiacum*), was discovered in 2018 at Farish.
- **2019:** Fifteen noxious weed species were prioritized for manual treatments by CNHP for the first time. The strategy to include multiple visits within the same growing season to treat sprouts is expected to yield reductions for 2020. Surveying West Monument Creek for

garlic mustard was added to the tasks. A new list B species, oxeye daisy (*Leucanthemum vulgare*), was added to the noxious weed list at the Academy.

- **2020:** 17 species were monitored and 16 noxious weed species were prioritized for manual treatments by CNHP for the second year. A new list B species, common tansy (*Tanacetum vulgare*), was mapped in 2020.
- **2021**: 17 species were monitored with 15 noxious weeds prioritized for manual treatments by CNHP for the third year.

METHODS

The objective of this project is to identify trends and evaluate the effectiveness of ongoing management of noxious weeds at the Academy. Since 2002, four types of monitoring have been utilized to measure the changes in noxious weed cover, density and distribution at the Academy and Farish.

- **Basewide weed mapping** includes visiting all known occurrences and surveying for new occurrences and new noxious weed species. This is the most intensive survey and it is conducted once every five years (a complete census of targeted species).
- **Annual mapping** occurs in between the basewide mapping years and is conducted by re-visiting the known occurrences of rapid response species or those with limited distributions.
- **Permanent plot monitoring** is used to determine trends for the most widespread species. At the Academy, five species have been targeted for permanent plots: Canada thistle, leafy spurge, hoary cress, knapweeds (spotted, diffuse and hybrids) and musk thistle. Photo plots are used to monitor musk thistle while a transect survey sampling method is used on the other four species. Plot monitoring was suspended since 2019.
- **Monitoring with treatments** was added in 2019 as a method to address weed increases by rapid response species. This new method combines areal mapping with treatments and includes multiple visits to sites that had plants at the initial monitoring visit to look for sprouts.

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. Permanent plot sampling methods are described in Appendix B. The long-term monitoring plots were not surveyed in 2019 and 2020 to allow time for more focus on the targeted monitoring and manual treatments that will be implemented.

Basewide weed mapping in 2018 was performed using a census survey method where weeds were documented by walking the property using GPS and GIS technology. Field technicians mapped noxious weed occurrences at the Academy from May through September in 2018 and in August of 2017 at Farish. Infestations were mapped as points, lines, or polygons, depending on the size and shape of each occurrence. Points and lines were buffered to estimate actual size. Irregularly shaped features greater than approximately 30 meters in any direction were mapped as polygons. Data

were mapped using a Trimble Yuma rugged tablet with a built-in GPS receiver (accuracy between 2-5m) and ArcPad (ESRI 1995-2018), a portable version of Geographic Information Systems (GIS) software. Qualitative notes and actual counts and estimates for populations were made at each mapping site. When weeds were visible but exact locations were inaccessible, offsets were applied to the GPS or features were digitized heads-up using the 2015 NAIP or 2019 aerial photo for reference. Notes were taken to document non-standard, "on the fly" mapping techniques. A more detailed description of the mapping protocol is provided in Appendix C. The next basewide weed mapping will be targeted for 2023.

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. However, some of the noxious weed populations may 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. Common St. Johnswort, Canada thistle, musk thistle, bouncingbet, and leafy spurge are showing signs of significant impacts from biocontrol organisms and wildlife.

In 2019, some additional changes to the weed monitoring project were initiated to address the results from analyses of the first 15 years of monitoring data and the 2018 weed mapping survey (Smith and Greenwell 2019). The data are showing an increase in the coverage of weeds at the Academy. New locations as well as the re-occurrence of weeds in areas that have been previously treated were observed. In 2019, CNHP included manual weed treatments in addition to the areal monitoring protocol as a means to address some of the increases. The focus was on rapid response weed species and those with more limited coverage where a manual treatment was feasible. Manual treatments by CNHP were based on species specific information for appropriate manual treatment methodologies. Each treatment was based on the species lifecycle to make sure appropriate timing and manual treatments would be most effective. Manual treatments were conducted on 15 species. The treatment methods for each species and detailed descriptions are provided in Tables 2 and 3.

The timing of weed treatments is one of the most critical factors in effective weed control. Many of the species sprout, bloom and go to seed at different times throughout the growing season. A treatment schedule was created to provide the timing as well as the types of treatments in 2020 for 15 noxious weeds. To be able to conduct the treatments and make multiple visits to sites, the long term monitoring plots were not monitored in 2020-2021 (Tables 2 & 3). The decision to manually treat plants was made by the field team on a site by site basis, looking at the treatment necessary, number of individuals at the site, location, previous herbicide application or the presence of biocontrol, and the biomass that needed to be removed.

The changes and modification that began in 2019 are part of an adaptive management action. These changes are to be made when it is clear current management strategies are not effective or new information on treatments have become available as specified in the Academy's Integrated Noxious

Weed Management Plan (Carpenter and Perce 2004) as modified by Anderson and Lavender (2007), and Anderson and Lavender (2008b) and Smith et al. (2015).

Table 2. Summary of weed treatment methods and actions for 2021.

Latin Name	Common Name	2021 Methods/Actions	2021 Action
Acroptilon repens	Russian knapweed	Areal/Treat	Manual #1
Alliaria petiolata	Garlic mustard	Areal/Treat	Mapping/Manual 2, Method 3
Cynoglossum officinale	Houndstongue	Areal/Treat	Manual #1
Euphorbia myrsinites	Myrtle spurge	Areal/Treat	Manual #2
Galium verum	Yellow spring bedstraw	Areal/Treat	Manual #2
Hesperis matronalis	Dame's rocket	Areal/Treat	Manual #1
Hieracium aurantiacum	Orange hawkweed	Areal/ Treat	Manual #1&2
Hypericum perforatum	Common St. Johnswort	Areal/ Partial Treat	Manual #2 (< 100 plants)
Lepidium latifolium	Perennial pepperweed	Areal/Treat	Manual #1/Method #3
Leucanthemum vulgare	Oxeye daisy	Areal/Treat	Manual #2
Linaria dalmatica	Dalmatian toadflax	Areal/Treat	Manual #2
Onopordum acanthium	Scotch thistle	Areal/Partial Treat	Manual #1
Saponaria officinalis	Bouncingbet	Areal	Remove reproductive parts
Tamarix ramosissima	Salt cedar	Areal/Treat	Method #3
Tanacetum vulgare	Common tansy	Areal/Treat	Manual #1&2
Tripleurospermum perforatum	Scentless chamomile	Areal/Partial Treat	Manual #2
Long Term Monitoring Plot Species not Monitored in 2019 - 2022			
Cardaria draba	Hoary cress	Plot	---
Carduus nutans	Musk thistle	Photo Plot	---
Centaurea diffusa, C. maculosa and hybrid	Diffuse, spotted knapweeds	Plot	---
Cirsium arvense	Canada thistle	Plot	---
Euphorbia esula	Leafy spurge	Plot	---

Table 3. Description of weed treatment methods for 2021.

Type	Description of Actions
Manual #1	**Sever below crown with knife pre-flower or rosette; revisit before fall all sites that had plants.**
Manual #2	**Pull entire root pre-flower; revisit all sites in fall that had plants; for hawkweed be very careful to remove ALL root fragments (as much as possible)**
Method #3 flagging	**Flag for herbicide application – spot treatment (dates and herbicide recommendations may be discussed with applicator in spring meeting)**

A coordination meeting with the Academy Resource Manager and the herbicide applicator was held on April 05, 2021 to discuss timing and implementation of methods and coordination. Special maps

were prepared for the contractor by CNHP to help focus efforts and to track where treatments are occurring or flagging is needed by contractor to help locate plants. It is our hope that both parties communicate with one another for assistance on monitoring and treatment. Monitoring and manual treatments by CNHP began in May of 2021.

Noxious weed sites east of I-25 were not monitored after discussions with the Academy. I-25 east is being developed and Pine Creek is a highly disturbed system where treating weeds is futile without a restoration plan.

RESULTS AND RECOMMENDATIONS

U.S. Air Force Academy

Noxious weeds have been increasing throughout the Academy since monitoring began in 2002 (Smith and Greenwell 2019, Figure 2).

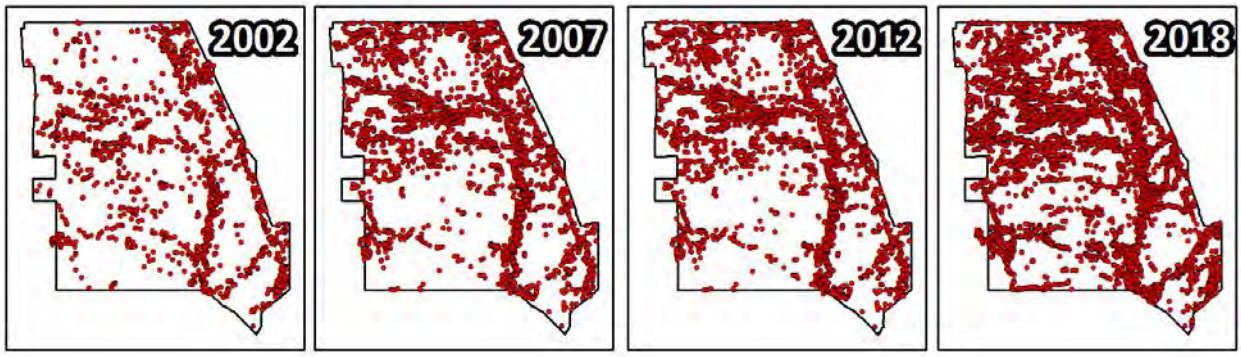


Figure 2. Distribution of known noxious weed occurrences at the U.S. Air Force Academy (excluding yellow toadflax).

A list of 17 species were proposed for monitoring and/or treatments for the 2021 season. In 2021, six species of noxious weeds at the Academy are showing decreasing trends (<5% change) since 2020 (Russian knapweed, yellow spring bedstraw, dame's rocket, orange hawkweed, perennial pepperweed, and common tansy). Myrtle spurge would also be considered to be declining or stable, but a single site experienced a seed bank release that resulted in 1,000 sprouts. Three species (common St. Johnswort, bouncingbet and salt cedar) are stable (5-10% change). Five species (houndstongue, myrtle spurge, oxeye daisy, Dalmatian toadflax and Scotch thistle) are showing moderate increases (10-100% change). Garlic mustard is the only species that showed an increase of >100% change since 2020. Tatarian honeysuckle and scentless chamomile have trends that are not clear due to lack of data as the entire populations were not sampled in 2021. As part of the manual treatments in 2021, there were a total of 1,158 site visits to manually treat plants including follow-up visits. A total of 18,180 shoots were removed and 71, 341 total individuals were mapped in 2021 (Table 1).

Medium priority species include Common St. Johnswort, bouncingbet, Tatarian honeysuckle and scentless chamomile. Local control and suppression are attainable. Biocontrols are frequently observed on Common St. Johnswort. The remaining 13 species are considered high priorities for treatment and monitoring. All 13 have a high likelihood of being eradicated. Salt cedar has only one extant occurrence and will likely be eradicated. Flooding, precipitation patterns, biocontrol agents as well as the multiple treatments to remove sprouts within the same season are all contributing to reducing the rapid response species at the Academy.

Detailed results are included in the individual species sections as monitoring and treatments vary by species. The mapping results for areal monitoring are updated using data from the early season site visits to make that data comparable to past years. New tables have been included in the treatment sections that focus on the current year treatments that include multiple site visits as well as summary data since 2019 when we began manual treatments. Some sites are also broken down by month to assist with future surveys to help understand the temporal distribution of sprouting throughout the season for different weed species at the Academy.

Precipitation

Annual precipitation, especially in the spring and summer months, can be a helpful indicator for interpreting weed monitoring data. Higher precipitation years often result in increased weed numbers for that year. The annual precipitation for 2021 was 15.53 inches and 12.62 inches recorded for spring and summer respectively. The average annual precipitation calculated for years (1961-1990) is 12.33 inches (WU 2018). In 2021, the annual precipitation was 3.2 inches above average. The highest spring and summer precipitation was recorded in 2015 with 25.25 inches which is over 60% above the average annual precipitation. 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, 2017, and 2021 were above average for spring and summer precipitation, while 2002, 2008 and 2012 were very dry years (Figure 3). Musk thistle, Scotch thistle, and houndstongue have population increases that are strongly correlated with higher precipitation patterns.

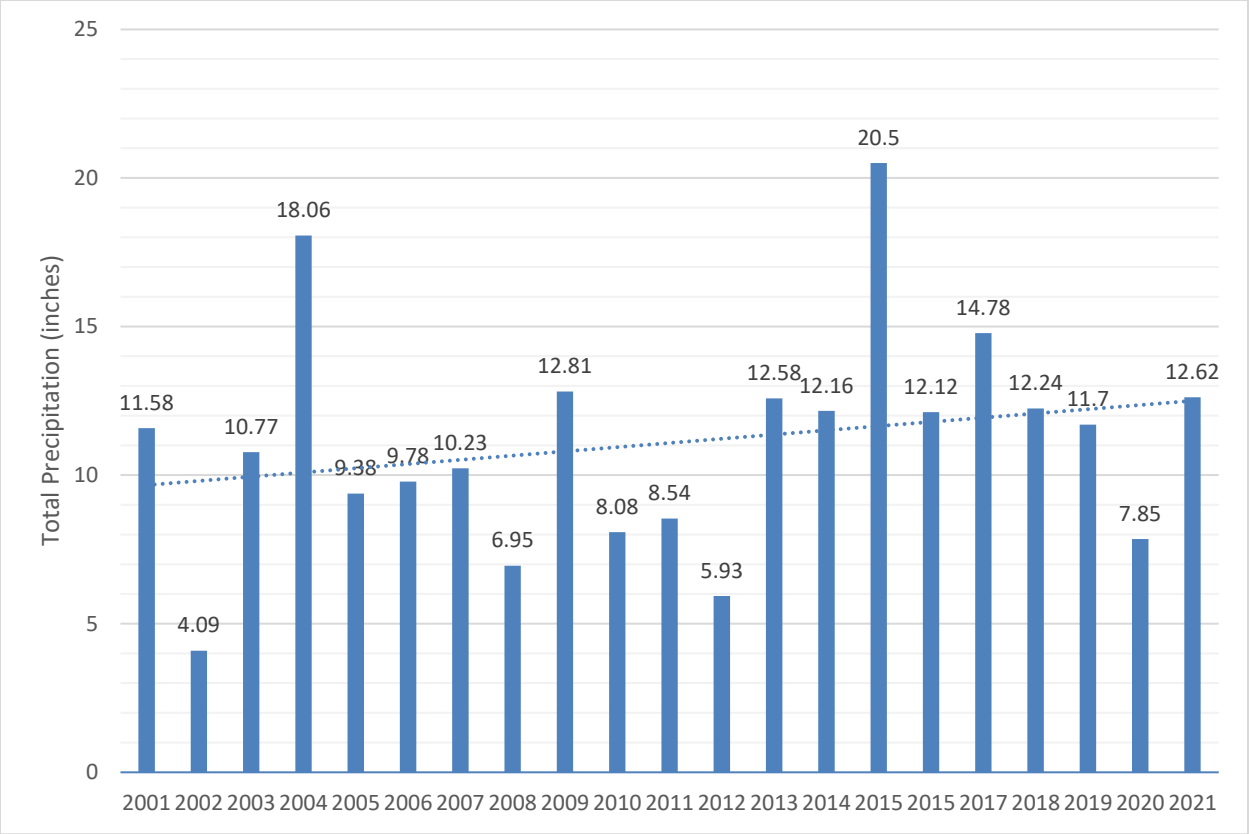


Figure 3. Average spring and summer precipitation at the Colorado Springs Municipal Airport (KWOS). Spring = March – May, Summer = June – August (WU 2022). Blue dotted line is trend line.

Russian Knapweed (*Acroptilon repens*)

Trend 2020-2021: Decreasing

Management Goals: Eradication

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 (CWMA 2020a)
- 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).

2021 Mapping Results

Russian knapweed has shown a decrease from 183 individuals in 2020 at two sites to 152 individuals at two extant sites in 2021. For a period of five years from 2013 to 2017, all known sites were eradicated (Table 4). The seed longevity of this species is thought to be five years. Basewide mapping in 2018 yielded three extant locations that included two new features (Table 4, Maps 2 and Map 3 - Grid D-3/E-7). Table 4 and Figure 4 below provide a summary of the data 2004-2021 and Table 5 in the treatment section details the treatments and follow-up treatments in the same growing season. Russian knapweed sites located east of I-25 have not been monitored since 2019 due to construction and a point was removed from the monitoring database that has been determined not to be Russian knapweed at a developed roadside area at Jack's Valley West.

Table 4. Mapping of Russian knapweed at the Academy.				
	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2004	?	?	3	0
2005	< 0.01	54	2	1
2007	0.03	200	2	2
2008	0.025	157	2	2
2009	?	?	2	2
2010	0	0	0	4
2011	0	0	0	4
2012	0.05	543	10	2
2013	0	0	0	12
2014	0	0	0	12
2015	0	0	0	12
2016	0	0	0	12
2017	0	0	0	12
2018	0.02	44	3	11
2019	0.18	94	3	11
2020	0.18	183	2	12
2021	0.18	152	2	11

Basewide weed mapping performed during shaded years.

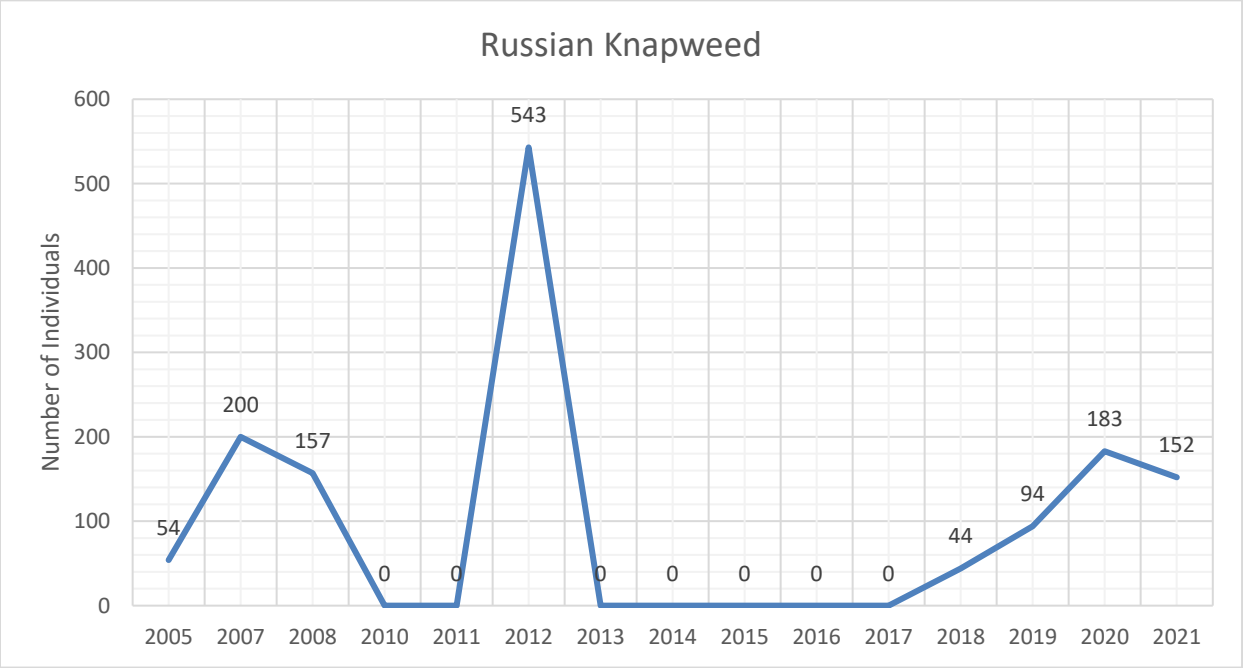


Figure 4. Number of Russian knapweed individuals, 2005-2021.

2021 Treatment

All sites except those east of I-25 were visited in 2021 at least once. There were a total of 152 individuals treated during the first site visit (Pass 1) at two extant sites. The majority of the plants (90%) removed were at the site northeast of the Natural Resources Building (Grid D-7, Map 3). A second pass was conducted in late summer to the three previously extant sites and 96 individuals were removed from one site at Grid D-7 (Map 3). Russian knapweed is known to sprout throughout the growing season from the deep root buds, so a third pass was conducted at the three previously extant sites and 6 shoots were removed at the location in Grid D-7 (northeast of the Natural Resources building). A total of 254 shoots were removed visiting 11 known sites in a total of 15 site visits (Table 5).

All plants were treated by severing the root crowns 4-6 inches below the soil surface or removing entire plants, bagging all cut plants and disposing of them in off-site dumpsters.

The 102 plants treated during the second and third passes, would have been missed if we waited a year to monitor these plants. This demonstrates the importance of multiple follow-up site visits to remove sprouts throughout the growing season which weakens the underground root system and prevents seed production. The number of shoots mapped and treated was lowest in 2019 and highest in 2020 (Table 5). While the 2020 to 2021 trend is decreasing, Russian knapweed is still considered to be increasing overall (Maps 2 & 3).

Table 5. Monitoring and treatment of Russian knapweed sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	11	152	152	2	9
Pass 2	3	96	96	1	2
Pass 3	1	6	6	1	0
TOTALS	**15**	**254**	**254**	---	---
2020	**15**	**293**	**293**	---	---
2019	**14**	**116**	**116**		

Recommendations

The management urgency continues to be high for 2022 for Russian knapweed at the Academy. This species has very low cover but has the potential to expand rapidly if not controlled due to extensive underground parts with root buds that sprout throughout the growing season. Recommendations for Russian knapweed:

- Visit all sites in early summer to remove any sprouts to prevent seed set later in the season.
- Follow-up visits in middle and late summer to any sites with Russian knapweed present and all three of the sites that were extant in 2021.

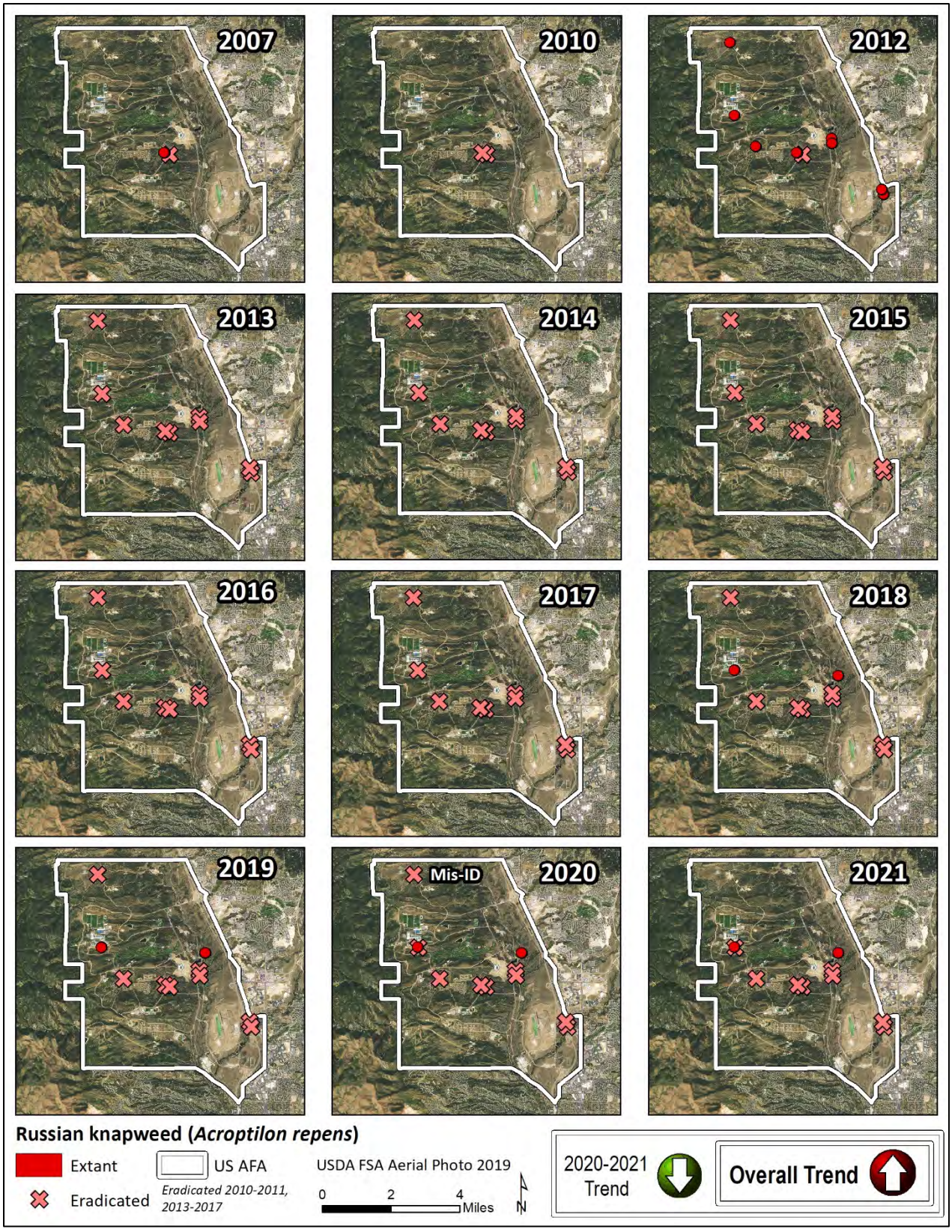
- Continue to remove all sprouts when found and as much of the root as possible while minimizing soil disturbance.

Russian knapweed is found to be very susceptible to fall-applied herbicides (Beck 2008) which are not currently recommended. Biological control is not yet available for Russian knapweed and currently the populations are not large enough to consider an application. As long as the numbers continue to decrease at the two active sites, manual removal is recommended at least three times during the growing season. Seed longevity is estimated to be five years; follow-up visits should be maintained for at least five years from the last extant occurrence. Encouraging native grasses to grow in areas where Russian knapweed has been treated is a recommended cultural control (Beck 2008, CDA-CSU 2020a).

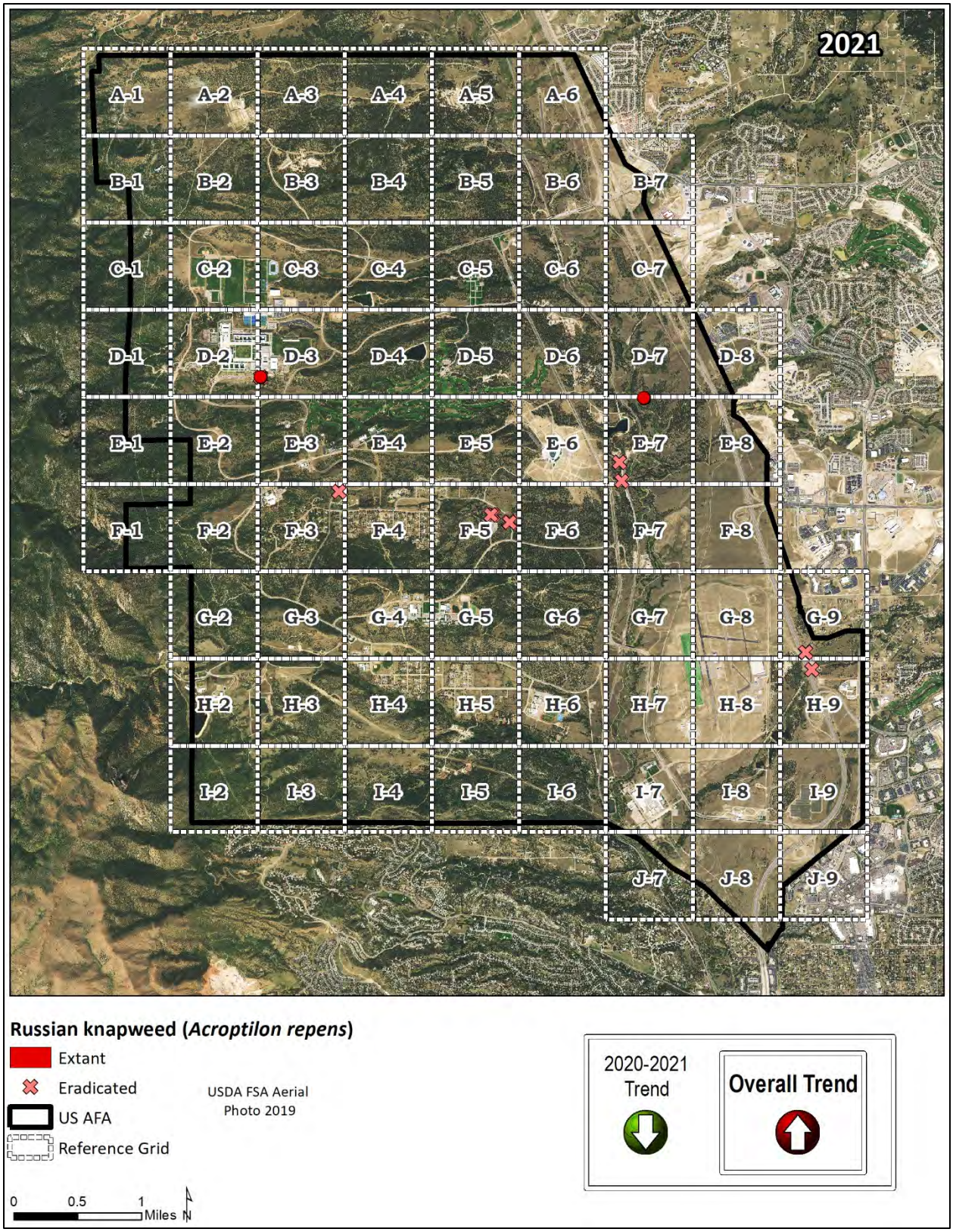
History of Sampling and Treatments:

- 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.
- 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.
- 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.
- In 2018, fourteen sites were visited and three had Russian knapweed plants. One of the three sites represents a new location; it was found on the east side of the Academy with 35 individuals.
- In 2019, 11 out of 14 total sites were visited in the summer and three sites were extant. The three sites east of I-25 were not visited. In late summer the three extant sites were re-visited and two sites had sprouts that were removed. A total of 116 individuals were removed and no plants went to seed.

- In 2020, 11 sites were visited and two sites contained Russian knapweed plants. Three sites east of I-25 were not visited. A total of 293 individuals were removed during the summer. No plants went to seed in 2020.
- In 2021, 11 sites were visited (west of I-25) and two sites contained Russian knapweed plants. A total of 254 individuals were manually treated. Plants sprouted throughout the growing season at the site northeast of the Natural Resources Building.



Map 2. Distribution of Russian knapweed at the Academy between 2007 and 2021.



Map 3. Distribution of Russian knapweed at the Academy in 2021 with the reference grid.

Garlic Mustard (*Alliaria petiolata*)

Trend 2019-2021: Increasing

Management Goals: Eradication /Containment

State List: Watch List

- Annual/Biennial (winter annual)
- Self-fertile
- Germination early spring and fall
- Reproduction by seed
- Seeds viable for 7-10 years
- Allelopathic
- Crushed leaves smell like garlic (King County 2018)

Photos: Garlic mustard first year leaves (top) and second year plants (http://nyis.info/invasive_species/garlic-mustard/)

2021 Mapping Results

On April 25 2021, the full extent of West Monument Creek was surveyed for garlic mustard; 42 sites were mapped (only one was eradicated) with an estimated 50,890 individuals and a cover of 1.73 acres. The increase since it was first mapped in 2018 is substantial (Table 6, Maps 4 & 5). Most of the increase is due to the 28 new populations mapped in 2021. The 14 points mapped in 2020 with 24,660 individuals is similar when compared to the same 14 sites monitored in 2021 with 20,010 individuals. Some of these sites had been subjected to weed treatments including herbicide. The newly mapped points in 2021 accounted for 50% of the increase in individuals and cover observed

from 2020 to 2021. The 2021 mapping also yielded a new point 55 meters upstream from the westernmost point mapped in 2020 (Table 6, Figures 5 &6, Maps 4 & 5). Roughly 2,100 meters of ~5,500 meters surveyed of West Monument Creek has known populations of garlic mustard and all are downstream of the stables (Figure 5).

Figure 5. Garlic mustard mapped along West Monument Creek in 2021. Yellow dots are garlic mustard sites, rectangle includes surveyed area, circle is horse stable area.

Table 6. Mapping of garlic mustard at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2012	---	---	---	---
2018	0.12	4,011	7	0
2019	0.21	6,564	8	0
2020	1.03	24,660+	12	2
2021	1.73	50,890	41	1

Basewide weed mapping performed during shaded years.

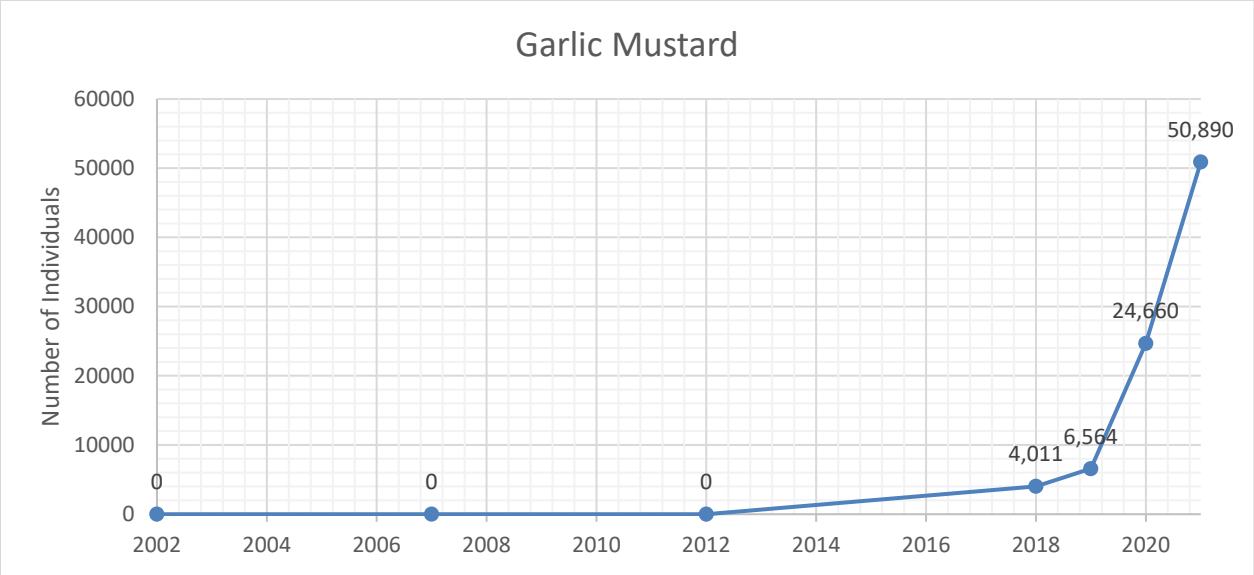


Figure 6. Number of garlic mustard individuals, 2002-2021.

2021 Treatment

In 2020 and 2021, a combination of pulling and aggressive herbicide applications were used to control the garlic mustard. Manual treatments are more time consuming but have far less off target damage to native vegetation which is the best defense against invasion (Photos 1 & 2). Herbicides cover larger areas but are very destructive to native vegetation (Photo 3). While these methods did appear to control garlic mustard initially, sprouts are continuing to be mapped along the banks of West Monument Creek. However, it was the new sites that accounted for the substantial increase in cover and numbers of individuals between 2020 and 2021. All of the new occurrences have been found downstream of the horse barns and downslope of large, landscaped lawns (Photo 4). The dramatic increase since 2019 of 6,564 individuals to over 51,000 individuals in 2021 is shown in Table 7. Not all garlic mustard sites were treated due to the large number of sites and plants. The manually treated sites were on the east side where manual treatments had been done previously and at sites where there were small populations that could be easily removed.

Table 7. Monitoring and treatment of garlic mustard sites at the Academy in 2021.

	# Sites Visited	Estimated # Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	42	50,890	1,102	41	1
Pass 2	2	510	10	2	0
TOTALS	**44**	**51,400**	**1,112**	---	---
2020	**22**	**24,791**	**2,422**	---	---
2019	**11**	**6,564***	**5,997**	---	----

*Pass 1

Photo 1. Easternmost garlic mustard site prior to spring manual removal in May 2019 (left). Photo 2. view of same site in June 2020 showing little soil disturbance. P. Smith (right).

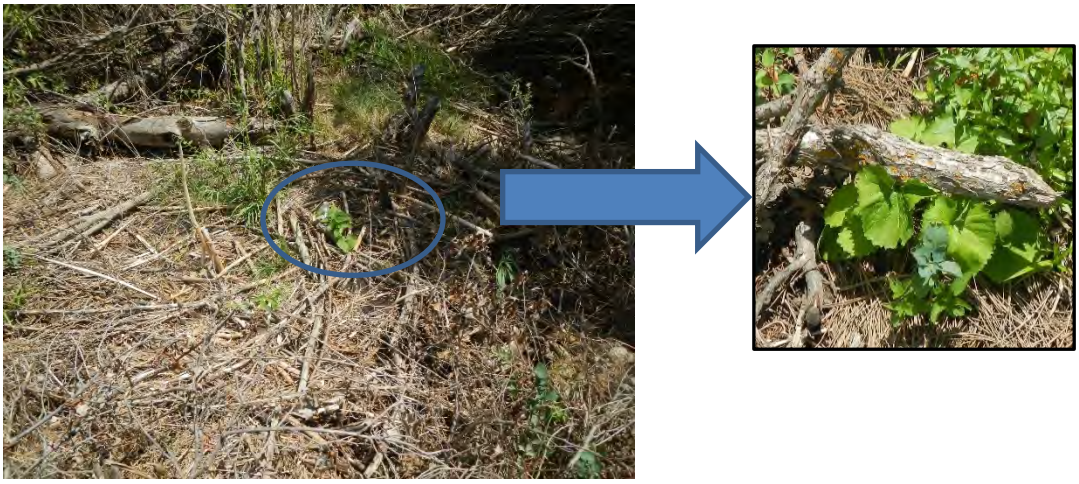


Photo 3. Herbicide treatment area for garlic mustard with off-target impacts to native vegetation including woody plants. Note new sprout of garlic mustard in the treatment area (insert on right). Photo P. Smith 2020.

Potential sources of garlic mustard seeds are the horse barns upstream and the residential sites upslope of West Monument Creek. Many garlic mustard infestations have been documented as being introduced from cultivated landscapes where yard waste is discarded into drainages (King County 2018). There are three factors that point to this at the Academy: 1) all occurrences along West Monument Creek are downstream and down slope from the horse barns and large manicured landscapes, 2) yard waste was observed in dump areas on the slopes of West Monument Creek and 3) common garden escapes were observed downslope of these residences including the wayfaring tree (*Viburnum lantana*), white campion (*Silene latifolia*), common tansy (*Tanacetum vulgare*) a new List B noxious weed found in 2020, as well as a state watch listed noxious weed, hoary alyssum (*Berteroa incana*). Contacting residents might be worthwhile to prevent continued introduction of noxious weeds into West Monument Creek.

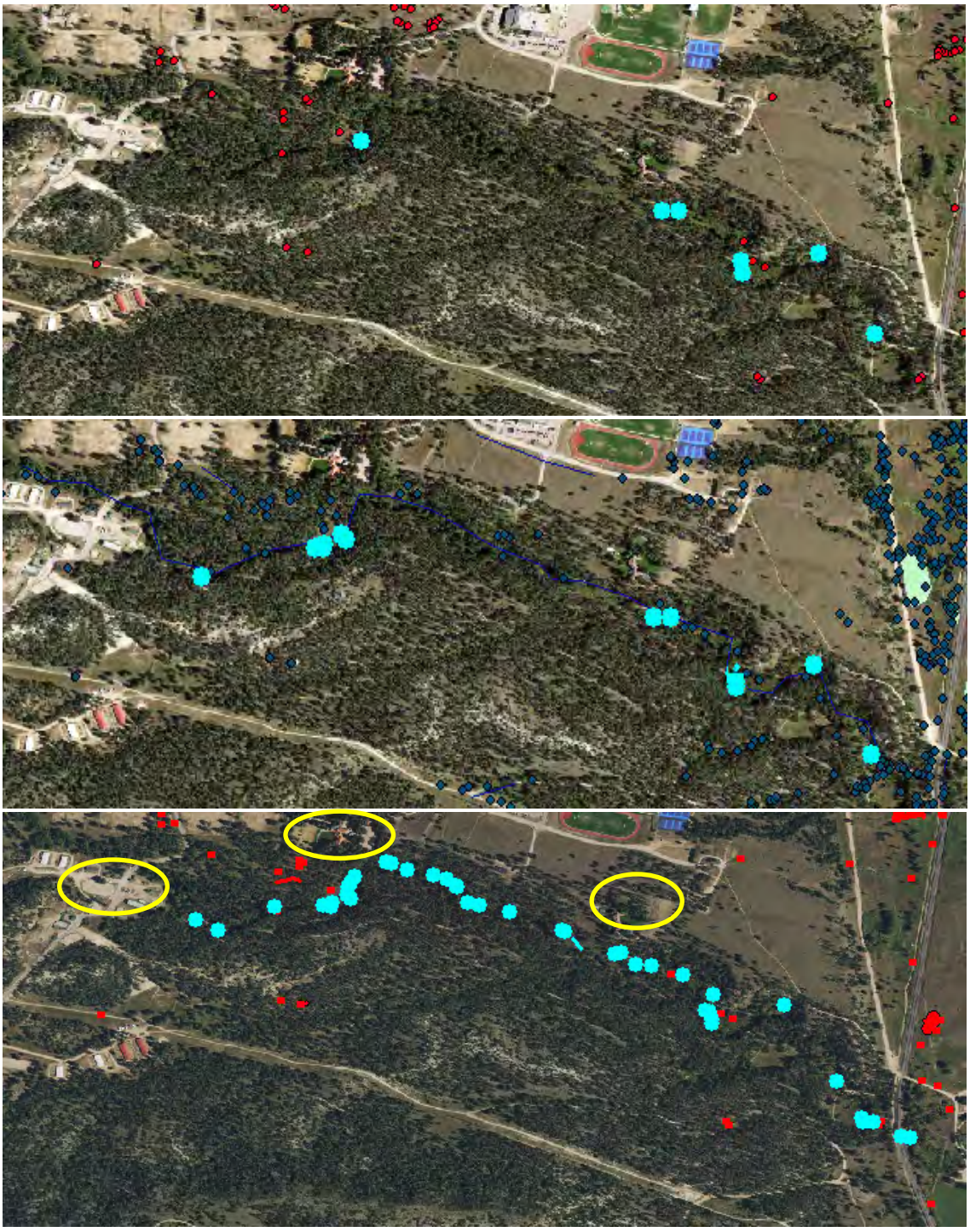


Photo 4. Progression of garlic mustard increase (blue dots) from 2018/19 top, 2020 middle and 2021 bottom. Yellow circles where yard waste was observed on the slopes behind large residences and horse barns.

Watch List is defined by the Colorado Department of Agriculture as "intended to serve advisory and educational purposes only. Its purpose is to encourage the identification and reporting of these species to the Commissioner in order to facilitate the collection of information to assist the

Commissioner in determining which species should be designated as noxious weeds." (https://ag.colorado.gov/conservation/noxious-weeds/species-id). Garlic mustard is also a watch list species but it has shown itself to be highly invasive at the Air Force Academy while hoary alyssum has not. The Resource Managers can decide if hoary alyssum is worth monitoring to document spread. So far, from our experience, hoary alyssum has been noted in this area for a couple of years but does not appear to be highly invasive and has stayed in the immediate disturbed area but it has not been mapped to document this.

Recommendations

Garlic mustard is a highly invasive species that has become established in West Monument Creek along the eastern part of the Academy. This species is extremely difficult to impossible to control once established due prolific seed production. The stream banks are frequently scoured and provide a constant source of open habitats that promote seed establishment. The cover is high and local treatments may reduce the populations. However, the removal of the plants whether by chemical or manual methods, leave behind the open soils that are ripe for more invasion. Without a way to control inputs or a means to conduct continuous plant removal throughout the growing season, control of this plant is unlikely. Recommendations for garlic mustard:

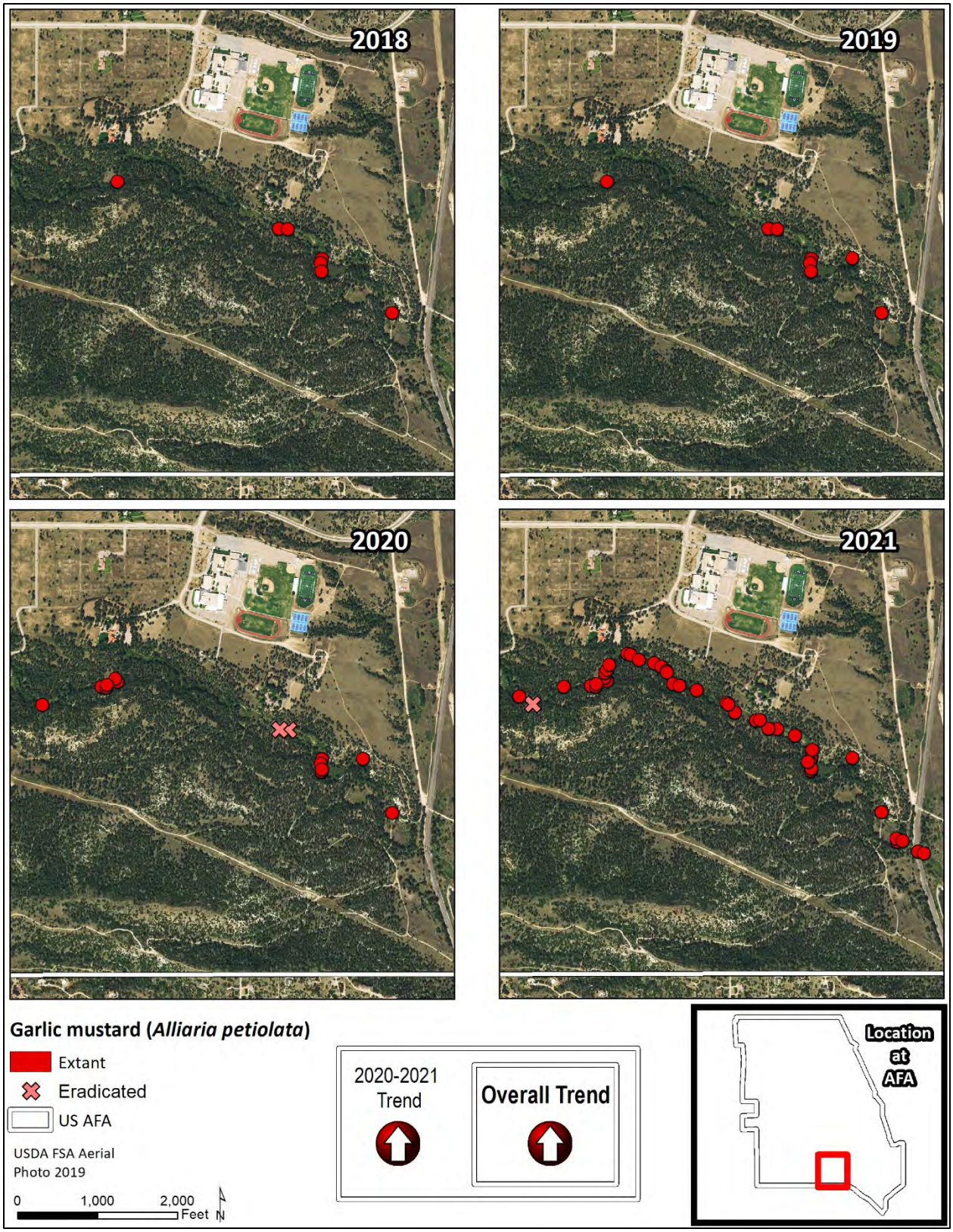
- Consider the potentially constant source of seed influx from the surrounding properties and the difficulty of treating garlic mustard at this stage of infestation. Treatment of garlic mustard is likely a waste of resources if the seeds are being contributed by land uses upstream and upslope along West Monument Creek.
- Areal monitoring of garlic mustard may or may not take place based on conversations with Academy Natural Resource staff in 2022.
- Talk to upslope landowners or residents and survey the properties if possible for potential noxious weed inputs. Many of the species sold on the internet and through garden stores are invasive, especially in riparian areas. The hay (even "weed-free" hay) used for the horses may be a noxious weed seed contributor to West Monument Creek.
- If weed treatments are undertaken for garlic mustard, monitoring the sites needs to be included as part of the plan. After reviewing studies from the eastern U.S. where garlic mustard has been around much longer, it is clear there is no sure way to remove garlic mustard once it has become established. However, manual treatments are more effective in the long-term, but they have to be conducted repeatedly over many years (if you can reduce the incoming seed source).

History of Sampling and Treatment:

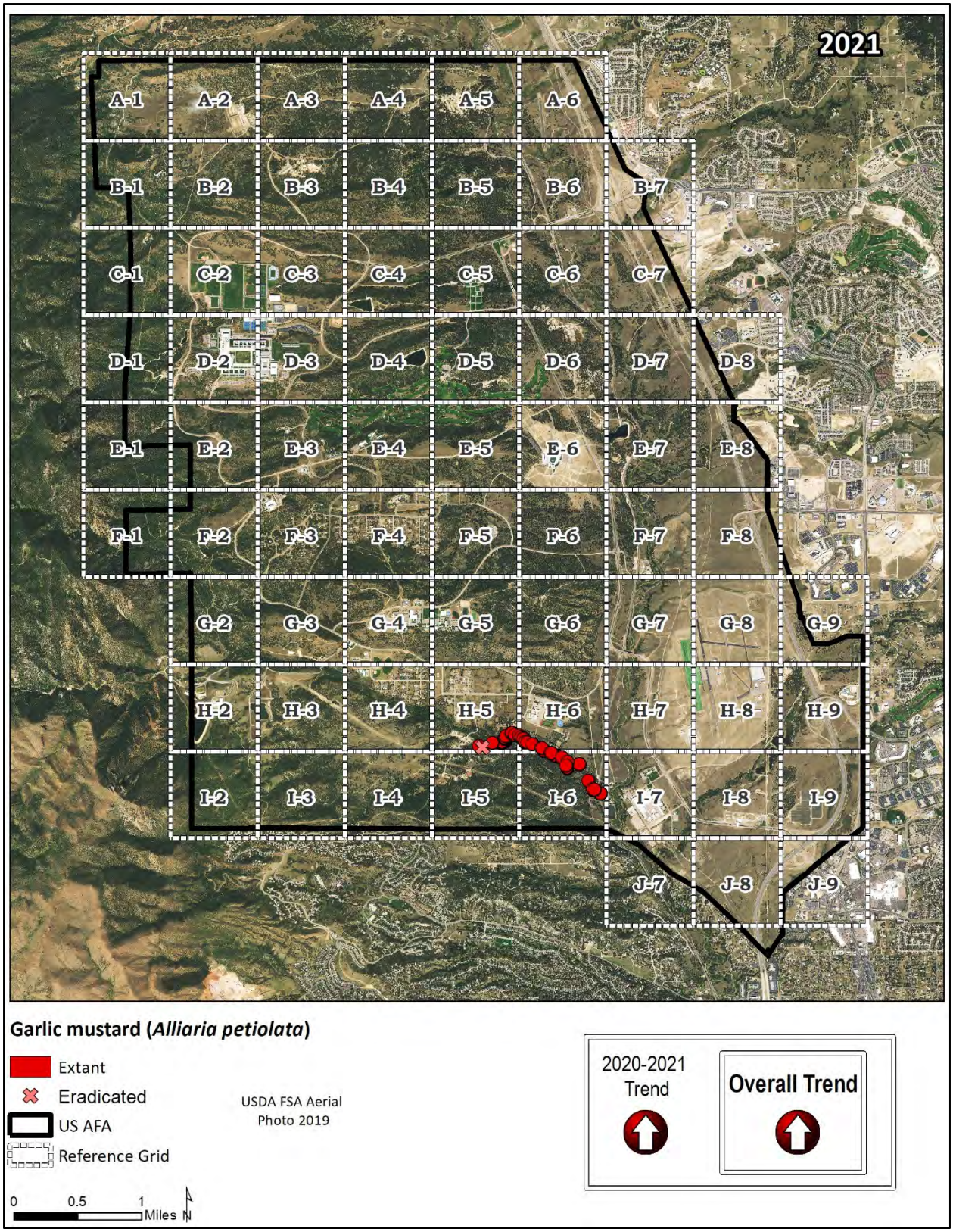
- Garlic mustard was first discovered during the 2018 basewide survey at seven mapped sites. Herbicide applications were applied to at least two populations along West Monument Creek.
- In 2019, an eighth site was mapped and the populations have continued to expand. Hand-pulling was done at five sites with one site set up as a monitoring plot to track results. The monitoring plot showed there is likely an extensive seed bank as thousands of sprouts

appeared after each manual treatment. The garlic mustard seeds may be coming from residential lawn clippings along West Monument Creek.

- In 2020, a very large increase in the number of sprouts was observed along with an increase in the number of mapped sites. A plan to survey earlier and include the entire western part of West Monument Creek, and monitor and treat more frequently is planned for 2021.
- In 2021, West Monument Creek was surveyed from the west side to the east side of the Academy to map the full extent of garlic mustard; the footprint along Monument Creek was extended by 55 meters to the west and 28 new sites were mapped with over 50,000 individuals representing a significant increase since 2020.



Map 4. Close-up of garlic mustard at the Academy between 2018 and 2021.



Map 5. Distribution of garlic mustard at the Academy in 2021 with the reference grid.

Houndstongue (*Cynoglossum officinale*)

Trend 2020-2021: Moderately Increasing

Management Goals: Eradication/Suppression

State List: B

- Biennial, short-lived perennial (FEIS 2022a)
- Not strictly monocarpic, can flower 1-3 yrs (FEIS 2022a)
- Reproduction only by seed
- Seedlings cluster in high densities around parent plant (FEIS 2022a)
- Flowers May-July
- Thick, black, woody taproot
- Forms rosette first year
- Several rosettes can be linked to a single plant (FEIS 2022a)
- Seeds fall close to plant but Velcro©-like seeds allow transport by animals
- Seeds are sensitive to precipitation levels, negative correlation on dry years (FEIS 2022a)
- Plants thrive in disturbances and open dry ground caused by grazing and other soil disturbances that reduce competition from other plants (FEIS 2022a)
- Seed longevity 2-3 (5) years (Colorado Code of Regulations 2014, FEIS 2022a)

Photo by M. DiTomaso, University of California - Davis

Houndstongue rosette, Kingcounty.gov

2021 Mapping Results

In 2021, houndstongue is moderately increasing across the Academy. There are 93 known locations for houndstongue representing an increase of nine new sites mapped since 2020 (84 known locations). In 2021, there were 4,567 individuals mapped at 65 sites and 28 were eradicated (Table 8). Overall, houndstongue continues to increase across the Academy (Table 8, Figure 7, Maps 6 & 7).

Table 8. Mapping of houndstongue at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2009	0.09	95	8	0
2010	0.02	11	1	6
2011	<0.01 (10 m²)	21	2	6
2012	0.01	70	3	9
2013	0.05	48	7	8
2014	0.04	102	8	8
2015	0.20	534	22	11
2016	0.20	480	22	14
2017	0.41	787	26	13
2018	0.51	4,514	50	22
2019	0.62	3,056	57	26
2020	0.65	3,691	49	35
2021	0.83	4,567	65	28

Basewide weed mapping performed during shaded years.

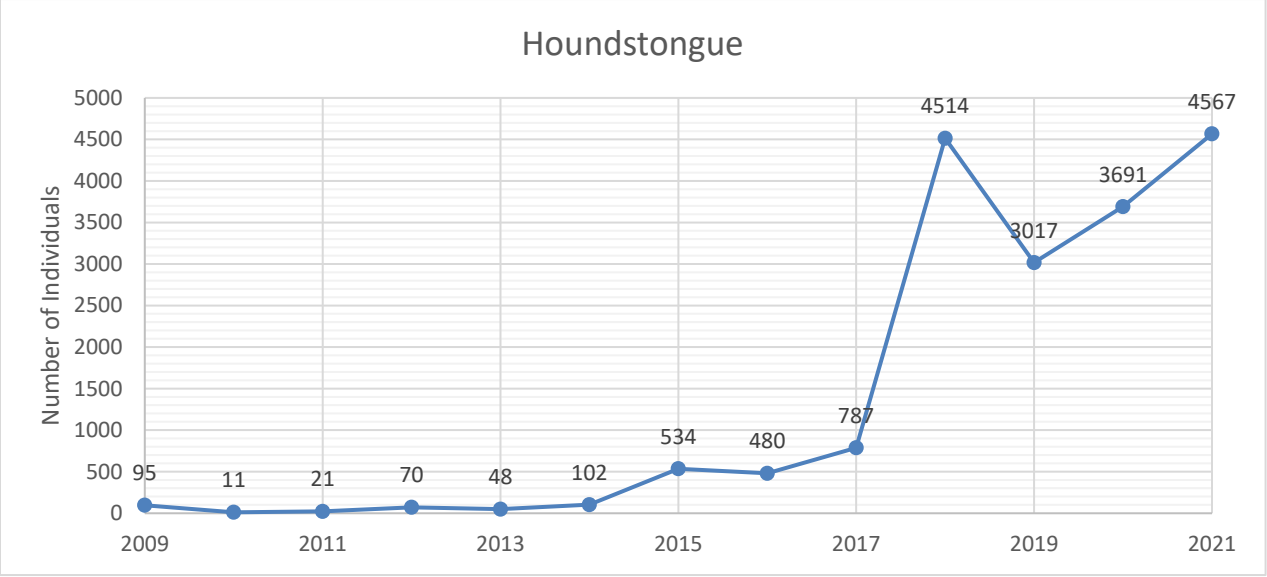


Figure 7. Number of houndstongue individuals, 2009-2021.

2021 Treatment

In 2021, there were 3,396 shoots mapped at 62 locations for the first pass. We conducted a total of 128 site visits to 62 sites and manually treated 3,840 plants out of a total of 5,330 mapped (Table 9). A total of 31 sites were not visited in 2021: Pine Creek drainage, I-25 construction zone, as well as the wastewater treatment plant (WWTP) and three sites within the active floodplain of Monument Creek in grids G7 and F7 (Map 7). Sites that were visited but not treated included densely vegetated areas on the forested cliffs on the eastern side of Monument Creek (Grid G-7, Map 7) and some areas with hundreds of plants (along Ice Lake Road). Several areas were targeted for treatments throughout the season.

Table 9. Monitoring and treatment of houndstongue sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	62	3,396	1,906	34	28
Pass 2	32	1,225	1,225	23	9
Pass 3	23	538	538	13	10
Pass 4	11	171	171	7	4
TOTALS	**128**	**5,330**	**3,840**	---	---

One of the sites targeted for multiple treatments was Jack's Valley East which has a number of rare plant species within a distinctive seep area. In 2021, four visits were made throughout the growing season to manually remove all of the houndstongue plants found within the Jack's Valley East in April, June, August and September of 2021. The survey data demonstrate houndstongue seeds sprouted continuously throughout the entire summer season of 2021 with a peak in June. For the August and September treatments, almost all of the plants were sprouts. All sites except two eradicated sites, had increasing numbers of houndstongue compared to 2020. Six sites dramatically increased (1,666 individuals), and six new points were mapped adding an additional 364 individuals accounting for the large jump from just 161 individuals in 2020 to 2,365 in 2021 at Jack's Valley East (Table 9, Figure 8).

Location of 27 treated houndstongue points (blue dots) at Jack's Valley East in 2021. (Red dots are other noxious weeds.)

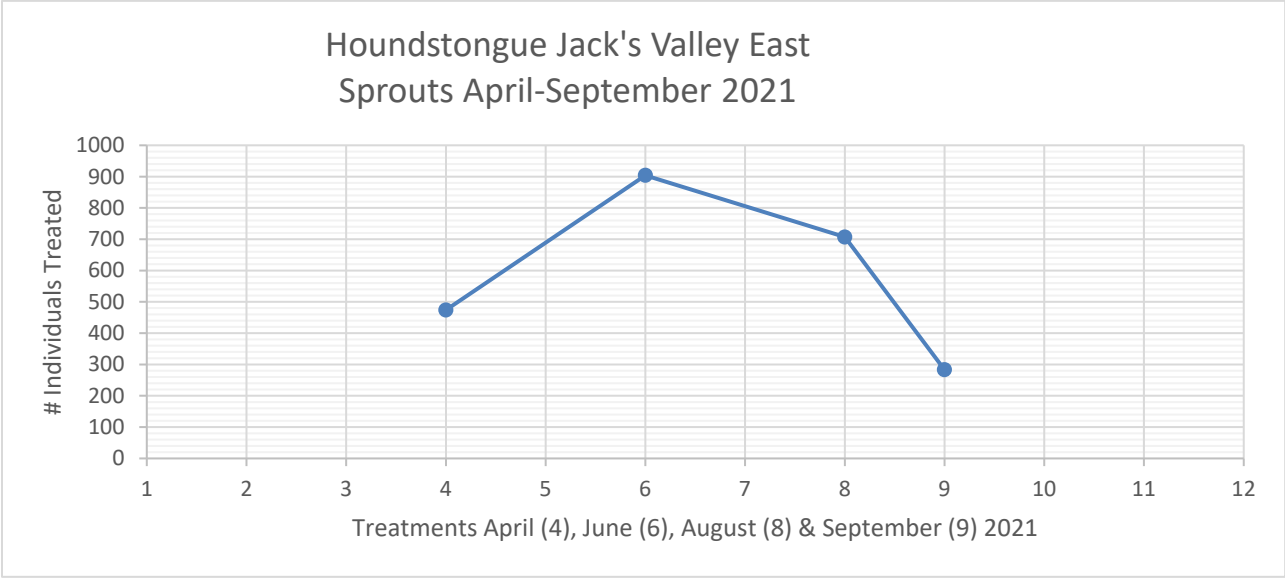


Figure 8. Number of houndstongue individuals April, June, August and September 2021.

Recommendations

Spring precipitation is strongly correlated with increased sprouting of houndstongue (FEIS 2022a). This is consistent with a much dryer year in 2020 with spring-summer precipitation of 7.85 inches compared to 12.62 inches recorded in 2021 (Figure 2 Introduction). Boom and bust cycles are typical of biennials, with large population increases following conditions that lead to larger

numbers of sprouts and new plants, and large decreases or even local extinctions following situations that do not promote germination (too dry, competition, disturbance regime). Annual disturbances (too frequent), as well as absence of disturbance can be fatal for biennial plant development including houndstongue. Therefore, most habitats are usually only temporarily suitable for biennials (FEIS 2022a). This makes a case for leaving some populations of houndstongue without treatments, especially those with dense cover of other vegetation like the sites on the east side forested bluffs above Monument Creek (Map 7, Grid G-7) and around the WWTP. While houndstongue may eventually work its way out of a system with healthy vegetation, in lands that are severely disturbed (e.g. top soil and plants removed, roadsides), houndstongue has been known to persist indefinitely (FEIS 2022a).

Several reasons for recommending continued yearly intense manual treatments at the focus sites include the relatively short seed life (2-3 (5) years and the short dispersal distances of seeds, which are thought to stay within five meters of the plant. Studies have shown that most seeds are not transported successfully long distances (FEIS 2022a). Thus, there is a good probability of seriously reducing or even eradicating houndstongue at Jack's Valley East and the other focused treatment areas at the Academy. Targeting the young plants is most effective with much less soil disturbance. Recommendations for houndstongue:

- Focus monitoring and treatments at sites where eradication or control is possible.
- Treat sites by removing all parts of the plant or severing large plants at least 4 inches below the root crown.
- Begin monitoring/treatments at as many sites as possible in the spring to prevent plants from going to seed.
- Re-visit as many sites as possible throughout the growing season.
- Consider leaving plants in areas of dense native plants and intact habitat untreated.

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). If herbicides are utilized (which we do not recommend), follow the Guidelines for Herbicide Use in Natural Areas section of the report. Many weeds targeted for treatments are located in moist areas near wetlands and drainages, and some contain rare plant and animal species. Make sure all applicators can recognize rare plants and the rosette stage of houndstongue and are using wetland appropriate chemicals and adjuvents. For example, the basal leaves of houndstongue resemble Rocky Mountain blazing star (*Liatris ligulistylis*) and grow together at the Academy in seeps and moist areas.

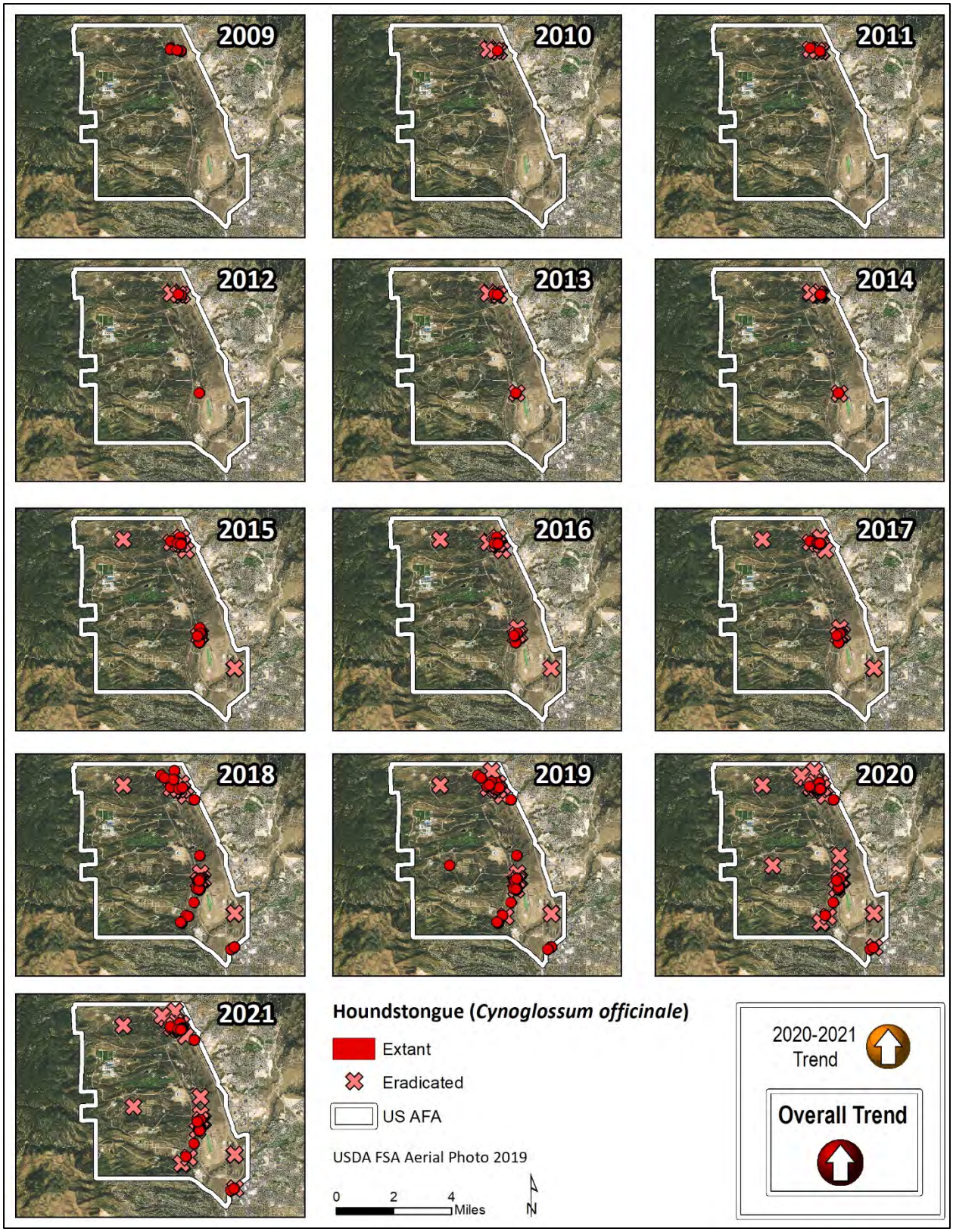
Because of the method of herbicide application (not applied to individual plants), the off-target damage from herbicides which is lethal to many other species including native plant provides fresh habitat for infestations of houndstongue and other weeds (Photo 5). In addition, since herbicides are not designed to be used multiple times during the same growing season, sprouts and plants that get missed will continue to grow and set the stage for further increasing houndstongue.

Photo 5. Herbicide treated area left bare soils in a wet meadow that now supports the target weed, houndstongue, as well as Canada thistle and common mullein due to the residual seed bank. P. Smith 2015

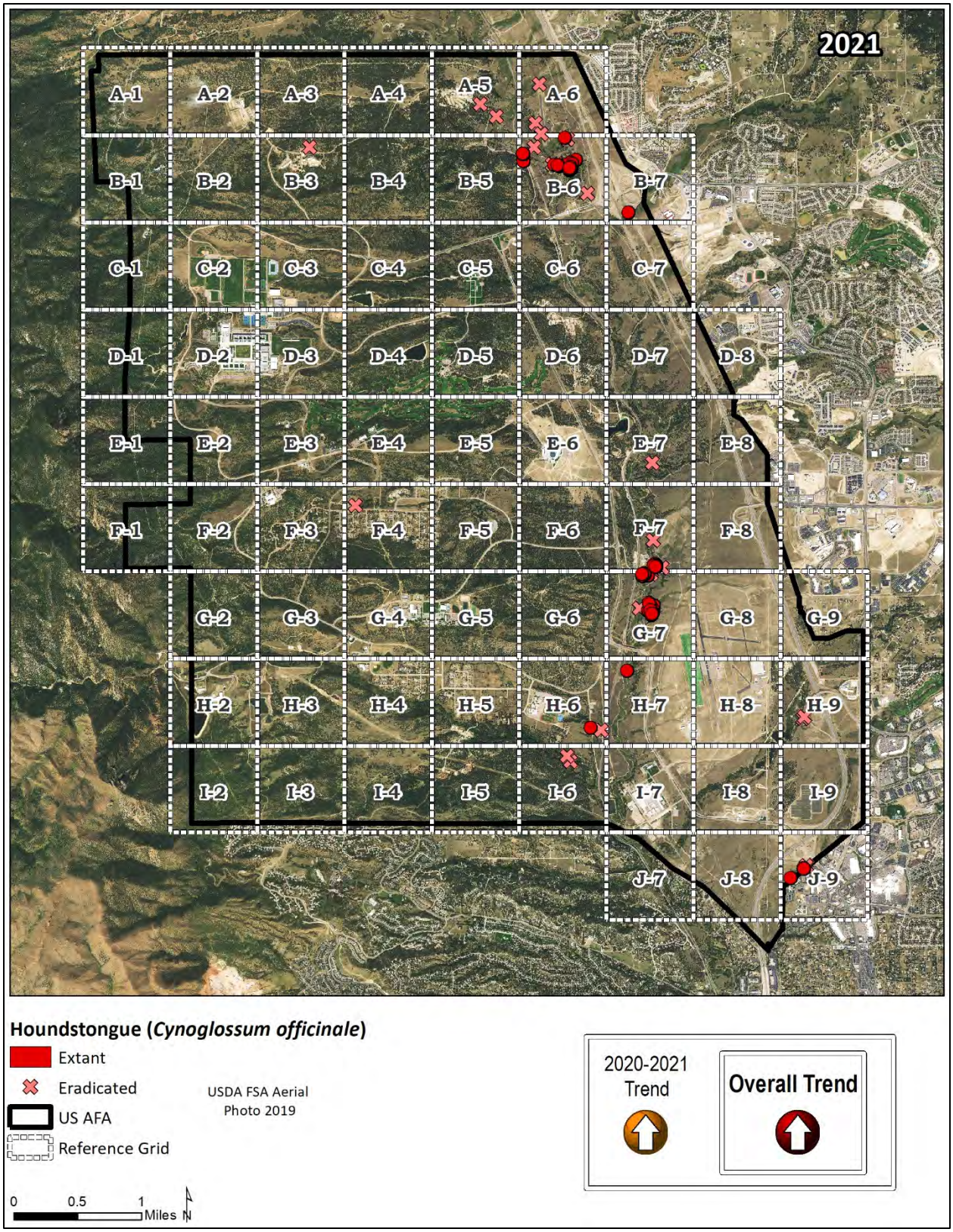
History of Sampling and Treatment

- First populations discovered in 2009 at the Academy.
- Aggressively treated with herbicide in 2010. Populations declined but extant plants remained in 2010 and 2011.
- In 2012 a new site was located south of the existing known sites during the basewide weed survey.
- 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.
- 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.

- In 2018, basewide mapping showed 4,514 plants in 72 extant features. Much of the increased features were along Monument Creek.
- In 2019, 3,573 shoots were mapped at 57 extant features. The majority of the plants are found at three sites: Ice Lake Road, the waste water treatment facility and a site along Monument Creek east side.
- In 2020, houndstongue is increasing in numbers of shoots but decreasing in the number of extant sites. Nine sites contain the majority of the plants.
- In 2021, a large increase in the number of sprouting plants over the summer season compared to 2020 was noted and appears to be correlated with a significant increase precipitation in the spring and summer of 2021.



Map 6. Distribution of houndstongue at the Academy between 2009 and 2021.



Map 7. Distribution of houndstongue at the Academy in 2021 with the reference grid.

Myrtle Spurge (*Euphorbia myrsinites*)

Trend 2020-2021: Moderately Increasing

Management Goals: Rapid Response

State List: A

- Evergreen perennial
- Reproduction by seeds projected 15 feet from plant by seed pods
- 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 2020b)

Photo: Dave Anderson

Photo: Wikimedia Commons

2021 Mapping Results

Myrtle spurge increased moderately from 63 shoots in 2020 to 103 in 2021 for the beginning of the monitoring season. There were 19 sites with plants and 48 sites with no plants (Table 10, Figure 9). Three sites were dropped from monitoring in 2021 (east of I-25, a site that eroded into Monument Creek and a site in the northeast part of the base that is thought to have been an erroneous report). Myrtle spurge is found throughout the Academy (Maps 8 & 9).

Table 10. Mapping of myrtle spurge at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2005	?	25	7	0
2006	?	243	10	0
2007	0.18	1,021	7	6
2008	0.66	419	13	5
2009	2.4	464	12	6
2010	0.5	56	10	12
2011	0.25	57	12	16
2012	0.23	113	10	25
2013	?	129	19	12
2014	0.7	179	7	27
2015	1.04	173	14	26
2016	0.70	185	17	26
2017	1.15	501	25	23
2018	0.51	222	26	35
2019	0.97	375	34	29
2020	0.41	63	16	47
2021	0.86	103	19	43

Basewide weed mapping performed during shaded years.

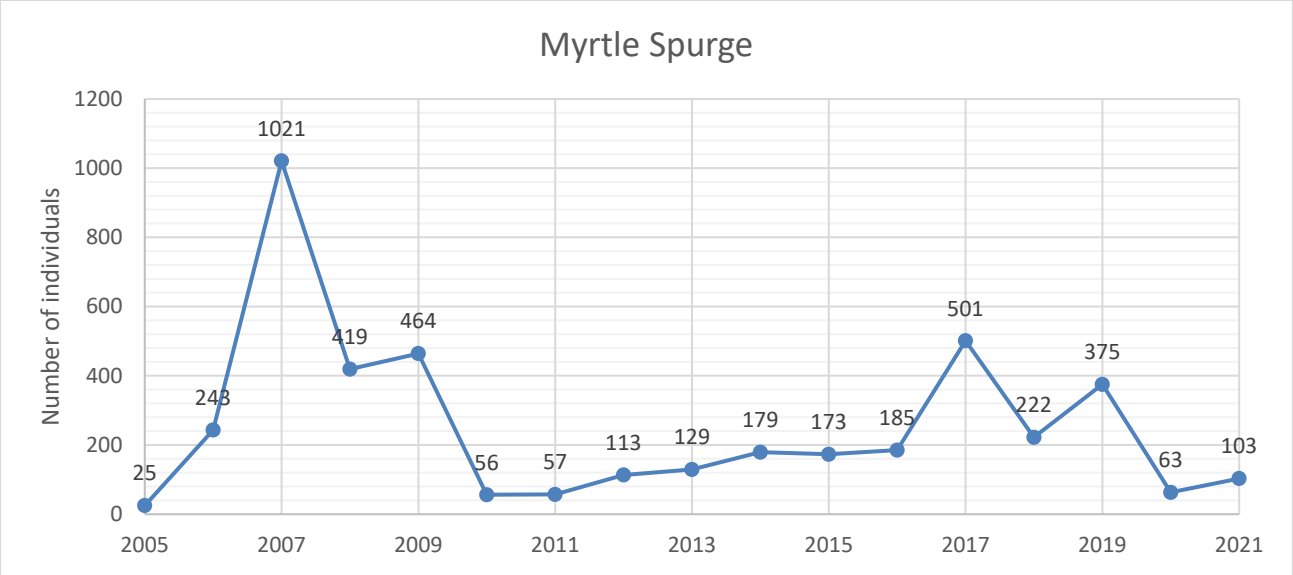


Figure 9. Number of myrtle spurge individuals, 2005-2021.

2021 Treatment

In 2021, treatments began in early spring to 60 sites that yielded 29 sprouts. Subsequent visits to the same sites resulted in finding sprouts throughout the season (Table 11). The passes in Table 11 are not interpreted seasonally but by how many site visits occurred. Figure 10 shows a month by month distribution of sprouts encountered across the summer. A significant jump in individuals occurred in August of 2021, with a single site contributing 1,000 tiny sprouts, indicating a seed germination event in August (Figure10). This distribution of high sprouting rates in the late summer may be related to 2021 precipitation. The annual precipitation for 2021 was 12.62 inches compared to 7.85 inches in 2020. This likely resulted in conditions that released the seed bank in localized areas. A total of 159 visits were made to 60 sites and 1,355 individuals (all vegetative) were removed (Table 11). No myrtle spurge plants went to seed in 2021.

A comparison of data since we started manually treating myrtle spurge in 2019 showed a decrease in sprouts for 2020 (a much dryer year compared to 2021) and without the seed burst event, the number of shoots would have been less than 2019 and 2020. Overall, the number of extant sites are declining (Table 11).

Table 11. Monitoring and treatment of myrtle spurge sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	60	29	29	12	48
Pass 2	44	1,090	1,090	9	35
Pass 3	38	221	221	9	29
Pass 4	17	15	15	5	12

TOTALS	**159**	**1,355**	**1,355**	---	---
2020	**78**	**132**	**132**	---	---
2019	**93**	**432**	**432**	---	---

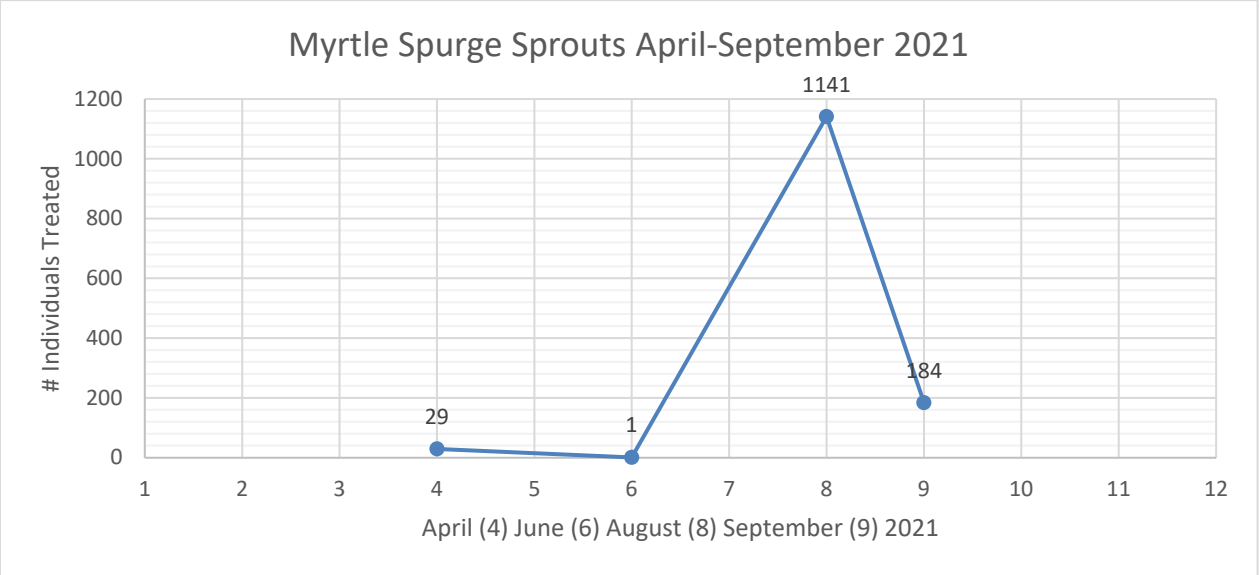


Figure 10. Number of myrtle spurge individuals April, June, August, and September of 2021.

Recommendations

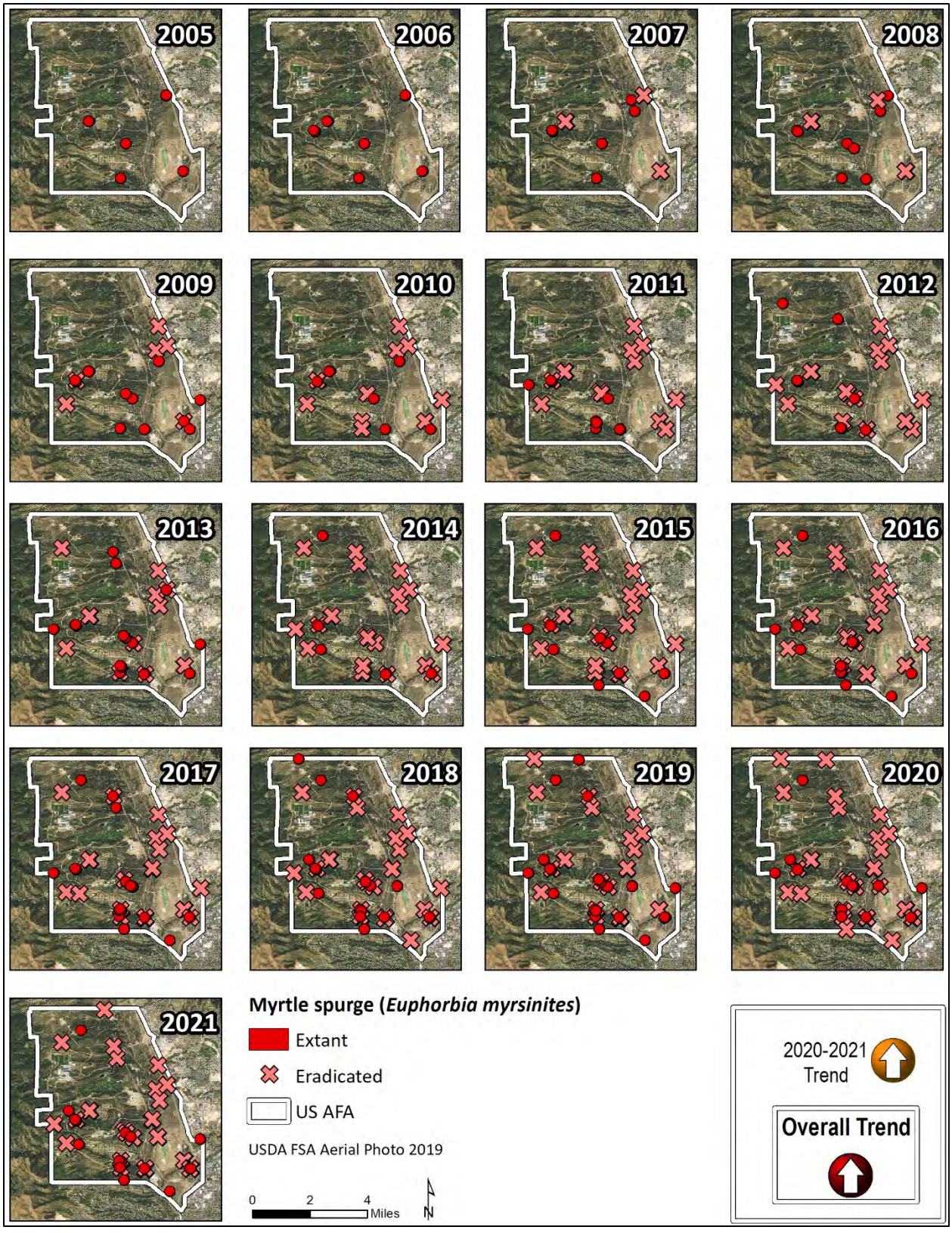
Myrtle spurge is a high management priority at the Academy as a List A species. It is a perennial species that reproduces by seed. At the Academy there is a high probability for eradication or control. Myrtle spurge plants are found throughout the base at a cover just under an acre. Cover of more than an acre for many species is often a level where eradication is difficult. In addition, the plants are widely distributed across the Academy and the seed longevity is thought to be eight years (CWMA 2020b). A large seed burst event at one site this summer resulted in a large jump in the number of individuals (1,000 at a single site) but the overall cover at the Academy has remained stable since 2018. Recommendations for myrtle spurge:

- Continue to monitor all known myrtle spurge sites in the spring (myrtle spurge blooms as early as March).
- Continue to remove all plants and prevent from going to flower/seed.
- Continue to re-visit as many sites as possible to treat sprouts two or three times during the growing season.

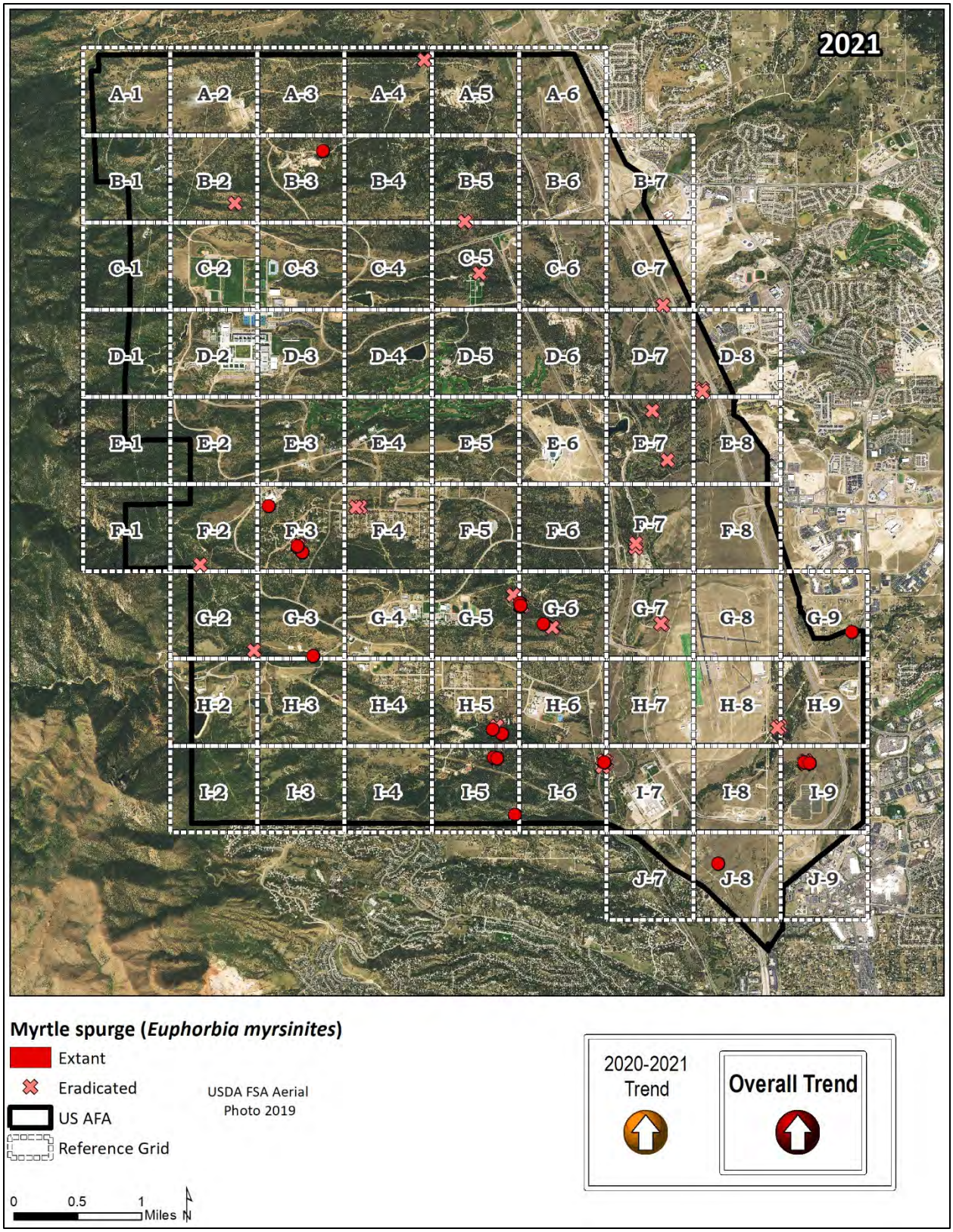
History of Sampling and Treatment:

- 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.

- 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.
- In 2017, we saw an increase in plants at or near known sites from 185 individuals in 2016 to 501 in 2017.
- In 2018, a basewide mapping effort showed myrtle spurge has spread across the entire property and continues to be found even in treated areas.
- In 2019, sprouts were pulled in the spring and throughout the summer. No seeds were produced at the known sites in 2019.
- In 2020, there was a reduction in the number of sites and number of individuals compared to 2019. Sprouts were pulled early in the spring and throughout the summer which resulted in no seed production at the sites.
- In 2021, the number of extant sites remained stable while the number of individuals jumped mid-summer due to a sprouting event at a single site likely due to higher precipitation amounts.



Map 8. Distribution of myrtle spurge at the Academy between 2005 and 2021.



Map 9. Distribution of myrtle spurge at the Academy in 2021 with the reference grid.

Yellow Spring Bedstraw (*Galium verum*)

Trend 2019-2021: Decreasing

Management Goals: Eradication – Rapid Response

State List: NA (Garden Escape)

- 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

Yellow Spring Bedstraw at Air Force Academy 2015, Pam Smith, CNHP

2021 Mapping Results

There was a decrease in yellow spring bedstraw with 940 shoots mapped in 2020 and 210 shoots in 2021. Yellow spring bedstraw is a garden escape that was first documented in 2010. It was treated and then found again in 2015, 2018, 2020 and 2021 (Table 12, Figure 11, Maps 10 & 11).

Table 12. Mapping of yellow spring bedstraw at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2010	<0.01	700	1	0
2011	<0.01	1	1	0
2012	0	0	0	1
2013	0	0	0	1
2014	0	0	0	1
2015	<0.01	10	1	0
2016	0	0	0	1
2017	0	0	0	1
2018	<0.01	102	1	0
2019	0	0	0	1
2020	0.08	940	2	0
2021	0.08	210	3	0

Basewide weed mapping performed during shaded years.

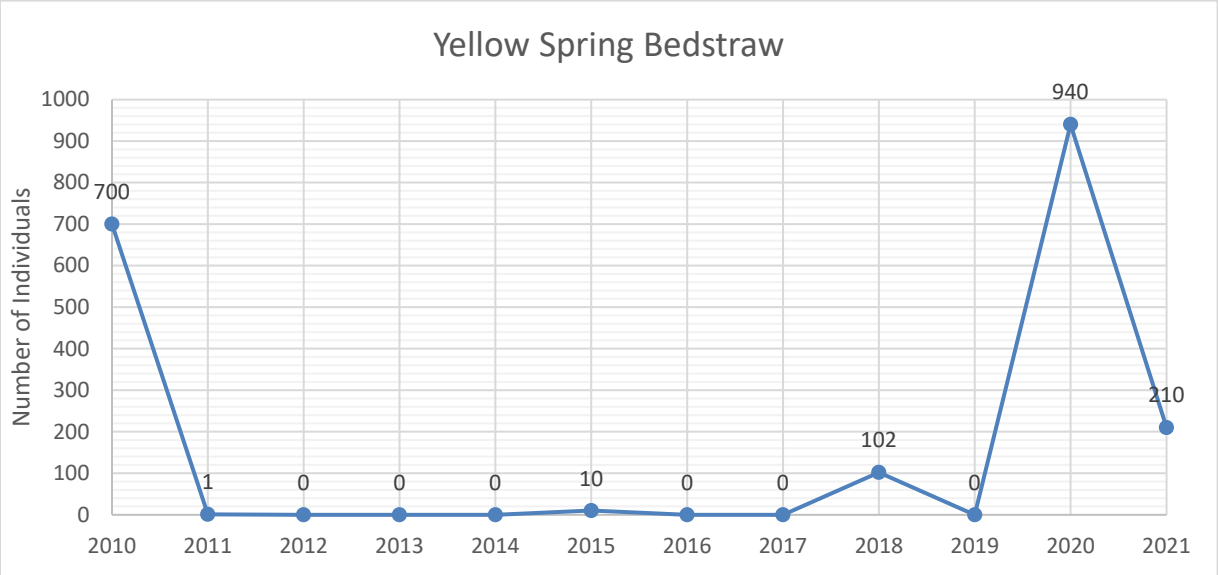


Figure 11. Number of yellow spring bedstraw individuals, 2010-2021.

2021 Treatment

In 2021, three yellow spring bedstraw sites were visited and a total of 327 individuals were counted and removed over the summer (Table 13).

Table 13. Monitoring and treatment of yellow spring bedstraw sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	3	210	210	3	0
Pass 2	1	0	0	0	1
Pass 3	1	97	97	1	2
Pass 4	1	20	20	1	2
TOTAL	**4**	**327**	**327**	---	---
2020	**4**	**1,049**	**749**	---	---
2019	**1**	**0**	**0**	---	---

Recommendations

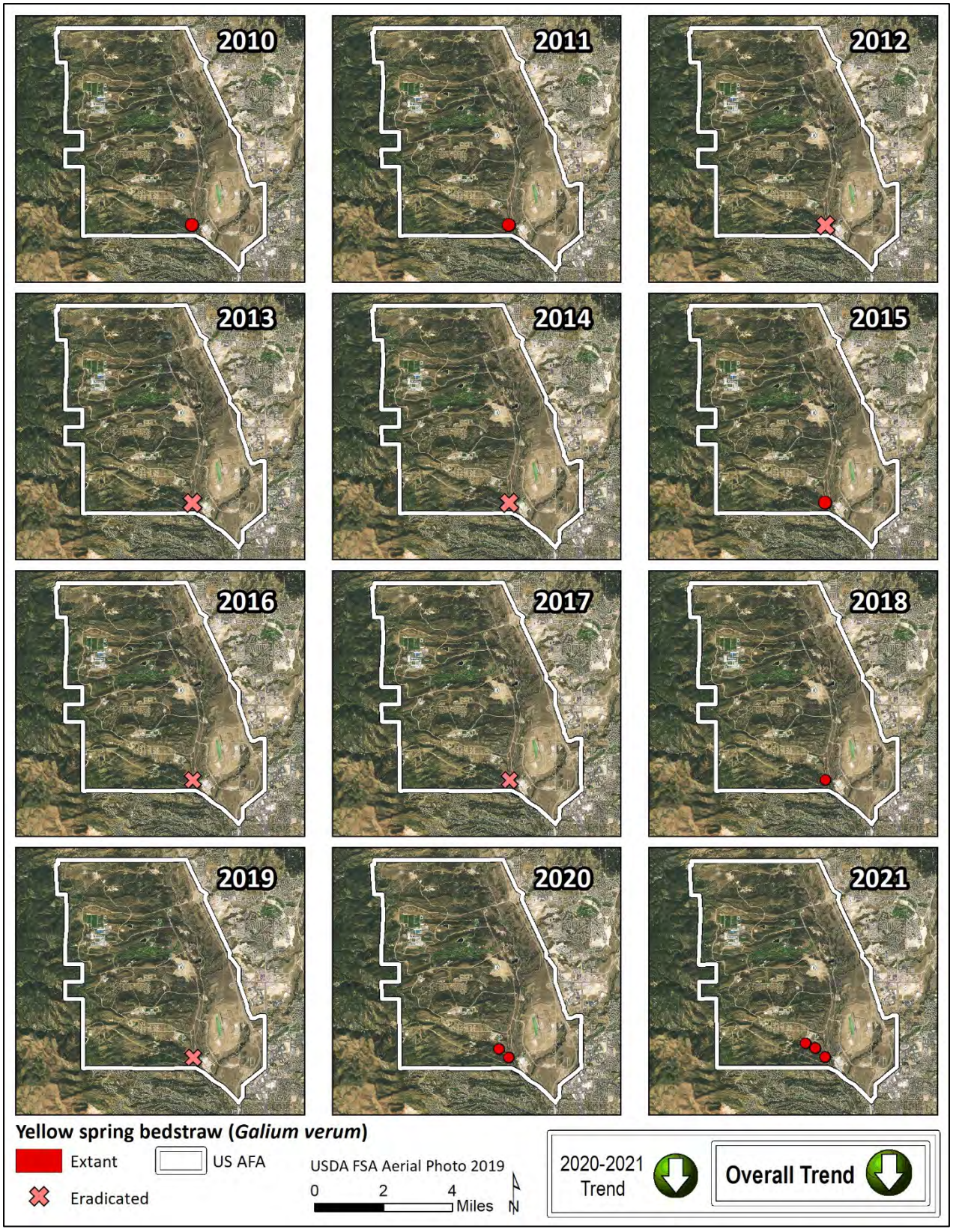
Yellow spring bedstraw is a high management priority due to the relative low cover at this time and the potential to increase quickly. The seed longevity of this plant is not known. Although this plant is not on the State of Colorado noxious weed list, it is a garden escape that has been shown to be 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 disturbed riparian areas with many native shrubs and herbs at the Academy. Recommendations for yellow spring bedstraw:

- Continue to monitor all known locations.
- Remove all plants when found with as little soil disturbance as possible.
- Revisit sites throughout the summer.
- Look for potential seed sources in residential areas.

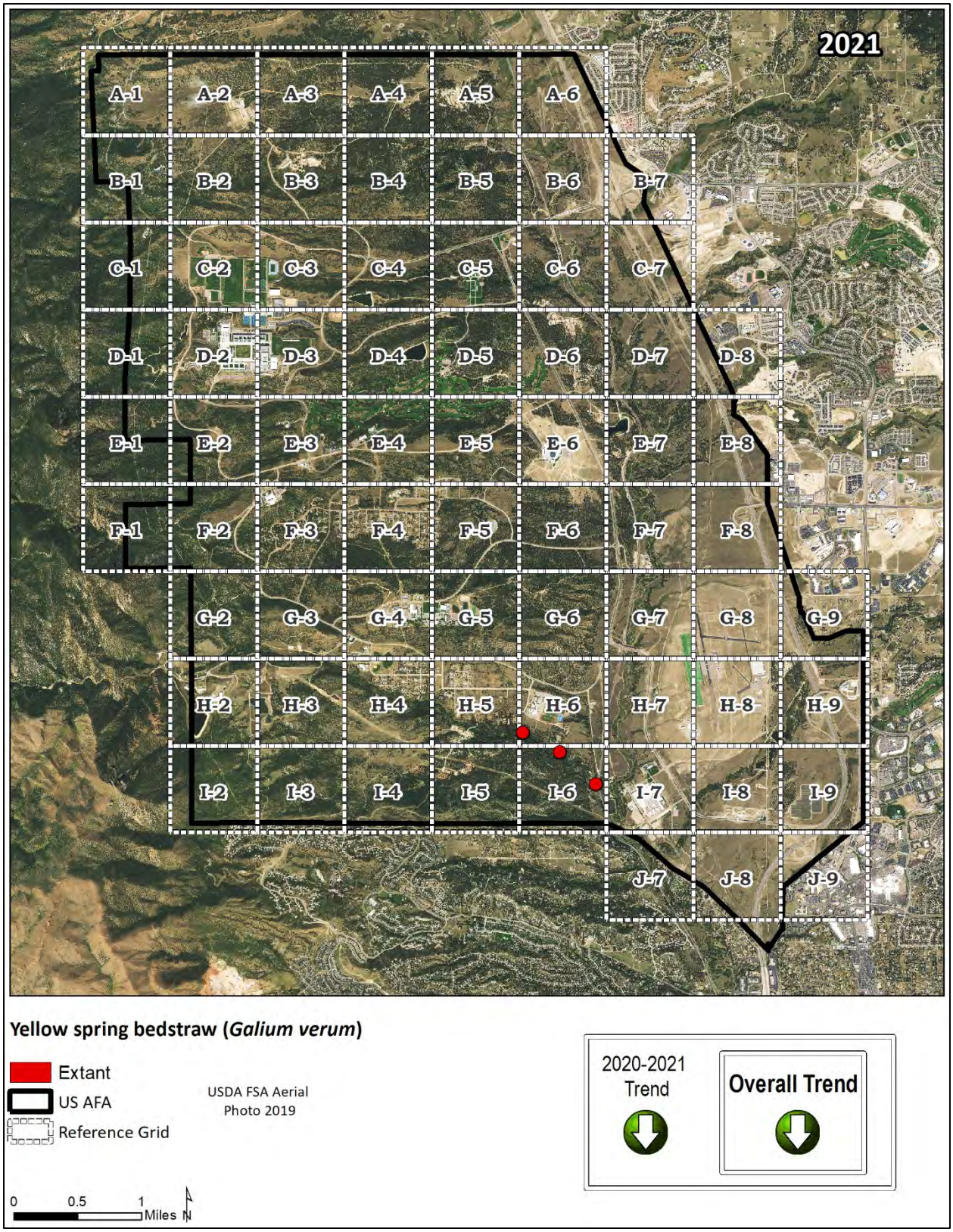
History of Sampling and Treatment:

- This species was discovered at the Academy in 2010 with one occurrence found near Ice Lake. 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.
- In 2018, 102 shoots were found at the same location where it was originally discovered.
- In 2019, no shoots were found.
- In 2020, the known site had 640 new sprouts which were pulled. Two more follow-up visits were conducted removing 100 and 9 plants respectively. A new site with at least 300 individuals was located along West Monument Creek and flagged for herbicide application.
- In 2021, all three known sites were visited in the spring and sprouts were present at all three sites.



Map 10. Distribution of yellow spring bedstraw at the Academy between 2010 and 2021.



Map 11. Distribution of yellow spring bedstraw at the Academy in 2021 with the reference grid.

Dame's Rocket (*Hesperis matronalis*)

Trend 2020-2021: Decreasing

Management Goals: Eradication

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 2020c)

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

2021 Mapping Results

Dame's rocket has shown a decrease in 2021 on the west side of I-25. Two sites have been visited by CNHP along Kettle Creek; in 2021, one of the sites was flooded by beaver activity and no dame's rocket plants were observed at the other site (Grids I-7& J-7, Maps 12 & 13). Two sites near the southwest corner of the southern boundary have been monitored and treated (3 individuals) by Academy staff (Table 14).

East of I-25 NOT VISITED SINCE 2019
Dame's rocket is known from 21 occurrences on Academy property east of I-25 and another on adjacent private property along the eastern boundary. Occurrences east of I-25 were not monitored in 2019 -2021. The populations east of I-25 have had shoot numbers up to 16,871 that were reduced to less than 300 and then began to increase after 2016 (Table 14, Maps 12 & 13). The I-25 corridor is under construction and many of the dame's rocket plants will likely be impacted.

Table 14. Mapping of dame's rocket at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
East and West of I-25				
2002	---	---	---	---
2007	---	---	---	---
2012	0.83	16,871	14	0
2013	?	?	?	?
2014	?	?	?	?
2015	0.08	280	2*	14
2016	0.08	294	3	14
2017	?	?	?	?
2018	0.04	633	7	14
West of I-25				
2019	<0.01	32*	1	3
2020	<0.01	32	1	3
2021	<0.01	3	1	3

Basewide weed mapping performed during shaded years.
* herbicide application

2021 Treatment

Two monitoring sites near Kettle Creek were visited in 2021; one site was flooded due to beaver activity, and no plants were found at the other site. One of the two sites (very close together) near the southwest corner (Grid I-3, Map 13) were visited in June by the Academy Natural Resource manager and three individuals were pulled (pers. comm. Brian Mihlbachler 2/22/2022) (Table 15).

Table 15. Monitoring and treatment of dame's rocket sites at the Academy in 2021.					
	# Site Visits	**# Shoots Mapped**	**# Manually Treated Shoots**	**# Sites with Plants**	**# Sites without Plants**
Pass 1	4	3	3	1	3
Total	**4**	**3**	**3**	---	---
2020	**2**	**0**	**0**	---	---
2019	**2**	**0**	**0**	---	---

Recommendations

Dame's rocket seed longevity is unknown, but these plants are known to remain dormant in the soil for many years (CWMA 2020c). Thus, cutting flowering tops is recommended as well as manual removal of the entire plant. Because the seed longevity is quite long, all of the sites should be monitored for multiple years.

Recommendations for dame's rocket:

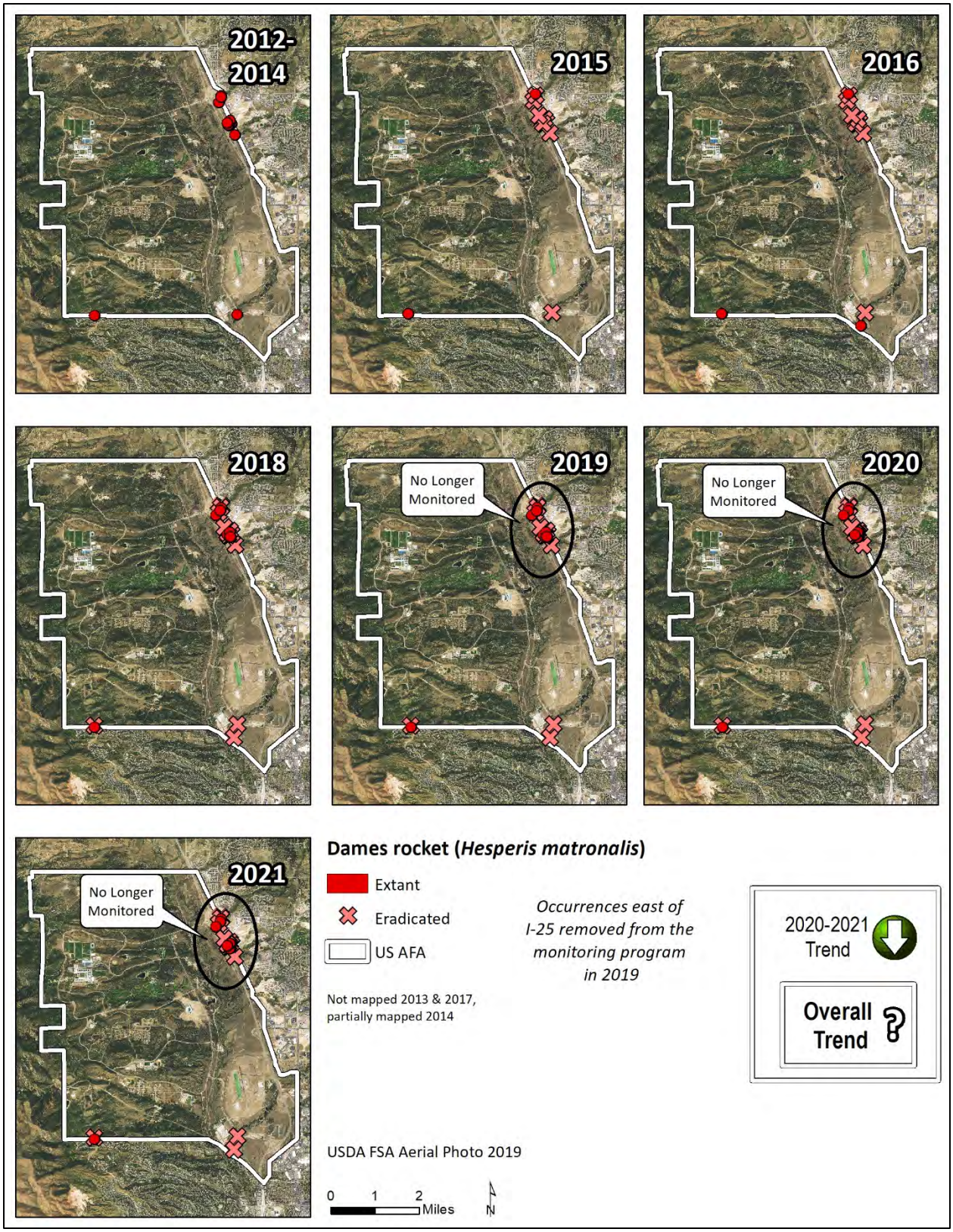
- Continue to monitor known sites for dame's rocket along Kettle Creek and in the southwest part of the Academy in the spring before seed set.
- Remove all vegetative parts for small populations when found.

History of Sampling and Treatment:

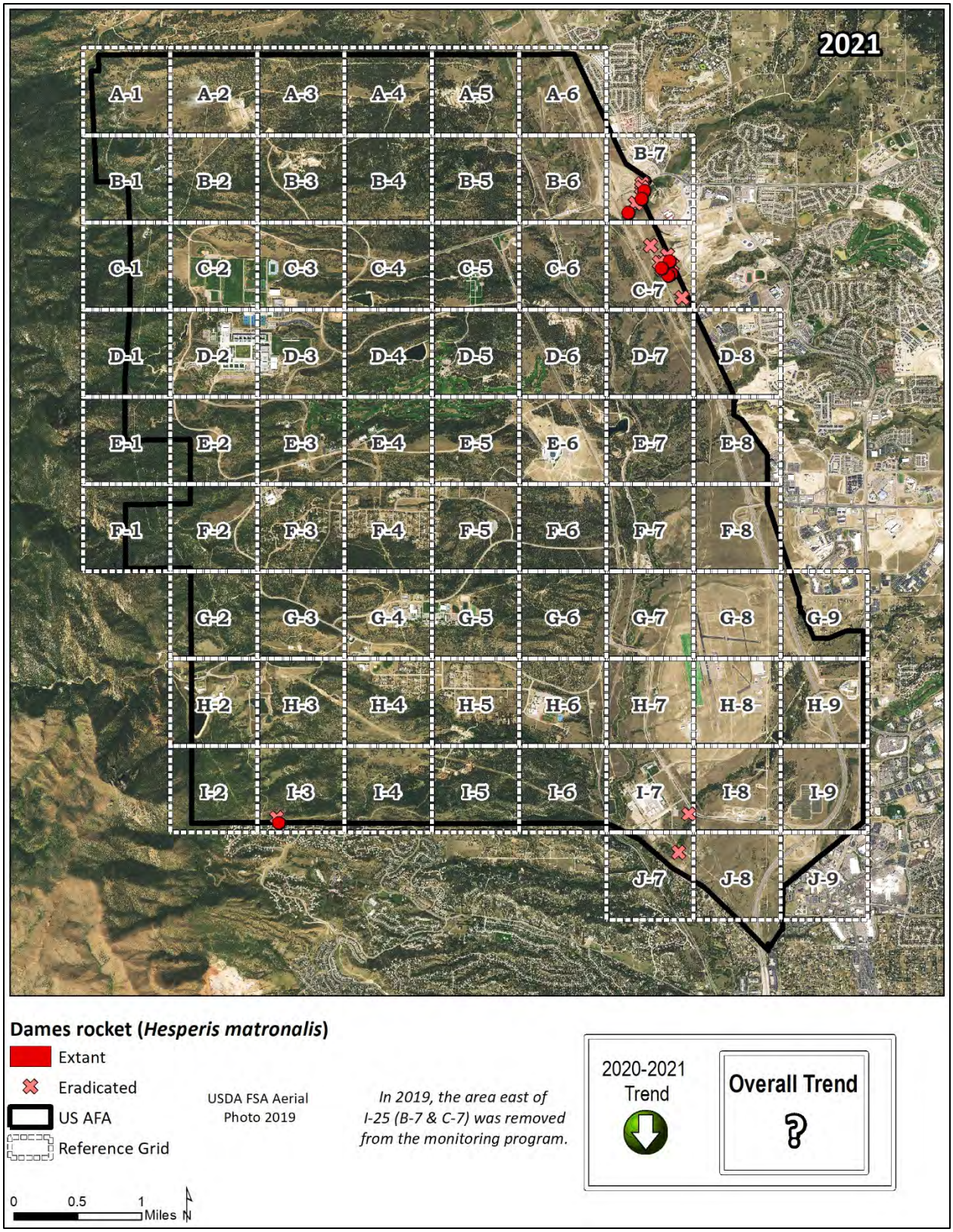
- Dame's rocket was first discovered in 2012, near I-25. The 2012 mapping project (Rondeau and Greenwell 2013) documented 0.18 occupied acres with 16,871 shoots in 14 locations.
- Dame's rocket was not monitored in 2013 and visited too late in the season in 2014.
- In 2015, there were two extant locations out of a total of 15 known locations. 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.
- In 2018, more than half of the known locations had dame's rocket plants. No new locations were mapped.
- In 2019, only two sites west of I-25 along Kettle Creek were visited and no plants were found. The contractor sprayed 32 individuals at one of the two westernmost sites, and the

second site was eradicated. No sites east of I-25 were visited due to construction and development activities.

- In 2020, two sites east of I-25 along Kettle Creek were visited by CNHP, one site was flooded by beaver activity and the other was eradicated. No sites east of I-25 were visited.
- In 2021, Dame's rocket is decreasing at sites west of I-25 with only one site out of four monitoring sites extant (3 individuals).



Map 12. Distribution of dame's rocket at the Academy between 2012 and 2021.



Map 13. Distribution of dame's rocket at the Academy in 2021 with the reference grid.

Orange Hawkweed (*Hieracium aurantiacum*)

Trend 2020-2021: Decreasing (Farish)

Management Goals: Eradication

State List: A

Photo: Pam Smith CNHP, Sept 2018 Farish

- Perennial
- Reproduction by seed, rhizomes and stolons
- Flowers June-August
- Native look-a-like is orange agoseris (*Agoseris aurantica*)
- Seeds are viable for seven years
- 100 to 1,000 seeds/plant (CWMA 2020d)

2021 Mapping Results

In 2021, orange hawkweed has continued to decline at Farish Recreation Area since it was first observed at Farish Recreation Area in 2018 with 200 plants. No treatment took place in 2018 (Tables 16 & 17, Figure 12, Map 14). The large reduction observed in 2019-2021 demonstrates the importance of same season follow-up visits and represents a very large decrease since manual treatments began.

Table 16. Mapping of orange hawkweed at Farish.				
	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2012	---	---	---	---
2017	---	---	---	---
2018	<0.01	200	1	0
2019	<0.01	600	1	0
2020	<0.01	145	1	0
2021	<0.01	59	1	0

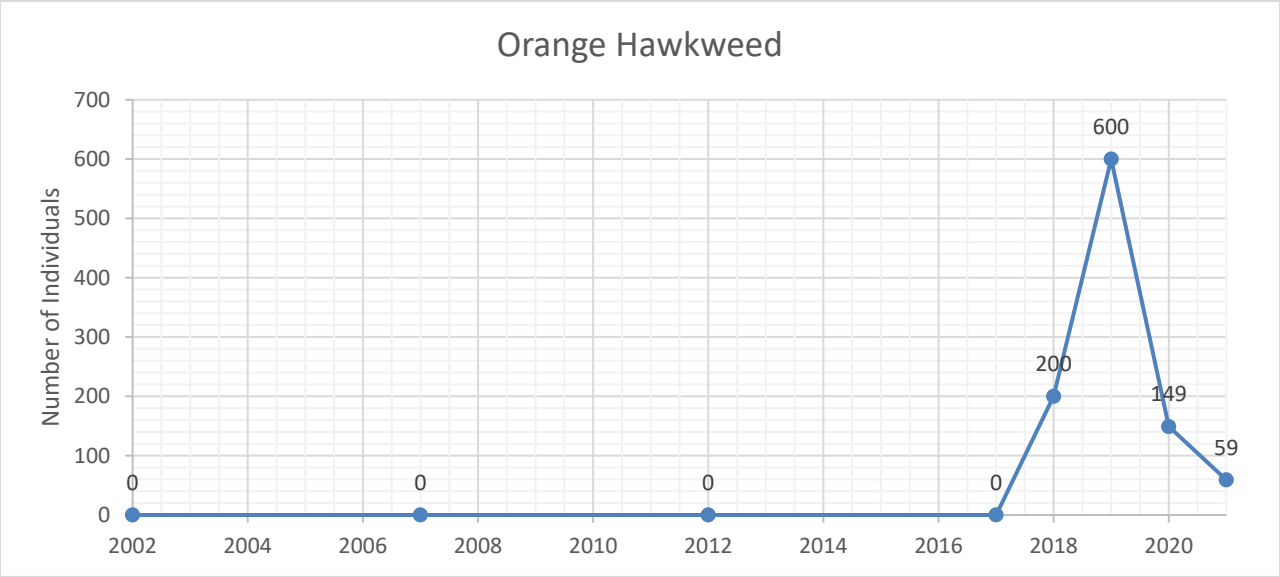


Figure 12. Number of orange hawkweed individuals, 2002-2021.

2021 Treatment

In 2021, no sprouts were present on June 04, 2021 which was too early to monitor this year. On August 15, 2021, 59 small sprouts were removed and another eight were removed on September 14, 2021 bringing the total number of sprouts to 67. This is a significantly smaller number of individuals compared to all other years since it was first discovered, and with a much smaller biomass. Most of the individuals were sprouts an inch or less tall (Table 17). No plants went to seed in 2019 -2021.

Table 17. Monitoring and treatment of orange hawkweed sites at Farish in 2021.					
	# Site Visits	**# Shoots Mapped**	**# Manually Treated Shoots**	**# Sites with Plants**	**# Sites without Plants**
Pass 1	1	59	59	1	0
Pass 2	1	8	8	1	0
TOTALS	**2**	**67**	**67**	---	---
2020	**2**	**245**	**245**	---	---
2019	**2**	**1,257**	**1,257**	---	---

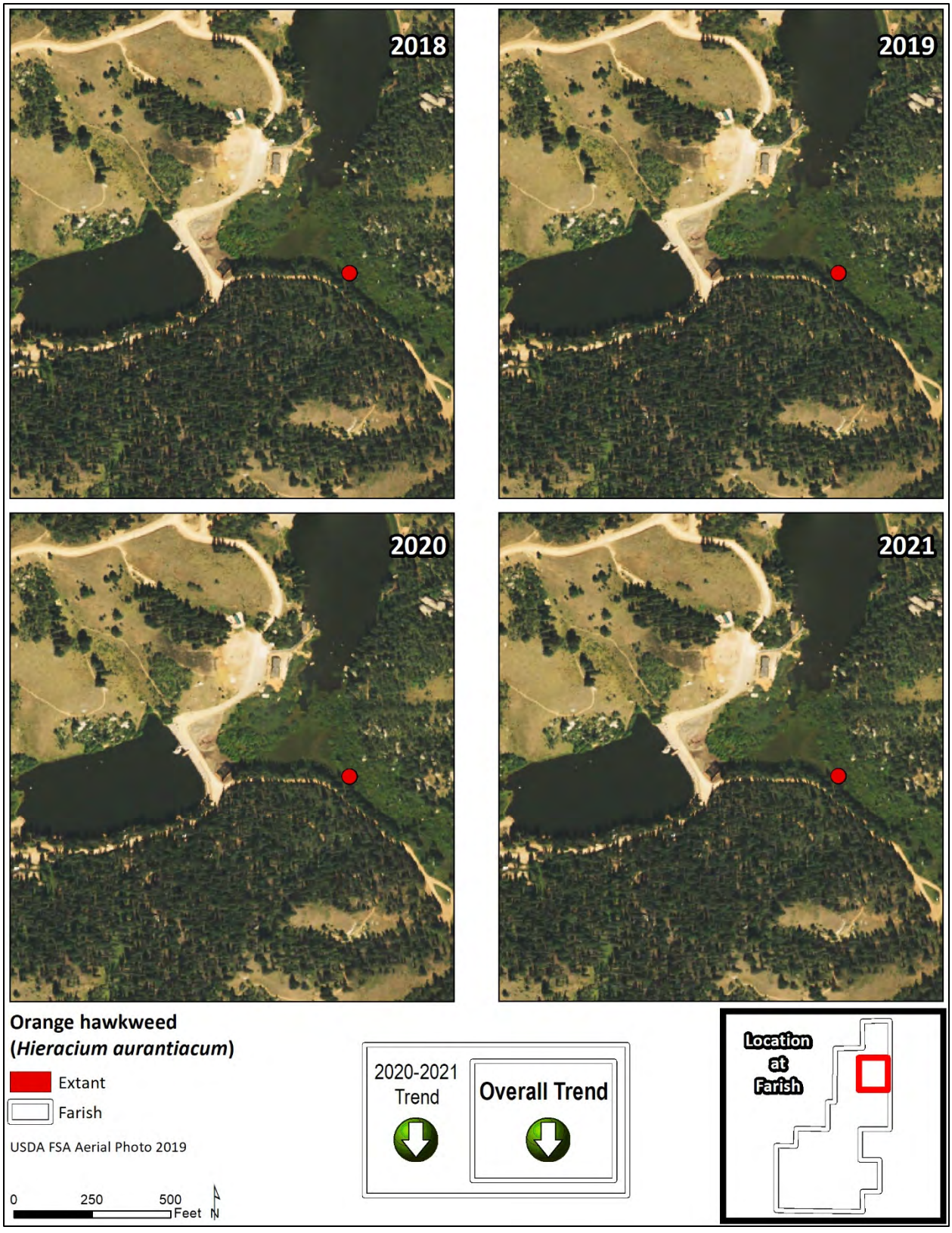
Recommendations

The management urgency for this species is high due to low cover at only one site. Manual treatments have resulted in reducing the population. Recommendations for orange hawkweed:

- Continue to visit the site in mid-June before flowers are produced to remove sprouts and underground parts with minimal soil disturbance.
- Re-visit the sites in August or early September to remove sprouts.

History of Sampling and Treatment:

- Orange hawkweed was first discovered at Farish on September 20, 2018, while conducting a survey of a nearby wetland in the campground area.
- In 2019, 600 plants were removed manually in the spring, followed by the removal of another 657 sprouts in late summer. No plants went to seed.
- In 2020, 145 plants were removed manually in the spring, followed by the removal of another 100 in the late summer. No plants went to seed. Only very small sprouts less than one inch tall were observed (and removed). Two additional sites were reported by the weed contractor which were not found.
- In 2021, manual treatments are resulting in a significant decrease from past years.



Map 14. Close-up of orange hawkweed at Farish between 2018 and 2021.

Common St. Johnswort (*Hypericum perforatum*)

Trend 2020-2021: Stable

Management Goals: Containment

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, CNHP

Photo by Michelle Washebek, CNHP

2021 Mapping Results

In 2021, we estimate that common St. Johnswort is continuing to decrease in cover and number of shoots and has remained stable since 2020. The estimated number of shoots went from 11,543 in 2019 to 8,987 in 2020, and to 8,766 in 2021. (Table 18, Figure 13, Maps 15 & 16).

Table 18. Mapping of common St. Johnswort at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002†	<0.10	363	5	---
2007	0.86	44,647	8	0
2008	1.07	130,371	13	0
2009	2.02	95,883	21	2
2010	1.47	82,733	20	6
2011	1.44	87,128	26	5
2012	1.16	83,115	29	10
2013	0.85	2,621	22	21
2014	1.12	3,604	33	19
2015	1.27	3,102	27	29
2016	1.02	6,717	32	27
2017	1.31	4,202	47	23
2018	1.26	16,416	57	27
2019	1.41	11,543	74	28
2020	1.29	8,987	65	39
2021	1.41	8,766	62	40

†2002 values from field notes, not adequately mapped in GIS.
Basewide weed mapping performed during shaded years.

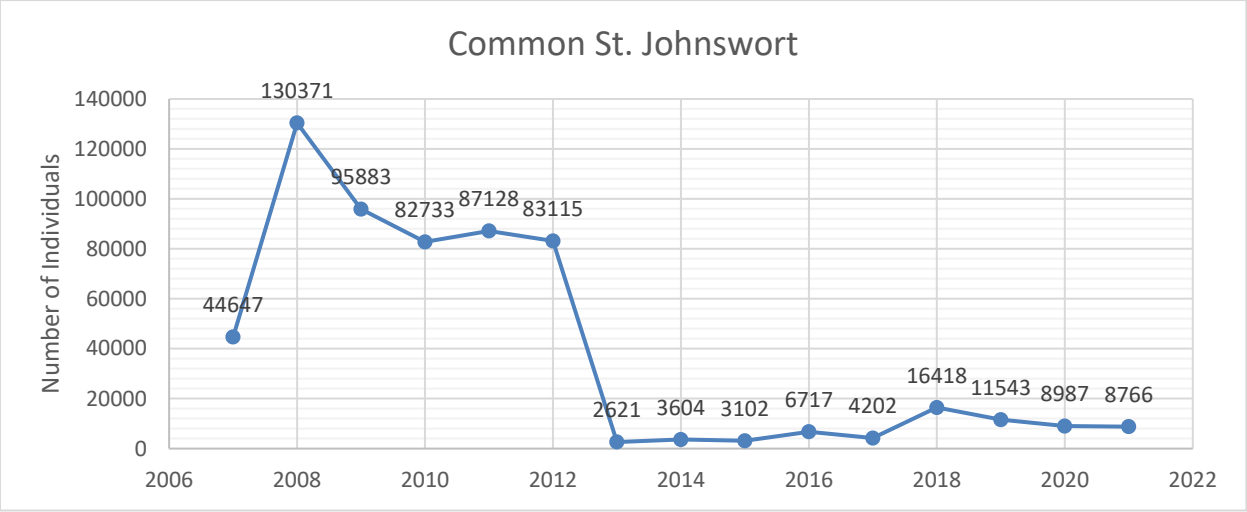


Figure 13. Number of common St. Johnswort individuals, 2007-2021.

2021 Treatment

In 2021, a total of 51 common St. Johnswort features were visited for monitoring and treatment out of 102 known sites. Of those 51 sites, 27 were extant and contained 2,630 shoots. At a second visit later in the season to 10 previously visited sites in 2021, 45 individuals were found as well as seven eradicated features. A total of 1,803 shoots were manually treated (Table 19).

Fifty percent of the known sites were not visited in 2021. The majority of the sites not treated were either too large to treat manually, treated with herbicides, were flooded or had active biocontrol agents observed in 2021. In addition, some of the sites were not visited due to changes in prioritization of weed treatment efforts in 2021.

Table 19. Monitoring and treatment of common St. Johnswort sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Site with Plants	# Sites without Plants
Pass 1	51	2,584	1,757	27	24
Pass 2	10	45	45	3	7
Pass 3	3	1	1	1	2
TOTALS	**64**	**2,630**	**1,803**	---	---

A comparison of the same 49 sites visited in both years showed 2,510 shoots in 2021, while the same 49 sites had 2,630 individuals in 2020. This sub-sampling shows a decreasing trend.

Recommendations

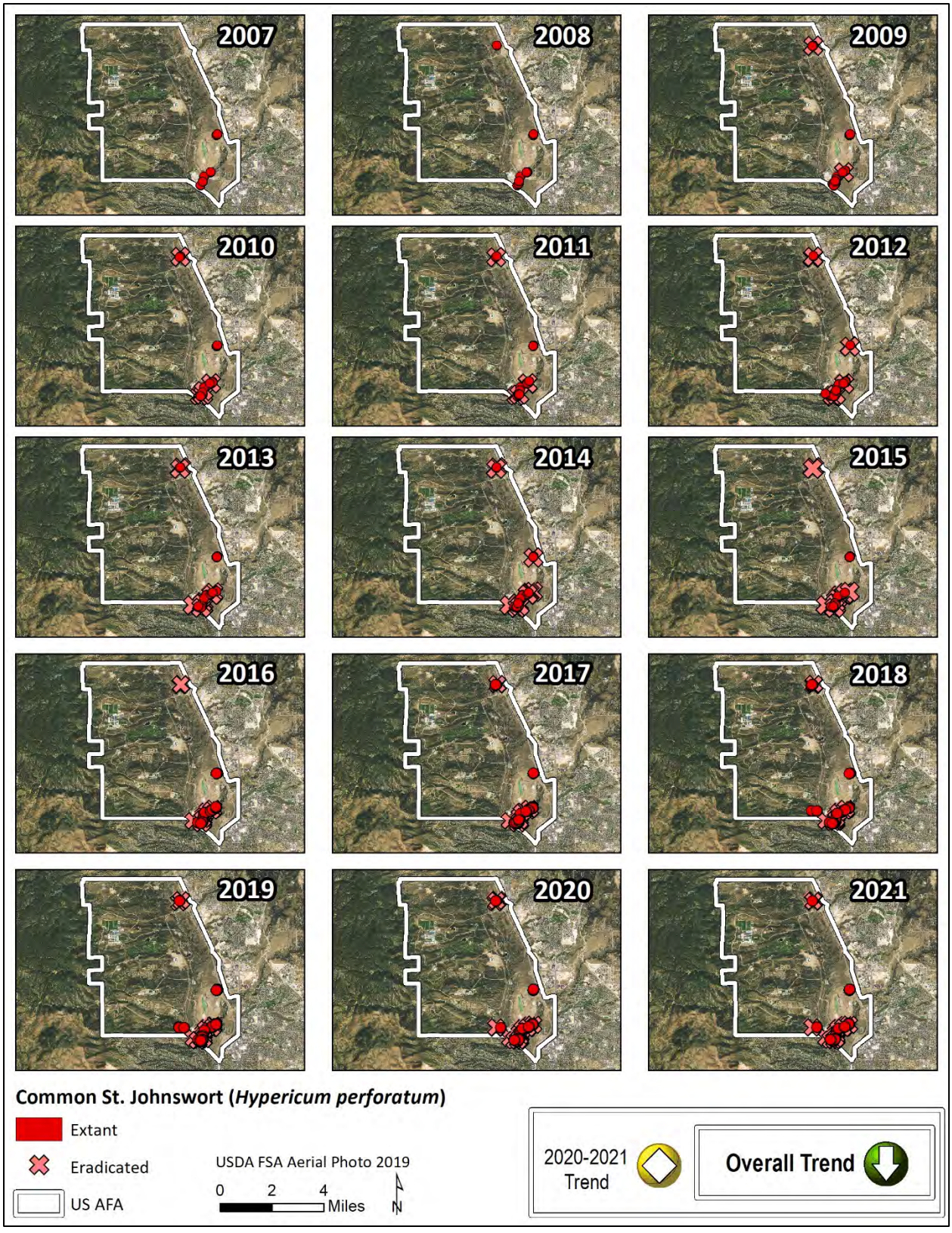
The management urgency for common St. Johnswort is medium. The active floodplain of Kettle Creek as well as some of the upper benches, are prone to infestations of common St. Johnswort. The floodplain areas are easily invaded if the soils are disturbed (Photo 6). Large numbers of plants are removed during flooding events and washed downstream. In addition, biocontrol organisms are present and active at the Academy. Continued manual treatments could continue for small, isolated sites as long as nearby vegetation is protected from treatments; biocontrols are most effective for large populations. Recommendations for common St. Johnswort:

- Continue to monitor all or most of the populations and look for biocontrol organisms.
- Manually treat small isolated populations.
- Consider not treating larger populations with biocontrol organisms present.
- Protect intact habitats in the vicinity of common St. Johnswort plants.

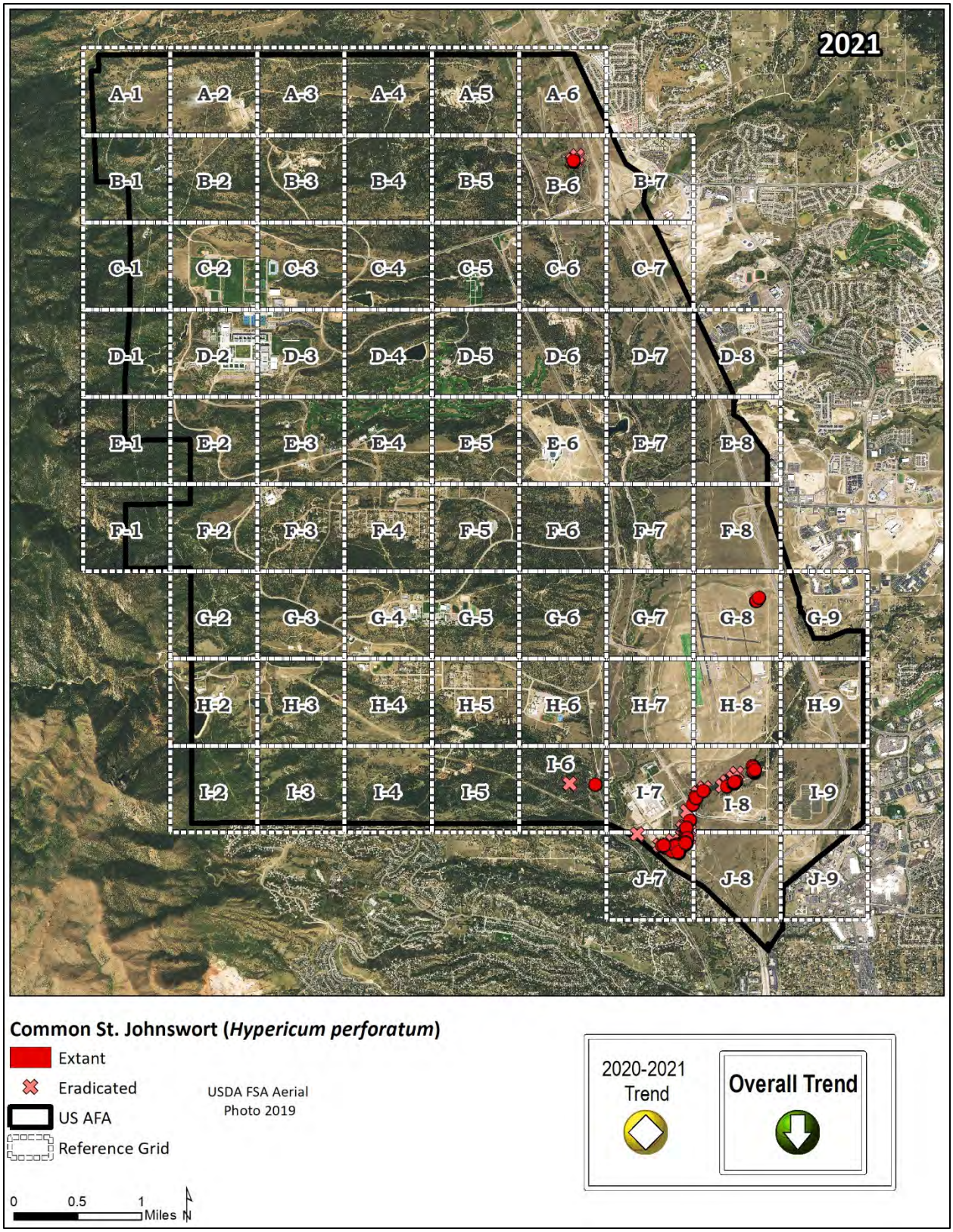
Photo 6. Native grasslands like this one along the Kettle Creek floodplain are thought to prevent the spread of noxious weeds like common St. Johnswort. September 2019 P. Smith

History of Sampling and Treatment:

- Common St. Johnswort was first seen at the Academy in 2002, but was described in field notes and not comprehensively mapped using the GPS.
- Common St. Johnswort was added to the monitoring list in 2007.
- The populations peaked in 2008-2009.
- 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.
- In 2018, basewide mapping showed an increase in the number of individuals and mapped features while the occupied acres remained relatively stable.
- In 2019, there was a decrease in the number of shoots compared to 2018 with a slight increase in occupied acres. Biocontrol organisms were observed at multiple sites.
- In 2020, there was a slight increase in the number of shoots compared to 2019. Biocontrol was observed at many sites and herbicide treatments were being applied.
- In 2021, 50% of the sites were mapped and all but two were manually treated. A comparison between the same sites in 2020 shows a decrease in the number of individuals.



Map 15. Distribution of common St. Johnswort at the Academy between 2007 and 2021.



Map 16. Distribution of common St. Johnswort at the Academy in 2021 with the reference grid.

Perennial Pepperweed (*Lepidium latifolium*)

Trend 2020-2021: Decreasing

Management Goals: Eradication, Rapid Response

State List: B

Photo: Kate Wright CNHP 2018 at the Academy

- Perennial
- Reproduction by seed and creeping roots
- Flowers May-July
- Roots to 9 feet deep and 10 feet lateral spread
- Seeds often transported by water (FEIS 2022b)
- Seed longevity not well-know, estimated to be 2 years (FEIS 2022b).

2021 Mapping Results

The two known perennial pepperweed locations at the Academy (Grids A-6 & I-9, Map 18) decreased in the number of shoots in 2021 from 2020 for the first monitoring pass of the season. The occupied acres have remained the same, and no new populations were observed (Table 20, Figure 14, Maps 17 & 18). However, as the season progressed more sprouts were removed from the sites compared to 2020.

Table 20. Mapping of perennial pepperweed at the Academy.				
	Occupied Acres	**Estimated # of Shoots**	**# of Extant Features**	**# of Eradicated Features**
2002	---	---	---	---
2007	---	---	---	---
2012	---	---	---	---
2018	0.02	213	2	0
2019	0.03	212	2	0
2020	0.03	23	2	0
2021	0.03	4	2	0

Basewide weed mapping performed during shaded years.

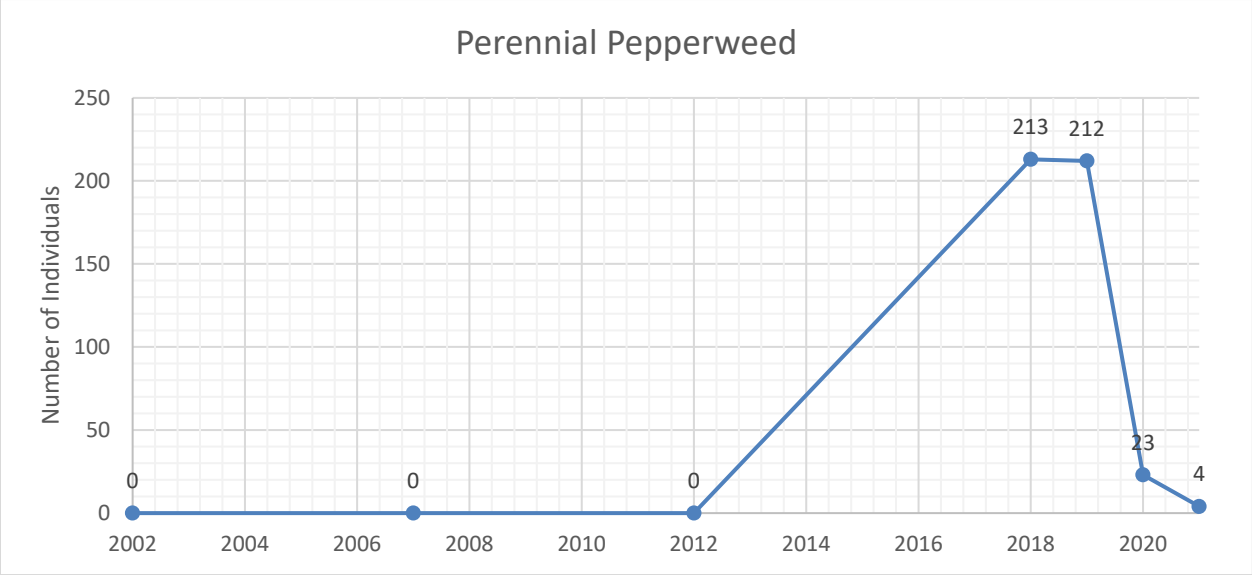


Figure 14. Number of perennial pepperweed individuals, 2002-2021.

2021 Treatment

There were two individuals counted and treated for spring of 2021 at the southern site, no plants were observed at the northern site. A total of four visits were made to conduct manual treatments throughout the summer for eight visits (Table 21). The northern site (Aardvark runway) had far fewer plants but has been invaded by other noxious weeds.

Sprouts were removed at all four visits to the southern site. A total of 179 shoots were removed in 2021(Grids A-6 & I-9, Map 18). Most of the shoots were observed in the June and August with the spring sprouts (1st pass) showing a decline. However, in 2020, there were a total of 88 plants

removed during the season in five passes showing an increase of ~50% in 2021, with the majority of the plants new sprouts (Table 21).

Table 21. Monitoring and treatment of perennial pepperweed sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	2	2	2	1	1
Pass 2	2	117	117	2	0
Pass 3	2	52	52	2	0
Pass 4	2	8	8	2	0
TOTALS	**8**	**179**	**179**	---	---
2020	**6**	**114**	**114**	---	---
2019	**8**	**6**	**6**	---	---

In 2019, CNHP flagged plants for herbicide treatment. Plants re-sprouted later in the season (Photo 7) and again in 2020 and 2021. The sites have been treated manually multiple times a season to remove sprouts and vegetative sprouts of plants that come up throughout the growing season since the herbicide was applied. The off-target damage was limited during the herbicide application for the southern site, protecting native grasses in the vicinity of the pepperweed plants. However, at the northern site, patches of dead native grasses and forbs in the overspray zone have been replaced with Canada thistle, other non-native grasses, and bare soils in the overspray zone (Photo 8).

Photo 7. Two top-killed perennial pepperweed plants (left) that sprouted leaves and flowers later in summer of 2019. P. Smith

Photo 8. Perennial Pepperweed herbicide treatment one-year post application (left) at northern site, shows overspray area killing nearby native species and leaving open soils (2019). Two years post herbicide application at the same site (right photo), shows Canada thistle and other non-native species invading the overspray area (P. Smith 2021).

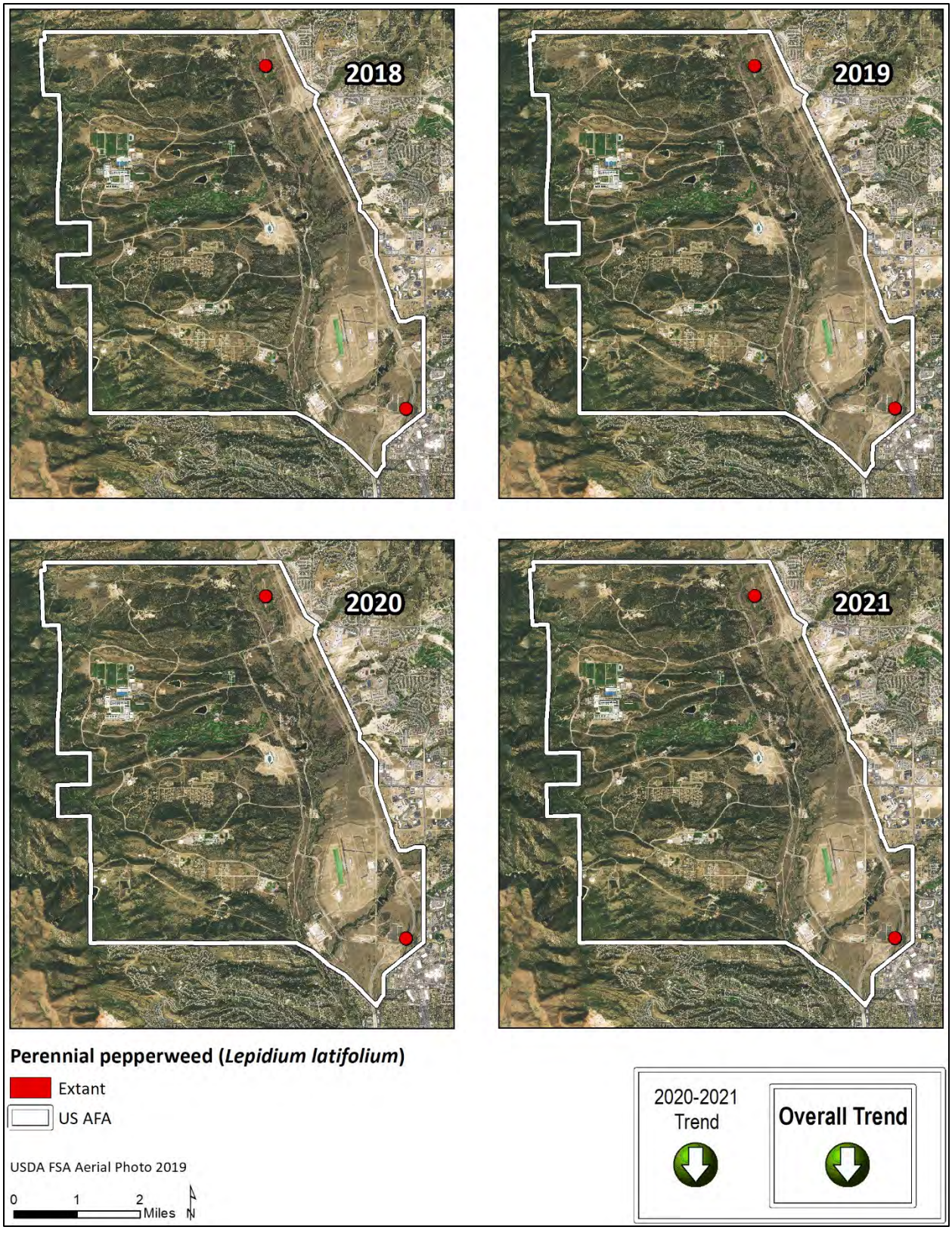
Recommendations

The management urgency for perennial pepperweed is high. This species has the potential to get out of control quickly and form dense colonies due to its deep root system and prolific seed production. To manage this species, the root reserves need to be depleted and seed production stopped. In addition, the protection of surrounding plants, especially native grasses, is important in preventing spread/invasion (Young et al. 2002). The populations at the Academy are of a practical size to treat manually. Although the seedling counts were higher in 2021, the footprint has remained the same. Additionally, the higher spring precipitation likely contributed to the increase in summer sprouts. Recommendations for perennial pepperweed:

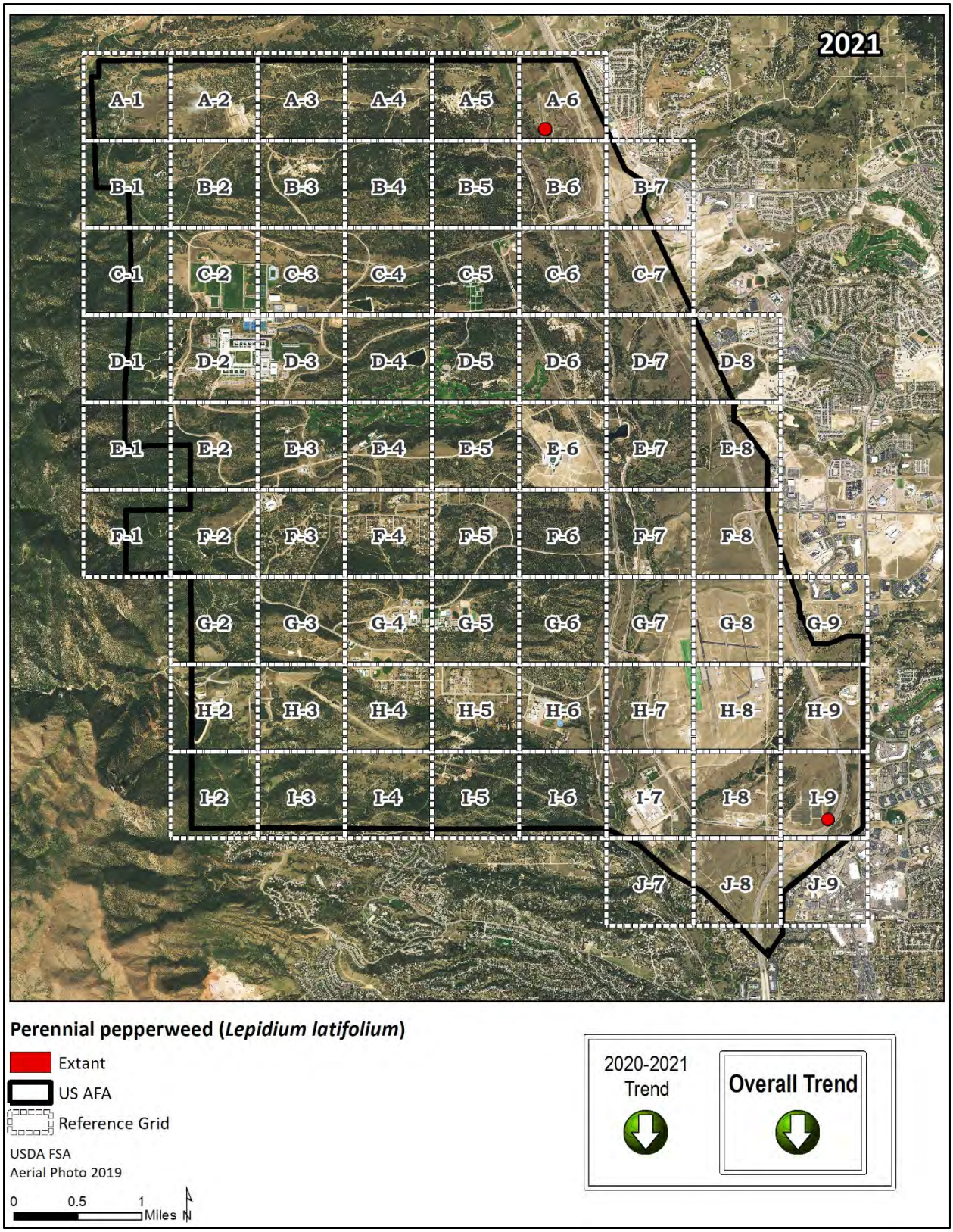
- Continue to monitor known sites throughout the growing season.
- Remove as much of the plant and root system as possible with minimal soil disturbance.
- Re-visit all sites multiple times to prevent plants from going to seed.

History of Sampling and Treatment:

- Perennial pepperweed was first documented by CNHP during the 2018 basewide weed survey, although herbicide treatment data suggest it has been present since 2015.
- In 2019, the number of shoots were almost identical to 2018. All plants were treated with herbicide in early summer. Six plants re-sprouted and were removed manually in late summer. No plants went to seed at the known sites in 2019.
- In 2020, there was a significant decrease in plants at both known locations, and plants were prevented from going to seed.
- In 2021, perennial pepperweed increased mostly at the southern site. Plants were found sprouting in April, June, August and September. Flowers were produced, some may have gone to seed. The increase is likely related to much higher precipitation in 2021.



Map 17. Distribution of perennial pepperweed at the Academy between 2018 and 2021.



Map 18. Distribution of perennial pepperweed at the Academy in 2021 with the reference grid.

Oxeye Daisy (*Leucanthemum vulgare*)

Trend 2020-2021: Moderately Increasing

Management Goals: Eradication

State List: B

Left: Basal leaves of Oxeye Daisy, Joseph M. DiTomaso, Univ. California, Bugwood.org. Right: Mary Ellen Harte, Bugwood.org

- Garden Escape
- Short-lived perennial
- Reproduction by seeds, roots and root fragments
- Shallow root system
- Blooms June -August
- Resembles Shasta Daisy but much smaller (2 vs 4 ft tall, head less than 3' across vs up to 5")
- Upper leaves clasp the stem, lower leaves have petioles and are spoon shaped
- Seed longevity 38+ years (CDA-CSU 2015)

Diagram by Mary Eaton/ Wikimedia Commons

2021 Mapping Results

In 2021, there was a moderate increase in the number of sites and numbers of individuals since oxeye daisy was first observed in Kettle Creek in 2019. Since its discovery in 2019, oxeye daisy has expanded from five known sites to 11 in 2021. The numbers of individuals have also increased from 40 to 616 in 2021 (Table 22, Figure 15). Of the 11 known sites, four are eradicated. The two new sites are in the vicinity of existing sites. Most of the increase seems to be due to new sprouts in 2021. This species appears only to occur at Kettle Creek (Map 19 & 20, Grids I-7, I-8).

Table 22. Mapping of oxeye daisy at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2012	---	---	---	---
2018	---	---	---	---
2019	<0.01	40	5	---
2020	0.02	455	6	3
2021	0.02	616	7	4

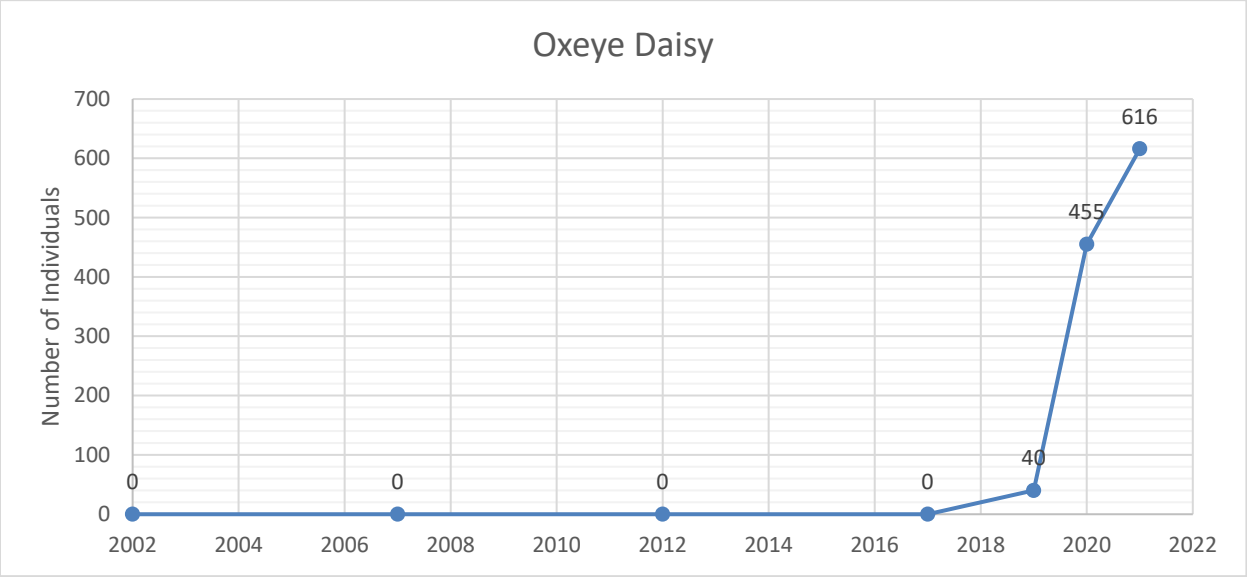


Figure 15. Number of oxeye daisy individuals, 2002-2021.

2021 Treatment

The first pass to 11 sites (2 new in 2021) resulted in 616 individuals mapped and pulled (Maps 19 & 20). An additional 753 plants were pulled during the second pass, 53 in a third pass, for a total of 1,422 individuals (Table 23). This is double the number of plants removed in 2020 (706). It is important to follow-up and pull sprouts throughout the season to prevent seed set and remove the late season sprouts. This species can gain control very quickly and is difficult to remove manually

once it reaches over 100 individuals at a site. The spring and summer precipitation for 2021 was 4.8 inches higher than what was received in 2020 (7.85 inches in 2020 to 12.62 in 2021, Figure 3) and may be related to the jump in sprouts throughout the season.

Table 23. Monitoring and treatment of oxeye daisy sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	11	616	616	7	4
Pass 2	10	753	753	4	6
Pass 3	3	53	53	2	1
Total	**24**	**1,422**	**1,422**	---	---
2020	**15**	**706**	**706**	---	---
2019	**5**	**52**	**52**	---	---

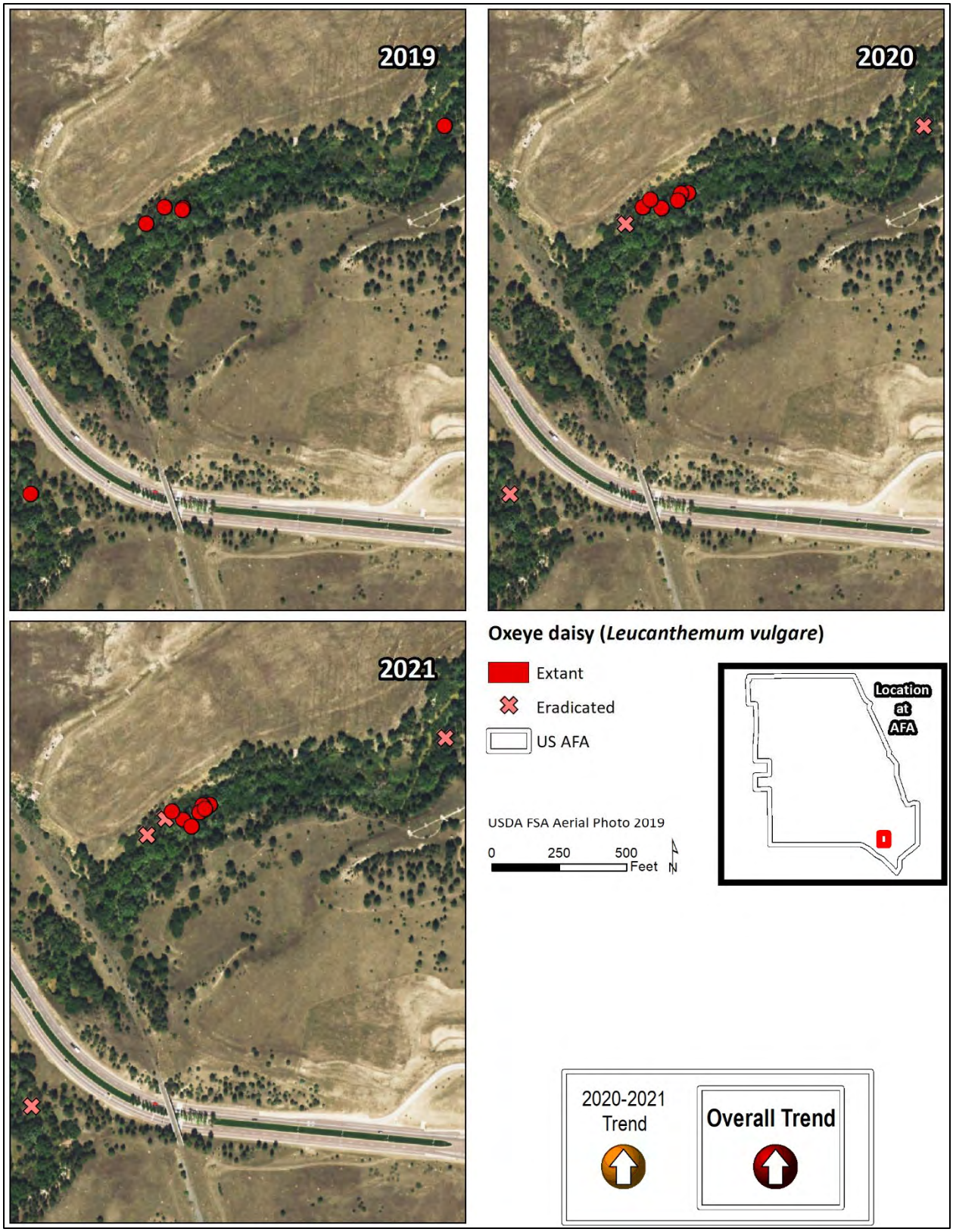
Recommendations

The management urgency for oxeye daisy is high. These plants are difficult to remove and rapid response is extremely important to get control at this stage in the infestation. At this point eradication seems possible but could get out of hand quickly without yearly multi-season surveys and treatment. Same season follow-up is essential to keep this species from increasing due to the continuous sprouting. The source of seeds is most likely residential properties as oxeye daisy commonly escapes from gardens to wild lands. It is a short-lived perennial that can reproduce via both root fragments and seeds and can spread quickly. The seed longevity is extremely long. However, the shallow root system and low number of individuals observed makes manual removal a viable option (CDA-CSU 2015b) and continual monitoring is a necessary not only at Kettle Creek but across the base to look for new occurrences. Recommendations for oxeye daisy:

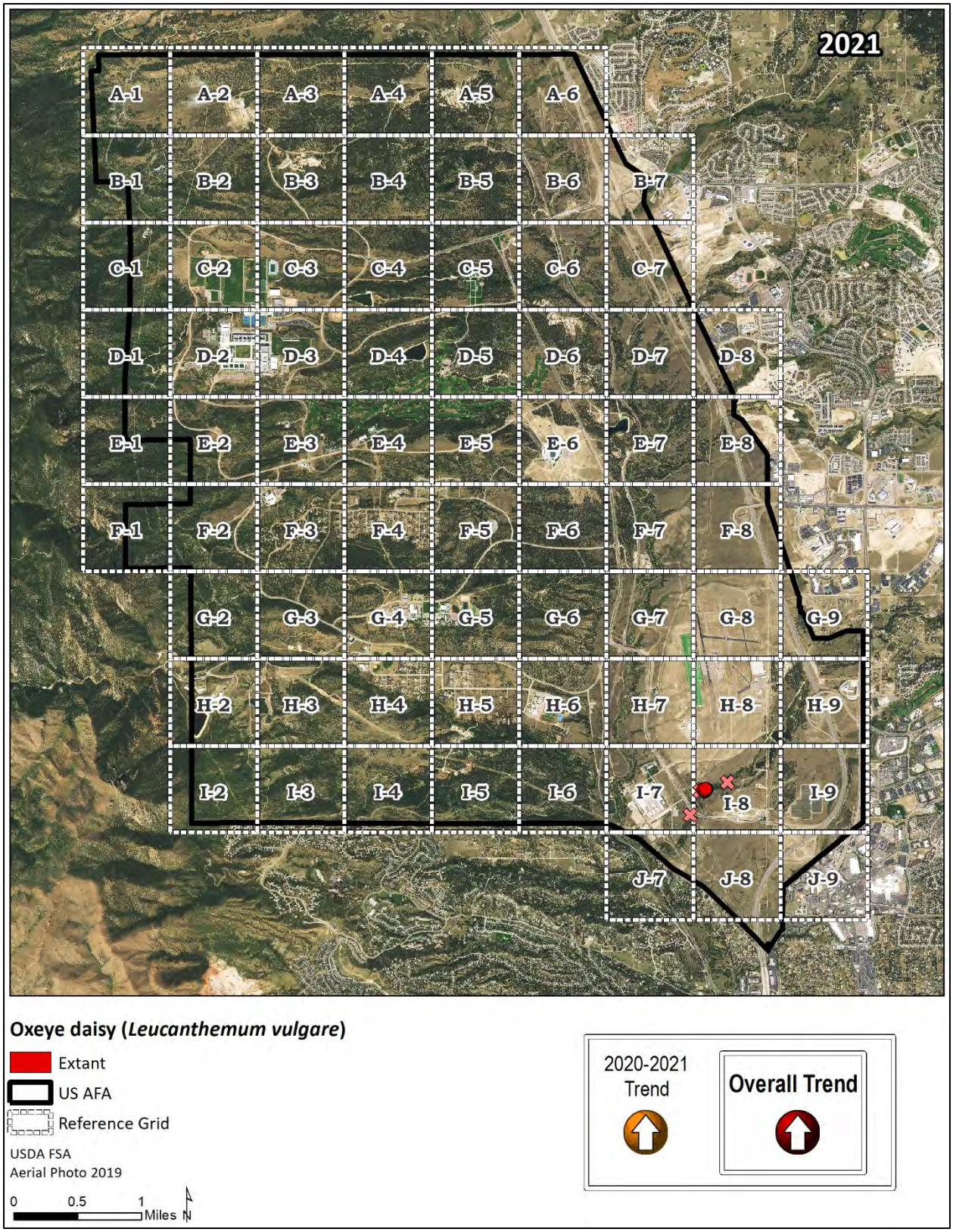
- Continue to monitor Kettle Creek multiple times during the growing season.
- Remove all plants found including roots.
- Revisit all sites at least once or twice during the season.

History of Sampling and Treatment

- 2019 is the first year oxeye daisy has been found at the Academy. All 40 individuals were removed at five features.
- In 2020, there was an increase in the number of sites from five in 2019 to nine in 2020, and an increase from 40 in 2019 to 455 shoots in 2020.
- In 2021, oxeye daisy continues to increase. The higher precipitation received in 2021 may have influenced the higher number of sprouts compared to 2020.



Map 19. Distribution of oxeye daisy at the Academy between 2019 and 2021.



Map 20. Distribution of oxeye daisy at the Academy in 2021 with the reference grid.

Dalmatian Toadflax (*Linaria dalmatica*)

Trend 2020-2021: Moderately Increasing

Management Goals: Eradication, 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 2014)
- Seed longevity estimate to be greater than 10 years (FEIS 2022c)

2021 Mapping Results

In 2021, no plants were observed in June at the four known locations (Grids H-2 & I-8, Map 22). However, in August, two flowering plants were found at a new site near a known location on the north shore of the Kettle Ponds boat launch area (Table 24, Figure 16, Maps 21 & 22).

Based on past surveys, Dalmatian toadflax seems to reappear after three to five years when conditions are right. There is a very strong correlation with annual spring-summer precipitation amounts at or around 12 inches and the presence of Dalmatian toadflax at the Academy. All five years with no plants mapped had spring-summer precipitation amounts of 5.93-11.7 inches, below the annual yearly average of 12.33 inches. The year 2015 was an exception with 20 inches of annual spring-summer precipitation which was 7.5 inches above the annual average and it had been preceded by the driest year with only six inches of rain (Figure 3).

Table 24. Mapping of Dalmatian toadflax at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2009	?	10*	1	0
2010	0.50	107*	2	1
2011	0	0	0	3
2012	0	0	0	3
2013	?	12*	1	3
2014	<0.01	7*	1	3
2015	0	0*	0	4
2016	<0.01	1*	1	3
2017	<0.01	480*	1	3
2018	0.01	52*	1	3
2019	0	0	0	4
2020	0	0	0	4
2021	0.02	2*	1	4

Basewide weed mapping performed during shaded years. * Years with spring-summer annual ppt >12".

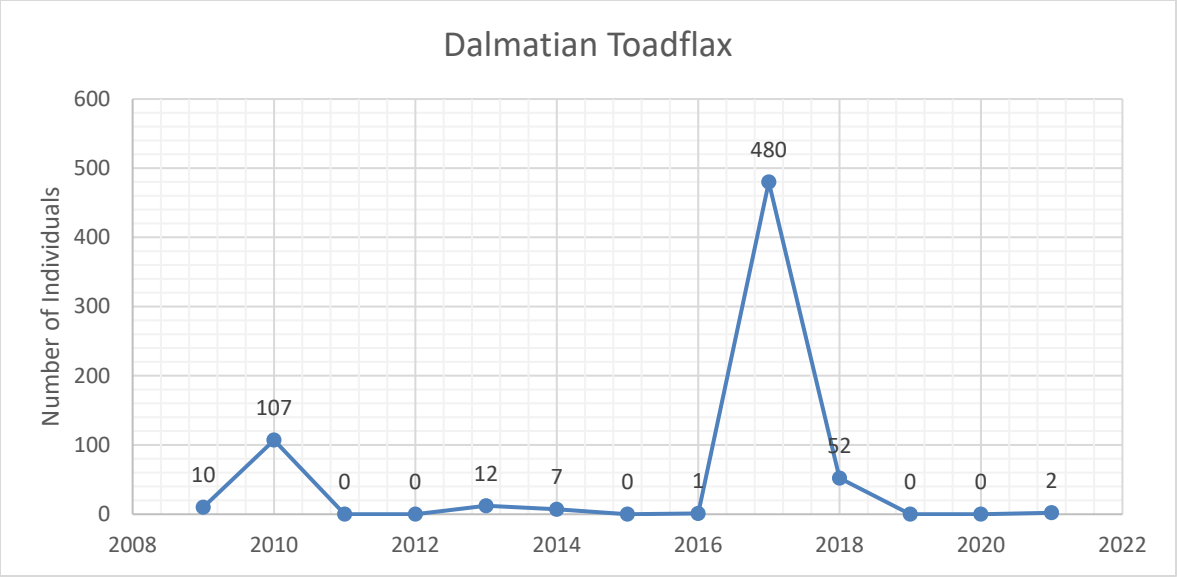


Figure 16. Number of Dalmatian toadflax individuals, 2009-2021.

2021 Treatment

In 2021, there were no Dalmatian toadflax plants found at four known sites in June. However, two plants were found during the second pass in August at a new point in the vicinity of the three existing points at Kettle Pond boat launch area (Table 25).

Table 25. Monitoring and treatment of Dalmatian toadflax sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	4	0	0	0	4
Pass 2	5	2	2	1	4
Pass 3	5	0	0	0	5
TOTAL	**14**	**2**	**2**	---	---
2020	**8**	**0**	**0**	---	---
2019	**8**	**0**	**0**	---	---

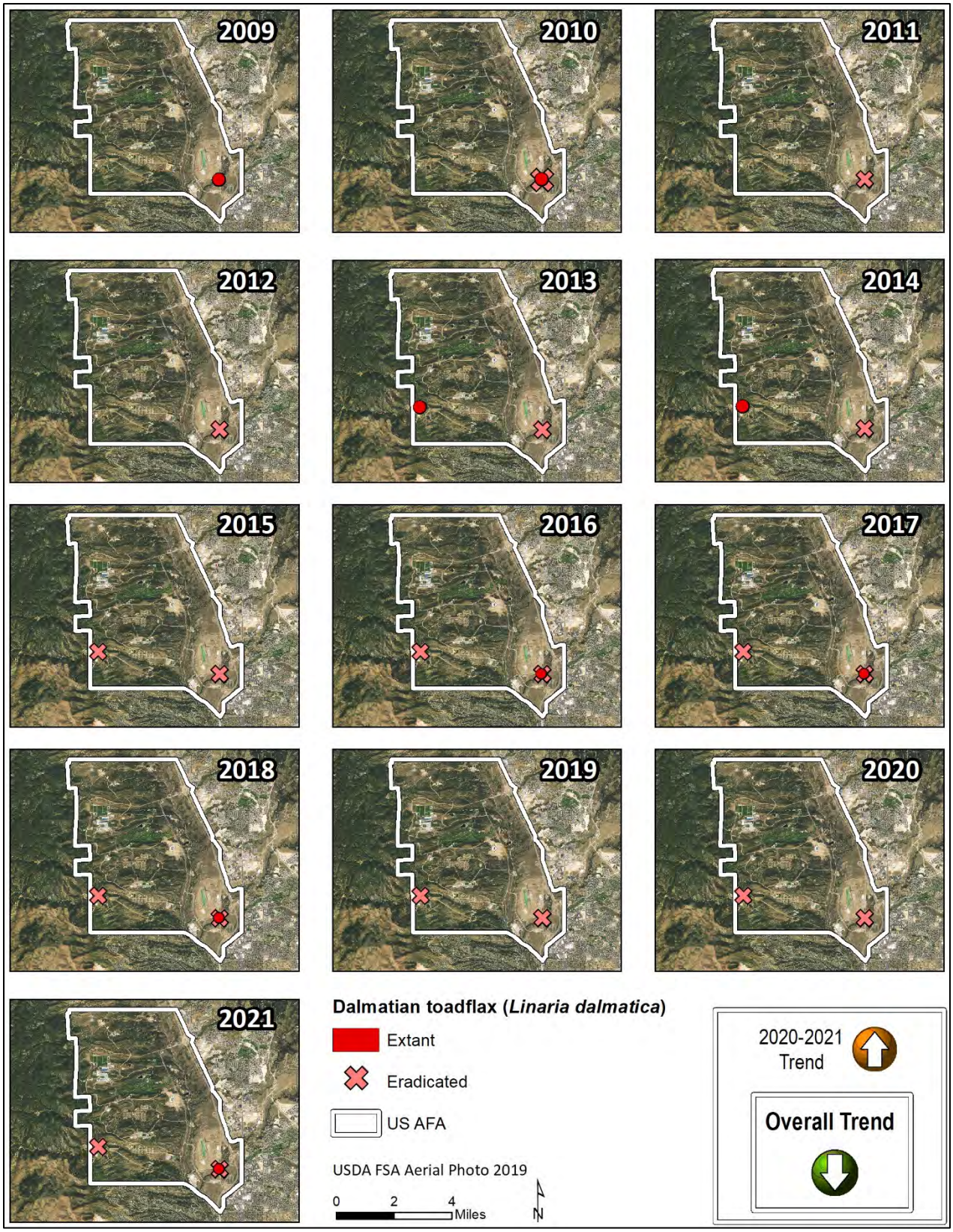
Recommendations

The management urgency for Dalmatian toadflax is considered high. This species has years where no plants are found, followed by sudden and often substantial increases. All but one of the years where plants have been found are correlated with higher than average spring-summer annual precipitation. Recommendations for Dalmatian toadflax:

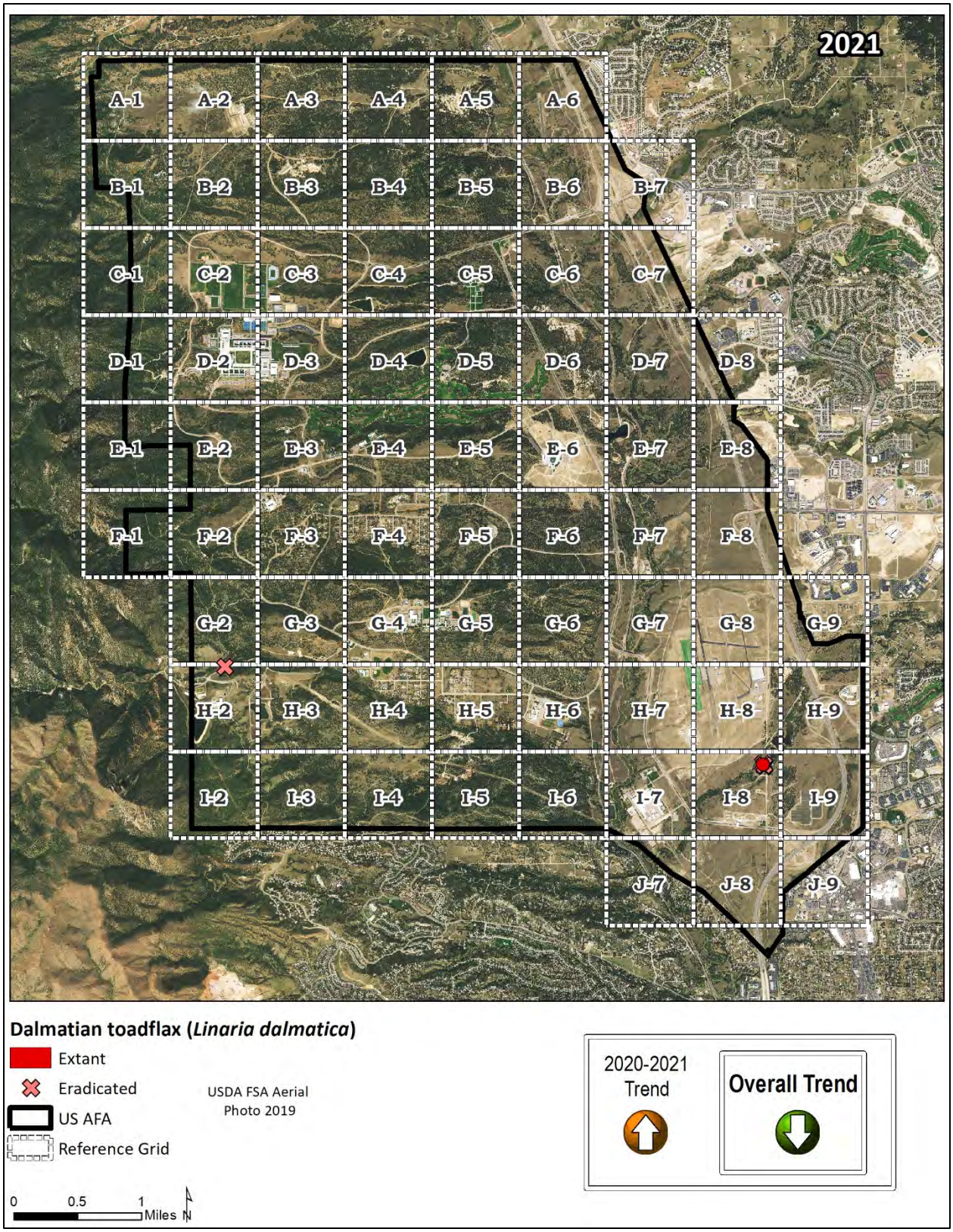
- Continue to monitor all known sites annually.
- Remove new shoots as they are found and re-visit sites with plants in the same season.

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 with 107 shoots that covered approximately 203 m^2 (0.05 acres). 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.
- 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.
- In 2018, 52 plants were observed at the Kettle Lake #1 site and at no other locations.
- In 2019 no plants were observed at the four known sites.
- In 2020, no plants were observed at the four known sites.
- In 2021, two plants were observed at a new point eight meters from the closest existing mapped site, bringing the total of sites from four to five. All previously existing sites were eradicated.



Map 21. Distribution of Dalmatian toadflax at the Academy between 2009 and 2021.



Map 22. Distribution of Dalmatian toadflax at the Academy in 2021 with the reference grid.

Tatarian Honeysuckle (*Lonicera tatarica*)

?

Trend 2020-2021: Unknown

Management Goals: Containment

State List: NA (Garden Escape)

- 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
- Plants can sprout after treatments

Photos: Wikimedia Commons

2021 Mapping Results

There are a total of 45 mapped locations of Tatarian honeysuckle at the Academy. Fourteen sites were mapped in 2021 while visiting other higher priority weed sites. One new feature was located with three individuals within 10 meters of known occurrences along West Monument Creek (Table 26, Map 23 & 24). The other 13 sites were stable.

Table 26. Mapping of Tatarian honeysuckle at the Academy.				
	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2008†	0.15	20	1	0
2012†	0.15	20	1	0
2013	0.18	28	5	0
2014	0.21	31	5	2
2015	0.40	48	9	1
2016	0.24	22	8	4
2017	0.24	8	6	3
2018	0.60	132	35	5
2020	0.81	113	35	9
2021	0.95	148	37	8

Basewide weed mapping performed during shaded years. † 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.

2021 Treatment

The resource management staff conduct all treatments for Tatarian honeysuckle at the AFA. In 2021, we conducted 14 site visits and found 83 individuals (Table 27). One site was new and had three individuals in 2021. Sites appear to be stable between 2020 and 2021.

Table 27. Monitoring and treatment of Tatarian honeysuckle sites at the Academy in 2021.					
	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	14	83	0	11	3
TOTAL	**14**	**83**	**0**	---	---

Recommendations

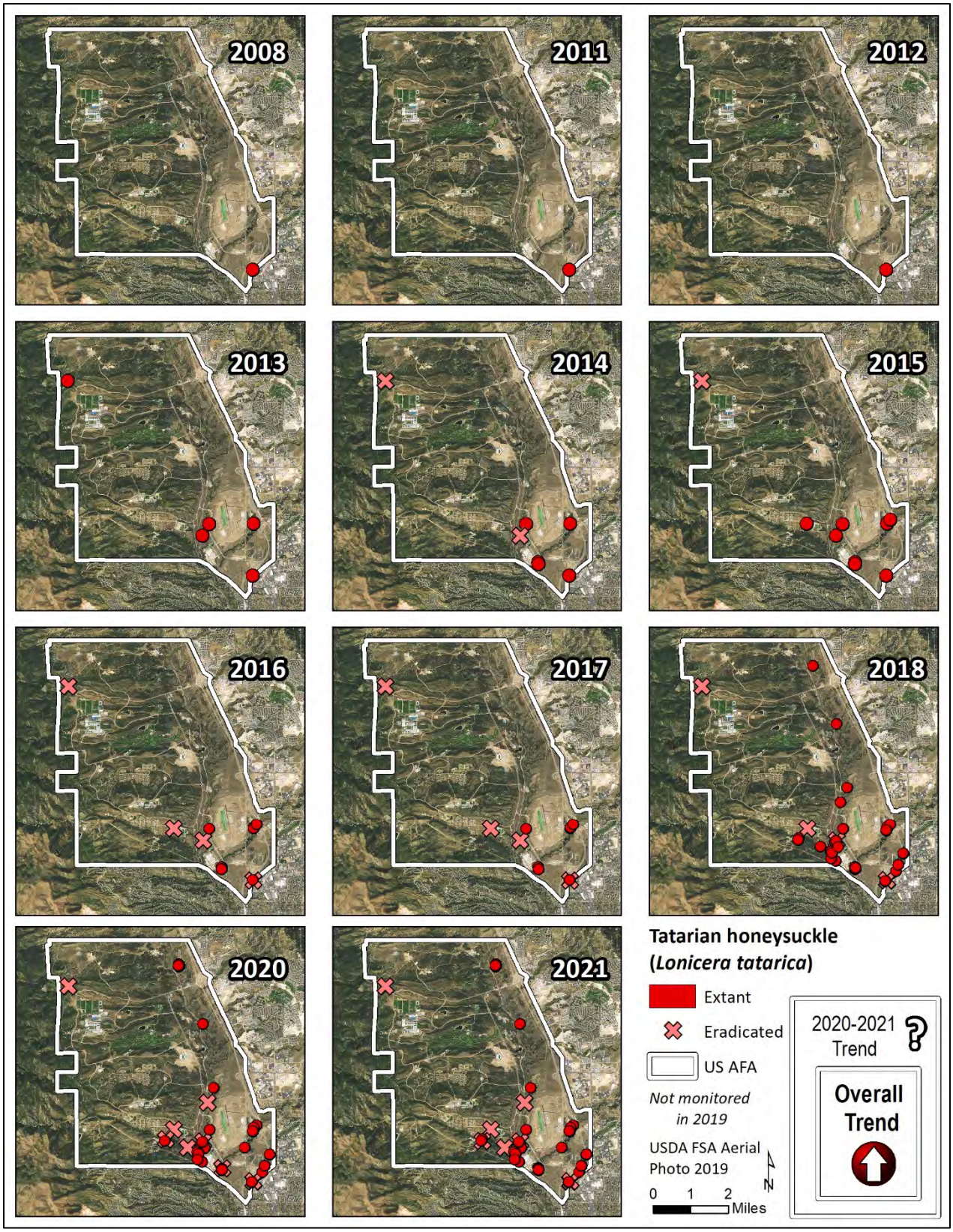
The management urgency for Tatarian honeysuckle is medium. Tatarian honeysuckle is a prolific seed producer but most of the plants found at the Academy are small trees or large shrubs and have been present for a number of years. Most of the increases are due to finding new occurrences of mature plants or sprouting individuals from known locations. When Tatarian honeysuckle is not flowering it is very easy to miss in surveys of dense vegetation. It does not appear to be highly invasive at the Academy. The Academy personnel have been conducting removal of Tatarian honeysuckle.

Recommendations for 2021:

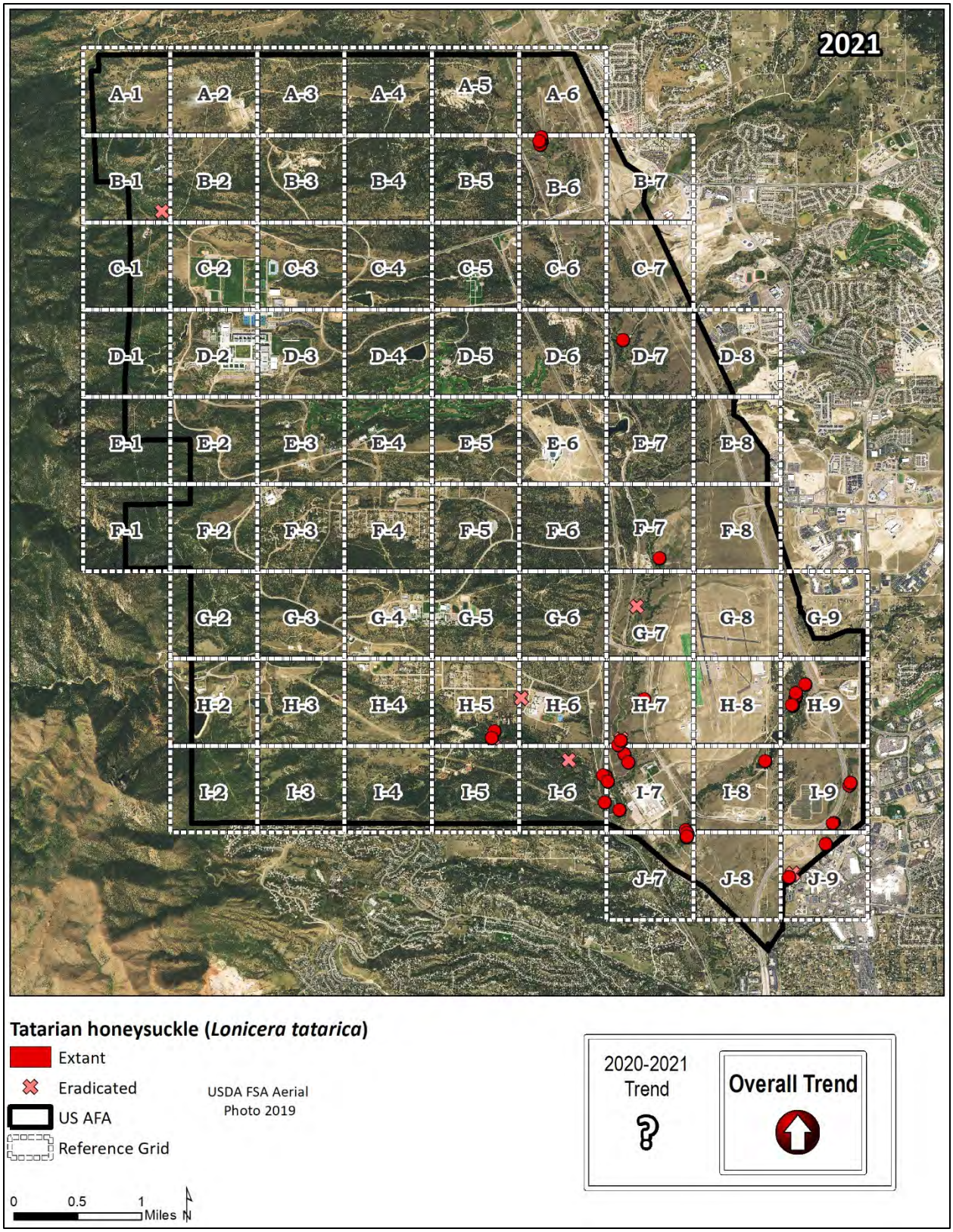
- Continue to incidentally monitor known sites in between basewide monitoring activities.

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. 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.
- In 2018, the basewide mapping shows an increase from one individual in 2012 to 35 in 2018. Some of the trees are mature and those don't reflect an increase. Some increases are sprouts that occur as a result of treatments.
- In 2019, Tatarian honeysuckle was not monitored.
- In 2020, 27 sites were visited with 85 individuals at 80 extant sites. No sites were visited East of I-25 along Pine Creek which included eight features with 31 individuals mapped in 2018.
- In 2021, 14 sites were visited while monitoring other higher priority noxious weeds in the vicinity. One new location was mapped with three individuals.



Map 23. Distribution of Tatarian honeysuckle at the Academy between 2008 and 2021.



Map 24. Distribution of Tatarian honeysuckle at the Academy in 2021 with the reference grid.

Scotch Thistle (*Onopordum acanthium*)

Trend 2020-2021: Moderately Increasing

Management Goals: Containment/Eradication

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-CSU 2016)

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

2021 Mapping Results

There was a moderate increase in the occupied acres, number of individuals and number of extant features at the Academy compared to 2020. Scotch thistle has been mapped at over 400 sites since 2002 and currently occupies an estimated 3.81 acres at the Academy. In 2021, 301 different sites were visited with 322 follow up visits and 21 new sites mapped. Higher precipitation in 2021 has likely contributed to the increase in this biennial species (Table 28, Figures 17 & 18, Maps 25 & 26).

A very large population of Scotch thistle in an area east of the Academy track (Grid C-3), sites east of I-25 and nine points scattered around the base at Grids B-6 (under bridge), C-4 (on the dam), D-5, E-5 golf course), G-7(1 eradicated site), I-7, I-8 (3 points on Kettle Creek) and H-6 (1 eradicated site) were not mapped in 2021.

Table 28. Mapping of Scotch thistle at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002†	0.17	52	7	0
2005	0.42	137	12	0
2007	1.31	1,307	36	0
2008	1.14	144	27	17
2009	3.47	1,710	50	34
2010	0.66	669	61	30
2011	0.64	293	39	56
2012	0.30	889	66	73
2013	?	970	48	85
2014	0.84	1,224	74	81
2015	1.60	1,629	157	76
2016	1.13	1,331	128	127
2017	1.35	791	120	155
2018	2.04	1,914	275	143
2019	2.35	3,137	290	135
2020	3.59	3,364	268	163
2021	3.81	3,859	276	172

Basewide weed mapping performed during shaded years. †2002 values from field notes, not adequately mapped in GIS

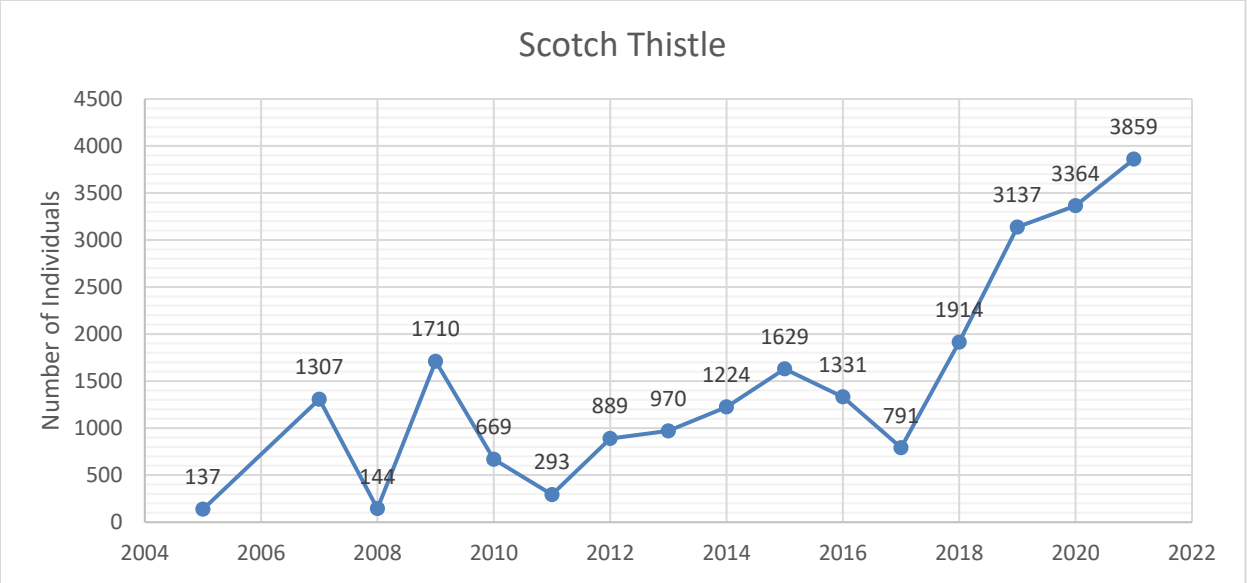


Figure 17. Number of Scotch thistle individuals, 2005-2021.

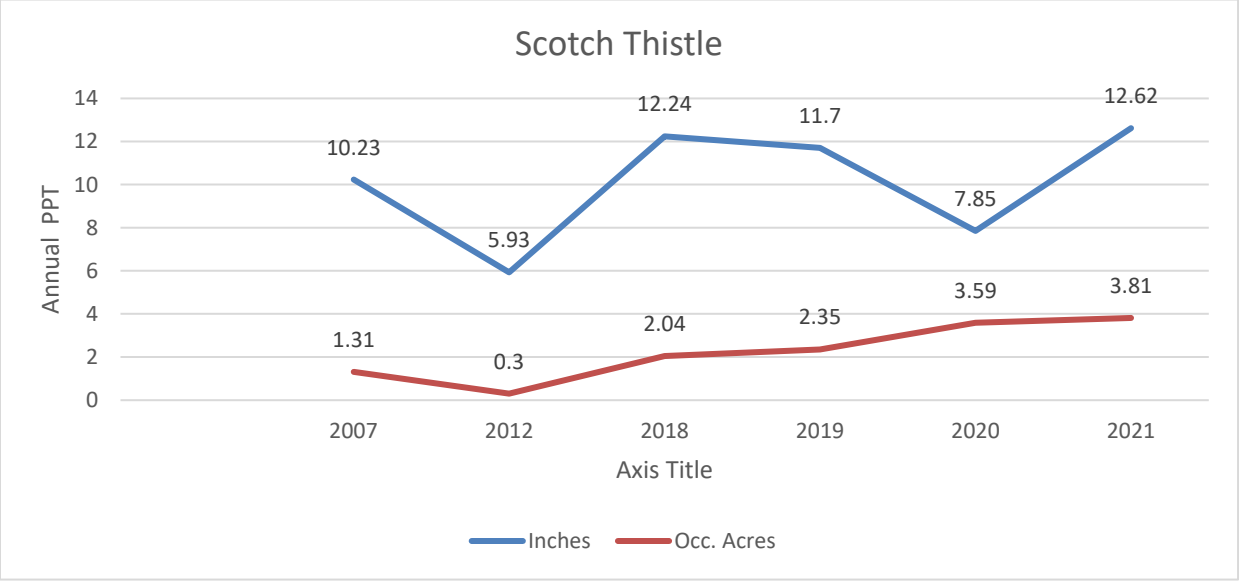


Figure 18. Comparison of annual spring-summer precipitation and occupied acres of Scotch thistle at the Academy, 2007-2021.

2021 Treatment

The cover of Scotch thistle at the Academy is the highest of all of the targeted weeds for manual treatments at just under four acres. The area with the largest number of individuals is east of the Academy track and it was not visited in 2021. This area could be targeted in the future but may need a restoration plan. Almost all other sites were visited and include a number of areas that were treated multiple times over the season (some beginning in 2019). In 2021, a total of 301 sites were visited with 148 extant sites containing 1,710 individuals for the first pass of the season. Some sites

contained just a few individuals while others contained up to several hundred. All rosettes encountered were pulled. Large plants post flower that had dropped their seeds (dead standing) were not removed. Over the summer we removed 6,662, plants which were largely rosettes with few bolted individuals, at a total of 623 site visits throughout the season. In 2021, there was a large increase in the number of treated / mapped individuals compared to 2020 and 2019. Much of the increase is likely due to higher spring precipitation received in 2021 and other conditions that support large sprouting events (Table 29). The majority of sprouts occurred in June and August (Tables 29, 30 & Figure 19). The removal of plants could also stimulate the seed bank by opening up and disturbing the soil.

Table 29. Monitoring and treatment of Scotch thistle sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	301	1,710	1,274	148	153
Pass 2	226	5,134	5,112	131	95
Pass 3	76	247	239	34	42
Pass 4	20	43	37	9	11
TOTALS	**623**	**7,134**	**6,662**	---	---

Table 30. Monitoring and treatment of Scotch thistle sites at the Academy in 2021 (by month).

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
April	260	1,062	627	119	141
June	163	3,612	3,581	98	65
August	152	2,163	2,153	78	74
September	47	297	287	26	21
TOTALS	**623**	**7,134**	**6,662**	--	---

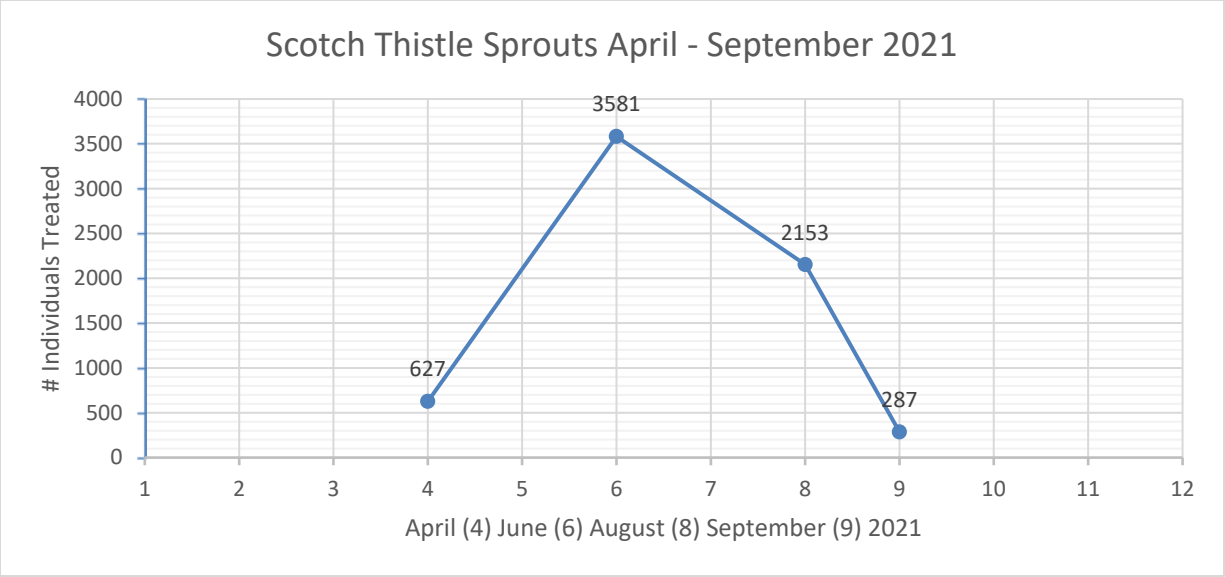
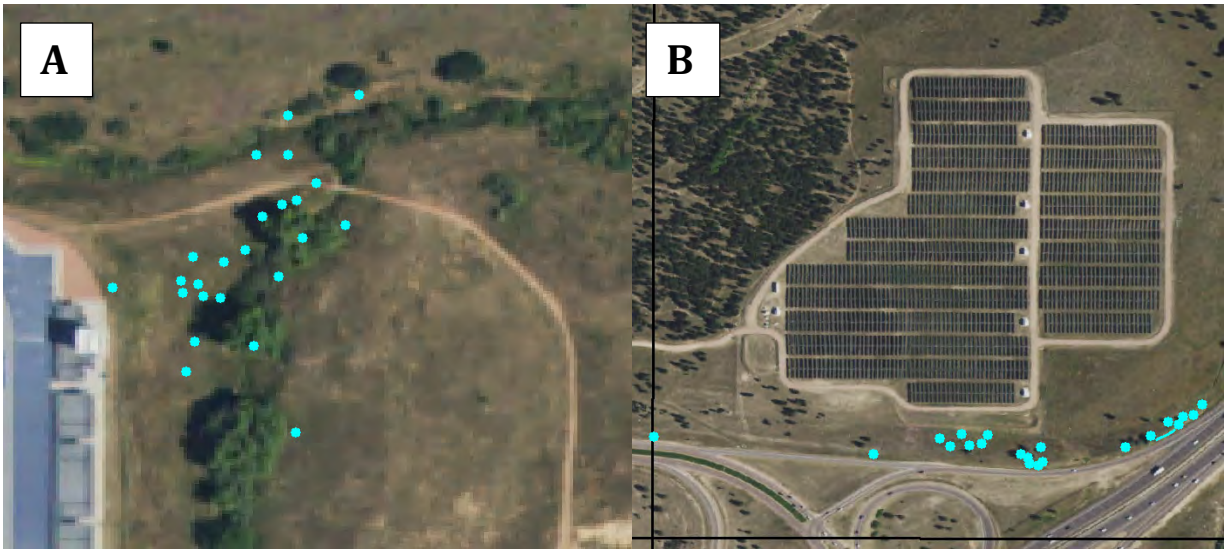


Figure 19. Number of Scotch thistle individuals April, June, August and September 2021.

In 2021, five areas of the Academy targeted for manual treatments included a small population close to the Academy track (and west of a very big population not mapped in 2021), a population just south of the solar arrays near I-25, and two populations near Ice Lake Road one at the intersection of Stadium and Pine Drive, east of the High School and a large population near the Dean's residence (Photos A-E). All these populations were treated multiple times during the 2021 growing season. The largest population (Photo E) surrounds the Dean's house, which has 116 sites that were visited twice with 4,184 individuals removed. Table 31 shows the comparison of treatments since 2019 for each of these five areas.



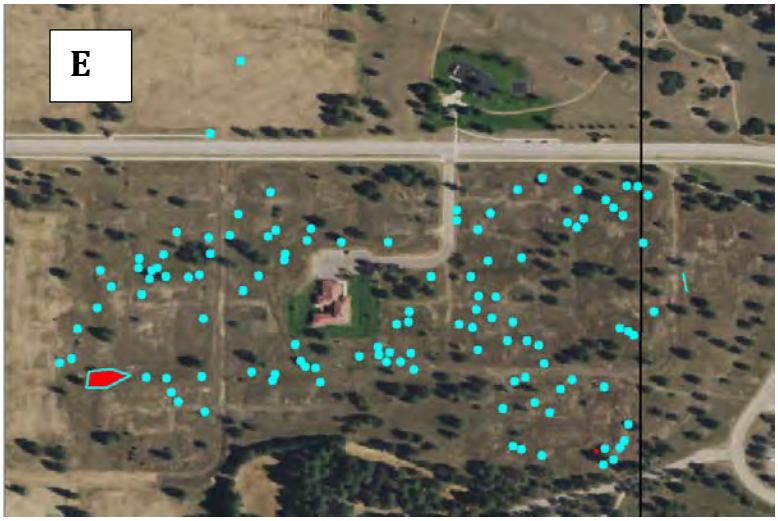


Table 31. Number of Scotch thistle individuals treated at 5 sites (A-E) at the Academy in 2021.

	Site	2019	2020	2021
Photo A	E of Academy Track Grid C-3	47	91	376
Photo B	S of Solar Array Grid I-9	139	144	180
Photo C	Stadium & Pine Drive Grid G-7	131	31	22
Photo D	E of High School Grids H-6 H-7	91	469	126
Photo E	Deans Residence Area	---	---	4,184

Recommendations

The management urgency for Scotch thistle is high since it is a biennial and reproduces only by seed. The cover at the Academy has reached a point where eradication is unlikely. Recommendations for treating Scotch thistle:

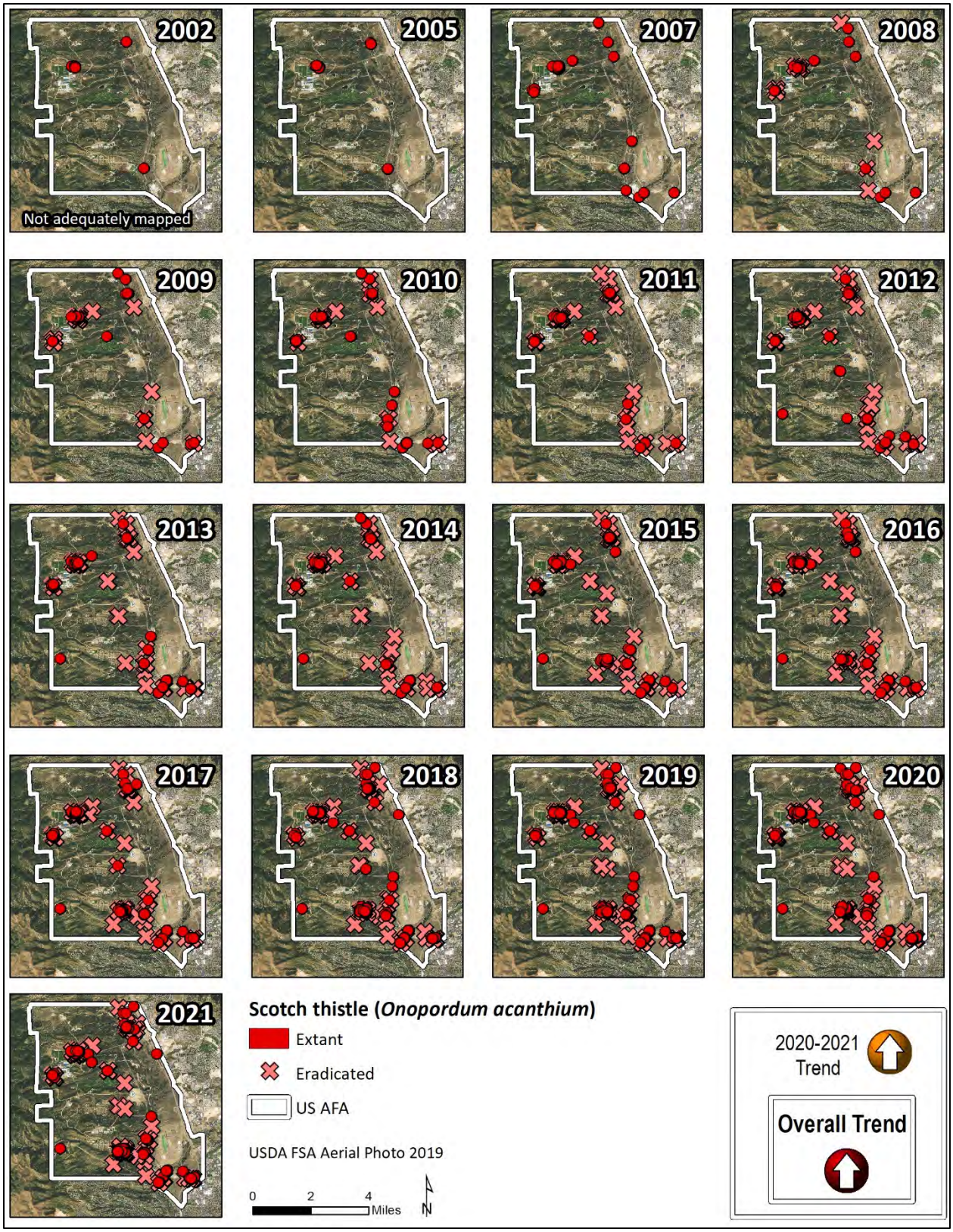
- Continue spring surveys to remove as many Scotch thistle rosettes as possible.
- Revisit as many sites as possible throughout the growing season to remove plants before seeds set and before the plants get to a large size.

Seeds are the only way this species reproduces, so preventing plants from going to seed and removing sprouts throughout the growing season should yield decreases. A single plant can result in hundreds of new plants the following season. For example, in 2018, seven weed points with a total of 51 individuals (untreated) had 300 plants the following year. The key is removal of rosettes throughout the growing season as they sprout, with the goal of having no seed production. The smaller the rosettes are when they are treated the less soil disturbance. Bolted individuals are the most difficult to treat effectively and viable seeds can still be produced (Photo 9). Seed longevity is noted as 7- 20 years (CDA-CSU 2016).

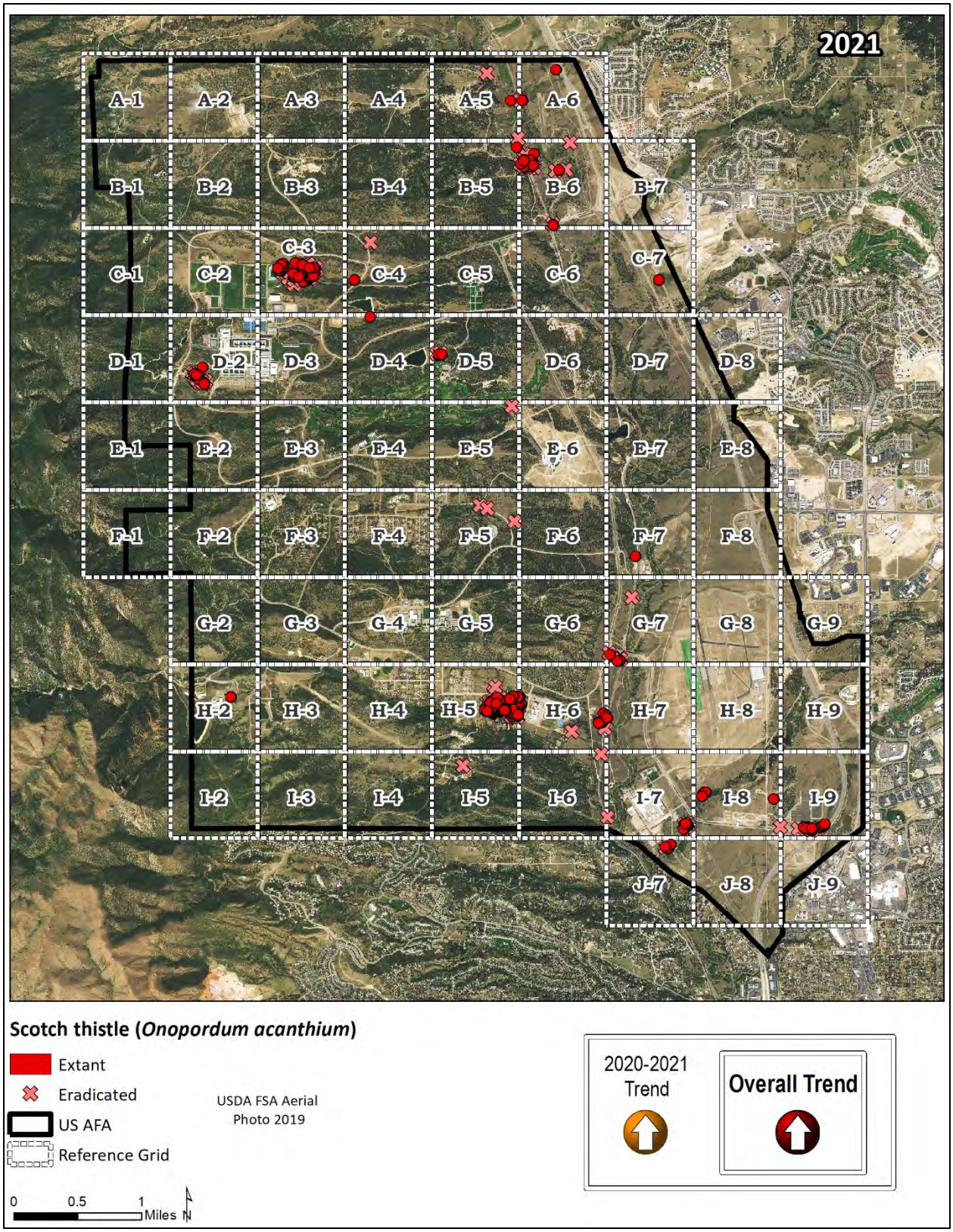
Photo 9. Bolted heads of treated Scotch thistle with houndstongue and cheatgrass. P. Smith 2015

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.
- 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 fewer individuals were observed.
- In 2018, the basewide mapping showed 275 extant sites with almost 2,000 individuals observed.
- In 2019, Scotch thistle continues to increase with 290 extant features and 3,137 individuals mapped.
- In 2020, there were 296 sites visited with half of the sites eradicated. Scotch thistle continues to increase across the base with new locations in newly disturbed areas.
- In 2021, Scotch thistle increased in numbers of individuals, cover and number of sites. Higher spring-summer precipitation and other conditions resulted in numerous sprouts throughout the season.



Map 25. Distribution of Scotch thistle at the Academy between 2002 and 2021.



Map 26. Distribution of Scotch thistle at the Academy in 2021 with the reference grid.

Bouncingbet (*Saponaria officinalis*)

Trend 2020-2021: Stable

Management Goals: Eradication

State List: B

- Perennial
- Self-fertile
- Reproduction from seeds
- Colony former
- Blooms summer-fall
- Seed longevity is unknown (CDA-CSU 2019a)

Photo: ct.botanicalsociety.org

Photo: Leaves of mature plant, missouristate.edu

2021 Mapping Results

In 2021, bouncingbet populations are stable with an estimated 2,236 individuals at 31 features. Four new features and 11 eradicated features were mapped in 2021 at the Academy (Table 32, Figure 20, Maps 27 & 28). Of the 42 known sites, 26 were visited in 2021 by CNHP.

Table 32. Mapping of bouncingbet at the Academy.				
	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	?	?	1	0
2007	---	---	---	---
2012	---	---	---	---
2013	0.50	42,092	8	0
2014	0.14	42	2	6
2015	0.09	608	8	5
2016	0.05	535	8	6
2017	0.05	401	6	8
2018	0.17	4,585	26	8
2019	0.24	4,063	29	8
2020	0.20	2,337	24	14
2021	0.26	2,236	31	11

Basewide weed mapping performed during shaded years.

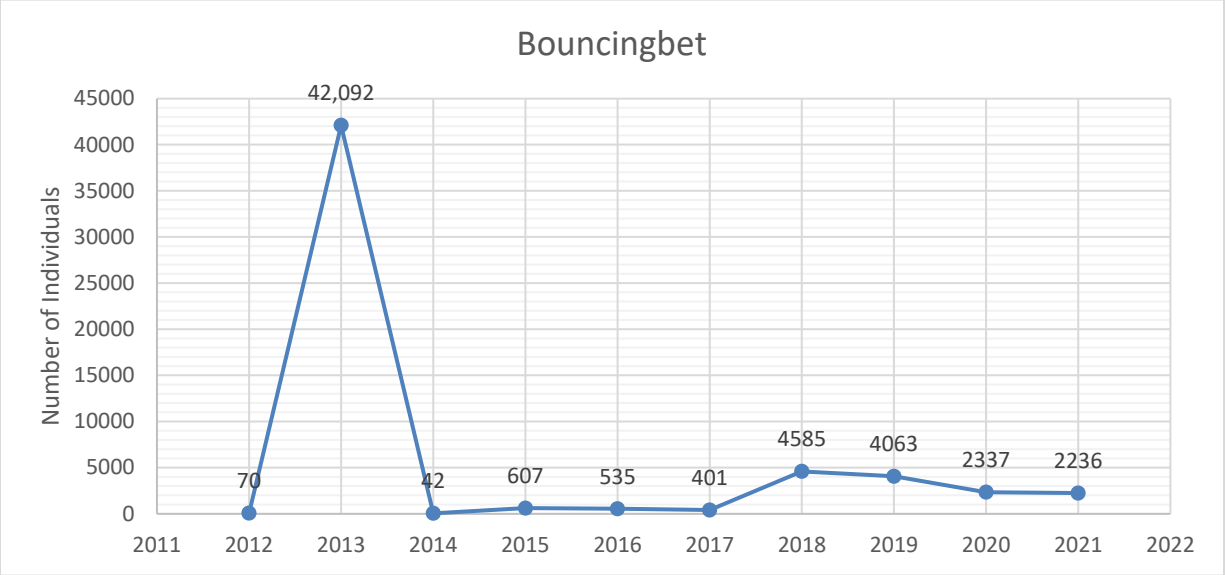


Figure 20. Number of bouncingbet individuals, 2012-2021.

2021 Treatment

In 2021, 26 mapped bouncingbet features were visited for monitoring and treatment. Of those, there were 898 individuals mapped and treated at 19 extant features (Table 33). Of the 26 sites visited in 2021, 15 were also visited in 2020. A comparison between these points showed a decrease in number by 179 individuals from 2020 to 2021.

Table 33. Monitoring and treatment of bouncingbet sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	26	856	898	19	7
Pass 2	2	2	2	1	1
Pass 3	1	40	40	1	0
Total	**29**	**898**	**898**	---	---

Recommendations

Management urgency for bouncingbet is considered to be medium. Recommendations for bouncingbet:

- Continue to monitor all known sites.
- Protect native vegetation in the vicinity of the plants.
- Remove reproductive parts to prevent seed production.

Flooding has removed at least 60 individuals in 2019 along Monument Creek from beaver activity. Wildlife continue to graze the flower tops. One of the most interesting observations for 2016 through 2021 is that flower tops and buds are significantly browsed by ungulates (Photo 10).

Photo 10. Browsed bouncingbet flower tops in 2016. P. Smith

While herbicides appear to be suppressing bouncingbet for a few years, many areas re-sprout due to the deep root system of this perennial species. Cheatgrass (List C) and smooth brome (a rhizomatous non-native grass) are common in many areas with bouncingbet (Photo 11). This needs to be considered when treating this species. Annual precipitation, seed bank and soil disturbances are contributing factors that may influence populations of bouncingbet.

Photo 11. Bouncingbet herbicide treatment area with bouncingbet and cheatgrass in in drainage area. P. Smith 2016.

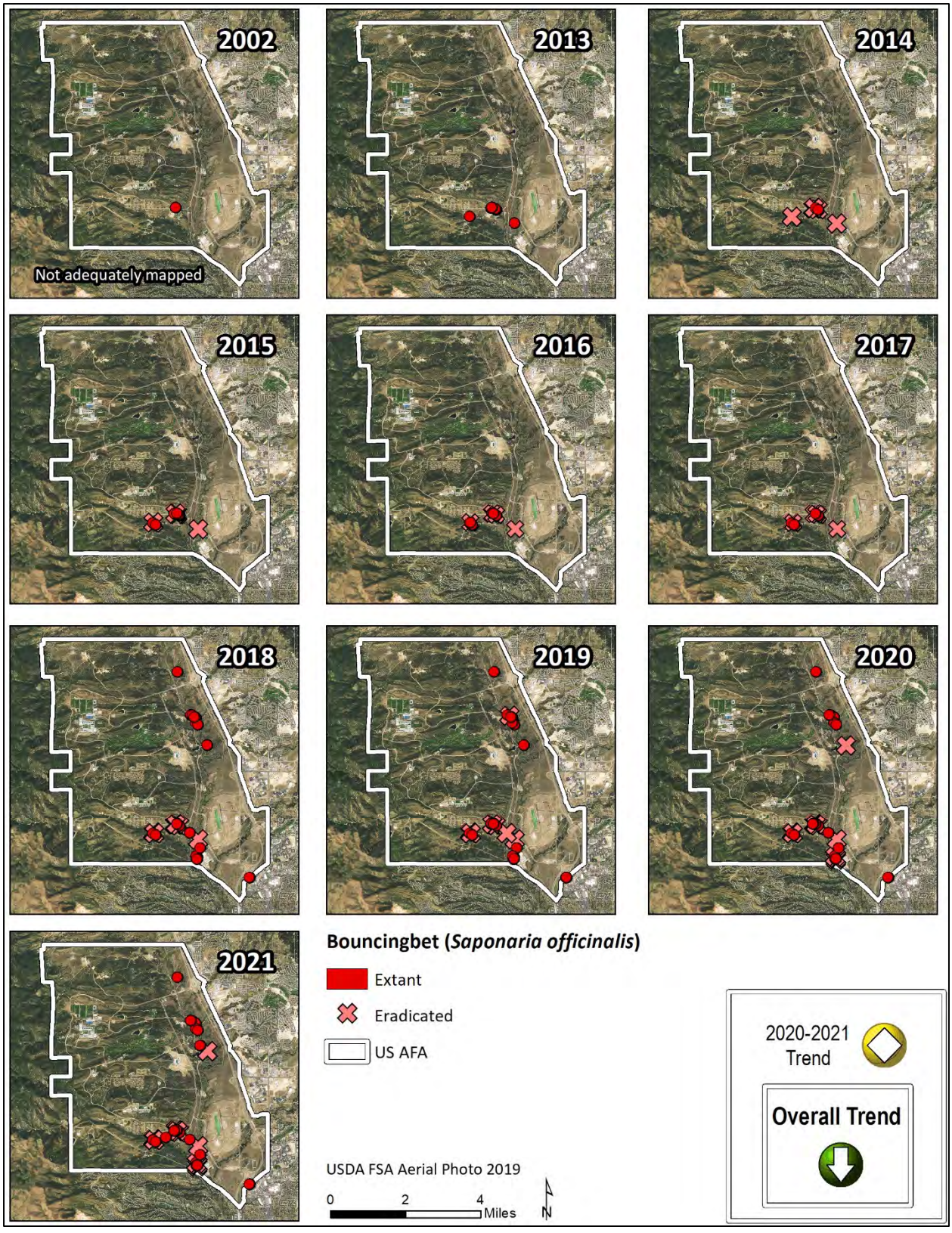
Bouncingbet also occurs in dense vegetation along the floodplains of Kettle and Monument Creeks. The dense growth and steep terrain are both obstacles to treatments. Most treatments result in vegetative growth from the deep root system (CDA-CSU 2019a). There are no recommendations for herbicide or mechanical treatments alone. In addition, there are no herbicides recommended for treating bouncingbet in wildlands**,** only recommendations for rangelands and pastures (CDA-CSU 2019a). Leaving as much native vegetation as possible is likely the best defense from keeping bouncingbet from spreading. Treatments that leave open bare soils are not recommended.

History of Sampling and Treatment:

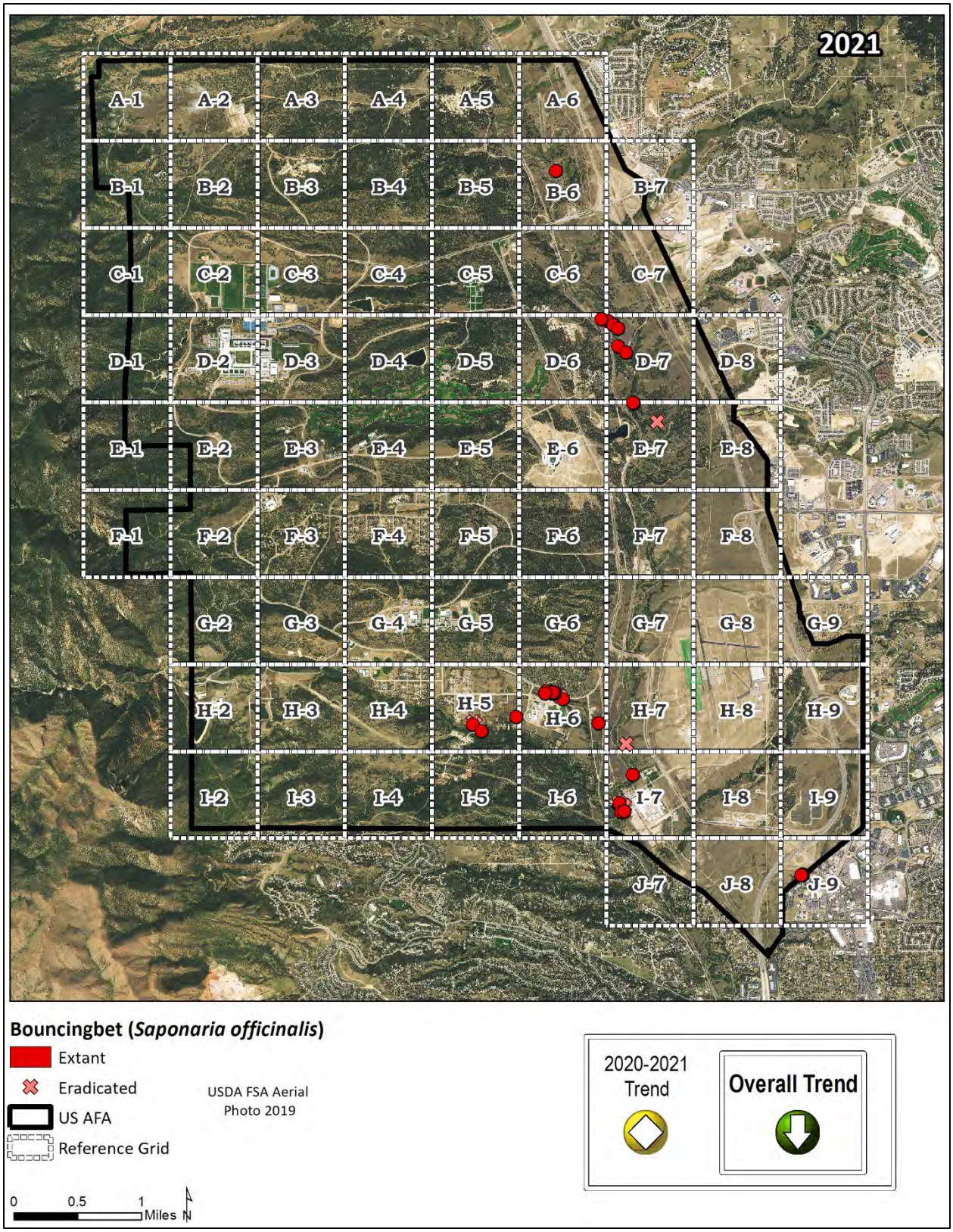
- Bouncingbet was mapped at one location in 2002 and not surveyed again until 2013.
- In 2013, three distinct areas were mapped, but distribution was still localized.
- The westernmost infestation was huge, representing almost 40,000 individuals.
- The 2013 locations were treated by the Academy.
- In 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.
- The first year for basewide mapping for bouncingbet is 2018. The data show an overall decrease since it was first mapped in 2013, with an increase in mapped features.
- In 2019, there was an increase in mapped features and a decrease in number of individuals.
- In 2020, there was a decrease from 2019 in numbers of individuals, occupied acres and an increase in eradicated sites. The very dry conditions of 2020, shoreline flooding and perhaps continuous removal of reproductive parts have contributed to the decrease.
- In 2021, we estimate bouncingbet is decreasing. Not all sites were visited in 2021.



Map 27. Distribution of bouncingbet at the Academy between 2002 and 2021.



Map 28. Distribution of bouncingbet at the Academy in 2021 with the reference grid.

Salt Cedar (*Tamarix ramosissima*)

Trend 2020-2021: Stable

Management Goals: Eradication, Rapid Response

State List: B

- Tall shrub or small tree
- Reproduction by roots, submerged stems and seeds
- Flowers April-September
- Sprouts if stumps are cut
- Seed longevity is short <1 year (CWMA 2020e)
- Provides habitat for nesting birds (USFS FEIS 2016)

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

2021 Mapping Results

In 2021, only one extant location of salt cedar was mapped out of two sites visited by CNHP. The population is thought to be stable at the Academy. There are a total of 10 known occurrences at the Academy: eight were not visited in 2021, four on the south side of the airport, one along Monument Creek floodplain (Grid F-7, Map 30), two south and west of the parking lots off of Park Drive (Grids I-7, J-7 Map 30) and one on the east of I-25 (Grid I-9, Map 30); all are thought to be extirpated (Table 34, Maps 29 & 30). The only extant feature is located along a roadside in Jack's Valley West and has been there for many years. It has been manually treated by Academy staff but continues to re-sprout. This species has a very high likelihood of being eradicated.

Table 34. Mapping of salt cedar at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	<0.01	1	1	0
2007	<0.01	1	1	1
2008	0	0	0	1
2009	<0.01	2	2	3
2010	0	0	0	5
2011	<0.01	1	1	4
2012	<0.01	1	1	4
2013	<0.01	1	1	5
2014	<0.01	1	1	6
2015	.03	6	4	5
2016	<0.01	1	1	8
2017	<0.01	1	1	8
2018	0.01	2	2	8
2019	<0.01	1	1	9
2020	<0.01	1	1	9
2021	<0.01	1	1	9

Basewide weed mapping performed during shaded years.

2021 Treatment

In 2021, two sites were visited and one extant occurrence was located with one individual. This species is treated by Academy staff (Table 35).

Table 35. Monitoring and treatment of salt cedar sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	2	1	0	1	1
Total	2	1	0	---	---

Recommendations

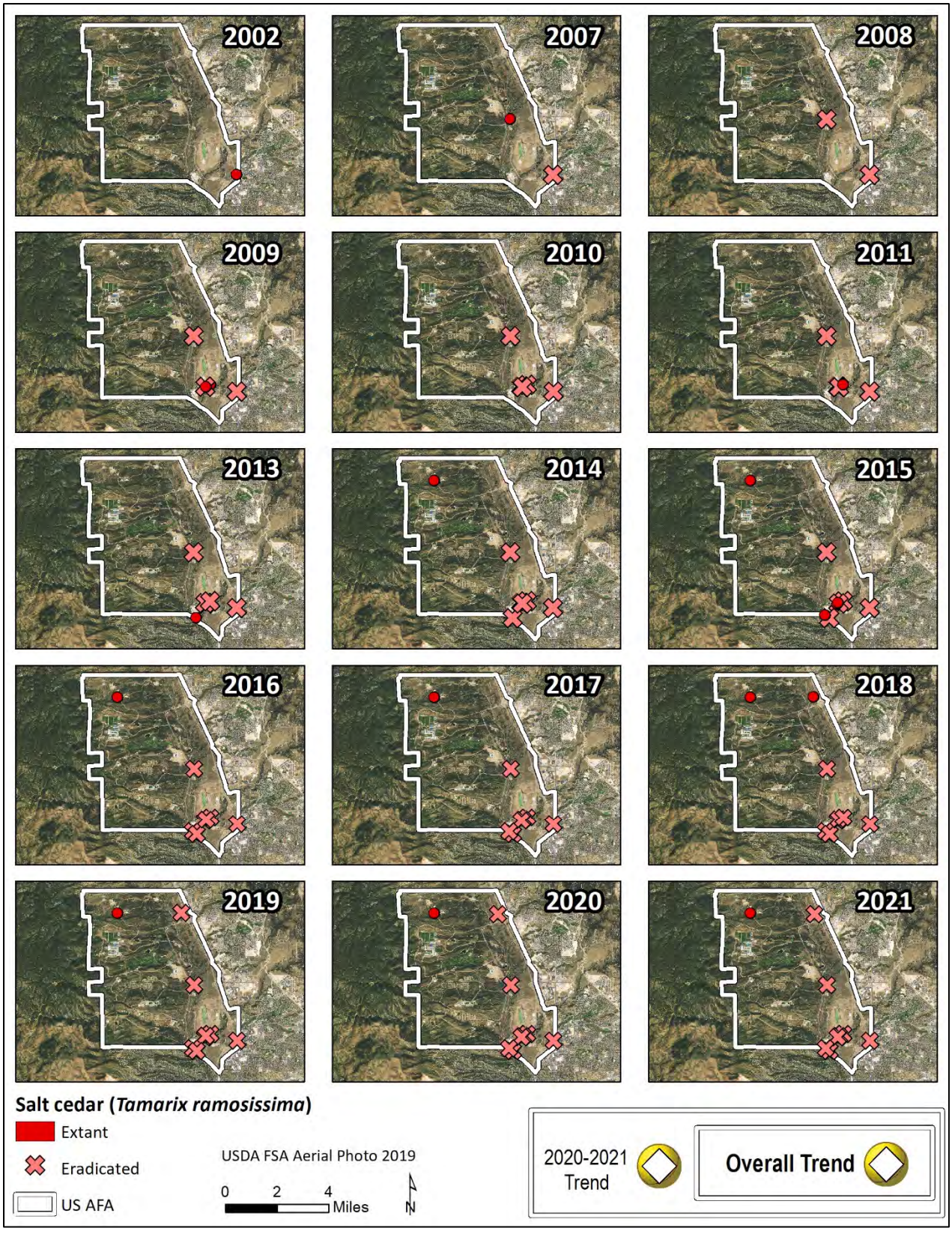
Management urgency for salt cedar is considered to be high due to low cover and high potential for eradication. Recommendations for salt cedar:

- Continue to monitor known sites.
- Be on the lookout for salt cedar in ditches, drainages and floodplains.

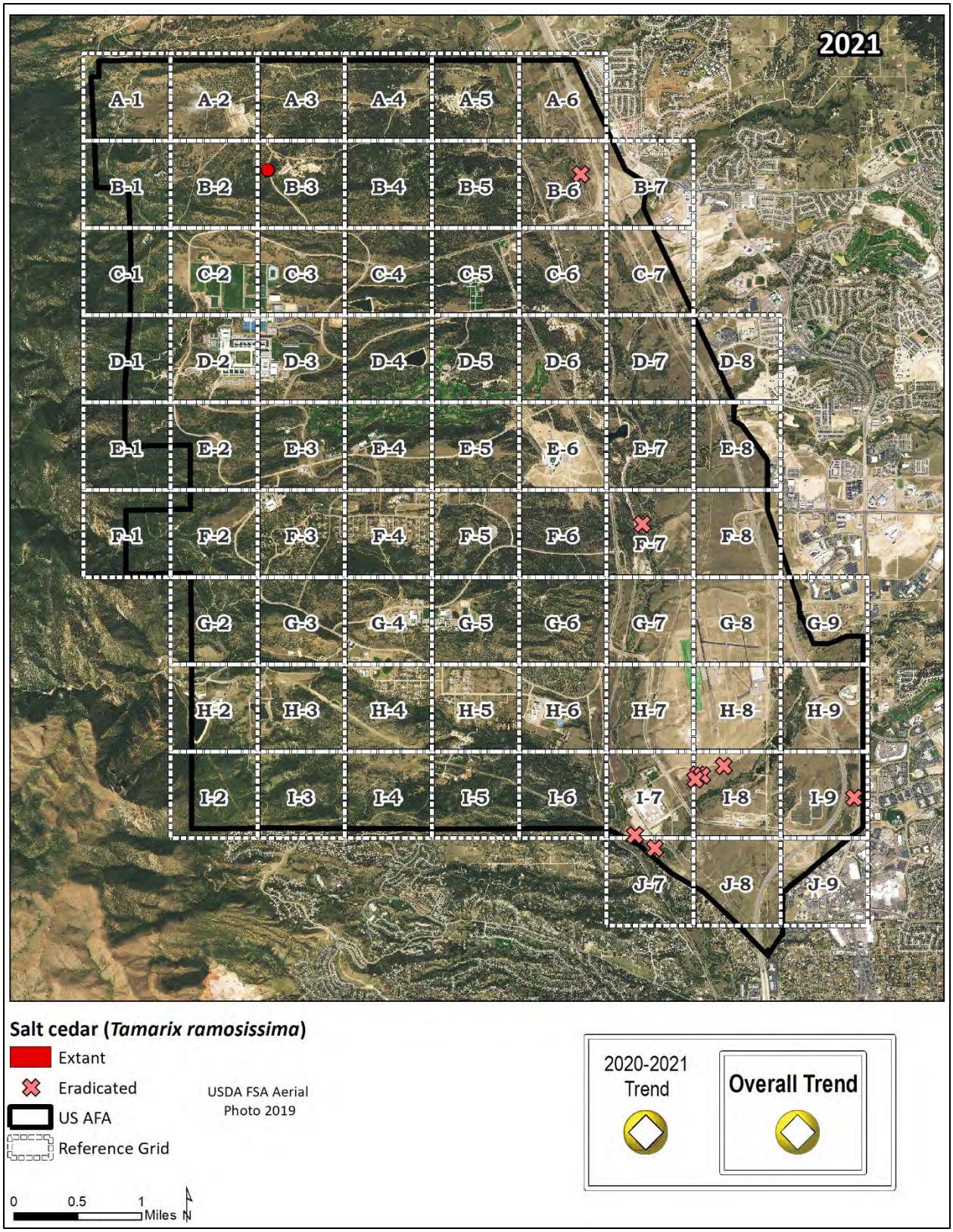
The Academy is treating the only known extant site using a cut stump with herbicide method recommend for salt cedar. For this method to be effective, plants are cut as close to the ground as possible (within 5 cm). According to Colorado Natural Areas BMPs for salt cedar, herbicide should be applied immediately (within seconds) to the cut as the wound will heal quickly and decrease the amount of herbicide 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 (CPW 2013). Staff and contractors monitor eradicated sites as well as ditches, drainages and riparian areas for new occurrences at the Academy.

History of Sampling and Treatment:

- Salt cedar was known from five separate sites between 2002 and 2013.
- 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.
- In 2018, two extant locations of salt cedar were mapped, each with a single individual. Natural Resource Managers pulled them in 2018.
- In 2019, there was only one extant location of salt cedar.
- In 2020, only one extant location was observed out of five sites visited. The five sites not visited were located along the south side of the airfield and one east of I-25, all did not have plants present in 2019.
- In 2021, one extant feature was located out of two sites visited.



Map 29. Distribution of salt cedar at the Academy between 2002 and 2021.



Map 30. Distribution of salt cedar at the Academy in 2021 with the reference grid.

Common Tansy (*Tanacetum vulgare*)

Trend 2020-2021: Decreasing

Management Goals: Eradication, Rapid Response

State List: B

- Perennial, woody forb
- Reproduction by seed, some vegetative
- Flowers June-September
- Escaped ornamental
- No long distance wind dispersal appendages, plants stay close to parents
- Seed longevity in soil is thought to be short 2 years (CDA-CSU 2019b)
- Seeds viable on dried heads to three years (White 1997)

Common tansy at the Academy in 2020. P. Smith

Photo (left) Common tansy with close-up of flowers and leaves. Minnesota Department of Agriculture

2021 Mapping Results

Common tansy (List B noxious weed) was added to the weed list at the Academy in 2020. Common tansy has decreased at the site with 15 individuals in 2020 and only one individual for the first visit in 2021 (Table 36, Maps 31 & 32).

Table 36. Mapping of common tansy at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	<0.01	0	0	0
2007	<0.01	0	0	0
2012	<0.01	0	0	0
2018	<0.01	0	0	0
2020	<0.01	15	1	0
2021	<0.01	1	1	0

2021 Treatment

In 2021, one sprout was found and treated in the spring followed by four more during the season (Table 37). All tops of the plants and as much of the extensive underground root system were removed. The root system produced sprouts in April, August and September in 2021.

Table 37. Monitoring and treatment of common tansy sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	1	1	1	1	0
Pass 2	1	3	3	1	0
Pass 3	1	1	1	1	0
TOTALS	**3**	**5**	**5**	---	---
2020	**1**	**15**	**0**	---	---
2019	**---**	**---**	**---**	---	---

Recommendations

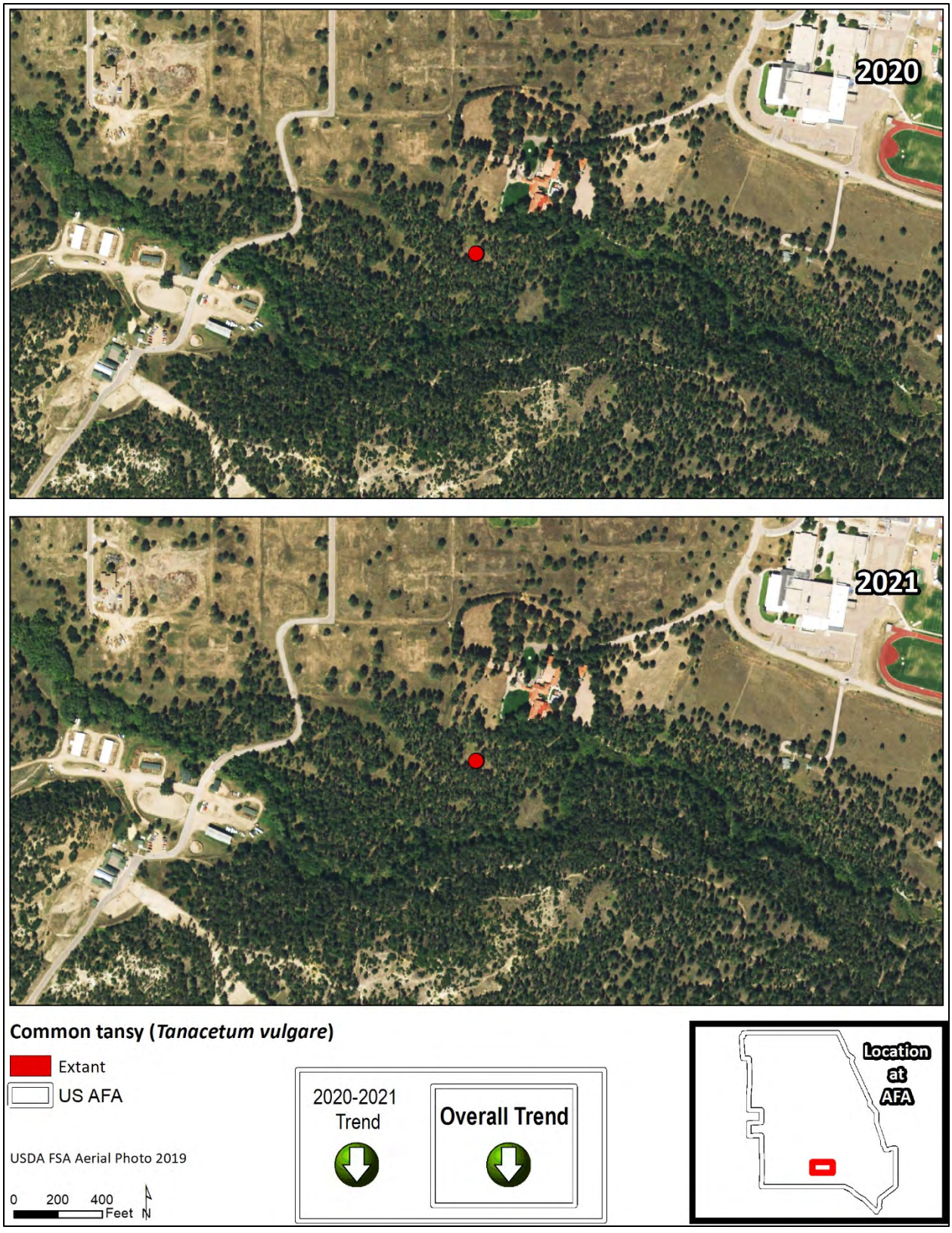
Management urgency for common tansy is considered to be high due to low cover and high potential for eradication. Recommendations for common tansy:

- Continue to monitor and treat all known sites.
- Remove as much of the root system as possible, limiting soil disturbance.
- Remove all sprouts, flower heads and seeds from the site.
- Consider monitoring or talking to people who manage residences about where they put yard waste and potentially invasive species they might be planting.

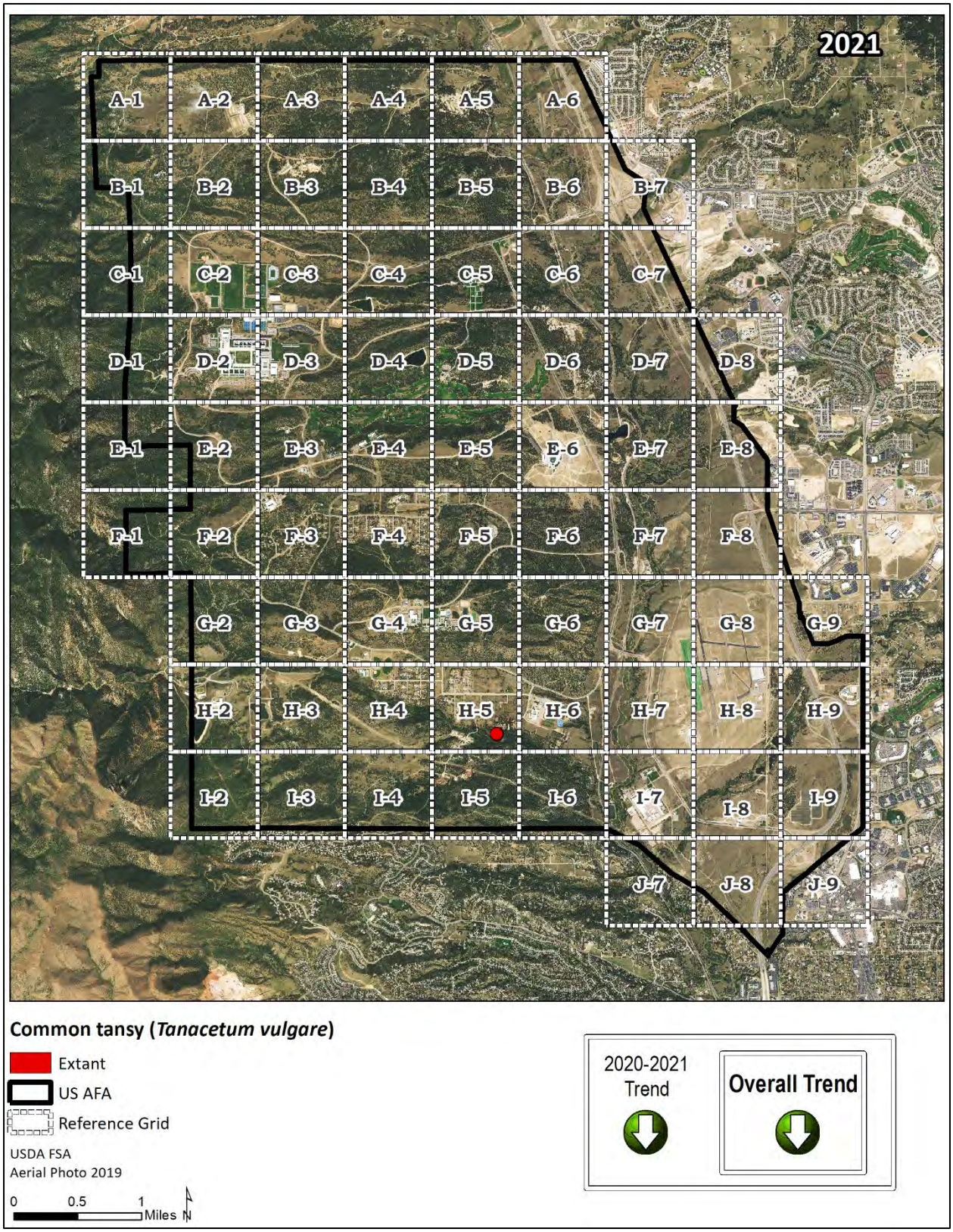
Common tansy has an extensive root system but most of the reproduction is from seeds. The seeds have a relatively short longevity (2-3 years) and efforts to prevent flowering and the removal of sprouts and roots should result in successful treatments (CDA 2019b, White 1997). The site where common tansy was located is also where a number of garden escape species have been observed. The area is downslope of residences with manicured lawns/gardens that have been discarding yard waste into the drainage and where seeds and plant fragments have likely been transported off these properties during rain or snow melt into the West Monument Creek drainage. Contacting the residents is recommended as some of the species have been quite invasive at the Academy and include garlic mustard and yellow spring bedstraw. Hoary alyssum (CDA Watch List Noxious Weed) has also been observed there along with non-native shrubs and grasses found on manicured properties.

History of Sampling and Treatment:

- In 2020, common tansy was added to the monitoring list for the Academy.
- In 2021, sprouts and underground roots were manually treated throughout the growing season.



Map 31. Distribution of common tansy at the Academy in 2021.



Map 32. Distribution of common tansy at the Academy in 2021 with the reference grid.

Scentless Chamomile (*Tripleurospermum (inodorum) perforatum*)

?

Trend 2019-2020: Unknown (Overall Increasing)

Management Goals: Rapid Response – Kettle Creek, Containment - Monument Creek

State List: B

Photo: Pam Smith, Kettle Creek, July 2016

- Annual, biennial to short-lived perennial
- Seedlings emerge in the spring, flowers June-October
- 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 2020f)

2021 Mapping Results

This species is widespread in Monument Creek with a total of 120 known sites. It is estimated that there are 102 extant features that include 2,599 individuals and 18 eradicated sites that occupy an estimated 0.39 acres based on data from 2020, 2021 and basewide mapping in 2018 (Table 38, Maps 33 & 34). Kettle Creek was where Scentless chamomile was first observed at the Academy in 2016, and it has not been observed there since 2019.

Table 38. Mapping of scentless chamomile at the Academy.

	Occupied Acres	Estimated # of Shoots	# of Extant Features	# of Eradicated Features
2002	---	---	---	---
2007	---	---	---	---
2012	---	---	---	---
2016	<0.01	2	1	0
2017	<0.01	1	1	1
2018	0.41	2,530	117	2
2019	0.42	2,525	116	3
2020	0.40	2,462	112	8
2021	0.39	2,599	102	18

Basewide weed mapping performed during shaded years.

2021 Treatment

In 2021, 18 features were visited and 80% were eradicated with 251 individuals removed from the remaining extant sites visited along Monument Creek (Table 39).

Table 39. Monitoring and treatment of scentless chamomile sites at the Academy in 2021.

	# Site Visits	# Shoots Mapped	# Manually Treated Shoots	# Sites with Plants	# Sites without Plants
Pass 1	18	251	251	4	14
Total	**18**	**251**	**251**	**---**	**---**

Recommendations

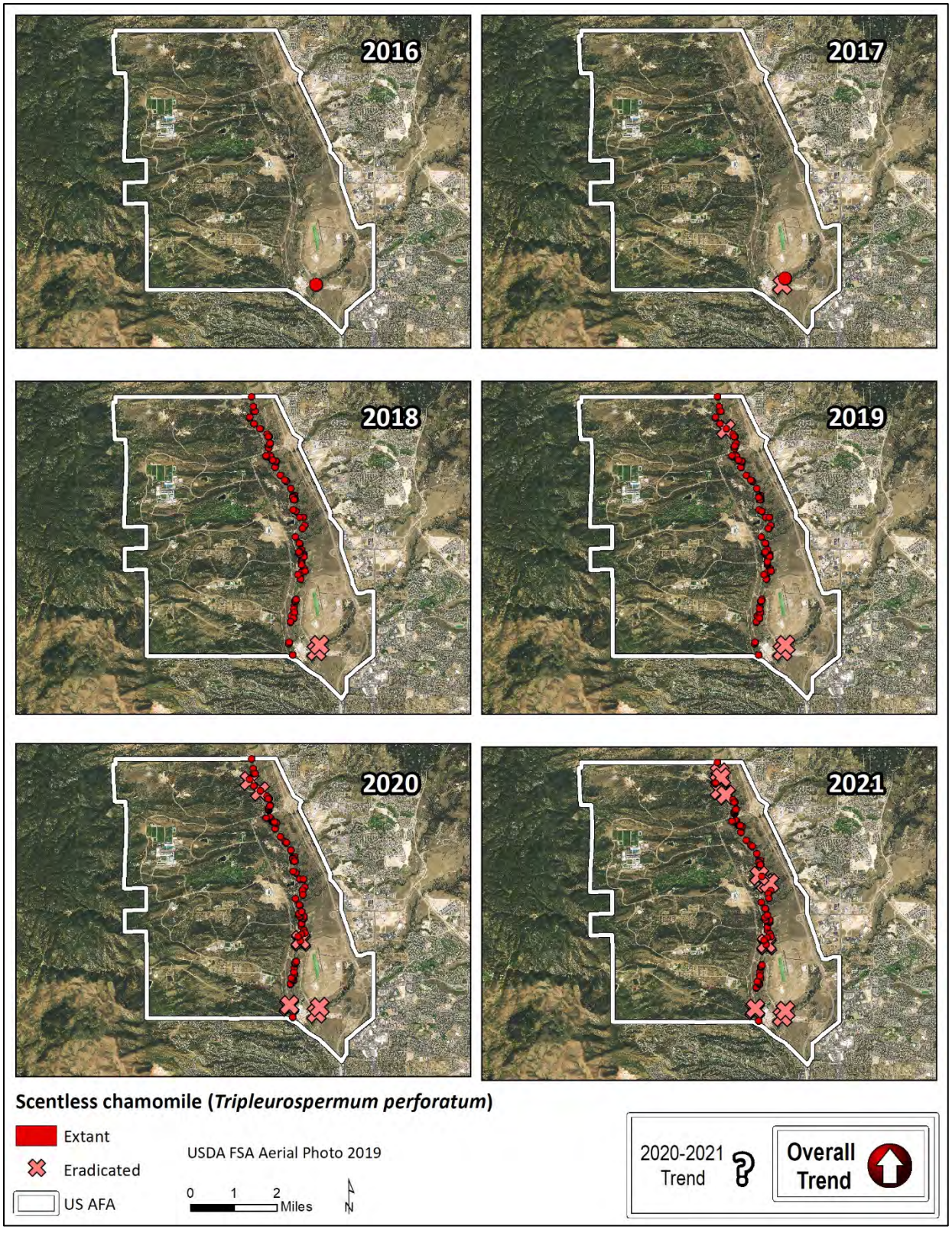
Management urgency for scentless chamomile is considered to be high for Kettle Creek and medium for Monument Creek. Recommendations for scentless chamomile:

- Continue to monitor Kettle Creek for new occurrences of scentless chamomile.
- Consider a new strategy for Monument Creek.

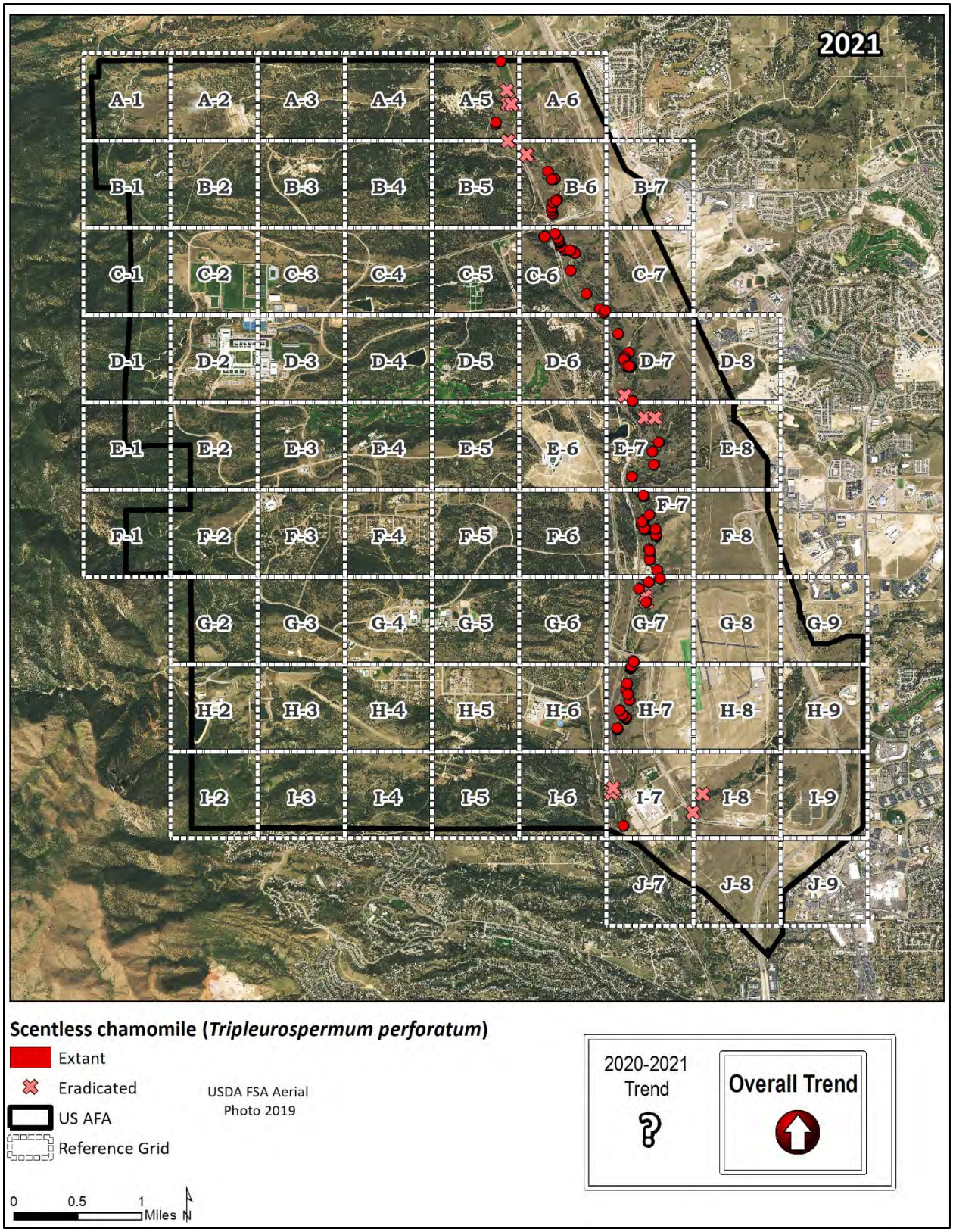
In 2021, we hoped to visit many more sites than we did in 2020. We had discussed moving plants out of the drainage with Natural Resources instead of trying to carry them back for disposal. However, the Monument Creek floodplain is very large in many areas. Carrying the large biomass out of the drainage across densely vegetated floodplains became impractical. In addition, considering the frequent and extremely flashy flooding cycles it would be difficult to remove the seed sources of the pulled plants out of the local watershed. These characteristics, along with approximately six linear miles of floodplain and at least 120 known locations make control or treatment a very large undertaking. In addition, inputs from upstream that likely supply a continuous flow of scentless chamomile seeds combined with the continuous flooding disturbances may make it impractical and perhaps futile to put large efforts into treating this species.

History of Sampling and Treatment:

- The first observation of scentless chamomile was in 2016 at the Academy. It was also a county record for El Paso County. 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.
- In 2018, the first basewide mapping for noxious weeds was conducted since scentless chamomile had been discovered in 2016. Over 2,500 plants were mapped along Monument Creek and none were mapped on Kettle Creek where it was originally found.
- In 2019, it was apparent there were too many plants along Monument Creek to consider eradication as a goal. Kettle Creek and all other small drainages should still be targeted for rapid response activities. For Monument Creek, restoration and planting of native species may be the only way to control on scentless chamomile.
- In 2020, we visited only a portion of the known sites (23 sites) to monitor previously treated areas to see if the plants were returning. We found that eight of the sites had remained free of plants for one or more growing seasons. A plan to coordinate efforts with the Academy staff will be implemented to remove more scentless chamomile plants along Monument Creek in 2021 and to carefully monitor other drainages at the Academy.
- In 2021, we visited 18 sites with hopes of treating many more sites. The treatments along Monument Creek need to be re-evaluated at the spring meeting in 2022.



Map 33. Distribution of scentless chamomile at the Academy between 2016 and 2021.



Map 34. Distribution of scentless chamomile at the Academy in 2021 with the reference grid.

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APPENDIX A. SUMMARY OF MONITORING ACTIVITIES BY SPECIES AT THE ACADEMY SINCE 2002

Monitoring activities (not necessarily mapping) are indicated by brown shading. M = mapped, PM = partially mapped, * indicates year discovered.

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Russian knapweed (*Acroptilon repens)*			M*	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Garlic mustard (*Alliaria petiolata*)																	M*	M	M	M
Siberian peashrub (*Caragana arborescens)*											M						M			
Hoary cress (*Cardaria draba)*	M	M				M					M						M			
Musk thistle (*Carduus nutans)*	M					M					M						M			
Diffuse knapweed (*Centaurea diffusa)*	M					M					M						M			
Diffuse / spotted knapweed hybrid (*C.* x *psammogena*)				M*		M					M						M			

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Spotted knapweed (*Centaurea stoebe)*	M			M	M	M					M						M			
Canada thistle (*Cirsium arvense*)	M					PM					M						M			
Bull thistle (*Cirsium vulgare*)	M					M					M						M			
Field bindweed (*Convolvulus arvensis*)	M					M														
Houndstongue (*Cynoglossum officinale*)								M*	M	M	M	M	M	M	M	M	M	M	M	M
Common teasel (*Dipsacus fullonum*)	M					M					M						M			
Russian olive (*Elaeagnus angustifolia*)	M	PM		PM		M					M						M			
Leafy spurge (*Euphorbia esula*)	M					M					M						M			
Myrtle spurge (*Euphorbia myrsinites*)				M*	M	M		M	M	M	M	M	M	M	M	M	M	M	M	M
Yellow spring bedstraw (*Galium verum*)									M*	M	M	M	M	M	M	M	M	M	M	M

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dame's rocket (*Hesperis matronalis*)											M*		PM	M	PM		M	PM	PM	PM
Orange hawkweed (*Hieracium aurantiacum*)																	M*	M	M	M
Common St. Johnswort (*Hypericum perforatum*)	M			M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Perennial pepperweed *(Lepidium latifolium)*																	M*	M	M	M
Oxeye daisy (*Leucanthemum vulgare*)																		M*	M	M
Dalmatian toadflax (*Linaria dalmatica*)								M*	M	M	M	M	M	M	M	M	M	M	M	M
Yellow toadflax (*Linaria vulgaris*)	M					PM					PM						PM			
Tatarian honeysuckle (*Lonicera tatarica*)							M*			M	M	M	M	M	M	M	M		PM	PM
Scotch thistle (*Onopordum acanthium*)	M			M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	PM	PM
Bouncingbet (*Saponaria officinalis*)	M*											M	M	M	M	M	M	M	M	PM

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Salt cedar (*Tamarix ramosissima*)	M					M	M	M	M	M	M	M	M	M	M	M	M	M	PM	PM
common tansy (*Tanacetum vulgare*)																			M*	M
scentless chamomile (*Tripleurospermum perforatum*)															M*	M	M	PM	PM	PM

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)

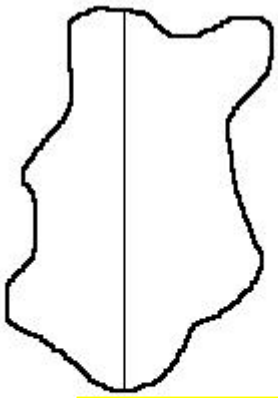
Materials for SURVEY ONLY:
Quadrat 50 x 50 cm (2)
50 m survey tape (minimum of 2, however 3 can also work well.
GPS unit, with the current year's shapefile for data entry

Standard survey procedure:

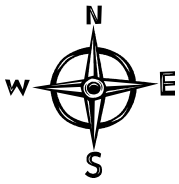
- The technique outlined here will apply to the majority of sites
- The general concept is to aim for a 50 m transect through the center of weed infestation. Sometimes it may be necessary to do a shorter transect in order to stay within the habitat. Ideally, the 25 m long bisecting transects have the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



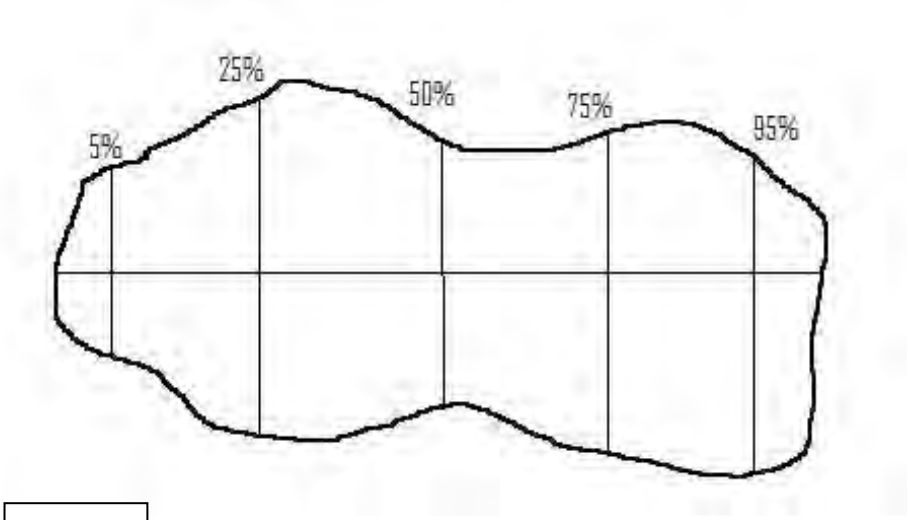


Fig. 2

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.

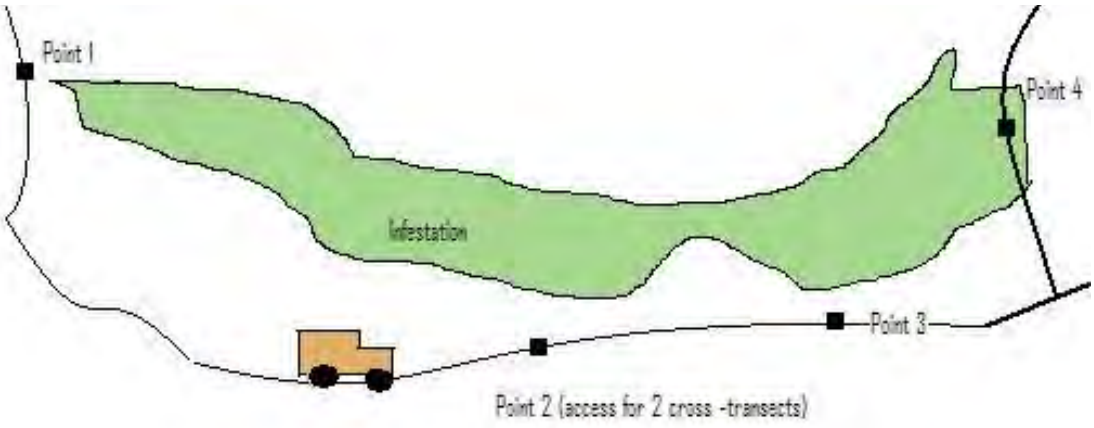

Point 1
Point 4
Infestation
Point 3
Point 2 (access for 2 cross -transects)

Fig. 3

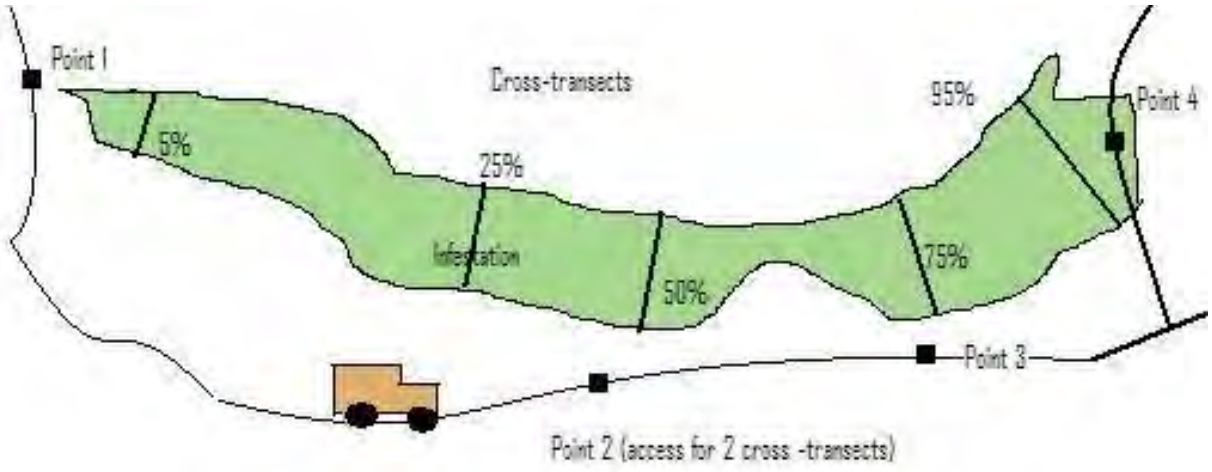

Point 1
Cross-transects
95%
Point 4
5%
25%
Infestation
50%
75%
Point 3
Point 2 (access for 2 cross -transects)

Fig. 4

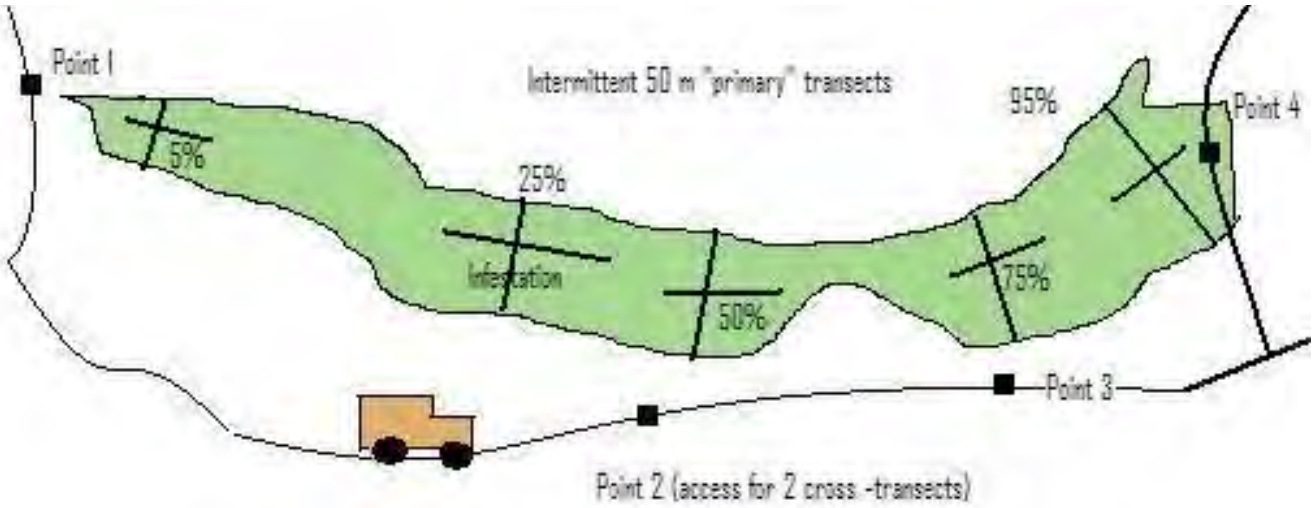


Fig. 5

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

Noxious weed occurrences were mapped in the field using ArcPad version 10.2 R5 (ESRI 1995-2018), 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 for outdoor use, 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 (Position Dilution of Precision) exceeded 6 and the EPE (Estimated Position 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, depending on the size and configuration of the occurrence. 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 track 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 2019 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, native thistles) 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.

In 2019, monitoring protocols were adjusted for rapid response species. Occurrences were mapped and attributed and then plants were mechanically removed from most sites. Occurrences with plants were revisited multiple times during the growing system for most species. Subsequent visits documented the visit date and the number of remaining plants. For consistency, mapping comparisons over the years rely on the footprint of the noxious weed occurrences during the first pass.

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

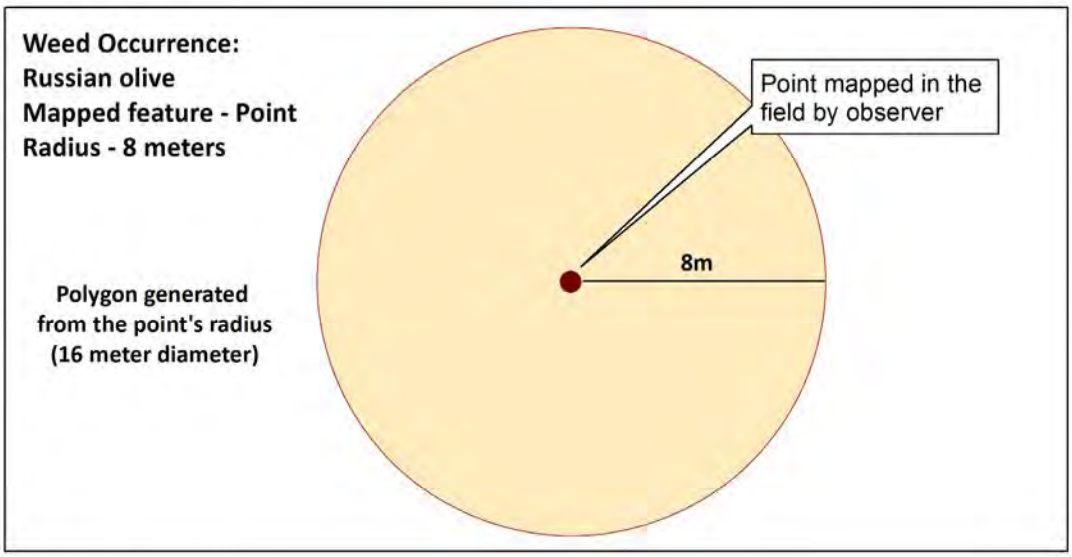
COUNTRY - Country

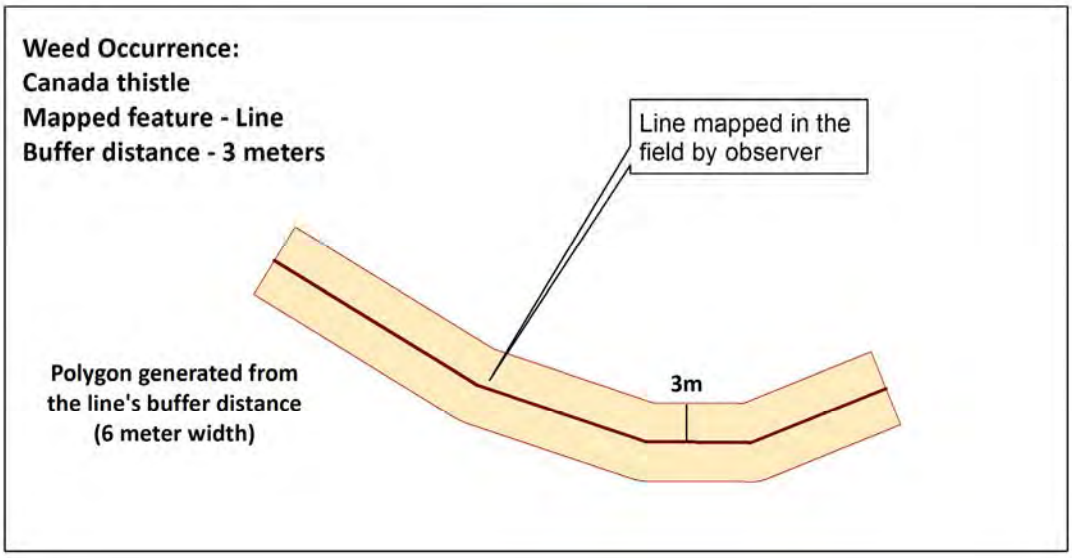
EXAMINER –Field observer

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. 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:

APPENDIX E. SOURCES FOR HERBICIDE USE RECOMMENDATIONS:

A. **The Nature Conservancy** https://www.invasive.org/gist/products/handbook/methods-handbook.pdf Weed Control Methods Handbook, The Nature Conservancy, Tu et al.

"PURPOSE These Guidelines are designed to ensure that you carefully consider the overall impacts of herbicide use on your conservation targets, other native species, and the ecological system. Base all decisions whether to control weeds, and whether to use herbicides instead of other methods, on the conservation targets and management goals for the site. In addition, the health and safety of applicators and others in the vicinity must be considered BEFORE pesticides are applied. Simply put, one should be confident that the proposed herbicide will do more conservation good than harm and not endanger the health of the applicators or others in the area.

TO SPRAY OR NOT TO SPRAY? Determining the right course of action in weed management can be difficult. For many land managers, whether to apply herbicides is an ethical decision that is not taken lightly. Herbicides are often used as a last resort, when other attempts have failed, and action is imperative. The following checklist summarizes the steps that need to be taken to ensure that proper consideration has been given to current weed problems, and that the use of herbicides is warranted for each individual case.

1. Determine whether invasive plants threaten conservation targets or management goals on the site. Use herbicides (versus other control methods) only if confidant they can be used safely and will do more conservation good than harm.
2. If you decide to use herbicides, record your reasons for doing so. TNC's Site Conservation Program (http://www.consci.org/scp) can help you identify targets and threats, and make a Site Conservation Plan. TNC's Site Weed Management Plan Template (http://tncweeds.ucdavis.edu/products.html) can help you set control priorities and develop a plan to implement them.

B. **Boulder County** https://assets.bouldercounty.org/wp-content/uploads/2017/03/weed-policy.pdf

The County uses herbicides with the lowest rates recommended for effective weed control, that have the lowest toxicity and volatility, and are spot sprayed whenever possible, instead of broadcast on weed infestations. Almost all herbicides used are selective for control of broadleaf weed species. Grasses are unaffected. Notification of herbicide applications in areas with public access are posted daily at 303-441-3940.

Boulder County Open Space and Parks

https://www.bouldercounty.org/open-space/management/weeds/

"Staff utilizes an integrated pest management approach to controlling weeds that include mowing, hand pulling, insect bio-control, cultural control (tilling weeds and planting desirable vegetation), and herbicide application. Herbicides are only used in targeted areas.

When controlling noxious weeds on open space properties, staff are careful to use the least damaging and most effective weed control strategies available. Staff always consider the local ecology to maintain and support the rich ecosystems of open space lands."

C. **El Paso County**:
El Paso County Community Services Department Environmental Division: Noxious Weeds and Control Methods Updated 2018
https://assets-communityservices.elpasoco.com/wp-content/uploads/Environmental-Division-Picture/Noxious-Weeds/Noxious-Weed-Control-Book.pdf

"Herbicides are used when there is no better alternative. You must decide if the treatment will result in less weeds over time."

D. **TNC** Illinois Nature Preserves
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5386111.pdf

Herbicide Use in Natural Areas: A Guide for Volunteer Land Stewards TNC Illinois Nature Preserves 2011

"Philosophy of Herbicide Use in Nature Preserves: Use of herbicides on Illinois nature preserves should be limited to situations in which managers or decision makers determine that no other reasonable means of control area available. Herbicides are potential damaging to the environment, and these hazards dictate that herbicides should be used only when less potentially damaging methods are available, effective, or feasible. Natural or mechanical methods of controlling invasive plant species (i.e. introduction of fire, mowing, cutting, or hand removal) are preferable to chemical control."

E. **Wagner**, V., Antunes, P.M., Irvine, M. and C.R. Nelson. 2017. Herbicide usage for invasive non-native plant management in wildland areas of North America. Journal of Applied Ecology, Vol. 54, Issue 1 pp. 198-204 https://doi.org/10.1111/1365-2664.12711

Although controlling established non-native invasive species should be a last resort in the chain of management actions, as prevention and detection are generally more effective (Leung *et al*. 2002; Olson & Roy 2005), management programs tend to invest in controlling established populations rather than in prevention strategies (Finnoff *et al*. 2007; Radosevich, Holt & Ghersa 2007).

Choosing an appropriate control method is challenging because managers need to consider key biological and ecological aspects of the target species, predict the efficacy of treatment, anticipate potential adverse effects on non-target organisms and take into account technical and economic feasibility (e.g. Derickx & Antunes 2013). In addition, a manager's choice for a control method will be constrained by external factors, such as policy regulations and public opinion (Veitch & Clout 2001; Radosevich, Holt & Ghersa 2007).

Herbicides were initially developed to control unwanted weeds in crop systems but now are widely used in invasive non-native plant management (hereafter invasive plant management) in more natural ecosystems (Radosevich, Holt & Ghersa 2007, Clout & Williams 2009 Fig. 1). Herbicides offer several advantages relative to other management methods: they can control invasive non-native plants quickly, require little human labour, can be relatively inexpensive and do not directly physically disturb soil structure (Clout & Williams 2009. However, there is evidence that at least some herbicides pose risks to non-target organisms (Freemark & Boutin 1995; Wagner & Nelson 2014) and to human health (Alavanja, Hoppin & Kamel 2004).

Unfortunately, the use of herbicides as a management tool for wildlands has not been adequately assessed for North American agencies or countries. Additionally, although there is a large body of scientific literature on the efficacy of herbicides for controlling target weeds (e.g. Kettenring & Reinhardt Adams 2011), most of this research focuses exclusively on the target plant rather than on the desirable natives, monitors outcomes only over a short period of time (but see Crone, Marler & Pearson and Ortega 2009) and does not consider economic aspects of management actions.