Noxious Weed Monitoring at the US Air Force Academy- Year 2 Results

2005

2006

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U.S. Air Force Academy Department of Natural Resources

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EXECUTIVE SUMMARY

In the summers of 2002 and 2003 the Colorado Natural Heritage Program (CNHP) mapped 14 selected noxious weeds found on the U.S. Air Force Academy ("the Academy") and the Farish Outdoor Recreation Area ("Farish"). The project was undertaken to provide the U.S. Air Force Academy Department of Natural Resources with information on noxious weeds to serve as the basis for the development of a formal Integrated Weed Management plan for U.S. Air Force Academy properties, and to meet the requirements of a comprehensive weed management plan.

In 2004, an integrated noxious weed management plan was produced for the Academy. This plan designated 14 noxious weed species as targets for eradication, suppression, or containment. The plan stipulated a monitoring program to measure the effectiveness of management efforts at the Academy and to provide some measure of progress towards meeting goals for weed management and eradication.

In 2005, the Colorado Natural Heritage Program established a monitoring program for 13 species of noxious weeds at the Academy (Russian knapweed, hoary cress, musk thistle, diffuse knapweed, spotted knapweed, Canada thistle, bull thistle, Fuller's teasel, Russian olive, leafy spurge, common St. Johnswort, yellow toadflax, and Scotch thistle). This program was established following the guidelines provided in the Academy's Integrated Noxious Weed Management Plan.

Permanent baseline monitoring plots were established for 10 of the target species (Russian knapweed, hoary cress, musk thistle, diffuse knapweed, Canada thistle, bull thistle, Fuller's teasel, leafy spurge, common St. Johnswort, and yellow toadflax). Three permanent plots were established for each species (except Russian knapweed and common St. Johnswort). The permanent plots employed combinations of photopoints, transects with quadrats, belt transects, perimeter mapping, and photopoints. The methods used were contingent upon the growth form and distribution pattern of each species.

In 2006, all permanent plots established in 2005 were resampled. Another species, myrtle spurge (*Euphorbia myrsinites*) was added to the monitoring program because it is listed on Colorado's A list (requiring eradication). Significant change was observed in most permanent plots between 2005 and 2006. This appears to be the result of climatic variation between years in most cases because most plots were not treated.

Post-hoc power analysis in 2006 indicated that power to detect the minimum detectable change required in the management plan was sufficient in all but one of the twelve permanent plots employing quadrat sampling for cover. To improve the sensitivity of these plots to change and minimize the risk of Type II errors, the sampling intensity was doubled at these plots for the target species. In 2007, post-hoc power analysis will be used to determine if the changes to the sampling design had the desired effect.

Occurrences of three rare plant species (plains ironweed (*Vernonia marginata)*, Southern Rocky Mountain cinquefoil (*Potentilla ambigens*), and American currant (*Ribes americanum*) were visited and documented, and the threats to those occurrences from noxious weeds were assessed.

INTRODUCTION

Weeds are known to alter ecosystem processes, degrade wildlife habitat, reduce biological diversity, reduce the quality of recreational sites, reduce the production of crops and rangeland forage plants, and poison livestock (Sheley and Petroff 1999). All of these impacts are occurring in Colorado (Colorado Department of Agriculture 2001). In recognition of their enormous detriments to our society and environment, many local governments now require public and private landowners to manage noxious weeds. The U.S. Air Force Academy (referred to herein as "the Academy") must conform to state (Colorado Department of Agriculture Plant Industry Division 2005) and county (El Paso County 2005) weed control regulations for noxious weeds. The Academy has also established management objectives for weed control to remain compliant with local weed regulations.

In 2002 and 2003, the Colorado Natural Heritage Program (CNHP) mapped selected noxious weeds found at the Academy and the Farish Outdoor Recreation Area ("Farish") (Anderson et al. 2003). The project was undertaken to provide the U.S. Air Force Academy Department of Natural Resources with information on noxious weeds that will serve as the basis for development of a formal Integrated Weed Management Plan, and to meet the requirements of a comprehensive management plan. In 2002, 3,936 infestations were mapped for 14 target species at the Academy and Farish, and additional infestations were mapped in 2003.

In 2004, an integrated noxious weed management plan was developed based on the results of the weed mapping exercise (Carpenter and Perce 2004). The purpose of this plan is to guide the management of noxious weeds at the Academy and Farish in the most efficient and effective manner. This plan supports the 2003-2008 *Integrated Natural Resources Management Plan* for the Academy. The plan set weed management objectives (Table 1) and recommended weed management protocols for the Academy and Farish. The plan also underscored the importance of monitoring weed infestations as a means of measuring the effectiveness of management practices, and recommended monitoring protocols.

As noted by Carpenter and Perce (2004), the purpose of monitoring is to provide a rational basis for determining if weed management actions are effective in moving toward the weed management objectives. Carpenter and Perce (2004) recommended annual weed monitoring and analysis of monitoring data for three consecutive years once a monitoring program is initiated. Thereafter, weed management actions for the forthcoming year can be changed, as needed, if indicated by the results of the monitoring. After the first three years of monitoring, the data may show that less frequent or less intensive monitoring is acceptable for certain weed species.

This project was undertaken to evaluate the effectiveness of ongoing management of noxious weeds at the Academy, and to determine whether weed management objectives are being met. The recommendations for the design and deployment of monitoring plots offered by Carpenter and Perce (2004) were adhered to closely in this study. To determine whether the weed management objectives set by Carpenter and Perce (2004) are being met, this monitoring study needs to detect a minimum change of between 50% and 90% in cover, density, or seed production.

In 2005, a monitoring program for 13 species of noxious weeds (Russian knapweed (*Acroptilon repens*), hoary cress (*Cardaria draba*), musk thistle (*Carduus nutans*), diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*Centaurea maculosa*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), Fuller's teasel (*Dipsacus fullonum*), Russian olive (*Elaeagnus angustifolia*), leafy spurge (*Euphorbia esula*), common St. Johnswort (*Hypericum perforatum*), yellow toadflax (*Linaria vulgaris*), and Scotch thistle (*Onopordum acanthium*)) was established at the Academy. Of the 13 species targeted for monitoring in this study, 12 are species that had been mapped in 2002 and 2003. A total of 14 species were mapped in 2002 and 2003, but two species (Tamarisk, *Tamarix ramosissima*, and field bindweed, *Convolvulus arvensis*) were not targeted for monitoring. Tamarisk was not targeted for monitoring because the single plant discovered in 2002 has been destroyed and there have been no new reports of this species at the Academy. Field bindweed was not targeted for monitoring because it occurs sporadically in relatively small infestations in a limited area of the Academy, mostly near infrastructure. Russian knapweed was discovered at the Academy in 2004, so it was not mapped in 2002 and 2003 but is included as a monitoring target because of its legal status and invasiveness.

In 2006, all permanent monitoring plots established in 2005 were resampled. A fourteenth species, myrtle spurge (*Euphorbia myrsinites*) was added to this study because it is listed on Colorado's A List of noxious weeds, and eradication of this species is

Table 1. Noxious weed management objectives for species targeted in this study (from Carpenter and Perce 2004). Myrtle spurge (in bold) was not included in the management plan, but since it is on Colorado's A list of noxious weeds, eradication is required.

Species	**Weed Management Objective**	**Recommended Reduction**	**Prioritization**	**Action**
Russian knapweed	Eradicate	100%	All	Eliminate all plants
Scotch thistle	Eradicate	100%	All	Eliminate all plants
Spotted knapweed	Eradicate	100%	All	Eliminate all plants
Hoary cress	Suppress	90%	All	Reduce canopy cover
Musk thistle	Suppress	50%	All	Prevent all seed dispersal
Diffuse knapweed	Suppress	50%	All	Reduce density
Canada thistle	Suppress	50%	High Priority Areas	Reduce canopy cover
Bull thistle	Suppress	90%	All	Prevent all seed dispersal
Fuller's teasel	Suppress	50%	All	Prevent all seed dispersal
Russian olive	Suppress	90%	All	Reduce density
Leafy spurge	Suppress	90%	All	Reduce canopy cover
Common St. Johnswort	Suppress	90%	All	Reduce canopy cover
Yellow toadflax	Suppress/ Containment	50%	High Priority Areas	Reduce canopy cover
Myrtle spurge	**Eradicate**	**100%**	**All**	**Eliminate all plants**

required under state law (Colorado Department of Agriculture 2005). This provided the opportunity to assess whether the protocols established in 2005 were appropriate for obtaining the data needed to inform weed management at the Academy. This report focuses on methodological changes that were made to this study as a result of the assessment of this study made in 2006. Preliminary results are also presented, although these are not emphasized here; they will be discussed in-depth in the final report for this project.

METHODS

Methods recommended by Carpenter and Perce (2004) were employed for monitoring and assessing the 14 noxious weed species targeted in this study. The methods presented in this report are limited to changes in the monitoring approach implemented in 2006. These changes are intended to improve statistical power of this study, and to incorporate myrtle spurge into the study. See Anderson and Lavender (2006) for details regarding the selection and establishment of plots, and the methodology employed for each sampling technique in this study.

Mapping and Assessment

Because nearly all previously known occurrences of Russian olive were revisited in 2005, and because it is a relatively slow growing species, these were not revisited in 2006, but will be reassessed in 2007. All infestations of spotted knapweed and Russian knapweed were mapped and revisited in 2006. Myrtle spurge was also added to the list of species targeted for mapping and assessment.

Permanent Plots

Permanent plots were resampled in 2006 for ten targeted noxious weed species (Russian knapweed, hoary cress, musk thistle, diffuse knapweed, Canada thistle, bull thistle, Fuller's teasel, leafy spurge, common St. Johnswort, and yellow toadflax). In 2006, permanent photopoint monitoring plots were installed at all three known infestations of myrtle spurge on the Academy. Table 2 summarizes the methods employed for monitoring each target species in 2006, highlighting changes from 2005 methodology.

Quadrat Sampling

Rhizomatous species (hoary cress, Canada thistle, common St. Johnswort, Russian knapweed, and yellow toadflax*)* were sampled using a series of quadrats along a transect to estimate cover in 2005 and 2006. Percent cover was chosen as the metric for these species because they tend to occur in dense populations where numbers of ramets cannot be easily quantified.

In 2005, 10 quadrats were sampled along a transect at each permanent plot for these species, resulting in a total of 12 transects. Within each quadrat, the percent cover of the target species and all other species present in the quadrat was estimated. The cover of non-target species was estimated because as management theoretically results in a decrease of cover of the target species, other species will replace it.

Table 2. Summary of sampling methods used at permanent plots in 2006. Changes from 2005 methods are indicated in bold.

Species	**Sampling Methods**	**Plot 1**	**Plot 2**	**Plot 3**
Russian knapweed	*Transect/ photopoint/ photoplot/ perimeter mapping*	25 m transect w/ **20** quadrats, 5 photoplots, 3 photopoints	Census, GPS, photographs. *Rationale:* small, localized population	Photos, GPS. *Rationale:* no plants were found at this site for this species in 2005 **or in 2006**.
Hoary cress	*Transect/ photopoint/ photoplot*	50 m transect, **20** quadrats, 5 photoplots, 2 photopoints	50 m transect, **20** quadrats, 5 photoplots, 2 photopoints	50 m transect, **20** quadrats, 5 photoplots, 2 photopoints
Musk thistle	*Photopoint*	1 photopoint	1 photopoint	1 photopoint
Diffuse knapweed	*Belt Transects/ photopoints*	4 25 m belt transects, **each divided into five segments**, 2 photopoints	4 25 m belt transects, **each divided into five segments**, 2 photopoints	4 25 m belt transects, **each divided into five segments**, 2 photopoints
Canada thistle	*Transect/ photopoint/ photoplot*	50 m transect, **20** quadrats, 5 photoplots, 2 photopoints	50 m transect, **20** quadrats, 5 photoplots, 2 photopoints	50 m transect, **20** quadrats, 5 photoplots, 2 photopoints
Bull thistle	*Photopoint*	1 photopoint	1 photopoint	1 photopoint
Fuller's teasel	*Photopoint*	1 photopoint	2 photopoints	1 photopoint
Leafy spurge	*Perimeter mapping/ survey transects/ photopoint*	Perimeters mapped, 5 E-W survey transects spaced 20m apart, one photopoint	Perimeters mapped, 4 E-W survey transects spaced 20m apart, one photopoint	Perimeters mapped, 4 E-W survey transects spaced 20m apart, one photopoint
Common St. Johnswort	*Transect/ photopoint/ photoplot/ perimeter mapping*	2 photopoints, perimeter mapping. *Rationale:* excessive poison ivy precluded the use of transect method	25 m transect w/ **20** quadrats, 5 photoplots, 3 photopoints, perimeter mapping	25 m transect w/ **20** quadrats, 5 photoplots, 2 photopoints, perimeter mapping
Yellow toadflax	*Transect/ photopoint/ photoplot*	25 m transect, **20** quadrats, 5 photoplots, 2 photopoints	25 m transect, **20** quadrats, 5 photoplots, 2 photopoints	25 m transect, **20** quadrats, 5 photoplots, 2 photopoints
Myrtle spurge	***Perimeter mapping/ photopoint***	**Perimeter mapping, 1 photopoint**	**Perimeter mapping, 2 photopoints**	**Perimeter mapping, 1 photopoint**

Carpenter and Perce (2004) set management goals for the reduction of each species at the Academy (Table 1). Therefore, the minimum detectable change in this study must meet or exceed these goals if this study is to provide feedback for managing these species. To determine whether the sampling intensity of this study was sufficient to reliably detect these changes, the 2005 and 2006 monitoring data were used to perform a post-hoc power analysis. A freeware program called DSTPLAN version 4.3, (Brown et al. 2000) was used to conduct two sided, one sample tests for each plot, as recommended by Elzinga et al. (1998).

The results of these tests indicated that there was less than a 10% chance of a type II error (falsely rejecting the null hypothesis) in 11 out of 12 plots. However, the sample design of all plots was modified to improve power and to increase the sensitivity of these plots to change (decrease the minimum detectable change). Figure 1 illustrates the sample design as it was initially deployed in 2005. Figure 2 illustrates the changes that were made in 2006 to increase the sampling intensity. Ten additional quadrats were sampled at each plot in 2006 in which only cover of the target species was measured.

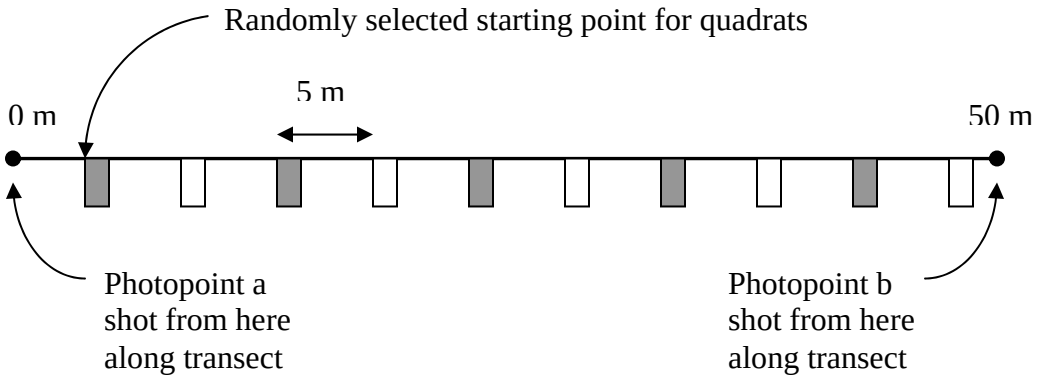

Figure 1. The layout of plots in which a 50-meter transect was used, as implemented in 2005. Photoplots were sampled at shaded transects.

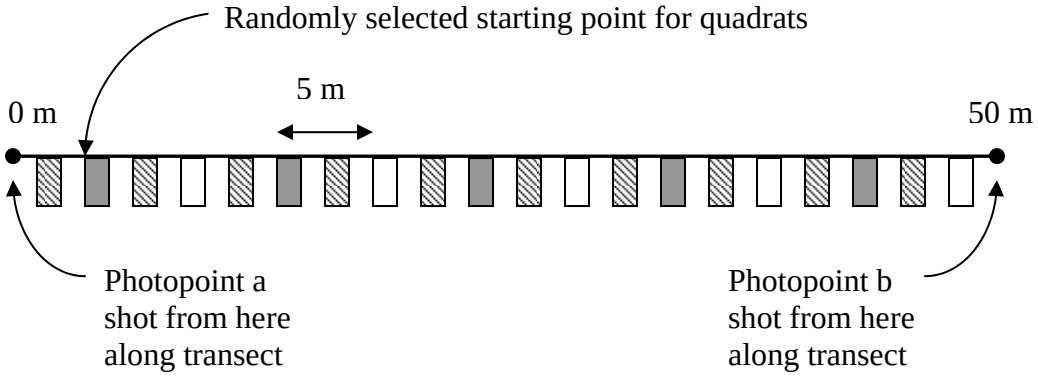

Figure 2. Plot layout as modified in 2006. Hatched quadrats were added in 2006 to improve statistical power. Cover is estimated for the target species only within these quadrats.

Belt Transects

Diffuse knapweed was sampled using 25 x 1.5m belt transects. The width of 1.5 m was determined through experimentation with different widths, and was determined to be the maximum width that could be reliably censused in a single pass. A meter tape was outstretched on one side of each belt transect, and a 1.5 m long pole was used to determine whether plants at the distal side of the belt fell within the transect. In 2005, a total of four transects were sampled at each permanent plot. In 2006, each of these transects was sampled as 5 meter segments to improve the statistical rigor of the analysis. (Figure 3). As in 2005, all plants rooted within the belt transects were counted using a tally counter. Plants were not counted if the canopy projected into the transect but the individual was not rooted in the transect.

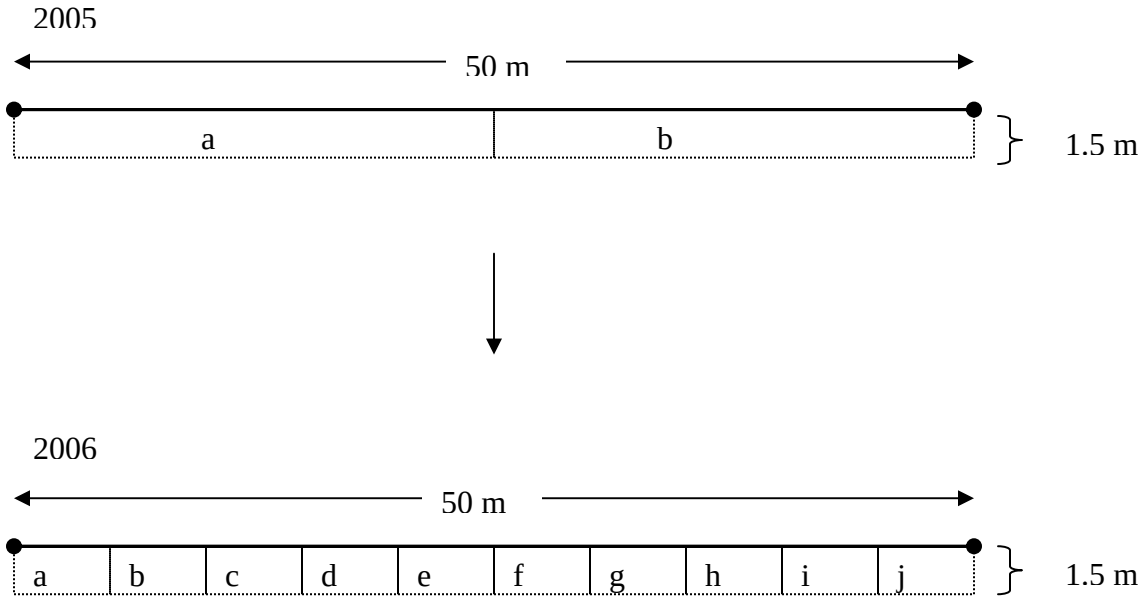

Figure 3. Layout of belt transects used for measuring density of diffuse knapweed at permanent monitoring plots, as modified in 2006.

Photopoints

Photopoints were resampled for all permanent plots in 2006. Three photopoints were added to this study for myrtle spurge in 2006. A census and perimeter mapping will also be conducted at each infestation of myrtle spurge to augment the photopoint data.

Perimeter Mapping and Systematic Survey Transects

Perimeter mapping was used in monitoring Russian knapweed, leafy spurge, common St. Johnswort, and myrtle spurge in 2006. Perimeter mapping was used at all known infestations of Russian knapweed, common St. Johnswort, and myrtle spurge at the Academy, and it was used at the three permanent plot sites for leafy spurge. Systematic survey transects were resampled for the three leafy spurge permanent plots in 2006.

RESULTS

Mapping and Assessment

Spotted knapweed has continued to show an alarming trend. It is currently in a phase of nearly exponential growth at the Academy. The number of infestations known from the academy more than doubled between 2005 and 2006 (Table 3). Some of this apparent trend may be due to a failure to detect infestations in 2005, although there has clearly been considerable spread in some areas. The area with the greatest increase in spotted knapweed from 2005 to 2006 was in the vicinity of Non-potable Reservoir #3 and its access road and at Non-potable Reservoir #2. At Non-potable Reservoir #2, many small points were mapped in 2005. However, in 2006 these small infestations had spread and amalgamated into two large polygon shaped infestations. Current management efforts appear to be having little impact on this species. It appears that more aggressive techniques are needed if this species is to be controlled on the Academy.

Table 3. Summary of 2006 assessment for five noxious weed species at the U.S. Air Force Academy.

Species	New Infestations	Extant in 2005	Extant in 2006
Scotch thistle	1	8 of 9	3 of 10
Russian olive	NA	46 of 173	not assessed
Russian knapweed	0	2 of 3	2 of 3
Spotted knapweed	101	79 of 83	160 of 184
Myrtle spurge	NA	NA	3 of 3
TOTAL		135 of 268	165 of 190

Permanent Plots

A total of 32 permanent plots were sampled for 11 target species (Table 2). Three new plots were established for myrtle spurge (Table 4). These are located near the stables, at the west side of Douglass Valley, and near the Archery Range.

Table 4. Coordinates and summary information for the new permanent plots established in 2006 for myrtle spurge. All UTM coordinates are projected in NAD 83 CONUS.

PLOT #	Date	UTM E	UTM N
1	6/8/2006	512849	4312584
2a	6/8/2006	510396	4315186
2b	6/8/2006	510325	4315254
3	6/8/2006	513159	4314507

Quadrat Sampling

Quadrat sampling was completed at twelve plots in 2006. Paired T-tests were used to compare data for the target species at each plot in 2005 and 2006. At all plots except one, a significant decrease in cover was observed in 2006 (Table 5). Power analysis indicates that the sampling intensity was sufficient at all but one plot (*Linaria vulgaris* 3). Power was also low in *Acroptilon repens* 1, but since eradication is required for this species the results of census and perimeter mapping are more important for measuring the success of management activities on this species. The sampling intensity was doubled at all plots for the target species only to improve power.

At all but one plot, the observed change in cover was not the result of treatment, but instead was the result of annual climatic variation. It was extremely dry during May and June of 2006, resulting in very large declines in cover of *Cardaria draba*. Although July and August monsoons were intense in 2006, the cover of other target species remained lower than in 2005. One plot, *Hypericum perforatum* 2, was treated in 2006 and the target species was not observed at this plot.

Table 5. Summary statistics for comparison of permanent plot data from 2005 and 2006. P values (a) are for paired T-tests performed on 2005 and 2006 data. Power to detect a 90% change (b) and a 50% change with a 10% chance of type II error was assessed for all permanent plots. The gray cells indicate the appropriate power for each target species based on the recommended reductions in Carpenter and Perce (2004, see Table 1). Power was below the desired level of .90 in one plot (*Linaria vulgaris* 3).

Target	Plot	avg 05	sd 05	avg 06	sd 06	P[a]	power 90%, .1[b]	power 50%, .1[c]
Acroptilon repens	1	3.35	5.17	4.00	7.99	0.65	0.85	0.44
Cardaria draba	1	59.50	21.18	26.00	8.68	0.00	1.00	1.00
Cardaria draba	2	14.30	11.97	1.05	1.40	0.01	0.93	0.49
Cardaria draba	3	8.20	7.00	1.15	1.42	0.01	0.94	0.49
Cirsium arvense	1	33.50	19.27	15.50	14.52	0.00	1.00	0.99
Cirsium arvense	2	24.70	8.60	4.20	3.46	0.00	1.00	0.99
Cirsium arvense	3	33.50	25.46	14.50	10.43	0.00	1.00	0.94
Hypericum perforatum	2	27.10	19.54	0.00	0.00	0.00	0.98	0.65
Hypericum perforatum	3	21.30	13.70	13.15	13.22	0.09	1.00	0.93
Linaria vulgaris	1	9.50	4.45	5.30	4.35	0.00	1.00	1.00
Linaria vulgaris	2	32.00	9.87	11.70	7.36	0.00	1.00	1.00
Linaria vulgaris	3	11.00	9.81	6.25	5.47	0.07	1.00	0.82

Photoplots and Photopoints

Photoplots were resampled for Russian knapweed, hoary cress, Canada thistle, common St. Johnswort, and yellow toadflax. Five photoplots were sampled at each transect, for a total of 60 (only five photoplots were sampled for Russian knapweed and 10 for common St. Johnswort).

A total of 51 photopoints were sampled, with at least one photopoint at each permanent plot. Four photopoints were added to this study in 2006 for myrtle spurge. A comparison of 2005 and 2006 photopoints is included in Appendix 1. An analysis of data from these plots will be presented in the year 3 report.

Perimeter Mapping and Systematic Survey Transects

Perimeter mapping was completed for all infestations of Russian knapweed, common St. Johnswort, and myrtle spurge that could be found. The infestation of common St. Johnswort reported from southwest of the RV lot could not be relocated in 2006, and it appears that herbicide treatment applications may have successfully extirpated this occurrence. Perimeter mapping was completed at three permanent plots for leafy spurge in the vicinity of the Jack's Valley Training Complex.

A new infestation of leafy spurge was found at plot 3 at the west end of the area, which was mapped as a point. The previously known point was mapped as a polygon. Infestations within plot 2 were found to be contiguous with a large infestation to the west in 2006. To keep this plot manageable, the extent of the plot was set to a birm to the west of the plot and a ditch to the south. Some infestation appeared to have amalgamated into larger polygons. Leafy spurge was probably more easily seen in 2006 than in 2005, so the apparent increase in infestation size may be due to changes in detectability.

Other Results

Four occurrences of rare plants (plains ironweed, American currant, and two occurrences of Southern Rocky Mountain cinquefoil) were visited and documented, and the threats to those occurrences from noxious weeds were assessed. Element occurrence records for these species were completed in the field and will be incorporated into the Biodiversity Tracking and Conservation System (BIOTICS) (Colorado Natural Heritage Program 2006).

Plains ironweed (*Vernonia marginata*, G5?S1) is known from a single occurrence at the Academy, along Academy Drive north of the Fire Station, where it was originally discovered by J.D. Ripley in 1979. All of the marked clumps observed in 2005 were present and extant in 2006.

One occurrence of Southern Rocky Mountain cinquefoil (*Potentilla ambigens*, G3S2) was discovered in 2006, near the Santa Fe Trail north of the biosolids application area. Five individuals were found at this site. The plant that was seen in 2005 at plot 2 for common St. Johnswort was not seen this year. Broadleaf herbicide was applied to this plot late in 2005, and very few dicots of any species were seen here in 2006.

The single occurrence of American currant (*Ribes americanum*, G5S2) known from the Air Force Academy was revisited on June 8, 2006 with Brian Mihlbachler. A total of approximately 200 individuals were observed along 50 meters of the small creek at this location (Figure 4). Non-native species including Canada thistle, Fuller's teasel,

and crack willow (*Salix fragilis*) were observed at this location and pose a possible threat to the viability of this occurrence.

Figure 4. American currant (*Ribes americanum*) at the U.S. Air Force Academy on June 8, 2006.

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APPENDIX 1: PHOTOPOINTS FROM 2005 AND 2006

Carduus nutans 1 2005

Carduus nutans 1 2006

Carduus nutans 2 2005

Carduus nutans 2 2006

Carduus nutans 3 2005

Carduus nutans 3 2006

Cirsium vulgare 1 2005

Cirsium vulgare 1 2006

Cirsium vulgare 2 2005

Cirsium vulgare 2 2006

Cirsium vulgare 3 2005

Cirsium vulgare 3 2006

Dipsacus fullonum 1 2005

Dipsacus fullonum 1 2006

Dipsacus fullonum 2A 2005

Dipsacus fullonum 2A 2006

Dipsacus fullonum 2B 2005

Dipsacus fullonum 2B 2006

Dipsacus fullonum 3 2005

Dipsacus fullonum 3 2006