

## Project Narrative

**Project Title:** Biological control of spotted knapweed in the southeastern US.

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### I. Description of Work:

#### **Project Goals and Supporting Objectives**

**Project goals:** This project is designed to implement a biological control program targeting spotted knapweed (*Centaurea stoebe* L. subsp. *micranthos* (Gugler) Hayek) using a strategic plan to provide long-term sustainable control of this invasive species. Knapweeds have been significant weeds of rangeland and forest systems in the western US for nearly a century, but knapweeds are a more-recent invader to the southeastern US. Biological control of knapweeds in the west is beginning to suppress the weeds, but no concerted efforts have been undertaken in the southeast. Knapweeds continue to spread south, where conditions differ greatly from the western US due to a longer growing season and different management tactics. Knapweeds and the natural enemies introduced to control them will likely interact differently in the southeast. We have a unique opportunity to launch a knapweed biological control program with a strong probability of success in a coordinated, highly visible program. The project will focus on what impact current vegetation management approaches (e.g., controlled burns, mowing) have on knapweed spread and on the efficacy of a newly implemented biological control program. Additionally, we will develop and refine existing remote sensing techniques to provide vegetation mapping and analysis in a GIS context. Current remote sensing tools developed largely in the arid northwest need considerable refinement as a result of distinctly different flora in the southern range of this pest. The project's ultimate goal is to provide long-term sustainable control of spotted knapweed while educating and engaging our stakeholders.

#### ***Supporting Objectives to meet goals:***

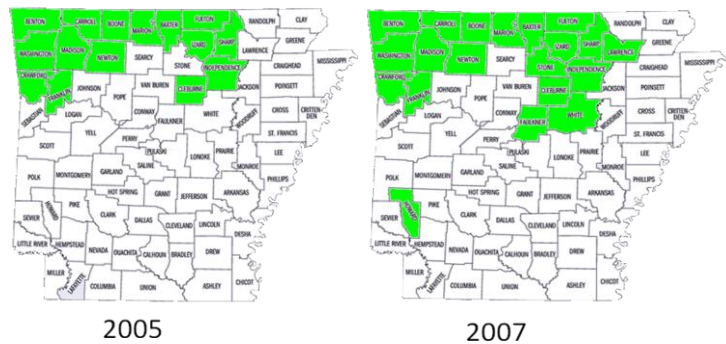
1. To expand the existing biological control program of spotted knapweed by increasing redistribution of a seed head weevil (*Larinus minutus*) and by initiating a release program for a root weevil *Cyphocleonus achates*.
2. To examine the relationship of controlled burns and other vegetation management tactics on knapweed invasion/spread along roads, forest edges and other forest systems.
3. To develop and refine remote sensing techniques to aid in GIS-based vegetation analysis which provide data on knapweed spread and control as biological control agents impact knapweed populations.

**Project Justification/Urgency** (relevance and significance, impact of invasive on forest and rangeland in short and longer term, potential spread).

***Spotted knapweed in the southeastern US:*** Spotted knapweed (*Centaurea stoebe* L. ssp. *micranthos* (Gugler) Hayek) is an herbaceous perennial plant accidentally introduced in the 1890's, into North America from Europe where it is distributed from eastern Russia to the Mediterranean (Hufbauer and Sforza 2008, Mauer et al., 1987). Spotted knapweed is found in

Canada from Nova Scotia to British Columbia and has been recorded in 46 of the 50 United States (Eddleman and Romo, 1988). Spotted knapweed infests over 3 million ha in the US (DiTomaso 2000) and increases soil surface runoff and stream sediment yields (Westbrooks 1998), reduces soil infiltration, inhibits canopy undergrowth due to allelopathic effects (Bais et al. 2003), reduces native plant diversity, and contributes to a 50-90 % loss of available forage (Sheley and Barko 1999). The weed displaces desirable forage and quickly dominates habitats, making invaded rangeland less valuable, as cattle avoid feeding on the weed (MacDonald et al. 2003). In Montana alone, annual direct and indirect economic losses from knapweeds was \$ 42 million on 810, 000 ha (Duncan et al. 2004).

Although first detected at a single site in Arkansas in mid 1940's (UA Herbarium records), the recent expansion of the weed into multiple habitats southward in Arkansas has been dramatic and is cause for concern (see below). It has shown a steady increase in geographical distribution over the last three years and has spread from the Ozark Plateau, to the Arkansas River Valley, and into the West Gulf Coastal Plain (Minteer, 2007). Spotted knapweed populations have been confirmed in 20 Arkansas counties (Minteer 2007), and is listed as a weed of new concern by the University of Arkansas Division of Agriculture and the Arkansas State Plant Board (2008). It has been targeted for removal from the McIlroy State Game Management Area in northwestern Arkansas. While no economic analysis of spotted knapweed has been done in Arkansas, it is a dominant roadside weed and quickly invades mowed or disturbed areas in both natural and managed settings. The progress of the weed's spread and types of habitat invaded in Arkansas are typical of experience in other southern states, so we expect our findings and deployment methods to be directly transferrable to several southern and Midwestern states, particularly Tennessee and Kentucky.



**Current southern knapweed management:** There have been no regional efforts to specifically manage knapweed populations or to mitigate the weed's movement in any southern state. Rather, management practices for spotted knapweed (primarily herbicides and mowing) are included as part of general broadleaf control efforts in both agricultural and non-agrarian areas. Management of spotted knapweed is possible through application of cultural (introduction of competitors, preventing introduction), chemical, mechanical (mowing, tillage, fire) and biological practices. Generalized weed management contributes to the increasing dominance of invasive knapweeds, as reinvasion is more severe following application of broad spectrum herbicides (SLC Weed Control Program 2008). Mowing reduces spotted knapweed stature, but plants resprout after mowing and subsequent flowers form lower than the level of the mower deck, adding to the seed bank. Spotted knapweed produces 5,000-40,000 seeds/m<sup>2</sup> (Sheley and Barko 1999) which remain viable for 8 years. Mowing also effectively spreads knapweed populations by transport of seeds and/or capitula on the mower deck. In rangeland settings, biological and cultural controls may be the only viable approaches for sustainable management of spotted knapweed (Knochel and Seastedt 2009). Fire is not an effective management technique, but when fire is used in forest management programs, the potential to increase

knapweed post fire is a serious consideration (Ferguson et al. 2007). Knapweed is also spread on equipment used in fire management programs (esp. brush hogs).

***Knapweed biological control efforts:*** Since 1973, 13 biological control agents have been released in North America to control knapweeds. Only one of these agents, *Urophora quadrifasciata* (known as the UV fly), currently occurs in Arkansas (Duguma et al. 2009). Studies conducted in our lab demonstrated that in Arkansas *U. quadrifasciata* does not significantly reduce the number of seeds produced early in the season, when knapweed is most robust (Duguma, 2008). Thus, the UV fly alone will not significantly suppress knapweed populations in Arkansas, or stop its spread further into the southern United States. Introduced natural enemies have recently begun to provide adequate suppression of some populations of knapweed in the Western United States and Canada (Myers 2004, Smith 2004). Mortality to mature plants may be induced by large populations of adult seed head weevil *Larinus minutus* as well as by larval root weevil, *Cyphocleonus achates*. The root weevil induces significant spotted knapweed mortality and is considered the most important species in reducing knapweed populations in Montana (Corn et al. 2006, Story et al. 2006). However, others suggest that knapweed populations have been reduced by combinations of herbivores which reduce seed production and plant vigor and increase plant mortality (Corliet and Northrop 2006, Corn et al. 2006, Michels et al. 2007). For the related diffuse knapweed, Myers et al. (2009) suggests that, even after the introduction of 12 biological control agents, knapweed populations did not significantly decline until the establishment of *L. minutus*. Although most authors note *Larinus* spp. have the greatest influence on diffuse knapweed, growing evidence in Colorado indicates a significant role of *C. achates* in reducing spotted knapweed populations (Michels et al., 2009). Therefore, we conclude as do Knochel and Seastedt (2009, and references therein), that *Larinus minutus* and *Cyphocleonus achates* are essential agents needed to provide significant suppression of spotted knapweed. In the summer of 2008 we made a preliminary release of 300 *Larinus minutus* adults in Washington Co., AR using the methods outlined in this project. Larvae were recovered in the fall from the release areas in 2008 and the first recovery of adults was made at the same locale in May, 2009, giving us great confidence that the release program as designed will be successful. No releases of *C. achates* have been made in the southern US.

This project will allow us to document the ability of a single or small group of released biological control agents to reduce spotted knapweed populations: an action that has not been possible among all the other research studies that must conduct retrospective evaluations due to the establishment of most or all of the 13 species originally released for control of knapweeds in North America. Thus, Arkansas represents a blank canvas where we are poised to implement a highly visible implementation and research project to manage an invasive weed.

This research will establish links between the fundamental ecological relationship of the weed and released biological control agents operating in non-agricultural areas (open fields, forest edges and fence rows). The contribution of non-agricultural areas may serve as a source or sink (or neutral) for the released biological control agents and are often ignored, but may be essential elements for a successful weed management program (Knochel and Seastedt 2009).

A unique aspect of this project is afforded by the maturity of the knapweed biological control program in North America. Specifically, by releasing the two agents deemed as having the best potential for success in suppressing spotted knapweed populations alone (on each side of the state) and together (in the central part of the state), we will be able to document the relative impact of these two species in a large-scale ecological experiment not conducted before.

Repetition of release locations in each region of the state will allow us to use spatial statistical techniques to better attribute differences in knapweed growth and survival to one or both released species. As stated above, all previous evaluations have been retrospective and/or limited to cage studies, and this project will provide a real-world assessment of these biological control agents on a scale never done before.

***Remote sensing of invasive weeds:*** Remote sensing techniques are of tremendous value in tracking the occurrence of known invasive weed species when human observation is impractical (Carson et al. 1995). Spotted knapweed's characteristic blue-green color of new stems and distinctive red-brown color of senescent stems provides a unique reflective signature (Lass et al. 2002). Incipient populations of spotted knapweed are detectable using hyperspectral imagery, thus allowing quantification of even small efforts to control the weed (Lass et al. 2002). However, there is no record of application of these techniques to quantify knapweed distribution. New remote sensing platforms such as Worldview 2 (DigitalGlobe Inc.) launched in October 2009 provide high resolution (1.8 m pixel) imagery with 8 multispectral sensor bands and could be used to verify the applicability of the spectral radiometer results to wide-scale satellite images.

## **II. Federal Role:**

This program addresses the control of a weedy invasive species, the spotted knapweed. The weed is expanding its range across the US. The federal funds are necessary, and requested, to combat this invasive species directly through the redistribution of known, safe natural enemies which have had excellent success in reducing the damaging effects of this invasive weed. Additionally, we will develop techniques which will allow better and more efficient tracking of this and other invasive weed species across the US.

## **III. Methodology/Timetable**

We will conduct this project addressing three objectives concurrently. T. J. Kring has led all of the work done in Arkansas on knapweed biological control (survey for knapweed agents and evaluation of the one species known), and will serve as the overall project leader. R. W. Wiedenmann has significant prior experience with an implementation biological control projects in Illinois (e.g., purple loosestrife, Wiedenmann et al. 2007). F. M. Stephen has experience with biological control in forest ecosystems in cooperative development of remote sensing and mapping techniques in forest ecosystems.

***Redistribution of knapweed biological control agents:*** The seed head weevil *L. minutus* was released in northwestern Arkansas during 2008 and 2009, and reproduction has been observed at release sites. We intend to use these release locations as field nurseries for further redistributions in the region during 2010, and will supplement them with additional field collections from Colorado. Current colonies of *L. minutus* in Arkansas occur on controlled sites on experiment station and private property, and redistributions will focus on minimally disturbed areas, particularly on or near state and federal managed forests and game preserves. Additionally, we will begin releases of the root weevil *C. achates* in central Arkansas in 2010 and 2011 with collections of adults from central Colorado. Releases of these beetles on opposite sides of the knapweed range will allow us to independently evaluate their impact on knapweed populations (before their distributions are allowed to overlap). Previous release programs in

North America attempted to release most or all of the 13 approved species, so there have been no single-species evaluations of any of these agents (an exception is our evaluation of *U. quadrifasciata* in Arkansas, Duguma 2008). Establishment of previous releases and successful colonization of the releases in 2010-11 will be verified through collections both within and subsequent to the year of release. Release permits are in hand for both species for Arkansas (USDA-APHIS-PPQ Permit # P526P-08-02053).

***Impact of current knapweed cultural management efforts on knapweed spread and its natural enemies:*** We will identify and categorize knapweed populations based on their habitat: (a) undisturbed natural settings, (b) regularly disturbed systems (e.g., roadsides prone to mowing) (c) undisturbed forest edges and (d) recently forested or managed lands (e.g., areas of controlled burns, etc.). We will determine the relative abundance of the one already-established knapweed natural enemy (UV fly) among these habitats, and will establish release sites for the two weevil species in the two disturbed and two minimally-disturbed habitats. We expect variation within the two main factors (disturbance level and proximity to forest), as spotted knapweed is a strong invader in disturbed systems and is not very shade tolerant. However, given the lack of any data on either weevil species in the south, we have cannot surmise the impact of either factor on natural enemy efficacy. Ultimately, we intend to collect data on the biological parameters of the two released species within each category of habitat. These data allow efficacy comparison among the different habitats and exploration of the differences in the natural enemies from published literature from the western US. Dynamics of the UV fly will be determined by sweep net and collection of flower heads (capitula) where the larvae develop (Duguma et al. 2009). These methods will also serve to determine the presence and activity of seed head weevils. The presence of the root weevil is most easily determined through visual observation of adult weevils feeding on flower heads and terminals late in the season. Root weevil larval collections require digging root sections and will not be conducted until establishment of the species is verified (i.e., year 3, beyond the scope of this project).

***Remote sensing techniques for spotted knapweed detection:*** We will use an ASD FieldSpec<sup>®</sup> Handheld spectroradiometer with sensitivity from 325-1,075 nm at three distinct spotted knapweed growth stages (bolting, flowering and senescence) to obtain suitable spectral signatures. Worldview-2<sup>®</sup> satellite imagery will be purchased for a small clear-cut area that includes forest edges, roads and early seral land that contains significant populations of spotted knapweed. Cost of this high spatial resolution (2x2 m per pixel) imagery for the 45km<sup>2</sup> area will be approximately \$1,440. The geometric accuracy of this Worldview-2 imagery is quite good; each pixel has an estimated maximum circular error of about 6.5 m 90% of the time. Spectroradiometer data will be analyzed alongside the WorldView-2 image data to determine the feasibility of detecting the weed on this land. This relationship will then be used as a model for comparison with other images. This is meant to be only a preliminary test of feasibility of weed detection, and not a comprehensive evaluation of weed distribution or management. Development of signature data and establishments of “training sites” for the system will be conducted as future projects.

## Timetable

	2010			2011				2012	
	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd
<b>OBJECTIVE 1</b>									
Release site sampling	X	X						X	
Additional <i>Larinus</i> releases	X	X			X	X			X
Establish <i>Cyphocleonus</i> plots	X			X					
Make <i>Cyphocleonus</i> releases		X			X	X			
Plot evaluations		X	X		X	X	X		X
<b>OBJECTIVE 2</b>									
Identify infested burn plots	X	X							
Characterize weed populations	X	X	X	X	X	X	X	X	
Characterize agent populations		X	X		X	X	X		X
Management presentation/pub			X	X			X	X	
<b>OBJECTIVE 3</b>									
Establish reflectance baselines	X	X	X	X	X	X	X		
Correlate imagery to populations			X	X					
Obtain new plot images				X	X	X	X	X	X
Evaluate management options			X	X	X	X	X		
Remote sensing presentations/pub							X	X	X

## IV. Accomplishments Expected

Given the recoveries in Arkansas of overwintering seed head weevils this past season from small releases in 2008, we are confident in our ability to establish *Larinus minutus* in Arkansas within the life of this project and that it can be established across the southern range of knapweed in the US (esp. TN, NC and KY). We will know by the completion of the project if the root weevil *Cyphocleonus achates* will tolerate the southern conditions as we expect. Early establishment of these effective natural enemies will not only reduce existing populations but should reduce further spread of this noxious weed in the south. We would plan to expand this project into a community-based natural enemy redistribution effort utilizing citizen teams (of affected landowners) as well as county-based extension personnel. We will model this approach after the successful purple loosestrife outreach project (Wiedenmann 2007) in order to educate the general public not only about spotted knapweed, but biological control of weeds in general. Finally, the remote sensing techniques developed in this project will aid future projects to determine additional spread of spotted knapweed in the southern US as well as to provide additional evidence in our evaluation of the impact of the biological control program on established knapweed populations. Dr. Jason A. Tullis, from the Department of Geosciences and Center for Advanced Spatial Technologies will cooperate on this project.

## V. Detailed Budget Information

**A. Personnel** - List each position by title and name of employee, if available. Show the annual salary rate and the percentage of time to be devoted to the project. Compensation paid for employees engaged in grant activities must be consistent with that paid for similar work within the applicant organization.

<b>Name/Position</b>	<b>Computation</b>	<b>Cost</b>
Graduate Student	17,000/yr	\$ 34,000
Hourly	13,000/yr	\$ 26,000
		<b>Total \$ 60,000</b>

**B. Fringe Benefits** - Fringe benefits should be based on actual known costs or an established formula. Fringe benefits are for the personnel listed in budget category (A) and only for the percentage of time devoted to the project. Fringe benefits on overtime hours are limited to FICA, Workman's Compensation, and Unemployment Compensation.

<b>Name/Position</b>	<b>Computation</b>	<b>Cost</b>
GRA Fringe Benefits	3.9%, \$663/yr	\$ 1,326
Hourly Fringe Benefits	6.5%, \$845/yr	\$ 1,690
		<b>Total \$ 3,016</b>

**C. Travel** - Itemize travel expenses of project personnel by purpose (e.g., staff to training, field interviews, advisory group meeting, etc.). Show the basis of computation (e.g., six people to 3-day training at \$X airfare, \$X lodging, \$X subsistence). In training projects, travel and meals for trainees should be listed separately. Show the number of trainees and unit costs involved, identify the location of travel, if known. Indicate source of travel policies applied, applicant or federal travel regulations.

<b>Purpose of Travel</b>	<b>Location</b>	<b>Item</b>	<b>Computation</b>	<b>Cost</b>
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Travel to collect agents	Colorado Springs, CO	1	Airfare (\$345), lodging (\$645) and subsistence (\$300) per trip (2 trips)	\$ 1,290
Travel for sampling in AR	statewide	1	2,500 miles/yr @ 0.43/mile (\$1,075/yr)	\$ 2,150
Travel to attend meeting for PI and grad student	TBD	1	Airfare (\$345), lodging (\$500) and subsistence (\$300) per trip (2 trips)	\$ 2,560
				<b>\$ 6,000</b>

**D. Equipment** - List non-expendable items that are to be purchased (Note: Organization's own capitalization policy for classification of equipment should be used). Expendable items should be included in the "Supplies" category. Applicants should analyze the cost benefits of purchasing versus leasing equipment, especially high cost items and those subject to rapid technical advances. Rented or leased equipment costs should be listed in the "Contractual" category. Explain how the equipment is necessary for the success of the project. Attach a narrative describing the procurement method to be used.

**Total: \$ 0**

**E. Supplies** - List items by type (office supplies, postage, training materials, copying paper, and expendable items such as books, hand held tape recorders) and show the basis for computation. Generally, supplies include any materials that are expendable or consumed during the course of the project.

Supply Items	Computation	Cost
Collecting bags, pruners, gloves, alcohol and mailing expenses for Colorado collections.	2,992/yr	\$ 5,984
		<b>Total \$ 5,984</b>

**I. Indirect Costs** - Indirect costs are allowed only if the applicant has a federally



approved indirect cost rate. A copy of the rate approval (a fully executed, negotiated agreement) must be attached. If the applicant does not have an approved rate, one can be requested by contacting the applicant's cognizant federal agency, which will review all documentation and approve a rate for the applicant organization, or if the applicant's accounting system permits, costs may be allocated in the direct costs categories. N/A

**Budget Summary** - When you have completed the budget worksheet, transfer the totals for each category to the spaces below. Compute the total direct costs and the total project costs. Indicate the amount of Federal requested and the amount of nonfederal funds that will support the project.

<b>Budget Category</b>	<b>Amount</b>
A. Personnel	\$ 60,000
B. Fringe Benefits	\$ 3,016
C. Travel	\$ 6,000
D. Equipment	\$ 0
E. Supplies	\$ 5,984
F. Construction	\$ 0
G. Consultants/Contracts	\$ 0
H. Other	\$ 0
Total Direct Costs	\$ 0
I. Indirect Costs	\$ 0
<b>TOTAL PROJECT COSTS</b>	<b>\$ 75,000</b>
Federal Request	\$
Nonfederal Amount	\$ N/A

## Literature Cited

- Bais, H. P., Vepachedu, R., Gilroy, S., Callaway, R., Vivanco, J. M., 2003. Allelopathy and Exotic plant Invasion: From Molecules and Genes to species Interactions. *Science*. 301, 1377-1380.
- Carson, H. W., L. W. Lass and R. H. Callihan. 1995. Detection of yellow hawkweed with high resolution multispectral digital imagery. *Weed Technology*. 9: 477-483.
- Corn, J. G., J. M. Story, and L. J. White. 2006. Impacts of the biological control agent *Cyphocleonus achates* on spotted knapweed, *Centaurea maculosa*, in experimental plots. *Biological Control* 37:75-81.
- Cortilet, A. B and N. Northrop. 2006. Biological Control of European Buckthorn and Spotted Knapweed. Minn. Dept. Agri. Final Program Report, St. Paul, MN. (available at: [http://www.mda.state.mn.us/news/publications/pestsplants/weedcontrol/knapweedlcmrfin\\_alreport.pdf](http://www.mda.state.mn.us/news/publications/pestsplants/weedcontrol/knapweedlcmrfin_alreport.pdf)).
- DiTomaso, Joseph M. 2000. Invasive weeds in rangelands: species, impacts, and management. *Weed Science*. 48(2): 255-265.
- Duguma, Demisse, D. 2008. Seasonal dynamics and impact of *Urophora quadrifasciata* (Meigen) (Tephritidae: Diptera) on spotted knapweed in the Arkansas Ozarks. MS Thesis, University of Arkansas. 106pp.
- Duguma, D. D., T. J. Kring, and R. N. Wiedenmann. 2009. Seasonal dynamics of *Urophora quadrifasciata* on spotted knapweed in the Arkansas Ozarks. *Canadian Entomologist*. 141: 70-79.
- Duncan, C. A., John, J. J., Brown, M. L. Carrithers, V. F., Clark, J. K., DiTomaso, J. M., Lym, R. G., McDaniel, K. C., Renz, M. J., Rice, P. M., 2004. Assessing the economic, environmental and societal losses from invasive plants on rangeland and wildlands. *Weed Technology*. 18, 1141-1416.
- Eddleman, L. E., and J. T. Romo. 1988. Spotted knapweed germination response to stratification, temperature, and water stress. *Canadian Journal of Botany*. 66:653-657.
- Ferguson, D. E., C. L. Craig and K. Z. Schneider. 2007. Spotted knapweed (*Centaurea biebersteinii* DC) response to forest wildfires on the Bitterroot National Forest, Montana. *Northwest Science*. 81(2): 138-146.
- Hufbauer, R. A. and R. Sforza. 2008. Multiple introductions of two invasive *Centaurea* taxa inferred from cpDNA haplotypes. *Diver. Distrib.* 14: 252-261.
- Knochel, D. G., and T. R. Seastedt. 2009. Sustainable control of spotted knapweed (*Centaurea stoebe*), pp. 211-225. In Inderjit (ed.), *Management of Invasive Weeds*. Springer Science and Business Media B.V., Netherlands.
- Lass, L. W., D. C. Thill, B. Shafii and T. S. Prather. 2002. Detecting spotted knapweed (*Centaurea maculosa*) with hyperspectral remote sensing technology. *Weed Technology*. 16: 426-432.
- Lass, L. W., T. S. Prather, N. F. Glenn, K. T. Weber, J. T. Mundt and J. Pettingill. 2005. A review of remote sensing of invasive weeds and example of the early detection of spotted knapweed (*Cenaurea maculosa*) and babysbreath (*Gypsophila paniculata*) with a hyperspectral sensor. *Weed Science*. 53: 242-251.
- MacDonald, N.W., M. T. Koetje and B. J. Perry. 2003. Native warm-season grass establishment on spotted knapweed-infested gravel mine spoils. *Journal of Soil and Water Conservation*, 58 (5): 243-251.

- Mauer, T., M. J. Russo and M. Evans. 1987. Element stewardship abstract for *Centaurea maculosa*. The Nature Conservancy. Arlington, VA.
- Michels, G. J., C. A. Carney, D. Jurovich, S. Kassymzhanova-Mirik, E. Jones, K. Barfot, J. Bible, M. Mirik, S. Best, E. Bustos, B. Karl, and D. Jimenez. 2007. Biological control of noxious weeds on federal installations in Colorado and Wyoming. Texas Agric. Exper. Station. 2006 Annual Report, 222pp. (available at: [http://amarillo.tamu.edu/programs/entotaes/CNWB Annual Reports.htm](http://amarillo.tamu.edu/programs/entotaes/CNWB%20Annual%20Reports.htm)).
- Michels, G. J., H. L. Lindon and D. Lunsford. 2009. Biological control of noxious weeds along the Colorado-Wyoming front range. Texas Agric. Exper. Station. 2006 Annual Report, 42pp. (available at: [http://amarillo.tamu.edu/programs/entotaes/Reports/Colorado/2009 Colorado Biological Control Program Review of 2008 Denver 041409 II.pdf](http://amarillo.tamu.edu/programs/entotaes/Reports/Colorado/2009%20Colorado%20Biological%20Control%20Program%20Review%20of%202008%20Denver%20041409%20II.pdf)).
- Minteer, C. 2007. *Centaurea stoebe* subsp. *micranthos* (spotted knapweed) [Asteraceae] an invasive species in southern Ozarks: infested vs non-infested sites and a ploidy level study. MS thesis, Department of Biological Sciences, University of Arkansas. Fayetteville, AR. 54p.
- Myers, J. H. 2004. A silver bullet in the biological control of diffuse knapweed. ESA 2004 Annual meeting abstract. <http://abstracts.co.allenpress.com/pweb/esa2004/document/36421>.
- Myers, J. H., C. Jackson, H. Quinn, S. R. White, and J. S. Cory. 2009. Successful biological control of diffuse knapweed, *Centaurea diffusa*, in British Columbia, Canada. *Biological Control* 50:66-72.
- Sheley, R. L. and J. K. Barko (Eds.). 1999. Biology and management of noxious rangeland weeds. Oregon State University Press, Corvallis. 438pp.
- Smith, L. 2004. Impact of biological control agents on *Centaurea diffusa* (diffuse knapweed) in central Montana, pp. 589-593. In J. M. Cullen, D. T. Briese, D. J. Kriticos, W. M. Lonsdale, L. Morin and J. K. Scott (eds.), Proceedings of the XI International Symposium on Biological Control of weeds, April 27-May 2 2003, Canberra, Australia.
- Story, J. M., N. W. Callan, J. G. Corn and L. J. White. 2006. Decline of spotted knapweed density at two sites in western Montana with large populations of the introduced root weevil, *Cyphocleonus achates* (Fahraeus). *Biological Control*. 38: 227-232.
- Westbrooks, Randy G. 1998. Invasive plants: changing the landscape of America. Fact Book. Washington, DC: Federal Interagency Committee for the Management of Noxious and Exotic Weeds. 109 pp.
- Wiedenmann, R.N., S.L. Post, M.R. Jeffords and D.J. Voegtlin. 2007. Biocontrol for everyman: public participation in a weed project, pp. 92-104. In Vincent, C., M.S. Goettel, and G. Lazarovits (eds.) *Biological Control; A Global Perspective*, CABI, Oxfordshire, UK.
- WorldView-2. <http://www.digitalglobe.com/index.php/88/WorldView-2>