Economics of Invasive Weed Control: Chemical, Manual/ Physical/Fire, Biological, and Doing Nothing

by Dr. K. George Beck, Colorado State University

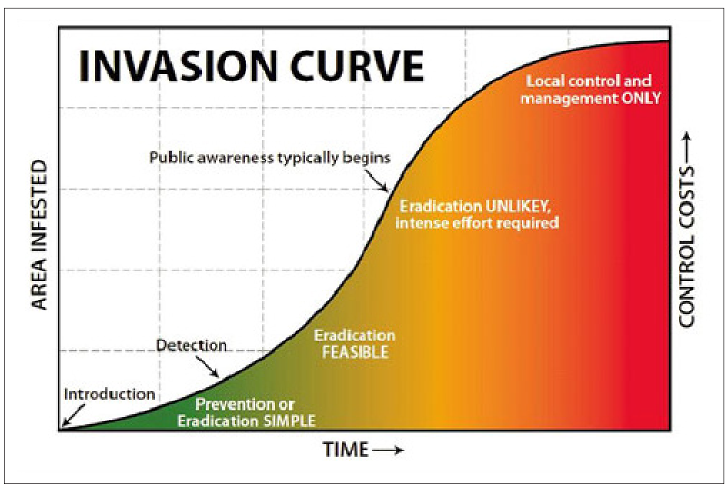
Financial Costs Per Acre and Impacts to Budgets

Regardless of whether working for private enterprise or government, land management personnel must stretch limited budgets yet be effective simultaneously. Labor is the most expensive portion of a weed management project. It is incumbent upon land managers to use methods that minimize labor costs, and this is especially so with public land managers because they are dependent upon tax dollars to execute their programs.

Using herbicides and biological control agents to decrease the population abundance of a target invasive weed are approaches that utilize the least labor to affect initial and continued reduction of the target species. Because biocontrol is developed using public funds, it seems inexpensive to the end user, which includes federal agencies. Biocontrol is a very attractive and highly useful approach to control invasive weed species, however, success has been inconsistent in space and time. There are numerous successful biocontrol endeavors and the literature offers many examples. The USDA Forest Service's Fire Effects Information System website (www.fs.fed.us/database/feis/) is one of the best and most complete information sources for the biology and management of many invasive weed species. Another outstanding source of information on managing invasive weeds which recently became available is *Weed Control in Natural Areas in the Western United States* (Joseph DiTomaso et al., 2013: University of California Weed Research and Information Center). It too describes where and upon what species biocontrol has been successful and extensively outlines all management options. If biocontrol is the method selected, land managers must carefully research choices for their effectiveness. The spatial and temporal variation associated with biocontrol performance may be due to many genetic and environmental reasons—from habitat preference by the biocontrol agent to the production of new genotypes from previously geographically separated genotypes now growing in proximity to one another, and many as yet to be discovered reasons.

Fire too can be a good tool to decrease populations (DiTomaso et al. 2006) of some invasive weeds, most notably annual grasses and forbs such as cheatgrass *(Bromus tectorum)*, medusahead *(Taeniatherum caput-medusae)*, and yellow starthistle *(Centaurea solstitialis)*. As with other integrated management systems for weeds, the use of fire to manage invasive weeds must be integrated with other tools, such as seeding, to provide competition to ward off recovering weed species and allow for completion of land management goals and objectives. Burning mixed brush-cheatgrass stands destroys some to many weed seeds and allows about one season of desirable vegetation to establish before cheatgrass re-establishes and dominates the site again (Evans and Young 1978; Young and Evans 1978; Young 2000). Establishing competitive perennial grass species may successfully keep cheatgrass from re-establishing. If, however, the system is left alone after burning, cheatgrass or medusahead will re-invade. Burning stands of yellow starthistle also can provide excellent population control if combined with herbicide treatment and seeding (DiTomaso et al. 2006b). Burning stands of a perennial weed, such as Canada thistle *(Cirsium arvense)*, leafy spurge *(Euphorbia esula)*, Russian knapweed *(Acroptilon repens)* and other knapweeds, or tamarisk *(Tamarix* spp.), is rarely effective because of the plants' ability to re-grow from its root system and dominate a site again. These and other similar invasive weeds may recover soon enough after a prescribed burn to preclude establishment of seeded species. If fire is used to control perennial forbs or grasses, herbicides will likely have to be integrated into the management system to allow sufficient suppression of the target weed for a long enough time to

Figure 1. Most invasive species populations develop in a sigmoid curve pattern, which charts the lag time following their introduction, exponential growth, and eventual limitation due to resource availability.



give seeded species the opportunity to establish.

Of all the methods used to decrease weed population abundance, herbicides are the most researched and arguably the best understood. In the course of their development, consistent performance in space and time is an extremely important factor that must be established before a product reaches the consumer. Because of known performance developed from extensive research, and the decreased labor associated with their use, herbicides often represent the most cost-effective means to control invasive weed populations so land restoration or rehabilitation may proceed (especially when using tax payer dollars).

Doing Nothing

The decision to do nothing about an invasive species population seems inexpensive and harmless on the surface; however, nothing could be farther from reality. The problem with invasive species is their populations always seem to expand and cause harm, albeit, a species can be problematic in one location or setting and not another (Beck et al. 2008). Most invasive species and certainly invasive weed populations develop in a sigmoid curve pattern; after a lag time following introduction, their populations increase exponentially until site saturation, when their populations are limited by resource availability (Figure 1). The problem is that one never knows where on the curve the population lies at any given time. Even with cheatgrass, the invaded location/site might be new and at the bottom of the curve, when population control is most easily obtained, or it might be at beginning of the exponential phase, but it is difficult at best to make such a determination. The best response is to *never do nothing*. Doing nothing can be the most expensive decision one can make due to the subsequent population growth by the invasive weed and the resulting havoc it wreaks upon the native plant community and the animals it supports. Doing nothing simply yields the site to the invasive species.

Importance of Prevention and Early Detection and Rapid Response/Eradication

Prevention often is thought of as the most powerful form of weed management and, indeed, the least expensive weed to control is the one that is not present; however, prevention is not free. The perception that prevention is simply steps taken to keep out stuff that currently does not exist in a particular location is accurate for certain and possibly represents the greatest cost savings to taxpayers. Cleaning equipment between uses and locations seems a logical approach to prevention—along with using certified weed seed-free hay, forage, mulch, and gravel, and carefully screening of ornamental and agricultural introductions—and can be of tremendous benefit in the battle against invasive species. Prevention, however, can be expensive when it arbitrarily impedes trade. Benefit : risk assessment is an important if not an essential component of screening programs, so decisions that impact trade are transparent, logical, and acceptable.

Prevention also means decreasing the population abundance of existing weed infestations so they are not a source for new ones to develop. It is quite appropriate to think of extending prevention as a management strategy to efforts that decrease target populations in an infestation that is part of a project area. In fact, this may be the best "first light" under which to examine prevention efforts; that is, how to keep current infestations from serving as sources for others. The silo (or stovepipe) approach to any weed management project is dangerous. Invasive species management should always be thought of as a continuum among the strategies and methods

Table 1. A hypothetical comparison of the costs of controlling spotted knapweed manually or chemically, demonstrating the importance of early detection and rapid response.

	MANUAL CONTROL		CHEMICAL CONTROL				RESEEDING	TOTAL COST	
			Application cost ($)						
Initial patch size	Labor (hours)	*Manual control cost ($)*[a]	Spot spray[b]	Broadcast spray[b]	Herbicide cost ($)[c]	*Chemical control cost ($)*	Native plant seed cost ($)[d]	Manual control and reseeding ($)	Chemical control and reseeding ($)
10 feet	0.25	*3.00*	0.20	—	0.003	*0.203*	0.00[e]	3.00	0.203
100 feet	0.50	*6.00*	2.00	—	0.030	*2.030*	0.46	6.46	2.490
1 acre	145.00	*1,742.00*	—	20.00	14.000	*34.000*	200.00	1,942.00	234.000
10 acres	1,450.00	*17,420.00*	—	200.00	140.000	*340.000*	2,000.00	19,420.00	2,340.000
100 acres	NR[f]	—	—	2,000.00	1,400.000	*3,400.000*	20,000.00	—	23,400.000

[a] Cost is based on the following information: handpulling/digging wages = $12/hour.

[b] Cost is based on the following information: application cost ($20/acre) and labor ($12/hour).

[c] Cost comparisons based upon: Milestone® herbicide ($300/gallon).

[d] Cost of native plant seed: $200/acre.

[e] A 10 ft^2 patch of knapweed likely will not have eliminated competition and natural recruitment is the typical response of a land manager in such a situation.

[f] Not realistic (NR).

used to manage such species. All this must be kept in mind because prevention and early detection and rapid response (EDRR) are the first lines of defense against invasive species.

Economics and Pest Expansion Models Can Help Set Program Priorities

Almost every person recognizes that it is much simpler to pull a single, newly found invasive weed than to let it go and try to eradicate the large infestation that undoubtedly will occur over time. It is puzzling, then, that people tend to wait because, "that weed is not causing me a problem … now," knowing that it inevitably will do so. The sooner an incipient patch of an invasive weed is controlled, regardless of proximity to the source, the less expensive it will be to control, the greater the success will be, and most likely one will have eradicated a new or small dispersed population. Table 1 shows the increasing control cost associated with waiting in a hypothetical example of a newly found patch of spotted knapweed *(Centaurea maculosa; C. stoebe)*. Table 1 also compares the decision to control the knapweed infestation manually versus using a herbicide, and reseeding costs are shown for both methods.

These comparisons clearly show that the decision to wait to respond to a new weed infestation can be very costly. Regardless of the method, the cost of management increases several thousand times, but the cost of manual control exceeds the cost of using a herbicide by 800 to 1500%. This example shows the value of monitoring to find incipient invasive weed populations so they can be effectively controlled or eradicated at a fraction of the expense, compared to waiting for impact and havoc to occur. These comparisons also show the dramatic fiscal savings associated with using a herbicide, compared to handpulling or similar manual methods of control. The decisions to act quickly when new or small infestations are found and to use a herbicide to decrease the target weed population represent efficient and responsible use of taxpayer dollars and the stretching of limited budgets.

Tables 2 and 3 compare the costs associated with different methods to decrease target weed populations on Colorado and Montana rangeland in the late 1990s (cost estimates in Table 2 are hypothetical). Diffuse knapweed (*Centaurea diffusa)* was targeted in Colorado, where handpulling twice annually was compared to mowing three times annually, to mowing twice followed by herbicide in fall, to herbicide

Table 2. A hypothetical comparison of costs of different control methods for diffuse knapweed on Colorado rangeland in 1997, and subsequent control one year after original treatments were applied (Sebastian and Beck 1999).

	TREATMENT COSTS									EFFECTIVENESS OF CONTROL	
	Manual control			Chemical control							
Control method	Cost per acre ($)	Times per year	Manual control cost per acre ($)	Herbicide cost per pint ($)	Pints used per acre	Herbicide cost per acre ($)	Application cost per acre[a] ($)	Chemical control cost per acre ($)	**Total cost per acre ($)**	Rosette[b] (%)	Bolted[b] (%)
Handpull[c]	1,339.00	2	*2,679.00*	—	—	—	—	—	**2,678.00**	0c	0d
Mow[d]	50.00	3	*150.00*	—	—	—	—	—	**150.00**	0c	0d
Mow + herbicide application[e] (Tordon®)	50.00	2	*100.00*	10.75[f]	1.0	10.75	20.00	*30.75*	**130.75**	84a	100a
Mow + herbicide application (Transline®)	50.00	2	*100.00*	38.75[g]	1.0	38.75	20.00	*58.75*	**158.75**	43b	100a
Herbicide application (Tordon®)	—	—	—	10.75[f]	1.0	10.75	20.00	*30.75*	**30.75**	74a	96b
Herbicide application (Transline®)	—	—	—	38.75[g]	1.3	50.38	20.00	*70.38*	**70.38**	8c	94bc
Herbicide application (Banvel® + 2,4-D)	—	—	—	11.25[h]	2.0	22.50	20.00	*42.50*	**42.50**	0c	89c
Control	0.00	0	*0.00*	0.00	0.0	0.00	0.00	*0.00*	**0.00**	0	0

[a] In addition to the herbicide used, each application costs $20 per acre in miscellaneous costs (labor, transportation, equipment, etc.).

[b] Values followed with the same letter do not significantly differ (p=0.05).

[c] The cost of handpulling is based on the following information: labor = $9/hour; time required to handpull an area of 1,200 ft^2 = 4.1 hours; ($36.90/1,200 ft^2) × (43,560 ft^2/acre) = $2,679/acre.

[d] It takes approximately 1.1 hours to mow one acre.

[e] It takes approximately 25 minutes to treat one acre with herbicide.

[f] Cost based on the following information: 1 gallon Tordon® costs $86 and treats 8 acres; ($86/gal. = $10.75/pint).

[g] Cost based on the following information: 1 gallon Transline® costs $310 and treats 8 acres; ($310/gal. = $38.75/pint).

[h] Cost based on the following information: 1 gallon Banvel® + 2,4-D costs $90 and treats 4 acres; ($90/gal. = $11.25/pint).

application alone. Control of diffuse knapweed rosettes and bolted plants was best one year after treatments were exerted where a herbicide was used alone or in combination with mowing compared to mowing alone or handpulling. Herbicides alone were about 1% of the total cost of handpulling, and the latter was completely ineffective.

The second experiment (Table 3) was conducted in Montana on spotted knapweed. It differed from the Colorado experiment in that biocontrol was also evaluated, and the treatments were exerted for two years and data was collected shortly (one to two months) thereafter. Handpulling prevented 100% of plants from going to seed (bolted plants were targeted for pulling), but controlled only about one-half of spotted knapweed plants. Herbicides alone kept 93–100% of plants from going to seed and controlled 79–100% of spotted knapweed plants. Mowing combined with herbicide use produced similar results to herbicides alone. Biocontrol was ineffective, but insufficient time had passed to allow successful establishment much less spotted knapweed population decrease. As with the Colorado study, the use of herbicides alone was less than 1% of the cost associated with handpulling and controlled almost twice as much knapweed.

Both of these experiments show the strong monetary and weed control advantages associated with using herbicides to decrease target weed populations. All government land managers, regardless of the level of government, must demonstrate fiscal responsibility to taxpayers and that not only translates into total dollars spent but also what benefit or return was realized from the expenditures.

Control Risks vs. Harm Caused by Invasive Weeds

Duncan and Clark (2005) cite numerous examples of the environmental and economic impacts caused by invasive weeds. Pimentel et al. (2005) calculated that invasive species impact the US economy by more than $120 billion annually and $36 billion of which was caused by invasive weeds. The problems associated with invasive weeds are very clear and very expensive. The harm, real or potential, from invasive species is always a much greater risk than the tools used to control any invasive taxa but especially invasive weeds. If this was not the case, the species in question would not be considered invasive. Invasive species alter evolved relationships among organisms that share a habitat or ecosystem, which is highly significant biologically, ecologically, and economically.

Herbicides are the most efficacious, most economical, and most consistent means of decreasing the population

Table 3. Cost of different control methods invoked for two consecutive years for spotted knapweed in Montana, and subsequent control one year after initial treatments applied and one month after final treatments (Brown et al. 1999).

Treatment	Rate [a]	Plant growth stage	Application date 1997 (month/day)	Application date 1998 (month/day)	Aug. 4, 1998 control Flower (%) [b]	Aug. 4, 1998 control Plant (%) [b]	Cost/acre over two years ($) [c]
Handpull (bolted plants)	2 ×	Early and late bud	6/20 7/20	6/20 7/22	100a	56d	13,900.00
Tordon® plus handpull (rosettes + mature)	0.125 1 ×	Bolt Late bud	6/2 —	— 7/21	100a	98ab	97.90
Mowing	2 ×	Early and late bud	6/20 7/20	6/19 7/17	99a	0f	200.00
Mowing plus Tordon®	1 × 0.125	Late bud Fall regrowth	7/20 9/29	— —	100a	100a	75.37
Mowing plus Curtail®	1 × 0.095 + 0.5	Late bud Fall regrowth	7/16 9/29	— —	100a	93b	77.67
Tordon®	0.125	Fall regrowth	9/29	—	100a	96ab	25.37
Curtail®	0.095 + 0.5	Fall regrowth	9/29	—	100a	79c	27.67
Tordon®	0.25	Bolt	6/2	—	99a	98ab	30.75
Curtail®	0.19 + 1	Bolt	6/2	—	93b	93b	35.37
Cyphocleonus achates	30/plot	Flower	8/27	—	0d	0f	90.00
Tordon® *Cyphocleonus achates*	0.09 30/plot[d]	Bolt Flower	6/2 8/27	— —	46c	46e	113.58
Untreated					0d	0f	
LSD (0.05)					4.96	6.11	

[a] Herbicide rate (lb/acre), x = number of times.

[b] Values followed with the same letter do not significantly differ (p=0.05).

[c] Cost based on the following information: Handpulling wages $9.00/hr; weevils $1.00/insect; mowing $50/A; Tordon® $86.00/gal.

[d] Due to low density of spotted knapweed plants, one plot received only 15 weevils in the Tordon® plus root weevil treatment.

abundance of invasive weeds. A common theme is readily apparent when attempting to recover an infested habitat; that is, a land manager must first decrease the population of the invasive weed before beginning any seeding operation or the latter effort will fail. Other site characteristics also may be in need of attention to fully realize restoration and these too should be addressed before expecting establishment of seeded species. Many of these characteristics could be very expensive to repair and thus, all the more reason to use the most economically viable tool to decrease invasive weed populations and use taxpayer dollars to the greatest extent possible.

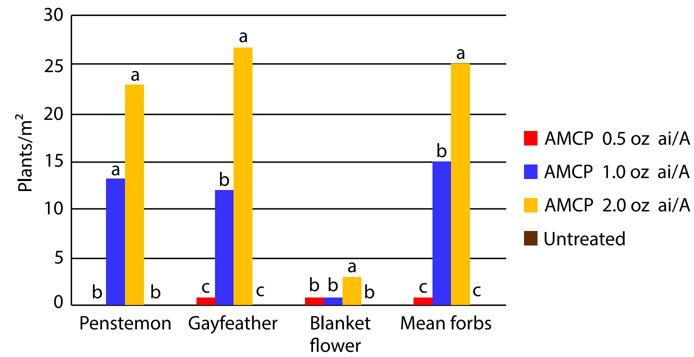
One serious concern about using herbicides to decrease target invasive weed populations is their effect on native plants, especially native forbs and shrubs. Many people believe that using a herbicide that will control invasive weedy forbs will strongly select for grasses and eliminate native forbs and shrubs, which are essential components of any native plant community. This is, in fact, not the case and the weed research community is developing databases to define the injury to native grasses, forbs, and shrubs caused by herbicides used to control invasive weeds. Erickson et al. (2006) sprayed Paramount® (quinclorac) or Plateau® (imazapic) directly onto the western prairie fringed orchid *(Platanthera praeclara)* in fall, when it was senescing, to mimic when these herbicides would be used to control leafy spurge. Data were collected on orchid survival and fecundity 10 and 22 months after treatments (MAT) were applied. Neither herbicide influenced orchid survival. Plateau® decreased orchid height by 43% at 10 MAT but this effect was no longer apparent at 22 MAT. Plateau® also decreased raceme length by 58% and flower number by 70% at 22 MAT. Quinclorac, however, had no such effects on the orchid and the researchers concluded that it was safe to use Paramount® to control leafy spurge in the presence of the western prairie fringed orchid. The researchers further concluded that, while Plateau® caused temporary stunting and decreased fecundity of the orchid, most of these symptoms disappeared the second year following treatment.

Rice et al. (1997) studied the effects of plant growth regulator herbicides (picloram, clopyralid, and clopyralid + 2,4-D) on native grasses, forbs, and shrubs applied to control spotted knapweed in Montana over an eight-year period at four sites. Herbicides were applied once in either spring or fall to control spotted knapweed in 1989 and re-treated again in 1992 to control the recovering invasive weed. Plant community data were collected annually over the eight-year period and compared back to the floristic composition of each study site determined before initiation of the experiments. Herbicides controlled spotted knapweed very well (98–99% control) and shifted the plant community to dominance by grasses but the depression on plant community diversity was small and transient. By the end of the third year after initial treatment there were no differences in species diversity among treatments, and some herbicide-treated plots began to surpass untreated plots in plant community diversity measurements. They also found that late-season herbicide application after forbs had entered summer-drought induced dormancy minimized the impact on plant community diversity. The effects of the pyridine herbicides (picloram and clopyralid) on the native plant community diversity were small, temporary, and minimal compared to the reported impacts caused by spotted knapweed on the plant community (Tyser and Key 1988; Tyser 1992).

University researchers worked with Dow AgroSciences to test a new pyridine herbicide, Milestone® (aminopyralid), effects on native grasses, forbs and shrubs (http://techlinenews.com/ForbShrubTolerancetoMilestone.pdf) at 14 locations throughout the western U.S. Individual tolerance rankings were established for 90 native forb and 19 native shrub species to Milestone® applied at 5.0 or 7.0 oz/a in spring, late summer, or fall. Of the 90 forb species studied in this experiment, 23, 14, 19, and 34 were ranked as susceptible (more than 75% stand reduction), moderately susceptible (51–75% stand reduction), moderately tolerant (15–50% stand reduction), and tolerant (less than 15% stand reduction) one year following application. Many of these forbs recovered by the end of the second year following application and only 19 of the 90 forbs were ranked either as moderately susceptible or susceptible at that time. Interestingly, shrubs generally were more tolerant of Milestone® than were forbs. Of the 19 shrubs in the study, 74% were ranked as moderately tolerant or tolerant two years after herbicides were applied and *Rosaceae* shrubs were generally the most susceptible species. These data also demonstrate the transitory nature of injury to native forbs and shrubs caused by herbicides used to decrease the populations of invasive weeds.

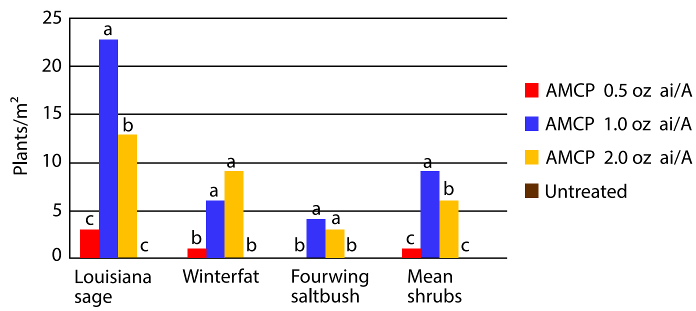
Aminocyclopyrachlor (AMCP) is a new herbicide developed by DuPont and can be used to control susceptible invasive weedy forbs and woody species. It is a reduced-rate herbicide (typical maximum rate for selective weed control is 2.0 oz of active ingredient per acre (a.i./a) that was placed on a fast-track registration by the US Environmental Protection Agency. An experiment was conducted on a rangeland site north of Denver, Colorado (Sebastian et al. 2011), to assess the establishment of native forbs and shrubs after using AMCP to decrease the population abundance of Russian knapweed. The herbicide was applied at 0.0, 0.5, 1.0, and 2.0 a.i./a on 14 May 2009 and 10 native forbs, four native shrubs, and two native, cool-season perennial grass species were drill-seeded in April 2010 and data were collected in fall 2010. Data for a penstemon species, gayfeather *(Liatris punctata),* and blanketflower *(Gaillardia pulchella)* showed the highest establishment at the highest herbicide rate, where Russian knapweed control was greatest (Figure 2) and the same effect was observed for the average of all

Figure 2. Russian knapweed control using aminocyclopyrachlor (AMCP) and native forb establishment. Fall 2010 data; compare within species.



RK control: 0.5 oz ai = 31%: 1.0 oz ai = 38%: 2.0 oz ai = 87%: untrt = 0%

Figure 3. Russian knapweed control using aminocyclopyrachlor (AMCP) and native forb establishment. Fall 2010 data; compare within species.



RK control: 0.5 oz ai = 31%; 1.0 oz ai = 38%; 2.0 oz ai = 87%; untrt = 0%

forbs; blanketflower, however, appeared more susceptible to the herbicide residue than did the penstemon species and gayfeather. Shrubs in general seemed to be more susceptible than forbs to AMCP soil residues (Figure 3). Greatest establishment of all seeded shrubs was realized at the 1.0 oz a.i./a rate of AMCP. Louisiana sage *(Artemisia ludoviciana)* established best at the 1.0 oz rate of AMCP, but winterfat *(Krascheninnikovia lanata)* and fourwing saltbush *(Atriplex canescens)* established similarly at the 1.0 and 2.0 oz rates of AMCP and all three species established better than in plots where the Russian knapweed was not controlled. The latter is a key response and our research results are very clear regardless of the target species and herbicides used to decrease its populations—the target weed species populations must be decreased to give seeded species the opportunity to establish or failure of the latter will ensue. Overall summary of this experiment showed that 50% of grasses, 8% of forbs, and no shrubs established in the untreated controls whereas 100% of grasses, 93% of forbs, and 88% of shrubs established in plots treated with 2 oz a.i./a of aminocyclopyrachlor where Russian knapweed control was maximized.

A similar studied was conducted at a foothills location west of Longmont, Colorado, but on an established plant community (Sebastian et al. 2012). It is a harsh site with thin topsoils and a very robust native plant community that was invaded by Dalmatian toadflax *(Linaria dalmatica)*. ACMP was applied at 0.0, 0.5, 1.0, and 2.0 oz a.i./a in May 2009 and data were collected in fall 2010. Dalmatian toadflax adults were controlled well at 1.0 and 2.0 a.i./a (Figures 4 and 5) but a flush of toadflax seedlings was apparent, suggesting that the herbicide residue was insufficient to control these germinants (data not shown). The mean density of all native forbs (Figure 4) decreased 22, 18, and 40% at the 0.5, 1.0, and 2.0 oz a.i./a AMCP rates, respectively. Native shrubs appeared more sensitive to ACMP than forbs; mean shrub densities decreased 33, 42, and 75% at the 0.5, 1.0, and 2.0 oz a.i./a rates (Figure 5). Overall, native forb richness by species decreased 22–44% and shrubs decreased 33–75%, but neither native functional group were eliminated by ACMP. Warm season grass abundance increased 227% (data not shown) over the course of the experiment likely in response to increased summer precipitation that occurred in 2010. The harsh conditions at this site—that is, thin soils and typically dry climatic

Figure 4. Change in native forb species richness and Dalmatian toadflax response to aminocyclopyrachlor (AMCP). 2010 data; compare forbs to Dalmatian toadflax.

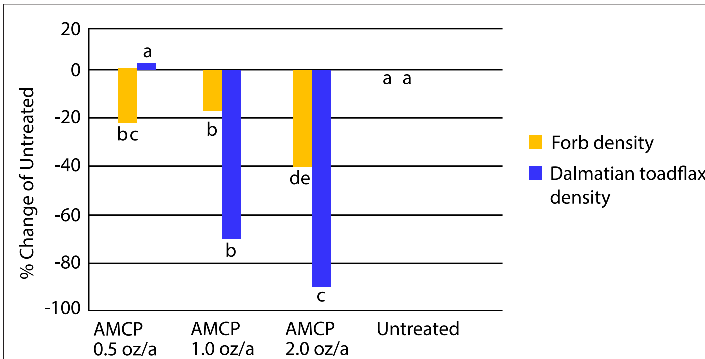
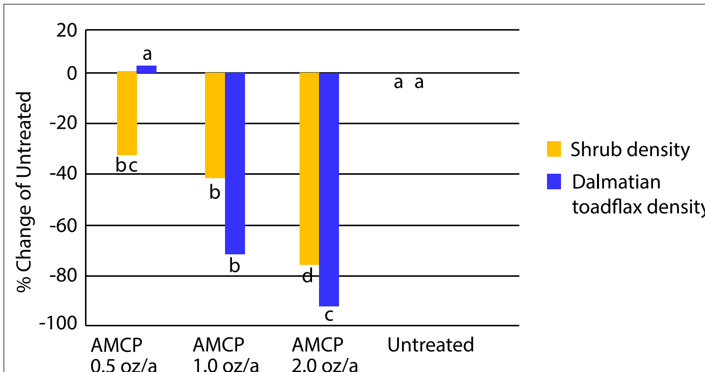


Figure 5. Change in native shrub species richness and Dalmatian toadflax response to aminocyclopyrachlor (AMCP). 2010 data; compare shrubs or Dalmatian toadflax.



conditions replaced by abundant summer precipitation—appeared to have influenced results and this experiment is currently being repeated at three additional sites nearby. We will continue to monitor changes at all four sites for at least four years following herbicide application to detect temporary and permanent shifts in the native plant community.

Continual monitoring for incipient patches or introductions is of critical importance for successful invasive species management. Bear in mind that invasive species have earned such declaration and their populations almost always increase, often exponentially so. New ecological relationships vary drastically from their points of origin—there are over 20 hypotheses associated with invasion success, but they all share the common theme that invasive species populations, regardless of species, increase dramatically in new homes. Invasive weed populations throughout the US should be managed assertively by all land managers, but especially by public land managers who are responsible for large tracts of land for the benefit of the American public. Management systems developed to help restore or reclaim infested habitats should be effective and efficient. One of the most important aspects associated with being effective and efficient is the decrease in the population abundance of invasive weeds that must occur before seeded species can successfully establish. Herbicides represent the most effective and fiscally efficient means to decrease target invasive weed populations. Databases are under development that carefully define the injury to native grasses, forbs, and shrubs caused by herbicides used to control invasive weeds. These databases will provide land managers with the appropriate information to design ecologically-based, invasive plant management systems that include herbicides yet allow recovery of productive native plant communities so land management goals and objectives can be realized.

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