TechLine
Information for Noxious Weed Control Professionals

June, 1993

Effects On Plant Community Diversity After Herbicide Control of Spotted Knapweed

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Adapted from a study completed by Peter Rice, Donald Bedunah (both at University of Montana), and Clinton Carlson, USFS, published by the USFS Intermountain Research Station.

Spotted knapweed and other invasive noxious weeds can pose a serious threat to pastures, rangelands, and native wildlands. To manage these undesirable plants and protect our natural resources requires an integrated systems approach. Integrated management systems may use a combination of biological, cultural, physical, and chemical control options to manage noxious weeds.

Since herbicides may be one integrated option, it is legitimate to ask what the effect of herbicides might be on non-target plant species. Will native forbs be eliminated and grass "monocultures" be created by herbicide treatments? What is the response of natural bunchgrass and forest plant communities following herbicide control of spotted knapweed infestations?

Peter Rice, Donald Bedunah – both at the University of Montana, and Clinton Carlson – USFS, recently completed an intensive study to answer this question. This issue is a detailed summary of their study and its conclusions.

Introduction

Spotted knapweed causes reduced vigor of native plant poplulations, less plant diversity on infested sites, and economic losses because of reduced livestock production. Spotted knapweed reduces forage production, thus it can impact wildlife populations. Spotted knapweed also can expand slowly into natural grassland sites that are undisturbed by human or livestock activites, cause declines in plant community diversity (Forcella and Harvey 1983; Tyser and Key 1988). It can invade forested sites disturbed by timber harvesting, thinning, and livestock grazing. Spotted knapweed has aggressively invaded extensive areas of rangelands and forest sites with open overstories at low to mid-elevations in the Northern Rockies (Losensky 1987). The weed had infested more than 7 million acres in Montana and adjoining states and provinces by 1988 (Lacey, C. 1989). As knapweed increases, cover of more desirable - but less competitive - grasses and forbs is significantly reduced, sometimes as much as 60% to 90% (Baker and others 1979; Bucher 1984; Harris and Cranston 1979).

An example of one of the grassland sites which was originally grazed by cattle in the 1950s, but now is only used by wildlife.

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Spotted knapweed is susceptible to low rates of certain herbicides. Tordon* 22K (picloram), Transline (clopyralid), Curtail* (clopyralid and 2,4-D), and 2,4-D have high efficacy when applied properly. But biologists and land managers are concerned about the effect of herbicides on non-target plant species.

- Will native forbs be eliminated and grass "monocultures" be created by herbicide treatments?
- What is the response of natural bunchgrass and seral forest communities following herbicide control of spotted knapweed infestations?

This study addresses these practical questions. Preliminary results suggest that herbicides are a feasible vegetation management option for land managers concerned about noxious weed invasions and biological diversity.

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Research Summary

Herbicides were applied to replicated treatment plots at four sites in west-central Montana with light to moderate spotted knapweed infestations. Plant community diversity was determined for two seasons before the herbicide treatments and diversity measurements have been completed for two years after herbicide application.

- Although knapweed suppression was high, the communitites were not converted to grass monocultures by using herbicides.
- No large declines in diversity were caused by these herbicide treatments. Three years after the spray treatments, community response data collected from a limited set of pilot study plots suggested that the herbicide treatments had increased diversity.
- Depressions in plant community diversity measurements due to herbicide treatment were small and temporary.
- Transline had the least effect on plant diversity.
- Plots treated with Tordon and plots treated with Curtail showed a small one year post spray decline in plant diversity. Diversity increased during the second post spray growing season.
- Soil samples found small amounts of herbicide below 10 inches. Herbicide residuals in the soil at the 10 to 20 inch depth increment were generally undetectable and did not exceed 26 parts per billion at 30 days, trace after one year, and none were detected after two years.

Sites 3 & 4 are forest land sites, located side-by-side, in a clearcut that was logged and dozer-piled in the mid 1960s. The area was grazed by cattle but for the study they were fenced out in 1988. Deer and elk grazing on the sites is light.

Methods

In Missoula County in west-central Montana, researchers conducted a pilot study to estimate species diversity changes at two sites where herbicides had been applied in 1985 to control spotted kanpweed. In 1988 the pilot diversity data were collected–3 years post spray. Those data were then used to plan an indepth formal community response study at four new sites in the same county.

Pilot Diversity Study

The 1988 measurements from the two pilot study sites showed moderate knapweed cover values of 27% and 30%. The Fort Missoula site—a bluebunch wheatgrass series habitat type—had low overall plant diversity. The site was also dominated by knapweed – the result of long and severe disturbance by livestock and human activities. The Lolo site was dominated by spotted knapweed, but the plant community was much more diverse and representative of a rough fescue potential natural community.

Herbicides had been applied to replicated test plots in the spring of 1985. Tordon 22K at 1 pint/acre and Transline at a rate of 2/3 pint/acre were used at both sites, and a mixture of Tordon 22K (1/2 pint/acre) and Transline (1/3 pint/acre) was applied at the Lolo site. Herbicide treatments and check plots were replicated three times at the Lolo site and twice at Fort Missoula. Livestock grazing was excluded, but not wildlife access. Community response was measured in the 1988 cool season (May and June) using a cover microplot method (Hann and Jensen 1987) adapted from Daubenmire 1959.

Formal Community Response Study

The formal community diversity study used four sites with low to moderate spotted knapweed infestations and diverse plant communities. The average spotted knapweed absolute cover for the 1988 warm season was:

Site 1– 21%
Site 2– 7%
Site 3– 10%
Site 4 - 3%

Disturbed sites with 60% to 90% spotted knapeed cover are not uncommon in western Montana. During the 1988 growing season, below-average soil moisture and precipitation also limited plant growth. Two of the sites are grassland habitat types with gravelly-loam textures. Two are forest habitat types with silt-loam textures.

Site 1 is a rough fescue/bluebunch wheatgrass habitat type (h.t.) (Mueggler and Stewart 1980) at 3,200 ft. elevation with a northwest aspect. It was used as cattle pasture through the 1950s, but since then has been grazed only by wildlife.

Site 2 is Idaho fescue/bluebunch wheatgrass h.t.-western needlegrass phase. At 4,200 ft. the aspect is south to southwest. Site 2 was grazed by cattle through the 1970s but now is grazed only by wildlife, with significant elk use in winter and spring.

Sites 3 and 4 are adjacently located in a clearcut that was logged and dozer-piled in the mid-1960s. The habitat type (Pfister and others 1977) is Douglas fir/snowberry. At 4,050 ft elevation, the aspect of site 3 is south to southwest, while site 4 is almost flat. The logging returned sites 3 and 4 to an earlier stage of development, with Richardson's needlegrass and rough fescue being the most abundant grasses. The location was being grazed by cattle and wildlife. A fence was erected in the summer of 1988 to exclude cattle but not deer or elk from sites 3 and 4. Deer and elk use on these sites is relatively light.

Canopy cover and frequency of occurrence by species were determined by cover microplot method. Each replicated treatment plot (1/20-acre) had five random transects; each transect had five permanently marked microplot locations (10- by 20-inch Daubenmire frames). The cover value of every species was determined for each microplot. Pretreatment plant community data were collected for the 1988 warm season (July-September) and the 1989 cool season (May-June).

Treatment

Herbicides were applied with a carbon dioxide pressure-regulated backpack research sprayer in 1989 starting after the cool season pretreatment readings for each site. "Early" herbicide treatments were made when spotted knapweed was in the rosette to early bolt stage. "Late" treatments were made when knapweed was in the early to mid-flower stage. Herbicides were Tordon 22K at 1 pint/acre, Transline at 1 pint/acre, and 2 qt./acre of Curtail. Each of the four sites contained six treatments and an untreated check plot with three randomized blocks or replications.

Postspray data collection began one year after the 1989 herbicide applications. Each microplot was re-read twice a year—during the cool season (May-June) and again in the warm season (July-August). The 1990 and 1991 read-

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Table 1 - Community Status 3 Years Post Spray on Pilot Plots

	Average % Canopy Cover			Diversity Measurements		
Treatment	Spotted Knapweed	Other forbs	Grasses	Average No. Species	Total No. Species	S-W Index* Average
	Fort Missoula					
Check Plots	27	7	8	16.0	22	0.76
Tordon	3	6	28	16.0	22	0.94
	Lolo					
Check Plots	30	20	27	35.3	57	1.13
Tordon	3	17	46	34.3	58	1.26
Tordon + Stinger	4	16	47	37.7	59	1.29
Stinger	16	22	37	37.0	58	1.27

*A practical range for the Shannon-Weaver Index in this type of community is 0.5-2.0. A field of weeds would be 0.5 and a field that's very rich and diverse would be 2.0.

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ings are completed with the data listed in this study. The researchers determined community composition through at least 1992.

Plant community data summaries, including average species richness, total number of species, and Shannon-Weaver indices, have been calculated by treatment (Keane and others 1990) through the 1991 warm season. The statistical model is a form of randomized complete blocks with repeated measures in time of the same transect/microplots (Winer 1971). Species richness is defined as the number of different species present in a specific area. The Shannon-Weaver index indicates whether the total biomass (expressed as canopy cover) of the plant community is evenly distributed among a large number of species (thus a high Shannon-Weaver Index). If only a few species account for most of the biomass, i.e. canopy cover, then the Shannon-Weaver Index number is low. A practical range for the Shannon-Weaver Index in this study is 0.5-2.0. A weed field would be 0.5 and 2.0 would be very rich and diverse. The goal is for a rich, diverse community.

Results and Discussion

Both the pilot diversity study and the formal community response study suggested that plant diversity could be maintained or even enhanced when these herbicide treatments were used to control spotted knapweed.

Pilot Diversity Study

The two pilot diversity study sites, which had been sprayed in 1985, and the community status measured three years later indicated that diversity on the herbicide-treated plots was as high as or higher than on the check plots (Table 1). Spotted knapweed control of 87% to 90% was still being maintained on the Tordon-treated plot but had declined to 53% on the plots that had been sprayed with Transline alone.

Table 2 - Average Number of Species by Herbicide For All Sites, Times & Applications

	Pretreatment		1 Year Post spray		2 Years Post spray	
	1988	1989	1990		1991	
	Warm*	Cool	Cool	Warm	Cool	Warm
Check	25.6	38.8	40.2	34.8	37.7	33.8
Tordon	24.7	38.4	34.4	28.7	35.8	32.9
Stinger	24.5	39.2	39.0	33.8	38.0	35.0
Curtail	25.8	38.7	37.6	31.5	37.8	34.4

*Warm/cool (season) refers to when the community data were collected: cool = May & June; warm = July & August

Formal Community Response Study

All six herbicide treatments provided good control of spotted knapweed one and two years post spray. Little difference occurred between early and late herbicide treatments. Absolute canopy cover of spotted knapweed in individual treatment plots one and two years after spraying ranged from less than 0.5% to a maximum of 9.2%, with all but three of the 72 herbicide-treated plots having less than 3% spotted knapweed cover.

"Both the pilot diversity study and the formal community response study suggested that plant diversity could be maintained or even enhanced when these herbicide treatments were used to control spotted knapweed."

Table 3 - Mean Shannon-Weaver Diversity Index* By Herbicide For All Sites and Times of Application

	Pretreatment		1 Year Post spray		2 Years Post spray	
	1988	1989	1990		1991	
	Warm**	Cool	Cool	Warm	Cool	Warm
Check	1.126	1.365	1.363	1.257	1.345	1.281
Tordon	1.082	1.345	1.262	1.164	1.319	1.253
Stinger	1.077	1.349	1.340	1.240	1.346	1.307
Curtail	1.090	1.344	1.311	1.198	1.341	1.290

*A practical range for the Shannon-Weaver Index in this type of community is 0.5-2.0. A field of weeds would be 0.5 and a field that's very rich and diverse

**Warm/cool (season) refers to when the community data were collected: cool = May & June; warm = July & August

Blind QA/QC rereading indicated excellent precision in determining the community diversity

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Herbicide Residue Sampling Results

The study also included herbicide soil residue checking for three depth increments — 0 to 2, 2 to 10, and 10 to 20 inches — at 30 days and 1 year after spraying. A fourth increment— 20 to 40 inches — was sampled for Tordon 22K* herbicide at 1 year. The study also measured Tordon 22K residues at 2 years in the 0 to 2 inch and 2 to 10 inch depth increments. Twelve subsamples were collected for each combination of sampling date-site-treatment-depth increment. The like subsamples were mixed to form a composite field sample. The composite samples (two split replicates each) were frozen. The residue analyses were conducted at the Agricultural Experiment Station Analytical Laboratory at Montana State University, Bozeman.

Methods followed quality assurance and quality control (QA/QC) procedures for both the ecological field measurements and the herbicide residue analysis work. Researchers randomly selected microplots a second time for canopy cover at the end of each sampling period for each site. The second reading was blind; that is, the evaluator did not refer to the data from the first reading. The data was combined from the blind microplots to form synthetic transects, then we calculated diversity values. Diversity values for synthetic transects were also calculated from the original readings of the same set of microplots. Researchers quantified the precision of community measurements as relative standard deviations for paired original and blind synthetic transects.

Soil samples submitted to the residue analysis laboratory included blind split field duplicates and blind herbicide-free check plots soils. The laboratory used internal QA/QC procedures approved by the Environmental Protection Agency. Those methods included analyses of duplicate sample splits, estimating recovery of known addition to herbicide-free check plot soils from the study sites, and incorporation of reagent blanks in the analytic stream.

Results showed no detectable herbicides in the reagent blanks (n=18). The method detection limit (MDL) was 10 parts per billion (ppb). Instrumental responses below MDL are reported as trace.

Herbicide residues in the soil declined rapidly with time and depth. Although it had the highest surface layer concentrations at day 30 because of its higher initial application, 2,4-D degraded most quickly. The maximum concentration of 2,4-D below 10 inches at day 30 was 14 ppb. Only the early treatment on Site 1 still had trace (<10 ppb) detectable 2,4-D below 2 inches after one year.

Tordon was the most persistent of the three herbicides. The maximum concentration of Tordon below 10 inches did not exceed 26 ppb at day 30 and did not exceed trace amounts below 10 inches at one year. Tordon was not detected below 2 inches at two years, and only trace amounts were measured in the surface (0 to 2 inches) soil increment. Transline* herbicide was not detected below 10 inches, and at one year could not be detected below 2 inches depth. ◆

Soil samples started at 0 inches and went as deep as 40 inches two years after treatment. Tordon was not detected below 2 inches at two years, and only trace amounts were measured in the surface soil (0 to 2 inches) increment.

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variables. The average relative standard deviation was 5.8% for species richness and 5.6% for the Shannon-Weaver index (n=22 rereadings). The variance among plots receiving the same treatment within a site was usually small, although some outliers occur in the data base.

The check plot sets generally had the highest average pre-spray diversity values (Table 2 & 3). A graphic inspection of the data for the period 1988 through 1991 shows that, overall, the impact of the herbicides on diversity was small and temporary. Tordon-treated plots had the lowest average diversity one and two years post spray, Curtail was intermediately lower, and Transline plots were similar to the check plots. The one-year post spray differences between treatments decreased in the second year post spray. The measured average number of species and the Shannon-Weaver index were higher for the Transline and Curtail plots than for the untreated plots by the second year post spray.

Suppression of competitive and dominant spotted knapweed releases resources to support growth of other plant species. The grasses and some forbs and shrubs that are inherently tolerant or not exposed to this group of herbicides are able to respond during the year of spraying. Herbicide-susceptible forbs and shrubs respond to the limiting resource release in subsequent growing seasons as the herbicide residuals decline. Resistant individuals expand and new plants, including spotted knapweed, establish from various propagules.

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