Report 4

Diffuse Knapweed Control Study

4. Monitoring Summary for Diffuse Knapweed Control Study

4.1 Introduction

Diffuse knapweed (*Centaurea diffusa*) is a noxious weed that has become increasingly widespread across the Front Range of Colorado. Over the past several years, the spread of this species has become a serious threat with regard to managing the natural resources in the Buffer Zone at the Rocky Flats Environmental Technology Site (the Site). Under the Colorado Noxious Weed Act, diffuse knapweed is listed as a noxious weed that must be controlled by property owners, and it is listed as one of the top ten prioritized species for control in the state (CRS 1996).

Diffuse knapweed is a very aggressive competitor in dry conditions such as those found at the Site. Studies elsewhere have shown that it rapidly invades overgrazed range lands, disturbed sites, and even undisturbed plant communities, often becoming a dominant species and altering the species composition of the plant community (Powell 1990; FEIS 1996; Sheley et al. 1998). Studies have also shown that diffuse knapweed–infested lands exhibit increased soil erosion, degraded water quality, lower wildlife habitat value, reduced grazing capacity, and less aesthetic and recreational value (Sheley et al. 1997, 1998).

At the Site, one of the rare plant communities that is increasingly affected by the spread of diffuse knapweed is the relict xeric tallgrass prairie. The Site contains a substantial portion of what has been identified as the largest remaining stand of this plant community known to occur in Colorado, and potentially in all of North America (CNHP 1995). The herbicide Tordon 22K (trademark of DowElanco [picloram]) is one of the more effective chemicals for controlling diffuse knapweed infestations, because its multi-year residual effect can prevent the seeds from germinating for several years after application (Beck 1994). Because the xeric tallgrass prairie is an important plant community, it is important to evaluate what effect the herbicide might have on the native species. A study was begun on the Site in 1997 to evaluate the effectiveness of Tordon 22K in controlling diffuse knapweed on the Site and to identify any potential effects on desirable species in the xeric tallgrass prairie. This report summarizes the four years of data collected thus far.

The following general questions were proposed for investigation:

- How effective is Tordon 22K on controlling diffuse knapweed under Site conditions?
- How long is a single application of Tordon 22K effective in controlling diffuse knapweed?

- How does Tordon 22K affect species richness, cover, and individual species abundance on the xeric tallgrass prairie?

4.2 Study Site Location and Characteristics

The study site is located north of the T130 trailer complex, west of the Industrial Area (Figure 4-1). The xeric tallgrass prairie at the Site is located primarily on the pediment, which is underlain by Rocky Flats Alluvium (SCS 1980). The soils are classified as Flatirons very cobbly sandy loams (SCS 1980). The study site is essentially flat, with only a 1° slope to the northeast. The area was chosen because it was large enough for placement of both control and treatment plots (each 60 × 65 m), and an abundance of diffuse knapweed was present where the two plots would be located.

4.3 Methods

A control plot (no herbicide applied) and a treatment plot (herbicide applied) were established. Within both the control and treatment plots, five parallel, randomly located, 50-m transects were established from a baseline using X and Y coordinates generated by a computerized random number generator (Figure 4-2). Transects were permanently marked, assigned numbers, and labeled. Although it would have been preferable to collect a full year's worth of data prior to herbicide application in 1997, logistics and the required time frame allowed for only a single spring sampling prior to herbicide application.

The treatment plot was sprayed with Tordon 22K, applied at a rate of 1 pint/acre, on June 23–24, 1997, using a truck-mounted spray unit with a 16.75-m (55-ft) boom. The boom was held approximately 0.6–1.0 m (2–3 ft) above the vegetation. A uniform application rate was obtained across the area using a computerized spray system that regulated the application pressure rate according to the speed of the truck. Some diffuse knapweed plants had already bolted and were in the bud stage at the time the spraying occurred, but many rosettes were still present. Sampling during 1997 was conducted on June 16–19 and again on September 2–4. In 1998, sampling was conducted on June 17–19 and August 24–27. In 1999, sampling was conducted on June 14–18 and August 30–September 1. In 2000, sampling was conducted on June 12–16 and August 28–31.

Species richness was determined in a 2-m-wide belt centered along the length of each 50-m transect. Every plant species rooted within the 100-m^2 area was recorded. In addition, the numbers of woody plant stems and cactus stems were counted and recorded for the 100-m^2 area. Basal cover and foliar cover estimates were made using a point-intercept method along each of the 50-m transects. A 2-m-long rod, with a 6-mm diameter, was dropped vertically at 50-cm increments along the transect to record a total of 100 intercept points. Two categories of hits were recorded, basal and foliar. Basal cover hits indicated what material the rod contacted at the ground surface. Hits could be vegetation (live plants), litter (fallen dead material), rock (pebbles and cobbles that were

greater than the rod diameter), bare ground, or water, in that order of priority based on the protection from erosion that each type of cover provided. Basal vegetation hits were recorded by species only if the rod was touching the stem or crown of the plant where the plant entered the ground. Foliar vegetation hits (defined as a portion of a plant touching the rod) were recorded by species in three categories defined by height and growth form. The topmost hit of each growth form was recorded. The growth forms measured were herbaceous, woody <2 m in height, and woody >2 m in height.

Frequency information by species was gathered by randomly locating 25 1-m^2 quadrats (5 per transect) in each of the control and treatment plots and recording all species present in each plot. Stem density counts for diffuse knapweed also were made using these same quadrats. No distinctions were made during counts between seedlings, rosettes, or adult plants. More detailed summaries of these specific methods are found in the *Environmental Monitoring Department Operating Procedures Manual* (DOE 1995), the *High Value Vegetation Survey Plan for the Rocky Flats Environmental Technology Site* (K-H 1997), and the 2000 *Ecological Field Monitoring Plans for the Rocky Flats Environmental Technology Site* (K-H 2000a).

Species richness data were summarized by generating species lists for the control and treatment plots for each sampling period. In addition, other species diversity variables were calculated from the species lists. Basal cover data were reported as total percent cover of vegetation, litter, rock, and bare ground. Foliar cover data were reported as frequency, absolute cover, and relative cover for each species encountered. Frequency from the cover data was defined as the percent of point-intercept transects in which a species occurred, out of the total five possible sampled per plot. Absolute foliar cover was the percentage of the number of hits on a species out of the total number of hits possible at a plot (500). This value is the actual cover of a species. Relative foliar cover was the number of hits on a species relative to the total number of vegetative hits recorded per plot (i.e., the percent of total vegetative cover [100 percent] represented by the species).

Both absolute and relative foliar cover values are means averaged over the five transects. Frequency based on quadrats (n=25) was defined as the number of quadrats in which a species was recorded, divided by 25 (the total number of quadrats possible), multiplied by 100. Density count data were summarized as the mean number of stems per square meter based on the 25 quadrats sampled within each plot (n=25).

For most results, descriptive comparisons were made between the control and treatment plots from the four years of data to examine potential changes over time—pre-treatment to post-treatment. Species richness, cover, and frequency were summarized by combining data from the five control transects and five treatment transects for each sampling event, respectively. A Sorensen coefficient of similarity was used to assess the species composition similarity between the control and treatment data (Brower and Zar 1977). A Shannon-Weaver diversity index was used to calculate diversity and was conducted using the relative foliar cover data (Brower and Zar 1977). Statistical analysis of the results was conducted only when mean values were different enough to suggest a

meaningful interpretation. Where normality, variance, and dependence requirements were met, parametric tests were used to compare results; otherwise, non-parametric tests were used. Independent samples (i.e., the control and treatment plots) were compared using one-way analysis of variance (ANOVA), t-tests, or Mann-Whitney U tests (SigmaStat 1997; Fowler and Cohen 1990; Sheskin 1997), as appropriate. Dependent sample comparisons (i.e., within treatment over time) were done using paired t-tests, Wilcoxon's test for matched pairs, or Friedman's repeated measures ANOVA (SigmaStat 1997; Fowler and Cohen 1990; Sheskin 1997), as appropriate. Where applicable, a Tukey test was used for pairwise multiple comparison procedures to isolate groups that differed from one another (SigmaStat 1997). Frequency analyses were done using a McNemar test (Sheskin 1997).

4.4 Results

4.4.1 Species Richness

Overall species richness in the treatment plot initially declined by 12 species after the herbicide application in 1997 (from 74 to 62 species), but rebounded the following spring to 70 species. Over the past four years since treatment, species richness in the treatment plot has fluctuated between 68 and 73 species (Tables 4-1 and 4-2, Figure 4-3). Species richness in the control plot during the same time period remained stable from 1997 to early 1999, but then declined from summer 1999 through 2000 (Tables 4-1 and 4-3, Figure 4-3). Species richness has been 7 to 15 species lower in the control plot compared to the treatment plot over the past 1.5 years.

The treatment plot had fewer species per quadrat than the control plot initially and during all subsequent sampling events. Examination of the mean number of species per quadrat has shown parallel seasonal responses in both the control and treatment plots from 1997 through 1999 (Tables 4-1, 4-2, and 4-3, Figure 4-4). In 2000, however, the mean number of species per quadrat in the treatment plot did not parallel that of the control plot, but remained lower (Figure 4-4).

A Sorensen coefficient of similarity was used to compare initial 1997 species composition to that in 2000 for both the control and treatment plots. Comparing spring 1997 to spring 2000 resulted in a Sorensen index value of 0.82 for the control plot and 0.86 for the treatment plot, indicating slightly higher similarity in species composition in the treatment plot, four growing seasons after the herbicide application. The spring 1997 control-versus-treatment Sorensen index value was 0.80, and it was 0.77 in summer 2000. Thus, four growing seasons after the herbicide application, the similarity of species composition between the control and treatment plots is less than prior to the start of the study, largely due to the change in composition over time in the control plot.

4.4.2 Diffuse Knapweed Response

Diffuse knapweed densities declined significantly in the treatment plot after the herbicide application and continued to remain at low levels in 2000, four growing seasons after the herbicide application (Table 4-1, Figure 4-5; Friedman's repeated measures ANOVA by Ranks, $X^2 = 55.7$, df = 7, P <0.001). In the treatment plot, spring diffuse knapweed densities (a measure of seedling and rosette density) decreased significantly after herbicide treatment, from 23 plants/m^2 in 1997 to 1.8 plants/m^2 in 1999 (Table 1, Figure 5; Friedman's repeated measures ANOVA by Ranks, $X^2 = 55.7$, df = 7, P <0.001).

Large seasonal fluctuations were observed in diffuse knapweed densities in the control plot (Table 4-1, Figure 4-5). Spring diffuse knapweed density showed a statistically significant increase in the control plot, from 5.6 plants/m^2 in 1997 to 26.1 plants/m^2 in 1999 (Table 4-1, Figure 4-5; Friedman's repeated measures ANOVA by Ranks, $X^2 = 68.0$, df = 7, P <0.001). However, in spring 2000, no large increase in diffuse knapweed density was observed, as had occurred in 1998 and 1999 (Figure 4-5).

Diffuse knapweed frequency has remained fairly stable in the control plot from 1997 through 2000, with the exception of a sharp peak (increase) during spring 1999 (Table 4-1). In the treatment plot, during the same time period, diffuse knapweed frequency declined steadily, from 80 percent before herbicide treatment in 1997 to a low of 20 percent in summer 1998. During the summer of 1999, it increased to 44 percent, with an additional increase to 48 percent in 2000 (Table 4-1). Diffuse knapweed frequency in the treatment plot still remains below its initial starting point and below that of the control plot.

4.4.3 Cactus Density Response

Cactus densities in the control plot for twistspine prickly pear (*Opuntia macorhiza*) and hedgehog cacti (*Echinocereus viridiflorus*) remained generally stable from 1997 to 2000, showing only a slight increase in 1999 (Table 4-1; Figures 4-6 and 4-7). In the treatment plot, however, densities for these two species both declined after the herbicide treatment (Table 4-1; Figures 4-6 and 4-7). The twistspine prickly pear density decreased significantly, by 87 percent from 1997 to 1999 (Figure 4-6; Friedman's repeated measures ANOVA by Ranks, $X^2 = 10$, df = 2, P <0.001). It declined only slightly more in 2000, and remains far below that of pre-treatment levels or that found in the control plot. The frequency of the twistspine prickly pear also decreased significantly, by more than 50 percent (Table 4-1; McNemar test, $X^2 = 8.1$, df = 1, P <0.01). Hedgehog cactus density and frequency also decreased significantly in the treatment plot from spring 1997 to spring 2000 (Table 4-1, Figure 4-7; Friedman's repeated measures ANOVA by Ranks, $X^2 = 11.1$, df = 3, P <0.05; McNemar test, $X^2 = 6.1$, df = 1, P <0.05), with the density decreasing by over 50 percent. Continued monitoring will detect if and when the cacti begin to return to these areas.

4.4.4 Diversity Response

Shannon-Weaver diversity indices for the control and treatment plots are shown, by sampling event, in Table 4-1 and Figure 4-8. No significant changes were observed in the control plot from 1997 through 2000 (Figure 4-8). In the treatment plot, a statistically significant loss of diversity was observed from spring 1997 to summer 1998 as a result of the herbicide treatment (Figure 4-8; Friedman's repeated measures ANOVA by Ranks, $X^2 = 15.5$, df = 7, P = 0.03). In 1999, however, diversity began to increase to pre-treatment levels, and was no longer statistically different from the control plot (Figure 4-8; P >0.05). In 2000, however, the diversity in the treatment plot dropped during the summer and was again significantly different from that in the control plot (Figure -8; T-test, t = 3.54, df = 8, P = 0.008). Further numerical increases in diversity are needed at the treatment plot before a complete return to pre-treatment levels is reached.

4.4.5 Plant Frequency Response

Individual species frequencies measured during each sampling event are presented in Tables 4-4 and 4-5 for the control and treatment plots, respectively. Taking into account changes that occurred from spring 1997 to spring 2000 in the control plot (i.e., assumed to be natural variability in species frequency), those species in the treatment plot that showed the greatest change in frequency are shown in Table 4-6. Only those species that showed changes of 12 percent or more (negative or positive) are listed, because the presence of a species in a single quadrat represents 4 percent (n=25). Changes of 8 percent or less are as likely explained by chance as by any response to the herbicide application, given the natural variability of species on the prairie. The species showing the greatest decreases were twistspine prickly pear and diffuse knapweed, with decreases of 56 and 28 percent, respectively, in the treatment plot compared to the control plot. Of the other 12 species listed as having experienced declines in frequency, 10 were native species and 2 were non-native (Table 4-6). Several species also showed increases in frequency in the treatment plot versus control plot analysis (Table 4-6).

4.4.6 Vegetation Cover Response

Basal cover amounts for total basal vegetation, rock, bare ground, and litter cover did not change by any meaningful amounts in either the control or treatment plots from 1997 to 2000 (Table 4-1).

Foliar cover results, by species and species groupings, for the control and treatment plots for 1997 to 2000, by sampling session, are presented in Tables 4-7 and 4-8. Changes in species composition (relative cover) and actual cover (absolute cover) were evaluated by examining changes in the amounts of foliar cover provided by different species or groups of species. Examination of the cover data showed seasonal shifts in cover amounts for many of the species groupings (Tables 4-7 and 4-8). Total foliar cover, total native foliar cover, and total non-native foliar cover values for both the control and treatment plots showed essentially parallel responses from 1997 through 2000 (Tables 4-7 and 4-8;

Figure 4-9). The only fluctuation in total absolute foliar cover in the treatment plot compared to the control plot occurred in summer 1997, and most of this resulted from the loss of non-native foliar cover (Tables 4-7 and 4-8). Thus, the total absolute cover present on the grassland was not affected substantially by the herbicide treatment.

Species composition was affected, though. In the control plot, total relative forb cover varied slightly from 1997 through 2000, fluctuating only about 6 percent around an average of approximately 15 percent (Figure 4-10). Total relative forb cover in the treatment plot, however, dropped significantly—from more than 18 percent initially in 1997 to a low of less than 5 percent in summer 1998—in response to the herbicide (Figure 4-10; Friedman's repeated measures ANOVA by Ranks, $X^2 = 19.2$, df = 7, $P < 0.05$). In 1998, the treatment plot relative forb cover was significantly lower than the control plot (Figure 4-10; spring 1998, Mann-Whitney Rank Sum test, T = 40, $P < 0.05$; summer 1998, T-test, t = 3.211, df = 8, $P < 0.05$). During 1999 and 2000, relative forb cover recovered in the treatment plot and was no longer significantly different from the control plot ($P > 0.05$). However, in summer 2000, treatment-plot relative forb cover decreased again and was significantly different from that in the control plot (Figure 4-10; T-test, t = 3.102, df = 8, $P < 0.05$).

Non-native relative foliar cover was eliminated from the treatment plot throughout 1998, the second growing season after treatment, but began to return again in 1999 and remained stable at about 2 percent through the summer of 2000 (Figure 4-11). Non-native cover in the treatment plot was significantly below that in the control plot in the late summer of 2000. In the control plot, non-native cover also declined throughout 1998 and spring 1999, but returned to almost 8 percent by summer 2000. Diffuse knapweed accounted for the largest portion of non-native cover in both the control and treatment plots in summer 2000 (Tables 4-7 and 4-8). Native relative forb cover was equal in the control and treatment plots prior to the herbicide application (Figure 4-11). However, after the herbicide application, native relative forb cover dropped in the treatment plot and was significantly different from the control plot throughout 1998 (spring 1998, Mann-Whitney Rank Sum test, T = 40, $P < 0.05$; summer 1998, T-test, t = 2.409, df = 8, $P < 0.05$). By 1999, native relative forb cover was no longer significantly different from the control plot, and this condition prevailed through spring 2000, by which time it was essentially equal to that in the control plot ($P > 0.05$). In summer 2000, however, the native relative forb cover declined in the treatment plot and was significantly different from the control plot (Figure 4-11; T-test, t - 2.959, df = 8, $P < 0.05$).

Absolute (actual) graminoid cover in the treatment plot increased and surpassed that of the control plot after the herbicide application in 1997 (Figure 4-12). Since then, the absolute graminoid cover amounts in the control and treatment plots have paralleled each other in all but one sample session (Figure 4-12). Relative graminoid cover has not changed significantly in the control plot throughout the duration of the study (Figure 4-13; $P > 0.05$). In the treatment plot, however, relative graminoid cover increased significantly from 1997 to summer 1998 (Figure 4-13; Friedman's repeated measures ANOVA by Ranks, $X^2 = 17.89$, df = 5, P = 0.003). As a result of the herbicide application, relative graminoid cover was significantly higher in the treatment plot than in

the control plot throughout 1998 (Figure 4-13, spring 1998, Mann-Whitney Rank Sum test, T = 15, P <0.05; summer 1998, T-test, t = –3.211, df = 8, P <0.05). By 1999 and spring 2000, however, treatment plot relative graminoid cover was no longer statistically different from the control plot (Figure 4-13; P >0.05). In summer 2000, however, relative graminoid cover in the treatment plot increased again and was significantly different from the control plot (Figure 4-13; T-test, t = –3.102, df = 8, P <0.05). Split out by cool-season and warm-season graminoid species, the relative cover of both has increased in the treatment plot as a result of the herbicide application, with warm-season species increasing slightly more than the cool-season species (Figure 4-14).

The relative foliar cover provided by the dominant native species—big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), mountain muhly (*Muhlenbergia montana*), and Porter's aster (*Aster porteri*)—at the control and treatment plots from 1997 to 2000 is shown in Figures 4-15 and 4-16, respectively. Both plots had just over 50 percent of the cover provided by these species prior to the herbicide application in spring 1997. The treatment plot showed an increase in cover of these species during summer 1997, but then returned to pre-treatment levels, with some slight fluctuation through spring 2000. Another peak occurred in summer 2000. Both peaks were due to increases in big bluestem and mountain muhly. Porter's aster, an endemic species along the Front Range of Colorado, has remained at stable levels from 1997 through summer 1999. Its drop in cover during 2000 was evident in both the control and treatment plots.

4.5 Discussion

The effect of the herbicide Tordon 22K on diffuse knapweed and other species in the xeric tallgrass prairie was examined to provide important information for weed control and resource management activities at the Site. In 1998, the second growing season after the initial herbicide application, a number of measured plant-community variables continued to show declines as a result of the herbicide application. In addition to diffuse knapweed, forbs in general were affected; overall forb cover decreased considerably, and species richness, cactus density, and species diversity all declined initially (K-H 1998, 1999). Data from the 1999 and 2000 field seasons, however, have shown the expected reversal of many of these initial responses (K-H 2000b).

Although overall species richness in the treatment plot declined by 12 species immediately after the herbicide application in 1997, by 1999, overall species richness had essentially returned to pretreatment levels (only one species less than the original number; Figure 4-3). Currently, species richness is higher in the treatment plot than in the control plot. The declines shown in both the control and treatment plots in 2000, relative to 1999, are best explained by the very dry winter and summer in 2000. A Sorensen coefficient of similarity index (an index used to evaluate species similarity between locations), was used to evaluate the species richness similarity within the control and treatment plots from spring 1997 to summer 2000. Index values of 0.82 for the control plot and 0.86 for the treatment plot suggest a very high similarity in species richness between pre- and post-treatment for both plots. Additional comparisons of

similarity between the control plot and the treatment plot, for spring 1997 and summer 2000, showed essentially no difference either, thus indicating that no long-term loss of species occurred as a result of the herbicide application. Examination of the species lists through time (from 1997 through 2000) for both the control and treatment plots (Tables 4-2 and 4-3), shows little difference in the overall species richness of either plot. The data show numerous species in both plots that appear and disappear during different years. For those few species, in either plot, that were present to begin with but disappeared during the course of the study, examination of the cover and frequency data showed that these species occurred in very small amounts to begin with. Thus, it is not really possible to attribute their disappearance to the herbicide or any other factor, but rather, it is most likely just part of the natural variation on the grassland.

Species diversity (Shannon-Weaver) declined immediately after the herbicide application in the treatment plot reaching its lowest level in summer 1998, when it was significantly different from the control plot (Figure 4-8). However in 1999, species diversity in the treatment plot was no longer significantly different from the control plot. Continued gains in spring 2000 were reversed in summer 2000. The loss of species diversity is largely attributable to the loss of forb cover; both measures showed parallel responses (Figure 4-10). It is interesting that the control plot showed no loss in either species diversity or forb cover in summer 2000 (Figures 4-8 and 4-10)—in fact, both measures increased. The loss shown in the treatment plot may be a response of the combined stresses from the drought and herbicide or a result of increased competition from the graminoids. Continued monitoring will reveal whether species diversity on the xeric tallgrass prairie at the Site returns to pre-treatment levels next year.

The effect on diffuse knapweed, the primary target species of the herbicide application, has been dramatic. The herbicide application reduced and continues to control the diffuse knapweed in the treatment plot, where diffuse knapweed densities remain far below their original values (Figure 4-5). Diffuse knapweed cover also remains at less than 2 percent of the total relative foliar cover (Table 4-8). In the control plot, however, diffuse knapweed densities have fluctuated widely on a seasonal and annual basis, and continue to increase from pre-treatment levels (Figure 4-5).

The effective control of diffuse knapweed observed in the treatment plot is critical, because the longer the control continues, the fewer adult plants there are to produce additional seeds and blow across the landscape spreading the seeds. Thus, the control of diffuse knapweed documented from 1997 through 2000 in the treatment plot has and continues to reduce diffuse knapweed seed production in the area, and has substantially reduced the chances for spread of the species from this area. Both of these criteria are important for controlling diffuse knapweed. Another important consideration, however, is that with time, diffuse knapweed density will begin to increase again in the treatment plot as a result of the seed bank that remains, and from immigration of new seed from offsite sources (e.g., grasslands and mining areas to the west). If no further control measures are taken, the densities will reach and could potentially exceed pre-treatment levels in a few years. In fact, although diffuse knapweed densities continue to be controlled to low levels, frequency data for diffuse knapweed in the treatment plot

showed that after bottoming out at 20 percent in 1998, diffuse knapweed frequency increased to 44 percent in 1999, and 48 percent in 2000 (Table 4-1). Clearly, diffuse knapweed is slowly returning to the area.

It is also important to recognize that these data are from a small area of the grassland. Therefore, monitoring should be done at various scales to better evaluate the overall effectiveness of the herbicide application. In the larger area surrounding the treatment plot, which received the same herbicide application, weed mapping results have begun to show an increase and return of diffuse knapweed to the larger area. Thus, although the herbicide application in the treatment plot continues to control the diffuse knapweed, long-term integrated weed control using multiple methods is necessary for sustainable control of this species. Additionally, spot control of missed areas or small locations where infestations have begun to return would help extend the length of effective control across the larger area. The use of spot control methods becomes especially important because of the potential long-term impacts that the native plants in the community could experience in response to repeated large-scale, long-term herbicide applications. Cooperative weed control in conjunction with surrounding landowners would help address the issue of seed being transported onto the Site. More details on the weed mapping that has been done at the Site during the same time frame as this study are available elsewhere in this and earlier versions of the Annual Vegetation Report for the Site (K-H 1998, 1999, 2000b).

The response of the non-target species on the xeric tallgrass prairie varied but fell within generally expected parameters. Total absolute (actual) cover on the xeric tallgrass prairie was not substantially affected by the herbicide treatment—changes in the treatment plot generally paralleled changes in the control plot (Figure 4-9). This is important because it illustrates that no large, barren, unvegetated areas were created on the prairie as a result of the herbicide application. Instead, other species (graminoids) expanded, moving in and filling in the canopy to replace the species that were reduced by the spraying.

The forb, or non-grass, component of the prairie, both non-native and native, was affected by the herbicide treatment. This was not unexpected, because the herbicide Tordon 22K, though considered a selective herbicide, affects a number of plant families. Two growing seasons after the herbicide application, however, total relative forb cover in the treatment plot was no longer significantly different from the control plot (Figure 4-10). The significant loss of forb cover observed in the treatment plot during the summer of 2000 is most likely either a result of the drought that occurred and/or increased competition from graminoids.

Although native relative forb cover was equal in the control and treatment plots prior to the herbicide application, after treatment, the native relative forb cover dropped significantly in the treatment plot (Figure 4-11). However, by 1999, native relative forb cover was no longer significantly different from the control plot, and it remained that way through spring 2000. Examination of the non-native relative forb cover showed that by spring 2000, the difference in total forb cover between the control and treatment plots was due to the higher non-native forb cover in the control plot. The non-native forb

cover in the treatment plot was still being controlled by the herbicide treatment and was significantly below that found in the control plot. The loss of native forb cover in the treatment plot during the late summer of 2000 is likely explained by the reasons mentioned above.

The information on the forbs is important because it is not desirable to re-treat the area with a broadleaf herbicide if the native forb component of the community has not returned to its former level of abundance. Repeated broadcast applications of herbicide without allowing appropriate time for the native forbs to rebound could potentially stress them to the point of elimination from the grassland—an undesirable result. In a situation where the native species have not completely returned to pre-treatment levels, a broadcast application of a more species-specific herbicide—such as Transline, which controls diffuse knapweed very effectively, with less impact to other species—might be useful as a follow-up. This would continue to give the native species a chance to return. Drawbacks to Transline, however, are its higher cost and its lack of a multi-year residual effect. Therefore, it would require more frequent retreatment to maintain effective control.

The loss of forb cover in the treatment plot did not cause a loss of overall foliar cover—as mentioned above, the total foliar cover in the treatment plot paralleled the response in the control plot. The loss of relative forb cover was offset by an increase in relative graminoid cover in response to reduced competition from forb species (Figure 4-13). The increase in relative graminoid cover in the treatment plot began after the herbicide application, and it continues four growing seasons after the herbicide treatment.

One of the most affected non-target species groups was cacti. The density of the twistspine cactus has been reduced by about 87 percent, and hedgehog cactus by over 50 percent, since the herbicide application in 1997 (Figures 4-6 and 4-7). Most of the cacti turned yellow after the herbicide application and later died. Continued monitoring will document whether the cacti begin to return to the treatment plot, but any return will be gradual because the cacti grow slowly.

Data from the Site are consistent with data from other studies that have shown an initial decline of species diversity, loss of forb and weed cover, and increase in graminoid vigor and cover after spraying with Tordon 22K. Rice and Toney (1996) reported decreases in forb cover due to herbicide treatments on native prairie in Montana. They reported that these responses were transitory, however, and that forb values returned to pre-treatment levels after about three years. Rice et al. (1997) found that species diversity also declined after spraying with Tordon 22K, but recovered after 2–3 years. Both of these studies also indicated that, as a result of lost weed and forb cover (i.e., reduced competition), the graminoid component of the community responded vigorously. In the Lolo National Forest in Montana, Henry (1998) reported that two years after spraying with Tordon 22K, a mountain grassland community had a 95 percent reduction in weed biomass and an 86 percent decrease in forb biomass. Associated with this was a 714 percent increase in grass biomass.

Continued monitoring will document the recovery of the xeric tallgrass prairie under the conditions present at the Site. This information will be useful for developing improved weed control strategies and provide for better long-term management of the Site's grassland communities.

4.6 Conclusions

Application of Tordon 22K on the xeric tallgrass prairie at the Site continues to provide good control of diffuse knapweed, the primary target species, four years after herbicide treatment. In the treatment plot, initial declines in species richness were transitory, and no changes in overall foliar cover were observed. Although species diversity, overall forb cover, native forb cover, and non-native forb cover declined initially in the treatment plot as a result of the herbicide application, these measures were reversed by 1999. Reduced competition from forbs has improved the vigor and cover of the graminoid species. The results at the Site are consistent with previous studies that examined the effect of Tordon 22K on grassland communities. Continued monitoring in 2001 will provide additional information for management of the grassland communities at the Site.

4.7 References

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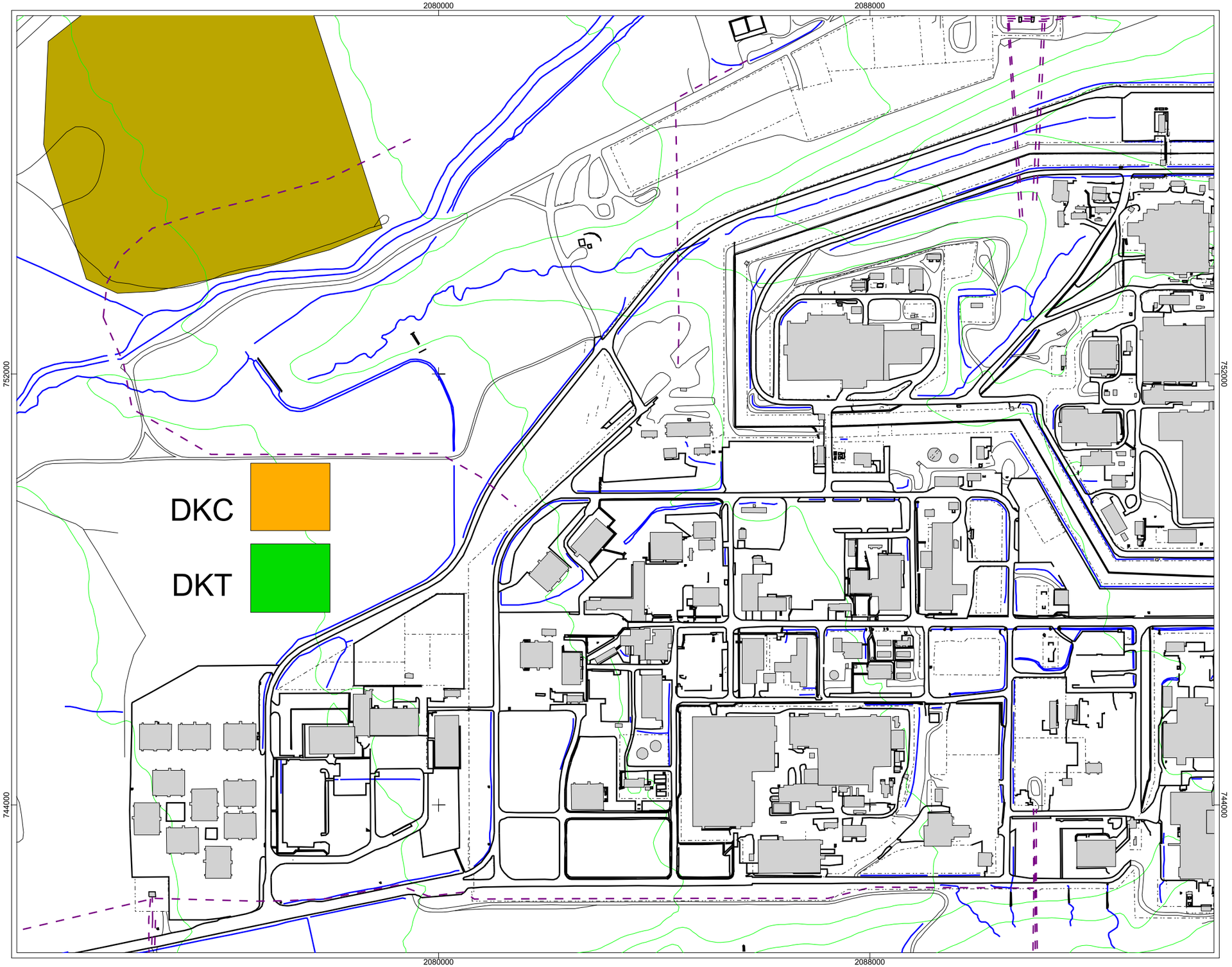

Diffuse Knapweed Herbicide Monitoring Plot Locations

Figure 4-1

LEGEND

- Control Plot
- Treatment Plot

Standard Features

- Buildings
- Lakes & ponds
- New Landfill
- Streams & ditches
- Fences
- Paved roads
- Dirt roads
- Contours (20 ft)
- Power Lines

DATA SOURCE BASE FEATURES:
Buildings, fences, hydrography, roads and other structures from 1994 aerial fly-over data captured by EG&G RSL, Las Vegas.
Digitized from the orthophotographs, 1/95
Hypsography derived from digital elevation model (DEM) data by Morrison Knudsen (MK) using ESRI Arc TIN and LATTICE to process the DEM data to create 5-foot contours. The DEM data was captured by the Remote Sensing Lab, Las Vegas, NV, 1994 Aerial Flyover at ~10 meter resolution. The DEM post-processing performed by MK, Winter 1997.

Data Source Ecology Features:
Location data provided by Exponent.
K-H Ecology Group POC; Karan North 303-966-9876.

N

1:5566

200 0 200 400 Feet

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by: Exponent®

For: Kaiser-Hill Company, LLC

RFETS GIS Dept. 303-966-7707

MAP ID: 2k-0038

May 3, 2001

\\Gissrv\GIS\ECO-projects\projects\2k-0038\veg monitoring locations 2001.apr/CEDI plots

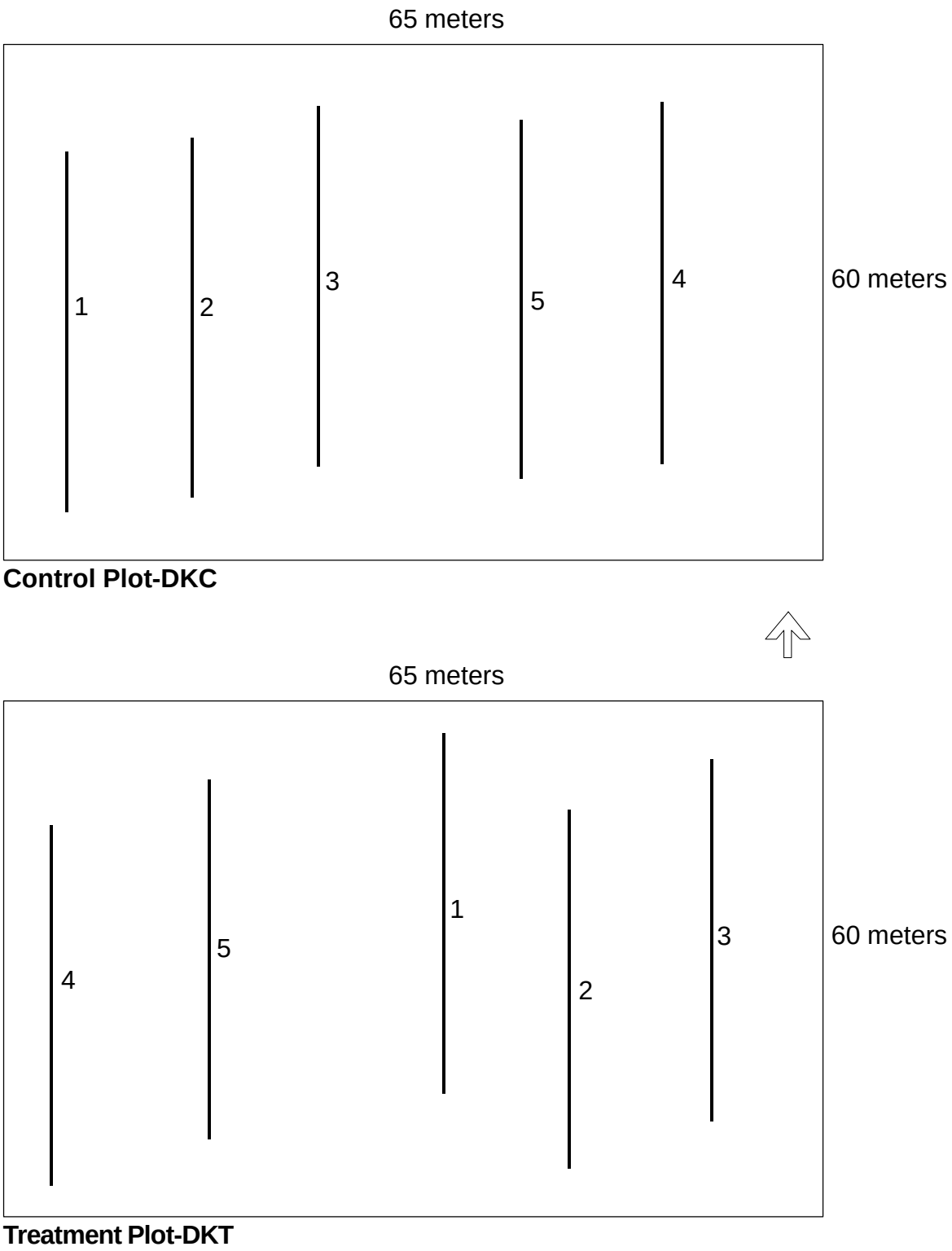

Figure 4-2. Diffuse knapweed monitoring plot and transect locations.

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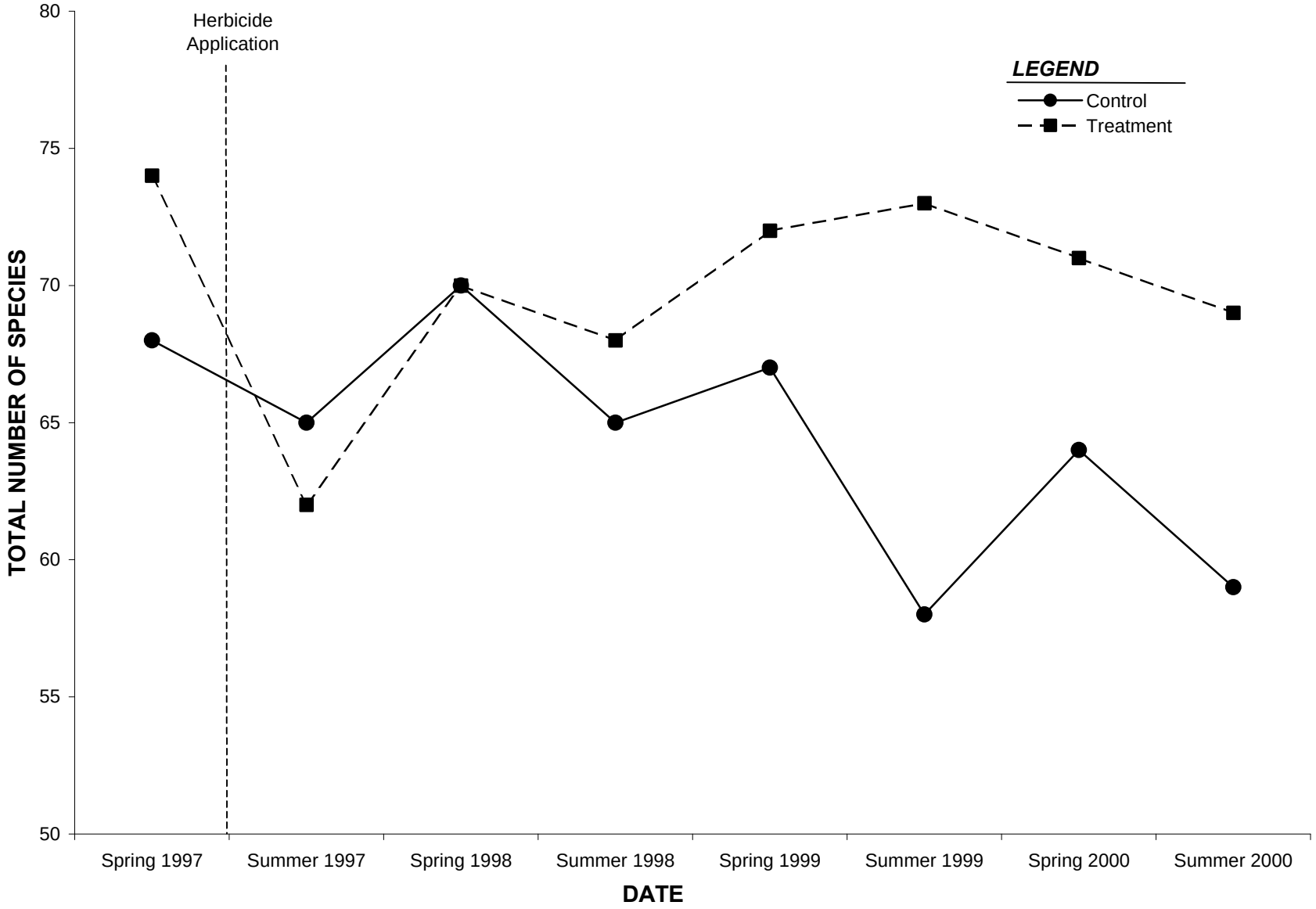

Figure 4-3. Diffuse knapweed herbicide monitoring study - species richness summary.

\\Boulder1\Groups\Graphics\1454\2001\2k CEDI tables and figures.xls Figure 3 5/3/01 CO

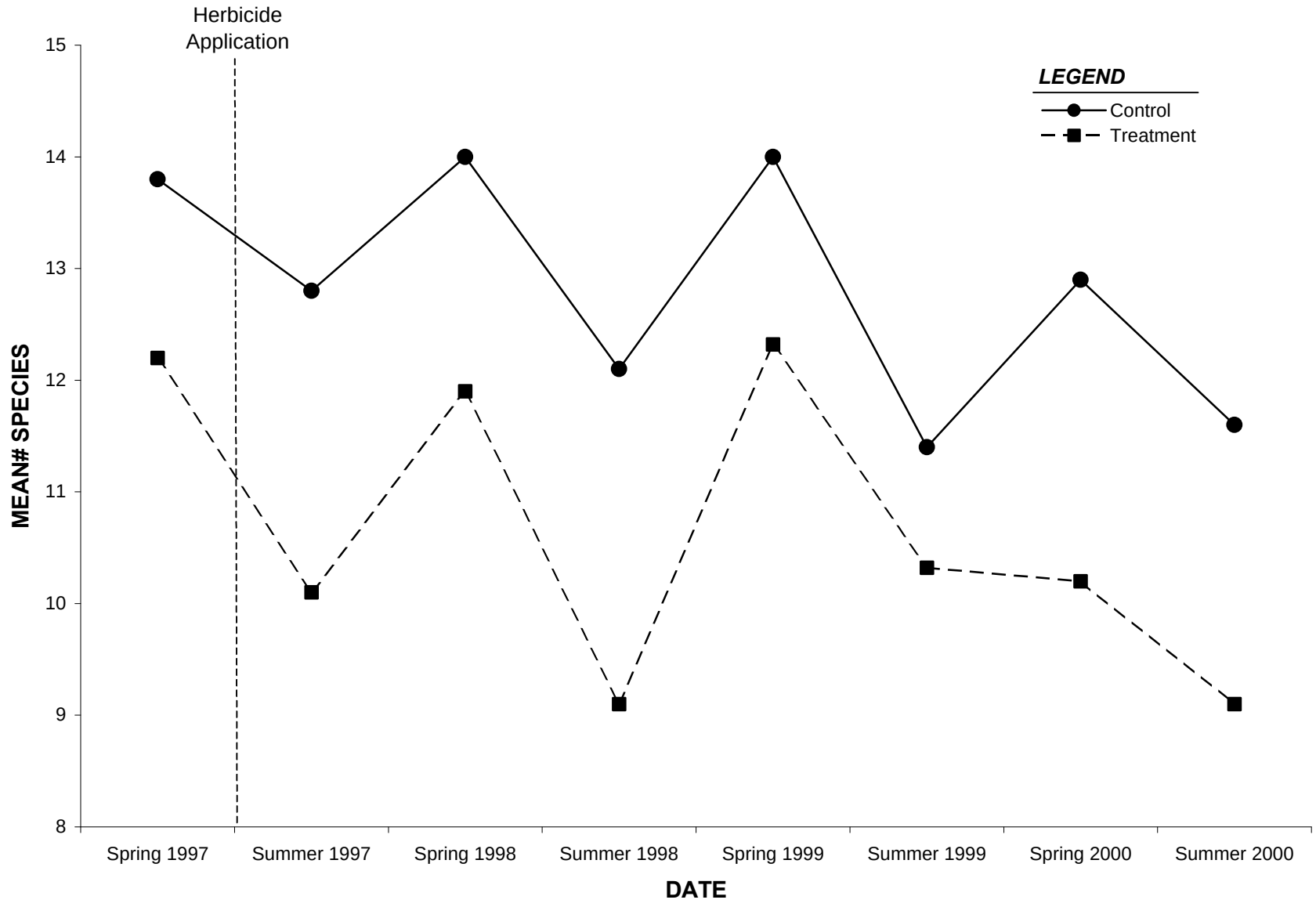

Figure 4-4. Diffuse knapweed herbicide monitoring study–#species/quadrat.

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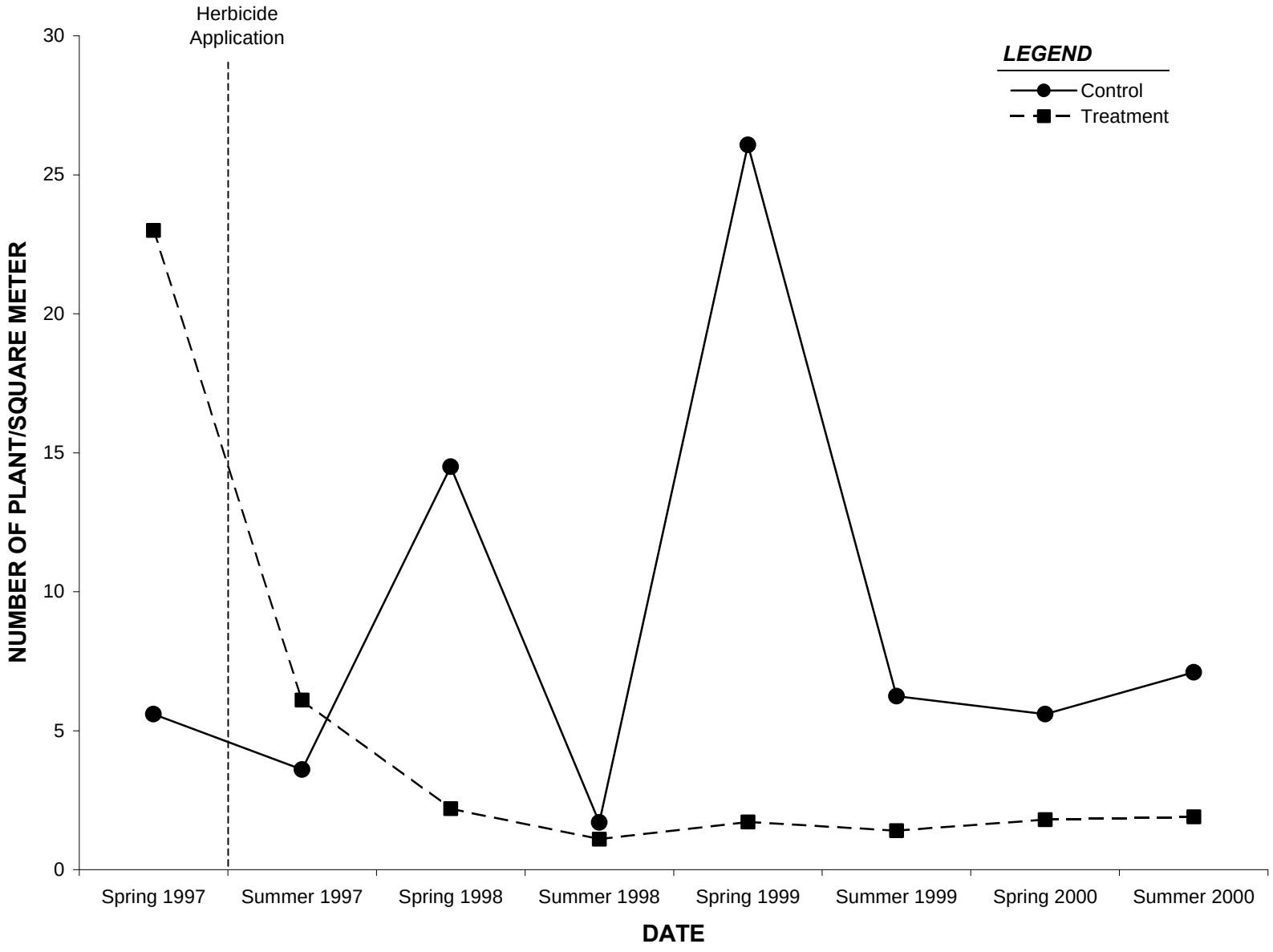

Figure 4-5. Diffuse knapweed herbicide monitoring study–Diffuse knapweed density.

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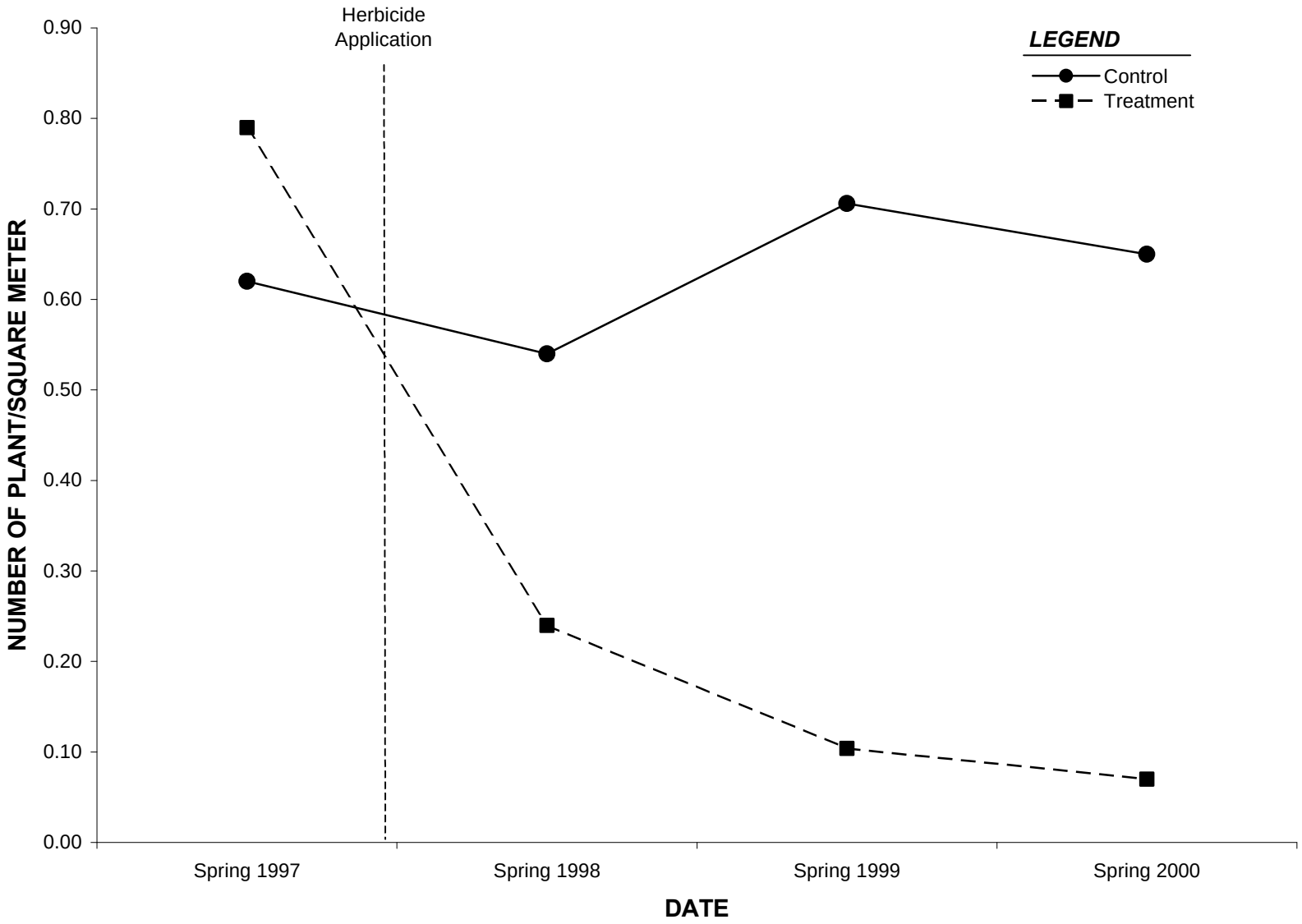

Figure 4-6. Diffuse knapweed herbicide monitoring study–Twistspine prickly pear cactus density.

\\\Boulder1\Groups\Graphics\1454\2001\2k CEDI tables and figures.xls Figure 6 5/3/01 CO

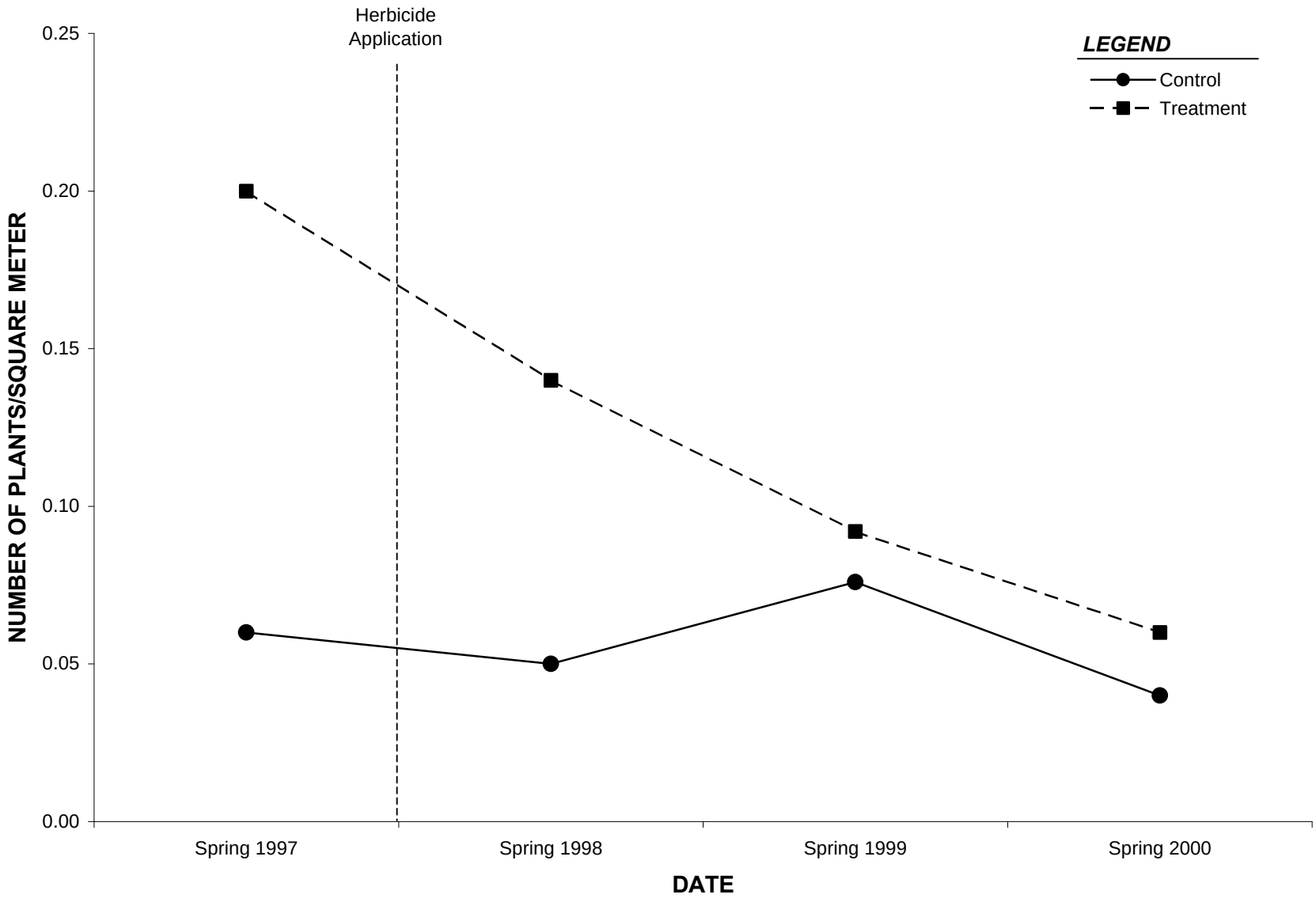

Figure 4-7. Diffuse knapweed herbicide monitoring study–Hedgehog cactus density.

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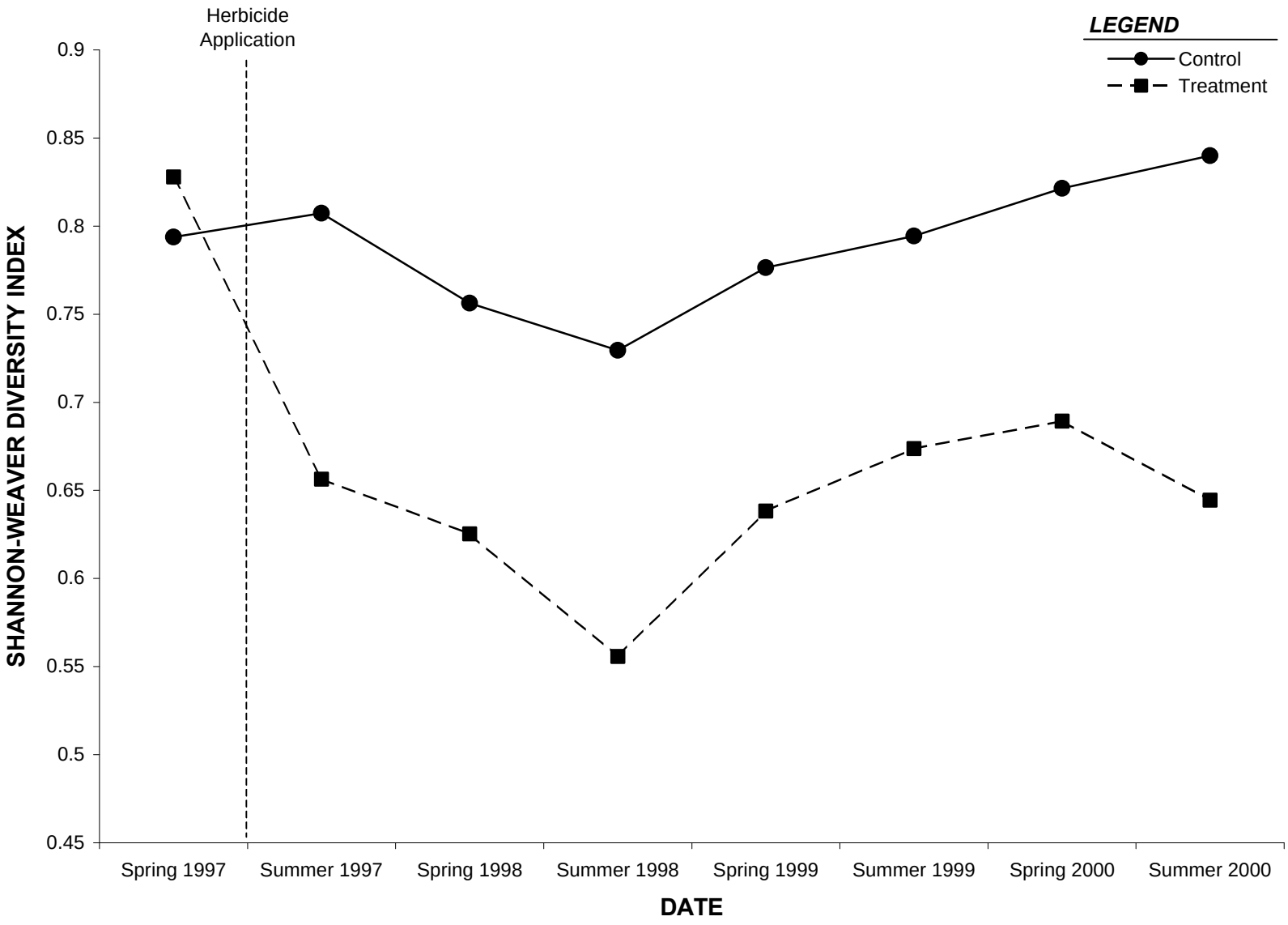

Figure 4-8. Diffuse knapweed herbicide monitoring study–Shannon-Weaver Diversity Index.

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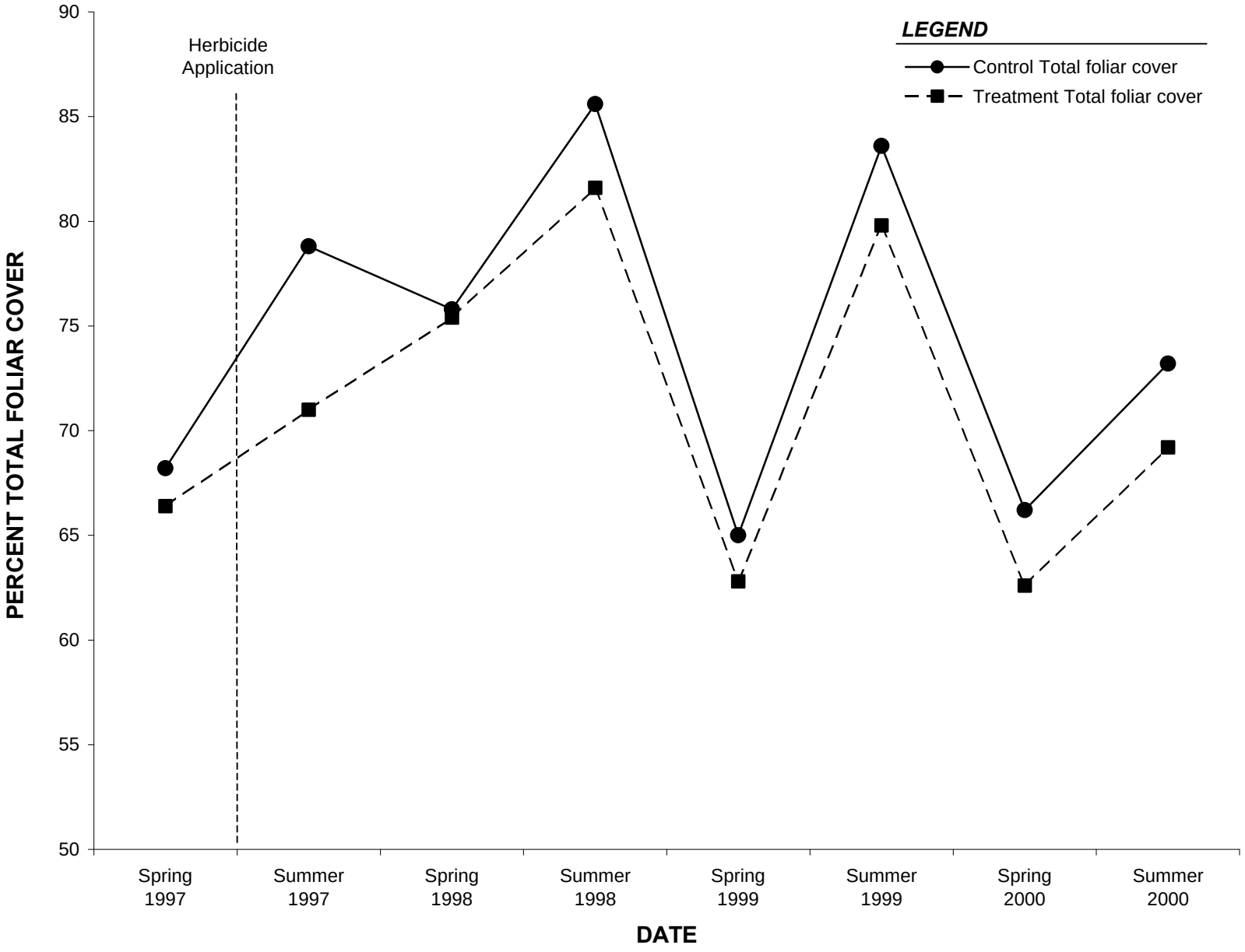

Figure 4-9. Diffuse knapweed herbicide monitoring study–Total foliar cover.

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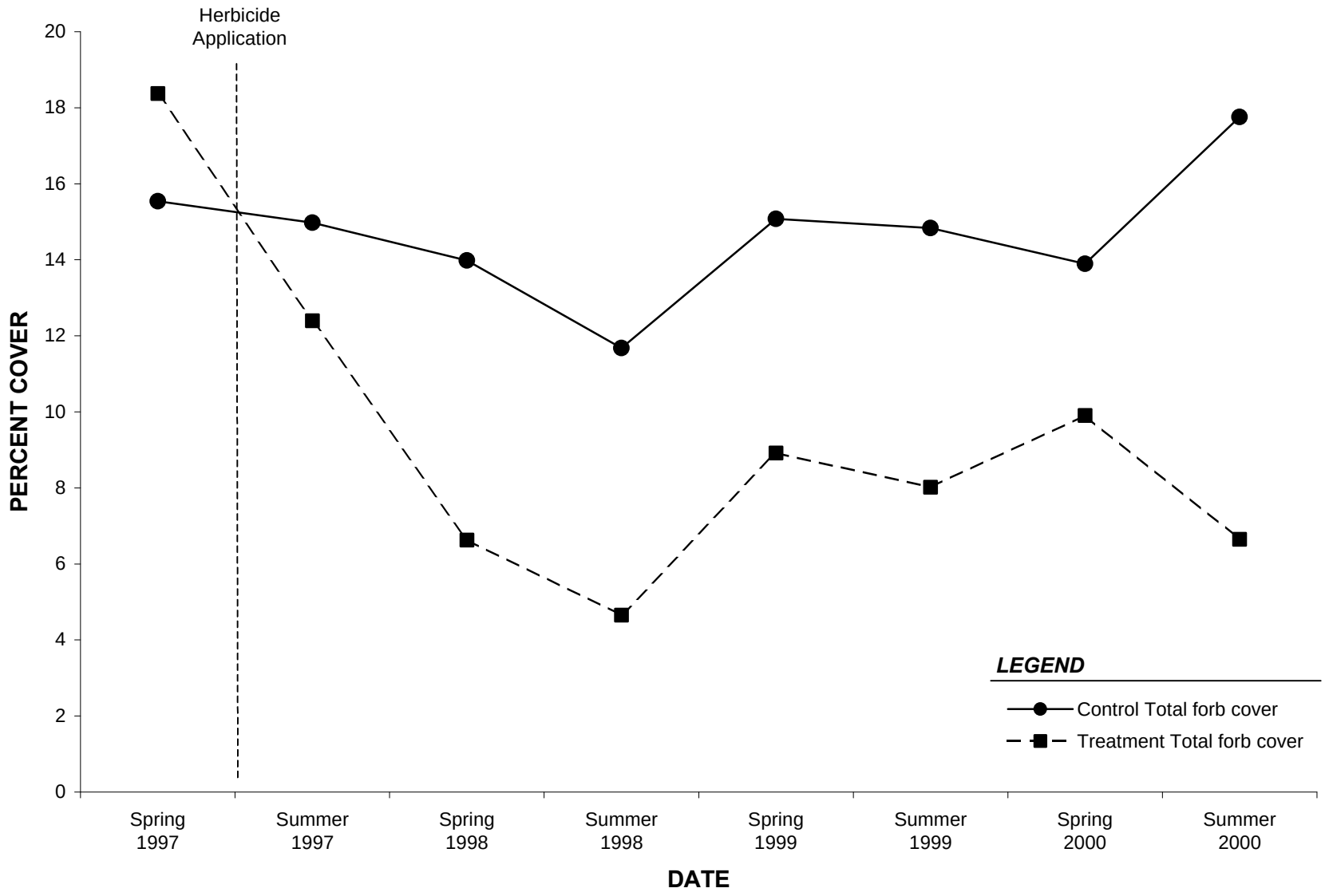

Figure 4-10. Diffuse knapweed herbicide monitoring study–Total relative forb cover.

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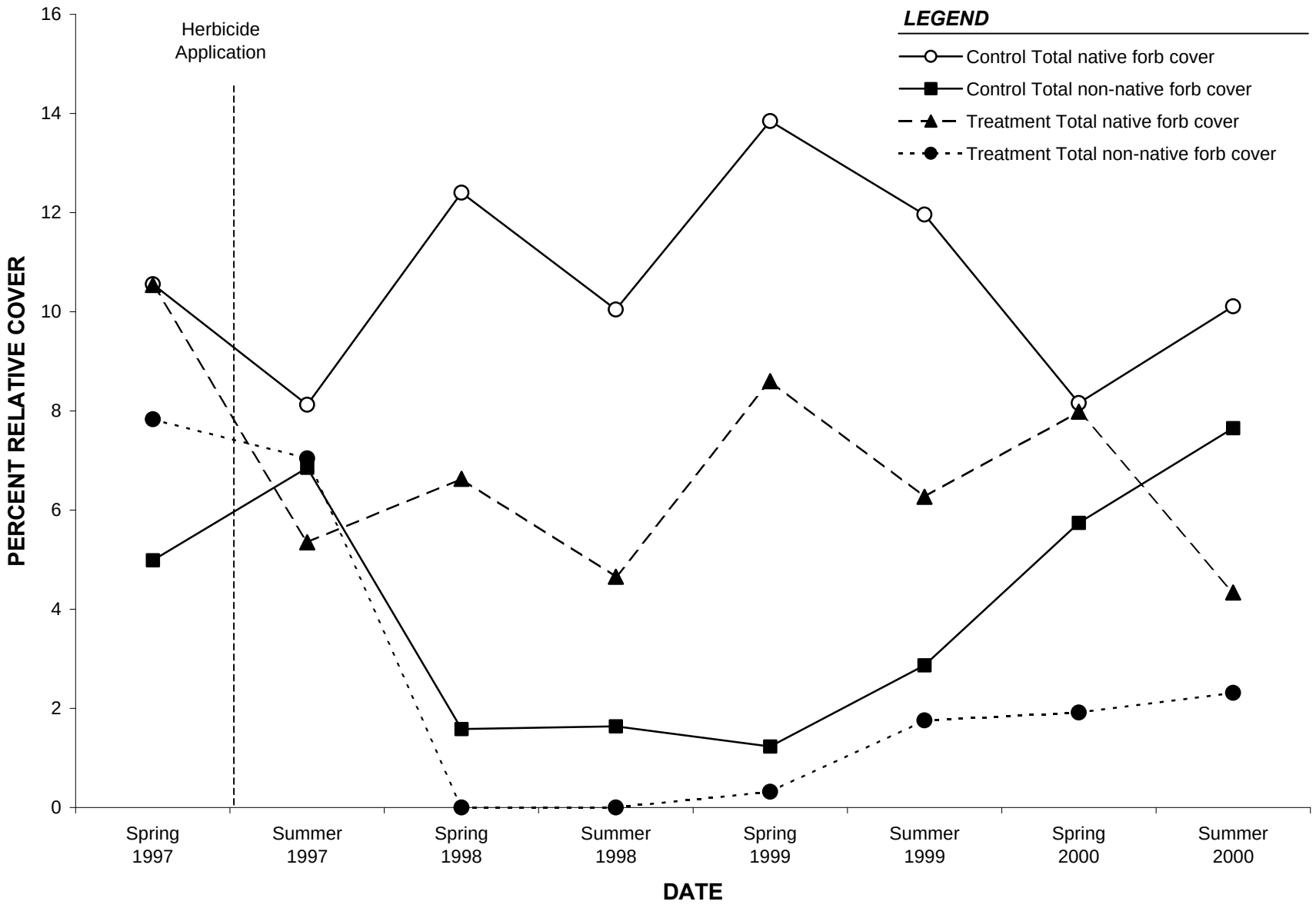

Figure 4-11. Diffuse knapweed herbicide monitoring study–Native vs. non-native forb cover.

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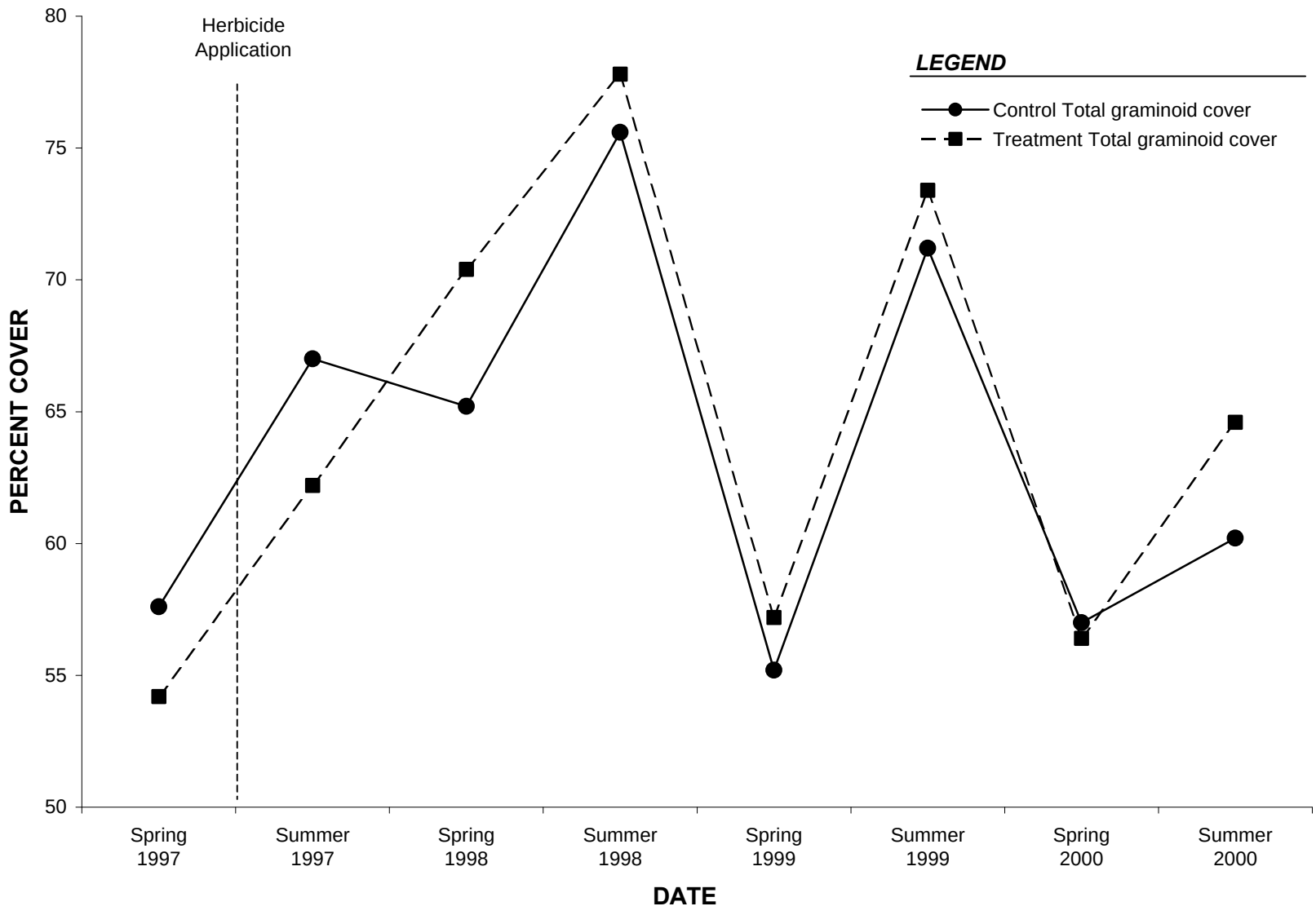

Figure 4-12. Diffuse knapweed herbicide monitoring study–Total absolute graminoid cover.

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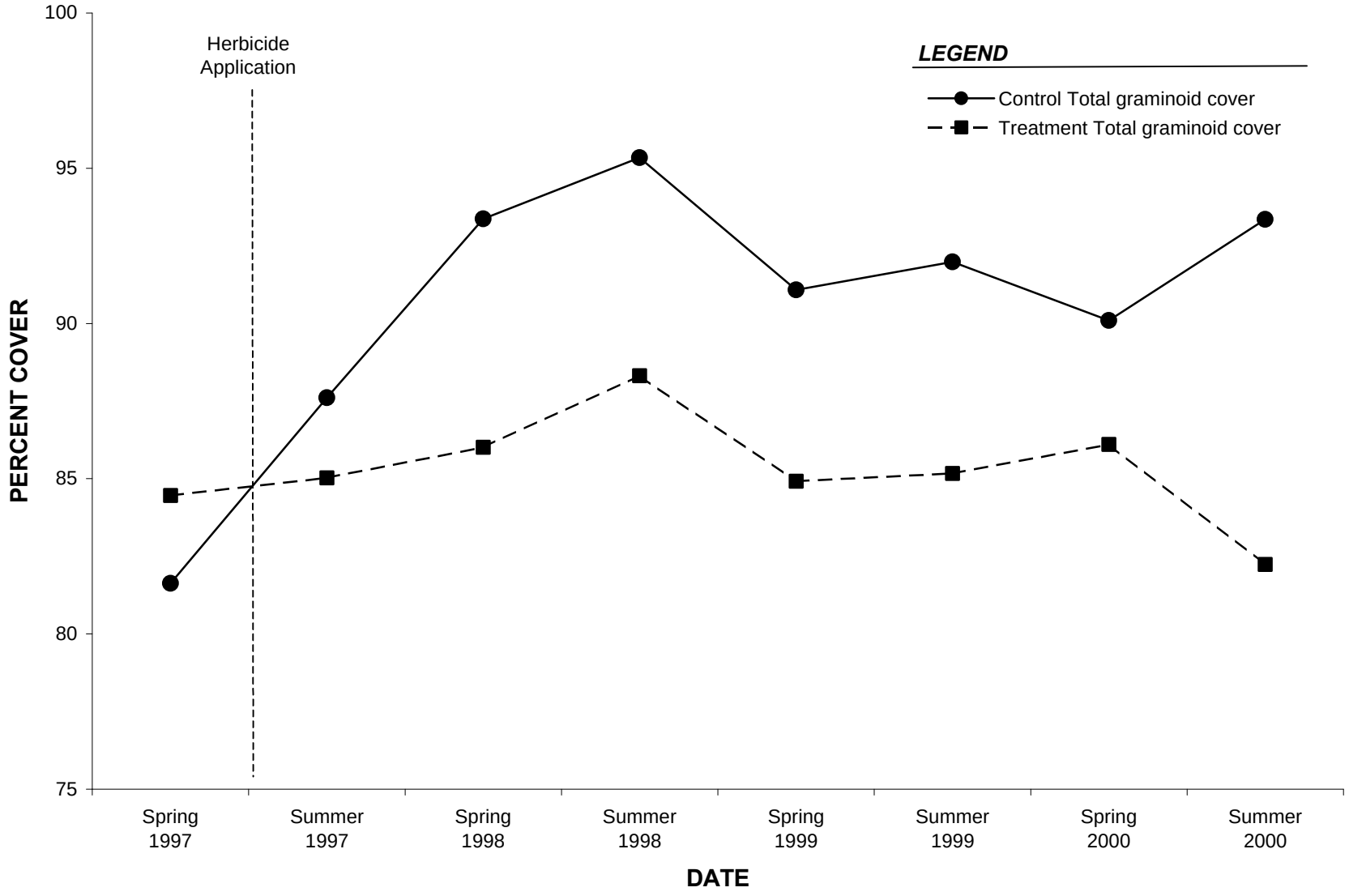

Figure 4-13. Diffuse knapweed herbicide monitoring study–Total relative graminoid cover.

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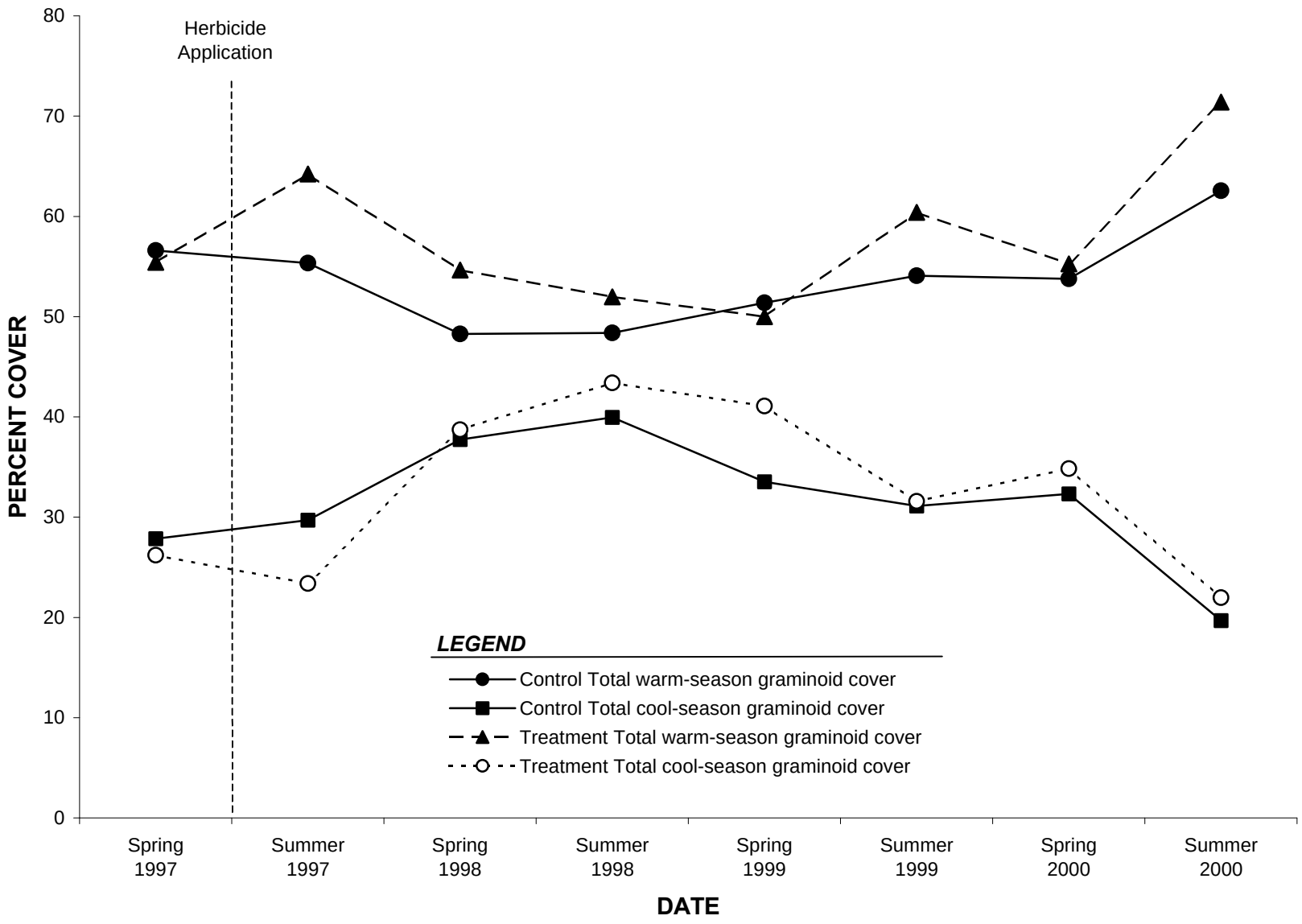

Figure 4-14. Diffuse knapweed herbicide monitoring study–Cool vs. warm season total relative graminoid cover.

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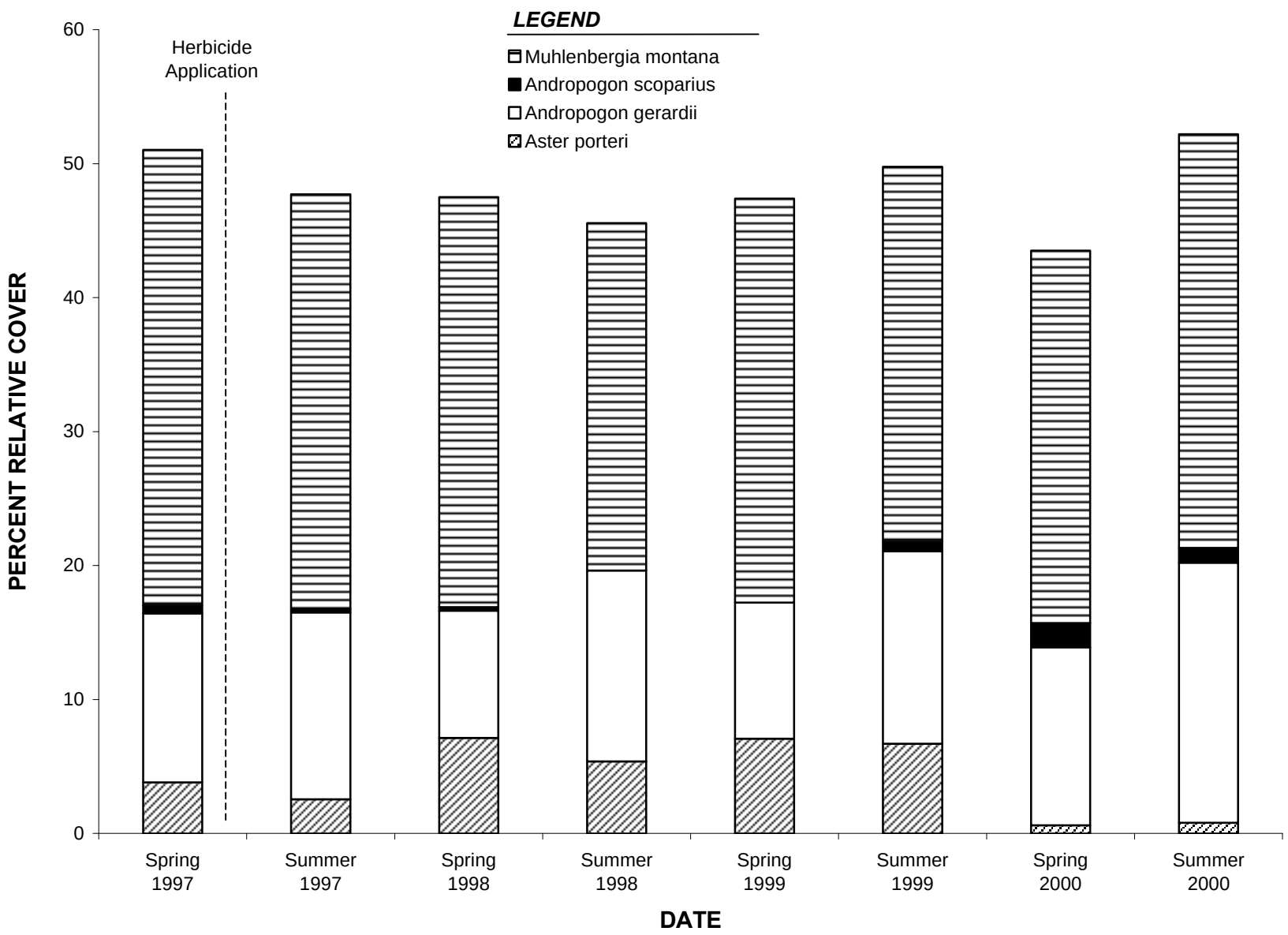

Figure 4-15. Diffuse knapweed herbicide monitoring study–Dominant species relative foliar cover 1997–2000, control plot.

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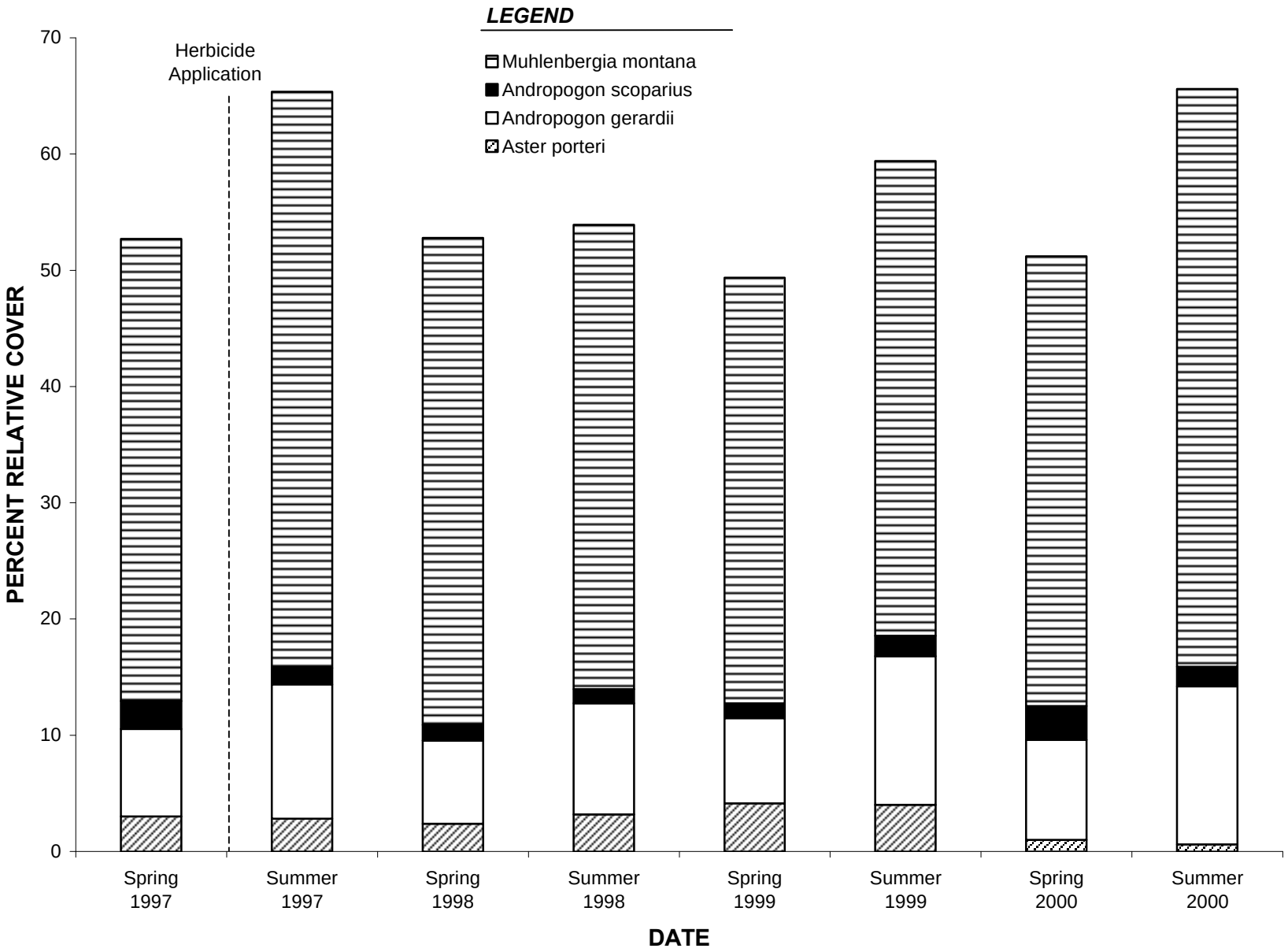

Figure 4-16. Diffuse knapweed herbicide monitoring study–Dominant species relative foliar cover 1997–2000, treatment plot.

\\Boulder1\Groups\Graphics\Jody\2k CEDI tables and figures for report.xls Fig 16 97-2k DomSp RelCovTreat 5/10/01 CO

Table 4-1. 1997-2000 Diffuse Knapweed Herbicide Monitoring Data Summary

	Spring97	Summer97	Spring98	Summer98	Spring99	Summer99	Spring2k	Summer2k
Species Richness Variables								
# species								
DKC - Control	68	65	70	65	67	58	64	59
DKT - Treatment	74	62	70	68	72	73	71	69
% natives								
DKC - Control	75	74	74	77	76	76	78	81
DKT - Treatment	73	77	77	79	75	76	75	75
mean # species/quadrat								
DKC - Control	13.8	12.8	14	12.1	14	11.4	12.9	11.6
DKT - Treatment	12.2	10.1	11.9	9.1	12.3	10.3	10.2	9.1
Ground Cover (Average Percent)								
total basal vegetation cover								
DKC - Control	10.8	8	11.2	9.2	10.4	9.6	3.8	5.8
DKT - Treatment	10.8	10.2	10.2	8.8	8.8	9.4	4.8	6.6
rock cover								
DKC - Control	12.8	12	10.2	10.8	13.4	9	13.8	7.6
DKT - Treatment	19.8	17.4	18.2	17.2	17.6	19.2	18.2	15.2
bare ground cover								
DKC - Control	11.6	4	3	2.2	5.8	2.6	5.2	3.2
DKT - Treatment	9	5.4	2.6	3	4	3.2	5.2	1.8
litter cover								
DKC - Control	64.8	76	75.6	77.8	70.4	78.8	77.2	83.4
DKT - Treatment	60.4	67	69	71	69.6	68.2	71.8	76.4
Diffuse Knapweed Density (mean # stems/m2)								
DKC - Control	5.6	3.6	14.5	1.7	26.1	6.2	5.6	7.1
DKT - Treatment	23	6.1	2.2	1.1	1.7	1.4	1.8	1.9
Diffuse Knapweed Frequency (%)								
DKC - Control	76	76	76	60	96	64	68	64
DKT - Treatment	80	60	52	20	44	44	44	48
Cactus Densities (mean # stems/m2)								
Twistspine prickly pear cactus								
DKC - Control	0.62		0.54		0.71		0.65	
DKT - Treatment	0.79		0.24		0.1		0.07	
Hedgehog cactus								
DKC - Control	0.06		0.05		0.08		0.04	
DKT - Treatment	0.2		0.14		0.09		0.06	

Table 4-2. 1997-2000 Diffuse Knapweed Monitoring Study Species Richness Summary - Treatment Plot

Family	Scientific Name	Speccode	Native	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
		UNKN							X		
APIACEAE	Lomatium orientale Coult. & Rose	LOOR1	Y	X	X	X	X	X	X	X	X
ASCLEPIADACEAE	Asclepias stenophylla A. Gray	ASST1	Y	X			X	X	X	X	X
ASCLEPIADACEAE	Asclepias viridiflora Raf.	ASVI1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	ACMI1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Ambrosia psilostachya DC.	AMPS1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Antennaria parvifolia Nutt.	ANPA1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Arnica fulgens Pursh.	ARFU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem.	ARCA1	Y	X	X	X					
ASTERACEAE	Artemisia frigida Willd.	ARFR1	Y	X							
ASTERACEAE	Artemisia ludoviciana Nutt. var. ludoviciana	ARLU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Aster porteri Gray	ASPO1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi	CANU1	N	X					X	X	X
ASTERACEAE	Centaurea diffusa Lam.	CEDI1	N	X	X	X	X	X	X	X	X
ASTERACEAE	Chrysopsis fulcrata Greene	CHFU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Chrysopsis villosa Pursh.	CHVI1	Y			X	X				
ASTERACEAE	Cirsium arvense (L.) Scop.	CIAR1	N	X		X		X			
ASTERACEAE	Conyza canadensis (L.) Cronq.	COCA1	Y						X		X
ASTERACEAE	Erigeron divergens T. & G.	ERDI1	Y	X	X		X	X		X	X
ASTERACEAE	Erigeron flagellaris A. Gray	ERFL1	Y	X	X	X					X
ASTERACEAE	Gaillardia aristata Pursh.	GAAR1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Grindelia squarrosa (Pursh.) Dun.	GRSQ1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Lactuca serriola L.	LASE1	N	X	X		X	X	X	X	X
ASTERACEAE	Liatris punctata Hook.	LIPU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Microseris cuspidata (Pursh.) Sch. Bip.	MICU1	Y	X		X		X		X	
ASTERACEAE	Scorzonera laciniata L.	SCLA1	N	X	X						X
ASTERACEAE	Senecio plattensis Nutt.	SEPL1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Senecio spartioides T. & G.	SESP1	Y		X		X	X	X	X	X
ASTERACEAE	Solidago mollis Bart.	SOMO1	Y	X	X	X	X		X	X	X
ASTERACEAE	Sonchus arvensis L. ssp. arvensis L.	SOAR1	N							X	X
ASTERACEAE	Taraxacum officinale Weber	TAOF1	N	X	X	X	X	X	X	X	X
ASTERACEAE	Tragopogon dubius Scop.	TRDU1	N	X	X	X	X	X	X	X	X
BORAGINACEAE	Mertensia lanceolata (Pursh.) A. DC.	MELA1	Y	X							
BRASSICACEAE	Alyssum alyssoides (L.) L.	ALAL1	N	X							
BRASSICACEAE	Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley	ALMI1	N	X	X	X	X	X	X	X	X
BRASSICACEAE	Arabis hirsuta (L.) Scop. var. pynocarpa (Hopkins) Rollins	ARHI1	Y	X	X			X	X	X	X
BRASSICACEAE	Barbarea vulgaris R. Br.	BAVU1	N	X	X	X		X	X	X	X
BRASSICACEAE	Camelina microcarpa Andrz. ex DC.	CAMI1	N	X		X	X	X	X	X	
BRASSICACEAE	Draba reptans (Lam.) Fern.	DRRE1	Y				X				
BRASSICACEAE	Erysimum capitatum (Nutt.) DC.	ERCA2	Y	X	X	X	X	X	X	X	X
BRASSICACEAE	Lepidium campestre (L.) R. Br.	LECA1	N	X	X	X	X	X	X	X	X
BRASSICACEAE	Lepidium densiflorum Schrad.	LEDE1	Y	X	X	X	X		X	X	

Table 4-2. (cont.)

Family	Scientific Name	Speccode	Native	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
BRASSICACEAE	Lesquerella montana (A. Gray) Wats.	LEMO1	Y	X	X	X	X	X	X	X	X
BRASSICACEAE	Sisymbrium altissimum L.	SIAL1	N			X		X	X		
CACTACEAE	Coryphantha missouriensis (Sweet) Britt. & Rose	COMI1	Y	X							
CACTACEAE	Echinocereus viridiflorus Engelm.	ECVI1	Y	X	X	X	X	X	X	X	X
CACTACEAE	Opuntia macrorhiza Engelm.	OPMA1	Y	X	X	X	X	X	X	X	X
CARYOPHYLLACEAE	Arenaria fendleri A. Gray	ARFE2	Y	X	X	X	X	X	X	X	X
CARYOPHYLLACEAE	Paronychia jamesii T. & G.	PAJA1	Y	X	X	X	X	X	X	X	X
CARYOPHYLLACEAE	Silene antirrhina L.	SIAN1	Y	X	X	X	X	X	X	X	X
CLUSIACEAE	Hypericum perforatum L.	HYPE1	N	X	X	X	X	X	X	X	X
COMMELINACEAE	Tradescantia occidentalis (Britt.) Smyth	TROC1	Y	X		X	X	X	X	X	
CRASSULACEAE	Sedum lanceolatum Torr.	SELA1	Y	X	X	X	X	X	X	X	X
CYPERACEAE	Carex heliophila Mack.	CAHE1	Y	X	X	X	X	X	X	X	X
CYPERACEAE	Eleocharis compressa Sulliv.	ELCO1	Y	X	X	X	X	X	X	X	X
FABACEAE	Dalea purpurea Vent	DAPU1	Y	X	X	X	X	X	X	X	X
FABACEAE	Medicago lupulina L.	MELU1	N	X							
FABACEAE	Psoralea tenuiflora Pursh.	PSTE1	Y	X	X	X	X	X	X	X	X
HYDROPHYLLACEAE	Phacelia heterophylla Pursh.	PHHE1	Y		X	X	X	X	X	X	X
JUNCACEAE	Juncus interior Wieg.	JUIN1	Y			X	X	X	X		X
LAMIACEAE	Hedeoma hispidum Pursh.	HEHI1	Y			X				X	
LILIACEAE	Allium textile A. Nels. & Macbr.	ALTE1	Y	X	X	X	X	X	X	X	
ONAGRACEAE	Oenothera villosa Thunb. ssp. strigosa (Rydb.) Dietrich & Raven	OEVI1	Y					X	X	X	X
OROBANCHACEAE	Orobanche fasciculata Nutt.	ORFA1	Y		X	X	X	X		X	X
PLANTAGINACE	Plantago lanceolata L.	PLLA1	N	X	X	X	X	X	X	X	X
PLANTAGINACE	Plantago patagonica Jacq.	PLPA1	Y	X							
POACEAE	Agropyron smithii Rydb.	AGSM1	Y			X		X			
POACEAE	Andropogon gerardii Vitman	ANGE1	Y	X	X	X	X	X	X	X	X
POACEAE	Andropogon scoparius Michx.	ANSC1	Y	X	X	X	X	X	X	X	X
POACEAE	Aristida purpurea Nutt. var. robusta (Merrill) A. Holmgren & N. Holmgr	ARLO1	Y						X		X
POACEAE	Bouteloua curtipendula (Michx.) Torr.	BOCU1	Y	X	X	X	X	X	X	X	X
POACEAE	Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	Y	X	X	X	X	X	X	X	X
POACEAE	Bouteloua hirsuta Lag	BOHI1	Y	X	X	X	X	X	X	X	X
POACEAE	Bromus japonicus Thunb. ex Murr.	BRJA1	N	X	X	X	X	X	X	X	X
POACEAE	Bromus tectorum L.	BRTE1	N	X	X	X	X	X	X	X	X
POACEAE	Buchloe dactyloides (Nutt.) Engelm.	BUDA1	Y	X	X		X	X	X	X	X
POACEAE	Koeleria pyramidata (Lam.) Beauv.	KOPY1	Y	X	X	X	X	X	X	X	X
POACEAE	Muhlenbergia montana (Nutt.) Hitchc.	MUMO1	Y	X	X	X	X	X	X	X	X
POACEAE	Muhlenbergia wrightii Vasey	MUWR1	Y			X	X	X		X	X
POACEAE	Panicum capillare L.	PACA1	Y						X		
POACEAE	Poa compressa L.	POCO1	N	X	X	X	X	X	X	X	X
POACEAE	Poa pratensis L.	POPR1	N	X	X	X	X	X	X	X	X
POACEAE	Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	SIHY1	Y	X	X		X	X	X	X	X
POACEAE	Sorghastrum nutans (L.) Nash	SONU1	Y		X	X	X		X	X	X

Table 4-2. (cont.)

Family	Scientific Name	Speccode	Native	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
POACEAE	Sporobolus heterolepis (A. Gray) A. Gray	SPHE1	Y	X	X	X	X	X	X	X	X
POACEAE	Stipa comata Trin. & Rupr.	STCO1	Y			X					
POLEMONIACEAE	Collomia linearis Nutt.	COLI1	Y	X		X	X	X	X		
POLYGONACEAE	Eriogonum alatum Torr.	ERAL1	Y	X	X	X	X	X	X	X	X
POLYGONACEAE	Polygonum arenastrum Jord. ex Bor.	POAR1	N					X			
POLYGONACEAE	Polygonum ramosissimum Michx.	PORA1	Y			X	X	X	X		
POLYGONACEAE	Rumex crispus L.	RUCR1	N	X		X	X	X	X	X	
PORTULACACEAE	Talinum parviflorum Nutt.	TAPA1	Y	X				X	X	X	X
ROSACEAE	Potentilla gracilis Dougl. ex Hook. var. glabrata (Lehm.) C. L. Hitchc.	POGR1	Y	X							
SCROPHULARIACEAE	Linaria dalmatica (L.) Mill.	LIDA1	N							X	X
SCROPHULARIACEAE	Penstemon virens Penn.	PEVI1	Y	X	X	X	X	X	X	X	X
SCROPHULARIACEAE	Veronica peregrina L. var. xalapensis (H. B. K.) St. John & Warren	VEPE1	Y			X	X	X	X		
	Number of Species			74	62	70	68	72	73	71	69
	Percent Native Species			73	77	77	79	75	76	75	75

Table 4-3. 1997-2000 Diffuse Knapweed Monitoring Study Species Richness Summary - Control Plot

Family	Scientific Name	Speccode	Native	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
APIACEAE	Lomatium orientale Coult. & Rose	LOOR1	Y	X	X	X	X	X		X	X
ASCLEPIADACEAE	Asclepias stenophylla A. Gray	ASST1	Y	X	X	X	X	X	X	X	X
ASCLEPIADACEAE	Asclepias viridiflora Raf.	ASVI1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	ACMI1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Ambrosia psilostachya DC.	AMPS1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Antennaria parvifolia Nutt.	ANPA1	Y	X	X	X		X	X		
ASTERACEAE	Arnica fulgens Pursh.	ARFU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem.	ARCA1	Y	X	X		X			X	X
ASTERACEAE	Artemisia ludoviciana Nutt. var. ludoviciana	ARLU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Aster porteri Gray	ASPO1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Carduus nutans L. ssp. macrolepis (Peterm.) Kazmi	CANU1	N	X	X	X	X				
ASTERACEAE	Centaurea diffusa Lam.	CEDI1	N	X	X	X	X	X	X	X	X
ASTERACEAE	Chrysopsis fulcrata Greene	CHFU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Chrysopsis villosa Pursh.	CHVI1	Y			X	X			X	
ASTERACEAE	Erigeron divergens T. & G.	ERDI1	Y				X	X		X	
ASTERACEAE	Erigeron flagellaris A. Gray	ERFL1	Y	X	X	X	X		X		X
ASTERACEAE	Gaillardia aristata Pursh.	GAAR1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Grindelia squarrosa (Pursh.) Dun.	GRSQ1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Lactuca serriola L.	LASE1	N	X	X	X	X	X	X		
ASTERACEAE	Liatris punctata Hook.	LIPU1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Microseris cuspidata (Pursh.) Sch. Bip.	MICU1	Y	X		X		X			
ASTERACEAE	Scorzonera laciniata L.	SCLA1	N	X	X	X		X		X	
ASTERACEAE	Senecio plattensis Nutt.	SEPL1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Solidago mollis Bart.	SOMO1	Y	X	X	X	X	X	X	X	X
ASTERACEAE	Solidago rigida L.	SORI1	Y		X	X	X	X	X	X	X
ASTERACEAE	Taraxacum officinale Weber	TAOF1	N	X	X	X	X	X	X	X	X
ASTERACEAE	Tragopogon dubius Scop.	TRDU1	N	X	X	X	X	X	X	X	X
BORAGINACEAE	Lithospermum incisum Lehm.	LIIN1	Y	X	X	X		X		X	X
BORAGINACEAE	Mertensia lanceolata (Pursh.) A. DC.	MELA1	Y			X		X			X
BRASSICACEAE	Alyssum alyssoides (L.) L.	ALAL1	N			X					
BRASSICACEAE	Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley	ALMI1	N	X	X	X	X	X	X	X	X
BRASSICACEAE	Arabis hirsuta (L.) Scop. var. pynocarpa (Hopkins) Rollins	ARHI1	Y			X	X				
BRASSICACEAE	Camelina microcarpa Andrz. ex DC.	CAMI1	N	X	X	X	X	X	X		
BRASSICACEAE	Draba reptans (Lam.) Fern.	DRRE1	Y	X	X	X		X			
BRASSICACEAE	Erysimum capitatum (Nutt.) DC.	ERCA2	Y	X	X	X	X	X	X	X	X
BRASSICACEAE	Lepidium campestre (L.) R. Br.	LECA1	N	X	X	X	X	X	X	X	X
BRASSICACEAE	Lepidium densiflorum Schrad.	LEDE1	Y	X	X						
BRASSICACEAE	Lesquerella montana (A. Gray) Wats.	LEMO1	Y	X	X	X	X	X	X	X	X
BRASSICACEAE	Sisymbrium altissimum L.	SIAL1	N	X	X						
CACTACEAE	Coryphantha missouriensis (Sweet) Britt. & Rose	COMI1	Y	X				X			
CACTACEAE	Echinocereus viridiflorus Engelm.	ECVI1	Y	X	X	X	X	X	X	X	X
CACTACEAE	Opuntia macrorhiza Engelm.	OPMA1	Y	X	X	X	X	X	X	X	X
CARYOPHYLLACEAE	Arenaria fendleri A. Gray	ARFE2	Y	X	X	X	X	X	X	X	X

Table 4-3. (cont.)

Family	Scientific Name	Speccode	Native	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
CARYOPHYLLACEAE	Paronychia jamesii T. & G.	PAJA1	Y	X			X			X	
CARYOPHYLLACEAE	Silene antirrhina L.	SIAN1	Y	X	X	X		X		X	
CLUSIACEAE	Hypericum perforatum L.	HYPE1	N	X	X	X	X	X	X	X	X
COMMELINACEAE	Tradescantia occidentalis (Britt.) Smyth	TROC1	Y	X							
CYPERACEAE	Carex heliophila Mack.	CAHE1	Y	X	X	X	X	X	X	X	X
CYPERACEAE	Eleocharis compressa Sulliv.	ELCO1	Y	X	X	X	X	X	X	X	X
FABACEAE	Dalea purpurea Vent	DAPU1	Y	X	X	X	X	X	X	X	X
FABACEAE	Oxytropis lambertii Pursh.	OXLA1	Y	X					X		
FABACEAE	Psoralea tenuiflora Pursh.	PSTE1	Y	X	X	X	X	X	X	X	X
JUNCACEAE	Juncus interior Wieg.	JUIN1	Y		X	X	X	X	X	X	X
LILIACEAE	Allium textile A. Nels. & Macbr.	ALTE1	Y	X	X	X	X	X	X	X	X
LILIACEAE	Leucocrinum montanum Nutt.	LEMO2	Y	X		X		X			
NYCTAGINACEAE	Mirabilis linearis (Pursh.) Heimerl	MILI1	Y								X
ONAGRACEAE	Oenothera villosa Thunb. ssp. strigosa (Rydb.) Dietrich & Raven	OEVI1	Y	X	X	X	X	X	X	X	X
OROBANCHACEAE	Orobanche fasciculata Nutt.	ORFA1	Y	X				X		X	
PLANTAGINACE	Plantago lanceolata L.	PLLA1	N	X	X	X	X	X	X	X	X
POACEAE	Agropyron smithii Rydb.	AGSM1	Y	X							X
POACEAE	Andropogon gerardii Vitman	ANGE1	Y	X	X	X	X	X	X	X	X
POACEAE	Andropogon scoparius Michx.	ANSC1	Y	X	X	X	X	X	X	X	X
POACEAE	Aristida purpurea Nutt. var. robusta (Merrill) A. Holmgren & N. Holmgr	ARLO1	Y		X				X	X	X
POACEAE	Bouteloua curtipendula (Michx.) Torr.	BOCU1	Y	X	X	X	X	X	X	X	X
POACEAE	Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	Y	X	X	X	X	X	X	X	X
POACEAE	Bouteloua hirsuta Lag	BOHI1	Y	X	X	X	X	X	X	X	X
POACEAE	Bromus inermis Leyss. ssp. inermis	BRIN1	N	X	X	X	X	X	X	X	X
POACEAE	Bromus japonicus Thunb. ex Murr.	BRJA1	N	X	X	X	X	X	X	X	
POACEAE	Koeleria pyramidata (Lam.) Beauv.	KOPY1	Y	X	X	X	X	X	X	X	X
POACEAE	Muhlenbergia montana (Nutt.) Hitchc.	MUMO1	Y	X	X	X	X	X	X	X	X
POACEAE	Muhlenbergia wrightii Vasey	MUWR1	Y							X	
POACEAE	Poa compressa L.	POCO1	N	X	X	X	X	X	X	X	X
POACEAE	Poa pratensis L.	POPR1	N	X	X	X	X	X	X	X	X
POACEAE	Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	SIHY1	Y	X	X		X	X	X	X	X
POACEAE	Sorghastrum nutans (L.) Nash	SONU1	Y		X	X	X		X	X	X
POACEAE	Sporobolus heterolepis (A. Gray) A. Gray	SPHE1	Y	X	X	X	X	X	X	X	X
POACEAE	Stipa comata Trin. & Rupr.	STCO1	Y				X		X		
POLYGONACEAE	Eriogonum alatum Torr.	ERAL1	Y			X	X			X	X
POLYGONACEAE	Polygonum convolvulus L.	POCO2	N			X					
POLYGONACEAE	Polygonum ramosissimum Michx.	PORA1	Y			X	X				
PORTULACACEAE	Talinum parviflorum Nutt.	TAPA1	Y		X	X	X	X	X	X	X
ROSACEAE	Prunus virginiana L. var. melanocarpa (A. Nels.) Sarg.	PRVI1	Y	X	X	X	X	X	X	X	X
SCROPHULARIACEAE	Linaria dalmatica (L.) Mill.	LIDA1	N					X		X	
SCROPHULARIACEAE	Penstemon virens Penn.	PEVI1	Y	X	X	X	X	X	X	X	X
SCROPHULARIACEAE	Verbascum blattaria L.	VEBL1	N	X	X	X	X	X	X	X	X
SCROPHULARIACEAE	Veronica peregrina L. var. xalapensis (H. B. K.) St. John & Warren	VEPE1	Y			X	X	X			

Table 4-4. 1997-2000 Diffuse Knapweed Monitoring Study Species Frequency Summary - Control Plot

Family	Scientific Name	Native	Speccode	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
APIACEAE	Lomatium orientale Coult. & Rose	Y	LOOR1	92		92	48	100		96	4
ASCLEPIADACEAE	Asclepias stenophylla A. Gray	Y	ASST1	8	4			4	4		4
ASCLEPIADACEAE	Asclepias viridiflora Raf.	Y	ASVI1	8	12	8	8	12	12	8	8
ASTERACEAE	Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	Y	ACMI1	8	8	8	4	8	4	4	4
ASTERACEAE	Ambrosia psilostachya DC.	Y	AMPS1	72	68	64	68	64	60	60	64
ASTERACEAE	Arnica fulgens Pursh.	Y	ARFU1	36	16	40	28	40	12	32	8
ASTERACEAE	Artemisia ludoviciana Nutt. var. ludoviciana	Y	ARLU1	68	68	68	64	68	64	68	68
ASTERACEAE	Aster porteri Gray	Y	ASPO1	76	76	84	76	76	76	52	40
ASTERACEAE	Centaurea diffusa Lam.	N	CEDI1	76	76	76	60	96	64	68	64
ASTERACEAE	Chrysopsis fulcrata Greene	Y	CHFU1	8	8	8	4	4	4	4	8
ASTERACEAE	Erigeron divergens T. & G.	Y	ERDI1					4		4	
ASTERACEAE	Erigeron flagellaris A. Gray	Y	ERFL1	4	4	4	4		4		4
ASTERACEAE	Gaillardia aristata Pursh.	Y	GAAR1	12	4	8	4	12	8	4	8
ASTERACEAE	Grindelia squarrosa (Pursh.) Dun.	Y	GRSQ1	56	48	68	40	40	32	32	20
ASTERACEAE	Lactuca serriola L.	N	LASE1	12	12	28	8	20	4		
ASTERACEAE	Liatris punctata Hook.	Y	LIPU1	16	20	20	28	24	24	16	24
ASTERACEAE	Microseris cuspidata (Pursh.) Sch. Bip.	Y	MICU1	4		8		4			
ASTERACEAE	Senecio plattensis Nutt.	Y	SEPL1	8	4	4		16	4	4	8
ASTERACEAE	Solidago mollis Bart.	Y	SOMO1	24	24	28	28	28	24	28	24
ASTERACEAE	Tragopogon dubius Scop.	N	TRDU1	8	16	44	32	32	20	24	32
BORAGINACEAE	Lithospermum incisum Lehm.	Y	LIIN1	4	4						4
BORAGINACEAE	Mertensia lanceolata (Pursh.) A. DC.	Y	MELA1			4					
BRASSICACEAE	Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley	N	ALMI1	28	20	12	16	20	8	4	4
BRASSICACEAE	Camelina microcarpa Andrz. ex DC.	N	CAMI1	8				8	4		
BRASSICACEAE	Draba reptans (Lam.) Fern.	Y	DRRE1	16	4	4		12			
BRASSICACEAE	Erysimum capitatum (Nutt.) DC.	Y	ERCA2	8	4	8		4			
BRASSICACEAE	Lepidium campestre (L.) R. Br.	N	LECA1		4	4	4	12	8	4	
BRASSICACEAE	Lepidium densiflorum Schrad.	Y	LEDE1	4	4						
BRASSICACEAE	Lesquerella montana (A. Gray) Wats.	Y	LEMO1	8	8	12	16	28	16	12	12
CACTACEAE	Echinocereus viridiflorus Engelm.	Y	ECVI1	16	16	20	8	8	4	4	12
CACTACEAE	Opuntia macrorhiza Engelm.	Y	OPMA1	40	40	40	40	36	32	48	44
CARYOPHYLLACEAE	Arenaria fendleri A. Gray	Y	ARFE2	32	44	20	44	32	36	32	36
CARYOPHYLLACEAE	Silene antirrhina L.	Y	SIAN1	8	8	4		12		8	
CLUSIACEAE	Hypericum perforatum L.	N	HYPE1	52	64	44	16	24	16	20	28
CYPERACEAE	Carex heliophila Mack.	Y	CAHE1	64	72	72	68	56	60	68	76
FABACEAE	Dalea purpurea Vent	Y	DAPU1	8	4	8	8	8	8	8	8
FABACEAE	Psoralea tenuiflora Pursh.	Y	PSTE1	32	40	44	36	36	44	44	36
JUNCACEAE	Juncus interior Wieg.	Y	JUIN1		4		4		4		4
LILIACEAE	Allium textile A. Nels. & Macbr.	Y	ALTE1	20	4	8		8			
NYCTAGINACEAE	Mirabilis linearis (Pursh.) Heimerl	Y	MILI1								4
ONAGRACEAE	Oenothera villosa Thunb. ssp. strigosa (Rydb.) Dietrich & Raven	Y	OEVI1			4					
OROBANCHACEAE	Orobanche fasciculata Nutt.	Y	ORFA1					4		12	

Table 4-4. (cont.)

Family	Scientific Name	Native	Speccode	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
POACEAE	Andropogon gerardii Vitman	Y	ANGE1	88	88	88	84	88	92	84	84
POACEAE	Andropogon scoparius Michx.	Y	ANSC1	28	28	20	24	16	36	48	52
POACEAE	Aristida purpurea Nutt. var. robusta (Merrill) A. Holmgren & N. Holmgr	Y	ARLO1								4
POACEAE	Bouteloua curtipendula (Michx.) Torr.	Y	BOCU1	36	40	28	28	40	40	60	44
POACEAE	Bouteloua gracilis (H. B. K.) Lag ex Griffiths	Y	BOGR1		16	8	8	8	20	28	24
POACEAE	Bouteloua hirsuta Lag	Y	BOHI1	16	16	16	28	16	20	24	28
POACEAE	Bromus japonicus Thunb. ex Murr.	N	BRJA1			4	4	4			
POACEAE	Koeleria pyramidata (Lam.) Beauv.	Y	KOPY1	40	32	28	20	28	24	40	24
POACEAE	Muhlenbergia montana (Nutt.) Hitchc.	Y	MUMO1	100	100	96	100	96	100	100	100
POACEAE	Poa compressa L.	N	POCO1	92	100	100	100	100	96	100	100
POACEAE	Poa pratensis L.	N	POPR1	8	8	8	8	4	4	8	8
POACEAE	Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	Y	SIHY1	8	12			8	12		
POACEAE	Sorghastrum nutans (L.) Nash	Y	SONU1		4	4	4		4	4	4
POACEAE	Sporobolus heterolepis (A. Gray) A. Gray	Y	SPHE1	20	20	20	24	20	20	20	20
POACEAE	Stipa comata Trin. & Rupr.	Y	STCO1				4		4		
POLYGONACEAE	Polygonum ramosissimum Michx.	Y	PORA1				8				
PORTULACACEAE	Talinum parviflorum Nutt.	Y	TAPA1		4	4		8	4	4	
SCROPHULARIACEAE	Penstemon virens Penn.	Y	PEVI1	4		4	4	4	4	4	4
SCROPHULARIACEAE	Veronica peregrina L. var. xalapensis (H. B. K.) St. John & Warren	Y	VEPE1			4					

Numbers shown are percent frequency (n = 25).

Table 4-5. 1997-2000 Diffuse Knapweed Monitoring Study Species Frequency Summary - Treatment Plot

Family	Scientific Name	Native	Speccode	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
			UNKN						4		
APIACEAE	Lomatium orientale Coult. & Rose	Y	LOOR1	80	8	92	72	92	24	88	16
ASTERACEAE	Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	Y	ACMI1							4	
ASTERACEAE	Ambrosia psilostachya DC.	Y	AMPS1	32	32	12	16	16	12	28	28
ASTERACEAE	Arnica fulgens Pursh.	Y	ARFU1	16	12	16	12	20	8	20	8
ASTERACEAE	Artemisia campestris L. ssp. caudata (Michx.) Hall & Clem.	Y	ARCA1	4	4	4					
ASTERACEAE	Artemisia ludoviciana Nutt. var. ludoviciana	Y	ARLU1	36	36	32	16	24	16	20	16
ASTERACEAE	Aster porteri Gray	Y	ASPO1	80	84	80	72	80	72	44	48
ASTERACEAE	Centaurea diffusa Lam.	N	CEDI1	80	60	52	20	44	44	44	48
ASTERACEAE	Chrysopsis fulcrata Greene	Y	CHFU1					4	4	4	
ASTERACEAE	Erigeron divergens T. & G.	Y	ERDI1	4						4	
ASTERACEAE	Erigeron flagellaris A. Gray	Y	ERFL1		4						4
ASTERACEAE	Gaillardia aristata Pursh.	Y	GAAR1	8	4		4	4	4	4	8
ASTERACEAE	Grindelia squarrosa (Pursh.) Dun.	Y	GRSQ1	20	16	12		12	4	4	4
ASTERACEAE	Lactuca serriola L.	N	LASE1	20	8			28	16	4	
ASTERACEAE	Liatris punctata Hook.	Y	LIPU1	20	20	28	20	28	24	28	16
ASTERACEAE	Microseris cuspidata (Pursh.) Sch. Bip.	Y	MICU1	4		4		8			
ASTERACEAE	Scorzonera laciniata L.	N	SCLA1	4	4						
ASTERACEAE	Senecio plattensis Nutt.	Y	SEPL1	24	12	20	4	12	4	4	4
ASTERACEAE	Taraxacum officinale Weber	N	TAOF1	4							
ASTERACEAE	Tragopogon dubius Scop.	N	TRDU1	12	8		4	8	4	20	28
BORAGINACEAE	Mertensia lanceolata (Pursh.) A. DC.	Y	MELA1	4							
BRASSICACEAE	Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley	N	ALMI1	4	4	16	4	8	4	4	4
BRASSICACEAE	Arabis hirsuta (L.) Scop. var. pynocarpa (Hopkins) Rollins	Y	ARHI1	4				4	4	4	4
BRASSICACEAE	Barbarea vulgaris R. Br.	N	BAVU1	4							
BRASSICACEAE	Camelina microcarpa Andrz. ex DC.	N	CAMI1					4			
BRASSICACEAE	Draba reptans (Lam.) Fern.	Y	DRRE1				4				
BRASSICACEAE	Erysimum capitatum (Nutt.) DC.	Y	ERCA2	4				8	8	12	4
BRASSICACEAE	Lepidium campestre (L.) R. Br.	N	LECA1	16	8	16	12	20	12	4	
BRASSICACEAE	Lepidium densiflorum Schrad.	Y	LEDE1	12	8						
BRASSICACEAE	Lesquerella montana (A. Gray) Wats.	Y	LEMO1	12	16	12	12	20	20	12	12
CACTACEAE	Echinocereus viridiflorus Engelm.	Y	ECVI1	40	36	28	32	28	24	20	20
CACTACEAE	Opuntia macrorhiza Engelm.	Y	OPMA1	64	76	20	32	24	28	16	20
CARYOPHYLLACEAE	Arenaria fendleri A. Gray	Y	ARFE2	52	40	28	28	28	24	28	16
CARYOPHYLLACEAE	Paronychia jamesii T. & G.	Y	PAJA1	12	12	4	4	4	4	4	4
CARYOPHYLLACEAE	Silene antirrhina L.	Y	SIAN1	4		28		24	8	12	4
CLUSIACEAE	Hypericum perforatum L.	N	HYPE1	16	8	72	12	36	24	20	36
COMMELINACEAE	Tradescantia occidentalis (Britt.) Smyth	Y	TROC1	4		4		4	4	4	
CYPERACEAE	Carex heliophila Mack.	Y	CAHE1	32	40	52	40	36	28	36	36
FABACEAE	Dalea purpurea Vent	Y	DAPU1	12	12	8	12	12	12	16	16
FABACEAE	Psoralea tenuiflora Pursh.	Y	PSTE1	20	8	16	16	12	16	20	20
JUNCACEAE	Juncus interior Wieg.	Y	JUIN1				4				

Table 4-5. (cont.)

Family	Scientific Name	Native	Speccode	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
LILIACEAE	Allium textile A. Nels. & Macbr.	Y	ALTE1	36	12	24	12	28	16		
ONAGRACEAE	Oenothera villosa Thunb. ssp. strigosa (Rydb.) Dietrich & Raven	Y	OEVI1					4	4	4	4
OROBANCHACEAE	Orobanche fasciculata Nutt.	Y	ORFA1		4	4	4	20		40	12
POACEAE	Andropogon gerardii Vitman	Y	ANGE1	68	64	64	64	64	68	64	60
POACEAE	Andropogon scoparius Michx.	Y	ANSC1	20	40	20	20	20	28	28	32
POACEAE	Bouteloua curtipendula (Michx.) Torr.	Y	BOCU1	8	32	28	12	24	32	20	36
POACEAE	Bouteloua gracilis (H. B. K.) Lag ex Griffiths	Y	BOGR1	16	28	16	24	36	48	36	48
POACEAE	Bouteloua hirsuta Lag	Y	BOHI1	16			4	8	20	12	12
POACEAE	Bromus japonicus Thunb. ex Murr.	N	BRJA1	36	32	32	36	40	24	24	12
POACEAE	Bromus tectorum L.	N	BRTE1	8	4	12	8		12	12	8
POACEAE	Koeleria pyramidata (Lam.) Beauv.	Y	KOPY1	36	20	28	20	20	32	24	24
POACEAE	Muhlenbergia montana (Nutt.) Hitchc.	Y	MUMO1	96	96	92	92	96	100	96	96
POACEAE	Poa compressa L.	N	POCO1	96	96	100	100	100	100	100	100
POACEAE	Poa pratensis L.	N	POPR1			4	4	8	4		
POACEAE	Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	Y	SIHY1						4	4	4
POACEAE	Sorghastrum nutans (L.) Nash	Y	SONU1				4		4		4
POLEMONIACEAE	Collomia linearis Nutt.	Y	COLI1	4		4	4	4	4		
POLYGONACEAE	Polygonum ramosissimum Michx.	Y	PORA1			4	8	8	4		
POLYGONACEAE	Rumex crispus L.	N	RUCR1	4							
PORTULACACEAE	Talinum parviflorum Nutt.	Y	TAPA1					12	28	4	20
SCROPHULARIACEAE	Penstemon virens Penn.	Y	PEVI1	16		28	12	28	24	20	16
SCROPHULARIACEAE	Veronica peregrina L. var. xalapensis (H. B. K.) St. John & Warren	Y	VEPE1			72	32	60	16		

Numbers shown are percent frequency (n = 25).

Table 4-6. 1997-2000 Diffuse Knapweed Monitoring Species Frequency Changes Summary

Scientific Name	Native	Speccode	Control Change	Treatment Change	Control vs. Treatment Change
Opuntia macrorhiza Engelm.	Y	OPMA1	8	-48	-56
Centaurea diffusa Lam.	N	CEDI1	-8	-36	-28
Arenaria fendleri A. Gray	Y	ARFE2	0	-24	-24
Artemisia ludoviciana Nutt. var. ludoviciana	Y	ARLU1	0	-16	-16
Senecio plattensis Nutt.	Y	SEPL1	-4	-20	-16
Lepidium campestre (L.) R. Br.	N	LECA1	4	-12	-16
Allium textile A. Nels. & Macbr.	Y	ALTE1	-20	-36	-16
Aster porteri Gray	Y	ASPO1	-24	-36	-12
Psoralea tenuiflora Pursh.	Y	PSTE1	12	0	-12
Andropogon scoparius Michx.	Y	ANSC1	20	8	-12
Bouteloua curtipendula (Michx.) Torr.	Y	BOCU1	24	12	-12
Bouteloua hirsuta Lag	Y	BOHI1	8	-4	-12
Bromus japonicus Thunb. ex Murr.	N	BRJA1	0	-12	-12
Koeleria pyramidata (Lam.) Beauv.	Y	KOPY1	0	-12	-12
Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	Y	SIHY1	-8	4	12
Draba reptans (Lam.) Fern.	Y	DRRE1	-16	0	16
Erysimum capitatum (Nutt.) DC.	Y	ERCA2	-8	8	16
Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley	N	ALMI1	-24	0	24
Orobanche fasciculata Nutt.	Y	ORFA1	12	40	28
Hypericum perforatum L.	N	HYPE1	-32	4	36

Control and Treatment Change column values based on Spring 1997 and Spring 2000 differences. See Tables 4 and 5.

Line separates negative and postive changes. Only those changes (+ or -) than 12 percent are shown.

Table 4-7. 1997-2000 Diffuse Knapweed Monitoring Study Foliar Cover Summary - Control Plot

					Frequency (%)								Absolute Cover (%)								Relative Cover (%)							
Scientific Name	Speccode	Growth Form	Native	Cool/ Warm Season	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
Centaurea diffusa Lam.	CEDI1	F	N		100	100	40	80	40	60	100	100	2.6	4.8	0.4	1.0	0.6	2.0	3.2	4.8	3.8	6.1	0.5	1.2	0.9	2.4	4.8	6.6
Lepidium campestre (L.) R. Br.	LECA1	F	N		20	20	20	20		40			0.4	0.2	0.2	0.2		0.2			0.6	0.3	0.3	0.2		0.2		
Hypericum perforatum L.	HYPE1	F	N			20								0.2								0.3						
Camelina microcarpa Andrz. ex DC.	CAMI1	F	N					20								0.2								0.2				
Tragopogon dubius Scop.	TRDU1	F	N		40	20	60		40	20	60	40	0.4	0.2	0.6		0.2	0.2	0.6	0.8	0.6	0.3	0.8		0.3	0.2	0.9	1.1
Ambrosia psilostachya DC.	AMPS1	F	Y		60	60	100	80	80	60	40	100	1.2	0.6	1.2	1.4	1.8	1.4	1.0	2.4	1.8	0.8	1.6	1.6	2.8	1.7	1.5	3.3
Gaillardia aristata Pursh.	GAAR1	F	Y			20			20					0.2			0.2					0.3			0.3			
Achillea millefolium L. ssp. lanulosa (Nutt.) Piper	ACMI1	F	Y								20								0.2								0.3	
Chrysopsis fulcrata Greene	CHFU1	F	Y								20	20							0.2	0.2							0.3	0.3
Aster porteri Gray	ASPO1	F	Y		100	100	100	100	100	100	20	40	2.6	2.0	5.4	4.6	4.6	5.6	0.4	0.6	3.8	2.5	7.1	5.4	7.1	6.7	0.6	0.8
Dalea purpurea Vent	DAPU1	F	Y			20	20		20	20				0.2	0.2		0.2	0.2				0.3	0.3		0.3	0.2		
Arenaria fendleri A. Gray	ARFE2	F	Y		40	20		40	20	40	40		0.4	0.2		0.4	0.6	0.4	0.6		0.6	0.3		0.5	0.9	0.5	0.9	
Arnica fulgens Pursh.	ARFU1	F	Y		20		20			20			0.2		0.2			0.2			0.3		0.3			0.2		
Grindelia squarrosa (Pursh.) Dun.	GRSQ1	F	Y		40	80		20			20		0.4	1.2		0.2			0.2		0.6	1.5		0.2			0.3	
Artemisia ludoviciana Nutt. var. ludoviciana	ARLU1	F	Y		100	20	40	40	40	40	40	60	1.0	0.2	0.6	0.4	0.6	0.4	0.6	1.2	1.5	0.3	0.8	0.5	0.9	0.5	0.9	1.6
Asclepias stenophylla A. Gray	ASST1	F	Y		20	20				40	20		0.2	0.2				0.4	0.2		0.3	0.3				0.5	0.3	
Erigeron divergens T. & G.	ERDI1	F	Y						40								0.4								0.6			
Psoralea tenuiflora Pursh.	PSTE1	F	Y		40	80	40	80	20	100	80	100	0.8	1.4	0.8	1.6	0.2	1.4	1.4	2.6	1.2	1.8	1.1	1.9	0.3	1.7	2.1	3.6
Liatris punctata Hook.	LIPU1	F	Y		20							40	0.2							0.4	0.3							0.5
Lomatium orientale Coult. & Rose	LOOR1	F	Y				60		40		40				0.8		0.4		0.6				1.1		0.6		0.9	
Silene antirrhina L.	SIAN1	F	Y		20								0.2								0.3							
Erigeron flagellaris A. Gray	ERFL1	F	Y			20	20							0.2	0.2							0.3	0.3					
Poa pratensis L.	POPR1	G	N	C	20	40	40	20				40	0.4	0.6	0.8	0.2				0.4	0.6	0.8	1.1	0.2				0.5
Poa compressa L.	POCO1	G	N	C	100	100	100	100	100	100	100	100	17.2	20.8	25.4	31.8	19.2	24.2	19.6	11.8	25.2	26.4	33.5	37.1	29.5	28.9	29.6	16.1
Koeleria pyramidata (Lam.) Beauv.	KOPY1	G	Y	C	40	20	20	20	40	40	20		0.4	0.2	0.2	0.2	0.4	0.4	0.2		0.6	0.3	0.3	0.2	0.6	0.5	0.3	
Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	SIHY1	G	Y	C		20			20					0.2			0.2					0.3			0.3			
Eleocharis compressa Sulliv.	ELCO1	G	Y	C	20		20			20		20	0.4		0.2			0.2		0.2	0.6		0.3			0.2		0.3
Carex heliophila Mack.	CAHE1	G	Y	C	60	100	80	80	60	60	80	80	0.6	1.6	2.0	2.0	2.0	1.2	1.6	2.0	0.9	2.0	2.6	2.3	3.1	1.4	2.4	2.7
Andropogon gerardii Vitman	ANGE1	G	Y	W	100	100	100	100	100	100	100	100	8.6	11.0	7.2	12.2	6.6	12.0	8.8	14.2	12.6	14.0	9.5	14.3	10.2	14.4	13.3	19.4
Sporobolus heterolepis (A. Gray) A. Gray	SPHE1	G	Y	W	100	100	100	100	100	100	100	100	5.6	6.2	4.8	6.0	5.6	6.4	5.0	6.4	8.2	7.9	6.3	7.0	8.6	7.7	7.6	8.7
Andropogon scoparius Michx.	ANSC1	G	Y	W	20	20	20			60	80	40	0.4	0.2	0.2			0.6	1.2	0.8	0.6	0.3	0.3			0.7	1.8	1.1
Bouteloua curtipendula (Michx.) Torr.	BOCU1	G	Y	W	40	80	40	80	40	60	60	40	0.4	1.8	1.0	0.8	1.2	2.0	1.4	1.0	0.6	2.3	1.3	0.9	1.8	2.4	2.1	1.4
Bouteloua hirsuta Lag	BOHI1	G	Y	W			20		20	40	40				0.2		0.2	0.4	0.4				0.3		0.3	0.5	0.6	
Muhlenbergia montana (Nutt.) Hitchc.	MUMO1	G	Y	W	100	100	100	100	100	100	100	100	23.2	24.4	23.2	22.2	19.6	23.4	18.4	22.6	34.0	31.0	30.6	25.9	30.2	28.0	27.8	30.9
Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	G	Y	W	20			20	20	20	60	60	0.4			0.2	0.2	0.4	0.4	0.8	0.6			0.2	0.3	0.5	0.6	1.1
Total foliar cover													68.2	78.8	75.8	85.6	65.0	83.6	66.2	73.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total forb cover													10.6	11.8	10.6	10.0	9.8	12.4	9.2	13.0	15.5	15.0	14.0	11.7	15.1	14.8	13.9	17.8
Total native forb cover													7.2	6.4	9.4	8.6	9.0	10.0	5.4	7.4	10.6	8.1	12.4	10.0	13.8	12.0	8.2	10.1
Total non-native forb cover													3.4	5.4	1.2	1.4	0.8	2.4	3.8	5.6	5.0	6.9	1.6	1.6	1.2	2.9	5.7	7.7
Total graminoid cover													57.6	67.0	65.2	75.6	55.2	71.2	57.0	60.2	84.5	85.0	86.0	88.3	84.9	85.2	86.1	82.2
Total native cover													47.2	52.0	48.4	52.2	45.0	57.0	42.8	55.4	69.2	66.0	63.9	61.0	69.2	68.2	64.7	75.7
Total non-native cover													21.0	26.8	27.4	33.4	20.0	26.6	23.4	17.8	30.8	34.0	36.1	39.0	30.8	31.8	35.3	24.3
Total warm-season graminoid cover													38.6	43.6	36.6	41.4	33.4	45.2	35.6	45.8	56.6	55.3	48.3	48.4	51.4	54.1	53.8	62.6
Total cool-season graminoid cover													19.0	23.4	28.6	34.2	21.8	26.0	21.4	14.4	27.9	29.7	37.7	40.0	33.5	31.1	32.3	19.7

Absolute cover = Absolute foliar cover is the percentage of the number of hits on a species out of the total number of hits possible (500).
Relative cover = Relative foliar cover was the number of hits a species had relative to the total number of all vegetative hits recorded per site (i.e., the percent of vegetative cover the species represented).
All cover values presented are means (n = 5).
Native categories: Y = Native, N = Non-Native
Form categories: C = Cactus, F = Forb, G = Graminoid
Cool/Warm Season categories: C = Cool season species, W = Warm season species

Table 4-8. 1997-2000 Diffuse Knapweed Monitoring Study Foliar Cover Summary - Treatment Plot

					Frequency (%)								Absolute Cover (%)								Relative Cover (%)							
Scientific Name	Speccode	Growth Form	Native	Cool/ Warm Season	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000	Spring 1997	Summer 1997	Spring 1998	Summer 1998	Spring 1999	Summer 1999	Spring 2000	Summer 2000
Alyssum minus (L.) Rothmaler var. micranthus (C. A. Mey.) Dudley	ALMI1	F	N						20	20	20						0.2	0.2	0.2						0.3	0.3	0.3	
Centaurea diffusa Lam.	CEDI1	F	N		100	100				20	40	60	4.4	4.8				0.6	0.4	1.2	6.6	6.8				0.8	0.6	1.7
Hypericum perforatum L.	HYPE1	F	N		20	20					20	20	0.2	0.2					0.2	0.2	0.3	0.3					0.3	0.3
Lactuca serriola L.	LASE1	F	N							20								0.2								0.3		
Lepidium campestre (L.) R. Br.	LECA1	F	N		20								0.2								0.3							
Plantago lanceolata L.	PLLA1	F	N		20								0.2								0.3							
Tragopogon dubius Scop.	TRDU1	F	N		20					40	40	20	0.2					0.4	0.4	0.2	0.3					0.5	0.6	0.3
Allium textile A. Nels. & Macbr.	ALTE1	F	Y		20	20	20						0.2	0.2	0.2						0.3	0.3	0.3					
Ambrosia psilostachya DC.	AMPS1	F	Y		80					20	40	60	1.6					0.2	0.6	1.0	2.4					0.3	1.0	1.4
Arenaria fendleri A. Gray	ARFE2	F	Y		20								0.4								0.6							
Arnica fulgens Pursh.	ARFU1	F	Y		60	20	20	40	40		20		0.6	0.2	0.4	0.4	0.8		0.6		0.9	0.3	0.5	0.5	1.3		1.0	
Artemisia ludoviciana Nutt. var. ludoviciana	ARLU1	F	Y		20	60		60		60	40	20	0.4	1.0		0.6		0.6	0.6	0.2	0.6	1.4		0.7		0.8	1.0	0.3
Aster porteri Gray	ASPO1	F	Y		80	100	60	60	60	80	20	40	2.0	2.0	1.8	2.6	2.6	3.2	0.6	0.4	3.0	2.8	2.4	3.2	4.1	4.0	1.0	0.6
Asclepias stenophylla A. Gray	ASST1	F	Y		20			20					0.2			0.2					0.3			0.2				
Dalea purpurea Vent	DAPU1	F	Y			20	20				20			0.2	0.2				0.2			0.3	0.3				0.3	
Grindelia squarrosa (Pursh.) Dun.	GRSQ1	F	Y		60	20	20		20		20	20	0.6	0.2	0.2		0.2		0.4	0.2	0.9	0.3	0.3		0.3		0.6	0.3
Lesquerella montana (A. Gray) Wats.	LEMO1	F	Y							20	40							0.2	0.4							0.3	0.6	
Liatris punctata Hook.	LIPU1	F	Y		20		20			40	60	40	0.2		0.2			0.6	0.8	0.4	0.3		0.3			0.8	1.3	0.6
Lomatium orientale Coult. & Rose	LOOR1	F	Y		60		80		80		40		0.8		1.6		1.2		0.4		1.2		2.1		1.9		0.6	
Penstemon virens Penn.	PEVI1	F	Y				20					20			0.2					0.2			0.3					0.3
Senecio plattensis Nutt.	SEPL1	F	Y				20								0.2								0.3					
Senecio spartioides T. & G.	SESP1	F	Y							20	20	20						0.2	0.4	0.4						0.3	0.6	0.6
Talinum parviflorum Nutt.	TAPA1	F	Y									20								0.2								0.3
Tradescantia occidentalis (Britt.) Smyth	TROC1	F	Y						20								0.4								0.6			
Veronica peregrina L. var. xalapensis (H. B. K.) St. John & Warren	VEPE1	F	Y						20								0.2								0.3			
Bromus japonicus Thunb. ex Murr.	BRJA1	G	N	C	60	80	40	60	40	40	20		2.2	2.4	2.0	2.2	1.2	0.8	0.2		3.3	3.4	2.7	2.7	1.9	1.0	0.3	
Bromus tectorum L.	BRTE1	G	N	C	20		40	40		20			1.8		1.2	0.6		0.6			2.7		1.6	0.7		0.8		
Poa compressa L.	POCO1	G	N	C	100	100	100	100	100	100	100	100	12.2	12.4	25.0	31.6	23.8	22.8	20.4	13.0	18.4	17.5	33.2	38.7	37.9	28.6	32.6	18.8
Poa pratensis L.	POPR1	G	N	C	20	20	20					20	0.2	0.4	0.2					0.2	0.3	0.6	0.3					0.3
Carex heliophila Mack.	CAHE1	G	Y	C	60	40	60	40	40	40	20	60	0.8	1.2	0.8	0.8	0.6	0.8	1.0	2.0	1.2	1.7	1.1	1.0	1.0	1.0	1.6	2.9
Koeleria pyramidata (Lam.) Beauv.	KOPY1	G	Y	C	40	20			20		20		0.2	0.2			0.2		0.2		0.3	0.3			0.3		0.3	
Sitanion hystrix (Nutt.) Sm. var. brevifolium (Sm.) Hitchc.	SIHY1	G	Y	C				20		20						0.2		0.2						0.2		0.3		
Andropogon gerardii Vitman	ANGE1	G	Y	W	80	100	80	100	100	100	100	100	5	8.2	5.4	7.8	4.6	10.2	5.4	9.4	7.5	11.5	7.2	9.6	7.3	12.8	8.6	13.6
Andropogon scoparius Michx.	ANSC1	G	Y	W	80	60	80	60	40	40	60	80	1.6	1	1	1	0.8	1.4	1.8	1.2	2.4	1.4	1.3	1.2	1.3	1.8	2.9	1.7
Bouteloua curtipendula (Michx.) Torr.	BOCU1	G	Y	W	60	40	60	20	60	80	40	80	0.8	0.4	1.4	0.2	1.6	2	0.6	2.4	1.2	0.6	1.9	0.2	2.5	2.5	1.0	3.5
Bouteloua gracilis (H. B. K.) Lag ex Griffiths	BOGR1	G	Y	W	40	20	80			80	60	40	0.6	0.2	1.2			0.8	1	1.2	0.9	0.3	1.6			1.0	1.6	1.7
Bouteloua hirsuta Lag	BOHI1	G	Y	W	80			20	40		80	20	0.8			0.2	0.6		1	0.2	1.2			0.2	1.0		1.6	0.3
Muhlenbergia montana (Nutt.) Hitchc.	MUMO1	G	Y	W	100	100	100	100	100	100	100	100	26.4	35.2	31.6	32.6	23	32.6	24.2	34.4	39.8	49.6	41.9	40.0	36.6	40.9	38.7	49.7
Sorghastrum nutans (L.) Nash	SONU1	G	Y	W						20	20							0.2	0.2							0.3	0.3	
Sporobolus heterolepis (A. Gray) A. Gray	SPHE1	G	Y	W	60	20	40	40	40	40	20	40	1.6	0.6	0.6	0.6	0.8	1	0.4	0.6	2.4	0.8	0.8	0.7	1.3	1.3	0.6	0.9
Total foliar cover													66.4	71.0	75.4	81.6	62.8	79.8	62.6	69.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total forb cover													12.2	8.8	5.0	3.8	5.6	6.4	6.2	4.6	18.4	12.4	6.6	4.7	8.9	8.0	9.9	6.6
Total native forb cover													7.0	3.8	5.0	3.8	5.4	5.0	5.0	3.0	10.5	5.4	6.6	4.7	8.6	6.3	8.0	4.3
Total non-native forb cover													5.2	5.0	0.0	0.0	0.2	1.4	1.2	1.6	7.8	7.0	0.0	0.0	0.3	1.8	1.9	2.3
Total graminoid cover													54.2	62.2	70.4	77.8	57.2	73.4	56.4	64.6	81.6	87.6	93.4	95.3	91.1	92.0	90.1	93.4
Total native cover													44.8	50.8	47.0	47.2	37.6	54.2	40.8	54.4	67.5	71.5	62.3	57.8	59.9	67.9	65.2	78.6
Total non-native cover													21.6	20.2	28.4	34.4	25.2	25.6	21.8	14.8	32.5	28.5	37.7	42.2	40.1	32.1	34.8	21.4
Total warm-season graminoid cover													36.8	45.6	41.2	42.4	31.4	48.2	34.6	49.4	55.4	64.2	54.6	52.0	50.0	60.4	55.3	71.4
Total cool-season graminoid cover													17.4	16.6	29.2	35.4	25.8	25.2	21.8	15.2	26.2	23.4	38.7	43.4	41.1	31.6	34.8	22.0

Absolute cover = Absolute foliar cover is the percentage of the number of hits on a species out of the total number of hits possible (500).
Relative cover = Relative foliar cover was the number of hits a species had relative to the total number of all vegetative hits recorded per site (i.e., the percent of vegetative cover the species represented).
All cover values presented are means (n = 5).
Native categories: Y = Native, N = Non-Native
Form categories: C = Cactus, F = Forb, G = Graminoid
Cool/Warm Season categories: C = Cool season species, W = Warm season species