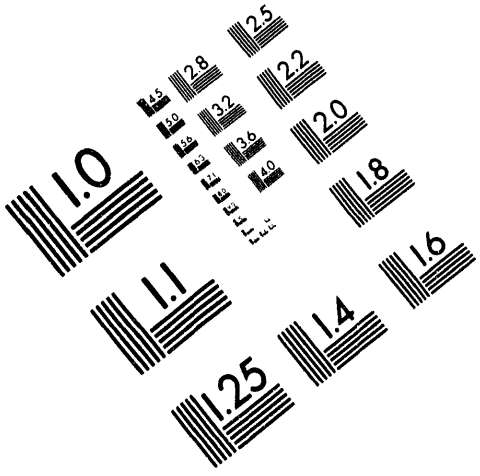

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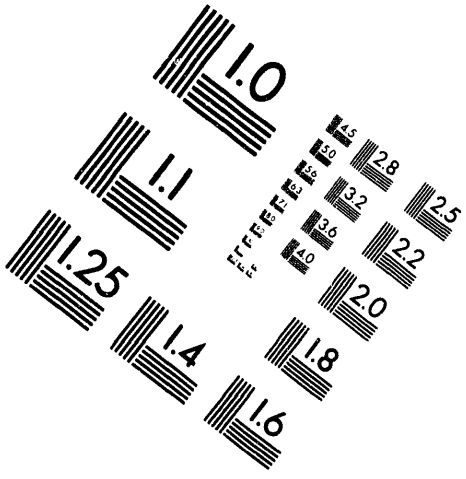

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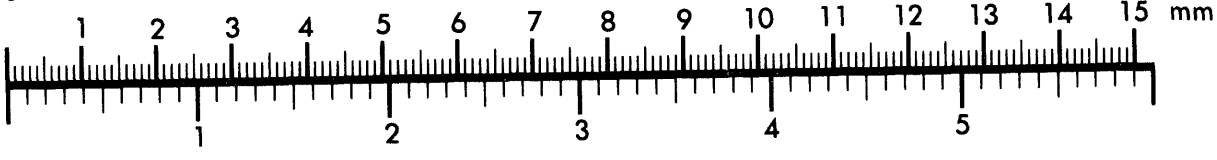

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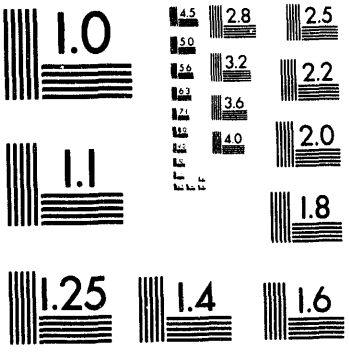

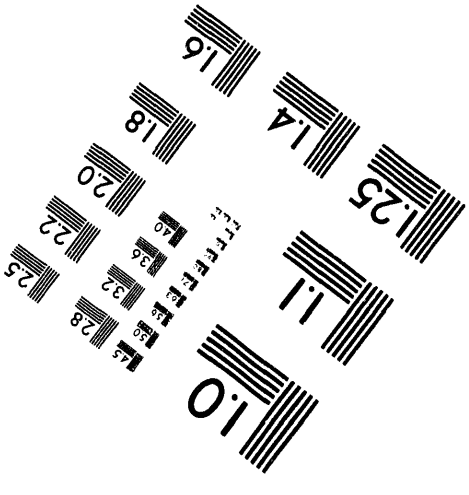

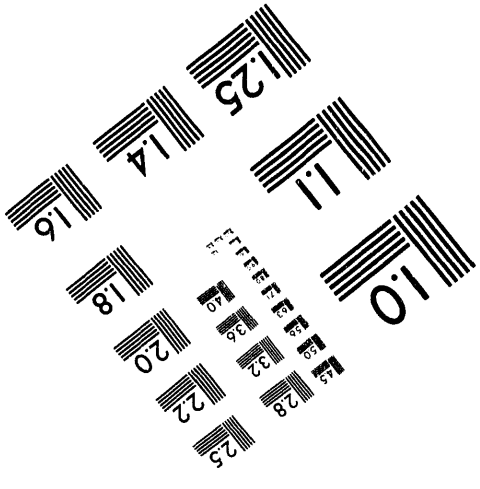

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# VEGETATION SURVEY OF KNAPWEED ON THE YAKIMA TRAINING CENTER--1992

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# Summary

This report summarizes and discusses the results of a vegetation survey conducted in 1992 on a portion of the Yakima Training Center (YTC). Pacific Northwest Laboratory (PNL) conducted this survey and a similar survey in 1991 for the U.S. Department of the Army. The objectives of the survey were to evaluate the impact of the herbicide picloram on forbs where aerial applications of picloram were made in 1988, 1989, and 1991 to control knapweed (*Centaurea* spp.) infestations. Forbs are of special interest because they are an important part of the spring and summer diet of the western sage grouse (*Centrocercus urophasianus phaios*), which is a U.S. Fish and Wildlife Service candidate species for the threatened and endangered list. We also conducted a limited evaluation of the effectiveness of the spray program in controlling the spread of knapweed. This document is a companion document to the report detailing results of the vegetation surveys conducted in 1991 (Eberhardt et al. 1992).

Percent plant canopy cover and number of forbs were measured on 120 transects on the herbicide-treated (78 transects) and untreated control (42 transects) areas. The 1992 survey showed that areas treated with picloram in 1988, 1989, and 1991 continued to show evidence of knapweed suppression compared to control areas. Herbicide treatment in 1991 resulted in a significant reduction in knapweed based on percent cover and density. The treatment areas also all had lower percent canopy cover of perennial forbs and fewer perennial forbs compared to control areas.

Canopy cover of shrubs and annual, biennial, and perennial forbs measured on the YTC increased between the 1991 and 1992 survey, which may indicate a recovery of these vegetation types after disturbance. These increases also could reflect the mild 1992 winter and superior growing conditions in the spring of 1992.

We recommend that these vegetation transects continue to be monitored for an additional growing season to evaluate 1) whether knapweed increases to its previous abundance in the 1991 herbicide-treated area, 2) the efficacy of herbicide application on transects along roadways, and 3) the increase in invasive annuals in herbicide-treated areas and the possible effects on community vegetation structure and sage grouse habitat.

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# 1.0 Introduction

Knapweeds (*Centaurea* spp) are considered noxious weeds and are widely distributed throughout the Yakima Training Center (YTC) with particularly heavy infestations along the Selah Creek drainage (Figure 1.1). On portions of the YTC, several aerial applications of herbicide have been made to control knapweed infestations. At the request of the U.S. Army, Pacific Northwest Laboratory (PNL) conducted vegetation surveys in 1991 and 1992 to evaluate the impact of the herbicide spray program on the forb component of the local plant communities and provide information on the effectiveness of the spray program in controlling the spread of knapweed. Results of the spring 1992 survey are summarized in this report and compared with survey results from 1991.

The forb component of the plant communities is of special interest because it constitutes an important portion of the spring and summer diet of the western sage grouse (*Centrocercus urophasianus phaios*), which inhabits the YTC (Eberhardt and Hofmann 1991). The sage grouse is a U.S. Fish and Wildlife Service candidate species for the threatened and endangered listing as well as being a Washington State candidate species.

The four species of knapweed of concern on eastern Washington rangelands and specifically the YTC are diffuse knapweed (*Centaurea diffusa*), spotted knapweed (*C. maculosa*), Russian knapweed (*C. repens*), and yellow starthistle (*C. solstitialis*) (Roché and Roché 1988). These noxious weeds are extremely competitive and often can displace the native vegetation. Mature knapweeds are unpalatable to livestock, and dense stands of knapweed result in decreased production of livestock forage (Harris and Cranston 1979; Kelsey and Mihalovich 1987; Maddox 1979). A serious infestation of knapweed can increase the potential for erosion, reduce wildlife habitat and populations, and reduce property values (Cranston 1985). Knapweed infestations are often associated with human-induced disturbance of native plant communities.

On the YTC, native plant communities are subject to disturbances that result from training activities such as weapons firing and field maneuvers on the site. In particular, Ranges 10, 10Z, and 55, which form the core of the study area, are used extensively for training maneuvers. Tracers and flares used in training activities often ignite the vegetation during summer months. In addition to the impacts of off-road mechanical disturbance and burning, the Selah Creek Valley has been grazed by both sheep and cattle under a grazing management plan.

In an effort to slow the spread of knapweed on the YTC, the herbicide picloram was applied aerially to areas in the Selah Creek drainage in 1987, 1988, 1989, and 1991. Picloram is a restricted-use pesticide for control of broadleaf annuals and perennials and may be residual

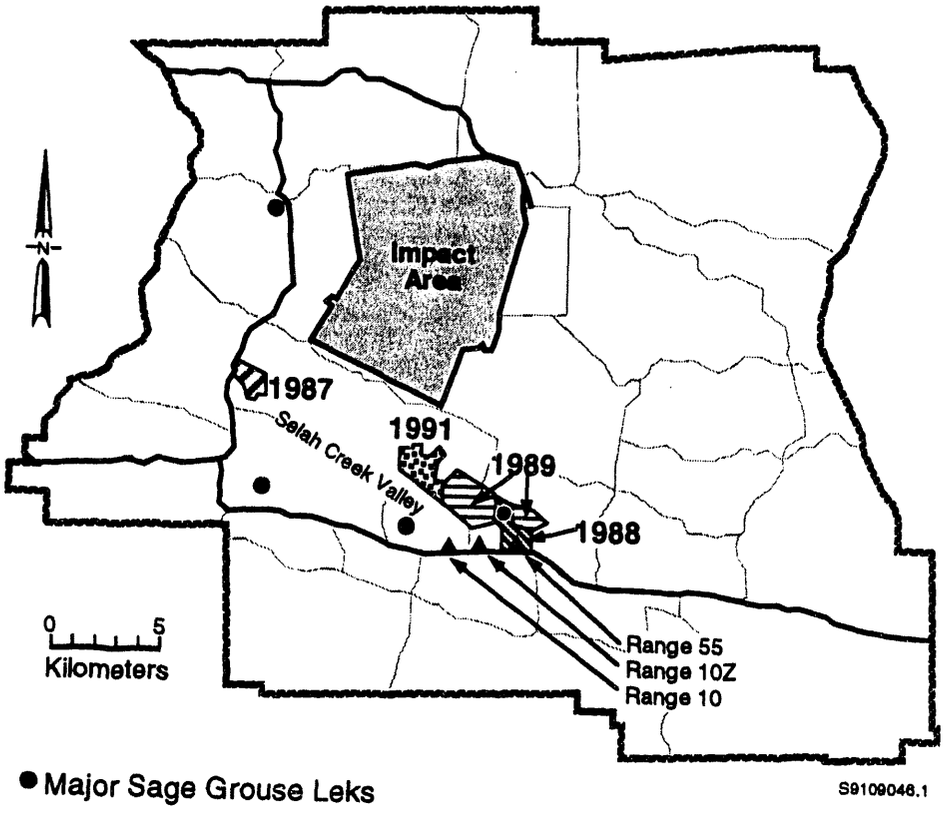


**Figure 1.1.** Map of the Yakima Training Center

in soils for months. Survival of broadleaf seedlings may be affected for up to 2 years. Use of picloram as a control agent is likely to be included as part of an integrated management plan that may include the introduction of biological agents (insects) specific to knapweed, enhanced fire suppression, improved road networks, reseeding, and application of herbicides to roadside lanes where knapweed infestations usually begin.

Within the Selah Creek drainage, most of the herbicide has been applied to areas near two of the four main sage grouse breeding leks on the YTC (Figure 1, Eberhardt and Hofmann 1991). Picloram is not specific to knapweed. It also kills annual and perennial forbs, which are a main food source for sage grouse during the spring and early summer. PNL staff conducted vegetation surveys during spring 1991 (Eberhardt et al. 1992) and again during spring 1992.

# 2.0 Methods

The YTC encompasses approximately 1,058 $km^2$ in Yakima and Kittitas counties in south-central Washington. Vegetation surveys were conducted during May 1992 on permanent sampling transects in the Selah Creek Valley area between Ranges 10 and 55 and on the YTC (Figure 2.1). The study area ranges in elevation from 732 to 808 m, with generally south-facing slopes. Soils in the area are primarily silt loams with shrub-steppe vegetation cover (Daubenmire 1970). The climate is characterized by hot, dry summers and moderately cold, wetter winters. Annual precipitation is approximately 20 cm, and temperature extremes range from -40° C in January to 40° C in July.

Vegetation on the YTC was assessed in 1992, using the same study areas and survey methods that were used in 1991 (Eberhardt et al. 1991). Vegetation transects were established in 1991 on landscape areas that had been sprayed with herbicide (picloram) in 1988, 1989, and 1991 (Table 1 in Eberhardt et al. 1992). The area treated in 1987 was not sampled because it was remote from major sage grouse leks. Four control areas with similar elevation and plant community composition were selected adjacent to the areas treated with herbicide. As described in Eberhardt et al. (1992), the herbicide was applied by helicopter in late March or early April, soon after knapweeds began growth. The area treated in 1988 also received picloram in pellet form along roadside lanes.

## 2.1 Survey Methods

Transects, each 21 m long, were randomly located in each spray area (1988, 1989, 1991) and in each of the four control areas (NE control, NW control, S control, and SE control) as described by Eberhardt et al. (1992). The number of transects located in each area was proportional to the size of the area (Table 1 from Eberhardt et al. 1992) as estimated from geographic information system (GIS) boundary measurements.

Approximately 20% of the transects in each sampling unit were allocated to sites near roads because roadways are known sites of knapweed introduction and infestation. These transects were placed approximately 10 m from the roadway and ran parallel to the road. The other 80% of the transects, randomly located in each sampling unit, were run in a north-south direction where possible. Of the 135 marked transects established in 1991 (Figure 2.1), 120 transects were located and resampled in spring 1992 (Table 2.1). As in spring 1991, 20 microplots (0.2 x 0.5 m) were regularly spaced at 1-m intervals along each transect.

For each of the 20- x 50-cm microplots, a visual estimate of canopy cover (percent) was made and the number of rooted forbs and shrubs was counted (Daubenmire 1970). Although

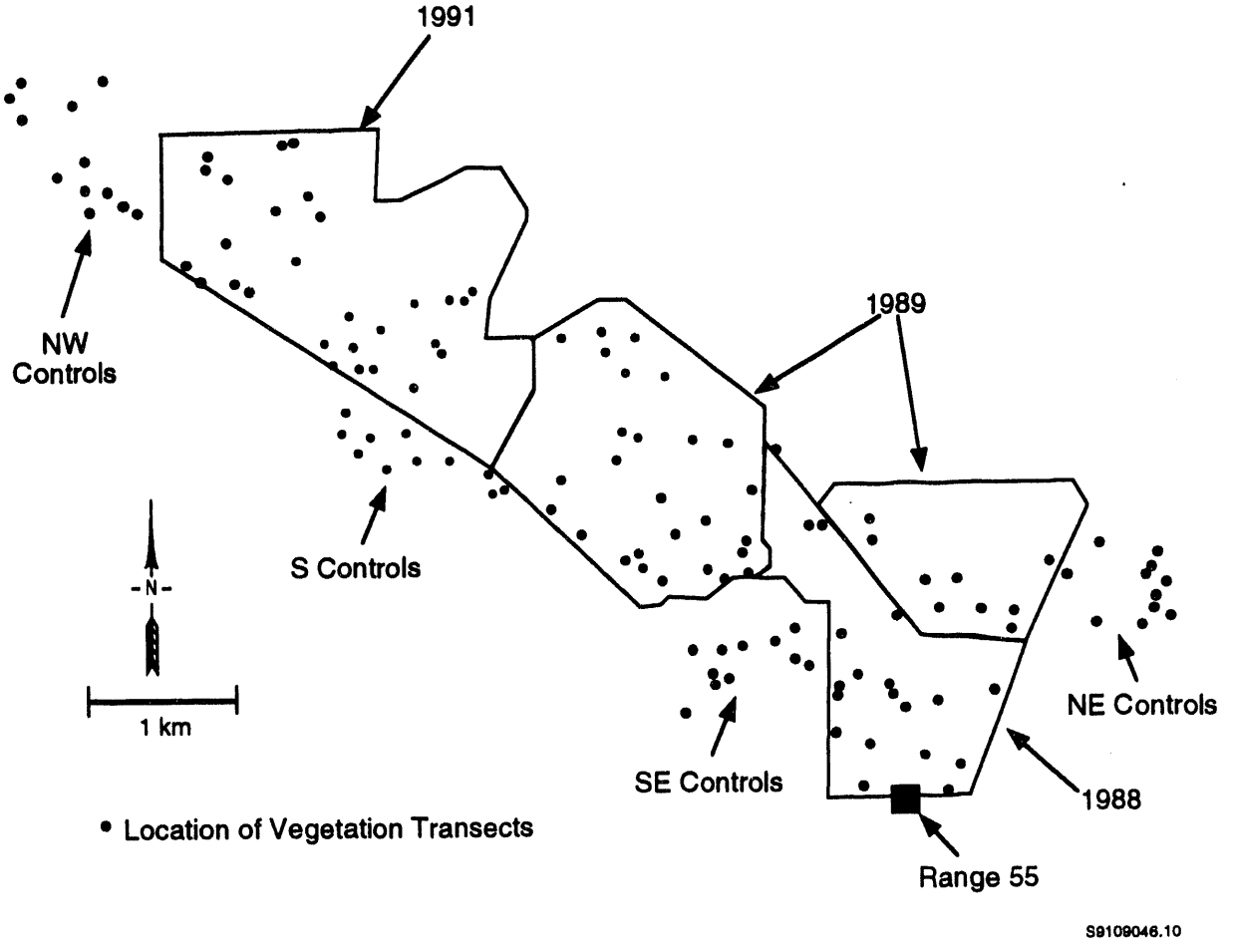


**Figure 2.1.** Location of Vegetation Transects on 1988, 1989, and 1991 Herbicide-Treated Areas

estimating percent plant canopy cover by species is time consuming, this method provides data that can be easily interpreted and readily compared with other data sets. Frequency of occurrence for each species was determined as the number of plots in which the species occurred divided by the number of plots in the total sample (frequency is usually reported as a percentage).

## 2.2 Data Analyses

All data were entered from the field data sheets into Microsoft Excel spreadsheets to summarize the data. Unpaired Student t-tests were used to test for significant differences in the composition of vegetation on herbicide-treated and control-untreated areas. A statistical information software package, RS/1 (Bolt, Beranek, and Newman) was used to compare the data. All percent plant cover data were transformed to approximate a normal distribution using the

**Table 2.1.** Allocation of Vegetation Sampling Transects to Areas Treated with Herbicide and Nearby Control Areas on the Yakima Training Center

| Treatment Area | Size of Area (ha) | Allocation of Transects: No. Near Roads | | No. Distant from Roads | | Total | |
|---|---|---|---|---|---|---|---|
| | | 1991 Survey | 1992 Survey | 1991 Survey | 1992 Survey | 1991 Survey | 1992 Survey |
| 1988 | 243 | 5 | 5 | 15 | 14 | 20 | 19 |
| 1989 | 492 | 8 | 6 | 31 | 28 | 39 | 34 |
| 1991 | 356 | 9 | 5 | 20 | 20 | 29 | 25 |
| NW control | | 3 | 2 | 9 | 8 | 12 | 10 |
| NE control | | 1 | 0 | 11 | 10 | 12 | 10 |
| S control | | 3 | 3 | 9 | 9 | 12 | 12 |
| SE control | | 0 | 0 | 11 | 10 | 11 | 10 |

transformation $\sqrt{Y+0.5}$. Although percent canopy cover data were recorded by species, the data were reduced by combining individual species into five general categories: perennial grasses, annual grasses, shrubs, annual and biennial forbs, and perennial forbs. Knapweed was considered a separate category for some analyses. Mean percent canopy cover of each of the five categories and knapweed were calculated for each transect. These data were combined to obtain mean percent canopy cover for the three treatment and four control areas. For these analyses, the transects represent subsampling within experimental units. That is, the true experimental replicates are the three treatment areas and the four control areas (Eberhardt and Thomas 1991). Extensive subsampling was necessary to obtain a more precise estimate of vegetation composition and cover.

Percent canopy cover data were also examined with respect to transect location and treatment. The percent canopy cover of knapweed on transects near roads versus transects distant from roads were compared using unpaired t-tests for treatment and control areas.

Survey data for 1991 were compared with survey data for 1992 using unpaired t-tests, and significance was determined at the 1% level. We wanted to evaluate the residual effects of the herbicide on plant cover and community composition between years, so the data were analyzed in the following manner. Because each spray and control area actually represent a

replicate, the 1991 and 1992 survey data for each of the herbicide-treated areas were compared by randomly splitting the transects in each replicate area for each survey year into two groups. For example, 1991 survey data for the 1988 spray area were split into two groups, and 1992 survey data for the 1988 spray area were split into two groups. The resulting four groups were used to generate mean values to compare percent canopy cover of 1991 survey data and 1992 survey data for the 1988 spray area. The level of significance was set at $p = 0.01$ to protect against committing a Type I error because we could not be absolutely sure that the variance obtained from split areas would represent true within-replicate variance. This method was used to compare percent canopy cover of knapweed, perennial forbs, and annual forbs in each of the herbicide-treated areas and the untreated areas for the two growing seasons.

# 3.0 Results and Discussion

Vegetation was surveyed on 120 of the 135 transects located on the YTC (Figure 2.1): 78 herbicide-treated transects (16 near roads and 62 distant from roads) and 42 control transects (5 near roads and 37 distant from roads). A number of posts marking the location of transects near roads had been removed since the previous year, and we were unable to relocate the remaining 15 plots.

More species were observed during the spring 1992 survey (83 plant species identified; Appendix A) than during the previous year (64 plant species identified), most likely because spring rains prolonged the growing season for some species. Mean percent canopy cover by category varied greatly from transect to transect (Appendix B). The disturbance history (e.g., mechanical disturbance or previously burned) at each transect site could account for some of this variability.

Perennial grasses accounted for the largest percentage of canopy cover on each of the treatment and control areas (Table 3.1) as was found in the 1991 knapweed survey. Comparison of canopy cover of perennial grasses on the YTC with measurements made by Daubenmire (1970, p. 91-92 as reported in Eberhardt et al. 1992, p. 10) and with measurements taken during 1992 on the Arid Lands Ecology (ALE) site (part of the U.S. Department of Energy's Hanford Site in south-eastern Washington) show that canopy cover of these grasses is lower on the YTC (Table 3.1). The data from the ALE site represent a native community that established after fires removed the shrub component. Higher percent canopy cover of annual grasses and annual forbs was measured on the YTC than in the relatively pristine stand on ALE and the pristine vegetation measured by Daubenmire (1970).

The frequent disturbances to which the landscape of the YTC is subjected (i.e., burning, mechanical disturbance from vehicles, and grazing) probably contribute to the lower perennial grass cover and the greater occurrence of invasive annual grasses and forbs. These invasive annuals are particularly competitive in mechanically disturbed areas such as along roadsides. The canopy cover of shrubs and perennial forbs on the YTC increased between 1991 and 1992. This increase may indicate a recovery of these vegetation types after disturbance, but the increase could also reflect the mild winter and moist spring growing conditions existing in 1992. Precipitation during the winter and early spring (November through March) usually infiltrates into the soil profile and may remain in the soil root zone for uptake by plants in the following growing season. Nearly twice as much precipitation fell in the winter period preceding the 1992 growing season (3.82 in.) as fell during the winter period preceding the 1991 growing season (2.04 in.).

The areas treated with picloram continued to show evidence of knapweed suppression. Percent canopy cover of knapweed and density (number per square meter of land area) of knapweed plants were higher on untreated control areas than on the herbicide-treated areas

($p = 0.06$ and $p = 0.13$, respectively; Table 3.2). The average density of knapweed plants $m^{-2}$ on the untreated control areas was twice that measured on the herbicide-treated areas. Percent canopy cover and density of perennial forbs were also statistically lower ($p = 0.008$ and $p = 0.05$, respectively) on the herbicide-treated plots than on the control areas. These data agree with 1991 survey data, indicating that perennial forb cover remains reduced on the herbicide-treated plots.

**Table 3.1.** Comparison of Percent Cover of Vegetation Found on the Knapweed Study Area in 1991 and 1992 with that Found by Daubenmire (1970) on Undisturbed Sites at Similar Elevations and to that Measured in 1992 on the Arid Lands Ecology Site in Benton County

| | Range in Percent Cover | | | |
|---|---|---|---|---|
| Vegetation Type | YTC 1991[a] | YTC 1992[a] | ALE 1992[b] | Daubenmire[c] |
| Perennial grasses | 29 - 52 | 31 - 50 | 69 | 77 - 122 |
| Annual grasses | 1 - 12 | 2 - 11 | 0.5 | <0.5 - 6 |
| Shrubs | 1 - 12 | 1 - 16 | 0 | 6 - 20 |
| Perennial forbs excluding knapweed | 1 - 7 | 1 - 12 | 10 | <0.5 - 2 |
| Annual forbs | <0.5 - 2 | 1 - 5 | 3.4 | <0.5 - 2 |

(a) Includes both treated and untreated areas.
(b) Data from undisturbed steppe on ALE where fire removed the shrub component.
(c) Data from stand numbers 10, 26, 27, 42, and 43 in Daubenmire (1970, pp. 91-93).

**Table 3.2.** Mean Percent Canopy Cover and Density[a] of Forbs on Herbicide-Treated[b] and Untreated Control Areas on the YTC Measured in Spring 1992

| | Treated | | Untreated | | % |
|---|---|---|---|---|---|
| Forbs | % Cover (n=3) | no. $m^{-2}$ | % Cover (n=4) | no. $m^{-2}$ | Difference in Cover |
| Shrubs | 4.8 | 1.3 | 6.5 | 2.5 | 1.7 |
| Annuals/biennials | 3.2 | 30.8 | 0.65 | 26.7 | 2.55 |
| All perennials | 4.7 | 28.7 | 12.8 | 64.8 | 8.10 |
| Knapweed | 1.7 | 23.7 | 5.6 | 52.2 | 3.9 |
| Perennial forbs excluding knapweed | 2.9 | 5.0 | 7.3 | 12.5 | 4.4 |

(a) Previous year's survey data (Eberhardt et al. 1992) were reported in terms of numbers of plants per 0.1 $m^2$ plot.
(b) Includes 1988, 1989, and 1991 herbicide-treated areas.

In 1992, canopy cover of knapweed was lowest (less than 1%) on the areas treated with herbicide in 1991 (Table 3.3). The percent cover of perennial forbs was also lowest in the 1991 spray area. The low values for knapweed on the 1991 spray area indicate that the application of picloram was effective in limiting growth of knapweed (Figure 3.1) in the first year following herbicide application. The 1988 herbicide-treated area also continued to exhibit lower values for canopy cover and density of knapweed than the 1989 treatment area. This may indicate that pelletized picloram applied along roadsides in 1988 was more effective in providing long-term control of knapweed. However, no information is available on canopy cover and density of knapweed on the 1988 treatment area before the herbicide was applied. The 1988 treatment area has higher percentages of shrubs, annual and biennial forbs, and annual grasses and could have had less knapweed than the other areas before spraying.

Analyses of the survey data indicate that the frequency and number of knapweed plants occurring along roadsides is greater than in areas distant from roadways (Table 3.4). Again, these data agree with 1991 survey data, indicating that the largest infestations of knapweed are near roads. Note that fewer roadside transects were relocated and measured in the 1992 spring survey (Table 2.1). Measuring fewer roadside plots may account for apparent decreases in the percent cover and number of *Lupinus*, *Astragalus*, and *Phlox* species between 1991 and 1992 because these species occurred infrequently along roadsides. Comparison of the mean percent cover of knapweed in control and treatment areas, near and distant from roads (Figure 3.1), indicates that the decreases in knapweed after herbicide application are statistically significant ($p < 0.05$) in areas away from roads. Canopy cover of knapweed was reduced by 57% in near-road transects and by 70% in transects distant from roads. These areas are not subject to as much continual disturbance from traffic and training activities as those areas alongside roadways. Areas with continued disturbance may be more readily invaded by knapweed. Areas where the native vegetation has not been disturbed are less likely to be invaded by knapweed (Borman, Krueger, and Johnson 1991).

Comparison of 1991 with 1992 survey results indicates that percent cover of knapweed on the 1988 herbicide-treated plot increased (Figure 3.2). However, the increase in 1989 was statistically significant at the 1% level. On the 1991 herbicide-treated plots, percent cover of knapweed decreased significantly ($p=0.01$) between 1991 and 1992 surveys. The decrease between 1991 and 1992 surveys may be explained in part by the short time period between herbicide application in the spring of 1991 and the 1991 survey of the area. Eberhardt et al. (1992) stated that 76% of the knapweed plants counted on the 1991 herbicide-treated area showed signs of stress--senescence or dying leaves.

Perennial forbs on the 1991 herbicide-treated plots also decreased significantly (Figure 3.3) between the 1991 and 1992 surveys. This decrease also appears to be a continued response to the spring 1991 application of herbicide.

Increases in canopy cover of perennial forbs on the 1988 and 1989 herbicide-treated plots between the 1991 and 1992 surveys were not statistically significant; however, percent canopy

**Table 3.3.** Mean Percent Canopy Cover by Category (± one standard error) Measured in Spring 1992 on Herbicide-Treated and Untreated Control Areas on the Yakima Training Center

| | Herbicide Treated | | | Untreated Control | | | |
|---|---|---|---|---|---|---|---|
| Plant Category | 1988 | 1989 | 1991 | NE | NW | S | SE |
| Perennial grass | 31.2±3.6 | 49.4±2.7 | 49.2±3.7 | 48.0±4.3 | 37.8±4.3 | 40.3±3.2 | 36.6±3.6 |
| Annual grass | 10.8±3.1 | 6.3±2.2 | 6.3±1.6 | 1.6±0.5 | 11.1±4.6 | 3.0±0.8 | 1.5±0.7 |
| Shrubs | 10.1±1.9 | 3.2±1.0 | 1.1±0.3 | 2.5±1.1 | 0.97±0.5 | 7.2±1.5 | 15.5±3.1 |
| Annual/biennial forb | 4.9±1.3 | 3.0±0.6 | 1.7±0.9 | 3.7±1.0 | 2.8±0.6 | 1.2±0.3 | 0.68±0.6 |
| Perennial forb | 4.97±1.3 | 7.5±1.4 | 1.6±0.4 | 16.6±3.4 | 12.1±1.9 | 9.2±1.4 | 13.3±2.5 |
| Knapweed | 1.73±0.9 | 2.79±0.8 | 0.82±0.3 | 8.32±2.5 | 8.76±1.8 | 3.8±1.1 | 1.34±0.9 |
| Perennial forb excluding knapweed | 3.3 | 4.7 | 0.8 | 8.3 | 3.3 | 5.4 | 12.0 |
| Total canopy cover | 63.7 | 72.3 | 60.8 | 80.7 | 73.5 | 64.7 | 69.0 |
| Total herbaceous cover | 53.6 | 69.1 | 59.7 | 78.2 | 72.5 | 57.5 | 53.5 |
| Vegetation Categories as Percentage of Total Herbaceous Cover (excluding shrubs) | | | | | | | |
| Perennial grass | 58.3 | 71.6 | 82.5 | 61.4 | 52.1 | 70.2 | 68.5 |
| Annual grass | 20.1 | 9.2 | 10.5 | 2.0 | 15.3 | 5.2 | 2.7 |
| Annual/biennial forb | 9.1 | 4.3 | 2.9 | 4.7 | 3.9 | 2.1 | 1.3 |
| Perennial forb | 9.3 | 10.9 | 2.7 | 21.3 | 16.7 | 16.0 | 24.9 |
| Knapweed | 3.2 | 4.1 | 1.4 | 10.6 | 12.1 | 6.6 | 2.5 |

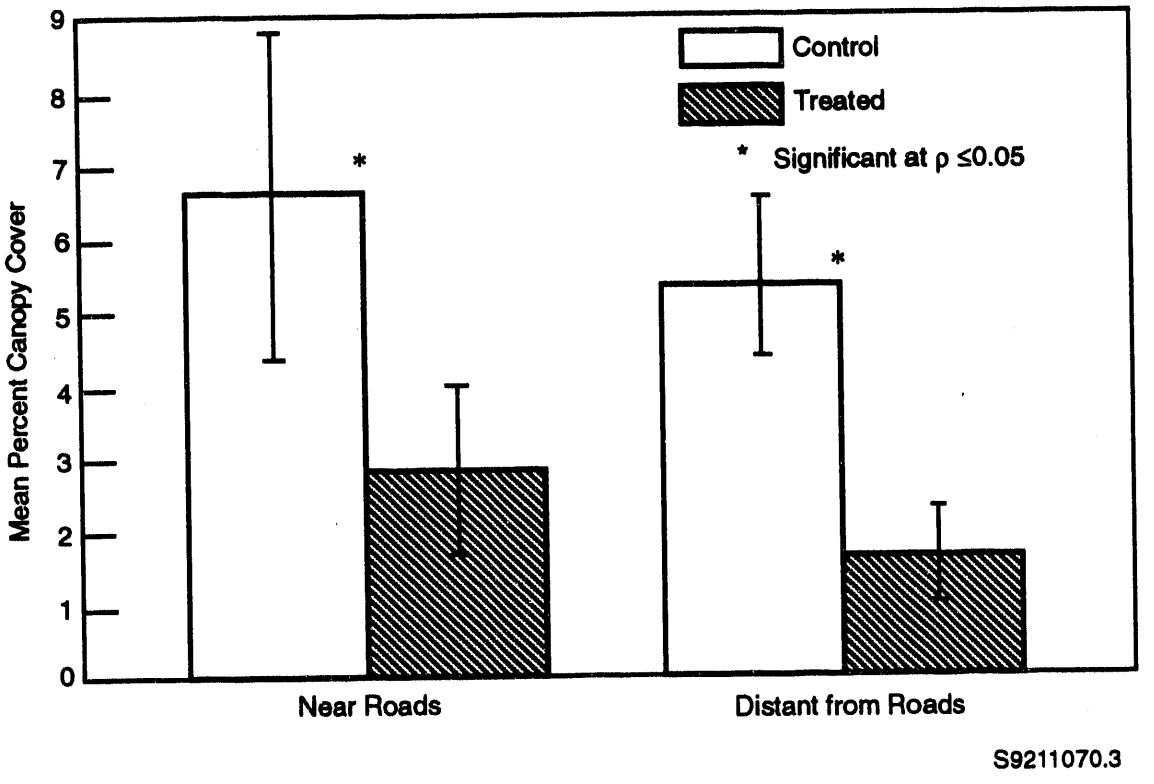


**Figure 3.1.** Mean Percent Cover of Knapweed on Transects <10 m from Roads and on Transects >10 m from Roads for Treated and Untreated Areas (Error bars are ±1 standard error of the mean)

cover of perennial forbs did increase significantly on the control areas. Increases in perennial forbs in control areas are likely a result of optimum spring growing conditions in 1992. Additional surveys would be needed to assess the potential for perennial forbs on treated areas to recover to levels similar to those found on control areas.

Increased canopy cover of annual and biennial forbs from 1991 to 1992 (Figure 3.4) was statistically significant for the 1989 herbicide-treated area. However, the mean values for percent canopy cover of annual and biennial forbs in the 1988 and 1989 treatment plots are much higher than those for 1991 treatment plots and control areas. Decreases in the number and percent cover of perennial forbs, including knapweed on the treatment areas, compared to control areas could contribute to the increases in annual and biennial forbs on the treatment areas. Many of the annual forbs counted during the survey are non-native competitive Eurasian plants. These plants readily move into disturbed areas, the same types of areas invaded and occupied by knapweed.

**Table 3.4.** Frequency of Knapweed and Three Perennial Forb Species at Plots Near Roads and Plots Distant from Roads

| | Near Road Plots | | | | Distant Plots | | | |
|---|---|---|---|---|---|---|---|---|
| | Treated Averages | | Control Averages | | Treated Averages | | Control Averages | |
| | 1991 Data | 1992 Data | 1991 Data | 1992 Data | 1991 Data | 1992 Data | 1991 Data | 1992 Data |
| Frequency (%) | | | | | | | | |
| Knapweed | 26.59 | 35.39 | 52.86 | 74.00 | 12.58 | 22.66 | 36.75 | 50.14 |
| *Astragalus* spp. | 2.50 | 0 | 6.42 | 12.00 | 5.08 | 6.21 | 8.25 | 15.27 |
| *Lupinus* spp. | 0.90 | 0.88 | 7.14 | 6.00 | 2.12 | 2.82 | 5.62 | 6.89 |
| *Phlox longifolia* | 7.04 | 3.53 | 29.29 | 44.00 | 12.42 | 16.29 | 23.62 | 34.60 |
| Average Number of Plants | | | | | | | | |
| Knapweed | 13.68 | 71.00 | 40.57 | 165.00 | 3.60 | 35.84 | 17.60 | 100.46 |
| *Astragalus* spp. | 0.18 | 0 | 1.14 | 2.40 | 0.61 | 0.72 | 0.74 | 1.94 |
| *Lupinus* spp. | 0.18 | 0.12 | 1.28 | 1.40 | 0.38 | 0.47 | 0.87 | 1.35 |
| *Phlox longifolia* | 1.73 | 0.59 | 8.71 | 13.80 | 2.82 | 4.64 | 4.03 | 11.89 |
| % Cover | | | | | | | | |
| Knapweed | 2.92 | 2.85 | 9.11 | 6.63 | 1.02 | 1.62 | 4.44 | 5.31 |
| *Astragalus* spp. | 0.12 | 0 | 0.66 | 1.84 | 0.48 | 1.11 | 0.94 | 2.83 |
| *Lupinus* spp. | 0.05 | 0.07 | 0.90 | 0.60 | 0.19 | 0.33 | 0.57 | 0.93 |
| *Phlox longifolia* | 0.36 | 0.16 | 2.43 | 3.14 | 0.63 | 1.02 | 1.47 | 2.06 |

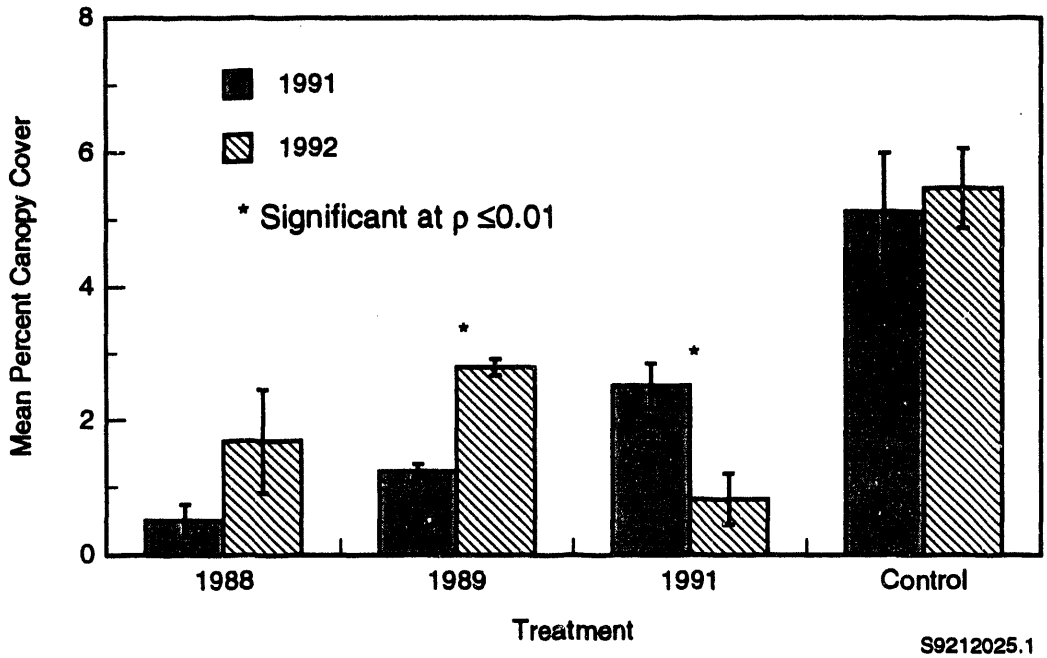


**Figure 3.2.** Mean Percent Canopy Cover of Knapweed in 1991 and 1992 for the 1988, 1989, and 1991 Treatment and Control Areas (Error bars are ±1 standard error of the mean.)

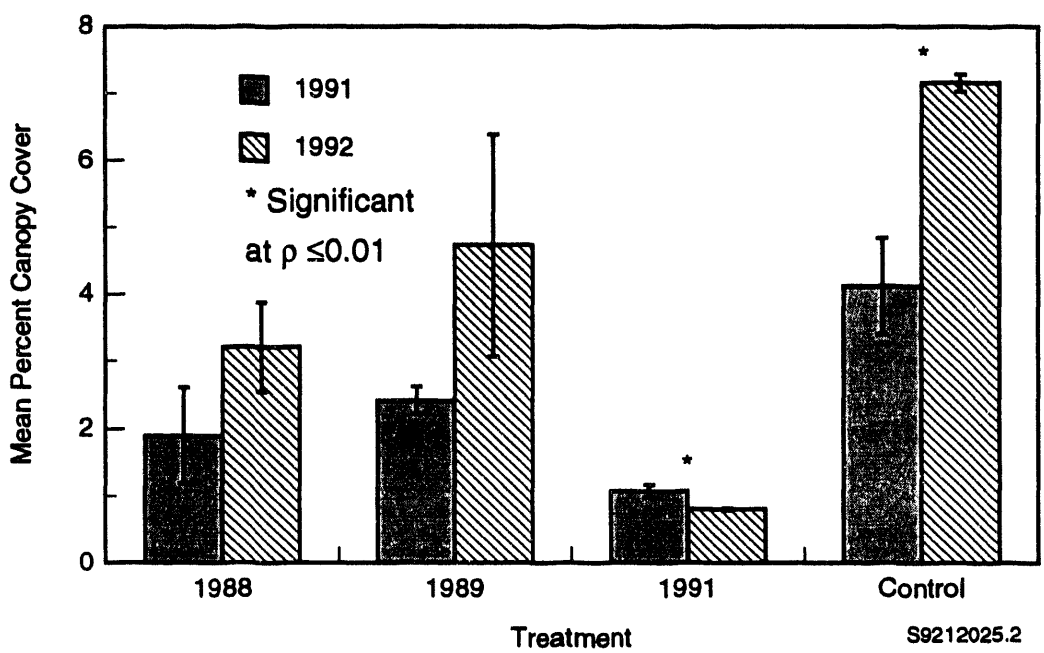


**Figure 3.3.** Mean Percent Canopy Cover of Perennial Forbs in 1991 and 1992 for 1988, 1989, and 1991 Treatment and Control Areas (Error bars are ±1 standard error of the mean.)

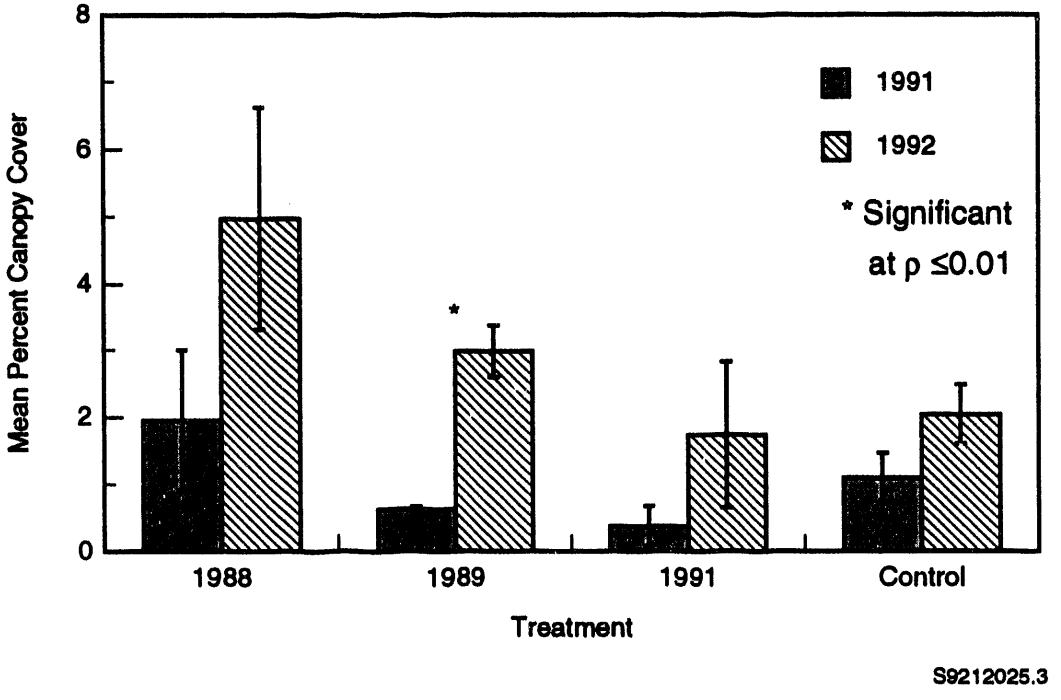


**Figure 3.4.** Mean Percent Canopy Cover of Annual and Biennial Forbs Measured in 1991 and 1992 for the 1988, 1989, and 1991 Treatment and Control Areas (Error bars are ±1 standard error of the mean.)

# 4.0 Conclusions

Herbicide treatment significantly reduced density and percent cover of knapweed (compared to control areas) measured during the 1992 survey on the 1988, 1989, and 1991 treatment areas. Applying herbicide was more effective in limiting the growth of knapweed in areas distant from roads than in areas less than 10 m from roadways. Comparisons of 1992 survey data with 1991 data suggest substantial recovery of knapweed in the 1989 treatment area. Knapweed increases in the 1988 herbicide-treated area were not significant because of highly variable percent cover, which may be a result of applying picloram in pelletized form along roadways. However, the number of transects remaining along roadways in all treatment areas is insufficient to statistically determine whether pelletized picloram used in the 1988 treatments was more effective than spraying for long-term control of knapweed along roadways.

Both knapweed and other perennial forbs were significantly decreased by herbicide application in the 1991 treatment area. Although percent cover of perennial forbs increased between 1991 and 1992 on the 1988 and 1989 treatment areas and on the control areas, only the increase on control areas was statistically significant. Percent canopy cover of annual and biennial forbs measured in 1992 was higher in all treatment and control areas compared to 1991 measurements. However, only the increase on the 1989 treatment area was statistically significant.

Suggestions for further investigations include continuing the survey for an additional growing season to determine 1) whether knapweed increases to its previous abundance in the 1991 herbicide-treated area, 2) the relative effectiveness of spraying versus pellet application along roadways, and 3) the impacts of herbicide treatment on long-term community vegetation structure as it relates to sage grouse habitat requirements.

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# Appendix A

## Summary of Plant Species Observed on the Yakima Training Center Knapweed Study Area

**Table A.1.** A Summary of Plant Species Observed on the Yakima Training Center Knapweed Study Area

**Perennial Graminoids**

*Agropyron cristatum*
*Agropyron (desertorum/cristatum)*
*Agropyron spicatum*
*Distichlis spicata*
*Koeleria cristata*
*Oryzopsis hymenoides*
*Poa cusickii*
*Poa sandbergii (secunda)*
*Sitanion hystrix*
*Stipa comata*
*Stipa thurberiana*
*Elymus* sp.
*Carex* spp.
*Juncus* sp.

**Annual Grasses**

*Bromus tectorum*
*Festuca (Vulpia) octoflora*
*Festuca (Vulpia) microstachys*

**Shrubs**

*Artemisia rigida*
*Artemisia tridentata*
*Chrysothamnus nauseosus*
*Chrysothamnus viscidiflorus*
*Eriogonum microthecum*
*Tetradymia canescens*

**Annual and Biennial Forbs**

*Agoseris* sp.
*Amsinckia* spp.
*Bassia* sp.
*Crisium* spp.
*Collinsia parviflora*
*Crypahtantha pterocarya*
*Descurainia pinnata*
*Descurainia sophia*
*Draba verna*
*Epilobium paniculatum*
*Erodium cicutarium*
*Holosteum umbellatum*
*Kochia* spp.
*Lactuca serriola*
*Lappula redowskii*
*Lepidium perfoliatum*
*Microsteris gracilis*
*Phacelia liniaris*
*Plantago* spp. *patogonica*
*Ranunculus testiculatus*
*Salsola kali*
*Sisymbrium altissimum*
*Tragopogon dubius*

**Perennial Forbs**

*Achillea millefolium*
*Allium* spp.
*Antennaria dimorpha*
*Arenaria franklinii*
*Arenaria* sp.
*Astragalus purshii*
*Astragalus speirocarpus*
*Astragalus* spp.
*Balsamorhiza hookeri*
*Brodiaea douglasii*
*Calochortus macrocarpus*
*Centaurea* spp.
*Chaenactis douglasii*
*Crepis atrabarba*
*Cymopterus terebinthinus*
*Erigeron filifolius*
*Erigeron linearis*
*Erigeron* spp.
*Eriogonum* spp.
*Eriophyllum* sp.
*Haplopappus stenophyllus*
*Iris missouriensis*
*Lithospermum ruderale*
*Lomatium grayi*
*Lomatium triternatum*
*Lomatium* spp.
*Lupinus* spp.
*Machaeranthera canescens*
*Phacelia hastata*
*Phlox hoodii*
*Phlox longifolia*
*Potentilla* sp.
*Ranunculus* spp.
*Taraxacum officinale*
*Trifolium* spp.
*Veronica* sp.
*Zigadenus* sp.

# Appendix B

## Average Percent Plant Cover for 20-m Transects Located in Herbicide-Treated and Untreated (Control) Areas on the Yakima Training Center, 1992 Data

## Table B.1. Average Percent Plant Cover for 20-M Transects Located in Herbicide-Treated and Untreated (Control) Areas on the Yakima Training Center, 1992 Data

| 1989 TREATMENT TRANSECT NUMBER | 1RD | 2RD | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10RD | 11 | 12RD | 13RD | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 34.15 | 37.8 | 45.65 | 49.25 | 57.3 | 33.6 | 27.2 | 11.2 | 18.75 | 11.9 | 4.5 | 16.9 | 24.5 | 27.45 | 42.4 | 23.4 | 23.1 | 58.3 | 45.75 | no data |
| ANNUAL GRASSES | 6.95 | 8.05 | 0.1 | 0.3 | 0.9 | 6.15 | 4.05 | 4.8 | 0.85 | 40.9 | 0 | 34.75 | 13.05 | 27.5 | 2.3 | 14.4 | 1.3 | 36.6 | 1.7 | no data |
| SHRUBS | 7.75 | 5.8 | 6.75 | 4.5 | 11.75 | 10.65 | 21 | 23.45 | 17.15 | 17.75 | 0 | 7.15 | 10.5 | 6.55 | 5.4 | 6 | 29.5 | 0 | 0 | no data |
| ANNUAL&BIENNIAL FORBS | 2.5 | 4.25 | 2.55 | 0.05 | 2.35 | 1.25 | 3.7 | 0.45 | 2.35 | 11.3 | 8.15 | 20.3 | 9.6 | 14.3 | 1.1 | 3.9 | 0.25 | 3.8 | 0.6 | no data |
| PERENNIAL FORBS | 0 | 0.15 | 1.55 | 10.85 | 6 | 7.7 | 13.25 | 0.15 | 0 | 0.6 | 11.65 | 1 | 3.05 | 10.05 | 11 | 0.5 | 1.15 | 0.2 | 15.7 | no data |
| KNAPWEED | 0 | 0.15 | 0 | 0 | 0 | 0.1 | 0 | 0.1 | 0 | 0.6 | 0 | 1 | 2.05 | 6.1 | 6.9 | 0 | 0 | 0.2 | 15.65 | no data |
| PER FORB KWEED | 0 | 0 | 1.55 | 10.85 | 6 | 7.6 | 13.25 | 0.05 | 0 | 0 | 11.65 | 0 | 1 | 3.95 | 4.1 | 0.5 | 1.15 | 0 | 0.05 | no data |

| 1989 TREATMENT TRANSECT NUMBER | 1RD | 2RD | 3RD | 4 | 5 | 6RD | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 43.85 | 13 | 29.35 | no data | 61.7 | 76 | 47 | 57.5 | 24.8 | 61.25 | 71.25 | 31.15 | 56.9 | 61 | 55.6 | 57.55 | 38.4 | 59.85 | no data | 64.45 |
| ANNUAL GRASSES | 1.75 | 66 | 21.5 | no data | 0 | 0 | 0.05 | 0.1 | 0.4 | 0.05 | 0.45 | 6.7 | 0.5 | 10.5 | 1 | 0.2 | 18.35 | 2.25 | no data | 9.85 |
| SHRUBS | 2 | 0.15 | 3.85 | no data | 0.35 | 0 | 3.5 | 0 | 0.25 | 0.25 | 0 | 0.75 | 0 | 0 | 2.8 | 13.5 | 2 | 5.15 | no data | 0 |
| ANNUAL&BIENNIAL FORBS | 5.55 | 4.4 | 4.15 | no data | 0.35 | 0.45 | 0.1 | 0.65 | 0.7 | 4.95 | 7.7 | 1.85 | 0.35 | 6.7 | 2.05 | 2.55 | 1.5 | 1.1 | no data | 0.8 |
| PERENNIAL FORBS | 1.45 | 17.45 | 11 | no data | 19.2 | 1.45 | 5.35 | 0.05 | 8.15 | 0.3 | 1.5 | 17.4 | 2.4 | 1.7 | 3.65 | 0.4 | 0.6 | 4.8 | no data | 6.05 |
| KNAPWEED | 1.45 | 17.45 | 11 | no data | 0.55 | 0.2 | 0.1 | 0.05 | 0 | 0 | 0.25 | 0.75 | 0.15 | 0.7 | 0 | 0 | 0.5 | 0 | no data | 2.95 |
| PER FORB KWEED | 0 | 0 | 0 | no data | 18.65 | 1.25 | 5.25 | 0 | 8.15 | 0.3 | 1.25 | 16.65 | 2.25 | 1 | 3.65 | 0.4 | 0.1 | 4.8 | no data | 3.1 |

| 1989 TREATMENT( Cont'd) TRANSECT NUMBER | 21 | 22 | 23 | 24RD | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33RD | 34 | 35 | 36 | 37RD | 38RD | 39 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 50.25 | 55.6 | 80 | no data | 43.2 | 26.65 | 51.7 | 32.95 | 34.3 | 53.25 | no data | 76.75 | 50.1 | 53.1 | 35.6 | 32.75 | 42.5 | no data | 51.7 |
| ANNUAL GRASSES | 4.55 | 5.7 | 0 | no data | 2.4 | 0.05 | 0.25 | 0 | 0.2 | 0.15 | no data | 0.45 | 6.55 | 7.55 | 8.2 | 3.1 | 29.75 | no data | 6.9 |
| SHRUBS | 0 | 0.35 | 6 | no data | 2.25 | 30.25 | 0 | 1.5 | 1.55 | 0 | no data | 0 | 3.05 | 0 | 6 | 0.1 | 7.55 | no data | 16 |
| ANNUAL&BIENNIAL FORBS | 1.75 | 8.1 | 0.2 | no data | 0.75 | 0.2 | 13 | 5.95 | 0.35 | 0.4 | no data | 0.95 | 6.1 | 1.85 | 13.1 | 0.45 | 1.65 | no data | 0.75 |
| PERENNIAL FORBS | 11.75 | 6.35 | 0.1 | no data | 21.8 | 11.6 | 6.05 | 15.55 | 26.55 | 6.85 | no data | 0.75 | 4.05 | 0.9 | 4.3 | 29.85 | 4.9 | no data | 1.75 |
| KNAPWEED | 11.75 | 5.15 | 0.05 | no data | 2.15 | 0 | 4.2 | 12 | 4.2 | 1.55 | no data | 0.3 | 3.9 | 0.9 | 0.9 | 10.3 | 1.2 | no data | 0.5 |
| PER FORB KWEED | 0 | 1.2 | 0.05 | no data | 19.65 | 11.6 | 1.85 | 3.55 | 22.35 | 5.3 | no data | 0.45 | 0.15 | 0 | 3.4 | 19.55 | 3.7 | no data | 1.25 |

| 1991 TREATMENT TRANSECT NUMBER | 1 | 2RD | 3RD | 4RD | 5 | 6 | 7 | 8RD | 9RD | 10RD | 11 | 12 | 13 | 14RD | 15RD | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 49.65 | no data | 32.85 | no data | 67 | 78.1 | 56.75 | 74.15 | 67.7 | 17.9 | 48.4 | 44.9 | 31.6 | 21.6 | 17.2 | 37 | 35.8 | 45.5 | 32.9 | 61.6 |
| ANNUAL GRASSES | 3.65 | no data | 23.1 | no data | 0 | 0.05 | 0 | 0.5 | 1.6 | 5.65 | 4.7 | 20.65 | 8.7 | 5 | 33.15 | 2.35 | 5.3 | 2.95 | 4.95 | 6.95 |
| SHRUBS | 1.25 | no data | 0 | no data | 0 | 0 | 4 | 1 | 0 | 6 | 0 | 1.95 | 0 | 2.3 | 3.9 | 0 | 0 | 1 | 0 | 0 |
| ANNUAL&BIENNIAL FORBS | 0.35 | no data | 23.6 | no data | 0.05 | 0.1 | 0 | 0.2 | 0.8 | 4.1 | 1.65 | 1.25 | 0 | 0.85 | 2.25 | 2.1 | 1.65 | 0.2 | 0.05 | 1.45 |
| PERENNIAL FORBS | 0.1 | no data | 6.85 | no data | 0 | 0.15 | 0.95 | 0 | 0 | 0.1 | 0 | 0 | 1.8 | 3.25 | 1.1 | 1.9 | 3.95 | 0 | 0 | 0.8 |
| KNAPWEED | 0 | no data | 6.85 | no data | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.45 | 1.9 | 0.7 | 1.6 | 2.45 | 0 | 0 | 0.75 |
| PER FORB KWEED | 0.1 | no data | 0 | no data | 0 | 0.15 | 0.95 | 0 | 0 | 0.1 | 0 | 0 | 1.35 | 1.35 | 0.4 | 0.3 | 1.5 | 0 | 0 | 0.05 |

| 1991 TREATMENT (Cont'd) TRANSECT NUMBER | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29RD |
|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 42.15 | 35.45 | 50 | 55.3 | 74 | 54.75 | 55.65 | 91 | no data |
| ANNUAL GRASSES | 10.35 | 13.1 | 3.3 | 4.7 | 2.9 | 0 | 0 | 0 | no data |
| SHRUBS | 0 | 1.25 | 0 | 5.35 | 1.5 | 0 | 0 | 0 | no data |
| ANNUAL&BIENNIAL FORBS | 0.6 | 1.15 | 0.2 | 1.65 | 0.1 | 0.1 | 0.7 | 0 | no data |
| PERENNIAL FORBS | 0.95 | 0 | 0.5 | 2.35 | 0.15 | 7.2 | 6.85 | 3.25 | no data |
| KNAPWEED | 0.3 | 0 | 0 | 2.05 | 0 | 2.4 | 1.8 | 0 | no data |
| PER FORB KWEED | 0.65 | 0 | 0.5 | 0.3 | 0.15 | 4.8 | 5.05 | 3.25 | no data |

## Table B.1. (continued)

| NW CONTROL<br>TRANSECT NUMBER | 1RD | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11RD | 12RD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 42.15 | 33.3 | 37.55 | no data | 33.95 | 23.8 | 23.1 | 52.65 | 55.8 | 56.1 | 19.6 | no data |
| ANNUAL GRASSES | 4.1 | 3.3 | 2.2 | no data | 14.65 | 15.05 | 26.45 | 0.85 | 0 | 0 | 44 | no data |
| SHRUBS | 4.5 | 0.6 | 0 | no data | 0 | 1.25 | 2.85 | 0 | 0 | 0 | 0.5 | no data |
| ANNUAL&BIENNIAL FORBS | 0.65 | 6.3 | 3.65 | no data | 2.25 | 2.2 | 2.65 | 1.2 | 0.9 | 2.35 | 6.05 | no data |
| PERENNIAL FORBS | 14.6 | 13.05 | 6.55 | no data | 12 | 19.85 | 23.1 | 5.75 | 7.15 | 6 | 12.75 | no data |
| KNAPWEED | 8.7 | 9.9 | 4.45 | no data | 12 | 8.8 | 22.2 | 3.7 | 4.05 | 4.65 | 9.1 | no data |
| PER FORB KWEED | 5.9 | 3.15 | 2.1 | no data | 0 | 11.05 | 0.9 | 2.05 | 3.1 | 1.35 | 3.65 | no data |

| NE CONTROL<br>TRANSECT NUMBER | 1 | 2RD | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | no data | no data | 45.65 | 46.3 | 59.95 | 42.65 | 71.8 | 59.5 | 27.1 | 35.5 | 54.8 | 36.9 |
| ANNUAL GRASSES | no data | no data | 4.95 | 1.3 | 0.1 | 0.55 | 0.85 | 1.15 | 0.9 | 2.8 | 0.2 | 2.7 |
| SHRUBS | no data | no data | 0 | 5.65 | 0.45 | 9.35 | 0 | 2.8 | 6.9 | 0 | 0.15 | 0 |
| ANNUAL&BIENNIAL FORBS | no data | no data | 1.55 | 6 | 8.45 | 0.45 | 2.85 | 8.8 | 0.7 | 0.7 | 3.4 | 3.75 |
| PERENNIAL FORBS | no data | no data | 6.25 | 3.75 | 31.95 | 25.7 | 18.6 | 12.85 | 2.7 | 15.75 | 16.4 | 32.45 |
| KNAPWEED | no data | no data | 5.7 | 3.2 | 12.3 | 6.1 | 3.65 | 5.35 | 0.25 | 5.7 | 13.45 | 27.45 |
| PER FORB-KWEED | no data | no data | 0.55 | 0.55 | 19.65 | 19.6 | 14.95 | 7.5 | 2.45 | 10.05 | 2.95 | 5 |

| SE CONTROL<br>TRANSECT NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 49.65 | 25.85 | 34.9 | 33.75 | 32.3 | 31.6 | 25.75 | 26.7 | 58.4 | 47.25 | no data |
| ANNUAL GRASSES | 0.15 | 0.1 | 2.6 | 0.6 | 0.35 | 0.65 | 3.2 | 7.35 | 0.05 | 0 | no data |
| SHRUBS | 17.25 | 15.75 | 24.35 | 15.95 | 32.25 | 25.15 | 11.2 | 8.25 | 2.5 | 2.4 | no data |
| ANNUAL&BIENNIAL FORBS | 0 | 0.05 | 0.1 | 0.25 | 0.2 | 0.1 | 0.3 | 5.75 | 0.05 | 0 | no data |
| PERENNIAL FORBS | 9.75 | 5.4 | 9.25 | 9.6 | 10.6 | 4.65 | 29.6 | 22.25 | 16.7 | 15.3 | no data |
| KNAPWEED | 0 | 0.35 | 0 | 0.1 | 0 | 0.05 | 3.45 | 8.6 | 0.05 | 0.8 | no data |
| PER FORB-KWEED | 9.75 | 5.05 | 9.25 | 9.5 | 10.6 | 4.6 | 26.15 | 13.65 | 16.65 | 14.5 | no data |

| S CONTROL<br>TRANSECT NUMBER | 1 | 2 | 3 | 4 | 5 | 6RD | 7 | 8 | 9 | 10 | 11RD | 12RD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERENNIAL GRASSES | 32 | 25 | 24.65 | 34.25 | 47.7 | 49.55 | 64.4 | 35.25 | 40.55 | 46.75 | 40.35 | 43.55 |
| ANNUAL GRASSES | 1.15 | 0.95 | 1.2 | 0.6 | 0.25 | 7.15 | 9.65 | 1.95 | 4 | 2.45 | 3.95 | 2.75 |
| SHRUBS | 0 | 8.6 | 4.15 | 2.65 | 7.3 | 11.05 | 8.3 | 11.5 | 6.55 | 18.9 | 2.85 | 4.4 |
| ANNUAL&BIENNIAL FORBS | 0.5 | 1.75 | 0.55 | 0 | 0.25 | 0.5 | 1.9 | 1.75 | 1 | 0.25 | 1.75 | 3.95 |
| PERENNIAL FORBS | 15.45 | 12.25 | 6.75 | 14.15 | 4.85 | 11.6 | 4.4 | 3.75 | 6 | 2.55 | 13.4 | 15 |
| KNAPWEED | 8.1 | 6.45 | 6.65 | 2.6 | 4.8 | 0.15 | 0 | 0.3 | 1.35 | 0 | 12.35 | 2.85 |
| PER FORB-KWEED | 7.35 | 5.8 | 0.1 | 11.55 | 0.05 | 11.45 | 4.4 | 3.45 | 4.65 | 2.55 | 1.05 | 12.15 |

| ALE CONTROL<br>TRANSECT NUMBER | 1 | 2 | 3 |
|---|---|---|---|
| PERENNIAL GRASSES | 85.25 | 75.75 | 45.8 |
| ANNUAL GRASSES | 0.8 | 0.5 | 0.1 |
| SHRUBS | 0 | 0 | 0 |
| ANNUAL&BIENNIAL FORBS | 6.85 | 2.7 | 0.6 |
| PERENNIAL FORBS | 9.65 | 8.5 | 10.25 |
| KNAPWEED | 0 | 0 | 0 |
| PER FORB-KWEED | 9.65 | 8.5 | 10.25 |

# Appendix C

## Average Number of Shrubs and Forbs per Microplot for Transects Located in Herbicide-Treated Areas and Untreated (Control) Areas on the Yakima Training Center, 1992 Data

Table C.1. Average Number of Shrubs and Forbs per Microplot for Transects Located in Herbicide-Treated and Untreated (Control) Areas on the Yakima Training Center, 1992 Data

| 1988 TREATMENT TRANSECT NO. | 1RD | 2RD | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10RD | 11 | 12RD | 13RD | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0 | 0.1 | 0.15 | 0.15 | 0.15 | 0.2 | 0.95 | 0.6 | 0.35 | 1.65 | 0.00 | 0.05 | 0.2 | 0.15 | 0.2 | 0.05 | 0.5 | 0 | 0 | no data |
| ANNUAL&BIENNIAL FORBS | 4.5 | 11.15 | 5.6 | 0.05 | 6.2 | 2.85 | 5.25 | 0.65 | 6.55 | 5.6 | 1.75 | 17.15 | 9.35 | 16.7 | 1.4 | 7.6 | 0.3 | 1.25 | 0.55 | no data |
| PERENNIAL FORBS | 0 | 0.3 | 0.2 | 0.95 | 0.7 | 2 | 3.95 | 0.2 | 0 | 0.1 | 6.35 | 4.6 | 11.2 | 39.7 | 9.55 | 0 | 0.25 | 0.2 | 1.95 | no data |
| KNAPWEED | 0 | 0.3 | 0 | 0 | 0 | 0.2 | 0 | 0.15 | 0 | 0.1 | 0.00 | 4.6 | 11.1 | 37.65 | 9.25 | 0 | 0 | 0.2 | 1.9 | no data |

| 1989 TREATMENT TRANSECT NO. | 1RD | 2RD | 3RD | 4 | 5 | 6RD | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0 | 0.05 | 0.35 | no data | 0 | 0 | 0.05 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0.15 | 0.35 | 0.05 | 0.25 | no data | 0 |
| ANNUAL&BIENNIAL FORBS | 2.8 | 1.85 | 7.7 | no data | 0.5 | 0.7 | 0.1 | 0.4 | 1.65 | 1.2 | 6.9 | 1 | 0.45 | 2.55 | 2.3 | 2.5 | 0.65 | 1.45 | no data | 1.1 |
| PERENNIAL FORBS | 1.5 | 5.2 | 14.75 | no data | 3.85 | 0.3 | 0.45 | 0.05 | 1.1 | 0.1 | 0.55 | 0.55 | 0.4 | 1.5 | 0.4 | 0.85 | 0.15 | 0.6 | no data | 6.6 |
| KNAPWEED | 1.5 | 5.2 | 14.75 | no data | 1.65 | 0.2 | 0 | 0.05 | 0 | 0 | 0.5 | 0.1 | 0.05 | 1.4 | 0 | 0 | 0.1 | 0 | no data | 6.3 |

| 1989 TREATMENT (Cont'd) TRANSECT NO. | 21 | 22 | 23 | 24RD | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33RD | 34 | 35 | 36 | 37RD | 38RD | 39 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0 | 0 | 0.15 | no data | 0.15 | 0.45 | 0 | 0 | 0.1 | 0 | no data | 0 | 0.05 | 0 | 0.1 | 0.1 | 0.15 | no data | 0.5 |
| ANNUAL&BIENNIAL FORBS | 0.5 | 2.85 | 0.25 | no data | 1.15 | 0.2 | 9.8 | 0.95 | 0.25 | 0.35 | no data | 2 | 4.5 | 1.5 | 10.55 | 0.75 | 1 | no data | 1.05 |
| PERENNIAL FORBS | 1.7 | 0.4 | 0.15 | no data | 8.25 | 0.65 | 10.7 | 3.45 | 7.35 | 0.65 | no data | 2.1 | 4.65 | 0.05 | 1.55 | 8.8 | 0.55 | no data | 1.95 |
| KNAPWEED | 1.7 | 0.3 | 0.05 | no data | 6.4 | 0 | 9.85 | 3.15 | 6.35 | 0.1 | no data | 0.8 | 4.65 | 0.05 | 1.25 | 7.05 | 0.3 | no data | 0.95 |

| 1991 TREATMENT TRANSECT NO. | 1 | 2RD | 3RD | 4RD | 5 | 6 | 7 | 8RD | 9RD | 10RD | 11 | 12 | 13 | 14RD | 15RD | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0 | no data | 0 | no data | 0 | 0 | 0.05 | 0.1 | 0 | 0 | 0 | 0.05 | 0 | 0 | 0.1 | 0 | 0 | 0.05 | 0 |
| ANNUAL&BIENNIAL FORBS | 0.55 | no data | 19.25 | no data | 0.05 | 0.1 | 0 | 0.1 | 0.35 | 2.7 | 1.5 | 0.95 | 0 | 1.3 | 3.15 | 2.6 | 0.75 | 0.25 | 0.1 |
| PERENNIAL FORBS | 0.05 | no data | 17.15 | no data | 0 | 0 | 0.1 | 0 | 0 | 0.05 | 0 | 0 | 0.35 | 0.75 | 0.35 | 0.3 | 10.75 | 0 | 0 |
| KNAPWEED | 0 | no data | 17.15 | no data | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.4 | 0.1 | 0.2 | 10.45 | 0 | 0 |

| 1991 TREATMENT (Cont'd) TRANSECT NO. | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29RD |
|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 | 0 | 0 | no data |
| ANNUAL&BIENNIAL FORBS | 0.85 | 0.45 | 1.25 | 0.4 | 2.15 | 0.1 | 0.1 | 2.35 | 0 | no data |
| PERENNIAL FORBS | 0.35 | 0.5 | 0 | 0.05 | 8.55 | 0.05 | 0.7 | 1.4 | 0.2 | no data |
| KNAPWEED | 0.3 | 0.45 | 0 | 0 | 8.45 | 0 | 0.35 | 0.35 | 0 | no data |

| NW CONTROL TRANSECT NO. | 1RD | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11RD | 12RD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 1.6 | 0 | 0 | no data | 0 | 0 | 0.05 | 0 | 0 | 0 | 0.15 | no data |
| ANNUAL&BIENNIAL FORBS | 0.45 | 10.2 | 6.05 | no data | 1.35 | 2.5 | 2.15 | 0.25 | 0.9 | 1.85 | 6 | no data |
| PERENNIAL FORBS | 10.65 | 18.15 | 5.7 | no data | 16.05 | 13.7 | 7.9 | 2.65 | 2.6 | 11.45 | 8.75 | no data |
| KNAPWEED | 9.85 | 18 | 5.25 | no data | 16.05 | 12.9 | 7.75 | 2.4 | 1.9 | 10.8 | 8.45 | no data |

| NE CONTROL TRANSECT NO. | 1 | 2RD | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | no data | no data | 0 | 0.15 | 0.45 | 0.3 | 0 | 0.45 | 0.15 | 0 | 0.05 | 0 |
| ANNUAL&BIENNIAL FORBS | no data | no data | 3.2 | 13.25 | 8.45 | 0.55 | 7.75 | 10.45 | 1.3 | 0.45 | 3.6 | 7.45 |
| PERENNIAL FORBS | no data | no data | 2.4 | 1.65 | 31.95 | 2.85 | 8.5 | 10.8 | 0.95 | 4.95 | 8.5 | 10.4 |
| KNAPWEED | no data | no data | 2.15 | 1.3 | 12.3 | 1.3 | 7 | 10.05 | 0.15 | 3.5 | 7.75 | 9.9 |

| SE CONTROL TRANSECT NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0.45 | 1.35 | 1.1 | 0.5 | 0.35 | 0.45 | 0.25 | 0.25 | 0.05 | 0.15 | no data |
| ANNUAL&BIENNIAL FORBS | 0 | 0.1 | 0.1 | 0.25 | 0.2 | 0.1 | 0.2 | 6.25 | 0 | 0 | no data |
| PERENNIAL FORBS | 0.7 | 1.9 | 1.1 | 1.5 | 0.4 | 0.65 | 1.2 | 3.4 | 2.45 | 1.6 | no data |
| KNAPWEED | 0 | 0.05 | 0 | 0.1 | 0 | 0.05 | 0.5 | 2.55 | 0.2 | 0.3 | no data |

## Table C.1. (continued)

**S CONTROL**

| TRANSECT NO. | 1 | 2 | 3 | 4 | 5 | 6RD | 7 | 8 | 9 | 10 | 11RD | 12RD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHRUBS | 0 | 0.15 | 0.05 | 0.05 | 0.4 | 0.1 | 0.2 | 0.2 | 0.15 | 0.6 | 0.1 | 0.05 |
| ANNUAL&BIENNIAL FORBS | 0.45 | 2.1 | 0.5 | 0 | 0.55 | 1.45 | 2 | 1.05 | 0.75 | 0.25 | 2.35 | 2.4 |
| PERENNIAL FORBS | 12.15 | 5.35 | 21.25 | 1.2 | 6.45 | 2.6 | 1.25 | 0.6 | 0.75 | 0.35 | 21.55 | 2.9 |
| KNAPWEED | 11.55 | 4.7 | 21.25 | 0.45 | 6.4 | 0.45 | 0 | 0.1 | 0.2 | 0 | 21.5 | 1 |

**ALE CONTROL**

| TRANSECT NO. | 1 | 2 | 3 |
|---|---|---|---|
| SHRUBS | 0 | 0 | 0 |
| ANNUAL&BIENNIAL FORBS | 15.45 | 6.1 | 1.65 |
| PERENNIAL FORBS | 2.05 | 0.6 | 1.15 |
| KNAPWEED | 0 | 0 | 0 |

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