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Ungulate Damage to Safflower in San Juan County, Utah

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UNGULATE DAMAGE TO SAFFLOWER IN

SAN JUAN COUNTY, UTAH

by

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ABSTRACT

Ungulate Damage to Safflower in San Juan County, Utah

by

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Utah State University, 2011

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In Utah, farmers are concerned that ungulates are damaging safflower (*Carthamus tinctorius*) fields. I examined elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) damage to safflower production in San Juan County, Utah during 2009 and 2010. Data on damaged safflower plants were collected within 28 fields, totaling 1,581 ha (13 fields totaling 963 ha during 2009; 15 fields totaling 618 ha during 2010). I compared 3 methods to assess losses: ungulate-proof exclosures, adjacent plant compensation method, and counting the number of damaged plants in 50-m transects (safflower count method). Exclosures were of limited use because they could not be erected until farmers stopped using cultivating their fields. Hence, this method did not account for ungulate damage to young plants. The adjacent plant compensation method assessed yields within 1 m of a randomly-selected damaged plant to account for any compensatory growth of neighboring plants but this method proved inaccurate because ungulate herbivory was concentrated so that a browsed plant was often surrounded by other browsed plants so no compensatory growth by surrounding plants occurred. The most accurate method was the safflower count method which determined the number of damaged plants within a field and then multiplied this number by the decrease in yield from an average damaged plant. I used this method to examine 981,000 plants for damage. Deer and elk damaged or killed 7.2% of safflower plants during 2009 and 1.4% of plants during 2010. Overall yield reduction was 2.9% during 2009 and 0.6% in 2010. The total value of safflower loss within all surveyed fields in 2009 was $9,023 for a loss of $9.42 / ha. The loss of value within surveyed fields in 2010 was $2,330, or $3.77 / ha. The best model for predicting ungulate damage in 2009 included distance to canyon from field edge and the percent of a field bordered by a fallow field, while the best model for 2010 included distance to canyon from field edge and the percent of a field bordered by a wheat field. Safflower farmers were surveyed in the spring of 2010 to compare perceived losses in their fields during 2009 to those measured in this study. Farmers believed that damage by deer and elk reduced their yields by 20% with most damage caused by elk ($\bar{x}$ =12% by elk, 7% by deer, 1% by other wildlife). On average, perceptions of damage were 5.2 times higher than the actual levels I measured during 2009. This was not surprising because farmers usually surveyed their field from the field’s edge and ungulate damage was concentrated along the edge of the fields.

(104 pages)

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Michael Haney

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In Utah, farmers are concerned that ungulates are damaging safflower (*Carthamus tinctorius*) fields. Safflower is a member of the sunflower family and is a highly branched, thistle-like annual, usually with many long sharp spines (Smith 1996). Each branch usually has 1–5 flower heads, and each of these contains 15–30 seeds. In the normal crop rotation for arable dryland, safflower is grown following wheat because of its ability to extract water and nitrogen from the soil with a taproot system that can penetrate to depths of 3 m (Berglund et al. 2007).

Safflower provides 3 main products: meal, seed, and oil. Safflower meal contains about 24% protein and is used as a protein supplement in cattle and poultry feed (Berglund et al. 2007). Safflower seed is often used in birdseed mixes (Gyulai 1996, Peterson 1996). Safflower oil has many economically important uses including the production of cosmetics, infant formulas, margarine, salad dressing, and cooking oils (Berglund et al. 2007).

There are considerable health benefits associated with safflower oil. High oleic safflower oil is lower in saturates and higher in monounsaturates than olive oil (Smith 1996). High linoleic safflower oil contains polyunsaturated fats. Both oil types are considered "high quality" edible oils, and are beneficial in preventing coronary heart disease by lowering low-density lipoprotein (bad cholesterol) levels without affecting high-density lipoprotein (good cholesterol) levels (Smith 1996, Boland 2009). Increased public awareness of the importance of lowering LDL has made safflower an important vegetable oil crop.

Elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) provide great benefits and costs to society (Conover 1997). Yet the costs and benefits are not equally distributed throughout all segments of society. The public and hunters receive much of the benefits wildlife provide, while farmers and ranchers are faced with much of the cost associated with feeding these animals on their property. This causes a conflict among different stakeholder groups. Hunters and others would like ungulate populations to increase while farmers and ranchers would like populations to decrease (Conover 2002).

Many western states such as Utah, Wyoming, Colorado, New Mexico, Nevada, Idaho, and Arizona have enacted laws to compensate agricultural producers for losses caused by deer and elk (Musgrave and Stein 1993, Utah Code 2008). Many wildlife agencies also help farmers protect their crops by providing information, fencing material, repellents, or labor (Wagner et al. 1997). Crop owners in Utah may destroy depredating big game animals if the animals are not removed by the Utah Division of Wildlife Resources (UDWR) within 72 h of notification (23-16-3.1, Utah Code 2003). Utah crop owners may also receive monetary compensation for damage caused by big game animals (23-16-4, Utah Code 2008).

Safflower is grown throughout northern Utah in Box Elder and Cache County, and in southeastern Utah in San Juan County. Box Elder has the highest number of safflower hectares planted in Utah (2,900 ha) followed by San Juan County (2,200 ha) and Cache County (1,600 ha; Census of Agriculture 2007). San Juan County ranks 11th in the nation for total safflower hectares planted (Census of Agriculture 2007). In 2007, 2,200 ha of safflower were planted in San Juan County for a total seed production of 1,360,276 kg valued at $560,800 (Census of Agriculture 2007, USDA 2010). In 2007, the UDWR paid farmers in San Juan County, Utah, $29,000 in compensation for ungulate damage to oilseed crops, this value increased to $165,000 in 2008 (UDWR 2008). While most of the damage occurred to sunflower, damage to safflower accounted for $35,000 of payments made in 2008. Safflower damage payments were calculated by the UDWR by visually selecting 1 damaged area, harvesting the safflower seeds in the damaged area, and comparing yields obtained to yields from 1 visually selected non-damaged area of the same size (G. Wallace, UDWR, personal communication). Loss in yield was then extrapolated across the farmer's entire safflower acreage and a payment was made. The field location where damage estimates were collected was selected by the farmer due to high levels of damage, and was located adjacent to a small pond and sunflower field. The UDWR was concerned that their damage calculations were incorrect, because there was no replication and no randomization.

The estimated population of elk in agricultural areas of San Juan County (east of Highway 191) has remained stable to increasing from 2008 to 2011 despite increased hunting permits. Using helicopter surveys conducted in January and applying an 80% sight-ability factor, UDWR estimated the elk population at 415 in 2008 and 438 in 2011 (J. Shannon, UDWR, personal communication). The estimated population of mule deer in the area is unknown. Following crop depredation concerns, more elk hunting permits were offered in the form of depredation permits, mitigation permits, over-the-counter cow elk permits, and the opening of a bull elk hunting season when any bull elk could be shot in areas east of Highway 191 and south of Highway 491. The opening of the bull elk season in 2009 attracted 266 bull elk hunters yet only 26 bulls were harvested (UDWR 2009). Despite increased hunting permits for elk, success rates for all hunts were low (0–12%) due to a high proportion of private land, dense escape cover, and deep rugged inaccessible canyons (UDWR 2009). An additional factor complicating efforts to reduce ungulate populations within crop depredation areas is the presence of the Spring Creek Dodge Cooperative Wildlife Management Unit (CWMU). The Spring Creek Dodge CWMU is adjacent to many crop depredation areas, generates revenue from the sale of deer and elk permit vouchers, and is the second largest CWMU in Utah encompassing 44,200 ha. The CWMU Rule (R657-37) states that operators need to develop "strategies and methods that avoid adverse impacts to adjacent landowners resulting from the operation of the CWMU" (Utah 1999). The operator of the CWMU has agreed to pay for half of the total elk damage on adjacent crop lands up to $10,000 per year (K. Lewis, CWMU operator, personal communication).

Objectives of my research were to determine the effects of ungulate damage on safflower yields in San Juan County, Utah. I determined the extent of damage based on both dollar value and percent of crop lost. Another objective was to survey safflower farmers to compare their perceived damage levels to those I measured. This research will help UDWR determine appropriate compensation levels for safflower damage.

STUDY AREA

San Juan County is located in southeastern Utah within the Colorado Plateau along the Colorado and Arizona borders. It is the largest county in Utah and the second largest county in the United States, with 20,254 km^2 (U.S. Census Bureau 2009). In 2007, private land comprised 164,451 ha of which 57,964 ha were in cropland; 19,493 ha of this were harvested during 2007; the balance of cropland was fallow or in the U. S. Department of Agriculture's Conservation Reserve Program (CRP; Census of Agriculture 2007). Common crops grown include alfalfa, pinto beans, oats, safflower, sunflower, and winter wheat. In 2009, 2,628 ha of safflower were planted, and in 2010, 2,469 ha were planted. Safflower is planted May through June, cultivated in late-July, and harvested in October or November when seed moisture is <8%.

Common native vegetation occurring near safflower fields includes antelope bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*), Indian ricegrass (*Achnatherum hymenoides*), pinyon pine (*Pinus edulis*), rubber rabbitbrush (*Ericameria nauseosus*), Utah juniper (*Juniperus osteosperma*), and western wheatgrass (*Elymus smithii*). Common weed species occurring in safflower fields includes alfalfa (*Medicago sativa*), common sunflower (*Helianthus annuus*), field bindweed (*Convolvulus arvensis*), prostrate pigweed (*Amaranthus blitoides*), quack grass (*Elymus repens*), Russian thistle (*Salsola iberica*), and volunteer wheat (*Triticum aestivum*). Elevation of the safflower fields surveyed ranged from 2,020–2,120 m. Water was scarce throughout the area, but some water occurred year round in seeps and springs located throughout the canyons, and in retention ponds constructed for livestock use. When it rained, water often collected within the field along field terraces and grass waterways. Precipitation totals for the growing season (May to October) from the nearest weather station in Dove Creek, Colorado were 130 cm in 2009 and 179 cm for 2010 (Gibbas et al. 2011). In 2009, most precipitation occurred May through June, in 2010 most occurred from July through October (Fig. 1). Temperatures ranged from –5 to 35º C (May to October).

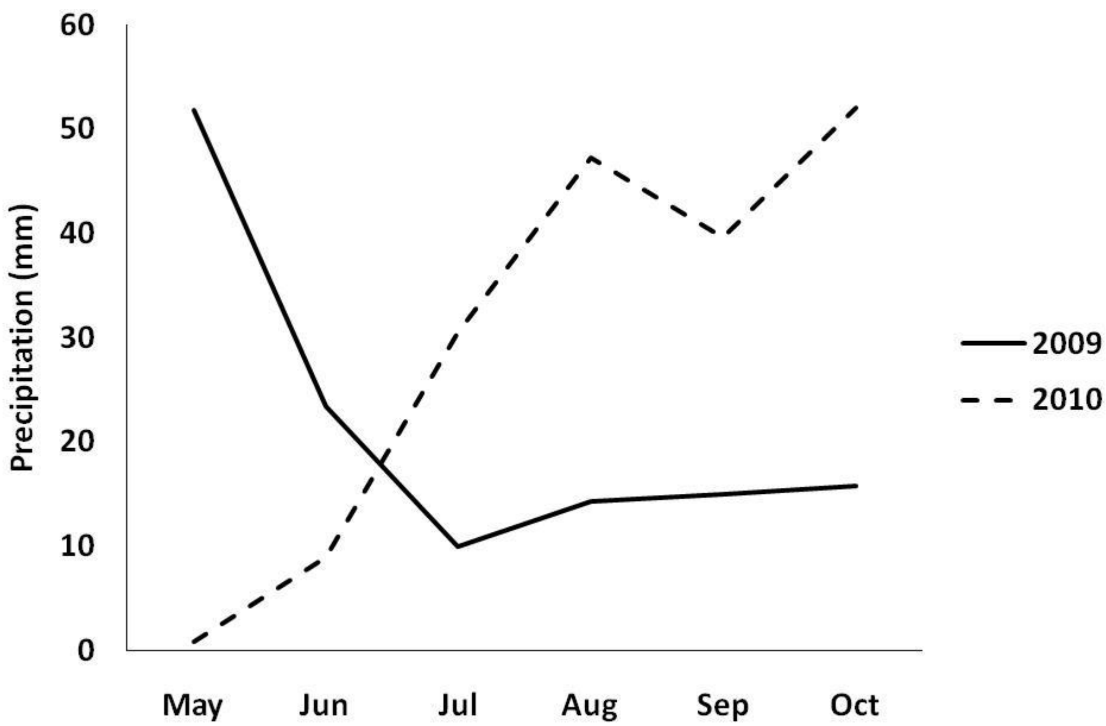

Figure 1. Precipitaion during my study as measured at the weather station in Dove Creek, CO which was the closest one to my study site.

2009 Fields

In 2009, I surveyed 13 safflower fields throughout San Juan County, Utah (totaling 963 ha; Fig. 2). Fields were located approximately 25 km east of Monticello, Utah, in Cedar Point (5 fields), Eastland (2 fields), Ucolo (2 fields), and along the west Summit road (4 fields). Fields surveyed in 2009 included: Cedar F1 (80.5 ha), Cedar F2 (72.8 ha), Cedar F3 (17.0 ha), Cedar F4 (36.6 ha), Cedar F5 (87.8 ha), Eastland F1 (39.8 ha), Eastland F4 (109.0 ha), Summit F1 (102.2 ha), Summit F2 (159.3 ha), Summit F3 (5.0 ha), Summit F4 (145.8 ha), Ucolo F1 (34.3 ha), and Ucolo F2 (72.6 ha). All 13 fields were bordered by dense stands of pinyon pine and juniper, farmland idled under CRP, or other cropland. Four of the 13 fields (Cedar F1, F2, Cedar F5, Eastland F1) were adjacent to deep rugged canyons which provide habitat and escape cover for deer and elk. Three of the fields were <1 km away from deep rugged canyons (Cedar F3, F4, Eastland F4) while the remaining were >4 km away (Summit F1, F2, F3, F4, Ucolo F1, F2).

2010 Fields

In 2010, I surveyed 15 safflower fields located throughout San Juan County, Utah (totaling 618 ha; Fig. 3). Fields were located in Cedar Point (9 fields), Eastland (2 fields), Ucolo (2 fields), along the west Summit road (1 field), and 1.5 km southeast of Highway 491 and the Colorado border (1 field). Fields surveyed in 2010 included: Big Butts (61.0 ha), Brelove (6.9 ha), Carhart (29.3 ha), Cedar (34.7 ha), Daniels (36.6 ha), Frost (52.4 ha), Gilbroth (10.9 ha), Johnny Funk (34.5 ha), Kay Johnson (111.4 ha), Little Butts (17.7 ha), Lucious (39.5 ha), Martinez (28.5 ha), Rich (108.1 ha), Rogers (19.8 ha), and West Long Draw (26.7 ha). In 2010, 14 of the sites surveyed were in new fields because fields used during 2009 were rotated out of safflower and into another crop. Only 1 field was planted in safflower both years, Cedar F4 in 2009, and later named Daniels in 2010. All fields except 1 (Rich) were bordered by dense stands of pinyon pine and juniper, and all fields were bordered by CRP or other cropland. Five of the 13 fields (Johnny Funk, Kay Johnson, Lucious, Martinez, Rogers) were adjacent to deep rugged canyons which provide habitat and escape cover for deer and elk. Five of the fields were <1 km away from deep rugged canyons (Carhart, Cedar, Daniels, Rich, West Long Draw), 2 were 1–2 km away (Brelove, Gilbroth), while the remaining were >4 km away (Big Butts, Little Butts, Frost).

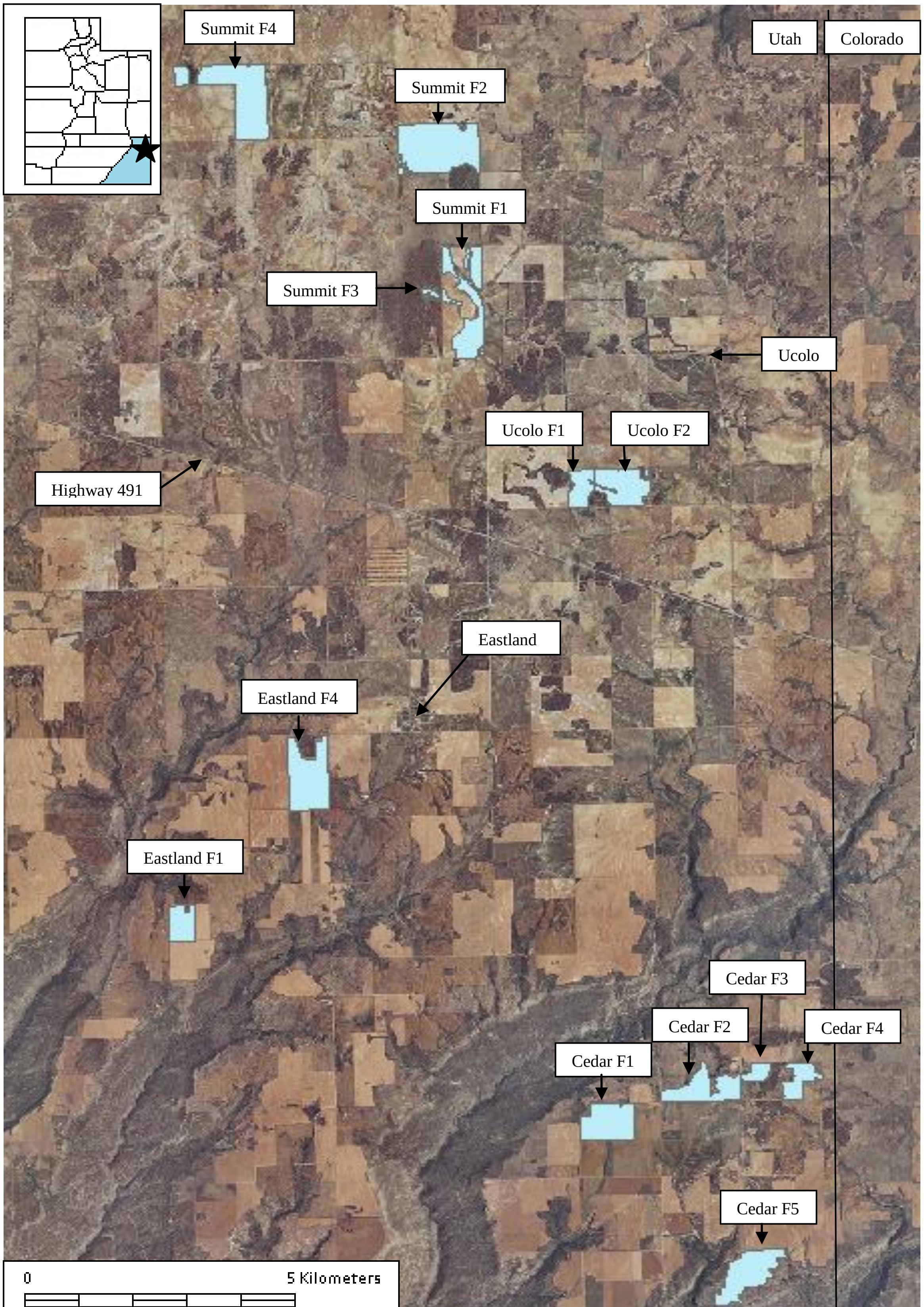

Figure 2. Locations of safflower fields that I surveyed in 2009 in San Juan County, UT.

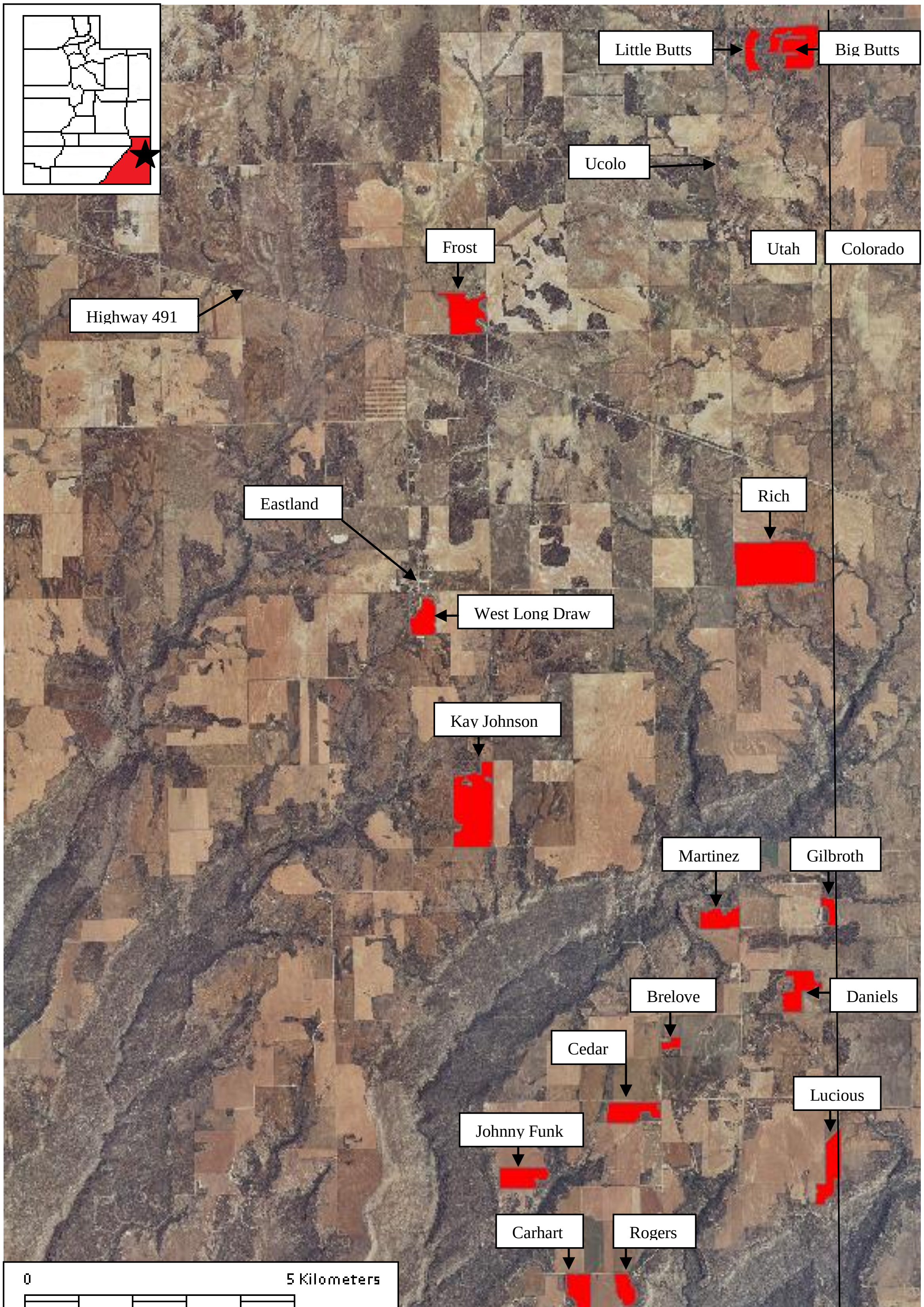

Figure 3. Locations of safflower fields that I surveyed in 2010 in San Juan County, UT.

METHODS

Safflower Counts

From June 11 to October 9, 2009, I collected data on damaged safflower plants located within 13 fields. From June 14 to November 3, 2010, I collected data within 15 fields. Safflower data collection coincided with seedling emergence and ended immediately prior to harvest. Along each field edge, we randomly selected 2 locations for a total of 8 locations within each field, but narrow fields (<29 ha) had 6 locations and small fields (<17.5 ha) had only 4 locations. Two locations were placed along each edge of the field because ungulates are likely to enter the field from 1 side more than others. At each of these locations, I established 5 transects, each 50-m in length and 0.91-m in width to correspond with row spacing so that the transect was centered on 1 row of safflower. At each location, 1 transect was randomly placed within each field at the following distances from the field's edge: 0–10 m, 10–20 m, 20–40 m, 40–80 m, and 80–200 m. Transects ran parallel to the edge of the field (Fig. 4).

I recorded the number of safflower plants within the transect 3 times during the growing season and determined if any of these plants were damaged or browsed by ungulates. For each damaged or browsed plant identified, I attempted to identify the species that had caused the damage from tracks located near the damaged plant. Damage by species was recorded as unknown if tracks near a damaged plant were unclear, washed away, or were from both deer and elk. Plants were considered dead if all seed heads had been removed by browsing or if the main stem had been broken off from being stepped on by ungulates. All dead safflower plants were counted and removed from the transect to avoid double counting them on subsequent sampling dates. Plants damaged by army cutworms (*Euxoa auxiliaris*) and pale western cutworms (*Agrotis orthogonia*) were counted but excluded from my analysis; plants damaged by cutworms were stunted, yellow, and had substantial thinning of the leaves near the crown of the plant. Plants damaged during cultivation or damaged by other farming operations were also counted but excluded from the analysis. Transects were checked during safflower counts for ungulate travel paths that intersect the transect and for deer and elk pellet groups. All pellet groups found within the transect were removed to avoid double counting. Plants browsed by ungulates other than safflower were counted and recorded to species. I also recorded the percent cover of bare ground, grasses, and forbs other than safflower within each transect. Their percent cover was determined using the point-intercept method (Goodall 1952). With this method, I recorded the number of times a wire pin contacted either bare ground, forbs, or grasses within each transect at 20 random points with a minimum distance of 1 m between points. If the wire pin contacted a safflower plant, it was not counted and a new point was selected.

Exclosure Method

I erected 8 exclosures and selected 8 paired sites within each field (smaller fields <29 ha had 6 exclosures; fields <17.5 ha had 4 exclosures) to assess the impact of ungulates on crop yields. Exclosures and paired sites were 2.74 m × 2.74 m in size to encompass 3 rows of safflower. The exclosure was located adjacent to and on the right side of a randomly selected transect. Paired sites were placed 0–30 m from exclosures and located on the same safflower rows as the exclosures (Fig. 4).

In each exclosure and at each random paired site, I recorded plant density and noted the presence of any dead or eaten plants at the beginning and end of the growing season. Exclosures were erected following cultivation in late-July. All plants in the exclosures and at the random sites were harvested immediately before the farmer harvested the crop and exclosures were removed so they did not interfere with the farmer's harvesting equipment.

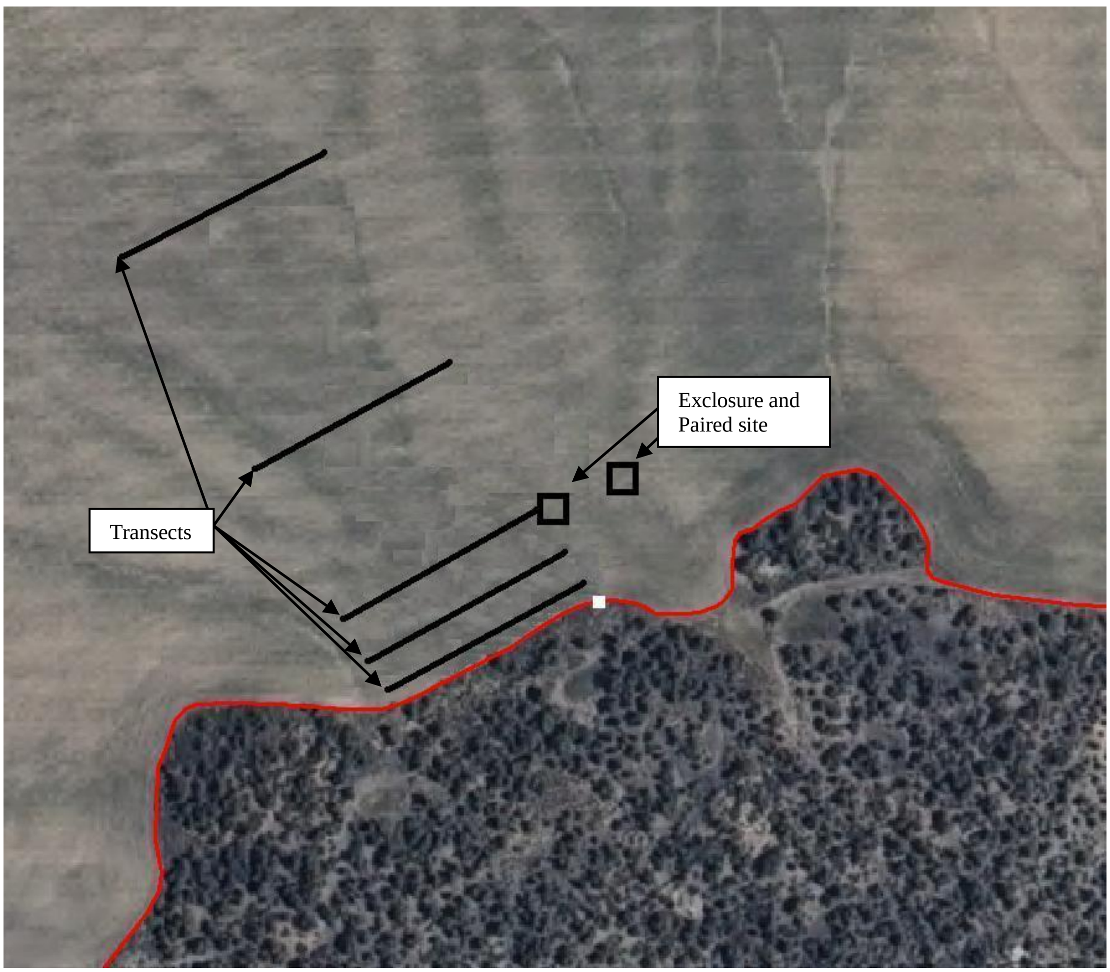

Figure 4. A total of 5 transects, 50-m in length were located parallel to the field edge at each location. The exclosure was located adjacent on the right side of a randomly selected transect; the exclosure paired site was located on the same safflower rows as the exclosure, 0–30 m to the right of the exclosure.

Safflower Count Method

I clipped plants damaged by ungulates and undamaged plants within each field to assess the impact of ungulates on crop yields. Plants were identified as damaged if plants had been browsed or had been stepped on by ungulates. Plants with all seed heads browsed or the stem completely broken off were identified as killed and counted but they were not clipped; I assumed 100% yield reduction for plants that were killed. I located a damaged plant near the exclosure, clipped the damaged plant and clipped the first healthy plant located >0.91-m away to the right of the damaged plant. One sample of 15 healthy plants and 1 sample of 15 damaged plants were clipped at each location within the field for a total of 8 samples for healthy plants and 8 samples for damaged plants for each field (total of 120 healthy plants and 120 damaged plants clipped for each field). Damaged plants were located visually by walking down rows near the exclosure. If I and 2 technicians were unable to find 15 damaged plants at a location after searching for 45 minutes, I concluded the search for damaged plants and used the damaged plants (<15 plants) for my analysis.

Adjacent Plant Compensation Method

In 2010, I located and clipped damaged plants and neighboring plants along the same row within 0.91-m on both sides (1.82-m total) of the damaged plant to determine if adjacent plants grew larger and therefore were able to compensate for ungulate herbivory. I compared a 1.82-m section centered on a damaged plant to a 1.82-m section centered on the first healthy plant located >1.82-m to the right of the damaged plant. One sample consisting of 2 clipped sections centered on a damaged plant and 1 sample consisting of 2 clipped sections centered on a healthy plant were clipped at each location within the field for a total of 8 samples centered on damaged plants and 8 samples centered on healthy plants for each field.

Safflower Seed Processing

For each sample, I used a Vogel thresher (Bill's Welding Shop, Pullman, WA) to separate seeds from the rest of the safflower plant. Seeds were placed in a drying oven for 48 hrs at 60^{o} C and then screened twice with a 1-cm screen to remove any foreign material. Safflower seed samples were then weighed. Every 20th sample was selected, and all foreign material was removed by hand and weighed.

Ungulate Counts

I counted ungulates in safflower fields and in field types other than safflower to determine if ungulate use was higher within safflower fields than within other field types. Safflower fields were observed for ungulates on the same day that safflower counts were conducted, for a 5-min period prior to sunrise. Nearby safflower fields were also observed if time permitted. Each field was observed 4–11 times per season with most fields observed ≥6 occasions or about once per month. Safflower fields located far from other safflower fields were not observed as frequently as those located close together. Whenever a deer or elk was seen in or near a field, I noted its location and plotted it on a map. I also observed what plant species deer and elk were eating, and their travel paths to and within the field. While driving to and from fields I recorded the number of ungulates observed within fields other than safflower. Field types where ungulates were observed included alfalfa, CRP, oats, pinto beans, and wheat.

Safflower Damage Survey

After the crops were harvested in 2009, I mailed surveys to farmers who grew safflower in San Juan County to evaluate their perceptions of ungulates, crop damage caused by ungulates, and management strategies to mitigate damage. I did not provide to the farmers any indication of how much damage I had measured in their fields prior to conducting the survey. I obtained a list of all 12 farmers in San Juan County who grew safflower. In the spring of 2010, I mailed a survey to each of these farmers. The survey posed 35 multiple-choice and fill-in-the-blank questions regarding the farmer's farming history, farming practices, perceived safflower crop damage from ungulates and other wildlife, and opinions about ungulates and ungulate management (IRB protocol number 2614; Appendix A). I estimated that the survey would take about 15 minutes to complete and asked that it be returned in the postage-paid mailer provided. As a reminder, I contacted farmers by phone 10 days after mailing the questionnaire, followed by a second phone call 2 weeks after the first call.

Statistical Analysis

I digitized each field using ArcMap version 10.0 (ESRI, Inc., Redlands, CA) to determine total field area using satellite imagery taken in the summer of 2009 (National Agricultural Imaging Program, NAIP 2009_SanJuan_North, 1-m orthophotography). I then used a multiple ring buffer to determine the amount of area contained within each of the following distance classes located away from the edge of the field 0–10m, 10–20m, 20–40m, 40–80m, and >80m (Fig. 5). These areas corresponded to the areas used in my transects. I also calculated total field area, the circumference of a field, field circumference to volume ratio, distance from closest point within field to nearest canyon edge, and the percent of the field area not visible from roads (Appendix F). Percent of the field bordered by county roads, pinion-juniper, sagebrush, CRP fields, wheat fields, bean fields, fallow fields, other safflower fields, and sunflower fields was calculated for each field (Appendix F).

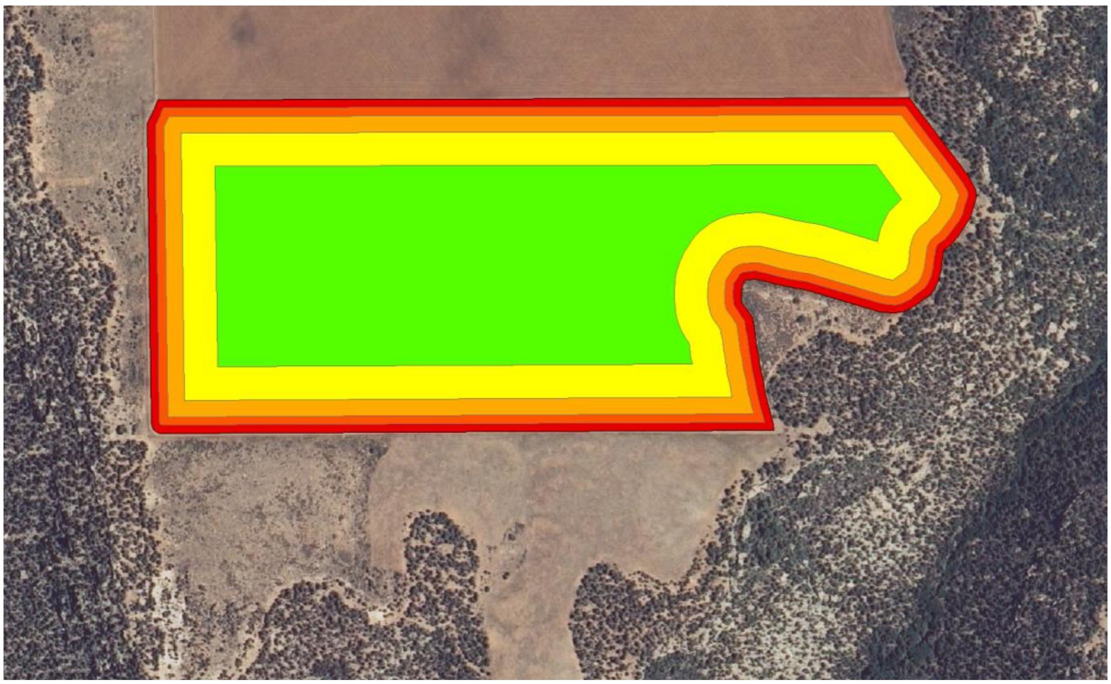

Figure 5. Field boundaries were digitized using ArcMap and areas within each distance class were calculated using a multiple ring buffer based on the distance from the field's edge.

To calculate mean plants per m^2 for each distance class, the mean number of plants per transect was divided by the transect area or 45.72 m^2. This process was repeated for plants injured and killed to determine mean number of plants injured per m^2 and mean number of plants killed per m^2. To estimate the total number of healthy, injured, and killed plants within each distance class, I multiplied the mean number of healthy, injured, and killed plants per m^2 by the area within each distance class. The sum of healthy, injured, and killed plants across all distance classes was used to determine the total number of healthy, injured and killed plants within the entire field. To determine the percentage of plants damaged by ungulates, I divided the estimated number of injured and killed plants by ungulates by the estimated total number of plants. Plants that were counted as dead during earlier sampling dates were included in calculations despite being removed from the transect at time of death.

Safflower seed samples were collected using the safflower count method; using samples collected I estimated average yield per healthy plant and average yield loss per damaged plant for each field. Average yield per healthy plant was determined from samples of 15 healthy plants collected from 8 locations around the field ($n = 120$). By multiplying average yield per healthy plant by the estimated total number of plants within a field I was able to estimate theoretical yield. Theoretical yield was divided by field area to determine yield in kg per ha for each field. Yield loss was the difference between the actual yield and the theoretical yield in the absence of ungulate damage. Yield loss was calculated for the safflower count method using the equation: loss per field = (total number of live damaged plants in the field × loss in yield per live damaged plant) + (total number of plants killed in the field × yield per plant).

Safflower seed samples were also collected using the exclosure method; using samples collected I estimated average yield per m^2 within exclosures and average yield per m^2 in paired sites where ungulates were free to forage. Average exclosure yield per m^2 was determined by dividing yields obtained within the exclosure area or 7.52 m^2 averaged across all 8 exclosure locations within the field. To estimate theoretical yield, I multiplied average exclosure yield per m^2 by total field area. Theoretical yield was divided by field area to determine yield in kg per ha for each field. To calculate yield loss per m^2, I calculated the difference between average exclosures yield m^2 and average paired sites yield m^2. Yield loss per field was calculated using the equation: loss per field = loss per m^2 × total field area.

I calculated the value of seeds lost by multiplying kg of safflower seeds lost per field by the value of safflower. I contacted local farmers to determine what price they had received for safflower they had sold. I used the average value of organic safflower for my calculations which was $ 0.45 per kg in 2009 and $0.50 per kg in 2010. All yield calculations were adjusted to include 8% moisture content because this is when farmers harvest and sell their crop.

For the exclosure method, yields obtained within exclosures were compared to yields obtained within paired sites where ungulates were free to forage using a 2–way factorial in split-plot design with whole plots in blocks. The blocking factor was field, and the whole plots were transects within fields, and the whole-plot factor was transect distance from the field edge. The split plots were the exclosures and paired sites, and the split-plot factor was the yield obtained within exclosures versus paired sites. I used a generalized linear mixed model (PROC GLIMMIX; SAS Institute 2008) to test the results for statistical significance ($P \leq 0.05$). For this analysis, yield within exclosure and paired site were my experimental unit. For the safflower count method, I repeated the analysis replacing the split plot factor exclosures and paired sites with damaged and not damaged to compare yields obtained from healthy plants and damaged plants. For this analysis, yield from 15 damaged plants and 15 healthy plants were my experimental unit. For the adjacent plant compensation method, I repeated the analysis replacing damaged and not damaged with damaged section and healthy section to compare yields from a row section centered on a damaged plant to yields from a row section centered on a healthy plant. For this analysis, yield from 2 1.82-m sections centered on a damaged plant and 2 1.82-m sections centered on a healthy plant were my experimental unit. I used a square root transformation on yield for all models across years so that assumptions of normality and constant variance were met. I analyzed 2009 data separately from 2010 data because of differences in damage and yield across years. Distance from the field edge was removed from the model because no relationship was found between distance from the field edge and yield. Summit F3 was excluded from all 2009 analyses because it was not harvested. For the exclosure method analysis for 2010, I excluded West Long Draw S1 exclosure and paired site yields because the exclosure was located in the bottom of a field terrace that was underwater for >1 month, killing all the plants within the exclosure. I used compound symmetry structure as my covariance structure for all analyses. I used the Kenward–Roger method for calculating degrees of freedom for 2009 analyses and the between-within method for 2010 analyses.

I compared yield estimates between years and among methods using a generalized linear mixed model (PROC GLIMMIX; SAS Institute 2008). For this analysis, field yield (grand mean) was my experimental unit. I used a square root transformation on yield across years so that assumptions of normality and constant variance were met. For this analysis, I excluded Little Butts estimated field yield using the safflower count method because the farmer's seeder was not calibrated correctly resulting in 10 times the number of plants per m^2 along the west edge of the field. I also compared damage between years and between methods using a generalized linear mixed model (PROC

GLIMMIX; SAS Institute 2008). For this analysis, I used field damage (grand mean) as my experimental unit. I used a square root transformation on damage across years so that assumptions of normality and constant variance were met. To calculate degrees of freedom, I used the containment method for the yield analysis and the Kenward–Roger method for the damage analysis.

I used simple linear regressions (PROC REG; SAS Institute 2008) to determine if damage varied among fields with different field areas, edge to volume ratios, distances to the nearest canyon edge, and the percentages of field areas not visible from county roads. I also compared damage to the percentage of field edge bordered by roads, pinyon-juniper, sage, CRP, wheat fields, bean fields, fallow fields, other safflower fields, and sunflower fields. I used field damage (grand mean) as my experimental unit for these analyses.

I used a generalized linear mixed model (PROC GLIMMIX; SAS Institute 2008) to test if damage per transect decreased as transect distance from the field edge increased. I also tested if there were differences in damage per transect across years. I used percent damage per transect as my experimental unit for this analysis. I used a log + 0.5 transformation on percent damage so that assumptions of normality and constant variance were met.

I compared the number of deer tracks per transect counted as distance increased from the field edge across years using a generalized linear mixed model (PROC GLIMMIX; SAS Institute 2008). For this analysis, the number of deer tracks per transect was my experimental unit. For elk tracks, I repeated the analysis replacing the deer tracks per transect with the elk tracks per transect. To simplify the analyses, I used categorical distance classes instead of actual transect distance from the field edge. I used a log + 0.5 transformation on tracks so that assumptions of normality and constant variance were met.

Ungulate count data for 2009 and 2010 were analyzed using a Chi-square goodness-of-fit test to determine if ungulate use was higher within safflower fields than within other crop types in relation to field availability. Use is considered selective if certain crop types were used disproportionately to their availability (Johnson 1980). I obtained county-wide hectares across both years for the following crop types: alfalfa, CRP, oats, pinto beans, and wheat (Table 1; D. Christensen, U. S. D. A. Farm Service Agency, personal communication). I categorized count data by animal type (i.e. buck, doe, and fawn deer; and bull, cow, and calf elk) along with crop type where they were observed (i.e. alfalfa, CRP, oats, pinto beans, safflower, and wheat). I calculated expected ungulate field use values using the proportion of area planted in each crop type multiplied by total number of animals observed for each animal type. Chi–squared values were obtained using the formula: $\sum$ (number of animals observed – expected number of animals)^2 / expected number of animals. For this analysis, each observed animal was the experimental unit.

Due to the low number of farmer's surveyed (12 farmers), I was limited in my ability to analyze surveys using statistics. Instead, I have included descriptive statistics for each quantitative question, and I have looked for patterns within responses for qualitative questions. Perceived damage levels were compared to those I measured using a paired Student's *t*-test (PROC TTEST; SAS Institute 2008). When respondents only included general descriptions about locations of fields, perceived levels were compared to measured levels averaged across fields surveyed within the general area. General descriptions about locations of fields were received for 2 fields in Eastland, 1 field along the state-line, and 3 fields for west Summit Point. Perceptions of damage for Eastland were compared to the Eastland average, west Summit Point perceptions were compared to the Summit average, and the field along the state-line was compared to a study-wide average.

Table 1. County-wide area (ha) planted in different crop types during 2009 and 2010.

Crop type	2009	2010
Alfalfa	1,922	202
CRP	13,881	13,881
Oats	355	0
Pinto beans	323	344
Safflower	2,628	2,469
Wheat	12,204	11,938

RESULTS

Safflower Damage

In 2009, I examined 444,202 safflower plants for damage. Surveys were conducted on 13 fields which included 452 transects surveyed 3 times during the season for a total of 1,356 transects surveyed during 2009 (Appendix D). Overall 7.1% of plants were damaged by deer and elk (5.0% plants damaged but still living plus 2.1% killed). Yields of plants damaged but still alive were reduced by 36.6% compared to undamaged plants. Of the 2.2% of plants killed by ungulates, yields were reduced 100% because all seed pods were completely eaten or the plant was broken off at the stem. Overall yield loss estimated using the exclosure method was 7.9% while the safflower count method estimated overall yield loss at 2.9% (Tables 2 and 3). Based on the exclosure method, the total value of safflower loss within all surveyed fields in 2009 was $13,000 for a loss of $13.50 / ha. The safflower count method estimated loss at $9,023 for a loss of $9.42 / ha.

Plant yields inside exclosures were not significantly different from yields outside exclosures ($F_{1,9.8} = 4.15$, $P = 0.07$). Plant yields from healthy plants were significantly different than yields from damaged plants (healthy plant $\bar{x} = 8.5$ g per plant; damaged plant $\bar{x} = 5.0$ g per plant; $F_{1,10.7} = 48.98$, $P \leq 0.001$). Compensation for damage by adjacent healthy plants did not occur. Yields from 1.82-m section of row centered on a healthy plant ($\bar{x} = 114.9$ g) and on a damaged plant ($\bar{x} = 86.3$ g) were different ($F_{1,14} = 9.69$, $P = 0.007$). Estimated yields from 2009 ($\bar{x} = 581.5$ kg per ha) and 2010 ($\bar{x} = 870.1$ kg per ha) were different ($F_{1,49} = 11.30$, $P \leq 0.001$). Yield estimates did not differ between the exclosure and safflower count method ($F_{1,49} = 1.96$, $P = 0.17$) and there was no interaction between year and estimation method ($F_{1,49}$ = 0.01, P = 0.92). Estimated damage from 2009 ($\bar{x}$ = 2.9%) and 2010 ($\bar{x}$ = 0.6%) were different ($F_{1,25}$ = 17.51, $P \leq$ 0.001).

Ungulate field use varied by the type of crop being grown (buck χ_5^2 = 123.7, $P \leq$ 0.001; doe χ_5^2 = 38.1, $P \leq 0.001$; fawn χ_5^2 = 16.3, P = 0.006; bull χ_5^2 = 227.9, $P \leq 0.001$; cow χ_5^2 = 934.0, $P \leq 0.001$; and calf χ_5^2 = 363.0, $P \leq 0.001$) with the highest use in safflower fields for both deer and elk (Table 4). Use in safflower fields in 2009 was 3.6 times higher than expected for buck deer, 1.5 times for doe deer, and 1.9 times for fawn deer. Use in safflower fields was 4.6 times higher than expected for bull elk, 8.1 times for cow elk, and 7.6 times for calf elk.

Damage was concentrated along field edges ($F_{4,100}$ = 44.49, $P \leq 0.001$; 2009 damage Figs. 6 and 7; 2010 damage Figs. 12 and 13). Deer tracks were concentrated along field edges ($F_{4,100}$ = 7.98, $P \leq 0.001$; 2009 Fig. 8; 2010 Fig. 14). The number of deer tracks did not vary across years ($F_{1,25}$ = 3.47, P = 0.07), and no interaction was found between distance from the field edge and year ($F_{4,100}$ = 2.00, P = 0.10). Elk tracks were concentrated along field edges ($F_{4,100}$ 4.16, P = 0.004; 2009 Fig. 9; 2010 Fig. 15), and more elk tracks were counted in 2009 ($\bar{x}$ = 3.3 per transect) than in 2010 ($\bar{x}$ = 0.6 per transect; $F_{1,25}$ = 8.19, P = 0.008), and an interaction was found between distance from the field edge and year ($F_{4,100}$ = 5.49, $P \leq 0.001$).

Table 2. Exclosure method of assessing loss for 2009, showing estimated yield per ha, loss per ha, and loss for the entire field in both kg and dollars due to ungulate damage. Negative values indicate yields were lower within exclosures than paired sites where ungulates were able to forage.

	Estimated yield	Loss	Field loss	
Location	Kg per ha	Kg per ha	Kg	$
Eastland F1	783	13.2	526	$ 238
Cedar F2	727	28.9	2,102	$ 950
Cedar F3	649	169.3	2,887	$ 1,305
Ucolo F2	605	–1.3	–95	$ –43
Ucolo F1	439	53.2	1,823	$ 824
Summit F2	399	–51.7	–8,230	$ –3,720
Eastland F4	501	137.1	14,939	$ 6,752
Summit F1	292	–26.5	–2,703	$ –1,222
Summit F4	370	37.8	5,509	$ 2,490
Cedar F4	565	41.0	1,499	$ 677
Cedar F5	600	82.5	7,246	$ 3,275
Cedar F1	719	40.5	3,262	$ 1,474
Total			28,764	$ 13,000

Table 3. Safflower count method of assessing loss for 2009, showing estimated yield per ha, loss per ha due to plants injured by ungulates (live loss), loss per ha due to plants killed by ungulates (dead loss), and loss for the entire field in both kg and dollars due to ungulate damage.

	Estimated yield	Live loss	Dead loss	Field loss	
Location	Kg per ha	Kg per ha	Kg per ha	Kg	$
Eastland F1	1,150	15.0	4.7	786	$ 355
Cedar F2	656	0.9	0.1	71	$ 32
Cedar F3	738	4.8	9.9	250	$ 113
Ucolo F2	578	7.6	6.9	1,056	$ 477
Ucolo F1	457	18.0	2.5	703	$ 318
Summit F2	433	4.4	21.6	4,140	$ 1,871
Eastland F4	1,145	52.7	3.9	6,174	$ 2,790
Summit F1	335	16.7	23.4	4,091	$ 1,849
Summit F4	451	8.3	3.3	1,687	$ 762
Cedar F4	699	5.1	5.8	402	$ 181
Cedar F5	512	2.3	0.1	212	$ 96
Cedar F1	560	4.1	0.8	396	$ 179
Total				19,965	$ 9,023

Table 4. Ratio of observed to expected use of crop type in 2009 by deer and elk. A number greater than 1.0 signifies that the animals were selecting for that crop while a number less than 1.0 indicates avoidance of that crop.

	Deer			Elk		
Crop type	Buck	Doe	Fawn	Bull	Cow	Calf
Wheat	0.7	0.9	0.8	0.5	0.1	0.0
Safflower	3.6	1.5	1.9	4.6	8.1	7.6
Alfalfa	0.7	1.1	1.4	0.5	0.6	1.6
Pinto beans	0.0	3.3	0.0	0.0	0.0	0.0
Oats	0.0	0.0	0.0	0.0	0.0	0.0
CRP	0.9	0.9	1.0	0.6	0.2	0.0

Regression analyses were performed to examine variation in damage among fields. The top 2 models for predicting ungulate damage in 2009 were distance from the canyon edge to field * percent of field bordered by fallow fields ($R^2 = 0.80$, $F = 15.75$, $P = 0.002$) and field area * percent of field bordered by sagebrush ($R^2 = 0.74$, $F = 11.68$, $P = 0.004$).

Most damage to live plants occurred during June to August when plants were still green and palatable (Fig. 10). Damage to plants in September and October often resulted in the plant's death because plants began to dry out and become brittle (Fig. 11). Live plant damage ranged from 0.7% in Cedar F2 to 12.5% in Summit F1 while plants killed ranged from 0.4% in Eastland F1 to 7.0% in Summit F1. For 85% of damaged or killed plants, I was unable to determine if the plants had been damaged by deer or elk; often tracks near a damaged plant were unclear, washed away, or were from both deer and elk. I was able to positively identify that deer had eaten 4% of damaged plants, while elk had eaten 11%. I estimate that deer caused 25% of the damage while elk caused 75%. Overall, 41% of tracks we counted in the fields were from deer, and 59% were from elk (Table 5).

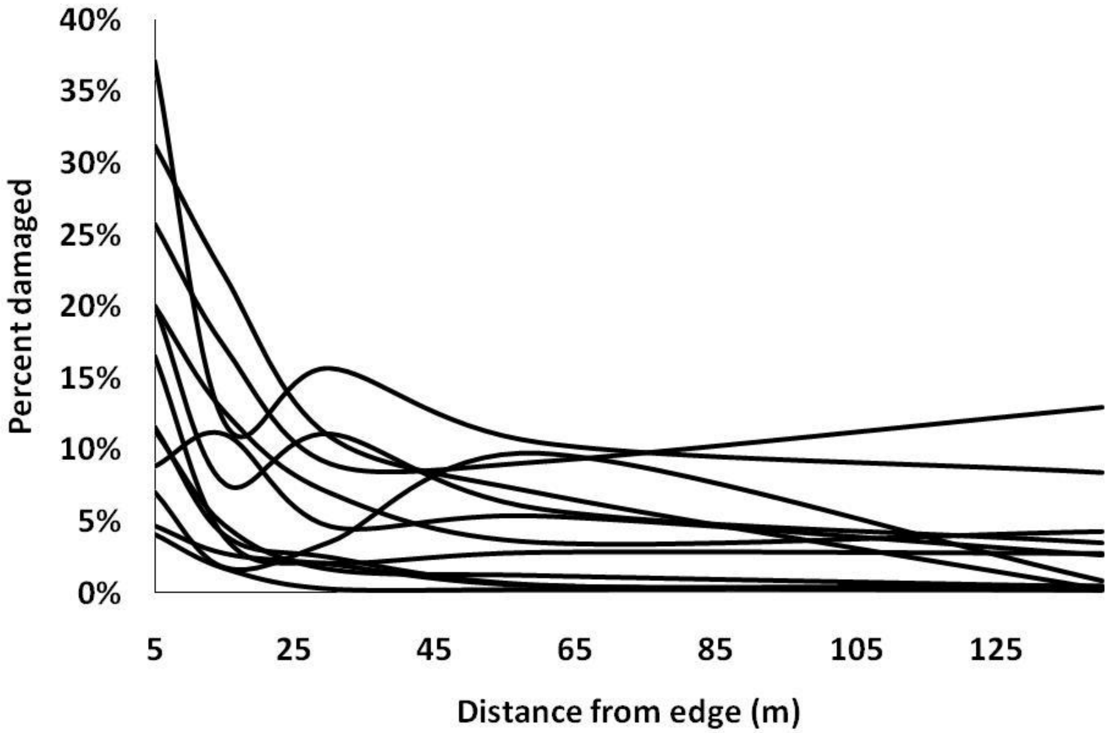

Figure 6. Percent of live plants damaged by ungulates at different distances from the field's edge in each of the fields surveyed during 2009.

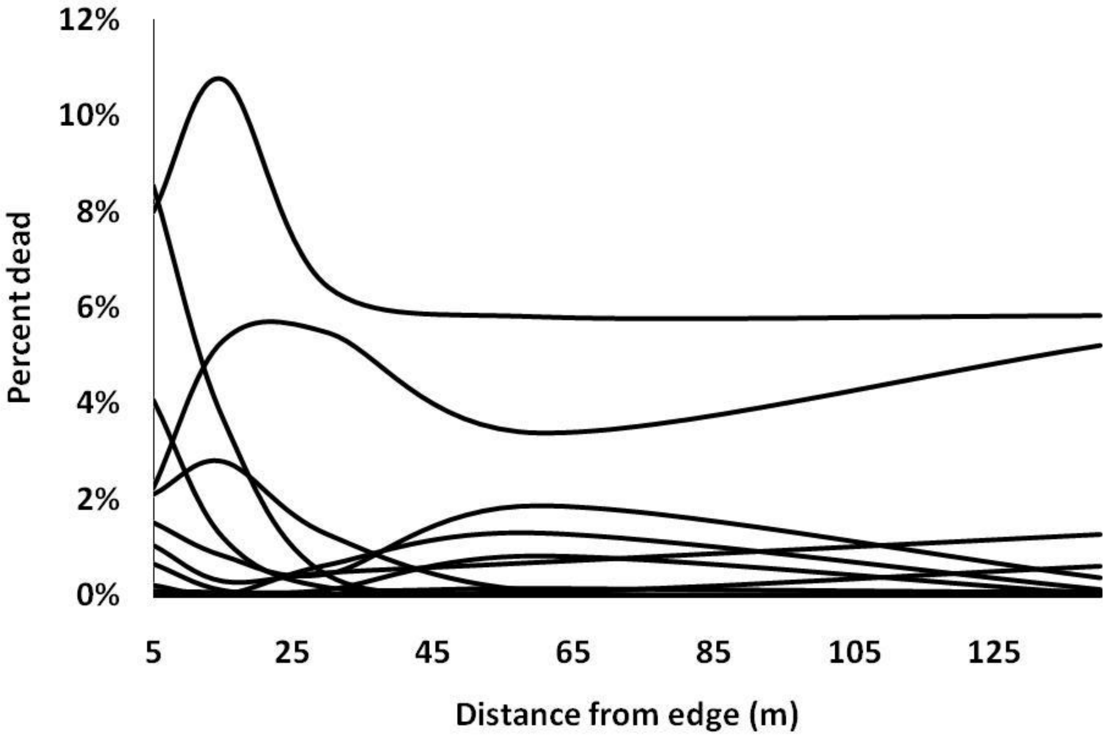

Figure 7. Percent of plants killed by ungulates at different distances from the field's edge in each of the fields surveyed during 2009.

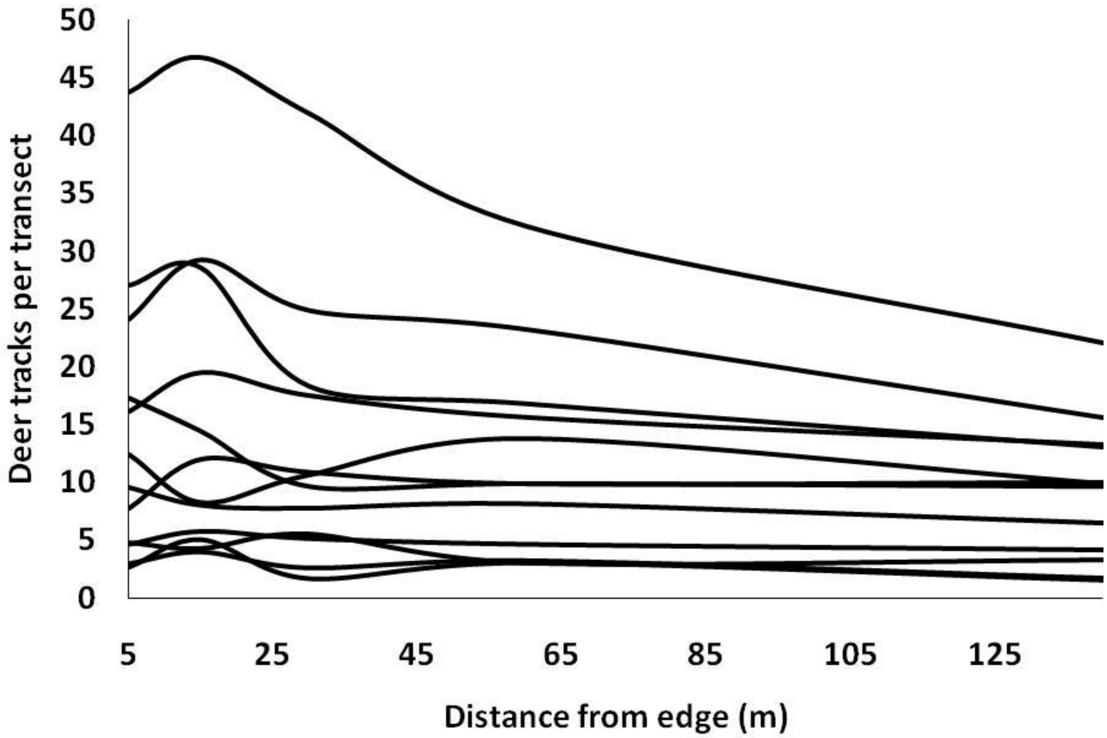

Figure 8. Number of deer tracks at different distances from the field's edge in each of the fields surveyed during 2009.

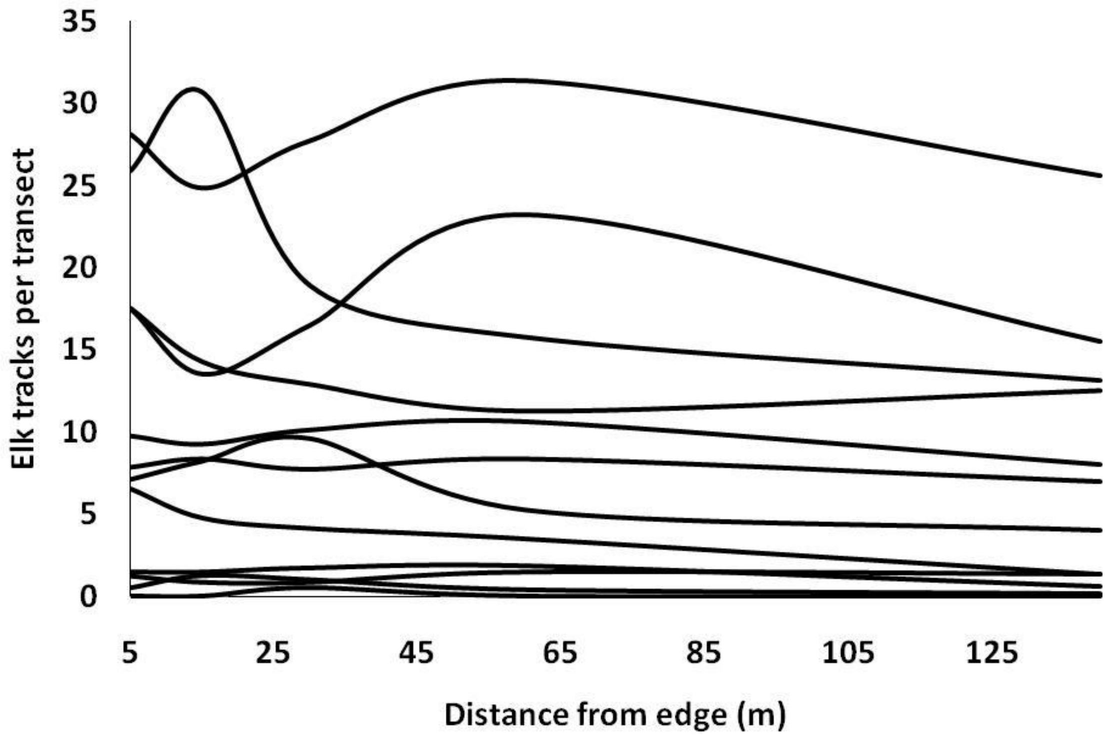

Figure 9. Number of elk tracks at different distances from the field's edge in each of the fields surveyed during 2009.

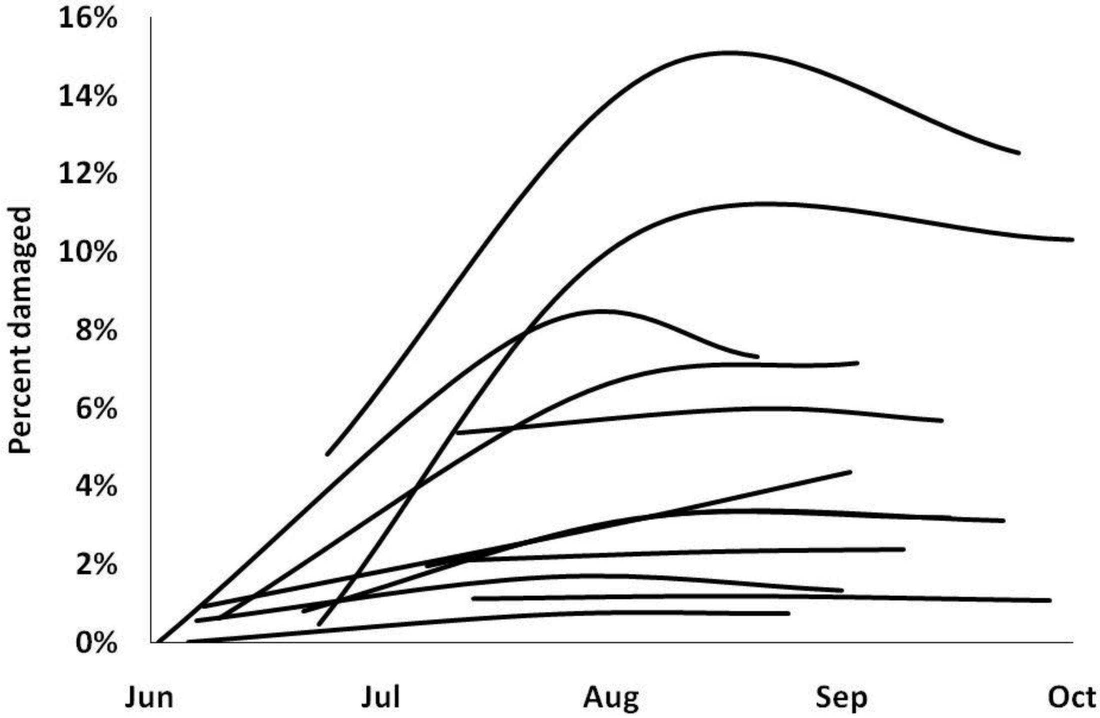

Figure 10. Percent of plants damaged by ungulates at different times during the 2009 safflower growing season.

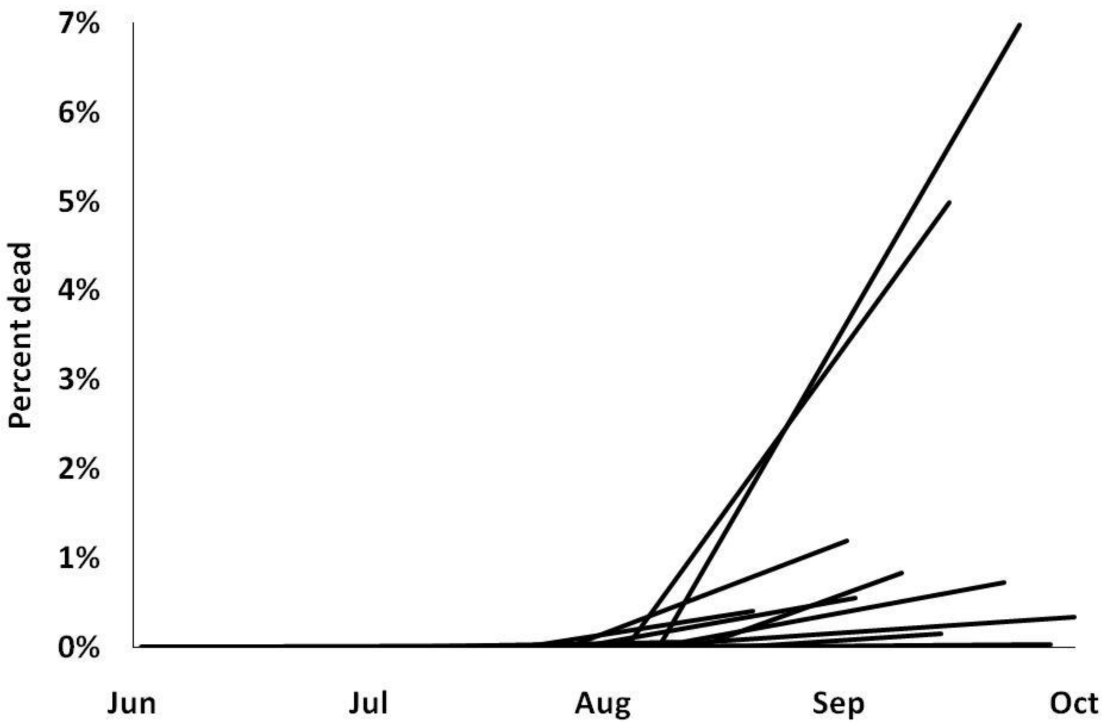

Figure 11. Percent of plants killed by ungulates at different times during the 2009 growing season.

Table 5. Number of tracks counted, average number of tracks per 50-m transect, and percent of deer tracks to elk tracks by location for 2009.

	Deer tracks		Elk tracks		Deer to elk
Location	*N*	$\bar{x}$	*N*	$\bar{x}$	%
Eastland	2,273	12.6	1,554	8.6	59
Cedar Point	4,130	4.6	651	0.7	86
Ucolo	1,330	5.5	2,362	9.8	36
Summit	882	14.1	5,378	15.1	14
Overall	8,615	6.5	9,945	7.5	41

In 2010, I examined 536,748 safflower plants for damage. Surveys were conducted on 15 fields which included 560 transects surveyed 3 times during the season for a total of 1,680 transects surveyed during 2010 (Appendix E). Overall 1.4% of plants were damaged by deer and elk (1.1% plants damaged but still living plus 0.3% killed). Yields of plants damaged but still alive were reduced by 34.5% compared to undamaged plants. Of the 0.3% of plants killed by ungulates, yields were reduced 100% because all seed pods were eaten completely or the plant was broken off at the stem. Overall yield loss calculated for fields surveyed using the exclosure method was –0.1% while the safflower count method estimated overall yield loss at 0.6% (Tables 6 and 7). Based on the exclosure method, the total value of safflower loss within all surveyed fields in 2010 was $2,713 for a loss of $4.39 / ha. The safflower count method estimated loss at $2,356, for a loss of $3.81 / ha.

Plant yields inside exclosures were not significantly different from yields outside exclosures ($F_{1,14} = 0.12$, $P = 0.74$). Plant yields from healthy plants were significantly different than yields from damaged plants (healthy plant $\bar{x} = 11.7$ g per plant; damaged plant $\bar{x} = 6.9$ g per plant; $F_{1,14} = 15.42$, $P = 0.002$).

Table 6. Exclosure method of assessing loss for 2010, showing estimated yield per ha, loss per ha, and loss for the entire field in both kg and dollars due to ungulate damage. Negative values indicate yields were lower within exclosures than paired sites where ungulates were able to forage.

	Estimated yield	Loss	Field loss	
Location	Kg per ha	Kg per ha	Kg	$
Cedar	594	–13.7	–474	$ −235
Little Butts	836	–69.5	-1,233	$ −612
W Long Draw	791	34.8	930	$ 461
Brelove	733	–57.8	–402	$ −199
Kay Johnson	1,158	52.9	5,893	$ 2,923
Big Butts	617	7.3	446	$ 221
Martinez	716	–42.9	–1,224	$ −607
Daniels	1,046	126.2	4,620	$ 2,292
Gilbroth	899	–147.3	–1,602	$ −795
Frost	455	–28.4	–1,488	$ −738
Rogers	730	–58.0	–1,149	$ −570
Carhart	1,620	275.5	8,071	$ 4,003
Johnny Funk	1,049	–43.3	–1,494	$ −741
Rich	521	–49.8	–5,384	$ −2,671
Lucious	893	–23.6	–933	$ −463
Total			5,470	$ 2,713

Table 7. Safflower count method of assessing loss for 2010, showing estimated yield per ha, loss per ha due to plants injured by ungulates (live loss), loss per ha due to plants killed by ungulates (dead loss), and loss for the entire field in both kg and dollars due to ungulate damage.

	Estimated yield	Live loss	Dead loss	Field loss	
Location	Kg per ha	Kg per ha	Kg per ha	Kg	$
Cedar	637	0.0	0.0	0	$ 0
Little Butts	3,268	7.3	6.1	258	$ 128
W Long Draw	1,192	12.1	4.6	484	$ 240
Brelove	1,616	1.1	0.0	8	$ 4
Kay Johnson	1,103	4.7	6.3	1,314	$ 652
Big Butts	1,195	3.3	8.0	742	$ 368
Martinez	1,352	4.7	1.3	187	$ 93
Daniels	1,016	7.1	3.9	438	$ 217
Gilbroth	1,021	9.8	0.2	118	$ 58
Frost	534	6.8	3.8	599	$ 297
Rogers	211	0.1	0.2	6	$ 3
Carhart	624	0.2	0.0	5	$ 3
Johnny Funk	1,264	0.3	2.2	95	$ 47
Rich	664	2.4	1.0	400	$ 198
Lucious	1,138	2.0	0.3	97	$ 48
Total				4,750	$ 2,356

Field use varied by the type of crop being grown for bucks (χ_4^2 = 33.5, $P \leq 0.001$), does (χ_4^2 = 316.2, $P \leq 0.001$), fawns (χ_4^2 = 256.2, $P \leq 0.001$), bulls (χ_4^2 = 11.5, P = 0.02) and calves (χ_4^2 = 30.0, $P \leq 0.001$; Table 7). Cow elk field use did not vary by the type of crop being grown (cow χ_4^2 = 6.7, P = 0.15). Use in safflower fields in 2010 was 1.6 times higher than expected for buck deer, 1.2 times for doe deer, and 0.7 times for fawn deer than expected based on field availability. Use in safflower fields was 2.5 times higher than expected for bull elk, and 7.3 times for calf elk.

Table 8. Ratio of observed to expected use of crop type in 2010 by deer and elk. A number greater than 1.0 signifies that the animals were selecting for that crop while a number less than 1.0 indicates avoidance of that crop. Cow elk* use by crop type was non-significant.

	Deer			Elk		
Crop type	Buck	Doe	Fawn	Bull	Cow*	Calf
Wheat	0.6	1.3	1.8	0.0	0.5	0.6
Safflower	1.6	1.2	0.7	2.5	3.5	7.3
Alfalfa	1.6	11.0	12.1	0.0	0.0	0.0
Pinto beans	3.9	0.4	0.0	0.0	0.0	0.0
CRP	1.0	0.6	0.2	1.6	1.0	0.3

Regression analyses were performed to explain variation in damage among fields. The top 2 models for predicting ungulate damage in 2010 were distance from the canyon edge to field * percent of field bordered by wheat fields (R^2 = 0.39, F = 3.81, P = 0.05) and distance from the canyon edge to field * field edge to volume ratio (R^2 = 0.31, F = 2.72, P = 0.11).

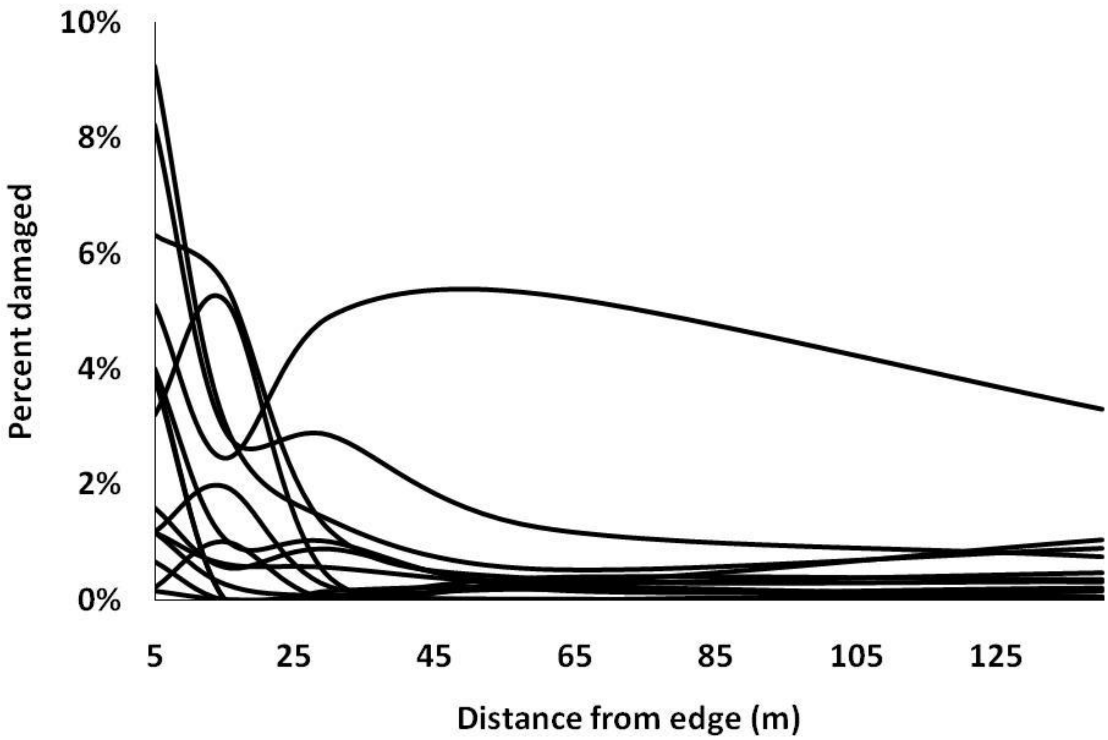

Figure 12. Percent of live plants damaged by ungulates at different distances from the field's edge in each of the fields surveyed during 2010.

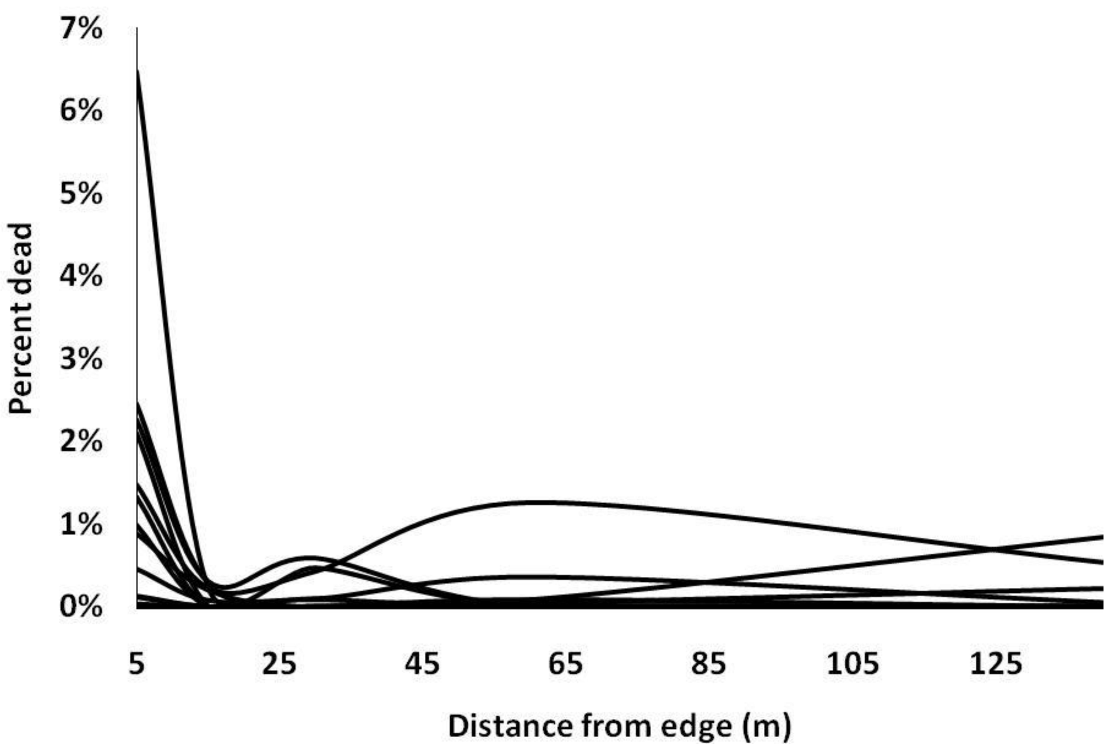

Figure 13. Percent of plants killed by ungulates at different distances from the field's edge in each of the fields surveyed during 2010.

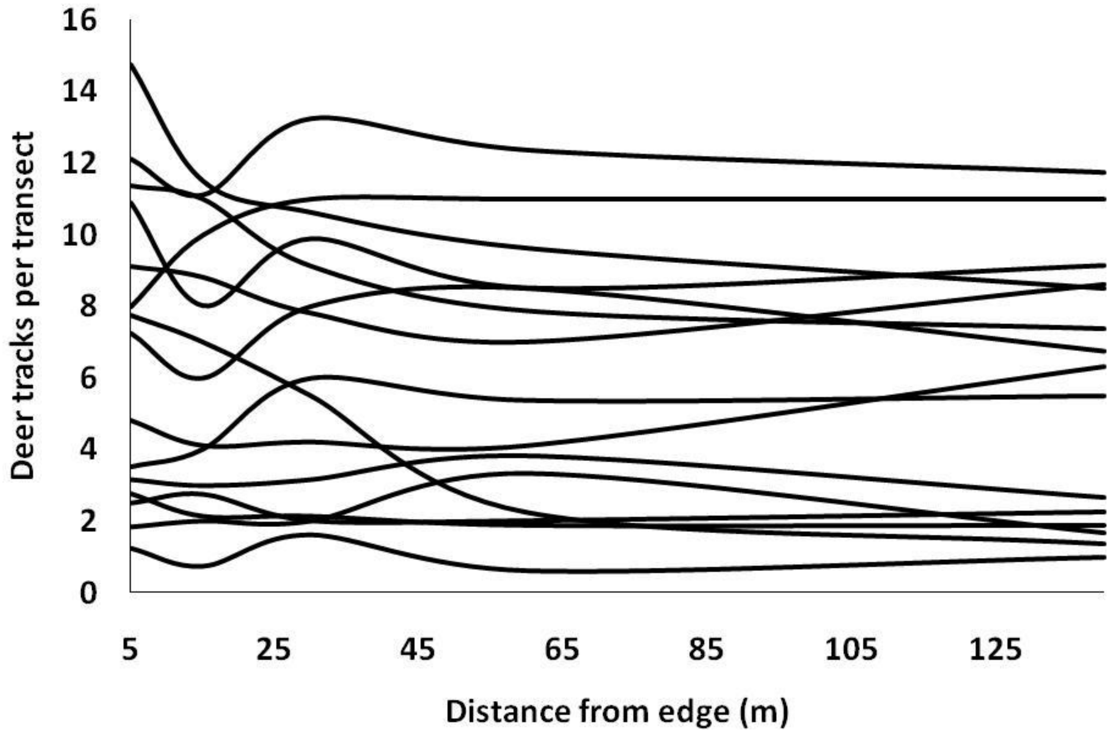

Figure 14. Number of deer tracks at different distances from the field's edge in each of the fields surveyed during 2010.

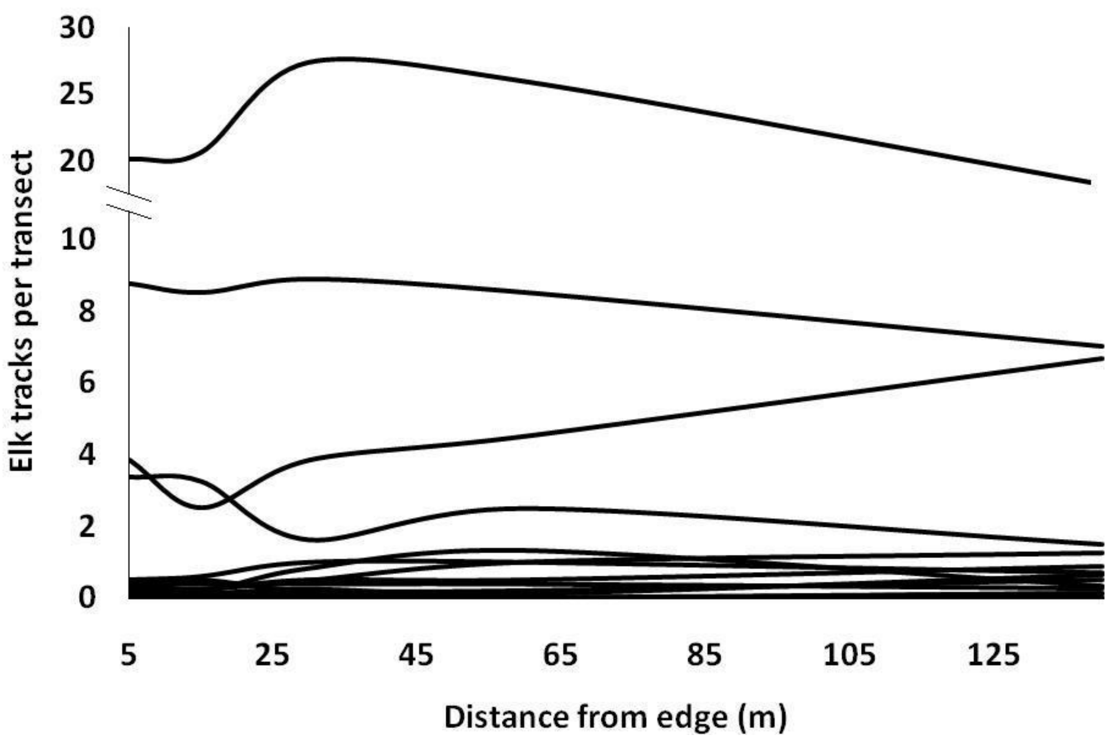

Figure 15. Number of elk tracks at different distances from the field's edge in each of the fields surveyed during 2010.

Most damage to live plants occurred during June to August when plants were still green and palatable (Fig. 16). Damage to plants in mid-August through October often resulted in the plant's death because plants began to dry out and become brittle (Fig. 17). Live plant damage ranged from 0.0% in Cedar to 4.0% in Frost, while plants killed ranged from 0.0% in Cedar to 0.7% in Frost. I was unable to distinguish between plants eaten by deer versus elk most of the time (60%); often tracks near a damaged plant were unclear, washed away, or were from both deer and elk. I was only able to positively identify that deer had eaten 21% of damaged plants counted, while elk had eaten 19%. For plants stepped on, 27% were stepped on by deer, 54% were stepped on by elk, and 19% were stepped on by unknown. For this reason, I estimate that deer caused 50% of the damage while the remaining 50% was caused by elk. Overall, 35% of tracks we counted in the fields were from elk and 65% were from deer (Table 9).

Table 9. Number of tracks counted, average number of tracks per 50-m transect, and percent of deer tracks to elk tracks by location for 2010.

	Deer tracks		Elk tracks		Deer to elk
Location	*N*	$\bar{x}$	*N*	$\bar{x}$	%
Eastland	1,653	6.3	232	0.9	88
Cedar Point	2,881	3.2	392	0.4	88
Ucolo	425	1.8	625	2.6	40
Frost	467	3.9	1,659	13.8	22
Rich	416	2.8	204	1.4	67
Overall	5,854	3.5	3,132	1.9	65

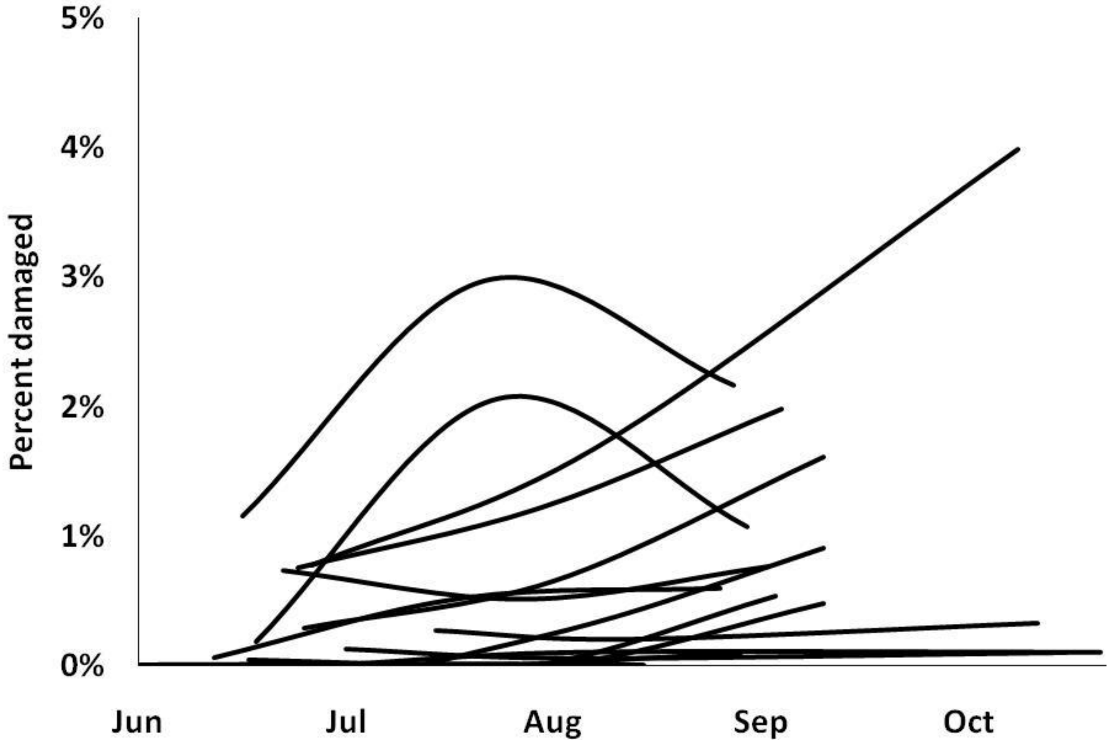

Figure 16. Percent of plants damaged by ungulates at different times during the 2010 safflower growing season.

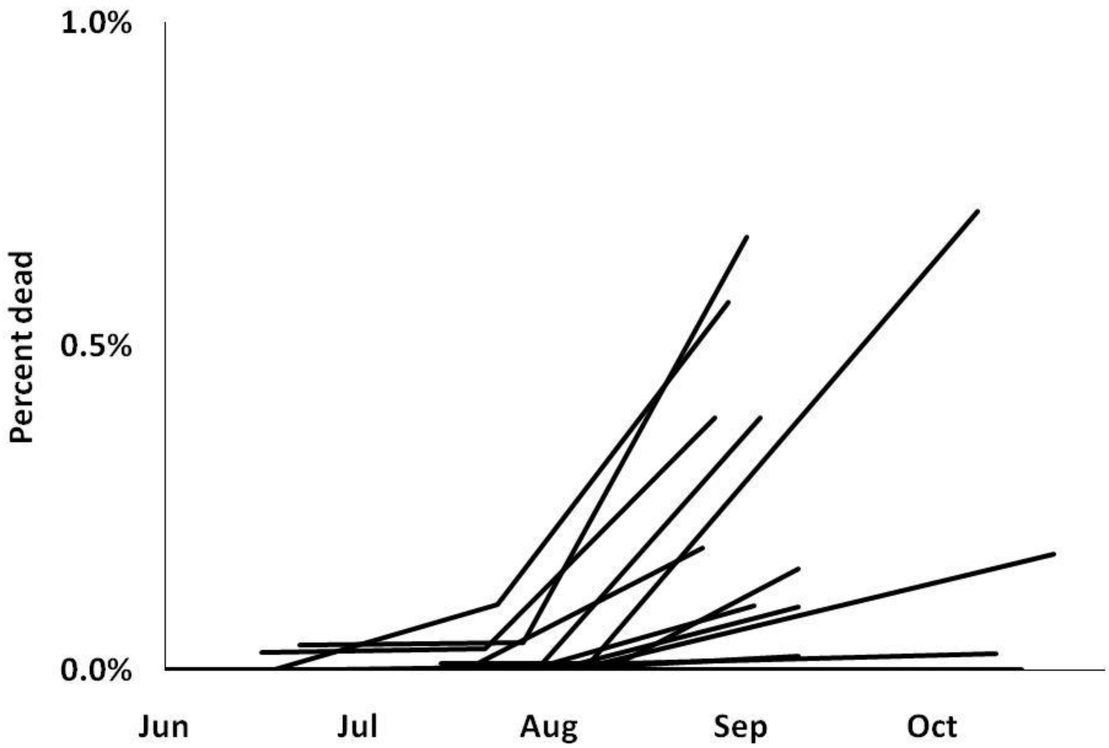

Figure 17. Percent of plants killed by ungulates at different times during the 2010 safflower growing season.

Safflower Damage Survey

I received 8 responses for a response rate of 66%. Respondents had grown safflower for an average of 20 years (range 10–25 years). All grew high-oleic oilseed safflower, and 70% grew a single variety (S-208), which is the standard variety grown for birdseed. All indicated they had experienced safflower crop damage by ungulates. Perceptions of yield losses due to wildlife were 20% ($\bar{x}$ = 12% elk, 7% deer, 1% other wildlife). Farmer perceptions of ungulate damage were 5.2 times higher than damage I measured during 2009 ($t_{18} = 5.97$, $P \geq 0.001$). There was also no correlation between farmer perceptions and field estimates of damage ($R^2 = 0.005$; Fig. 18). Respondents indicated that they were willing to tolerate yield losses of 4% for deer and 3% for elk. Half of the respondents indicated that deer damage to safflower has increased over the last 10 years, the other half indicated that it has stayed the same, and none indicated that it had decreased. Respondents (70%) reported an increase in elk-related damage over the past 10 years, 30% indicated that it had stayed the same, and none indicated that it had decreased. When asked when deer and elk damage occurs, 53% indicated September or October (7% May, 18% June, 14% July, 7% August, 36% September, 18% October). When asked about possible changes to deer management, 83% indicated hunters should be given more permits, 83% indicated that UDWR should kill less deer through sharp shooting by UDWR employees, 60% indicated that the UDWR should harass deer less at night, and 43% indicated that farmers should receive more deer permits. When asked about possible changes to elk management, 86% indicated that farmers should receive more elk permits, 83% indicated hunters should be given more permits, 57% indicated that UDWR should kill less elk through sharp shooting by UDWR employees, and 57%

indicated that the UDWR should harass elk less at night. All respondents indicated they hunted, that others in their family hunted, and 83% had neighbors that hunted. Forty-three percent allowed the public to hunt deer on their land while 71% allowed the public to hunt elk. Three farmers were members of a local CWMU that sell tags to hunt deer and elk within the CWMU (Messmer et al. 1998, Utah 1999), and one respondent who was not a member of the CWMU leased his land for deer hunting.. When asked if changes to farming practices have been made as a result of deer and elk damage, 71% indicated that they no longer planted sunflowers. Only 1 respondent felt adequately compensated for deer and elk damage to his safflower field. This respondent, a member of a CWMU, was the only respondent that indicated damage by deer and elk had not increased, and was willing to tolerate 5% deer damage, and 5% elk.

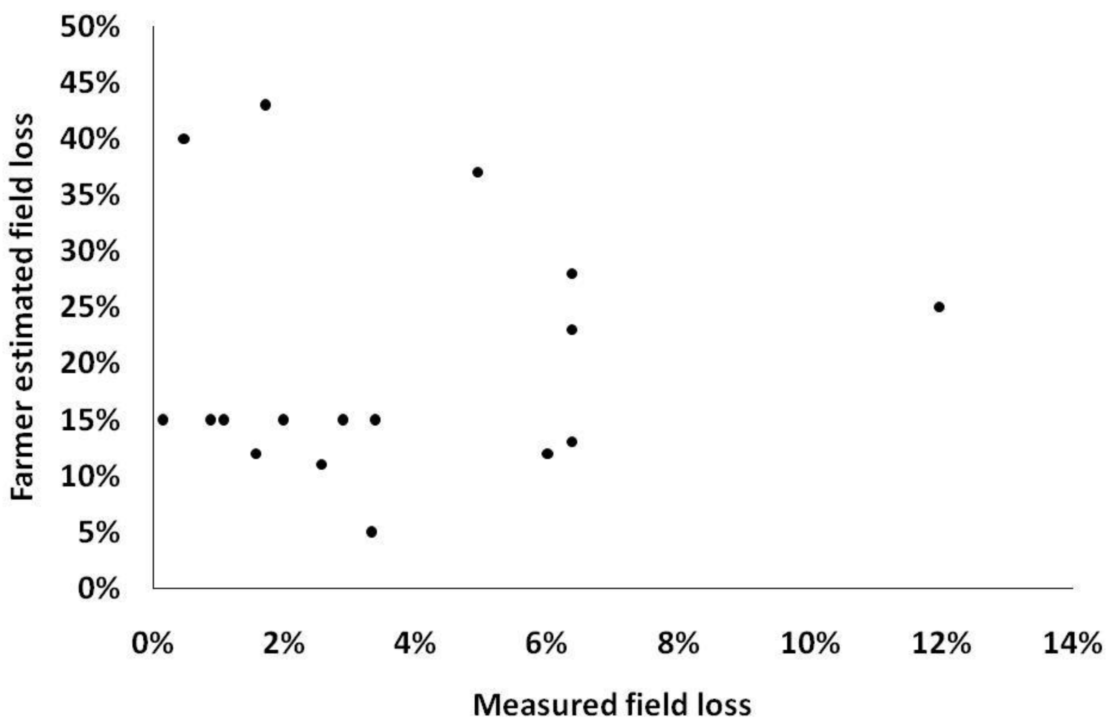

Figure 18. Safflower farmer estimates of safflower loss to ungulates for 2009 as reported on safflower damage survey versus my estimates of ungulate damage based on field sampling.

DISCUSSION

Damage from ungulate herbivory early in the season (June to July) often resulted in removal of >75% of the plant's aboveground biomass. Plants at this time were still green and palatable, had not developed protective spines, and were able to grow back following herbivory. From late-July to mid-August plants began to develop seedheads, and protective spines. Seedheads were extremely spiny from mid-August until harvest; yet contained high oil and protein levels (Berglund et al. 2007). Browsing by ungulates from seed set in mid-August until harvest was generally on ripening energy rich seedheads. From September to October, plants began to dry out making them vulnerable to damage from ungulate browsing and movements. When plants were completely dry, usually 1–2 weeks prior to harvesting (late-September to November), plants and seedheads became brittle and were susceptible to shatter-loss caused by ungulate movements.

While the estimated population of ungulates did not change in areas east of Highway 191 from 2009 to 2010 (J. Shannon, personal communication), the number of ungulates observed within fields, and tracks counted per transect declined drastically between years. In areas closed to bull elk hunting (north of Highway 491), the proportion of elk tracks to deer tracks along field transects remained similar from 2009 to 2010. In areas open to bull elk hunting (south of Highway 491) during 2009 and 2010, I observed a decrease in proportion of elk tracks to deer tracks along field transects. The opening of bull elk hunting (south of Highway 491) in the fall of 2009, may have educated elk to avoid fields where they were exposed.

In 2009, most precipitation arrived during the early portion of the growing season from May through June; in 2010, most precipitation arrived from July through October. The amount of precipitation differed between 2009 and 2010, with 2010 receiving 1.4 times more rain than 2009. Safflower plants have an extensive taproot system allowing plants to remain green late in the summer despite dry conditions. When surrounding crops and rangeland vegetation dried out in 2009, safflower fields were the only crop in the area that remained green late in the summer. In 2010, late summer rains, and an increase in total rain, kept vegetation green and allowed ungulates to forage in areas away from fields where alternative forage and water were plentiful. Surrounding crops and rangeland vegetation never dried out in 2010.

Factors that influenced field damage in 2009 were different from those in 2010. The best model for 2009 included distance to canyon from field edge and the percent of a field bordered by a fallow field, while the best model for 2010 included distance to canyon from field edge and the percent of a field bordered by a wheat field. Factors that did not influence the amount of damage a field received included percent of weeds between rows, and the percent of the field's edge that was bordered by county roads, pinion-juniper, sagebrush, CRP fields, bean fields, other safflower fields, and sunflower fields. Other studies have shown that crop damage is negatively related to field size, with larger fields having lower damage rates (Flyger and Thoerig 1962, Shope 1970, DeVault et al. 2007). However, other authors have found an inconsistent relationship between field size and rate of damage (DeCalesta and Schwendeman 1978, Braun 1996).

Methods to evaluate ungulate damage varied in their effectiveness. The exclosure method suffered from high intra-field variability in ungulate damage because of small areas sampled (8 exclosures; 8 paired sites) relative to the size of the fields. For example in Summit F2, I identified that 8.2% of plants were damaged by ungulates yet yields inside exclosures were less than yields outside in paired sites where ungulates were free to forage. Another problem with the exclosure method was that I was unable to erect exclosures until the farmer stopped cultivating the field in late-July because I did not want to interfere with the farmer's cultivation equipment. Hence, this method did not account for any losses early in the growing season prior to when exclosures were erected. Twenty-two of 92 exclosures erected during 2009 and 2 of 120 during 2010 received ungulate damage prior to exclosure erection. The exclosure method required extensive time and energy to place and remove exclosures, clip, thresh, dry, sift, and weigh samples, and to store exclosure materials. Many locations (55%) within fields that had been selected for exclosures were inaccessible from a road and required walking 1–2 km. Time required erecting exclosures and counting plants within exclosures varied from 15–20 min per exclosure and walking time varied from 5–60 min, for a total time of 20–80 min per exclosure. Removing exclosures and clipping plants within exclosures and paired sites generally varied from 35–100 min per exclosure, also dependent mainly on travel time between the road and the exclosure. Following clipping, a threshing machine was used to remove seeds from clipped seedheads; a 3-person team was able to thresh approximately 30 samples per hr. Following seed drying, each sample was sifted by hand to remove foreign materials which required 5–45 min per sample, dependent on the sample's size and quantity of foreign material present.

Counting plants was a more effective and practical method for assessing safflower depredation than the exclosure method. I counted plants within 40 transects in each field or an area of 1820 m^2 per field. Plant counts coupled with area calculations from satellite imagery allowed me to estimate the total number of plants injured or killed by deer and elk in each field. By clipping and comparing healthy plants to damaged plants, I determined that yields were reduced 36% per damaged plant.

Yield loss estimates per plant should overestimate loss because healthy plants adjacent to injured or killed plants should compensate for losses by producing increased yields in response to greater availability of nutrients, moisture, and sunlight (Belsky 1986). Sadras (1996) found that healthy cotton plants were able to fully compensate for their damaged neighbors. Coulter et al. (2011) observed that corn was able to partially compensate for stand reductions of 50% with observed yield losses of 17% by increasing per-plant grain yield by 37–46%. Despite these findings, Nault et al. (1995) found that potatoes were unable to compensate for their damaged neighbors. Our results indicate that compensatory growth from neighboring plants did not occur in safflower. The reason for this was because ungulate damage within fields was not uniformly distributed; damaged plants were often located next to other damaged plants, preventing adjacent plants from growing larger and compensating for their damaged neighbors.

Identifying ungulate damage from damage caused by natural factors and normal farming operations is often difficult. I have included in the appendix a guide for identifying ungulate damage and how to locate random points within fields (Appendices B and C). To identify damage caused by ungulates, plant counts would only need to be conducted at the end of the growing season, 1–2 weeks prior to harvest. The time required to count plants within a 50-m transect varied from 20–40 min per transect; or 15–25 hrs per field. To simplify future safflower damage assessments, I recommend treating the entire field as a single unit and randomly placing points throughout the field where plant counts can be conducted. The number of random points located within each field will depend on it size, level of ungulate damage received, and the farmer's tolerance of damage; I recommend using 20–30 random points per field. At each of the 20–30 random points, plants should be counted within a 50-m transect along the closest row to determine the number of plants damaged and still living, plants killed, and the total number of healthy plants. Harvested yield and market value of safflower can be obtained from docket tickets obtained by farmers at time of sale. Individual yields and hectares planted in safflower can be compared to average safflower yields county-wide and hectares planted in safflower by contacting the local Farm Service Agency office. The following equations can be used to calculate damage expressed as proportion of yield lost due to ungulates, and dollars lost:

Damage = (number of damaged plants still living / number of healthy plants) × 0.36 yield reduction per live plant) + (number of plants killed / number of healthy plants).

Loss $ = damage × harvested yield × market value $.

Farmers' perceptions of ungulate damage were much higher than levels that we measured from field sampling. Because safflower plants are highly branched, thistle-like, and grow up to 1.2 m tall, farmers generally do not to venture into fields; rather farmers survey their fields from the edges. Damage by ungulates was concentrated along field edges providing farmers with an elevated perception of ungulate damage.

Other studies on ungulate crop depredation indicate that grazing does not decrease winter wheat yield (Sprague 1954, Austin and Urness 1995, Brelsford et al. 1998). Grazing of cereal crops by livestock in fall and spring during the tillering growth stage has been a common practice throughout most of the U. S. Farmers who do so receive forage benefits of livestock grazing while experiencing no loss in grain yields (Swanson 1935). Mule deer consume 2.4 kg of alfalfa per day (Austin et al. 1998). Intake rates of alfalfa per unit of body weight were found to be very similar between deer and elk (Austin and Urness 1987). Hence, elk are estimated to consume 9.6 kg of alfalfa per day based on a deer to elk weight ratio of 4:1 (Anderson et al. 1974, Thorne 1976, Austin et al. 1998). In contrast to ungulate grazing on cereal crops, herbivory by ungulates causes serious reductions in yield of sunflowers (Kamler et al. 2009). Ungulate damage to sunflower from fallow deer (*Dama dama*) and roe deer (*Capreolus capreolus*) was found to be greatest early, 0–30 days prior to flowering; with yield reductions estimated at approximately 30% in areas near the forest edge (Kramer et al. 2009). Pilson and Decker (2002) simulated damage by clipping 13–30% of sunflower leaves following flowering with observed yield losses of <10% per damaged plant. Moriondo et al. (2003) simulated damage by clipping 50% of leaves, 24–85 days after plant emergence and observed yield losses of <25% per damaged plant. Deer damage to soybeans occurs early in plant growth (DeCalesta and Schwendeman 1978) with yield losses observed only when plants are defoliated >67% (Garrison and Lewis 1987).

MANAGEMENT IMPLICATIONS

My results indicate that damage by ungulates to safflower was relatively low, despite perceptions of farmers that damage was higher. I found that damage varies from year to year presumably because of changes in precipitation and elk management. Damage also varies across fields.

I found that counting safflower plants was the best and most accurate method to assess safflower damage estimates. Plant counts can be conducted once, 1–2 weeks prior to harvesting to determine the ratio of damaged to healthy plants. I have included in the appendix guides for identifying ungulate damage and how to locate random points within fields (Appendices B and C). Using the ratio of damaged to healthy plants, coupled with harvested yields and the value of safflower, managers will be able to accurately compensate for safflower damage in the future.

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APENDICES

APPENDIX A. SAFFLOWER DAMAGE SURVEY

USU IRB Approval: April 19, 2010
Approval Terminates: 04/18/2011

Protocol #2614

IRB Password Protected per IRB

UtahStateUniversity

February 1, 2010

Dear Respondent,

We are in the Wildland department at Utah State University and are conducting a research study of safflower damage by deer and elk in San Juan County, Utah. This research project is funded by the Utah Division of Wildlife Resources [UDWR]. The objective of this research project is to understand current damage levels to safflower fields caused by deer and elk and current landowner perceptions of damage.

Enclosed with this letter is a brief questionnaire. We are asking you to complete the questionnaire and send it back to us in the enclosed postage-paid envelope. We hope you will take a few minutes to complete this questionnaire. Without the help of people like you, research on damage to safflower could not be conducted.

Your participation is voluntary and there is no penalty if you do not participate. Your responses will not be identified with you personally, nor will anyone be able to determine which landowner you are. Nothing you say on the questionnaire will in any way influence any compensation you may receive. This research is considered minimal risk. Results from this research may help managers obtain information about damage levels, evaluate the effectiveness of various damage reducing methods and assess the social acceptability of various management strategies.

If you have any questions or concerns about completing the questionnaire or about participating in this study, you may contact Dr. Michael Conover at (435) 797-2436 or at mike.conover@usu.edu or Michael Haney at (801) 851-0987 or at michael.haney@aggiemail.usu.edu.

The Institutional Review Board for the protection of human participants at USU has approved this research study. If you have any pertinent questions or concerns about your rights or a research-related injury, you may contact the IRB Administrator at (435) 797-0567 or email irb@usu.edu. If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

Sincerely,

Michael Conover
Michael Conover, Ph.D.
Department of Wildland Resources

Michael Haney
Master's Candidate
Utah State University

Utah State University

Perceptions of Utah Safflower Growers About Wildlife Damage to Their Safflower Crops: Survey Questions

Michael J. Haney, Department of Wildland Resources, Utah State University, Logan, UT 84322, USA
Michael R. Conover, Department of Wildland Resources, Utah State University, Logan, UT 84322, USA

How many years have you been growing safflower?
____

What variety of safflower do you grow?
____

What percent of your crop do you feel was lost due to damage by deer, elk or other wildlife species?

	Deer	Elk	Other wildlife	Location of field
Field 1	____%	____%	____%	________________________
Field 2	____%	____%	____%	________________________
Field 3	____%	____%	____%	________________________
Field 4	____%	____%	____%	________________________
Field 5	____%	____%	____%	________________________
Field 6	____%	____%	____%	________________________
Overall	____%	____%	____%	________________________

Over the last 10 years do you feel that damage by deer to your safflower crop is increasing, decreasing, or staying the same (circle the correct answer)?

Over the last 10 years do you feel that damage by elk to your safflower crop is increasing, decreasing, or staying the same (circle the correct answer)?

During which month last year did you feel damage by deer was the highest?

May June July August September October

During which month last year did you feel damage by elk was the highest?

May June July August September October

What level of damage (% loss) would you be willing to tolerate for damage caused by
Deer______%
Elk______%
All wildlife combined_____%

What changes would you like to see for managing deer in San Juan County? (Circle either more, less, or same based on what changes you would like.)

Deer depredation permits for landowners. (More, less, or same number).
Deer killed by Utah Division of Wildlife Resources employees. (More, less, or same number).
Deer permits for hunters. (More, less, or same number).
Effort at harassing deer at night by DWR employees. (More, less, or same amount).

What changes would you like to see for managing elk in San Juan County? (Circle either more, less, or same based on what changes you would like.)

Elk depredation permits for landowners. (More, less, or same number).
Elk killed by DWR employees. (More, less, or same number).
Elk permits for hunters. (More, less, or same number).
Effort at harassing elk at night by DWR employees. (More, less, or same amount).

Do you or members of your immediate family hunt (circle correct answer)? Yes, No.

Do you allow others to hunt on your land? Yes, No.

Do adjacent landowners allow hunting? Yes, No.

Have you made changes to farming practices as a consequence of deer damage? Yes, No.

If so what changes have you made?

Have you made changes to farming practices as a consequence of elk damage? Yes, No.

If so what changes have you made?

Would you allow the public to hunt deer on your private land in order to minimize damage caused by deer? Yes, No.

Would you allow the public to hunt elk on your private land in order to minimize damage caused by elk? Yes, No.

Are you a member of a Cooperative Wildlife Management Unit? Yes, No.

If so, does the money you receive compensate you for your losses? Yes, No.

Do you lease your land for hunting? Yes, No.

If so, does the money you receive compensate you for your losses? Yes, No.

If you participated in the safflower study in 2009 do you have any questions about how the study was conducted?

APPENDIX B. GUIDE FOR IDENTIFYING UNGULATE DAMAGE

Safflower plants become damaged from ungulate browsing and movements, insects, and during normal farming operations. Plants browsed early in the growing season (June to July) are generally eaten flush with the ground with the apical meristem of the plant removed (Fig. 19). Plants during this time of the growing season remain green and palatable, have not developed protective spines, are able to grow back, and are rarely damaged by ungulate movements. Plants are extremely resilient during their early stages of growth (emergence to stem elongation); plants during this part of the growing season rarely die from ungulate damage. From late-July to mid-August plants begin to develop seedheads, and protective spines; browsing during this time occurs to both the seedheads and vegetative plant parts. During September, plants begin to desiccate, becoming vulnerable to damage from ungulate movements because of their branching structure and increased size. Plants damaged from ungulate movements during this period are difficult to identify; often plants appear healthy despite having multiple broken branches. From mid-September to October, browsing occurs mainly on seedheads; plants missing seedheads at this time have been browsed. Two weeks prior to harvesting (late-September to November), plants fully desiccate, seedheads open slightly exposing seeds within, and plants become brittle. Plants during this time are susceptible to wind damage and shatter-loss from ungulate movements (Fig. 20). Plants are considered dead if all seedheads have been removed by browsing or if the main stem has been broken off from being stepped on by ungulates, because these plants will not produce seedheads that can be harvested by a combine.

Army cutworms (*Euxoa auxiliaries*) and pale western cutworms (*Agrotis orthogonia*) cause considerable damage to safflower fields early in the growing season (June to mid-July). Adult army cutworm moths can lay from 1,000 to 3,000 eggs in the soil of newly planted or tilled cropland from late-August to October (Hein et al. 2006). Pale western cutworm moths can lay from 250 to 300 eggs. Army cutworm eggs hatch shortly after being exposed to moisture, larvae continue to feed as long as temperatures are favorable, and overwinter in the soil. Pale western cutworms hatch during warm spells in early fall or winter, but most hatch early in the spring when temperatures are favorable. Feeding by larvae continues when temperatures increase in the spring. Larvae are caterpillar-like, tan to green in color and attained lengths up to 40 mm (Fig. 21). Army cutworms climb plants and "graze" on aboveground portions of plants while pale western cutworms primarily damage plants below the soil surface. Cutworms cut the plant stem off below the soil surface by notching or completely severing the stem. If plants are easily pulled from the soil and no roots are attached, damage is classified as being from a pale western cutworm. Damaged plants that survive exhibit symptoms late into the growing season; plants are stunted, somewhat yellow, have smaller seed pods, and leaves near the crown of the plant are smaller with narrow leaf margins (Fig. 22). Damage is often concentrated along a row or extended in a circular pattern. Severe infestations reduce safflower stand density, and may completely destroy entire safflower fields. In 2010, I observed 3 entire safflower fields that were destroyed by cutworm damage (approximately 120 ha); numerous landowners cultivated out entire sections of fields due to extensive cutworm damage (Fig. 23).

Safflower plants infected by fungal pathogens are yellow, stunted (¼ to ½ the size of healthy plants), and have thick leaf cuticles with necrotic leaf margins (Fig. 24).

Damage by farming operations includes damage during cultivation, spraying, and if landowners drive through fields. Damage from cultivation equipment occurs primarily on turn-rows near the field edge where straight rows meet rows planted perpendicular to them. Plants damaged from being run over by the tractor can be detected because identical damage will appear a few rows over where the other tire ran over the row. Plant damage when cultivation equipment cuts plants below the soil surface can be detected when entire rows are missing with identical damage occurring on all adjacent rows. Damage from spraying or overspray often appears across several rows and matches the width of the sprayer. It often starts and stops sharply so that the dead or injured plants are in a rectangular area. Plants damaged from spraying will appear burned, wilted, bent, and generally will die (Fig. 25).

Figure 19. Apical meristem removed following deer herbivory, June 28, 2009.

Figure 20. Extensive elk damage, 1 week prior to harvest when plants are extremely susceptible, October, 8 2009.

Figure 21. Larvae of the army cutworm (bottom) and the pale western cutworm (top) (Hein et al. 2006).

Figure 22. Plants damaged by cutworms that survived exhibit symptoms late into the growing season; plants are stunted, somewhat yellow, have smaller seed pods, and leaves near the crown of the plant are smaller with narrow leaf margins, October 7, 2009 .

Figure 23. Cutworm damage reduces safflower stand density and extensively damaged areas are often cultivated out, August 25, 2010.

Figure 24. Safflower plant in foreground is infected by a fungal pathogen; plant is yellow, stunted, and has thick leaf cuticles with necrotic leaf margins, August 8, 2010.

Figure 25. Plants damaged from spraying or overspray are in a circular pattern, appear burned, wilted, bent, and generally die, August 25, 2010.

APPENDIX C. LOCATING RANDOM POINTS WITHIN FIELDS

To randomly select points within each field print a map of each field and overlay the map with the included transparency grid (Fig. 26). Use a random number generator to select x and y coordinates on the grid, mark randomly selected points on the map. If the coordinates fall outside field areas on the map, re-select new coordinates until the desired number of points are selected. To determine the scale of each grid dot, measure the distance between 2 points on the edge of the field that you can see in the map, count the number of grid dots between points, and divide the distance between the 2 points by the number of grid dots between them on the map. Use the map, grid, and a laser rangefinder to locate the location of points on the ground.

To create random points that can be downloaded to a GPS unit use ArcGIS to construct a polygon around a field using the feature editor. Select the created polygon and use the create random points (data management) tool to create a shapefile containing random points and their coordinates within the selected polygon. These points can be then transferred to a GPS unit using DNR Garmin.

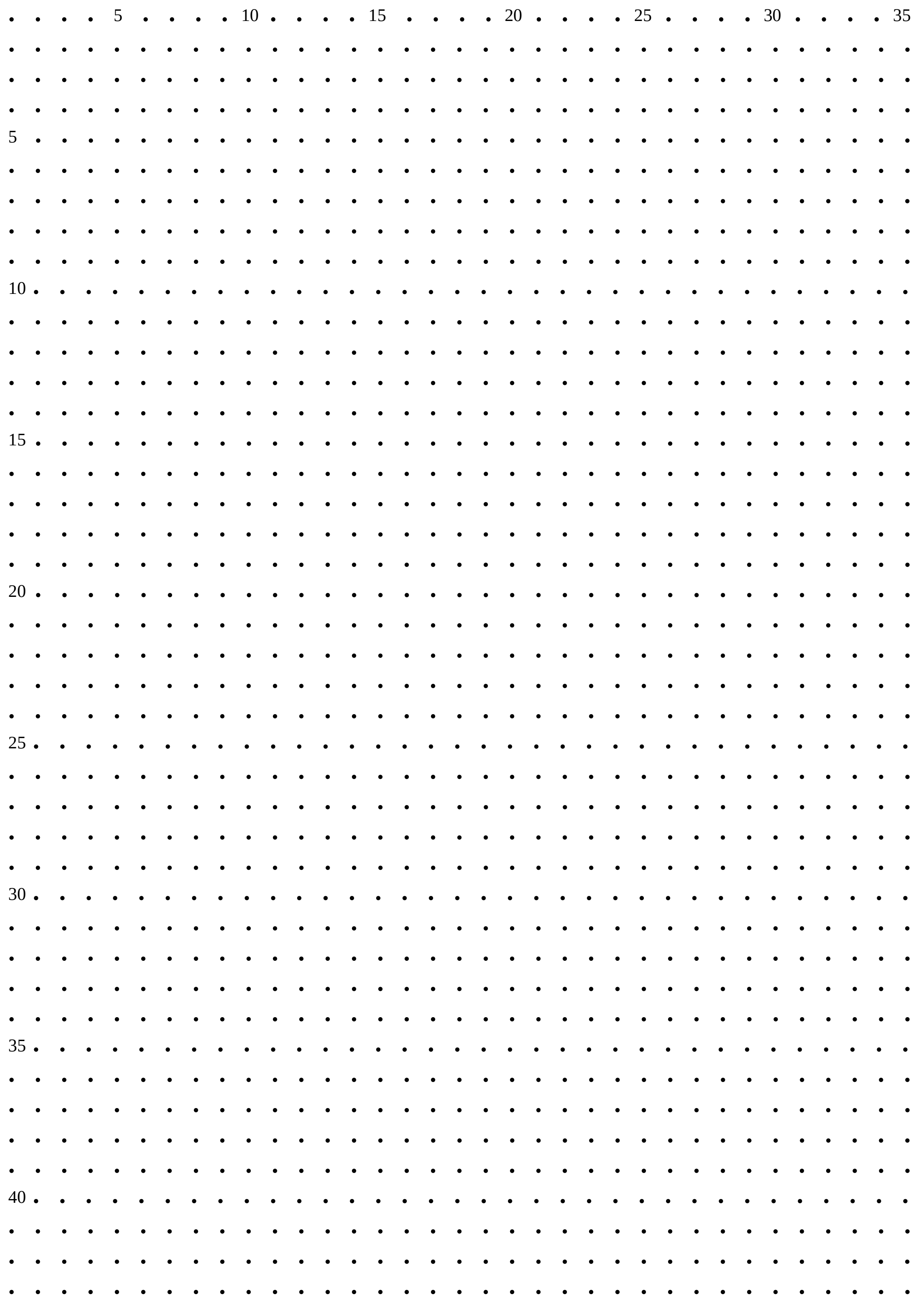
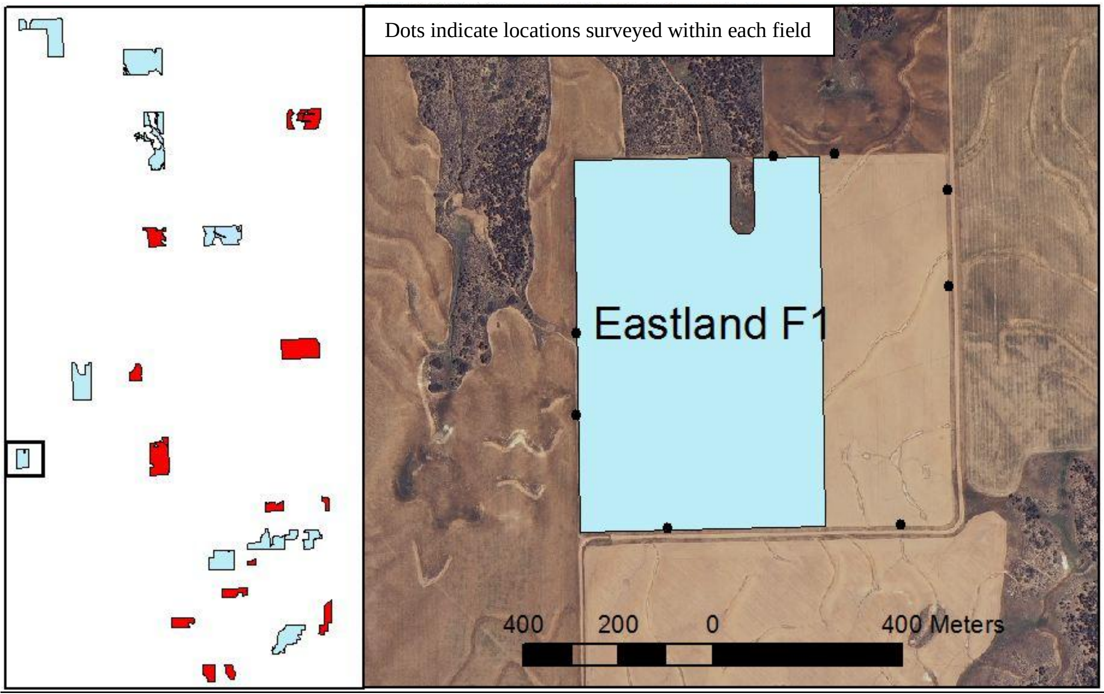


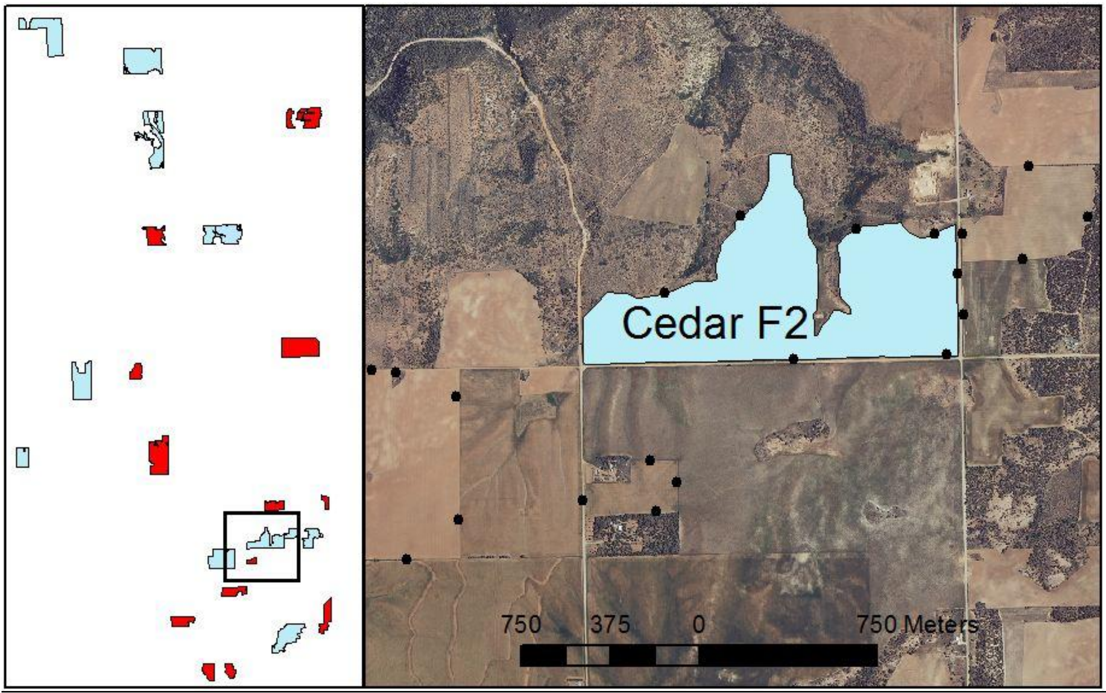
Figure 26. Transparency grid that can be used for selecting random points in a field.

APPENDIX D. FIELDS SURVEYED IN 2009



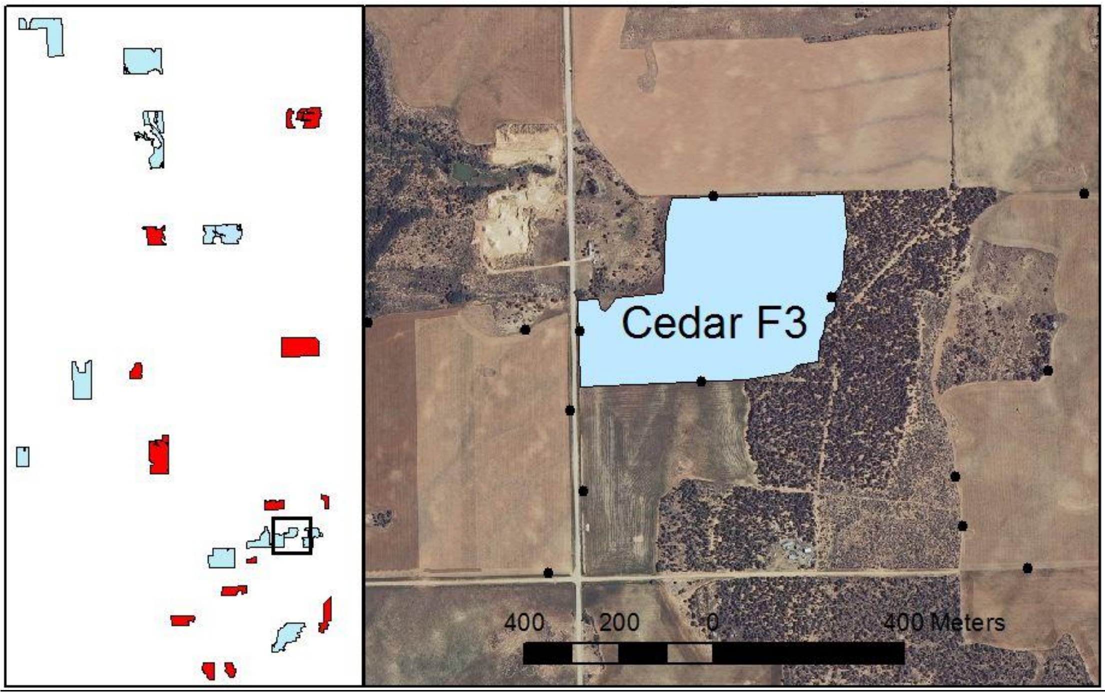
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Eastland F1	0-10m	28629.0	172669.2	0.0	0.0	4	24
6/11/2009	10-20m	27776.1	167069.9	0.0	0.0	2	19
	20-40m	52917.9	243061.3	0.0	0.0	1	19
	40-80m	93143.2	410506.2	0.0	0.0	0	16
	>80m	196005.3	961377.7	0.0	0.0	0	2
	Total	398471.5	1954684.4	0.0	0.0	7	80
		Percent damaged		0.00%	0.00%		
Eastland F1	0-10m	28629.0	161084.9	45867.7	0.0	5	34
7/29/2009	10-20m	27776.1	146869.6	31135.8	0.0	2	32
	20-40m	52917.9	224253.0	21412.5	0.0	1	39
	40-80m	93143.2	375873.0	25975.0	0.0	1	15
	>80m	196005.3	974239.0	26794.3	0.0	1	21
	Total	398471.5	1882319.4	151185.2	0.0	10	141
		Percent damaged		8.03%	0.00%		
Eastland F1	0-10m	28629.0	158736.7	49624.8	313.1	19	70
8/28/2009	10-20m	27776.1	169500.0	37514.8	0.0	17	54
	20-40m	52917.9	231197.6	25174.2	1446.8	22	66
	40-80m	93143.2	396754.8	27502.9	5093.1	12	93
	>80m	196005.3	987100.2	2143.5	1071.8	13	62
	Total	398471.5	1943289.3	141960.2	7924.8	83	345
		Percent damaged		7.31%	0.41%		

yield (kg per ha)	$ loss	Overall percent loss
1150.4	$ 355.07	1.71%



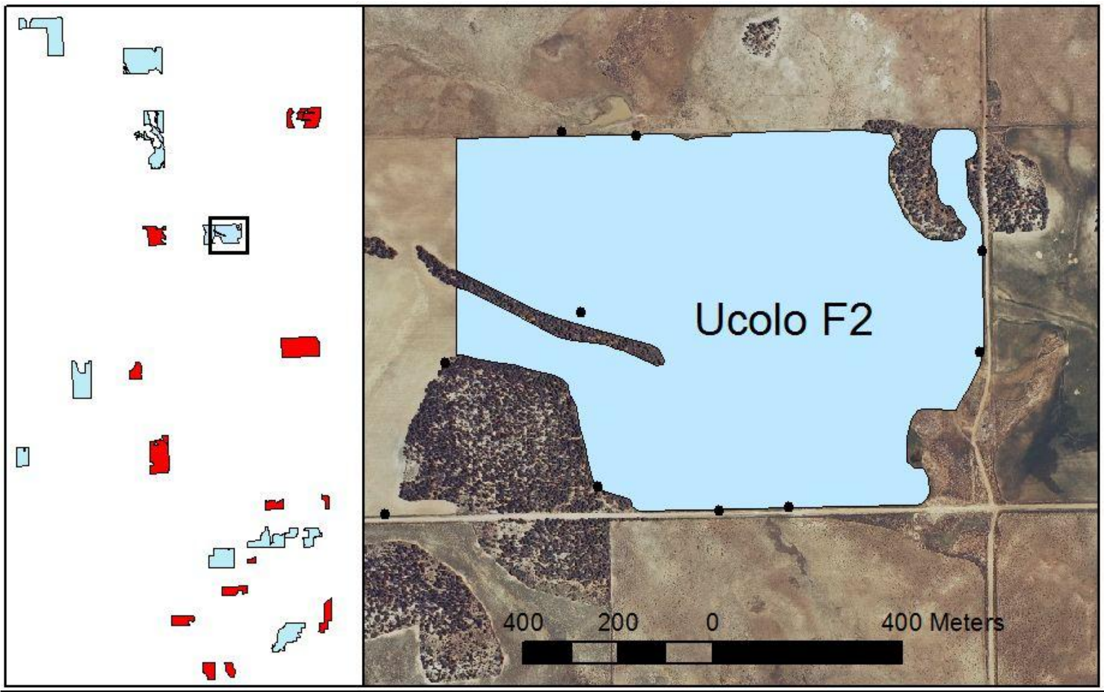
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Cedar F2	0-10m	54883.3	605613.5	1200.4	0.0	23	2
6/15/2009	10-20m	54023.1	525963.5	0.0	0.0	17	3
	20-40m	105329.5	981704.5	0.0	0.0	13	4
	40-80m	186666.8	1805629.8	0.0	0.0	8	7
	>80m	327369.2	3002853.4	0.0	0.0	2	2
	Total	728272.0	6921764.7	1200.4	0.0	63	18
		Percent damaged		0.02%	0.00%		
Cedar F2	0-10m	54883.3	611915.7	28810.2	0.0	77	10
7/31/2009	10-20m	54023.1	482391.7	5021.8	0.0	93	6
	20-40m	105329.5	970185.6	3167.7	0.0	77	5
	40-80m	186666.8	1741325.3	2551.8	0.0	60	9
	>80m	327369.2	2965261.8	8950.4	0.0	38	9
	Total	728272.0	6771080.0	48501.9	0.0	345	39
		Percent damaged		0.72%	0.00%		
Cedar F2	0-10m	54883.3	594509.6	24158.5	600.2	129	4
8/31/2009	10-20m	54023.1	458759.5	7828.2	295.4	156	10
	20-40m	105329.5	970761.5	2879.7	288.0	140	8
	40-80m	186666.8	1764291.2	4593.2	0.0	125	3
	>80m	327369.2	2927670.2	10740.5	0.0	106	1
	Total	728272.0	6715992.0	50200.1	1183.6	656	26
		Percent damaged		0.75%	0.02%		

yield (kg per ha)	$ loss	Overall percent loss
656.4	$ 31.86	0.15%



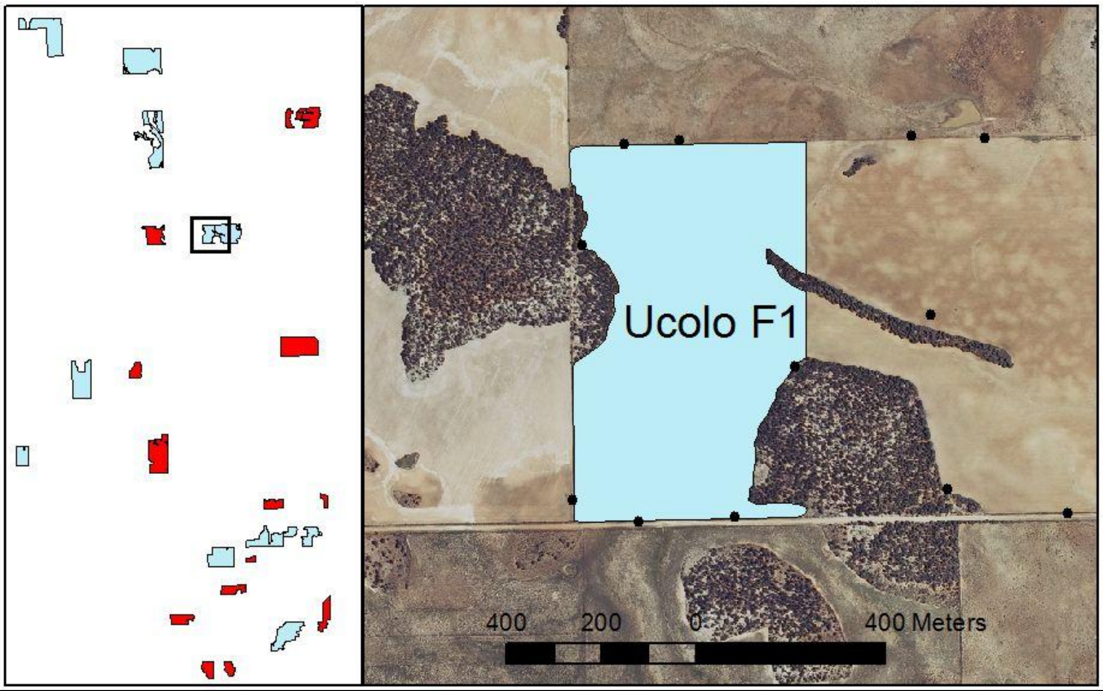
	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Cedar F3	0-10m	17996.5	72722.0	0.0	0.0	18	3
6/16/2009	10-20m	17159.8	131738.9	5723.7	0.0	15	4
	20-40m	31479.1	169203.5	0.0	0.0	11	3
	40-80m	52539.2	348480.1	0.0	0.0	5	5
	>80m	51343.7	299280.5	0.0	0.0	6	4
	Total	170518.3	1021425.0	5723.7	0.0	55	19
		Percent damaged		0.56%	0.00%		
Cedar F3	0-10m	17996.5	74788.5	4034.6	0.0	72	0
8/2/2009	10-20m	17159.8	104058.7	4597.7	0.0	69	0
	20-40m	31479.1	189687.0	5852.4	0.0	54	0
	40-80m	52539.2	325209.8	287.3	0.0	33	0
	>80m	51343.7	315283.3	2246.0	0.0	22	0
	Total	170518.3	1009027.3	17018.1	0.0	250	0
		Percent damaged		1.69%	0.00%		
Cedar F3	0-10m	17996.5	74099.6	3444.2	0.0	108	0
9/8/2009	10-20m	17159.8	102651.2	2814.9	0.0	114	0
	20-40m	31479.1	188482.1	3786.9	0.0	73	2
	40-80m	52539.2	326071.7	1723.7	0.0	67	0
	>80m	51343.7	311914.3	1684.5	0.0	52	0
	Total	170518.3	1003218.9	13454.2	0.0	414	2
		Percent damaged		1.34%	0.00%		

yield (kg per ha)	$ loss	Overall percent loss
737.5	$ 113.06	1.99%



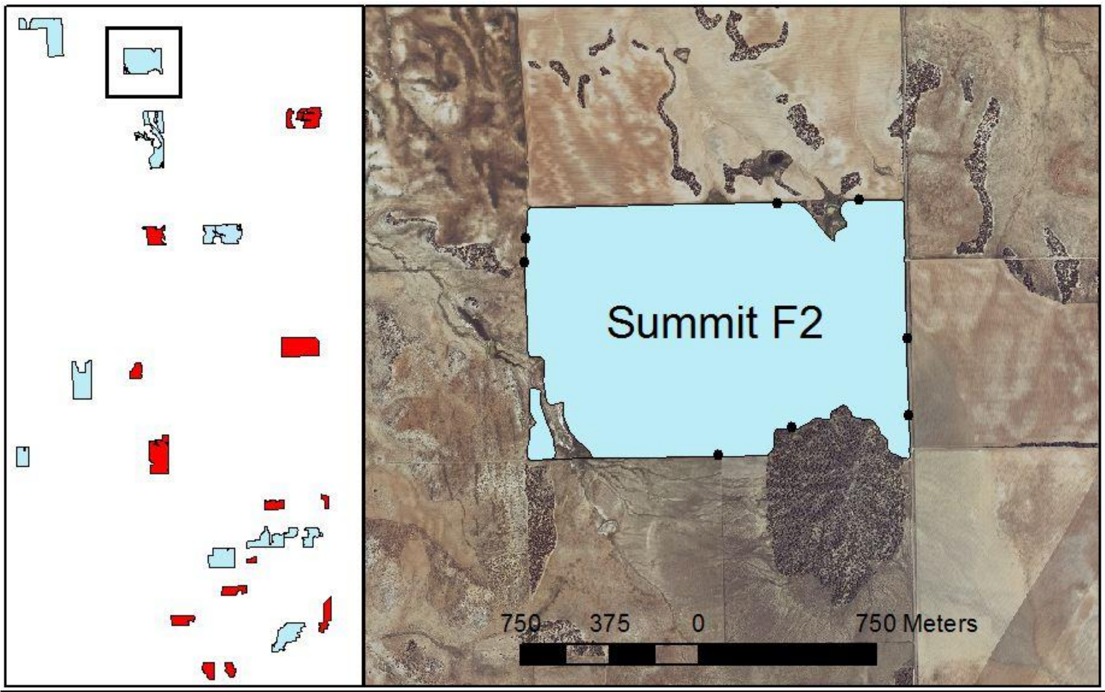
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Ucolo F2	0-10m	50677.1	339454.6	17042.0	0.0	44	34
6/17/2009	10-20m	49513.9	316907.3	9882.2	0.0	30	22
	20-40m	90093.3	719741.8	15518.0	0.0	19	18
	40-80m	141219.4	1054049.0	6563.7	0.0	9	14
	>80m	394625.1	2905526.9	0.0	0.0	2	3
	Total	726128.9	5335679.5	49005.9	0.0	104	91
		Percent damaged		0.92%	0.00%		
Ucolo F2	0-10m	50677.1	366472.4	22861.2	0.0	28	85
8/4/2009	10-20m	49513.9	337483.9	17056.9	0.0	22	72
	20-40m	90093.3	729348.2	25124.5	0.0	15	57
	40-80m	141219.4	1067562.4	54826.0	0.0	13	45
	>80m	394625.1	2837555.1	32367.5	1078.9	7	35
	Total	726128.9	5338422.0	152236.2	1078.9	85	294
		Percent damaged		2.85%	0.02%		
Ucolo F2	0-10m	50677.1	353725.5	31174.4	30204.5	138	207
9/8/2009	10-20m	49513.9	314064.5	34655.4	11506.7	115	245
	20-40m	90093.3	717032.3	33253.0	2955.8	77	151
	40-80m	141219.4	1052504.6	56370.4	772.2	79	126
	>80m	394625.1	2822450.2	74445.4	18341.6	77	105
	Total	726128.9	5259777.1	229898.5	63780.8	486	834
		Percent damaged		4.37%	1.21%		

yield (kg per ha)	$ loss	Overall percent loss
578.3	$ 477.11	2.51%



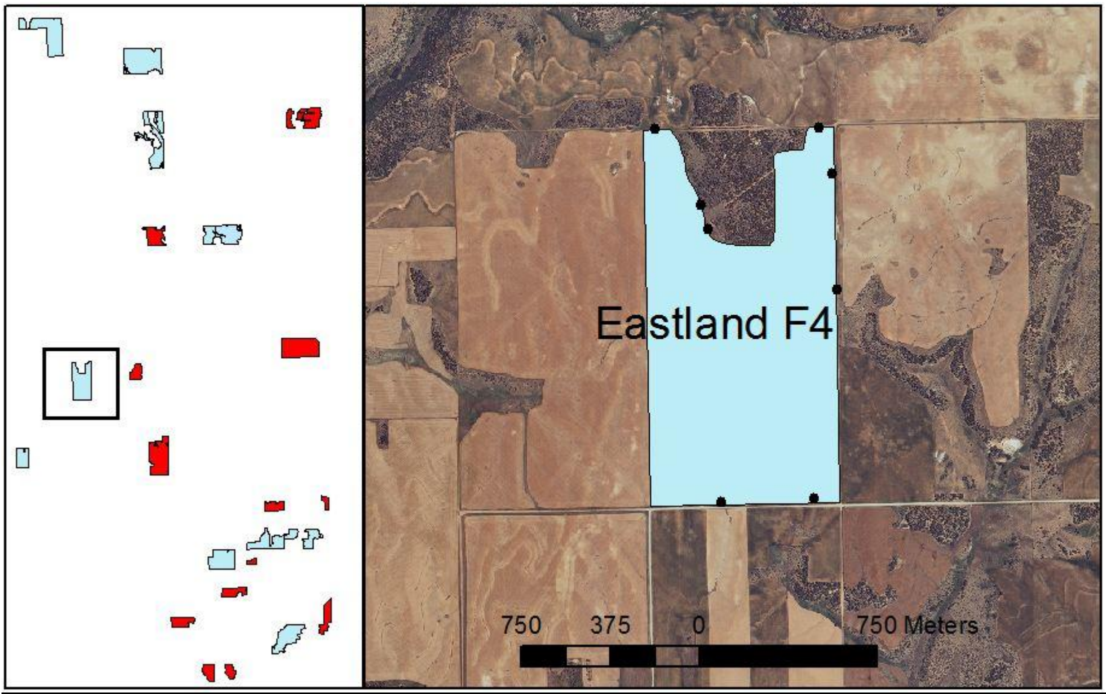
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Ucolo F1	0-10m	29710.6	236784.8	10641.1	0.0	26	26
6/19/2009	10-20m	27726.9	213697.9	606.5	0.0	21	27
	20-40m	49789.9	349166.1	2178.0	0.0	15	28
	40-80m	86990.9	652859.8	475.7	0.0	16	24
	>80m	148699.7	894003.6	406.6	0.0	10	17
	Total	342918.0	2346512.2	14307.8	0.0	88	122
		Percent damaged		0.61%	0.00%		
Ucolo F1	0-10m	29710.6	240846.3	50849.8	0.0	46	103
8/5/2009	10-20m	27726.9	206496.3	12204.8	0.0	32	102
	20-40m	49789.9	362098.2	43016.2	0.0	25	121
	40-80m	86990.9	691627.0	29967.3	0.0	16	73
	>80m	148699.7	882213.6	17075.1	0.0	9	75
	Total	342918.0	2383281.5	153113.3	0.0	128	474
		Percent damaged		6.42%	0.00%		
Ucolo F1	0-10m	29710.6	222082.2	44595.2	9016.5	99	140
9/9/2009	10-20m	27726.9	211347.9	16070.9	2501.6	66	114
	20-40m	49789.9	356789.2	39613.0	544.5	85	103
	40-80m	86990.9	699951.3	40907.8	951.3	110	90
	>80m	148699.7	948887.8	32930.6	406.6	79	100
	Total	342918.0	2439058.5	174117.4	13420.5	439	547
		Percent damaged		7.14%	0.55%		

yield (kg per ha)	$ loss	Overall percent loss
456.9	$ 317.58	4.49%



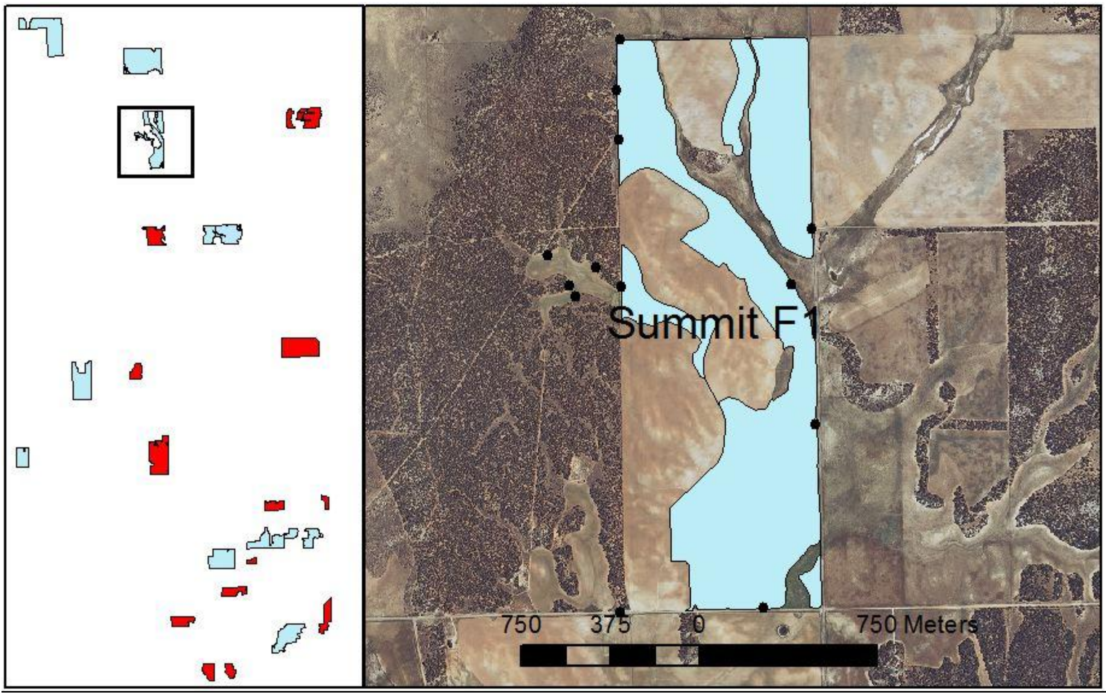
	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Summit F2	0-10m	64377.3	452344.8	55443.0	0.0	6	82
6/30/2009	10-20m	62871.3	549883.3	12720.0	0.0	4	50
	20-40m	116220.6	1395879.6	1271.0	0.0	5	28
	40-80m	204459.4	1169984.4	8944.0	0.0	2	16
	>80m	1144989.7	8921753.7	21913.1	0.0	1	9
	Total	1592918.2	12489845.7	100291.1	0.0	18	185
		Percent damaged		0.80%	0.00%		
Summit F2	0-10m	64377.3	454456.9	80260.4	0.0	9	183
8/10/2009	10-20m	62871.3	577042.3	23033.6	0.0	10	115
	20-40m	116220.6	1426383.6	35270.3	0.0	8	117
	40-80m	204459.4	1255511.2	26272.9	0.0	14	102
	>80m	1144989.7	9798276.9	262957.0	0.0	3	91
	Total	1592918.2	13511670.9	427794.2	0.0	44	608
		Percent damaged		6.42%	0.00%		
Summit F2	0-10m	64377.3	463609.4	76916.2	10384.6	24	63
9/22/2009	10-20m	62871.3	598528.8	23033.6	31800.1	32	67
	20-40m	116220.6	1540456.2	31775.1	84204.0	21	62
	40-80m	204459.4	1188990.3	33539.9	40247.9	26	67
	>80m	1144989.7	9923494.5	272348.3	516522.6	14	56
	Total	1592918.2	13715079.2	437613.1	683159.1	117	315
		Percent damaged		3.19%	4.98%		

yield (kg per ha)	$ loss	Overall percent loss
432.7	$ 1870.82	6.01%



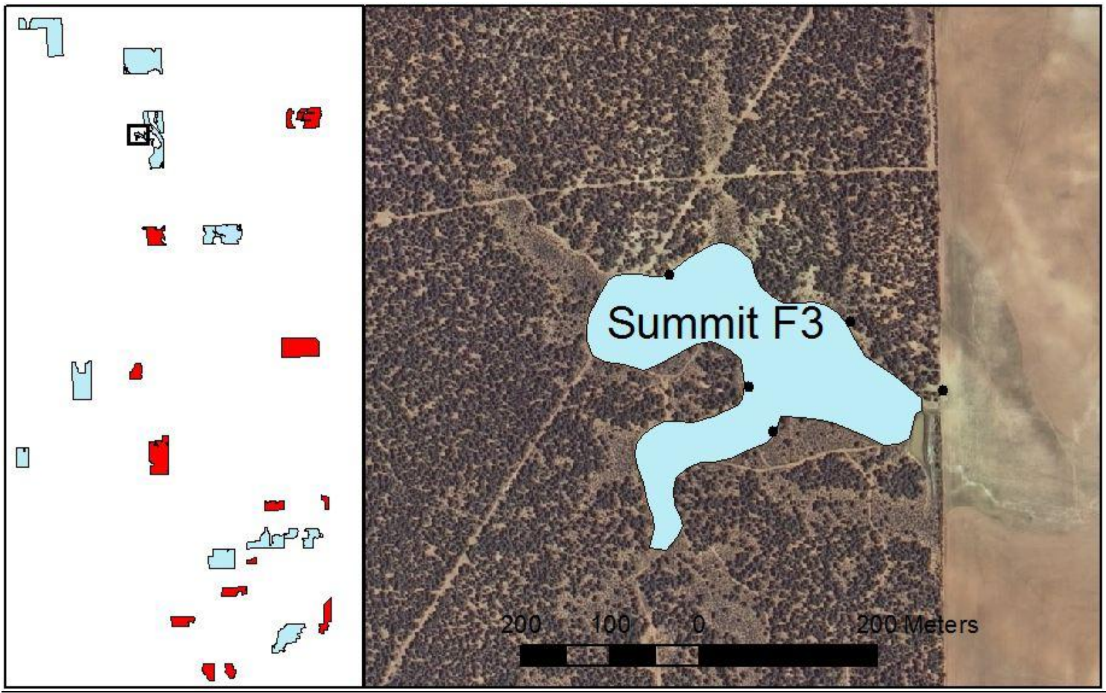
	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Eastland F4	0-10m	55018.2	96570.6	1053.0	0.0	14	38
7/1/2009	10-20m	54213.5	188093.0	4743.1	0.0	6	39
	20-40m	105944.6	397987.3	2317.2	0.0	6	41
	40-80m	199933.2	761447.2	10385.9	0.0	4	26
	>80m	674549.8	2622511.6	0.0	0.0	1	22
	Total	1089659.2	4066609.7	18499.1	0.0	31	166
		Percent damaged		0.45%	0.00%		
Eastland F4	0-10m	55018.2	86642.8	35950.7	0.0	175	100
8/13/2009	10-20m	54213.5	169713.6	20158.1	0.0	172	122
	20-40m	105944.6	399725.2	52138.1	0.0	138	105
	40-80m	199933.2	729196.3	83086.8	0.0	91	116
	>80m	674549.8	2589315.3	226841.7	0.0	74	105
	Total	1089659.2	3974593.2	418175.5	0.0	650	548
		Percent damaged		10.52%	0.00%		
Eastland F4	0-10m	55018.2	93712.6	34747.4	1955.5	350	57
10/8/2009	10-20m	54213.5	176531.8	20899.2	4891.3	374	66
	20-40m	105944.6	395670.0	61986.4	4924.2	335	77
	40-80m	199933.2	782218.9	81993.6	546.6	257	42
	>80m	674549.8	2677838.9	224997.5	1844.2	176	32
	Total	1089659.2	4125972.1	424624.0	14161.8	1492	274
		Percent damaged		10.29%	0.34%		

yield (kg per ha)	$ loss	Overall percent loss
1145.2	$ 2790.21	4.95%



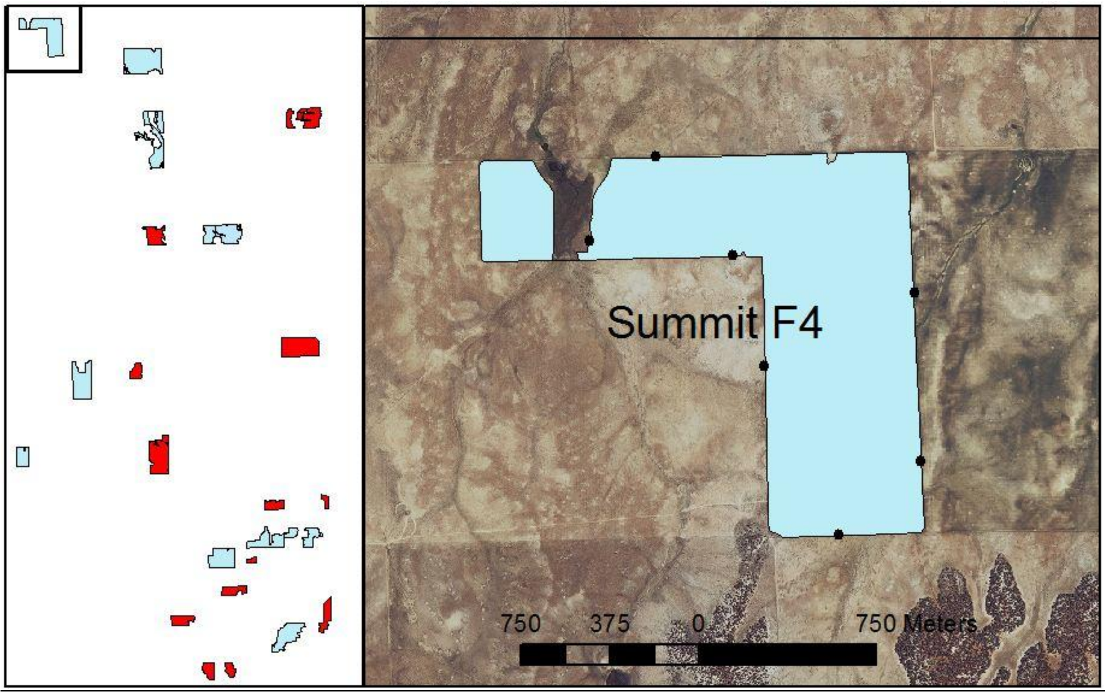
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Summit F1	0-10m	122681.3	720806.5	123432.7	0.0	15	111
7/3/2009	10-20m	116496.2	1311282.7	46820.1	0.0	10	100
	20-40m	202740.9	3005415.8	146889.6	0.0	12	105
	40-80m	273046.1	1948409.9	83609.9	0.0	18	64
	>80m	306637.2	1751326.1	20120.5	0.0	8	35
	Total	1021601.7	8737241.0	420872.8	0.0	63	415
		Percent damaged		4.82%	0.00%		
Summit F1	0-10m	122681.3	686594.2	223050.9	0.0	17	314
8/16/2009	10-20m	116496.2	1165726.2	284424.4	0.0	18	341
	20-40m	202740.9	2851874.7	394107.5	0.0	15	362
	40-80m	273046.1	1938705.2	168712.9	0.0	20	284
	>80m	306637.2	1705216.5	161802.7	0.0	5	186
	Total	1021601.7	8348116.7	1232098.4	0.0	75	1487
		Percent damaged		14.76%	0.00%		
Summit F1	0-10m	122681.3	679885.9	175086.5	54337.2	21	225
10/1/2009	10-20m	116496.2	1245352.3	213398.0	133771.9	40	199
	20-40m	202740.9	2640686.3	238349.1	169615.9	13	222
	40-80m	273046.1	1823741.5	167219.9	106005.4	24	251
	>80m	306637.2	1565211.0	202882.2	91380.8	12	205
	Total	1021601.7	7954877.0	996935.7	555111.2	110	1102
		Percent damaged		12.53%	6.98%		

yield (kg per ha)	$ loss	Overall percent loss
334.7	$ 1848.85	11.96%



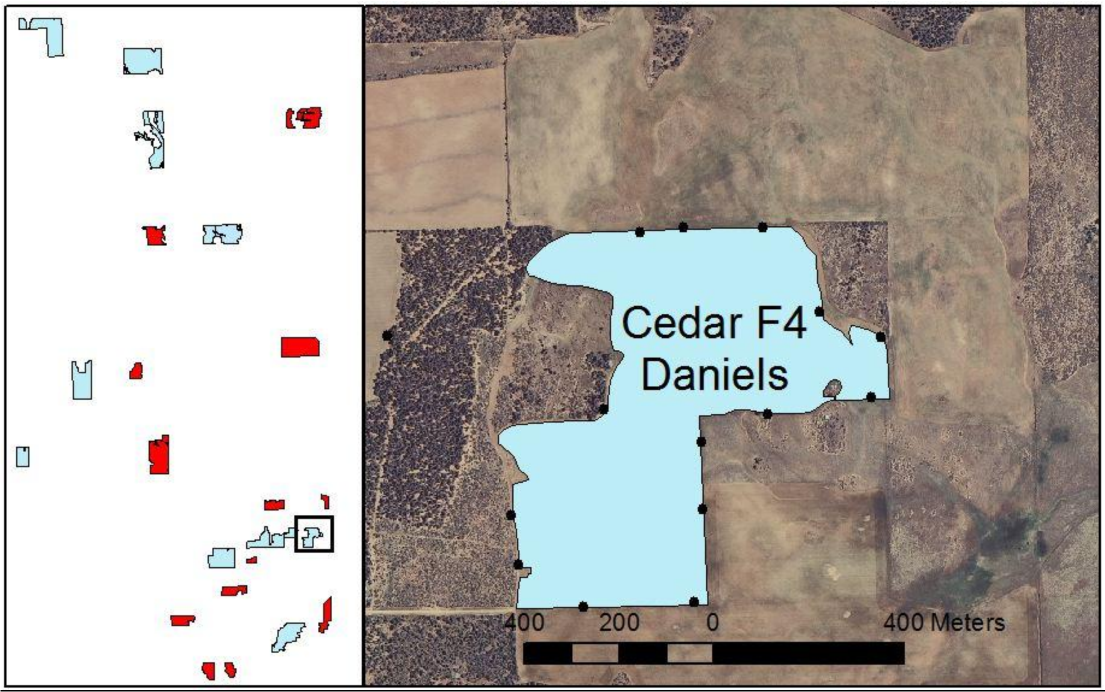
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Summit F3	0-10m	14417.3	67482.6	20654.7	0.0	27	188
7/8/2009	10-20m	13100.0	87462.5	42907.5	0.0	24	183
	20-40m	22700.7	96448.1	44065.7	0.0	30	174
	Total	50218.0	251393.3	107628.0	0.0	81	545
		Percent damaged		42.81%	0.00%		
Summit F3	0-10m	14417.3	63304.4	44462.8	157.7	36	410
8/18/2009	10-20m	13100.0	80872.4	71345.4	214.9	28	391
	20-40m	22700.7	88007.4	79442.5	0.0	17	383
	Total	50218.0	232184.1	195250.7	372.6	81	1184
		Percent damaged		84.09%	0.16%		
Summit F3	0-10m	14417.3	59126.1	27986.4	26094.3	7	393
10/1/2009	10-20m	13100.0	74282.3	27721.5	42047.9	6	359
	20-40m	22700.7	84655.9	19860.6	60574.9	6	356
	Total	50218.0	218064.3	75568.5	128717.1	19	1108
		Percent damaged		34.65%	59.03%		

yield (kg per ha)	$ loss	Overall percent loss
144.3	$ 233.37	71.26%



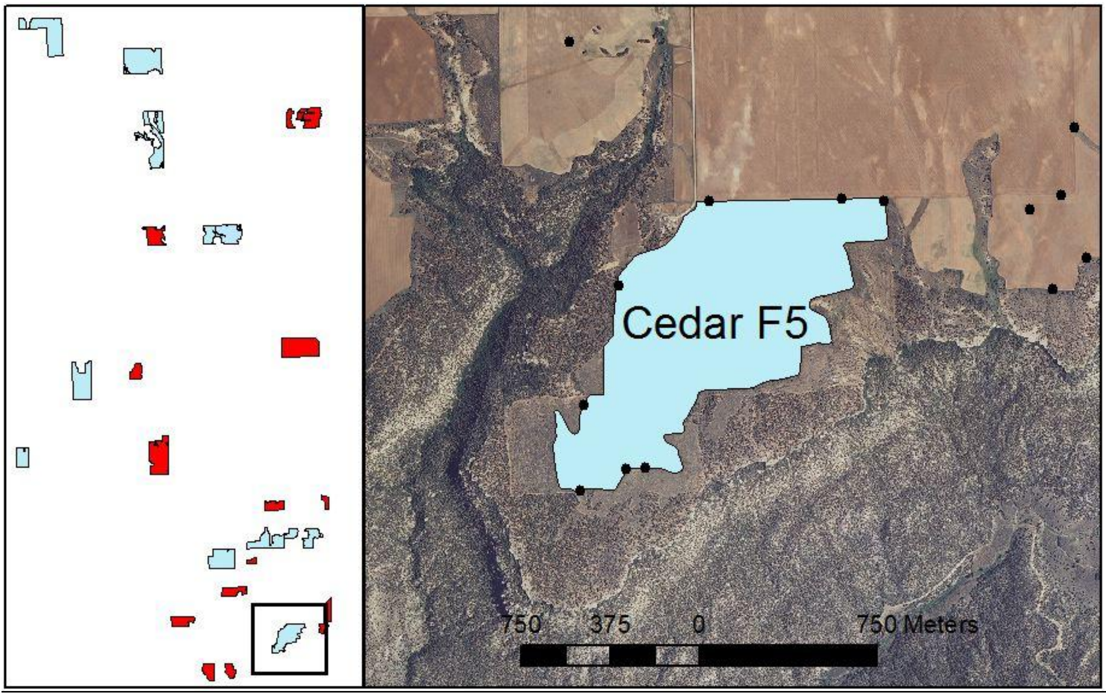
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Summit F4	0-10m	73349.9	575151.8	31083.9	0.0	10	123
7/15/2009	10-20m	71647.6	561020.3	7051.9	0.0	4	94
	20-40m	137641.6	1398392.9	14300.0	0.0	2	88
	40-80m	255404.0	1775733.7	88681.9	0.0	1	127
	>80m	920185.4	6050541.3	60379.6	0.0	2	60
	Total	1458228.6	10360840.0	201497.4	0.0	19	492
		Percent damaged		1.94%	0.00%		
Summit F4	0-10m	73349.9	606035.1	36498.5	802.2	10	92
8/19/2009	10-20m	71647.6	568464.0	11165.6	391.8	7	72
	20-40m	137641.6	1335171.7	40265.9	376.3	5	74
	40-80m	255404.0	1763862.8	194122.7	2793.1	1	100
	>80m	920185.4	6342376.1	70442.9	2515.8	9	54
	Total	1458228.6	10615909.8	352495.5	6879.2	32	392
		Percent damaged		3.32%	0.06%		
Summit F4	0-10m	73349.9	610848.1	42915.8	10027.1	62	78
9/29/2009	10-20m	71647.6	574928.2	9990.2	5093.1	96	74
	20-40m	137641.6	1437153.6	50802.8	6773.7	87	81
	40-80m	255404.0	1840674.0	179458.7	37009.0	79	85
	>80m	920185.4	6226648.5	50316.4	25158.2	80	64
	Total	1458228.6	10690252.4	333483.9	84061.0	404	382
		Percent damaged		3.12%	0.79%		

yield (kg per ha)	$ loss	Overall percent loss
451.1	$ 762.24	2.56%



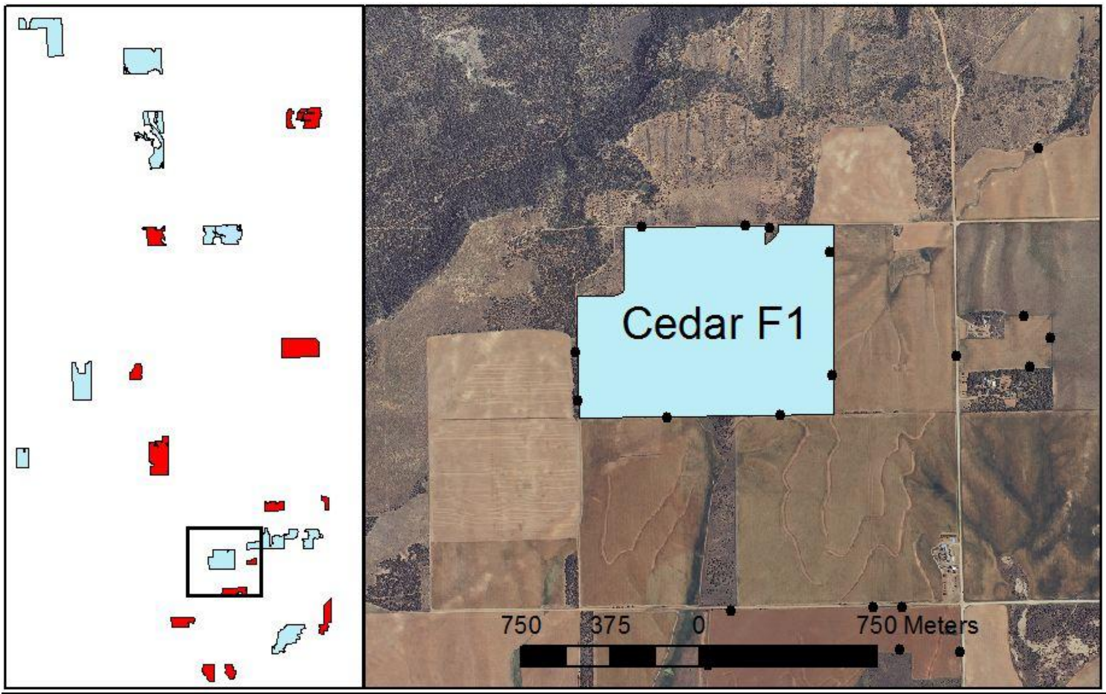
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Cedar F4	0-10m	35886.2	267458.6	28845.5	0.0	94	15
7/16/2009	10-20m	34475.3	292667.1	13950.0	0.0	51	6
	20-40m	65192.4	514217.4	6951.3	0.0	44	5
	40-80m	103560.4	721151.6	6229.0	0.0	19	8
	>80m	126833.7	998344.0	1733.8	0.0	14	6
	Total	365948.1	2793838.6	57709.7	0.0	222	40
		Percent damaged		2.07%	0.00%		
Cedar F4	0-10m	35886.2	280507.8	30807.8	196.2	73	2
8/22/2009	10-20m	34475.3	293326.9	13950.0	0.0	61	5
	20-40m	65192.4	535071.3	6594.8	0.0	46	1
	40-80m	103560.4	743236.3	9909.8	0.0	36	2
	>80m	126833.7	1019496.8	5201.5	0.0	36	2
	Total	365948.1	2871639.0	66463.9	196.2	252	12
		Percent damaged		2.31%	0.01%		
Cedar F4	0-10m	35886.2	275700.2	31298.3	3041.5	76	10
9/16/2009	10-20m	34475.3	289933.6	13667.2	848.3	64	7
	20-40m	65192.4	527585.3	8733.7	2495.3	62	7
	40-80m	103560.4	746067.7	9060.4	5096.5	65	12
	>80m	126833.7	969215.5	4161.2	12136.9	52	11
	Total	365948.1	2808502.3	66920.9	23618.5	319	47
		Percent damaged		2.38%	0.84%		

yield (kg per ha)	$ loss	Overall percent loss
699.2	$ 181.45	1.57%



	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Cedar F5	0-10m	51371.4	107866.5	14045.1	0.0	29	13
7/21/2009	10-20m	50193.8	142583.7	5763.7	0.0	26	3
	20-40m	96080.1	384047.3	9456.7	0.0	10	1
	40-80m	175646.9	613727.0	1440.7	0.0	3	1
	>80m	505300.6	1865036.6	4144.5	0.0	2	3
	Total	878592.9	3113261.1	34850.8	0.0	70	21
		Percent damaged		1.12%	0.00%		
Cedar F5	0-10m	51371.4	109411.5	12359.7	0.0	37	15
8/25/2009	10-20m	50193.8	164403.5	5763.7	0.0	47	10
	20-40m	96080.1	405850.3	12083.6	0.0	33	7
	40-80m	175646.9	637258.0	1920.9	0.0	25	4
	>80m	505300.6	1870562.6	5526.0	0.0	17	2
	Total	878592.9	3187485.9	37653.9	0.0	159	38
		Percent damaged		1.18%	0.00%		
Cedar F5	0-10m	51371.4	106602.5	12359.7	702.3	193	12
10/5/2009	10-20m	50193.8	147386.8	5901.0	137.2	234	12
	20-40m	96080.1	395080.1	9719.4	0.0	199	14
	40-80m	175646.9	651664.7	3361.6	0.0	186	15
	>80m	505300.6	1869181.1	2763.0	0.0	125	5
	Total	878592.9	3169915.2	34104.6	839.5	937	58
		Percent damaged		1.08%	0.03%		

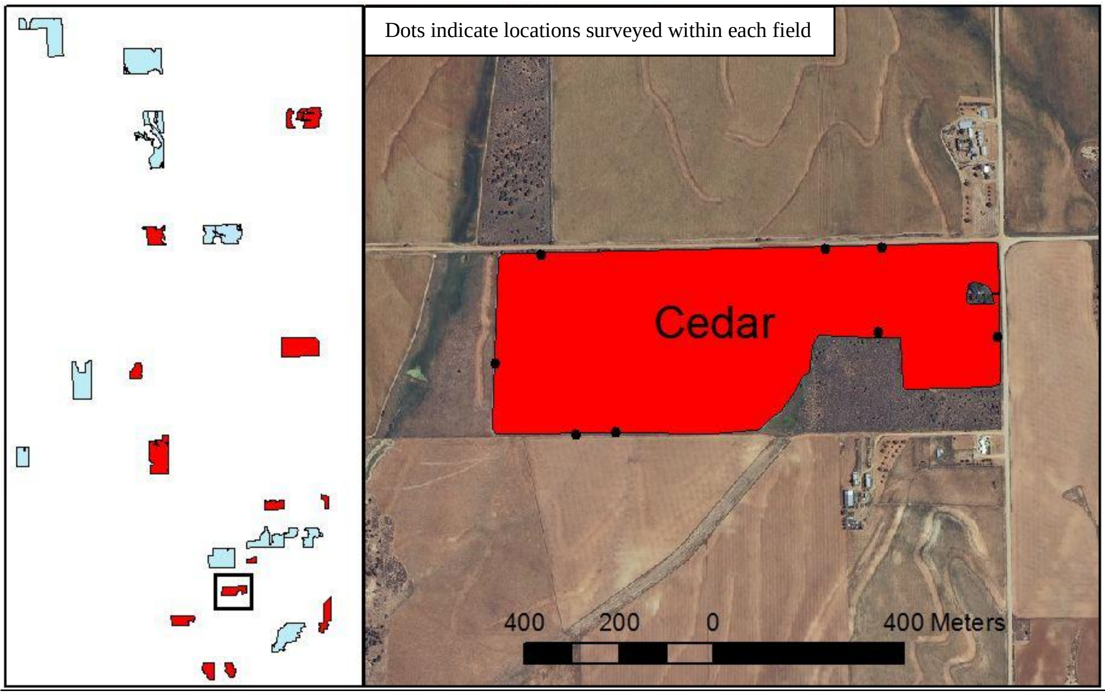
yield (kg per ha)	$ loss	Overall percent loss
511.5	$ 95.67	0.47%



	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Cedar F1	0-10m	38364.4	390189.5	84645.9	0.0	18	23
7/20/2009	10-20m	37406.1	458883.2	56043.7	0.0	20	15
	20-40m	71922.4	867960.6	55451.9	0.0	8	6
	40-80m	132890.1	1160100.1	12353.1	0.0	3	3
	>80m	524306.7	5034353.6	215020.8	0.0	0	2
	Total	804889.7	7911487.0	423515.5	0.0	49	49
		Percent damaged		5.35%	0.00%		
Cedar F1	0-10m	38364.4	372463.1	76884.1	314.7	33	35
8/26/2009	10-20m	37406.1	462053.6	55634.6	204.5	37	26
	20-40m	71922.4	849869.9	57221.7	0.0	24	20
	40-80m	132890.1	1118317.6	49049.0	0.0	27	24
	>80m	524306.7	4631547.9	206420.0	0.0	24	15
	Total	804889.7	7434252.2	445209.4	519.2	145	120
		Percent damaged		5.99%	0.01%		
Cedar F1	0-10m	38364.4	387357.5	77723.2	314.7	37	52
9/21/2009	10-20m	37406.1	474939.5	59929.9	511.3	46	38
	20-40m	71922.4	804053.3	56041.9	983.2	41	33
	40-80m	132890.1	1151743.6	40329.2	9446.5	37	28
	>80m	524306.7	5263709.1	225055.1	1433.5	33	11
	Total	804889.7	8081803.0	459079.3	12689.2	194	162
		Percent damaged		5.68%	0.16%		

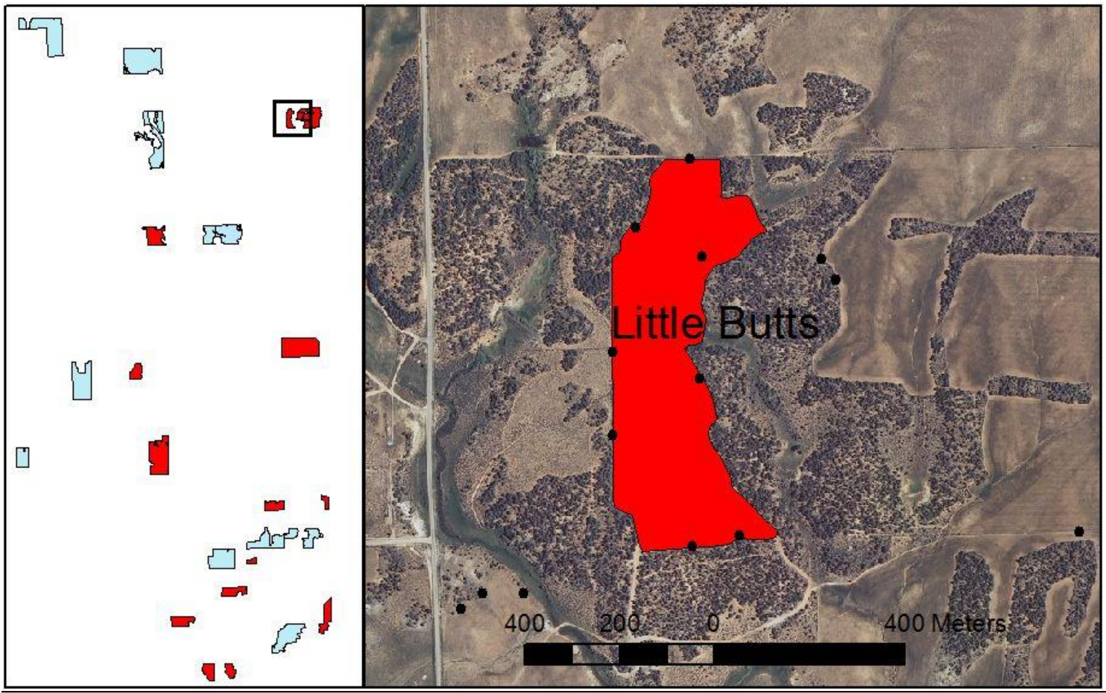
yield (kg per ha)	$ loss	Overall percent loss
559.6	$ 179.11	0.88%

APPENDIX E. FIELDS SURVEYED IN 2010



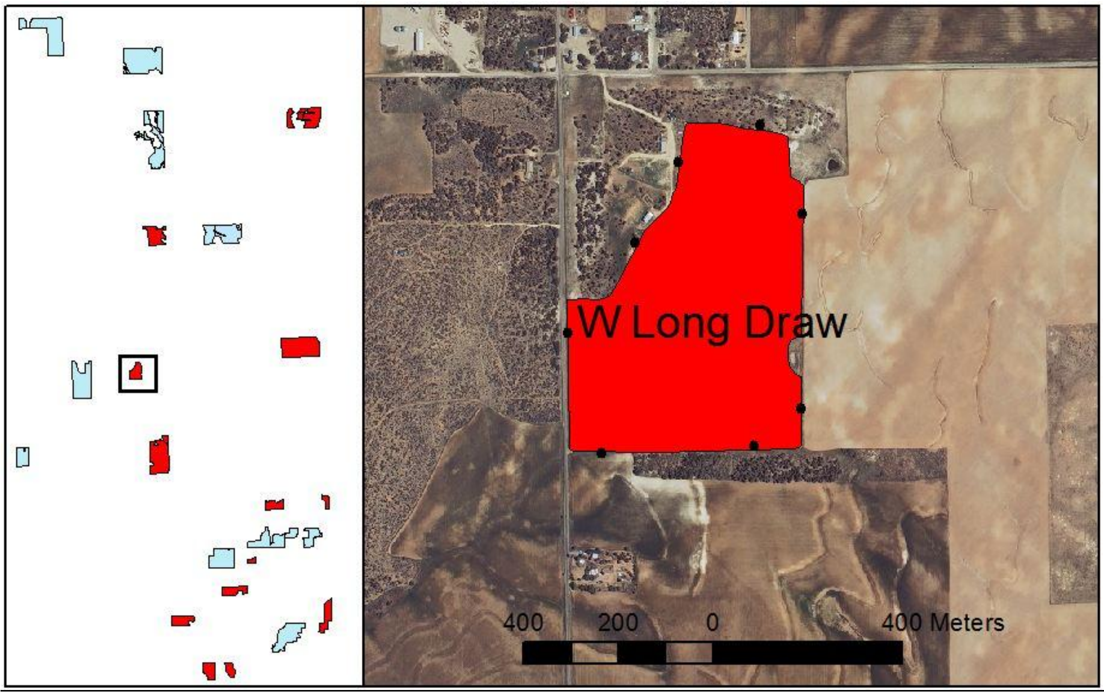
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Cedar	0-10m	31611.2	128688.4	0.0	0.0	16	1
6/14/2010	10-20m	30363.6	168105.6	249.0	0.0	22	1
	20-40m	57735.2	540478.3	0.0	0.0	10	1
	40-80m	100777.0	856615.5	0.0	0.0	10	1
	>80m	126369.0	895528.3	0.0	0.0	7	6
	Total	346856.0	2589416.1	249.0	0.0	65	10
		Percent damaged		0.01%	0.00%		
Cedar	0-10m	31611.2	115897.4	0.0	0.0	17	1
7/29/2010	10-20m	30363.6	151170.5	83.0	0.0	19	1
	20-40m	57735.2	444347.6	315.7	0.0	8	2
	40-80m	100777.0	753292.6	0.0	0.0	10	1
	>80m	126369.0	870652.6	0.0	0.0	16	1
	Total	346856.0	2335360.7	398.7	0.0	70	6
		Percent damaged		0.02%	0.00%		
Cedar	0-10m	31611.2	113304.6	172.9	0.0	10	0
8/30/2010	10-20m	30363.6	150838.4	0.0	0.0	6	0
	20-40m	57735.2	460290.5	0.0	0.0	13	0
	40-80m	100777.0	745577.9	0.0	0.0	5	0
	>80m	126369.0	845776.8	0.0	0.0	8	1
	Total	346856.0	2315788.1	172.9	0.0	42	1
		Percent damaged		0.01%	0.00%		

yield (kg per ha)	$ loss	Overall percent loss
637.3	$ -0.01	-0.01%



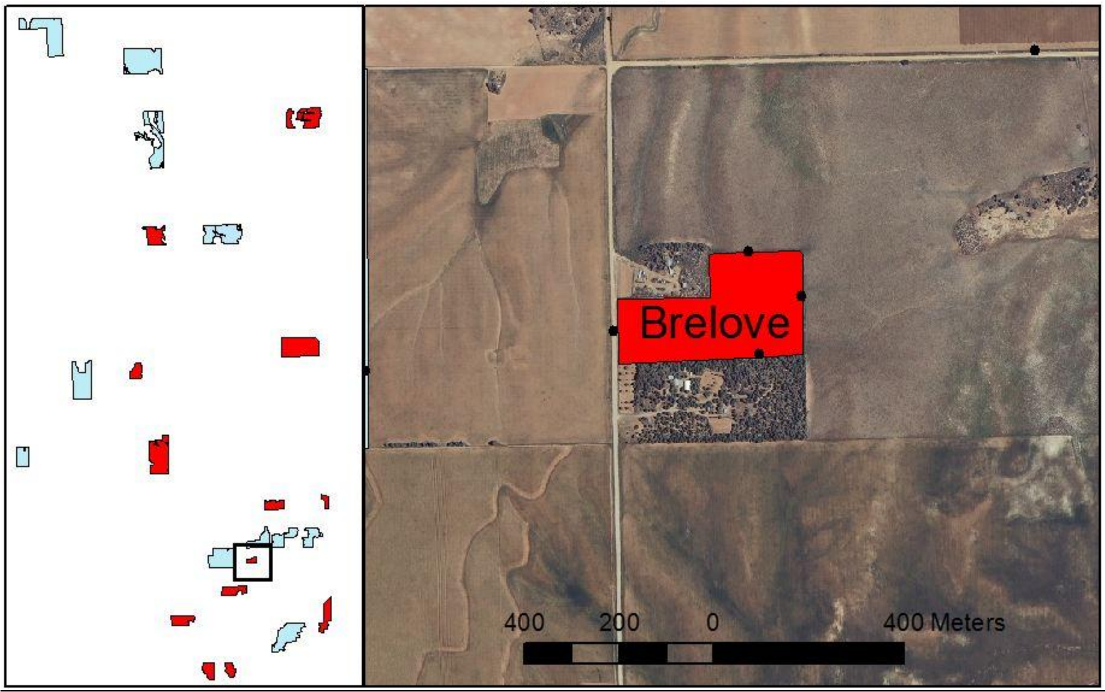
	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Little Butts	0-10m	23105.3	501385.5	568.5	0.0	2	10
6/25/2010	10-20m	22206.4	431912.5	1578.5	0.0	7	11
	20-40m	41187.1	954005.7	0.0	0.0	4	7
	40-80m	69033.8	1129235.6	0.0	0.0	8	7
	>80m	21767.2	271792.4	0.0	0.0	13	8
	Total	177299.8	3288331.8	2147.1	0.0	34	43
		Percent damaged		0.07%	0.00%		
Little Butts	0-10m	23105.3	562724.2	2653.2	0.0	4	2
7/31/2010	10-20m	22206.4	440776.6	2185.7	0.0	7	8
	20-40m	41187.1	912904.1	1801.7	0.0	5	11
	40-80m	69033.8	1160566.6	11135.7	0.0	3	2
	>80m	21767.2	336898.8	0.0	0.0	2	7
	Total	177299.8	3413870.4	17776.2	0.0	21	30
		Percent damaged		0.52%	0.00%		
Little Butts	0-10m	23105.3	523558.4	6190.7	4674.6	20	70
9/6/2010	10-20m	22206.4	410480.8	8074.8	850.0	22	68
	20-40m	41187.1	847817.4	1914.3	0.0	16	71
	40-80m	69033.8	944836.0	1698.7	188.7	16	68
	>80m	21767.2	318271.5	178.5	0.0	18	56
	Total	177299.8	3044964.1	18057.1	5713.4	92	333
		Percent damaged		0.59%	0.19%		

yield (kg per ha)	$ loss	Overall percent loss
3267.9	$ 127.90	0.41%



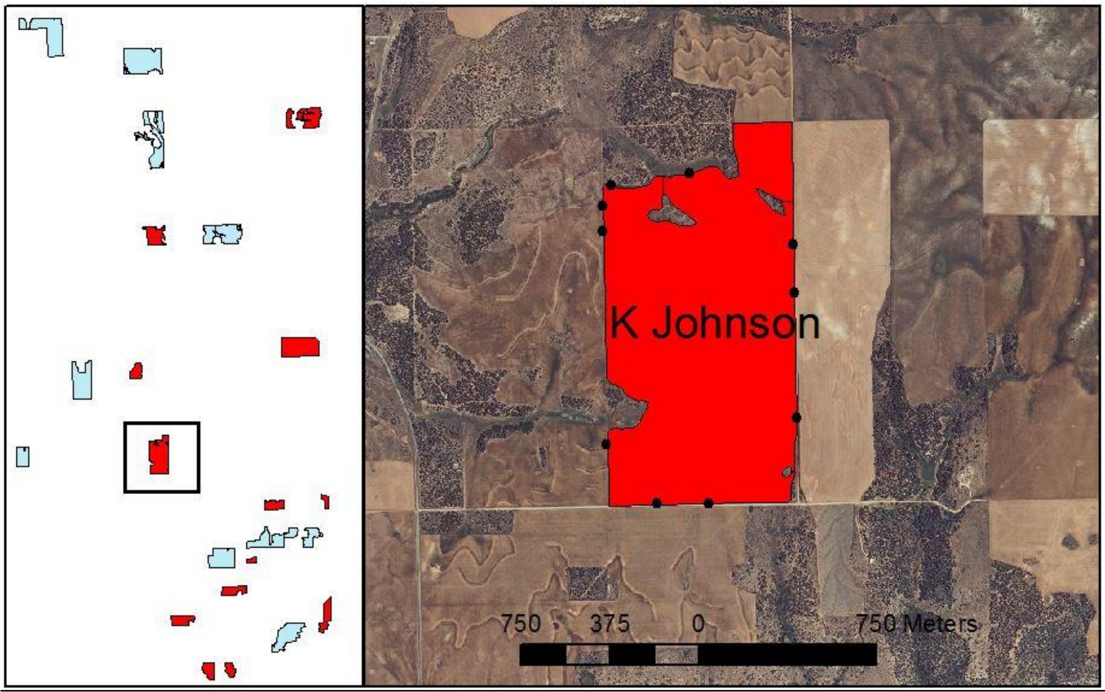
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
W Long Draw	0-10m	21889.1	171158.2	9455.6	0.0	135	1
6/29/2010	10-20m	21120.9	215620.7	5890.0	57.7	90	4
	20-40m	39791.5	310490.3	6962.6	108.8	91	2
	40-80m	69497.8	438921.5	1900.1	380.0	54	1
	>80m	114605.0	969768.4	0.0	0.0	31	1
	Total	266904.3	2105959.1	24208.3	546.6	401	9
		Percent damaged		1.15%	0.03%		
W Long Draw	0-10m	21889.1	151588.7	13525.1	0.0	12	1
8/3/2010	10-20m	21120.9	176411.7	5543.5	57.7	9	1
	20-40m	39791.5	269584.8	14034.1	108.8	15	0
	40-80m	69497.8	334606.4	4940.2	380.0	11	0
	>80m	114605.0	793540.4	13249.5	0.0	5	0
	Total	266904.3	1725732.0	51292.5	546.6	52	2
		Percent damaged		2.97%	0.03%		
W Long Draw	0-10m	21889.1	149015.4	12268.3	3650.6	97	1
9/8/2010	10-20m	21120.9	163245.8	4792.9	462.0	89	0
	20-40m	39791.5	225089.2	6418.7	217.6	106	0
	40-80m	69497.8	319405.6	3990.2	1140.1	99	0
	>80m	114605.0	630427.8	4700.0	313.3	94	0
	Total	266904.3	1487183.7	32170.1	5783.5	485	1
		Percent damaged		2.16%	0.39%		

yield (kg per ha)	$ loss	Overall percent loss
1191.8	$ 239.82	1.41%



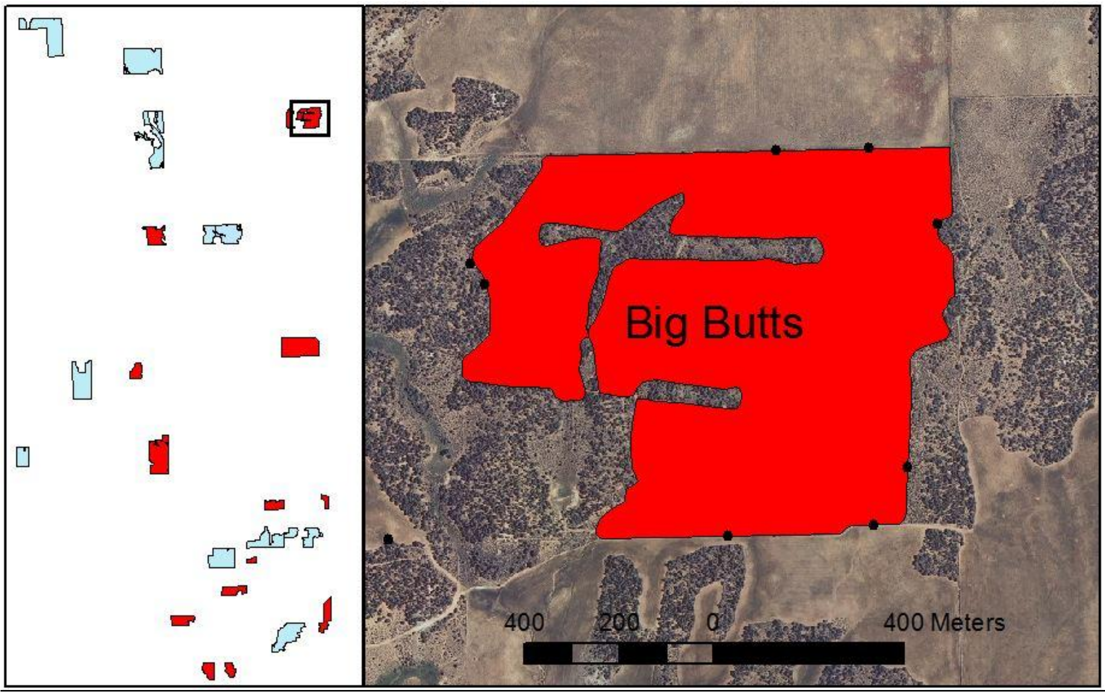
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Brelove	0-10m	11849.9	36545.0	194.4	0.0	1	0
6/30/2010	10-20m	11055.7	72060.3	0.0	0.0	0	0
	20-40m	19591.6	137766.8	0.0	0.0	0	0
	40-80m	24641.2	180416.5	0.0	0.0	0	0
	>80m	2429.3	18490.7	0.0	0.0	0	0
	Total	69567.7	445279.4	194.4	0.0	1	0
		Percent damaged		0.04%	0.00%		
Brelove	0-10m	11849.9	40238.3	0.0	0.0	4	0
8/4/2010	10-20m	11055.7	72423.1	0.0	0.0	3	0
	20-40m	19591.6	140873.5	0.0	0.0	5	0
	40-80m	24641.2	177317.5	0.0	0.0	12	0
	>80m	2429.3	18836.1	26.6	0.0	10	0
	Total	69567.7	449688.5	26.6	0.0	34	0
		Percent damaged		0.01%	0.00%		
Brelove	0-10m	11849.9	39979.2	259.2	0.0	32	0
9/9/2010	10-20m	11055.7	68251.8	0.0	0.0	40	0
	20-40m	19591.6	130053.6	107.1	0.0	44	0
	40-80m	24641.2	155489.6	0.0	0.0	44	0
	>80m	2429.3	17149.1	26.6	0.0	44	0
	Total	69567.7	410923.3	392.9	0.0	204	0
		Percent damaged		0.10%	0.00%		

yield (kg per ha)	$ loss	Overall percent loss
1616.1	$ 3.93	0.06%



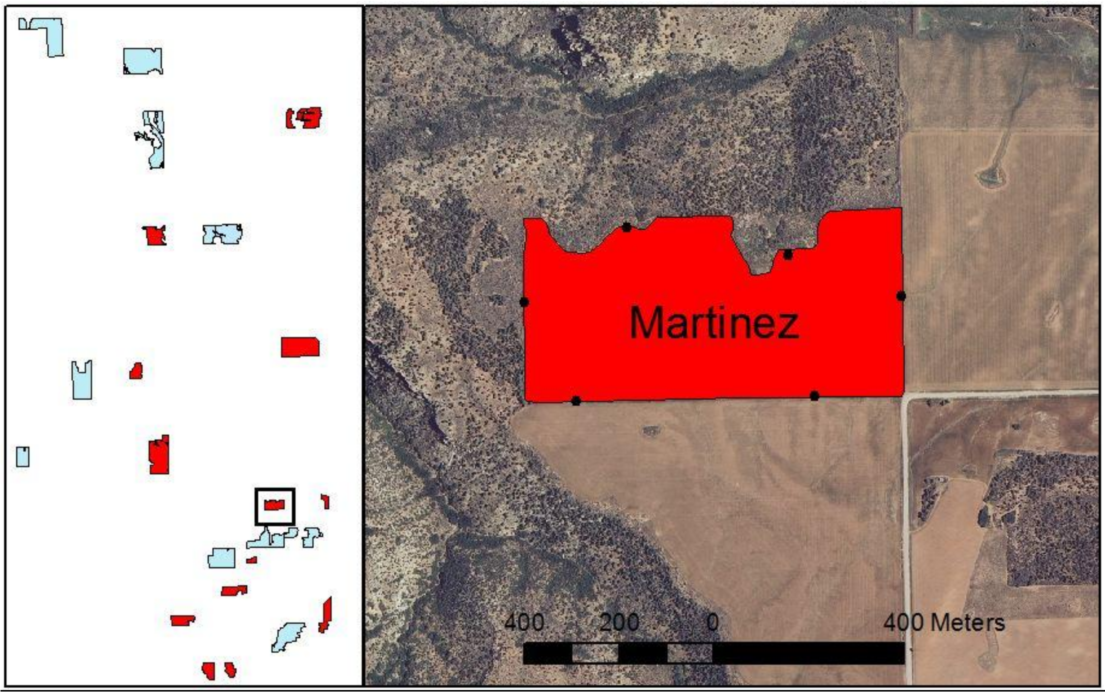
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
K Johnson	0-10m	62889.3	336042.3	5502.1	0.0	91	8
7/1/2010	10-20m	61147.9	335297.0	3076.1	0.0	74	6
	20-40m	115757.0	644107.2	1519.1	0.0	54	15
	40-80m	205197.0	1167809.7	897.6	0.0	22	9
	>80m	668895.0	4242772.3	1463.0	0.0	35	1
	Total	1113886.0	6726028.5	12458.0	0.0	276	39
		Percent damaged		0.19%	0.00%		
K Johnson	0-10m	62889.3	353649.1	34388.3	412.7	14	37
8/5/2010	10-20m	61147.9	372611.7	33569.8	0.0	2	22
	20-40m	115757.0	617775.8	12912.5	0.0	1	21
	40-80m	205197.0	1148062.0	6732.2	0.0	3	27
	>80m	668895.0	3748269.9	40964.7	5852.1	6	36
	Total	1113886.0	6240368.4	128567.5	6264.8	26	143
		Percent damaged		2.06%	0.10%		
K Johnson	0-10m	62889.3	326551.2	20633.0	1513.1	91	5
9/10/2010	10-20m	61147.9	319782.7	17520.5	267.5	88	6
	20-40m	115757.0	549668.5	6582.9	506.4	78	10
	40-80m	205197.0	983347.8	3590.5	897.6	70	10
	>80m	668895.0	3284491.0	10241.2	27797.5	86	7
	Total	1113886.0	5463841.2	58568.0	30982.0	413	38
		Percent damaged		1.07%	0.57%		

yield (kg per ha)	$ loss	Overall percent loss
1102.8	$ 651.93	0.99%



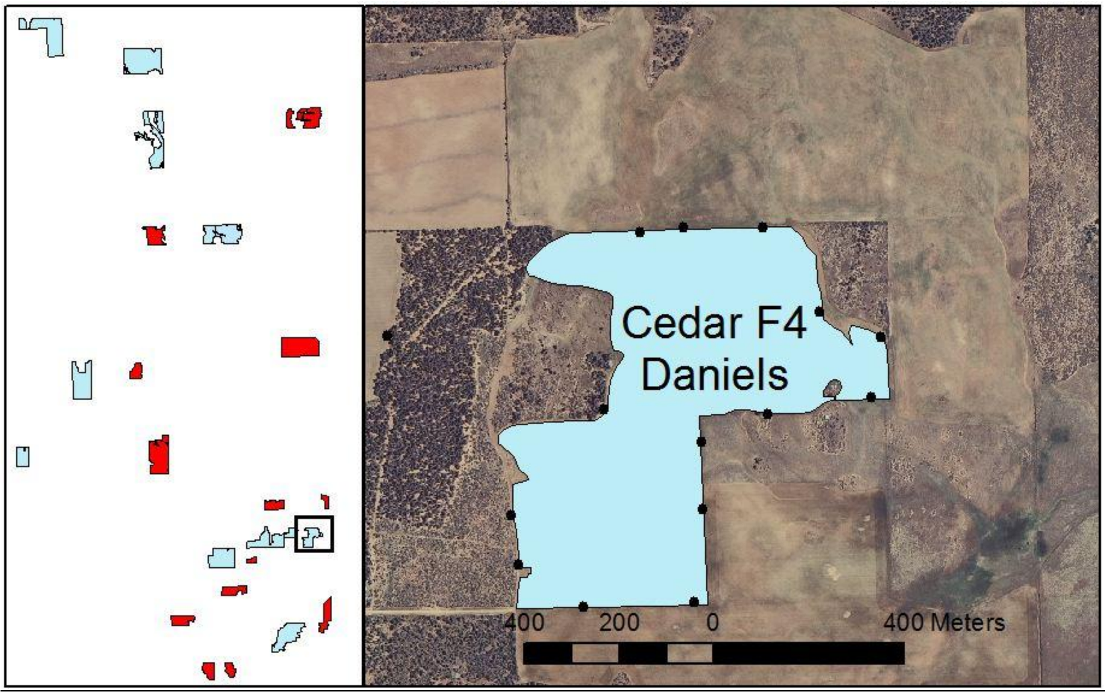
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Big Butts	0-10m	61267.9	193974.8	1005.1	0.0	33	32
7/5/2010	10-20m	60353.2	227875.6	12540.6	0.0	19	30
	20-40m	116079.0	460494.9	1904.2	952.1	13	13
	40-80m	185742.0	683532.2	0.0	0.0	9	21
	>80m	186419.0	885816.4	2548.4	0.0	12	8
	Total	609861.1	2451694.0	17998.2	952.1	86	104
		Percent damaged		0.73%	0.04%		
Big Butts	0-10m	61267.9	185264.4	1340.1	0.0	0	5
8/9/2010	10-20m	60353.2	210549.8	2145.1	0.0	1	7
	20-40m	116079.0	475411.0	6664.6	952.1	0	1
	40-80m	185742.0	598217.6	507.8	0.0	0	4
	>80m	186419.0	802739.3	1019.4	0.0	0	0
	Total	609861.1	2272182.1	11677.0	952.1	1	17
		Percent damaged		0.51%	0.04%		
Big Butts	0-10m	61267.9	183924.3	7370.4	11893.1	62	27
9/13/2010	10-20m	60353.2	218635.1	2310.1	495.0	56	26
	20-40m	116079.0	410351.5	4125.7	1904.2	44	13
	40-80m	185742.0	565209.0	1015.6	0.0	18	20
	>80m	186419.0	761455.6	1529.0	0.0	11	12
	Total	609861.1	2139575.5	16350.9	14292.3	191	98
		Percent damaged		0.00%	0.00%		

yield (kg per ha)	$ loss	Overall percent loss
1194.8	$ 367.83	0.94%



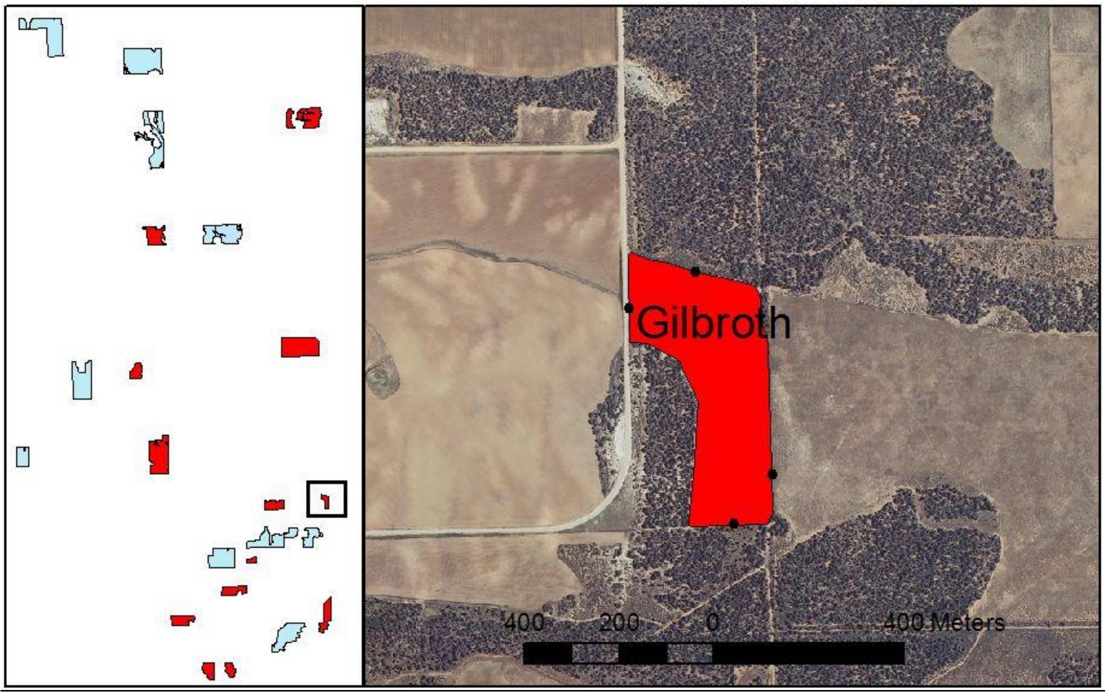
	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Martinez	0-10m	25967.1	123247.2	0.0	0.0	0	0
7/6/2010	10-20m	25147.3	120937.5	0.0	0.0	1	0
	20-40m	46889.4	235113.6	0.0	0.0	0	1
	40-80m	80740.2	421846.4	0.0	0.0	0	0
	>80m	106482.0	695789.5	0.0	0.0	1	0
	Total	285226.0	1596934.2	0.0	0.0	2	1
		Percent damaged		0.60%	0.00%		
Martinez	0-10m	25967.1	109332.2	4733.0	0.0	12	13
8/10/2010	10-20m	25147.3	116514.4	0.0	0.0	24	9
	20-40m	46889.4	227849.1	1367.4	0.0	20	11
	40-80m	80740.2	407645.0	588.7	0.0	24	11
	>80m	106482.0	695207.3	2717.2	0.0	25	14
	Total	285226.0	1556547.9	9406.3	0.0	105	58
		Percent damaged		0.53%	0.10%		
Martinez	0-10m	25967.1	113591.9	4354.4	1514.6	19	23
9/14/2010	10-20m	25147.3	112022.5	0.0	0.0	18	15
	20-40m	46889.4	241865.3	0.0	0.0	19	23
	40-80m	80740.2	389985.3	1471.6	0.0	23	27
	>80m	106482.0	674246.3	2329.0	0.0	16	40
	Total	285226.0	1531711.2	8155.0	1514.6	95	128
		Percent damaged		0.76%	0.67%		

yield (kg per ha)	$ loss	Overall percent loss
1351.9	$ 92.52	0.45%



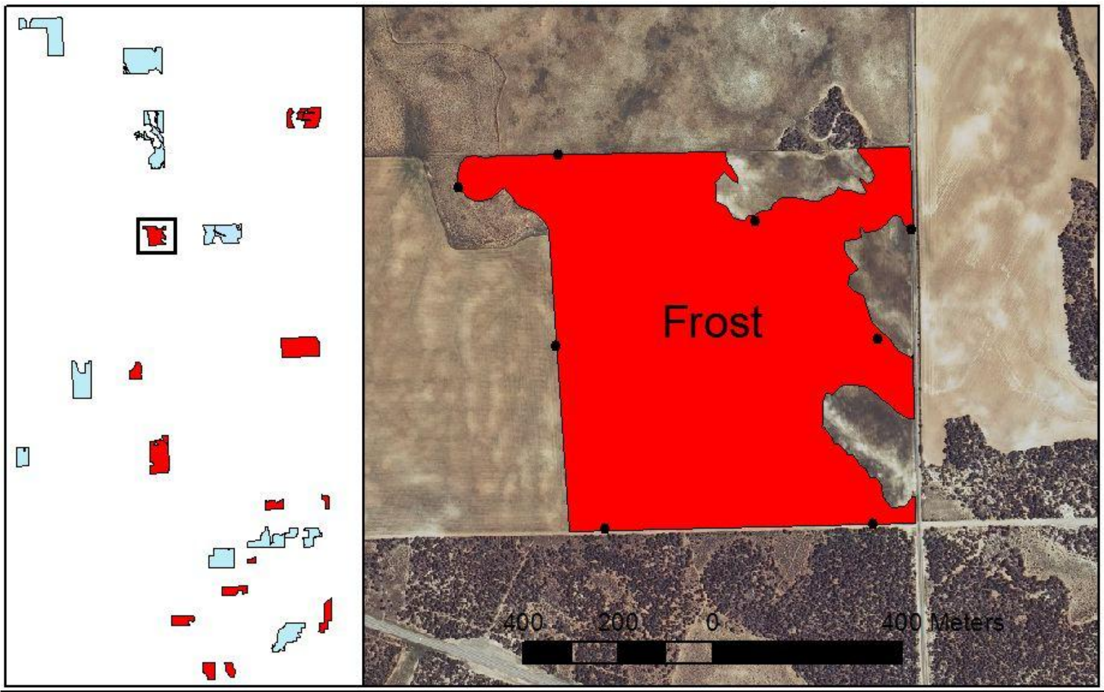
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Daniels	0-10m	35887.0	205749.8	9321.0	0.0	24	0
7/7/2011	10-20m	34475.0	184929.9	5184.1	0.0	25	0
	20-40m	65192.0	369129.0	0.0	0.0	9	0
	40-80m	103560.0	564574.1	0.0	0.0	7	1
	>80m	126834.0	606497.9	0.0	0.0	11	1
	Total	365948.0	1930880.7	14505.1	0.0	76	2
		Percent damaged		0.75%	0.00%		
Daniels	0-10m	35887.0	211538.6	15109.9	0.0	64	4
8/11/2010	10-20m	34475.0	229418.6	3864.5	0.0	48	3
	20-40m	65192.0	409232.4	1960.6	0.0	49	5
	40-80m	103560.0	655744.1	1698.8	0.0	51	3
	>80m	126834.0	699778.6	4161.2	0.0	29	3
	Total	365948.0	2205712.3	26795.0	0.0	241	18
		Percent damaged		1.21%	0.00%		
Daniels	0-10m	35887.0	220761.6	20408.2	5003.9	118	3
9/15/2010	10-20m	34475.0	218107.9	6692.2	659.8	92	2
	20-40m	65192.0	427412.6	5881.8	2495.3	85	4
	40-80m	103560.0	645834.3	3397.6	0.0	77	4
	>80m	126834.0	585691.8	5201.5	0.0	68	7
	Total	365948.0	2097808.1	41581.3	8159.0	440	20
		Percent damaged		1.98%	0.39%		

yield (kg per ha)	$ loss	Overall percent loss
1015.5	$ 217.27	1.09%



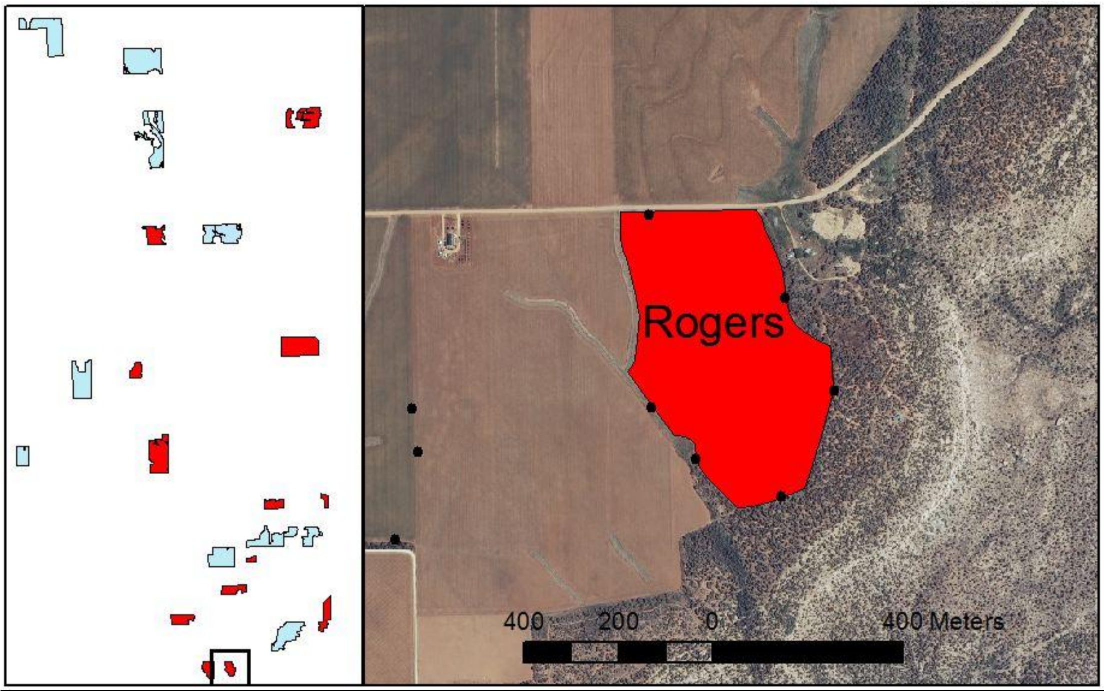
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Gilbroth	0-10m	15760.0	146845.1	1206.5	0.0	8	0
7/8/2010	10-20m	14954.0	103356.6	735.9	0.0	5	0
	20-40m	27430.1	155239.2	0.0	0.0	3	0
	40-80m	44204.7	227453.1	0.0	0.0	2	0
	>80m	6410.8	35966.1	0.0	0.0	2	0
	Total	108759.6	668860.2	1942.4	0.0	20	0
		Percent damaged		0.29%	0.00%		
Gilbroth	0-10m	15760.0	176576.1	4567.4	0.0	4	0
8/13/2010	10-20m	14954.0	138272.2	572.4	0.0	1	0
	20-40m	27430.1	219584.8	0.0	0.0	3	0
	40-80m	44204.7	290540.5	483.4	0.0	2	3
	>80m	6410.8	36912.6	0.0	0.0	8	6
	Total	108759.6	861886.2	5623.2	0.0	18	9
		Percent damaged		0.65%	0.00%		
Gilbroth	0-10m	15760.0	151498.7	4825.9	172.4	29	1
9/21/2010	10-20m	14954.0	118402.2	6132.7	0.0	24	1
	20-40m	27430.1	204885.8	749.9	0.0	32	2
	40-80m	44204.7	271686.8	725.1	0.0	34	4
	>80m	6410.8	38384.9	175.3	0.0	27	5
	Total	108759.6	784858.4	12609.0	172.4	146	13
		Percent damaged		1.61%	0.02%		

yield (kg per ha)	$ loss	Overall percent loss
1020.7	$ 58.46	0.98%



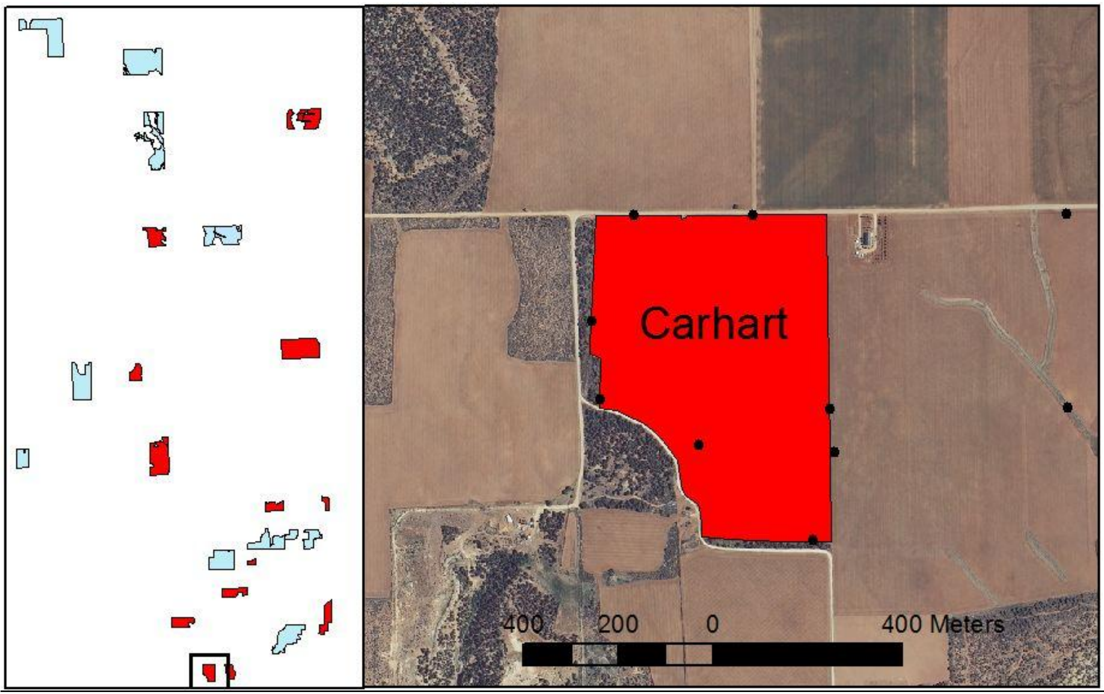
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Frost	0-10m	44155.1	337054.5	9174.8	0.0	26	92
7/9/2010	10-20m	41607.5	315218.7	2047.6	0.0	11	40
	20-40m	76049.0	444949.9	5613.9	0.0	14	58
	40-80m	110207.0	498968.7	2711.8	0.0	15	52
	>80m	252467.0	1540645.1	4831.8	0.0	13	42
	Total	524485.6	3136836.8	24379.9	0.0	79	284
		Percent damaged		0.78%	0.00%		
Frost	0-10m	44155.1	408642.3	13279.4	120.7	2	113
8/19/2010	10-20m	41607.5	347753.0	2957.7	113.8	7	78
	20-40m	76049.0	463038.9	7485.1	0.0	1	101
	40-80m	110207.0	549890.0	9039.3	0.0	3	101
	>80m	252467.0	1657988.1	24849.1	0.0	4	82
	Total	524485.6	3427312.4	57610.6	234.5	17	475
		Percent damaged		1.68%	0.01%		
Frost	0-10m	44155.1	349971.7	17866.8	5191.0	87	161
10/19/2010	10-20m	41607.5	300771.6	7394.2	682.5	64	165
	20-40m	76049.0	486949.8	23910.9	2079.2	79	219
	40-80m	110207.0	500776.6	26515.2	6327.5	68	208
	>80m	252467.0	1545476.9	51078.7	8283.0	73	147
	Total	524485.6	3183946.5	126765.8	22563.3	371	900
		Percent damaged		3.98%	0.71%		

yield (kg per ha)	$ loss	Overall percent loss
534.0	$ 297.15	1.98%



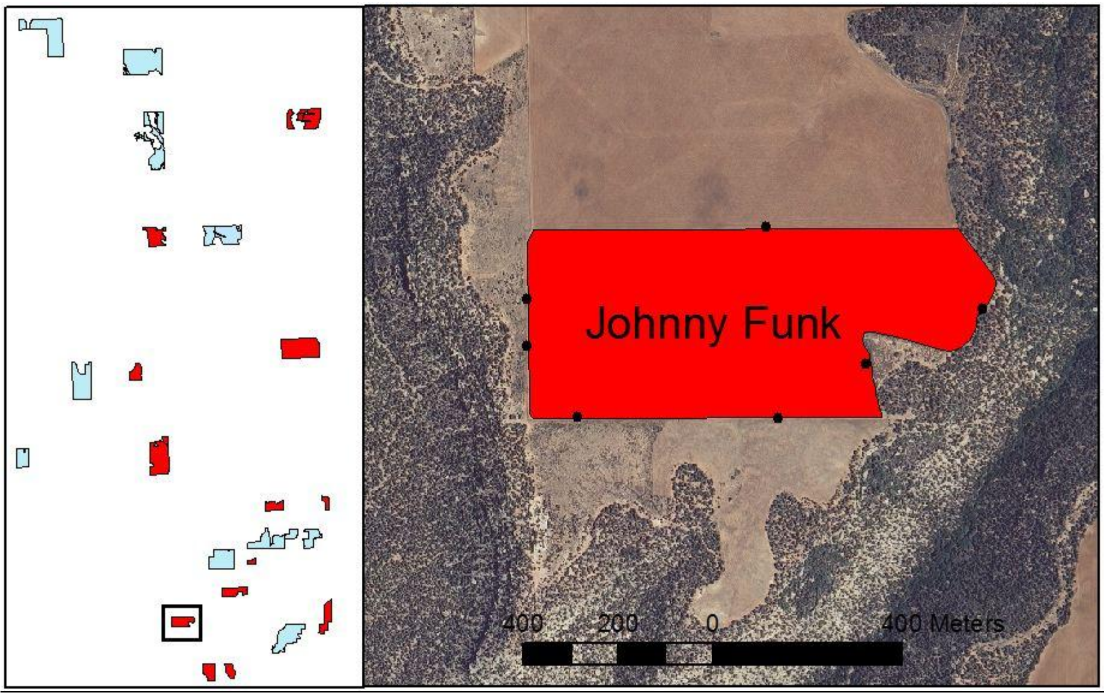
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Rogers	0-10m	17911.2	105709.5	130.6	0.0	3	0
7/9/2010	10-20m	17188.9	95368.6	0.0	0.0	1	0
	20-40m	32195.7	204685.4	0.0	0.0	1	0
	40-80m	55557.1	300954.5	0.0	0.0	0	0
	>80m	75212.6	383027.1	0.0	0.0	1	0
	Total	198065.5	1089745.2	130.6	0.0	6	0
		Percent damaged		0.01%	0.00%		
Rogers	0-10m	17911.2	126929.8	130.6	0.0	10	0
8/14/2010	10-20m	17188.9	129956.9	0.0	0.0	14	0
	20-40m	32195.7	210905.8	0.0	0.0	6	0
	40-80m	55557.1	375686.9	0.0	0.0	6	0
	>80m	75212.6	525599.9	0.0	0.0	9	0
	Total	198065.5	1369079.2	130.6	0.0	45	0
		Percent damaged		0.01%	0.00%		
Rogers	0-10m	17911.2	132871.4	5223.4	1305.9	11	1
9/21/2010	10-20m	17188.9	133967.1	0.0	0.0	12	1
	20-40m	32195.7	223111.8	352.1	0.0	12	5
	40-80m	55557.1	358877.2	810.1	0.0	20	8
	>80m	75212.6	487214.9	0.0	0.0	10	2
	Total	198065.5	1336042.4	6385.6	1305.9	65	17
		Percent damaged		0.48%	0.10%		

yield (kg per ha)	$ loss	Overall percent loss
210.8	$ 3.07	0.14%



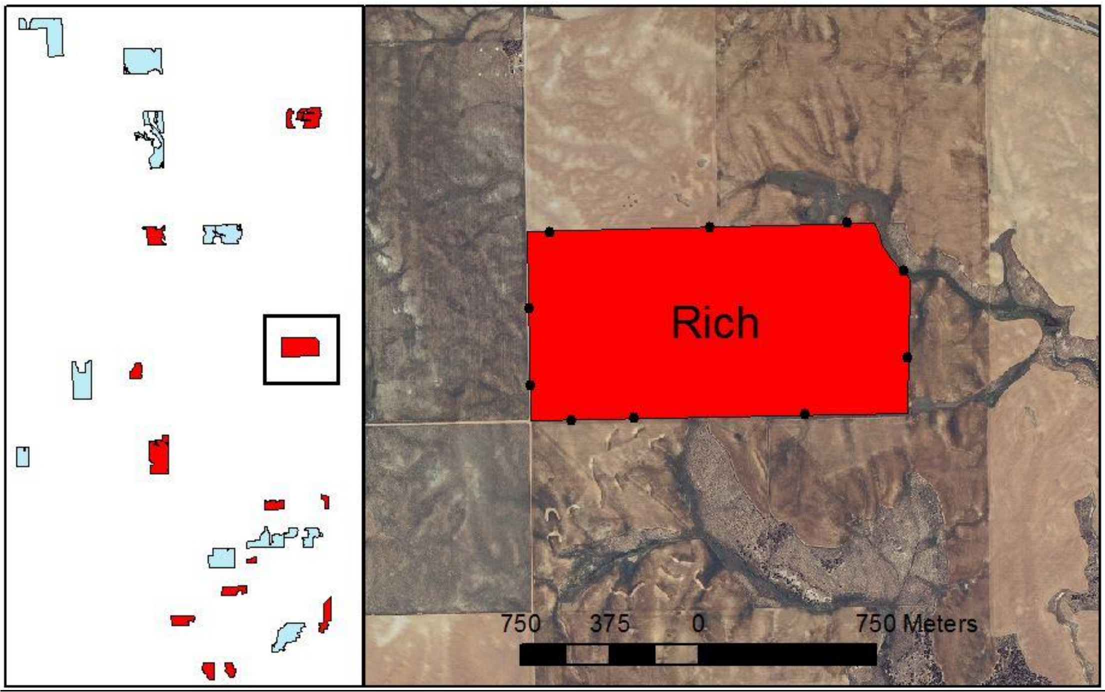
	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Carhart	0-10m	22275.9	77529.6	1461.7	0.0	0	0
7/14/2010	10-20m	21398.7	115780.9	234.0	0.0	1	0
	20-40m	40276.5	208231.8	0.0	0.0	1	0
	40-80m	70615.9	285544.9	0.0	0.0	0	0
	>80m	138366.0	681691.6	0.0	0.0	0	0
	Total	292933.0	1368778.9	1695.7	0.0	2	0
		Percent damaged		0.12%	0.00%		
Carhart	0-10m	22275.9	101281.8	852.6	0.0	15	0
8/16/2010	10-20m	21398.7	139767.9	0.0	0.0	10	0
	20-40m	40276.5	237412.9	0.0	0.0	6	0
	40-80m	70615.9	335935.2	0.0	0.0	6	0
	>80m	138366.0	801990.2	0.0	0.0	3	0
	Total	292933.0	1616387.9	852.6	0.0	40	0
		Percent damaged		0.05%	0.00%		
Carhart	0-10m	22275.9	88553.0	1035.4	0.0	28	1
10/26/2010	10-20m	21398.7	134502.4	351.0	0.0	32	1
	20-40m	40276.5	233118.3	110.1	0.0	48	2
	40-80m	70615.9	305623.8	0.0	0.0	43	1
	>80m	138366.0	777022.5	0.0	0.0	44	5
	Total	292933.0	1538820.1	1496.5	0.0	195	10
		Percent damaged		0.10%	0.00%		

yield (kg per ha)	$ loss	Overall percent loss
623.8	$ 2.66	0.03%



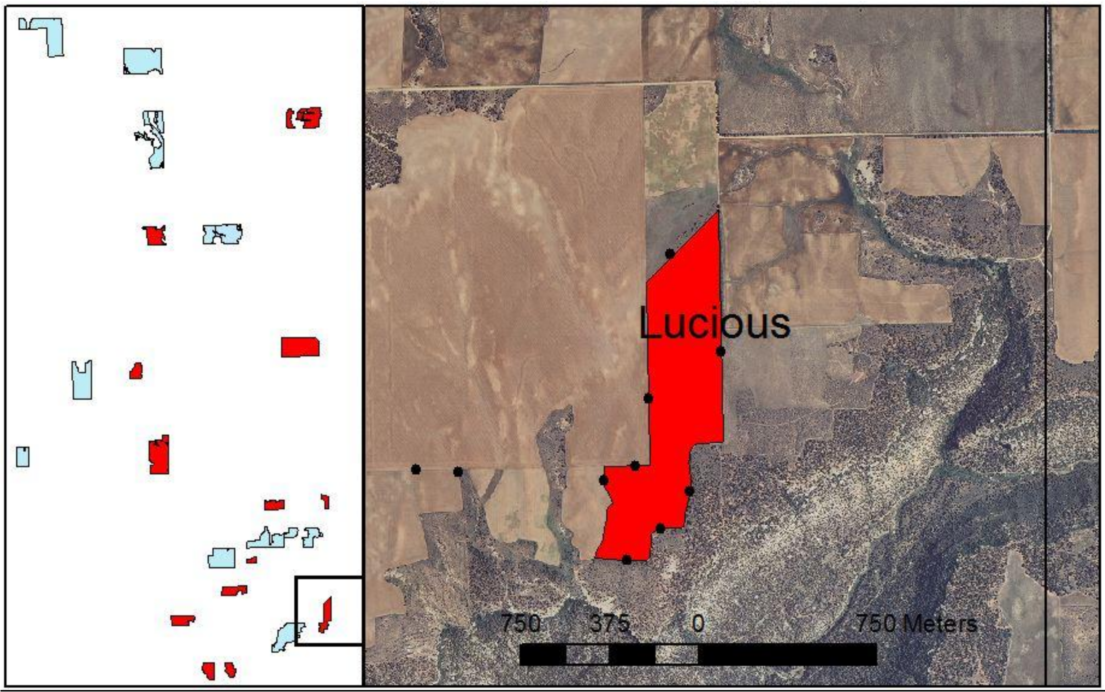
	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Johnny Funk	0-10m	27031.8	154241.5	73.9	0.0	0	0
7/15/2010	10-20m	26294.8	138533.7	143.8	0.0	0	0
	20-40m	50266.7	271151.0	0.0	0.0	0	0
	40-80m	90911.4	467531.6	0.0	0.0	1	0
	>80m	150707.0	657200.5	0.0	0.0	1	0
	Total	345211.7	1688658.3	217.7	0.0	2	0
		Percent damaged		0.01%	0.00%		
Johnny Funk	0-10m	27031.8	197254.7	739.1	0.0	6	6
8/17/2010	10-20m	26294.8	171747.3	1078.4	0.0	3	9
	20-40m	50266.7	305371.3	0.0	0.0	1	2
	40-80m	90911.4	613184.7	248.6	0.0	0	4
	>80m	150707.0	793173.1	0.0	0.0	0	4
	Total	345211.7	2080731.0	2066.0	0.0	10	25
		Percent damaged		0.10%	0.00%		
Johnny Funk	0-10m	27031.8	172939.7	369.5	3621.4	22	3
10/31/2010	10-20m	26294.8	164845.7	1653.5	0.0	17	3
	20-40m	50266.7	307295.3	0.0	0.0	17	3
	40-80m	90911.4	628098.0	0.0	0.0	15	3
	>80m	150707.0	755677.6	0.0	0.0	15	2
	Total	345211.7	2028856.3	2023.0	3621.4	86	14
		Percent damaged		0.10%	0.00%		

yield (kg per ha)	$ loss	Overall percent loss
1264.0	$ 47.36	0.20%



	Distance	Area m^2	# of plants	# damaged live	# dead	# deer	# elk
Rich	0-10m	43799.3	190427.1	4364.2	0.0	25	42
7/25/2010	10-20m	43234.8	264359.8	1996.4	0.0	29	33
	20-40m	84605.3	511563.1	1439.3	0.0	17	22
	40-80m	156799.1	954558.5	0.0	0.0	13	12
	>80m	739176.1	4156832.6	1796.4	0.0	24	25
	Total	1080845.0	6077741.2	9596.2	0.0	108	134
		Percent damaged		0.16%	0.00%		
Rich	0-10m	43799.3	175737.9	2235.3	0.0	22	14
8/22/2010	10-20m	43234.8	273185.8	630.4	0.0	15	8
	20-40m	84605.3	576742.2	0.0	0.0	16	3
	40-80m	156799.1	956082.8	381.1	0.0	14	5
	>80m	739176.1	4158629.0	19760.2	0.0	6	22
	Total	1080845.0	6140377.7	23007.0	0.0	73	52
		Percent damaged		0.37%	0.00%		
Rich	0-10m	43799.3	166690.2	2661.1	212.9	48	4
9/21/2010	10-20m	43234.8	258580.8	1471.0	0.0	41	5
	20-40m	84605.3	580648.8	5140.3	0.0	42	2
	40-80m	156799.1	990759.4	3048.5	381.1	41	2
	>80m	739176.1	4133479.6	43113.2	8981.9	63	5
	Total	1080845.0	6130158.9	55434.1	9575.9	235	18
		Percent damaged		0.90%	0.16%		

yield (kg per ha)	$ loss	Overall percent loss
663.6	$ 198.43	0.52%



	Distance	Area m²	# of plants	# damaged live	# dead	# deer	# elk
Lucious	0-10m	36968.9	293418.4	3335.4	0.0	86	12
7/27/2010	10-20m	35961.0	278241.6	589.9	0.0	79	9
	20-40m	68677.0	551654.2	563.3	0.0	44	7
	40-80m	123691.0	773068.8	2029.1	338.2	22	13
	>80m	130253.0	1286291.1	2136.7	0.0	20	4
	Total	395550.9	3182674.0	8654.4	338.2	251	45
		Percent damaged		0.27%	0.01%		
Lucious	0-10m	36968.9	315250.4	1819.3	0.0	73	3
8/24/2010	10-20m	35961.0	297020.4	688.2	0.0	61	2
	20-40m	68677.0	568928.6	4318.6	0.0	44	1
	40-80m	123691.0	811620.7	0.0	338.2	37	4
	>80m	130253.0	1364636.6	0.0	0.0	31	0
	Total	395550.9	3357456.8	6826.2	338.2	246	10
		Percent damaged		0.20%	0.01%		
Lucious	0-10m	36968.9	259760.7	3032.2	101.1	91	2
10/22/2010	10-20m	35961.0	284239.0	1769.7	0.0	88	1
	20-40m	68677.0	536257.4	3004.2	0.0	73	1
	40-80m	123691.0	745676.6	2029.1	676.4	63	0
	>80m	130253.0	1379593.5	712.2	0.0	59	1
	Total	395550.9	3205527.2	10547.5	777.4	374	5
		Percent damaged		0.33%	0.02%		

yield (kg per ha)	$ loss	Overall percent loss
1137.9	$ 48.00	0.20%

APPENDIX F. FIELD VARIABLES

Table 10. Field variable I measured using on-the-ground sampling and ArcGIS.

Location	Damage	Area	Edge	Edge to area	Canyon	Weeds	Not visible	Road	PJ	Sagebrush	CRP	Wheat	Bean	Fallow	Oats	Safflower	Sunflower
		ha	m	m / ha	km	% cover	%	%	%	%	%	%	%	%	%	%	%
Eastland F1	1.7%	39.8	2914	73.1	0	23%	0%	18%	1%	20%	0%	53%	0%	27%	0%	0%	0%
Cedar F2	0.1%	72.8	5572	76.5	0	3%	0%	42%	20%	37%	40%	0%	0%	0%	0%	3%	0%
Cedar F3	2.0%	17.1	1794	105.2	0.4	3%	0%	10%	43%	7%	20%	20%	0%	0%	0%	10%	0%
Ucolo F2	2.5%	72.6	5093	70.1	6.1	3%	0%	12%	47%	9%	30%	6%	0%	0%	0%	8%	0%
Ucolo F1	4.5%	34.3	3035	88.5	6.9	1%	0%	16%	38%	2%	33%	0%	0%	13%	0%	14%	0%
Summit F2	6.0%	159.3	6543	41.1	5.1	28%	25%	17%	15%	6%	39%	4%	0%	37%	0%	0%	0%
Eastland F4	4.9%	109.0	5590	51.3	0.4	30%	100%	43%	27%	3%	0%	25%	0%	45%	0%	0%	0%
Summit F1	12.0%	102.2	9253	90.6	6.2	25%	0%	32%	11%	2%	40%	47%	0%	0%	0%	1%	0%
Summit F4	2.6%	145.8	7332	50.3	9	37%	0%	0%	0%	59%	16%	22%	0%	0%	0%	0%	3%
Cedar F4	1.6%	36.6	3411	93.2	1	0%	50%	21%	11%	34%	19%	19%	0%	18%	0%	0%	0%
Cedar F5	0.5%	87.9	5153	58.7	0	18%	40%	2%	17%	68%	0%	0%	0%	15%	0%	0%	0%
Cedar F1	0.9%	80.5	3753	46.6	0	0%	25%	37%	26%	26%	0%	48%	0%	0%	0%	0%	0%
Cedar	0.0%	34.7	3039	87.6	0.6	32%	0%	45%	4%	32%	7%	31%	16%	10%	0%	0%	0%
Little Butts	0.4%	17.7	2372	133.8	4.5	9%	100%	0%	83%	11%	6%	0%	0%	0%	0%	0%	0%
W Long Draw	1.4%	26.7	2226	83.4	0.6	10%	0%	21%	38%	10%	18%	27%	0%	0%	0%	6%	0%
Brelove	0.1%	7.0	1247	179.2	1.2	1%	0%	11%	32%	24%	33%	0%	11%	0%	0%	0%	0%
Kay Johnson	1.0%	111.4	5076	45.6	0	18%	0%	47%	14%	17%	0%	30%	23%	12%	5%	0%	0%
Big Butts	0.9%	61.0	6120	100.4	4.5	16%	100%	0%	72%	3%	14%	11%	0%	0%	0%	0%	0%
Martinez	0.4%	28.5	2644	92.7	0	14%	0%	0%	17%	38%	0%	0%	0%	30%	15%	0%	0%
Daniels	1.1%	36.6	3411	93.2	1	1%	50%	21%	11%	34%	19%	19%	0%	18%	0%	0%	0%
Gilbroth	1.0%	10.9	1631	150.0	1.7	0%	25%	12%	48%	11%	29%	12%	0%	0%	0%	0%	0%
Frost	2.0%	52.4	3431	65.4	4	15%	0%	45%	21%	21%	20%	20%	0%	19%	0%	0%	0%
Rogers	0.1%	19.8	1828	92.3	0	17%	0%	17%	45%	6%	5%	17%	27%	0%	0%	0%	0%
Carhart	0.0%	29.3	2268	77.4	0.3	11%	0%	69%	41%	4%	3%	0%	30%	0%	15%	0%	7%
Johnny Funk	0.2%	34.5	2761	80.0	0	2%	20%	42%	14%	34%	19%	0%	0%	0%	0%	33%	0%
Rich	0.5%	108.1	4695	43.4	1.8	23%	0%	17%	0%	0%	25%	17%	0%	21%	0%	37%	0%
Lucious	0.2%	39.6	3758	95.0	0	3%	0%	52%	25%	24%	0%	27%	0%	10%	0%	13%	0%