



Deer use of irrigated alfalfa along the Yellowstone River, Custer County, Montana
by Ryan Lee Rauscher

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish
and Wildlife Management
Montana State University
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Abstract:

Wild ungulates use agricultural croplands and can reduce yields. In Montana, many agricultural producers perceive damage to growing hay and haystacks to be a serious problem. I measured white-tailed deer and mule deer (*Odocoileus virginianus* and *O. hemionus*) use of irrigated alfalfa (*Medicago sativa*) along the Yellowstone River to determine extent and timing of alfalfa depredation from June 1993 until August 1994. Differences between protected and unprotected plots were used to determine extent and timing of depredation. Daily and seasonal use patterns by deer were determined using daylight and nocturnal counts. The amount of deer use required to cause significant crop yield reduction was estimated using simulated grazing. Landscape arrangement and its influence on deer use of alfalfa was evaluated using multiple linear regression. No significant yield reduction took place during the study. Deer generally used alfalfa fields more intensively during dusk and night periods than dawn and day periods. No differences were detected between summer, spring and fall. Deer used alfalfa fields the least amount during winter. Simulated grazing indicated that 7.6 deer/ha/day to 30.9 deer/ha/day ($x=19.1$) were required to have a 95% probability of detecting a significant yield reduction (7%-17%). Of 5 models testing interactions of landscape variables and deer use, only 1 successful model explained a substantial portion of the variability in deer use. Important landscape variables included in this model were the amounts of alfalfa field bordered by buildings, adjacent croplands other than alfalfa, woods within a 1 km radius and breaks within a 1 km radius.

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APPROVAL

of a thesis submitted by

Ryan Lee Rauscher

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

24 April 1995
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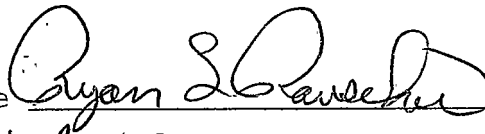
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ABSTRACT

Wild ungulates use agricultural croplands and can reduce yields. In Montana, many agricultural producers perceive damage to growing hay and haystacks to be a serious problem. I measured white-tailed deer and mule deer (*Odocoileus virginianus* and *O. hemionus*) use of irrigated alfalfa (*Medicago sativa*) along the Yellowstone River to determine extent and timing of alfalfa depredation from June 1993 until August 1994. Differences between protected and unprotected plots were used to determine extent and timing of depredation. Daily and seasonal use patterns by deer were determined using daylight and nocturnal counts. The amount of deer use required to cause significant crop yield reduction was estimated using simulated grazing. Landscape arrangement and its influence on deer use of alfalfa was evaluated using multiple linear regression. No significant yield reduction took place during the study. Deer generally used alfalfa fields more intensively during dusk and night periods than dawn and day periods. No differences were detected between summer, spring and fall. Deer used alfalfa fields the least amount during winter. Simulated grazing indicated that 7.6 deer/ha/day to 30.9 deer/ha/day ($\bar{x}=19.1$) were required to have a 95% probability of detecting a significant yield reduction (7%-17%). Of 5 models testing interactions of landscape variables and deer use, only 1 successful model explained a substantial portion of the variability in deer use. Important landscape variables included in this model were the amounts of alfalfa field bordered by buildings, adjacent croplands other than alfalfa, woods within a 1 km radius and breaks within a 1 km radius.

INTRODUCTION

Montana encompasses 38 million ha of which 24 million ha are considered croplands and rangeland. Approximately 1.8 million ha of this agricultural land are hayland producing 4.1 million metric tons annually. Hay ranks first in order of value of farm commodities (Software Toolworks 1992). Wild ungulates use agricultural croplands and can cause yield reductions to hay lands (Adkins 1991, Cole 1956, Compton 1986, Egan 1957, Selting 1994). Agricultural producers perceive wildlife damage to growing hay and haystacks to be a serious problem (MAES 1993). Unlike other western states, Montana by statute does not compensate agricultural producers for wildlife damage to agricultural crops (Aderhold 1985). Thus, depredation by wildlife has the potential to create friction between wildlife and agricultural interests.

To assess to what degree deer reduce crop yields, wildlife managers need more information on how extensively deer feed on irrigated alfalfa. This information will allow them to identify appropriate techniques to resolve wildlife damage complaints. Currently, the most effective tool to alleviate game damage to hay lands is population reduction by hunting (Aderhold, 1985). With additional information, managers may be able to refine strategies for using hunting

or other damage control techniques to deal with damage and/or perception of damage.

Irrigated alfalfa in Custer County, Montana occurs in the greatest amounts along the Yellowstone River. Past studies have documented the strong association between deer and riparian-agriculture complexes (Herriges 1983, Swenson et al. 1983, Dusek et. al. 1989, Wood 1989). Other studies involving deer along the Yellowstone River utilized radio telemetry and visual counts to investigate the ecology of white-tailed deer, deer movements and habitat use, and use of agricultural crops (Herriges 1983, Compton 1986, Dusek et. al. 1989). This study focused on deer utilization patterns of specific alfalfa fields over time. The primary objective was to quantify timing and extent of deer damage to irrigated alfalfa. Ancillary objectives included determining diel and seasonal deer use patterns of irrigated alfalfa fields, quantifying the amount of deer use required to significantly reduce yield, and determining the influence of landscape arrangement on deer use of irrigated alfalfa fields.

DESCRIPTION OF STUDY AREA

Location

The study area, located in Custer County, Montana, was situated along the Yellowstone River in east-central Montana (Fig. 1). The study area included 2 primary sites. Fort Keogh Agricultural Research Station (FKARS), located 2 km east of Miles City, Montana, was used to determine timing and extent of depredation and diel use patterns of irrigated alfalfa by deer. The Kinsey site located 25 km east of Miles City, Montana, in conjunction with the FKARS site, was used to determine seasonal use patterns and the influence of landscape arrangement on deer use of irrigated alfalfa fields. The study area included irrigated alfalfa fields along approximately 45 km of the Yellowstone River.

Three irrigated alfalfa fields located on FKARS were used in the evaluation of diel use patterns and extent and timing of depredation. Fields were selected to encompass low, moderate, and high levels of use by deer. One additional field in 1993 and 2 in 1994 were used in combination with Kinsey area fields to determine landscape arrangement influence on deer use.

Twenty irrigated alfalfa fields were selected on the Kinsey site and used to determine seasonal use patterns and

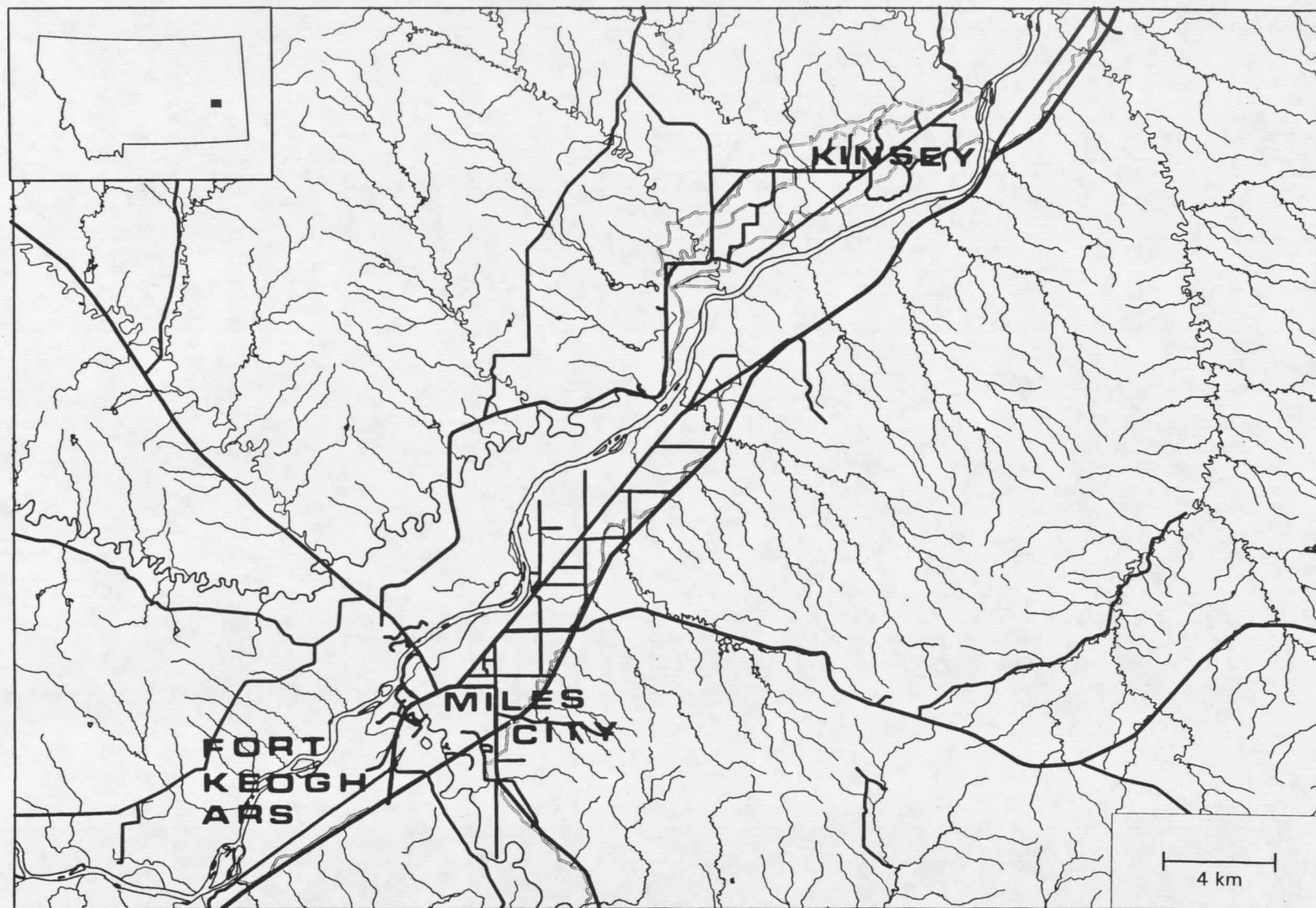


Figure 1. Map of Fort Keogh ARS and Kinsey study areas.

landscape influences on deer use in 1993. The number of fields was reduced to 17 in 1994 when 3 fields were planted with alternate crops. Study fields at the Kinsey site were selected such that they were close to roads allowing yearlong access, were in areas offering a diversity of land uses, and could be sampled without interfering with landowner operations.

Physical Characteristics

Elevations at Fort Keogh ARS and Kinsey are 716 m and 707 m, respectively. The sedimentary bedrock of the area, the Fort Union formation, was formed during the late Cretaceous Period and consists of soft mudstone and sandstone (Alt and Hyndman 1986). Soils of the Yellowstone floodplain are alluvial lithosols consisting of clay and clay-loam underlain with soft shale and sandstone (Southard 1969).

Climate

Climate of the Miles City area is semi-arid with an average annual rainfall of 35.75 cm and average annual temperature of 7.6 C. Average monthly temperatures vary from -9 C in January to 23 C in July. Temperatures were below average during 1993 and slightly above average in 1994 (Fig. 2). Average monthly precipitation varies from 1.1 cm in

February to 7 cm in June. Precipitation was above average during the growing season in 1993 and slightly below average during the growing season in 1994 (Fig. 3). The study site has an average of 145 frost-free days (NOAA, 1993,1994)

Land Use

Agriculture is the dominant land use in the Yellowstone River valley near Miles City. Irrigated crops, including alfalfa, corn, sugar beets, small grains and various silage crops, are concentrated in the flood plain of the Yellowstone River. The majority of irrigation consists of leveled terraces and gated irrigation pipe. Wheel-line sprinkler, center-pivot sprinkler and flooding are used to a lesser extent.

Riparian areas immediately adjacent to the Yellowstone River are generally unsuitable for crop production and are utilized to graze livestock. Vegetation in riparian areas are comprised of cottonwood (*Populus spp.*), shrubs (*Symphoricarpos occidentalis*, *Rosa woodsii*, *Ulmus americana*, *Acer negundo*, *Sheperdia argenta*, *Elaeagnus angustifolia*, *Sarcobatus vermiculatus*), green ash (*Fraxinus pennsylvanica*), willow (*Salix spp.*) and grasslands. Upland areas above the Yellowstone River floodplain are dominated by sagebrush-grasslands and grasslands (*Artemisia spp.*,

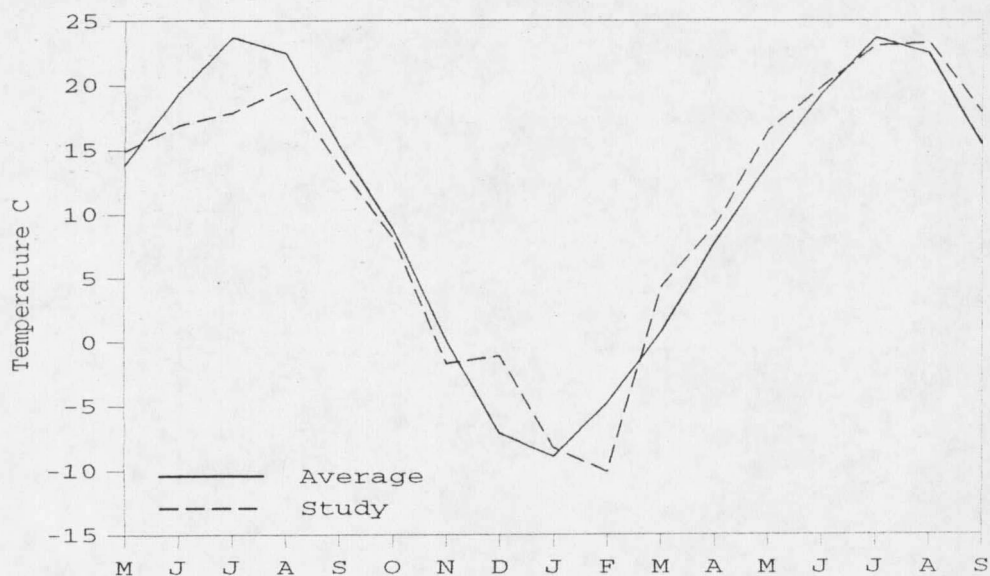


Figure 2. Average monthly temperatures from May 1993 to September 1994 relative to the longterm average.

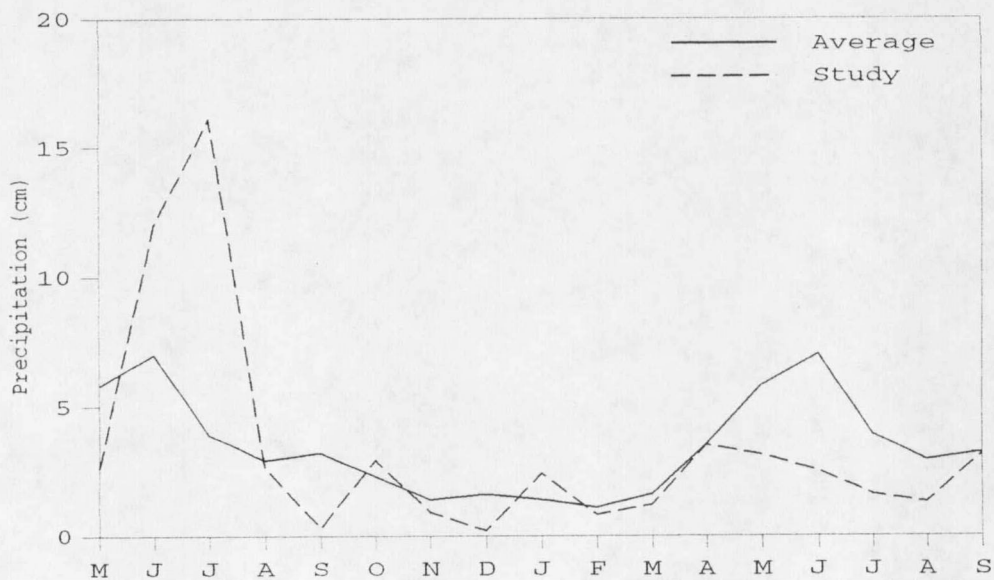


Figure 3. Average monthly precipitation values from May 1993 to September 1994 relative to the longterm average.

Bouteloua gracilis, *Agropyron smithii*, *Bromus japonicus*,
Stipa comata) habitats. Livestock grazing is the primary
land use of the upland areas.

METHODS

Extent and Timing of DepredationExtent of Depredation

Extent of deer depredation on irrigated alfalfa was determined by comparison of oven-dried alfalfa weights from protected and non-protected quadrats on 3 irrigated alfalfa fields located on FKARS. Quadrats measured 60 cm by 60 cm (0.36 m^2). Exclosures were used to protect alfalfa within control quadrats from defoliation by deer. Thirty large exclosures, 10 per field, were constructed to measure utilization during the growing and dormant seasons. Each exclosure was constructed of 81 cm netted fencing. Exclosure fences were 1.5 m in height and measured approximately 3 m in diameter (9.4 m circumference). Each exclosure was held in place by a steel fence post. Exclosures were randomly positioned in the field using methods described by Tebaldi and Anderson (1982).

Twenty small exclosures were constructed to measure overwinter deer use of alfalfa fields. These exclosures were made using methods described for the large exclosures but had a diameter of approximately 1 m. Positioning followed methods for the large exclosures.

Non-protected quadrats were located by following the plant rows from the enclosed control quadrat and randomly

selecting a distance between 2 m and 4 m from the exclosure. Preliminary data collected in May, 1993 indicated approximately 6 paired quadrats were needed per field to detect statistical differences among treatments at the desired level. The number of paired quadrats was increased to 10 to allow for possible livestock and wildlife damage to the exclosures and increased variability due to irrigation and deer use variability within fields.

Alfalfa within all quadrats was clipped to ground level using hand clippers. All alfalfa clipped was bagged, oven dried at 60 C for ≥ 48 hours and weighed to the nearest 0.1 gram. Paired t-tests (Box et. al. 1978) were used to test for significant differences among treatments. Significance was established at $P < 0.05$.

Timing of depredation

Timing of deer depredation was determined by clipping alfalfa within paired quadrats at sampling intervals reflecting different deer use periods (Table 1). The clipping schedule was based on the annual growth cycle of irrigated alfalfa. Alfalfa within paired quadrats was clipped and exclosures removed prior to harvest to avoid interference with harvest operations. Exclosures were replaced in the field soon after each harvest was completed.

Table 1. Schedule of sampling intervals for removal and replacement of large exclosures (R. Ditterline pers. commun.).

Time Period	Reason and Situation
23 Jun 93 - 9 Jul 93	Initial placement after first harvest
29 Jul 93 - 8 Aug 93	Clipping prior to second harvest and replacement after fields were cleared
11 Aug 93 - 16 Aug 93	Clipping prior to third harvest and replacement after fields were cleared
1 Nov 93 - 3 Nov 93	Clipping and repositioning at the start of winter dormancy
22 Apr 94 - 24 Apr 94	Clipping and repositioning at the start of growing season
9 Jun 94 - 11 Jun 94	Clipping prior to first harvest and replacement after fields were cleared
20 Jul 94 - 1 Aug 94	Clipping prior to second harvest and replacement after fields were cleared
3 Sep 94 - 9 Sep 94	Final clipping prior to third harvest

Positions previously sampled were excluded from repeat sampling. Siting, clipping, and replacement of quadrats continued through the study period. Winter use in 1993 and early spring use 1994 were determined by separation of dead material from green material at the start of the growing season 1994.

Reduction of first harvest yield by fall, winter and

early spring deer use was determined by placing 20 small exclosures in 2 alfalfa fields that would not be grazed by cattle following the third cutting in September, 1993. The exclosures were left in place until the week prior to first harvest in June, 1994 when alfalfa plants within the paired quadrats were clipped, oven-dried and weighed to the nearest 0.1 grams. Paired t-tests (Box et. al. 1978) were used to test for significant differences among treatments. Significance was established at $P < 0.05$.

Exclosure Effects

The possibility of increased or decreased production due to exclosures was examined once in 1993 and twice in 1994. A fenced area designed to exclude deer was constructed to encompass 9 small exclosures and 9 quadrats outside the small exclosures following the first harvest in 1993. Eighteen quadrats were defined inside the fence and a coin toss determined if a quadrat was inside an exclosure. Alfalfa within quadrats was clipped immediately prior to the second harvest in July, 1993.

Following the first harvest in June, 1994, 10 paired quadrats were defined inside the deer exclusion fence and a coin toss determined which quadrat was encompassed in an exclosure. Ten small exclosures and 10 quadrats were enclosed in the deer exclusion fence. Alfalfa within the

quadrats was clipped immediately prior to the second harvest in July, 1994. Following the second harvest in 1994, 10 large exclosures and 10 quadrats were arranged inside the deer exclusion fence using the same methods described for the small exclosures. Alfalfa within quadrats was clipped immediately prior to the third harvest in September, 1994.

Comparison of oven-dried weights of alfalfa from quadrats inside and outside exclosures determined if exclosures had a significant influence of alfalfa growth and if adjustments to dried alfalfa weights of enclosed quadrats were necessary. A paired t-test (Box et al. 1978) was used to test for significant differences ($P < 0.05$).

The possibility of deer selection or avoidance of areas in the fields containing exclosures was examined by comparison of oven dried weights of alfalfa from non-protected quadrats near the exclosures and quadrats selected midway between exclosures. Immediately prior to the first harvest 1994, 10 quadrats in each field were selected approximately midway between large exclosures. Alfalfa within selected quadrats was clipped, bagged, oven dried at 60 C for ≥ 48 hours, and weighed to the nearest 0.1 g. Dried alfalfa weights from non-protected quadrats located 2 - 4 m from exclosures and quadrats selected midway between exclosures (approximately 100-300 m from nearest exclosure)

were compared to determine if non-protected alfalfa weights required correction for deer selection or avoidance of exclosures.. A paired t-test (Box et al. 1978) was used to test for significant differences ($P < 0.05$).

Field Composition

Although alfalfa was the dominant species, none of the fields I sampled consisted of only alfalfa. Forbs and grasses occurred in varying amounts. The proportion of alfalfa in hay harvested from alfalfa fields was determined by selecting 10 quadrats approximately midway between exclosures in each of the 3 irrigated alfalfa fields on FKARS prior to the first cutting of alfalfa in June, 1994. Herbage within the quadrats was clipped to ground level prior to first harvest. Species present in the samples were identified and separated into alfalfa and non-alfalfa. Samples were oven dried at 60 C for ≥ 48 hours and weighed to the nearest 0.1 gram. Percent by weight of alfalfa and species present was determined from the samples.

Diel and Seasonal Use Patterns

Diel Use Patterns

Diel use patterns were determined by counting the number of deer present during four time periods in irrigated

alfalfa fields on FKARS. Time periods were: dawn ($\frac{1}{2}$ hour before sunrise to $\frac{1}{2}$ hour after sunrise), day (2 hours after sunrise to 2 hours before sunset), dusk ($\frac{1}{2}$ hour before sunset to $\frac{1}{2}$ hour after sunset), and night (1 hour after sundown to 1 hour before sunrise).

Deer using irrigated alfalfa fields were counted while driving a vehicle along roads adjacent to alfalfa fields. All deer seen within the field boundary were recorded. The horn of the vehicle was used at irregular intervals as an attention-eliciting device (Cypher 1991). The order in which fields were counted was varied. Counts were not conducted when visibility was impaired due to poor weather conditions, e.g. fog, rain, or snow. Night counts were conducted using a 750,000 candle power spotlight. Binoculars (8x40) were used to record deer whose tapetum reflections were not seen. Counts were conducted approximately 10 times in each time period during each clipping interval defined in Table 1. Due to non-normality of data, a multiple comparison Kruskal-Wallis test (Conover, 1980) was used to test for significant differences ($P < 0.10$) among time periods.

Seasonal Use Patterns

Seasonal use patterns were determined by counting deer present on FKARS and Kinsey irrigated alfalfa fields. Deer

present on irrigated alfalfa fields at night in the Kinsey area were counted using the methods described for FKARS. Deer counts on FKARS and Kinsey were combined to avoid possible localized effects of landscape arrangement, livestock presence, and farming practices on deer use of irrigated alfalfa fields. FKARS and Kinsey deer counts were compared to determine if timing of use on FKARS was similar to timing of deer use on the Kinsey site and if combining counts would confound either data set. A Chi-square test (Moore and McCabe 1989) was used to test for a significant difference ($P < 0.05$).

Seasons were defined as: summer (June-August), fall (September-November), winter (December-February), and spring (March-May). To reduce variability, only counts conducted on FKARS the same night as counts in the Kinsey area were combined. The direction of the Kinsey route was varied. Deer using Kinsey site fields were counted approximately once per week during each growing season evaluated (June 1993 - October 1993, May 1994 - August 1994) and monthly during dormant season (November 1993- April 1994). No counts were conducted on the Kinsey site during December. Weekly and monthly counts were combined to estimate seasonal use. Due to non-normality of the data, a multiple comparison Kruskal-Wallis test (Conover, 1980) was used to test for significant differences ($P < 0.10$) among seasons.

Deer counts conducted on FKARS and Kinsey alfalfa fields were also compared to determine if there were significant differences ($P < 0.05$) between deer densities (deer/ha) on irrigated alfalfa fields during the growing seasons. Growing seasons examined were July - October 1993, May - August 1994. Significance differences were determined using a Kruskal-Wallis test (Conover, 1980).

Deer Use Required To Significantly Reduce Yield

Simple linear regression and simulated grazing were used to estimate the amount of deer use required to significantly ($P < 0.05$) reduce alfalfa yield. In addition to the control quadrat, two simulated grazing quadrats were located in each of the large exclosures during harvest periods (Fig. 4). Simulated grazing was accomplished by removing 50% of the alfalfa canopy in one simulated grazing quadrat and 100% in the other using a hand clipper. Seven alfalfa stems within the quadrat, 3 on opposite sides and 1 in the middle, were measured and stem height was averaged to determine mean canopy height and amount to be removed. The simulated grazing quadrats were treated midway between harvest operations. Alfalfa clipped during the simulated grazing treatment was bagged, oven dried at 60 C for ≥ 48 hours and weighed to the nearest 0.1 g. To minimize the

possibility of edge effects on alfalfa growing in simulated grazing and control quadrats, an area larger than the quadrats inside the exclosures was exposed to the control and simulated grazing treatments. The treated area measured 1.0 m^2 and the simulated grazing quadrats were centered inside the larger area and measured 60 cm by 60 cm (0.36 m^2).

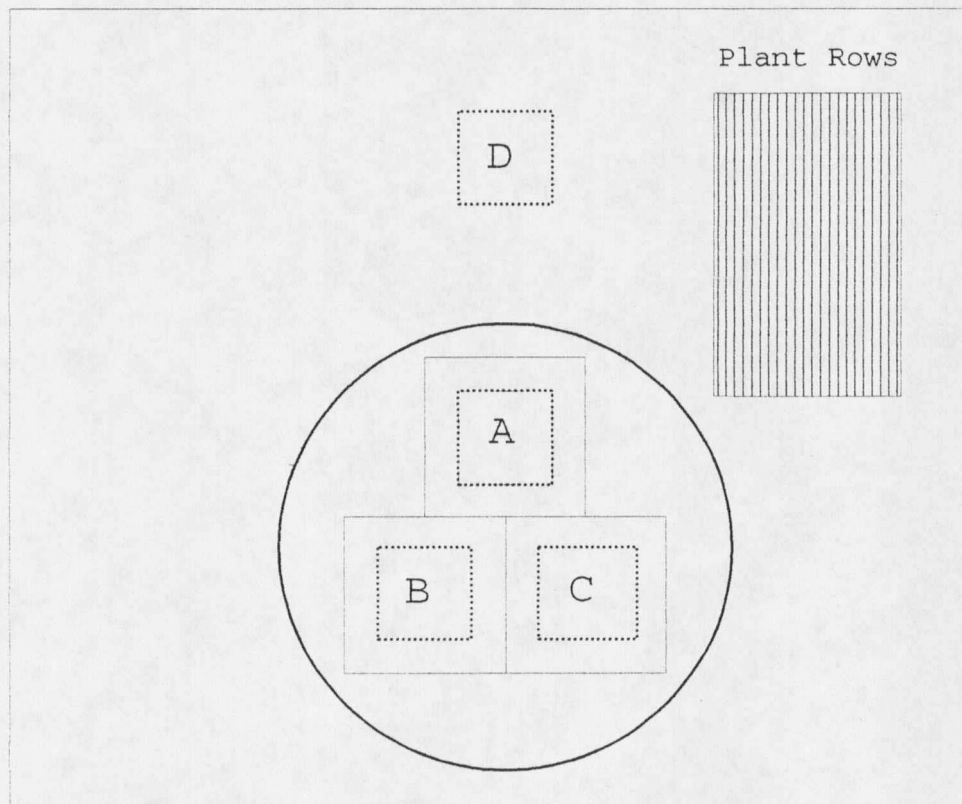


Figure 4. Arrangement of control (A), 50% simulated grazing (B), 100% simulated grazing (C), non-protected (D), quadrats (dashed line) and treatment area (thin solid line) in relation to a large enclosure (thick solid line).

The treated alfalfa remaining within simulated grazing quadrats was allowed to regrow until 1-3 days prior to harvest in the field. The alfalfa within the quadrats was then clipped to ground level. All alfalfa removed was bagged, oven-dried at 60 C for ≥ 48 hours, and weighed to the nearest 0.1 gram. Differences between simulated grazing quadrat yields and control yields allowed calculation of amount of total yield reduction (kg/ha) imposed by the simulated grazing treatment.

Deer use required to consume the amount of alfalfa clipped in the simulated treatment was calculated using percentage of alfalfa in the diet and daily consumption rates estimated in other studies. Rumen analysis conducted by Dusek et al. (1989) along the Yellowstone River east of Miles City and microhistological fecal analysis conducted by Tebaldi and Anderson (1982) from samples taken from northeastern Wyoming both produced estimates of 30% of alfalfa in deer diet during harvest periods. I used this percentage as an estimate of alfalfa in diets of deer in my study area and an estimated deer consumption rate of 1.5 kg/day (Hesselton and Hesselton 1990) to calculate the number of deer required to consume the amount of alfalfa removed in the simulated grazing treatment. Deer use (deer/ha/day) required to consume the amount of the alfalfa clipped in the simulated grazing treatment and the yield

reduction per hectare imposed by the simulated grazing treatment were averaged for the 10 exclosures on the 3 fields on FKARS for each of the 5 harvest periods.

Simple linear regression was used to model the relationship between estimated deer use and yield reduction imposed by the simulated grazing (Moore and McCabe, 1989). Yield reduction was the independent variable and deer use was the dependent variable.

Ninety five percent confidence intervals for the control means within exclosures were calculated and used to estimate the amount of alfalfa yield reduction (kg/ha) that would be required for detection of a decrease in yield in each alfalfa field during each harvest period evaluated on FKARS. Using these data and the linear equation from the regression model, deer use (deer/ha/day) required to consume an amount that would exceed 0.95 confidence interval (kg/ha) in each field was calculated. Averages for the 3 fields during all harvest periods produced an estimation of the mean deer use required for significant alfalfa yield reduction for the study period.

Influence of Landscape Arrangement on Deer Use

Multiple linear regression was used to determine the influence of landscape arrangement and adjacent land uses on

deer use of alfalfa fields. Landscape features, their size, and distance of features to sampled fields were measured using a Numonics Electronic Planimeter and 1993 and 1994 Agricultural Stabilization and Conservation Service (ASCS) areal compliance photographs. The landscape features measured were: field size, amount and type of edge, size and land use of adjacent areas, distance to permanent water and nearest cover, amount of nearest cover, distance to nearest buildings, distance to nearest topographical relief, and amount and type of land use within a 0.5 km and 1.0 km radius. All distances were measured from the center of the field.

Relationships between landscape variables were examined by calculating correlation coefficients (SAS Institute Inc. 1987). One variable from a pair of variables with significant correlation coefficients ($r \geq 0.7745$, $P < 0.05$) was removed from further testing. The choice of which variable to retain was based on which variable I believed to be most important to deer. Using a stepwise procedure for adding independent variables (SAS Institute Inc. 1987), interactions between landscape features and deer density were tested with multiple linear regression (Moore and McCabe, 1989). Deer density was the dependent variable and landscape features were independent variables.

RESULTS

Extent and Timing of Deer DepredationExtent of Depredation

Comparisons of dried alfalfa weights from protected and non-protected quadrats in the 3 fields on FKARS for the study period showed no significant differences ($P>0.05$, Table 2). Deer use of irrigated alfalfa between the third harvest in August, 1993 and the first harvest in June, 1994 did not significantly reduce first harvest yield ($P>0.05$). Mean differences between control and grazed quadrats varied from -19.6 to 10.3 g/quadrat. As no significant depredation occurred, timing of depredation could not be determined.

Exclosure Effects

These tests indicated that exclosures did not significantly influence alfalfa growth and suggested that no corrections for exclosure effects were required. Comparison of dried alfalfa weights from quadrats inside of the small exclosures ($\bar{x}=171.2$ g) and dried alfalfa weights from quadrats outside the exclosures ($\bar{x}=200.2$ g) but inside the encompassing fence approached significance ($P=0.0505$) at the second harvest in 1993 (Table 3). No significant differences were detected at the second or third harvest in 1994 ($P=0.15$ and 0.30 , respectively).

Table 2. Paired t-test results for dried weights (g/0.36m²) of alfalfa from study fields on Fort Keogh ARS for 1993 and 1994.

Clipping Interval	Field	Mean		Difference	P-value
		In	Out		
Second 1993	1	146.2	150.2	-4.0	.6678
	5	125.6	131.6	-6.0	.4535
	9	144.6	149.5	-4.9	.7097
Third 1993	1	117.1	115.4	+1.7	.7889
	5	128.9	131.5	-1.7	.7690
	9	119.7	122.7	-3.0	.4789
Fall 1993	1	31.1	28.8	+2.3	.0881
	5	22.5	19.4	+3.2	.0682
	9	17.7	17.9	-0.2	.9429
Winter 1993	1	28.1	24.1	+4.0	.2818
	9	26.1	28.6	-2.5	.1111
Spring 1994	1	31.8	31.4	+0.4	.5630
	9	23.9	27.3	-3.4	.1690
Overwinter 1994	1	153.3	157.7	-4.4	.5527
	9	194.9	183.3	+11.6	.4152
First 1994	1	178.0	167.7	+10.3	.3999
	5	180.9	180.7	+0.2	.9870
	9	185.9	188.0	-2.1	.8954
Second 1994	1	158.6	178.2	-19.6	.0547
	5	183.6	197.9	-14.3	.1854
	9	188.7	197.9	-9.2	.4038
Third 1994	1	186.5	196.5	-10.0	.5630
	9	185.3	188.6	-3.3	.6536

No significant differences ($P > 0.05$) occurred between dried alfalfa weights from non-protected quadrats near exclosures and quadrats located midway between exclosures.

Deer did not select or avoid areas near exclosures. Therefore, no adjustments for sample site position in fields were justified.

Table 3. Results from paired t-tests for exclosure effects tests for 1993 and 1994.

Year	Field	n	Mean		Difference	Exclosure	P-value
			In	Out			
1993 ^a	5	9	171.2	200.2	-29.0	Small	.0505
1994 ^a	9	10	175.6	193.2	-17.6	Small	.1529
1994 ^a	9	10	172.6	187.0	-14.4	Large	.3081
1994 ^b	1	10	170.8	167.7	+3.1	Large	.7857
1994 ^b	5	10	180.9	180.7	+0.2	Large	.8386
1994 ^b	9	10	185.9	188.0	-2.1	Large	.2929

^aDried alfalfa weights from quadrats inside deer exclusion fence

^bDried alfalfa weights from quadrats midway between exclosures (In) and non-protected quadrats outside exclosures (Out)

Field Composition

Alfalfa averaged 92.7% by weight of composition samples collected from FKARS alfalfa fields at first harvest 1994. Individual fields varied from 97% alfalfa to 89% alfalfa. Various grasses and forbs averaged 7.3% by weight of composition samples. Species present in samples included: *Kochia scoparia*, *Taraxacum* spp., *Trogopogon* spp., *Amaranthus* spp., *Descurainia* spp., *Capsella bursa-pastoris*, *Thlaspi arvense*, *Bromus inermis*, *B. tectorum*, *Poa* spp., and *Agropyron* spp.

Diel and Seasonal Use Patterns

Diel Use Patterns

A total of 352 time-period counts were conducted and 3,769 deer were counted on irrigated alfalfa fields on FKARS during the study period; 99% were whitetails and 1% were mule deer. Diel use patterns varied among seasons (Fig. 5). Of the seasons when deer use between time periods varied significantly, dusk and night generally produced greater counts than dawn and day, and night counts were usually higher than dawn and dusk, (Table 4).

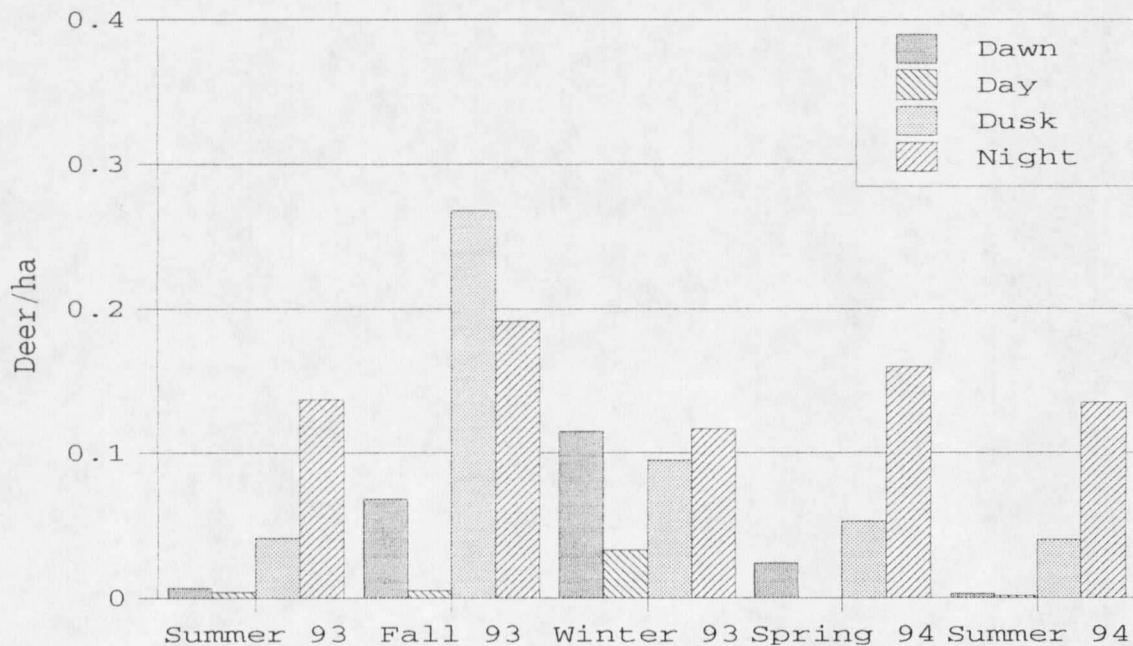


Figure 5. Seasonal average deer/ha counted during diel time periods on all Fort Keogh ARS alfalfa fields from July 1993 to August 1994.

Table 4. Diel time period use patterns on Fort Keogh ARS fields and Kruskal-Wallis Mean Scores for the 5 seasons evaluated.

Season	Time Period	Mean Score ^a
Summer 1993	Night	133.2 a
	Dusk	96.3 a b
	Dawn	80.1 b
	Day	79.5 b
Fall 1993	Dusk	224.2 a
	Night	205.0 a
	Dawn	143.3 b
	Day	103.8 c
Winter 1993	Dusk	47.9 a
	Night	38.9 a b
	Dawn	34.2 a b
	Day	32.0 b
Spring 1993	Night	57.6 a
	Dusk	47.6 a b
	Dawn	44.3 a b
	Day	40.0 b
Summer 1994	Night	237.8 a
	Dusk	186.6 b
	Dawn	133.4 c
	Day	131.0 c

^aScores within a season with the same letter are not significantly different ($P \geq 0.10$)

Seasonal Deer Use Patterns

A total of 41 combined counts of deer using irrigated alfalfa fields in the Kinsey area and on Fort Keogh ARS were conducted and 2,314 deer counted during the study period; 95% were whitetails and 5% were mule deer.

Timing of deer use on irrigated alfalfa fields did not differ significantly ($P > 0.05$) between FKARS and the Kinsey

site (Fig. 6). Deer densities were greater on FKARS than the Kinsey site during 1993 and 1994 growing seasons ($P=0.012$ and 0.01 , respectively). Average density of deer counted in irrigated alfalfa fields on FKARS and the Kinsey site did not vary between 1993 and 1994 ($P=0.11$). Deer use of irrigated alfalfa fields did not vary between summer 1993 and summer 1994 ($P>0.10$). Deer use did vary by season within each year (Fig. 7). No significant differences ($P>0.10$) were detected between summer, fall and spring periods (Table 5). Alfalfa fields in winter received less use ($P<0.10$) than all other seasons.

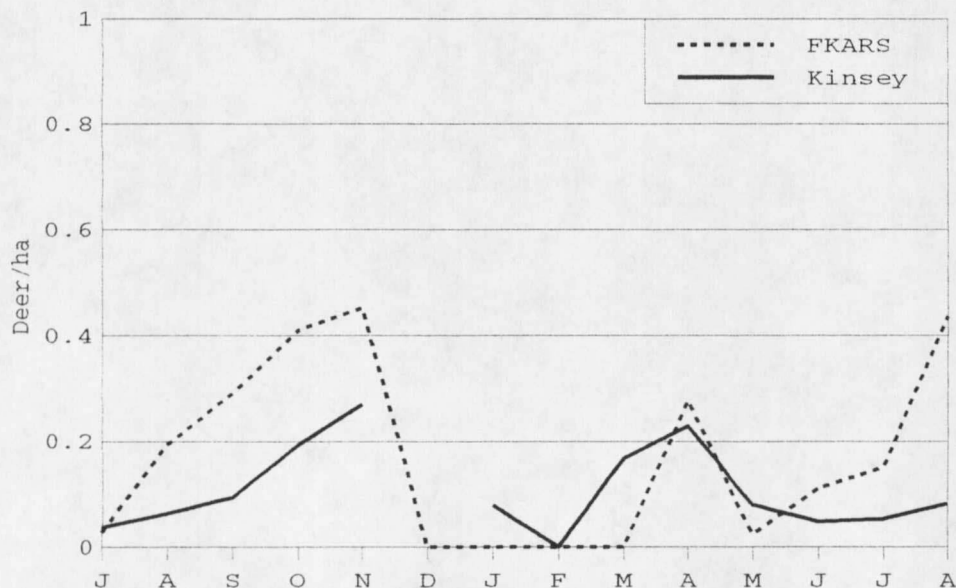


Figure 6. Comparison of monthly average deer/ha counted on Fort Keogh ARS and Kinsey area alfalfa fields from July 1993 to August 1994.

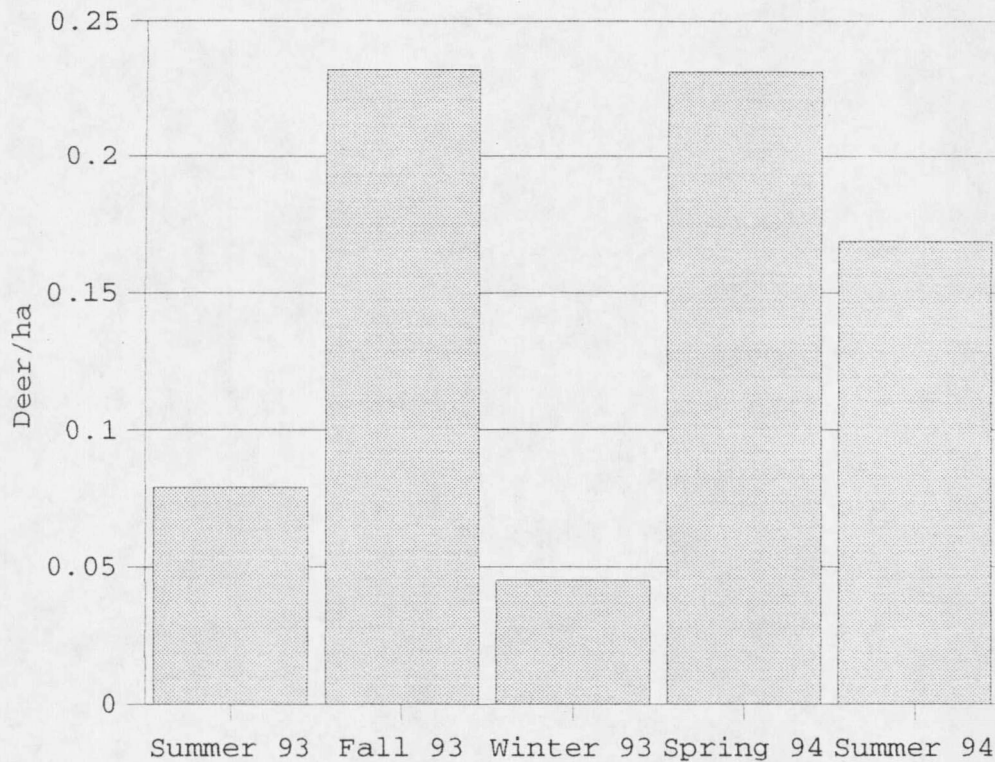


Figure 7. Seasonal average deer (deer/ha) counted on Fort Keogh ARS and Kinsey study fields from July 1993 to August 1994

Table 5. Seasonal deer use of Fort Keogh ARS and Kinsey fields combined and Kruskal-Wallis Mean Scores.

Year	Season	Mean Score ^a
1993	Fall	70.00 a
1994	Summer	64.19 a
1994	Spring	57.71 a
1993	Summer	52.70 a
1993	Winter	29.19 b

^aScores with the same letter are not significantly different ($P \geq 0.10$).

Deer Use Required to Significantly Reduce Yield

Simulated grazing treatment amounts varied from 389 kg/ha to 3,667 kg/ha for the 50% treatment and the 100% treatment, respectively (Table 6). Deer use required to consume the treatment amounts during the harvest period ranged from 22.7 deer/ha/day to 269.8 deer/ha/day for the two grazing treatments, assuming daily consumption rates of 1.5 kg dry weight per day of which 30% of the diet is alfalfa and 27 to 49 days of grazing between harvest periods. Yield reductions imposed by the simulated grazing treatments varied from 27% to 97% (1,000 kg/ha to 5,028 kg/ha) for 50% treatment and the 100% treatment, respectively.

A simple linear regression model was constructed using SAS software (Schlotzehauer and Littell, 1987) with deer/ha/day required to consume simulated grazing treatments the dependent variable and yield reduction imposed by the simulated grazing treatment as the independent variable (Fig 8). The model ($Y = .0437X - 4.903$) explained 75% ($R^2 = .7481$, $P < 0.001$) of the variability in deer/ha/day.

Confidence intervals (0.95) of the control quadrat means varied from ± 285.3 kg/ha to ± 820 kg/ha (Table 7). Using these results and the linear equation from the model, I estimated that 7.5 to 30.9 deer/ha/day ($\bar{x} = 19.1$)

consuming 1.5 kg/day of dry matter of which 30% is alfalfa was required to cause a significant amount (kg/ha) of yield reduction to irrigated alfalfa fields on FKARS during the 5 harvest periods evaluated.

Table 6. Simulated grazing treatment amounts (kg/ha), number of days in harvest period, deer use required to consume treatment amounts (deer/ha/day), and yield reductions (kg/ha) from simulated grazing quadrats on Fort Keogh ARS alfalfa fields for 50% and 100% quadrats for the 5 harvests evaluated.

Harvest	Quadrat	Field	Grazing Treatment	Days	Deer Use	Yield Reduction
Second 1993	50%	1	1164	36	73.7	1639
		5	1472	41	79.8	1000
		9	1000	30	74.1	1528
	100%	1	3306	36	204.1	3667
		5	2861	41	155.1	3140
		9	2528	30	187.2	3417
Third 1993	50%	1	889	30	65.8	1167
		5	667	40	37.0	1083
		9	389	38	22.7	1500
	100%	1	1833	30	135.8	2889
		5	1250	40	69.4	2611
		9	1528	38	89.4	2861
First 1994	50%	1	1306	47	61.7	2361
		5	1778	49	80.6	2639
		9	1639	39	74.3	2528
	100%	1	2889	47	136.6	4556
		5	3444	49	156.2	4583
		9	3667	49	166.3	4917
Second 1994	50%	1	1167	35	74.1	1972
		5	917	27	75.5	1389
		9	1278	29	97.9	2306
	100%	1	3500	35	222.2	4306
		5	3277	27	269.8	4194
		9	3389	29	259.7	5028
Third 1994	50%	1	944	39	53.8	1472
		9	778	34	50.8	1472
	100%	1	3166	39	180.4	4444
		9	2222	34	145.2	4000

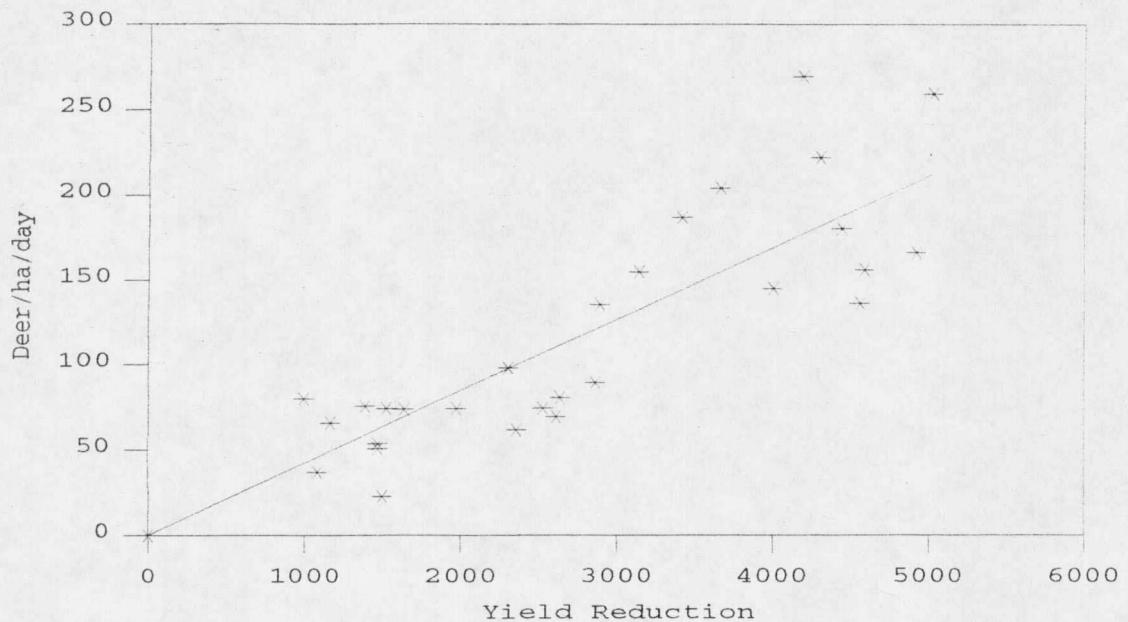


Figure 8. Linear regression model with yield reduction (kg/ha) imposed by simulated grazing as the independent variable and deer use (deer/ha/day) required to consume simulated grazing treatment as the dependent variable.

Influence of Landscape Arrangement on Deer Use

Five best multiple regression models, 1 for each season during the study, were developed through stepwise procedures (SAS Institute Inc. 1987). Twenty-nine landscape variables were measured for each alfalfa field in the Kinsey area and on FKARS for each season during the study. Correlation analysis determined that 4 pairs of landscape variables in 1993 and 6 pairs of landscape variables in 1994 were significantly correlated. Four variables in 1993 and 5 in 1994 were removed from further testing. Of the remaining

variables, only independent variables that contributed significantly ($P < 0.05$) to the model were retained in the final model. All five models detected significant relationships ($P < 0.05$) between deer densities and land use variables. Only 1 model explained a substantial amount of the variation ($R^2 > 0.60$) in deer densities (Table 8).

Table 7. Confidence interval (0.95) of control means (kg/ha) and deer use (deer/ha/day) required to significantly reduce alfalfa yields for the alfalfa fields on Fort Keogh ARS during the 5 seasons evaluated.

Harvest	Field	Control mean	Confidence interval	Deer use
Second 1993	1	4061	± 285.3	7.55
	5	3489	± 335.3	9.73
	9	4017	± 688.9	25.20
Third 1993	1	3252	± 498.6	16.88
	5	3581	± 610.0	21.75
	9	3325	± 321.9	9.15
First 1994	1	4945	± 643.8	23.20
	5	5025	± 544.4	19.32
	9	5164	± 820.0	30.94
Second 1994	1	4406	± 521.1	17.86
	5	5100	± 761.7	28.39
	9	5242	± 364.7	11.02
Third 1994	1	5181	± 608.6	21.69
	9	5147	± 675.0	24.60

Nine landscape variables were utilized in the 5 models. Three models contained 1 variable while 1 model had 2 variables and 1 model had 4 variables. No two models

contained the same variable(s). Important landscape variables included: alfalfa field edge bordered by other crops, roads, and buildings, amount of adjacent woods and crops other than alfalfa, amount of alfalfa within a 0.5 km and 1.0 km radius, and amount of breaks and woods within a 1.0 km radius.

Table 8. Multiple regression models, R^2 and P-values for the 5 seasons evaluated with deer densities as the dependent variable and land use variables as independent variables^a.

Season	R^2	P-value	Model
Summer 1993	.32	0.012	$Y = 0.000116X_1 + 0.00176X_2 - 0.00616$
Fall 1993	.22	0.001	$Y = -0.0117X_3 + 0.440$
Winter 1993	.18	0.036	$Y = -0.000973X_4 + 0.674$
Spring 1994	.33	0.020	$Y = -0.00555X_5 + 0.760$
Summer 1994	.75	0.002	$Y = -0.00122X_6 + 0.00691X_7 + 0.00397X_8 + 0.00874X_9 + 0.829$

^aIndependent variables included in models:

X_1 =Amount of alfalfa field edge bordered by crops other than alfalfa in meters

X_2 =Amount of adjacent woods in hectares

X_3 =Amount of alfalfa within 0.5 km radius in hectares

X_4 =Amount of alfalfa field bordered by roads in meters

X_5 =Amount of alfalfa within a 1 km radius in hectares

X_6 =Amount of alfalfa field bordered by buildings in meters

X_7 =Amount of adjacent crops other than alfalfa in hectares

X_8 =Amount of breaks within a 1.0 km radius in hectares

X_9 =Amount of woods within a 1.0 km radius in hectares

DISCUSSION

Deer Depredation of Irrigated Alfalfa

Irrigated croplands along the Yellowstone River occupy much of the floodplain from Livingston, Montana to the North Dakota border wherever topographical, soil and water conditions will allow profitable irrigation. Only lands that are generally unsuitable for crop production are allowed to retain the riparian plant community. Forty percent of the irrigated cropland in my study area was planted to alfalfa.

The majority of the deer I observed in irrigated alfalfa fields in my study area were whitetails, both on FKARS and the Kinsey site. White-tailed deer are most abundant in riparian type complexes in eastern Montana and elsewhere and are closely tied to agriculture (Swenson et al. 1983, Matschke et al. 1984, Murphy et al 1985, Dusek et al. 1988). River and creek riparian complex types accounted for 71% of all whitetails observed by Swenson (1984) during winter. The river-irrigated agriculture subtype accounted for 56.4%. Dusek (1990) noted that eastern Montana whitetails are non-migratory and inhabit riparian areas yearlong.

Mule deer generally prefer more broken terrain and are

less closely tied to agriculture in eastern Montana (Swenson et al. 1983, Wood 1987, and Wood et al. 1989). Creek and river riparian complexes accounted for 3.6% of all mule deer observed by Swenson during winter. Mule deer were observed only occasionally on 2 fields on Fort Keogh and 5 fields in the Kinsey area.

One field in the Kinsey area did receive more mule deer use than whitetail use. This field was located at the outer limit of irrigated cropland immediately adjacent to breaks and received the greatest use during fall. Selting (1994) also found greater use of alfalfa by mule deer during fall. Mule deer may select alfalfa in the fall when available because of extended succulence and relative high crude protein levels caused by early phenological development resulting from harvesting (Selting 1994). In addition, native vegetation becomes desiccated at this time. Matschke (1984) and Austin and Urness (1992) noted that crop damage increases with decreasing quality of native vegetation.

Fort Keogh ARS is unique to the area because the alfalfa raised is utilized for winter forage for cattle on the station and is not commercially marketed. Therefore, croplands in excess of what is required to produce needed silage and hay have been retired from hay production. Also, several areas suitable for irrigated production have been left to native vegetation. As a result, FKARS has more

riparian cover than the Kinsey area. The patterns of deer use on FKARS and the Kinsey site were not significantly different. Deer densities during the growing seasons were significantly higher on FKARS. Even with higher deer densities and generally fewer alfalfa fields, I did not detect any measurable reduction in yield to irrigated alfalfa on FKARS during the harvest periods evaluated.

Compton (1986) found a significant positive relationship between the amount of riparian cover and white-tailed deer density. Dusek (1990) also suggested that whitetail numbers in eastern Montana are limited by allocation of forage and cover by adult females and not by winter forage availability. With riparian cover limited in my study area by agricultural production, whitetail population levels may be limited to numbers insufficient to cause widespread depredation to irrigated alfalfa. Mule deer numbers may also be limited to sub-damage levels by landscape arrangement; breaks are generally distant from irrigated alfalfa fields.

Alfalfa plants, and consequently future yields, may be damaged by late fall or early spring grazing (Smith 1975, R. Ditterline pers. commun.) Grazing at these times forces plants to utilize winter and spring root reserves and may stunt growth, kill the plant, or lower resistance to disease. I detected no differences between spring, summer.

and fall deer use on my study area. I did not detect significant differences in standing biomass in protected and non-protected quadrats during fall and early spring when plants were likely to be most vulnerable to over use (Smith 1975, R. Ditterline, pers. commun.).

Selting (1994) found that mule deer and white-tailed deer selected alfalfa in fall and white-tailed deer selected alfalfa during all periods except summer. Compton (1986) found that white-tailed deer selected alfalfa on 2 of 3 areas evaluated during spring and on all areas he evaluated during fall and summer. These use patterns indicated a potential for damage to plants.

I found that alfalfa was used less in winter than other seasons. Standing crop reduction from cumulative deer use from the last harvest in the fall to the first harvest the following year was minimal. This probably reflects limited whitetail numbers, lack of mule deer winter habitat, and large acreages of alfalfa on the study area. Even in an area with significantly higher deer densities than average on the study area, there were not enough deer available to consume the amount of forage necessary to cause detectable reductions in alfalfa yield.

Deer Use Required to Significantly Reduce Yield

Alfalfa production on my study area was highly variable within fields, among fields, and between years. Alfalfa production was generally lower in 1993 when temperatures were below normal and precipitation was above normal. Tebaldi and Anderson (1985) and Austin and Urness (1993) noted that alfalfa production was highly variable on their study areas.

Because of variability in production, simulated grazing results were highly variable. Mean simulated grazing treatment amounts varied almost 5 fold for the 50% quadrats and 3 fold for the 100% quadrats among harvest periods. Yield reductions from the simulated grazing treatments varied 3 fold for the 50% quadrats and 2 fold for the 100% quadrats, and the confidence intervals for the control means for the 3 fields during the 5 harvest seasons were also highly variable. In 1993, confidence intervals varied 2.4 fold and 1.8 fold in 1994. Therefore, the estimated deer use required to reduce alfalfa yields was varied over a wide range (7.5 - 30.1 deer/ha/day, $\bar{x}$ = 19.1).

The model I tested assumed a consumption rate of 1.5 kg/day and alfalfa composed 30% of the diet. This resulted in an alfalfa loss per deer-day of 0.45 kg. If alfalfa composed 100% of the daily intake of 1.5 kg, a mean of 6

deer/ha/day would have been required to produce a detectable yield reduction on FKARS during the study period. Other studies (Bartmann 1972, Tebaldi and Anderson 1982, Austin and Urness 1992,1993) have estimated alfalfa loss to deer between 6.5 kg/deer-night for mule deer to 0.35 kg/deer-night for female white-tailed deer. The high variability of alfalfa loss per deer probably reflects the high variability in alfalfa production and grazing at different phenological stages.

Removing a substantial amount of plant material before alfalfa plants reach 20 cm may have greater effects on growth than after plants reaches 20 cm (R. Ditterline, pers. commun.). Thus, deer use in early spring or following harvests before plants reach 20 cm may reduce yields more than the same intensity of grazing later in the growing period. Wolf and Allen (1990) found that early spring grazing of alfalfa by steers when plants reached 10 cm did not reduce subsequent yields, but summer grazing when plants reached 15 cm and both spring and summer grazing reduced ensuing yields. The amount of foliation removed by steer grazing was undetermined. Austin and Urness (1993) also noted that grazing by deer affected alfalfa plant growth.

By removing part of the canopy and allowing regrowth, I incorporated limited grazing effects on growth into the model. I was not able to incorporate grazing effects when

plants were less than 20 cm as simulated grazing treatments were conducted when alfalfa was approximately 25-35 cm tall. Therefore, this model may not be applicable if substantial defoliation occurs before alfalfa plants reach 20 cm tall. On my study area, this does not appear to be a problem as I did not observe a difference between deer counts conducted during the early part of harvest periods when alfalfa was less than 20 cm tall and deer counts during the later part of harvest periods when alfalfa was greater than 20 cm tall.

The lowest density of deer required to produce a detectable reduction in yield in my model was similar to the mean prediction in a model developed by Austin and Urness (1993). Austin and Urness (1993) estimated that 7.3 deer/ha would be required to detect alfalfa loss at $P < 0.05$ based on an average 2.2 kg alfalfa loss per deer. This estimate was developed based on caged and uncaged plots and spotlight counts of deer using alfalfa fields. The lower deer use estimate needed for damage in the Austin and Urness model was presumably due to their inclusion of losses due to trampling, and a higher percent of alfalfa in deer diets, as well as grazing effects.

Both models would have predicted no losses on FKARS. The average deer/ha/day peaked at 0.4 deer/ha on FKARS and the highest average density I recorded in a single field on the study area was 2.8 deer/ha. The highest density for a

single count was 7.9 deer/ha. All of these densities occurred during fall, 1993. Densities during the growing seasons were lower.

Influence of Landscape Features on Deer Use of Alfalfa

The stepwise procedure in the multiple regression package I used identified 9 landscape variables that contributed significantly to the models. Although all variables were different in each model, they all were related to either cover, forage, or edge. The variables associated with cover were positively related to deer densities and included the amount of adjacent woods, woods and breaks within a 1 km radius, and the amount of adjacent crops other than alfalfa. Variables associated with forage were negatively related to deer densities and included the amount of alfalfa within a 0.5 km and a 1.0 km radius. Edge variables also tended to be negatively related to deer densities. These included amount of an alfalfa field bordered by crops other than alfalfa, buildings and roads.

Matschke et al. (1984) noted that heaviest crop damage occurs in fields bordered by woodlands. Flyger and Thoeirig (1962) reported corn fields offer similar cover as woodlands during summer. Dusek et al. (1989) reported that during summer, radio-collared deer were generally within 0.5 km of

riparian cover and some deer regularly traveled 2 km or greater to feeding areas from upland draws in eastern Montana. I frequently observed white-tailed deer traveling from nearby breaks to feed in alfalfa fields on my study area. Alfalfa fields associated with greater amounts of these cover types would be used to a greater extent than fields without nearby cover.

Murphy et al. (1985) reported that irrigated croplands on his study area were used less than expected by white-tailed deer due to their large size. Deer use of alfalfa fields on my study area was negatively related to the amount of alfalfa within a 0.5 and 1.0 km radius. With greater amounts of alfalfa, deer are evidently distributed over a larger area thereby reducing deer use on the sampled field.

The negative relationship between human activity (buildings and roads) and deer numbers is likely due to deer aversion of human activity (Marchinton and Hirth 1984). Areas with buildings and roads are centers of human activities and were frequently avoided by deer.

The amount of alfalfa field bordered by crops other than alfalfa was positively associated with deer density. Some crops, such as corn, may provide cover similar to woodlands (Flyger and Thoeirig 1962). As these crops provide additional cover, deer use of adjacent alfalfa fields would increase (Matschke et al. 1984). On one alfalfa field on

FKARS, I often observed a whitetail doe with two fawns leaving an adjacent corn field to feed in the alfalfa field and returning to the corn field when disturbed.

Of the 5 best models identified by the multiple regression stepup procedure, only 1 model explained a substantial amount of the variation in deer use. The model for summer 1994 explained 75% of the variation in deer densities on alfalfa fields based on the amount of building edge, adjacent croplands other than alfalfa, woods within a 1.0 km radius and amount of breaks in 1.0 km radius. The amount of building edge was negatively related to deer use while the other variables were positively related. Too much variation in deer use of alfalfa field existed in fall spring and winter to predict deer use based on landscape variables. The 1993 summer evidently did not produce a usable model because of the extended growing season for native vegetation that occurred due to the high rainfall and low temperatures over the summer. Deer apparently used native vegetation more while use of irrigated alfalfa varied more than the summer of 1994.

Other authors have attempted to produce models based on landscape variables that would predict wild ungulate use of agricultural lands (Tebaldi and Anderson 1982, Selting 1994). Tebaldi and Anderson (1982) noted the data they collected were too variable to be used on other fields and

in other years. Selting (1994) reported that only 2 of 12 regression models detected significant relationships between wild ungulates and landscape variables and the two models did not explain a substantial amount of the variability in ungulate densities.

Although damage to irrigated alfalfa was not widespread during my study, localized deer damage to irrigated alfalfa did occur during the study period (J. Witcher and B. Hagemiest, pers. commun.). Deer damage on two farms occurred on small, relatively isolated alfalfa fields not included in the study. These fields were adjacent to, and partially surrounded by large areas of riparian cover. When local deer densities are high, depredation is more likely where alfalfa fields are in close association with large areas of riparian cover. Matschke (1984) indicated that damage is more severe on smaller fields, but other variables may have a greater influence on damage than size. Palmer et al. (1985) detected significant damage to alfalfa for 3 cuttings during two consecutive years on a small field (3.3 ha) near to forested area. Additionally, Suring and Vohgs (1979) found that habitats supplying both food and cover were heavily used by Columbian white-tailed deer while those only providing forage were used only near adjacent cover.

CONCLUSIONS

Widespread deer damage to irrigated alfalfa is unlikely to occur along the Yellowstone River near Miles City under current land use patterns because most riparian cover has been converted to open fields. Because deer densities are limited by the amount of riparian cover and not abundance of winter forage, deer densities are unlikely to reach densities to cause serious yield reduction of alfalfa. During the growing seasons, densities of 19.1 deer/ha/day for 30 days or more would be required to significantly reduce alfalfa yields.

Localized depredation does occur along the Yellowstone River. Significant yield reduction is most likely to occur when small alfalfa fields are sited next to large riparian areas with tree and shrub cover.

Landscape variables that predicted use were associated with cover, forage and edge. Use patterns on irrigated alfalfa were most predictable in the relatively dry summer of 1994. In this season, use of alfalfa fields was positively associated with larger areas of cover and negatively associated with human activity.

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