Seasonal variation of fecal nitrogen and forage succulence in relation to condition and movements of two southeastern Montana mule deer populations
by Thomas Joseph Olenicki

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

Abstract:
Seasonal variation in nutrition and habitat use are important in understanding the ecology of mule deer (Odocoileus hemionus) in eastern Montana. Consequently, I used fecal nitrogen (FN) to assess nutrition of mule deer during summer and winter in a prairie habitat (Boxelder study area) and a ponderosa pine habitat (Ashland study area). Forage succulence predicted summer FN values ($R2=O.93$, $P<0.01$) on the Boxelder area but not on the Ashland area. Winter values of FN were lower than summer values for both areas, with those on Boxelder lower than Ashland. There was a curvilinear relationship ($R2=O.82$, $P<0.001$) between FN and rumen forage nitrogen. Kidney fat index was related linearly ($R2=O.83$, $P<0.001$) to rumen forage nitrogen and curvilinearIy ($R2=O.59$, $P<0.05$) to FN. Fawn girth measurements were greater ($P<0.01$) at Ashland than Boxelder. Deer use of cover types differed (P

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Thomas Joseph Olenicki

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.

6 April 1993
Date

Chairperson, Graduate Committee

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6 April 1993
Date

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4/7/93
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Date 4/6/93

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ABSTRACT

Seasonal variation in nutrition and habitat use are important in understanding the ecology of mule deer (Odocoileus hemionus) in eastern Montana. Consequently, I used fecal nitrogen (FN) to assess nutrition of mule deer during summer and winter in a prairie habitat (Boxelder study area) and a ponderosa pine habitat (Ashland study area). Forage succulence predicted summer FN values (R^2=0.93, P<0.01) on the Boxelder area but not on the Ashland area. Winter values of FN were lower than summer values for both areas, with those on Boxelder lower than Ashland. There was a curvilinear relationship (R^2=0.82, P<0.001) between FN and rumen forage nitrogen. Kidney fat index was related linearly (R^2=0.83, P<0.001) to rumen forage nitrogen and curvilinearly (R^2=0.59, P<0.05) to FN. Fawn girth measurements were greater (P<0.01) at Ashland than Boxelder. Deer use of cover types differed (P<0.001) between winter and summer on both areas. Aerial observations indicated greater use by deer of pine dominated cover types than was indicated by ground observations for the Ashland area. Mesic sites appeared to be important on both areas. Telemetry relocations at Boxelder indicated movement of deer onto the main drainage for a short period during late summer and fall. Most deer at Ashland were yearlong residents of the same areas, with 7 of 58 marked deer using distinct summer and winter ranges. Population estimates indicated higher population growth rates and densities at Boxelder than Ashland since the mid-1980s. Weather data from the Broadus NOAA station provided a better prediction of winter conditions on the Boxelder area than NOAA stations at Albion and Ridgeway. Seasonal and yearly differences in FN may be useful in estimating physical condition of deer; thereby helpful in predicting population trends based on relative periods of energy gain and loss.

INTRODUCTION

Weather and climate may be the ultimate variables controlling year round energetics of rocky mountain mule deer (*Odocoileus hemionus hemionus*) by influencing forage quantity and quality in summer and rate and extent of energy loss during winter. This may be especially true in prairie habitats of eastern Montana where climatic conditions and deer population numbers both vary widely. The ability to predict changes in deer numbers based on climatic factors would be beneficial from a management standpoint to balance hunter opportunity with landowner tolerance to high population levels.

The New Mexico deer model (Green-Hammond 1986) and the Hobbs model (Hobbs 1989) are potential management tools that include weather as an input for predicting trends in deer population levels. The relationship between vegetation, rumen nitrogen, and fecal nitrogen are important in the New Mexico model. Griffiths (1990) found this model to offer potential application in southeastern Montana, although it needed to be modified to reflect specific deer-habitat relationships. Likewise, the Hobbs model predicts overwinter mortality based on winter weather limiting the availability and digestibility of forage.

Work by Griffiths (1990) was the start of an effort to develop predictive capability of mule deer populations in southeastern Montana. My study was a continuation of this effort, undertaken as an exploratory study to better define fecal nitrogen (FN) patterns and its usefulness as an indicator of nutrition. Specific objectives were to: 1)examine the accuracy of FN as a measure of consumed protein 2)determine the relationship of forage succulence (as a general indicator of forage quality) to FN 3)evaluate seasonal variation in nutrition of deer and relate their movements and use of cover types in response to declining forage quality during the year.

I conducted field work full time during the summer of 1990 and winter of 1990-91. Additional field work was done part time between these periods and after the winter season.

DESCRIPTION OF STUDY AREAS

Two separate study areas approximately 140 km apart in southeastern Montana were used for this study. Topography and habitat types were distinct for each area. Boundaries were identical to those used by Griffiths (1990).

Boxelder Study Area

The 142 km^2 Boxelder study area was located approximately 10 km northeast of Hammond, Montana in Carter county. Bounded areas were the Boxelder Creek road to the northwest, Alzada Ridge to the southeast, the divide between T.L. Creek and Cow Creek to the northeast, and the divide between Steep Creek and Groat Creek to the southwest (Fig. 1). Population trends on this area have been monitored by MDFWP since 1979.

Elevations range from 1,045 m along Boxelder Creek to 1,235 m on Alzada Ridge. Buttes are present throughout the rolling terrain.

The study area is characterized by highly eroded ephemeral streams. In some areas, stream width is only 1 m, with vertical sides reaching a depth greater than 2 m. In other areas, undercutting and slumping have increased stream width to >15 m with terraced sides. Branching and sinuosity have greatly increased stream length throughout

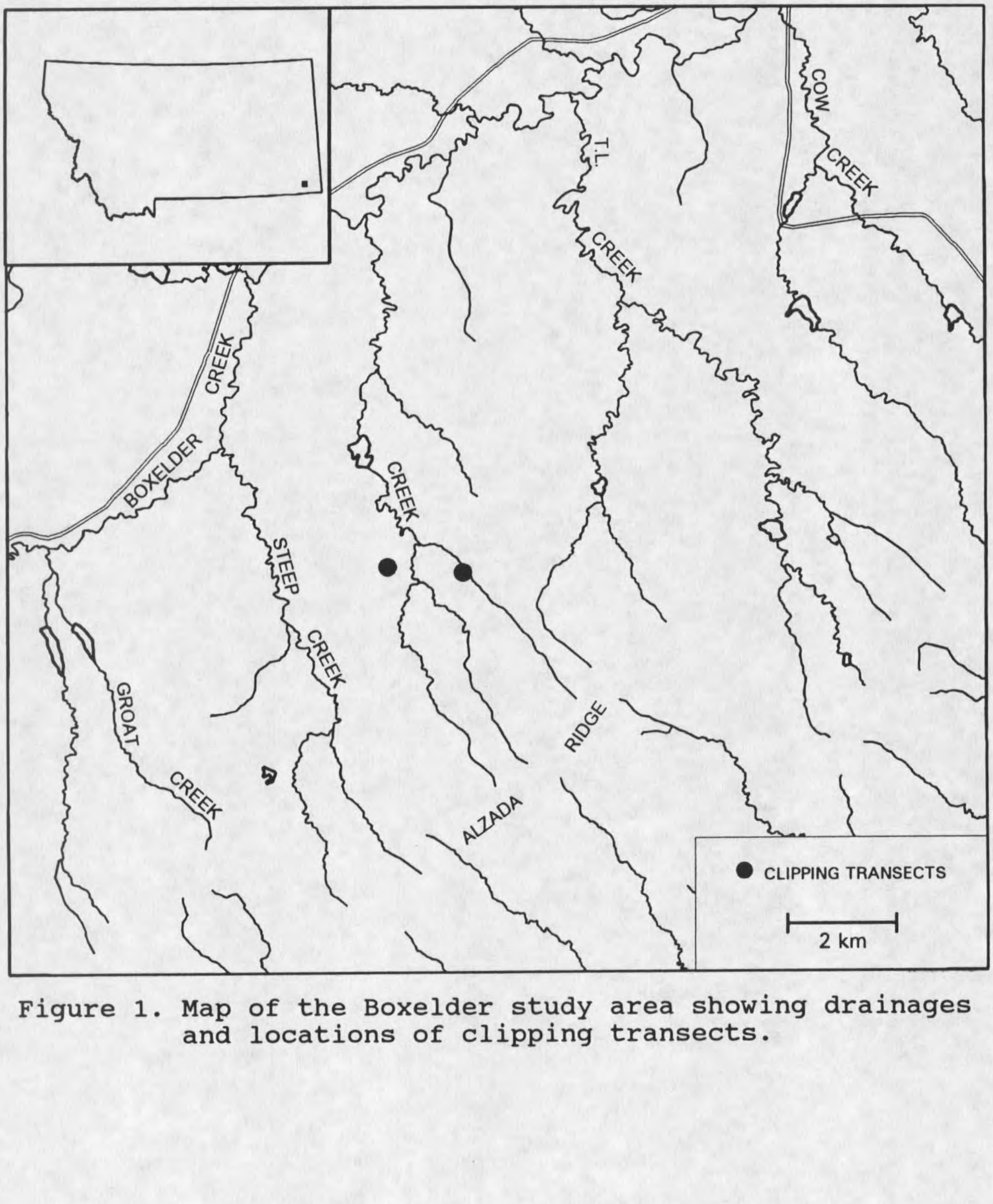

Figure 1. Map of the Boxelder study area showing drainages and locations of clipping transects.

the study area. Water flow generally occurs only in spring or after heavy rainfalls.

During summer, temperatures were often cooler in the bottoms of ephemeral streams. On 1 occasion, I measured a temperature of 27°C in a creek bottom compared to 57°C in the sun on the adjacent bank.

Boxelder Creek flows northeast through the study area into the Little Missouri River. Flows were yearlong from at least 1950 to the early 1980's, but have been only seasonal since the early 1980's (Ralph Brownfield, pers. comm.).

Vegetation on the study area is predominantly a sagebrush-grassland community. Climax grass species include western and thickspike wheatgrass (*Agropyron* spp.), green needlegrass (*Stipa viridula*), little bluestem (*Andropogon scoparius*), bluebunch wheatgrass (*Agropyron spicatum*), and prairie junegrass (*Koeleria macrantha*) (Ross and Hunter 1976). Big sagebrush (*Artemesia tridentata*) is present throughout the study area.

Saltbush (*Atriplex gardneri*) dominates ridges and the sides of many buttes. The occurrence of greasewood (*Sarcobatus vermiculatus*) increases in the southeast portion of the study area. Various shrubs and hardwood trees are common along Boxelder Creek but occur only in scattered areas along side creeks. Important species include snowberry (*Symphoricarpos* spp.), rose (*Rosa woodsii*), cottonwood (Populus deltoides), and boxelder maple (Acer negundo). Fragrant sumac (Rhus aromatica) [fragrant sumac (Rhus aromatica)=skunkbush (Rhus trilobata)] occasionally occurs in draws on the sides of some buttes. Big sagebrush reaches a height of over 75 cm along creeks, with reduced height farther away. Yellow sweetclover (Melilotus officinalis), a biennial of widely varying occurrence, was common on the study area during the summer of 1990. Plant nomenclature follows Dorn (1984).

Land ownership consists of approximately 51% private land, 43% public land administered by the Bureau of Land Management (BLM), and 5% state-owned land. Cattle and sheep ranching is the major land use. Livestock are wintered along Boxelder Creek. The current grazing management allows grazing over virtually the entire area at some point during the year. Roughly 30 stock ponds are located on the study area.

Pronghorn antelope (Antilocapra americana) and red fox (Vulpes vulpes) were commonly seen, and limited numbers of white-tailed deer (Odocoileus virginianus) were present. Coyote (Canis latrans) populations are rigorously controlled by landowners and I observed only 1 individual during the study.

Deer hunting on private land within the study area is controlled by landowners, with over half receiving some form of pay hunting. Hunting on BLM land is probably minimal due to limited access.

Mean monthly temperature on the Boxelder area is estimated to range from -8.3° C in January to 20.6° C in July. Mean annual precipitation is 356-406 mm with 60% of it occurring between April and July (Fig 2). The frost-free season lasts approximately 110-120 days, although most plant growth is normally completed by mid summer (July). All weather data are extrapolated values from the Montana State University MAPS (Montana Agricultural Potential System) computer program.

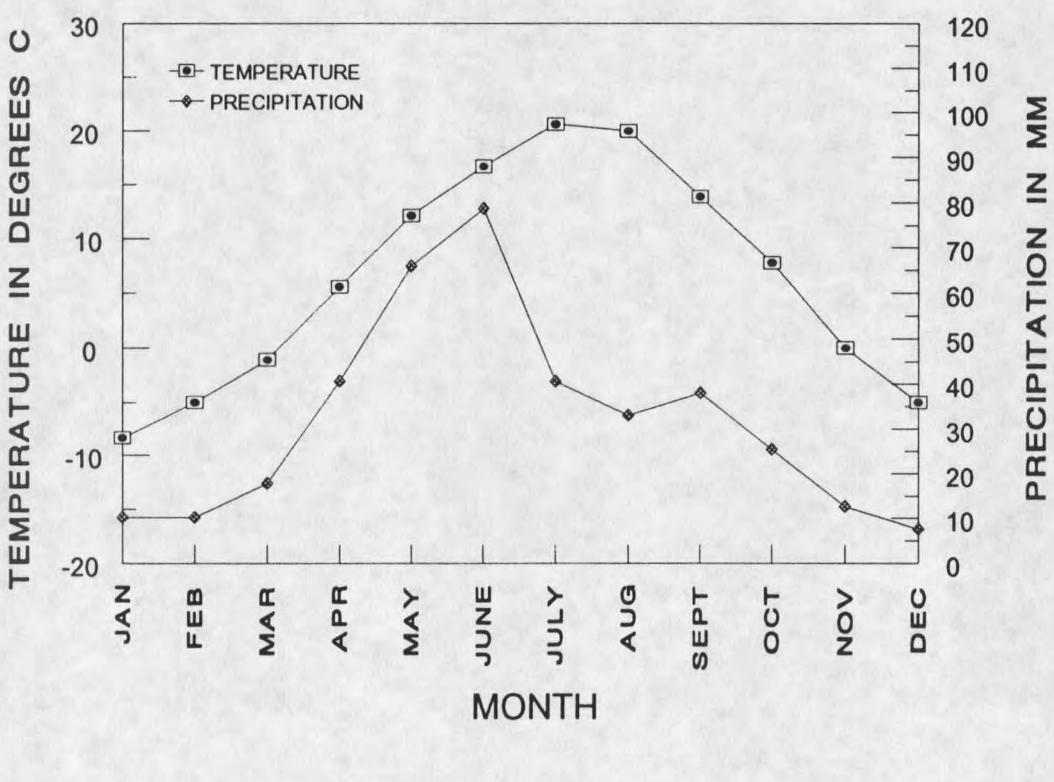

Figure 2. Mean monthly temperature and precipitation on the Boxelder study area (MAPS).

Snowfall during the winter averages 127-245 cm (MAPS). Maximum monthly snowfall during 1952-1989 at 3 nearby weather stations (Broadus, Ridgeway, and Albion, Montana) has never exceeded 76cm. Mean monthly snowfall values are all below 22 cm, with highest readings occurring in March or April (NOAA 1952-89).

Ashland Study Area

The 357 km^2 Ashland study area is located northwest of the Boxelder study area, near Ashland, in Rosebud and Powder River counties, Montana. Boundaries consist of State Highway 212 on the north, Otter Creek road on the east, and Cow Creek road to the south. The western boundary includes portions of the Tongue River, O'Dell Creek, and Stocker Branch road (Fig. 3). Deer populations have been monitored by MDFWP on a portion of this area (Otter Creek trend area) since 1979 (Fig. 3).

Topography varies throughout the study area. A distinct north-south ridge reaching an elevation of 1,265 m runs through the middle of the study area. This becomes a high plateau along the southern boundary, with rolling terrain over the rest of the area. A low point of 890 m is reached along the Tongue River to the west.

Steeply-eroded ephemeral streams similar to those on the Boxelder area are present throughout the rolling

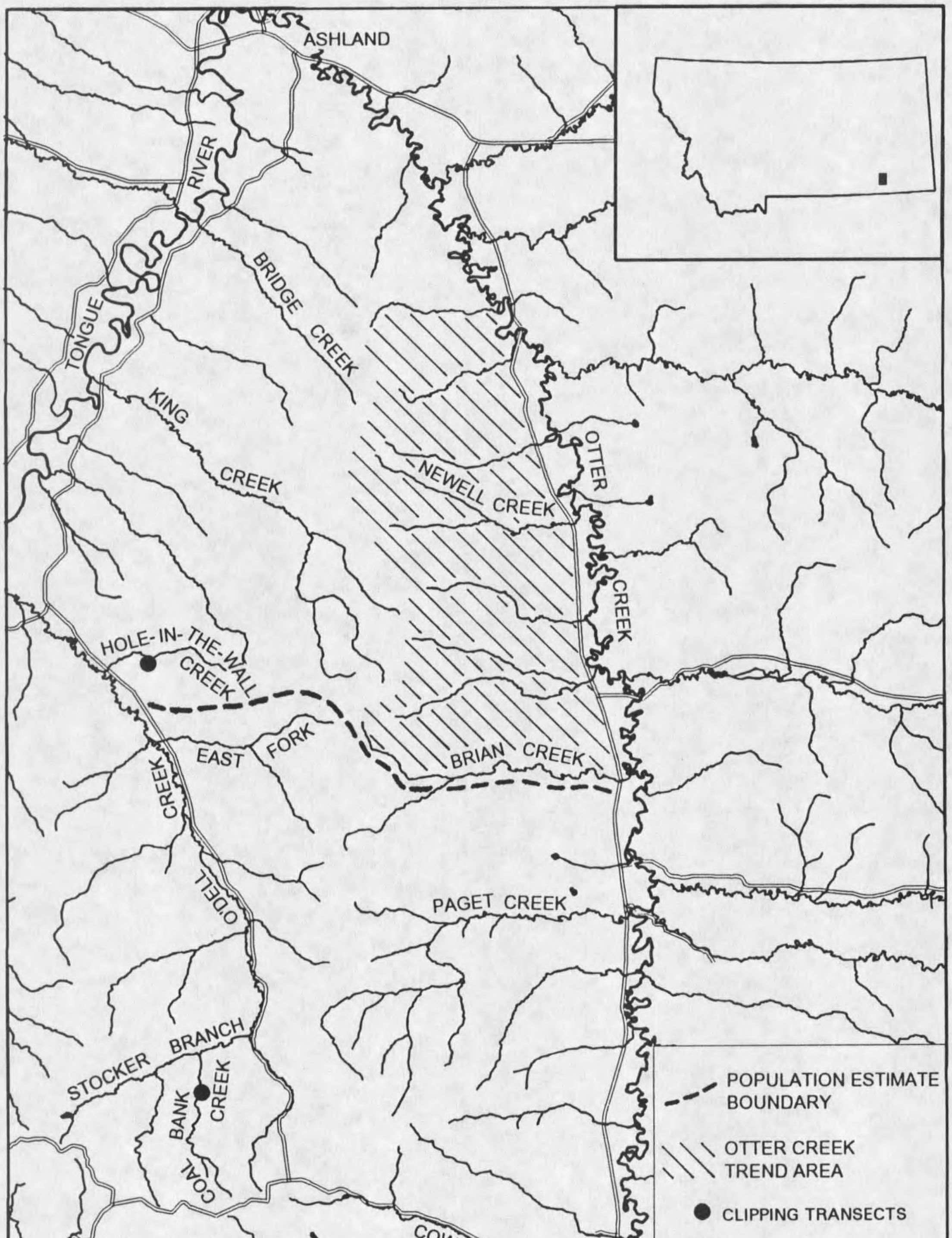

Figure 3. Map of the Ashland study area showing drainages, location of the Otter Creek trend area, boundary of the population estimate area, and locations of clipping transects.

portions, but they are less abundant than on the Boxelder area. Water flows yearlong in the Tongue River and Otter Creek. Numerous stock tanks and a few developed springs also occur.

The higher portions of the central and southern parts of the area are dominated by ponderosa pine (Pinus ponderosa) interspersed with grassland. This gives way to a mixture of pine, juniper (Juniperus scopulorum), big sagebrush, and mixed grassland at intermediate elevations. Grassland and sagebrush-grassland is most common at lower elevations and in northern portions of the area, although patches of pine and juniper also occur. Climax grasses in lower areas are similar to those on the Boxelder study area. Idaho fescue (Festuca idahoensis), sideoats gramma (Bouteloua curtipendula), big bluestem (Andropogon gerardii), and prairie sandreed (Calamovilfa longifolia) are found under the pine canopy at higher elevations (Ross and Hunter 1976).

Chokecherry (Prunus virginiana), serviceberry (Amelanchier alnifolia), buffaloberry (Shepherdia canadensis), and snowberry were present in more mesic areas, and fragrant sumac occurred on hillsides throughout the study area. Yellow sweetclover was common during the summer of field work.

Land ownership is about 63% national forest, 32% private, 3% BLM, and 2% state land. Hay and grain are grown along the Tongue River and Otter Creek. Only a small portion is irrigated. A rotational grazing system allows cattle use on practically the entire area at some point during the year. No sheep are present. Numerous roads exist throughout the study area.

I often observed coyotes, antelope, white-tailed deer, red fox, and bobcats (*Felis rufus*) on the study area. Two credible mountain lion (*Felis concolor*) sightings were reported during the summer of 1990.

The southern part of the study area is cooler and wetter than the northern portion. Mean temperature near Ashland is -7.2° C in January and 21.7° C in July. The number of frost-free days is about 100-125. Mean annual precipitation ranges from 305-356 mm in the north to 406-457 mm near Coal Bank Creek in the south, with approximately 57% occurring between April and July (Fig. 4). Annual snowfall on the northern portion averages 64-127 cm , whereas that on the southern part ranges from 64 to 254 cm. All weather data are from MAPS.

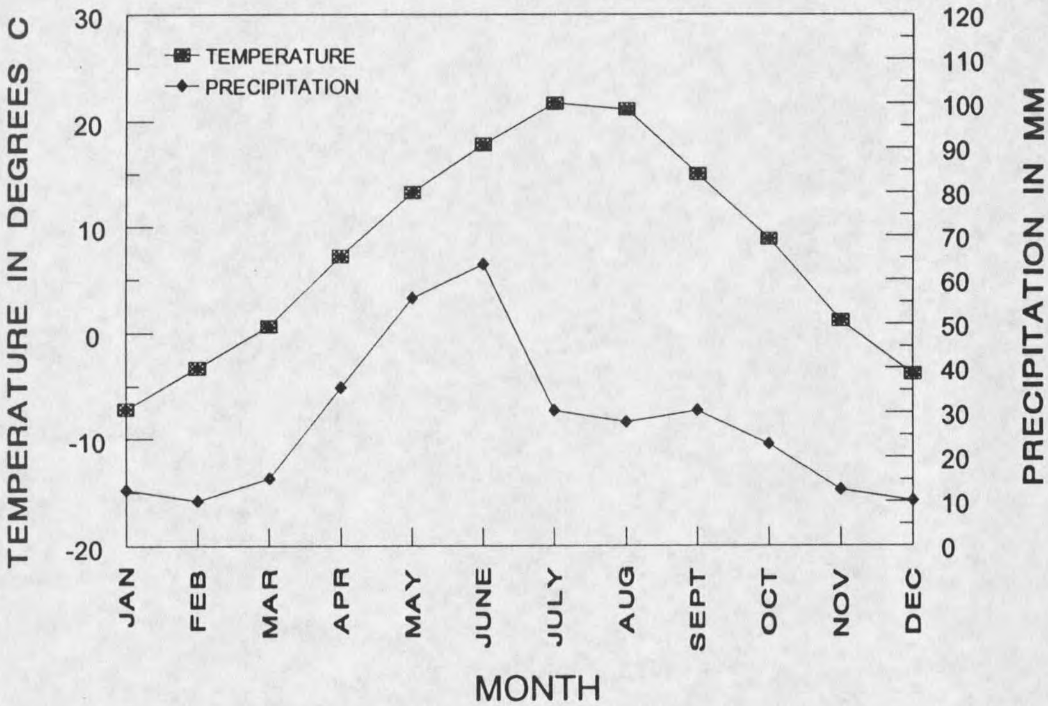

Figure 4. Mean monthly temperature and precipitation on the Ashland study area (MAPS).

METHODS

Forage Succulence

During the summer of 1990, vegetation clipping sites were established on 1 sagebrush-grassland site and 1 mesic site on each study area. I selected sites that appeared to best represent vegetation across the study areas. The Boxelder sites were located less than 1 km from each other along Park Creek (Fig. 1). Clipping sites on the Ashland area were about 12.5 km apart (Fig. 3) because the southern portion contains more mesic vegetation while the northern portion contains more sagebrush. Additionally, I moved the sagebrush-grassland site (northernmost site) on the Ashland area about 1.5 km after the first clipping because I felt the new location was more representative of the area.

Each clipping site consisted of two 25 m transect lines. All forbs and grasses in five 2x5 dm plots along each transect line were clipped biweekly to a height of approximately 2 cm. This resulted in 10 total plots from each clipping site. Plots were spaced 4.7 m apart, and locations were shifted 4 dm at each clipping to avoid clipping the same spot more than once.

To assess the characteristics of the lushest forage available to deer, beginning in July I clipped 5 plots in the most succulent appearing vegetation on each study area. I refer to these plots as "reference plots". On the

Boxelder area, reference plots were on small bends along Park Creek that were too small to run a transect line. On the Ashland area they were located in a dry creek bed adjacent to the sagebrush-grassland site. All reference plots were clipped within 1 km of transect lines.

Forbs clipped from the 10 plots on each clipping site were combined; grasses were also pooled. Reference plots were treated in the same manner. This resulted in one sample each of forbs and grasses from the mesic site, the sagebrush-grassland site, and the reference clippings for each study area. Fresh weights and dry weights were determined for each sample. Dry weights were measured after oven drying at 90° C (Milner and Hughes 1968) for 24 hours to remove all moisture. Forage succulence (percent moisture) was determined by dividing the difference between fresh and dry weights by fresh weight.

Fecal Nitrogen

Fecal pellets were periodically collected from both study areas for analysis of fecal nitrogen (FN) content. Only pellet groups considered fresh, (moist appearance and texture) were collected. For convenience, I define "sample group" as a collection of fecal pellets from 5 different pellet groups.

During the summer, sample groups were collected near (<3 km) vegetation clipping sites and within 2 days following clipping. Fecal collection near transects allowed a comparison between FN values and forage succulence of adjacent areas. Distance between clipping sites resulted in 2 sample groups from the Ashland area and 1 from the Boxelder area. To avoid mistakenly collecting domestic sheep droppings on the Boxelder area, no pellets were collected within 1 km of areas sheep were observed feeding. Beginning in August, a second sample group was collected from hayfields along Boxelder Creek where deer often were observed feeding. One additional sample group was collected in September from an irrigated hayfield on the Ashland study area.

Sample groups were collected during the winter from the same general areas as during the summer. Two sample groups were again obtained from each study area. Pellets from within the fenced area surrounding haystacks replaced those obtained from hayfields on the Boxelder area during the summer, but were only collected on 2 different occasions.

Throughout the study, pellets were obtained from deer of known sex or age whenever possible. This was done when deer were seen defecating, or when an animal was disturbed from a bed and fresh pellets were found. Age of males was estimated according to antler growth as yearling, 2-year old, or older. These samples were analyzed separately for nitrogen content.

Jenks et al. (1989) found no difference in nitrogen values between pellet groups analyzed separately and taking a mean value, or those obtained by combining equal amounts of each pellet group and making a single measurement. Therefore, after cleaning of foreign debris and air drying in paper bags, 2.0 gm from each pellet group in each sample group was ground with a mortar and pestle and combined into a 10.0 gm sample.

Nitrogen content is calculated on a percent weight basis. Thus, all fecal samples were simultaneously oven dried and sealed in plastic bags before being sent to the Montana State University Chemistry Station Analytical Laboratory for analysis by the Kjeldahl technique (Williams 1984). Moisture content of 2 random sample groups was obtained as an estimate of moisture content for all sample groups. Gross energy was determined by Parr Bomb method (Williams 1984) for several sample groups to determine if any seasonal trends were evident.

Physical Attributes Of Individual Deer

Seven deer were collected on the Boxelder area and 6 on the Ashland area during the 1990 hunting season. Kidneys with attached fat were removed and kidney fat index (KFI) was calculated according to the method described by Riney (1955). Both a combined KFI value for both kidneys (Anderson et al. 1972) and individual KFI for each kidney were obtained. Field-dressed animals were weighed and aged according to tooth replacement and wear (Robinette et al. 1957).

Fecal and rumen samples were collected from each deer and analyzed individually for nitrogen content. Fecal samples were cleaned, dried, and analyzed as described above. Rumen samples were washed through a filter to remove endogenous nitrogen and retain only consumed forage. Forage samples were simultaneously air dried and analyzed separately by the Montana State University Chemistry Station Analytical Laboratory (Kjeldahl technique, Williams 1984). Percent moisture was obtained for 1 sample.

Twelve additional deer were collected during January 1991 when the MDFWP area biologist obtained a kill permit to alleviate deer depredation on a ranch about 45 km northwest of the Boxelder study area. Habitat of the ranch was similar to the Boxelder area. Weights, ages, kidney fat index, and fecal nitrogen values were obtained from these animals.

Classification Of Cover Types

Cover types on each study area were identified according to land use and type and quantity of observed vegetation. Differences in habitat types between the 2 study areas resulted in a distinct classification system for each one.

I separated the Boxelder study area into 2 zones and identified 6 cover types within each zone. Zone 1 (main drainage) consisted of all land within approximately 1 km of Boxelder Creek (Fig. 1), and was the largest continuous source of the most mesic vegetation on the study area. All area >1 km from Boxelder Creek was designated zone 2 (upland zone). Lengths of all creeks were measured on 1:24000 U S Geological Survey (USGS) topographic maps with a cartometer.

The Ashland area was not separated into zones. All cover types identified could have occurred anywhere on the study area.

Capture of Deer

During February 1991, 57 deer were captured by helicopter drive-netting (Beasom et al. 1980) on the Ashland and Boxelder study areas. Telonics model 500 radio transmitters with mortality sensors and individually recognizable neckbands were fitted on 25 females $\geq$ 1 1/2 years of age. All remaining females, including fawns, were marked only with individually recognizable neckbands. Fawn neckbands were made to expand as the animal grew by stapling adult-size neckbands to a smaller circumference. These staples pulled out as the animal's neck became larger. All deer caught, including males, received metal eartags in both ears and were aged using tooth replacement and wear (Robinette et al. 1957).

Chest girth has been shown to provide a good estimate of live mass (Weckerly et al. 1987, Watkins et al. 1991). Girth was recorded for all fawns captured and used to estimate live weight according to Anderson et al. (1974). Eartag numbers, ages, and neckband identification symbols are listed in Appendix Table 18 and 19.

Visual Observations Of Marked And Unmarked Deer

I selected specific roads on each study area as routes for visual observations of deer (1 deer = 1 observation). Two survey routes were designated on each study area. Within the Boxelder area, 1 route was established in each zone. These routes were alternately driven except when weather made the route through the upland zone impassable. The occurrence of all identified cover types on both Ashland route made alternating routes less important, but this procedure was generally followed. Radio telemetry was not used in these surveys, but observations of marked animals were noted. Routes were driven within 2 hours after sunrise or during the last 2 hours before sunset.

Location, activity, sex and age when possible, and cover type used were recorded for every deer observed. Deer were classified as male, female, or fawn during the summer, and as adult or fawn during the winter. Activities were categorized as feeding, bedding, or traveling. Locations were recorded in Universal Transverse Mercator (UTM) coordinates on USGS topographic maps. Cover types were for the specific microsite being used. Ground observations made in addition to those on survey routes were recorded in the same manner.

Aerial surveys, using a Piper Supercub, were flown for complete coverage on each area during fall 1990 and winter 1991. Surveys began approximately 1/2 hour before sunrise and were completed within 2 hours after sunrise. Flight paths generally followed drainages, a method similar to previous surveys flown by MDFWP biologists on these areas, and used elsewhere in Montana (Mackie et al.1981). This method provided the best observability of all terrain, and reduced the chance of double-counting deer because they generally ran along the drainage when disturbed by the airplane. Complete coverage was obtained by flying more than 1 pass when width of the drainage or dense vegetation required closer coverage.

Location (UTM coordinates on USGS topographic maps), sex and age class when possible, and number of deer were recorded during aerial surveys. For flight observations on the Ashland area, cover types were the same as during ground observations. On the Boxelder area, I recorded deer in 3 general categories (Boxelder Creek, ephemeral streams, rest of area) because the large number of deer and disturbance from the airplane made it difficult to use the same cover types as for ground observations. The "Boxelder Creek" category was identical to zone 1 used in ground observations. Aerial observations within 100 m of an ephemeral stream were categorized as "ephemeral streams", and any observations made on the rest of the area were listed as "rest of area".

Telemetry Relocations

I located marked deer using radio telemetry during complete aerial surveys and on specific relocation flights in May, July, and October 1991. Relocations were also made from the ground whenever time permitted. Ground relocations were considered valid when either visual contact was made or when triangulation from a half-circle indicated a specific point.

Deer had been previously marked on the Boxelder area during 1983-86, and on the Ashland area during 1986-87. Relocations of these animals (1601 relocations of 128 does on the Boxelder area, 522 relocations of 47 does on the Ashland area) were obtained from MDFWP area personnel (Steve Knapp, Greg Risdahl, pers. comm.). Current status of as many of these deer as possible was determined (Appendix Table 20).

Population Estimates

Population estimates (mark-recapture) were made on both study areas during late winter 1991. Each area was flown at sunrise without the use of radios, counting total number of deer seen and noting any marked animals. After completing the survey, radios were used to determine if there were radio-marked deer on the study area that were not seen. The northern part of the Ashland area (Fig. 3) was divided into 2 sections with 1 section completed each day; the entire Boxelder area was surveyed on a single flight. Any neck-banded deer seen on the areas within 5 days before or after flights were included in the number of marked deer present. I observed little movement by deer at the time of year estimates were made, and assumed these deer were on the study area during the estimates. I also assumed that no movement occurred between the 2 sections of the Ashland area during the 2 day period. Population estimates for the same portion of the Ashland area were made for 1986-90 using relocations of deer marked during 1986-87.

Mortality

During May 1991, a deer mortality survey was conducted on a portion of the Boxelder study area that received heavy use by deer during the previous winter. Remains of deer that died during winter were generally found near ephemeral streams. Therefore, the survey searched areas adjacent to these streams. The proportion of the area searched was estimated by measuring the total length of survey routes with a cartometer on USGS 1:24000 topographic maps and dividing by total length of all upland streams beds. Age and sex were determined, and femur marrow was examined for signs of malnutrition whenever possible. Remains of deer found during the course of other field work on both study areas were examined in the same manner. A survey of landowners was conducted on the Boxelder area to determine hunting mortality during the 1990 season. Neither survey was conducted on the Ashland study area.

Weather Conditions

Beginning in January, 1991, a thermograph and wind recorder were used to record minimum and maximum temperatures and wind speed on the Boxelder study area. The wind recorder was placed at a height of 1 m, the approximate height of a standing mule deer (Leckenby and Adams 1986). A precipitation gage was also set up, but use was abandoned after erroneous readings during windy conditions were noted. Weather data was recorded until mid July.

Analytical Methods

All statistical tests were made using SAS (SAS Institute 1987). Unless noted otherwise, *P*-values less than 0.05 were considered significant.

Forage Succulence And Fecal Nitrogen

Stepwise regression (SAS Institute 1987) with an entry-exit value of 0.20 was used to predict summer fecal nitrogen content from the 4 forage succulence values and time (Julian date). Only forage succulence values from transects and FN values from sample groups collected adjacent to the transects were used in regressions. Variance inflation factor (VIF) (Neter et al. 1985) was used to detect multicollinearity between factors. Any model with a VIF greater than 10.0 was rejected.

Certain biological criteria were required of acceptable regression equations. Regression models were required to have an intercept at or below any observed summer FN value so that higher FN resulted from an increase in succulence. Therefore, models containing only negative coefficients or those having larger absolute values of negative than positive coefficients were rejected.

Fecal nitrogen values were also graphed against time. A t-test was used to compare seasonal FN means between locations when graphs did not indicate declines over time, and when stepwise regression did not predict a decline due to forage succulence.

Physical Attributes Of Deer

A paired t-test was used to compare KFI values between pairs of kidneys and between a summed value from both kidneys to each individual side. A paired *t*-test also was used to determine any difference between bare kidney weights. Correlation analysis was used to compare eviscerated weight to a summed value of bare kidney weights for each animal.

Simple linear regression was used to predict KFI from FN, and KFI from rumen forage nitrogen. Logarithmic or inverse transformations were used to account for curvilinear relationships. Because body fat content of young deer is confounded by growth (Anderson et al. 1990), KFI from animals <1 1/2 years were not used in these regressions. Deer collected in January were also excluded due to the decline of KFI values that occurs during the winter.

Anderson et al. (1974) determined no difference in weights between male and female fawns until 12-17 months of age. Therefore, after using a *t*-test to discern any difference in girth between sexes for each study area, fawn girth measurements were combined and a *t*-test was used to determine any difference in mean girth measurements between study areas. Girth measurements were used to estimate live weights according to Anderson et al. (1974).

Population Estimates

All population estimates were made using the computer program MRPE (Dan Gustafson, Montana State University Dept. of Biology, pers. comm.). MRPE calculates a maximum likelihood estimate identical to the Lincoln index (Davis and Winstead 1980), a median, and an unbiased estimate of population size. It also can compute the probability that one population estimate is larger than either another estimate or a fixed value. Confidence intervals are based on the Bayesian approach (Johnson 1977).

Use of Cover Types

All ground observations of deer were used to calculate percent use by activity in each cover type on a monthly basis for both study areas. Because field work was completed shortly after deer were radio-collared, all telemetry locations from the ground that included visual contact were included in these calculations. Aerial observations were used to estimate percent use of cover types for each flight.

Chi-square analysis was used to compare cover type use between summer and winter. Air and ground observations were separately determined on the Boxelder area; only ground observations were used in chi-square analysis for the Ashland area because flight data were inadequate for comparison. Seasonal differences in deer use of zones was also tested on Boxelder. Requirements of chi-square analysis (Siegel 1956) were met by combining cover types when appropriate.

March and September observations were included in winter and summer observations, respectively. Any observed differences during March and September that may be associated with a change in season were described qualitatively.

Availability of cover types was not measured, so use versus availability was not determined. Comparisons are presented to show general trends on the study areas, and for general comparisons with findings of studies in similar habitats elsewhere.

Home Ranges

Relocations obtained during this study were combined with those obtained from previously-marked deer to estimate minimum convex polygon home ranges (Mohr 1947) and average activity radii (Robinette 1966) using the computer program TELDAY (Lonner and Burkhalter 1986). Relocations were plotted to determine seasonal movements.

Estimates of home range size generally increase as the number of relocations increase (Jenrich and Turner 1969), and the closer relocations occur in time, the less likely they are to be independent (White and Garrot 1990). Deer marked by MDFWP during 1983-87 were used to determine observability of deer during aerial surveys. Flights were generally flown on 2 consecutive days during most months of that study. Some deer were located both days; others were located only when radios were used. This resulted in the same number of relocations for some deer in 6 different months as for other animals in 12 different months. Deer with 12 relocations over 12 different months would provide a better estimate of home range size than deer with 12 relocations over 6 months. To avoid any bias in home range estimates due to the timing and number of relocations obtained during the observability study, the number of different months in which relocations were made (rather than total number of relocations) was analyzed for a correlation to home range size estimated for each deer. Animals with fewer relocation months were consecutively deleted until a *P*-value greater than 0.10 was reached. Only those animals remaining were used to calculate mean values, but all relocations of these deer were used for estimates. This method was used for each time period a home range estimate was obtained. A t-test was used to compare mean home range size between years.

Ephemeral streams on Boxelder generally flowed in a north-south direction; those on Ashland were more variable. To determine if home range shapes followed drainages, a paired t-test was used to compare the standard deviation in the north-south direction to the east-west direction for home range estimates.

Dates for all seasonal and annual home range estimates are based on movements of animals. Hamlin and Mackie (1989) found no difference in life home range size after 29 relocations were made over 24 consecutive months. This same time period was used for lifetime estimates on these 2 areas, although the minimum number of relocations was dependent on the method described above.

Weather

Minimum and maximum daily temperatures measured during the winter on Boxelder were compared to NOAA weather stations at Broadus, Ridgeway, and Albion, Montana. Simple linear regression was used to determine which station provided the best prediction (highest R^2) of temperatures on the study area.

RESULTS

Succulence and Dry Weight of Forage

Boxelder Study Area

Moisture content of all forage from the Boxelder transect lines was highest during the first clipping in June (Fig. 5 and 6, Appendix Table 21). Succulence declined thereafter with only a slight upward shift at the end of summer.

Moisture in forbs on the sage site declined faster than the creek site and was lower in all but 1 clipping. Reference clippings were consistently higher in moisture content and generally exceeded both transects.

Grass was consistently more succulent on the creek than sage transect. However, clippings from reference plots had higher moisture content than either transect during all sampling periods. Succulence of all 3 types of grass clippings reached their lowest values on the same date.

Average dry weight of grass on the sage site increased from the first to second clipping before remaining fairly constant the remainder of the summer (Table 1). On the creek site, grass weight increased over the first 3 clipping

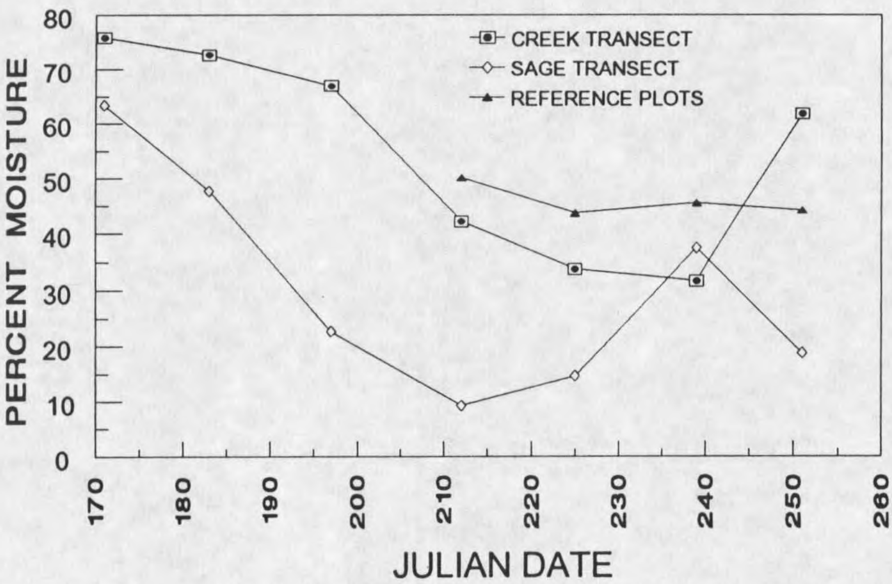

Figure 5. Average moisture content (%) of forbs from plots clipped on the Boxelder study area.

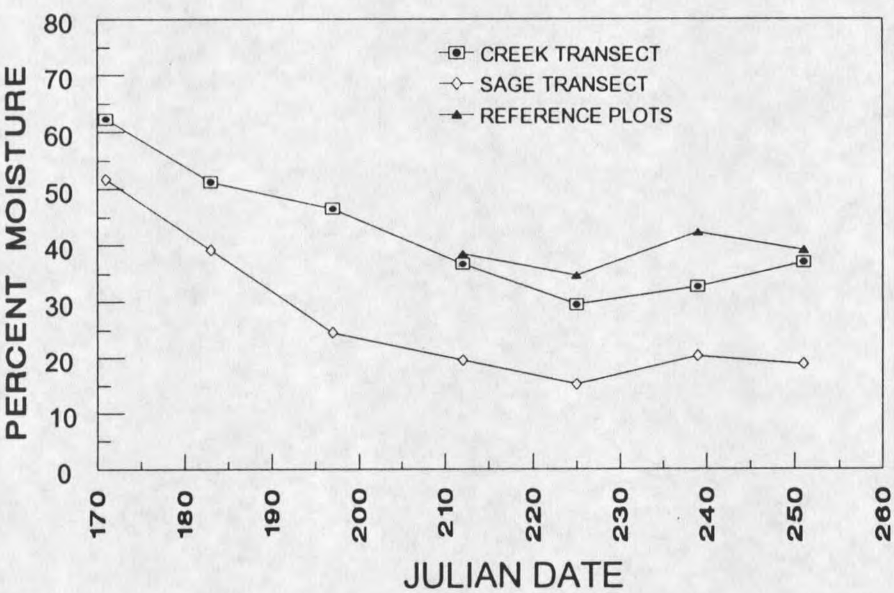

Figure 6. Average moisture content (%) of grass from plots clipped on the Boxelder study area.

periods and then declined. This decline was concurrent with use of the pasture by cattle. Average dry weights from the reference plots also declined from the first to last clipping. Overall, average dry weights were greatest for the reference site, followed by the creek and sage site.

Table 1. Average dry weight (grams) of grass and forbs for clipping sites on the Boxelder study area. Sage and creek sites are averages for 10 plots, reference site is the average for 5 plots.

Julian	Grass			Forbs		
date	Sage	Creek	Reference	Sage	Creek	Reference
171	5.12	18.84	--	1.91	5.77	--
183	9.08	23.41	--	1.39	5.67	--
197	8.99	28.16	--	0.41	3.57	--
212	7.91	22.80	24.04	0.35	2.35	6.24
225	9.26	19.65	22.12	0.35	0.65	5.80
239	7.71	17.48	19.08	0.10	0.65	2.74
251	7.90	18.23	19.34	0.13	0.34	3.18

Average dry weight of forbs on transect lines showed the same trend as grass; an early increase followed by a decline the remainder of the summer. Forb weight on the creek transect was greater than the sage transect in every case. However, reference plots were greater than both transects in every period they were collected.

Ashland Study Area

Moisture content of all forage on the Ashland area declined through the summer similar to the Boxelder area (Figures 7 and 8, Appendix Table 21). However, little if any increase in succulence occurred at the end of summer at Ashland. For both grass and forbs, moisture content of the sage transect declined faster and was always lower than the creek transect. Forage succulence was always higher on reference plots than on the adjacent sage transect, but percent moisture was often greater on the creek transect than reference plots.

Percent moisture of grass and forbs on Ashland were initially higher than corresponding values at Boxelder. Thereafter, percent moisture of grass from the creek transect remained higher through summer at Ashland, whereas succulence of both forbs and grass from the sage transect were generally higher at Boxelder. Succulence of forbs from the creek transect and reference plots were fairly comparable between the 2 study areas except for an increase

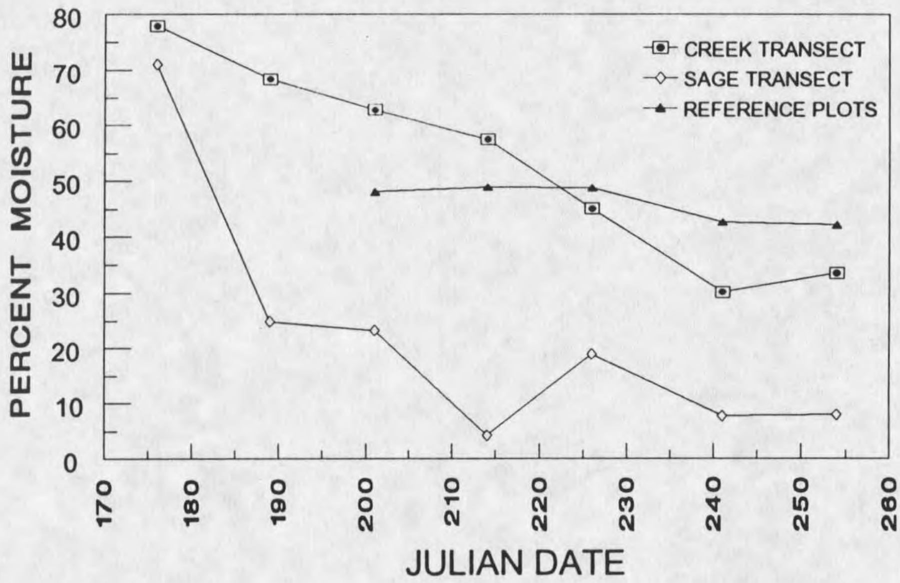

Figure 7. Average moisture content (%) of forbs from plots clipped on the Ashland study area.

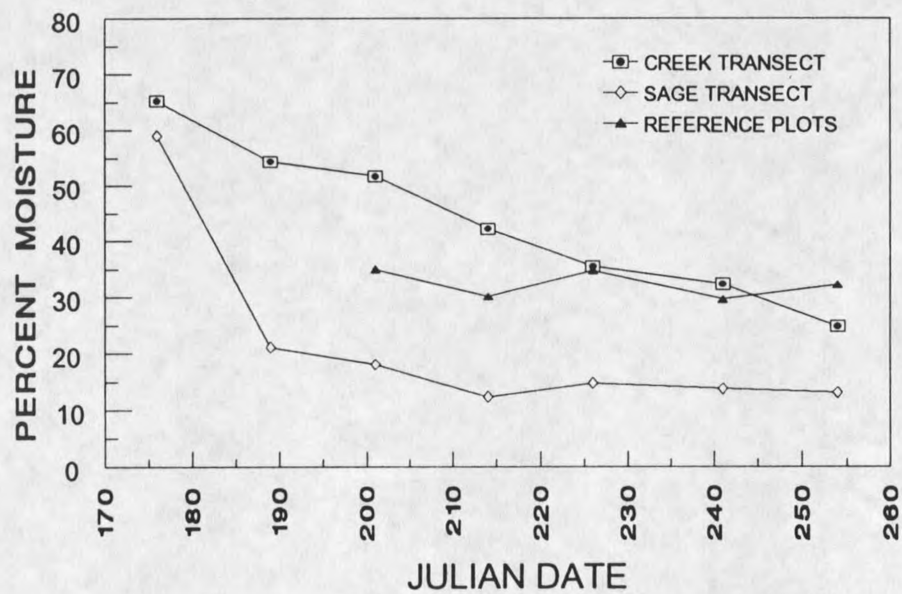

Figure 8. Average moisture content (%) of grass from plots clipped on the Ashland study area.

in succulence of forbs from the creek site on Boxelder during the last clipping.

Average dry weight of grass and forbs from reference plots were generally greater than either transect (Table 2). Weights of forbs were greater on the creek transect than on the sage transect, but weights of grass were similar for both.

Table 2. Average dry weight (grams) of grass and forbs for clipping sites on the Ashland study area. Sage and creek sites are averages of 10 plots, reference site is the average of 5 plots.

Julian	Grass			Forbs		
date	Sage	Creek	Reference	Sage	Creek	Reference
173	9.78	6.94	--	0.09	2.42	--
189	13.67	10.87	--	0.71	2.57	--
200	10.40	11.50	9.94	0.23	2.22	4.02
214	12.83	11.58	15.44	0.55	3.60	6.06
227	11.52	10.09	14.58	0.34	3.24	2.48
241	9.59	9.83	16.58	0.12	1.34	4.80
253	8.56	11.41	14.36	0.16	0.97	2.44

Average dry weight of grass from the sage transect at Ashland was always greater than the corresponding transect at Boxelder, whereas grass from the creek transect was greater at Boxelder. Weights of forbs from creek transects were greater at Boxelder the first half of the summer and then declined to a point lower than Ashland the second half. All reference clippings were greater on Boxelder except for one instance of forbs.

Fecal Nitrogen Content During Summer

Boxelder Study Area

FN content from the Park Creek collection area on Boxelder generally declined throughout the summer, from 3.5% at the initial collection in June (day 171) to 1.7% at the second to last collection (day 239) in August (Fig. 9, Appendix Table 22). FN in hayfield samples declined from 2.8% on day 219 to 2.3% on day 251.

Pellets from 4 deer of known sex and age were collected during the summer. Fecal samples from 2 yearling bucks collected along Park Creek on days 239 and 242 had nitrogen values of 2.1% and 2.2% respectively. Pellets collected from 2 fawns, one from Park Creek on day 212 and the other from a hayfield on day 251, both had a FN content of 2.7%.

Stepwise regression predicted FN values at the Park Creek site on Boxelder with the following model:

$$Y=1.71+(0.087\ \text{S-grass})-(0.045\ \text{S-forbs}), \quad R^2=0.93.$$

Factors are expressed in percent moisture where S-grass and

S-forbs equal moisture content of grass and forbs from the sage clipping transect respectively. The variance inflation factor was less than 10 (VIF=5.75). The model passed all biological criteria with the intercept at or lower than all observed FN values and the absolute value of the positive factor was greater than the negative one.

Ashland Study Area

FN content in samples from the Coal Bank Creek site on the Ashland study area varied between 2.0% and 2.7% throughout summer. For the Hole-in-the-Wall (HIW) site, FN ranged between 2.0% and 3.0% (Fig. 10, Appendix Table 22). Little if any seasonal decline was noted at either location.

A sample from an adult male near the HIW site had a FN value of 3.2%. Collection of a sample group from an irrigated hayfield near the HIW site on day 241 contained 2.9% nitrogen.

Regression analysis did not provide an acceptable prediction of FN on the Ashland study area, either for collection areas individually or by using a mean value from both sites. Combining FN values from the 2 collection sites into a single data set did not provide an acceptable model either. Because FN from the 2 sites did not decline during summer, they were compared with a *t*-test. Mean FN content

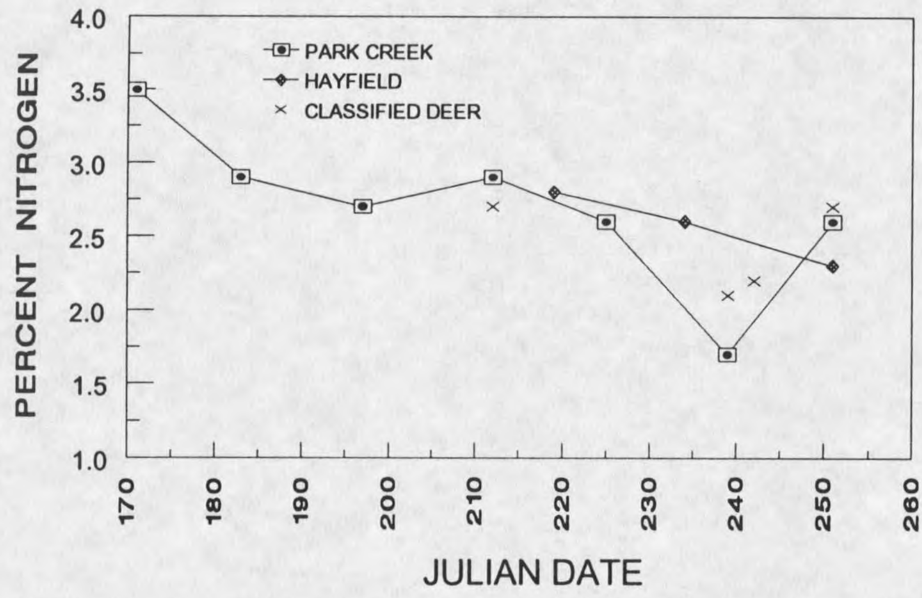

Figure 9. Percent nitrogen of fecal samples collected during summer on the Boxelder study area.

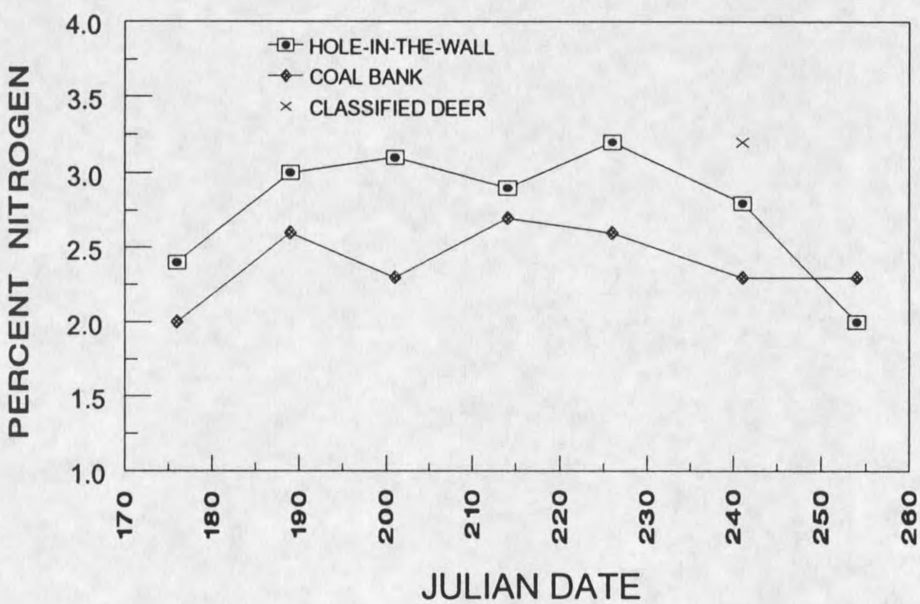

Figure 10. Percent nitrogen of fecal samples collected during summer on the Ashland study area.

from the HIW site was not significantly greater than the CB site at the 0.05 probability level (P=0.069).

Fecal Nitrogen Content During Winter

Boxelder Study Area

FN content of sample groups collected during winter on the Boxelder study area showed little variation. Samples from the Park Creek collection site ranged from 1.2 to 1.4% nitrogen, and the 2 sample groups from the haystack site had identical values of 2.2% (Fig. 11, Appendix Table 22). The low number of haystack samples precluded a statistical comparison between the 2 sites.

Ashland Study Area

Winter sample groups from Ashland showed more variation in FN content than Boxelder, ranging from 1.4 to 1.9% nitrogen on both the north and south collection sites (Fig. 12, Appendix Table 22). All FN values from the Ashland samples matched or exceeded those from Park Creek, but were less than FN values from haystacks on the Boxelder area. There was no significance difference (P=0.754) in percent FN between the two Ashland sites, but FN was significantly greater (P<0.05) on both Ashland sites than the Park Creek site on Boxelder.

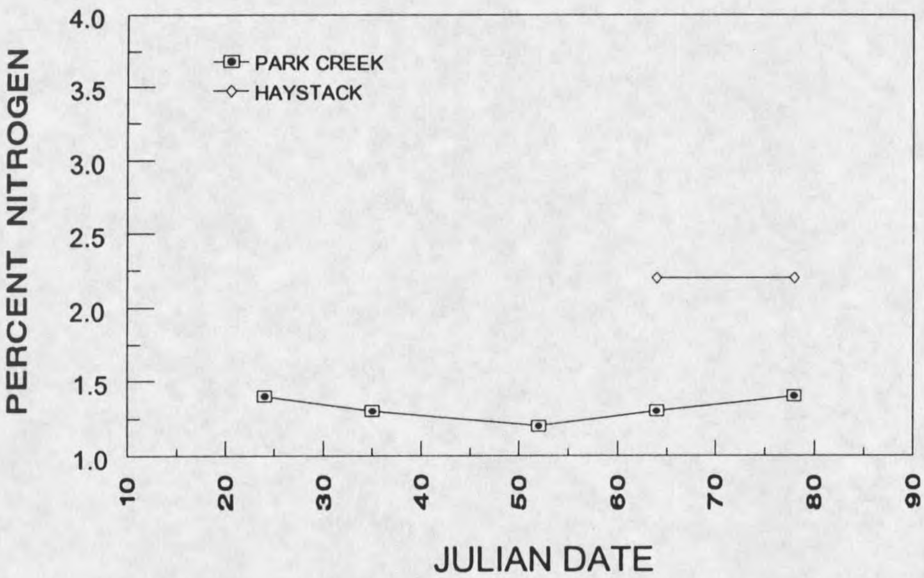

Figure 11. Percent nitrogen of fecal samples collected during winter on the Boxelder study area.

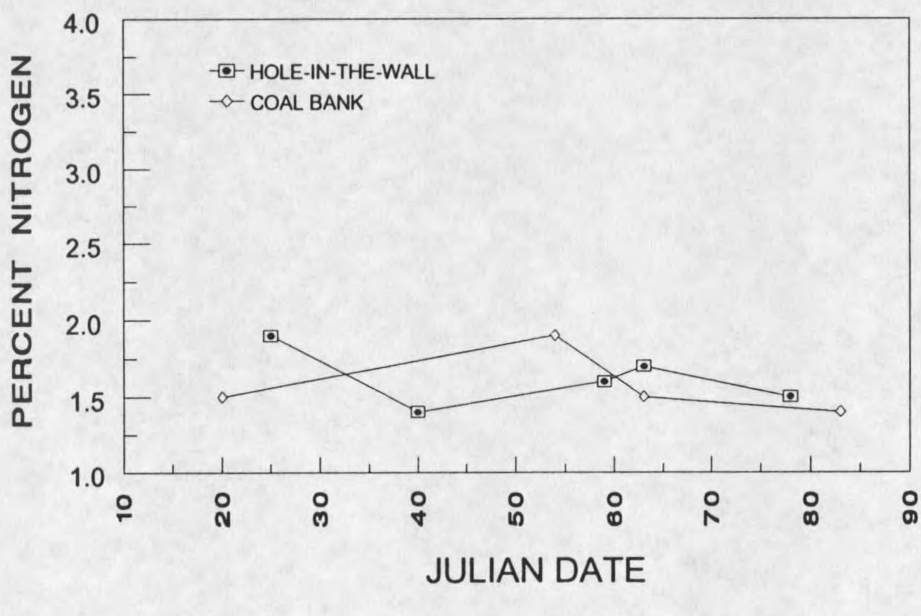

Figure 12. Percent nitrogen of fecal samples collected during winter on the Ashland study area.

Gross Energy and Moisture Content of Fecal Samples

No trend was observed in gross energy for the 5 fecal sample groups analyzed (Appendix Table 23). Gross energy for the Park Creek samples was highest in September and lowest in March, with the same value for June and February. The single hayfield sample had a lower energy level than the Park Creek sample for the same date.

Moisture content of 2 randomly selected fecal sample groups collected for FN analyses was 4.3% and 4.8%. All FN values in tables, figures, and text are reported for an "as is" basis and are not adjusted for moisture, but were handled the same and should be of similar moisture content. Adjusting FN values to a dry weight basis according to the amount of moisture found in the 2 random samples would raise all values by approximately 0.1%, with little if any increase in reported values due to round-off error.

Attributes Of Collected Deer

Fecal Nitrogen

FN in pellets of 7 animals collected during the hunting season on the Boxelder area ranged from 1.5 to 3.2% (Table 3). Deer #BE4, with the lowest FN content, was taken approximately 5 km from the main drainage near the head of Park Creek. All other deer were taken within 2 km of the main drainage. The average FN content for deer collected during fall (2.3%) was lower than all but 1 of the summer sample groups and higher than all winter values.

Samples from 2 additional animals were collected during the winter. A yearling doe that died during drive-netting near the head of Park Creek on day 43 had a FN value of 1.5%, and a 2 1/2 year-old male found shot along Boxelder Creek on day 82 had a FN value of 2.8% (Table 3). By comparison, fecal sample groups collected from Park Creek on similar dates during the winter had FN values of 1.3% and 1.4%, respectively.

Table 3. Sex, age, eviscerated weight in kg (lbs), fecal and rumen forage nitrogen (%), and kidney fat index (KFI) of deer collected on the Boxelder study area during fall and winter 1990-91.

Collection period			Characteristics			
ID#	Sex	Age	Weight	Fecal N	Rumen N	KFI
Hunting Season						
BE1	M	2 1/2	286	3.2	2.05	241.2
BE2	F	1/2	70	2.5	1.74	4.3
BE3	F	1 1/2	200	2.1	1.95	221.9
BE4	F	3 1/2	200	1.5	1.20	63.5
BE5	F	1/2	48	2.8	2.08	4.2
BE6	F	1/2	84	1.9	--	5.5
BE7	F	1 1/2	196	2.1	1.71	161.3
Winter						
BE8	F	1 1/2	--	1.5	--	61.9
BE9	M	2 1/2	--	2.8	2.34	24.1

FN percentages for deer collected during the hunting season on the Ashland area ranged from 1.5 to 2.0% with an average of 1.7% (Table 4). The average was lower than any summer composite for the Ashland area. All animals except AS1 were taken within 2 km of each other on the same date. AS1 was collected 2 weeks earlier in a different location on the study area, but all were taken from habitats containing a mixture of pine-grass and juniper cover types.

Table 4. Sex, age, eviscerated weight in kg (lbs), fecal and rumen forage nitrogen (%), and kidney fat index (KFI) of deer collected on the Ashland study area during fall 1990.

ID#	Sex	Age	Weight	Fecal N	Rumen N	KFI
AS1	M	1 1/2	191 (87)	1.7	1.42	155.6
AS2	F	7 1/2	187 (85)	1.5	1.03	14.6
AS3	F	1/2	106 (48)	1.6	0.97	23.0
AS4	M	1 1/2	200 (91)	1.5	0.89	81.6
AS5	F	3 1/2	191 (87)	1.6	1.07	31.4
AS6	F	2 1/2	183 (83)	2.0	1.26	33.9

FN from deer collected by permit at the end of January averaged 1.7% (1.5-1.8%) (Table 5). All deer were taken within 1 km of each other near a haystack.

Kidney Fat Index

Kidney fat index (KFI) for deer collected from the 2 study areas during the hunting season ranged from 4.2 to 241.2 (Tables 3 and 4). Adult males and yearling females tended to have the highest KFI, and fawns were lowest. The single fawn from the Ashland area had a higher KFI than all 3 fawns from the Boxelder area.

Fawns collected in January (Table 5) had greater KFI than fawns collected on the Boxelder area in November, but lower than the single fawn from Ashland. Yearling males and females taken in January had lower indexes than comparable animals from both study areas in fall. No trend was noted for older animals.

Table 5. Sex, age, eviscerated weight in kg (lbs), fecal nitrogen (%), and kidney fat index (KFI) of deer collected during January 1991.

ID#	Sex	Age	Weight	Fecal N	KFI
KP1	F	2 1/2	205 (93)	1.6	12.1
KP2	F	>1 1/2	183 (83)	1.7	36.3
KP3	M	1 1/2	183 (83)	1.5	29.8
KP4	M	1 1/2	187 (85)	1.8	14.7
KP5	F	1/2	97 (44)	1.8	9.5
KP6	M	1 1/2	207 (94)	1.8	12.6
KP7	F	2 1/2	209 (95)	1.7	43.1
KP8	F	1/2	108 (49)	1.7	10.6
KP9	F	1 1/2	161 (73)	1.6	23.8
KP10	F	1 1/2	167 (76)	1.5	43.8
KP11	F	1/2	86 (39)	1.6	6.1
KP12	M	1/2	114 (52)	1.7	10.4

KFI values in Tables 3, 4, 5, are calculated from the summed weight of both kidneys and the associated fat. A comparison between bare kidney weights and KFI values for each side (Appendix Table 24) showed no difference in weights between left and right kidneys or between KFI calculated for each side ($P>0.05$). Also, no difference ($P>0.05$) was found between the summed value of KFI and each individual value. A positive correlation ($R^2=0.80$, $P=0.001$) was noted between the summed weights of both kidneys and eviscerated deer weights.

Rumen Forage Nitrogen

Percent nitrogen of rumen contents from deer taken on both study areas during November ranged from 0.89 to 2.08% (Tables 3 and 4). Nitrogen content of rumen forage from Ashland deer was less than all Boxelder deer except BE4. The single winter sample on Boxelder (BE9) exceeded all fall values. Species composition of rumen forage was not determined, but BE9 was noted to have a large amount of corn present.

FN increased curvilinearly as rumen forage nitrogen increased, with a log transformation of both variables providing the best fit for a regression (Fig. 13). FN and nitrogen content of rumen forage from deer collected on each study area were combined for this regression.

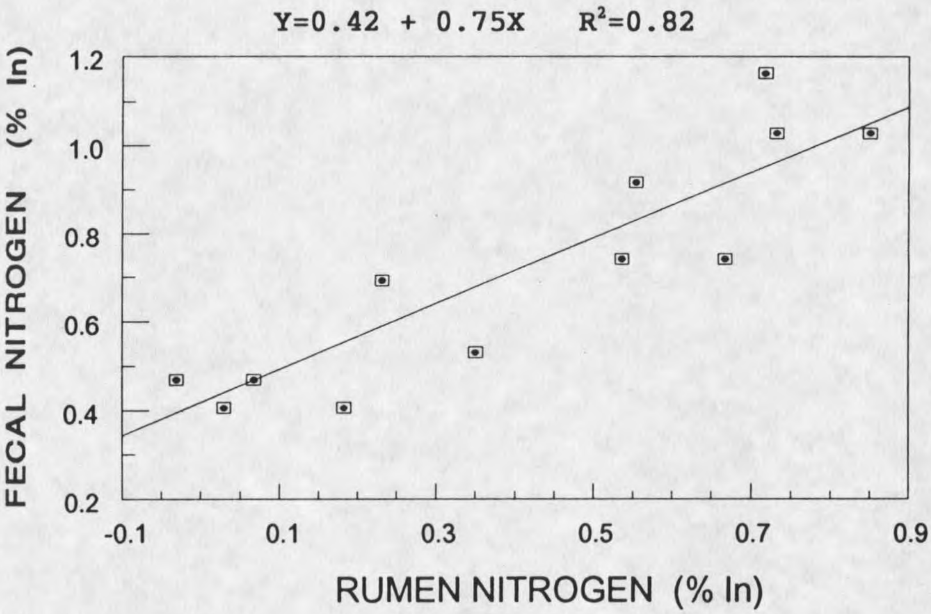

Figure 13. Regression of nitrogen content of rumen forage to FN for all deer collected on the Ashland and Boxelder study areas during fall 1990.

Data from adults collected during fall on each study area were combined and used to compare KFI to rumen forage nitrogen and KFI to FN. KFI increased linearly as rumen nitrogen increased (Fig. 14). KFI increased curvilinearly as FN increased, with an inverse transformation of FN providing the best fit of a regression (Fig. 15).

The single rumen sample analyzed for moisture contained 85.2% water. FN and rumen forage nitrogen used in tables and regressions are not adjusted for moisture. Intercepts and coefficients of regression equations would change when moisture weight is accounted for, but the relationship between variables would not be altered.

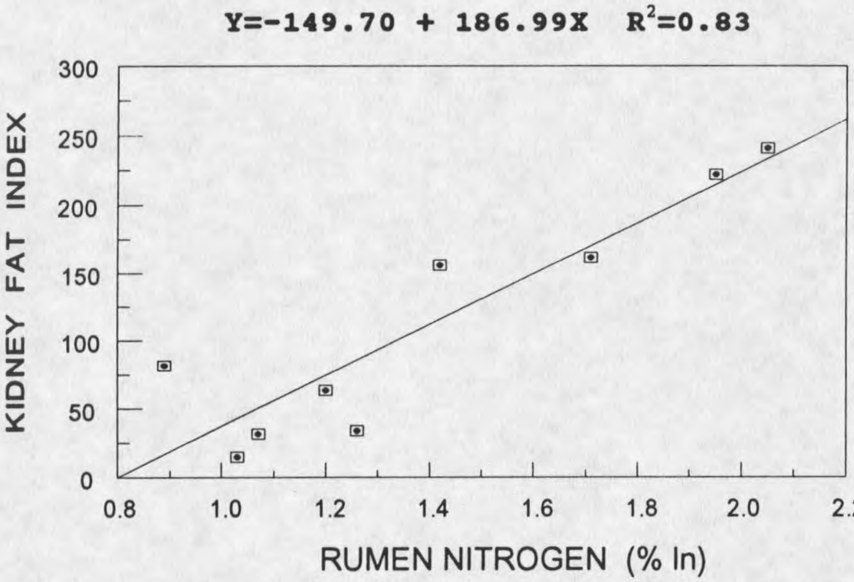

Figure 14. Regression of kidney fat index to rumen nitrogen for all adult deer collected on the Boxelder and Ashland study areas during fall 1990.

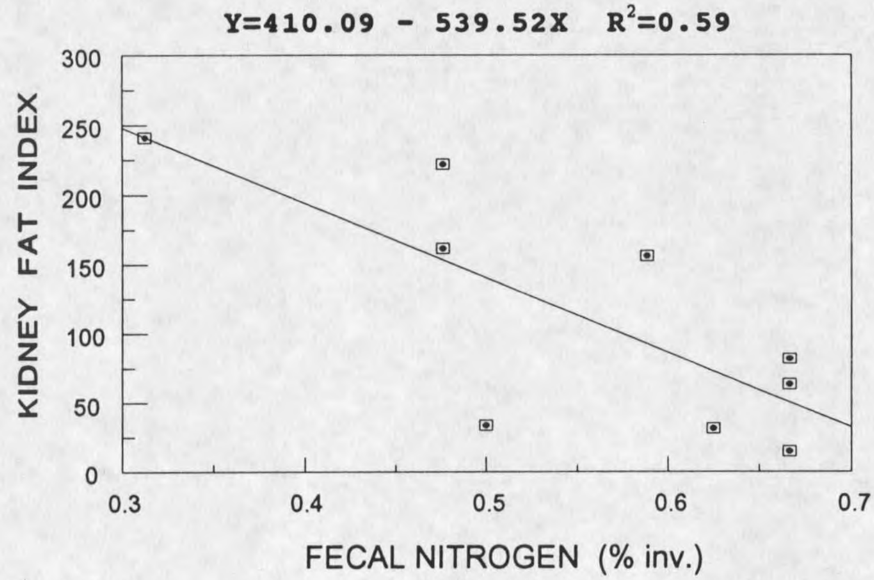

Figure 15. Regression of kidney fat index to fecal nitrogen for all adult deer collected on the Boxelder and Ashland study areas during fall 1990.

Girth Measurements

Girth measurements and corresponding estimates of bled carcass weights from 18 fawns captured during drive netting are listed in Appendix Table 25. The average girth measurement of fawns on the Ashland area ($\bar{X}$=82.67, SD=6.44) was significantly greater (*P*=0.003) than that for fawns from the Boxelder area ($\bar{X}$=72.50, SD=4.32). A comparison between males ($\bar{X}$=82.57, SD=8.22) and females ($\bar{X}$=82.80, SD=3.56) from the Ashland area showed no significant difference (*P*=0.96). Only 2 female fawns were captured on the Boxelder area, but no difference (*P*=0.37) was seen between males ($\bar{X}$=73.75, SD=5.66) and females ($\bar{X}$=70.00, SD=3.77).

Population Characteristics

Fawn Ratios

Observed numbers of fawns per 100 does increased during the summer on both study areas, with the highest ratios observed in September (Table 6). Ratios of fawns were higher on Boxelder than at Ashland throughout summer. In winter, numbers of fawns per 100 adults increased from January to March for both areas, with March ratios similar for the 2 areas.

Observations of bucks tended to fluctuate throughout the summer. The highest buck:doe ratios on each area were recorded in July and August, with ratios at Ashland exceeding those at Boxelder during both months.

Table 6. Monthly fawn ratios from air and ground surveys for the Boxelder and Ashland study areas. n includes unclassified animals.

Ratio Month	Location Boxelder	 Ashland
Buck:doe:fawn ratios		
June	34:100:0 (n=63)	20:100:0 (n=17)
July	44:100:35 (n=170)	86:100:14 (n=106)
August	66:100:73 (n=276)	57:100:43 (n=216)
September	34:100:98 (n=358)	39:100:77 (n=255)
Adult:fawn ratios		
January	100:23 (n=801)	100:22 (n=118)
February	100:51 (n=426)	100:27 (n=151)
March	100:56 (n=1331)	100:53 (n=89)

Population Estimates

The estimated population size for the Boxelder study area on 16 March 1991 was 865 deer (Table 7). This estimate was greater ($P<0.05$) than all except 1 estimate made between 1983-1987 (Knapp 1987, MDFWP unpublished data). The single exception ($P=0.09$) was an estimate of 750 made on 20 April 1983.

Table 7. Population estimates, standard deviation (SD), and confidence intervals (CI) for the Boxelder and Ashland study areas.

Location Date	Estimate	SD	95% CI Low	95% CI High
Boxelder				
3/16/91	865	71.15	789	1036
Ashland				
*3/15/86	311	56.45	248	444
10/7/86	85	27.31	67	153
*12/14/86	133	84.25	82	333
10/20/87	217	98.46	138	456
12/26/87	278	--	102	2134
*2/27/88	253	48.19	210	373
*3/31/89	222	43.0	193	332
9/25/89	186	298.46	93	768
1/4/90	236	--	77	7949
*2/7/91	161	52.62	114	289

* = dates used for comparison of population estimates

Population estimates on the Ashland area ranged from 85 to 311 deer (Table 7). The 5 dates in Table 7 indicated by an asterisk are for time periods excluding the hunting season and are for periods when seasonal migratory movements by deer would have had a similar influence on the number of deer present on the study area. These dates also exclude 2 times when the numbers of recaptured animals were considered too low to give a reliable estimate (Appendix Table 28). Probabilities of higher estimates between any 2 dates were calculated for all possible combinations of these 5. The estimate of 15 March 1986 was greater than the estimate of 7 February 1991 ($P<0.05$), while all other combinations were not significant ($P>0.05$).

Mortality on Boxelder

The remains of 29 deer were found on the Boxelder study area between November, 1990 and May 1991. Four were fawns found during early November, with femur marrow depleted (red-gelatinous) in the single sample examined. Of 11 animals (8 fawns, 3 adults) found between January and March, marrow was depleted in all except 1 fawn.

Nine fawns and 3 adults were found in a spring mortality survey encompassing approximately 6% of the upland ephemeral streams. Marrow was not depleted in 2 adults, 1 of which was a previously radioed doe between 10 and 11 years old. The condition of 1 fawn was not determined because neither femur was found.

Two deer captured in February 1991 died during this study. One was found during May with depleted femur marrow, the other was found dead during July. The doe found in July had been alive during the May relocation flight, and condition of the carcass indicated it had probably died about the beginning of July. At least 2 marked deer were shot during the 1991 hunting season.

Approximately 122 deer (59 bucks, 63 does) were killed on the study area during the 1990 hunting season (pers. comm. with landowners). The estimates obtained from landowners were said to be typical of most years. The 7 deer used in this study are not included in these totals.

Mortality at Ashland

Three carcasses were found on the Ashland study area. One was a fawn found dead of unknown causes in August, and the other 2 were adults found during the winter. One of the adults was a 9 1/2 year-old female (previously radio-marked in 1987) found close to a road, indicating a possible road-kill. Condition of femur marrow could not be made for these 3 deer.

Classification and Characteristics Of Cover Types

Cover types identified on the Boxelder and Ashland study areas are described in Tables 8 and 9 respectively. Cover types are specific for each study area, although similarities exist in certain types identified on both. For example, the riparian type on both study areas consists of land adjacent to creeks, but species composition and plant abundance was often greater for riparian cover on the Ashland area.

Classification of ephemeral streams on the Ashland area was based on vegetation within and along the stream bank.

Table 8. Cover types identified on the Boxelder study area.

Zone Cover type	Description
Zone 1 - main drainage	
Agriculture	About 370 acres of land cultivated for grain production.
Riparian	Mesic areas contiguous to Boxelder Creek containing hardwood trees and shrubs. Length of Boxelder creek through the study area is about 23.5 km., with an additional 17.4 km of short gullies adjacent to Boxelder Creek containing similar vegetation.
Grass-hay	1,450 acres of grass and alfalfa cut for hay. Approximately 200 acres are irrigated.
Haystacks	Haystacks and stack yards.
CRP land	About 100 acres in the conservation reserve plan. Except for Riparian, this type contained the tallest vegetation on the area.
Grass-1	Areas containing a mixture of grass and sagebrush.
Zone 2 - upland areas	
Mesic	Mesic areas along ephemeral streams and adjacent to stock ponds. Width 2-30 m. Length of creekbeds and short washes that feed them is about 227.2 km. Generally contains the tallest big sagebrush.
Tall sage	Areas not contiguous to creeks where big sagebrush is >45 cm and has >35% canopy coverage.
Short sage	Big sagebrush <45 cm tall, but still >35% canopy coverage.
Grass-2	Grass dominates, with <35% canopy coverage of shrubs. Includes grassy coulees on sides of buttes. Occasionally, fragrant sumac and yucca occur.
Greasewood	Scattered greasewood mixed with sagebrush, generally along the southeast portion of the study area.
Saltbush	Exposed ridges containing almost exclusively saltbush and bare ground.

Table 9. Cover types identified on the Ashland study area.

Cover type	Description
Agriculture	Grain and alfalfa fields along the Tongue River and Otter Creek. A small portion is irrigated.
Riparian	Uncultivated mesic areas along the Tongue River and Otter Creek.
Mesic-sage	Land along and within ephemeral streambanks through sagebrush-grassland. Mixed forbs, grass, snowberry, and occasional juniper may be present.
Mesic-pine	Ephemeral streams within areas containing ponderosa pine. Mixed forbs, chokecherry, snowberry, and pine usually occur.
Sumac	Open stands of fragrant sumac <15m in diameter surrounded by grass. Stands occur throughout the study area and contain from 1 to many plants.
Sagebrush	Various heights of big sagebrush with >35% canopy coverage. Grass also present.
Grass	Areas dominated by grass with <35% canopy of trees or shrubs. Includes grassy areas within sagebrush and meadows surrounded by pine. Alfalfa, yucca, and yellow sweet-clover may be present.
Pine	Dense stands of pine <12 cm diameter with little or no understory.
Pine-grass	Mature stands of Ponderosa pine with an understory of grass and forbs.
Juniper	Areas containing an overstory of >25% juniper. Ponderosa pine and big sagebrush also present.

Therefore, a stream could be classified by 2 different cover types over its entire length depending on surrounding vegetation.

Use Of Cover Types

Boxelder Study Area

Ground Observations. Deer were observed using all cover types except haystacks during summer (Table 10), with the main drainage zone accounting for 56% of the total number of observations. The mesic type received the greatest total use (25.8%); riparian, grass-hay, CRP land, and grass-2 all received >10% use. Less than 5% of all observations were made in each of the remaining cover types.

Ninety-one percent of feeding observations during summer were made in 4 cover types. Grass-hay was used most in August when the greatest number of feeding observations was made and also received the highest use in September. Riparian and mesic received the most number of feeding observations in July. In June, feeding observations were distributed about equally among 4 different cover types. The 100 acres of CRP land were consistently used throughout the summer with the highest use in August.

Mesic and grass-2 types received similar use for bedding, with 90% of the observations occurring in these 2 types. Many grass-2 observations were in grassy coulees on

Table 10. Mule deer cover type use (% of all visual ground obs.) by activity for each month and summer overall, 1990, on the Boxelder study area.

Zone	Month and activity												June-September total			
Cover	June			July			August			September						All
type[a]	F[b]	B	T	F	B	T	F	B	T	F	B	T	F	B	T	activities
Main drainage zone																
AG	--	--	--	0.5	--	--	0.5	--	1.0	--	--	--	1.0	--	1.0	0.9
R	1.5	--	--	9.8	--	1.0	7.0	6.3	1.0	2.8	--	--	21.1	6.3	2.0	16.0
GH	2.3	--	--	2.0	--	2.0	21.2	--	4.9	5.1	--	5.9	30.6	--	12.7	23.9
CRP	2.0	1.6	--	3.5	--	--	13.1	--	3.9	--	--	--	18.7	1.6	3.9	14.1
HS	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
G1	--	--	--	--	--	--	1.5	--	--	--	--	--	1.5	--	--	1.1
Upland zone																
M	2.3	25.4	12.7	11.9	11.1	3.9	6.8	9.5	15.7	--	--	--	21.0	46.0	32.4	25.8
SS	--	--	--	0.5	--	7.8	--	--	1.0	1.8	--	--	2.3	--	7.8	3.0
TS	--	--	--	0.3	1.6	6.9	--	--	2.0	--	--	--	0.3	1.6	8.8	2.0
GW	--	--	--	--	--	2.0	--	--	--	--	--	--	--	--	2.0	0.4
G2	--	--	--	1.0	17.5	9.8	0.3	27.0	14.7	2.3	--	--	3.5	44.4	24.5	11.9
SLT	--	--	1.0	--	--	--	--	--	3.9	--	--	--	--	--	4.9	0.9
N=	32	17	14	117	19	34	200	27	49	47	0	16	396	63	102	561

[a] AG= Agriculture, R= riparian, GH= grass-hay, CRP= land in CRP program, HS= haystacks, G= grass, M= mesic, SS= short sage, TS= tall sage, GW= greasewood, SLT= saltbush. See Table 8 for complete description of cover types.

[b] F= feeding, B= bedded, T= traveling.

the sides of buttes. Overall, observations of bedded deer occurred in fewer cover types than of feeding or traveling deer.

Frequencies of observations in each cover type were significantly different (X^2=690, P<0.001) between winter (Table 11) and summer, as were numbers of observations in each zone (X^2=321, P<0.001). The upland zone accounted for 85% of the total winter observations. All cover types in this zone received greater use than the most used cover type in the main drainage zone.

The grass-2 cover type received the largest number of feeding observations during February and March as well as the greatest total number of winter feeding observations. However, 91% of all deer observed feeding during February were seen the last week of the month. Haystacks received the greatest use in January.

Mesic and grass-2 were important types for bedding, both in winter and summer. These 2 cover types accounted for just over half the bedded observations during the summer and over 90% during winter. Most other observations of bedded deer occurred in tall sage, greasewood, and saltbush types.

March observations occurred in a greater diversity of cover types and activities than recorded for any other winter month. Use of cover types in the upland zone accounted for this increase, because the number of

Table 11. Mule deer cover type use (% of all visual ground obs.) by activity for each month and winter overall, 1991, on the Boxelder study area.

Zone Cover type[a]	January F[b]	January B	January T	February F	February B	February T	March F	March B	March T	January-March total F	January-March total B	January-March total T	January-March total All activities
Main drainage zone													
AG	--	--	--	2.2	--	--	3.3	--	--	5.5	--	--	2.5
R	0.4	--	0.9	1.8	--	--	--	--	--	2.2	--	0.9	1.2
GH	2.4	--	--	--	--	--	--	--	--	2.4	--	--	1.1
CRP	--	0.2	--	3.9	--	4.4	0.2	--	--	4.0	0.2	4.4	2.7
HS	8.4	--	--	1.8	--	--	1.3	1.1	--	11.6	1.1	--	5.6
G1	3.7	--	--	0.6	--	--	--	--	--	4.2	--	--	1.9
Upland zone													
M	2.2	2.7	--	4.2	21.9	5.3	6.2	9.8	5.7	12.7	34.4	11.0	20.2
SS	5.3	--	16.2	2.8	--	3.5	4.0	--	13.2	12.1	--	32.9	11.6
TS	--	--	--	--	9.1	--	7.2	17.8	19.3	7.2	26.9	19.3	16.6
GW	--	--	--	--	--	--	0.6	8.4	14.4	0.6	8.4	14.5	6.0
G2	3.1	4.6	--	16.5	8.0	2.2	10.3	7.5	14.9	30.0	20.1	17.1	23.9
SLT	--	--	--	6.6	--	--	1.1	8.7	--	7.7	8.7	--	6.6
N=	139	33	39	220	171	35	186	234	154	545	438	228	1211

[a] Ag= agriculture, R= riparian, GH= grass-hay, CRP= land in CRP program, HS= haystacks, G= grass, M= mesic, SS= short sagebrush, TS= tall sagebrush, GW= greasewood, SLT= saltbush. See Table 8 for complete description of cover types.

[b] F= feeding, B= bedded, T= traveling.

combinations of types and activities recorded in the main drainage zone decreased in March. Only 2 of the possible use-type combinations were not observed in the upland zone during March, compared to 12 and 8 for January and February respectively.

<u>Flight Observations</u>. Flight data showed a similar seasonal distribution of deer in relation to drainages as ground observations (Table 12), with significant differences (X^2=489, P<0.001) between survey dates. The greatest number of observations along Boxelder Creek occurred in September, and the fewest seen during March when deer dispersed from Boxelder Creek to the upland zone.

Table 12. Percent of mule deer observed in each of 3 areas on the Boxelder study area during complete coverage aerial surveys.

	Date		
Location	Sept. 90	Jan. 91	March 91
Boxelder creek	31.1	5.6	2.4
Ephemeral streams	56.4	77.8	41.3
Rest of area	12.5	16.6	56.3
N=	305	590	757

Weather conditions during the January flight were sunny, with light wind and temperatures ranging from -21°C (-6°F) along Boxelder Creek to -26°C (-15°F) on the ridge forming the southeast boundary of the study area. Over 5 cm of snow had fallen the previous day. Many deer were observed bedded and partially covered by snow, indicating they had not moved since the snow stopped falling the previous evening. Weather during the September flight was overcast and breezy with mostly brown groundcover. The March flight was conducted under sunny conditions, with temperatures of -1°C (30°F), and about 3 cm of new snow on the ground.

Ashland Study Area

Ground Observations. At least 1 observation was recorded for each cover type on the Ashland area during the summer (Table 13). The greatest total use for all activities was recorded in the mesic-sage type; riparian received the least (<1%).

Agriculture cover type received the most feeding observations during the summer with 29%. Most of these occurred in August, with 12% of all feeding observations recorded 1 night when a full moon made it possible to observe animals after dark. The grass type became important for feeding in September. Fragrant sumac and mesic-sage cover types were consistently used by deer for feeding throughout the summer.

Bedded deer were seen most often in the pine cover type during summer, followed by mesic-sage, juniper, and

Table 13. Mule deer cover type use (% of all visual ground obs.) by activity for each month and summer overall, 1990, on the Ashland study area.

Cover	Month and activity												June-September total			
	June			July			August			September						All
type[a]	F[b]	B	T	F	B	T	F	B	T	F	B	T	F	B	T	activities
P	--	1.1	--	--	0.8	0.6	--	0.2	--	--	0.2	--	--	2.3	0.6	3.0
PG	--	0.2	0.4	1.9	0.4	1.5	1.5	0.2	1.5	--	--	--	3.4	0.8	3.4	7.6
AG	0.2	--	--	0.8	--	--	10.6	--	0.8	3.8	--	0.4	15.5	--	1.3	16.8
FS	1.5	--	--	2.8	0.2	0.2	3.6	0.2	0.4	1.1	--	--	8.9	0.4	0.6	10.0
R	--	--	--	0.2	--	--	--	--	--	--	--	--	0.2	--	--	0.2
MS	--	--	0.2	3.0	0.2	1.5	5.9	1.1	0.6	1.3	--	11.7	10.2	1.3	14.0	25.5
MP	--	--	--	1.7	--	0.8	--	--	0.4	0.6	--	--	2.3	--	1.3	3.6
S	--	--	--	1.5	--	1.3	--	--	3.8	2.1	--	2.5	3.6	--	7.6	11.3
G	--	--	--	1.1	--	1.5	0.6	--	5.7	7.2	--	0.8	8.9	--	8.1	17.0
J	--	--	--	0.4	--	--	--	0.8	3.8	--	--	--	0.4	0.8	3.8	5.1
N=	8	6	3	63	8	35	105	12	81	76	1	73	252	27	192	471

[a] P= pine, PG= pine-grass, AG= agriculture, FS= fragrant sumac, R= riparian, MS= mesic-sage, MP= mesic-pine, S= sage, G= grass, J= juniper. See Table 9 for complete description of cover types.
[b] F= feeding, B= bedded, T= traveling.

pine-grass types. Pine was the only cover type in which deer were not seen feeding.

Deer were observed in only 5 of 10 cover types on the Ashland area during winter (Table 14). For the small sample observed, the grass type received the highest total winter use with all observations coming in March. Sagebrush ranked second and received consistent use each month.

Table 14. Percent of mule deer ground observations in each cover type during winter on the Ashland study area.

Cover	Month			Season
type	January	February	March	total
Pine	--	--	--	--
Pine-grass	3.5	--	2.6	6.1
Agriculture	--	1.8	--	1.8
Sumac	--	--	--	--
Riparian	--	--	--	--
Mesic-sage	--	--	--	--
Mesic-pine	--	--	--	--
Sagebrush	5.3	10.5	3.5	19.3
Grass	--	--	59.6	59.6
Juniper	0.9	--	12.3	13.2
N=	11	14	89	114

For a statistical comparison of relative use between seasons, riparian, mesic-sage, and mesic-pine types were combined in a general riparian category. Also, types in which ponderosa pine dominated (pine and pine-grass) were combined, as were grass and fragrant sumac types. Use of all other types was kept separate. Using these combinations of cover types, observations occurred in all but 1 category or type, and all requirements for statistical testing were met. Chi-square analyses indicated a significant difference (X^2=93, P<0.001) in use of cover types between summer and winter (cover type seasonal totals, tables 13 and 14).

Flight Observations. Aerial surveys during September, January, and February indicated similar use (>30%) of the pine-grass cover type (Table 15). Mesic-sage and grass received more observations during September's flight; sage and juniper received more during January and February. Percent use of other cover types never exceeded 6.5% for any flight.

September flight data indicated greater use by deer of pine-grass and less use of agriculture and sumac types than summer ground observations, while use of mesic-sage was high for both. Use of other cover types was similar between September air observations and all summer ground observations.

In winter, air and ground observations were in the same 5 cover types, though frequencies of use were different. As in summer, both winter flights indicated greater use of pine-grass than ground observations. Use of sage was higher in air survey data, with increased use from January to February.

Table 15. Percent of mule deer flight observations in each cover type on the Ashland study area.

Cover	Date		
type	September 90	January 91	February 91
Pine	--	--	--
Pine-grass	37.4	39.3	31.4
Agriculture	--	--	2.2
Sumac	--	--	--
Riparian	--	--	--
Mesic-sage	31.7	6.5	--
Mesic-pine	4.9	--	--
Sagebrush	5.7	19.6	54.0
Grass	17.1	6.5	4.4
Juniper	3.3	28.0	8.0
N=	123	107	137

Distribution, Movements and Home Ranges of Radio-marked Deer

Boxelder Study Area

Relocations during 1983-85 indicated radio-marked deer tended to move toward the main drainage between 15 July and 15 November (Fig. 16 and 17). Timing and pattern of movement varied by individual animal and year. Some deer moved >4 km to Boxelder Creek annually, whereas others

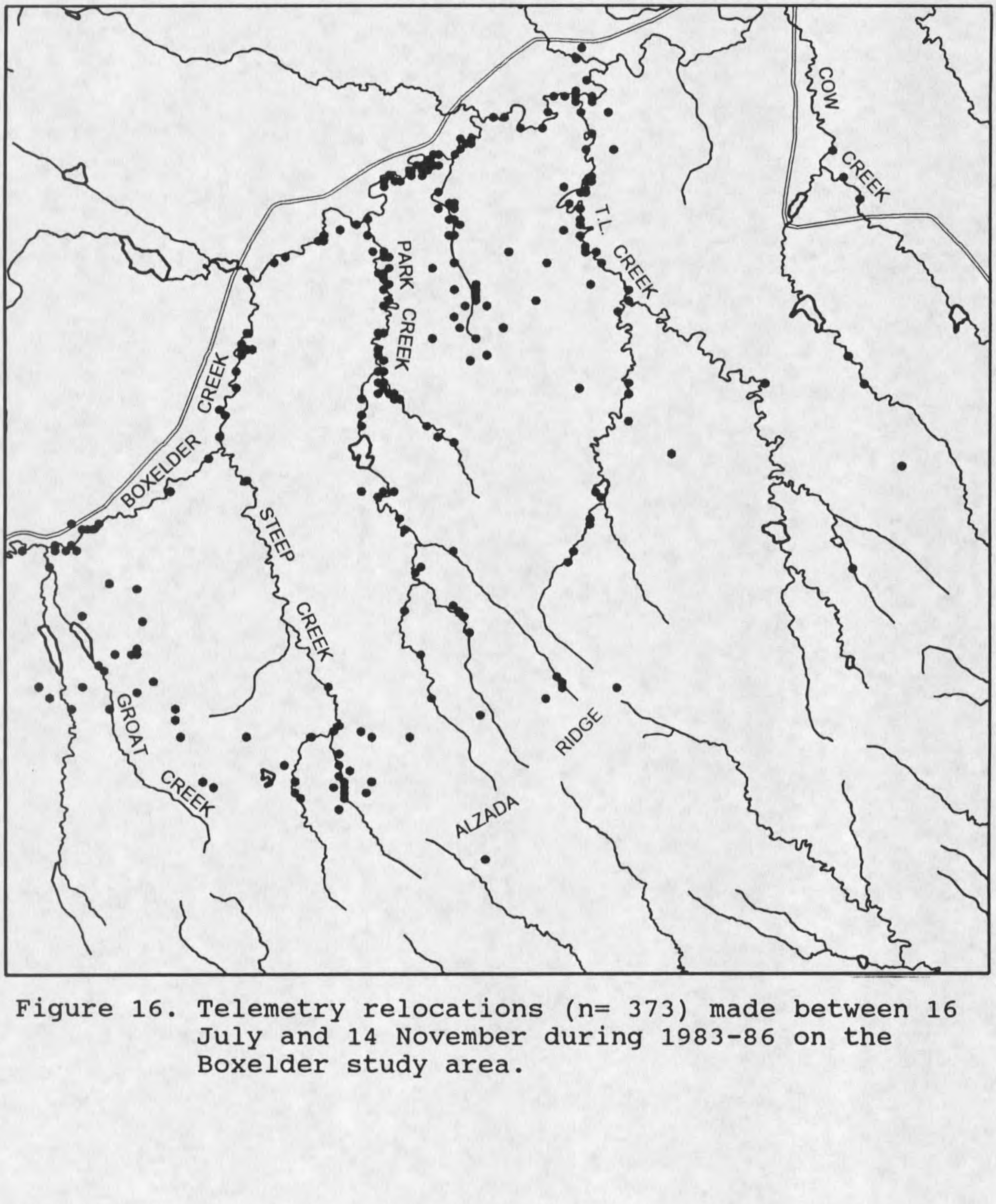

Figure 16. Telemetry relocations (n= 373) made between 16 July and 14 November during 1983-86 on the Boxelder study area.

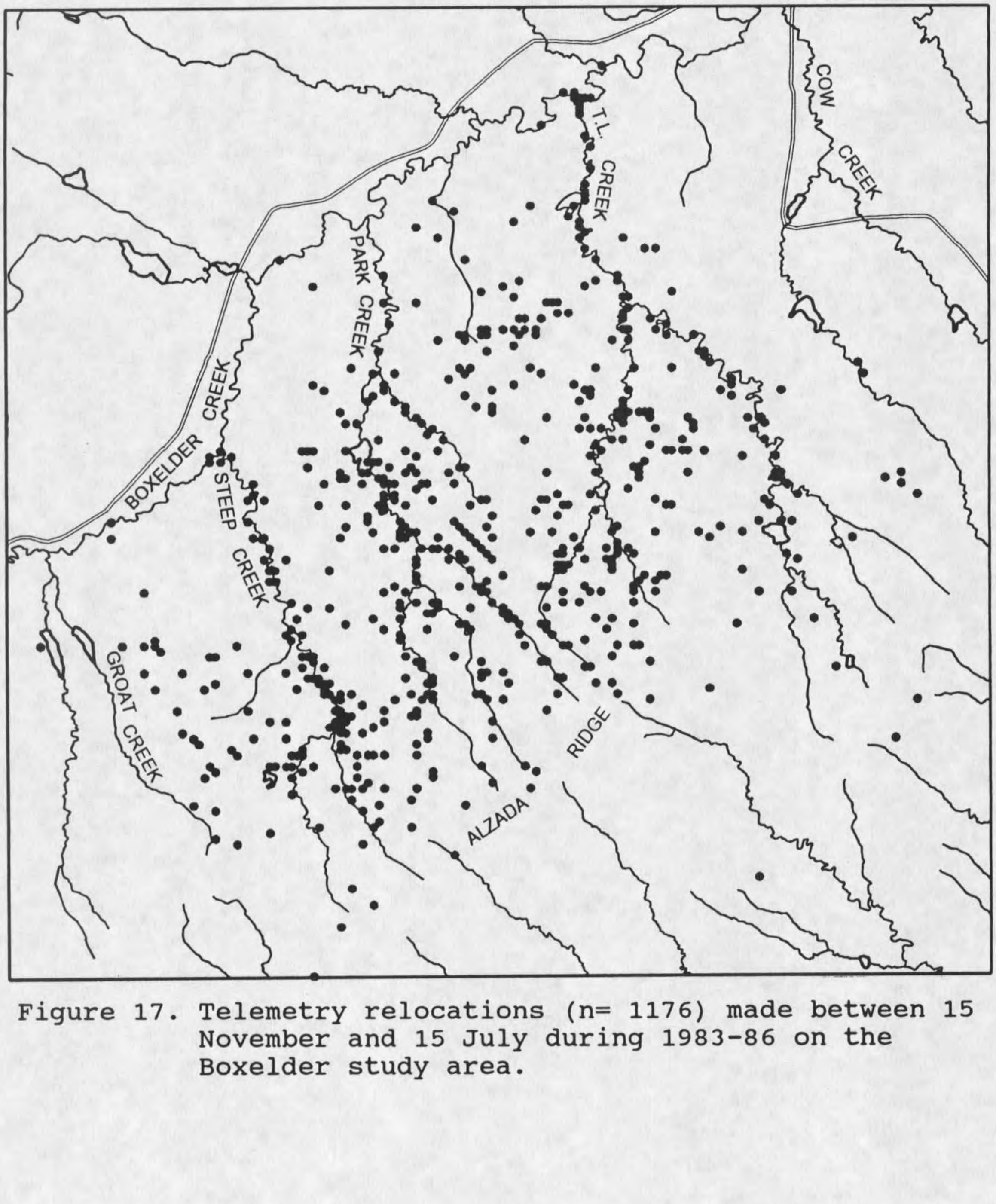

Figure 17. Telemetry relocations (n= 1176) made between 15 November and 15 July during 1983-86 on the Boxelder study area.

showed this movement only during certain years. Relocations after mid-November were generally near those made prior to 15 July.

Deer that did not show distinct movements (approximately >2 km) between July and November were often located in the part of their home range closest to Boxelder Creek during this period. Some deer were relocated near the main drainage during other months, especially early spring, but monthly geographic activity centers (GAC) of all radio locations between 1983 and 1986 indicate this movement occurred most consistently between July and November (Appendix Table 26).

Some deer may have moved off the study area during summers of 1983-86. Nine deer were relocated on the study area only between September and May in at least 2 consecutive years; 2 others were found on the study area only between October and April.

Movements of deer captured during 1991 were consistent with those recorded during 1983-85. During October 1991, 2 deer marked the previous February were located east of the study area on Boxelder Creek, at least 8 km from the GACs of their previous locations. One of these does moved between 7 July and 9 October, the other doe moved sometime between 16 May and 9 October.

Two additional marked does were also located on the main drainage during the October flight. One was also located on Boxelder Creek during May and July flights, whereas the other one had moved about 4 km from the GAC of all previous locations.

Among other deer radio-marked in 1991, 3 were located approximately 1 km closer to Boxelder Creek during the October flight than at any previous time. No change was noted in 4 others, and 1 deer was consistently located within 2 km of the main drainage after capture in February.

Mean annual polygon home range (PHR) size and average activity radius (AAR) were larger than seasonal periods that excluded the period between 15 July and 15 November when deer moved toward Boxelder Creek (Table 16). The larger annual PHR and AAR may reflect the greater number of relocations used to calculate annual values. However, correlation analysis indicated the number of relocations was significantly correlated ($P<0.05$) to PHR size only during 1983-84 and 1985-86. This correlation was determined by combining data for seasonal and annual estimates of PHR and correlating the number of months relocations were made to the PHR estimates.

Seasonal and annual values for 1991 are for the same 12 individuals. Estimates for 1983-86 included all marked animals.

The standard deviation of relocation distances from the GAC in the north-south direction was significantly greater ($P<0.05$) than the east-west direction for all home range

Table 16. Annual, seasonal, and life polygon home range (PHR in km^2) size and average activity radius (AAR in km) for deer on the Boxelder study area.

Type [a]			PHR			AAR		
Year	N	No. months relocated	Mean	SD	Range	Mean	SD	Range
Annual								
1983-84	29	6-12	6.92	5.70	1.79-30.07	1.73	0.75	0.75-3.29
1984-85	28	6-11	7.18	4.82	1.28-21.66	1.90	0.68	0.81-3.14
1985-86	16	5-7	10.04	6.44	1.61-20.79	2.24	0.55	1.27-3.36
1991	12	4-5	9.54	6.21	1.80-20.36	2.23	0.65	1.44-3.22
Seasonal								
1983-84	30	4-8	3.20	2.03	0.15-8.48	1.36	0.62	0.28-3.04
1984-85	10	6-7	5.49	2.58	1.05-8.70	1.69	0.62	0.59-2.71
1985-86	28	3-5	3.32	2.24	0.46-10.35	1.47	0.52	0.59-2.42
1991	12	3-4	6.72	4.13	0.60-15.49	1.92	0.50	1.08-2.90
Life	38	15-42	16.86	7.84	4.06-48.52	2.01	0.53	0.79-3.09

[a] Annual= 15 July to 15 July. Seasonal= 15 November to 15 July. Life= relocations over at least 24 months.

values except 1985-86 (*P*=0.093). This is the general direction of all secondary drainages on the study area and indicates deer moved primarily along rather than across drainages.

Seasonal PHR for 1984-85 and 1991 were both greater (*P*<0.05) than 1983-84 and 1985-86, but no difference was observed between any other combination of years. No difference in annual PHR was observed amongst years either.

Moisture did not appear to be correlated with differences in PHR size between years. The 2 years with lowest seasonal PHR estimates had the greatest winter precipitation one year and the least the other. Spring moisture did not suggest a difference either.

The mean seasonal AAR for 1991 was greater (*P*<0.05) than 1983-84 or 1985-86, whereas annual AAR was greater in 1985-86 than 1983-84. No other differences in AAR were detected. Numbers of months used to calculate annual estimates of PHR and AAR during 1985-86 and 1991 were less than 1983-84 and 1984-85, but the 2 years with the least number of relocation months had the largest estimates.

I relocated individuals more than once per day on 11 occasions during March 1991. Distance between relocations on the same day ranged from 0.28 to 3.23 km ($\bar{x}$=2.28), with 5 distances >2 km. The time period between these relocations did not exceed 4.5 hours.

On 4 occasions, the same individual was relocated on 2 consecutive days. Distance between daily relocations varied from 1.02 to 2.27 km ($\bar{x}$=1.85).

Ashland Study Area

Use of distinct summer and winter ranges separated by >8 km (migratory movements) was exhibited by 7 of 58 deer marked during 1986-87 on the Ashland study area. Known dates on summer range for these animals were 31 May to 25 September, and known dates for winter range were 21 October to 31 March. Movements are described by Griffiths (1990).

For non-migratory animals, PHR and AAR estimates did not differ (P<0.05) between summer and winter (Table 17). Dates used for these calculations were derived from seasonal movements of migratory animals. Home range estimates for 1991 animals were made during an 8 month period spanning both seasons and were not statistically comparable to other home range data.

Standard deviation of relocation distances from the GAC was not significantly different (P>0.05) in either direction for home range estimates on the Ashland area. Although animals were captured directly adjacent to the Otter Creek trend area, few deer were relocated within its boundaries.

Weather

Mean daily minimum temperatures measured on the Boxelder study area between 23 January 1991 and 31 March