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RANGES, HABITAT, AND MORTALITY OF PRONGHORNS AT THE NORTHERN LIMITS OF THEIR RANGE

by

© MORLEY W. BARRETT

A THESIS

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Supervisor

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Date April 15, 1982

ABSTRACT

From 1971 to 1979, I investigated ecological aspects of the seasonal distribution, habitat relationships, and mortality of pronghorn (Antilocapra americana) at the northern limits of their range. The research centered on the two primary bottlenecks affecting population stability, namely: 1) factors influencing behavior, habitat use, and survival of fawns; and 2) impact of winter on animal distribution and mortality.

Fawn mortality in Alberta in the first 60 days following parturition approached 50% annually. Predation on radio-collared fawns caused primarily by coyote (Canis latrans) and to a lesser extent by bobcat (Lynx rufus) accounted for 67.5% of the known mortality. Bedding sites selected by fawns were described and differed markedly from some previously published descriptions. No evidence of traditional fawning areas was found. Fawns did not use vegetative cover in proportion to its availability; they preferred heavy native vegetation and under-used cultivated land. Such bedding sites increased their chances for survival. The high annual mortality of fawns has not limited pronghorn numbers nor the capacity of the provincial population to recover following periodic high winter losses.

Seasonal herd sizes, vegetative associations, and general movement patterns were determined for pronghorns throughout Alberta. Exclusive of the Suffield Military Range, 11 major winter ranges totalling 3,037 km^2 were identified. Wintering areas were characterized by large open basins along drainage systems, and all contained substantial quantities of sagebrush (Artemisia cana). Pronghorns preferentially selected rangelands with sagebrush during winter. None of the major winter ranges had more than 21.4% of their land area under cultivation.

During the severe winter of 1977-78, estimated mortality among the 14,360 pronghorns entering winter was 48.5%. Because of deep snow, only 34% of the animals observed occupied typical wintering areas. Animals selected areas with reduced snow depths. Those dead from malnutrition had significantly less ($P < 0.05$) body weight, kidney fat, and femoral fat than animals sampled during the fall. Fawns and adult males were most susceptible to winter kill. Dead, mummified fetuses were observed in the majority of malnourished does necropsied. Some behavioral and physiological phenomena observed, appear to be adaptive features that promote the survival of pronghorns in winter.

Nitrogen alone and in combination with phosphorus was applied to a pronghorn winter range in an effort to increase forage production and quality. Forage production was increased in each of 3 years monitored following a single spring application of fertilizer. The addition of phosphorus alone produced no significant effect. Forage quality increased only during the growing season. Application of fertilizer increased the total yield of forage on winter ranges but did not increase the nutrient content in cured plants.

Based on this study several management recommendations are evident. Summer inventory surveys should more closely reflect land

use practices. Sport hunting units should be revised to promote the management of pronghorns on a local population or herd basis. Both fawns and adults have preferred habitats that promote their survival and management plans that recognize the importance of these areas should be developed. Although high annual fawn losses and periodic severe winters curtail pronghorn numbers at the northern limits of their range, the fate of this species in Alberta will ultimately be decided by land use patterns.

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Introduction.

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INTRODUCTION

Pronghorn (Antilocapra americana) in Alberta exist at the northern limits of their range (O'Gara 1978) and typically exhibit major fluctuations in numbers. Since the introduction of aerial surveys in 1955, the estimated number of pronghorns in the province has fluctuated between 7 and 25 thousand animals (Wishart 1970, Cook 1981). Recruitment and density of pronghorn are lower at the northern limits than in the more central parts of their rangeland in Wyoming and southeastern Montana (Vriend and Barrett 1978).

Human settlement of the western prairies has had a major impact on pronghorns through cultivation of land and hunting. At the beginning of the 19th century, pronghorn numbers in North America may have approached 35 million (Nelson 1925) but early in the 20th century the species seemed threatened, as the total continental population was estimated at 13,000 animals (Hoover et al. 1959). Through habitat recovery and improved wildlife management techniques there was in excess of a 1000% increase in pronghorn numbers in North America between 1924 and 1964 (Yoakum 1968). In Alberta the story has been similar and the early historical population levels have been described by Rand (1947) and Mitchell (1980).

The field phase of my thesis research spanned 9 years, between 1971 and 1979. When this project started, two intensive studies on pronghorns had been conducted in Alberta. Mitchell (1965) had studied the natality and some aspects of the habitat, herd movements, and mortality of pronghorns in selected areas of Alberta between the years 1955 and 1964. Bruns (1969) had studied 6 herds totalling approximately 220 pronghorns near Wildhorse, Alberta and had documented some of the behavioral adaptations of pronghorns during the winter of 1968-69. These early studies provided important perspectives on the biology of pronghorns but much quantitative information was still needed for management purposes.

In December of 1969, wildlife biologists in Alberta summarized the management objectives for pronghorns and outlined the need for further studies (Wishart 1970); my research on pronghorns evolved from this meeting. Additional research was needed on population characteristics, seasonal movements and ranges, habitat, fawn and adult mortality, predation, diseases, and management options for pronghorns in Alberta. Much of the data available in published literature at that time, was of a more general nature or had only indirect relevance to pronghorns that were on grasslands at the northern limits of their range. My thesis research was a direct response to this recognized need for additional information.

Clearly, pronghorns are sensitive to land use practices and available habitat (Rand 1947, Buechner 1960, Yoakum 1980). Part of my research was designed to delineate the seasonal habitat relationships, social structure, and distribution of animals in Alberta. I hypothesized that at the northern limits of their range, these factors would be clearly evident on a seasonal basis and that this information would be directly applicable to understanding and managing pronghorns at this latitude by highlighting critical aspects of their habitat.

Based on mid-summer surveys, the number of fawns per 100 females in Alberta averaged only 67.5 for the period 1972 to 1981 (Cook 1981). However, Mitchell (1965) had shown that the natality of mature does in Alberta was high. Together these factors suggested that while initial production was high the neonatal mortality of fawns approaches 50% annually (Vriend and Barrett 1978). Part of my research was designed to investigate the causes and severity of pronghorn fawn mortality.

Some preliminary evidence suggested that fawns sought seclusion in vegetative cover resembling that of their birth site (Fichter 1974). Additional data indicated that fawn mortality as a result of predation could be influenced by the vegetative cover that fawns used (Bodie 1978, Autenrieth 1980). To date, much of the research on the behavior and mortality of pronghorn fawns has been conducted on rangelands dominated by sagebrush (Artemisia spp). (Pyrah 1974, Autenrieth 1976, Bodie 1979); comparatively little research has been conducted on the vast grasslands that characterize pronghorn range in much of North America, including Alberta (Yoakum 1972). Part of my research was designed to describe the bedding sites, behavior, movements, and habitat relationships of fawns in southeastern Alberta during the 60 days following birth.

At northern latitudes, severe winters have long been recognized to cause extensive mortality of pronghorns (Mitchell 1965, Martinka 1967, Wishart 1970). Heavy snowfall and lack of access to woody browse are cited most commonly as the direct cause of death of animals (Martinka 1967, Compton 1970, McKenzie 1970, West 1970).

Some behavioral adaptations of pronghorns to conserve energy during winter have been described by Bruns (1977). I hypothesized that habitually during winter, animals would select distinctive wintering areas. Part of the research was designed to determine whether discrete wintering areas existed and to describe vegetative relationships observed. The severe winter of 1977-78, provided the opportunity to evaluate the effects of winter on these animals through study of their behavior and mortality. Data obtained on the distribution, vegetation use, and mortality of pronghorns would be important for devising management plans for this species in Alberta.

The main thrusts of my research and the relationships investigated are summarized in a systems flow diagram (Fig. 1). Many of these relationships have been incompletely described for pronghorns at the northern limits of their range. The primary purpose of the research was to describe the interactions of the indicated auxillaries on the rates of parturition, fawn mortality, and winter mortality. This approach would determine the relative importance of the many biotic and abiotic factors that regulate the seasonal distribution and numbers of pronghorns in Alberta.

When this research program was conceived, I did not know the importance of diseases to pronghorn fawns and adults, and consequently, the study of infectious agents was included in the orginal research protocol (see Fig. 1). However,I have not included findings on diseases and blood physiology in my thesis as these factors were found to have limited impact on the population and were of less significance to management than were other factors. Most of these research findings have been reported elsewhere and relevant citations are included in the vita section at the end of this thesis.

The thesis is divided into 6 chapters, each of which is a related but distinct unit of research. Chapters 1 and 2 deal with the behavior, habitat relationships, and mortality of fawns. In chapter 1 I report on the characteristics and importance of bedding site selection by neonates <1 week of age. In chapter 2 I detail changes in the movement patterns, vegetative relationships, and predation on fawns in the first 60 days following birth.

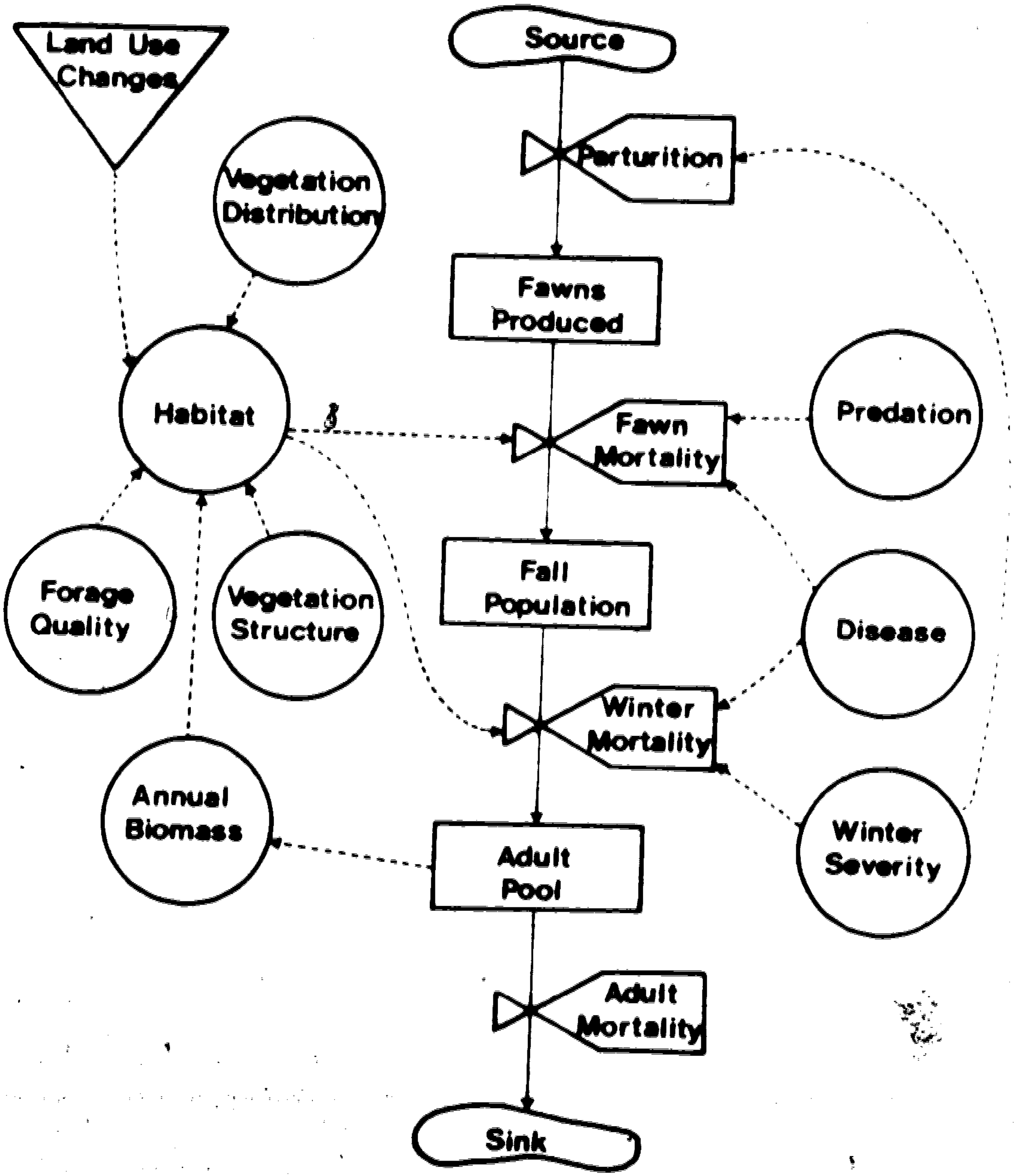
The seasonal habitat associations and herd structure of pronghorn are described in chapter 3. The distribution of vegetative types available within winter ranges is described. The relationships between pronghorn stocking rates and the distribution and use of sagebrush (A. cana) are reported.

The impact of severe winter weather on pronghorns is documented in chapter 4. I present data on the behavior, distribution, and mortality of animals and contrast the findings with those for more normal winters. This work helped formulate hypotheses on potential adaptive values of some of the observed behavioral and physiological phenomona as they relate to survival during periods of extreme winter stress.

Chapters 5 and 6 deal with some management aspects of my research. In chapter 5 I describe the location of key wintering areas for pronghorns. I discuss improved aerial survey methods that reflect local land use practices. On the basis of examining the location of key wintering areas, local movement patterns, and population stability, I propose a major realignment of the sport hunting boundaries for Alberta.

The response of vegetation to the application of nitrogen and phosphorus fertilizer on pronghorn winter range is described in Chapter 6. Total forage production increased for 3 consecutive years following a single application of fertilizer but the nutrient content of cured forage did not increase. When examined on a year-long basis, the treated plots were selected preferentially by animals only during the growing season. The inability to improve the quality of forage in winter limits the value of this technique for improving pronghorn winter ranges.

Figure 1. Systems flow diagram summarizing the major relationships investigated in a population ecology study of pronghorns at the northern limits of their range.


Land Use Changes
Source
Perturition
Vegetation Distribution
Fawns Produced
Habitat
Predation
Fawn Mortality
Fall Population
Forage Quality
Vegetation Structure
Disease
Winter Mortality
Annual Biomass
Adult Pool
Winter Severity
Adult Mortality
Sink

LITERATURE CITED

Autenrieth, R.E. 1976. [illegible] study of birth sites selected by pronghorn doe[illegible] the bed sites of fawns. Proc. Bienn. Pronghorn Antelope Workshop. 7:127-134.

__________. 1980. Vulnerability of pronghorn fawns to predation. Abstract. Proc. Bienn. Pronghorn Antelope Workshop. 9:77-78.

Bodie, W.L. 1978. Pronghorn fawn mortality in the upper Pahsimeroi River drainage of central Idaho. Proc. Bienn. Pronghorn Antelope Workshop. 8:417-428.

__________. 1979. Mortality of pronghorn fawns in the Upper Pahsimeroi River Valley. M.S. Thesis. Univ. Montana. Missoula. 98 pp.

Bruns, E.H. 1969. A preliminary study of behavioural adaptations of wintering pronghorn antelopes. M.S. Thesis. Univ. Calgary, Alberta. 60 pp.

__________. 1977. Winter behavior of pronghorns in relation to habitat. J. Wildl. Manage. 41:560-571.

Buechner, H.K. 1960. Regulation of numbers of pronghorn antelope in relation to land use. Int. Union Cons. Nature and Nat. Res. Warsaw. 105-136.

Compton, H.O. 1970. Southeastern Montana antelope population trends in relationship to severe winters. Proc. Bienn. Pronghorn Antelope Workshop. 4:50-54.

Cook, A.R. 1981. Antelope aerial survey and population analysis, July 20-28, 1981. Alberta Energy and Natural Res., Fish and Wildl. Div. Edmonton. 162 pp.

Fichter, E. 1974. On the bedding behavior of pronghorn fawns. <u>In</u>: The Behavior of Ungulates and its Relation to Management. V. Geist and F. Walther, Eds. Vol. I and II. IUCN Public. NO. 24. Morges, Switzerland. 352-355.

Hoover, R.L., C.E. Till, and S. Olgilvie. 1959. The antelope of Colorado - a research and management study. Colo. Dep. Fish and Game. Denver. Tech. Bull. 4. 110 pp.

Nelson, F.W. 1925. Status of the pronghorn antelope, 1922-1924. U.S. Dept. Agr. Washington D.C. Bull. 1346:64 pp.

Martinka, C.J. 1967. Mortality of northern Montana pronghorns in a severe winter. J. Wildl. Manage. 31:159-164.

McKenzie, J.V. 1970. Two killer winters 1964-1965 and 1968-1969 in North Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:36-40.

Mitchell, G.J. 1965. Natality, mortality and related phenomena in two populations of pronghorn antelope in Alberta, Canada. Ph.D. Thesis, Washington State Univ. Pullman. 205 pp.

_________. 1980. The pronghorn antelope in Alberta. University Regina. Regina, Sask. Monogr. 165 pp.

O'Gara, B.W. 1978. <u>Antilocapra americana</u>. Mammalian species. 90:1-7.

Pyrah, D. 1974. Antelope fawn bedding cover selection in central Montana. Proc. Bienn. Pronghorn Antelope Workshop. 6:113-121.

Rand, A.L. 1947. The 1945 status of the pronghorn antelope, <u>Antilocapra americana</u> (Ord), in Canada. National Museum Canada. Ottawa. Bull. 106. 34 pp.

Vriend, H.G. and M.W. Barrett. 1978. Low pronghorn recruitment --

Is it an issue? Proc. Bienn. Pronghorn Antelope Workshop. 8:360-379.

West, D.R. 1970. Effects of prolonged snow and cold winter on pronghorn mortality and reproduction in South Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:41-49.

Wishart, W.D. 1970. A brief historic review of the pronghorn antelope in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 4:128-130.

Yoakum, J. 1968. A review of the distribution and abundance of American pronghorn antelope. Proc. Bienn. Pronghorn Antelope Workshop. 3:4-14.

________. 1972. Antelope - vegetative relationships. Proc. Bienn. Pronghorn Antelope Workshop. 5:171-179.

________. 1980. Habitat management guides for the American pronghorn antelope. U.S. Dep. Interior, B.L.M., Denver. Tech. Note 347:77 pp.

Chapter 1. Environmental characteristics and functional significance of pronghorn fawn bedding sites in northern grassland habitat

Abstract: Reduced recruitment and declining populations of pronghorn (Antilocapra americana) in Alberta prompted this study of bed-site selection by neonates. Characteristics of bedding sites of free-ranging fawns were studied on a 9,300-km^2 study area within the grassland range of southeastern Alberta. During 1971-76, 465 bedded fawns, estimated mean age 2.8 days, were located and captured. Fawns commonly bedded on slopes, in native vegetation, in small depressions, on patches of bare ground, or adjacent to clumps of silver sagebrush (Artemisia cana), rock, or cow dung. Many appeared to select sites that had characteristics that served as suitable vertical and horizontal sign stimuli, and thus stimulated bedding selection behavior. Sagebrush was sparse on the study area, and 75% of the fawns bedded on grassland ranges that had little or no brush cover. Wind velocity at fawn bedding sites was 59.5% less than readings taken 150 cm above the beds. No evidence of traditional fawning areas was found. The number of marked fawns relocated was used as an index of fawn survival. Estimated survival was higher for animals bedded in native range, and increased with greater cover density and use of depressions; significantly fewer fawns were relocated if they had been initially found bedded on cultivated land. Habitat diversity provided by silver sagebrush, small depressions, and stands of grasses or forbs >25 cm tall constituted important bedding cover, and contributed to above-average survival

of fawns on the study area. Managers should recognize the value of these features when making land use decisions for this kind of rangeland.

INTRODUCTION

Annual systematic surveys for pronghorns in Alberta indicated that in 1969 the population had declined to a 15-year low of 7,000 animals (Wishart 1970:128). Reduced recruitment of young was noted at that time, although Mitchell (1965) had shown that the birth rate of pronghorns in Alberta was high. These factors led to a study in 1971 of the biology of pronghorn fawns.

The occurrence and significance of low fawn recruitment in North America were reviewed by Vriend and Barrett (1978). In recent years, predation has been shown to be a locally important mortality factor for fawns in several areas (Beale and Smith 1973, Barrett 1978, Beale 1978, Bodie 1978, Von Gunten 1978). The characteristics of bedding sites of neonates may be related to fawn survival, although little relevant information is available. In the first 3 weeks of life, fawns spend approximately 90% of their time bedded.

Autenrieth and Fichter (1975:38-46) described the behavior of pronghorn fawns that were selecting bedding sites. Some characteristics of fawn bedding sites, particularly as they related to sagebrush-dominated rangelands, have been reported for pronghorns in Montana (Pyrah 1974) and Idaho (Autenrieth 1976). Bromley (1977:79-97) presented data on bedding-site selection by fawns in a small population of pronghorns in Wind Cave National Park, South Dakota. Studies conducted to date have shown important differences in vegetative types selected as bedding sites by pronghorn fawns. Characteristics of fawn bedding sites in grassland communities typical of most of the pronghorn range in Alberta have not been reported. Yoakum (1972:176) estimated that the proportion of pronghorns living in grassland communities in North America was 68%, as opposed to 31% living in grassland-brushland communites. The remaining animals were on hot or cold deserts.

The purposes of my study were to describe bedding sites of pronghorn fawns throughout a predominantly grassland range in southeastern Alberta, and to determine whether fawn survival was related to the characteristics of these bed sites.

STUDY AREA AND METHODS

This study was conducted during 1971-77 in southeastern Alberta, south of 51°N and east of 112°W (Fig. 1). Pronghorn range within the 9,300-km^2 study area is part of the mixed-grass prairie region (Webb et al. 1967). The study area is primarily in the Brown soil zone. The climate is semiarid; mean annual precipitation (1941-70) measured at the Agriculture Canada Research Substation, Manyberries, was 327 mm. Dominant grass species are western wheatgrass (Agropyron smithii), needle-and-thread (Stipa comata), and blue grama (Bouteloua gracilis). Silver sagebrush is the dominant shrub, although lesser amounts of western snowberry (Symphoricarpos occidentalis), rose (Rosa spp.), silverberry (Elaeagnus commutata), and creeping juniper (Juniperus horizontalis) are present. Brush growth was limited to bottomlands and other small areas with favorable moisture regimes. The topography varies from gently rolling plains to hilly, although bottomlands are abundant. Numerous intermittent watercourses transect the study area. More detailed descriptions of the area were presented by Coupland (1950, 1961) and by Mitchell and Smoliak (1971).

Pronghorns range freely throughout the study area at altitudes generally <1,200 m.

Aerial photographs taken in 1970 showed that 81% of the study area was in native vegetation. Cereal crops and tame pasture occupied the remaining 19% (Clark 1979). These proportions have not changed appreciably in the past few years. Nearly all native grasslands are grazed seasonally by domestic livestock. With the exception of the Cypress Hills Park area, which pronghorns use infrequently, no major natural or artifical barriers restrict pronghorn movements or distribution. During the 7 years of investigation, the average fawn:doe index in the study area in midsummer was 50:100; the overall pronghorn density, including fawns, averaged 0.56/km^2 in midsummer. Potential predators of pronghorn fawns included coyote (Canis latrans), bobcat (Lynx rufus), and golden eagle (Aquila chrysaetos).

Locating and Capturing Fawns

Most fawns were located by systematic search around the locations where parental does were seen. These "blind searches" accounted for 78% of all fawns captured. The remaining neonates were observed with the doe, and then allowed to bed before the searches were started. The search and capture methods followed those described by Hoover et al. (1959) and were outlined in more detail by Barrett (unpubl. Rep., Alberta Dep. Recreation, Parks and Wildl., 1978). When a fawn was located, an extended search for a potential sibling was conducted. Fawns were captured in their bedding sites with an oval-shaped net, measuring 0.6 x 1 m, with a 3-m handle.

Captured fawns were held in a supine position to promote calmness and to measure rectal temperature. The age of each fawn was estimated by its size, behavior, and condition of hair coat and umbilicus. I generally followed the age-class descriptions of fawns outlined by Bromley (1977). The age and sex of each fawn were recorded, and each animal was measured and weighed. Before release, 370 fawns were fitted with color-coded, expandable, 7.5-cm-wide neck collars; radio transmitters were placed on an additional 62 fawns. All were released at their bedding sites.

Efforts were made to relocate all marked fawns to test the hypothesis that neonatal survival was influenced by characteristics of their bedding sites. During the 7 years of the study, >1,500 man-days were spent by project personnel in the study area, and >50 days/year were directed toward relocating marked animals. Aircraft were used extensively. Few observations of marked fawns were made before the neonates were active and had integrated with groups of adults. Many sightings were made on their fall and winter ranges in the first year following marking. I present information only on whether marked ~~fawns~~ were observed alive, 2 weeks or longer after marking. In the context of this paper, relocation information was used as an index of survival of fawns. Fawns not relocated during the study were presumed to have died during the 2 months following their birth, a period during which they become integral members of summer herds. No distinction was made between type of collar, year of marking, number of relocations per individual, or other factors for these analyses. Animals were simply classified as relocated or not relocated. Survival of fawns for each habitat type was based on the number of marked individuals relocated from each type.

Data Collected at Capture Site

The general classifications of topography and vegetation best describing the square kilometer surrounding the bedding site were recorded. Topography was classified into 3 categories of increasing relief (flatland, gently rolling, and hilly). Cultivated land within the study area had little relief, and was categorized as flatland. In the last 3 years of the study a more specific category, topographical site, was added. This category contained 5 classes: flatland, depression, and top, middle, and bottom 1/3 of slope. Classification of vegetation of native range reflected numerous associations, but native-grass prairie (NGP) supporting substantial amounts of sagebrush was dividied into 4 categories based on the number of sagebrush plants intercepted by a randomly selected 60-m straight-line transect. The 4 categories, NGP-sparse sagebrush, NGP-light sagebrush, NGP-medium sagebrush, and NGP-heavy sagebrush, reflected sagebrush densities of <3, 3-10, 11-25, and >25 plants/transect. Cultivated lands were further subdivided to group the proportions of these lands in tame pasture, seeded cereal crop, stubble, and summer fallow. Additional categories of vegetation accounted for less than 1% of the bedding sites found and were combined as "others" for tabular presentaton; these sites included areas dominated by western snowberry and rose, dried slough bottoms, and cactus(*Opuntia* spp.) flats.

Details concerning substrate, the direction of exposure of bedding sites, and fawn positioning relative to any notable landform were recorded. The tendency of fawns to select bedding sites that provided obvious concealment was investigated. Project personnel made an assessment of whether the exact bedding site offered appreciably more concealment to the neonate than would have been the case if it had bedded randomly in the same general habitat. In this context, concealment referred primarily to the use of vegetative matter, but also included other physical features such as rocks and cattle feces where their use was apparent. The distances from fawn bedding sites to the nearest sagebrush plant >3.5 cm in height, to heavy cover, and to water were measured; distances >100 m were estimated. The height of the nearest sagebrush plant was recorded. The heavy-cover classification included NGP-medium and heavy sagebrush, equivalent densities of wild rose, snowberry, and other brush species, and stands of grasses and forbs >25 cm in height.

A hand-held thermometer and an anemometer were used to measure the temperature and wind speed respectively, at each bedding site. Temperatures were taken at 3 heights: on the ground immediately above the bedsite, 10 cm off the ground immediately above the bed, and 150 cm above the bed. The thermometer was always shaded for the 150-cm reading. The wind speed was recorded at the 10- and 150-cm distances above the ground at the bed sites. The 10-cm readings were selected to approximate the height of a bedded fawn. Precipitation and cloud cover were noted.

Statistical Treatment

Data were processed by an Amdahl 470 V/6 computer using the SPSS statistical package (Nie et al. 1975). For selected variables, differences in relocation success were investigated using Chi-square analysis within the program CROSSTABS. When significant Chi-square relationships were found, differences between proportions for component cells for a given variable were investigated by comparing the percentage of fawns relocated for that cell to the overall relocation success for the marked population of fawns, using a binomial distribution analysis.

RESULTS

Characteristics of Captured Fawns

During the study, 465 pronghorn fawns were captured. Mean estimated age of neonates was 2.8 days (range 4 hours-10 days), and 95% of the fawns were estimated to be 6 days of age or less. Males constituted 57% of the fawns captured. A twin could not be located for 217 (47%) of the neonates captured. The mean distance between siblings for the 248 fawns that were part of twin groups was 48.0 ± 5.6 (SE) m. Siblings bedded within 5 m of each other 26% of the time, whereas 19% were bedded at sites >80 m apart. Mean weight of fawns captured was 4.2 kg, and no appreciable size difference existed between sexes. Mean rectal temperature of 391 fawns was 39.6 C (range 37.1-42.2 C).

During late May, more than 1,500 mature females were observed during the 6 years of study. Observations on the proportion of pregnant and parental does observed each day and the estimated age of fawns provided information on the chronology of parturition. Little noticeable difference occurred in the synchrony of parturition from year to year, but peak activity appeared to lag by 1 or 2 days in 1972. Generally, in all years, an estimated 75% of does delivered between 23 and 30 May. By 1 June of each year, >90% of the mature does were estimated to have given birth.

Habitat Characteristics of Bedding Sites

Data for 404 fawns indicated that most selected bedding sites on slopes or crests of hills. Fawns were located in flat terrain in 31% of the cases. Gently rolling and hilly terrains accounted for 40 and 29% of bedding sites located, respectively. These categories described only the general nature of the topography in the immediate area of bedding sites.

In the last 3 years of the study the location of fawns relative to topographical site was recorded for 167 bedding sites. On 58 occasions, beds were located on flat land having no appreciable relief, and on 29, 27, and 25 occasions bedding sites were located at the top, middle, and bottom 1/3 of slopes, respectively. Additionally, 28 bedding sites were located in depressions that were on either slopes or flat land. These depressions were formed primarily by water and wind erosion or by livestock activity on unstable soils, and were irregularly shaped, and 1-3 m in diameter and 10-30 cm deep. Commonly, these depressions were deep enough to completely conceal a bedded fawn from horizontal view. No consistent direction of exposure was selected by bedded pronghorns.

During all years, most bedding sites were located on the NGP-sparse and NGP-light sagebrush rangelands that characterized most of the study area (Table 1) (Fig.2). NGP-medium and heavy sagebrush types were used only moderately throughout the study, but these vegetation types did not represent a large proportion of the area. Fawn bedding sites were found on cultivated land in 14% of the cases. Bedding sites were found on all major vegetation types available throughout the study area. The estimated mean distance between the bedding sites and the nearest available water for 356 cases was 586 ± 31 (SE) m; the maximum distance was >4 km.

Fewer than 1/3 of the bedded fawns were on sites where vegetation or other features provided appreciable concealment. Among 297 fawns, 30% were concealed, 3% were partially concealed, and 67% were not concealed. Of the concealed fawns, 55% were bedded in sagebrush, 13% in tall grass or forbs, and 18% in physical depressions. The remaining 15% were bedded adjacent to various features, including rocks, tire ruts, clumps of cactus, cow dung, and other objects. Typically, fawns bedded with their backs against an obstacle. When siblings were bedded within 5 m of each other, they ususally faced in different directions. When bedded on a slope, fawns faced downhill. All habitat types had considerable vegetative and physical diversity that provided some visual camouflage. More than half of the unconcealed fawns, however, were bedded on NGP-sparse or NGP-light sagebrush rangelands (Table 1), and were without appreciable physical cover in the immediate area to hide them. In most cases, cryptic coloration was the prime source of concealment for bedded fawns.

The substrate of fawn bedding sites was predominantly grass species in 62% of cases, whereas bare soil, either disturbed or undisturbed, composed the main bedding-site substrate in 36% of cases examined. In some cases, fawns bedded on a combination of the 2 main types. Many of the bedding sites with predominant grassland vegetation also contained various proportions of the matforming ground cover, spikemoss selaginella (_Selaginella densa_).

The mean distance to the nearest sagebrush plant was 102 ± 12 (SE) m (N = 362), and the maximum distance was 1.6 km. The mean height of the nearest sagebrush plant was 26.2 ± 0.9 cm, and the maximum height was 76.2 cm. The mean distance from the bedding sites to the nearest heavy vegetative cover suitable to visually conceal fawns was 325.9 ± 31.5 m (N = 238). In 64% of the cases, the heavy cover consisted of sagebrush. Other main types of heavy cover included native grasses, snowberry, wild rose, and forbs.

Microclimate of Bedding Sites

Mean and maximum temperatures decreased with increasing distances above the ground (Table 2). The mean temperature at ground level was 18.8% higher than the value obtained at 150 cm. Mean wind speed was greatly reduced in bedding sites. Mean and maximum wind speeds at the 10-cm level were reduced 59.5 and 46.7%, respectively, over those at the 150-cm level. Most fawns were bedded in sunny places, although there was no obvious preference for sunshine. Rectal temperature of fawns increased with increasing ambient temperature, as revealed by the correlation $r=0.43$.

($P < 0.01$) between the rectal temperature of fawns and the ambient temperature measured 10 cm above the ground.

During parturition and shortly thereafter, heavy rainfall, wind, and cold weather occur commonly throughout pronghorn ranges in Alberta. Snowfall in excess of 20 cm is not rare in portions of the ranges in late May. The effect of adverse weather on fawn survival was not measured specifically, but cases were observed in which short-term exposure to moisture reduced the body temperature of fawns. Two cases illustrate the point. In the first, a set of twins was located, 1 fawn was captured, and its rectal temperature was 40.7 C. The sibling had run approximately 400 m, bedded, and was caught after being in a 10-minute rain shower. The temperature of this partially dry twin 10-12 minutes after capture and handling was 37.6 C, or 3.1 C lower than that of its sibling before the shower. The first twin, which had been released before the shower, was recaptured. Although it was nearly dry by that time, its rectal temperature had fallen 1.9 C, to 38.8 C.

In the second case, a set of twins was located, and during netting of the first animal, its sibling fled approximately 200 m and ran into a 30- to 35-cm-deep slough and stood there for nearly 5 minutes before it was captured. Six minutes after the fawn was retrieved from the water its rectal temperature was 37.2 C. The temperature of the dry fawn was 41.2 C. The previously wet fawn was recaptured the following day, was dry, and had a temperature of 40.9 C.

Bedding-Site Characteristics and Fawn Survival

Excluding sightings made during the first 14 days following markings, 127 fawns were relocated and identified at least once. There was no significant chi-square relationship between the success in relocating fawns and general topography, exposure, or bed substrate of their capture sites. Data for concealed and partially concealed fawns were combined for analysis, and revealed that these fawns were relocated 33.3% of the time, compared to 19.3% for unconcealed fawns; these differences were significant ($P < 0.03$). Other significant relationships existed between the success in relocating fawns and topographical site (Table 3) and vegetation type (Table 4) noted at the bedding sites where they were first located.

With respect to vegetation type, the proportion of fawns relocated was 2.36 times greater if the initial capture sites were on native rangeland as opposed to cultivated land (Table 4). The proportion of fawns relocated was highest for native range with heavier cover. The success rates in relocating fawns that were concealed or partially concealed and those that were located on NGP-light sagebrush or heavy native vegetation were similar, and suggested comparability of these types in relation to fawn survival.

The distribution of does and fawns during the 7 years of my study did not provide substantive evidence for the existence of traditional fawning areas for local populations. Certain topographical and vegetative features appeared to be preferred as parturition sites, but these were widely distributed throughout the study area. Preferred parturition areas were not typified, however, by predictable annual increases in pronghorn densities in local areas. In the study area, the mean group size during the parturition period, exluding fawns, of all groups having at least 1 parental female was 1.7 (N=413 groups). The distribution of mature does during late May of each year was not consistent. Variations in distribution of does during May were believed to reflect availability of succulent vegetation in a given year and severity of the previous winter, which often caused major shifts in the distribution of pronghorns during that period.

DISCUSSION

The high proportion of fawn bedding sites located in NGP-sparse and NGP-light sagebrush rangeland (Table 1) contrasted sharply with findings in Montana (Pyrah 1974) and Idaho (Autenrieth 1976). Additional evidence on the lack of dependence on sagebrush as bedding cover in Alberta was the mean distance of 102 m between bedded fawns and the nearest sagebrush plant. Pyrah (1974:113) measured 85 fawn bedding sites and reported a mean canopy coverage of 21.2% big sagebrush (_A. tridentata_), 32.0% grass, and 13.5% forbs. He reported that all bedding sites selected by pronghorn fawns were in vegetative types containing big sagebrush. Autenrieth (1976:130) analyzed 131 bedding sites in Idaho, and reported that 73% were located in big sagebrush and the remainder in low sagebrush (_A. arbuscula_). In that study, pronghorn fawns reportedly selected bedding sites with greater-than-average brush canopy cover, total vegetation cover, and brush height.

The sharp contrast between habitat types in southeastern Alberta and the fawn study areas of Pyrah (1974) and Autenrieth (1976) is evident from the work of Mitchell and Smoliak (1971). In a 2,496-km^2 portion of my study area, Mitchell and Smoliak (1971:241) reported a mean canopy coverage on native range of 2.3, 10.0, and 87.7% shrubs, forbs, and grasses and sedges, respectively. In contrast to the situation in Alberta, fawns in the Montana and Idaho study areas apparently rarely bedded in rangeland with such limited brush cover (Pyrah 1974, Autenrieth 1976).

The use of small depressions as bedding sites by some fawns in Alberta differs from findings of Autenrieth and Fichter (1975) but agree with Walther's (1968) findings. Walther (1968:110) reported that gazelle fawns (Gazella spp.) selected bedding sites characterized by a vertical object plus a small hollow place; Autenrieth and Fichter (1975:40) rejected Walther's observation as being generally applicable to pronghorn fawns on their study area. The tendency of some neonates in Alberta to bed in hollows, on patches of bare ground, in wheel ruts, or adjacent to rocks, cow dung, or small clumps of vegetation, however, suggested that Walther's (1968) criteria for bedding sites of gazelles were met commonly by bedded pronghorn fawns in Alberta. The same conclusion was reached by Bromley (1977:95), who observed that pronghorn fawns in Wind Cave National Park selected bedding sites that satisfied both horizontal and vertical criteria. Fawns on Bromley's (1977:91-93) study area preferentially selected patches of bare ground as bedding sites, and such areas, in his view, satisfied the criterion of a small hollow area.

In Alberta and in Wind Cave National Park, and presumably in other locations where brush cover available to fawns is limited, the tendency to select bedding sites using features to satisfy both vertical and horizontal sign stimuli may be more apparent. In keeping with the general requirements of pronghorns, rangelands with abundant diversity and that readily provide preferred fawn bedding sites, should provide greater security for resident animals.

Low density of pronghorns and wide variation in distribution during the parturition period supported the conclusion that traditional fawning areas were not present in southeastern Alberta. Similarly, Autenrieth (1976:129) observed major shifts in the distributions of parturient does between years, and strongly questioned the existence of traditional fawning grounds on his Idaho study areas. However, other authors have supported or described the existence of traditional fawning areas (Einarsen 1948, Ingold 1969). Mace (1954:4) described open basins containing sagebrush as preferred fawning grounds. Furthermore, the 1962 guidelines for antelope management listed "kidding grounds" as one of the key areas of antelope range that a management agency should identify (Griffith 1962:106).

The definition of what constitutes a traditional fawning area has not been well established. Where such areas exist, increased pronghorn densities during the parturition period may reflect a limited availablity of seasonally preferred forage and terrain. Annual variation in climatic conditions and vegetation growth would be expected to cause corresponding shifts in the distribution of pronghorns during that period. The presence or absence of traditional fawning grounds throughout the pronghorn range may be an additional facet of the regional biology of this species that shows great variation between areas. A suggested hypothesis for the lack of traditional fawning grounds in Alberta is the abundance of habitat areas selected commonly by parturient females in relation to the generally low density of pronghorns.

Bromley (1978) discussed the behavioral characteristics of pronghorn fawns in relation to the ecological pressures of climate, availability of food, predation, and habitat structure. He believed that behavioral patterns at the birth site were adaptive responses to climate and predation. Bromley had no measurements of weather to support his hypothesis. Meteorological data from my study indicated that fawn bedding sites had reduced wind velocity and higher ambient temperatures than were recorded 150 cm directly above the bedding sites. Regrettably, meteorological values for areas not selected as bedding sites were not obtained for comparative purposes during my study. Similarly, comparative weather data for other pronghorn ranges beyond Alberta are not published.

The contribution of cold, wet weather to pronghorn fawn mortality has not been well documented. Hepworth (1965:2) reported that disease, in combination with inclement weather, was believed primarily responsible for low fawn: doe ratios in Wyoming. Beale (1978:446) reported that some fawns on his Utah study area died from pneumonia and adverse weather; data on the number of fawns affected were not presented. Bodie (1978:425) stated that several dead fawns were found after spring snowstorms in Idaho. Similar weather-related mortality of pronghorn fawns is probable in Alberta during periods of adverse conditions, but confirmation is lacking.

The proportion of fawns relocated following marking and release was highest if their bedding sites had been in small depressions or on native rangeland, particularly in areas with heavy vegetative cover (Tables 3, 4). Undisturbed fawns usually bed in a head-up posture, and depressions or heavy cover may be particularly effective in reducing their visibility to predators. The relocation statistic was used as an index of survival, and indicated that a minimum of 29.4% of the marked fawns survived at least 2 weeks, and most of these much longer. This is in general agreement with the estimated 41.3% survival to 2 months of age for all fawns in southeastern Alberta during the same time period (Barrett 1978:439). A small but unknown proportion of the fawns were possibly rejected by their dams, whereas some marked survivors were probably not relocated. These factors, however, should have occurred independently of bedding-site characteristics. The highest incidence of predation in Alberta occurred when fawns were 11-20 days old (Barrett 1978), a period during which the characteristics of fawn bedding sites should play an important role in survival. The hypothesis was that the probability of being relocated, i.e., fawn survival, was unaffected by the characteristics of fawn bedding sites. Based on available data, this hypothesis was rejected. In a preliminary conclusion, Bodie (1978:426) also reported contrasting mortality rates for pronghorn fawns that used 2 distinct vegetation types on his study area in Idaho.

Characteristics of bedding sites are important because of the assumption that fawns continue to select bedding sites with biotic and abiotic features similar to those in which they are born. Observations on the habitat characteristics of 15 birth sites in my study showed them to be similar to the bedding sites reported herein. Similarly, Autenrieth (1976:130-131) reported that his initial data supported the argument for habitat imprinting between birth site and subsequent fawn bedding sites. More conclusively, Bromley (1977:92-93) showed that the characteristics of bedding sites of fawns in Wind Cave National Park did not change significantly with increasing age of fawns during their first month of life.

My study contrasted the effectiveness of different habitats in providing protection for the fawn. In the 3-week interval following parturition, fawns are bedded apart from their dams approximately 90% of the time (Autenrieth and Fichter 1975). Bromley (1978:461) hypothesized that bedding-site selection was essentially a response to predation. Predation has been shown to be a major cause of fawn mortality in southeastern Alberta (Barrett 1978) and elsewhere (Compton 1958, Beale and Smith 1973, Beale 1978, Bodie 1978, Von Gunten 1978). Considering present knowledge, additional research on characteristics of bedding sites of pronghorn fawns, and in particular on mortality rates of pronghorn fawns using different vegetation communities, appears warranted throughout most of the pronghorn range.

Based on my findings, several management recommendations are made. Sagebrush rangeland, although limited on the study area, contributed to the highest survival of fawns, and should be retained wherever possible. Large cultivated tracts on important pronghorn ranges should be avoided. Habitat diversity provided by small depressions, stands of grasses or forbs >25 cm tall, and small areas of bare ground all constituted important fawn bedding cover, and should be retained and incorporated into any habitat development or mitigation programs designed to improve pronghorn range. Preferred fawning grounds should be evaluated on the basis of habitat characteristics and not solely by geographical areas.

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Table 1. Vegetation types at pronghorn fawn bedding sites in southeastern Alberta.

	Sagebrush plants/ 60-m transect	Bedding sites found	
Vegetation type		N	%
NGP[a]-sparse sagebrush	<3	162	41.2
NGP-light sagebrush	3-10	129	32.8
NGP-medium sagebrush	11-25	29	7.4
NGP-heavy sagebrush	>25	11	2.8
Stubble field		11	2.8
Summer fallow		18	4.6
Seeded field		22	
Tame pasture		5	1.3
Other[b]		6	1.5
Totals		393	100.0

[a] NGP-native grass prairie.

[b] Includes 4 types of native pasture each of which represent <1% of the cases.

Table 2. Meteorological data taken at bedding sites of pronghorn fawns in southeastern Alberta.

Measurement	N	$\bar{x}$	SE	Range
Temperature, C				
Ground level[a]	279	20.3	0.4	3.3-47.8
10 cm above ground[a]	243	18.3	0.4	3.3-35.6
150 cm above ground[b]	321	17.1	0.3	3.3-30.6
Wind speed, km/hour				
10 cm above ground	284	6.4	0.3	0-22.5
150 cm above ground	303	15.8	0.5	0-48.3
Cloud cover, %	240	62		0-100

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[a] Temperature taken with no unnatural shading.

[b] Thermometer always shaded for this reading.

Table 3. Success of relocating pronghorn fawns in relation to topographical characteristics of their bedding sites in southeastern Alberta.

	Fawns relocated[a]		Fawns not relocated[a]	
Topographical site	N	%	N	%
Flatland	18	26	50	74
Top 1/3 of slope	8	28	21	72
Middle 1/3 of slope	2	7[b]	25	93
Bottom 1/3 of slope	7	28	18	72
Small depression	13	46[c]	15	54

[a] Chi-square probability of obtaining the relationships in the column by chance is <0.01.

[b] Relocation rate was less ($P < 0.05$) than that of the entire marked population.

[c] Relocation rate was greater ($P < 0.01$) than that of the entire marked population.

Table 4. Success of relocating marked pronghorn fawns in relation to vegetative characteristics of their bedding sites in southeastern Alberta.

Vegetation type	Sagebrush plants/60-m transect	Fawns relocated[a]		Fawns not relocated[a]	
		N	%	N	%
NGP[b]-sparse sagebrush	<3	42	26	120	74
NGP-light sagebrush	3-10	41	32	89	68
Heavy native vegetation[c]	>10	14	33	29	67
Cultivated land		7[d]	12	50	88

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[a] Chi-square probability of obtaining the relationships in the column is <0.05.

[b] NGP-native grass prairie.

[c] Includes equivalent densities of other shrub species and stands of grasses and forbs >25 cm tall.

[d] Relocation rate was lower ($P < 0.008$) than that of the entire marked population.

Figure 1. Location of pronghorn fawn study area in southeastern Alberta.

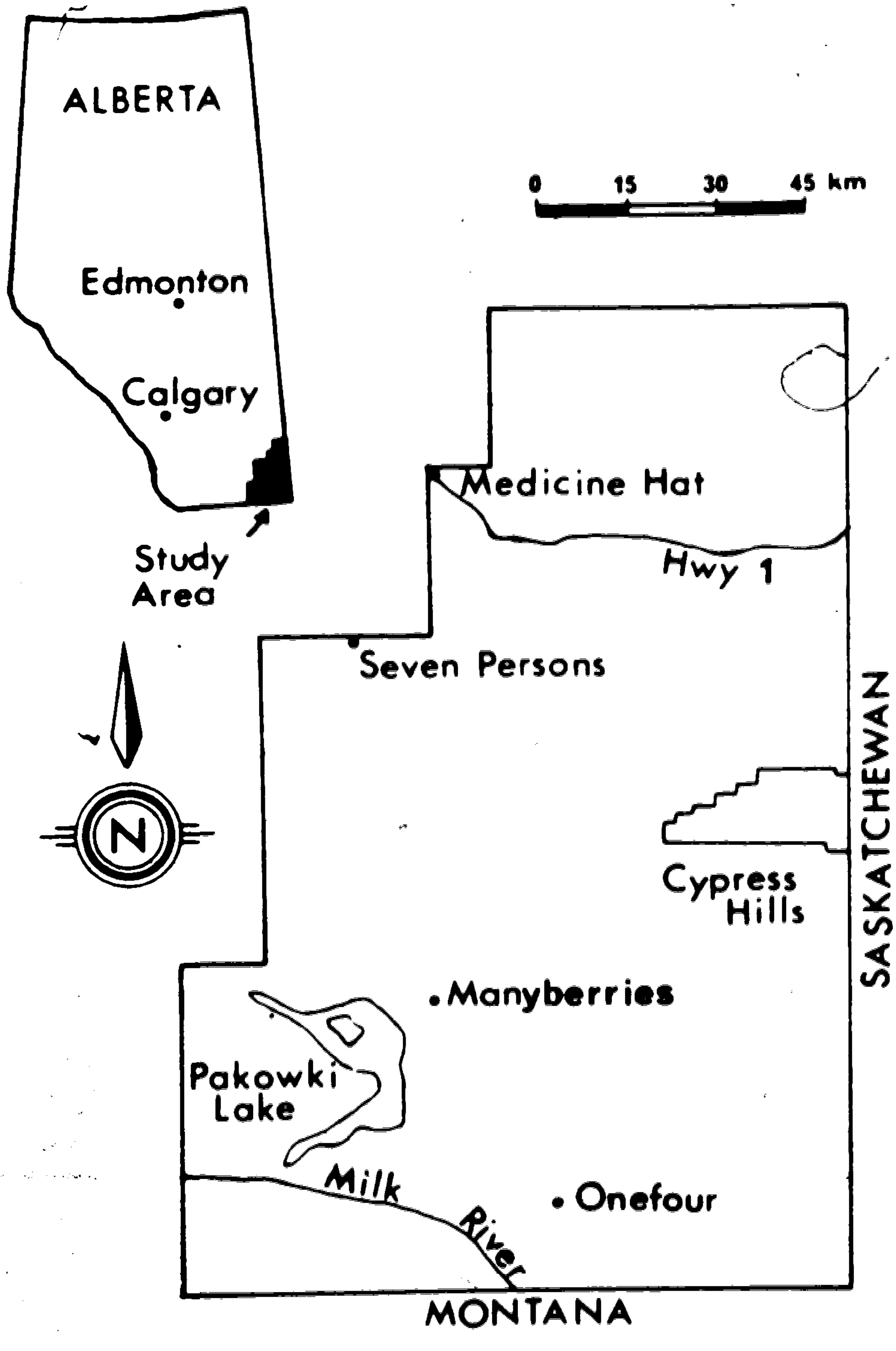
ALBERTA
Edmonton
Calgary
Study Area
0 15 30 45 km
Medicine Hat
Hwy 1
Seven Persons
Cypress Hills
SASKATCHEWAN
Manyberries
Pakowki Lake
Milk River
Onefour
MONTANA

Figure 2. Two day old pronghorn fawn bedded on native grassland that typified much of the study area.

LITERATURE CITED

Autenrieth, R. E. 1976. A study of birth sites selected by pronghorn does and the bed sites of fawns. Proc. Bienn. Pronghorn Antelope Workshop . 7:127-134.

_________, and E. Fichter. 1975. On the behavior and socialization of pronghorn fawns. Wildl. Monogr. 42. 111pp.

Barrett, M. W. 1978. Pronghorn fawn mortality in Alberta. Proc. Bienn. Pronghorn Antelope Workshop 8:429-444.

Beale, D. M. 1978. Birth rate and fawn mortality among pronghorn antelope in western Utah. Proc. Bienn. Pronghorn Antelope Workshop 8:445-448.

__________, and A. D. Smith. 1973. Mortality of pronghorn antelope fawns in western Utah. J. Wildl. Manage. 37:343-352.

Bodie, W. L. 1978. Pronghorn fawn mortality in the upper Pahsimeroi River drainage of central Idaho. Proc. Bienn. Pronghorn Antelope Workshop 8:417-428.

Bromley, P. T. 1977. Aspects of the behavioural ecology and sociobiology of the pronghorn (Antilocapra americana). Ph.D. Thesis. Univ. Calgary, Alberta. 370pp.

__________. 1978. Ultimate factors, behaviour and fawn recruitment. Proc. Bienn. Pronghorn Antelope Workshop 8:449-471.

Clark, J. 1979. Alberta (1979) antelope range classification. Alberta Energy and Natural Res., Fish and Wildl. Div. Lethbridge. Unpub. Rep. 64 pp.

Compton, H. O. 1958. The effects of predation on pronghorn antelope numbers in south central Oregon. M.S. Thesis. Oregon State Univ., Corvallis. 71pp.

Coupland, R. T. 1950. Ecology of mixed prairie in Canada. Ecol. Monogr. 20:271-315.

__________. 1961. A reconsideration of grassland classification in the northern Great Plains of North America. J. Ecol. 49:135-167.

Einarsen, A.S. 1948. The pronghorn antelope and its management. Stackpole Co., Harrisburg, Pa. 238pp.

Griffith, G. K. 1962. Guidelines for antelope management. Trans. Interstate Antelope Conf. 13:102-114.

Hepworth, B. 1965. Investigation of pronghorn antelope in Wyoming. Proc. Bienn. Pronghorn Antelope Workshop 1:1-12.

Hoover, R.L., C. E. Till, and S. Ogilvie. 1959. The antelope of Colorado. Colo. Dep. Fish and Game. Denver. Tech. Bull. 4. 110pp.

Ingold, D. A. 1969. Social organization and behavior in a Wyoming pronghorn population. Ph.D. Thesis. Univ. Wyoming, Laramie. 142pp.

Mace, R. U. 1954. Oregon's pronghorn antelope. Oregon. State Game Comm. Wildl. Bull. 1. 26pp.

Mitchell, G. J. 1965. Natality, mortality, and related phenomena in two populations of pronghorn antelope in Alberta, Canada. Ph.D. Thesis. Washington State Univ., Pullman. 205pp.

__________, and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Nie, N.H., C.H. Hull, J.G. Steinbrenner, and D.H. Bent. 1975. Statistical package for the social sciences, 2nd ed. McGraw-Hill Book Co., New York. 675pp.

Pyrah, D. 1974. Antelope fawn bedding cover selection in central Montana. Proc. Bienn. Pronghorn Antelope Workshop 6:113-121.

Von Gunten, B. L. 1978. Pronghorn fawn mortality on the National Bison Range. Proc. Bienn. Pronghorn Antelope Workshop 8:394-416.

Vriend, H. G., and M. W. Barrett. 1978. Low pronghorn recruitment--Is it an issue? Proc. Bienn. Pronghorn Antelope Workshop 8:360-379.

Walther, F. 1968. Verhalten der gazellen. A. Ziemsen Verlag, Wittenberg Lutherstadt. 144pp.

Webb, R., A. Johnston, and J.D. Soper. 1967. The prairie world. Pages 93-115 in W. G. Hardy, ed. Alberta, a natural history. Hurtig Publishers, Edmonton, Alberta

Wishart, W. D. 1970. A brief historic review of the pronghorn antelope in Alberta. Proc. Bienn. Pronghorn Antelope Workshop 4:128-130.

Yoakum, J. 1972. Antelope-vegetative relationships. Proc. Bienn. Pronghorn Antelope Workshop 5:171-179.

Chapter 2. Movements, habitat use, and predation on pronghorn fawns in Alberta.

Abstract: In a 1054 km^2 area of southeastern Alberta, 62 pronghorn (Antilocapra americana) neonates were fitted with electronic collars and located daily for 58 days or until their death. There were 1737 total relocations. The mean distance between bedded siblings was 73.4 m; they were first seen bedded together at 7 days of age and after 24 days they were inseparable. The mean daily movement of fawns and their minimum area polygons were significantly ($P < 0.001$) correlated with age. Bedding site selection and general vegetation used by fawns did not change markedly throughout the 2 month observation period. Fawns used vegetative cover in significantly different ($P < 0.001$) proportion from its availability and generally preferred heavy native vegetation and under-used cultivated land. Most fawns of all ages were located on native grassland ranges with light sagebrush (Artemisia cana) cover. Predation caused primarily by coyote (Canis latrans) and to a lesser degree, bobcat (Lynx rufus) caused the death of 27 of the 62 (43.5%) marked fawns. Predation rate was highest on fawns 4 - 15 days old (2.7 deaths / 100 animal days) but remained important for animals between 16 and 57 days old (1.5 deaths / 100 animal days). During the past 10 years in Alberta, fawn mortality, primarily from predation, has been approximately 50% annually, but losses of this magnitude have not regulated pronghorn numbers nor have they limited the capacity of the provincial population to grow.

INTRODUCTION

High mortality of fawns has been recognized as a characteristic of pronghorn populations with chronic low recruitment and density (Vriend and Barrett 1978, Yoakum 1978). With the advent of miniaturized telemetry systems, researchers have been able to examine mortality in detail (Mech 1967) and in many cases have shown predation to be a locally important factor (Beale and Smith 1973, Barrett 1978, Beale 1978a, Bodie 1978, Von Gunten 1978). Bromley (1978) theorized that the behavior of bed site selection by fawns was a consequence of the interaction of predation pressure and habitat structure. Some aspects of the behavior and socialization of pronghorn fawns have been described in detail (Autenrieth and Fichter 1975) but many important habitat relationships have not been reported.

In Alberta the mean annual mortality of fawns in the first 60 days following parturition approaches 50% (Barrett 1978). Habitat quality should contribute directly to fawn survival, and although this relationship has not been investigated conclusively through field studies, some initial observations are useful. Mitchell (1980:139) suggested that increased survival of fawns in his northern-most study area in Alberta was a reflection of larger quantities of forb and browse cover. In Idaho, Bodie (1978) reported increased predation on fawns bedding in tall sagebrush - foothill community type when compared with those using short sagebrush - grassland community type. In Alberta, highest survival was observed for fawns bedding on native rangeland with high cover density (Barrett 1981).

Characteristics of bedding sites of fawns <1 week of age have been described for Alberta (Barrett 1981). This paper represents the next phase in the chronological development of fawns and reports the spatial and behavioral relationships of free ranging animals from the time they were first radio-collared until they integrated into doe-fawn summer groups. This report also highlights the temporal influence on the use of key habitat components by fawns and the impact of predation. Some of the data presented in this paper were reported previously in a preliminary paper dealing with pronghorn fawn mortality in Alberta (Barrett 1978).

STUDY AREA AND METHODS

The study was conducted during 1975 and 1976 in a 1054 km^2 area of southeastern Alberta (Fig. 1). The study area was located in the Brown soil zone and is part of the mixed-grass prairie region. The climate is semiarid with a mean annual precipitation (1941-70) of 327 mm as measured by The Agriculture Canada Research Substation at Onefour.

Western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), and needle-and-thread (*Stipa comata*) were the dominant grass species. The primary shrub was silver sagebrush (*Artemisia cana*) but western snowberry (*Symphoricarpos occidentalis*) and rose (*Rosa* spp.) were present in bottom lands and along the many intermittent water courses that transect the area. The topography varies from gently rolling plains to limited hills. The altitude is <1,100 m. Detailed descriptions of this general area were published by Coupland (1950, 1961) and by Mitchell and Smoliak (1971).

The 1054 km^2 study area contained few roads and the land was divided into large pastures by conventional 3 or 4 strand barbed wire fence. Domestic cattle ranged throughout the area during the summer grazing season. No major features restricted pronghorn distribution and all habitats and animal populations present were contiguous with those found outside the study area.

Aerial photographs were used to delineate the major vegetative types within the study area; all areas were subsequently ground truthed. Mapping was completed on a 1:50,000 scale. The area of each vegetative type was calculated using both a planimeter and a 1:50,000 scale dot grid. All calculations were done in duplicate and the results were replicable to within a 4% error factor. Native grass prairie (NGP) was divided into 4 categories based on the number of sagebrush plants intercepted by a randomly selected 60-m straight-line transect. The 4 categories, NGP-sparce sagebrush, NGP-light sagebrush, NGP-medium sagebrush and NGP-heavy sagebrush contained <3, 3-10, 11-25, and >25 sagebrush plants/transect and represented 40.9, 41.2, 3.2, and 4.1% of the study area, respectively. Cultivation occurred on 9.5% of the area and brush species other than sagebrush covered 1.2% of the area. Small ponds, sloughs, and reservoirs covered 1.8% of the area and were distributed throughout all vegetative types (Fig. 1).

Radio-collaring and Relocation of Fawns

During 1975 and 1976, 62 fawns were captured (31 each year) and fitted with expandable radio collars (A.V.M. Instrument Co., Champaign, Illinois). The fawns averaged 2.8 days of age when marked. Additional details on the procedure for capturing and handling fawns have been documented by Barrett (1981). All marked fawns were released at the site at which they were captured. An A.V.M. LA 12 receiver and a 3-element hand-held Yagi antenna were used to locate each marked fawn daily for 58 days or until it was found dead. Fawns were not handled and only occasionally disturbed from their bed sites as a result of the daily monitoring. A daily location of each fawn was recorded on a 1:50,000 map sheet. These locations were used to calculate their activity areas, by use of the minimum area polygon method.

When dead fawns were found and predation was suspected, a detailed search of the area was conducted for the presence of tracks, scats, hair, killing manner, predator feeding habits and manner of carcass concealment. Carcasses were subjected to detailed necropsies at the Provincial Veterinary Diagnostic Laboratory at Lethbridge. To identify the species of predator involved, I reviewed the relevant desciptions of predator kills provided by Cook et al. (1971), Giles (1971), Beale and Smith (1973), White (1973), Henne (1975), Roy and Dorrance (1976), Beale (1978a), and O'Gara (1978).

Data Recorded at Relocation Sites

When fawns were located daily the data recorded were the same as those used to characterize the initial capture sites of young, as described previously (Barrett 1981). The general classifications of topography and vegetation best describing the square kilometer surrounding the relocation site were recorded. Topography was classified into 3 categories of increasing relief namely, flatland, gently rolling, and hilly. A more specific category, topographical site, was used to describe the location of fawns with respect to relief. This category contained 5 classes: flatland, small depressions, and the top, middle, and bottom 1/3 of slopes. For the vegetation classification, native grass prairie (NGP) was divided into 4 categories: NGP-sparce sagebrush, NGP-light sagebrush, NGP-medium sagebrush, and NGP-heavy sagebrush, as described for the vegetation mapping of the study area. Cultivated lands were divided into 5 classes: tame pasture, seeded cereal crop, stubble, summer fallow, and abandoned cultivation.

The distance of fawns from the nearest water, stand of sagebrush or other heavy brush cover, and cultivated land was recorded; distances >100 m were estimated. The heavy-cover designation included NGP-medium and heavy sagebrush, equivalent densities of snowberry, wild rose, and other brush species, and stands of grasses and forbs >25 cm in height. The distance between the tracking personnel and the fawn was recorded whenever a bedded animal fled. The distance between bedded siblings was recorded.

The herd composition of all groups containing a radio-collared fawn was determined whenever possible. The behavior of the nearest attendent parental doe with respect to her reaction to search personnel, vocalization, and observation of the search procedure was noted. The nearest parental doe was presumed to be the dam of the collared fawn.

Data were processed using the SPSS statistical package (Nie et al. 1975). The relationship between age groupings and fawn use of defined vegetation types was investigated using the Chi-square analysis. Pearson's correlation procedure was used to examine the relationship between ages of fawns and their daily minimum movements. Regression equations were calculated to illustrate the relationship between the ages of fawns and their mean minimum area polygons over defined age ranges. The statistical relationships between defined age groups and the distance to prescribed features were examined using a one-way analysis of variance. Differences between means of age groups were examined using the Scheffe contrast (Nie et al. 1975) for the distances to water, heavy cover, sagebrush stands, and previous locations. Duncan's multiple range test was used to contrast distances between marked fawns and the parental females for prescribed age groupings. The minimum level of significance to reject the null hypothesis was $P < 0.05$.

RESULTS

There were 1737 total relocations of the 62 instrumented fawns. Telemetric procedures were used to locate nearly all animals as only 4% were observed prior to an electronic search. The closest adult female, presumed to be the parental doe, positioned herself to observe the search procedure in 77.5% (N=1059) of the cases. The mean minimum distance between search personnel and the parental doe was 276.2 ± 6.6 (SE) m (N=1295). Alarm calls were heard from parental does on 24.8% of searches. Does appeared most agitated and alarmed when fawns were <5 days of age. The mean distance between the initial location of the closest adult female and each telemetered fawn averaged 114.5 ± 5.6 (SE) m (N=1506).

During 1359 of the fawn locations, the complete herd composition was recorded. The mean number of adult females was 2.3 ± 0.1 (SE), but solitary does were observed on 55.9% of the cases. No adult male was present 86.4% of the time and one male was present with 13.4% of the groups. Yearling females were present in only 3.0% of the herds and yearling males were rare (0.4%).

Spatial Relationships and Age of Fawns

The mean distance between bedded siblings throughout the relocation period was 73.4 ± 9.5 (SE) m, (N=643). This relationship was negatively correlated with age $r=-0.27$ ($P < 0.001$) and was useful to illustrate some of the behavioral development of fawns (Fig. 2). With the exception of the first few hours following parturition, siblings between 1 and 6 days of age were not observed bedded together and they appeared to interact with their dam on an individual basis. Between 7 and 24 days of age, the siblings exhibited progressively greater interaction; their feeding and activity bouts occurred commonly at the same time, and they tended to bed closer to each other (Fig. 2). Although rare, siblings were first observed bedded together at 7 days of age, and by 14 days of age, such behavior was common. Siblings older than 24 days were virtually inseparable at all times (Fig. 2).

During the 2 month monitoring period, the minimum daily movement of fawns increased progressively with age ($r=0.44$, $P < 0.001$). Fawns of all ages moved an average of nearly 500 m a day. For fawns >25 days of age, the minimum distance moved per day exceeded an average of 1 km (Table 1).

The area occupied by fawns increased progressively as animals aged. Mean area polygons were developed for each animal on a daily basis. Mean area curves were calculated for fawns from 3 to 58 days of age (Fig. 3). A strong significant ($P < 0.001$) correlation $r=0.77$ existed between the age of fawns and their mean area polygons. A near linear relationship existed ($r=0.99$) between the minimum area polygons and age of fawns for the interval from 3 to 52 days (Fig. 3).

Fawns that were <5 days of age remained bedded and motionless and could be approached closely by project personnel. As fawns grew older their tendency to remain bedded while personnel approached decreased (Table 2). A significant positive correlation ($r=0.36$, $P < 0.001$) existed between the age of fawns and their flight distance from approaching personnel. The transition from remaining bedded at the approach of danger to fleeing occurred most rapidly when fawns were approximately 24 days old. In all cases when fawns were between 10 and 30 days, approaching within 10 m of a bedded animal was difficult. The influence of age on the development of fawn mobility was also illustrated by the distance between a bedded fawn and its dam. The distance decreased significantly for fawns more than 24 days of age (Table 3) and appeared to reflect the ability of fawns to travel and intergrate with adult pronghorns.

Age of Fawns and Use of Habitat

Gently rolling terrain typified the location of 1265 fawns (74.0%) while the remainder were found on flatland (19.8%) or on hilly (6.2%) terrain. No preference ($P > 0.05$) by fawns for use of different aspects of slopes was noted.

Data on topographical site were recorded for 1003 cases when bedding sites were accurately located. On 309 occasions, beds were located on flatland having little discernable relief, and on 244, 164, and 139 occasions, the fawns bedded on the top, middle, and bottom 1/3 of slopes, respectively. Small depressions 1-3 m in diameter and 10-30 cm deep, that were located on slopes or flatland, were used as bed sites on 99 occasions. Linear habitat features such as roadsides, banks of irrigation ditches, and dry creek beds were used as bedding sites 31 times and dry slough bottoms were selected 17 times. The substrate of fawn bedding sites was predominantly grass species in 74.2% of the cases, whereas bare soil was the primary substrate in nearly all of the remaining cases.

Fawns of all ages tended to bed on the NGP-sparce and NGP-light sagebrush rangelands that dominated the study area (Table 4). Rangelands with medium and heavy stands of sagebrush provided bedding sites for only 11% of fawns. On a relative basis, agricultural areas were used sparingly (Table 4).

The use of specific habitat features changed as fawns aged. Animals <7 days old were bedded significantly ($P < 0.05$) closer to stands of sagebrush than were older fawns, and those >40 days of age were bedded farthest from sagebrush (Table 5). When all types of heavy cover were included, the relationship was similar to that for sagebrush; younger (<7 days old) fawns were bedded significantly ($P < 0.05$) closer and older fawns (>40 days old) were bedded significantly farther from heavy cover. No discernable trends ($P > 0.05$) were noted in the distances fawns bedded from water or the nearest cultivated land. Fawns of all ages bedded a mean distance of 479 ± 10.9 (SE) m from water.

The location of telemetered fawns relative to vegetative types was examined using a Chi-square analysis to determine preferential use of specific habitats and changes occurring with age. The NGP medium and heavy sagebrush stands and equivalent densities of other shrub species and stands of grasses and forbs >25 cm tall were combined under one category called heavy native vegetation for this analysis. Similarly, all types of domestic and cereal crops were combined under the cultivated land category. Fawns of all age classes examined used vegetative types in a significantly ($P < 0.05$) different proportion from that available in the study area (Table 6). All but the >40 day old group consistently under-used cultivated lands whereas all but the 15-24 day-old group over-used the heavy native vegetation. NGP-light sagebrush rangeland was over-used only by the <3 day-old animals. When observations for all age groups were combined, fawns exhibited a tendency to over-use NGP-light sagebrush rangelands. Most apparent however, was their selection for heavy native cover and their tendency to underuse cultivated lands (Table 6).

Mortality of Fawns

During both 1975 and 1976, predation was the predominant cause of mortality among the 62 marked fawns and accounted for 27 deaths or 67.5% of the total mortality. Coyotes, and to a lesser extent bobcats, appeared to be responsible for all predation confirmed. Project personnel examined all kill sites and carcasses for evidence of tracks, hair, scats, feeding patterns, killing techniques and preferences for disposing uneaten portions of the carcass, but we could not, in all cases, identify conclusively the species responsible for the predation.

I concluded that 21 of the 27 predator related deaths were coyote-related on the basis of the following descriptions and published data. On 10 occasions, the predator crushed portions of the skull of fawns. In these cases, 1 or more of the frontal, parietal, occipital, orbit, nasal, or maxilla bones were fractured. Typically, there was also a single or bilateral fracture of the verti[illegible] rami of the mandibles. Six of the 10 fawns with crushed skulls also had bite marks on the neck and throat region. Two additional fawns appeared to have been killed by seizing the throat and choking the prey. On 7 occasions, only bone chips or widely scattered remains were found at the kill site. Five fawns had numerous bone fractures but the predator had consumed only muscle tissue from the upper hind limb. On 8 occasions only the head and neck, or head, neck, severed rib cage, and front limbs were left; in 7 of these cases, the remains were neatly buried in shallow soft soil and packed in or topped with debris. Fresh coyote tracks were found at the site of 2 of the kills and the remains of 2 fawns, 1 of which was buried, were found at coyote dens. Coyote hair was collected at 3 kill sites, including 1 site where the remains were buried and neatly concealed.

Two of the 27 predator kills were attributed to bobcats. In both cases the fawns were killed by bites to the neck that would represent a choking hold. The remains of both fawns were located in sagebrush and nearby debris dragged over them to give partial concealment. Bobcat tracks were observed at the sight of 1 of these caches.

I was unable to confirm the cause of death for 4 fawns. Typically only the blood stained collar, and on 2 occasions a small amount of pronghorn hair, was present. These animals were believed killed by mammalian predators, presumably coyotes, but this conclusion could not be confirmed.

Twelve fawns died from malutrition or unknown causes and were found 2-6 days after they were marked. Typically these fawns had marked depletion of fat reserves at the base of the ear, pericardial sac, epicardium, sciatic nerve, omentum, and perirenal areas. No milk was in the abomasum and only a small amount of tightly impacted green feed was present. The urinary bladder was moderately or heavily distended in all animals. The bone marrow of abandoned fawns was dark red and gelatinous in appearance. Histologically, the heart, lung, liver, spleen, kidney, skeletal muscle, pericardial and perirenal tissue, and adrenal gland appeared normal except for changes induced by freezing the carcass in the field. On 2 occasions, small ulcerations were observed at the pylorus. In 3 of the 12 cases, a parental doe, believed to be the dam of the malnourished fawn was observed daily near the fawn until its death. On 2 occasions, the sibling of an unnourished fawn was observed to nurse the dam. On 1 of the 2 occasions, the accepted sibling had been radio-collared and in the second case, the dam was neck-collared. The most probable cause of death of these malnourished fawns was rejection or abandonment by the dam.

Two of the 12 malnourished fawns were substantially below normal weight and lacked vigor when they were captured. No evidence of trauma was noted in any of these fawns. One fawn was killed when it was stepped on by a domestic cow. Of the 62 fawns marked, only 22 (35%) survived to 2 months of age.

No predation occurred on marked fawns that were <4 days of age. However, predation was highest on fawns in the 4-15 day-old range (Table 7). Data for the 12 malnourished fawns were excluded from Table 7. The rate of predation, as expressed by deaths per 100 animal days, remained relatively constant for fawns between 16 and 57 days of age despite the marked changes in the mobility and social organization of fawns during that period. The vegetative composition within the minimum area polygons of fawns was not significantly ($P > 0.05$) different for those that died and those that survived the 60 day monitoring period.

DISCUSSION

Social Organization

The social organization of animals in the predominantly grassland range on the study area was comparable to that reported for pronghorns in Idaho (Fichter and Autenrieth 1980) and Montana (Pyrah 1970). Parental females were alone or with yearling females on 59% of observations. Kitchen (1974:48) reported that 68% of all adult females were alone or with a yearling doe following parturition in the National Bison Range in Montana.

During their first 3 weeks of life pronghorn fawns have a period of "lying secluded" for approximately 90% of the time (Autenrieth and Fichter 1975, Kitchen 1974:81). Following the active socialization and imprinting period that occurs in the doe-fawn relationship during the first few hours after parturition (Autenrieth and Fichter 1975), siblings bedded separately. The maximum distance between bedded siblings occurred during the first 10 days, a period during which pronghorns are highly vulnerable to predation (Bodie and O'Gara 1980). The physical separation between siblings during their time of maximum vulnerability appears to be an adaptive response to promote the survival of at least one fawn from predation. The selection of bedding sites by pronghorns that satisfy both horizontal and vertical criteria

(Bromley 1977:95, Barrett 1981:128) seems to be primarily a direct response to predation pressure.

Siblings were first observed bedded together at 7 days of age and by 24 days of age they were never observed to bed separately. On the National Bison Range, siblings were first reported bedded together between 2 - 3 weeks of age (Kitchen 1974:80). Smith and Beale (1980) reported that 2 of 9 pairs of siblings were bedded together at 11 days of age and by the 19th day all sibling pairs bedded together in their Utah study area.

The minimum daily movement and the minimum area polygons of fawns increased as they aged. Autenrieth and Fichter (1975:40) suggested that fawns tended to move longer distances in search of bedding sites as they age. These factors, however, did not lead to an increased distance between bedded fawns and the nearest adult female. Progressively greater unity and coordination of activities apparently occurs between dam and offspring(s) as fawns age and this behavior leads to the formation of the doe-fawn social groups. Similarly, the inseparable nature of siblings >24 days of age reflects a change in social orientation and could be viewed as an interim step in the formation of doe-fawn groups. Bromley (1967) considered fawns to be functional members of summer herds by the time they were 6 weeks old.

Predation and Habitat Use

Predation was the cause of 67.5% of the mortality of marked fawns. Barrett (1978:439) examined the structure of pronghorn herds in the same area and concluded that mortality rate of fawns as revealed by telemetry was generally indicative of the mortality in the population at large. Similarly, Beale and Smith (1973) reported that radio collars did not alter the behavior of marked fawns nor change their rate of mortality when compared with unmarked animals. Predation was highest when fawns were between 4 and 15 days old, a period during which they were bedded 90% of the time.

Without question, coyotes are the primary predator on pronghorn fawns in Alberta. Coyotes are widely distributed throughout the province whereas bobcat distribution is limited and tends to follow the river valleys in the extreme south of the province (Soper 1964, Roy and Dorrance 1976). In Alberta, winter losses of pronghorns to coyote predation have been reported frequently (Rand 1947, Bruns 1970, Mitchell 1980, Barrett 1982), but prior to this study, the impact of coyotes on fawn mortality was unknown. Between 1967 and 1977, the coyote population in Alberta was estimated at approximately 60,000 animals and the annual harvest averaged 22,000 animals (Todd 1977). Within the pronghorn range in southeastern Alberta, Todd (1977) conservatively estimated the coyote density at 1 per 13 km^2 and reported that in the previous 5-6 years numbers on the prairies were stable or increasing. Dorrance and Roy (1976) reported that predation by coyotes was responsible for 88% of predator related losses of domestic sheep in Alberta in 1974.

Initially, I was reluctant to distinguish between coyote and bobcat predation (Barrett 1978), particularly when the remains of carcasses were buried, because the literature contains some inconclusive statements. Cook et al. (1971) and White (1973) reported that the remains of white-tailed deer (Odocoileus virginianus) fawns that were killed by coyotes had been strewn about with no attempt to conceal them. Giles (1971), Henne (1975), Bowns (1976), and Roy and Dorrance (1976) have published guidelines or criteria to identify predators of domestic livestock and wildlife but these descriptions make no mention of coyotes concealing or burying the remains of carcass. By contrast, Cook et al. (1971) suspected that bobcats were responsible for predation if the remains were scrapted together under a shrub and neatly covered with grass, leaves or small sticks. Similarly, Beale and Smith (1973) and Roy and Dorrance (1976) indicated that bobcats commonly cover and conceal carcass remains with debris.

On 7 occasions, I found the head and neck, or head, neck, and front limbs of pronghorn fawns neatly buried and completely concealed; I have concluded that these animals were killed by coyotes. Some support for this conclusion is available in the literature. Beale (1978b) stated that coyotes, but not bobcats will freqently dig a hole to cache the remains of a carcass. O'Gara (1978) reported that coyotes will occasionally bury their prey by covering it with soil, and neatly packing the site. Additional evidence indicative of coyote predation in these 7 cases was the presence of coyote hair at 1 site, a nearby coyote den at another site, and the near absence of the rough terrain favored by bobcats (Gashwiler et al. 1960, Soper 1964, Beale and Smith 1973) at 5 kill sites. The available evidence suggests that coyotes, not bobcats, were responsible for burying and concealing the remains of carcasses. Furthermore, the manner in which the fawns were killed was consistent with that reported for coyotes. Field studies conducted without the use of telemetric devices would have no chance of locating buried remains or documenting the prevalence of this behavior.

High predation rates on pronghorn fawns have been reported frequently (Beale and Smith 1973, Barrett 1978, Beale 1978a, Bodie 1978, Von Gunten 1978, Neff and Woolsey 1980). Coyotes, and to a lesser extent bobcats and avian predators, account for most of the predation documented in the literature (Yoakum 1978). The extent to which pronghorn fawns are vulnerable to predation appears to be a reflection of their behavior and use of available habitat.

Fichter (1974) suggested that fawns <3 weeks old tended to seek seclusion in vegetative cover resembling that in which they were born. Initial observations by Autenrieth (1976) and by Barrett (1981) support this possibility. My study indicates that throughout the first 2 months of life fawns use vegetative types in essentially the same proportion as those <1 week old (Barrett 1981). Similarity, Bromley (1977:92-93) demonstrated that bedding sites of fawns <30 days old in Wind Cave National Park did not change with age. Collectively, these studies indicate that despite the great variation in habitat composition within the pronghorn range in North America, there appears to be consistency in the selection of bedding sites by fawns on a regional basis.

Bromley (1978:461) hypothesized that bed site selection by fawns was essentially a behavioral response to predation. This hypothesis was strengthened by findings of Barrett (1981) who determined that differential survival of fawns can be related to the characteristics of bedding sites of animals <1 week of age. In Alberta the pronghorn range is essentially a grassland community and fawns of all ages bed predominately in NGP-sparce and NGP-light sagebrush range. By contrast, fawn bedding sites in portions of Montana and Idaho were dominated by the presence of big sagebrush (A. tridentata) (Pyrah 1974, Autenrieth 1976). During my study, fawns of all ages used vegetative cover in proportions significantly different from its availability (Table 6). Although limited on the study area, scattered pockets of heavy native cover were preferred by fawns; this habitat preference appeared to contribute to increased survival of young (Barrett 1981).

Conclusions on the impact of predation on fawns seem limited without an understanding of the role of available habitat. Based on research near the Salmon River area of Idaho, Autenrieth (1980) viewed recruitment as a direct reflection of fawn vulnerability to predation during the period in which they lie secluded and reported that vulnerability to avian and mammalian predators varied inversely with vegetative cover. By contrast, in the Pahsimeroi River area of Idaho, Bodie (1978, 1979) reported higher predation rates on fawns bedded in tall sagebrush-foothill community type than for those in the short sagebrush-grassland community type. Neff and Woolsey (1979) speculated that high mortality of fawns from predation by coyotes was a result of inadequate tall cover in which fawns could bed and hide on their Arizona study area. Smith and Beale (1980) reported that does in their study area in Utah did not select fawning sites in higher vegetation and seemed to prefer areas offering good visibility as opposed to those with better concealment. Vegetative cover varies markedly throughout the range of pronghorns (Yoakum 1972) and fawn use of habitat reflects these differences. However, growing evidence indicates that, on a regional basis, there is consistency and that fawns tend to select habitat types that serve to reduce their vulnerability to predation.

Connolly (1978) reviewed the literature concerning the role of predation in regulating ungulate populations and highlighted the many and often conflicting arguments. There remains little doubt that predators kill substantial numbers of pronghorns, particularly fawns (Knowlton 1968, Beale and Smith 1973, Barrett 1978, Beale 1978, Bodie 1978, 1979, Von Gunten 1978, Neff and Woolsey 1979, 1980). Arrington and Edwards (1951) presented strong evidence that fawn survival and population levels of pronghorns in their Arizona study area were limited by predation. A similar argument would be difficult to defend in Alberta. Average annual fawn mortality in Alberta was estimated at nearly 50% from 1965 to 1977 (Vriend and Barrett 1978). The loss of approximately 50% of the fawns through predation appears to be a normal event in this province. Despite this high annual loss of neonates the provincial population of pronghorns has shown dramatic capacity for growth. The estimated provincial population in summer increased from 10,627 to 17,953 animals from 1973 to 1977 and from 10,919 to 20,707 animals from 1978 to 1981, respectively (Cook 1981). Clearly, predation has not limited the population growth of pronghorns in Alberta at recent levels of predator and prey densities.

Several management considerations should be recognized. Severe winters appear to be one of the primary factors controlling pronghorn numbers in Alberta (Barrett 1982). Because of periodic large die-offs in winter, pronghorns may never approach carrying capacity, and consequently, populations are not self regulating. Predation on fawns may limit recruitment and retard population recovery but it does not regulate ultimate population growth. Although predation is likely a non-compensatory source of fawn mortality it should have no significant long-term impact on pronghorn populations in Alberta if regulated hunting and quality habitat are retained.

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Table 1. Relationship between the age and the minimum daily movement of telemetered fawns.

Age group (days)	N	Minimum daily movement of fawns (m) $\bar{x}$	SE
1-3	49	536.9	81.9
4-7	182	495.7[b]	33.5
8-15	347	657.7	30.8
16-24	306	787.4	41.9
25-40	434	1000.3[a]	42.4
>40	327	1793.1[a,c]	118.0

[a] Means significantly ($P < 0.05$) greater than other 4.

[b] Mean significantly ($P < 0.05$) less than others.

[c] Mean significantly ($P < 0.05$) greater than others.

Table 2. Relationship between the age of bedded pronghorn fawns and the flight distance from approaching personnel.

Age group (days)	N	Flight distance from personnel (m)		
		$\bar{x}$[a]	Minimum distance	Maximum distance
0-3	0	0	0	0
4-7	15	14.8	0.9	45.7
8-15	51	13.2	0.6	36.6
16-24	27	23.3	3.0	68.5
25-40	63	187.6	4.6	804.7
>40	30	213.8	32.0	1609.3

[a] Distance between personnel and bedding site when fawn fled.

Table 3. Relationship between the age of bedded telemetered fawns and the distance to the nearest adult female pronghorn.

Age group (days)	N	Distance to dam (m) $\bar{x}$	SE
1-3	75	269	49.8
4-7	138	244	18.0
8-15	234	250	12.8
16-24	165	240	16.3
25-40	136	131[a]	18.0
>40	36	117[a]	78.1

[a] Means are significantly ($P < 0.05$) less than remaining four using Duncan's multiple range test.

Table 4. Location of pronghorn fawns with respect to vegetative types in southeastern Alberta.

Vegetation type	Sagebrush plants/ 60m transect	Bedding sites found	
		N	%
NGP[a]-sparce sagebrush	<3	728	42.7
NGP-light sagebrush	3-10	674	39.6
NGP-medium sagebrush	11-25	134	7.9
NGP-heavy sagebrush	>25	53	3.1
Stubble field		19	1.1
Summer fallow		32	1.9
Seeded field		16	0.9
Tame pasture		18	1.1
Abandoned cultivation		26	1.5
Others		3	0.1
Totals		1703	100.0

[a] NGP-native grass prairie

Table 5. Relationship between the age of telemetered fawns and their distance from the nearest stand of sagebrush.

Age group (days)	N	Distance to sagebrush (m) $\bar{x}$	SE
1-3	33	111.6[a]	39.9
4-7	104	183.0[a]	27.3
8-15	184	233.7	24.9
16-24	154	338.1	34.0
25-40	205	314.1	25.8
>40	93	379.5[b]	58.6

[a] Means significantly ($P < 0.05$) less than remaining four.

[b] Mean significantly ($P < 0.05$) greater than others.

Table 6. Relationship between the age of telemetered pronghorn fawns and their location with respect to available vegetative cover.

Age group (days)		NGP-sparce sage-brush	NGP-light sage-brush	Heavy native vegetat.	Cultiv. land	Chi-square probab.
0-3	Observed[a]	27	49	11	6	<0.03
	Expected[b]	38	38	7	9	
4-7	Observed	69	79	31	19	<0.001
	Expected	80	81	15	20	
8-15	Observed	164	125	43	15	<0.0001
	Expected	141	142	27	34	
16-24	Observed	154	119	16	17	<0.001
	Expected	125	126	24	30	
25-40	Observed	196	169	50	17	<0.0001
	Expected	176	177	34	42	
>40	Observed	118	133	39	37	<0.03
	Expected	113	134	26	32	
All ages	Observed	728	694	190	111	<0.0001
	Expected	696	701	136	168	

[a] Actual count of the number of fawns per age group observed on the specified habitat types.

[b] Expected count based on the proportion of the total study area composed of the specified habitat types.

Table 7. Relationship between the age of telemetered pronghorn fawns and mortality from predation.

Age group (days)	No. of animal days	No. of mortalities	Mortalities per 100 animal days
1-3	72	0	0
4-7	165	4	2.4
8-15	321	9	2.9
16-24	288	5	1.7
25-40	412	5	1.2
41-57	234	4	1.7
All ages	1492	27	1.8

Figure 1. Location of pronghorn fawn study area and a computerized representation of the distribution of vegetative types within the area.

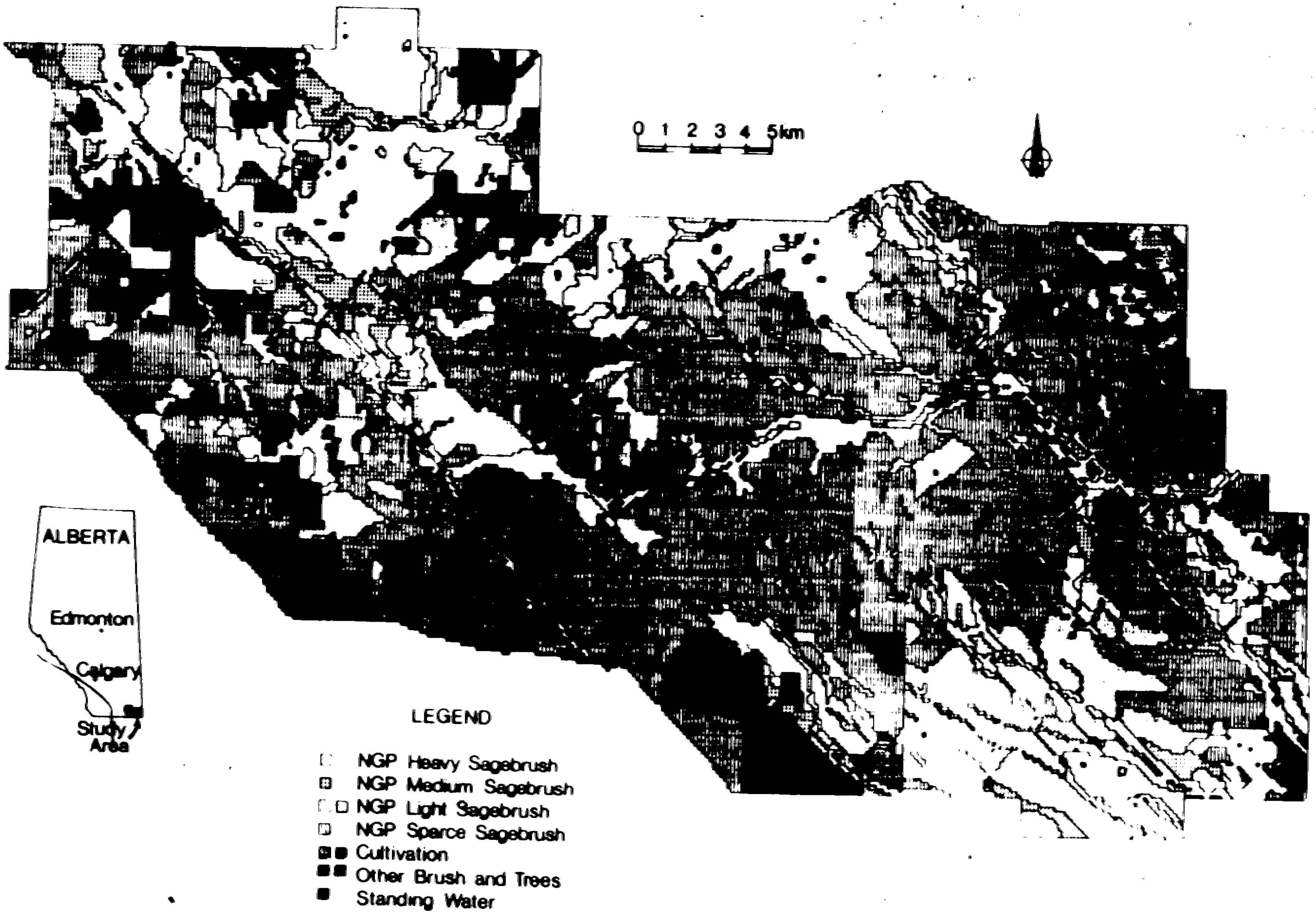

0 1 2 3 4 5km
ALBERTA
Edmonton
Calgary
Study Area
LEGEND
NGP Heavy Sagebrush
NGP Medium Sagebrush
NGP Light Sagebrush
NGP Sparce Sagebrush
Cultivation
Other Brush and Trees
Standing Water

Figure 2. Spatial relationship between pronghorn siblings expressed as a function of age.

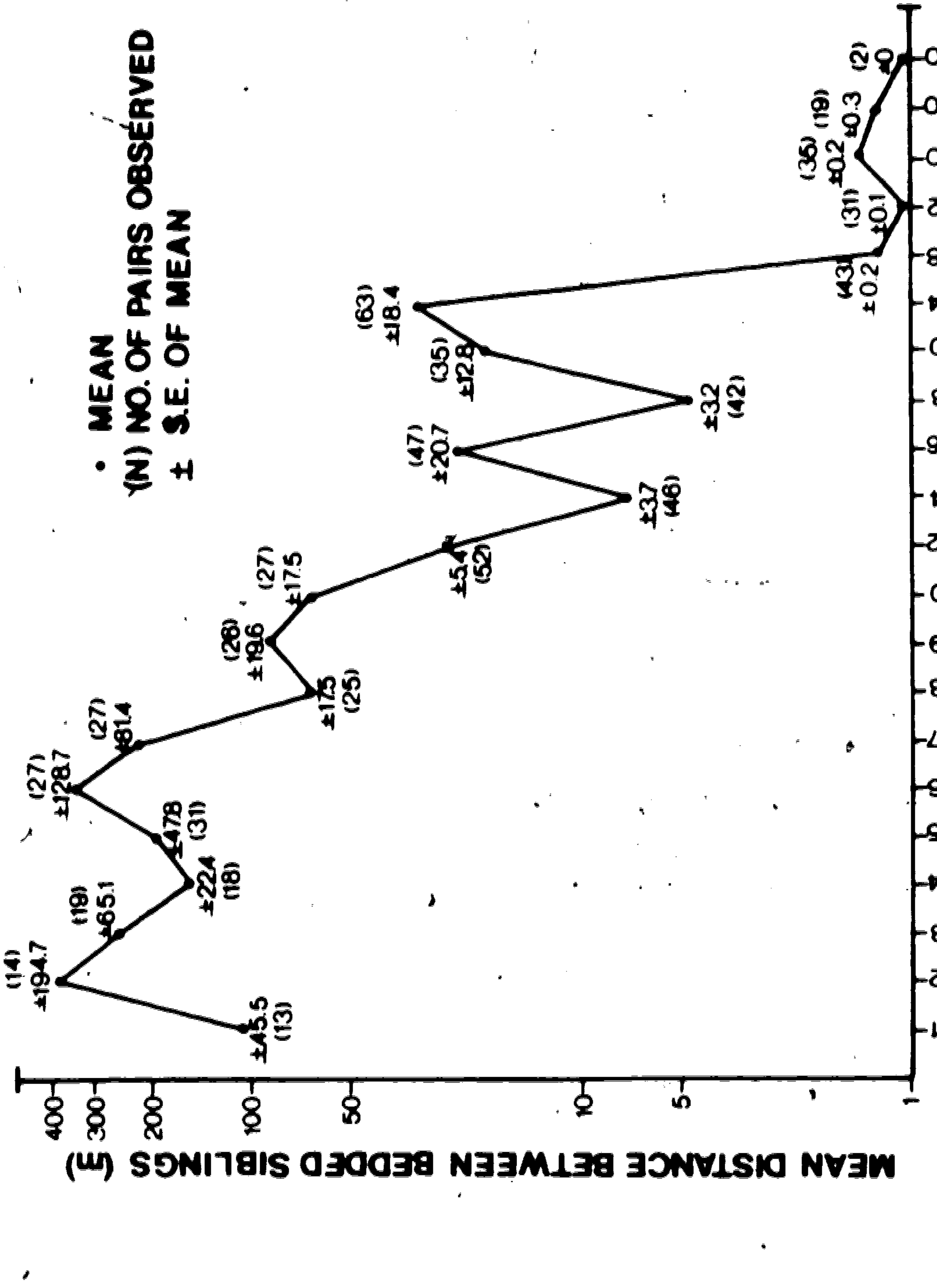
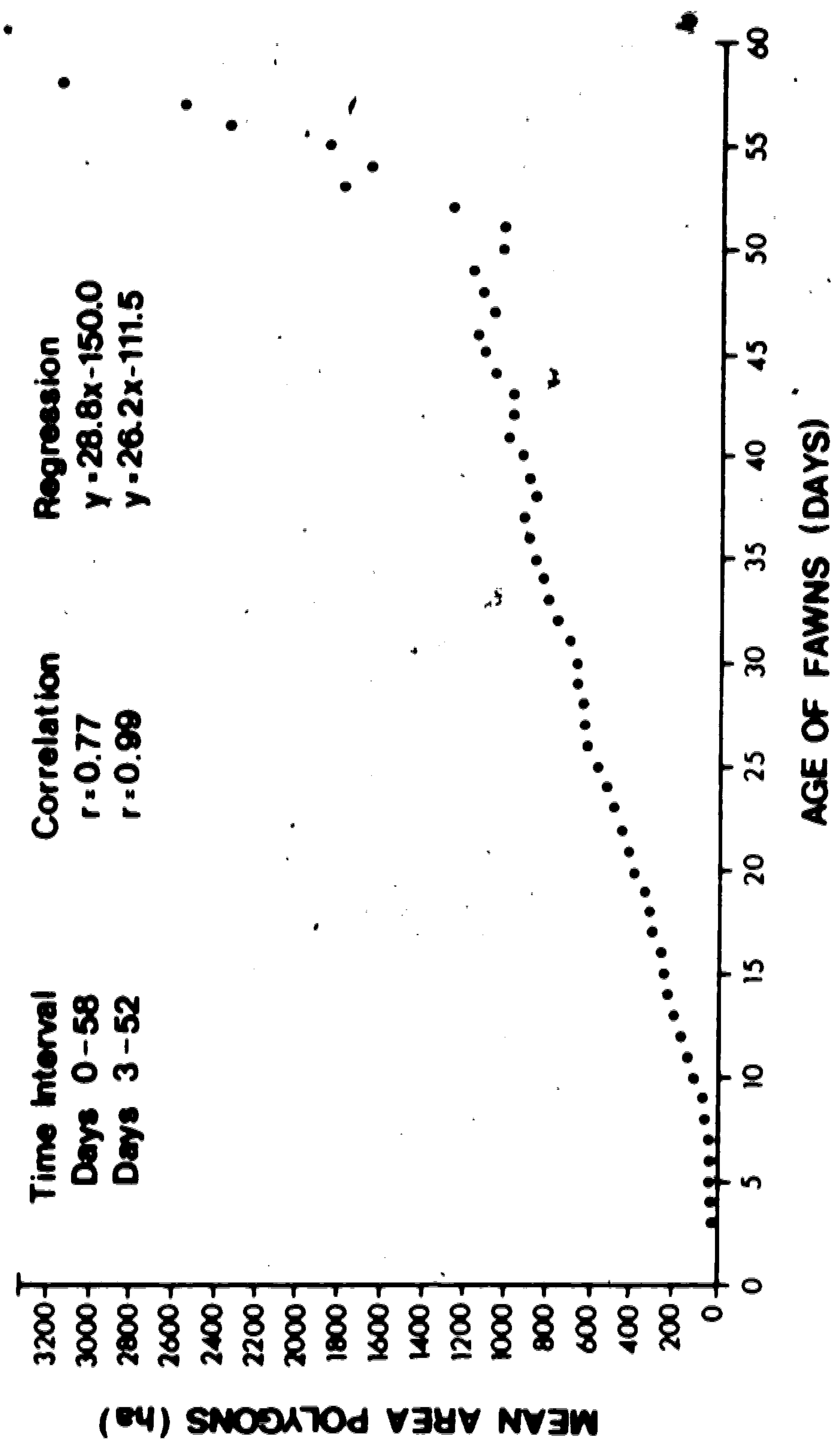

• MEAN
(N) NO. OF PAIRS OBSERVED
± S.E. OF MEAN
MEAN DISTANCE BETWEEN BEDDED SIBLINGS (m)
400
300
200
100
50
10
5
1
AGE GROUP (DAYS)
1
2
3
4
5
6
7
8
9
10
11-12
13-14
15-16
17-18
19-20
21-24
25-28
29-32
33-40
41-50
>50
±45.5 (13)
(14) ±194.7
(19) ±65.1
±22.4 (18)
±47.8 (31)
(27) ±128.7
(27) ±81.4
±17.5 (25)
(26) ±19.6
(27) ±17.5
±5.4 (52)
±3.7 (46)
(47) ±20.7
±3.2 (42)
(35) ±12.8
(63) ±18.4
(43) ±0.2
(31) ±0.1
(35) ±0.2
(19) ±0.3
(2) ±0

Figure 3. Mean cumulative minimum area polygons for radio marked pronghorn fawns in Alberta.


Time Interval
Days 0-58
Days 3-52
Correlation
r=0.77
r=0.99
Regression
y=28.8x-150.0
y=26.2x-111.5
MEAN AREA POLYGONS (ha)
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
45
50
55
60
AGE OF FAWNS (DAYS)

LITERATURE CITED

Arrington, O.N. and A.E. Edwards. 1951. Predator control as a factor in antelope management. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 16:179-193.

Autenrieth, R.E. 1976. A study of birth sites selected by pronghorn does and the bed sites of fawns. Proc. Bienn. Pronghorn Antelope Workshop. 7:127-134.

_________. 1980. Vulnerability of pronghorn fawns to predation. Abstract. Proc. Bienn. Pronghorn Antelope Workshop. 9:77-78.

_________, and E. Fichter. 1975. On the behavior and socialization of pronghorn fawns. Wildl. Monogr. 42:111 pp.

Barrett, M.W. 1978. Pronghorn fawn mortaility in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 8:429-444.

_________. 1981. Environmental characteristics and functional significance of pronghorn fawn bedding sites in Alberta. J. Wildl. Manage. 45:120-131.

_________. 1982. Distribution, behavior and mortality of pronghorns during a severe winter in Alberta. J. Wildl. Manage. 46: In press.

Beale, D.M. 1978a. Birth rate and fawn mortality among pronghorn antelope in western Utah. Abstract. Proc. Bienn. Pronghorn Antelope Workshop. 8:445-448.

_________. 1978b. Participant in discussion on pronghorn fawn mortality. Proc. Bienn. Pronghorn Antelope Workshop. 8:444.

_________, and A.D. Smith. 1973. Mortality of pronghorn antelope fawns in western Utah. J. Wildl. Manage. 37:343-352.

Bodie, W.L. 1978. Pronghorn fawn mortality in the upper Pahsimeroi River drainage of central Idaho. Proc. Bienn. Pronghorn Antelope Workshop. 8:417-428.

_________. 1979. Mortality of pronghorn fawns in the Upper Pahsimeroi River valley. M.S. Thesis Univ. Montana. Missoula. 98 pp.

_________, and B.W. O'Gara. 1980. A description of "Weak fawn syndrome in pronghorn antelope". Proc. Bienn. Pronghorn Antelope Workshop. 9:59-70.

Bowns, J.E. 1976. Field criteria for predator damage assessment. Utah Science. 37:26-30.

Bromley, P.T. 1967. Pregnancy, birth, behavioral development of the fawn, and territoriality in the pronghorn (Antilocapra americana Ord) on the National Bison Range, Moiese, Montana. M.S. Thesis, Univ. Montana, Missoula. 132 pp.

_________. 1977. Aspects of the behavioral ecology and sociobiology of the pronghorn (Antilocapra americana). Ph.D. Thesis. Univ. Calgary, Alberta. 370 pp.

_________. 1978. Ultimate factors, behavior and fawn recruitment. Proc. Bienn. Pronghorn Antelope Workshop. 8:449-471.

Bruns, E.H. 1970. Winter predation of golden eagles and coyotes on pronghorn antelopes. Can. Field Nat. 84:301-304.

Cook, A.R. 1981. Antelope aerial survey and population analysis, July 20-28, 1981. Alberta Energy and Natural Res., Fish and Wildl. Div. Rep. 162 pp.

Cook, R.S., M. White, D.O. Trainer, W.C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas J. Wildl. Manage. 35:47-56.

Connolly, G.E. 1978. Predators and predator control. Pages 369-394. in J.L. Schmidt and D.L. Gilber [illegible] game of North America, ecology and managemen [illegible] Books, Harrisburg, Pa.

Coupland, R.T. 1950. Ecology of the mixed prairie [illegible] Canada. Ecol. Monogr. 20:271-315.

________. 1961. A reconsideration of grassland classification in the northern Great Plains of [illegible] ica. J. Ecol. 19:135-167.

Dorrance, M.J. and L.D. Roy. 1976. Predation losses of domestic sheep in Alberta. J. Range Manage. 29:457-460.

Fichter, E. 1974. On the bedding behavior of pronghorn fawns. In The Behavior of ungulates and its relationship to management. V. Geist and F. Walther, Eds. Vol. I and II. IUCN Public. 24. Morges, Switzerland. 352-355.

________, and R.E. Autenrieth. 1980. More on pronghorn groups. Abstract. Proc. Bienn. Pronghorn Antelope Workshop. 9:292-293.

Giles, R.H. 1971. Wildlife management techniques, 3 rd. ed. The Wildl. Soc. Washington, D.C. 633 pp.

Gashwiler, J.S., W.L. Robinette, and O.W. Morris. 1960. Foods of bobcats in Utah and eastern Nevada. J. Wildl. Manage. 24:226-229.

Henne, D.R. 1975. Domestic sheep mortality on a western Montana ranch. M.S. Thesis. Univ. Montana, Missoula. 53 pp.

Kitchen, D.W. 1974. Social behavior and ecology of the pronghorn. Wildl. Monogr. 38. 96 pp.

Knowlton, F.F. 1968. Coyote predation as a factor in management of antelope in fenced pastures. Proc. Bienn. Pronghorn Antelope Workshop. 3:65-74.

Mitchell, G.J. 1980. The pronghorn antelope in Alberta. University Regina. Regina, Sask. Monogr. 165 pp.

_________, and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta.. J. Wildl. Manage. 35:238-250.

Mech, L.D. 1967. Telemetry as a technique in the study of predation. J. Wildl. Manage. 31:492-496.

Neff, D.J., and N.G. Woolsey. 1979. Effect of predation by coyotes on antelope fawn survival on Anderson Mesa. Arizona Game and Fish Depart. Special Rep. 8:36 pp.

_________, and _________. 1980. Coyote predation on neonatal fawns on Anderson Mesa, Arizona. Proc. Bienn. Pronghorn Antelope Workshop. 9:80-93.

Nie, N.H., C.H. Hull, J.G. Steinbrenner, and D.H. Bent. 1975. Statistical package for the social sciences, 2nd ed. McGraw-Hill Book Co., New York. 675 pp.

O'Gara, B.W. 1978. Differential characteristics of predator kills. Proc. Bienn. Pronghorn Antelope Workshop. 8:380-393.

Pyrah, D. 1970. Antelope herd ranges in Central Montana. Proc. Bienn. Pronghorn Antelope Workshop. 4:16-20.

________. 1974. Antelope fawn bedding cover selection in central Montana. Proc. Bienn. Pronghorn Antelope Workshop. 6:113-121.

Rand, A.L. 1947. The 1945 status of the pronghorn antelope, Antilocapra americana (Ord), in Canada. National Museum Canada. Ottawa. Bull. 106. 34 pp.

Roy, L.D., and M.J. Dorrance. 1976. Methods of investigating predation of domestic livestock. Alberta Agric. Res. Rep. Edmonton. 54 pp.

Smith, A.D., and D.M. Beale. 1980. Pronghorn antelope in Utah: some research and observations. Utah Div. Wildl. Resources, Publ. 80-13:88 pp.

Soper, J.D. 1964. The mammals of Alberta. Queens Printer, Edmonton. 402 pp.

Todd, A. 1977. The status of coyotes in Alberta. Alberta Recreation, Parks and Wildl., Fish and Wildl. Div. Rep. Edmonton. 14 pp.

Von Gunten, B.L. 1978. Pronghorn fawn mortality on the National Bison Range. Proc. Bienn. Pronghorn Antelope Workshop. 8:394-416.

Vriend, H.G., and M.W. Barrett. 1978. Low fawn recruitment - Is it an issue? Proc. Bienn. Pronghorn Antelope Workshop. 8:360-379.

White, M. 1973. Description of remains of deer fawns killed by coyotes. J. Mammal. 54:291-293.

Yoakum, J. 1972. Antelope - vegetative relationships. Proc. Bienn. Pronghorn Antelope Workshop. 5:171-179.

__________. 1978. Pronghorn. Pages 103-121. in J.L. Schmidt and D.L. Gilbert eds. Big game of North America, ecology and management. Stackpole Books, Harrisburg, PA.

Chapter 3. Seasonal herd size and habitat associations of pronghorns in Alberta

Abstract: Habitat associations and herd size of pronghorn (Antilocapra americana) in Alberta were determined over a 6 year period. Largest herd sizes (>50 animals per herd) and heavy use of ranges containing silver sagebrush (Artemisia cana) were documented during winter. The major vegetation types occurring in the key winter ranges of pronghorns are presented. Grassland ranges with >10 sagebrush plants per 60 m transect were preferred by pronghorns but these areas represented only 9.2% of the area of winter ranges. The distribution of pronghorns within winter ranges demonstrated that areas containing sagebrush were utilized more consistently over a period of years. The maximum land area under cultivation within any winter range was 21.4%. Pronghorn use of sagebrush was determined during 4 winters within a 200 ha enclosure and provided a regression ($r^2 = 0.97$) for estimating from browse analysis, the average winter densities of pronghorns. Length - weight relationships of sagebrush leaders were measured. Reduced growth of sagebrush may result as a consequence of heavy winter browsing by pronghorns.

INTRODUCTION

Numerous researchers have investigated the food habits of pronghorns on specific study areas in northern ranges (Dirschl 1963; Bayless 1969, Mitchell and Smoliak 1971, Barrett 1974). Collectively, these studies indicated that forbs were consumed year round by pronghorns and that browse, primarily sagebrush (Artemisia spp.), was heavily utilized during winter. The seasonal distribution of pronghorns, described by Barrett and Vriend (1980), revealed the existence and location of key winter ranges. Little information is available on the important seasonal habitat relationships of pronghorns on northern ranges. Use of sagebrush by pronghorns on open ranges has been reported by Barrett (1974) and by Wiltse (1978). Measurements of the use of sagebrush by a known density of pronghorns under near natural conditions, however, has not been reported previously.

This study describes the habitat associations of pronghorns with particular emphasis on vegetative cover available on winter ranges. This information should facilitate recognition of habitat types deemed to be critical to pronghorns in Alberta and presumably, on other northern ranges. The specific objectives of this study were to describe: 1) the seasonal habitat associations and herd structure of pronghorns; 2) the habitat types within winter ranges; and 3) some of the relationships between pronghorn density and the use and growth of sagebrush.

Portions of this study were conducted over the entire pronghorn range within Alberta. This area conforms largely to Brown and Dark Brown soil zones. General descriptions of the area have been presented by Coupland (1950; 1961) and by Mitchell and Smoliak (1971). Pronghorn range within Alberta is part of the mixed-grass prairie region (Webb et al. 1967). From 1973 to 1977, the relationships between the density of pronghorns and the use of sagebrush were investigated within a 200 ha enclosure in southeastern Alberta; the vegetation within this enclosure has been described previously (Barrett 1979).

METHODS

While conducting a variety of investigations, project personnel spent in excess of 2000 man-days throughout the range of pronghorns in Alberta from 1971 to 1977, inclusive. When pronghorns were observed, the herd size, herd composition, predominant activity, and habitat association of each group were recorded. Habitat associations were separated into 4 major classifications of vegetation, namely: 1) native grass prairie (NGP)- sparce sagebrush (<3 sagebrush plants per 60 m linear transect); 2) NGP-light sagebrush cover (3 - 10 sagebrush plants per 60 m linear transect); 3) NGP-heavy sagebrush cover (>10 sagebrush plants per 60 m linear transect); and 4) cultivated lands (includes summerfallow, cereal crops and tame pasture).

The key wintering areas in Alberta as described by Barrett and Vriend (1980) were examined using aerial photography to determine the major vegetation types present; the vegetative types in all areas were ground truthed. The distribution of pronghorns in winter relative to these vegetation types was recorded. Nine vegetative cover types were identified within the winter ranges.

NGP was divided into four categories based on the number of sagebrush plants intercepted by a randomly selected 60 m linear transect. The 4 categories, NGP sparce sagebrush, NGP-light sagebrush, NGP-medium sagebrush, and NGP-heavy sagebrush reflected densities of <3, 3 - 10, 11 - 25 and >25 plants per transect, respectively. Cultivated land was divided ihto 1) forage or tame pasture areas, and 2) lands used to produce cereal crops. Lands covered by stands of trees such as aspen (Populus tremuloides) and willow (Salix spp.) and covering more than ½ ha in area were noted. Brushland included lands covered with low brush species other than sagebrush and were usually dominated by snowberry (Symphoricarpos occidentalis), rose (Rosa spp.) and silverberry (Eleagnus commutata). Water bodies referred to areas covered year round by water.

The names for the winter ranges follow those presented by Barrett and Vriend (1980). The distribution of pronghorns relative to major habitat types is presented for the Walsh winter range and is generally representative of findings on the remaining wintering areas.

Habitat mapping of all winter ranges was accomplished initially using aerial photography. Mapped habitat types were confirmed by extensive ground truthing in each winter range. Mapping was completed on a 1:50,000 map scale. Areas of the winter ranges and the habitat types were calculated using both a planimeter and a 1:50,000 scale dot grid. Calculations were done in duplicate and results were replicable to within a 4% error factor. The entire range of pronghorns in Alberta was examined using 1970 aerial photographs and the percentage of the area in native rangeland and area under some form of cultivation was determined.

Pronghorn use of sagebrush was investigated within a 200 ha enclosure in which winter densities of pronghorns between 1973 and 1977 were maintained between 4.4 and 13.0 animals per km^2. With the exception of an occasional visit by a mule deer (Odocoileus hemionus), pronghorns were the only large herbivore to use the enclosure. Habitat mapping followed the procedure used for the winter ranges. Random browse transects were established within the sagebrush areas of the enclosure and the percentage of leaders browsed during winter was determined in April of each year (Cole 1963). A linear regression was calculated for the density of pronghorns based on the percentage of sagebrush stems clipped.

The length of unbrowsed sagebrush leaders was examined in relation to 3 previous grazing regimes, namely, 1) spring and summer use by cattle, 2) year round use by pronghorns, and 3) no use. The no-use areas were within exclosures and the cattle-use area was outside the pronghorn enclosure. The length - weight relationships for sagebrush stems was determined using the current year's growth on unbrowsed sagebrush plants within the pronghorn enclosure.

RESULTS

Herd Size and Habitat Associations

The mean herd size of pronghorns was markedly lower in the 7 month period from April to October and higher during the winter months (Fig. 1). Pronghorns were more widely distributed and occurred in smaller herds during the month of May than at any other time of the year; that time period coincides with the parturition period for pronghorns in Alberta. During December and January, the mean herd sizes were largest (>50 animals) and pronghorns typically occupied their winter ranges.

During all seasons of the year, approximately 25% of pronghorns were distributed on NGP-light sagebrush rangelands (Fig. 2). Heavy sagebrush cover was used by >40% of the animals from December to March. Conversely, during the winter months the proportion of pronghorns using NGP rangelands diminished sharply (<20% of animals). Cultivated land was used by <15% of animals in all months except in October and November when nearly 25% of pronghorns sought fall seeded crops and stubble fields.

Increased use of sagebrush communities in late fall coincided with the dramatic increase in mean herd size (Fig. 1). During that period, pronghorns moved from their summer to winter ranges. Conversely, in late winter the process reversed, as pronghorns dispersed from their wintering areas, separated into small groups and increased their use of NGP (Fig. 2). Occupation of predominantly grassland ranges during the summer months does not imply that pronghorn were consuming primarily grasses but rather that their forage was selected from a grassland community.

Vegetation Types in Winter Ranges

The key winter ranges for pronghorns as reported by Barrett and Vriend (1980) are outlined in Figure 3. Detailed habitat mapping was conducted on all winter ranges except the Suffield, Murray Lake and Canal Creek areas. Native grasslands represented the largest single land use type (42.5%) and grassland with light sagebrush was the next most abundant type (30.1%) (Table 1). Medium and heavy sagebrush communities, while exceedingly important to wintering pronghorns, represented only 9.2% of the area of the winter ranges. Cultivated lands represented 12.2% of the area of the winter ranges (Table 1) but 29.6% of the area within the total pronghorn range in Alberta.

The major habitat types and the size of the different winter ranges are summarized in Table 2. Cultivation was virtually absent in the Lodge Creek wintering area but represented a high of 21.4% of the Walsh wintering area. Sagebrush rangelands varied from a low of 4.6% in the Milk River Ridge wintering area to a high of 56.5% in the Lake Newell wintering area.

The Walsh winter range illustrates the importance of the different habitat types. The distribution of pronghorns during winter was determined over a 5 year period and specific high use areas identified (Fig. 4). Habitat mapping of the same area revealed that the high use areas also contained a high proportion of sagebrush rangelands and a moderate proportion of grassland range (Fig. 5). Areas that were predominantly under cultivation were seldom reported as high use areas within a winter range. Furthermore, no areas of the province with more than 25% of the land area in cultivation were used consistently as wintering areas by pronghorns.

Pronghorn - Sagebrush Relationships

The relationship between pronghorn density and the use of sagebrush was determined within a 200 ha enclosure constructed on a portion of the Lodge Creek winter range (Fig. 6). Habitat mapping revealed that 40% of the area was native grassland, and 23, 17 and 19% was NGP-light, NGP-medium, and NGP-heavy sagebrush, respectively. Mean over-winter densities varied from 4.4 to 13.0 animals per km^2. The percentage of leaders browsed during winter ranged between 24.1 and 80.4% (Table 3). A significant ($r^2 = 0.97$) linear regression of mean over-winter density of pronghorns and use of sagebrush leaders was developed (Fig. 7).

Nearly half of the weight of sagebrush stems occurred in the leaves and distal ½ of the annual growth (Table 4). Only 31% of the weight of the annual growth was contained in the proximal ½ of the stems. Browsing pressure that removes most of the leaves and half of the length of annual growth is indicative of heavy use.

Summer grazing by cattle stocked at 27 ha per animal unit on open range had no measurable impact on the growth of sagebrush. Heavy use of sagebrush by pronghorns during the winters of 1975-76 and 1976-77, (Table 3) appeared to be responsible for reduced growth of sagebrush during the following summer (Table 5). Reduced growth of leaders in all areas sampled during 1976 was attributable to arid conditions.

DISCUSSION

Selection of forage by pronghorns in Alberta was described by Mitchell and Smoliak (1971) and to a lesser degree by Bruns (1969, 1977) and Barrett (1974). The habitat associations of pronghorns presented in this paper indicate preferences for specific vegetative types. Wiltse (1978) reported habitat associations for pronghorns in Saskatchewan but presented no monthly or seasonal breakdown. Over 72% of 9,044 animals observed in Saskatchewan were on native rangeland and of these, most were observed on a sagebrush-grassland association (Wiltse 1978). The seemingly high preference and perhaps dependence of pronghorns on sagebrush-rangelands in winter underscore the need to maintain this important vegetative type in Alberta.

The formation of large herds of pronghorns in winter has been reported previously. Mitchell (1980) observed a smaller number of herds in Alberta between 1952 and 1965 and reported findings similar to mine with respect to general seasonal trends, however, extensive differences occurred in the monthly herd sizes. Differences in the average density of pronghorns and a very limited sample size for some months could explain some of the variation observed by Mitchell in relation to my findings.

Considerable consistency was noted in the annual chronology of movements to and from winter ranges but early snowfall hastened the formation of large herds in fall. Hoskinson and Tester (1980) suggested that decreasing moisture content of forage provides the stimulus for movement of pronghorns in the fall. Similarly, dispersal of pronghorns in late winter appeared to be inversely related to the persistence of snow cover. During 1974, a late April snowfall in southern Alberta resulted in a return to the winter range of approximately half of the previously dispersed pronghorns. Hoskinson and Tester (1980) reported that spring dispersal of pronghorns appeared to be related to the disappearance of snow in Idaho.

Key wintering areas appear critical to the survival of pronghorns in northern latitudes. Habitat evaluation within these areas should provide managers with priority guidelines for determining and preserving vital ranges. The relationship between the winter distribution of pronghorns and available habitat types further indicates the importance of sagebrush communities in Alberta. During an exceptionally open winter, with little snowfall (1972-73), pronghorns tended to be more widely scattered and showed less dependence on defined winter ranges than in normal winters. During the severe winter of 1977-78, many pronghorns left these winter ranges, apparently in response to heavy accumulations of snow; overwinter mortality was high, but animals that retained access to sagebrush areas fared best (Barrett 1978).

The importance of sagebrush habitat ~~to~~ pronghorns in northern ranges seems indisputable. Browse, predominantly sagebrush, frequently forms more than 75% of the winter diet of pronghorns in northern ranges (Dirschl 1963, Wentland 1968, Bayless 1969, Beale and Smith 1970). During severe winters, browse is particularly critical for pronghorns. Martinka (1967) reported that pronghorns restricted to grasslands in Montana died during a severe winter whereas those with access to sagebrush survived. This dependency on woody browse by pronghorns in severe winters has also been reported by Compton (1970), by McKenzie (1970), and by West (1970).

Browse transects have been used commonly to measure the impact of ungulates on their forage base (Cole 1963, Wiltse 1978). My study provided a regression (Fig. 7) that may assist with the interpretation of data obtained from browse transects conducted on winter ranges. I do not recommend that browse-use surveys of the type described herein be used to estimate the dry matter intake of pronghorns. Future research may reveal that such an application is valid and consequently the length-weight relationships presented in this paper are an initial step in that direction.

Reduced lengths of sagebrush leaders following heavy winter use by pronghorns (Table 5) suggest that these animals can reduce the productivity of their preferred forage. Leaders that had been browsed during the growing season in which they were measured, were, of course, excluded from these samples. This preliminary information suggests that additional research is required to study mechanisms by which pronghorns alter their habitat. Compton (1970) noted previously that heavy use of sagebrush on winter ranges increased the vulnerability of animals to winter kill. If heavy utilization in one winter results in reduced sagebrush production in the following year, the problem compounds itself.

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Table 1. Summary of habitat occurring on pronghorn winter ranges in Alberta.

Habitat type	Sagebrush plants/60 m transect	Total area (km^2)	Proportion of winter range (%)
Native grass prairie (NGP)	<3	1251.5	42.5
NGP-light sagebrush	3-10	885.9	30.1
NGP-medium sagebrush	11-25	161.2	5.5
NGP-heavy sagebrush	>25	108.5	3.7
Cultivation - forage		23.8	0.8
Cultivation - cereal		338.4	11.4
Treed areas		72.2	2.5
Brushland		51.6	1.7
Water bodies		54.0	1.8
Total		2947.3	100

Table 2. Summary of major classifications of vegetation within identified pronghorn winter ranges in Alberta.

Winter range	Area of range (km^2)	Percentage of area vegetated by: Sagebrush rangelands[a]	Grasslands	Cultivated lands
Red Deer River	456.7	31.5	41.3	11.5
South Sask. River	205.4	36.5	54.6	5.8
Walsh Flats	593.8	18.3	52.3	21.4
Lodge Creek	235.7	39.1	55.8	0.5
Sage Creek	283.6	39.9	50.0	7.2
Milk River Valley	336.3	11.9	75.8	8.9
Milk River Ridge	337.5	4.6	73.9	19.9
Grand Forks	151.8	47.1	43.2	7.6
Lake Newel	202.5	56.5	29.3	11.3
Mean	311.5	31.8	52.9	10.5

[a] Sagebrush rangelands includes all areas where sagebrush plants occurred more than 3 times per 60m linear transect.

Table 3. Relationship between pronghorn density and the proportion of sagebrush leaders browsed during winter within a 200 ha enclosure.

		Mean per transect			
Winter period[a]	No. of transects	Stems available	Stems browsed	Percent browsed	Mean density of pronghorns per km²
1973 - 74	2	145	35	24.1	4.4
1974 - 75	14	176	120	68.2	10.5
1975 - 76	14	172	138	80.2	13.0
1976 - 77	14	173	139	80.4	11.5

[a] Transects read in early April.

Table 4. Length weight relationships of 40 sagebrush stems measured in late October[a].

	Leaves	Distal ¼	Disto-medial ¼	Proxo-medial ¼	Proximal ¼	Total
Mean weight (g)	13.1	16.8	12.0	9.1	9.7	60.7
Percent of total weight	21.5	27.7	19.8	15.0	16.0	100

[a] Stems had an average of 7.1 leaders and 27.3 cm of current years growth.

Table 5. Length of sagebrush leaders under different grazing regimes.

Growth year	No. leaders sampled in each type	Leader length after growing season (cm)		
		Open cattle range[a]	Pronghorn enclosure[b]	Ungrazed areas
1976	400	6.7	5.2	6.9
1977	400	10.3	7.0	9.2

---

[a] Stocking rate approximately 27 ha per animal unit (cattle).

[b] Stocking rate approximately 8 ha per animal unit (pronghorns).

Figure 1. Mean monthly herd size for 80,866 pronghorns observed in Alberta over a 6 year period.

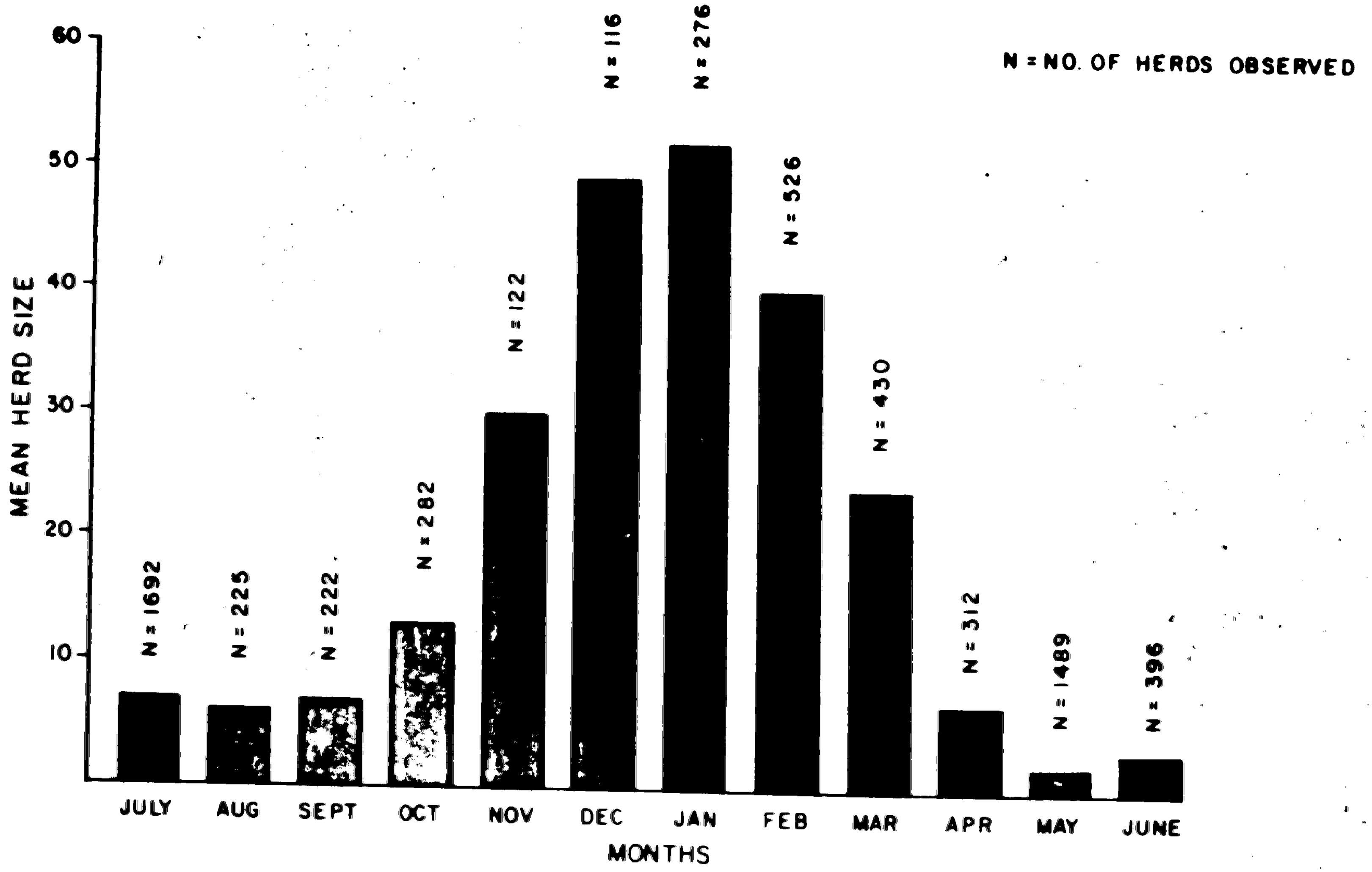
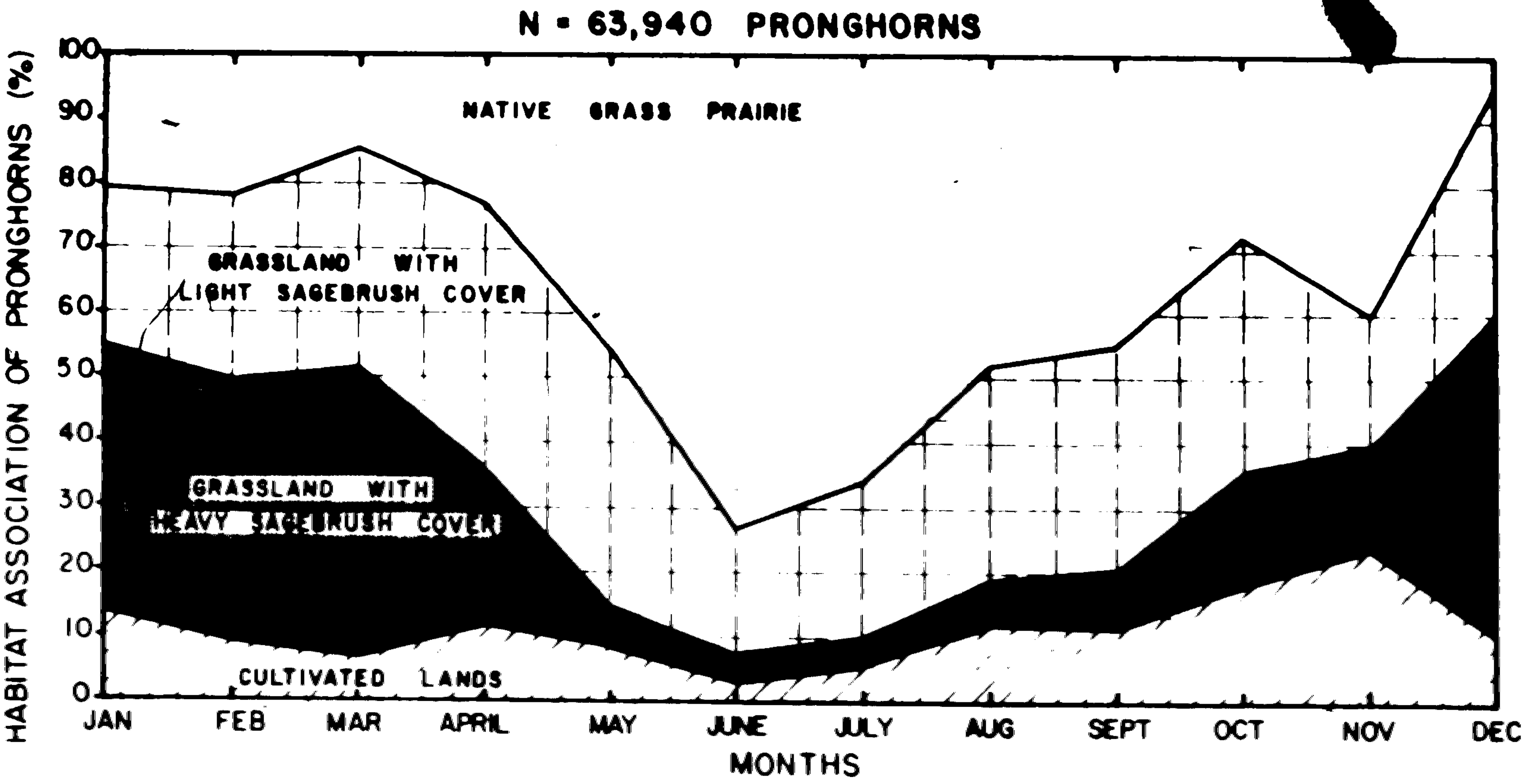
N = NO. OF HERDS OBSERVED
MEAN HERD SIZE
60
50
40
30
20
10
N = 1692
N = 225
N = 222
N = 282
N = 122
N = 116
N = 276
N = 526
N = 430
N = 312
N = 1489
N = 396
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
MONTHS

Figure 2. Monthly distribution of pronghorns in relation to habitat types as determined over a 6 year period.

Figure 3. Delineation of the summer distribution, and winter ranges of pronghorns in Alberta.


N = 63,940 PRONGHORNS
NATIVE GRASS PRAIRIE
GRASSLAND WITH LIGHT SAGEBRUSH COVER
GRASSLAND WITH HEAVY SAGEBRUSH COVER
CULTIVATED LANDS
HABITAT ASSOCIATION OF PRONGHORNS (%)
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APRIL
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
MONTHS

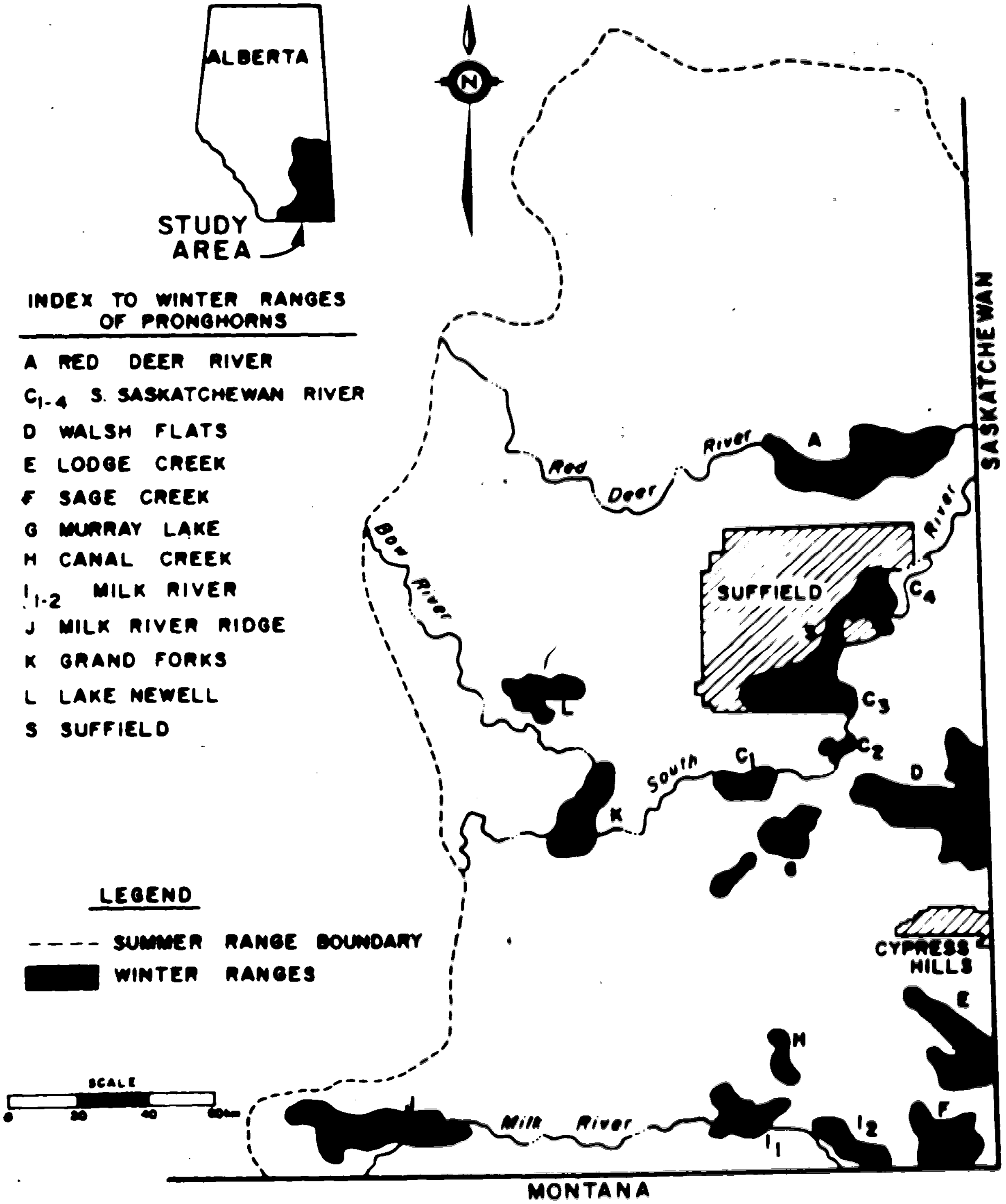

ALBERTA
STUDY AREA
N
INDEX TO WINTER RANGES OF PRONGHORNS
A RED DEER RIVER
C1-4 S. SASKATCHEWAN RIVER
D WALSH FLATS
E LODGE CREEK
F SAGE CREEK
G MURRAY LAKE
H CANAL CREEK
I1-2 MILK RIVER
J MILK RIVER RIDGE
K GRAND FORKS
L LAKE NEWELL
S SUFFIELD
LEGEND
SUMMER RANGE BOUNDARY
WINTER RANGES
SCALE
0
20
40
60km
SASKATCHEWAN
MONTANA
Red Deer River
Bow River
South
River
SUFFIELD
CYPRESS HILLS
Milk River
A
C1
C2
C3
C4
D
E
F
G
H
I1
I2
J
K
L
S

Figure 4. Outline of the Walsh winter range of pronghorns showing the frequency of occupation by pronghorns during a 5 year monitoring period.

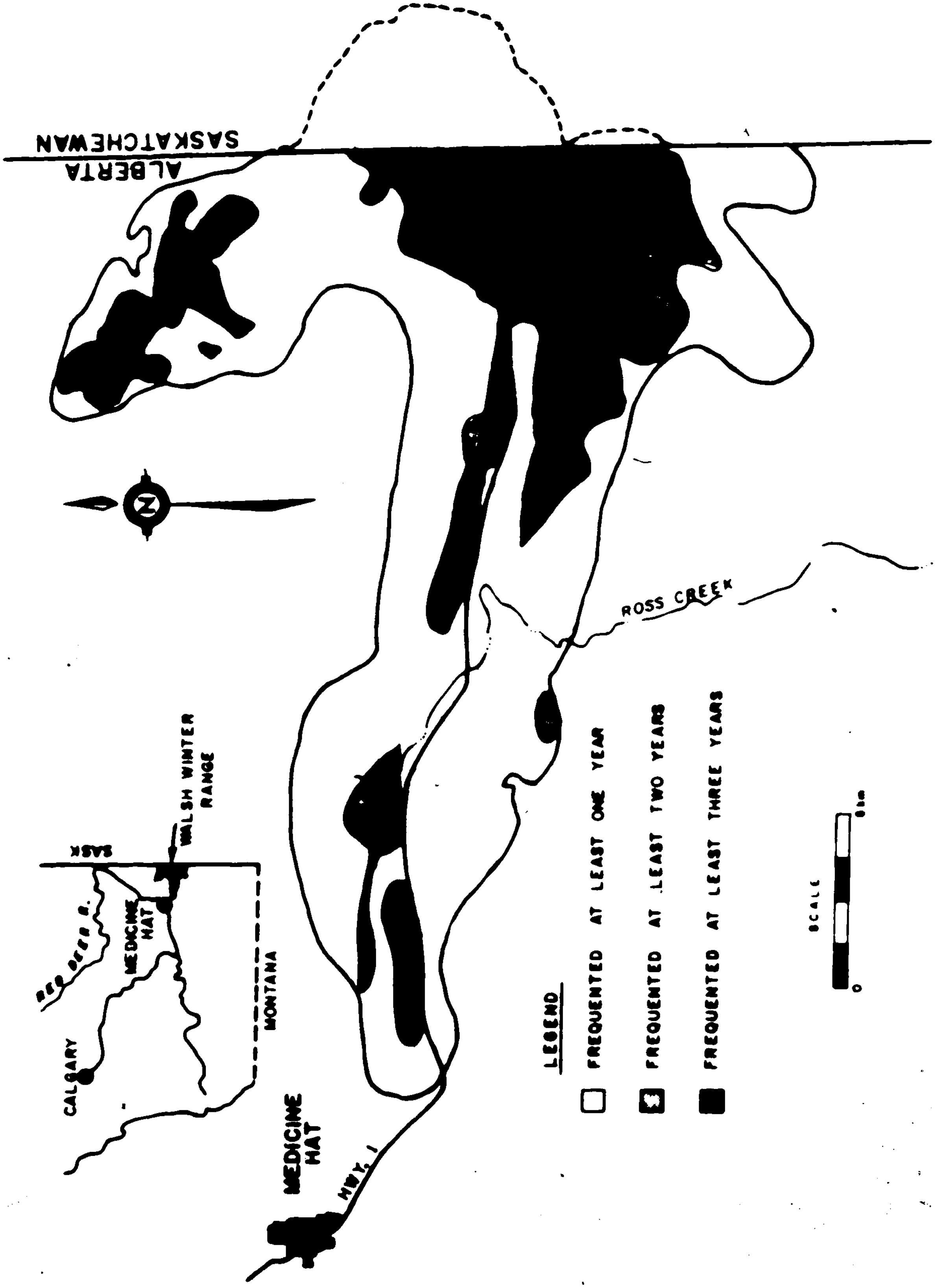

SASKATCHEWAN
ALBERTA
N
ROSS CREEK
MEDICINE HAT
HWY. 1
SASK
WALSH WINTER RANGE
RED DEER R.
MEDICINE HAT
CALGARY
MONTANA
LEGEND
FREQUENTED AT LEAST ONE YEAR
FREQUENTED AT LEAST TWO YEARS
FREQUENTED AT LEAST THREE YEARS
SCALE
0
8 km

Figure 5. Distribution of 3 major types of land classification on the Walsh winter range of pronghorns.

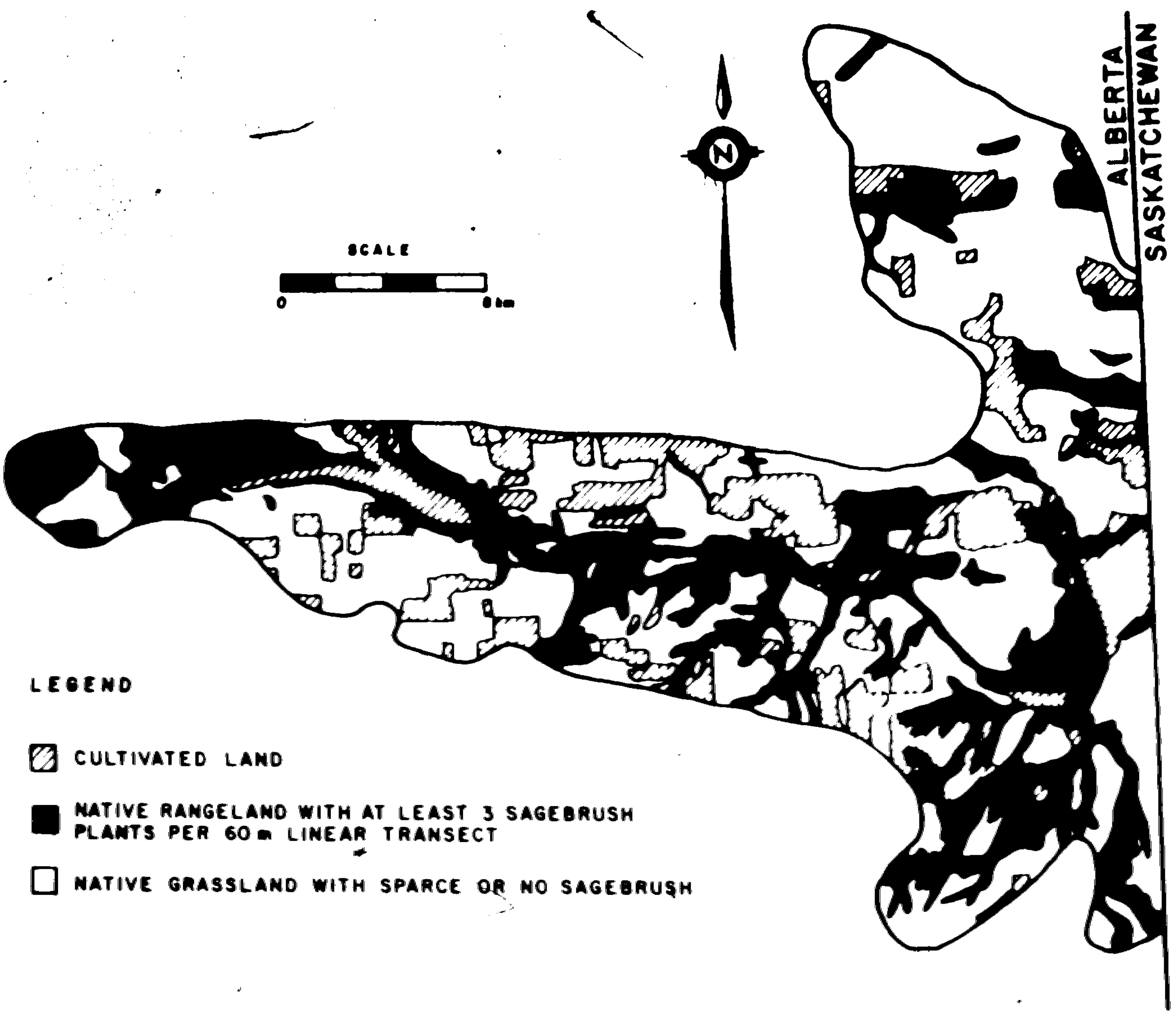

ALBERTA
SASKATCHEWAN
N
SCALE
0
8 km
LEGEND
▨ CULTIVATED LAND
■ NATIVE RANGELAND WITH AT LEAST 3 SAGEBRUSH PLANTS PER 60 m LINEAR TRANSECT
☐ NATIVE GRASSLAND WITH SPARCE OR NO SAGEBRUSH

Figure 6. Vegetative cover within a 200 ha enclosure for pronghorns.

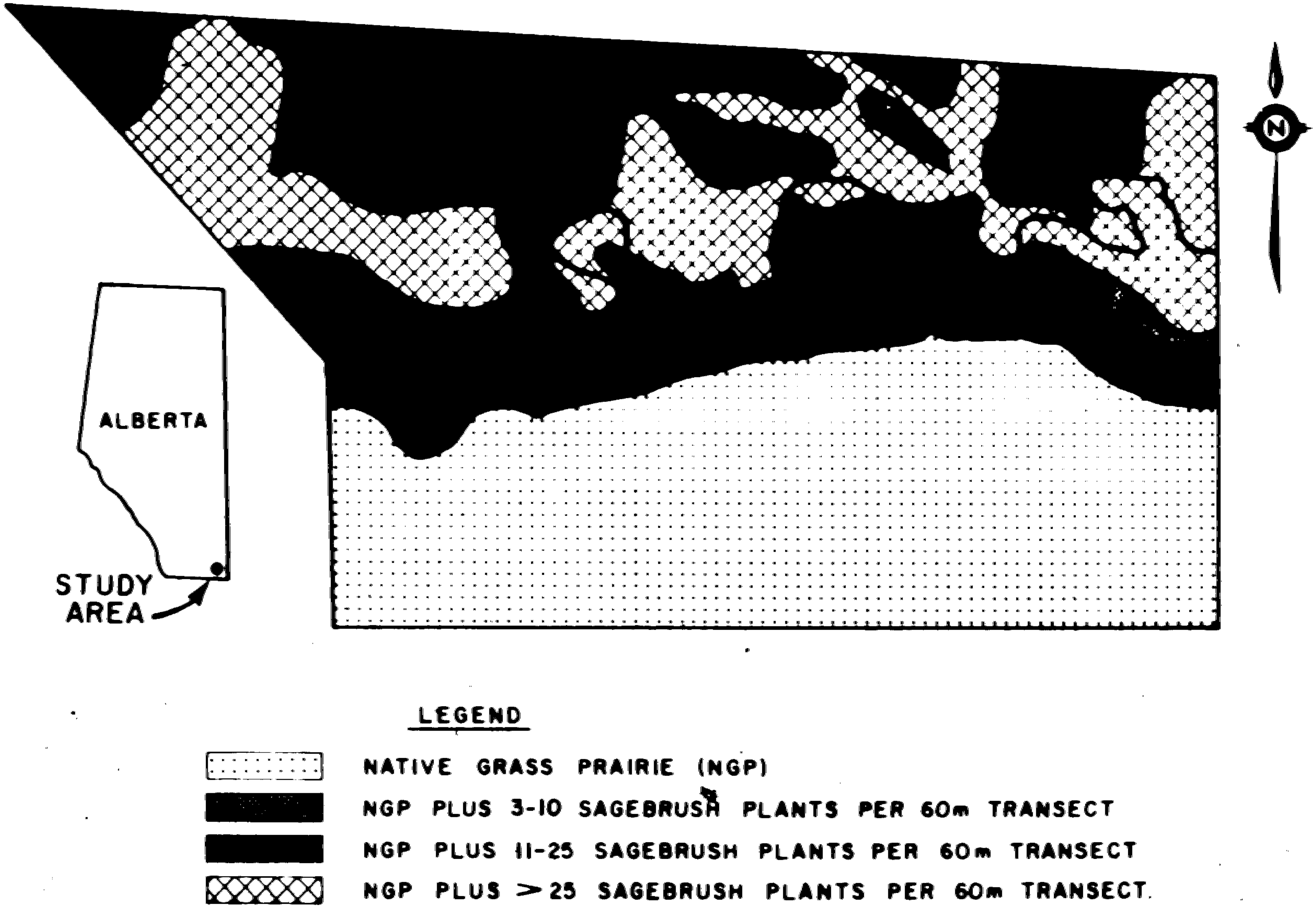
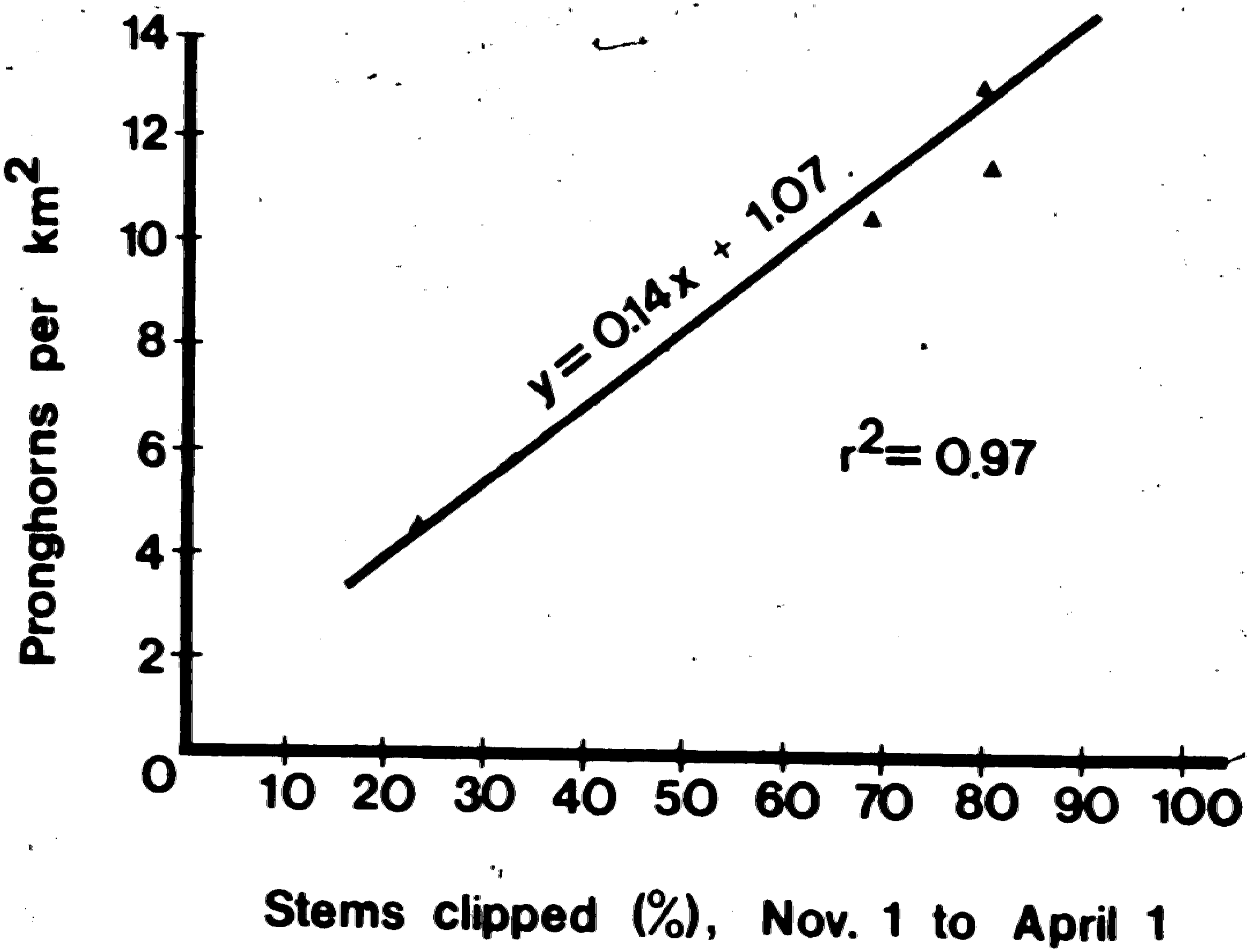

N
ALBERTA
STUDY AREA
LEGEND
NATIVE GRASS PRAIRIE (NGP)
NGP PLUS 3-10 SAGEBRUSH PLANTS PER 60m TRANSECT
NGP PLUS 11-25 SAGEBRUSH PLANTS PER 60m TRANSECT
NGP PLUS > 25 SAGEBRUSH PLANTS PER 60m TRANSECT.

Figure 7. Linear regression of mean-over-winter density of pronghorns on utilization of sagebrush.


Pronghorns per km^2
14
12
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
100
Stems clipped (%), Nov. 1 to April 1
$y = 0.14x + 1.07$
$r^2 = 0.97$

LITERATURE CITED

Barrett, M. W. 1974. Importance, utilization and quality of <u>Artemisia</u> <u>cana</u> on pronghorn winter ranges in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 6:26-57.

____________. 1978. Participant in discussion on the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop. 8:337-359.

____________. 1979. Evaluation of fertilizer on pronghorn winter range in Alberta. J. Range Manage. 32:55-59.

__________, and H. G. Vriend. 1980. Management implications of the distribution of pronghorns and land use practices in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:196-214.

Bayless, S. R. 1969. Winter food habits, range use, and home range of antelope in Montana. J. Wildl. Manage. 33:538-551.

Beale, D.M. and A. D. Smith. 1970. Forage use, water consumption and productivity of pronghorn antelope in western Utah. J. Wildl. Manage. 34:570-582.

Bruns, E. H. 1969. A preliminary study of behavioural adaptations of wintering pronghorn antelopes. M. S. Thesis. Univ. Calgary, Alberta. 60 pp.

__________. 1977. Winter behavior of pronghorns in relation to habitat. J. Wildl. Manage. 41:560-571.

Cole, G. F. 1963. Range Survey guide. U.S. Dept. Int., Nat. Park Service, Moose, Wyoming.

Compton, H. O. 1970. Southeastern Montana antelope population trends in relation to severe winters. Proc. Bienn. Pronghorn Antelope Workshop. 4:50-54.

Coupland, R. T. 1950. Ecology of the mixed prairie in Canada. Ecol. Monogr. 20:272-315.

————————. 1961. A reconsideration of grassland classification ~~in the Northern Great~~ Plains of North America. J. Ecol. 49:135-167.

Dirschl, H.F. 1963. Food habits of the pronghorn in Saskatchewan. J. Wildl. Manage. 27:81-93.

Hoskinson, R. L. and J. R. Tester. 1980. Migration behavior of pronghorn in southeastern Idaho. J. Wildl. Manage. 44:132-144.

Martinka, C. 1967. Mortality of northern Montana pronghorn in a severe winter. J. Wildl. Manage. 31:159-164.

McKenzie, J. V. 1970. Two "killer winters" 1964 - 1965 and 1968 - 1969, in North Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:36-40.

Mitchell, G. J. 1980. The pronghorn antelope in Alberta. University Regina, Regina, Sask. Monogr. 165 pp.

————————, and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Webb, R., A. Johnston, and J. D. Soper. 1967. The prairie world. Pages 93 - 115 in W. G. Hardy, ed. Alberta, a natural history. Hurtig Publishers, Edmonton, Alberta.

Wentland, H. J. 1968. Summer range habits of the pronghorn antelope in central Montana with special reference to proposed sagebrush control study plots. M. S. Thesis, Montana State Univ. Bozeman. 65 pp.

West, D. R. 1970. Effects of prolonged deep snow and cold winters on pronghorn mortality and reproduction in South Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:41-49.

Wiltse, E. 1978. Summary of southwestern Saskatchewan antelope studies. Proc. Bienn. Pronghorn Antelope Workshop. 8:162-178.

Chapter 4. Distribution, behavior and mortality of pronghorns during a severe winter at the northern limits of their range

Abstract: Aspects of the distribution, behavior and mortality of pronghorn (*Antilocapra americana*) were documented in southeastern Alberta during the severe winter of 1977-78. As an apparent response to record snowfall in portions of their range, only 34% of the pronghorns observed during aerial surveys in January and February occupied typical winter ranges characterized by open basins with silver sagebrush (*Artemisia cana*). Many herds selected sites with reduced snow accumulation. Estimated mortality among the approximately 14,360 pronghorns entering the 1977-78 winter was 48.5%. Necropsies revealed significant ($P < 0.05$) losses in body weight, kidney fat, and femoral fat content of carcasses when compared with values for animals sampled before winter. Fawns of both sexes and adult males were more susceptible to winter-kill than were adult females. Mummification and desiccation were evident in 68 of 82 fetuses examined. Potential adaptive values of the observed behavioral and physiological phenomena are discussed.

INTRODUCTION

In Alberta, periodic severe winters have long been recognized as a major source of mortality for pronghorns (Wishart 1970). Typical of animals at the northern limits of their range, the physical features of pronghorns in Alberta appear to conform with both Allen's and Bergmann's rules (Mitchell 1971). Further behavioral adaptations for survival of pronghorns in winter have been described by Bruns (1977).

Prolonged heavy snowfall and lack of access to woody browse have caused heavy mortality among pronghorns (Martinka 1967, Compton 1970, McKenzie 1970, West 1970). Some abnormal movements and deaths attributable to exposure and malnutrition were reported in Alberta by Mitchell (1965, 1980) following the 1964-65 winter. In Alberta pronghorns use widely different ranges throughout the year but most occupy specific wintering areas (Barrett and Vriend 1980). Preferred winter ranges contain an average of 88% native vegetation consisting primarily of grasslands with varying densities of silver sagebrush cover (Barrett 1980).

Previous accounts of extensive winter losses of pronghorns have provided little quantitative information on many facets of die-offs. This paper documents the abnormal distribution of pronghorns, extent of mortality, necropsy results, and general response to supplemental feed during a severe winter in Alberta.

STUDY AREA AND METHODS

Weather Conditions

During winter 1977-78, pronghorn range in Alberta received below normal temperatures, unusually early snowfall, and in portions of the range, frequent and extreme blizzard conditions. The southeast corner of the province received more snowfall than that recorded during any of the preceding 50 years as monitored by Agriculture Canada Research Sub-Station, Manyberries (Table 1). Pronghorn range south and east of Medicine Hat (Fig. 1) had unusually frequent winds resulting in severe ground blizzards throughout much of January and early February 1978; crusting of snow was extensive. Snow depths were greatest in browse communities and least on summer fallow fields and grasslands where wind action periodically opened slopes. During a helicopter survey on 10 February 1978 snow depths in the pronghorn winter range along the Milk River were measured periodically and ranged between 70 and 105 cm. Although storm intensities varied throughout the range, conditions could be described summarily as severe and representative of the "killer winters" that occasionally frequent the Alberta prairie.

Distribution of Pronghorns

The distribution of pronghorns during winter 1977-78 was determined by extensive ground and aerial surveys. Initial information on abnormal distribution of pronghorns was obtained during the aerial survey for deer (Odocoileus spp.) conducted in mid-December throughout much of the pronghorn winter range.

Subsequently, the 12 known pronghorn winter ranges (Barrett and Vriend 1980) and adjacent areas were monitored by 14 separate fixed-wing and 4 helicopter surveys during 18 January-23 February 1978. Ranges with few pronghorns present were surveyed from the air only once, whereas areas with large herds were covered frequently. From mid-January to 31 March, project personnel monitored some of the larger herds in the Taber - Medicine Hat area on an almost daily basis. Further information on distribution of pronghorns was provided by wildlife enforcement officers, ranchers, and concerned sportsmen. Behavior and habitat selection by pronghorns, and age and sex composition of herds, were recorded whenever possible.

Supplemental Feeding

Members of the Alberta Fish and Game Association, a sportsmen's group of concerned individuals, set up feeding stations for pronghorns at 4 separate areas in the province. I had no direct control over the location or type of supplement offered. Feed provided varied with time and area, but included alfalfa hay, timothy hay, baled prairie grasses, alfalfa cubes, pea vines and sugar beet tops. Feed was provided _ad libitum_ at each site. In the Taber area project personnel closely assessed the response of 4 herds of pronghorns to supplemental feed and more superficially monitored the feeding program at Medicine Hat. Information on use of feed, behavior, and mortality of the animals present was recorded. Composite samples of timothy, sugar beet tops, and 3rd cutting alfalfa were taken at the Taber feeding site and submitted for protein analysis to the Soil and Feed Testing Laboratory, Alberta Department of Agriculture, Edmonton.

Mortalities

Numerous dead pronghorns were reported by ranchers and observed by project personnel. Whenever possible, carcasses were collected and necropsied. Frequently, accumulations of snow made ground travel difficult and many carcasses were observed from aircraft but were not recovered for examination.

Sex and age (Dow and Wright 1962) of animals found dead were recorded. Each carcass was weighed. Condition of animals and number and weight of any fetuses present were recorded. Condition assessment included a general examination of fat deposited in the omentum, aortic groove, and rump area, and calculation of kidney fat indices (Riney 1955). Femoral fat content was determined by oven-dry weight of marrow (Neiland 1970). Whenever lesions were observed, tissues were submitted to the Provincial Veterinary Diagnostic Laboratory, Lethbridge for further examination.

Weight, kidney fat indices, and femoral marrow fat content of winter-killed animals were compared with values obtained for pronghorns live-trapped or shot during 30 September-15 December 1971-75. Age and sex composition of summer populations were obtained during the annual July aerial surveys conducted throughout the pronghorn range in Alberta.

Statistical Analyses

Statistical comparison of sex and age composition of summer populations and winter-killed animals was by Chi-square analysis (summer population was the expected frequency). Differences in means of carcass weight, fetal weight, femoral and kidney fat between pronghorns sampled in fall and those found dead in winter were examined using student's *t* test. The null hypothesis was rejected at $P < 0.05$.

RESULTS

Distribution and Behavior of Pronghorns

Only 34% of the pronghorns located in January and February 1978 were in typical locations (Table 2). In the Taber and Medicine Hat areas, large herds were located where few animals normally winter. In the Manyberries area, traditional winter ranges were virtually unoccupied as record snowfall forced pronghorns off these areas beginning in mid-December (Fig. 1). Herds moved to areas with reduced snow depths or to areas where vegetation was visible above the snow. Most animals occupied upper river breaks or stubble, summer fallow, or harvested potato and sugar beet fields; wind action resulted in less snow in these areas. Although inconsistent with normal pronghorn behavior, some herds used cover provided by silverberry (*Elaeagnus commutata*), quaking aspen (*Populus tremuloides*) and willow (*Salix* spp.).

Pronghorns became relatively sedentary by mid-to late-January and their daily activities and locations became predictable. Mean number of pronghorns per herd in late January was 46.3 (N = 187 herds). During severe storms, pronghorns bedded in tightly knitted cliques; animals assumed a neo-natal bedding posture and held their heads low or curled back along their body. Following storms, many pronghorns were found dead. One adult female, subsequently determined to have been in good body condition, was found near death with just the distal portion of her legs and muzzle protruding above the snow. This animal was trapped by hard-packed snow covering her abdomen, chest and neck. Repeated use of the same bedding site on many occasions, tended to deepen these sites and to increase the vulnerability of animals to entrapment during blizzards. The hair of several dead pronghorns was frozen into the ice at the bottom of bedding sites, but whether this icing occurred ante- or post-mortem is unknown.

Mortality of Pronghorns and Necropsy Findings

Unusually heavy mortality of pronghorns became evident by the middle of January as dead or moribund animals were associated with nearly every herd observed. Mortality continued throughout the winter and into April despite milder temperatures and little snow during the last half of March and most of April. The July 1978 aerial survey accounted for only 7,390 (51.5%) of the estimated population of 14,360 pronghorns which entered the preceding winter. In the Pakowki Lake - Onefour area (Fig. 1), over-winter mortality approached 65%. Mortality was least in the Milk River Ridge (41%) (winter range J - Fig. 1) and Medicine Hat (36%) areas. Improved survival appeared to be directly related to reduced accumulation of snow. I located 380 pronghorn carcasses between 16 January and 18 April 1978, and performed necropsies on 191.

In terminal stages of malnutrition pronghorns were reluctant to stand or move, were unsteady on their feet and notably weak in their rear limbs. Pronghorns in this condition were highly vulnerable to predation by domestic dogs and coyote (Canis latrans). Reports from wildlife officers and the general public about predation by dogs were unusually prevalent and widespread, and in many instances reflected the close proximity of wintering pronghorns to farmsteads or urban communities.

More than one-half of the dead animals recovered during winter were fawns. Mature males were the next most frequently observed group and dead adult females were observed least often (Table 3). Sex and age compositions of the winter-killed animals differed ($P < 0.05$) from those of the population observed during the previous July aerial survey. Fawns died earlier in winter than did older animals; mature males appeared to be the next most vulnerable class. Proportionately, mature females were substantially more resistant to winter-kill and died last.

Necropsies revealed that all sex and age classes had lost a significant ($P < 0.0I$) percentage of normal prewinter weight (Table 4). Little variation was noted in the percentage of weight lost between sex and age groupings, but male fawns lost the least (18.8%) and adult males the most (27.7%) weight prior to death. Because fawns and adult males generally died earlier in the winter than did adult females, their rate of weight loss was more rapid than that for adult females. In Alberta, pronghorns probably lose some weight during normal winters but the extent of this annual weight loss has not been documented.

In general, winter-killed pronghorns had catabolized all normal body reserves and no visible adipose tissue remained in traditional depot areas which include the aortic groove, the peri-renal area, the dorsal rump and the omentum. With few exceptions, at most, a trace of peri-renal fat remained, and kidney fat indices for these winter-killed pronghorns ranged between 0 and 10. By comparison, the mean kidney fat index for a mixed sex and age group of 47 pronghorns, sampled between 30 September and 15 December was 111 (range 36-293).

Femoral marrow fat content for all age and sex groups was less than 25%; fawns averaged only 12.5% marrow fat (Table 5). Femoral marrow fat content for 16 pronghorns sampled prior to winter was 88.8% (range 76.3 - 97.0). Among winter-killed animals, fawns had lower ($P < 0.05$) femoral marrow fat content than did yearlings and adult females. Yearlings had more ($P < 0.05$) marrow fat than adult males; the mean marrow fat for adult males was less ($P < 0.05$) than that for adult females (Table 5).

Fetal mummification was a common finding during necropsy of mature females (Fig. 2). Of 82 fetuses examined, only 14 were normal, viable specimens. Most fetuses reflected advanced stages of desiccation with extensive reduction of soft tissues while 21 fetuses had initial signs of discoloration and desiccation (Table 6). Most mature does carried twins and both fetuses were in a similar condition in all but 2 instances. In the 1st exception, 1 fetus was normal whereas initial signs of desiccation were present in the other fetus. The 2nd exception involved a set of triplets in which 2 fetuses showed only initial signs of desiccation and had a mean weight of 291.9 g whereas the 3rd fetus reflected advanced atrophy and weighed only 34.4 g. Whenever fetal mummification was observed, appreciable fetal fluids were absent (Fig. 2).

In February and March, up to 50% of the pronghorns in some herds limped and had badly swollen lower front limbs, apparently the result of walking and pawing in crusted snow. Lesions typical of foot rot were observed in many of the animals examined. Swabs taken from the fetlock area of 2 animals yielded *Corynebacterium pyogenes* on culture.

Fewer than 10% of the animals necropsied showed other gross abnormalities. Pulmonary lesions were most prominent and consisted of a fibrinous pneumonia affecting the anteroventral portions. Affected lungs were swollen, firm, had a reddish to black coloration and occasionally had a light fibrin coat on the visceral pleura. Histologically, the pneumonias were characterized by extensive hemorrhage, edema, necrosis and bacterial colonization. Scattered areas of intense suppuration occurred within the parenchyma. Cellular debris and polymorphonuclear leukocytes were observed frequently in bronchioles. Bacterial colonies occurred commonly in the veins. Bacteriologically, the affected lungs yielded *C. pyogenes* and, on 1 occasion, *Pasteurella multocida*.

Response to Supplemental Feeding

The response of pronghorns to the provision of supplemental feed was highly variable. In the Brooks area, east of Lake Newell, pronghorns failed to use baled prairie grasses or pea vines over a 2-week period; that feeding program began on 14 February 1978. Initial avoidance of feed provided was not uncommon but in most instances, pronghorns eventually used feeding sites. Characteristically, pronghorns responded slowly but within 3 weeks most feeding sites were used regularly (Fig. 3). Most feeding sites were located before the end of January. Pronghorns that were provided with an assured supplemental food supply did little foraging for natural feed. In some instances, feeding sites were established in locations that provided little natural forage for animals. Pronghorns dependent upon supplemental feed, accommodated to the presence of humans and vehicles. Most feeding programs were terminated with warmer weather in mid-March but pronghorns remained on or adjacent to feeding sites for an additional 7-10 days before dispersing.

Despite daily use of supplemental feed, mortality of pronghorns remained high. In the Taber area, mortality rates of 32% and 40% were noted for 2 herds of 73 and 125 animals, respectively. These mortality rates are minimal estimates and are based on actual carcasses retrieved from the herd during a 10-week period. In most instances, food quality appeared good. On a dry weight basis, protein content of feed provided at Taber varied from 14.5% for timothy and 14.8% for sugar beet tops to 22.4% for 3rd cutting alfalfa. Necropsies revealed widespread catabolism of fat stores and general carcass appearance indistinguishable from that of animals that died of malnutrition. Occasionally, evidence of pneumonia and scouring existed but these lesions were not common findings. Chronology of pronghorn mortalities throughout winter, was similar for artificially fed and unsupplemented herds. No problems relative to initial physiological adjustment by pronghorns to supplemental feed were detected.

DISCUSSION

High winter mortality of pronghorns during severe winters has long been recognized by biologists, but few associated parameters have been quantified. Mitchell (1965) noted that the severe winter of 1964-65 reduced forage availability and caused a "general debilitation" of pronghorns throughout southeastern Alberta. Wishart (1970) suggested, but presented no substantiating data, that severe winters in Alberta caused increased emigration, starvation, losses from predation, and depressed production of young the following year. Similarly, the severe winters of 1964-65 and 1968-69 resulted in high losses of pronghorns in Montana, North Dakota, and South Dakota (Compton 1970, McKenzie 1970, West 1970). These authors attributed extensive mortality to malnutrition apparently caused by lack of access to woody browse.

The disproportionately high mortality of fawns and adult males in Alberta was similar to the findings of Martinka (1967) following a severe winter in Montana. Adult females in Alberta enter winter with greater body fat stores than fawns and adult males, (Barrett, unpubl. data) and consequently have the greatest resistance to prolonged nutritional stress. I could find no published data for winter-killed pronghorns to compare with my observations of weight loss, kidney fat indices, and femoral fat. Martinka (1967:161) applied Cheatum's (1949) criteria and reported gelatinous marrow indicative of malnutrition in 57 of 59 femurs from winter-killed pronghorns. No seasonal trends in femoral fat levels were found in pronghorns collected in Colorado by Bear (1971:586) and few specimens had less than 70% fat; kidney and visceral fat reserves were highest in early winter and declined progressively with prolonged winter severity (Bear 1971).

Low kidney fat indices and femoral fat content of most dead pronghorns indicated that malnutrition was the underlying cause of death. The kidney fat index is an imprecise measurement of fat stores over a wide range of condition (Ransom 1965, Anderson et al. 1972, Dauphine 1975) but values <10 suggest a grave prognosis. The femoral fat content is a more reliable indicator of animals in poor condition and variations of this technique have been used to assess nutritional status in a variety of wildlife (Cheatum 1949, Bischoff 1954, Ransom 1965, Greer 1968, Neiland 1970, Verme and Holland 1973, Franzmann and Arneson 1976).

The term resorption is commonly used in wildlife literature to describe the process of fetal atrophy depicted in Fig. 2. However, this process, which involves resorption of uterine fluids and desiccation of soft tissues, is generally referred to as mummificaiton by veterinary pathologists (Jubb and Kennedy 1970); I have followed this terminology. To my knowledge, fetal mummification as a consequence of winter malnutrition has not been reported for pronghorns. A previous report related fetal resorption in pronghorns in Texas to the ingestion of large quantities of American tarbrush (*Flourensia cernua*) (Hailey et al. 1966). W. Runge and G. Wobeser (pers. commun.) reported fetal resorption in 4 white-tailed deer (*O virginianus*) in Saskatchewan following the severe 1973-74 winter and Nichols (1978) indicated that the same phenomenon can occur in malnourished Dall's sheep (*Ovis dalli*) ewes.

If fetal mortality was widespread in a population as a consequence of a severe winter, recruitment would probably be substantially curtailed for 2 years. Weather severe enough to induce mummification would almost certainly cause high mortality among fawns from the previous year.

The provision of supplemental feed for pronghorns did not eliminate further mortality among the herds involved. The feeding program was probably begun too late to save many of the animals lost. Similarly, emergency feeding programs in North Dakota (Samuelson 1970), Wyoming (Helms 1978) and Montana (Gjersing 1978, Pyrah 1978) were largely ineffective for this species. Emergency feeding in winter can lead to increased damage to natural range as a result of increased concentration of animals (Anderson et al. 1975, Mautz 1978*a*, Rue 1980). De Calesta et al. (1975) successfully refed most penned mule deer (*Odocoileus hemionus*) that had been starved from 10 to 64 days. These authors suggest that after deer lose approximately 30% of prestarvation weight some animals are in such depressed physiological state that they cannot be saved by refeeding. The 1978 feeding program for pronghorns had a minimal impact on the provincial population because of the logistical impracticality of reaching most animals with feed. De Calesta et al. (1977) postulated that supplemental feeding of deer could save from starvation a portion of the herd that was not already close to death. Similarly, the feeding program may have contributed to the survival of some pronghorns in Alberta but supplemental feeding does not appear to be a practical management approach.

During winter 1977-78 pronghorns moved to areas with reduced snow accumulation and to those in which vegetation was visible above snow. In these areas, animals would expend fewer calories searching for and ingesting feed. As might be expected for animals at the northern limits of their range, pronghorns have developed distinctive behavioral adaptations to promote survival during winter (Bruns 1977). Pronghorns probably have metabolic adaptations as well. Wesley et al. (1973) detailed the metabolic response of pronghorns to a wide range of ambient temperatures and estimated their daily intake necessary for maintenance in winter. Some ungulates have reduced intake and metabolism during winter (Ozoga and Verme 1970, Thompson et al. 1973, Kirkpatrick et al. 1975, Westra and Hudson 1981). Decreased food consumption in winter is common even when high quality feed is provided (Mautz 1978b, Hawley et al. 1981). This may, in part, explain the ineffectiveness of emergency feeding programs. However, Ullrey et al. (1975) reported that white-tailed deer fed a protein-energy supplement block increased their dry matter intake of traditional browse. In normal circumstances, native ungulates survive during winter through catabolism of body stores and consumption of available forage (Mautz 1978b).

During summer and fall, pronghorns in Alberta consume lush forage and build up large body fat reserves. During normal winters, these endogenous energy stores, in combination with abundant sagebrush rangelands promote good survival. Hoskinson and Tester (1980) suggested that low-moisture content of fall vegetation prompted migration of pronghorns to winter range and that once there, animals selected areas with reduced snow depth. I suggest that, in severe winters the energetic cost of foraging for food in deep snow in sagebrush flats is greater than energetic benefits. Survival appears to be enhanced by occupying areas with reduced snowfall and by ingesting readily available, albeit low quality, forage. Lower intake in winter should enhance the digestion of the limited forage available because reduced intake increases the digestion of fibrous feeds (Hawley et al. 1981).

From a management perspective, it seems important to recognize that obstacles which restrict the mobility of pronghorns during severe winter conditions can also restrict their ability to survive. When conditions permit, pronghorns select habitual wintering areas (Barrett 1980). However, less preferred habitats such as native grassland slopes can become critically important to pronghorns trying to cope with heavy snowfall. In Alberta, good prewinter fat reserves, extensive mobility of individual herds, and use of readily available forage combine to promote the survival of a nucleus population of pronghorns during severe winters.

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Table 1. Weather conditions in southeastern Alberta during the 1977-78 winter as recorded at the Agriculture Canada Research Sub-Station, Manyberries.

Month	Monthly temperature, C		Monthly snowfall, cm		Wind, km/h	
	$\bar{X}$	Variation from normal	$\bar{X}$	Percent of normal	$\bar{X}$	Maximum hourly gust
Nov	-5.1	-2.7	25.2	194	20.4	69.2
Dec	-13.3	-8.6	47.0	285	21.7	62.8
Jan	-17.4	-12.8	51.3	249	_[b]	_[b]
Feb	-13.4	-9.2	55.9	339	21.5	55.0
Mar	-5.0	-4.8	10.9	54	18.6	60.0
Apr	4.9	+4.8	16.8[a]	97	22.6	53.0

[a] Also received 53.2 mm of rain which was 475% of normal for Apr.

[b] Data not available.

Table 2. Distribution and proportion of pronghorns observed during winter surveys in normal years (1970-71 to 1976-77) VS. a severe winter (1977-78) in southeastern Alberta.

Population parameter	Year(s)	
	1970-1976	1977
A. Average summer population, (Jul surveys)	10,784	17,953
B. Average estimated population[a] entering winter (80% of A)	8,627	14,362
C. Average number of pronghorns[b] observed during winter surveys, number/(%)	6,729[c] (78)	8,209 (57)
D. Proportion of observed population (C) on traditional wintering areas (%)	73	34

Table 2. (continued)

[a] Approximately 20% reduction based on losses due to regulated hunting seasons, predation, and miscellaneous factors.

[b] Surveys conducted during Jan and Feb of each subsequent year.

[c] In most years only limited surveys were conducted beyond the traditional wintering areas; data for the 1972-73 winter were omitted because of open winter and poor survey conditions.

Table 3. Approximate sex and age composition of summer population (Jul 1977) and winter-killed pronghorns (Jan - Apr 1978) in Alberta.

	Fawns		Animals over 1 year			
			Males		Females	
	N	%	N	%	N	%
Summer survey	1080	28.7	806	21.4	1877	49.9
Winter-killed animals	168	53.3[a]	78	24.8[a]	69	21.9[a]

[a] Chi-square probability of obtaining these percentages based on summer survey results is $\chi^2 = 37.3$, $P < 0.01$.

Table 4. Normal fall weight of pronghorns compared with weight following death from malnutrition during winter 1977-78 in Alberta.

	Weight (Kg) of entire pronghorn carcasses											
	Fawns				Yearlings				Adults			
	Males		Females		Males		Females		Males		Females	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Normal fall weight[a]	31.6	0.6	30.2	0.4	46.0	0.6	42.3	0.5	50.6	0.6	46.3	0.3
N	41		48		22		38		60		197	
Weight at death[b]	25.3[c]	0.4	23.7[c]	0.4	34.2[c]	0.9	33.7[c]	1.6	36.6[c]	1.1	35.2[c]	0.9
N	31		30		15		11		10		19	

[a] Animals sampled during 30 Sept to 15 Dec 1971-75, inclusive.

[b] Carcasses recovered between 20 Jan and 31 Mar 1978.

[c] Means are less ($P < 0.01$) than mean for fall weights.

Table 5. Fat content of femoral bone marrow collected from winter-killed pronghorns in Alberta in 1977-78.

	Fat content of femoral marrow, %								
	Fawns			Yearlings			Adults		
	$\bar{X}$	SE	N	$\bar{X}$	SE	N	$\bar{X}$	SE	N
Males	12.3	1.8	29	20.2	5.4	13	7.9^a	1.2	9
Females	12.7	1.3	30	20.2	6.1	9	22.0	5.0	20
Totals	12.5^b	1.1	59	20.2^c	4.0	22	17.6	3.7	29

[a] Mean less ($P < 0.05$) than mean for adult females.

[b] Mean less ($P < 0.01$) than mean for all yearlings and mean for adult females.

[c] Mean more ($P < 0.05$) than mean for adult males.

Table 6. Size and appearance of fetuses recovered from a sample of winter-killed pronghorns, 2 Feb - 29 Mar 1978, Alberta.

Fetal appearance	N	Weight of fetuses, g		
		$\bar{X}$	Min	Max
Normal fetuses	14	266.7	57.9	469.0
Partial desiccation	21	173.9[a]	49.2	350.3
Advanced desiccation	47	60.7[b]	3.0	260.9

[a] Mean less ($P < 0.05$) than mean for normal fetuses.

[b] Mean less ($P < 0.01$) than mean for normal and partially desiccated fetuses.

Figure 1. Distribution of pronghorns during normal winters and during the severe winter of 1977-78 in Alberta.

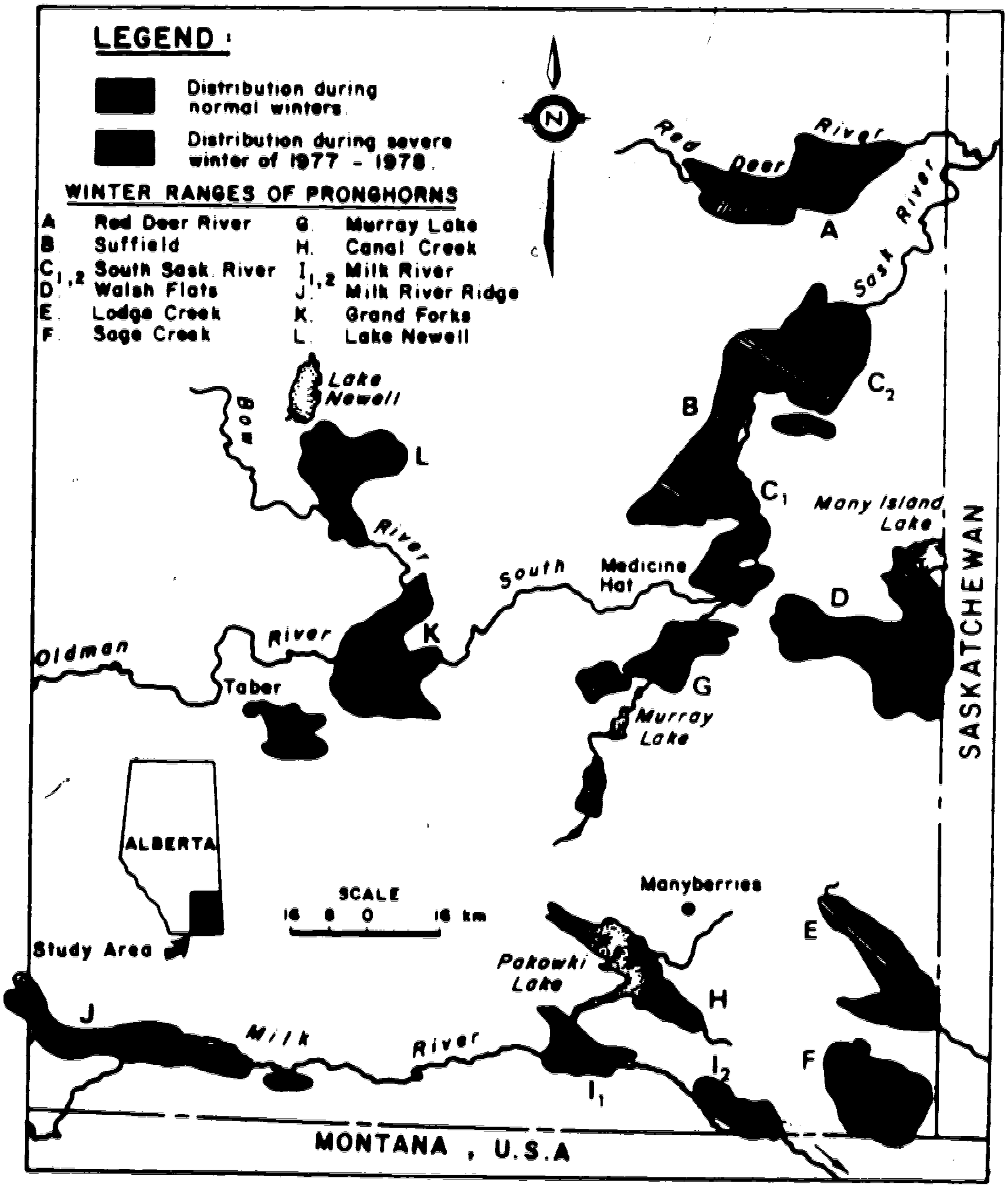
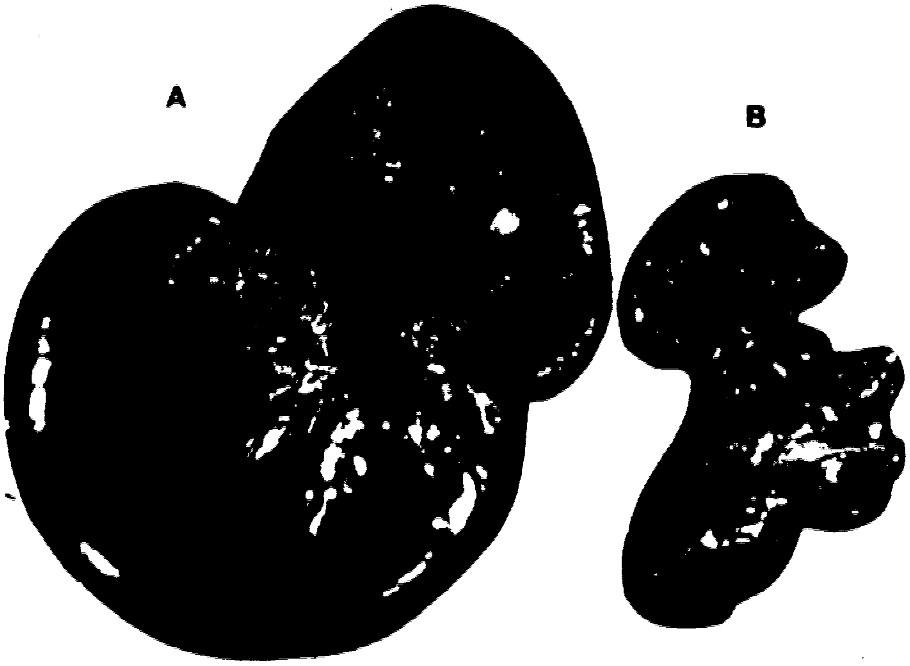

LEGEND:
Distribution during normal winters.
Distribution during severe winter of 1977 - 1978.
WINTER RANGES OF PRONGHORNS
A Red Deer River
B Suffield
C1,2 South Sask. River
D Walsh Flats
E Lodge Creek
F Sage Creek
G Murray Lake
H Canal Creek
I1,2 Milk River
J Milk River Ridge
K Grand Forks
L Lake Newell
N
Red Deer River
A
Sask River
C2
B
C1
Lake Newell
Bow
L
River
South
Medicine Hat
Many Island Lake
D
SASKATCHEWAN
Oldman
River
K
Taber
G
Murray Lake
ALBERTA
Study Area
SCALE
16 8 0 16 km
Manyberries
E
Pakowki Lake
H
J
Milk
River
I1
I2
F
MONTANA, U.S.A

Figure 2. Top plate. Appearance of uterus containing a normal fetus (A) and 1 containing a mummified fetus (B).

Bottom plate. Range of appearances of normal fetus (A) and those mummified following different stages of development (B, C, D). Fetuses were collected on the same day from does dead from malnutrition.


A
B

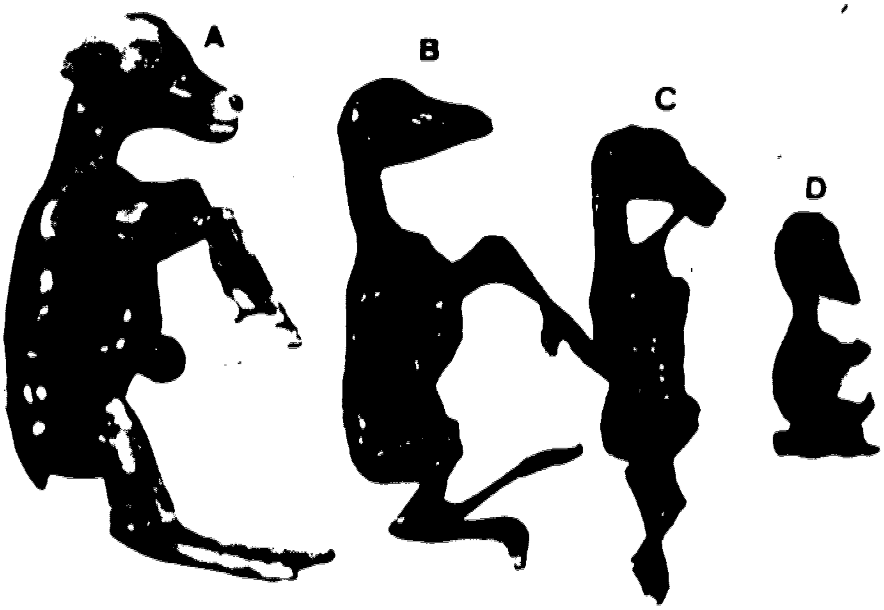

A
B
C
D

Figure 3. Top plate. Farmer near Taber distributing feed for pronghorns during severe winter of 1977-78.

Bottom plate. Animals responding to the availability of supplemental feed in the form of second cutting alfalfa hay.

LITERATURE CITED

Anderson, A.E., D.E. Medin, and D.C. Bowden. 1972. Indices of carcass fat in a Colorado mule deer population. J. Wildl. Manage. 36:579-594.

Anderson, R.H., W.G. Youatt, and D.E. Ullrey. 1975. A winter field test of food supplemental blocks for deer. J. Wildl. Manage. 39:813-814.

Barrett, M.W. 1980. Seasonal habitat associations of pronghorns in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:174-195.

_______, and H.G. Vriend. 1980. Management implications of the seasonal distributions of pronghorns and land use practices in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:196-214.

Bear, G.D. 1971. Seasonal trends in fat levels of pronghorns, *Antilocapra americana*, in Colorado. J. Mammal. 52:583-589.

Bischoff, A.I. 1954. Limitations of the bone marrow technique in determining malnutrition in deer. Proc. West. Assoc. State Game and Fish Comm. 34:205-210.

Bruns, E.H. 1977. Winter behavior of pronghorns in relation to habitat. J. Wildl. Manage. 41:560-571.

Cheatum, E.L. 1949. Bone marrow as an index of malnutrition in deer. New York State Conserv. 3(5):19-22.

Compton, H.O. 1970. Southeastern Montana antelope population trends in relationship to severe winters. Proc. Bienn. Pronghorn Antelope Workshop. 4:50-54.

Dauphine, T.C. 1975. Kidney weight fluctuations affecting the kidney fat index in caribou. J. Wildl. Manage. 39:379-386.

De Calesta, D.S., J.G. Nagy, and J.A. Bailey. 1975. Starving and refeeding mule deer. J. Wildl. Manage. 39:663-669.

_____, _____, and _____. 1977. Experiments on starvation and recovery of mule deer does. J. Wildl. Manage. 41:81-86.

Dow, S.A. Jr., and P.L. Wright. 1962. Changes in mandibular dentition associated with age in pronghorn antelope. J. Wildl. Manage. 26:1-18.

Franzmann, A.W., and P.D. Arneson. 1976. Marrow fat in Alaskan moose femurs in relation to mortality factors. J. Wildl. Manage. 40:336-339.

Gjersing, F. 1978. Participant in discussion on the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop. 8:337-359.

Greer, K.E. 1968. A compression method indicates fat content of elk (wapiti) femur marrows. J. Wildl. Manage. 32:747-751.

Hailey, T.L., J.W. Thomas, and R.M. Robinson. 1966. Pronghorn die-off in Trans-Pecos Texas. J. Wildl. Manage. 30:488-496.

Hawley, A.W.L., D.G. Peden, and W.R. Stricklin. 1981. Bison and hereford steer digestion of sedge hay. Can. J. Anim. Sci. 61:165-174.

Helms, B. 1978. Participant in discussion on the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop. 8:337-359.

Hoskinson, R.L., and J.R. Tester. 1980. Migration behavior of pronghorn in southeastern Idaho. J. Wildl. Manage. 44:132-144.

Jubb, K.V.F., and P.C. Kennedy. 1970. Pathology of domestic animals. Vol. I. Academic Press, New York, N.Y. and London, U.K. 593pp.

Kirkpatrick, R.L., D.E. Buckland, W.A. Abler, P.F. Scanlon, J.B. Whelan and H.E. Burkhart. 1975. Energy and protein influences on blood urea nitrogen of white-tailed deer fawns. J. Wildl. Manage. 39:692-698.

Martinka, C.J. 1967. Mortality of northern Montana pronghorns in a severe winter. J. Wildl. Manage. 31:159-164.

Mautz, W.W. 1978a. Nutrition and carrying capacity. Pages 321-348 in J.L. Schmidt and D.L. Gilbert, eds. Big game of North America, ecology and management. Stackpole Books, Harrisburg, Pa.

_____. 1978b. Sledding on a bushy hillside: The fat cycle in deer. Wildl. Soc. Bull. 6:88-90.

McKenzie, J.V. 1970. Two killer winters 1964 - 1965 and 1968 - 1969 in North Dakota. Proc. Bienn. Pronghorn Antelope Workshop 4:36-40.

Mitchell, G.J. 1965. Natality, mortality and related phenomena in two populations of pronghorn antelope in Alberta, Canada. Ph.D. Thesis, Washington State Univ., Pullman. 205pp.

_____. 1971. Measurements, weights, and carcass yields of pronghorns in Alberta. J. Wildl. Manage. 35:76-85.

_____. 1980. The pronghorn antelope in Alberta. University Regina. Regina, Sask. Monogr. 165pp.

Neiland, K.A. 1970. Weight of dried marrow as indicator of fat in caribou femurs. J. Wildl. Manage. 34:904-907.

Nichols, L. Jr. 1978. Dall's sheep. Pages 173-189. *in* J.L. Schmidt and D.L. Gilbert, eds. Big game of North America, ecology and management. Stackpole Books, Harrisburg, Pa.

Ozoga, J.J., and L.J. Verme. 1970. Winter feeding patterns of penned white-tailed deer. J. Wildl. Manage. 34:431-439.

Pyrah, D. 1978. Participant in discussion on the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop 8:337-359.

Ransom, A.B. 1965. Kidney and marrow fat as indicators of white-tailed deer condition. J. Wildl. Manage. 29:397-398.

Riney, T. 1955. Evaluating condition of free-ranging red deer (*Cervus elaphus*), with special reference to New Zealand. N.Z. J. Sci. and Tech. 36:429-463.

Rue, L.L. 1980. The deer of North America. Times Mirror Magazines, Inc., Crown, N.Y. 463pp.

Samuelson, J. 1970. Participant in discussion on winter mortality of pronghorns. Proc. Bienn. Pronghorn Antelope Workshop. 4:56.

Thompson, C.B., J.B. Holter, H.H. Hayes, H. Silver, and W.E. Urban, Jr. 1973. Nutrition of white-tailed deer. I. Energy requirements of fawns. J. Wildl. Manage. 37:301-311.

Ullrey, D.E., W.G.Youatt, H.E. Johnson, L.D. Fay, R.L. Covert, and W.T. Mage[illegible] 1975. Consumption of artificial browse supplements by penned white-tailed deer. J. Wildl. Manage. 39:699-704.

Verme, L.J., and J.C. Holland. 1973. Reagent-dry assay of marrow fat in white-tailed deer. J. Wildl. Manage. 37:103-105.

Wesley, D.E., K.L. Knox, and J.G. Nagy. 1973. Energy metabolism of pronghorn antelopes. J. Wildl. Manage. 37:563-573.

West, D.R. 1970. Effects of prolonged snow and cold winter on pronghorn mortality and reproduction in South Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:41-49.

Westra, E., and R.J. Hudson. 1981. Digestive function of wapiti calves. J. Wildl. Manage. 45:148-155.

Wishart, W.D. 1970. A brief historic review of the pronghorn antelope in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 4:128-130.

Chapter 5. Management implications of the seasonal distributions of pronghorns and land use practices in Alberta

Abstract: This paper reviews the historical methods used to estimate the summer population of pronghorn (Antilocapra americana) in Alberta. Surveys that more closely reflect land use practices and local densities are recommended. The winter distribution of pronghorns within the province was determined through aerial and ground surveys conducted over a 5 year period. In addition to the Suffield Military Range, 11 sites, totalling 3,037·km^2 that received consistent use by pronghorns during winter were identified. Populations in southeastern Alberta were more stable than northern herds and had access to winter ranges with higher densities of sagebrush (Artemisia cana). Pronghorn densities and population stability within hunting areas were analyzed and revealed substantial local variation. I recommend revised hunting areas that recognize these differences and that promote the management of pronghorns on a local population or herd basis. The locations of proposed hunting areas are based on the current available knowledge and reflect the known winter ranges, local movement patterns, and density and stability of regional populations of pronghorns.

INTRODUCTION

Sporadic pronghorn censusing in Alberta first began in 1955 and the survey was modified in subsequent years to provide a better estimate of the summer population (Mitchell 1980). There has been a continuing need to provide reliable estimates of the total population, and since 1963, summer surveys have been gradually modified to provide more accurate data (Wishart and Hall 1967, Barrett 1970, Cook 1981).

Despite the importance of secure winter range to pronghorns, their winter distribution had not been studied in detail prior to 1970. In that year, documentation of winter ranges selected by pronghorns in Alberta began. Data gathered on summer and winter pronghorn densities, population characteristics, pronghorn movements and use of winter forage have suggested pronounced differences in local pronghorn populations throughout Alberta. Existing hunting areas were defined in 1964 (Mitchell 1980) and did not reflect the considerable differences in regional population characteristics which were largely unknown at that time. A precisely regulated harvest of the different population units is difficult under the present system.

The objectives of this study were: 1) to review and recommend modifications in the survey methods used to determine the annual summer population estimate for pronghorns, 2) to confirm the existence and identify the location of key wintering areas for pronghorns, and 3) to review and recommend modifications in the hunting zones used to regulate the harvest of pronghorns in Alberta.

SUMMER AERIAL SURVEYS

Historical Review

Aerial surveys of pronghorns in Alberta first began in 1955 when transects spaced 19 to 29 km apart were flown as part of a waterfowl censusing program. From 1957 to 1963 surveys for pronghorns became progressively more intensive. In 1963 most of the pronghorn range was surveyed by transects spaced 10 km apart. Intensive study areas in the Lake Newell and Pakowki Lake area were surveyed by transects spaced 1.6 km apart. From 1963 to 1969 antelope surveys consisted, in theory, of flying one-third of the pronghorn range annually at 50% coverage to obtain a total count on those areas. The remaining area was sampled by random surveys to establish production indices. Data obtained were used as the basis for estimating the provincial population of pronghorns. Total count surveys were shifted to different portions of the range annually so that after 3 years the entire pronghorn range would be surveyed (Mitchell 1965). Because of manpower and fiscal restraints, this program was not always faithfully adhered to. Secondly, because the quality of pronghorn range and the density of animals varied from area to area, this system was less than ideal.

Proposed Changes

In 1970 the current system was adopted whereby representative blocks were flown annually (Barrett 1970). Initially, only a portion of Alberta's pronghorn range was surveyed by this method; however, in 1972 the system was expanded to include the entire range. The transect blocks (Fig. 1) located in a variety of representative habitat types are flown at 50% coverage. In 1979 further changes were made in the survey system. It had become apparent that certain land use types within the pronghorn range were not being surveyed as intensively as others (Fig. 1). As a result, a new block, SF, was established within the cultivation zone. Block E was changed for 25% coverage and a larger area was sampled as a result. Block S was converted to 25% coverage and the complement of flying time used for a new block, X, north of the Red Deer River (Fig. 1). Transects on this block were spaced 10 km apart and enabled the survey crew to sample a much larger portion of the northern pronghorn range than did the survey blocks P and V.

Summer surveys are best suited to provide data on; 1) annual changes in total numbers on the blocks, 2) an index to fawn recruitment, and 3) population composition. Nine years of summer surveys have indicated that pronghorn populations south of the South Saskatchewan River (Region 1) were more stable than those populations on the northern and western portions of Alberta's pronghorn range (Region 11). Table 1 illustrates the degree of change in pronghorn populations in these areas.

There is a continuing need to provide reliable population estimates and to relate pronghorn densities to land use practices. In 1966, Alberta's pronghorn range was mapped using 1960 aerial photographs. Cultivated areas were indicated on 1:250,000 scale topograhical maps. In 1979, using 1970 aerial photos, the range was again mapped. The percentage of cultivation and native grass prairie (NGP) were determined for each township and 3 general land use zones were identified (Fig. 1). Cultivation zones consisted of

>75% cultivation, transition zones consisted of 25-75% cultivation and NGP zones consisted of <25% cultivation. The percentage of cultivation within each antelope hunting area and summer survey block was also determined.

Fawn recruitment and pronghorn density on the survey blocks are presented with the proportion of land under cultivation (Table 2). No correlation existed between fawn recruitment and pronghorn density (r=0.02). A positive correlation (r=0.32) exists between recruitment and percent cultivation; however, the relationship is a weak one with fawn recruitment on areas with less than 30% cultivation (N=13) averaging 66.49 fawns/100 does. Areas with more than 40% cultivation (n=3) had an average recruitment of 68.27 fawns/100 does. The difference of 1.78 fawns is too small to be of management significance.

Pronghorn density was negatively correlated (r=-0.36) with percent cultivation. This relationship is stronger with animal densities of 0.64/km^2 on areas with <30% cultivation (N=13) compared to 0.43 pronghorns/km^2 on areas with >40% cultivation (N=3). Only one survey area had >50% cutlivation, however, I feel a larger sample in high percentage cultivation range types would strengthen the relationship.

WINTER RANGES

Location of Ranges

Winter ranges for pronghorns were suspected to be critical for the maintenance of the population at northern latitudes. At the onset of winter, pronghorns in Alberta, changed their distribution.

Prior to 1970, no documentation of the location of these wintering areas had taken place. Pronghorn management was based almost exclusively on the result of summer surveys and harvest records.

In 1970, delineation of pronghorn winter ranges began with extensive file searches, landowner interviews, and ground surveys. A number of areas where animals concentrated was recognized. From 1971 to 1975, an extensive aerial survey program was undertaken to outline these and other winter ranges. Each winter approximately 35 hours of flying time were used exclusively to document pronghorn distribution. All potential winter ranges and all drainage systems throughout the pronghorn range were surveyed. Additional data on the distribution of pronghorns were obtained through extensive flying associated with the relocation of marked pronghorns and the annual winter deer surveys.

During the 5 year monitoring period, winter ranges received coverage on at least 5 occasions and most areas were surveyed 10 times. Some wintering areas in the Medicine Hat and Cypress Hills areas were surveyed >20 times as part of a program to monitor the location of marked pronghorns. The winter range boundaries were determined on the basis of pronghorn distribution. A series of paralleling flights resulted in complete coverage of areas with known or suspected previous use. Random flights beyond these areas were employed to look for additional wintering areas. All herd locations were recorded on 1:250,000 topographical maps. In all winter ranges, results from aerial surveys were supplemented by ground observations on an annual basis.

Five years of winter surveys delineated 12 winter ranges (Fig. 2). Some additional areas surveyed appeared to have potential for wintering pronghorns but received negligible use (i.e. Empress Sandhills, Manyberries Creek). Most of the winter ranges were associated with drainage systems of the prairies and all wintering areas contained sagebrush. During winter periods with little or no snow cover, pronghorns strayed extensively from the defined wintering areas.

Excluding Suffield, which is a Department of National Defence training area in which no hunting is allowed, 3,037 km^2 of winter range were delineated. Table 3 presents the maximum and minimum pronghorn numbers and densities observed for these winter ranges for the period 1971-75, inclusive.

General movements of animals in the southeast corner of Alberta were determined from pronghorns that were marked with color coded or radio equipped collars (Barrett, unpubl. data). Probable movement patterns of pronghorns in other portions of their range (Fig. 2) are not confirmed by marked animals but are based on familiarity with the seasonal distribution of pronghorns derived through 9 years of investigations on the species. I also used information presented by Bruns (1977) and by Mitchell (1980) to supplement my knowledge of animal movements. Movements of pronghorns in the extreme southeast corner of Alberta are more extensive than those of northern populations. In Saskatchewan, pronghorns exhibit this same tendency with average movements to wintering areas of 24.8 km recorded on northern ranges and 129 km on southern ranges (Wiltse 1978).

Amstrup (1978) recorded movements of 15-36 km for 8 radio-collared pronghorns along the Montana-Wyoming border.

Relationship to Sagebrush

Pronghorn dependence on Artemisia spp. is well documented (Alberta: Barrett (1974), Mitchell and Smoliak (1971); Saskatchewan: Dirschl (1963); Montana: Bayless (1969)). Maintenance of pronghorn populations at a level that results in less than 50% use of Artemisia spp. is considered optimal for Alberta (Barrett 1974) and should maintain the health and vigor of the sagebrush. Thirty-five permanent browse transects, using silversage as the key species, were established on the winter ranges. Procedures were described by Barrett (1974). Habitat mapping determined the extent of silversage communities on winter ranges (Barrett 1980). Densities of sagebrush were determined using 60-m straight line intercepts. Rates of utilization of sagebrush were compared to observed winter densities of pronghorns (Table 4).

Correlation coefficient for percent leaders browsed to percent annual growth utilized was r=0.96. The percent of growth utilized was positively correlated (r=0.91) with pronghorn density.

Winter ranges in southeastern Alberta have higher densities of sagebrush (26.1 plants/60-m line intercept) compared with the remainder of the winter ranges (13.9 plants/60-m line intercept). Two winter ranges received substantially higher use of sagebrush (39.2% and 55.2%) relative to use on other winter ranges. A more detailed description of the vegetative types found within winter ranges of pronghorns in Alberta is available (Barrett 1980).

SPORT HUNTING UNITS

Historical Review

After 1960, more reliable pronghorn surveys were conducted in Alberta and in 1964 the pronghorn range was divided into Wildlife Management Units (WMU's) (Mitchell 1980). WMU boundaries using major geographical landmarks and transportation networks were selected. Seven pronghorn hunting areas were established based on these WMU boundaries (Fig. 3). Since then, 15 years of research and improved survey methods suggest that revisions are needed to improve the management of pronghorns.

Alberta's pronghorn population is comprised of a number of different population units that are basically centered around a winter range. Vegetative cover and population characteristics of these units vary considerably throughout the province. For example, pronghorn movements in the southeast corner of Alberta were greater than those in northern Alberta but fawn recruitment was lower than in the north. Low fawn recruitment and greater movements are characteristic of pronghorns in portions of their range in hunting areas A, B and C; this same area has a greater relative abundance of winter range with high densities of sagebrush. Hunting areas A, B and C also contain some populations that interchange little with the remainder of Alberta's pronghorns (e.g. winter ranges J and D). Pronghorn winter densities on these ranges are above average; sagebrush use on these winter ranges is also high (55.2% and 39.2%, respectively). These same hunting units contain areas with extensive cultivation, low pronghorn densities, high recruitment and no winter range. Present sport hunting boundaries do not reflect these contrasting population characteristics and subject these different population units to the same hunting regime.

Boundaries of existing hunting areas separated some distinct population units into 2 or more different hunting areas. Pronghorns, wintering on Walsh Flats (winter range D), summer in hunting areas F and C. The Grand Forks population (winter range K) summers in 3 different hunting areas (C, D and F). The Red Deer River population (winter range A), also split into 2 hunting areas, G and F.

Generally, pronghorn populations south of the South Saskatchewan River (Region 1) were more stable than those north of the river (Region 11). During the 9 year monitoring period (1971-1979), summer pronghorn populations (1971-79) in Region 1 fluctuated 52.7% between 6,241 animals in 1975 and 9,527 in 1977. Region 11 populations fluctuated 271.6% between an estimated 1,569 in 1971 and 5,830 in 1979. Pronghorn summer densities in Region 1 varied from 1.4 to 2.1 animals per km^2 compared to 0.39 to 1.5 animals per km^2 for Region 11. I hypothesize that the more stable southern populations were a reflection of reduced snow depths, larger areas of winter range, and higher densities of sagebrush.

Proposed Changes

The proposed changes in hunting area boundaries will separate the majority of the provincial pronghorn population into distinctive herd units (Fig. 4). These changes would allow for more effective management based on unique population characteristics, availability of winter range, and degree of forage use. The proposed boundaries no longer dissect winter ranges.

Increasing cultivation has reduced pronghorn densities in my study area and has effectively eliminated pronghorns from much of their former range throughout North America (Autenrieth 1978, Leftwich and Simpson 1978). Within their traditional range, cultivation is regarded as the most severe factor limiting pronghorns in Alberta; survey and hunting areas should reflect this relationship. The proposed hunting boundary changes separate the most expansive tract of cultivation on pronghorn range into one management area (B) and allows for special management of this land use zone. Continued documentation of land use changes and their effect on pronghorns are necessary to promote effective land management for pronghorns.

ACKNOWLEDGMENTS

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Table 1. A comparison of pronghorn population changes in the different hunting areas in Alberta for the period 1971-1979.

Region	Hunting area[a]	Survey blocks[b]	Lowest recorded population	Hightest recorded population	High/low
1	A	A & B	1,341	3,649	2.72
	B	C	880	2,010	2.28
	C	D, E & I	1,649	3,236	1.96
	F	F, G & J	1,449	2,533	1.75
11	D	M & M-A	46	733	15.93
	E	K, N, T, R-W	485	2,357	4.85
	G	P & V	425	2,350	5.53
	Suffield	S	840	2,550	3.04

[a] See Figure 3 for a description of hunting zones.

[b] See Figure 1 for a guide to numbering system for survey blocks.

Table 2. Nine year average of summer recruitment and pronghorn density on the survey blocks (1971-1979).

Survey block	Fawn recruitment		Pronghorns per km²	Cultivation %
	No. fawns / No. does	Fawns: 100 does		
A	1365/1755	77.2	1.01	8.51
B	302/683	44.2	1.01	7.68
C	807/1473	54.8	0.50	3.76
D	616/1414	43.6	0.69	0.52
E	497/778	63.9	0.64	43.09
F	550/732	75.1	0.68	27.34
G	369/673	54.8	0.43	20.05
H*	237/276	85.9	0.24	95.96
I*	337/613	55.0	0.40	40.10
MA**	466/560	83.2	0.96	21.83
S	2158/2807	76.9	0.66	0
N	225/335	67.2	0.66	2.68
T	510/660	77.3	0.84	5.46
J(Buffalo)	305/462	66.0	0.33	13.35
J(Tide L.)	217/285	76.1	0.39	3.35
P	106/156	67.9	0.17	9.30

*Eight years' data.

**Five years' data.

Table 3. Maximum and minimum pronghorn populations and densities on winter ranges in Alberta and 5 year average density as determined from aerial surveys.

Winter range	Area (km^2)	Maximum population	Maximum density (km^2)	Minimum population	Minimum density (km^2)	Average density over 5-year period/(km^2)
A	439	1,346	3.07	293	0.68	1.59
C_1-C_4	250	424	1.70	62	0.25	0.84
D	634	953	3.9	558	0.88	2.37
E	251	692	2.76	159	0.63	1.75
F	327	643	1.97	220	0.67	1.27
G	156	336	2.15	36	0.23	0.93
H	125	273	2.18	80	0.64	0.58
I_1, I_2	386	618	1.60	88	0.23	1.09
J	387	532	1.37	88	0.23	0.91
K	244	623	2.55	150	0.61	1.52
L	224	517	2.31	296	1.32	1.88

Table 4. Fall to spring utilization of sagebrush on permanent browse transects, each consisting of 25 tagged plants. Data are summarized for the winters of 1971-72 to 1974-75, inclusive.

Winter range	No. of transects	No. sagebrush plants per 60 m line intercept	Sagebrush use overwinter		Mean no. pronghorns per km^2 of sagebrush vegetation on range
			Leaders browed (%)	Annual growth used (%)	
A. Red Deer River	3	21.4	25.3	19.8	5.44
C. South Sask. River	3	5.8	23.8	18.1	2.65
D. Walsh Flats	5	21.6	55.5	39.2	8.25
E. Lodge Creek	4	27.2	25.0	14.7	4.78
F. Sage Creek	3	24.8	12.8	14.4	3.71
H. Canal Creek	2	28.0	17.3	8.4	-
I. Milk River Valley	3	29.0	28.5	26.5	10.51
J. Milk River Ridge	2	14.4	65.7	55.2	22.57
K. Grand Forks	2	12.6	22.3	19.8	5.22
J. Lake Newell	3	15.2	24.0	22.4	3.69
Mean		20.0	30.0	23.8	7.42

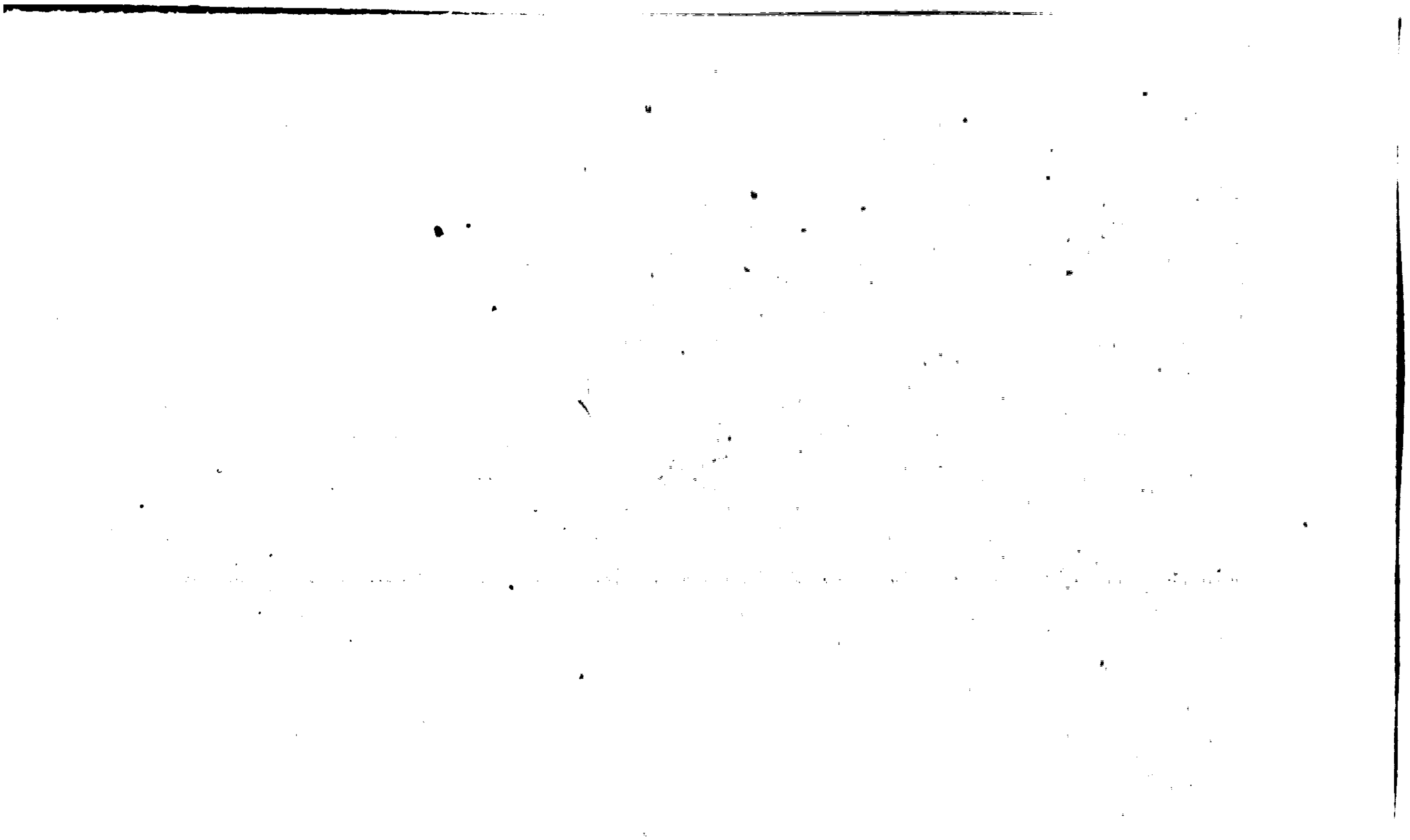


Figure 1. Major land use zones and survey blocks within the pronghorn range in Alberta.

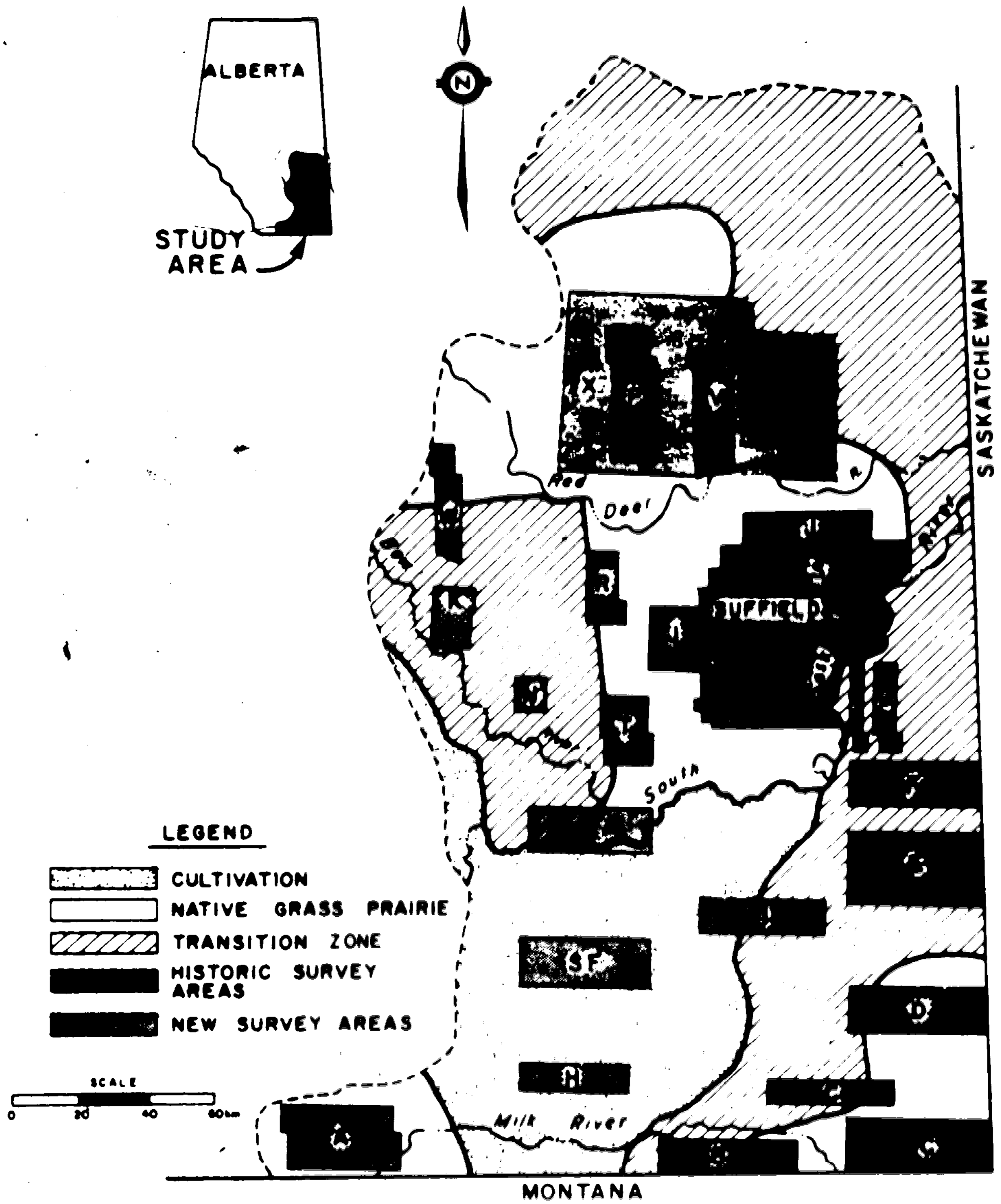

ALBERTA
STUDY AREA
N
SASKATCHEWAN
Red Deer R.
Bow
River
South
SUFFIELD
SF
Milk River
MONTANA
LEGEND
CULTIVATION
NATIVE GRASS PRAIRIE
TRANSITION ZONE
HISTORIC SURVEY AREAS
NEW SURVEY AREAS
SCALE
0
20
40
60 km

Figure 2. Delineation of the summer distribution, key winter ranges and general movement patterns of pronghorns in Alberta.

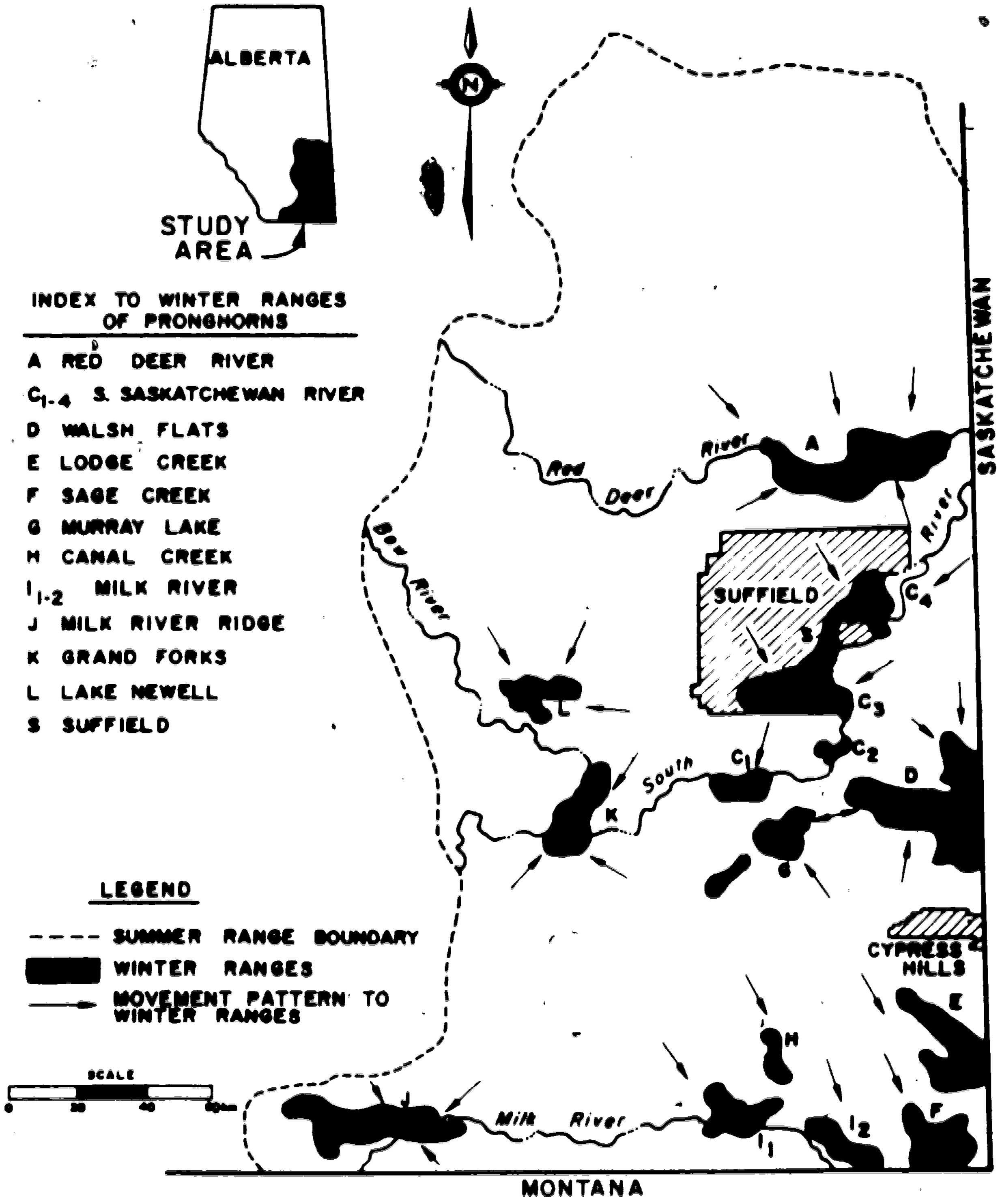

ALBERTA
STUDY AREA
INDEX TO WINTER RANGES OF PRONGHORNS
A RED DEER RIVER
C1-4 S. SASKATCHEWAN RIVER
D WALSH FLATS
E LODGE CREEK
F SAGE CREEK
G MURRAY LAKE
H CANAL CREEK
I1-2 MILK RIVER
J MILK RIVER RIDGE
K GRAND FORKS
L LAKE NEWELL
S SUFFIELD
LEGEND
SUMMER RANGE BOUNDARY
WINTER RANGES
MOVEMENT PATTERN TO WINTER RANGES
SCALE
0
20
40
60km
N
Red Deer River
Bow River
South
River
SUFFIELD
A
S
C1
C2
C3
C4
D
G
K
L
E
F
H
I1
I2
J
CYPRESS HILLS
Milk River
SASKATCHEWAN
MONTANA

Figure 3. Relationship of current hunting zones to key winter ranges of pronghorns in Alberta.

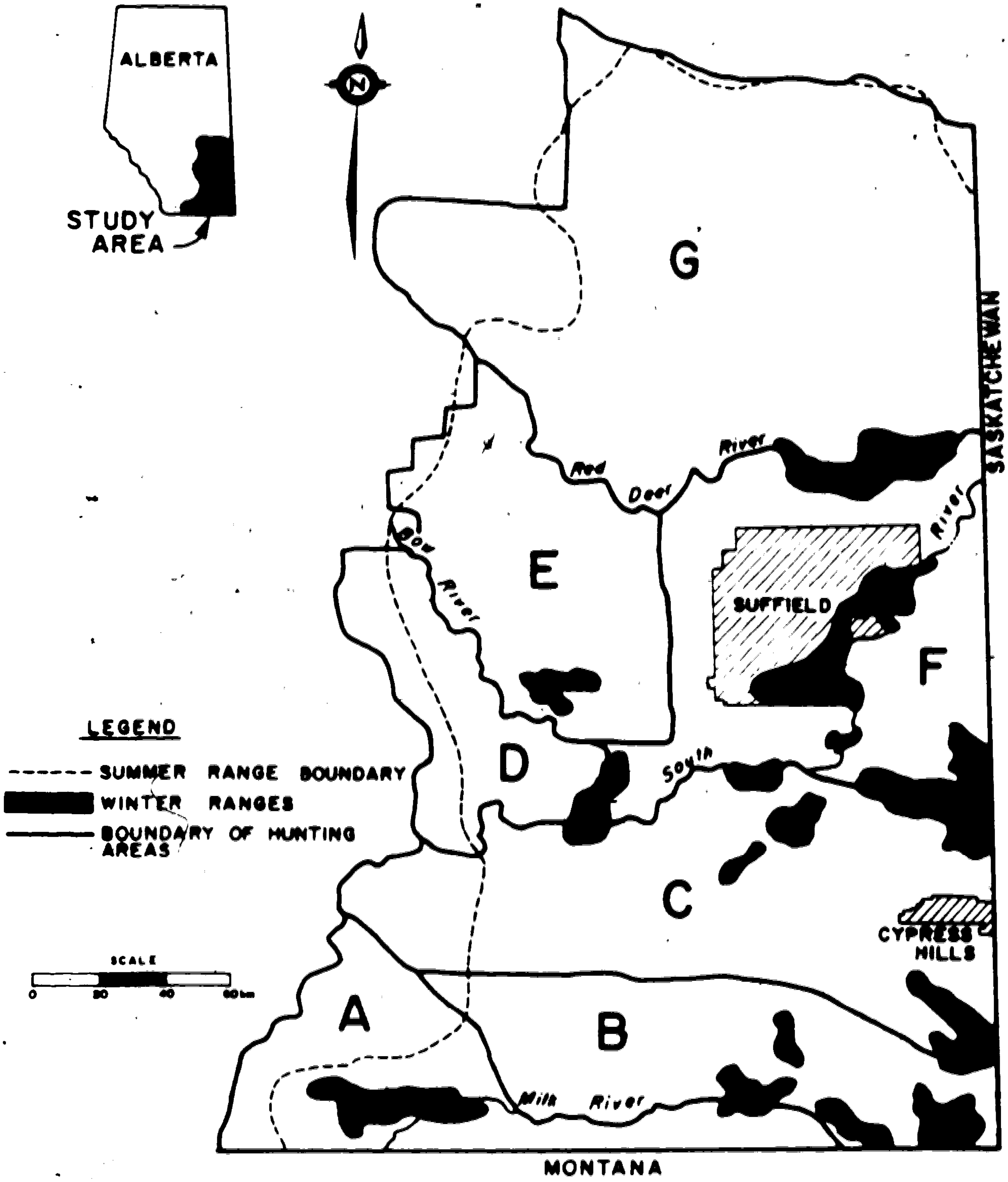
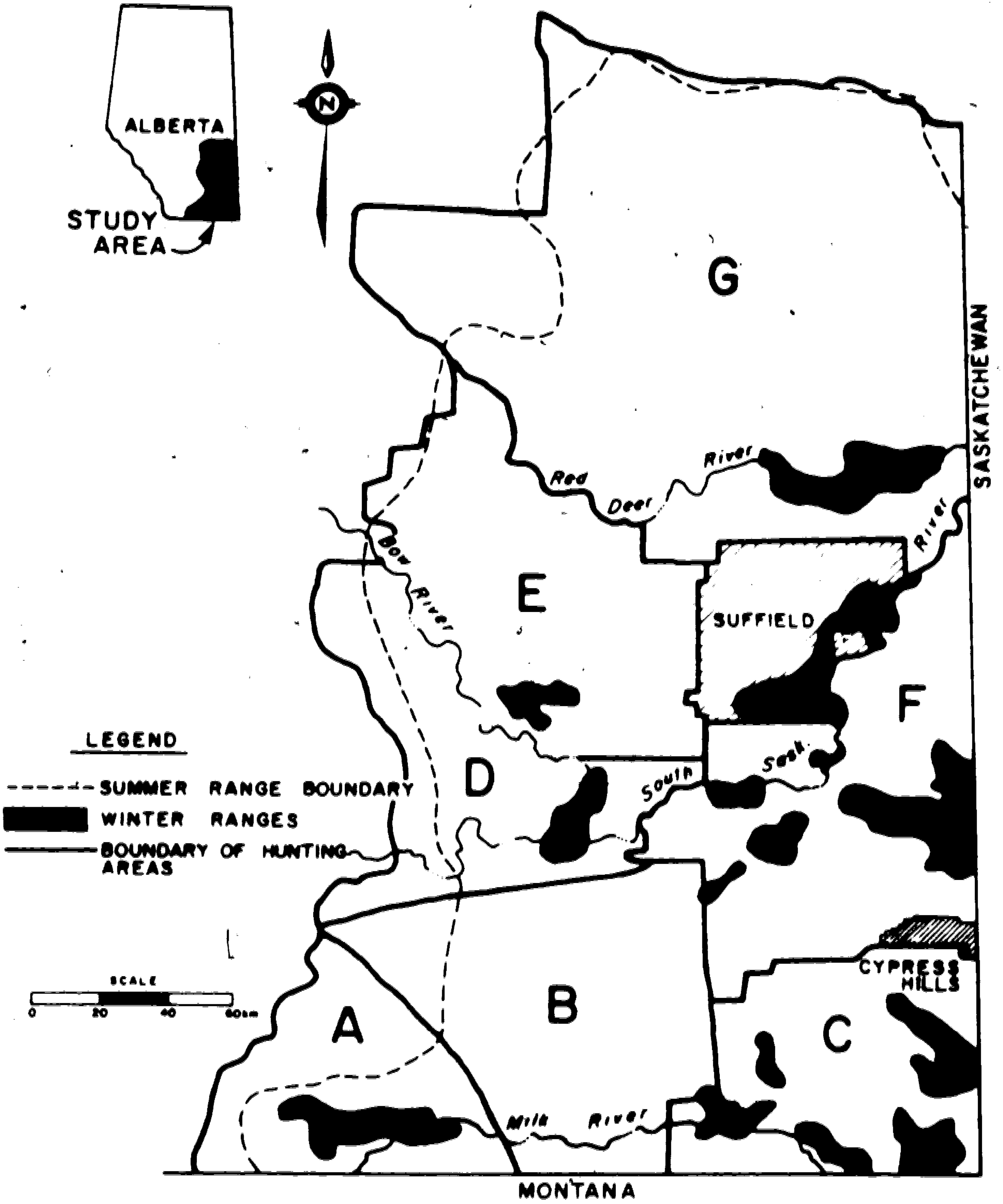

ALBERTA
STUDY AREA
N
G
E
D
F
C
A
B
SUFFIELD
CYPRESS HILLS
Red Deer River
Bow River
South
River
Milk River
SASKATCHEWAN
MONTANA
LEGEND
SUMMER RANGE BOUNDARY
WINTER RANGES
BOUNDARY OF HUNTING AREAS
SCALE
0
20
40
60 km

Figure 4. Relationship of key winter ranges of pronghorns to proposed hunting zones.


ALBERTA
STUDY AREA
N
G
SASKATCHEWAN
Red Deer River
Bow River
E
SUFFIELD
River
F
D
South Sask.
LEGEND
SUMMER RANGE BOUNDARY
WINTER RANGES
BOUNDARY OF HUNTING AREAS
SCALE
0
20
40
60km
CYPRESS HILLS
A
B
C
Milk River
MONTANA

LITERATURE CITED

Amstrup, S. C. 1978. Activities and habitat use of pronghorns on Montana-Wyoming coal lands. Proc. Bienn. Pronghorn Antelope Workshop. 8:270-303.

Autenrieth, R. 1978. Guidelines for the management of pronghorn antelope. Proc. Bienn. Pronghorn Antelope Workshop. 8:472-526.

Barrett, M.W. 1970. Antelope aerial surveys and estimated population, Lethbridge Region, 1970. Albert Fish and Wildl. Div. Rep. 26 pp.

____________. 1974. Importance, utilization and quality of Artemisia cana on pronghorn winter ranges in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 6:337-359.

____________. 1980. Seasonal habitat associations of pronghorns in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:174-195.

Bayless, S. R. 1969. Winter food habits, range use, and home range of antelope in Montana. J. Wildl. Manage. 33:538-551.

Bruns, E.H. 1977. Winter behavior of pronghorns in relation to habitat. J. Wildl. Manage. 41:560-571.

Cook, A.R. 1981. Antelope aerial survey and population analysis, July 20-28, 1981. Alberta Energy and Natural Res., Fish and Wildl. Div. Edmonton. 162 pp.

Dirschl, H. J. 1963. Food habits of pronghorn in Saskatchewan. J. Wildl. Manage. 21:81-93.

Leftwich, T. J. and C. D. Simpson. 1978. The impact of domestic livestock and farming on Texas pronghorns. Proc. Bienn. Pronghorn Antelope Workshop. 8:307-320.

Mitchell, G. J. 1965. Natality, mortality and related phenomena in two populations of pronghorn antelope in Alberta, Canada. Ph.D. Thesis, Wash. State Univ. 205 pp.

__________. 1980. the pronghorn antelope in Alberta. University Regina. Regina, Sask. Monogr. 165 pp.

__________, and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Wiltse, E. 1978. Summary of southwestern Saskatchewan antelope studies. Proc. Bienn. Pronghorn Antelope Workshop. 8:162-181.

Wishart, W., and W. K. Hall. 1967. Provincial antelope surveys and harvest, 1963-1967. Alta. Dept. of Lands and Forests, Wildl. Invest. Compl. Report, Project W-1-3-67. Job No. A-1. 25 pp mimeo.

Chapter 6. Evaluation of fertilizer on pronghorn winter range in Alberta

Abstract: Nitrogen (N) alone, and in combination with phosphorus (P), was applied to sagebrush (Artemisia cana)-grassland vegetation which formed part of a traditional winter range for pronghorn (Antilocapra americana) in southeastern Alberta. Fertilizer was applied once, in April of 1975, and forage quality, forage production, and pronghorn response were monitored for the next 3 growing seasons. Forage quality on fertilized plots increased initially, but by late summer of each year, nutritional content was essentially similar in fertilized and control areas. Forage production increased markedly in each of the 3 years. The application of P in addition to N had little impact on forage quality and production. In years 2 and 3 following fertilizer treatment, N levels of 84, 168, and 252 kg/ha resulted in progressively more forage produced with each increase in N. Pronghorns selectively use the fertilized plots more heavily than they did adjacent control areas. The inability to increase protein content in cured samples of sagebrush and pasture sage (A. frigida) through fertilizer treatment detracts from the value of this procedure for improving pronghorn winter ranges. The general increases in total forage production and hence total protein production, and the preference of pronghorns for treated areas, however, suggest that the procedure should be evaluated further.

INTRODUCTION

For many years wildlife managers have been investigating the nutritional requirements of most species of indigenous ungulates (Bandy et al. 1956, French et al. 1956, Dietz 1965, Murphy and Coates 1966, Ullrey et al. 1967, Nagy et al. 1969). More recently, greater emphasis has been placed on the interactions of range quality, environmental factors, and bioenergetics in determining the welfare of wildlife (Silver et al. 1969, 1971, Ullrey et al. 1970, Nordan et al. 1970, Wesley et al. 1973, Mautz 1978). There has also been a proliferation of literature concerning the nutrient content of a wide variety of plant species consumed by wildlife. Some authors have outlined nutritional limitations in forage available to ungulates (Nagy et al. 1969, Ullrey et al. 1971). Wallmo et al. (1977) have modelled the protein and energy requirements of mule deer (Odocoileus hemionus) and suggest that estimates of carrying capacity of ranges for wildlife should reflect the nutrient supplies available.

Range managers have conducted extensive research into the value of fertilizer as a tool for increasing the quality and quantity of forage produced for domestic livestock. Wight (1976) reviewed the effect of fertilizer in the Northern Great Plains region and concluded that N in particular, greatly increased forage production, water-use efficiency, forage quality, and palatability. Fertilizer application on traditional big game ranges has been explored on a limited basis for years (Gibbens and Pieper 1962, Wood and Lindzey 1967, Bailey 1968, Abell and Gilbert 1974, Anderson et al. 1974, Bayoumi and Smith 1976, George and Powell 1977), but despite obvious potential, the practice has never become a widely used tool of wildlife management.

In Alberta, winter range is critical for the survival of pronghorns, as the quality of forage and the distribution of suitable vegetation types within the pronghorn winter range are limited (Barrett 1974). Numerous fertilizer trials have been conducted on the semiarid grasslands of the northern Great Plains (Kilcher et al. 1965, Johnston et al. 1967, Lorenz and Rogler 1973) but no study has focussed on the sagebrush-grassland vegetation type that constitutes the critical element of pronghorn winter ranges in Canada. Furthermore, no information appears available on the response to fertilizer application on any pronghorn winter range.

The general objectives of this study were to evaluate the effects of N and P fertilizer on a traditional pronghorn winter range in Alberta. Specifically, efforts were made to document changes in (1) nutrient content of forage, (2) forage production, and (3) responses of pronghorn to forage as a result of fertilizer application.

STUDY AREA AND METHODS

The study area was a fenced 200-ha pronghorn enclosure located in the extreme southeastern corner of Alberta. The enclosure was established in 1973 and was situated on a portion of a traditional pronghorn winter range. As part of a long-term study on the carrying capacity of winter range, an average of 22 pronghorns were contained continuously in the enclosure at the time the fertilizer trials were conducted from April 1975 to November 1977. All fertilized plots were located within the enclosure but the total plot area represented less than 0.1% of the enclosure.

The study area is located in the Brown soil zone; the climate is semiarid. Mean annual precipitation (1941-1970) in the area as measured at the Agriculture Canada Research Sub-Station, Manyberries, 22 km southwest from the enclosure, is only 327 mm. Precipitation from April to July, inclusive, for the 3 years of the fertilizer trail was 295, 175, and 114 mm for 1975, 1976, and 1977, respectively (S. Smoliak, pers. comm.). General descriptions of the area have been presented by Coupland (1950,1961) and by Mitchell and Smoliak (1971). Specifically, the fertilized sites reflected a sagebrush-grassland vegetation type. The most prevalent browse, forb, and grass species, as determined by point quadrat analysis, were sagebrush, pasture sage (<u>A. frigida</u>), and western wheatgrass (<u>Agropyron smithii</u>). The sagebrush-grassland vegetation type was selected because of its importance in providing winter range for pronghorns in Alberta (Mitchell and Smoliak 1971, Barrett 1974).

Three rates of N and three rates of N plus P were applied on test plots. Firstly, ammonium nitrate was applied in combination with P at the rates of 84N-39P, 168N-78P, and 252N-118P kg/ha. P was applied in the form of triple superphosphate. Each of the 6 treatments was replicated twice, producing a total of 12 experimental plots. Two adjacent areas were used as control plots for each replicate. Plot size was 6 x 15 m. Treatment was assigned to each plot on a completely random basis. A hand-held cyclone seeder was used to apply the single application of fertilizer on

April 29, 1975; at that time no visible sign of spring growth was evident.

Forage for chemical analyses was collected from each of the fertilized plots and control areas on 5 occasions, namely, June 1975, September 1975, October 1975, August 1976, and August 1977. Each collection consisted of a composite sample of sagebrush, pasture sage, and western wheatgrass, representing the dominant species of browse, forb, and grass, respectively. Portions of current year's growth collected from 20 to 40 individual plants of each species were pooled to obtain the forage class sample from each plot for chemical analyses. Using standard analytical techniques of the AOAC (1960) determinations for moisture, protein, calcium (Ca), P, and fiber were conducted. Values for treatments were averaged for presentation and all results are expressed on a dry weight basis.

During late October 1975, soil samples from each control area were collected from depths of 0-10 cm, 10-30 cm, and 30-60 cm; the three collections were analyzed separately. Using standard techniques, N, P, potassium (K), conductivity, and pH values were obtained.

In August, after the growing season, forage production was determined for 3 consecutive years following fertilizer application. Twenty ¼ m² areas were clipped in each of the fertilized plots and control areas. Total annual production of browse, forbs, and grasses was separated, oven-dried and weighed. Data from each replicate are combined for presentation.

Leader lengths of sagebrush in each plot were sampled. In October of 1975, 1976, and 1977, 100 leaders were measured in each plot. In 1976 and 1977, an additional 400 leaders from adjacent protected areas that received no ungulate browsing were measured. Leader lengths reflected the current year's growth only. Values obtained for each treatment replicate are combined for presentation.

The plots were inspected periodically for evidence of use by pronghorns. In November of 1977, fecal pellet counts were made in 10 1-m^2 plots in each of the fertilized plots and 50 1-m^2 plots in the adjacent control areas. At the same time, the proportion of sagebrush leaders browsed inside each fertilized plot and in the adjacent control areas were determined using Cole's (1963) method for random transects.

Differences between sets of means were examined for statistical significance using the t test. Minimum level of probability for statistical significance was $P < 0.05$.

RESULTS

Protein content of sagebrush, pasture sage and western wheatgrass is summarized for the fertilizer treatments at each sampling period in Table 1. Sagebrush sampled from fertilized plots had a mean protein value significantly greater than that of the respective control value in June 1975 and August 1976; no significance existed between the different fertilizer rates. Protein values in samples of sagebrush collected in late summer, while generally higher than control values, were not enhanced significantly by fertilizer. Similarly, pasture sage from fertilized plots collected after the growing season did not have significantly increased protein values relative to controls (Table 1). Differences in fertilizer application rates did not produce significant differences in the protein content of pasture sage. Western wheatgrass had significantly greater protein values in samples from fertilized plots as compared to controls on each sampling occasion except August, 1977 (Table 1). The mean protein content of western wheatgrass increased progressively with each increase in N fertilizer; the mean protein value for 252 kg/ha N plots was significantly ($P < 0.05$) greater than the mean protein content in western wheatgrass from the 84 kg/ha N plots. The relative increase in protein content following the application of N was more pronounced in western wheatgrass than in pasture sage or sagebrush.

Protein content of control samples collected in September, 1975 and August 1976 and 1977 was compared for the 3 forage classes. Over the 3 years, the mean late summer protein content of sagebrush, pasture sage, and western wheatgrass was 10.8, 9.5, and 6.2%, respectively. The species means were significantly different ($P < 0.05$).

No consistent changes in Ca, P, Ca-P ratio, or fiber content of sagebrush, pasture sage, and western wheatgrass were evident as a result of fertilizer application. Consequently, analytical values obtained for fertilized and control samples were pooled (Table 2). The August and September samples of sagebrush had significantly more Ca and P content than did samples of pasture sage or western wheatgrass. Of all parameters examined, sagebrush contained higher nutrient values than did pasture sage or western wheatgrass (Table 2).

Analytical data for soil collected from the control areas are presented in Table 3. In general, soil in the test areas was deficient in N and rich in P and K.

Forage Production

Increases in grass and total forage production were evident at each level of fertilizer application in the year of treatment (Table 4). The largest increases occurred for the grass component. Because of decreased precipitation, the general conditions for plant growth deteriorated from 1975 through 1977, but the increased yield of vegetation in response to fertilizer treatment was apparent in each year. The values in Table 4 do not include cactus (Opuntia sp.) growth because of the sporadic distribution of this species and the potential of distorting forb production for any treatment plot. Slight increases in grass and browse production, although not significant, continued to be evident on fertilized plots after 3 growing seasons (Table 4).

Increased forage production as a result of N+P application was not evident when compared to corresponding levels of N fertilizer alone (Table 4). Consequently, forage produced for each level of N, with and without P, was combined to further examine the differences between the 3 levels of N application (Fig. 2); these values reflect total forage produced, including cactus. In 1975, total forage production on the fertilized plots was significantly higher ($P < 0.05$) for each level of N than on control plots but no significant difference existed between the fertilizer levels. In 1976 and 1977, forage production increased consistently with each corresponding increase in N application. The 1976 and 1977 forage increases, while biologically important, were not statistically different between fertilizer levels or between each fertilizer level and control.

Sagebrush Growth and Pronghorn Utilization

The mean leader lengths of sagebrush in response to different levels of N are summarized in Table 5. Consistently longer leaders were documented only in 1975, but presumably as a result of the great variability in individual leader lengths, the differences between the values for fertilized and control plots were not statistically significant. During each year, the growth of sagebrush in fertilized plots appeared more vigorous than in control areas, but the differences were not measurable by October of each year. By comparison, mean leader lengths of sagebrush in areas protected from browsing was 8.1 cm in 1976 and 10.5 cm in 1977.

On numerous inspections each summer, increased use of the fertilized plots by pronghorns was evident. All species of grass, forbs, and browse appeared to be more heavily utilized inside each fertilized plot than in adjacent areas. A count of pronghorn fecal pellets in November 1977 indicated that 20.8% more pellets were located in fertilized plots than in adjacent control areas. Similarly, a browse use study conducted in November 1977, showed that 34.4% of the 420 sagebrush leaders examined inside fertilized plots were browsed whereas only 17.5% of 850 leaders examined in adjacent control areas were browsed; these differences were highly significant ($P < 0.01$). Although supporting quantitative data are unavailable, signs indicated that pronghorns consumed significantly more grasses and forbs from within fertilized plots than from control areas.

DISCUSSION

Forage Quality

The lack of persistent increases in protein content of forbs and browse sampled from fertilized plots represents a limitation in the value of the technique for improving pronghorn winter range in Alberta. Although forage quality of cured plants was not enhanced greatly by fertilization, increased dry matter production, and hence increased total protein yield, resulted. Protein content in winter samples of sagebrush collected from Alberta winter ranges was only 7.6% (Barrett 1974) and appears to be less than optimal for overwintering pronghorns. Murphy and Coates (1966) reported that deer restricted to dietary protein rations of only 7% were less productive, had lower survival, and were in poorer condition than animals on a higher protein diet; pronghorn requirements may be similar to those of deer.

Pronghorns in Alberta do not appear restricted in terms of available summer nutrition and therefore little emphasis was placed on monitoring the forage quality during growing season. Pronghorns would derive the most benefit by increasing protein values in sagebrush and pasture sage during the fall and winter. My findings, however, were consistent with those of most studies conducted in the

Great Plains which showed that fertilizer generally increases protein content of forage most significantly during the growing season (Goetz 1975a, 1975b, Hanson et al. 1976, Wight 1976). Goetz (1975b) reported a progressive decline in protein content of all grass species as they approached maturity, irrespective of fertilizer treatment. He also reported that fertilizer treatment accelerated the rate of protein loss in late summer. In my study, fall samples of western wheatgrass from fertilized plots (Table 1) reflected the effect of fertilizer application more than did corresponding samples of cured sagebrush or pasture sage. During fall and winter, however, pronghorns in Alberta consume practically no grass (Mitchell and Smoliak 1971, Barrett 1974).

The addition of P in combination with N, produced few consistent benefits in terms of increasing forage production or quality. A similar lack of significant response to P application was reported by Goetz (1975a), Bayoumi and Smith (1976), and Wight (1976). The P content in winter samples of sagebrush in Alberta was only 0.16% and probably reflected a near minimum concentration for overwintering pronghorns (Barrett 1974). Phosphorus content in cured forage did not appear to be augmented by the application of P fertilizer. By contrast, Johnston et al. (1968) observed an increase in P content of rough fescue (Festuca scabrella) on southern Alberta grasslands in the Black soil zone that received much higher rates of P fertilizer than those used in my study.

Forage Production

Total forage production generally increased each year as a result of the single application of fertilizer (Table 4, Fig. 1). These findings are consistent with most reports on the effects of fertilizer on native range in the Northern Great Plains (Wight 1976). Treatment differences in total forage production as a result of differences in the rate of N application rates were not detected until the second and third growing seasons following fertilizer application (Fig. 1). Similarly, Wight (1976) stated that single applications of N at 56 kg/ha or less show limited carry-over effect, whereas applications of N over 112 kg/ha may have a residual effect for several years. Kilcher et al. (1965) reported that residual effects of 67 kg/ha N on grasslands in western Canada were evident for several years, probably as a consequence of low annual precipitation.

The production of forbs on fertilized plots was difficult to assess. Frequent visual inspections suggested that forb production on fertilized sites increased markedly each year but because pronghorns preferentially consumed them during the growing season, forb production was not measured accurately in August clippings. Also, growth of forbs in 1977 may have been restricted by the dry conditions during the growing season. An initial large increase in forb production following N fertilization, particularly at high application rates, has been reported by several authors (Kilcher et al. 1965, Johnston et al. 1967, Wight 1976). Wight (1976) indicated that pasture sage, in particular, responds readily to fertilizer but that the response decreases after the first year. Contrary to objectives for cattle grazing, increased forb production following fertilizer application would enhance the range for pronghorns but if the response of forbs is short-lived as Kilcher et al. (1965) suggested, then the technique is of less value.

Despite heavy utilization by pronghorns, increased browse production was a consistent measurable response to fertilizer treatment (Table 4). Increased leader length and a proliferation in growth of lateral twigs were most evident. The substantial increase in sagebrush production on fertilized plots, 3 years after treatment, was encouraging in view of the importance of sagebrush in the diet of pronghorns in Alberta (Mitchell and Smoliak 1971, Barrett 1974). The deep root system of sagebrush may account for the continuing response to fertilizer. Bayoumi and Smith (1976) reported an increase in production of big sagebrush (A. tridentata) in Utah following fertilizer application but they observed very little carry-over effect.

The great variation in total forage production between the 3 years of this study (Fig. 2) is a direct response to differences in precipitation. As the April to July precipitation declined from 295 mm in 1975 to only 175 mm and 114 mm in 1976 and 1977, respectively, forage production of grasses declined proportionately. The close relationship between spring precipitation and annual forage production in southeastern Alberta has been demonstrated by Smoliak (1956). Forage production may be particularly enhanced in dry years by fertilizer because of the better water use efficiency.

Palatability

Pellet group counts and forage utilization surveys indicated conclusively that pronghorns spent more time in fertilized plots and consumed significantly more of the available forage therein. Increased preference for fertilized range by domestic livestock has been a consistent finding. Similarly, fertilized range is usually preferentially used by wildlife (Gibbens and Pieper 1962, Anderson et al. 1974, Bayoumi and Smith 1976). Johnston et al. (1967) reported that white-tailed jackrabbit (Lepus townsendi) pellets on native range increased proportionately with increased levels of N and N-P fertilizer. The ability of pronghorns to select higher quality forage in winter has been documented previously (Bruns 1969, Barrett 1974). The continuation of their selection for fertilized range during the growing season, when most plants are comparatively high in palatability, underscores the sensitivity of their ability to detect differences in forage quality.

This paper represents the first published information available on the influence of fertilizer application on pronghorn range and consequently, the results should be considered as preliminary. Some of the findings are encouraging and further studies are required to more fully evaluate the technique. Particular attention appears warranted on the long range effect of fertilizer on forb and browse production, species composition, and palatability of forage for pronghorns.

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Table 1. Summary of protein content (%) of sagebrush, pasture sage, and western wheatgrass following fertilizer treatment in April, 1975[1].

Forage sampled	Sampling date June 1975	 Sept. 1975	 Oct. 1975	 Aug. 1976	 Aug. 1977
Sagebrush					
Treatment mean	20.9a[2]	12.4a	7.3a	10.9a	12.2a
Control	16.7b	11.4a	7.3a	9.5b	11.6a
Pasture sage					
Treatment mean	18.7a	11.8a	8.9a	10.6a	9.7a
Control	13.6b	10.5a	8.2a	9.4a	8.7a
Western wheatgrass					
Treatment mean	17.0a	8.2a	5.6a	8.1a	8.8a
Control	10.1b	5.5b	3.9b	5.9b	7.3a

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[1] For each sampling date, the mean value for each species reflects the average of all 6 fertilizer treatments.

[2] Within any column, the mean and control for a given forage species are significantly different ($P < 0.05$) if the values are followed by a different letter.

Table 2. Chemical analyses of forage collected on pronghorn winter range in Alberta in late summer of 1975 to 1977, inclusive.

	Forage sampled								
	Sagebrush			Pasture sage			Western wheatgrass		
Parameter	n	Mean*	S.D.	n	Mean	S.D.	n	Mean	S.D.
Ca (%)	48	0.98a	0.24	43	0.76	0.16	48	0.55c	0.16
P(%)	48	0.36a	0.08	41	0.22b	0.03	48	0.14c	0.03
Ca/P	48	2.72a	0.73	41	3.45b	1.06	48	3.93b	1.32
Fiber (%)	48	34.42a	3.36	41	40.26b	3.06	48	41.39b	2.36

* Each mean was derived by pooling data for all fertilizer levels and control areas, and represent August and September samples only.

[a] Within any row, means which are significantly different ($P < 0.05$) are denoted by a different letter.

Table 3. Analytical data for soil collected from control plots in October, 1975. Data from the 4 control plots were averaged to obtain values below.

Depth of sample (cm)	Soil elements (kg/ha) N	P	K	Soil pH	Conductivity (mmhos.)
0-10	5.9	69.1	1003.7	7.3	0.2
10-30	2.8	36.2	1047.2	7.9	0.3
30-60	2.0	28.1	879.3	8.5	0.9

Table 4. **Annual forage production (kg/ha) on sagebrush-grassland vegetative type in Alberta as determined one, two, and three growing seasons after fertilizer treatment.**

Fertilizer rate(kg/ha)		Forage production (kg/ha)											
		First growing season, 1975				Second growing season, 1976				Third growing season, 1977			
N	P	Grasses	Forb*	Browse	Total*	Grasses	Forbs*	Browse	Total*	Grasses	Forbs*	Browse	Total*
84	0	1403.9[a]	35.2	141.6	1580.7[a]	964.6	6.0	111.5	1082.1	134.2	24.4	240.2	398.8
84	39	1701.3[a]	29.6	806.1[a]	2537.0[a]	1063.7[a]	12.4	96.7	1172.8[a]	308.7	13.4	230.3	552.4
168	0	1883.9[a]	45.8	615.2	2544.9[a]	839.2	7.7	199.5	1046.4	337.2	4.2	378.7	720.1
168	78	1788.7[a]	42.8	483.8	2315.3[a]	1002.4[a]	6.8	55.3	1064.5	297.5	2.6	206.5	506.6
252	0	1717.7[a]	37.0	657.6	2412.3[a]	964.7	3.9	405.9	1374.5[a]	284.9	4.0	441.3	730.2
252	118	1640.2[a]	39.0	354.5	2033.7[a]	919.2	26.3	202.3	1147.8	298.5	20.0	304.5	623.0
Control		928.2	30.8	264.9	1223.9	747.7	21.4	190.1	959.2	275.1	17.9	177.5	470.5

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* These forage production values do not include data for <u>Opuntia</u> sp. which was encountered sporadically.

[a] Within any column, values which are significantly different ($P < 0.05$) than control values, are denoted by a letter.

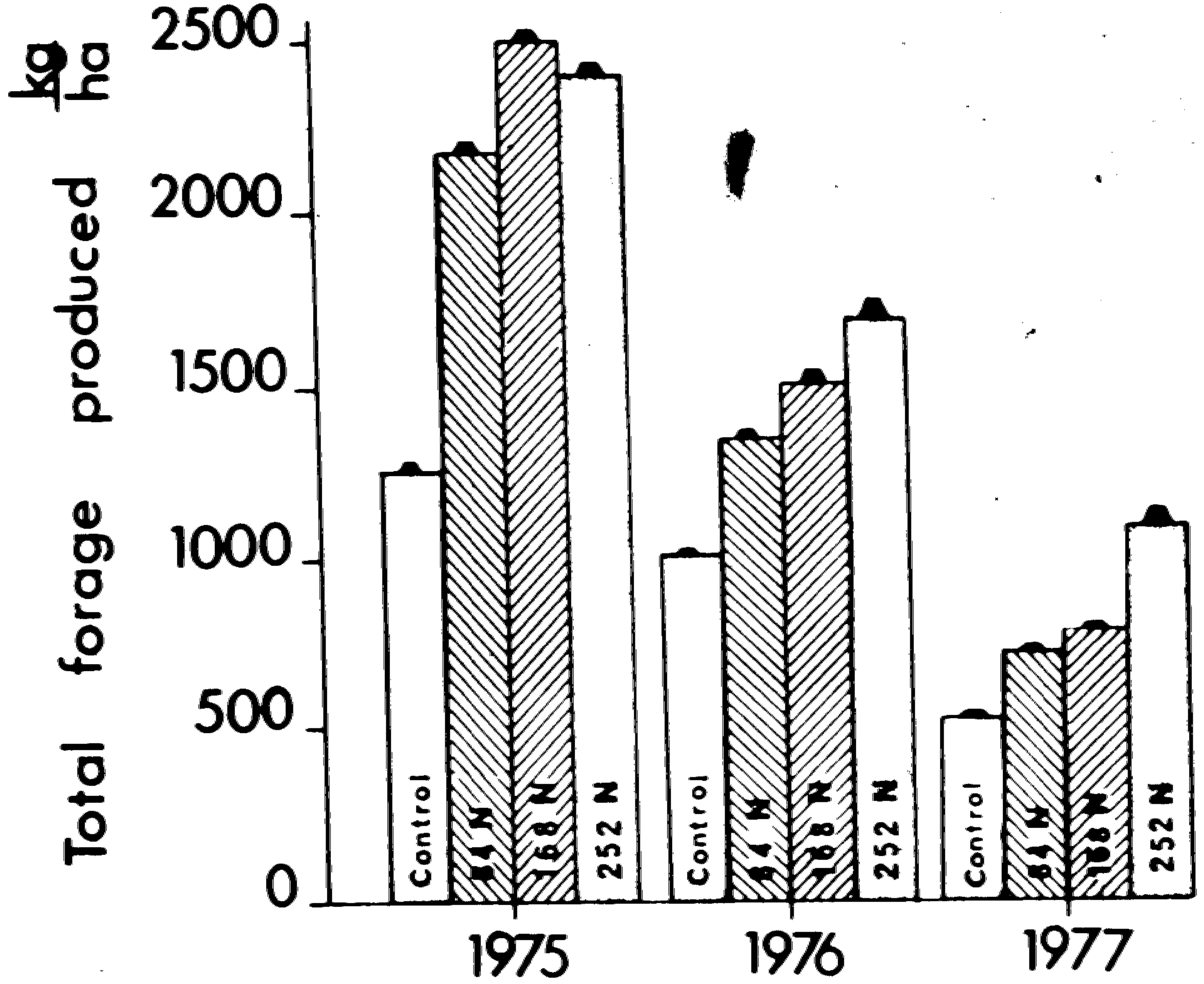
Table 5. Mean leader lengths (cm) of sagebrush associated with different levels of nitrogen fertilizer on pronghorn winter range.

Nitrogen rate[a] (kg/ha)	n	Mean leader length[b] (cm)					
		1975		1976		1977	
		Mean	S.E.	Mean	S.E.	Mean	S.E.
84	400	9.28	0.28	6.23	0.20	5.28	0.18
168	400	9.90	0.33	7.08	0.20	5.78	0.20
252	400	9.80	0.33	6.70	0.23	6.30	0.20
Control	400	7.63	0.25	6.65	0.15	5.75	0.23

[a] Fertilizer applied on April 29, 1975.

[b] Based on current year's growth as measured in October of each year.

Figure 1. Annual forage production on pronghorn winter range following fertilizer application in April, 1975. Projections of apex of each histogram represents one standard error.


Total forage produced kg/ha
2500
2000
1500
1000
500
0
Control
84 N
168 N
252 N
Control
84 N
168 N
252 N
Control
84 N
168 N
252 N
1975
1976
1977

LITERATURE CITED

Abell, D.H., and F.F Gilbert. 1974. Nutrient content of fertilized deer browse in Maine. J. Wildl. Manage. 38:517-524.

Anderson, B.L.. R.D. Pieper, and V.W. Howard, Jr. 1974. Growth response and deer utilization of fertilized browse. J. Wildl. Manage. 38:525-530.

A.O.A.C. 1960. Official methods of analysis (9th Ed.). Washington, D.C.

Bandy, P.J., I. McT. Cowan, W.D. Kitts, and A.J. Wood. 1956. A method for the assessment of the nutritional status of wild ungulates. Can. J. Zool. 34:48-52.

Bailey, J.A. 1968. Effects of soil fertilization on the concentration of crude protein in witchhobble browse. New York Fish and Game J. 15:155-164.

Barrett, M.W. 1974. Importance, utilization, and quality of _Artemisia cana_ on pronghorn winter ranges in Alberta. Proc. Bienn. Pronghorn Antelope Workshop 6:26-57.

Bayoumi, M.A., and A.D. Smith. 1976. Response of big game winter range vegetation to fertilization. J. Range Manage. 29:44-48.

Bruns, E.H. 1969. A preliminary study of behavioural adaptations of wintering pronghorn antelopes. M.Sc. Thesis, Univ. Calgary, Alberta. 60 pp.

Cole, G.F. 1963. Range survey guide. U.S. Dep. Int., Nat. Park Service, Moose, Wyo.

Coupland, R.T. 1950. Ecology of mixed prairie in Canada. Ecol. Monogr. 20:272-315.

__________. 1961. A reconsideration of grassland classification in the Northern Great Plains of North America. J. Ecol. 49:135-167.

Dietz, D.R. 1965. Deer nutrition research in range management. Trans. North Amer. Wildl. Nat. Res. Conf. 30:275-285.

French, C.E., L.C. McEwen, N.D. Magruder, R.H. Ingram, and R.W. Swift. 1956. Nutrient requirements for growth and antler development in the white-tailed deer. J. Wildl. Manage. 20:221-232.

George, J.F., and J. Powell. 1977. Deer browsing and browse production of fertilized American elm sprouts. J. Range Manage. 30:357-360.

Gibbens, R.P., and R.D. Pieper. 1962. The response of browse plants to fertilization. California Fish and Game. 48:268-281.

Goetz, H. 1975a. Availability of nitrogen and other nutrients on four fertilized range sites during the active growing season. J. Range Manage. 28:305-310.

__________. 1975b. Effect of site and fertilization on protein content of native grasses. J. Range Manage. 28:380-385.

Hanson, C.L., G.A. Schumaker, and C.J. Erickson. 1976. Influence of fertilization and supplemental runoff water on production and nitrogen content of western wheatgrass and smooth brome. J. Range Manage. 29:406-409.

Johnston, A., S. Smoliak, A.D. Smith, and L.E. Lutwick. 1967. Improvement of southeastern Alberta range with fertilizers. Can. J. Plant Sci. 47:671-678.

_________, L.M. Bezeau, A,D, Smith, and L.E. Lutwick. 1968. Nutritive value and digestibility of rough fescue. Can. J. Plant Sci. 48:351-355.

Kilcher, M.R., S. Smoliak, W.A[illegible]bbard, A. Johnston, A.T.H. Gross, and E.V. McCurdy. [illegible] Effects of inorganic nitrogen and phosphorus fertilizers on selected sites of native grassland in western Canada. Can. J. Plant Sci. 45:225-237.

Lorenz, R.J., and G.A. Rogler. 1973. Growth rate of mixed prairie in response to nitrogen and phosphorus fertilizer. J. Range Manage. 26:365-368.

Mautz, W.W. 1978. Sledding on a bushy hillside: The fat cycle in deer. Wildl. Soc. Bull. 6:88-90.

Mitchell, G.J. 1980. The pronghorn antelope in Alberta. University Regina. Regina, Sask. Monogr. 165 pp.

_________, and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Murphy, D.A., and J.A. Coates. 1966. Effects of dietary protein on deer. Trans. North Amer. Wildl. Nat. Res. Conf. 31:129-139.

Nagy, J.G., T. Hakonson, and K.L. Knox. 1969. Effects of quality on food intake in deer. Trans. North Amer. Wildl. Nat. Res. Conf. 34-146-154.

Nordan, H.C., I. McT. Cowan, and A.J. Wood. 1970. The feed intake and heat production of the young black-tailed deer (Odocoileus hemionus columbianus). Can. J. Zool. 48:275-282.

Silver, H., N.F. Colovos, J.B. Holter, and H.H. Hayes. 1969.

Fasting metabolism of white-tailed deer. J. Wildl. Manage. 33:490-498.

________, J.B. Holter, N.F. Colovos, and H.H. Hayes. 1971. Effect of falling temperature on heat production in fasting white-tailed deer. J. Wildl. Manage. 35:37-46.

Smoliak, S. 1956. Influence of climatic conditions on forage production of shortgrass rangeland. J. Range Manage. 9:89-91.

Ullrey, D.W., W.G. Youatt, H.E. Johnson, L.D. Fay, and B.L. Bradley. 1967. Protein requirements of white-tailed deer fawns. J. Wildl. Manage. 31:679-685.

__________, __________, __________, __________, B.L. Schoepke, and W.T. Magee. 1970. Digestible and metabolizable energy requirements for winter maintenance of Michigan white-tailed does. J. Wildl. Manage. 34:863-869.

__________, __________, __________, __________, D.B. Purser, B.L. Schoepke, and W.T. Magee. 1971. Limitations of winter aspen browse for the white-tailed deer. J. Wildl. Manage. 35:732-743.

Wallmo, O.C., L.H. Carpenter, W.L. Regelin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30:122-127.

Wesley, D.E., K.L. Knox, J.G. Nagy. 1973. Energy metabolism of pronghorn antelopes. J. Wildl. Manage. 37:563-573.

Wight, J.R. 1976. Range fertilization in the Northern Great Plains. J. Range Manage. 29:180-185.

Wood, G.W., and J.S. Linzey. 1967. The effects of forest fertilization on the crude protein, calcium, and phosphorus content of deer browse in a mixed oak forest. Pennsylvania Coop. Wildl. Res. Unit. 126 pp.

THESIS DISCUSSION

Habitat Relationships and Mortality of Fawns

This study revealed that pronghorn (Antilocapra americana) fawn mortality in Alberta in the years studied, exceeded 50% of those born. The overwhelming direct cause (67.5%) of fawn mortality was predation. Greatest losses occurred when fawns were between 4 and 15 days of age. With the advent of reliable telemetry systems, research on fawn mortality has received considerable attention in recent years. Direct measurements of high fawn mortality have been reported from Montana (Von Gunten 1978), Idaho (Bodie 1978) and Utah (Beale 1978, Beale and Smith 1973). Yoakum (1957) and Compton (1958) reported an apparent high mortality rate of fawns much earlier, but lacked refined, electronic instrumentation to investigate the relationships more fully.

Predation has been a consistent underlying cause of most of the reported mortality. Studies have identified the coyote (Canis latrans) as an important predator, but in addition, bobcat (Lynx rufus), and golden eagle (Aquila chrysaetos) have been involved (Barrett 1978, Beale 1978, Beale and Smith 1973, Bodie 1978, 1979, Von Gunten 1978). The status of the red fox (Vulpes vulpes), racoon (Procyon lotor), cougar (Felis concolor) and small raptors as predators on pronghorn fawns remains speculative (O'Gara 1978).

Entirely similar predator related mortality has been reported for white-tailed deer (Odocoileus virginianus) and mule deer (O. hemionus) fawns and the results of many studies have been summarized by Connolly (1978). Although less frequent than losses from predation, a "weak fawn syndrome" was described (Bodie and O'Gara 1980) as a plausible cause of early fawn mortality for a limited number of animals in Idaho.

Annual, mid-summer classification data for pronghorns are obtained by most provincial and state agencies responsible for the management of the species. Based on published survey results, high neonatal mortality is a consistent factor throughout much of the pronghorn range in North America (Vriend and Barrett 1978). The significant questions, however, are; 1) whether or not predation on fawns regulates pronghorn populations, and 2) how fawn mortality is influenced by the available habitat.

Arrington and Edwards (1951) reported that a widespread, aggressive coyote control program resulted in increased recruitment and total numbers of pronghorns in Arizona. Udy (1953) reported similar findings for Utah. Predator control has been shown to enhance reproductive success for white-tailed deer in southern Texas (Beasom 1974, Guthery and Beasom 1977). Consistently, predator control programs indicated that the control efforts must cover large geographic areas and that the effect was ususally short-lived. Recently, Neff and Woolsey (1980) reported that coyote predation on neonatal fawns was directly responsible for declining pronghorn populations in Arizona and once again they proposed predator control for that State. No management agency has yet adopted continuing, widespread, predator control as a primary management tool for pronghorns. In a general review of the value of predator control for game management purposes, Connolly (1978) found much of the available evidence to be inconclusive to the point that clear, general, recommendations could not be provided for wildlife managers.

In Alberta, predator control is not indicated. Despite continuing annual loss of approximately 50% of fawns, the provincial population appears to be regulated more by severe winters than by fawn mortality (Chapter 2, Barrett 1982). From a management perspective, however, fawn survival has a direct influence on the rate of population recovery following severe winters and is important in calculating the allowable annual hunting permits in Alberta.

The selection of bedding sites by fawns in Alberta indicated a lower dependence on sagebrush (<u>Artemisia cana</u>) rangelands than was observed in central Montana and Idaho (Pyrah 1974, Autenrieth 1976). Furthermore, the selection of specific habitat types by fawns influenced their chance of survival (Barrett 1981). Fawns that selected depressions or stands of heavy vegetative growth on native rangelands for their bedding sites had higher estimated survival rates. Animals whose initial bedding site was located on cultivated fields suffered the highest estimated rate of neonatal mortality. Although comparative data are scarce, Bodie (1978, 1979) reported contrasting rates of mortality for pronghorn fawns using different vegetation types on his study area in Idaho. Bodie (1979:52) concluded that bedding areas of pronghorns were selected primarily on the basis of reduced chance of encounters with predators and not on the basis of forage quality or quantity or the presence of hiding cover. Smith and Beale (1980) suspected that birth sites and fawn bedding sites were selected on the basis of offering good visibility as opposed to increased concealment.

Bromley (1978) postulated that the behavioral patterns of fawns at the birth site were adaptive responses to the ecological pressures of climate and predation. My observations of pronghorn fawns in Alberta supported his views in that bedding sites provided substantial relief from adverse weather conditions and that bedding site selection influenced the probability of fawn survival. Smith and Beale (1980) reported that fawns learned at an early age to select shelter and bedding sites that afforded them protection from the elements and increased their physical comfort. These findings are significant because pronghorn fawns are believed to select bedding sites that are generally representative of their birth site (Fichter 1974, Autenrieth 1976, Barrett 1981). The characteristics of bedding sites of fawns in South Dakota did not change significantly with increasing age of fawns during their first month of life (Bromley 1977). Bedding site selection during the first month of life is important to pronghorn fawn survival because neonates spend most of that time bedded (Autenrieth and Fichter 1975), and losses due to predation are at their highest level (Barrett 1978, Bodie 1978, Von Gunten 1978).

I found no convincing evidence that traditional fawning areas exist in Alberta. This conclusion concurs with the findings of Autenrieth (1976) in Idaho but differs from reports elsewhere (Einarsen 1948, Mace 1954, Ingold 1969). I hypothesized that the abundance of habitat areas preferred by parturient females and the general low density of pronghorns in Alberta eliminated the necessity to congregate in restricted areas. Furthermore, in preparation for delivery, pronghorn does seek seclusion (Autenrieth and Fichter 1975) and populations characteristically exhibit their yearly low in terms of mean herd size (Barrett 1980). Traditional fawning grounds, where they exist, may be more of a response to the availability of preferred habitats at that time of year than to a fidelity to a fixed geographic location.

The behavior of fawns appears to influence their vulnerability to predation. Bodie (1979) reported that large, active fawns appeared to be more susceptible to predation than small, more sedentary individuals. My study indicated that fawns 4-24 days of age had progressively increasing daily movements and minimum area polygons, and greater interactions between siblings; predation rate was highest during this time period. As fawns became more active, they were presumably easier for predators to locate. Fawns younger than 24 days of age generally bedded in response to danger and remained highly vulnerable to predation. I recorded no predation on fawns that were <4 days of age.

During the first 2 months following parturition, fawns used vegetative types in significantly different proportions from that of their availability (Chapter 2). They preferentially selected pockets of heavy vegetation on native rangeland, a behavior that was shown to increase their chance of survival (Barrett 1981). Similar observations on differential vulnerability of fawns have been reported by Autenrieth (1980) and by Bodie (1979) for contrasting vegetative cover. Despite a wide variation in cover types selected by fawns throughout their range, available evidence to date suggests that on a regional basis, preferred habitats offer increased protection from predation and promote survival. In Alberta, fawns bedded widely on grassland range and to a lesser extent, in small patches of sagebrush or tall forbs. However, fawns infrequently used large, contiguous, tracts of sagebrush, which afford protection for hunting bobcats and coyotes. On the basis of my research and information in the literature, I conclude that within any region, increased protection for fawns is apparently provided by vegetative cover that has the following characteristics: 1) is widely distributed; 2) has extensive diversity; and 3) is not preferred by predators.

Winter Distribution and Mortality

At the northern limits of their range, pronghorns occupied key wintering areas that represented approximately 8% of their summer range. Native rangelands containing sagebrush represented 39% of the 3500 km² of winter range. A high dependence on sagebrush during winter has been reported previously (Dirschl 1963, Bayless 1969, Beale and Smith 1970, Mitchell and Smoliak 1971, Barrett 1974). Strong evidence exists that lack of access to woody browse during severe winters is one of the primary causes of mortality (Martinka 1967, McKenzie 1970, West 1970, Barrett 1982). During normal winters, increased snow depth usually led to the formation of larger herds and more restricted distribution within winter ranges. During winter periods with little or no snowfall, pronghorns were widely distributed and typically were not found on normal wintering areas.

Variations in habitat and weather conditions have such a bearing on pronghorn distribution that comparisons from area to area are of little direct value (O'Gara 1978).

During the severe winter of 1977-78, many animals died in Alberta. Winters have long been recognized as a major source of mortality on northern ranges (Rand 1947) but little direct evidence existed previously. In Alberta, Wishart (1970) indicated, but presented no substantiating data, that severe winters caused increased emigration, starvation, losses from predation, and depressed production of young the following year. Mitchell (1965) reported that the severe winter of 1964-65 reduced forage availability and caused a "general debilitation" of pronghorns throughout southeastern Alberta. Some addition facets of winter mortality have been reported from Montana (Martinka 1967, Bayless 1969, Compton 1970), North Dakota (McKenzie 1970), and South Dakota (West 1970). Some behavioral adaptations of pronghorns during the severe winter of 1968-69 in Alberta were reported by Bruns (1977).

My study during the severe winter of 1977-78 showed that most animals (66%) did not occupy the traditional winter ranges documented in previous years (Barrett 1982). Pronghorns moved considerable distances and most sought and stayed on areas with reduced snow accumulation. As suggested by Bruns (1977), foraging in reduced snow areas would reduce energy expenditure. Based on the necropsy of pronghorns, I documented differential vulnerability of age and sex classes to winter loss, weight loss prior to death, and fat content of femoral marrow and kidney fat indices at death. The high prevalence of fetal mummification as a result of chronic winter malnutrition of adult does has never been reported previously for pronghorns. This may, in part, explain the low production of young that has been reported frequently following a severe winter. Fetal mummification during periods of nutritional stress may be an adaptive characteristic of pronghorns designed to promote the survival of adult females.

The provision of supplemental feed did not prevent continued mortality among wintering herds. De Calesta et al. (1975) successfully refed starving mule deer. However, animals starved to the point of nearing death may not be saved by supplemental feeding (De Calesta et al. 1977). Supplemental feeding programs for pronghorns have resulted in little success (Samuelson 1970, Gjersing 1978, Helms 1978, Pyrah 1978). Sociological and political realities dictate that emergency feeding rarely starts until animals begin to die and in all probability it is too late, at that time, to save animals that are near death; such was the case in Alberta during 1977-78.

Management Considerations

Numerous management recommendations have been generated through this study but perhaps none more important than those related to long-term land use. Buechner (1960) warned that, unless pronghorns became recognized as an important economic by-product of land use, populations will ultimately become much reduced as sagebrush vegetation on northern ranges is modified for agricultural purposes. Yoakum (1978) stated that the condition and structure of the vegetative community were the most important aspects of pronghorn habitat and management. The most import single habitat element for pronghorns in Alberta is the complex of identified winter ranges. These areas provide sufficient food and shelter to carry animals without high losses during most winters. For each of these areas, management plans that regulate the extent of cultivation, fall and winter cattle grazing, fence construction, industrial development, and access should be developed; guidelines to assist with the development of management plans are available (Autenrieth 1978, Yoakum 1980).

My research has shown that some changes can be made in the annual management program for pronghorns. Summer aerial surveys should record both population and habitat data. This change would allow managers to keep an index on land use and to relate animal densities and production to observed trends in agricultural practices. Sport hunting units should be revised to promote the harvest of animals based on a local population unit basis (Barrett 1980, Barrett and Vriend 1980). Current knowledge of wintering areas, seasonal movements, weather patterns, and land use practices make this recommendation a practical alternative at this time.

The application of fertilizer to winter range increased the total forage production but did not increase the nutrient content of cured samples of sagebrush or pasture sage (*A. frigida*) (Barrett 1979). Fertilized range was preferentially used by pronghorns during the growing season; preferential use has been reported previously for other wildlife with access to fertilized areas (Gibbens and Pieper 1962, Anderson et al. 1974, Bayoumi and Smith 1976). As a management tool, the application of fertilizer has limited value and should be considered in the future only when increased forage production is needed to maintain the carrying capacity of a winter range suffering from conflicting land uses.

In addition to the winter ranges, the diffuse areas of sagebrush scattered throughout the grasslands are preferred bedding sites and promote the survival of fawns. These areas should be retained whenever possible. Although coyotes prey heavily on fawns, my research has shown that there is no basis for active predator regulation as a means of increasing the long term population of pronghorns. A major shift occurs in the distribution of pronghorns as they move to and from winter ranges. A broader recognition of the type of fencing, which allows pronghorns to move freely (Spillett et al. 1967, Mapston 1970, Yoakum 1980), is required. Mobility is important to animals during severe winters as they search for areas with reduced snowdepths. Proper fencing for pronghorns, particularly along railway and road rights of ways, would reduce mortality of animals.

My thesis program addressed the original research objectives (see Introduction, Fig. 1) and has contributed new information to the literature. Specifically, I have shown that predation and to a lesser degree diseases, are important sources of mortality of pronghorns but these factors do not limit population growth. Winter severity has the greatest influence on population regulation. Pronghorns, although at the northern limits of their range in Alberta, have evolved over millions of years and have coped with the pressures of predation, disease, and weather. Unrestricted hunting and changes in land use associated with the settlement of western

North America, nearly descimated this species less than a century ago. Clearly, the ultimate factors limiting pronghorns in Alberta are related to the influence of land use practices on the availability and distribution of quality habitat within their historical range.

LITERATURE CITED

Anderson, B.C., R.D. Pieper, and V.W. Howard, Jr. 1974. Growth response and deer utilization of fertilized browse. J. Wildl. Manage. 38:525-530.

Arrington, O.N., and A.E. Edwards. 1951. Predator control as a factor in antelope management. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 16:179-193.

Autenrieth, R.E. 1976. A study of birth sites selected by pronghorn does and the bed sites of fawns. Proc. Bienn. Pronghorn Antelope Workshop. 7:127-134.

__________. 1978. Guidelines for the management of pronghorn antelope. Ed. Proc. Bienn. Pronghorn Antelope Workshop. 8:473-526.

__________. 1980. Vulnerability of pronghorn fawns to predation. Abstract. Proc. Bienn. Pronghorn Antelope Workshop. 9:77-78.

__________, and E. Fichter. 1975. On the behavior and socialization of pronghorn fawns. Wildl. Monogr. 42:111 pp.

Barrett, M.W. 1974. Importance, utilization and quality of _Artemisia_ _cana_ on pronghorn winter ranges in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 6:26-57.

__________. 1978. Pronghorn fawn mortality in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 8:429-444.

__________. 1979. Evaluation of fertilizer on pronghorn winter range in Alberta. J. Range Manage. 32:55-59.

__________. 1980. Seasonal habitat associations of pronghorns in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:174-195.

__________. 1981. Environmental characteristics and functional significance of pronghorn fawn bedding sites in Alberta. J. Wildl. Manage. 45:120-131.

__________. 1982. Distribution, behavior and mortality of pronghorns during a severe winter in Alberta. J. Wildl. Manage. 46:In press.

__________, and H.G. Vriend. 1980. Management implications of the seasonal distribution of pronghorns and land use practices in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:196-214.

Bayless, S.R. 1969. Winter food habits, range use, and home range of antelope in Montana. J. Wildl. Manage. 33:538-551.

Bayoumi, M.A., and A.D. Smith. 1976. Response of big game winter range vegetation to fertilization. J. Range Manage. 29:44-48.

Beale, D.B. 1978. Birth rate and fawn mortality among pronghorn antelope in western Utah. Abstract. Proc. Bienn. Pronghorn Antelope Workshop. 8:445-448.

__________, and A.D. Smith. 1970. Forage use, water consumption and productivity of pronghorn antelope in western Utah. J. Wildl. Manage. 34:570-582.

__________, and __________. 1973. Mortality of pronghorn antelope fawns in western Utah. J. Wildl. Manage. 37:343-352.

Beasom, S.L. 1974. Relationships between predator removal and white-tailed deer net productivity. J. Wildl. Manage. 38-854-859.

Bodie, W.L. 1978. Pronghorn fawn mortality in the upper Pahsimeroi River drainage of central Idaho. Proc. Bienn. Pronghorn Antelope Workshop. 8:417-428.

_________. 1979, Mortality of pronghorn fawns in the Upper Pahsimeroi River Valley. M.S. Thesis. Univ. Montana. Missoula. 98 pp.

_________, and B.W. O'Gara. 1980. A description of "weak fawn syndrome" in pronghorn antelope. Proc. Bienn. Pronghorn Antelope Workshop. 9:59-70.

Bromley, P.T. 1977. Aspects of the behavioral ecology and sociobiology of the pronghorn (Antilocapra americana). Ph.D. Thesis. Univ. Calgary, Alberta. 370 pp.

_________. 1978. Ultimate factors, behavior and fawn recruitment. Proc. Bienn. Pronghorn Antelope Workshop. 8:449-479.

Bruns, E.H. 1977. Winter behavior of pronghorns in relationship to habitat. J. Wildl. Manage. 41:560-571.

Buechner, H.K. 1960. Regulation of numbers of pronghorn antelope in relation to land use. Int. Union. Cons. Nature and Nat. Res. Warsaw. 105-136.

Compton, H.O. 1958. The effects of predation on pronghorn antelope numbers in south central Oregon. M.S. Thesis. Oregon State. Univ., Corvallis. 71 pp.

_________. 1970. Southeastern Montana antelope population trends in relationship to severe winters. Proc. Bienn. Pronghorn Antelope Workshop. 4:50-54.

Connolly, G.E. 1978. Predators and predator control. Pages 369-394. in J.L. Schmidt and D.L. Gilbert, eds. Big game of North America, ecology and management. Stackpole Books, Harrisburg, Pa.

De Calesta, D.S., J.G. Nagy, and J.A. Bailey. 1975. Starving and refeeding mule deer. J. Wildl. Manage. 39:663-669.

__________, __________, and __________. 1977. Experiments on starvation and recovery of mule deer does. J. Wildl. Manage. 41:81-86.

Dirschl, H.J. 1963. Food habits of the pronghorn in Saskatchewan. J. Wildl. Manage. 27:81-93.

Einarsen, A.S. 1948. The pronghorn antelope and its management. Stackpole Co., Harrisburg, Pa. 238 pp.

Fichter, E. 1974. On the bedding behavior of pronghorn fawns. In: The Behavior of Ungulates and its Relationship to Management. V. Geist and F. Walther, Eds. Vol. I and II. IUCN Public 24, Morges, Switzerland. 352-355.

Gibbens, R.P., and R.D. Pieper. 1962. The response of browse plants to fertilization. California Fish and Game. 48:268-281.

Gjersing, F. 1978. Participant in discussion an the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop. 8:337-359.

Guthery, F.S., and S.L. Beasom. 1977. Responses of game and non-game wildlife to predator control in south Texas. J. Range. Manage. 30:404-409.

Helms, B. 1978. Participant in discussion on the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop. 8:337-359.

Ingold, D.A. 1969. Social organization and behavior in a Wyoming pronghorn population. Ph.D. Thesis. Univ. Wyoming, Laramie. 142 pp.

Mace, R.U. 1954. Oregon's pronghorn antelope. Oregon State Game Comm. Wildl Bull. 1. 26 pp.

Mapston, R.D. 1970. Casper antelope pass studies. Proc. Bienn. Pronghorn Antelope Workshop. 4:116-124.

Martinka, C.J. 1967. Mortality of northern Montana pronghorns in a severe winter. J. Wildl. Manage. 31:159-164.

McKenzie, J.V. 1970. Two killer winters 1964-1965 and 1968-1969 in North Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:36-40.

Mitchell, G.J. 1965. Natality, mortality and related phenomena in two populations of pronghorn antelope in Alberta, Canada. Ph.D. Thesis, Washington State Univ. Pullman. 205 pp.

__________, and S. Smoliak. 1971. Pronghorn antelope range characteristics and food habits in Alberta. J. Wildl. Manage. 35:238-250.

Neff, D.J., and N.G. Woolsey. 1980. Coyote predation on neonatal fawns on Anderson Mesa, Arizona. Proc. Bienn. Pronghorn Antelope Workshop. 9:80-93.

O'Gara, B.W. 1978. Antilocapra americana. Mammalian species. 90:1-7.

Pyrah, D. 1974. Antelope fawn bedding cover selection in central Montana. Proc. Bienn. Pronghorn Antelope Workshop. 6:113-121.

__________. 1978. Participant in discussion on the impact of a severe winter on northern pronghorn ranges. Proc. Bienn. Pronghorn Antelope Workshop. 8:337-359.

Rand, A.L. 1947. The 1945 status of the pronghorn antelope, Antilocapra americana (Ord) in Canada. National Museum Canada. Ottawa. Bull. 106. 34 pp.

Samuelson, J. 1970. Participant in discussion on winter mortality of pronghorns. Proc. Bienn. Pronghorn Antelope Workshop. 4:56.

Smith, A.D., and D.M. Beale. 1980. Pronghorn antelope in Utah: some research and observations. Utah Div. Wildl. Resources. Pub. 80-13. 88 pp.

Spillett, J.J., J.B. Low, and D. Sill. 1967. Livestock fences -- how they influence pronghorn antelope movements. Utah Agric. Exp. Sta. Logan, Bull. 470. 79 pp.

Udy, J.R. 1953. Effects of predator control on antelope populations. Utah Dep. Fish and Game. Salt Lake City. Pub. 5. 48 pp.

Von Gunten, B.L. 1978. Pronghorn fawn mortality on the National Bison Range. Proc. Bienn. Pronghorn Antelope Workshop. 8:394-416.

Vriend, H.G., and M.W. Barrett. 1978. Low fawn recruitment -- is it an issue? Proc. Bienn. Pronghorn Antelope Workshop. 8:360-379.

West, D.R. 1970. Effects of prolonged snow and cold winter on pronghorn mortality and reproduction in South Dakota. Proc. Bienn. Pronghorn Antelope Workshop. 4:41-49.

Wishart, W.D. 1970. A brief historic review of the pronghorn antelope in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 4:128-130.

Yoakum, J. 1957. Factors affecting mortality of pronghorn antelope in Oregon. M.S. Thesis. Oregon State Univ., Corvallis. 112 pp.

__________. 1978. Pronghorn. Pages 103-121. In J.L. Schmidt and D.C. Gilbert, Eds. Big game of North America, ecology and management. Stackpole Books, Harrisburg, Pa.

__________. 1980. Habitat management guides for the American pronghorn antelope. U.S. Dep. Interior, B.L.M., Denver. Tech. Note. 347. 77 pp.

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Barrett, M.W. 1969. Response of ring-necked pheasants to ecological factors and reduced metabolizable energy levels. M.Sc. Thesis. Univ. of Guelph. 80 pp.

Barrett, M.W., and L.H. Karstad. 1971. A fluorescent erythrocyte test for lead poisoning in waterfowl. J. Wildl. Manage. 35:109-119.

Barrett, M.W., and E.D. Bailey. 1972. Influence of metabolizable energy on condition and reproduction of pheasants. J. Wildl. Manage. 36:12-23.

Barrett, M.W. 1972. A review of the diet, condition, diseases and parasites of the Cypress Hills moose. Proc. North Amer. Moose Conf. and Workshop. 6:60-79.

Barrett, M.W., and G.A. Chalmers. 1972. *Capillaria hepatica* (Nematoda: Trichuridae) in pronghorn antelope (*Antilocapra americana* Ord) in Alberta. J. Wildl. Diseases. 8:332-334.

Chalmers, G.A., and M.W. Barrett. 1974. Dermatomycosis in a mule deer in Alberta. J. Wildl. Diseases. 10:74-76.

Barrett, M.W. 1974. Importance, utilization and quality of *Artemisia cana* on pronghorn winter ranges in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 6:26-57.

Chalmers, G.A., and M.W. Barrett. 1974. Infectious pododermatitis in a pronghorn antelope in Alberta. J. Wildl. Diseases. 10:60-62.

Chalmers, G.A., and M.W. Barrett. 1974. *Echinococcus multilocularis* Leuckart, 1863 in rodents in Southern Alberta. Can. J. Zool. 52:1091.

Chalmers, G.A., and M.W. Barrett. 1974. Some problems associated with chasing pronghorns. Proc. Bienn. Pronghorn Antelope Workshop. 6:13-14.

Barrett, M.W., and G.A. Chalmers. 1975. A serologic survey of pronghorns in Alberta and Saskatchewan, 1970 - 72. J. Wildl. Diseases. 11:157-163.

Barrett, M.W., and G.A. Chalmers. 1975. Congenital anomalies in a neonatal white-tailed deer in Alberta. J. Wildl. Diseases. 11:497-501.

Samuel, W.M., M.W. Barrett, and G. Lynch. 1976. Helminths in moose of Alberta. Can. J. Zool. 54:307-312.

Chalmers, G.A., and M.W. Barrett. 1976. Trauma - induced paralysis in a moose calf. Can. Field Nat. 91:94-95.

Barrett, M.W., and G.A. Chalmers. 1976. Baseline hematologic and clinical chemistry values for pronghorns. Proc. Bienn. Pronghorn Antelope Workshop. 7:104-118.

Thorsen, J., L. Karstad, M.W. Barrett, and G.A. Chalmers. 1977. Viruses isolated from captive and free-ranging wild ruminants in Alberta. J. Wildl. Diseases. 13:74-79.

Chalmers, G.A., and M.W. Barrett. 1977. Capture myopathy in pronghorns in Alberta, Canada. J. Am. Vet. Med. Assoc. 171:918-923.

Lewis, R.J., G.A. Chalmers, M.W. Barrett, and R. Bhatnager. 1977. Capture myopathy in elk in Alberta, Canada: a report of three cases. J. Am. Vet. Med. Assoc. 171:927-932.

Barrett, M.W., and G.A. Chalmers. 1977. Hematological values for adult free-ranging pronghorns. Can. J. Zool. 55-448-455.

Barrett, M.W., and G.A. Chalmers. 1977. Clinicochemical values for adult free-ranging pronghorns. Can. J. Zool. 55:1252-1260.

Barrett, M.W. 1978. Population status and ecology of pronghorns in Canada. In Nature and Change on the Canadian Plains. W.A. Davis, Ed. 134-142.

Vriend, H.G., and M.W. Barrett. 1978. Low pronghorn recruitment - is it an issue? Proc. Bienn. Pronghorn Antelope Workshop. 8:360-377.

Barrett, M.W. 1978. Pronghorn fawn mortality in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 8:429-443.

Barrett, M.W. 1978. Editor, Proc. Bienn. Pronghorn Antelope Workshop. 8:532 pp.

Barrett, M.W. 1979. Evaluation of fertilizer on pronghorn winter range in Alberta. J. Range Manage. 32:55-59.

Barrett, M.W., and G.A. Chalmers. 1979. Hematological and clinicochemical values for free-ranging pronghorn fawns. Can. J. Zool. 57:1757-1766.

Barrett, M.W. 1980. Seasonal habitat associations of pronghorns in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:174-195.

Barrett, M.W., and H.G. Vriend. 1980. Management implications of the seasonal distributions of pronghorns and land use practices in Alberta. Proc. Bienn. Pronghorn Antelope Workshop. 9:196-214.

Barrett, M.W. 1981. Environmental characteristics and functional significance of pronghorn fawn bedding sites in Alberta. J. Wildl. Manage. 45:120-131.

Chalmers, G.A., and M.W. Barrett. 1982. Capture myopathy. Chapter in Non-infectious diseases of wildlife. Davis and Hoff, Eds. Univ. of Iowa Press, Ames. In press.

Barrett, M.W., J.W. Nolan, and L. Roy. 1982. Evaluation of a hand-held net-gun to capture large mammals. Wildl. Soc. Bull. In press.

Barrett, M.W. 1982. Distribution, behavior and mortality of pronghorns during a severe winter in Alberta. J. Wildl. Manage. 46:In press.