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Analysis of Summer Spotlighting for Determining Deer Populations Indices

Donald C. Duerre

ANALYSIS OF SUMMER SPOTLIGHTING FOR DETERMINING DEER POPULATION INDICES

BY

DONALD C. DUERRE

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ANALYSIS OF SUMMER SPOTLIGHTING FOR DETERMINING

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department

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CHAPTER I

INTRODUCTION

Man changes his environment to suit his needs. In so doing, he has destroyed forests, plowed the land, and built cities. Deer have adapted themselves to these changes, and in many instances populations have erupted as a result. Their ability to survive advancement of civilization and increasing hunting pressure has made deer the most important big-game animal in America. The importance of deer as a game animal has caused game agencies to institute more intensive management programs.

Proper management of this species has long been a problem of game technicians. In order to obtain an optimum annual harvest, the technician must be able to determine deer numbers and levels of area use by deer. Despite much research on these problems, considerable additional work is required for the development of an accurate, economical method of determining deer numbers.

The results of any census method largely depend on a knowledge of the habits and movements of the animal under study. Dahlberg and Guettinger (9) emphasized this in their study of the Wisconsin deer herd when they said (p. 52): "Where a deer or any other game animal is at a given time, or where he may be expected to go in a day or a season or a year must be known before intelligent management can be undertaken."

The South Dakota Department of Game, Fish and Parks, in searching for a practical deer-population index, established the spotlighting technique in 1944. Spotlighting was carried out on predetermined routes by two observers in a vehicle equipped with two mounted spotlights. All deer within range of the lights were tallied. At first, counts were made in October and early November. Although they provided a population sex ratio, as well as an index to deer numbers, no provisions were made to correct for the large variation in nightly counts; thus accurate census information was not obtained. In 1950, spring spotlighting replaced the fall work. It was thought that during the meadow "greening-up" period large numbers of hungry deer would be less susceptible to factors that influenced fall counts. Over a three year period (1950-1952) the counts were adversely affected by abnormal weather conditions when premature spring thaws followed by belated snow storms spread the peak of meadow use by deer. Consequently, comparable annual counts were not obtained. The technique, though improved considerably over the past 14 years, still left much to be desired.

Bever (2) requested that spotlighting be experimentally conducted during the summer months. He contended that after the deer had become established on their summer range, a reasonably constant number should be present in the same area each night. On this premise, this spotlighting study was initiated in the summer of 1958 and was set up to spotlight the same meadows each night from June 15 through September 15. During this period, data were kept on deer numbers, temperature, precipitation, time of observation, cloud cover, relative humidity, wind, lunar stages, phenology, and other factors known to influence deer movements. Evaluation of the effects of the above factors on deer movement and behavior may prove the summer spotlighting technique to be of value in future deer management.

CHAPTER II

REVIEW OF LITERATURE

Spotlighting as a Census Method

Several state wildlife agencies have used spotlighting in deer studies to obtain population indices, to measure population trends, and to collect sex ratio data. However, results of such studies remain largely unpublished. Correspondence with 33 State agencies and with three Canadian Provincial game departments indicated varying experience with the technique.

Five States and one Canadian Province - Virginia, Oklahoma, California, New Hampshire, Missouri, and British Columbia - made limited use of spotlights in deer research or management. The spotlighting activities of these state game organizations were too sporadic or of too short duration to develop special techniques, thus little usable information is available.

Other states have undertaken spotlighting programs. General observations are currently being made by Georgia Game Department personnel in conjunction with their deer capturing program on Ossabow Island. Downing (12) indicated the possibilities of spotlighting as a supplement to other deer census methods in Georgia. The Michigan Conservation Department has conducted deer spotlighting counts on various occasions; but, because of extreme variations in counts, the results were considered unreliable. It seems that the Michigan workers, like others, were unable to correct for factors influencing deer numbers, even in areas suitable for spotlighting operations (Eberhart, 13).

Currently Wisconsin is re-evaluating its existing spotlighting procedure for obtaining fall population ratios. Cook (7) of the Wisconsin Conservation Department said (personal letter): "We feel that some of our observers may be trying to identify, as to sex and age, at too great a distance; also weather conditions may play an important part in the ratio observed. . . . Next fall I plan to make some extensive observations on a study area."

Egan (14) and Boyd (3), working in Montana and Colorado respectively, noted the difficulties encountered in making counts of deer under spotlights. Both were counting deer involved in alfalfa damage complaints.

For several years North Carolina has been using sight counts on predetermined spotlighting routes and areas. Lack of a standardized technique resulted in sporadic counts which yielded little valuable information concerning factors that influenced deer numbers observed (Larimer, 18).

Biologists in South Dakota have found spotlighting an acceptable measure for deer populations and have gathered pertinent information since 1944. Originally the work was carried out during September and October. Berner (1) said (p. 12): "We aren't too satisfied with this method because of the big variation in counts along the same route on successive nights." Although these data collected in fall counts gave usable information, the program was changed to a spring operation to avoid certain factors (e.g. migrations, phenology) affecting census counts. Censuses for three consecutive years showed a rising population, but the validity of the method is doubtful in view of a doubling population segment on one transect in one year. The spotlighting technique was improved and satisfactory population trends were then obtained (Bever, 2). Both Berner and Bever indicated, however, that factors affecting deer numbers observed along spotlight routes must be evaluated before any great emphasis can be placed on yearly results.

Physiological Factors Influencing Spotlighting Results

Although there is very little that has been published about spotlighting as a deer-census method, considerable information concerning factors which affect deer movement and behavior, and ultimately spotlighting results is available. Pertinent publications are therefore reviewed below.

Fawning

When the spring migration, or the somewhat lesser movements have ended, deer establish themselves in home areas that will provide life's essentials. Does preparing to fawn seek seclusion and apparently establish a fawning site by late May. They then restrict their daily activities to a small area (Lindsey, 20).

Taylor (24) found that breeding peaks in mid-November across the Northern United States meant corresponding fawning would fall during the first part of June. Lindsey (20) also observed the greatest number of fawns were born during early June.

Fawns remain hidden in or near their birthplace for three weeks or more according to Taylor (24). Ruff (23) did not indicate the age of fawns when he observed that does with fawns feed largely at night and the fawns are kept in hiding during the day. Taylor (24) summarized fawn activity (p. 71):

> The duration of the hiding period varies with individuals. Sometimes the fawn begins to go with its mother after the first two or three weeks; at other times it seems to remain in seclusion for most of the summer. Occasionally very small fawns, not over a few days old, accompany their mothers to the feeding grounds. . . . Townsend and Smith do point out that when a doe had her fawn with her she was more nervous than when alone, and her stay on the feeding ground was shorter. Seemingly it would be an advantage to the feeding doe to have her young safely hidden.

Observations by the above authors would indicate that fawns tend to seek seclusion for three weeks or more after birth and that censusing dependent on voluntary deer movements would give low results during June and the first week of July. Because there is a variation in fawning dates, increases in numbers of fawns observed may extend over a greater period.

Antler Growth

Antler growth occurs in a cycle which is repeated year after year. Wislocki (27) noted that antlers begin to grow in April or May and become hard by September when the velvet is shed. Ruff (23), Cahalane (5), and Lindsey (20) also observed that obvious antler growth occurs during the period from May to September and that velvet rubbing starts about September first.

During the periods of early antler growth the buck stays by himself or will seek seclusion with other males. Movements are restricted to relatively small areas and invariably they can be found in the same place at the same time during the period of antler growth (Cahalane, 5, and Taylor, 24). These authors also referred to the increased activity of the buck as the summer progresses and as the breeding season approaches.

Progulske and Baskett (22) got their most precise deer movement information in spring, summer, and early fall; they wrote (p. 185):

> During these periods, several deer seemed to have rather small and distinct home ranges in which they could be found repeatedly. This pattern was well illustrated by one male which was observed 30 times during the 6-month period from March to September 1955. The deer was always seen within the same 360-acre area . . .

If daily observations were restricted to a single point, the inactivity of bucks would influence the number of deer observed during summer and early fall. Large increases in observed deer numbers could result as antler development progressed.

Feeding

Results of deer population studies extending over several seasons will be influenced by changes in daily and seasonal feeding habits. Preferred foods and preferred feeding periods change frequently; such habits are correlated with both meteorological and phenological conditions. Berner (1), Ruff (23), and Lindzey (20) found that deer concentrate on succulent green vegetation when it first appears in the spring and continue to feed on it whenever it is available throughout the summer. The latter two authors also noted that in late summer and early fall the drying of grasses causes deer to feed more intensely on forbs and on leaves and twigs of woody plants.

Many other workers have observed that deer feeding activities are related to availability of preferred foods. Such activities result in deer being particularly abundant at favorable feeding sites such as the open meadows observed in this study.

Ecological Factors Influencing Spotlighting Results

Weather and related ecological factors have a great influence on movements of deer and subsequently on the number of deer observed on any one area from night to night. It is difficult to separate the effects of one ecological factor from another. Linsdale and Tomich (21) pointed this out (p. 315): "The strength and weakness of light are closely associated with other atmospheric conditions that modify behavior of the deer, and this makes it difficult to detect any influence attributable to light alone." They also asserted that relative humidity is a factor dependent upon other weather phenomena.

It is generally agreed that any one weather factor cannot be expressed alone, but rather its effects modified by the complexities of other acting factors. Thus, only for convenience of discussion are the major weather factors separated below.

Moisture

Snow has a profound effect on movements of deer; the first heavy snow in the fall and the spring thaw directly regulates movements whether they be migratory or simply local shiftings. Ruff (23) noted that white-tailed deer[a] move about and feed more intensively before rain and snow. Dasmann and Taber (11), who studied the Columbian black-tailed

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[a]Scientific names are listed in Appendix A.

deer in California, discovered that precipitation and cloudiness stimulated activity of the animals at all hours but that heavy rains and wind drove deer to shelter. Darling (10) found wetness to be a potent influence on movements. He noted that a rain greatly stimulated activity and heavy rain and wind restricted it. He also observed that red deer banded together and moved down-slope just prior to a snowstorm.

In their work with mule deer, Linsdale and Tomich (21) found the same to be true and added (p. 310): "Long periods of rain can increase the tolerance of deer for rain."

The influence of humidity on deer behavior, though dependent on temperature and cloud cover, was studied by Hahn (17). He determined that there is a definite correlation between white-tailed deer movements, relative humidity, and sky cover during late afternoon. As the humidity increased he noted that deer movement decreased and therefore concluded that optimum weather for making deer counts is when humidity is low (70 percent or less) and when the sky is not more than 50 percent over cast. During spring spotlighting operations in the Black Hills of South Dakota, Bever (2) pointed out that high humidity is associated with the fewer numbers of deer observed in open meadows. This is in contrast to what Linsdale and Tomich (21) wrote (p. 317):

> The low humidity contributes to the discomfort of the deer for a large part of the day in the warm part of the summer. Morning activity subsides quickly with the drying of the air, and there is no more regular activity in the open until the moisture in the air begins to increase in the afternoon. . . . At the time humidity conditions become more favorable or reach their optimum, and most of the deer are up and about. A high humidity seems not to be detrimental to deer in any way.

A close association between moisture and temperature was found by Darling (10) in his activity studies of the red deer in Scotland. Clark (6) held that climatic conditions are important influences on daily movements of deer.

Temperature

Temperature variations throughout the year greatly affect deer activities. Deer, like many other animals, do not mind cold and often seek it, according to Darling (10). He observed that red deer while seeking the cooler areas tend to move toward the most even temperatures. The studies, however, were conducted on the damp coastal areas of Scotland. His findings indicated substantial correlation between temperature changes and movements. He noted the red deer move most on warm days and seek cover when the weather cools. Referring to temperatures he wrote (p. 108):

> Other influences may mask and overcome from time to time this rule of movement in relation to temperature but in analysis of behavior of red deer in Scotland it can be accepted as axiomatic. . . . Greatest daily movements occur in May to June when differences between daily maximum and minimum temperatures are greatest.

With the arrival of warmer weather, deer feed more at night, according to Clark (6). He also observed a great increase in night activity during extreme hot periods.

Linsdale and Tomich (21), Cronemiller and Bartholomew (8), and Dasmann and Taber (11), who worked on deer in California asserted that night activity varied directly with temperature. They did find, however, that daytime activity during the hot seasons increased when days were cloudy and cool.

Light

The effects of light upon deer activities are difficult to evaluate because of the close relationship of light with other ecological factors, particularly with moon phases and sky cover.

As seasons progress, changes in photoperiods directly affect deer behavior. Linsdale and Tomich (21) stated (p. 418): "From day to day the changes are generally small; in a week or a month, however, there may be great alteration in their program."

Daylight activities, partly the response to light, are subsequently reflected in night time movements and behavior. The effects of photoperiods during lunar phases has been noted by Linsdale and Tomich (21) (p. 394):

> The pattern of deer movement, feeding, and resting after dusk on the six nights showed no dependence on moonlight. Generally the alternate feeding and resting periods of afternoon continued into the night. . . . In all, deer made no detectable response to the progressively later moonset in increased activity or prolongation of alternate feeding and resting. Withdrawal to cover in the early hours of the morning is apparently determined by factors other than the presence or absence of moonlight and its intensity.

Ruff (23) also wrote of the effects of light (p. 226):

> Deer are generally as much nocturnal as diurnal. They rarely move during the middle of the day especially in warm weather; but from about four o'clock in the winter and somewhat later in summer until dusk, they begin to move freely, and can be seen feeding until almost midnight. Some individuals may move about the greater part of the night, but observations indicate that there is a period of inactivity during the night as there is in the day time. Many deer may continue to feed throughout the greater part of the day during cool weather, or during the winter critical period in order to obtain enough forage. . . .

Buss and Harbert(4), when studying the influence of moonlight on deer, observed the numbers of deer visiting a salt lick each day at 7

P.M. They determined that the most deer visited the lick during full moon and the least during new moon. According to Bever (2) the reverse was true for the Black Hills deer herd. He wrote that peak spotlighting counts for two areas occurred during the dark phase, or first quarter of the moon.

Wind

Wind, when associated with other factors, will have various effects on deer movements according to Darling (10). He found that deer have a varying degree of tolerance to wind associated with moisture and temperature variations. Linsdale and Tomich (21) are in agreement with this and report (p. 316):

> Wind accentuates the effects of cold; and on cold, windy days deer retire from otherwise favorable feeding places to leeward hillsides or protected clearings. The deer do not particularly avoid wind on hot days, although they usually are not then active in the open because of the adverse temperature and relative humidity. In mild weather, deer may freely feed or rest for hours in gentle or moderate wind. . . .

Other Factors Influencing Spotlighting Results

Factors other than those cited above have lesser effect on movements and behavior of deer which in turn would influence night census data.

During night observations of deer, Bever (2) was able to observe the deers' reaction to dogs, coyotes, and bobcats. The presence of these predators caused the deer to vacate the area immediately.

Road traffic was also evaluated in spotlighting operations by Bever (2). He contended that location of the study areas has a bearing upon effects of the traffic. He discovered that deer will build a tolerance to traffic along well-traveled roads; however, a vehicle's approach on lesser traveled back roads will alarm the deer, making them seek cover.

CHAPTER III

THE STUDY AREA AND DEER HERD

Description of the Black Hills

In the language of the Sioux the "Paha Sapa" stand as solitary eastern outposts of the Rocky Mountains. The Black Hills are aptly named; to the traveler first seeing them at a distance they do in fact appear as black mountains rising above the treeless plains. As reported by the U. S. Forest Service (26), the French Verendyre brothers - probably the first white men who saw them, in 1713 - spoke of the Black Hills as a wilderness of pine covered mountains, hills, canyons, gulches, and ravines, interspersed with fertile valleys and natural parks laced with clear streams. They referred to them as "a verdant oasis" in the midst of a barren, undulating prairie.

Extending about 100 miles from a southeasterly to a northwesterly direction and approximately 50 miles in width, the Black Hills lie mainly in South Dakota with a small extension into extreme Eastern Wyoming (Berner, 1). The gross area totals about 1,525,800 acres, of which all except 311,760 acres are federally owned (U. S. Forest Service, 26).

The dome-shaped uplift rises 3,000 to 4,000 feet above the plains. The eastern half of the area has been deeply eroded; the western half is still capped with a limestone stratum and can be spoken of as a six to seven thousand foot plateau. Several sharp granite peaks make the mountain interior jagged. As one traverses outward from the interior a series of ridges are crossed, down to the last encircling hogback of red clay. The permanent streams have cut deep canyons at the lower levels. Only bare rocks are void of tree vegetation at the highest elevations.

The climate patterns of the Black Hills are essentially the same as those affecting the Great Plains. The vagaries of air masses that inundate the area and their interaction at the higher elevation causes extreme climatic differences within the Hills themselves (Thornthwaite, 25).

The average annual precipitation varies from 18 inches in the southeastern sector to 24 inches at the higher elevations in the northwest (Figure 1). In the southeast sector the bulk of the moisture comes in the form of rain with only a few inches of snow. Two to three foot accumulations of snow in the higher western limestone and north central region account for the difference in amounts of annual precipitation.

Extremes of temperatures are characteristic of the Black Hills: temperature changes of 63° Fahrenheit within a few hours are not uncommon. The average annual temperature of the southeastern sector is less than four degrees warmer than the northwestern sector and central higher elevations. However, the two areas have five to ten degree daily temperature differences in the summer and spring months (Berner, 1).

Generally the Black Hills lack a varied flora. The dominant species is ponderosa pine which grows in pure stands and composes 90 percent of the timber. The moist northern exposures in the central and northern sectors have a few Black Hills spruce. Only limited areas still produce willow, aspen, chokecherry, serviceberry, white birch,

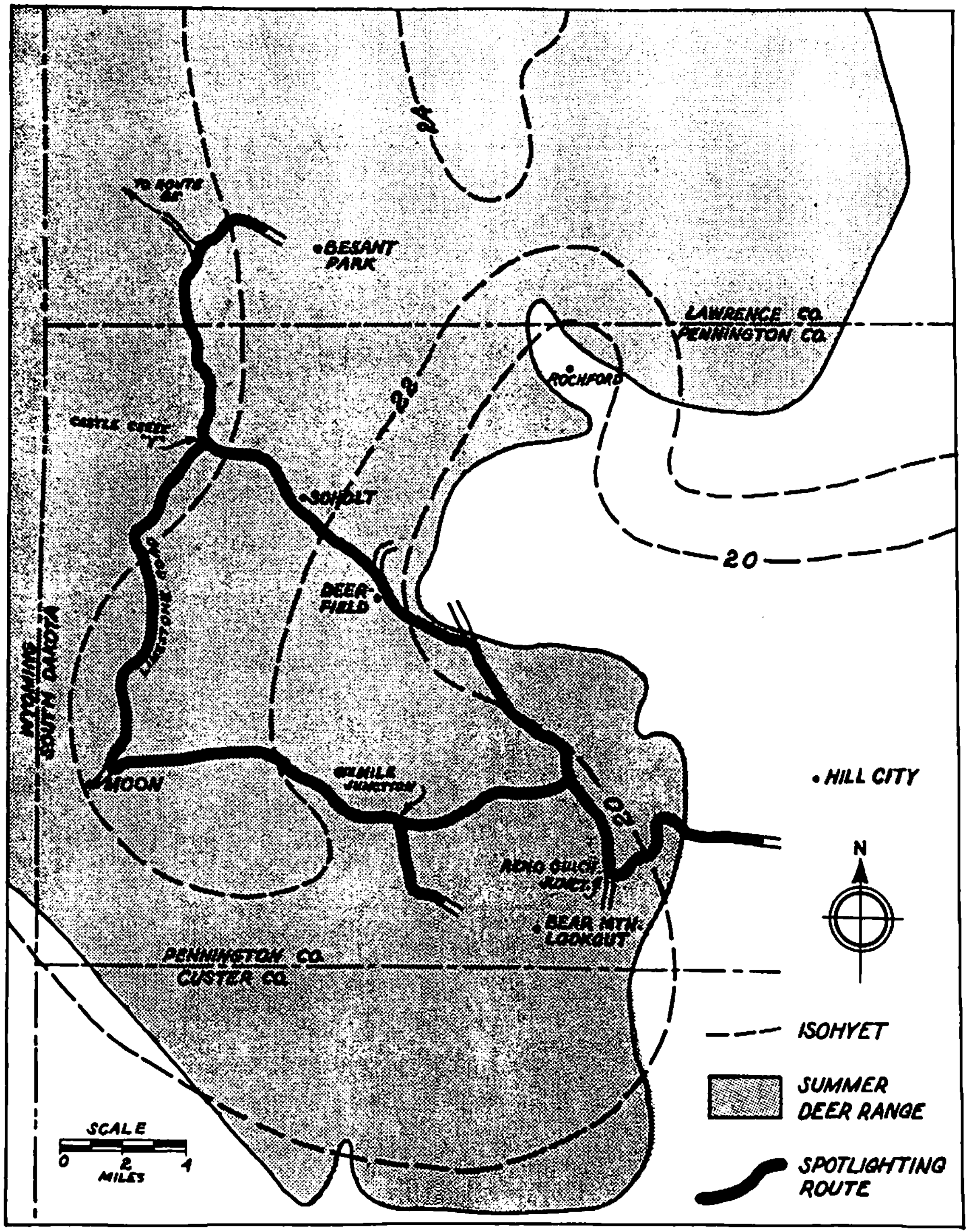

Figure 1. Location of Spotlighting Route Through Summer Deer Range in Central Black Hills. Note also Isohyets of Annual Precipitation for Area.

and similar species that once grew in abundance along creeks in bottom lands. Other ground cover and understory plants are Oregon grape, bur oak, common juniper, bearberry, mountain mahogany, Rocky Mountain juniper, and big sage.

Description of the Study Area

This spotlighting study was conducted within the Black Hills of South Dakota. It was restricted to the western and central portion of Pennington County with an additional four spotlighting miles extending into the northwest corner of Lawrence County.

Because of the time element and the prohibitive cost involved in running long straight routes covering large areas, the route was initially laid out in a circular pattern on secondary all-weather roads. Initial nightly surveys revealed areas with much higher deer numbers, and the original route was subsequently altered and used throughout the study (Figure 1). Through years of observations and an accumulation of data, game department personnel have been able to establish an arbitrary line separating the summer and winter deer range. The spotlighting route was set up primarily within the fluctuating limits of the summer range.

Elevations of 5,026 feet (Hill City) and 6,800 feet (Castle Creek "Y") are the extremes found within the study area. The change in elevation (1,774 feet) increases gradually from the eastern to the western limits of the spotlighting route.

Short growing seasons and adverse winter weather are undesirable factors contributing to the small number of permanent residents in the western portion of the Hills. Private land ownership is restricted to the large drainages which decrease across the study area. The U. S. Forest Service has leased a major portion of the public land of the Hills to private cattlemen and sheep owners for summer grazing.

Because of similarities in vegetation and in topography, the spotlighting route can be described in seven segments divided by landmarks shown in Figure 1.

Segment one, Reno Gulch, included only meadow number 32. This section was included in the study as it was the only satisfactory access road to the main route. The drainage has large acreages of private lands partly grazed by cattle. Dominant plant species are ponderosa pine, bluegrass, willow, aspen, domestic oats, and domestic hay. Elevations range from 5,026 to 5,490 feet. Water is present in limited amounts; pollution is evident.

The second segment, Reno Gulch "Y" to one-half mile southeast of Deerfield, included meadows one through five. Meadows 1 and 2 lie in public land heavily grazed by cattle while the other meadows are located on private land with some grazing. Dominant plant species are similar to the Reno Gulch segment except that willows are absent. The elevation range is 5,490 to 6,100 feet. Limited water is available.

Segment three, one-half mile southeast of Deerfield to one-half mile north of Castle Creek "Y", included meadows 6 through 10. The segment was ten continuous miles of open meadow arbitrarily divided into five study areas of equal length. The drainage is primarily private land, all ungrazed (summer months). Dominant plant species observed are those found in the first segment with the addition of Black Hills spruce.

The elevation range is 6,100 to 6,800 feet. Water, which is present at all times, comes mainly from Castle Creek. Land owners use water from this creek to irrigate cultivated fields of domestic hay and oats. Figures 2, 3, and 4 are representative of this segment. Lush growths of oats, grass, and willows combine to produce excellent cover but make spotlighting difficult.

Segment four, one-half mile north of the Castle Creek "Y" to one and one-half miles east of Rochford and Route 85 Junction, included meadows 11 through 14. It is on an eight and one-half mile stretch of open meadow divided into four equal study areas. The entire drainage, which is predominantly public land, is heavily grazed by cattle and sheep. There is only one homesite along this segment. Dominant plant species are Black Hills spruce, aspen, ponderosa pine, bluegrass, and willow. Elevations range from 6,800 to 6,549 feet. Water is present in limited amounts. Figure 4 is representative of portions of this segment. Dense aspen and pine thickets, as shown in Figure 5, are also numerous.

Segment five, from Castle Creek "Y" to one-half mile east of Moon Junction, was 12 continuous miles of open meadow divided into study meadows 15 through 20. The entire area, publically owned, is heavily grazed by cattle. Vegetation is predominantly bluegrass, aspen, Rocky Mountain juniper, ponderosa pine, and Black Hills spruce. The elevation range is 6,800 to 6,480 feet. Water, which is present in limited amounts, is found only on the north end of the segment. The drainage is wide throughout most of its length (Figure 6). The meadow edges are surrounded by aspen and pine thickets (Figure 5). Deer use was limited to the ridges of timber projecting into the open meadow (Figure 7).

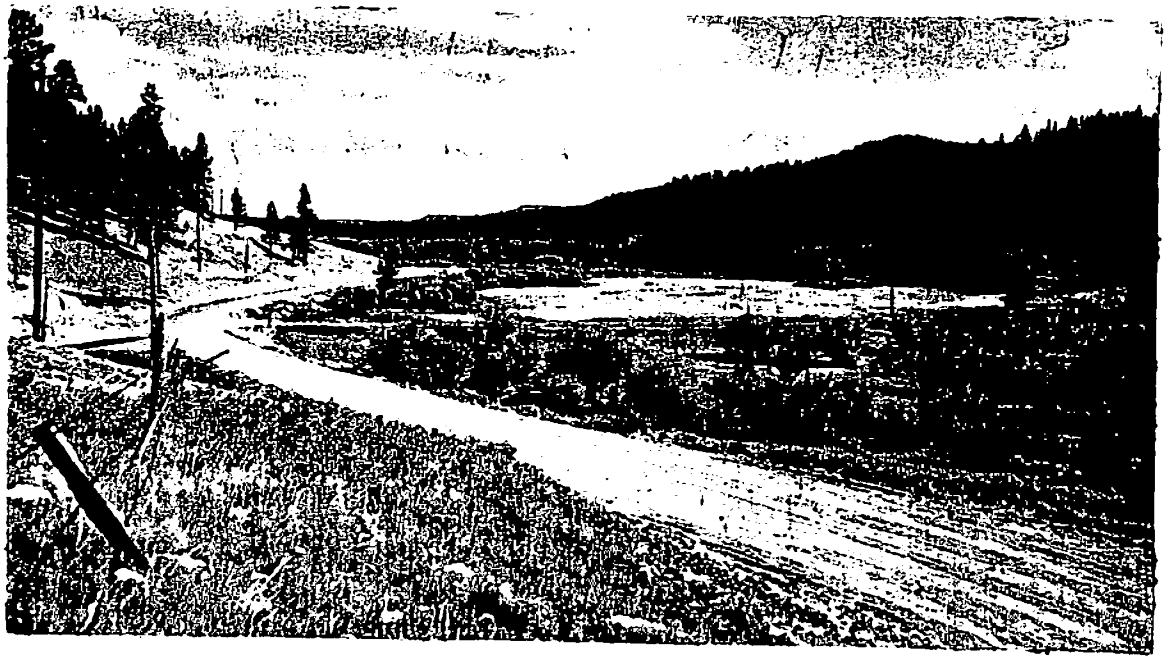

Figure 2. Meadow 7 on Castle Creek. Cover consists of Cultivated Oats, Bluegrass and Willows.

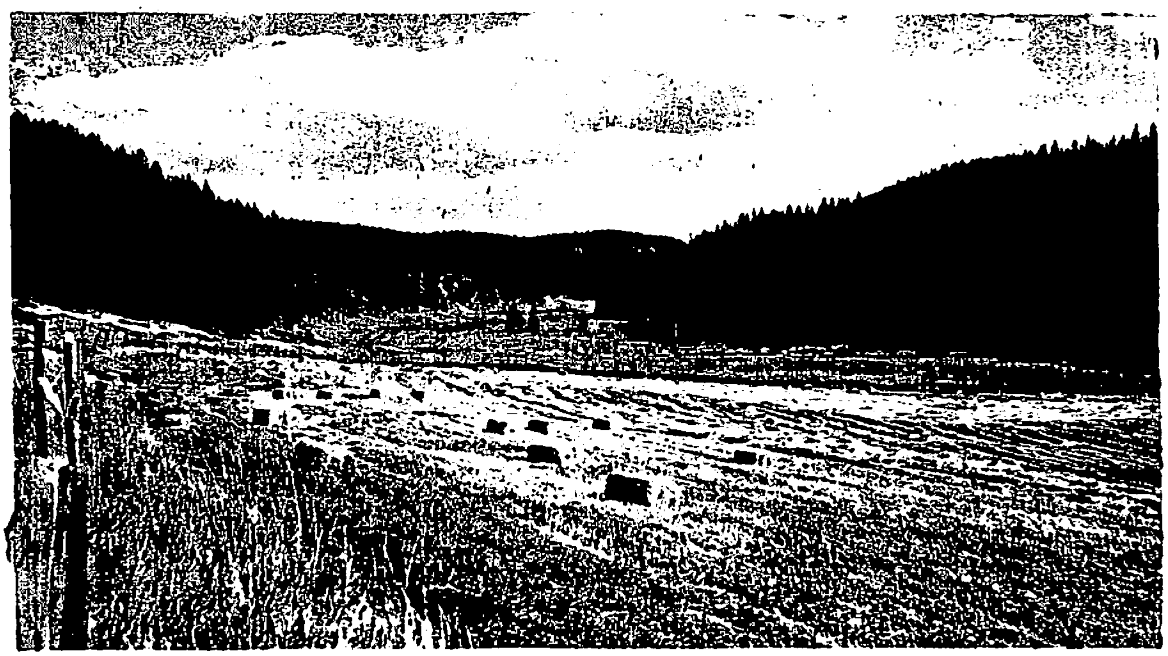

Figure 3. Meadow 9 on Castle Creek. Cover Mostly Fields of Cultivated Oats with Beaver Flowage in Distance.

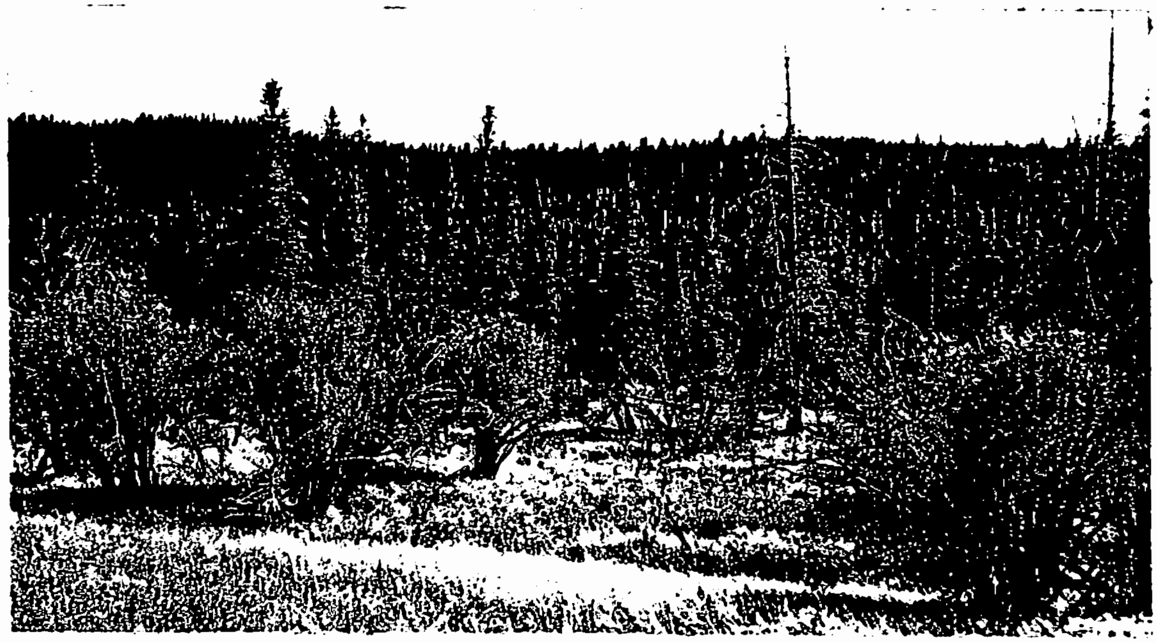

Figure 4. Meadow 9 on Castle Creek. Showing Typical Growth of Spruce, Willow, and Bluegrass Below a Beaver Dam. (Compare with Figure 3).

Figure 5. Meadow 15 Showing Dense Aspen Thicket Utilized by Deer and Cattle. Note Definite Plimsol Line.

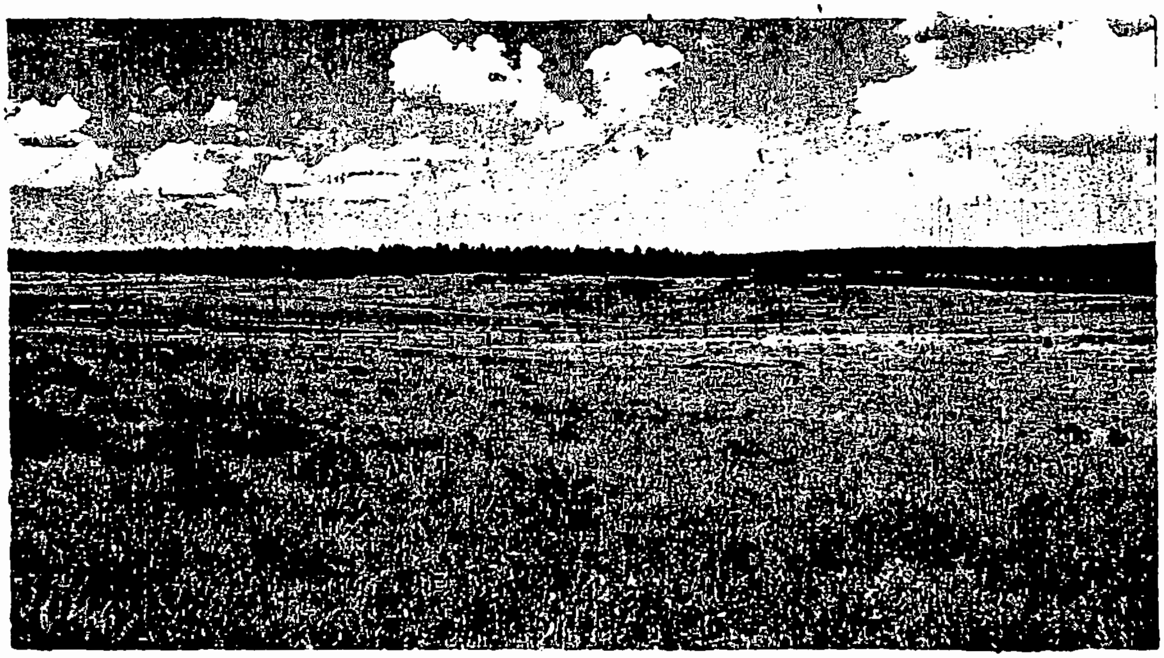

Figure 6. Meadow 18. A High Prairie Meadow Showing Expanse to Forest Edge. Area Heavily Grazed by Cattle.

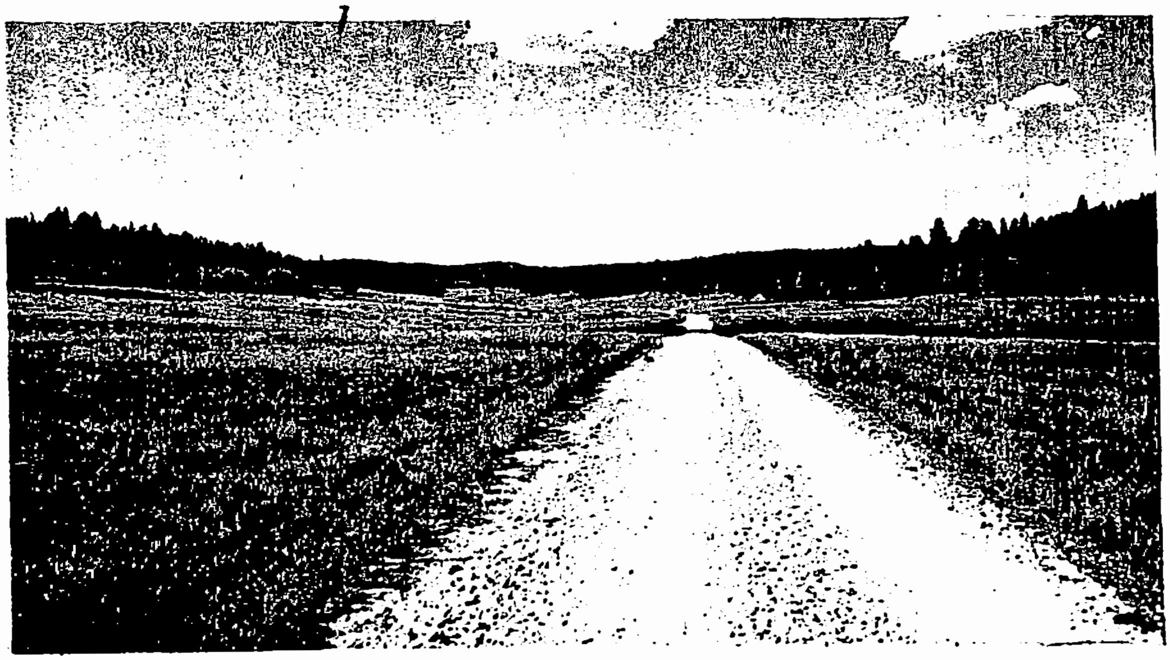

Figure 7. Meadow 16. Deer Use Confined to Timber Ridges Projecting into Meadow which is Heavily Grazed by Cattle.

Segment six was one-half mile east of Moon Junction to two and one-half miles southeast of Six Mile Junction. The lands along the segment are public and are heavily grazed by cattle. Dominant plant species are the same as along segment five except that Black Hills spruce is absent. The elevation is 6,480 feet at the western end and varies greatly throughout the segment to 6,571 feet at the eastern end. Water is present in impoundments constructed for livestock use. Figure 8 represents the narrow stringer meadows transversed by this segment of the spotlighting route. Figure 9 shows the small size of the summit meadows and vegetation present on them.

Segment seven, Six Mile Junction to a point four miles east, consisted of four continuous miles of open meadow equally divided into study meadows 30 and 31. The lands are public and are heavily grazed by sheep. Ponderosa pine, aspen, and bluegrass are the dominant plants. Elevations range from 6,571 to 6,243 feet. Free water is usually not present in the area.

The Deer Herd

Game Department biologists estimate that there are now 50,000 to 60,000 deer in the Black Hills of which 75 percent are white-tailed deer and the remainder mule deer. Deer are the most abundant big game species in segments of the Hills where a wildlife range management program is practiced; other species are elk and mountain goats. The latter are few in numbers and restricted primarily to the Norbeck Wildlife Refuge and to Custer State Park. Only three elk were observed on the study area.

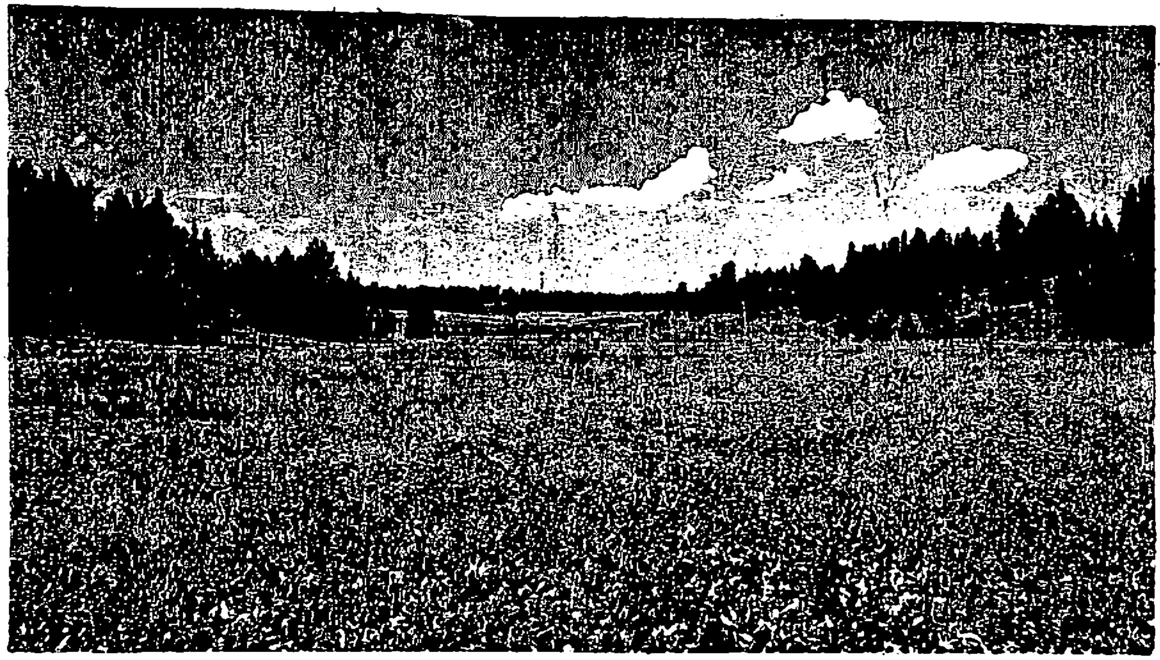

Figure 8. Meadow 22. A Long Narrow Meadow Transversely Crossed by Spotlighting Route.

Figure 9. Meadow 27. A Small Summit Meadow Heavily Utilized by Cattle.

There is little direct competition between deer and other game animals within the Hills; however, Berner (1) stated that beaver and cattle convert many brushy bottom lands to bluegrass meadows.

Approximately 22,000 cattle and 34,000 sheep annually using the National Forest compete directly with deer by overgrazing and overbrowsing the most productive bottom lands.

During normal winters many of the white-tailed deer migrate from the higher western portion of the Black Hills to as much as 25 miles east. Tagging records over the past ten years show individual herd movements. It is believed that the white-tailed deer follow major drainages east. In November of 1958, hunters killed two white-tailed deer (marked by the author in the summer of 1958) which had moved 14 and 25 miles eastward respectively. These deer followed the Castle Creek drainage, then crossed into the McVey burn north of Hill City where they were shot.

Mule deer which occupy the same areas as do the whitetails during the summer months move only to more favorable local exposures in the winter.

Berner (1), while evaluating big game management of the Hills, indicated that deer are the most important big game species, management-wise, except in the 50 square miles around Harney Peak where they become of secondary importance to the mountain goat.

CHAPTER IV

MATERIALS AND METHODS

Spotlighting Units

An attempt was made during this study to improve spotlighting equipment and the method by which it is used. Three different spotlighting units were tested; Figures 10 and 11 show the vehicles and light mountings.

A heavy-duty truck equipped with two 6-inch spotlights powered by the standard six-volt battery was the first unit checked. This unit had been used in previous years for the regular spring spotlighting work. The maximum distance deer could be readily observed was 225 yards (Figure 12). Deer beyond this distance, to 275 yards, were observed only if they turned so their eyes would reflect the light. The width of the field was seven yards at optimum range. It was noted after other lights had been tested that the light produced by the six-volt spotlights was a yellow light that is difficult to follow and causes considerable eye fatigue when used for long periods.

The second unit tested consisted of two 12-volt spotlights powered by a standard 12-volt battery and mounted on a 1955 Chevrolet station wagon (Figure 10). With this unit the optimum range was extended to 300 yards, an increase of 75 yards over the first unit tested. The width of the field increased proportionally to eight yards at optimum range (Figure 12). Eye reflections could be distinguished with little difficulty at 325 yards. Observations were more readily obtained under

Figure 10. Six Inch, 12-Volt Spotlight Units Tested During Study. Note Beam Shields on Lights.

Figure 11. Heavy Duty Spotlighting Unit. Consisting of 6 Inch, 110-Volt Floodlights Fitted with Beam Shields.

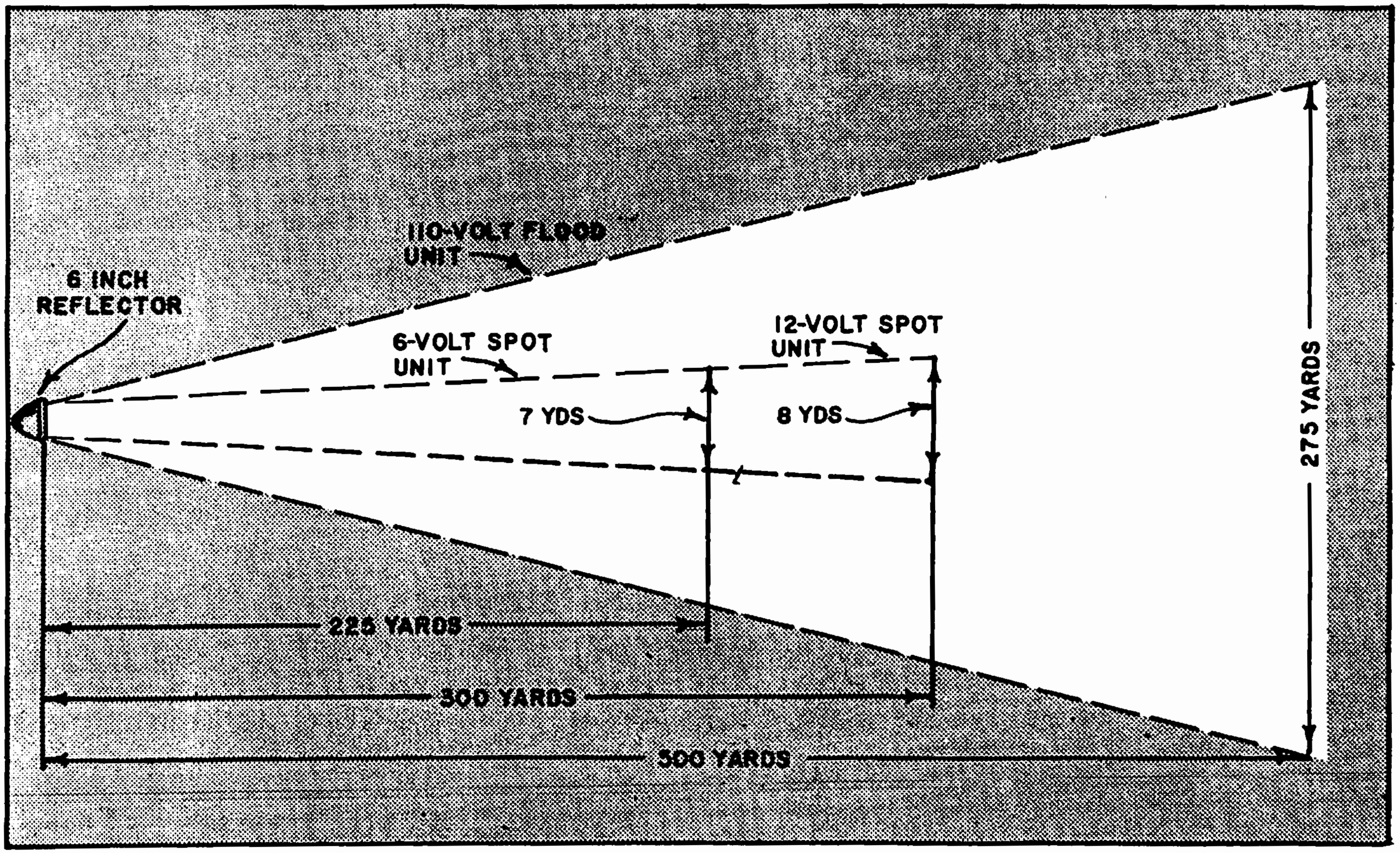

Figure 12. Comparison of Effective Ranges and Fields of Three Standard Sealed Beam Utility Light Units.

the more intense white light produced by the 12-volt units.

The third unit of the tests was a conversion of the first. The regular six-volt generator of the truck was replaced by a 110-volt A.C.-D.C. generator and the 6-inch, six-volt spotlights were replaced by six-inch, 110-volt, 100,000 candle power utility flood lamps (Figure 11). The power was supplied directly by the generator. Difficulties were encountered in that the engine had to be run at a constant speed to produce 110 volts, and the battery would not charge when the generator was producing 110 volts for the floodlight circuit. A unit to enable the engine speed to vary and produce only 110 volts at the light outlets is being installed for future use. The unit will also include a by-pass to the battery permitting it to charge when the 110 volt circuit is in operation.

The 110-volt floodlights were tested on the study area where the greatest open meadow distance occurred. The maximum spotlighting range of this unit (500 yards) was determined on meadow 17; deer could be readily observed at this distance. The definitive width of the field was 275 yards at 500-yards distance (Figure 12). The lights proved far superior to the others tested. It was not necessary when using the flood unit to repeatedly sweep an area with the light; deer in the meadow could be observed in a single sweep of the flood unit. An added advantage is that the intensity of the light reduced over-all fatigue of observers. Although tests were not run, it is felt that use of the 110-volt flood light will reduce observer error and also reduce the time necessary to spotlight an area.

All lights tested were equipped with light shields (Figures 10 and 11). The shield eliminated the side reflection produced by each light. The greatest reflections were from the curved windshield of the station wagon and from the smooth painted surface of the vehicles. Reflections were most severe from the 110-volt flood units. Constructed of .02 inch aluminum, the shields are six inches in diameter and four inches in length. They were placed between the seal beam unit and the light suspension ring; the ring was replaced, thus holding the shield and seal beam unit in the light housing.

Other equipment used during this study included standard weather instruments for recording climatological data at seven established stops along the spotlighting route.

Methods

Nightly field observations were made during the period June 14 through September 12. The route was run a total of 61 nights during this period. It was found early in the study that heavy rain and fog were not conducive to satisfactory spotlighting counts; therefore, the route was not run when fog was present or during periods of heavy rain.

The route was run in five different patterns so that various parts of the route could be spotlighted at different time intervals, because time intervals would influence temperature, relative humidity, moonlight, etc., and ultimately affect deer counts.

Two men starting one-half hour after sundown completed the route in eight hours. The passenger observer was responsible for tallying deer counts of individual meadows and for recording time and weather data throughout the route. It was the duty of the driver to spotlight all meadows on the left side of the road while the observer spotlighted the right side.

Accumulated field data were grouped for statistical analysis. Coefficients of correlation, standard deviation, and variance were computed as recommended by Goulden (16).

CHAPTER V

ANALYSIS AND RESULTS

This study was designed to evaluate physiological and ecological factors which influence counts of deer using selected meadows at night. Physiological factors were studied and included fawning, antler development, and feeding related to meadow vegetation.

Data were collected on the relationship of deer counts to such ecological factors as temperature, moisture, ~~sky~~ cloud cover, lunar phases, dew, and time. The time factor was considered from two viewpoints: the hour at which each observation was made and the date relative to phenomena of the seasons.

Portions of the data were treated statistically to ascertain the influence individual factors as well as combined effect of interacting factors had on nightly deer counts.

Physiological Factors

A progressive increase in numbers of deer of various age classes was noted on the study meadows from early to late summer. Because many observations were made at distances up to 400 yards, a large portion of the deer counted could not be easily sexed and aged with unaided eyes. Extensive use of binoculars would have disrupted the time schedule for running the spotlight route. Where deer could be readily sexed and aged without binoculars, records were kept; it is from these records that the influence of fawning and antler growth on total deer counts was estimated.

The first fawn of the season was seen on the night of June 18 as it followed a doe into woody cover adjacent to a meadow. On July 1 a pair of twin fawns was observed bedded together at the edge of a small clearing. Throughout July there was a gradual increase in the number of fawns spotlighted. On July 28, twenty-three of 414 deer recorded were fawns. It is felt that an even larger number of this count may have been fawns, but the heavy vegetation made identification difficult. Deer which were deep in the meadows or lying at the edge of the timber could only be located by eye reflection.

During the last two weeks of July and the first week of August there was a noticeable increase in fawn activity. Large groups of fawns would concentrate in open meadows and play for extended periods. They displayed no apparent alarm to the light until does, which had been feeding close by, called to them. The fawns would then quickly flee to cover which was seldom more than 30 yards away.

Because the total deer count had more than tripled by August 9, it was thought that a buck:doe:fawn ratio should be obtained which would be a basis for determining the portion of the population responsible for the increase. On August 13 the observed ratio was 20:100:93, but 197 of the deer observed during that night were neither sexed nor aged. At this time and for the next two weeks it was apparent that fawns travelled and fed with the does during early evening. Occasionally bedded fawns could be found during the later hours of evening by carefully searching the areas around feeding does.

Fawns became increasingly independent of does during the latter part of August and the first week in September. This was very evident by September 5 when fawns were observed feeding alone or with several bucks far removed from large groups of does and yearlings. On September 4 and 9, additional buck:doe:fawn ratios were observed, the results for two lots being 54:100:159 for 679 and 91:100:158 for 719 deer. It is apparent that the number of fawns increased continuously throughout the study. The periods of fawn and doe activity with respect to dates agree closely with the findings of Lindsey (20), Ruff (23) and Taylor (24). Data from these studies and the present study are plotted against the deer count trend (Figure 13). This population trend should remain constant for the Black Hills area provided the breeding season is not significantly delayed or prolonged.

The first buck with half-developed antlers was seen on July 1. Later observations of the same buck (captured and marked by the author) revealed that the velvet was lost before September 6.

From July 5 to August 5, bucks were occasionally observed at close range. On August 13, only 22 bucks were seen even with the aid of binoculars. No great increases in buck numbers were evident until August 25 when small groups were observed at the edges of open meadows. The sex ratios observed on September 4 and 9 showed large increases of bucks over the ratio observed on August 13. Sixty-seven of the bucks of the September 9 count were in three groups on meadow 7. With binoculars it was found that identification as to sex and age can only be accomplished within relatively short distances, though deer can be accurately counted with spotlights at much greater distances. This was especially true of "spike" and "fork-horn" bucks in early stages of antler development. Therefore, many of the deer not included in the sex and age ratios because of their doubtful identity may have been bucks.

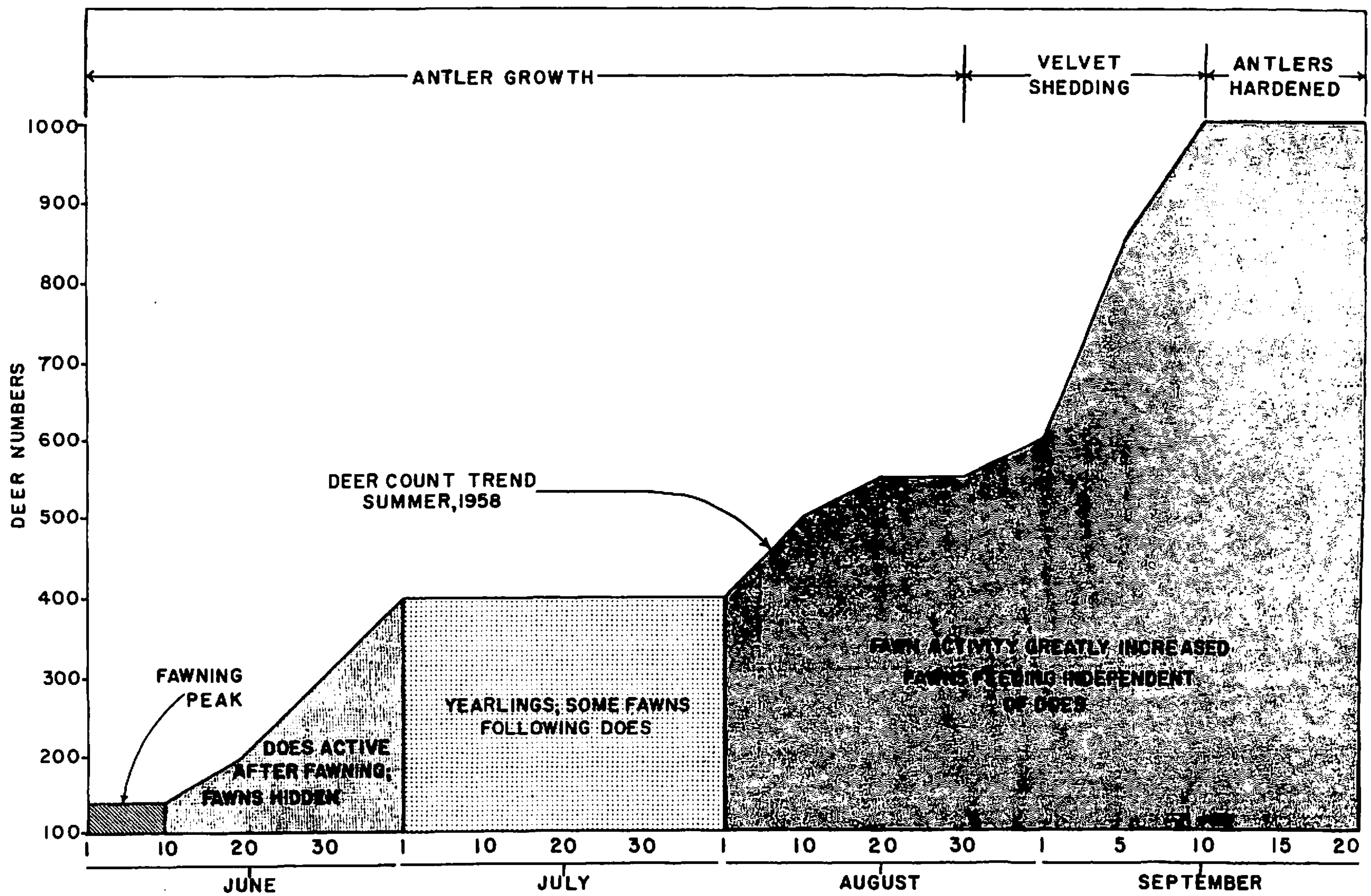

Figure 13. Trend in Deer Count as Associated with Various Seasonal Activities.

Evidence of restricted movements of bucks was noted. Several males having natural identifying characteristics and four carrying artifical markers were observed in the same area from day to day. This is in agreement with observations made by Progulske and Baskett (22) and Taylor (24).

The first evidence of velvet shedding was noted on September 1. The shedding progressed until mid-September when nearly all bucks observed had lost their velvet and many carried polished antlers. The sequence of antler development as related to behavior of the bucks was an important contribution to the increased total deer counts made from mid summer to early fall (Figure 13). Bucks left forested areas and appeared in meadows when velvet shedding was evident.

Movements of deer during the summer months were related to the availability of succulent foods. Berner (1), Ruff (23), and Lindsey (20) found that deer will concentrate on green vegetation from its first appearance in the spring and continue to use it when it is available in the summer.

Preferred forage plants in the study area were most abundant in the rich bottomlands which are both naturally and artifically irrigated from local streams. The cultivated fields of these bottomlands were planted in rotation to domestic hays and oats. Wild hay is also an important crop in the area. Highest deer concentrations were found on these ungrazed lands.

Because feeding habits are associated with phenological conditions, study plots were established at four different elevations on the study area. Phenological data were collected for at least four plant species on each study plot; bluegrass and domestic oats proved to be the best indicators of the effects of microclimates.

Data collected on nine different dates (from June 9 to September 6) revealed that the maturity of several plant species is approximately 12 days later at Castle Creek "Y" (elevation 6,800 feet) than at Hill City (elevation 5,026 feet).

The seasonal changes in cover conditions brought about by agricultural operations and grazing had a bearing on the number of deer observed. Unusual precipitation in early July delayed the hay harvest throughout the study area until July 25. The hay cutting began on July 25 and mowing continued until August 10 when nearly all ungrazed domestic and wild-hay meadows had been cut and the hay removed. Heavy deer use of the mowed meadows declined for about one week, after which large numbers of deer returned to the meadows to feed on the new growth. Damage to domestic oats by heavy frost and deer grazing prompted most ranchers to harvest the crop for hay by August 16. Deer left and did not reoccupy the mowed fields until August 23.

Grazing by cattle and sheep had the most direct effect on meadow usage by deer. Cattle, like deer, usually seek out tender green vegetation and graze on it intensively. Their movements, like those of deer, are regulated by climatic conditions. On many occasions both cattle and deer were observed grazing in the same areas but as the summer progressed deer left meadows heavily utilized by cattle.

Deer proved to be more tolerant of cattle than of sheep, and on no occasions were deer seen mixed with sheep. In most instances deer were far removed from areas previously used by sheep. Meadow 14 was used for nearly three weeks by 20 to 30 deer. A large flock of sheep which was moved into the meadow and grazed there for two weeks caused the deer to feed elsewhere. Twenty days elapsed from the time the sheep were taken off from the meadow until more than six deer were observed there in any one evening. The reoccurrence of deer was very rapid after a rain shower had brought on new growth of the heavily-grazed bluegrass. The nightly counts on this meadow increased to 126 deer by September 4.

TABLE I. COMPARISONS OF 1958 SUMMER TEMPERATURES AND PRECIPITATION WITH THREE-YEAR AVERAGES AT DEERFIELD WEATHER STATION[a]

	Temperature			Precipitation		
Month	Three Year Average	1958 Average	Departure	Three Year Average	1958 Average	Departure
June	52.3	58.5	+6.2	3.47	2.08	-1.39
July	59.7	54.2	-5.5	2.63	4.46	+1.83
August	58.6	51.6	-7.0	2.57	4.01	+1.44
September	49.0	50.3	-1.3	1.09	.24	- .85

[a]No long-time mean available because of station establishment in 1955.

While it is expected that grazing and agricultural practices in the Black Hills will remain essentially the same in future years, some conditions specific to 1958 should be noted. The unusually wet period during July and August (Table I) may have delayed the period of maximum meadow use by deer. Observations on several open areas as well as on sparsely timbered hills above the meadows showed that grass did not dry up until

August 25. The drying of grass in the upper hills normally occurs about August 1, forcing deer to lower meadows where green grass persists in the moist areas.

Ecological Factors

Correlation coefficients were calculated to determine the effects of some of the indigenal climatological factors on deer counts. Certain of these factors were eliminated from correlation calculations because of the inadequacy of data.

Measurable amounts of wind blew on only six nights during the study period. On two nights of excessively high winds (34 m.p.h. and 38 m.p.h.) there was a noticeable effect on deer movements. Each time the winds were accompanied by heavy rains which drove the deer from open meadows to heavy cover. Limited data indicated variations in deer counts are affected by precipitation (Appendix B). Intensive feeding in open meadows occurred prior to rain showers. After the rain had started, the tolerance of deer was regulated by its intensity and duration. Precipitation data were included in the multiple correlation calculations because of their relationship to humidity, temperature, and cloud cover.

Counts made when fog was present were deleted because of their biased nature, even though deer apparently remained active during foggy periods.

A quantitative method for measuring frost was not available; thus, this variable was also eliminated from the study. Frost occurred on only seven nights throughout the study period; therefore, the sample size would not have been significant, had the effects of frost been calculated in conjunction with other factors. The high correlation between deer counts and temperature suggests that frost has a direct relationship to the number of deer feeding in meadows; i.e., frost conditions result in low deer counts.

The effects of time of observation as a variable were found to be directly related to deer counts (correlation coefficient [r] = 0.8327). It was calculated separately and is not included in the multiple correlation calculated later. The percentages of total deer counts on nine meadows were computed for five time intervals (Table II). The highest count (30 percent of the total) fell between the hours of 9 p.m. and 10 p.m. and the lowest count (10 percent of the total) occurred 12 p.m. and 1 a.m.

TABLE II. PERCENT OF DEER COUNTED DURING HOURLY INTERVALS FOR THE ENTIRE SPOTLIGHTING PERIOD[a]

Hourly Intervals	8-9 p.m.	9-10 p.m.	10-11 p.m.	11-12 p.m.	12-1 a.m.
Percent of the Total Count for Each Time Interval	26%	30%	22%	12%	10%

[a]Percentage calculated from the total deer counted on nine meadows of optimum size and type.

On two dates a small area was spotlighted from the same point at hourly intervals. The counts were made from one half hour after sunset until 2 a.m. (Table III). Deer activity which was noticeably different on the two dates may have been due to the lunar phases (July 27, full

TABLE III. DEER OBSERVED AT REGULAR TIME INTERVALS ON A PORTION OF MEADOW NUMBER 7

		Deer Observed					
		July 27			September 7		
Time		Standing	Lying	Total	Standing	Lying	Total
P.M.	6:48[a]				11 (100%)		11
	7:50[b]	16 (100%)[c]		16	36 (100%)		36
	8:50	17 (81%)	4 (19%)	21	50 (96%)	2 (4%)	52
	9:50	23 (68%)	11 (32%)	34	64 (100%)		64
	10:50	17 (51%)	16 (49%)	33	31 (74%)	11 (26%)	42
	11:50	16 (62%)	8 (38%)	24	26 (76%)	8 (24%)	34
A.M.	12:50	3 (14%)	18 (86%)	21	10 (48%)	11 (52%)	21
	1:50	4 (22%)	14 (78%)	18	9 (64%)	5 (36%)	14
	2:50	5 (83%)	1 (17%)	6	4 (31%)	9 (69%)	13

[a]Sunset plus 30 minutes September 7. No spotlight used on first observation.

[b]Sunset plus 27 minutes July 27. No spotlight used on first observation.

[c]Percent of total deer observed at indicated time.

moon minus three days; September 7, last quarter plus one day).

The high deer counts for any one hour (Table III) compared closely with the percentage calculations for the entire study period (Table II). Large decreases in the total counts were noted for the three periods of full moon. Full moon phases fell on July 1, July 30, and August 29. Variation in deer counts for these periods is indicated in Figure 14. Daily counts of deer in relation to moon phases are given in Appendix C.

Though it would be possible to correlate the effects of time on deer counts, this correlation may have limited usefulness. If the spotlighting is always conducted at the same time of the day with respect to sunset and during the darker phases of the moon, relative time will be a constant and can be disregarded in subsequent analyses of spotlighting data. The constant relative observation time would eliminate the need for any corrections or adjustments of counts for the effect of time.

Computations hereafter are based on data from 30 spotlighting runs when time was constant unless otherwise designated.

After the previously discussed factors were eliminated from statistical analysis five variables remained to be correlated to mean number of deer observed each night (X). They were cloud cover (N), temperature (M), precipitation (H), dew (E), and relative humidity (D). The multiple correlation coefficient of these five variables with deer counts was calculated as outlined by Goulden (16:146-150) and is presented in Appendix D.

The coefficient of multiple correlation (R) was 0.9235: the R^2 value, therefore, was 0.8528 which means that 85.28 percent of the

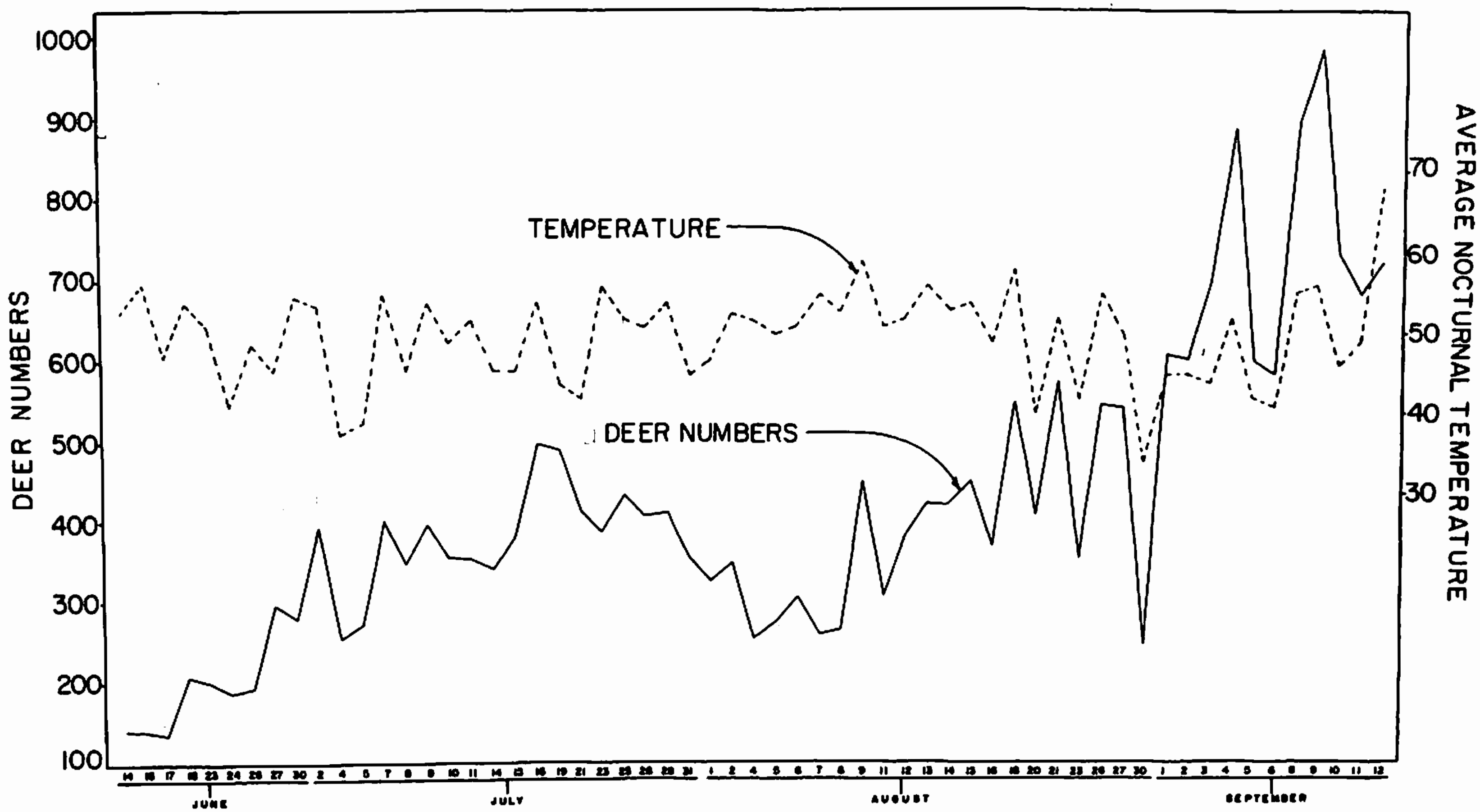

Figure 14. Actual Deer Counts in Relation to Average Nightly Temperatures at Meadows.

variation of deer counts on the spotlighting route could be accounted for by variation in the five climatological factors evaluated (Table IV).

Although the R value indicated a significant correlation between the numbers of deer counted and the climatological factors collectively, the possibility existed that this may have been due primarily to the influences of only part of the factors while the effects of the rest were negligible. In order to check this, the partial correlation coefficient for each pair of factors was calculated. This resulted in an understanding of the relationship between specific variables when all others were held constant. All partial correlations were significant at the 5 percent level of probability except for the coefficient for dew with precipitation.

If the portion of information furnished by any two variables tends to be related or interdependent, the correlation between the two tends to be high and R may not be much larger than the correlation of either with the number of deer observed. The effect of temperature was significantly greater when it was correlated with the number of deer observed for the entire season, ($r_{XM} = 0.8934$), which includes a much greater range of temperature than those used in determining the multiple correlation.

These high correlation coefficients indicate that reasonably good estimates of deer numbers can be made with only temperature as the independent variable. This may be of value if temperature measurements are the only available data for an area, because temperature data alone can be used to correct for variability in the counts due to weather. This would indicate that thermographs placed at the meadows would furnish very

TABLE IV. CORRELATION COEFFICIENTS, MULTIPLE CORRELATION COEFFICIENT AND CORRECTED CORRELATION COEFFICIENTS FOR FIVE CLIMATOLOGICAL FACTORS[a]

Original Coefficients						Partial Coefficients (all other variables constant)					
X	N	M	H	E	D	X	N	M	H	E	D
1.0000	-.0433[b]	+.2505	-.0692	-.2172	+.0059	1.0000	-0.5177	+0.5567	-0.2035	-0.2944	+0.2183
	1.0000	+.8126	+.0047	-.0746	-.0055		1.0000	+0.8731	-0.2576	-0.2440	+0.2616
		1.0000	+.1416	-.0609	-.1093			1.0000	+0.3047	+0.1921	-0.2735
			1.0000	+.1116	+.0038				1.0000	+0.0385	+0.0550
				1.0000	+.3247					1.0000	+0.3696
					1.0000						1.0000

$R_{1.23456} = \underline{0.9235}$ $R^2_{1.23456} = \underline{0.8528}$

X = Deer Count H = Precipitation

N = Cloud Cover E = Dew

M = Temperature D = Relative Humidity

[a] Correlations from extracted data when time was constant.

[b] Calculations as outlined by Goulden (16: 146-150).

valuable prediction data.

The direct relationship between daily temperatures and deer counts became very evident when such data were plotted (Figure 14). Large fluctuation in deer counts appearing in this figure may be misleading unless it is understood that the density of deer varied greatly throughout the study area. When the five time-patterns for running the route were put into effect large variations in total daily counts resulted. These variations were attributed to counts made on high deer areas during the late hours of the night.

The partial regression values in Appendix D can be used to set up a prediction equation as outlined by Goulden (16). This would permit estimation of the fraction of the total deer population likely to be present on meadows under specified climatic and ecological conditions. Thereby, very few counts could provide a reliable estimate of the true population trend, since the adjustments indicated for the particular conditions could be made either from the prediction formula or from a graph.

The variation in deer numbers as influenced by meadow size and type was computed for each meadow. Meadow measurements were made and each meadow was typed according to dominant plant species. Meadows from 201 to 300 acres in size and classified Type IV (bluegrass, cultivated oats, domestic hay, with interspersed brushy cover) carried the greatest average number of deer per acre (11.03). There were few meadows of this size and type. Thus, if a larger study area were desired it would be necessary to use Type II meadows (bluegrass, with interspersed brushy cover) which are more numerous. The size of Type II meadows did not greatly influence the average number of deer observed per acre (Table V).

TABLE V. AVERAGE DEER PER ACRE AND TOTAL DEER OBSERVED ON VARIOUS MEADOW TYPES AND SIZES FOR THE SPOTLIGHTING PERIOD

Size of Meadow in Acres	Meadow Type: Type I — Bluegrass	Type II — Bluegrass with Interspersed Brushy Cover	Type III — Bluegrass, Cultivated Oats, and Domestic Hay	Type IV — Bluegrass, Cultivated Oats, Domestic Hay, with Interspersed Brushy Cover	Total Deer Count
15-100	3.24	4.13	——	——	1,495
101-200	.45	3.00	1.53	——	2,415
201-300	.20	4.50	——	11.03	13,890
301-600	1.06	2.59	1.10	3.70	8,008
Total Deer Count	2,230	8,067	647	14,864	25,808

Careful consideration should be given to the selection of areas to be spotlighted in the event the study is carried further or results are used for management purposes. To illustrate the importance of meadow size and type, data for 12 days were extracted for meadows of Type I and Type IV (Table VI and Table VII). The data were taken when time was comparable and when the average nightly temperature was 43 degrees or over. Preference was given those days which fell within the dark phases of the moon because of the direct correlation between moon phase and deer count.

From the extracted data, standard deviations and coefficient of variations were calculated and confidence intervals were established for the two segments of the spotlighting route wherein Type I and Type IV meadows are found exclusively. Confidence limits at the 95 percent level for the two segments of the route are 23.11 to 30.89 deer (segment 6) and 216.70 to 243.30 deer (segment 3). The standard errors of the means are 3.89 and 13.30 deer, respectively. Subsequent data collected under the significant climatic and ecological conditions specified by this study and analyzed as above should furnish a reliable indication of the deer population trend within the study area.

TABLE VI. DAILY DEER COUNTS ON EIGHT SUMMIT AND STRINGER MEADOWS[a]

Date	Cloud Cover	Tempera- ture	Moon Phase with + or - Days	*Meadow Number* 21	22	23	24	25	26	27	28	Total Daily Count
7-14	Partly Cloudy	48	N -2	3	4	0	3	0	2	5	2	19
15	Partly Cloudy	49	N -1	3	4	0	1	1	1	1	5	16
16	Cloudy	55	N	1	9	1	3	4	5	2	2	27
17	Cloudy	57	N +1	4	6	0	1	6	6	7	8	38
19	Clear	48	N +3	4	3	0	1	5	7	7	3	30
20	Clear	52	FQ-1	5	3	1	3	1	5	2	4	24
21	Clear	49	FQ-2	2	4	0	1	2	6	7	4	26
8- 9	Cloudy	58	LQ+2	3	9	4	5	4	3	2	1	31
11	Clear	56	LQ+4	0	6	3	0	2	3	4	0	18
12	Cloudy	57	N -3	2	4	5	1	1	4	4	1	22
13	Cloudy	62	N -2	7	9	5	0	3	4	9	0	37
14	Clear	58	N -1	2	6	6	1	2	3	8	2	30
Total by Meadow				36	67	25	20	31	49	58	32	
Total All Days												318
Average by Meadow				3	6	2	2	3	4	5	3	
Average by Day												27
Standard Deviation												6.79
Coefficient of Variation												0.2562
Standard Error of the Mean												± 3.89

[a]Counts made between 8 and 10 pm on Moon to Six Mile Junction Segment.

TABLE VII. DAILY DEER COUNT ON SELECTED MEADOWS OF OPTIMUM SIZE AND TYPE[a]

Date	Cloud Cover	Temperature	Moon Phase with + or - Days	Meadow Number 6	7	8	9	10	Total Daily Count
7- 7	Cloudy	58	LQ-2	35	76	56	63	33	263
8	Clear	52	LQ-1	28	68	54	44	27	221
9	Cloudy	53	LQ	35	65	60	49	34	243
10	Clear	49	LQ+1	32	59	49	54	38	232
11	Partly Cloudy	49	LQ+2	27	56	52	34	32	201
23	Partly Cloudy	58	FQ	23	82	57	22	29	213
25	Cloudy	52	FQ+2	36	87	53	41	36	253
26	Cloudy	49	FQ+3	24	72	51	48	26	221
8- 9	Clear	56	LQ+2	26	75	50	40	34	225
12	Clear	52	N -3	25	90	49	48	20	232
13	Clear	54	N -2	25	91	41	34	31	222
14	Clear	48	N -1	35	73	59	35	30	232
Total by Meadow				351	894	631	512	370	
Total All Days									2,758
Average by Meadow				30	75	53	44	31	
Average by Day									230
Standard Deviation									22.93
Coefficient of Variation									0.0962
Standard Error of the Mean									± 13.30

[a]Counts made between 8 and 10 pm on Deerfield to Castle Creek "Y" Segment.

CHAPTER VI

SUMMARY AND CONCLUSIONS

1. This study was conducted to determine the effects of physiological and ecological factors on summer spotlighting of deer and to ultimately establish a technique for measuring population trends.

2. Field studies were made in the Black Hills of South Dakota during June - September, 1958. Grazing is permitted by lease on the 66 percent of the Hills in Federal ownership. The private lands are devoted to agricultural practices.

3. A 105-mile spotlighting route was established and run each night the weather permitted. The runs which were made during the period June 14 to September 12 began one half hour after sunset. Complete data were collected each night at the base station and at seven established weather stations along the route.

4. The seven segments of the spotlighting route were divided into study sections and included the meadows on which deer were spotlighted.

5. In order to determine the most satisfactory equipment, three spotlighting units were tested. A 110-volt, 100,000 candle power unit was found to be better than either the 6-volt or the 12-volt units. The 110-volt unit reduced fatigue and shortened the time required to complete the route. It also served to reduce observer error.

6. Fawning and fawn activity had a pronounced effect on spotlighting counts throughout the summer. Sex-age ratios taken on September 9 showed an increase of 300 fawns per nightly run above the initial

ratios observed July 28.

7. Bucks appeared in increasing numbers as antler development progressed. The first buck was positively identified by antler growth on July 1. The number of bucks observed each night increased to 187 when a sex ratio was taken on September 9.

8. Feeding activities of deer were related to phenological conditions. Bluegrass and domestic oats were the best indicator species. Deer use was heaviest on cultivated land. Deer shied away from areas on which cattle were grazing, and avoided sheep on all occasions.

9. Wind was not measureable on enough nights to be treated statistically. However, deer sought cover when high winds were accompanied by rains. Wind, frost, and fog could not be adequately measured and thus were eliminated from the statistical analyses.

10. The time of observation directly affected the total deer count. Calculations showed 78 percent of the deer were counted by 11 p.m. Data for calculations were extracted where time was constant because of the different densities of deer throughout the route.

11. A multiple correlation was calculated for five variables in order to obtain their combined effect on the total number of deer observed. The five factors were cloud cover, temperature, precipitation, dew, and relative humidity.

12. The multiple correlation coefficient (R) was 0.9235 and R^2 indicated that 85.28 percent of the variation in deer counts were due to the influence of the five climatological factors.

13. The correlation coefficient for temperature with deer counts for the entire spotlighting period, (r_{XM}), was 0.8934 which would in-

dicate that measurement of temperature alone may be all that is necessary in subsequent operations to get reasonable population trend estimates.

14. Subsequent data may be analysed by using the partial regression values calculated in a prediction equation, providing data is collected under specified ecological and climatological conditions.

15. Each study meadow was measured and classified according to dominant plant species. The meadows were grouped into four different types.

16. The density of deer on the study meadows during the summer varied from 0.20 to 11.04 deer per acre. Extracted data from two segments of the route showed variation in deer numbers on various meadow types. Segment 3 had a daily mean deer count of 230 with a standard error of plus or minus 13.30 deer. Segment 6 had a daily mean deer count of 27, the standard error being plus or minus 3.89 deer. These means can be used as a basis for future spotlighting counts.

17. Subsequent data collected from segments 3 and 6 under specified ecological and climatological conditions may be treated by the same statistical methods employed in this study and then compared with the means indicated above.

18. In further research, summer spotlighting counts of deer in the Black Hills should involve:

a. Use of the 110-volt flood units to reduce error and expense.

b. Thermographs in each study meadow to obtain local temperature variations.

c. Running only part of the route established for this study and the location of other suitable areas to be spotlighted for better coverage of the Black Hills.

d. Complete records on fawning, antler development, and phenology which may change from year to year.

e. Running an established route at the same time from the same point each night starting one hour after sunset.

f. Dividing routes into definite segments relative to vegetation.

g. Running of the route only when the temperature one hour after sundown is over 48 degrees.

h. Running of the route only during the dark phases of the moon.

i. Several observations of deer on the same area at different time intervals and under different climatic conditions to better understand their night activities.

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APPENDICES

APPENDIX A

SCIENTIFIC NAMES OF MAMMALS AND PLANTS INCLUDED IN THE TEXT

Mammals

Deer, white-tailed	*Odocoileus virginianus*
" , mule	*Odocoileus hemionus hemionus*
" , Columbian black-tailed	*Odocoileus hemionus columbianus*
" , red	*Cervus elaphus*
Elk	*Cervus canadensis*
Mountain goat	*Oreamnos americanus*
Beaver	*Castor canadensis*
Coyote	*Canis latrans*
Bobcat	*Lynx rufus*

Plants

Ponderosa pine	*Pinus ponderosa*
Black Hills spruce	*Picea glauca*
Aspen	*Populus tremuloides*
Big Sage	*Artemisia tridentata*
Chokecherry	*Prunus virginiana*
Oregon grape	*Berberis repens*
Rocky Mountain juniper	*Juniperus scopulorum*
Willow	*Salix* spp.
Serviceberry	*Amelanchier* spp.
White Birch	*Betula papyrifera*

Bur Oak	Quercus macrocarpa
Common juniper	Juniperus communis
Bearberry	Arctostaphylos Uva-uria
Mountain mahogany	Circocarpus Montaus
Bluegrass	Poa pratensis

APPENDIX B

COMPARISON OF PRECIPITATION AND RELATIVE HUMIDITY EFFECTS ON TOTAL DAILY DEER COUNTS

Date	Precipitation[a] Period Start	Stop	Amount	Time elapsed Between Deer Count and Next Precipitation (If under 36 Hours)	Relative Humidity	Deer Count
6-13	7pm	11pm	.27			
14	5am	11am	.38	9 Hours	62	144
16					56	143
17				5 Hours	67	139
18	6am	3pm	.21		74	213
20	5am	1pm	1.12			
21	5pm	7pm	.06			
22	7pm	12pm	.26			
23				24 Hours	68	205
24					64	191
26					56	196
27					68	300
30				24 Hours	87	278
7- 2	1am	6am	.16	During	84	381
3	6pm	12pm	.60			
4	12pm	4am	.60	15 Hours	74	258
5	3pm	6pm	.05	22 Hours	87	271
7	9pm	11pm	.10	During	72	404

COMPARISON OF PRECIPITATION AND RELATIVE HUMIDITY EFFECTS ON TOTAL DEER COUNTS (CONTINUED)

	Precipitation[a]			Time Elapsed Between Deer Count and Next Precipitation (If Under 36 Hours)		
	Period		Amount		Relative	Deer
Date	Start	Stop			Humidity	Count
7- 8				31 Hours	68	352
9	9am	11am	.14	7 Hours	76	397
10	12pm	4am	.26	During	52	386
11					66	384
12	7pm	9pm	.28	22 Hours		
14					60	343
15					85	379
16				22 Hours	90	495
17	7pm	10pm	.11			
18	10am	11am	.51			
19	2pm	4pm	.17	26 Hours	92	482
21	2pm	5pm	.23	29 Hours	90	417
22	1pm	2pm	.02			
23				During	74	386
24	1am	4am	.11			
25				15 Hours	82	437
26					94	408
28	6pm			During	91	414
29		4am	.27			
30	1am	2pm	.85			

COMPARISON OF PRECIPITATION AND RELATIVE HUMIDITY EFFECTS
ON TOTAL DAILY DEER COUNTS (CONTINUED)

Date	Precipitation[a] Period Start	Stop	Amount	Time Elapsed Between Deer Count and Next Precipitation (If Under 36 Hours)	Relative Humidity	Deer Count
7-31					88	356
8- 1					74	330
2				34 Hours	78	365
4	8am	10am	.01	10 Hours	80	255
5					64	276
6					72	308
7	7pm	9pm	.25	During	32	332
8					78	338
9				28 Hours	50	447
10	3pm	5pm	.11			
11					52	311
12					56	383
13					56	427
14				26 Hours	30	424
15	9am	10am	.01	During	74	453
16					44	367
18				24 Hours	60	549
19	7pm	10pm	1.50			
20					82	409
21				15 Hours	85	574

COMPARISON OF PRECIPITATION AND RELATIVE HUMIDITY EFFECTS ON TOTAL DAILY DEER COUNTS (CONTINUED)

Date	Precipitation[a] Period Start	Stop	Amount	Time Elapsed Between Deer Count and Next Precipitation (If Under 36 Hours)	Relative Humidity	Deer Count
8-22	4am	5am	.02	8 Hours		
23					80	360
24	5am	6am	.07			
25	2am	5am	.02			
26					94	542
27				22 ½ Hours	68	439
28	8am	10pm	.11			
29						
30					78	241
9- 1					46	612
2					50	604
3					86	699
4				32 Hours	68	880
5	4am	5am	.10	8 Hours	76	651
6					62	622
7						
8					76	894
9				36 Hours	80	980
10	8am	9am	.01	12 Hours	72	737
11					88	679

COMPARISON OF PRECIPITATION AND RELATIVE HUMIDITY EFFECTS ON TOTAL DAILY DEER COUNTS (CONTINUED)

Date	Precipitation[a] Period Start	Stop	Amount	Time Elapsed Between Deer Count and Next Precipitation (If Under 36 Hours)	Relative Humidity	Deer Count
9-12					82	729

[a]All readings of precipitation were taken at 6 pm daily. Whenever precipitation occurred after 6 pm and stopped before 12 pm same day, the amount was listed on the date it occurred and not on the date it was recorded.

APPENDIX C

SUMMARIZATION OF METEOROLOGICAL DATA

Date	Precipitation[a]	Daily Temperature[a] (Maximum-Minimum)		Average Nightly Temperature at Meadow Stations[b]	Relative Humidity at Base Station	Moon Phase with + or - Days	Deer Count
6-14	.38	56	50	52	62	N -2	144
16		56	54	56	56	N -1	143
17		60	29	48	67	N	139
18	.21	63	28	53	74	N +1	213
23	.26	64	42	51	68	FQ-1	205
24		61	32	41	64	FQ	191
26		67	24	48	56	FQ+2	196
27		79	31	46	68	FQ+3	300
30		78	45	54	87	F -1	278
7- 2	.16	74	32	53	84	F +1	381
4	.60	58	47	38	74	F +3	258
5	.05	62	53	39	87	LQ-3	271

SUMMARIZATION OF METEROLOGICAL DATA (CONTINUED)

Date	Precipitation[a]	Daily Temperature[a] (Maximum-Minimum)		Average Nightly Temperature at Meadow Stations[b]	Relative Humidity at Base Station	Moon Phase with + or - Days	Deer Count
7- 7	.10	70	35	55	72	LQ-2	404
8		68	45	46	68	LQ-1	352
9	.14	71	38	54	76	LQ	397
10	.26	70	40	49	52	LQ+1	386
11		72	32	52	66	LQ+2	384
14		58	41	46	60	N -2	343
15		63	35	46	85	N -1	379
16		68	40	54	90	N	495
19	.17	70	43	44	92	N +3	482
21	.23	71	33	43	90	FQ-2	417
23		80	40	56	74	FQ	386
25		73	37	52	82	FQ+2	437
26		70	42	51	94	FQ+3	408
28		72	33	54	91	F -2	414

SUMMARIZATION OF METEROLOGICAL DATA (CONTINUED)

Date	Precipitation[a]	Daily Temperature[a] (Maximum-Minimum)		Average Nightly Temperature at Meadow Stations[b]	Relative Humidity at Base Station	Moon Phase with + or - Days	Deer Count
7-31		70	40	45	68	F +1	356
8- 1		79	38	47	74	F +2	330
2		80	39	53	78	F +3	365
4	.01	60	46	52	80	LQ-3	255
5		60	39	50	64	LQ-2	276
6		79	30	51	72	LQ-1	308
7		83	45	55	32	LQ	332
8	.25	86	42	53	78	LQ+1	338
9		89	44	59	50	LQ+2	447
11		82	44	51	52	LQ+4	311
12		83	40	52	56	N -3	383
13		83	43	56	56	N -2	427
14		85	43	53	30	N -1	424
15	.01	75	41	54	74	N	453

SUMMARIZATION OF METEROLOGICAL DATA (CONTINUED)

Date	Precipitation[a]	Daily Temperature[a] (Maximum-Minimum)		Average Nightly Temperature at Meadow Stations[b]	Relative Humidity at Base Station	Moon Phase with + or − Days	Deer Count
8-16		86	41	49	44	N +1	367
18		80	44	58	60	N +3	549
20		65	46	40	82	FQ-1	409
21		73	28	52	85	FQ	574
23		63	34	42	80	FQ+2	360
26		80	37	55	94	F -3	542
27		76	38	50	68	F -2	439
30		71	28	34	78	F +1	241
9- 1		80	33	45	46	F +2	612
2		78	34	45	50	F +3	604
3		66	28	44	86	LQ-3	699
4		71	33	52	68	LQ-2	880
5	.10	71	40	42	76	LQ-1	651
6		74	36	41	62	LQ	622

SUMMARIZATION OF METEOROLOGICAL DATA (CONTINUED)

Date	Precipitation[a]	Daily Temperature[a] (Maximum-Minimum)		Average Nightly Temperature at Meadow Stations[b]	Relative Humidity at Base Station	Moon Phase with + or - Days	Deer Count
8		88	38	55	76	LQ+2	894
9	.01	74	37	56	80	LQ+3	980
10		75	43	46	72	N -3	737
11		79	39	48	88	N -2	679
12		88	40	67	82	N -1	729

[a]Taken from United States Weather Station records at Deerfield.

[b]At time nightly deer counts were made.

APPENDIX D

Regression and partial correlation coefficients? (See Goulden p 147)

MULTIPLE CORRELATION FOR FIVE CLIMATOLOGICAL FACTORS[a]

	X	N	M	H	E	D	X	N	M	H	E	D
X	1.0000	-.0433[b]	+.2505	-.0692	-.2172	+.0059	1	0	0	0	0	0
N		1.0000	+.8126	+.0047	-.0746	-.0055	0	1	0	0	0	0
M			1.0000	+.1416	-.0609	-.1093	0	0	1	0	0	0
H				1.0000	+.1116	+.0038	0	0	0	1	0	0
E					1.0000	+.3247	0	0	0	0	1	0
D						1.0000	0	0	0	0	0	1
7	1.0000	-.0433	-.2505	-.0692	-.2172	+.0059	1.0000	0				
8		-.0433	-.2505	-.0692	-.2172	+.0059	1.0000	0				
9		-.9981	-.8234	-.0017	-.0840	-.0052	+0.0433	1.0000	0	0		
10		1.0000	-.8250	-.0017	-.0842	-.0052	+0.0434	+1.0019	0	0		
11			-.2579	-.1575	-.0628	-.1065	-0.2862	-0.8250	+1.0000	0		
12			1.0000	-.6107	-.2435	-.4130	-1.1097	-3.1939	+3.8775	0		
13				-.9026	-.0581	+.0692	+0.2439	+0.5021	-0.6107	+1.0000	0	
14				1.0000	-.0644	+.0767	+0.2702	+0.5563	-0.6766	+1.1079	0	
15					-.9267	+.3470	+0.2748	+0.3174	-0.2042	-0.0644	+1.0000	0
16					1.0000	+.3744	+0.2965	+0.3425	-0.2204	-0.0695	+1.0791	0
17						+.8207	-0.2455	-0.4928	+0.5363	-0.0526	-0.3744	1.0000
18						1.0000	-0.2991	-0.6005	+0.6535	-0.0641	-0.4562	+1.2185
19	+.2455	+.4928	-.5364	+.0526	+.3744		+1.5403	+1.3361	-1.4957	+0.2668	+0.4085	-0.2991
20	-.3268	-.4539	+.3692	+.0364		+.3650		+4.3249	-3.9306	+0.5658	+0.5673	-0.6005
21	-.2391	-.5071	+.6245		+.0408	+.0574			+4.6862	-0.6968	-0.4651	+0.6535
22	+.3192	+.8388		+.1487	+.0992	-.1395				+1.1158	-0.0455	-0.0641
23	-.3089		+.9088	-.1308	-.1312	+.1388					+1.2499	-0.4562
24		-.8674	+.9710	-.1732	-.2652	+.1942						+1.2185
25	X = Deer Count						1.0000	-0.5177	+0.5567	-0.2035	-0.2944	+0.2183
26	N = Cloud Cover							1.0000	+0.8731	-0.2576	-0.2440	+0.2616
27	M = Temperature								1.0000	+0.3047	+0.1921	-0.2735
28	H = Precipitation									1.0000	+0.0385	+0.0550
29	E = Dew										1.0000	+0.3696
30	D = Relative Humidity											1.0000

$R_{1.23456} = \underline{0.9235}$ $R^2_{1.23456} = \underline{0.8528}$

[a]Correlations from extracted data when time was constant.

[b]Calculations as outlined by Goulden (16: 146-150).