Effects of Fire on a Sand Hills Grassland Environment

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INTRODUCTION

THE Nebraska Sand Hills constitute the largest sand dune area of the Western Hemisphere. Keech and Bentall (1971) indicate that this area consists of some 12 million acres of continuous, undivided grassland devoted almost exclusively to the production of forage for grazing animals. Beneath the grass-stabilized surface of the Sand Hills is a thick sequence of permeable rocks, sands and gravels, filled to overflowing with water. Water in storage beneath the Sand Hills is estimated at about 800 million acre-feet (Reed 1966). Streams rising from within the region are noted for their remarkably uniform rates of flow. Unlike other sand dune areas of the world, Nebraska's Sand Hills can hardly be considered a desert (Fig. 1).

This region occupies most of north-central Nebraska, and extends a short distance into South Dakota (Fig. 2). From east to west, the length of this diamond-shaped area is about 265 miles, while the north-south axis is about 130 miles. The area reaches an elevation of 4,200 feet in the northwest portion and decreases to 2,000 at the eastern edge. An aerial view would depict the rolling dunes interspersed with long valleys. The effects of wind erosion on the dune tops is characterized by the pock-marked appearance of small blowouts.

FIG. 1. View of Sand Hills showing fresh-water lake, hay meadows and rolling hills.

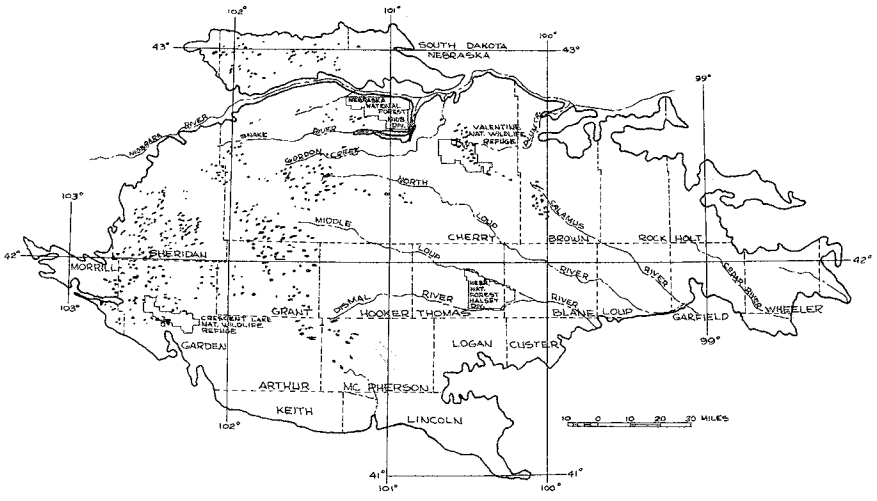

FIG. 2. The Sand Hills region of Nebraska. Taken from *Dunes on the Plains*, courtesy of U. S. Geological Survey.

It is generally agreed that the Sand Hills were formed in three distinct episodes (Smith 1965). The first occurred in the early stage of the last major continental glacial period. Eolian dune sand, derived from sheet-like alluvium, formed the long, linear dunes characteristic of the western part of the region. As new drainage systems developed, dunes were stabilized by vegetation. Dunes formed during the second episode were smaller and confined to the southeastern part of the region. The last dunes formed were still smaller, and are essentially superimposed upon the others. Most are related in origin to the crater-like blowouts on the older dunes.

Because of the unique biologic, geologic and hydrologic features of the region, a number of early collectors and scientists visited the Sand Hills. Prior to the turn of the century, Rydberg (1895) made an extensive tour in the heart of the region. A few years later, Pound and Clements (1900) provided one of the earliest comprehensive ecological analyses of the Sand Hill vegetation. Extensive studies by Pool (1914) provided a comprehensive inventory and ecological interpretation of the flora.

During this same general time period, Charles Bessey arrived at the University of Nebraska to serve as Professor of Botany. Based on his observations of valley and canyon relicts of woodland, chiefly yellow pine, he was convinced that trees could be grown in the Sand Hills. He persisted in his convictions until finally in 1891, the U.S. Department of Agriculture sent some tree seedlings for planting. From this beginning, forest reserves along the Dismal and Middle Loup (later to become the Bessey District), and the Niobrara Rivers were withdrawn from the public domain, thus establishing Nebraska's National Forest.

The Bessey District, Nebraska National Forest, located near Halsey, covers some 90,000 acres. Until 1965, it was composed of approximately 26,000 acres of man-planted trees with the remainder in prairie. The primary land use on the district is grazing, administered by the USFS under a permit system.

In early May, 1965, a lightning fire originating on the prairie west of the plantations burned over more than 18,000 acres of forest and rangeland. Since my agency was involved in a study of the life history and ecology of the sharp-tailed grouse on the Bessey District,

it followed that an opportunity was available to collect information on the effects of fire on a Sand Hills environment. The data reported in this paper was collected incidentally to our research studies on the forest dealing with sharp-tailed grouse.

Fire, natural or man-caused, is hardly new to a grassland complex such as the Sand Hills. Without exception, every early investigator alluded to fire and its effects on the prairie. The fire picture of today, however, has changed from that of pre-settlement times. Based on observations by pioneer ranchers, and on photographs taken at early railheads, the floristic composition of the range has changed dramatically in the last century. While extirpation of the buffalo could provide a partial explanation for the increased amount of vegetative cover now on the Sand Hills, deer and antelope numbers today are comparable to or greater than those of pre-settlement. Certainly some 1.5 million plus cattle existing on Sand Hill range create an impact comparable to the buffalo. Burzlaff (1962) has suggested that the limiting of fire has been of major importance in stabilizing the dune soils. Fire control efforts are now organized, and the summer prairie fires no longer constitute the threat to ranchers as they did to early prairie settlers and towns. This is not to say that range fires are now uncommon. Only their extent and recurrence has been limited. Lightning and the railroads are the primary causes of today's range fires. The Burlington Northern line, cutting diagonally across the Sand Hills, is responsible for a number of fires each year. Spring and summer thunderstorms, accompanied by lightning, are just as much a part of the climatic scene today as centuries ago. A lightning-caused fire on the Bessey Division of the Nebraska National Forest in May, 1965, was, therefore, a re-enactment of an age-old event. In this case, however, high winds coupled with a ready supply of fuel created a range fire that made news headlines over the state for many days.

To an observer with only limited exposure to forest fire control, the fire at Halsey in 1965 was an overwhelming experience. When the wind reached 48 mph on the ridge tops, the futility of control became immediately obvious. During the course of the following 2½ days, slurry bombers and fire crews of the U.S. Forest Service battled the fire. After the fire had been controlled (Fig. 3), some 16,710 acres had been burned on public land, 2,030 acres on private holdings.

Approximaely 42 percent of the 26,000 acres of plantations had burned along with 5,790 acres of rangeland on the Bessey District (Bond 1965). While the Forest Service was in the midst of mounting an immediate replanting and reseeding program, an ancient drama of nature had provided the opportunity to gather information on an extensive prairie wildfire.

METHODS

Previous experience with vegetation sampling on the grouse study area of the Forest indicated three distinct soil-associated range sites. Following the fire, soil and vegetation were sampled on the following three sites: dry valley, rolling sands, and choppy sands.

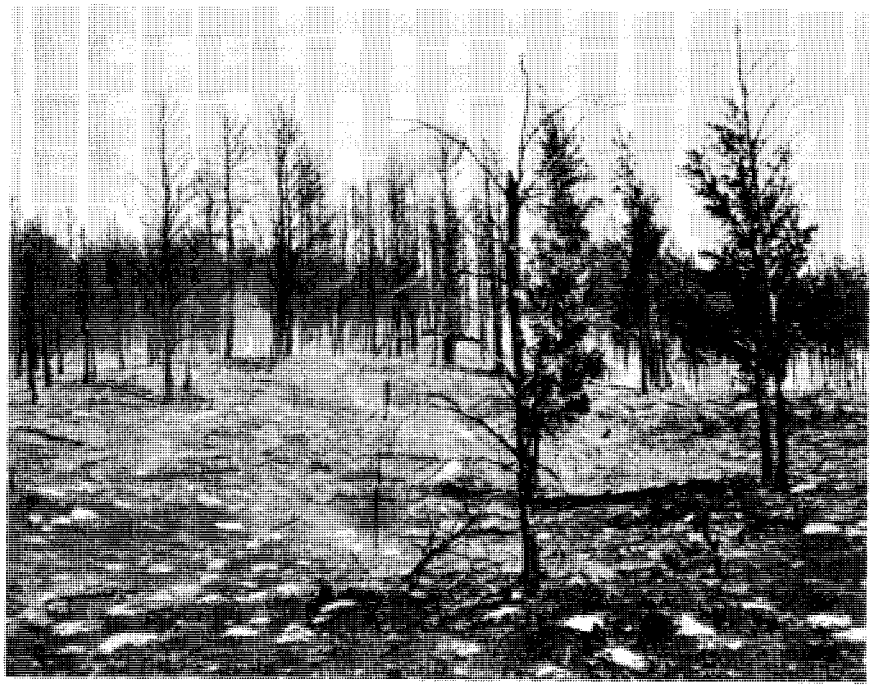

FIG. 3. Burned jack pine (*P. banksiana*) plantation, Bessey District, Nebraska National Forest. Note pocket gopher mounds.

The dry valley site is typically a flat valley between choppy or rolling sands. It may be as small as a few acres or as large as several hundred acres. The upper soil layer of this site is often dark. Shrub species, such as *Symphoriocarpus*, often characterize this site.

The rolling sand site (often referred to as sandy) is characterized by gently rolling, undulating hills lacking steep slopes or sharp features. Generally, this site is characterized by the presence of a *Calamovilfa-Andropogon* association.

The choppy sands site is semi-stabilized dune sand with sharp physiographic features. Slopes of 20 to 40 percent and local relief of 80 to 100 feet are characteristic of this site. The presence of yucca is common.

Sampling sites were selected on burned and unburned areas which were comparable in slope and exposure. Minor relief on all sampling sites was essentially uniform. Standard field procedures were used for soil sampling. Sampling was carried out to a 6-inch depth and included ground litter or ash. Samples were collected in May and August, 1965, and August, 1966. The University of Nebraska Soil Testing Laboratory completed standard laboratory analysis for pH, phosphorus, potassium, organic matter and conductivity.

Vegetation sampling was carried out adjacent to the soil sampling sites during July and August. The Forest Service three-step and the SCS methods of range analysis described by Dyksterhuis (1949) were used.

Since field observations during routine travel on our grouse research studies had been well documented since 1964, we utilized these to establish basic information on wildlife use of the plantations and prairie. Following the fire, field observations and mileage traveled were recorded for both burned and unburned areas.

FINDINGS

Soils

Results from soil analysis of burned and unburned sites are shown in Table 1. Soil site means of the unburned sites were noticeably higher than those reported by Burzlaff (1962) for similar sites. Dry valley sites showed higher organic matter content, lower pH values,

and higher potassium levels than the rolling or choppy sands sites.

Analysis of variance was utilized to separate effects of site, sampling date and treatment. Table 2 summarizes the findings. Organic matter, pH, phosphorus and potassium were affected significantly by site.

The time of sampling significantly affected ($P > .01$) organic matter levels. A significant *date X site* interaction was also noted for organic matter levels ($F = 4.30$). Burning had no significant effect on organic levels on any of the three range sites.

Potassium was the only soil constituent that appeared to be affected by fire. While an F-value of 3.94 was not significant at the 95 percent

TABLE 1. MEANS OF CHARACTERISTICS OF SAND HILL SOILS FROM THREE RANGE SITES.

Date of sample collection	pH	Phosphorus (ppm)	Potassium (ppm)	Conductivity (m. mhos.)	Organic matter (%)
UNBURNED RANGE SITE					
–Dry Valley–					
May 1965	6.2	4.0	128	0.20	1.30
August 1965	6.0	3.0	195	0.20	0.60
August 1966	6.2	11.2	222	0.30	1.98
–Rolling Sands–					
May 1965	6.5	8.0	128	0.20	1.40
August 1965	6.4	4.0	105	0.20	0.90
August 1966	6.4	4.2	117	0.24	1.12
–Choppy Sands–					
May 1965	6.6	7.0	100	0.20	1.00
August 1965	6.4	4.0	100	0.20	0.60
August 1966	6.4	4.2	81	0.26	0.80
BURNED RANGE SITE					
–Dry Valley–					
May 1965	6.2	9.5	170	0.26	1.78
August 1965	6.4	10.0	160	0.25	0.87
August 1966	6.1	11.8	141	0.22	2.04
–Rolling Sands–					
May 1965	6.4	4.7	97	0.17	1.00
August 1965	6.4	3.5	91	0.17	0.60
August 1966	6.3	4.0	95	0.28	1.12
–Choppy Sands–					
May 1965	6.5	4.0	82.5	0.15	0.67
August 1965	6.5	4.7	76	0.22	0.60
August 1966	6.4	3.8	76	0.26	0.54

confidence, an effect could be demonstrated at the 90 percent confidence level. The variation in potassium levels among sites for the sampling periods in 1965 and 1966 is shown in Figure 4.

TABLE 2. ANALYSIS OF VARIANCE SUMMARY TABLE.

Site	*F-VALUE*
Organic matter	11.4 **
pH	9.9 **
Phosphorus	4.3 *
Potassium	23.3 **
Sampling Date	
Organic matter	8.5 **
Sampling Date X Site Interaction	
Organic matter	4.3 **
Treatment	
Potassium	3.9 **

* P>0.05
** P>0.01

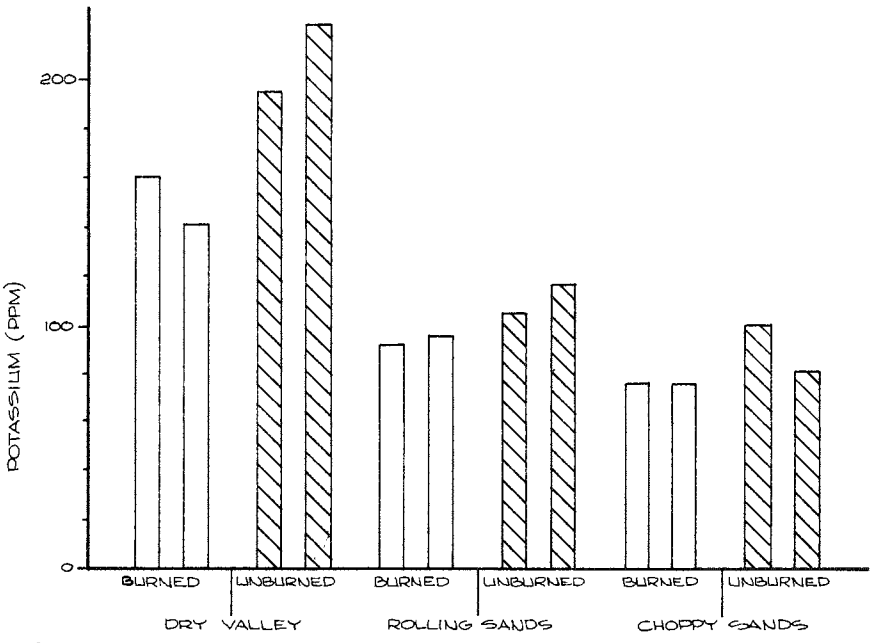

FIG 4. Changes in soil potassium levels on three Sand Hill range sites from August, 1965, to August 1966.

TABLE 3. RANGE CONDITION CATEGORIES ON THREE SAND HILL RANGE SITES.

Category	DRY VALLEY		ROLLING SANDS		CHOPPY SANDS	
	Burned/Unburned		Burned/Unburned		Burned/Unburned	
Ground cover index	76.2	97.0	47.0	97.0	37.5	96.0
Range condition class	58.5	67.0	64.5	71.0	79.0	85.0
Av. ht. (inches) growth current growing season	5.2	4.6	6.8	10.4	5.5	10.5
Percent light intercepted[1]	23.6	30.6	18.8	34.1	7.4	27.3

[1] Foot candles 4 inches above ground, 1 inch above vegetation

VEGETATION

Vegetation sampling was carried out in July and August, 2 to 3 months after burning. Results from the three range sites indicated substantial differences in some range condition categories as a result of burning (Table 3).

The ground cover index was significantly lower on burned sites While a gradually diminishing ground cover index was noted from the dry valley to the rolling sands sites, the greatest effect of burning was noted on the choppy sands site.

When the range condition of burned sites was examined, there was little difference as a result of burning. Fire had a significant effect on vegetative growth for the current growing season (GCGS) on the unburned choppy sands and rolling sands sites. Growth was 53 to 91 percent greater respectively on the unburned sites. On the dry valley site, growth was slightly greater on the burned area. The greater amount of organic matter along with a greater water-holding capacity on these sites was considered to account for comparable growth rates.

The amount of light intercepted by vegetation on the burned sites was noticeably lower than on the unburned sites. Only on the dry valley site was the percent of light intercepted comparable for both burned and unburned sites.

Vegetational aspects unrelated to methods utilized for purposes of habitat or range analysis provided some interesting sidelights on burning in a Sand Hills grassland. While these findings are not based on adequate sample numbers for statistical reliability, they merit brief mention.

In our habitat analysis flora is categorized into the following classification:

1) Grasses
2) Grass-like
3) Forbs
4) Tree-shrub

In examining the number of species present on the burned and unburned transects, we found that the number of plant species present in the grass, grass-like and tree-shrub categories remained essentially unchanged. In the forb category, the number of species present decreased approximately 35 percent on the burned range sites. Each of the three range sites exhibited slightly different response with respect to forbs. On the burned dry valley site, five forb species decreased (Table 4).

Interestingly, two of the species increasing on the burned dry valley site, *Liatris punctata* and *Helianthus petiolaris*, are considered decreasers under grazing. None of the five species decreasing after burning are considered range decreasers. Forbs remaining unchanged on both burned and unburned sites were western ragweed, pigweed and ground cherry.

On the burned rolling sands site, forbs decreasing included pigweed, narrowleaf goosefoot and snake cotton (Table 5). Forbs increasing were false boneset and Missouri goldenrod, both decreasers on rangeland under a grazing regime.

TABLE 4. EFFECT OF FIRE ON FORBS, DRY VALLEY SITE.

	Forbs Decreasing	
Pepperweed		*Lepedium sp.*
Virginia dayflower		*Commelina virginica*
Wooly plantain		*Plantago purshii*
Narrowleaf goosefoot		*Chenopodium leptophyllum*
Upright prairie coneflower		*Ratibida columnaris*
	Forbs Increasing	
Prairie sunflower	(D)*	*Helianthus petiolaris*
Dotted gayfeather	(D)	*Liatris punctata*
Snake cotton		*Froelichia floridana*
	Forbs Unchanged	
Western ragweed		*Ambrosia psilostachya*
Common pigweed		*Amaranthus sp.*
Clammy groundcherry		*Physalis heterophylla*

* Decreaser under grazing

TABLE 5. EFFECTS OF FIRE ON FORBS, ROLLING SANDS SITE.

	Forbs Decreasing	
Common pigweed		*Amaranthus sp.*
Narrowleaf goosefoot		*Chenopodium leptophyllum*
Snake cotton		*Froelichia floridiana*
	Forbs Increasing	
False boneset	(D)*	*Kuhnia eupatorioides*
Missouri goldenrod	(D)	*Solidago missouriensis*
	Forbs Unchanged	
Western ragweed		*Ambrosia psilostachya*
Prairie sunflower	(D)	*Helianthus petiolaris*
Dotted gayfeather	(D)	*Liatris punctata*
Missouri spurge	(D)	*Euphorbia missurica*

* Decreaser under grazing

On the burned choppy sands site, three species were noted to decrease (Table 6). They included narrowleaf goosefoot, wooly plantain and gromwell. Five species of forbs increased on the burned choppy sands. Four of these are considered decreasers.

Based on our limited data, the species of forbs on burned sites underwent an overall decline in numbers. But those species increasing on the burned sites were the preferred species from a range utilization aspect. Changes in vegetation response were not documented after 1965.

TABLE 6. EFFECTS OF FIRE ON FORBS, CHOPPY SANDS SITE.

	Forbs Decreasing	
Narrowleaf goosefoot		*Chenopodium leptophyllum*
Gromwell		*Lithospermum spp.*
Wooly plantain		*Plantago purshii*
	Forbs Increasing	
Ironplant		*Sideranthus spinulosus*
Dotted gayfeather	(D)*	*Liatris punctata*
False boneset	(D)	*Kuhnia eupatorioides*
Missouri goldenrod	(D)	*Solidago missouriensis*
Silky prairieclover	(D)	*Petalostemum villosum*
	Forbs Unchanged	
Stiff sunflower	(D)	*Helianthus laetiflorus*
Missouri spurge	(D)	*Euphorbia missurica*
Western ragweed		*Ambrosia psilostachya*

* Decreaser under grazing

WILDLIFE

In order to quantify the response of wildlife to burning, travel records and field observations were tabulated to provide base information (Table 7). We used the percent of each species observed in each habitat type per 100 miles of travel for a common denominator. Whitetail and mule deer sight records were tabulated for each month from 1964 through 1966. Mourning dove observations were tabulated only for the 4-month period of May through August for each of the 3 years. Observations and mileages were separated for each habitat type to determine if differences existed in fauna response.

Observations prior to the fire indicated that whitetails utilized the planted area more than 80 percent of the time (Fig. 5). Few white-

TABLE 7. BASE MILEAGE AND SPECIES OBSERVED DURING TRAVEL.

Year	DEER OBSERVATIONS (12 months)			MOURNING DOVE OBSERVATIONS (4 months)	
	Miles	White-tail	Mule Deer	Miles	Number
1964	1,038	63	141	2,860	708
1965	5,097	38	165	3,368	828
1966	6,204	27	131	3,959	2,305

tail observations were made in the burned plantation area. This appeared logical since the whitetail in the Sand Hills is essentially an animal of the tree-shrub community. Their use of the burned area constituted about 8 percent in 1965. Use declined to about 5 percent in 1966.

Mule deer, on the other hand, showed a very substantial response to the burned area (Fig. 6). While normally considered a deer of the prairie, baseline observations in 1964 showed that mule deer utilized the prairie only slightly more than the plantations (53 vs. 47 percent). After the 1965 fire, mule deer made about equal use of the burned and unburned plantation areas. During the same period, numbers of mule deer observed in the prairie declined substantially. By 1966, only about 28 percent of the mule deer observed were using the burned plantation area.

Mourning dove numbers were examined primarily because of the

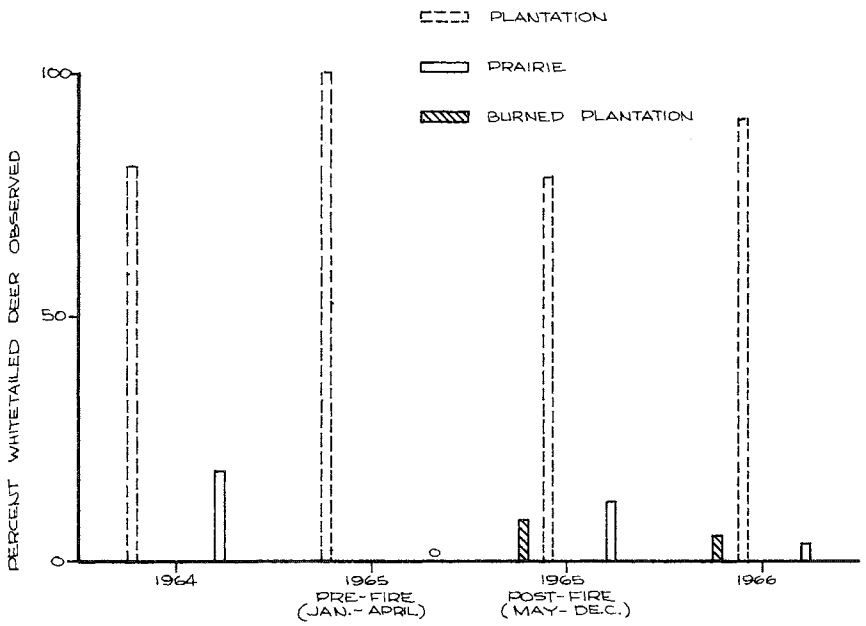

FIG. 5. Observations of white-tailed deer on the Bessey District, Nebraska National Forest.

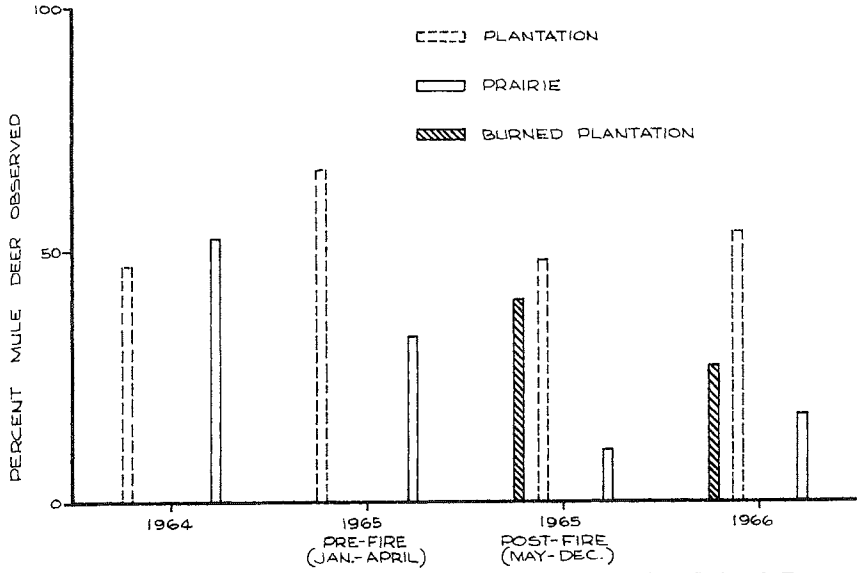

FIG. 6. Observations of mule deer, Bessey District, Nebraska National Forest.

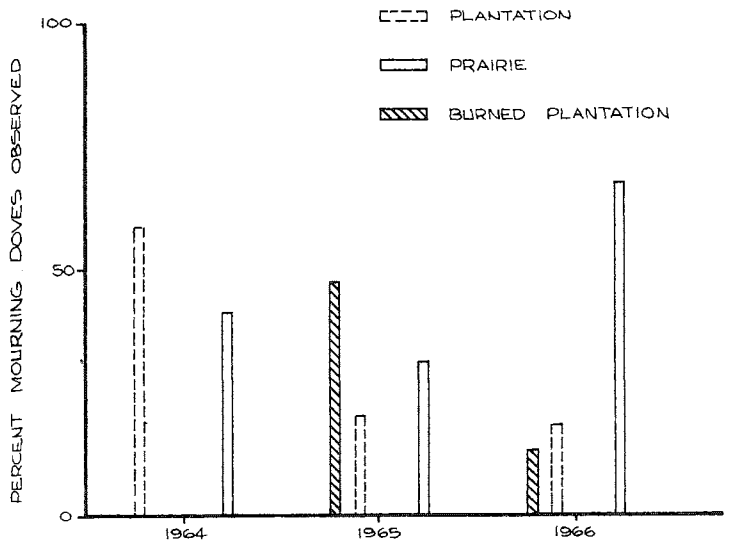

FIG. 7. Observations of mourning doves, Bessey District, Nebraska National Forest.

large summer population in the area, and also because the consistency of observation provided what we considered more reliability. Prior to the fire, doves were observed in the plantation area about 60 percent of the time (Fig. 7). After burning, approximately 50 percent of doves utilized the burned area. Use of the plantations, both burned and unburned, dropped substantially in 1966.

Many other observations related to wildlife have been recorded since the fire in 1965. Most, though, were of the field diary type. Bobwhite quail, for example, were observed in many areas where they had not been seen before. Seat-of-the-pants intuition indicated that this species responded positively to the habitat created by burning in the more open portions of plantation nearer the river. While these types of observations would not withstand scrutiny by the statistically-oriented scientists, they have and will continue to provide considerable food for thought in the utilization of fire as a management tool.

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