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ECOLOGICAL STUDIES IN A MIDWESTERN RANGE:

THE VEGETATION AND EFFECTS OF CATTLE ON ITS COMPOSITION AND DISTRIBUTION

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Native range and pastures are among the most important natural resources in the western half of the United States. According to Doctor J. E. Weaver and Mr. G. W. Tomanek, the purpose of this bulletin is to describe the effects of a half century of grazing on a large native prairie in eastern Nebraska. When native prairie is grazed and trampled various changes occur, the nature and extent of which vary somewhat directly with the degree of disturbance. Doctor Weaver is eminently fitted by long study of grasslands in Nebraska, the midwest, and far west to understand and analyze the problems of grazing native pastures. He knows that forage produced in pastures is an important crop largely within the control of man and that a study of the activities of the grazing animals as well as the vegetation is essential to an understanding of proper range management.

G. E. CONDRA, *Dean and Director*
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INTRODUCTION

There is continued need for a better understanding of range vegetation and its use by range animals. Range preservation and improvement in the midwest are largely matters of wise use and proper management of our natural grasslands. A more comprehensive understanding of the range itself is needed—its forage, soil, and water supply, and factors influencing a proper distribution of livestock. The degree of utilization of forage that will result in the maintenance of excellent or good range condition and the improvement of a range in fair condition should be ascertained. Soil conservation on range lands is accomplished primarily by improvement of the vegetation. Mechanical devices, as contour furrows, structures for water spreading, etc., are means of fostering recovery and improvement of the plant cover. Permanent protection of the soil can be had only by recovery and stabilization of the vegetation. We must know the present condition of the range, what types or groupings of vegetation occur, and the significance of each type. We should know scientifically just how good the range is and how much better it may become under proper use.

The pasture selected for study is almost completely surrounded by natural grassland. It is a part of a long range of rolling hills northwest, west, and southwest of Lincoln, Nebraska, which is covered with thousands of acres of natural grassland. Many of the larger prairies and ranges are scarcely changed from their original condition. Rattlesnakes, coyotes, and various species of the original rodent population are common. The cattle are not subjected to herding or driving but remain undisturbed throughout the summer. This range has been observed over a period of many years by the senior author, and intensive studies in it have been made during five years (1946-1950).

The purpose of this study was to ascertain the amount, composition, and consumption of forage, and the grazing activities and their effects upon the composition and distribution of the vegetation.

THE EXPERIMENTAL RANGE OR PASTURE

The experimental range is 5.5 miles north and 3 miles west of the University of Nebraska. It is a mile long, north to south, and a half-mile in width. About 30 acres in the southwest corner have been broken and cultivated; hence the area is approximately 290 acres. The topography is that of rolling upland. Hills 50 to 100 feet high are separated by deep ravines (Fig. 1). These are dry except for a few days after rains. An exception occurs near the center of the pasture where underground seepage produces a small but often continuous stream of water. Two artificial ponds are located at the lower end of this ravine. Formerly water was obtained at the farmyard one-fourth mile south of the west pond. The occurrence of water in only one place resulted in a very unequal distribution of grazing. This is accentuated by steepness of the hills, which often have slopes of 9 to 11 percent, and even steeper banks of ravines which must be crossed by the livestock.

Grazing began in this prairie in 1903, although hay was cut in autumn where grazing had been light (usually in the north end) and the topography permitted. Originally the vegetation was similar in all parts of the pasture, the cover being less dense, of course, on the ridges. But after several years it became clear that production in the south part was declining. This occurred because grazing was always closer in this area adjacent to the farmyard where water and salt could be obtained. The pasture has never been partitioned by fences. The rate of stocking in the past 47 years has been very constant according to the owner, Mr. R. J. Black, irrespective of seasonal growth of vegetation, markets, etc. About 85 animal units including 14 horses were carried each year. The rate is one animal for each 3.4 acres. This is greater than that recommended by experienced cattlemen, which is 4 to 5 acres per animal unit (Aldous 1938). Grazing began between April 15 and May 10 and ended late in October. The horses, however, had access to the pasture all winter. Since this heavy stocking was more or less concentrated in the southern two-thirds of the pasture, it could result only in overgrazing and deterioration of this part. In 1949, excellent range condition class was confined largely to the northern one-fourth of the prairie. Good condition class occurred over most of the north-central portion; much of the remainder was in only fair range condition (Figs. 2, 3, 4 and 5).

The major soil type, Carrington loam, is a zonal Prairie soil developed on leached glacial till. It has a dark grayish-brown

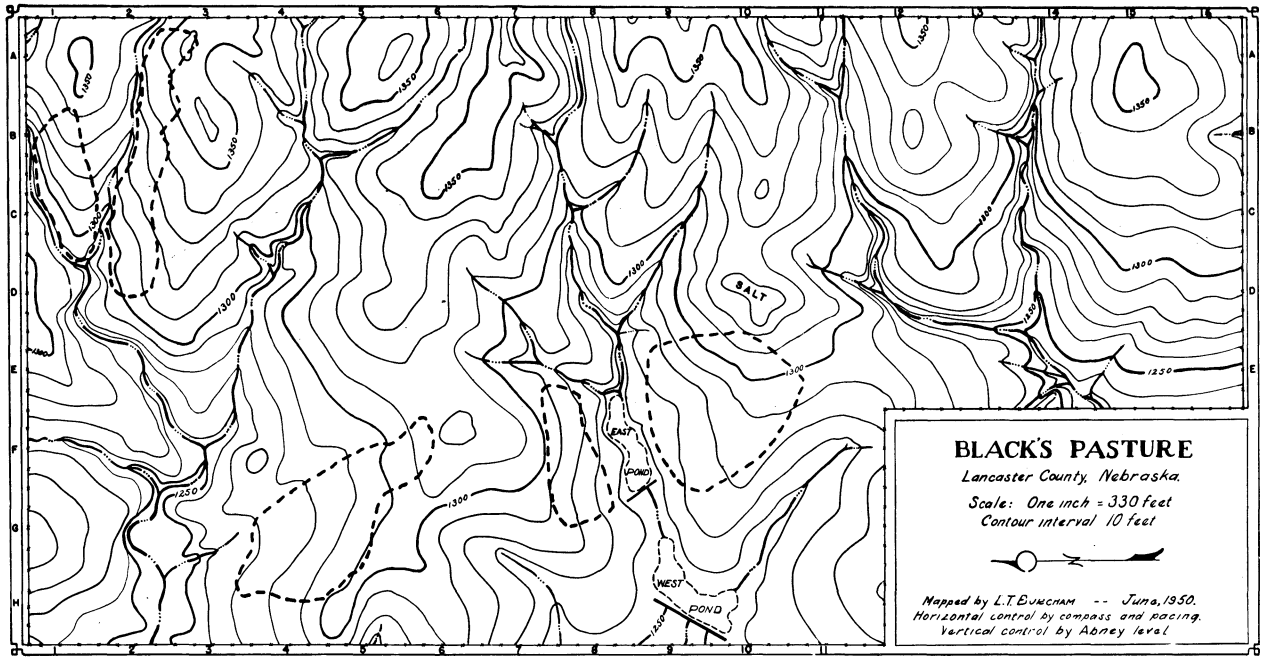

Fig. 1. Topographic map of the pasture with contour intervals of 10 feet. The general drainage is from east (top) to west. Note that five deep ravines cross or nearly cross the pasture. Hence there are six high hills or ridges that also transect or nearly transect the area from east to west. Altitude varies from 1,350 feet on the eastern side to 1,250 in the ravines and ponds on the west. Two areas near the ponds, enclosed by broken lines, were used for ascertaining yield and consumption of forage in fair range condition. One area, farther north (left), was used for similar sampling in good range condition, and two in the northeast corner were likewise used, in excellent range.

Fig. 2. View in south end of the pasture looking northward from the first hill across the ravine. Note large clumps of ironweed (*Vernonia baldwini*) in the ravine and patches of buckbrush (*Symphoricarpos occidentalis*) on the hill. This area is nearly all in the fair range condition class.

Fig. 3. View in south-central portion of the pasture including the west pond. The movable exclosures, made of 7-foot steel posts and heavy woven wire, each enclose 29 square feet from grazing. Note the paths in foreground. The closely grazed carpet of Kentucky bluegrass (*Poa pratensis*) and blue grama (*Bouteloua gracilis*) is representative of fair range condition class.

Fig. 4. View in central portion of the range (D 4 in Fig. 1 in foreground, and D 5 in center). The more distant livestock are on the central ridge a quarter-mile southward. Excellent range condition class is shown in foreground where bluestems are abundant.

Fig. 5. View in the northeastern part of the range looking southeast from position D 1 in Figure 1. This is typical of the rolling topography over which the cattle must travel in this pasture. The ravine is a main route of travel across the pasture east and west.

A horizon and a yellowish-brown or brown B horizon 2 to more than 3 feet thick. The parent material beneath is glacial till. There is one area of Carrington silty clay loam, and the Steinaur Series is represented in one tract of less than 10 acres. All of the places where yield and consumption were measured were on Carrington loam. The topsoil, which is 10 to 14 inches deep, is very mellow. Although the calcium carbonate in this soil has been leached from the solum, and no free lime is found to a depth of about 5 feet, the pH is usually about 6.5. This dark-colored, fine-granular soil is very receptive to water when clothed with grass. The precipitation, of about 27.5 inches annually, moistens the soil deeply. Both surface and internal drainage are good. The Carrington loam is a very productive soil which occurs widely in eastern Nebraska and Iowa. It supports vegetation which produces 1 to 1.5 tons of prairie hay per acre. The bluestem grasses extend their roots 4 to 6 feet deep on upland, and various forbs, including legumes, much deeper (Beesley *et al.* 1948; Weaver 1919, 1950; Weaver & Darland 1949).

RANGE CONDITION CLASSES

The manner in which True Prairie degenerates under continued grazing and the resulting grades of pasture or range condition classes have been described by Weaver and Hansen (1941). Their studies were preceded by several years of careful examination and analyses of hundreds of individual prairies scattered over a very extensive area (Weaver & Fitzpatrick 1932, 1934). The range condition classes were based upon the composition of vegetation.

The most abundant and important prairie plants have been grouped into three classes by Weaver & Hansen (1941) according to the manner in which they responded to grazing. The first class consists of decreasers and includes all grasses that become less abundant under grazing. Examples are big bluestem (*Andropogon furcatus*),[1] little bluestem (*A. scoparius*), and prairie dropseed (*Sporobolus heterolepis*). A second class includes all grasses, such as bluegrass (*Poa pratensis*), side-oats grama (*Bouteloua curtipendula*), and purple lovegrass (*Eragrostis spectabilis*), that increase under grazing. The third class consists of grasses which do not normally occur in true prairie but migrate into overgrazed pastures and replace the former prairie grasses. Examples are sand dropseed (*Sporobolus cryptandrus*), six-weeks

[1] The nomenclature of grasses follows Hitchcock's "Manual of the Grasses of the United States", that of other plants, unless authority is given, Britton and Brown's "Illustrated Flora".

fescue (*Festuca octoflora*), and beadgrass (*Paspalum stramineum*).

Forbs are affected by grazing in a manner similar to that of the grasses. Many decrease and may entirely disappear as do nearly all of the legumes, sunflowers, and blazing stars. Others that increase include prairie cat's-foot (*Antennaria campestris*), many-flowered aster (*Aster multiflorus*), ironweed (*Vernonia baldwini*), and numerous other species. Finally, forbs not common to prairie invade, especially into grasslands reduced to the fair or poor range condition class. Among a host of these, western ragweed (*Ambrosia psilostachya*), gumweed (*Grindelia squarrosa*), vervain (*Verbena stricta*), and horseweed (*Leptilon canadense*), are representative.

Recent analyses of three large and widely separated pastures in each of the four range condition classes have been made by Voigt & Weaver (1951). The percentage composition of the vegetation by species and by classes (decreasers, increasers, etc.) was ascertained and compared. Their results showed clearly the application and value of the method in comparing range condition classes. Placing it upon a percentage basis added greatly to the validity of the concept and more clearly definitized the differences between range condition classes.

CLASSES IN THE EXPERIMENTAL RANGE

Three range condition classes, excellent, good, and fair, occurred in the particular range under present consideration. Only a very small part had degenerated into the poor condition. After long and careful study the locations of the portions of the pasture in each range condition were mapped as shown in Figure 6. The basis for mapping was entirely the percentage composition of the vegetation. The method will be described after each range condition class is considered.

EXCELLENT RANGE CONDITION

In this class two decreasers, big bluestem and little bluestem, alone composed over 70 percent of the vegetation. The increasers, especially bluegrass, purple lovegrass and side-oats grama, furnished much of the remainder. Old ungrazed bunches of little bluestem and often those of tall dropseed (*Sporobolus asper*) were always prominent (Figs. 7 and 8). Bunches of Indian grass (*Sorghastrum nutans*) with flower stalks were common. Those of big bluestem were rare, since this grass is highly palatable and few tops of the season's growth escape some grazing, at least above

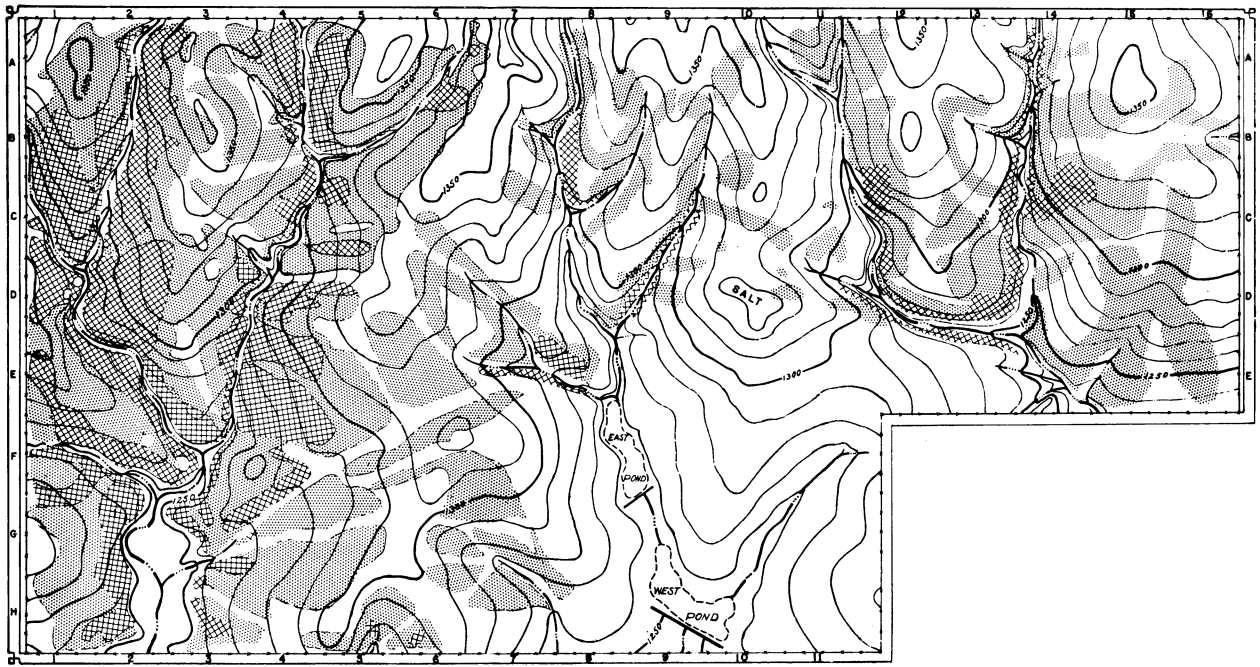

Fig. 6. Range condition classes superimposed upon the topographic map. The excellent condition (crosshatch) is mostly in the northern portion of the pasture; otherwise it nearly always occurs on steep banks bordering ravines. The unshaded areas, most extensive in the central and southern portions, represent the fair range condition class. Dotted areas represent vegetation in good range condition.

Fig. 7. View of excellent range condition class on a north-facing slope on May 6, 1950. It shows much vegetation ungrazed the preceding year. The bunches are mostly little bluestem (*Andropogon scoparius*), but there is approximately an equal amount of big bluestem (*A. furcatus*) between them.

the 5- to 8-inch level (Fig. 9). Half or more of the area was covered with roughs where the mulch was always excessive.[2] Much of this portion was grazed only a little. Here bluegrass was almost excluded. Closely grazed spots, if they occurred, were not abundant. About half of the area was characterized by less thickly spaced bunches, moderate amounts of debris, and small to large local areas where the bluestems were grazed irregularly and 3 to 5 inches high (Fig. 10). The greater the percentage of big bluestem in any site, the more uniformly was the vegetation removed.

This range condition class, which occupied 13 percent of the pasture, was usually found at a considerable distance from water, or elsewhere only on steep slopes. Because of the low percentage of the cool-season bluegrass and the dominance of warm-

[2] Roughs are places where the forage has not been removed for a year or more, either because of lack of grazing due to the presence of weeds or other less palatable species, or for other reasons. Often they occupy only a few square feet but sometimes many square yards. They give the vegetation a very uneven appearance.

An excessive mulch is one composed of a layer of dead and decaying vegetation which covers the soil to a depth of 1.5 to more than 4 inches. It is excessive only in the sense that it delays growth in spring and results in or at least accompanies a very low utilization of forage.

Fig. 8. Excellent range on south-facing slope in the north-central portion of the pasture on August 15, 1950. The old bunches of little bluestem are prominent and stand above the new foliage of big bluestem, side-oats grama (*Bouteloua curtipendula*), and grazed bunches of little bluestem. Chief forb is ironweed.

season bluestems the vegetation became green last in spring and little or no early grazing occurred here. By midsummer of drier years this range class was moderately utilized by livestock, but on wet years only a small amount of the crop of forage was consumed by that time. But in August and September, when the range furnished less new forage elsewhere, all of the big bluestem was sought and grazed at least several inches back from the top, and often, where the stand was nearly pure, to a height of 4 to 5 inches. Little bluestem was grazed to a considerable degree and the inflorescences were sometimes uniformly eaten.

GOOD RANGE CONDITION

In this type, which occupied 30 percent of the pasture, the cover of old standing bunches of little bluestem, tall dropseed, and prairie dropseed was not so continuous as before. Many

Fig. 9. Detail of nearly pure big bluestem in mid-June showing high grazing of shoots that have grown up through a layer of mulch about 4 inches thick. A good mulch is characteristic of excellent range condition.

Fig 10. View of excellent range condition showing irregular grazing. The bluestems and other grasses have been grazed 3 to 4 inches high on the left but bunches of little bluestem and prairie dropseed (*Sporobolus heterolepis*) remain ungrazed on the right. Photo July 9, 1949.

Fig. 11. General view in the good range class on May 11, 1950. Many of the bunches of little bluestem and prairie dropseed and all of the big bluestem have been grazed back to 2-5 inches. The remaining bunches are widely spaced. Note the abundance of unused forage which furnished an excellent soil mulch.

of the bunches had been reduced in stature (Fig. 11). While mulch was excessive in roughs, such areas were smaller than in the preceding class. The entire type had been grazed at some time, moderately in places but more closely in others. Hence, a large part of the current forage could be had without or with only moderate amounts of the old leaves and stems of the preceding year. The cover in the areas free of bunches or between them was denser, since it usually contained a mixture of about one-third bluegrass in addition to the bluestems and other grasses of the excellent class. The plants were more vigorous than in the next lower or fair class; vegetation developed more rapidly after grazing; and the amounts of forage produced were larger. On poor years for growth more of the area was grazed closely and old bunches disappeared entirely or in part; during favorable growing seasons parts of the general area temporarily developed into little-grazed roughs. Because of the abundance of forage, closely

Fig. 12. An example of spot grazing in good range condition class. Bluegrass rapidly increased in these closely grazed spots and patches. About half of this class of range consisted of such places which were often connected, forming a network in which close grazing regularly occurred.

grazed patches with an abundance of bluegrass and only a small amount of mulch alternated with vegetation that was grazed high and where the abundant debris had inhibited the invasion of bluegrass.

Grazing in spots or patches in the good pasture class was common (Fig. 12). It was largely by this means that the area was opened to final general grazing. Once a bit of vegetation a few square feet to a few square yards had been freed from the old growth, it was grazed again and again and was a center for the establishment of bluegrass. Such areas occur as spots or patches, but under continued use they are constantly enlarged. Later they merge to form a network of closely to moderately grazed places among ungrazed bunches and debris-filled vegetation. Finally the grazed areas predominate in extent over the roughs and relict bunches which occur only here and there. These also may be consumed in periods of drought or overstocking. But often before this has happened usually another type of grazing has occurred. This consists in grazing the tops, first of big blue-

stem, prairie dropseed and other plants but also of little bluestem and tall dropseed as well. The effect was to reduce the general level of the vegetation closer and closer to the soil. The decreased competition by most prairie grasses for light and water was very favorable to the spreading of bluegrass, sideoats grama and blue grama, and the invasion of weedy grasses and forbs. These increasers constituted practically half of the vegetation. Such areas were usually closely or at least moderately grazed. Continued overgrazing in the good pasture reduces it finally to the fair range condition class.

FAIR RANGE CONDITION

In this class, which covered 57 percent of the area, the range everywhere had the appearance of having been closely grazed (Fig. 13). In midsummer of 1950, for example, about half of it was closely and uniformly grazed but the other half was covered with low vegetation, mostly 4 to 8 inches high. This consisted of matured blue grama (*Bouteloua gracilis*), ripened hairy chess (*Bromus commutatus*), dried flower stalks of bluegrass, and

Fig. 13. View in typical fair range class. Nearly all of the bunches have been reduced almost to the general level of the closely grazed bluegrass and blue grama, which are now the dominant species. This is a portion of the south-facing slope of the most northeasterly hill. The photo (May 6, 1950) shows that very little unused forage was left as mulch on the soil. See also Figure 3.

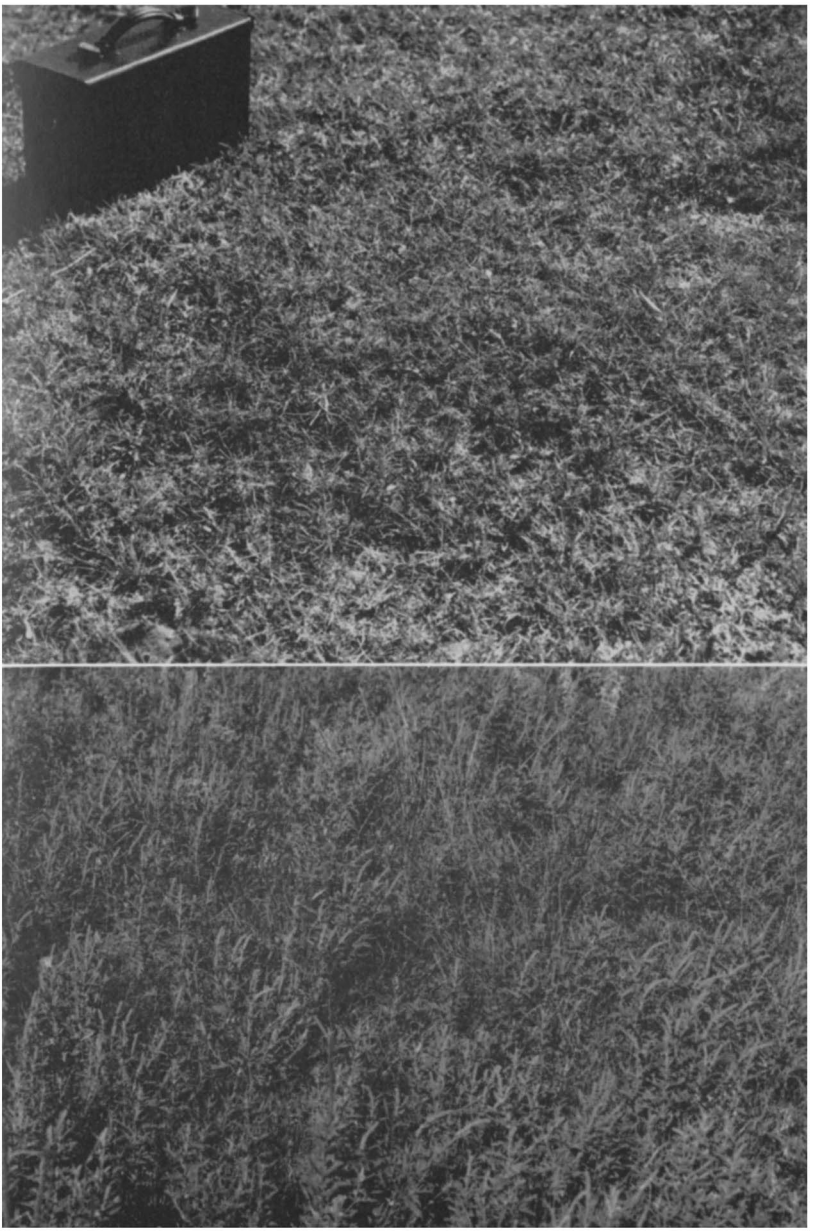

Fig. 14. Two detailed views in the fair range condition class on August 18, 1950. The upper one shows uniformly close grazing at 1.5 to 2 inches repeated frequently enough to consume all the available forage. In the lower view an abundance of western ragweed (*Ambrosia psilostachya*) discouraged uniform grazing in late summer.

prairie three-awn (*Aristida oligantha*). Intermixed were various taller, unpalatable forbs as western ragweed, ironweed, vervain, and thistles. The first condition occurred where bluegrass, blue grama, sand dropseed, relict prairie grasses, and most other vegetation had been kept closely and almost uniformly grazed. The second represented nonuniform or selective grazing during this season and probably in part during the preceding one (Fig. 14). In this range class very few or no relict bunches were found. Those that were present were almost always either remnants of tall dropseed or little bluestem. Such vegetation contrasted sharply with that of both the excellent and good range condition classes. Bluegrass or blue grama, often intermixed with various sedges and purple lovegrass, were the most important species.

Location of the closely grazed or selectively grazed portions of this class had no relation to the distance from water or the topography. Both closely grazed and selectively grazed areas were found in all portions of the pasture in fair range condition. The class itself, as shown in Figure 6, was found most extensively in areas less than a half-mile from water but also in all major ravines and in many minor ones which drain into these, in areas adjacent to trails, and along all of the boundaries, where the cattle collected near the fence. The fair class mostly grades into the good one but also often into the excellent range as well. It is the class most frequently grazed, most trampled, and the one where the soil is least protected by a mulch.

Only about 3 percent of the pasture had been reduced by overuse, trampling, etc., to the poor range condition class. These were places in and about paths, near the ponds and salting area, or under the shade of the few trees that were present. Such low-grade areas were more or less clearly demarked by an aggregation of the following species: prairie three-awn (*Aristida oligantha*), knotweed (*Polygonum aviculare*), fetid marigold (*Boebera pappposa*), sourdock (*Rumex* spp.), large-bracted vervain (*Verbena bracteosa*), snow-on-the-mountain (*Euphorbia marginata* Pursh.), spotted spurge (*E. maculata* L.), gumweed (*Grindelia squarrosa*) and buffalo bur (*Solanum rostratum*). Such vegetation has very little forage value and will not be considered here.

The patches of buckbrush (*Symphoricarpos symphoricarpos* and *S. occidentalis*) are not included in this study. Although most abundant in overgrazed places, they occurred nearly throughout the pasture and occupied 3 to 5 percent of the land. Such areas furnish practically no food from either grass or shrub.

EXPERIMENTAL AREAS FOR MEASURING YIELD AND CONSUMPTION OF FORAGE

Casual observation showed a gradual increase in both quality and quantity of forage as one proceeded from the southern and central part of the pasture toward the northern boundary. Closer study revealed the high degree of degeneration of vegetation in the central and southern part, the more moderate one northward, and the almost normal condition of the prairie cover in much of the more distant northern portion of the range. Changes in the vegetation, however, were far from uniform. It had been seriously damaged by the great drought of 1934 to 1940, especially on hilltops and south-facing slopes. Here, often, most of the little bluestem had died but was later replaced in part by big bluestem. Blue grama had increased considerably and tall dropseed became widespread. With the occurrence of wet years, bluegrass spread rapidly from the ravines and became abundant on the dry slopes and ridges partly denuded by drought. Thus, damage to vegetation had been partly repaired after eight years with good precipitation, but its composition was not that of the predrought stand (Weaver & Albertson 1944, Weaver 1950a). Hence, it seemed advisable to select areas for obtaining yield and consumption of forage mostly or entirely on north-facing slopes.

SELECTION OF AREAS

Three areas, ranging from 7 to 10 acres in extent, were selected in which to make detailed, quantitative studies. These selections were based on the concept of excellent, good, and fair grades of pasture or range condition classes defined by Weaver and Hansen (1941).

Selection of an area representative of excellent range condition was not difficult even in spring before growth was resumed, because of the abundance and character of the previous year's vegetation remaining on the soil. Flower stalks of little bluestem were abundant, much high-grazed big bluestem remained, the dried, curled leaves of side-oats grama were conspicuous, and there was a mulch of lodged plants or plant parts to a depth of 1 to 4 inches. Other evidence of an excellent range condition class was the prevalence of many of last year's prairie forbs, even the most palatable ones, such as lead plant (*Amorpha canescens*), many-flowered psoralea (*Psoralea floribunda*), silvery psoralea, (*P. argophylla*), and numerous others. Kentucky blue-

grass, while common, was far less abundant than in other parts of the pasture. This area had not degenerated greatly from normal prairie. The sampling area chosen was in two parts, both on the north-facing slopes of two hillsides (Fig. 1). The slope in both parts was 5 to 10 percent, and the two areas of vegetation were almost identical.

The sampling area in the good range condition class was chosen for its apparent uniformity of vegetation, degree of slope (4 to 7 percent), and northern exposure. Here it was evident that continued grazing had been sufficiently heavy to weaken or destroy much of the native vegetation and to permit a great spreading of bluegrass. This, of course, greatly increased the basal area. In excellent range the total basal area was 18 percent but in good range 29.3. It will be shown that bluegrass increased still further in fair range, where blue grama was also plentiful. Here the basal area was 38.8 percent. Voigt and Weaver (1951) have shown that in poor range basal area decreased, with the opening of the cover, to less than one-half that in fair range.

Patches of vegetation several square yards in extent containing mostly bluegrass occurred throughout the good range class. Other, smaller, closely grazed places were numerous. Conversely, many places where little bluestem had been ungrazed or at least grazed high were scattered about. These often bore the flower stalks and rank foliage of the preceding year. Other prairie grasses were abundant. There were fewer prairie forbs but some, as smooth goldenrod (*Solidago glaberrima*) and yarrow (*Achillea occidentalis*), had increased in abundance. Hoary vervain, western ragweed, and others not common to prairie were moderately abundant. It will be shown that this sampling area was divided into two parts by a grazing route along the main paths to more distant parts of the pasture. Vegetation along this route was in the next lower range condition class.

The larger portion of the central and southern parts of the pasture was representative of the fair condition range class. Bluegrass, blue grama, side-oats grama, sand dropseed, and many weedy forbs composed most of the vegetation. The short-lived hairy chess and little barley (*Hordeum pusillum*) were often abundant. Throughout a long period of years grazing had usually been so close that there was relatively little debris left on the soil. Paths occurred throughout in great numbers, most of them converging near the ponds or at the adjacent salting site on the hill.

Because of the same type of vegetation, sampling areas were selected on both north- and south-facing slopes. The upper portions had slopes of 2 to 3 percent, the lower ones about 6. The vegetation was representative of the fair range condition class which occurred widely.

COMPOSITION OF THE VEGETATION

Vegetation in each range condition class in the selected areas was sampled in numerous, well distributed, square-foot plots. Lines were marked out in such a manner that they crossed the entire sampling area lengthwise in at least two different places. Sampling along the lines was at random, usually at intervals of 12 paces. Of the 150 samples taken in each range condition class, 50 were obtained in June, 50 in July, and the remainder in August. Any one sampling was made over the entire area, but the later samples were taken between those obtained earlier. The apparatus and methods of sampling were the same as those described by Voigt and Weaver (1951).

METHODS

"The quadrat frame consisted of a strip of steel and was so constructed as to enclose three sides of a square foot. The strip was one-eighth inch thick and the frame half an inch high. The open side permitted the frame to be slid on the soil and through the vegetation of the selected area. The fourth side was then placed across the open end and fitted into slots to hold it in place. Location of the sample was at random and was determined by the position of the shoe of the investigator when, without observing the ground, the last step was taken. Two men cooperated in securing data. This not only facilitated the study but was an effectual check upon the observations. After placing the quadrat frame, the square foot was divided into four equal areas by laying long steel quadrat pins across the frame in two directions. The pins rested in shallow grooves made by filing the top of the frame . . . . The basal area occupied by the vegetation 1.5 inches above the soil surface was estimated in each part of the quadrat and the average of the four numbers was recorded. Percentage composition of the vegetation was next ascertained. In doing this, the total vegetation, regardless of its amount, was considered as unity or 100 percent. Usually two or three grasses formed the bulk of the vegetation, the total of their separate percentages of composition amounting to 80—90. The percent of each species was based upon the part of the total basal area (now

considered as 100 percent) that each furnished. Basal area of forbs was usually very small and it was not recorded unless it totaled 5 percent. Likewise the basal area of every grass or sedge was recorded only if it furnished at least 5 percent of the total basal area. Thus, the species in small amounts were ignored and the 100 percent basal area of the vegetation was divided among the remaining abundant species" (Voigt and Weaver 1951).

Each individual sample was classified on a percentage basis as grass decreasers, increasers, and invaders, and forbs. These figures of percentage were transformed to angles so that the data could be treated statistically. Such treatment of the data presented in this study has shown that the sampling was adequate for each range condition class.

RESULTS

The percentage composition in each of the three range condition classes is shown in Table 1. Even casual examination shows that the composition is distinctly different in each range condition class. The decreasers compose 81 percent in excellent class. But their amount has been reduced to 47 percent in the good class and to only 7 in the fair one. The bluestems furnish the bulk of this type of vegetation in each class, 72 percent in the first, 45 in the second, but only 7 in the third. It may also be seen that the two species of bluestems were not equally abundant, although big bluestem had gained greatly in amount following the great losses of little bluestem during the drought. Both tall dropseed and prairie dropseed occurred in the excellent class in moderate amounts, but very much less regularly than the bluestems. While big bluestem was found in 92 percent of the samples and little bluestem in 68, prairie dropseed was recorded (at least 5 percent) in only 8 percent and tall dropseed in 11. Indian grass was common but rarely occurred in large amounts.

The rapid gains of increasers from 18 percent to 50 and then to 66 closely paralleled losses by decreasers, except in fair grade where a large percentage (21) of invaders occurred. Bluegrass was the most abundant increaser. Although highly palatable, it withstands grazing well, it is persistent and aggressive. Moderate to close grazing of the prairie grasses and weather conditions favorable to the growth of bluegrass result in its occupation of more and more of a pastured prairie. Bluegrass has been more abundant both in mowed prairies and excellent pastures than

Table 1.—Percentage composition of the vegetation in each range condition class. The figures are the averages of 150 samples taken during the summer.

Species	Excellent	Good	Fair
DECREASERS			
Big bluestem	32.7	17.3	5.9
Little bluestem	39.0	28.1	1.0
Tall dropseed	5.4	.5	....
Prairie dropseed	2.4	.6	....
Indian grass	1.4	.4	....
Needlegrass [3]	.2	.....	....
Total	(81.1)	(46.9)	(6.9)
INCREASERS			
Kentucky bluegrass	11.4	28.4	36.3
Purple lovegrass	2.4	14.8	3.0
Side-oats grama	1.8	4.9	8.1
Blue grama	.....	.....	13.8
Sedges	1.8	1.3	3.6
Scribner's & Wilcox' panic grass	.4	.3	.3
Buffalo grass	.....	.....	.6
Hairy grama	.....	.....	.1
Total	(17.8)	(49.7)	(65.8)
INVADERS			
Sand dropseed	.1	.7	12.1
Beadgrass	.1	.4	3.4
Hairy chess	.....	.2	2.2
Little barley	.....	.....	2.9
Prairie three-awn	.....	.....	.2
Western wheat grass	.....	.....	.1
Tumblegrass	.....	.....	.1
Total	(.2)	(1.3)	(21.0)
FORBS	(.9)	(2.1)	(6.3)
Grand Total	100	100	100

[3] Scientific names of grasses not previously mentioned are needlegrass (*Stipa spartea*), Scribner's panic grass (*Panicum scribnerianum*), Wilcox' panic grass (*P. wilcoxianum*), buffalo grass (*Buchloe dactyloides*), hairy grama (*Bouteloua hirsuta*), western wheat grass (*Agropyron smithii*), and tumblegrass (*Schedonnardus paniculatus*).

before the drought, since it spread rapidly during the years with abundant rainfall. In the fair class (Table 1) it has more than tripled its abundance in the excellent class. Side-oats grama also showed a consistent increase, from 2 to 8 percent. Purple lovegrass increased about sixfold in the good range condition but was much less abundant in the fair class.

Invading grasses were only rarely sufficiently abundant to compose 5 percent of the vegetation in even one sampling area. But sand dropseed composed 12 percent in the fair class and six other species were present in smaller amounts. The total for invading grasses was 21 percent. Forbs, too, mostly western ragweed and other invaders, were by far the most abundant (6.3 percent) in this class.

COMPARISON WITH PREVIOUS STUDIES

Change in the composition of vegetation on a range is ordinarily a gradual process. Vegetation in one range condition class degenerates under poor management into the next lower one. Under protection or proper usage, vegetation denoting a higher range condition may develop. Since both degeneration and regeneration occur gradually, the resulting good pastures are not all equally good nor are the excellent ranges all of the same degree of excellence. As pointed out by Voigt and Weaver (1951), there is a considerable degree of variation in every range condition class. With continued observation and study one can

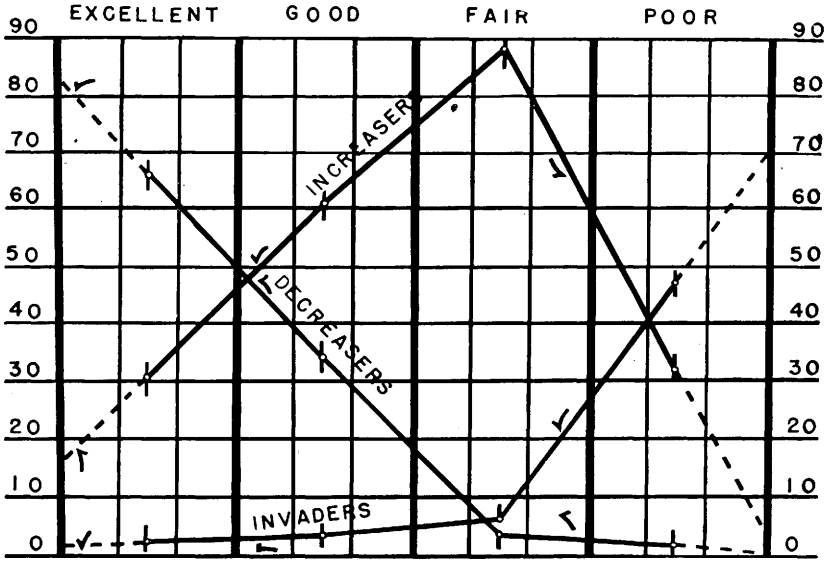

Fig. 15. Graphs showing the probable trends of grass decreasers, increasers, and invaders between actual points determined by averaging the percentages from each of three pastures in each range condition class. Projections of these lines (which are broken) show the probable relation to climax prairie on the extreme left and the low type of poor pasture on the right. The fair range condition in this study, according to the percentage of each class of grasses (check marks), is in the low type. But high type of both good and excellent range condition classes prevail.

soon recognize high, intermediate, and low types of good pastures or of fair ones. After analyzing the vegetation in 12 large pastures, including 3 of each range condition class, Voigt and Weaver (1951) summarized their results in Figure 15. The vertical columns under each range condition class indicate (from left to right) a high, intermediate, and low type of that particular class.

Since their studies were also made in the area near Lincoln, Nebraska, and only 2 to 20 miles distant from the present one, it is of interest to ascertain just what types of range condition classes occurred in this experimental pasture.

The excellent range condition class, with 81 percent increasers, 18 percent decreasers, and only .2 percent invaders, clearly belongs to the high type of excellent range condition. As already stated, it had almost the same composition as the annually mowed, surrounding prairie (Voigt and Weaver 1951). The good range condition class, with 47 percent decreasers, 50 percent increasers, and 2 percent invaders, belongs to the high type of good range condition. In both classes the forbs (not shown in Figure 15) composed only 1 to 2 percent. The fair range class with 66 percent increasers but only 7 percent decreasers, and 21 percent invading grasses is clearly a low type of the fair range condition class. Here the forb increment has increased to 6 percent. This is the result of the annual impact of excessive grazing and trampling during a long period of years. This portion of the pasture may soon degenerate into the poor range class.

MAPPING THE RANGE CONDITION CLASSES

The boundaries between range condition classes were based upon the composition of the vegetation. Once they were determined by close observation they were drawn as accurately as possible upon the topographic map. This was done early in May (Fig. 6). Areas with an abundance of bluegrass were easily sep-

Fig. 16. Nearest good range condition class (foreground) north of the west pond (Fig. 6). Transition to fair range condition on the hill (background) is very sharp as is indicated both by a decrease in bunches of grass and amount of mulch on the soil. Photo May 11, 1950.

Fig. 17. Abrupt transition from fair range class on left to excellent range condition on right. Composition of vegetation was studied on both sides of this very narrow ecotone. Photo August 15 at F 4 in Figure 6.

arated from those with smaller amounts. Thus, the areas of fair pasture were not confused with those in the excellent class, where a thick mulch delayed development of the sparse stand of bluegrass. In the good class, patches and larger areas with bluegrass sod alternated with a thick cover of the bluestems or dropseeds where there was little or none. The presence of old clumps of little bluestem and tall dropseed, widely scattered and in various advanced stages of degeneration, was an excellent indicator, especially along the outer margins of the fair condition class. A dense stand of these indicated vegetation of a better range condition (Figs. 16 and 17). Where excellent class contacted fair, the boundaries were easily observed. Those between the excellent and the good class were less obvious. But here the more open stand, less extensive roughs, abundant spots and patches of bluegrass, as well as areas with widely spaced clumps and bunches surrounded by bluegrass, identified the good grade from the excellent one. Not a single place was found where boundaries between the range condition classes could not be drawn, after the vegetation was carefully examined.

SAMPLING NEAR ECOTONES IN OTHER AREAS

As a means of confirming the proper separation of different areas of vegetation into various range condition classes, extensive sampling along their boundaries was done throughout the growing season. The transition from one class to the other was nearly always abrupt and all sampling was done on both sides of the narrow ecotones. Samples were taken 3 paces (about 9 feet) on both sides of the apparent boundary. They were spaced 8 paces apart. Since a total of 40 samples was taken on the two sides of any particular ecotone thus examined, the linear distance included in a single lot of samples was 160 paces (Figs. 18 and 19).

Fig. 18. Transition from fair range condition (foreground), where bluegrass and other increasers and invaders compose nearly all of the vegetation, to good range condition in background where decreasers and increasers are about equally abundant. The bunches are mostly little bluestem and tall dropseed (*Sporobolus asper*).

Examination of the map of range condition classes shows that the greatest linear extent of boundaries was between the good and fair classes (Fig. 6). Hence 7 different lots of samples were taken here. Where excellent range contacted the fair class, studies were made near 3 ecotones. Contact of excellent with the good class was studied in 4 different places. The examinations, 14 in all including 560 separate samples along about one and one-fourth miles, were made in all portions of the pasture. Three typical analyses are presented in Table 2, where for brevity, species of least importance are omitted.

Fig. 19. View showing sharp transition between good range in foreground and fair range class in background. The latter is characterized by patches (light) of ripened hairy chess (*Bromus commutatus*) and an abundance of inedible weeds among which hoary vervain (*Verbena stricta*) and ironweed are prominent.

Table 2.—Percentage composition of vegetation near boundaries between excellent and good, excellent and fair, and good and fair range condition classes, respectively.

Species	Excellent	Good	Excellent	Fair	Good	Fair
DECREASERS						
Big bluestem	19.3	16.0	25.8	2.8	16.3	3.3
Little bluestem	55.2	28.8	44.5	4.2	26.2	3.7
Tall dropseed	2.3	.5	6.0	.2	.....	.....
Prairie dropseed	3.0	.....	2.3	.....	.....	.....
Total	79.8	45.3	78.6	7.2	42.5	7.0
INCREASERS						
Kentucky bluegrass	10.0	41.5	10.7	59.0	24.0	68.5
Purple lovegrass	4.0	3.5	1.2	6.8	25.2	11.0
Side-oats grama	.8	5.0	4.2	5.5	3.5	4.3
Total	14.8	50.0	16.1	71.3	52.7	83.8
INVADERS						
Sand dropseed	.....	.....	.....	6.3	.5	3.5
Beadgrass	.....	.....	1.5	6.5	.....	.8
Prairie three-awn	.....	.....	.....	1.0	.....	.2
Total	.....	.....	1.5	13.8	.5	4.5

Difference in the total percentage of the decreasers in any class compared with a lower one is very marked: 80 to 45 percent from excellent to good range, 79 to 7 percent from excellent to fair class, and 43 to 7 from good to fair pasture. Conversely, the increasers became more abundant. In the same sequence their percentages are 15 and 50, 16 and 71, and 53 and 84. Moreover, each individual decreaser became less from higher to lower class, just as each increaser (with one exception) became more abundant. By comparing one excellent area of vegetation with the other (Table 2) or one good or fair area with the other, it becomes clear that the percentage composition is very much the same in similar classes, although actually the areas were widely separated.

The average composition of the vegetation in the edges of the different range condition areas, as far as the major decreasing and increasing grasses are concerned, is shown in Table 3.

Table 3.—Average percentage composition of vegetation in the experimental areas in each class, and composition near the boundaries of other areas of excellent, good, and fair range classes. Numbers of samples are shown in parentheses.

Range condition class	Species	Ave. percent in experimental areas	Average percent near ecotones	Average percent near one ecotone
Excellent		(150)	(120)	(20)
	Big bluestem	32.7	30.3	38.0
	Little bluestem	39.0	42.2	41.0
	Kentucky bluegrass	11.4	7.9	6.5
	Side-oats grama	1.8	1.6	.....
Good		(150)	(160)	(20)
	Big bluestem	17.3	19.4	16.3
	Little bluestem	28.1	27.1	26.2
	Kentucky bluegrass	28.4	27.3	24.0
	Side-oats grama	4.9	4.2	3.5
Fair		(150)	(280)	(20)
	Big bluestem	5.9	5.1	8.3
	Little bluestem	1.0	3.6	1.0
	Kentucky bluegrass	36.3	57.6	33.2
	Side-oats grama	8.1	5.9	8.2

A comparison of the average percentages of grasses in the several range condition classes selected for yield and consumption and in the other areas that were sampled later shows remarkable similarity (columns of percentages 1 and 2, Table 3). The variation in any species within each range condition class (with one exception) did not exceed about 3 percent and was

usually less. The exception is that of bluegrass in the fair class, where the large percentage of this species resulted from the inclusion of two almost pure bluegrass sampling areas (40 samples) in ravines. Even a single set of samples (as in column 3) usually showed very good correlation in percentage composition with the experimental areas.

A summary of the percentages of the different classes of grasses and of forbs in the experimental areas is given in Table 4. Also included are similar percentages derived by sampling in

Table 4.—Average percentage composition of decreasers, increasers, etc., in each range class in the experimental areas and near ecotones in other areas. Also percentages from single sets of samples.

Range condition class	Species	Average percent in experimental areas	Average percent near ecotones	Samples closest to average near one ecotone	Samples fartherest from average near one ecotone
		(150)	(120)	(20)	(20)
	Decreasers	81.1	83.7	81.0	90.7
	Increasers	17.8	14.4	17.5	8.3
Excellent					
	Invaders	.2	.2	.....	.....
	Forbs	.9	1.7	1.5	1.0
	Total	100	100	100	100
		(150)	(160)	(20)	(20)
	Decreasers	46.9	48.7	45.3	52.7
	Increasers	49.7	46.0	50.9	37.9
Good					
	Invaders	1.3	2.5	.....	6.2
	Forbs	2.1	2.8	3.8	3.2
	Total	100	100	100	100
		(150)	(280)	(20)	(20)
	Decreasers	6.9	8.7	7.2	.5
	Increasers	65.8	69.7	71.5	94.1
Fair					
	Invaders	21.0	16.1	14.0	.5
	Forbs	6.3	5.5	7.3	4.9
	Total	100	100	100	100

the same range condition near ecotones. A comparison of the second column of percentages with the first shows such remarkably close correlations in all classes of grasses (and in forbs) in the several range conditions that it leaves no doubt about the similarity of the vegetation. The third column adds data confirming the uniformity of the stands. Even the fourth column shows the major differences in the range condition classes. Here the samples in fair pasture are not typical since they are from

a nearly pure stand of bluegrass on lowland. After studying these data, one may re-examine the distribution of the range condition classes in Figure 6 with greater assurance of their validity.

YIELD AND CONSUMPTION OF FORAGE

The amount of each kind of forage produced and consumed each month was ascertained during both 1949 and 1950. Since most of the other studies were made in 1950, results for that year will be presented first.

METHOD

The method of exclosures and clipping was employed. The movable exclosures devised by Darland & Weaver (1945) and Weaver & Darland (1948) and employed by them in a four-year study of western wheat grass, bluegrass, and bluestems in a lowland pasture were again used. Weaver & Bruner (1948) likewise found the method very satisfactory in a study of a buffalo grass pasture in the loess hills and also in several vegetational types in mixed prairie in central Nebraska.

The areas selected for this study are shown in each range condition class in Figure 1. Ten separate sampling plots of about 10 square rods each were selected in each of the three grazing types. In each area one 29-square-foot exclosure, with its grazed control of similar size was located in early spring. In selecting the original location for an exclosure, two places were chosen within a distance of 10 to 20 feet in which the vegetation was as nearly alike as possible. In one the vegetation was to be clipped after a month of protection; the other, which was subjected to grazing, was also to be clipped at the same time. A coin was tossed to determine which of the two areas was to be protected. The exclosure was then set in place and stakes were driven into the soil in each corner to keep it from being pushed aside. Since its sides sloped inward from the base, it was rarely disturbed by the livestock (Fig. 3). The control area was also clearly marked. At the end of each month at the time of the clipping, new places for the exclosure and control were selected in the same general area. These were as nearly as possible like the former control area and were selected before clipping, since both of the former plots were now to be clipped by hand close to the ground, closer than the cattle could graze. No area once clipped was ever used again.

Before clipping, a folding iron frame, which included exactly 2 square meters, was placed where the exclosure had stood in

such a manner that it left a border of grass about three inches wide, entirely around it. This was the strip of vegetation just inside the exclosure. Clipping here and in the control was confined to the vegetation inside the frame. By subtracting the dry weight of vegetation of the control from that obtained from the exclosure, the monthly consumption from the two square meters was ascertained.

It was assumed that the yield in any range condition during the first month was represented by the average weight of the air-dry forage under the ten exclosures, since all debris from the previous year was carefully separated from the new vegetation and discarded. During the second month total yield was the amount of forage that grew on the area newly exclosed less the amount of new vegetation remaining ungrazed in the control area of the preceding month. Clipping was uniform at all times, since one of the writers was in direct charge each month (Klingman, *et al.* 1943; Fuelleman & Burlison 1939; Joint Committee 1943).

Each area was clipped selectively; that is, grass decreasers, increasers, and invaders were placed in separate bags for ascertaining dry weight and all forbs were placed in a fourth container. Average monthly yield and consumption of each kind of forage in each range condition is shown by means of bar graphs and total yield and consumption by line graphs.

RESULTS IN 1950

This year was characterized by a spring fully three weeks later than that of a normal year. On May 1 bluegrass, which usually begins growth in March, was only 1 to 2 inches tall and the invading hairy chess about 2 to 3 inches. The cattle, however, were placed in the pasture on May 8. The warm-season grasses put forth new shoots 7 to 10 days later. The soil was sufficiently moist for rapid development of forage; there was ample rainfall in May, but the mean temperature remained low (Fig. 20). There was a mild drought late in June, which had a rainfall deficiency of 2.5 inches. July was moist and the coolest for many years. Mean temperatures this month and in August rarely exceeded 75° F. There was much cloudiness, little wind, and high humidity throughout much of the summer. A part of August and most of September were moist, but there was much clear weather.

Yield and consumption in the fair range condition class will be considered first, since grazing began here earliest and, as

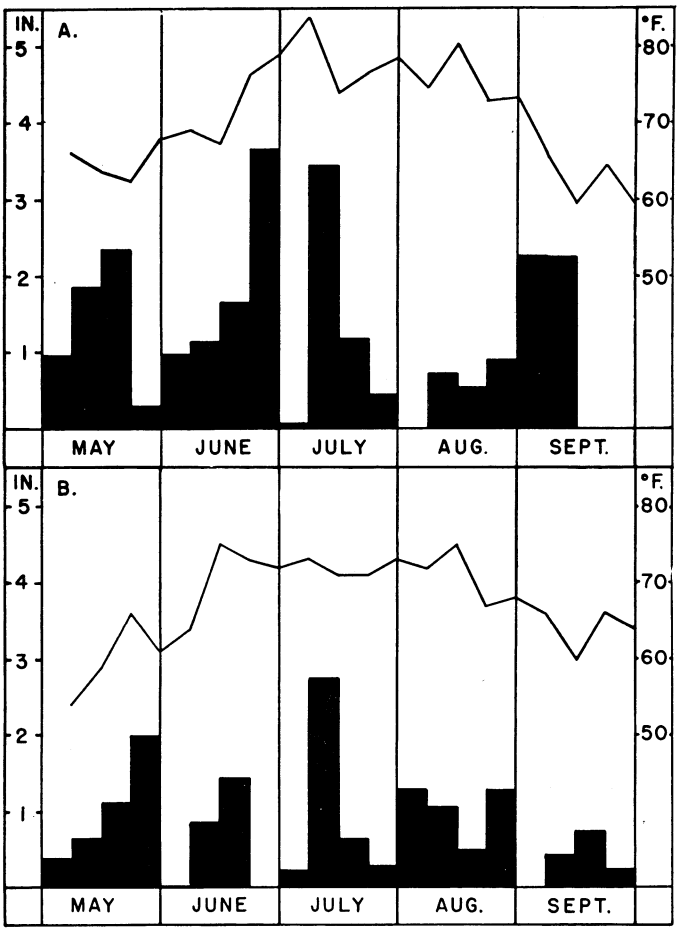

Fig. 20. Total rainfall in inches approximately by weeks and average weekly temperatures in degrees Fahrenheit, during the growing season (A) of 1949 and (B) of 1950. The much earlier spring and greater rainfall in 1949 are apparent.

will be shown, the cattle preferred grazing in this range class. The part of the good range condition class free from old standing forage was also much used. But amount of grazing in the remaining part of the good range and in excellent range was conditioned largely by the abundance or scarcity of forage available in the preceding favored grazing places.

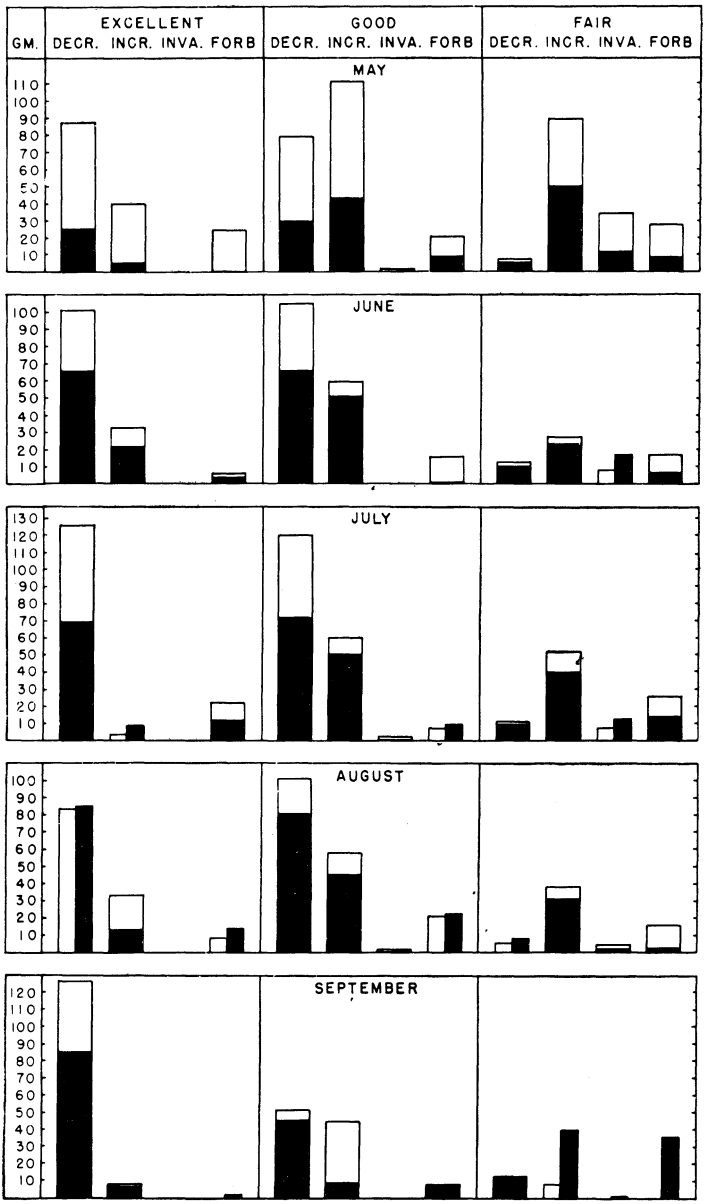

Fig. 21. Monthly yield and consumption of each class of grasses and of forbs in grams per unit area (2 sq. m.) in each range condition class in 1950. The height of each column indicates the total monthly yield. The height of the darkened portion is a measure of consumption. In the few instances where current consumption exceeded current yield, white and black narrow columns are shown separately.

AMOUNT AND COMPOSITION OF FORAGE IN EACH RANGE CONDITION CLASS

In the fair pasture, the bulk of the forage was furnished each month by the increasing grasses, chiefly bluegrass and blue grama (Fig. 21). The amount was highest in May. It decreased because of the drought in June, but a gain in yield occurred during the relatively cool, moist month of July. Yield then again became lower. Only a very little forage was furnished by decreasing grasses, which yielded best in mid and late summer. Invaders furnished only a moderate part of the yield. In June, hairy chess and little barley produced far less than their usual amount of forage because of the very late, dry spring. A part of this yield was eaten with blue grama and also some with bluegrass after these annuals had matured. This accounts for consumption of invaders exceeding their yield in June and July. Thereafter they furnished very little forage. Numerous weedy forbs developed rapidly in spring and added greatly to the total yield of forbs in May. Their annual yield was greater than that of invading grasses, and considerable amounts were regularly consumed even late in fall.

Forage consumed each month in fair pasture included practically all of the decreasers but increasers regularly furnished nearly half or more than half of the total (Fig. 21). Only during May did yield greatly exceed consumption. This indicates that in summer the forage was mostly kept closely grazed. But when blue grama or other grasses became dry, in places it was overgrown by ragweed and other plants of low palatability. Thus, some good forage remained for a time ungrazed. Consumption in September far exceeded the current yield. The monthly and seasonal yield and the amount of forage consumed are shown in Figure 22.

In the good range condition class, yield of decreasers somewhat exceeded that of the increasers every month except May (Figs. 21 and 23). The exception resulted from the later resumption of growth of the warm-season bluestems and the much earlier development of bluegrass in spring. Bluegrass and other increasers intermixed with a protecting cover of decreasers were not so greatly overgrazed as the unprotected, continuous stands in the fair pasture. Hence it was more vigorous and probably better rooted (Weaver 1950). At any rate the effect of the drought, which ended July 10, reduced its yield most in fair pasture in June. Total seasonal yield of increasers was 22 percent less than that of decreasers. Invading grasses added only a small fraction

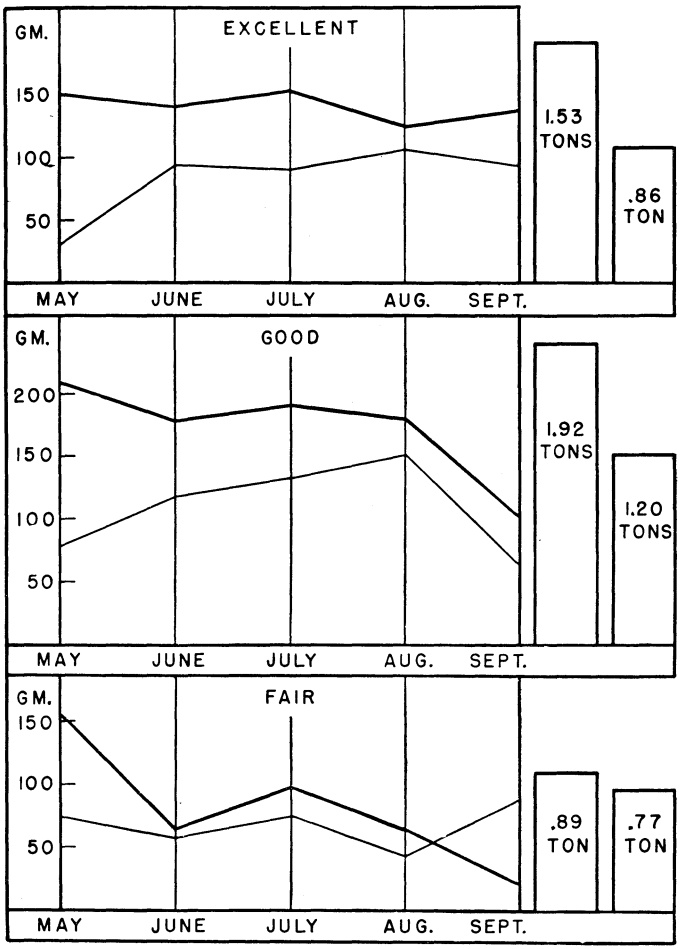

Fig. 22. Average monthly yield (heavy lines) and average monthly consumption (light lines) in grams per unit area (2 sq. m.) in excellent, good, and fair range condition classes in 1950. Seasonal yield and consumption are shown in tons per acre.

to the yield. Forbs furnished only about 10 percent of the total. Of these western ragweed was most abundant. Many forbs were grazed not from choice but incidentally with the grasses, especially when the forbs were young.

In May much less than half of the total new forage in good pasture was consumed. Thereafter a considerably larger per-

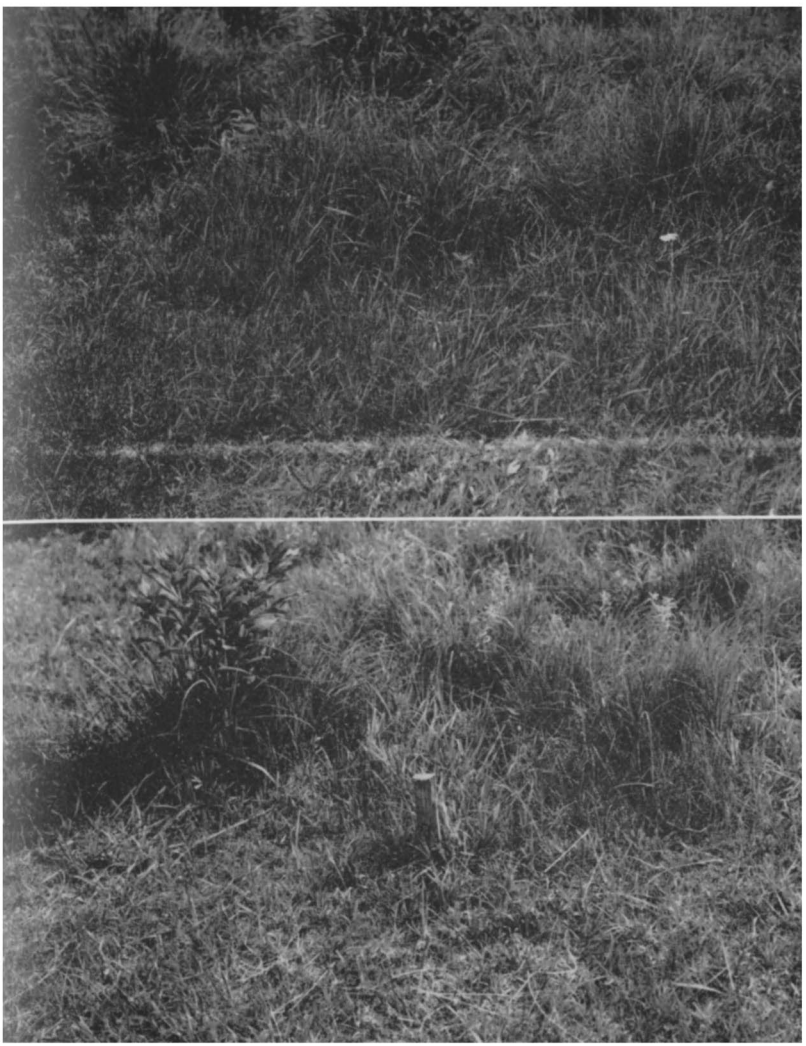

Fig. 23. (Upper) Enclosed area in good range class with exclosure temporarily removed. (Lower) Control area, a few paces distant, which was open to grazing. Photo July 2, 1950, just before clipping. Parts of the bunches in both sample areas contain some last year's stems which must be separated from the forage currently produced before weighing. Only about half of the forage in the control had been grazed closely in June.

centage of the total forage was eaten—an average of 70 percent of that from decreasers and 71 percent of that produced by increasers. The relation of consumption to yield is shown by months and season in Figure 22.

In the excellent range condition class, big bluestem and other decreasers furnished each month from 58 to 94 percent of the yield (Figs. 21 and 24). Here a thick mulch of debris retarded the warming of the soil in spring. Yield was less in May than in June and the greatest yields were produced in July and September. Yield of increasers (mostly bluegrass) was greatest

Fig. 24. Nearly pure stand of big bluestem under an exclosure (temporarily removed) in the excellent range. The unprotected control had been grazed high. Photo August 15, 1950.

in May, but this class of grasses usually produced about 2 to 27 percent of the forage throughout the summer. Invading grasses were practically absent. The prairie forbs, but also including some western ragweed, produced 0 to 16 percent of the total forage each month.

Consumption during May was very small, only about 20 percent of the yield. Yield of both increasers and decreasers usually greatly exceeded the amount of forage currently consumed. An

exception occurred in July when a little more forage of increasers was consumed than was produced that month. There were practically no invaders. Consumption of the irregularly distributed prairie forbs followed no general trend.

The weight of each class of grasses and of forbs and its percentage of the seasonal yield are shown in Table 5, which also includes similar data on consumption. Decreasers furnished the largest portion of the total yield in both excellent and good pastures, 74 and 50 percent, respectively. Even in fair pasture where they composed only 7 percent of the vegetation (Table 1) they furnished 12 percent of the yield. Consumption of decreasers

Table 5.—Average yield in grams per unit area (2 sq. m.) and percentage of the total forage furnished by the several classes of grasses and by forbs. Also grams and percentage of forage consumed (to October 1) that were furnished by each class of grass or by forbs.

Class of forage	Excellent		Good		Fair	
	Gm.	Percent	Gm.	Percent	Gm.	Percent
			Yield			
Decreasers	517	74	383	50	49	12
Increasers	116	17	301	40	212	53
Invaders	0	0	4	0	53	13
Forbs	60	9	73	10	86	22
			Consumption			
Decreasers	305	79	256	51	46	13
Increasers	51	13	192	38	185	54
Invaders	0	0	3	1	44	13
Forbs	31	8	49	10	68	20

was, in the same sequence, 79, 51, and 13 percent of the total yield. Increment of yield of increasers from excellent to fair pasture was 17, 40, and 53 percent of the total, but the actual yield was greatest (301 grams) in the good range class. Percentage of forage consumed in the several range classes was 13, 38, and 54, in the preceding order. In fair range only did invaders contribute more than 1 percent to the yield. Yield of forbs both by amount and percentage consumption increased directly in proportion to the degree of degeneration of the range. Their consumption increased in the same order.

MONTHLY AND ANNUAL YIELDS AND CONSUMPTION

The total amount of forage produced each month and the annual yield will now be compared with the monthly and annual consumption (Fig. 22). Yield in all three range classes showed at least a slight decrease in June. This may be attributed to the dry weather. It was most pronounced in the fair pasture where there

was not only an abundance of bluegrass, which is sensitive to drought, but also to the drying of several annual species, especially hairy chess. There was increased production in July followed by a decline in yield in all range classes in August. A marked decrease, except in excellent range, occurred in September, since in this month bluestems and most prairie species normally produce much less forage. While grazing back of tops of little bluestem was common in good pasture, in excellent range it produced flower stalks abundantly. This probably accounts for the late upward trend in yield in this class.

Consumption was about equal in the fair and good class in May. But in June and July it was at least twice as great in the good class where decreasers furnished more forage. Consumption declined in August in the fair class but increased in the good one. In September the reverse condition obtained when heavy rains and cool weather promoted a good growth of the widely distributed bluegrass in the fair class range. In grazing this closely, considerable amounts of dry forage, especially of blue grama, were also consumed. Moreover, this decreased the amount of grazing in the good pasture during September where the prairie grasses were producing less forage. In both good and excellent ranges consumption was less in September. Consumption in the excellent range was less each month, except in September, than that in the good pasture. But there was little or no decline here either in yield or consumption in September compared with August, a phenomenon which was very marked in the good pasture where bluegrass was abundant.

Total yield was highest in good pasture, 1.92 tons per acre, and less in the excellent class (1.53 tons). This is attributed to the smaller amount of debris (which hinders early growth) in good pasture, and especially to the intermixing of bluegrass with the prairie species. Yield was least, .89 ton, in the fair pasture where the forage was mostly shorter and less vigorous.

Percentage of consumption was least in the less accessible and debris-filled excellent class. Here only 56 percent of the vegetation was consumed. In the good class 63 percent consumption occurred. But it was greatest of all in the fair class where 87 percent of the current year's forage was eaten by October 1. In tons, the amounts consumed, in the preceding sequence of classes, was .86, 1.20, and .77, respectively. Thus, the amount of unused forage in the three range classes was 44, 37, and 13 percent, respectively.

In obtaining this forage, grazing was closest to the soil in fair pasture and very high and mostly far above the debris in excellent range. In the good class, grazing in previously closely grazed places was closer than in others where some last-year's forage remained; hence two grazing heights were recorded. The measurements were made in each of the 30 control areas selected and clipped each month. Heights of the grass after a month of protection under the exclosures are included for comparison (Table 6). Height of grazing each month was consistently closest in the fair class range (finally 1 to 1.5 inches), intermediate in the good class (often 1 to 3 and 4 to 8 inches), but always highest in the excellent class (4.5 to 10 inches). Similarly, average height of the grass protected one month was always least in fair class and greatest in the excellent class.

Table 6.—Height of grazing in the grazed (control) areas at the end of each month, and height attained by the vegetation in the exclosure after one month of protection from grazing. Measurements are in inches.

Month	Fair Class		Good Class			Excellent Class	
	Control	Exclosure	Control	Control	Exclosure	Control	Exclosure
May	1–3	4 –7	1–6	5– 7	6 – 8	4 –10	9–16
June	1–3	3 –6	1–4	5– 8	4.5–18	3.5– 9	11–18
July	1–2.5	3.5–6	1–3	4– 8	4.5–16	4.5–10	11–17
August	1–2.5	3 –8	1–3	5–12	4.5–21	5.5–12	9–22
Sept.	1–1.5	2 –5	1–2	4– 9	2.5–16	4 – 8	7–19

The most important fact revealed by this study is the relation of consumption to sustained yield. The fair range was constantly and greatly overgrazed to secure .77 ton of forage per acre. The good pasture furnished 1.20 tons without overuse and also left a third of the yield as a protective mulch on the soil. While the fair range was greatly overgrazed when .77 ton of forage per acre was consumed, .43 ton more was furnished by good pasture and more was available without danger of overuse of this better class of forage. More forage was obtained from the lightly grazed excellent range where the cattle selected only the very best (.86 ton per acre) than from the fair range where an abundance of less palatable weedy grasses and forbs was eaten.

Soon after the final harvest early in October, all portions of the pasture in each range condition class were carefully examined. This was done to ascertain how general grazing had been, approximately what percentage of the forage had been removed, and especially whether or not each range condition class was still well represented by the experimental area in it.

In the fair class considerable amounts of dried blue grama had been consumed. Forbs had been eaten or trampled to the ground since grazing had been so close and general that roughs were small and widely scattered. Here, as elsewhere over the pasture, the livestock had removed amounts similar to those in the sampling areas. About 15 percent of the forage usually remained on the soil.

A renewed green cover of bluegrass flourished in ravines, and also again clearly demarked the grazing routes. In excellent pasture and in large portions of good range, this grass had been grazed 1—1.5 inches in height and much of the area though intermixed with bluestems was free from bunches and unconsumed forage. Clearly the good range had been moderately well utilized. Although about a third of the forage still remained, not a single flower stalk of big bluestem was seen. In fact it had been sought and grazed, often closely, everywhere, even in the excellent range. Although more forage remained uneaten here than in the good condition class, grazing had opened the roughs and the cattle had trampled down most of the vegetation in them so that they were far less conspicuous than in the autumn of the previous year. Here again utilization of a little more than half of the forage was almost everywhere like that in the two areas where yield and consumption were measured. It should be emphasized that the purpose of the movable exclosures was not to sample the entire pasture but only the 7 to 10 acres selected as representative of each class. The percentage composition of the vegetation in these, however, was the same as that in all other similar areas sampled in each class. Therefore, it seems reasonable to conclude that yield and consumption for each sampling area must have been quite similar to that in other parts of the same range condition class. Thus, the results obtained apply generally to the entire range.

RESULTS IN 1949

Growth of vegetation began early in April and the cattle were driven to the pasture about April 18. The soil was wet several feet in depth and a good moisture content was maintained throughout the entire summer. While the weather was not unusually warm, average daily temperatures by weeks were mostly above 75° F. from late June until the last week in August. Similar averages were at times 80° and 84° (Fig. 20). The favorable environment resulted in the production of an abundance of forage.

AMOUNT AND COMPOSITION OF FORAGE IN EACH RANGE CONDITION CLASS

Total yields and yields of each class of vegetation in 1949 were somewhat similar to those in 1950. This may be shown briefly by comparing results obtained during the two years. But first it must be made clear that no September harvest was taken in 1949, and that growth was renewed much earlier and grazing began three weeks earlier than in 1950. A comparison of Tables 7 and 5 shows that decreasers again furnished the largest increment of the total yield in both excellent and good pastures. Percentages were 80, 50, and 15 in excellent to fair range condition compared with 74, 50, and 12 in 1950. Percentage consumption of decreasers was very similar to that of 1950 but a little higher in all classes of pasture. In this wet year when forage was more plentiful, consumption of all classes of grasses was less in excellent range than in 1950. Hence, the actual amount of decreasers consumed was greater in good than excellent range in 1949.

Table 7.—Average yield in grams per unit area (2 sq. m.) and percentage of the total forage furnished by the several classes of grasses and by forbs. Also the grams and percentage of forage consumed that were furnished by each class of grasses or by forbs.

Class of vegetation	Excellent		Good		Fair	
	Gm.	Per-cent	Gm.	Per-cent	Gm.	Per-cent
			Yield			
Decreasers	580	80	358	50	83	15
Increasers	102	14	318	45	271	50
Invaders	4	1	1	0	87	16
Forbs	41	5	37	5	100	19
			Consumption			
Decreasers	210	84	261	56	70	17
Increasers	29	12	203	43	252	62
Invaders	2	0	0	0	54	13
Forbs	10	4	6	1	27	8

Yield of increasers was again higher in good than in excellent range but decreased in fair pasture. Percentages were 14, 45 and 50 compared with 17, 40 and 53 in 1950. The actual yield of increasers was 17 percent greater in good than fair pasture; it was also greater in 1950. Percentage of forage from increasers consumed in the several range classes was 12, 43 and 62 from excellent to fair pastures; in 1950 it was 13, 38 and 54.

Yield from invading grasses was again almost negligible except in fair range where it was 16 percent as against 13 in 1950. Consumption of invaders both years amounted to 13 percent of

the total. Yield of forbs was again greatest in fair pasture, 19 percent of the total. In 1950 it was 22 percent.

MONTHLY AND ANNUAL YIELDS AND CONSUMPTION

Total seasonal yield and consumption in each range class during the two years may be directly compared in Figure 25. These data are for four months only, except in 1949 consumption for May also includes 12 days in April. Yield for May in both years includes all new growth until May 31. Yields in all range classes were high during April and May, 1949. They all decreased during June but the decrease was greatest in fair pasture (Fig. 25). The monthly yield decreased with remarkable regularity in excel-

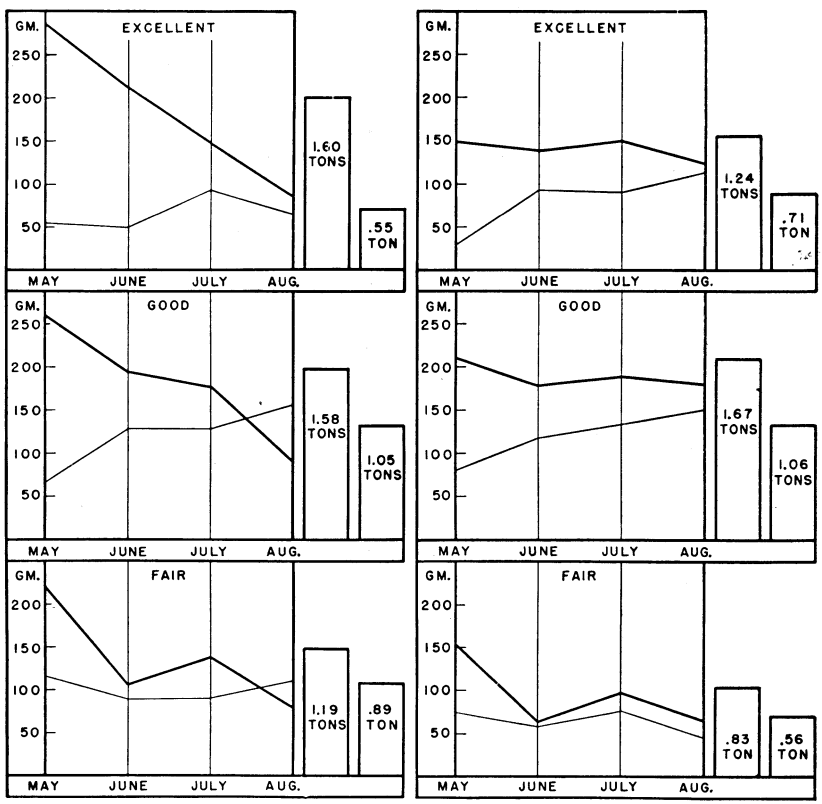

Fig. 25. Average monthly yield (heavy lines) and average monthly consumption (light lines) in grams per unit area (2 sq. m.) in each of the three range condition classes. Seasonal yield and consumption are shown in tons per acre. Left panel, 1949, and right panel, 1950.

lent pasture where prairie grasses composed almost all the forage and mostly remained ungrazed. The decrease was considerably less in good pasture where bluegrass was also abundant; in fair pasture there was an increase. Decrease in yield occurred in all pastures in August.

Consumption in excellent range was low until July, and decreased slightly again in August. In good pasture consumption increased, in general, with the progress of the season and in August it was a third greater than the yield. Cool-season annual grasses promoted early consumption in fair pasture. When they dried, total consumption decreased slightly but then maintained its level until August. After this it increased at a time when yield of new forage was less than the current amount consumed. Of the 1.19 tons yield in fair pasture 75 percent (.89 ton) was consumed. Yield was greater, 1.58 tons, in good pasture but relative consumption was much less, 1.05 tons or 66 percent. Only about a third of an almost similar yield (1.60 tons) was consumed in excellent range.

A comparison of yields in each range condition with those in 1950 shows many similarities but also a few differences. The greater initial yields in all pasture classes resulted from the earlier and more moist spring. Although the yields were lower in 1950 (except in good pasture) they were more uniform throughout. In 1950, .27 ton of the total forage was left in fair pasture, but .30 ton in 1949. On both years practically all of the available forage was consumed. In good pasture, .61 and .53 ton of uneaten forage remained, respectively. But in excellent range total unused forage was less on the drier year (.53 ton) than on the wetter one (1.05). Thus, the general pattern of grazing on this wet year was the same as in 1950. One-third of the yield from excellent range furnished .55 ton of forage per acre which left two-thirds unused. Good range furnished 1.05 tons of forage without overuse. This left a third of the total yield (but not that above the stubble height) on the soil. But in removing practically all the forage obtainable from fair range and leaving the soil much trampled and with a deficient mulch, only .89 ton had been obtained. Moreover, 8 percent of this was weedy forbs and 13 percent mostly inferior grasses (Table 7). It seems clear that such overuse of one portion of the range and underuse of another must be concerned with the activities and distribution of the cattle which will now be considered.

GRAZING PREFERENCE OF CATTLE

Grazing preference refers to the taste an animal displays for any plant. It is measured by the choice of an animal if given free access to various species of plants (Stoddart and Smith 1943). When a prairie is first grazed the process is highly selective. There are in the Lincoln area about 250 species of plants per square mile, which compose the vegetation (Steiger 1930). Practically all are edible. Most of these, however, occur in only small numbers, many are even rare. But among the common and abundant grasses, sedges, and forbs certain ones are greatly preferred by the cattle, others are less sought, and some are eaten only because they are intermixed with the best-liked species. Thus, selective grazing occurs in all range condition classes, at least where the amount of forage is plentiful.

Sampling for grazing preference was confined to the areas in each range condition class where yield and consumption were measured. The sampling was done at random along numerous predetermined lines. Samples were taken along these lines 5 to 10 paces apart. Twelve hundred samples were examined in May, and 1,500 during each of the three following months. The small area of the sample was that of a circle three inches in diameter. This was delimited at each sampling, by placing a steel cylinder a half-inch long over the vegetation directly in front of the shoe of the investigator at each space-interval. Each species of grass in the sample was listed by an assistant on a special field-record form. Whether or not the plant was grazed was recorded as well as the height of each grazed or ungrazed species. For the sake of clarity, the five most abundant species will be considered first, and especially the preference of the cattle for them in each range condition class. Then secondary species will be considered.

COMPARISON OF MOST ABUNDANT SPECIES

Big bluestem was found to be the most preferred grass in all classes of the range (Table 8). It grew so much more rapidly than bluegrass and blue grama, which furnished the matrix in fair pasture, that it was very conspicuous. Like little bluestem, the foliage was renewed so rapidly that it soon extended 2-4 inches above the general grazing level of other grasses. The preference for the two bluestems, where they were free from debris, was so marked that they were practically always grazed everywhere in fair pasture. The 10 percent that was ungrazed

resulted from the fact that the grasses were concealed in weeds or debris (*Cf.* Rogler 1944).

Tall dropseed was usually much less preferred than bluestems. But where grazed the previous year, as in fair pasture, the new foliage which was always conspicuous, was quite palatable; that is, it was eaten with considerable avidity.

Kentucky bluegrass, the most abundant grass in fair pasture and one of the very first to renew growth in early spring, was well liked and continuously grazed until it became dry in midsummer. During this year of favorable rainfall, bluegrass was grazed throughout the summer. In fair pasture it had a grazing preference rating almost as high as the bluestems (Table 8).

In good pasture grazing preference for big bluestem, unlike that of little bluestem, continued high. This was due first to its lack of protecting old flower stalks and secondly to its more

Table 8.—Percentage of times each species was grazed where it occurred in the 1,900 samples taken during the summer in each range condition class.

Species	Range Condition Class		
	Fair	Good	Excellent
Big bluestem	90	87	81
Little bluestem	90	53	33
Tall dropseed	83	37	34
Bluegrass	83	59	52
Prairie dropseed	....	57	39
Purple lovegrass	80	71	64
Side-oats grama	74	72	66
Blue grama	54	33	....
Sand dropseed	32	36	....

rapid height-growth above the old debris. Conversely, little bluestem was less preferred in the good range class because of an abundance of old flower stalks and dead leaves in the bunch of the preceding year. Preference for this grass was greater where it was intermixed with a uniformly grazed stand of bluegrass and other species in the cleared areas.

The preference for tall dropseed was less than half as great in the good class as in the fair one. It not only retained old flower stalks but the foliage of previous years was held high above the ground and tended to accumulate in the middle of the bunch. Most grazing of this species was not in the roughs and little disturbed bunches but primarily in old bunches that had been grazed out to a considerable degree. Only after the new foliage appeared above the debris of the old clumps were the tops of this species much grazed.

Prairie dropseed was well liked. It had disappeared from the fair pasture and was grazed in 57 percent of the samples in the good class. Although a bunch grass, the foliage spreads widely and if not removed lodges mostly beyond the bunch, although the leaves remain attached to the stems. Hence, the erect new shoots may be grazed early, a process which is but little hindered by the presence of the old debris.

Bluegrass was grazed in 59 percent of the samples in the good class compared with 83 in fair range. This probably resulted from two causes: first, the scarcity of the preceding, highly preferred grasses in fair pasture and secondly, the fact that much of the bluegrass in good pasture occurred in or between the bunches of various prairie species where it was protected by an abundance of debris.

Fig. 26. Selective grazing in excellent range. Big bluestem (center) is eaten back to a height of 10 inches while little bluestem on both sides of it remains ungrazed. Photo August 21, 1950.

In excellent range, grazing preference for big bluestem was high despite the greater abundance of debris, which included old bunches of other species. It was grazed in spring as soon as the new foliage extended a few inches above the debris. Ordinarily these new shoots were well exposed and were sought and grazed where they grew between the bunches of little bluestem or tall dropseed (Fig. 26).

Little bluestem was grazed less often in the excellent class. Only 33 percent of the samples where it occurred were grazed as compared with 53 in the good range. This seems to result very largely from its retention of the old flower stalks in an erect position with much of the unconsumed foliage on them. Hence there was little grazing of this species until the new foliage became very attractive. It did not reach the height of the old foliage until midsummer. Of course, bunches grazed the preceding year were again grazed much earlier.

Tall dropseed was grazed almost as often in the excellent class as in the good one. Percentage of samples grazed were 34 and 37, respectively. In this range class, the grazing was almost entirely that of the upper third of the bunch. Prairie dropseed was grazed in 39 percent of the samples in which it occurred.

The percentage of samples of bluegrass that were grazed remained relatively high. But it had decreased from 83 and 59 percent in fair and good pasture, respectively, to only 52 in excellent range class. Here it occurred more abundantly than elsewhere with the sod-forming big bluestem. Where it was intermixed with much debris, it was scarcely grazed.

LESS ABUNDANT SPECIES

Purple lovegrass was selected most frequently in the fair class (80 percent). This bunch grass was well liked until the large, abundant panicles were well developed, about August 15. After that time it was scarcely eaten until mid-September when the panicles broke off and were blown away. Where the bunches occurred they furnished much forage but they were seldom grazed closer than 2 to 3 inches. After the panicles were removed by the wind, little debris remained to prevent grazing in spring when this warm-season grass renewed growth. This species was less abundant in the fair class than in the good one. Even in the good class this increaser was usually well in the open and was not much protected by the old debris of other species. In excellent range it was less abundant and often indi-

cated local disturbance. Probably its decrease here in grazing preference was due to the very great abundance of big bluestem.

Side-oats grama is highly palatable. It was grazed in 74 and 72 percent of the samples in fair and good range, respectively. It retained the high rate of 66 percent in the excellent class. Here again the decrease was probably not due to the species but to the abundant debris through which it grew and the great abundance of very palatable decreasers.

Blue grama was grazed in far fewer samples than bluegrass, its chief associate in fair range. The percentages were 54 and 83, respectively. Blue grama was well liked when it was green but if it matured without being eaten or the foliage dried by midsummer it was neglected. Then the cattle showed a lower preference for it in fair pasture than for any of the preceding species. Hairy chess and little barley occurred regularly in areas dominated by blue grama. The forage was often so plentiful that these annuals remained ungrazed and their presence discouraged grazing of blue grama. There was not only much less blue grama in the good class but it was not sought to the degree that it was in fair pasture.

The invader, sand dropseed, was usually much more abundant in poor pastures than those of fair grade (Voigt and Weaver 1951). Usually local bared spots are a prerequisite to its invasion. In this fair pasture it occurred chiefly in the thinned stand of vegetation and one which was composed mostly of numerous invading forbs and unpalatable grasses like prairie three-awn. This probably accounts for its lower preference rating since the writers have evidence that preference for sand dropseed often exceeds that for blue grama. In the good range class, sand dropseed occurred only infrequently.

Forbs, as has been shown, played a minor role in furnishing forage for livestock. Many forbs were eaten because they were intermixed with the grasses. The greatest amount of grazing of forbs was found in very closely grazed areas and probably resulted from the lack of more palatable forage. Two legumes, lead plant (*Amorpha canescens*) and many-flowered psoralea (*Psoralea floribunda*), were eaten quite often (Fig. 27).

ACTIVITIES OF THE CATTLE

For a fuller understanding of the condition of the pasture and the causes of the distribution of the several range classes, it seems logical that one should study the activities of the cattle

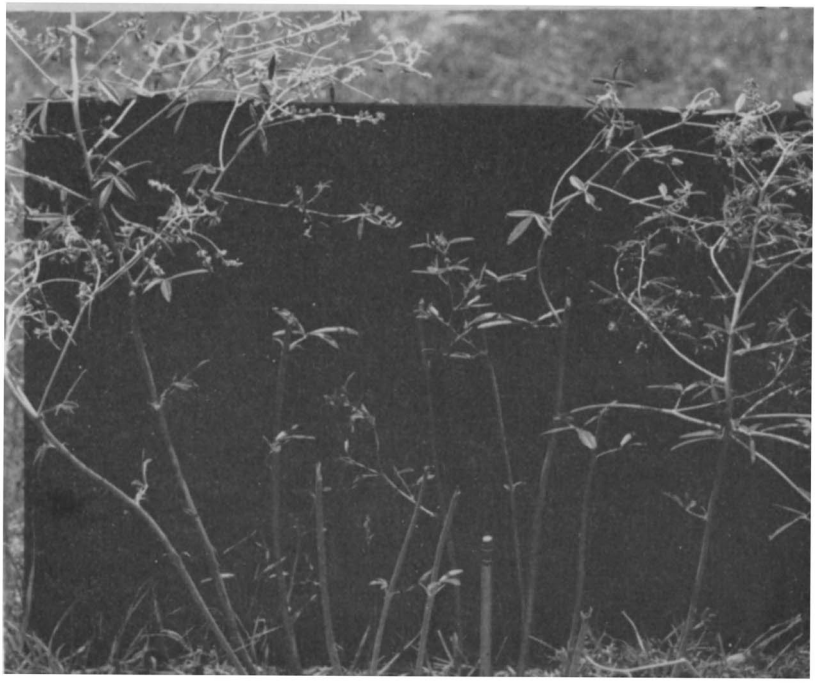

Fig. 27. A legume, *Psoralea floribunda*, bitten off at a height of 4 to 12 inches and eaten by livestock. Lead plant (*Amorpha canescens*) was far more plentiful and palatable. Both species had decreased in good range and occurred rarely in fair pasture.

as they graze and travel naturally on the range. Only in this way can one clearly observe what they do, and insofar as possible, ascertain just why they do it.

The activities of the cattle were studied by continuously watching them and making records of their behavior at intervals of 15 minutes by day and 30 minutes by night. The observer was careful not to approach close enough to the herd to disturb any individual animal or to affect its activities. This was not difficult on the rolling terrain, where one could observe the cattle clearly through a pair of binoculars. The studies were made during 8 separate days from 4 a.m. to 9 p.m. and 5 nights from dark to dawn. Unless the night was cloudless and the moonlight bright, a flashlight was employed. In addition, 16 half-days were spent in observation, and also practically every day during the grazing season isolated observations were recorded. The number of animals grazing, standing (which includes walking without

Fig. 28. A portion of the grazing herd resting near a diversion ditch not far from the lower pond. Much time was spent standing.

grazing), and lying were recorded on prepared blank records (Fig. 28).

In presenting the results of the studies on the activities of the cattle, it seems best to examine first those obtained during a typical summer day and night. This will be followed by their activities on a hot day and also on a cool one.

BEHAVIOR DURING A TYPICAL DAY

June 30, 1950, was selected as a typical day since all the weather conditions and other environmental factors were about average. Moreover, the data obtained during this 24-hour period are in very close agreement with similar day and night observations made at other times during the summer.

About two-thirds of the herd arose at daylight, 4:00 a.m. As was their habit, many animals arose, stretched and remained standing for some time before beginning to graze. Most of the cows found their calves and nursed them before grazing. But by 5:00 o'clock all of the cattle had arisen and 83 percent were grazing. All were grazing by 6:00 o'clock (Table 9). They moved leisurely as they grazed along a route leading toward the ponds (Fig. 29). As usual, the herd spread widely in early morning. Thus, the cattle arrived at the ponds in small groups; as commonly occurred, the younger ones reached the pond first. But

they were soon followed by the cows which traveled slower because of their calves.

The time for drinking extended over a period of two hours, from about 7:00 to 9:00 a.m. During this period many individuals made the relatively short trip to the adjacent hilltop where salt was available. After licking the blocks of salt for a time they returned to the ponds where they either drank again or merely stood about or lay down to rest. While some grazing occurred adjacent to the ponds, at 8:30 a.m. only 30 percent of the herd was grazing, 57 standing, and 13 percent lying down.

About 9:00 a.m. the cattle moved northward, grazing away from the water along a much-used route. As will be shown, they nearly always grazed in the general direction from which the wind was blowing. Although the somewhat devious route followed might not lead them directly into the wind, they eventually arrived at the windward side of the range. When the herd reached the top of a high hill, they discontinued grazing and stood for a time, apparently enjoying the breeze. This habit

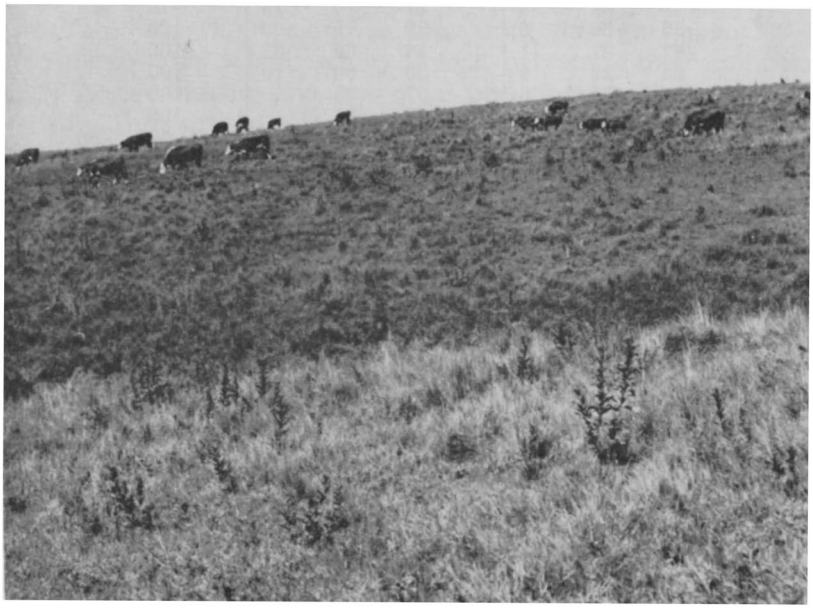

Fig. 29. Cattle in early morning, grazing in the bedding ground. Several calves still lie hidden in the grass. Most of the cattle have left the bedding ground and are grazing slowly toward the ponds.

Table 9.—Activities of the cattle on a typical day, June 30 (left panel), on a comparatively hot day, July 29 (center panel), and on a cool day, July 17 (right panel). All data are for 1950. The numbers represent the percentage of the herd engaged in each activity.

Time	°F	Grazing	Standing	Lying	°F	Grazing	Standing	Lying	°F	Grazing	Standing	Lying
					Early morning, 4 to 8 A.M.							
4	66	42	25	33	72	56	30	14	63	17	33	50
		42	25	33		57	24	19		19	31	50
5		83	17	....		59	27	14		25	33	42
		92	8	....		73	20	7		33	37	30
6		100	....	....		96	4	....		55	32	13
		75	25	....		100	....	....		67	33	....
7		67	33	....		100	....	....		58	42	....
		65	21	14		100	....	....		73	27	....
					Day, 8 A.M. to 5 P.M.							
8	67	50	18	32	72	10	80	10	63	47	32	21
		30	57	13		20	50	30		25	29	46
9		87	10	3		18	33	49		30	25	45
		87	9	4		26	37	37		25	25	50
10		90	5	5		21	17	62		48	17	35
		3	69	28		25	17	58		95	....	5
11		26	36	38		36	51	13		100	....	....
		74	15	11		62	38	....		62	25	13
12		48	35	17		50	50	....		33	50	17
		18	71	11		33	67	....		17	83	....
1	83	19	71	10	85	21	71	8	68	56	44	....
		....	91	9		17	70	13		75	25	....
2		55	36	9		20	71	9		100	....	....
		62	27	11		14	65	21		100	....	....
3		68	28	4		30	60	10		100	....	....
		71	24	5		57	43	....		100	....	....
4		58	26	16		75	25	....		100	....	....
		85	15	....		92	8	....		50	50	....
					Evening, 5 to 9 P.M.							
5	85	92	3	5	89	74	13	13	79	.....	100	....
		84	4	12		84	12	4		92	3	5
6		98	2	....		95	5	....		83	4	13
		98	2	....		100	....	....		98	2	....
7		100	....	....		100	....	....		98	2	....
		73	....	27		69	19	12		100	....	....
8		50	....	50		53	30	17		73	....	27
		25	....	75		42	25	33		50	....	50
					Night, 9 P.M. to 4 A.M.							
9	73	....	....	100	79	....	....	100	71	....	....	100
		....	....	100		....	....	100		....	....	100
10		....	....	100		....	....	100		....	....	100
		....	....	100		....	....	100		....	....	100
11		13	....	87		8	9	83		....	....	100
		13	....	87		50	....	50		....	....	100
12		25	....	75		42	....	58		....	....	100
		25	....	75		33	....	67		....	....	100
1	69	....	3	97	74	25	....	75	65	17	....	83
		....	3	97		8	....	92		42	....	58
2		....	....	100		2	....	98		8	....	92
		....	....	100		....	....	100		....	....	100
3		....	....	100		....	....	100		....	....	100
		....	....	100		....	....	100		....	....	100

has been repeatedly observed. On this day they remained resting upon a hill for about an hour, following their arrival at 10:30. Thereafter they continued grazing as they traveled northward a distance of a half-mile, when they arrived at the north fence. Here they again rested, switching off flies and chewing their cuds. Most of the herd remained idle from 12:30 until 2 p.m.; during this time 81 to 100 percent of the cattle were either standing or lying (Table 9).

About 2:00 p.m. most of the herd began to graze back and forth along the north end of the pasture. However, about a fourth of the cattle remained standing and a smaller percentage were lying. But between 4:30 and 5:00 o'clock grazing became general as the herd began moving leisurely southward toward one of their usual bedding grounds. When they arrived at 7:00 p.m. they continued to graze in the general area until 8:00 or 8:30.

During the evening, before it became dark, nearly two-thirds of the herd traveled southwestward in small groups, a distance of half a mile, to the ponds. Some of them again visited the salting station, but all returned to the bedding ground. By 9:00 o'clock the whole herd was bedded down on an area of about one acre (Table 9). They remained thus until daylight, about 4:00 a.m. An exception was shown by 13 to 25 percent of their numbers which grazed during the two-hour period from 11:00 p.m. to 1:00 a.m. They grazed close to the sleeping herd and had all lain down once more by 2:00 a.m.

BEHAVIOR DURING A HOT DAY

July 29 was selected as a very hot day (Table 9). The differences in temperatures between this day and the preceding typical one seem rather small until it is realized that during this July when the hot day occurred, temperatures were far below normal. The monthly average maximum (81.7° F.) was far below the July maximum (89.1°) for a long period of years. Only three days of July, 1950, had as high a maximum as the average for the month in preceding years; one of these was the selected hot day. Likewise, the average minimum for July was 3.5° less than a similar minimum for a period of years. Conversely, during June when the typical day was selected, the maximum monthly temperature was 1.5° above normal. This explains why June 30 was normal and July 29 relatively hot.

It had been observed that on hot, sultry days most of the grazing was done in early morning, in the evening, and much

more than usual at night. Grazing activities between 9:00 a.m. and 3:00 or 4:00 p.m., if any, were restricted to the vicinity of the ponds and the shade of two large cottonwood trees in a ravine only a short distance from the ponds. Under these trees about 40 cattle could stand in the shade at the same time.

On the very hot day, July 29, the cattle grazed constantly, beginning soon after they arose at 4:00 a.m., until they arrived at the ponds about 8:00. After satisfying their thirst, they did not wander more than 300 yards from the ponds until late in the afternoon. Soon after they drank, many of the cattle went to the salting place on the hill. Here they remained for relatively short periods. Soon the heat and flies became so oppressive and annoying that they returned to the ponds. Many waded into the water and thus partially escaped the flies and cooled themselves as well (Fig. 30). Others spent short periods grazing not far away. Many grazed between the cottonwood trees and the ponds. But rarely did the animals graze for more than half an hour at one time before they again cooled themselves either in the shade or in the water. Several times during this period, the herd grazed in small units until it reached the top of a large, nearby hill. Here the cattle stood in the breeze for 15 to 20 minutes but instead of continuing farther into the pasture they

Fig. 30. Cattle near and in the pond on a hot day in midsummer. Several trips were made during the day between ponds and the shade of two large cottonwood trees a few rods up a ravine, but little time was spent in grazing.

returned to the water. Thus, the entire hotter portion of the day was spent in or near the ponds and there were only short, intermittent periods of grazing, always in the immediate vicinity. This is an illustration of the fact that the actual grazing time from 8:00 a.m. to 4:00 p.m. was usually much less on hot days than on those with moderate or relatively low temperatures (Table 9).

About 4:00 p.m. the cattle wandered away from the ponds and grazed continuously on their way to the nearest bedding ground. Grazing toward a bedding ground occurred each evening. Often, as on this day, they arrived early and continued to graze in the vicinity until dark. At 7:30 some began to lie down. A third of the herd was lying at 8:30 and all of it by 9:00 when darkness was complete.

Their behavior on this hot night was quite different from that on either a normal or a cool one. As early as 11:00 p.m. some of the herd began to graze and by 11:30 half was grazing. Grazing by 25 to 42 percent of the cattle continued until they had satisfied their hunger at about 1:30 a.m. This, of course, was a compensation for the grazing time lost in idleness during the heat of the hot day. Not until 2:30 a.m. had all again lain down. They then rested the relatively short period until daylight at about 4:30.

BEHAVIOR DURING A COOL DAY

Opportunity was afforded for observation during the many cool days of this summer, which was characterized by unusually moderate temperatures. The record of the activities of the cattle on July 17 was selected as typical for this very cool month. The behavior pattern was quite similar to that on numerous other cool days. Quite unlike the early rising on warm or hot days, about a third of the herd remained lying and another third standing until 6:00 a.m. Only a few began to graze early and the number was augmented very slowly. This was in sharp contrast to their usual behavior, especially with that of a hot day (Table 9).

Only half to three-fourths of the herd grazed slowly until 8:30 a.m. The others were mostly merely standing. At this time many of them began to lie down; soon this included half the herd. The number grazing decreased to one-fourth, since another fourth was resting while standing. The cool, cloudy weather gave way about 10:00 a.m. when the sun came out and the low temperatures became more nearly normal. Almost at once the

herd responded by beginning to graze vigorously and also to move windward as a unit.

By 11:30 they had reached the northeastern part of the range. Thus, they had traveled, while grazing, one-fourth mile. Many ceased grazing, and some lay down to rest. From 12:00 m. to 1:00 p.m. most of the cattle stood in a rather compact group near the fence (Table 9). This rest period of an hour's duration began at almost the same time as that on a typical day, but it was shorter. Most of the cattle resumed grazing about 1:00 p.m., all were grazing at 2:00 and they continued to graze steadily until nearly 5:00 p.m. Then they traveled toward the ponds, a distance of about half a mile, where they took their first drink of water for the day. Some grazed about the ponds while others drank. Some, after drinking, grazed near the ponds.

About 6:30 the herd began to graze away from the ponds toward one of the usual bedding grounds. At 8:00 p.m. the cattle began to lie down. By 9:00 the entire herd had bedded down. But between 1:00 and 2:00 a.m. some arose to graze for an hour or less (Table 9). This grazing at night extended over a shorter period than that following a hot day or a typical one.

AVERAGE DAILY ACTIVITIES

The chief differences in the activities of the cattle in morning, day, evening, and night may be seen by an examination of Table 10. The average percentage of cattle grazing in the morning of a typical day was 71. This decreased to 43 percent on a cool day, but increased to 80 on a hot one. The number of animals grazing between 8:00 a.m. and 5:00 p.m. was greater on a cool day (65 percent) than on a typical one (52 percent) but it decreased to only 35 percent with marked increase in temperature.

Table 10.—Average percentage of grazing (numbers in first columns), standing, and lying (numbers in last columns) during three selected days in 1950.

Kind of day	Morning (4-8 a.m.)			Day (8 a.m.-5 p.m.)			Evening (5-9 p.m.)			Night (9 p.m.-4 a.m.)		
Typical	71	19	10	52	35	13	78	1	21	6		94
Cool	43	34	23	65	23	12	74	14	12	6	....	94
Hot	80	13	7	35	47	18	77	13	10	12	1	87

Grazing in the evening was practically the same on all three days. But grazing at night decreased, with the lowering of temperature, from 12 percent on the hot day to 6 on the typical and cool days. Moreover, the length of the period of grazing at night decreased in the same sequence, from 3.5 hours to 2 and then to 1.5, on the cool day (Table 9).

A summary of the average percentage of animals grazing in the morning, during the day, in the evening, and at night will now be given. This is from data obtained at 15-minute intervals during 8 days (4 a.m. to 9 p.m.) well distributed throughout the summer and during 30-minute periods on 5 nights (Table 11). The major part of the grazing occurred in the morning and evening, when 67 and 71 percent of the herd was thus engaged. The herd

Table 11.—Summary of activities of the cattle during the several day-night periods, expressed as percentage of the herd which was grazing, standing, and lying.

Time	Grazing	Standing	Lying
Morning (4 a.m.-8 a.m.)	67	21	12
Day (8 a.m.-5 p.m.)	47	37	16
Evening (5 p.m.-9 p.m.)	71	18	11
Night (9 p.m.-4 a.m.)	9	1	90
Average (24 hours)	44	20	36

spent more of the 24-hour day resting (56 percent) than grazing (44 percent). Twenty percent of the 24 hours was spent standing but 36 percent lying. The highest percentage of standing (37) occurred during the day (8 a.m. to 5 p.m.) but at night 90 percent of the time was spent lying down. The approximate time the herd spent in grazing, standing, and lying was 10.5, 5, and 8.5 hours, respectively.

EFFECTS OF CERTAIN ENVIRONMENTAL FACTORS

Certain conclusions have been reached from a study of the preceding data, from continuous records during eight days and nights, as well as from numerous isolated observations on the many days of field work during the two summers. The amount of grazing during any calendar day was about the same, but the time when it occurred varied greatly with differences in temperature. On very hot days the cattle were too much occupied in keeping comfortable between 9:00 a.m. to 5:00 p.m. to do the usual amount of grazing. Often it was limited to 35-40 percent of the total grazing time while on cool days 60-65 percent of the total grazing occurred between 9:00 a.m. and 5:00 p.m. This daytime loss was compensated for by more grazing in the evenings, mornings, and at night. On cool mornings the herd extended the night resting period an hour or two longer than usual. Also the cattle lay down to rest more often on cool days than on warm ones.

Not only did temperature affect the activities of the cattle but it also, in a high degree, determined their location. On very

hot days they rarely strayed more than a few hundred yards from the water. Moreover, they spent more time than normally on tops of adjacent hills to get full benefit of the wind. Conversely, on cool days their location was more dependent upon other factors, especially direction of the wind and abundance and kind of forage available.

There was a very close correlation between the location of the cattle on any day and the direction from which the wind was blowing. They were practically always found in that part of the pasture where they could get full benefit of the wind. They did not always face the wind, except most of the time in grazing toward that part, since once the windward side of the range was reached, they grazed in various directions but stayed in the same general area. From observations made on 62 different days, the cattle were in the windward portion of the pasture on all but two days. These were chilly and misty and the herd sought protection by grazing with the wind to the leeward side of the range.

The wind blew from a southerly direction—southwest, south, or southeast—during the summer of 1950 on 48 percent of the days. Over a representative period of five years at the Weather Bureau Station in Lincoln, the wind blew from some southerly direction, mostly from the southeast, 45 percent of the time. Only 4 percent of the days were calm. These data are for the grazing season only, May 1 to September 30. The prevailing winds may thus have contributed toward the greater degeneration of vegetation in the southern half of the pasture.

The cattle seemed always to endeavor to find the windiest place, presumably to help rid themselves of flies and to keep cool. Measurements of wind velocity on the hills and protected slopes showed repeatedly that it was three or more times greater on hilltops than on the lower slopes. During rainstorms behavior of the cattle was quite different. Then they tended to drift with the wind until they had reached the extreme leeward side of the pasture.

Some of the effects of water upon activities of the cattle have been discussed. The present location of the major portion of excellent range far from the ponds and the fair condition relatively nearer them has been pointed out. The herd undoubtedly spent much more time, year after year, in the vicinity of the water than far from it. Water for drinking and protection from flies was a powerful attraction as was also its cooling effect.

The number of trips to the ponds per day varied greatly with temperature. On cool days cattle seldom drank more than once, usually in the morning. On cool mornings with heavy dew, they often delayed drinking until midafternoon or evening. Normally they visited the ponds both morning and evening. But on hot days they remained near the ponds for long periods, drinking several times during the day.

MISCELLANEOUS ACTIVITIES

Cattle walk constantly when they graze but sometimes they travel without grazing. Most traveling is to or from water, to or from the salting place, and from one favorite grazing area to another. The network of paths about the ponds and salting station bears witness to the hundreds of times the cattle used these paths, one animal following behind another. They sometimes approached the ponds while the herd was spread out and grazing, and began walking steadily to water only when they were a few rods from it. But often they have been observed to walk continuously more than a half-mile to water. Almost immediately after drinking they may again walk, without stopping to graze, to the salting ground.

Instead of grazing steadily through the pasture along a straight course, the cattle usually grazed in areas kept free from old vegetation and where the new forage was young and succulent because of repeated grazing. It was estimated that about three-fourths of the time the cattle spent in grazing was in these areas. Such areas occurred mostly in regular grazing routes and in the fair range class, but they also occupied about half the extent of the good range class. In traveling from one cleared area to another, the cattle, especially in spring and early summer, usually walked without stopping to graze among the taller, older, and often debris-filled vegetation.

The usual time at which the cattle obtained salt was shortly after they drank. They rarely visited the salting grounds at other times, except to benefit from the breeze on this hill, but they often rested here while standing for a considerable time.

Calving time began in early spring (about April 1) and extended throughout spring and early summer. Hence, the effects of the young animals upon the herd were apparent during the entire grazing season. The effect of the calf upon the mother was quite marked, especially while the calf was very young. Usually she kept it hidden from the herd for a week or more. Since she

soon followed the herd, she had to do considerable traveling back and forth to nurse the calf. The place of concealment was in the taller grass or, especially, in the patches of buckbrush.

Sometimes when the herd was resting or grazing contentedly the bawling of the hungry or frightened calf, if within hearing distance, was immediately heard and distinguished by the mother, who left promptly to care for her offspring. When the calves joined the herd, for a time they slowed the rate of travel of their mothers. Often, because of this, the herd divided into two groups, one with calves and the other without. The young calves grazed sparingly and spent most of the time lying down. Hence, many times the herd grazed away from the sleeping calves for a distance of one-fourth to one-half mile. When the hungry calves discovered that they were left alone, they began bawling, whereupon the cows came to them quickly, sometimes running. This is a very usual occurrence, especially about nursing time. On a warm day in late spring the writers observed about 35 calves asleep in the sunshine on a south-facing hill. The cows had formed a complete circle about them and thus provided the best type of protection.

The time of nursing varied somewhat with different cows. Generally, however, the calves nursed at opportune times, as immediately after arising in the morning, following drinking at the ponds, or during resting periods. The urge for nursing seemed felt by both the cow and the calf. Sometimes the calf initiated the process when it was hungry; at other times the cow sought her calf to relieve herself of the pressure of too much milk. The number of nursings during the day became less, naturally, as the calves became older, and the effect on the grazing activities of the mothers and the whole herd was decreased.

The cattle paid scant attention to any one who worked in the pasture more or less regularly. But a stranger or a dog caused considerable disturbance, especially when the calves were small. The instinct to protect them was clearly shown not only by the mother but by every member of the herd.

Location of bedding grounds was ascertained. In addition to the all-night studies, the herd was often observed bedding down or getting up in the morning. A total of 25 such activities were recorded. The herd did not lie down at dark in any part of the range but only in certain preferred places. Three different bedding grounds were mostly used. One was on a north-facing slope a quarter of a mile east of the ponds, another was located on

the lower north-facing slope of the experimental area in the good range condition class, and a third was in the northeastern part of the pasture in the south experimental area of excellent range class, which was also on a north-facing slope (Fig. 1). All of these locations were in the good or excellent range classes where there were considerable quantities of uneaten new grass, much old forage, and a heavy mulch. These may be chief reasons for using north-facing slopes. On some of the cool evenings, however, when the wind blew from the north, the herd bedded down on south-facing slopes instead.

Late evening grazing in bedding grounds has been mentioned. Likewise in early morning the cattle often grazed for a short period in the bedding ground before they moved away from it. Hence, the forage in the general area was fairly well grazed by the end of summer. In this manner the location of bedding grounds affects the distribution of grazing. The size of the area thus used varied from an acre or less to several acres. The cattle always bedded down some distance above the main ravine. Mostly the herd was fairly well grouped.

Variations in the behavior of the cattle during different parts of the grazing season seemed to be, for the most part, due to such factors as temperature, wind, etc. Some activities, however, differed in spring and early summer from the remainder of the season. Early in the growing season, the herd was more widely distributed over the range than later. Sometimes the cattle occurred in small groups in various, widely separated places. Several reasons for this behavior were obvious. It was the calving time for some cows and the breeding time for others. Temperatures were lower, flies less bothersome, and new forage was not yet plentiful. Early spring grazing occurred largely in ravines where the cool-season bluegrass thrived. In fact, for a time, it furnished the bulk of the forage. This involved much traveling. Although many of the ravines were repeatedly grazed throughout the summer, in others the best forage became overgrown with weeds and was abandoned since excellent forage was abundant elsewhere.

Habits of the 15 horses and three colts varied considerably from those of the cattle although they often grazed near the herd. Since there was abundant forage, their presence affected the cattle but little in regard to the food supply. Infrequently they disturbed the normal activities of the cattle by dashing through the herd and causing its members to scatter in all di-

rections. Sometimes the horses took the first turn at licking the blocks of salt while the cattle waited. At other times they partially monopolized one portion of the ponds. In general, their effect on the cattle seemed slight.

DISTRIBUTION OF THE CATTLE

In studying the distribution of the cattle, a sheet of tracing paper the size of the topographic map was ruled into 2.5-acre squares and placed over the map. This was used not only on each of the 8 days already discussed, which were well distributed throughout the summer, but on 16 other widely distributed half-day periods. The entire number of cattle observed in each unit area was recorded, as nearly as possible, at 15-minute intervals between 4 a.m. and 9 p.m. The total number of animals found in each square—the sum of all the 15-minute observations —is shown in Figure 31, where each dot represents 15 cattle.

Even casual examination of Figure 31 clearly indicates that there were certain places where cattle congregated and other places where only a few or none were observed. The areas of greatest concentration, where there was a total of 500 or more cattle in each unit, were seven in number. The largest of these included the ponds and the much-grazed pasture immediately adjacent to them (areas F 7 and 8, and G and H 7, 8, and 9 in Figure 6). Nearly all of this is fair pasture. A second place of high concentration of livestock was in and near the salting

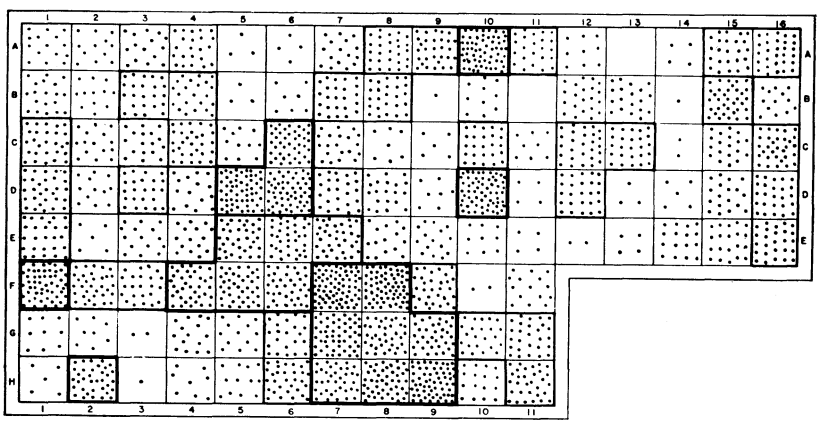

Fig. 31. Pasture divided into 2.5-acre units to illustrate the distribution of the cattle. Each dot represents 15 cattle. Seven areas of great concentration of livestock are bounded by heavy lines. Other units with less concentration are bounded by lines of intermediate width.

ground, nearly all fair pasture but with portions of poor grade (D 10). A favorite resting place near the east fence, including hilltop, south slope, and ravine, likewise had only a small amount of range above the fair class (A 10). A much larger area, including some good class range but mostly fair with many grazing routes, occurred in units C 6 and D 5 and 6. This was mostly on the hilltop but also extended over both upper north-facing and south-facing slopes. Another more extensive area, contiguous to the preceding and just west of it (E 5, 6, and 7 and F 4, 5, and 6) occupied somewhat similar terrain. While much of this was in good range condition and one unit in excellent condition, it was transected by several strips of fair pasture which led to the northern portion of the range (Figs. 6 and 32). It seems certain that most of the cattle were in the grazing routes in these units which adjoin those in the group about the ponds. Two more places of great concentration were found; both were in the northwestern portion of the pasture. In H 2 cattle frequently grazed or rested in the fair grade (nearly pure bluegrass) in the broad, level ravine. Although this 2.5 acres included some excellent range on the steep banks, this was scarcely ever grazed. The herd, or a portion of it, often grazed up this ravine eastward and then turned northward until it reached the fence. This area (F 1) with fair class pasture, except on the steeper slopes where excellent class prevailed, was a favorite resting place (Fig. 6).

There were 31 other unit areas in each of which a total of 325 to nearly 500 cattle were counted. About one-third of these were adjacent to the areas of greatest concentration and another third along the fences. Only 32 percent were in other units (Fig. 31). Eight of these 31 units were entirely in fair pasture, 18 in fair and good pasture, and only 5 in good and excellent range condition.

The map with squares was superimposed on the map of range condition classes. Where the square was entirely in the fair range condition class the total number of cattle found in that unit was recorded under this class. But where a fourth of the area was in the good class and the remainder in fair class then one-fourth of the number was placed under the good column and three-fourths under the fair. Had the cattle been distributed uniformly throughout the pasture, 13 percent of them should have been observed in excellent range, 30 percent in the good class, and 57 percent in the fair range condition class. Actually it was found that only 8 percent were observed in the excellent range con-

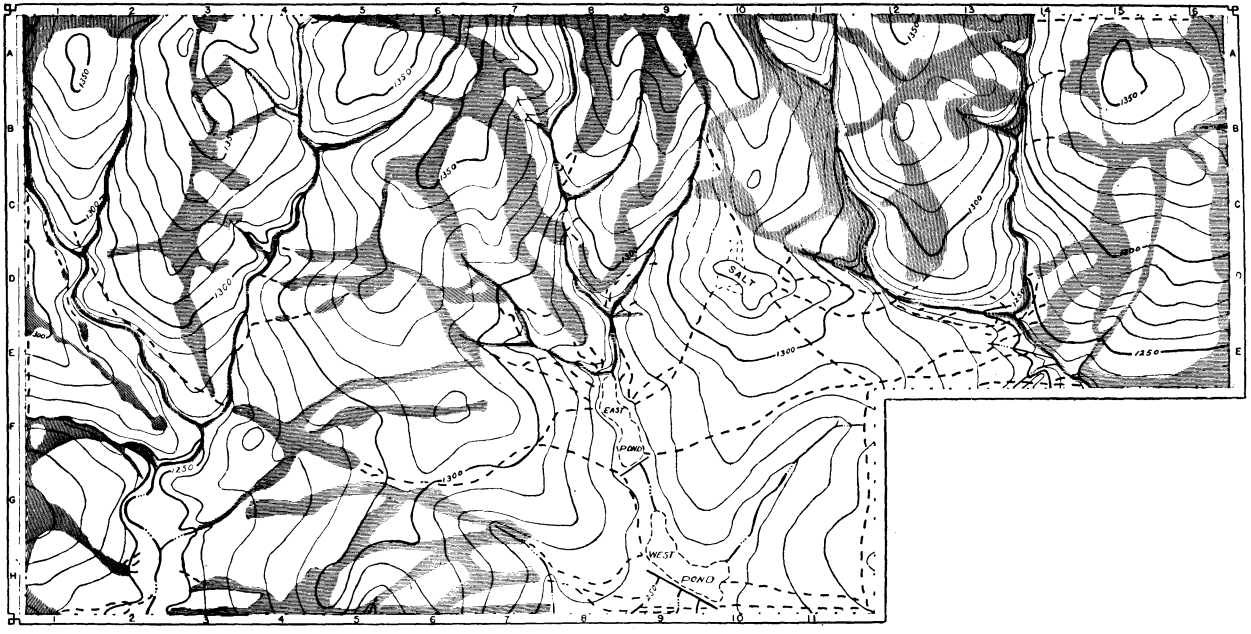

Fig. 32. Topographic map showing paths (broken lines) and the network of grazing routes (dark, mostly linear, irregular areas). Paths in the routes are not shown. Grazing routes do not occur in a considerable area about the ponds, since here all the vegetation is continuously grazed (Fig. 6).

dition class. The number in the good class was 27. But in the fair range class 65 percent of the cattle were observed.

PATHS AND GRAZING ROUTES

The movement of cattle through the pasture nearly always occurred either along paths or much wider, linear strips which will be designated as grazing routes. Paths made by cattle are usually about 12 inches wide. They are mostly worn down at least a little below the general level of the soil and trampled free of vegetation. Paths are used by cattle when they are traveling without grazing from one part of the pasture to another (Fig. 33). They are generally found to be the easiest routes of travel, as along the crests of ridges, crossing the saddle or low point on a ridge between hills, paralleling the flatter areas just above the steep banks of ravines, and also in ravines (Fig. 34). Many paths are more or less parallel with the contour lines. Locations of the principal paths in this pasture have evidently been the same

Fig. 33. Paths leading from the upper end of the east pond to the top of the hill where the salt was placed. Over these the livestock traveled daily, usually without stopping to graze. Note close grazing in fair range condition in the foreground which is similar to that across the ravine where the patches of buckbrush occur.

Fig. 34. (Upper) Main path northeastward from the ponds. It somewhat parallels the ravine and leads into a broad grazing route on the hilltop. This route extends far northward down the opposite slope (Lower) and connects with east-west grazing routes in the main ravines.

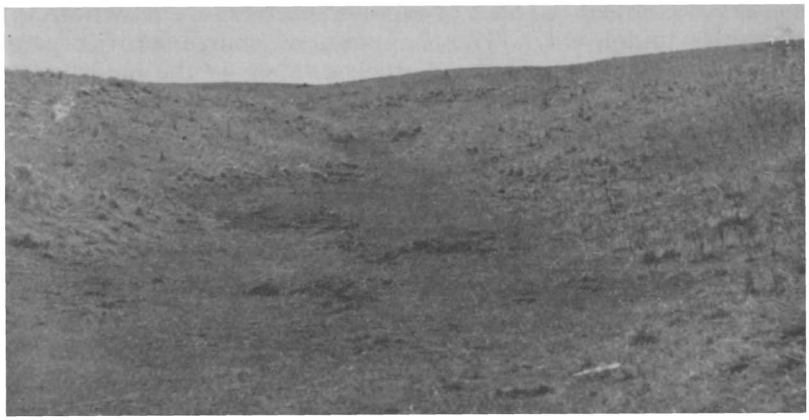

Fig. 35. One of the main grazing routes in the fartherest north ravine (A 2 in Fig. 32) where the vegetation has degenerated to bluegrass. It is a main route east and west between the hills. The banks on both sides are clothed with vegetation of the excellent range condition class.

for many years. The cattle use a path until it is worn down or eroded several inches deep. They then abandon it and start a new one beside and almost parallel with it. Paths have resulted in the main from the tendency of cattle to choose the easiest routes of travel but also from the attraction of choice grasses, such as big bluestem and bluegrass, especially in ravines. Apart from topography and choice of forage, the location of the ponds and salting place in the same area over a long period of years has resulted in a well-used network of paths (Fig. 32).

Grazing routes differ from paths in that they are usually much wider, often a hundred feet or more, and are clothed with vegetation. They are used as routes of travel while the cattle are grazing (Fig. 35). Since they too mostly occur along the easiest routes of travel, they often include some of the paths. But there are many grazing routes without them. Paths are especially common in ravines where the usually narrow grazing route frequently contains two to four. In Figure 32 the paths leading to grazing routes or connecting them are shown but not those within the routes.

Grazing routes have probably originated from the merging of isolated, preferred areas that have been grazed continuously for many years. During the grazing of these, and perhaps intermittent grazing in passing from one to the other, each individual area has been enlarged until it has finally merged with others to form a continuous grazing route or a network of grazing routes

(see areas D and E 1 and 2 or D 4 and 5 of Figure 32 where this process is under way). This happens, of course, only because the range is continuously well stocked. Most of the older routes in all parts of the pasture are clothed with vegetation of the fair range condition class, thus showing long-continued use. Some of those of more recent origin are in the good range condition class. But in only a few of those developed during the progress of this study does the composition of the vegetation indicate the excellent class.

The grazing routes with their connecting paths form a fairly continuous network which leads from the ponds to all parts of the pasture. Because of this, and since the cattle use them for the major portion of their grazing, some of the routes are bordered by the excellent type of range condition class. Transition from one class to another is often very sharp (Fig. 36). The main routes are most usually located along the ridges, in the ravines, or along fences. The upland and lowland routes are connected first by

Fig. 36. Portion of a grazing route (left) in fair condition range bounded on the right by good condition class. This grazing route extends from a hill crest to its lower slope and connects with another route in the ravine. Its boundaries were very definite throughout.

means of paths on the steep banks of ravines and then by lateral routes through branch ravines which join the main ones on the hills. The cattle walk along a path leading up the side of the main ravine and begin grazing only on the more gentle slope above, where they can do so with ease (Fig. 37). It is here that the lateral grazing route begins. Elsewhere there are areas where the forage is not very desirable, as in dense stands of tall dropseed. Cattle repeatedly walk through such places without grazing and in this manner form a path from one preferred grazing place to another. Thus, throughout the pasture there has been developed an intricate network of grazing routes and connecting paths. But by October of 1950, practically all parts of the pasture had been visited by livestock and some grazing had occurred nearly everywhere.

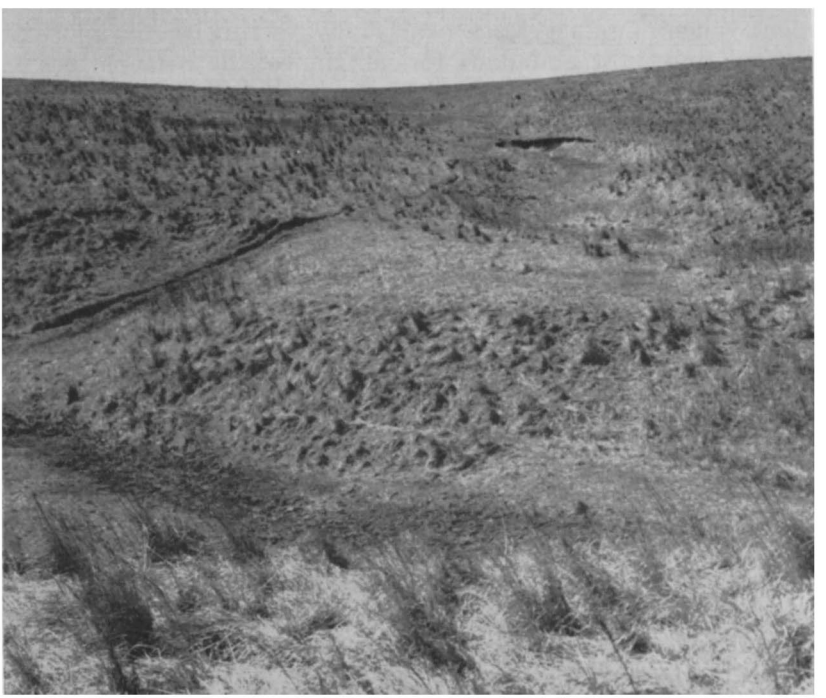

Fig. 37. General view of a well-grazed ridge (background). A path leads from the saddle on the ridge down a rather steep slope in the north-central part of the pasture. Although the path in this lateral ravine has been worn and eroded deeply and abandoned for a new, parallel one, excellent range condition prevails generally on this north-facing hillside.

Grazing routes are extremely important since here untilization of forage is greatest and since they are highways along which the cattle travel from one portion of the pasture to another. The grazing routes express in a high degree the effect of the activities of cattle upon both the present kind and distribution of the vegetation. Their total area, as shown in Figure 32, included 20 percent of the entire range.

DISCUSSION

Ecological methods are of great value in ascertaining the kind of vegetation on a range, the factors influencing its growth, and the amount that is produced. A knowledge of the kind and quantity of forage consumed by grazing animals is basic to proper forage management. What is there, how much there is of it, and what species are best liked by the grazing animals, are all fundamental questions. A knowledge of the ecological climax is necessary; it sets the ideal goal to be attained by range management, since climax grasses nearly always furnish the most nutritious and most abundant forage. Hence, the best pattern for range management will result in maximum forage production and soil stabilization as well as the most economic returns from livestock production.

Why various types of range conditions emerge from a once continuous, nearly uniform plant cover is a fascinating study. To ascertain how the underuse of certain areas and the overuse of others can be prevented is of great practical value. This can be best accomplished only after the attainment of considerable knowledge of the vegetation and the activities of the grazing animals.

In analyzing native range lands one must first learn to recognize the different range condition classes. These are ecological types which are based upon the occurrence in quantity or the decrease in amounts of a rather few key species. Such an analysis gives the most satisfactory view of range land types as a whole.

The movable exclosure method yields much more information that can be expressed in yield and consumption. In separating the component species of the selected vegetation, both grazed and ungrazed, and removing them each month, one learns much more than by walking through the area, regardless of how closely he may observe it. Various species not observed in grazed pasture are easily seen after a month for recovery from grazing. One cannot help but observe what the livestock eat, to what extent and to what height it is grazed, and what is not taken.

The exclosure method is most easily used in rather uniform stands of western wheat grass, bluegrass, or buffalo grass and blue grama or other low-growing species in uniform stands. Where tall or mid grasses are intermixed with bluegrass, for example, care must be taken to use representative samples. In the good range class it was observed that about half of the bluestems and other taller grasses had been grazed in past years to a level of 2 to 5 inches where intermixed with the invading bluegrass. The remaining half consisted of grasses grazed much higher and often very little. Hence both exclosures and controls were located on the half-and-half basis, each exclosure including somewhat more than a square meter of each type of forage. The excellent range class is the most difficult type to satisfactorily sample. This is because of the extensive roughs and irregularity of grazing. A few exclosures and control areas were located in nearly pure stands of big bluestem on lower slopes. The others were located with part of the exclosed area and control in and a part beyond places previously grazed. The composition of the vegetation was almost the same, whether it was grazed or ungrazed.

The separation of last year's debris from the forage is not difficult in closely grazed range, since there is little left that has not been eaten or trampled to the ground. In both good and excellent range class this requires considerable time and patience. However, by midsummer debris is much less abundant since much of it has been lodged close to the soil by rains or by trampling.

The method of exclosures has now been used for seven summers and in various types of ranges. It has been found entirely satisfactory. Eight to 10 exclosures give adequate sampling within a representative sampling area of 8 to 15 acres. Actually this means that 200 square meters of vegetation have been harvested between May and October. In one 70-acre pasture of pure buffalo grass in central Nebraska, yield and consumption had been ascertained during two years by means of 9 movable exclosures. That this moderately grazed pasture on rolling topography had been adequately sampled was ascertained by comparing the results from the original exclosures the third year with a similar group of 9 new exclosures used here for the first time. They were placed in 9 new sampling areas as similar as possible to those sampled by the first group but 40 to 100 yards distant. Average total consumption from the two similar sets of sampling areas

was 5,596 and 5,636 grams, respectively. Average total yield was 8,650 and 8,941 grams (Weaver and Bruner 1948).

In a study of selective grazing resulting from preference of cattle for certain plants, it soon became evident that both the botanical and chemical composition of the herbage consumed, at least where forage was plentiful, differed from the average of that present in the pasture as a whole. According to Cory (1930), preferences are due largely to the palatability and the abundance of the individual species, coupled with the ease with which it may be grazed. Palatability is affected by many factors only some of which, as carotene, high moisture content and succulence, reside in the plant itself (Sullivan and Garber 1947, Ahlgren 1947).

According to Cory (1927), "Young animals very soon learn to do more or less feeding on the range. They taste of various plants that their mothers do not feed upon, and apparently learn for themselves the palatability of the various plants." Johnstone-Wallace and Kennedy (1944) state: "It was apparent that the sense of smell largely determined the herbage gathered." It is well known that cattle select leafy herbage in an immature stage of growth even when taller herbage is plentiful. Conversely, they often eat the tops of the flower stalks of matured grass, as little bluestem in fall in the present study, since this portion containing the seeds is richer in protein and phosphorus than the leaves and stems.

A knowledge of the behavior of cattle continuously on the range is essential for a proper understanding of the principles involved in pasture management. A study of the grazing habits of beef cows during summer was made in New York by Johnstone-Wallace and Kennedy (1944). They were grazing on bluegrass and wild white clover. During each 24-hour period the cows spent 7 to 8 hours grazing: about 5 hours were actually employed in gathering herbage and the remainder in walking short distances or selecting herbage to be grazed. Twelve hours were spent lying down, but this was divided into 9 periods ranging from less than 1 to more than 6 hours. Forty percent of grazing was done during the night and 60 percent during the day. Frequency of drinking was once only, usually in late afternoon.

The grazing time of beef steers on permanent pastures at Beltsville, Maryland, as recorded by Hein (1935) was 8.75 hours where there was an abundance of forage but about 10 hours where herbage was not so plentiful. Approximately 66 percent

of the grazing occurred during the daylight period from 6 a.m. to 6 p.m. No grazing was done at night except when there was moonlight or visibility equal to that of twilight. Cattle grazed most intensively between 5 and 8 a.m. and 5 and 8 p.m. Grazing began somewhat earlier in the morning of hot days and, after the midday rest, it was resumed later in the evening.

Studies at Manhattan, Kansas, on cattle grazing in tame pastures, confirmed the fact that fewer of the daylight hours were spent in grazing good pastures than poor ones (Atkeson *et al.* 1942).

Activities of livestock on the range were studied by Cory (1927) on the Edwards Plateau of Texas where grazing is yearlong. The studies included such activities as traveling, grazing, drinking, licking salt, and resting, all during daylight between getting up in the morning and bedding down at night, about 13.6 hours. Of this time cattle spent 56 percent in feeding, 10 percent in traveling (an average daily distance of 3.3 miles), and 10 percent in idling.

Grazing habits of range cattle on the Santa Rita Experimental Range near Tucson, Arizona, have been investigated by Culley (1938). "Cattle were found to have rather definite grazing periods during the day. In the summertime from about 5 to 9 in the morning, and from 4 p.m. until dark, about 7:30 in the evening. . . . . The spring grazing hours were much the same as those for summer except for the fact that the evening period was usually longer, sometimes lasting as late as 11 o'clock at night." Thus, the total time was 7 to 8 hours per day, except in spring when it was about 9 hours.

Reasonably uniform grazing of all parts of a range is necessary for its most efficient use. Often, however, this does not occur because of unequal distances to water. Even on level land use of the range may decrease almost in direct proportion to the distance from water. The utilization of black grama (*Bouteloua eriopoda*) on the Jornada Experimental Range in southern New Mexico has been shown by Campbell (1943) to decrease consistently and materially with distance from water. The grazing use of the most important forage grasses in northeastern Arizona has likewise been found to decrease in a similar manner (Glendening 1944). A study of the distance from water as a factor in grazing capacity of range lands has been made by Valentine (1947). He states that in recent years, as more attention has been given to the study of range utilization, it became ap-

parent that even well-watered, level range is not equally used near and away from the water. He points out that while some earlier observers have noted a graduated use of forage out from water that this was not generally recognized as unavoidable, since no adjustment based on graduated use had been incorporated in range survey procedure. "Grazing capacity values obtained by means of forage utilization surveys likewise have often been excessive because these surveys also have assumed a more or less even utilization of vegetation as being proper, instead of graduated utilization" (Valentine 1947).

Although level land is grazed to best advantage, rolling range land can be fully utilized by cattle. In parts of the pasture under study, the cattle leave the steeper slopes unused or only partly utilized, especially those more distant from water.

Traveling too far to water results in excessive trampling. Excess trailing is especially harmful when the soil is wet. Cory (1927) says livestock will abstain from taking water regularly when they have to travel a mile or more to reach the supply. Culley (1938) in his study on southwestern ranges, found that most cattle drank daily in the morning; but some varied from this by drinking in the afternoon, an activity which requires only 10 to 15 minutes.

Our observations are not in accord with the common belief that cattle desire water after eating salt. "Some cattle alternate between eating salt and drinking water, others drank once then ate salt . . . . and left" (Culley 1938). Cory (1927) observed that all range livestock commonly do some licking of salt each day. Cattle may spend 8 to 15 minutes a day in this activity, which is usually a leisurely one which the range animals enjoy. Advantage of using salt to attract livestock to areas that would be lightly grazed and away from those grazed too closely and in danger of serious deterioration is evident. Proper quantity and distribution of salt in a large pasture go a long way toward controlling the grazing of livestock and obtaining satisfactory use and maintenance of the forage.

The conclusion on direction of wind greatly affecting the use of various portions of the range is confirmed by Allred (1950). "Domestic animals in the Southwest have the habit of grazing into the breeze. As a result the south side of a pasture is generally overused . . . . Some believe that the eyes, ears and nostrils, which have a good deal of tender tissue exposed, are given more freedom from insects when animals face the breeze."

The present study has shown why the network of paths and grazing routes have been developed and the causes for the present distribution of the range condition classes. Topography, distance from water, direction of prevailing winds, the placing of salt, and selection of bedding grounds have all played a part in affecting the behavior of the cattle. This has resulted in scanty forage in places and overabundance in others. The range is what it is today because of these activities.

The condition of a range is almost wholly under the control of the operator and his management will determine what kind, and how much forage his land produces. The ranchman should know not only the present condition of his range but also its productivity, and how proper use will improve the kind of vegetation and increase its amount. The proper use of a range cannot be accomplished by utilizing all of the herbage present; to preserve the important species, much material must remain unharvested. When forage is abundant cattle tend to graze conservatively, but when it becomes scarcer they graze more closely. A properly used bluestem range appears somewhat ragged, as in our good range condition class. While some grass is grazed short, some is only half used, and certain plants escape grazing almost entirely.

It has been observed that wherever the cover of bluestems and other unused forage has been removed by clipping, such places are thereafter repeatedly grazed year after year. This is in accord with the fact that mowing of old stands of bluestems in early spring will usually overcome irregular or spotty grazing.

Lack of proper distribution of the animals has resulted in the deterioration of more than half of the range to the fair class and the overuse of this class. Heavy grazing and trampling have caused many damaging results. Among these are the very great reduction in amount of bluestems, the thinning of the bluegrass and grama grass sod, a decrease in the number and abundance of legumes and other palatable forbs, a deficiency of production of seeds by all forage plants, and a decrease in amount of organic mulch. In fact, large portions of this pasture have almost reached the poor range condition class. This is indeed unfortunate since the writers believe that had there been a proper distribution of the cattle, there would have been plenty of forage for all with little or no overgrazing. Change to a lower class means not only a change in composition of vegetation but also

a change in the nutritive content of the forage plants as well. The management of the grazing should be such that it not only guards against the possible extermination of valuable forage plants or even their reduction in numbers, but also favors their increase.

The problem of proper management of this range is quite beyond the scope of the present study. But it is of great ecological interest. By impounding the water in the northwestern part of the area (which is now being done), by placing salt in several locations where the forage is least used, and by mowing the old, mostly uneaten bluestems in March, much better distribution of the grazing animals could be attained. The buckbrush, of course, should be eradicated by mowing and spraying. Fencing should be done in such a manner that the better portion of the range may be fully utilized while the best grasses in the poorer part are recovering their vigor and seedlings of these are established from seeds scattered over the soil. Grazing too early in spring should be avoided. Deferred grazing of bluestem pastures until mid-June in the famous bluestem ranges of eastern Kansas was found highly profitable. Although they were grazed more intensively, they were in better condition than the continuously grazed pastures (Aldous 1938, Anderson 1940).

Computations reveal that when the productivity of the 57 percent of this pasture which is in the fair range class becomes equal to that portion in the good range class, there will be a total increase in forage of 170 tons per year. This increase in grazing capacity has been conservatively estimated in total increase in net returns from the livestock. Within one or two years they would equal the cost of fencing and other suggested improvements.

SUMMARY

A study has been made of a mile-long, 290-acre range which, during a period of 47 years, has degenerated from excellent mostly to fair range condition class. The degree of degeneration has been studied in relation to topography, distance from water, and factors affecting the activities of the livestock, especially unequal distribution of grazing.

This native range is located in true prairie near Lincoln, Nebraska. The topography is that of rolling upland. Six large hills or ridges 50 to 100 feet high transect the half-mile wide area from east to west. They are separated by deep ravines. Water has been

available only south of the central-west part of the pasture from wells or ponds. Salt was placed on a nearby hilltop.

The stocking rate has been about the same each year—85 animal units, mostly cattle but including 14 horses. This rate of one animal unit for each 3.4 acres seems not to have been too great, but distribution of the livestock has been poor.

Although the Carrington loam soil is rich and deep and produces, under the mean annual precipitation of 27.8 inches, 1 to 1.5 tons of hay, yet the grazing was so concentrated in the southern two-thirds of the range that the native bluestems and accompanying prairie grasses have been replaced largely by Kentucky bluegrass and blue grama.

After long and careful observations three range condition classes were delimited and marked out on a specially constructed topographic map. The basis for mapping was entirely that of the percentage composition of the vegetation.

Excellent range, located largely in the northern third of the pasture, consisted mostly of grasses which decrease under heavy grazing, chiefly big bluestem and little bluestem. An abundance of old, ungrazed bunches of little bluestem and tall dropseed, together with very little bluegrass and much debris characterized this class which composed 13 percent of the range.

In good range class, which occupies 30 percent of the pasture, old standing bunches of the preceding decreasers were not so continuous. There was much less debris or mulch. All the vegetation had been grazed at some time, moderately in places but more closely in others. The increaser, Kentucky bluegrass, had spread in large amounts and, with the preceding characteristics, clearly demarked good from excellent range, most of which occurred in the north half or southeastern part of the pasture at a considerable distance from water.

Fair range class, which occupied 57 percent of the pasture, had the appearance everywhere of having been closely grazed. Only small areas occurred in the northern third of the range. Increasers, as bluegrass and blue grama, composed most of the vegetation, there were many invading grasses, as hairy chess and little barley, but bluestems and other decreasers were few.

Representative areas of 7 to 10 acres were selected in each range class. Here the composition of the vegetation was analyzed, and yield and consumption were measured. Vegetation in each area was sampled by 150, square-foot plots selected at random along predetermined lines.

In excellent range the two bluestems alone composed 72 percent of the vegetation, but 45 percent in good condition class, and only 7 percent in fair range. These and other decreasing grasses, as prairie dropseed and tall dropseed, composed 81 percent of the vegetation in excellent range, 47 in good pasture, but only 7 percent in the fair class.

Increasers, mostly bluegrass, purple lovegrass, and side-oats grama, composed only 18 percent in excellent range, but 50 in good condition class. With blue grama they composed 66 percent of the vegetation in fair range. Here invading grasses furnished 21 percent.

Hundreds of samples were taken at random 8 paces apart and at a distance of only 9 feet on both sides of the boundaries between the range classes as mapped. Comparison of these samples from a total distance of 1.25 miles showed that they were remarkably similar in percentage composition to the samples taken in the experimental area in each range class, respectively.

Monthly and annual yield and consumption of forage was ascertained by means of 29-square-foot, movable exclosures and grazed control areas of the same size. Ten of these were used in the experimental area in each range condition class. By selective clipping, yield and consumption of decreasers, increasers, and invaders among grasses, and forbs were ascertained separately.

In excellent range 74 percent of the yield and 79 percent of the consumption was that of decreasers, and 17 and 13 percent, respectively, that of increasers, in 1950. But in fair pasture percent of yield from decreasers was 12 and consumption 13, but increasers furnished 53 and 54 percent, and invaders 13 and 13 percent, respectively. Variations from month to month are shown as well as differences between the years 1949 and 1950.

Yield and consumption per acre (May to October, 1950) were .89 and .77 ton in fair range, 1.92 and 1.20 tons in good range, and 1.53 and .86 tons in excellent range, where there was little bluegrass and an excessive mulch. The fair range was constantly and greatly overgrazed to secure .77 ton of forage per acre; the good pasture furnished 1.20 tons without overuse and left a third of the yield as a protective mulch on the soil. Also more forage was obtained from the lightly grazed excellent range, where the cattle selected only the very best. Yield and consumption were mostly greater during the wetter year 1949, but even less forage was consumed in excellent range.

Grazing preference was highest for big bluestem in all range condition classes. It was equally high for little bluestem in fair range but decreased greatly in good pasture and even more in excellent range. Preference for bluegrass increased from excellent to fair range. Nine species were studied.

To ascertain the causes of the irregular deterioration of the range, activities of the cattle were studied by continuously recording their behavior at 15 to 30 minute intervals.

The herd arose at daylight (4:00 a.m.) or within an hour or more thereafter and all the cattle were grazing by 6:00 a.m. Rising was much more prompt on a hot day but considerably delayed on a cool one. About 2 hours (7:00 to 9:00 a.m.) were spent drinking, licking salt, and standing about the ponds. On a cool day drinking was postponed until late afternoon. The time was spent in resting. On a hot day the cattle remained in or near the ponds until about 4:00 p.m. They then grazed until dark. Grazing on the typical day was resumed about 9:00 a.m. and, except for a short period for rest, continued until 12:00 to 12:30. Many cattle rested until about 4:00 p.m., when grazing was resumed as they slowly traveled toward a bedding ground. About two-thirds of the cattle visited the ponds once again but immediately returned and all had bedded down by dark. A part of the herd grazed an hour or two (11:00 p.m. till 1:00 a.m.) at night. Grazing was extended over a greater period on a hot night.

The major part of the grazing occurred between 4:00 and 8:00 a.m. and 5:00 and 9:00 p.m., when 67 and 71 percent of the herd, respectively, was thus engaged. About 10.5 hours were spent in grazing, nearly 5 in standing or traveling, and 8.5 hours lying down.

Cattle almost always grazed into the wind. There was a close correlation between the location of the cattle on any day and the direction from which the wind was blowing. The wind blew from a southerly direction on 48 percent of the days in summer of 1950, and from some southerly direction, mostly southeast, 45 percent of the time during a five-year period.

Location of water and salt, as well as direction of wind, greatly affected the amount of grazing and trampling in different parts of the range. In general, both became less as the distance from water increased. Much traveling also occurred to and from selected bedding grounds.

The pasture was marked off in 2.5-acre units and the distribution of the cattle recorded each 15 minutes during 16 days

(4:00 a.m. to 9:00 p.m.). Greatest concentration was in fair range adjacent to the ponds or salt, on hilltops, and favored resting places, often near the fences.

Movement of cattle through the pasture did not occur uniformly but nearly always either along paths or much wider, linear strips designated as grazing routes. These were generally found to be the easiest routes of travel as along ravines, crests of ridges, etc. Aside from topography and choice of forage, location of the ponds and salting place in the same area over a long period of years has resulted in a well-used network of paths and grazing routes which was mapped.

Grazing routes probably originated from the merging of isolated, preferred areas that have been grazed continuously for many years. Nearly all of them were clothed with vegetation in only fair range condition class. Some were bordered by excellent range class. They spread outward from the large continuous area of fair range class about the ponds and salting area to form an irregular network (least developed in the northern third of the range) which occupied about 20 percent of the pasture.

Factors affecting the distribution of the livestock and the consequent overuse of some areas and underuse of others are discussed. Methods of proper utilization of the forage are suggested. The resulting increase in forage and gains of cattle would quickly repay the investment required for their proper distribution.

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