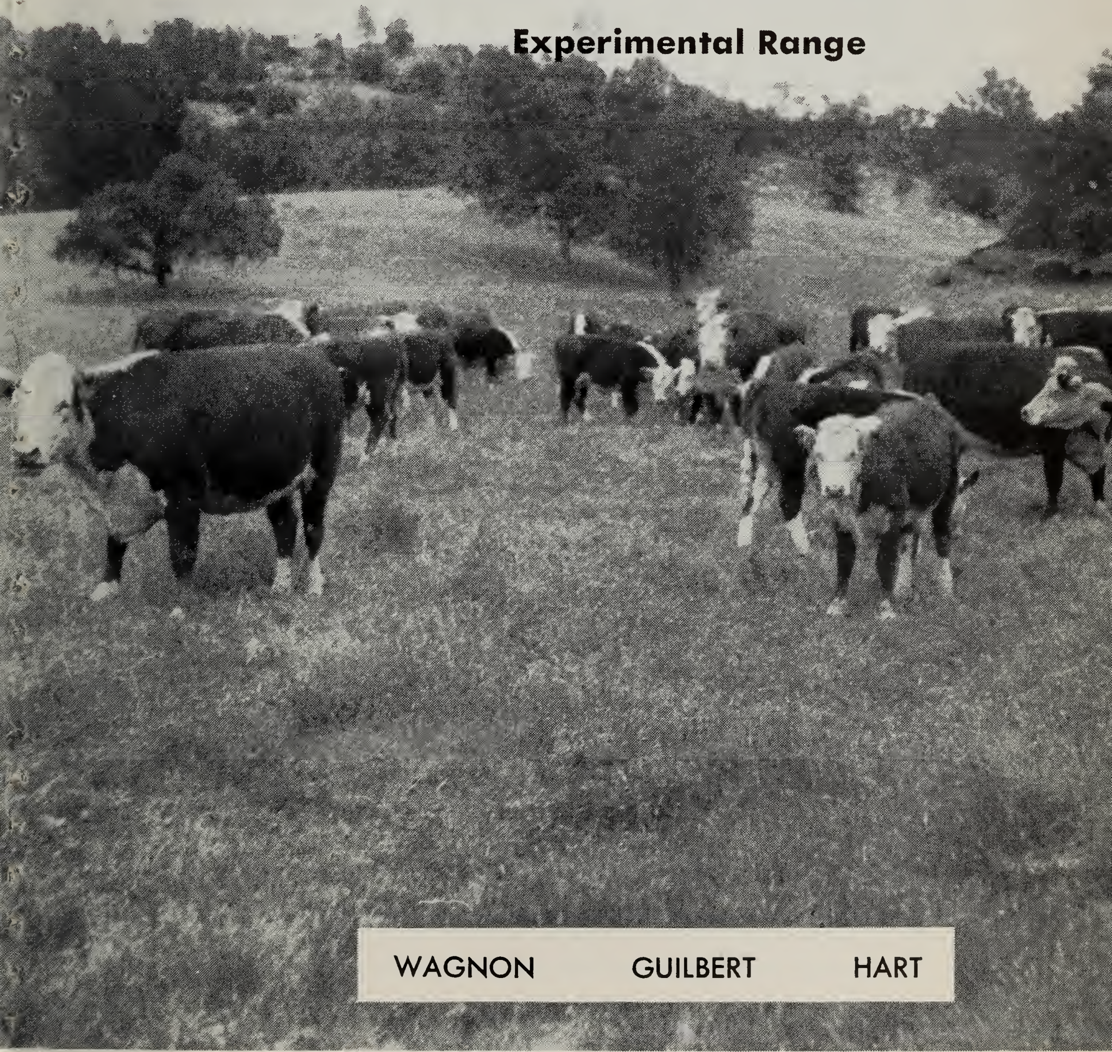
Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

BEEF CATTLE INVESTIGATIONS

on the San Joaquin Experimental Range



WAGNON GUILBERT HART

CALIFORNIA AGRICULTURAL
EXPERIMENT STATION

BULLETIN 765

In rangelands where annual plants make up most of the forage, pasturage is poor in fall and scanty in winter. On such rangelands . . .

Can beef cattle be kept in efficient production all year?

If so, how much acreage does it take?

Which nutrients are deficient in the forage and when?

What kind of supplements are needed to make up the deficiencies? How much of them? Will it pay to feed them to a breeding herd?

Is heavy stocking or moderate more profitable? Should pastures be used yearlong or rotated?

Can market cattle be finished on the range? Does it require supplements?

What gains can be expected?

What type of cattle enterprise is this range best suited to?

How much can a herd of ordinary range Herefords be improved by using good purebred sires?

To find the answer to such questions, experiments in beef-cattle production were carried out for thirteen years on a Sierra foothill range typical of the "granite" area, where most of the forage consists of annual plants. The data are to some degree applicable to many other areas of annual-type forage. The experiments showed that on this range . . .

By using supplements in the fall and winter, a breeding herd could be kept in efficient production year round on about 25 acres per cow.

The forage provided enough nutrients while the plants were green, but as plants matured and dried it became deficient in crude protein and low in phosphorus. Scant new forage growth during winter resulted in a deficiency of total energy.

The deficiencies could be met by feeding 1 pound of cottonseed cake per cow per day beginning about August 1, increasing this to 2 pounds when the cows began to calve, adding 1 pound of rolled barley after the first rains, and continuing this 3-pound ration until about February 1. Linseed meal could replace cottonseed cake in the ratio of 1⅓ pounds to 1. Fishmeal and molasses were also adequate supplements.

Feeding an average of 380 pounds of supplements per cow resulted in an average 83 per cent calf crop, the calves averaging 464 pounds at weaning. The unsupplemented herd had a 66 per cent calf crop averaging 406 pounds at weaning. This means 115 more pounds of weaned calf per breeding cow in the supplemented herd, or roughly $1.50 to $2.50 added income for each $1.00 of supplemental feed expense.

While heavily stocked pastures produced more beef per grazable acre than moderately stocked ones, the calves were in poorer flesh and worth less per pound. Cows kept yearlong on the same pasture, even through fed supplements during the fall and winter, had a lower percentage calf crop and a higher proportion of abortion and stillbirths than those on rotated pastures; but complicating factors make it uncertain whether the differences can be attributed—solely, at any rate—to the grazing practices.

Yearlings and 2-year-olds could not be finished for market without feeding them supplements during fall and winter, as well as during the finishing period. The amounts of supplements fed and the gains recorded for cattle marketed at these ages are reported in tables 7 through 11. Data on weaner calves are summarized in table 6.

Because of the frequency of poor forage years and the nutritional deficiencies of the range, this area is considered better suited for breeding-herd production and raising yearling feeders than for finishing yearlings on the range.

The use of Choice purebred bulls plus selection of replacement heifers and culling of cows on the bases of conformation and production records resulted in raising the average grade of the herds from Medium and low Good to Choice in eleven years.

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BEEF CATTLE INVESTIGATIONS ON THE SAN JOAQUIN EXPERIMENTAL RANGE[1]

K. A. WAGNON · H. R. GUILBERT · G. H. HART

INTRODUCTION

Earlier Work on Feeder Cattle in California

THE PROBLEMS of more efficient use of California's rangelands have been discussed since the turn of the century. Gordon H. True, while head of the Division of Animal Husbandry (1914–1926), made the first, but what proved to be an abortive attempt to study the problems. Through a special legislative appropriation of $50,000, a commercial herd of range cattle was purchased in 1920. Land was leased at Shingle Springs in El Dorado County which carried grazing rights on the Peavine Ridge and Wrights Lake areas of the Tahoe National Forest. The project, thereafter, was supposed to be largely self-sustaining—a dubious situation for the launching of any research enterprise. The great drop in cattle prices that shortly followed the initiation of this work soon resulted in depletion of available finances. Professor True's ill health coupled with failure at the time to appreciate the importance of the problems led to liquidation of the cattle and lease as a stop-loss procedure.

The investigation was ahead of its time and lacked public support. In its broad concepts, future production of feeder cattle on the ranges and the finishing in the valleys on pasture and in feedlots was visualized—a situation that was soon to be realized, but which was very unpopular with cattlemen at the time. Nevertheless, some start was made on obtaining information that soon was required by the industry. Calves and yearlings produced on the foothill and mountain ranges were fattened by the use of concentrates both on irrigated pasture and in feed lots (Howell, 1927).

Interrelations of heredity and environment were, perhaps, not fully appreciated by the investigators at the time. Probably too great reliance on "good bulls" as a "cure-all" with two little provision for research on environment, particularly specific knowledge of the nutritional limitations of the natural forage, were weaknesses of the original plan.

This was a period when California was known as a good place to eat lamb, a poor place to eat beef, and a very poor place to eat pork! Later competition of dressed meat from the Middle West and feedlot finished cattle from Colorado imported to meet the demand of a rapidly

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expanding population accustomed to "quality" beef quickly changed the thinking of producers in this state. Feedyards were rapidly installed and the quality of beef brought to the equal of that in any part of the country.

Establishment of the San Joaquin Experimental Range

Federal foresters coöperated in the present effort to tackle this enormous range problem, particularly E. I. Kotok, who later became Director of the California Forest and Range Experiment Station established by the U. S. Forest Service at the University of California in Berkeley. It was mainly through his efforts that the Government acquired in 1934 the land at O'Neals, now known as the San Joaquin Experimental Range (Talbot, Nelson, and Storie, 1942). The Forest Service then invited the University of California to place the livestock on the land and coöperate with them to the extent of carrying out the animal husbandry investigations.

When the coöperative agreement was arranged, the University in June, 1935, placed 70 head of grade Hereford 2-year-old bred heifers on the land, and registered purebred bulls were supplied from the University Hereford herd at Davis. One member of the staff of the Division of Animal Husbandry was placed in residence at the Experimental Range. An Advisory Committee of beef-cattle producers representing a wide area in the state, with Harvey Russell of Madera as chairman, was appointed by the Forest Service at the beginning of the work. These men gave valuable aid in the general planning of the procedures, and counsel as the experiments progressed.

Broad Objectives of the Coöperative Work

The general plan of the experiments was subjected to much discussion. Considered was the possibility of moving animals from the Experimental Range to National Forest areas in the high Sierra during the summer—a practice of livestock men long before the U. S. Forest Service was established. On the basis that the cattlemen's investment was largely in these foothill lands and future use of public lands was uncertain, it was finally decided to study means of efficient beef production with the breeding herd maintained year-long on the foothill range.

The broad objectives were to determine the limitations of the natural forage, and to manage livestock operations including the use of supplements to permit the animals to produce the most pounds of meat per acre consistent with maintenance of optimum productivity of the vegetative cover. Data were collected which would permit comparison of the effects of overgrazing on the annual plant growth that predominates in this area with similar information on perennial grasses in other regions, which largely formed the basis of the concepts of range management practices advocated by professional range managers.

An earlier publication (Hutchison and Kotok, 1942) gives a detailed description of the area, outlines the general program and the organization of the work, and reports experimental results of all phases of the project from 1935 to 1940. Studies on the effect of environmental factors, including livestock, on forage production, extending from 1935 through 1948, were also published (Bentley and Talbot, 1951). Some papers dealing with specific phases of the general program are cited later.

Specific Objectives of the Present Studies

This publication deals with all phases of the cattle investigations during 1935 through mid 1948, when the experiments herein reported were terminated. These experiments were directed principally toward determining the effects of the unimproved range and of certain management practices upon percentage calf crop, weight at weaning, growth of young stock, and weight of breeding animals. The management practices studied were mainly (1) feeding animals (both breeding herd and young stock) on range forage alone *versus* supplemental feeding designed to compensate for seasonal nutritional deficiencies in the forage; (2) rotational *versus* yearlong grazing; and (3) heavy *versus* moderate and light stocking. Some tests of different methods of supplemental feeding were included.

Another important objective of the investigations was to collect data on the relative advantages, under the conditions of this range, of finishing animals on the range with supplements and of disposing of fleshy feeders as calves, yearlings, or 2-year-olds to go into valley feedlots.

A third objective was to determine how much the breeding herd, originally of ordinary range quality, could be improved by the use of purebred bulls.

Although ascertaining causes of cattle morbidity and mortality was not a planned objective of these investigations, experimental conditions afforded an opportunity to collect more complete data on such causes than would be feasible on a commercial ranch, and the information was considered of sufficient interest to include.

RESUMÉ OF CLIMATIC CONDITIONS AND FORAGE PRODUCTION

The relation of climatic factors, forage growth, and livestock production is an old story to the range stockman. Rainfall not only varies from year to year, but also varies in wet and dry cycles of several years' duration. The average annual range and pasture condition is likewise quite variable (fig. 1), and while very good and poor forage crops may occur in alternating years, it is also possible to have a series of successive good or poor forage years. Since the range-cattle experiments reported herein are concerned with management procedures year-round upon the same range area, the effects of climatic factors upon the quantity and quality of forage produced are highly important.

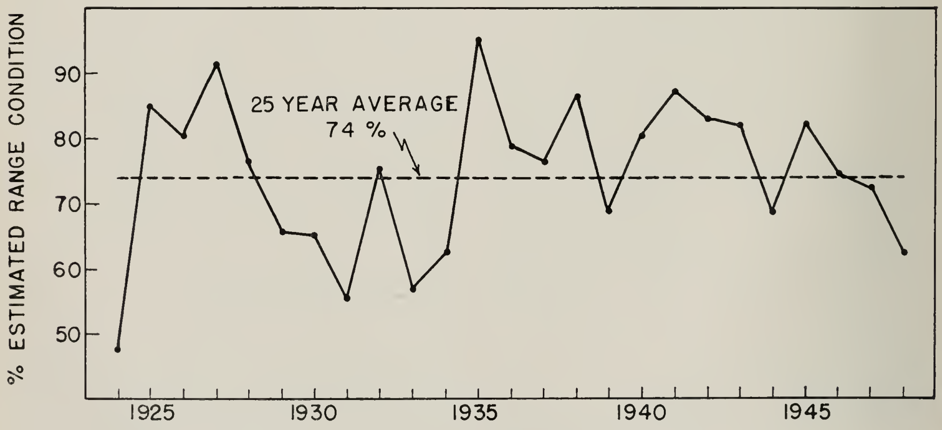

Fig. 1. Average yearly range and pasture condition for the San Joaquin Valley area, 1924 through 1948.

Data reported by California Crop and Livestock Reporting Service.

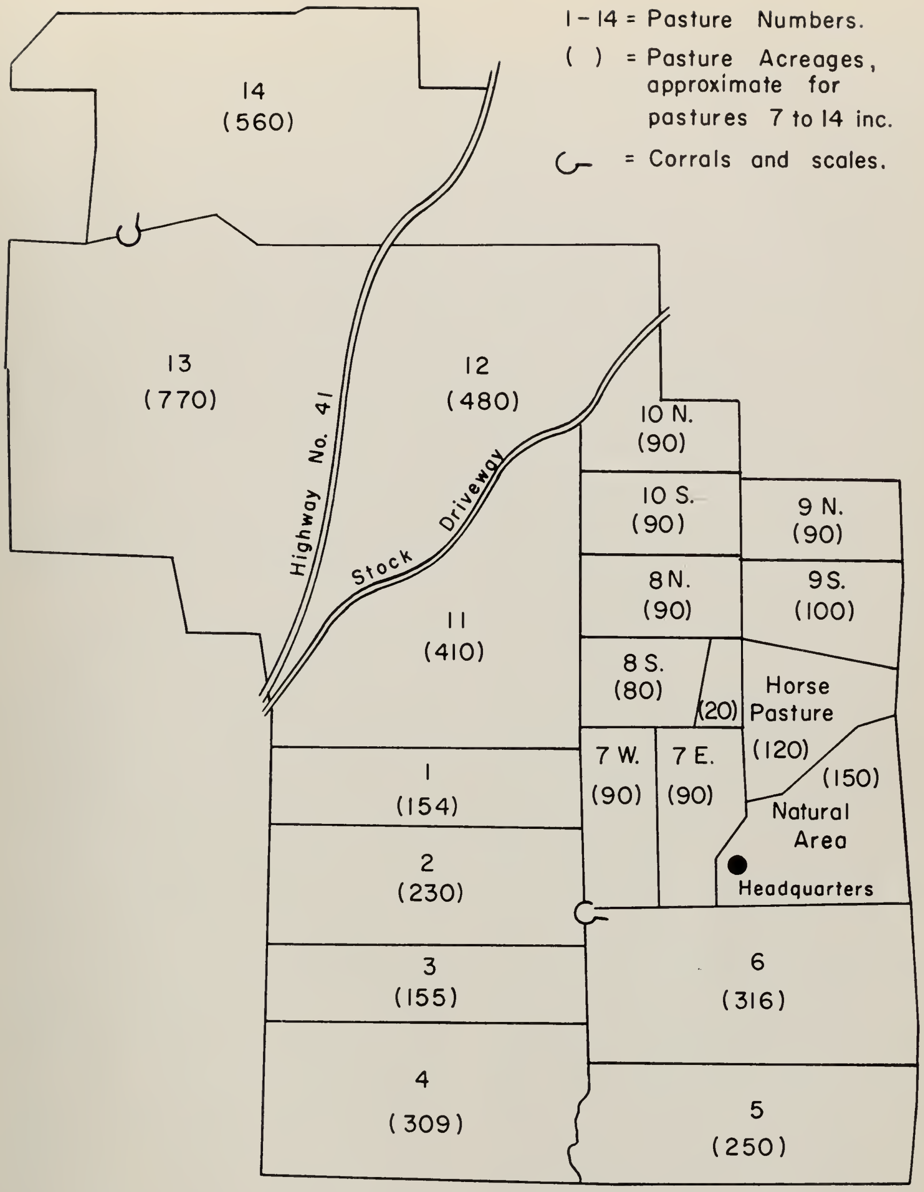

Fig. 2. Pasture diagram of the San Joaquin Experimental Range. Some of the original pastures, designated by numbers, were later divided into north and south, or east and west, sections.

The Experimental Area

The San Joaquin Experimental Range is an area of about 4,600 acres (Talbot, Nelson, and Storie, 1942) near the center of the state, in the so-called "granite" area of the Sierra Nevada foothills. The land is rolling, exposures in general southwesterly, and the elevation ranges from 700 to 1,700 feet above sea level, with most of the area between 1,000 and 1,500 feet (fig. 2). The area is typical of large areas of the poorer soil types in the foothills throughout the state; it is characterized by frequent granitic outcrops, and the soils are mostly residual and formed from the decomposition of the underlying granitic bedrock. About 12 per cent of the area is in narrow stringer-type swales consisting of a darker alluvial soil. Soil depths over much of the area are less than 2 feet.

The area is subdivided into a number of pastures (Bentley and Talbot, 1951; Talbot and Biswell, 1942). A study of the effects of different intensities of grazing on range and cattle was conducted in pastures 1 to 6. Studies on supplemental feeding of breeding cows were conducted in pastures 11, 12, 13, and 14. The remaining pastures were used for studies on supplementing weaner calves, pasture finishing, and pasturing of miscellaneous animals. To facilitate the weighing and handling of cattle two corrals were constructed, each with scales, large-animal squeeze chutes, and calf chutes.

Vegetation is of the woodland-grass type. The tree and brush cover consists of scattered trees of digger pine, blue oak, interior live oak, and California buckeye, with a variable shrub cover consisting mostly of wedgeleaf ceanothus and whitethorn ceanothus with considerable hollyleaf buckthorn. Other common woody plants are coffeeberry, Mariposa manzanita, elderberry, and poison oak. The herbaceous plant cover consists mainly of annual plants, many of which have been introduced from the Old World. In their study of this forage cover Talbot and Biswell (1942) found that it was composed of over 225 different species, but that the bulk of the forage was composed of broadleaf filaree, soft chess, and foxtail fescue. Perennials, mostly rushes, compose about 3 per cent of the forage cover (Bentley and Talbot, 1951). Bur-clover and redstem filaree, highly valued annual range plants, do not occur in significant amounts. There are, however, several true clovers and a lotus (Spanish clover) that are important constituents of the forage cover. Only two known poisonous plants, Mexican whorled milkweed and durango root (Wagnon and Hart, 1945), have been found on the area.

Rainfall and Temperature

The data in figure 4 (pp. 16, 17) show considerable variation in total annual rainfall, with a high of 31.90 inches in 1937–38 and a low of 12.42 inches the following season. Marked variations in total monthly rainfall for the same months of the twelve periods may also occur, as shown by a high of 9.94 inches in January, 1940, as compared with 0.06 inch for January, 1948. The average annual total rainfall for the twelve seasons reported was 19.21 inches, as compared with an estimated average of 17 to 18 inches (Bentley and Talbot, 1951).

The curves of monthly mean air temperature show considerable similarity for all of the twelve seasons. The monthly mean air temperature frequently drops below 50° F in November, where it remains through December and January, frequently through February, and at times even March. In two of the winters, 1936–37 and 1946–47, the monthly mean air temperature dropped below 40° F. In January, 1937, minimum temperatures dropped to a low of 16.9° F.

Common and Botanical Names of Plants Mentioned

Trees and shrubs

Blue oak	*Quercus douglasii*
California buckeye	*Aesculus californica*
Coffeeberry	*Rhamnus californica* supsp. *cupsidata*
Digger pine	*Pinus sabiniana*
Elderberry	*Sambucus glauca*
Hollyleaf buckthorn	*Rhamnus crocea* var. *ilicifolia*
Interior live oak	*Quercus wislizenii*
Mariposa manzanita	*Arctostaphylos mariposa*
Poison oak	*Rhus diversiloba*
Wedgeleaf ceanothus	*Ceanothus cuneatus*
Whitehorn ceanothus	*Ceanothus leucodermis*

Broad-leaved herbs and grasses

Broadleaf filaree	*Erodium botrys,* and *E. obtusiplicatum*
Bur-clover	*Medicago hispida*
Durango root	*Datisca glomerata*
Foxtail fescue	*Festuca megalura*
Maiden clover*	*Trifolium microcephalum*
Mexican whorled milkweed	*Asclepias mexicana*
Redstem filaree	*Erodium cicutarium*
Soft chess	*Bromus mollis*
Spanish clover	*Lotus americanus*
Spurge	*Euphorbia ocellata*
Tomcat clover*	*Trifolium tridentatum*
Tree clover*	*Trifolium cilialatum*
White-tip clover*	*Trifolium variegatum*

*True clovers.

Climatic Factors and Forage Growth

The quality and quantity of feed supply varies markedly from season to season according to rainfall and its distribution in relation to temperature. Nutritional deficiencies constitute a major problem of yearlong management of cattle. The amounts and time of precipitation and also soil temperature are highly important in the germination of the new forage crop, as well as its subsequent growth and species composition. Talbot and Biswell (1942) have shown that about 0.8 inch of rainfall is needed to insure a good germination of the new forage crop. If the initial rain is received in October, and subsequent precipitation is adequate, a fair amount of new forage growth may occur before the mean air temperature drops below 50° F and retards growth. In general forage growth during the fall and midwinter months is slow and uncertain. While snow is rare, winter temperatures frequently fall below freezing. The value of some old forage left upon the ground as a protection to the new forage crop is well known, and studies (Talbot and Biswell, 1942) have shown that under

The cover picture shows the contours and cover in the experimental area.

moderate grazing, forage growth was usually two or three weeks in advance of that upon closely grazed areas.

Rapid forage growth usually starts with rising temperatures, about March 1, and if the soil moisture is adequate the growth may be quite vigorous. Droughty conditions after this time not only restrict forage growth, but may also result in a great reduction of some species such as clovers. The marked effects that fluctuation of rainfall and temperature had upon the composition of the forage cover, for the years 1935 through 1949, are shown by Talbot and Biswell (1942). During this 5-year period the broadleaved plants varied from 43.5 to 74.8 per cent, the grasses from 20.6 to 55.5 per cent, and the grasslike plants from a trace to 3.6 per cent of the total forage cover.

Many of the annual plants may begin to dry the latter portion of April, but here again the rate of maturity and drying are greatly dependent upon moisture and temperature conditions. Rapid drying of the forage usually occurs in May; however, some green forage is usually available in the swales and upon easterly slopes through June. Some years, small amounts of green Spanish clover and a small spurge will be available until September.

The annual fluctuation of forage production per grazable acre for the period embraced in this study, is given by Bentley and Talbot (1951). While the average annual production of air-dry forage per acre was about 1,640 pounds, it varied from a low of 1,200 pounds to a high of 2,350 pounds. Detailed data on the variability in length of the "inadequate green forage period," "adequate green forage period," and "dry forage period" resulting from fluctuations in climatic factors, and on variations in forage production according to range-site classification, are also given.

With the complete drying of the forage cover there is little change in the forage composition except for "weathering." If the forage contains a high percentage of broadleaved plants, many of these will crumble and distintegrate so that their availability to livestock is greatly reduced. Rodents, trampling by grazing livestock, and wind hasten the process. Unseasonal rains upon the dry forage have been found (Guilbert, Mead, and Jackson, 1931) to decrease the nutritional value of the forage by leaching constituents of silica-free ash and nitrogen-free extract. Besides being of reduced value nutritionally, rained-upon dry forage is usually lowered in palatability. It should also be mentioned that the consumption of blue oak acorns by cattle subsisting on the dry range forage resulted in substantial weight losses (Hart, Guilbert, *et al.*, 1947).

Annual plants have the facility of producing viable seed under quite adverse growing conditions. Studies by Glading, Biswell, and Smith (1940) have shown that in the top ½ inch of plant litter and soil there was about 334 pounds of seed per acre. Thus it is evident that a more than adequate supply of seed is always available. While heavy germinations occur some years, evidence that all the seed does not germinate yearly is demonstrated by the marked variation in species composition of the forage crop that may occur in alternate years, or the heavy forage growth that may occur in a favorable year following a series of droughty years.

Seasonal Changes in Chemical Composition of Range Forage

Hart, Guilbert, and Goss (1932) studying the nutritive value of several of the principal annual forage plants from several range areas over the state, showed there was a marked seasonal change from a high nutritive value in the early growth stages to a low and often deficient nutritive level after drying. They also found that bur-clover and redstem filaree were of higher nutritive value

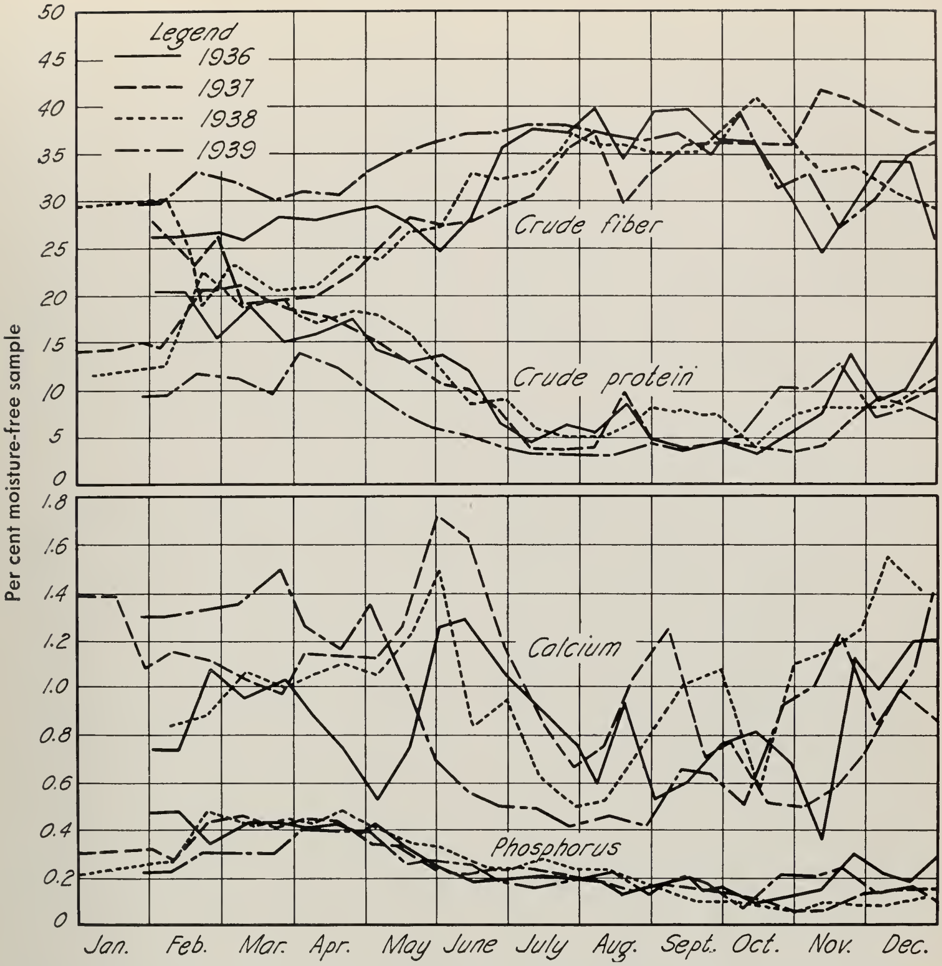

Fig. 3. Seasonal variation in chemical composition of forage samples collected to represent forage grazed by the cattle during 1936 to 1939 inclusive.

after maturity than were the majority of annual range plants. Gordon and Sampson (1939) made a similar study of the principal herbaceous plants, as well as the shrubby species, of the experimental area.

In order to secure information for this area on the varying seasonal plane of range-cattle nutrition within a single year, and also between years, grazing cows were observed and samples of the forage species being grazed were collected and analyzed from 1936 through 1939 (Wagnon, Guilbert, and Hart, 1942). The graph summarizing the data is reproduced in figure 3. The results indicated that protein content on a dry basis decreased from around 20 per cent early in the season to about 5 per cent by late July, and remained at fairly low levels until late fall. Calcium content, while erratic, was adequate at all times. In one year (1938) phosphorus was probably deficient in late fall. The results of this study and the ones on forage consumption and production were taken into consideration in planning the supplemental-feeding program.

Vitamin A deficiency has been shown to exist upon some California range areas (Hart and Guilbert, 1933) with a resultant lowering of reproductive efficiency of range cows. During the period of this study there have been no manifestations of a deficiency of this essential vitamin in any of the experimental groups. The few late-growing herbaceous plants plus a small amount of browse are very likely important sources of vitamin A after the bulk of the forage has matured and dried.

Forage Consumption

While the above data illustrate the seasonal changes in chemical composition of the forage consumed by the cows, they give no information on seasonal fluctuations in their forage consumption. The amount of new forage growth during the late fall and winter months is dependent upon the relation of several factors, particularly the amount of new seed germination, temperatures, available moisture, protection by old forage cover, and soil fertility. Immediately after the germination of the seeds the animals concentrate their grazing activities on the new growth even though it may only be about ½ inch in height. While the cattle avoid the old leached dry forage as much as possible, they are forced to eat certain quantities since the new seedlings usually make the most rapid early growth where protected by some old forage (Talbot and Biswell, 1942). On the other hand, they usually avoid the areas covered by a heavy mat of old forage because so much of the old leached herbage has to be eaten to get a small amount of new succulent growth. While the new forage growth is high in protein and mineral content it is also high in water content. Thus, for varying periods (Bentley and Talbot, 1951) during the winter months the cattle are feeding upon a forage growth that is not only inadequate in supply, but is also low in total digestible dry matter. In other words, the animals simply do not get enough to eat, even though there may be a superabundance of old dry feed; hence during this period we have a varying deficiency of total energy intake.

Variations in Forage Production

While above-average rainfall years often produce above-average forage crops, such is not always the case. Monthly rainfall distribution plus minimum air temperatures have been shown to have a direct influence upon new plant germination and growth (Bentley and Talbot, 1951; Talbot and Biswell, 1942). For example, in the 1936-37 season, with a total rainfall of 23.02 inches and with the monthly mean air temperature dropping to a low of 36.1° F, production of air-dry forage was 1,400 pounds per acre. In the 1944–45 season, with a total rainfall of 18.98 inches and the monthly mean air temperature dropping to 41.1°, forage production was 2,350 pounds per acre. The 1937–38 season, with the highest total rainfall of 31.90 inches and a monthly mean air temperature low of 43.6° F, produced only 2,200 pounds of forage per acre.

GENERAL MANAGEMENT PRACTICES

Herds A, B, and C

The foundation females for the experimental herds consisted of 70 head of 2-year-old, bred Hereford heifers grading Medium to Good. They were purchased in June, 1935, and all received supplemental feed during the fall and winter of 1935–36. They calved during October, November, and December. In January, 1936, they were divided into two comparable groups consisting of 33 head each, together with their calves. The plan was to feed supplements to herd A during the latter part of the summer, fall, and winter—the *supplement period*—until green forage would sustain the cows nursing calves. The objective was to feed amounts and kinds of supplements that, together with the range forage available, would meet the minimum nutrient requirement of the cattle for efficient production and reproduction. Herd B was to serve as a control and subsist on range forage alone except in emergency to prevent excessive death loss.

Because of the necessity of using these same animals in grazing-intensity investigations, conducted by the U. S. Forest and Range Experiment Station personnel (Talbot and Biswell, 1942; Bentley and Talbot, 1951), the general management of the herds was not strictly comparable with usual practice. From February 1 to August 1—*grazing period*—on the average, the cows of both groups ran together, being equally divided among pastures 1 to 6, which varied in size and forage production. The calves were dropped largely during October, November, and December and were weaned and removed from the six pastures the first of July at about eight months of age. From August 1 to February 1 (*supplement period*) the two herds were separated and placed in their respective fall and winter pastures. In general herd B had some advantages in amount of dry forage and distribution of north and south slopes. Both herds were allowed about 15 acres per head during the period. These pastures were subjected to little or no grazing between February and August. Thus the general management was fairly comparable to a commerical ranch where one portion of the range is used consistently for fall and winter pasture, and another during the growing season and early part of the dry forage period.

Because of the experimental design, the cattle could not always be moved to fresh feed when indicated by the condition of the forage or of the cattle, nor could supplemental feeding of herd A always be started as soon as trends in weights showed that it was desirable.

Later (1941) herd C was established on the basis of yearlong grazing in one pasture with supplemental feeding comparable with that for herd A.

Culling and the selection of replacements are discussed in detail in a later section, "Herd Improvement through Selective Breeding." Management practices and experimental methods used only in certain tests are described in connection with the relevant experiments.

Supplement-feeding Methods

On the basis of the information derived from the seasonal changes in chemical composition of the forage (fig. 3), the condition of the range, and the condition and weight changes of the cattle, an attempt was made to feed the concentrate supplements to buffer the difference between the more or less constant demand for nutrients by the cattle and the variable supply of nutrients from the forage. The general procedure was about as follows:

One pound per head daily of cottonseed cake (43 per cent protein) was fed beginning in August. From the start of calving until the first rains, 2 pounds daily were fed. At the time of the first rains, 1 pound of barley was added, bringing the total supplements to 3 pounds daily. This rate was continued until new forage growth was sufficient to discourage the cattle from coming to the feeding grounds for supplement. The total amount fed varied from 288 to 482 pounds per head according to the length of the period and the rate of feeding (a heavier rate was required in some years).

The first two calf crops are omitted from the summary because the cows all had similar treatment until after the breeding period for the second calf crop. Thus the effects of the two nutritional regimens did not become fully operative until the third calf crop in 1937.

Supplements were fed in troughs so as to prevent the loss of fine material. The troughs were so located in the pastures that cattle in all parts of the field might hear the feeder calling. It became general practice to call the animals at feeding time, and not round them up, because when the latter method was tried some animals appeared to acquire the habit of waiting for the feeder to come after them rather than responding to calling. Trough space was provided so that the animals were not crowded at feeding. The cattle were fed first thing in the morning. This made it possible to treat sick or injured animals the day found if necessary. It was also easier to take care of calving animals because there was time to hunt them up, if deemed necessary, the first day they failed to report for feeding.

Feeding and Conditioning of Bulls

In our breeding program it was ncessary to keep breeding records of each bull. Since our bulls were placed with the cows about December 28 when the poorest forage conditions of the year prevail, and at least two of the bulls were placed with as many as 45 cows each, it was essential that they be in good flesh when turned out.

In general the bulls subsisted upon native forage during the green-forage period. After the forage matured and dried they received alfalfa hay free choice, in addition to range forage. From late September until they were turned in with the cows they were fed about 6 pounds of grain mixture per head daily in addition to alfalfa hay. In order that the younger bulls might get their share of grain it was found necessary to feed them apart from the older or more aggressive animals. The bulls do not eat the supplements well when fed with the cows, since they usually take advantage of the daily assembling of the cows to see if any are in heat. The bulls were removed from the cow herd May 1.

Weighing

Since the animals were weighed individually frequently throughout the year care was taken in rounding them up and drifting them to the corrals so as to hold handling shrinkage to a minimum. From 1935 through 1939 the animals were weighed on a "full" basis. It was found, however, that the animals did not drink normally when offered water at the corrals before weighing and that there was considerable variation in fill. From 1940 on, in order to reduce the variation as much as possible, the animals were rounded up, allowed to water in field when possible, and drifted to the corrals shortly before nightfall. They were then confined to a corral for the night without feed and water and weighed first thing the following morning.

Branding, Castrating, Dehorning, and Vaccinating Calves

At the start of our experiments the calves were thrown to the ground and stretched out with ropes for the marking process. Calf chutes (both homemade and manufactured) were shortly added to our corral facilities and it was then possible to mark the calves with considerably less labor and gentler handling. In general it is our practice to mark the calves by the time the oldest are three months of age.

Dehorning was done with either stick caustic or caustic paste throughout the study period. Good results were obtained but care must be exercised in the use of the caustic or horn stubs will result.

Castration was done by cutting off the lower third of the scrotum, slitting the membrane covering each testicle, forcing out the testicles and severing their cord by scraping with a knife.

Branding was not done at the time the calves were marked as they were usually too small for the recorded brand and the individual number branded below the brand. For this reason they were tattooed when castrated and dehorned and then branded with caustic branding fluid about April when the weather was warmer and the calves larger.

Vaccinating for blackleg is also done at the time the calves are marked.

Blackleg is the only disease for which vaccinating was necessary. At the close of the experimental period vaccinating for brucellosis was initiated as an annual practice with the weaner heifers being kept for possible replacements.

FORAGE PRODUCTION AS MEASURED BY LIVESTOCK WEIGHT CHANGES

Since the weaning of the first calf crop June 30, 1936, a group of unsupplemented heifers have been raised each year. These heifers were raised as replacements for the unsupplemented breeding herd, from which they originated and consequently, only the supposedly better animals were kept.

During the Dry-Forage Period

After weaning, the group of heifers was placed in a pasture (a portion of pasture 8, 9, or 10, fig. 2) that had not been previously grazed that year. They were maintained here through the dry forage period and the winter period immediately following. With the advent of sufficient new forage growth to promote continuous rapid weight gains, the animals were moved to various other pastures. An attempt was made to maintain a moderate to light degree of stocking. No supplements other than plain stock salt were fed except for the 1937–38 winter, when it was thought necessary to feed the heifers 1 pound of supplements per head daily over a 48-day period to prevent death losses. The average weight curves of each of the heifer groups raised for the forage years 1936–37 through 1947–48 are presented in figure 4, along with a summation of the total monthly rainfall and monthly mean air temperature for each 12-month period. Each curve is a measure of feed conditions as reflected in animal gains and losses. A comparison of the curves indicates the variation in feed conditions between seasons and the influence of these upon the animals.

As previously stated, the mature dry forage crop, upon which the weaner heifers are first pastured, was produced by the previous growing season. Weight gains during this period, until rains of 0.5 inch or more start new plant germination, are mostly a reflection of the abundance of late-growing green plants such as the perennial rushes in the swales, and Spanish clover and spurge upon the slopes. The marked weight gain of the heifers at the start of the 1938–39 season is a reflection of late forage growth from the preceding wet 1937–38 season.

The heifers made initial weight gains in all the seasons except 1946–47 and 1947–48. The preceding forage growing periods for these two seasons were droughty, and consequently the forage not only dried early but was low in leguminous plants. In addition late rains leached the forage that had dried early.

At times a heavy acorn mast will result in marked animal weight losses even though the dry forage is of average value. Thus, in 1937–38, 1940–41, and 1942–43 there were weight losses from the ingestion of live-oak and blue-oak acorns before the advent of new forage growth. In 1943–44 there was a combination effect of acorn ingestion and leached dry forage. If fall rains start new forage growth before the acorns drop (1936–37) the green forage offsets the adverse effects of the acorns. In general, new forage has been started by the time the live-oak acorns begin dropping, but this was not so in 1937–38 and 1943–44.

Immediately after seed germination there is a marked reduction in rumen fill[3] (as determined by overnight shrinkage and some paunch measurements)

[3] Wagnon, K. A., and H. R. Guilbert. Unpublished data.

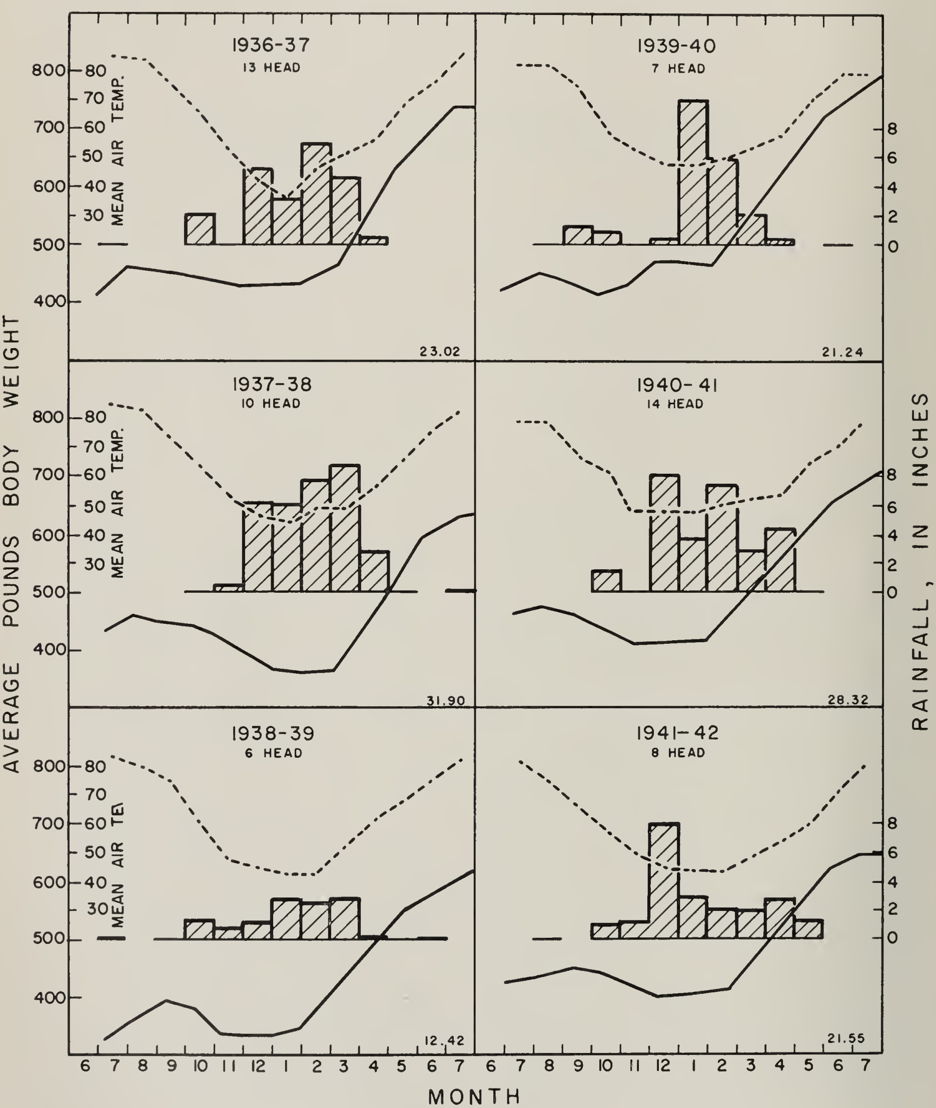

Fig. 4. The average weight curves of weaner heifer groups for the first year after weaning, with the monthly rainfall total and monthly mean air temperature. No supplements, other than plain stock salt, were fed except for a 48-day period in the 1937–38 winter.

as the heifers concentrate their efforts upon the new forage growth. Thus, the actual animal weight losses at this time were exaggerated. During the subsequent period of uncertain plant growth, livestock weight changes are mostly a reflection of new plant development. But during this period livestock weight losses may also be increased by exposure from adverse weather. This occurred during the extremely wet 1937–38 winter.

The dry-forage period plus the period of new forage development, up until the new forage growth has developed sufficiently to promote rapid animal

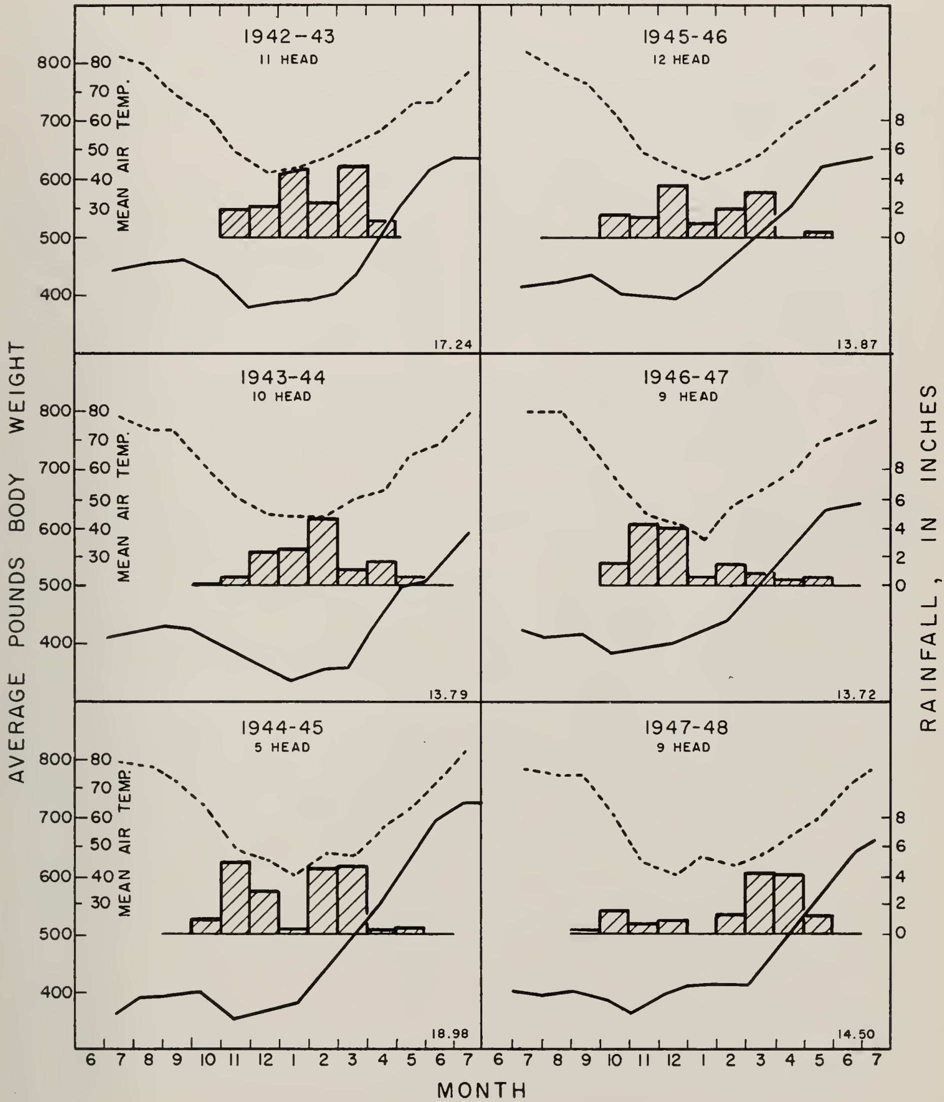

Fig. 4 (continued). For the text of this legend see page 16.

weight gains, has been termed the "supplement period" in this study. If the heifers suffer marked weight losses, in both phases of the supplement period, as in the 1937–38 season, the total weight loss may be considerable. On the other hand, substantial weight gains may also occur (1939–40). On the average (fig. 4), however, the heifers complete this period of about 7 months weighing about what they did at weaning.

During the Green-Forage Period

The period from the start of rapid continuous animal gains until their cessation with the drying of the forage crop has been termed the "grazing period" in this study. The heifer weight gains during this period are a measure of the growth of the new forage crop, the length of time green forage is available, and to some extent the quality of the forage; since the heifers (fig. 4) were always provided with more than adequate amounts of forage during this period, their weight gains were *not* a measure of total forage production. Average animal weight gains for the grazing period are variable, as for the supplement period, and range from a low of 219 pounds in the short droughty season of 1946–47 to a high of 347 pounds in the 1944–45 season.

Seasonal Total

As expected, the average total animal weight gain is quite variable, ranging from a low of 179 pounds in the 1943–44 season to a high of 366 pounds in the 1944–45 season.

SUPPLEMENTED VERSUS UNSUPPLEMENTED RANGE FORAGE FOR THE BREEDING HERD

Relation of Plane of Nutrition to Reproduction: Previous Work

The relation of plane of nutrition and of deficiencies in specific nutrients to reproduction in cattle has been reviewed by Hart and Guilbert (1928) and by Asdell (1949). Phillips (1949) and Guilbert (1942) reviewed the general relations of diet and reproduction and the endocrine relation involved in nutritional reproductive failure. Data collected under range conditions have shown that low percentage calf crop generally follows drought years and that wide fluctuations occur that are correlated with feed supply and condition of the cattle before and during the breeding season. Detailed studies have shown that general undernutrition involving significant weight loss will prevent the occurrence of heat; so will protein, phosphorus, or other deficiences that depress appetite. In addition to general systemic affect of low energy intake, the evidence indicates that the pituitary production of gonadotrophins is reduced. Protein and amino acid deficiency may have specific effects in this regard. There is thus a double effect upon the testes and ovaries which makes the reproductive function more sensitive to inadequate nutrition than other physiological functions. Since this tends to prevent the onset of reproduction under conditions that might jeopardize the life of both mother and offspring, it probably has value for survival of species in nature and is concerned with the cycles of abundance and scarcity of wild species that are related to the feed supply.

There is some indication that the degree of negative nutritional balance as well as the actual condition of flesh of the animal is involved in suppression of heat. Thus animals losing weight rapidly on a very poor ration may cease ovulating rather quickly and before reaching a state of emaciation. Very thin animals, on the other hand, may return to regular estrous cycles when returned to a high plane of nutrition and before they reach the condition at which cessation occurred during privation. Lactation in cows constitutes a nutritional drain affecting the degree of negative balance or rate of recovery of condition and thus also affects recurrence of heat after parturition. Endocrine relations concerned with lactation may also have some suppressing effect. This is a dominant factor in absence of heat during lactation in the pig and rat but evidently is of minor importance in the cow since under favorable conditions most cows will come into heat within 30 to 90 days after calving.

Table 1. Effects of Supplemental Feeding upon Reproduction, Weaning Weight, and Production per Breeding Cow

Item	Herd A, 1937–48	Herd B, 1937–48	Herd C, 1942–48
Supplement program:			
Average amount fed per cow	380 lbs.*	. . . †	424 lbs.*
Average length of period	175 days	. . .	187 days
Reproduction data, animal numbers			
Total cow-years	478	469	163
Cows culled	71	55	33
Replacements:			
Bred	2	3	6
Unbred	88	75	37
Total possible pregnancies‡	415	423	131
Dry cows	40	104	23
Pregnancies	375	319	108
Deaths:			
At parturition	5	4	1
Other causes	2	5	2
Stillbirths and abortions	20	21	15
Calf losses before weaning	13	18	5
Calves weaned	344	281	88
Reproduction data, percentages	per cent	per cent	per cent
Dry cows, per cent of possible pregnancies	9.6	24.6	17.6
Pregnancies, per cent of possible	90.4	75.4	82.4
Stillbirths and abortions, per cent of actual pregnancies	5.3	6.6	13.9
Calf losses before weaning, per cent of live births	3.7	6.0	5.4
Percentage calf crop: calves weaned as a per cent of possible pregnancies	82.9	66.4	67.2
Data on weaned calves			
Average weaning age	240 days	230 days	226 days
Average weaning weight	464 lbs.	406 lbs.	412 lbs.
Average pounds weaned calf per breeding cow	385 lbs.	270 lbs.	285 lbs.

* Concentrate supplement. Herd A, during one year when short of natural roughage, was fed an average of 135 pounds of alfalfa hay and 562 pounds of poor-quality grain hay per head. Herd C had 575 pounds of the grain hay per head in addition to concentrates during this year.

† Herd B was fed 125 pounds of supplement during a 64-day period in 1937 to prevent excessive death loss.

‡ The discrepancies between total cow-years, total culled, replacements, and possible pregnancies are caused by including records of known abortion or nonpregnant status of cow prior to culling.

Table 2. Percentage Calf Crop and Weaning Weight in Relation to Age of Dam on Two Planes of Nutrition

Herd A fed supplements, herd B no supplemental feeding

Age of cow, years	Number of cows		Percentage calf crop		Average weaning age, days		Average weaning weight, pounds		Production per breeding cow, pounds	
	Herd A	Herd B	Herd A	Herd B	Herd A	Herd B	Herd A	Herd B	Herd A	Herd B
3.....	69	64	87	73	240	232	446	406	388	296
4.....	61	57	82	65	226	221	442	396	362	257
5.....	80	81	79	59	239	231	469	392	370	231
6.....	59	60	80	68	241	231	482	426	385	290
7.....	43	50	88	80	232	229	465	432	409	346
8.....	31	37	77	68	234	216	466	414	359	281
9.....	21	21	71	76	245	226	482	416	342	316
10.....	15	10	100	50	239	257	454	425	454	212

Calf Production in Herds A and B

The average results for the 11-year period, 1937 to 1947 inclusive, are presented in table 1. Table 2 presents data on percentage calf crop and weaning weight of calves in relation to age of dam for the two planes of nutrition. Figure 5 shows the average weight curves for the herd A and B heifers from prior to first calving to the precalving weight at 5 years of age. Figure 6 shows for cows 5 years old and over the 11-year average yearlong trends in weight curves and the difference caused by supplemental feedings.

In comparing the performance of herds A and B, the major items of significance from table 1 are:

1. Fifteen per cent higher pregnancy rate in herd A than herd B.

2. Lower percentage of calves dying between birth and weaning in herd A.

3. Herd A calf crop weaned was 82.9 per cent; herd B, 66.4 per cent, a difference of 16.5 per cent.

4. Heavier calves at weaning from herd A (average difference, 58 pounds per head).

5. The combined difference in calf crop and weaning weight resulted in 115 pounds more weaned calf weight per breeding cow.

6. The results cited above are attributable to the supplemental feeding of herd A, which averaged 380 pounds yearly per breeding cow.

7. From a financial standpoint, the difference in calf production per cow in favor of herd A returned roughly from $1.50 to $2.50 added income for each dollar of supplemental feed expense. Other advantages that accrued from the supplemental feeding program were stabilization of the yearly calf crop percentage and to some extent weaning weight, greater value per pound of the calves, greater weight and salvage value of cull cows, more heifers from which to select replacements, and more accurate selections because of normal growth and development.

8. Calf crop percentage from herd B varied with weather and feed conditions from a low of 55 per cent to a high of 79.4 per cent. The average weaning weight of calves varied from 344 to 466 pounds. Thus yearly production and income from this herd was extremely variable.

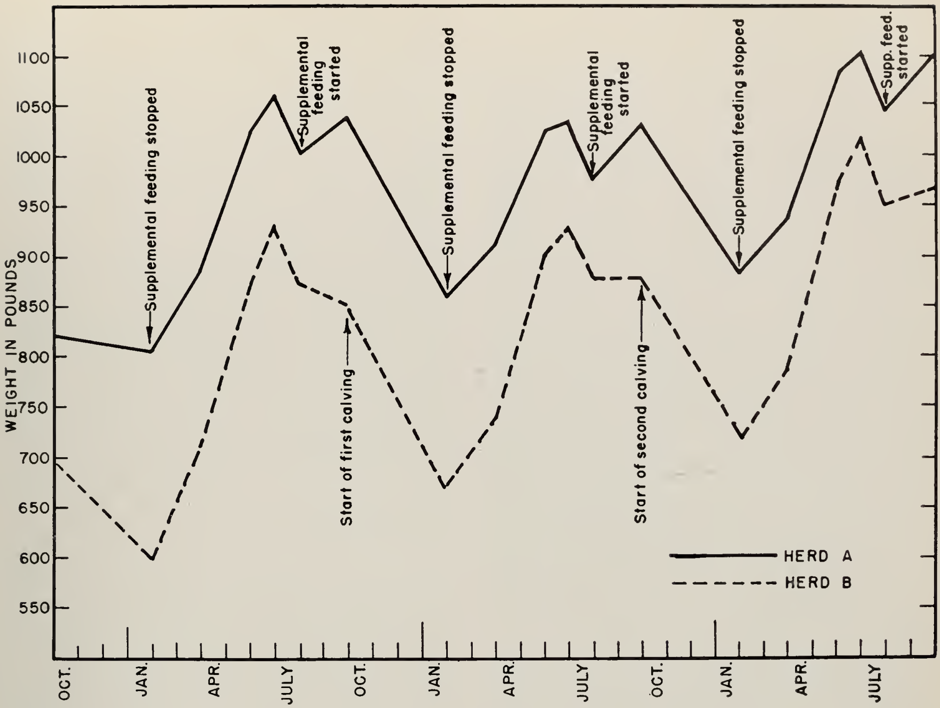

Fig. 5. Average weight curves for the herd A and herd B heifers from before first calving to the precalving weight at 5 years of age.

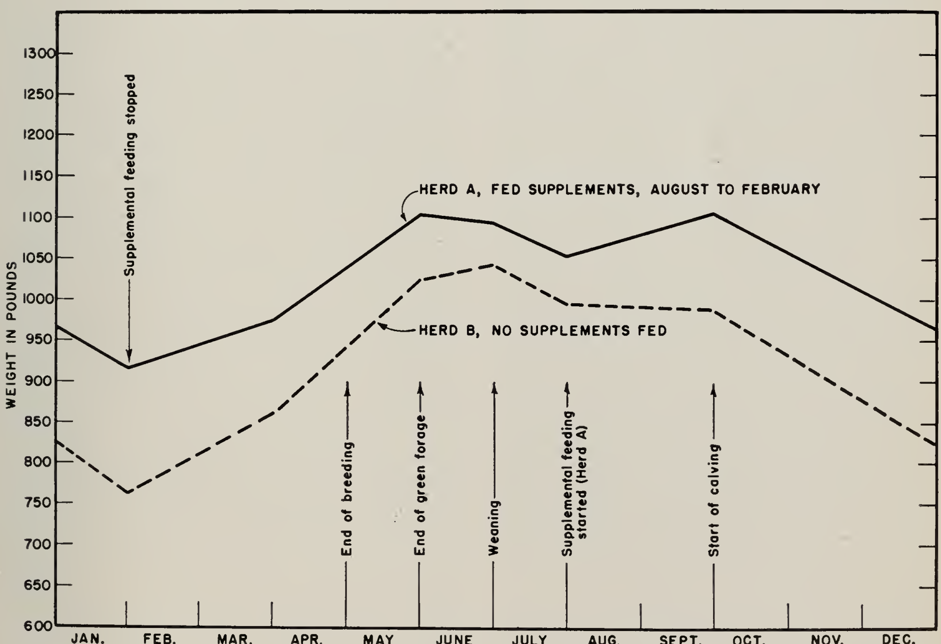

Fig. 6. Average yearlong trends in herd A and B weight curves showing the difference caused by supplemental feeding for cows 5 years old and over.

Time of Weight Gains in the Breeding Herds

The data for the weight curves shown in figures 5 and 6 were taken routinely at the beginning and end of the period during which herd A received supplements, at the start of rapid forage growth, at the end of the green forage season, at weaning time, and just before calving began.

The weight curves shown in figure 5 and 6 include dry cows as well as those with calves. The dry cows in herd B are much more numerous than in herd A, and since these dry cows of herd B often attained weight and condition exceeding that of herd A cows with calves, the difference in the weight curves are minimized. Thus the differences in weight of lactating animals of the two groups are greater than the averages shown in figures 5 and 6.

The general trends of the weight curves are similar. They differ, however, in two critical respects. *First, the difference in weight,* which reflects both growth and condition at the younger ages (fig. 5) and condition of mature animals (fig. 6). At the beginning of the season of adequate green forage, the disparity in weight between herd A and B heifers averaged 175 to 200 pounds. The lower-weight animals gained faster than their previously supplemented mates during the good forage season so that the weight margin was reduced about one half. For mature cows the corresponding maximum and minimum weight differences between the two groups averaged about 150 and 50 pounds, respectively. Both groups lost an average of about 50 pounds between the weaning of the calves (July 1) and the time cattle were transferred to their fall and winter pastures and supplemental feeding began for herd A.

The *second factor* that is considered critical is that herd A animals, already in good thrifty condition, gained in weight during the last 2 to 3 months before calving whereas herd B cows lost weight during this time.

The condition of the animals and the weight attained during breeding season are critical factors affecting the ability of the females to rebreed while still lactating and in the case of heifers, growing as well.

Gain in weight during the last third of pregnancy is considered essential to normal udder development and subsequent lactation. One may postulate that undernutrition inhibits hormone production or that even in the presence of normal hormonal stimulation an excess of incoming nutrients is essential to realize the udder growth which hormones make possible. The latter hypothesis involves the concept of nutrient priorities, more active tissues taking precedence over less active or less vital. In the case under discussion, the rapidly developing fetus appears to have a higher priority than the udder. Whatever the physiological explanation, the fact remains that the unsupplemented herd B animals generally were conspicuously lacking in udder development at time of parturition and this was reflected in marked difference in calf gains from birth to four months of age. Calf gains from four to eight months, when milk production normally declines to low levels in Hereford cows and when the calves are deriving a major portion of their livelihood from the forage, were essentially the same for both herds.

These results paralleled exactly the detailed studies of sheep by Wallace (1948) at Cambridge University, England. He found in ewes: (1) that low plane of nutrition throughout gestation resulted in poor udder development and subsequent lactation and lamb gains; (2) that a high plane of nutrition early in gestation and low (resulting in weight loss) during the last third of pregnancy was only slightly better; (3) that a low plane of nutrition early followed by a high plane during the last third of gestation resulted in udder development and lactation equal to or superior to continuous high plane of nutrition throughout pregnancy. Thus the actual condition of the animals at parturition was not so important as the shape of the weight curve. The ewes on the high-low and low-high regimens were in about the same condition at lambing but the performance of the low-high group was markedly better. This "steaming up" process during the last of gestation has long been an established practice in the dairy industry, and the significance of the principle should be more clearly recognized and applied in practice in meat-animal production.

Age of Dam

Data on percentage calf crop and weaning weight in relation to age of dam on the two planes of nutrition are shown in table 2. The herd was started in 1935 with heifers all of the same age. Culling and replacement was fairly heavy during the earlier years, not only to improve quality, but also to attain a normal age distribution in the herds as rapidly as possible. Neverthless, there is not an even distribution of the various ages for each year; consequently, there are some variations due to season as well as age effects in the data.

In both herds the percentage of pregnancies and calves weaned is lower for second than for first calving, and from the data in table 2 it is apparent that there was also a carryover effect to the third calving in herd B. In herd A the variations from 5 years on appear largely to be caused by seasonal influences and the occurrence in some years of significant numbers of non-specific abortions and stillbirths. The data show that the immature animal having demands for growth as well as gestation and lactation is more sensitive than the mature to undernutrition as it affects reproduction.

The calf weights at weaning for the first and second calvings for herd A and the first three calvings for herd B were lower than subsequent calvings. Comparing these earlier calvings with the peak weights when the cows were six years of age, the difference averaged around 40 pounds less for first calves in herd A, 30 pounds in herd B or about 8 and 7 per cent less respectively. Although the weights of calves in the University purebred herd at Davis are greater than in herd A, the difference between first and later calves is the same—approximately 40 pounds at 8 months. Knox and Koger (1945), in New Mexico, report that first calves averaged 60 pounds lighter than those from mature cows. Knapp, Baker, *et al.* (1942), in Montana, showed that first calves from 2-year-old heifers were about 50 pounds lighter at weaning than the maximum, which was obtained from cows 5 to 7 years of age. In both cases their more extensive data could be represented by a smooth curve of calf weaning weight from first calves to a maximum at 5 to 7 years, with a decline from 8 years of age onward. The Montana data showed that weaning weight of calves from 10-year-old cows was about the same as from first-calf heifers and at 11 years the weaning weight had declined to about 50 pounds below first-calf heifers. These data have a bearing on culling for age. The general policy practiced by commercial operators of culling at 9 years appears advantageous both from the standpoint of weaning weight and salvage value of the cows.

The data for herd C are shown in table 1 along with that for herds A and B previously discussed. Despite supplemental feeding of herd C in a manner similar to herd A and superior average condition of the cows (part of herd A animals were subjected to restricted forage conditions on the six pastures), the average percentage pregnancies for the seven-year period was 82.4 as compared with 90.4 in herd A. The calf crop weaned was only 67.2 as compared with 82.9 for herd A and insignificantly higher than for herd B, which received no supplemental feed. The stillbirths and abortions comprised 13.9 per cent of the pregnancies as compared with 3.7 and 6.0 for herds A and B, respectively. Weaning weights of the calves averaged only 6 pounds more than herd B, a difference of doubtful significance even when the small age difference is considered.

In addition to the data cited above there were several calves that for the most part appeared normal at birth but that failed to develop normally. Growth was retarded, the heads tended to be long, the jaw bone appeared straighter than normal, making the muzzle narrow from front to rear. The term "jug head" became applied to them! The possibility that these cases might in some way be a variation of the "acorn calf" was suggested by Hart, Guilbert, Wagnon, and Goss (1947). The animals tended to be narrow in the forerib and to some degree predisposed to bloat.

Some of the herd C calves continued to decline or do very poorly for 2 to 3 months after weaning in spite of supplemental feeding. A few individuals went into a "decline" that eventually resulted in death. The condition, although not entirely confined to herd C, has been much more prevalent in this group, confined yearlong to the same field. Similar cases are known to occur in some local commercial herds.

An example of the poor response of these calves to supposedly favorable nutrition is shown by the 1947 data. A calf creep was provided to which the herd C calves had access from March 16 to July 7. The average concentrate consumption per calf was 232 pounds for the period. The calves of herds A and B received no supplemental feed, yet during this time they gained more (275 and 260 pounds, respectively) than those of herd C (231 pounds).

These results are difficult to interpret. If some nutritional deficiency or deficiencies of a borderline nature exist in the area, it is possible that the practice of yearlong grazing in one area might exaggerate it. For example, it was observed that regardless of the general abundance of forage, the cattle tended to concentrate early in the season on swales and other more fertile soil areas. These sites through selective grazing were depleted of forage early in the season leaving the less favorable sites for use during the major part of the dry forage period. In contrast with this situation herds A and B were transferred to ungrazed dry forage in August, which provided some selection of forage as well as feed from swales and other superior soil sites. Despite this, the supplemental feeding of herd C made possible the *appearance* of thrifty condition in the cow herd.

Subsequent experiments involving pasture 13 in a two-pasture rotation with pasture 14 did not result in much improvement in production until a complete mineral mix was fed. This appeared to improve conception and percentage calf crop, with no detectable improvement in calf weaning weight. There appear to be complicating factors; and the results with herd C cannot be interpreted as being due solely to yearlong grazing on the same pasture.

On natural vegetation alone, confinement of cattle on limited areas throughout the year may result in underdevelopment. Rangelands vary in this respect within short distances. Management has long recognized this in rangeland utilization. It was the conclusion of Jones and Love (1945) as a result of an 8-year survey of practices in this state.

Because of reorganization of the research program in 1948, yearlong grazing in this area (pasture 13) was discontinued and was carried forward on a small scale (12 cows) in pasture 4. The possible role of trace-element deficiency is under investigation.

GRAZING INTENSITY

Methods

This investigation involving pastures 1 to 6 (figure 2), constituted initially the principal research project of the U. S. Forest and Range Experiment Station group in which cattle were employed. It was organized coöperatively with the Animal Husbandry Division of the University of California. Because of the limitations of land and cattle, it was necessary to use the same animals for grazing these areas and for the study of effects of supplemental feeding on yearlong cattle management in this foothill area. The primary stated objective was to determine the effect on the range and on the cattle of light, moderate, and heavy or close grazing.

Three pairs of duplicate-sized pastures were established in 1935. The approximate acreages were as follows: pastures 1 and 3, 160 acres; pastures 2 and 5, 240 acres; pastures 4 and 6, 320 acres. Subsequently, more detailed surveys gave the total acreages shown in table 3, which also reports swale area and grazable acreage. The general plan was to stock each pasture with 16 animals so that the rate of stocking would be 10, 15, and 20 acres per head for the small, medium, and large pastures respectively. After pasturing the areas a year or two, it became evident that the forage production varied widely between pastures and that there were 6 rates of stocking rather than 3 in duplicate. Much of the variation was accounted for by difference in amount of land in swale, tree and brush cover, rock outcroppings, slope exposure, and steepness of slope.

As previously discussed, the animals in herds A and B had to be separated into different pastures during the late summer, fall, and winter to permit supplemental feeding of herd A. The season of use of the six grazing-intensity pastures was thus fixed from the time forage had advanced sufficiently to support cows with calves in the medium-sized pastures without supplemental aid to the time when the forage in the most heavily grazed pasture was utilized to a degree designated as "close." Generally this period extended from February to August and the average time was 182 days. From the forage standpoint, grazing covered the period from before rapid growth, through maturity, to 2 to 3 months after the bulk of the forage was dry.

During the first year (1936), each pasture was stocked with 11 cows and their calves, as sufficient numbers were not available to stock at the desired rates. Subsequently each pasture was stocked with 15 head of cows together with their calves and one bull. The bull was removed each year about May 1, and the calves were weaned and removed to other pasture about July 1. The cows on the average remained an additional month, until August 1. Each pair of similar-sized pastures contained either 7 cows from herd A and 8 cows from herd B or the reverse. In order that the cumulative effects of the variation in feed supply might be measured, the same cows exclusive of death and culling, were returned to the same pasture each year.

Complications in Analyzing Data

The use of breeding herds on the grazing-intensity pastures resulted in numerous complications in analyzing and summarizing the data. Among these are the following:

1. The gains made by cows while on the several pastures were influenced not only by rate of stocking but also by their treatment during the remainder of the year. Thus, thin herd B cows wintered without supplement always gained more during the grazing period than herd A cows. This is a factor affecting total gain per head and per grazable acre.

2. While most of the cows had already calved before being placed in the pastures, there were a few that calved afterwards and the loss at calving time affected the total net gain figures. There were also variables involved with percentage calf crop, numbers of dry cows, death losses, and so on, not attributable to the experimental procedure but which complicate analysis of results.

3. The segregation of the data into comparable groups reduces the numbers so that the uncontrolled variables cause some erratic differences in the average results.

From the animal-husbandry point of view the most important objective of the over-all research program was to learn how to utilize the natural vegetation and to operate a breeding herd on an efficient production basis yearlong on the range. That animals do not thrive when they do not get enough to eat was not particularly new information. It was considered, therefore, that the procedure outlined would fairly well fulfill the requirements for studying the effect of grazing rate on the range and that the limitations of the cattle data would not detract seriously from the main animal-husbandry objectives.

Although perhaps not contributing greatly to the store of useful information of the observant operator with long experience on annual-type range, the investigation was important to secure more general recognition that the generalizations derived from experience with perennial-grass ranges did not necessarily apply to the annual type.

Herd Weights and Calf Production

The most important data from the livestock standpoint are presented in table 3. The data are arranged in order of degree of grazing as revealed by observation and measurement through the years.

Except for somewhat lighter average weights of pasture 3 cattle at the time they were placed in the pastures, there was no significant difference in initial weights as related to pasture size or productivity. Much of the difference existing when the cattle were removed from the pastures was equalized during the time on fall and winter pasture. The principal results shown in table 3 are itemized as follows:

1. With the exception of calves, all categories of herd B animals made greater gains than their herd A mates in the same pasture. This was caused in large measure by the greater initial weight and better condition of herd A animals that resulted from supplemental feeding during the previous fall and winter.

2. Dry cows also gained consistently more than cows with calves. Thus herd B cows that had calves the previous season and failed to rebreed because of inadequate nutrition and depletion of reserves, regained condition and thrift which enabled most of them to conceive the following year. That the dry cows in herd A were not the result of inadequate nutrition will be shown later.

3. Gains in weight of cows and heifers were restricted in close-grazed pasture 3 and to a lesser extent in pasture 1.

This resulted from inadequate forage supply early in the season and from keeping the cattle in the area until dry forage was depleted. At the height of the growing season, production exceeded consumption in all pastures. In other pastures there were no significant differences in gain related to feed supply.

4. Calf gains were also restricted in pasture 3 under close grazing. Otherwise there was no consistent difference between pastures nor between herd A and herd B calves. As previously discussed, the lighter weaning weight of herd B calves was caused largely by lack of milk during the first 3 to 4 months and

Table 3. Effect of Rates of Stocking on Reproduction and on Production, 1937–1947

Average length of period, 182 days, February to August

Item	Pasture no. and degree of grazing					
	3, close	1, moderate to close	5, moderate	4, light to moderate	6, light	2, light*
Stocking and acreage						
Average number of animal units	19.4	18.9	19.7	19.4	19.6	19.6
Total acreage	155	154	250	309	316	230
Total grazable acreage	104	136	162	205	257	183
Acreage in swales	8	15	5	6	16	20
Grazable acres per animal unit	5.4	7.2	8.2	10.6	13.1	9.3
Pregnancies and calf crop, in per cent of total possible pregnancies						
Pregnancies						
Herd A	88.5	85.5	91.7	91.3	86.9	92.8
Herd B	68.6	66.7	78.3	75.8	82.8	84.1
Calf crop						
Herd A	83.6	73.9	86.7	82.6	80.3	84.3
Herd B	61.2	58.7	72.5	66.1	75.7	69.8
Average seasonal gains, pounds						
Cows with calves						
Herd A	85	138	139	142	166	189
Herd B	147	197	235	205	256	236
Dry cows						
Herd A	165	245	219	207	155	297
Herd B	273	299	336	279	357	323
Replacement heifers						
Herd A	153	200	213	187	237	226
Herd B	236	300	279	282	322	326
Calves						
Herd A	252	283	269	279	268	276
Herd B	227	288	276	272	286	292
Gains per animal unit, both herds	223	273	287	274	300	316
Gains per grazable acre, both herds	42	38	35	26	23	34

* Because of the high acreage in swales and the good growth of forage on this pasture, it is considered lightly stocked, even though grazable acreage per unit is moderate.

before they were consuming significant quantities of forage.

5. Supplemental feeding of herd A during the late summer, fall, and winter met the conditions essential for conception so that the difference in feed supply on the six pastures did not affect percentage of pregnancies or calf crop weaned. The imposition of feed shortage early and late in the grazing season, in addition to weight losses suffered by herd B during the fall and winter, resulted in lower conception and calf-crop percentages in pastures 3 and 1.

6. The over-all result was significantly lower net gain per animal unit in close-grazed pasture 3 and a slight reduction in pasture 1 grazed "moderate to close." The lower gain per animal unit in pasture 4 may be explained in part by a large amount of south slope, which provided early feed but which matured and dried early also.

7. Despite the lower gain per animal, the larger number of animals and the complete utilization of the forage in pasture 3 resulted in slightly higher live weight gain per grazable acre. Variation of productivity *per acre* obviously affects these data and accounts for the relatively high gain per grazable acre in pasture 2 although much forage was wasted under light grazing. Although pasture 3 shows the highest returns in pounds of gain per grazable acre, it should not be concluded that this is the most profitable use. The cattle were always thinner, the gains contained less energy because of lack of fat, the calves weighed less at weaning, had less bloom, and were worth less per pound. Efficiency of production for those not receiving supplements was further reduced because of lower calf crops.

Figure 7 gives further evidence on the effect of plane of nutrition and the shape of the weight curve upon reproduction and weaning weight of calves. In addition to repetition of the average curves for herds A and B of figure 6, data are shown for herd A and B animals in pasture 3, the most heavily grazed pasture.

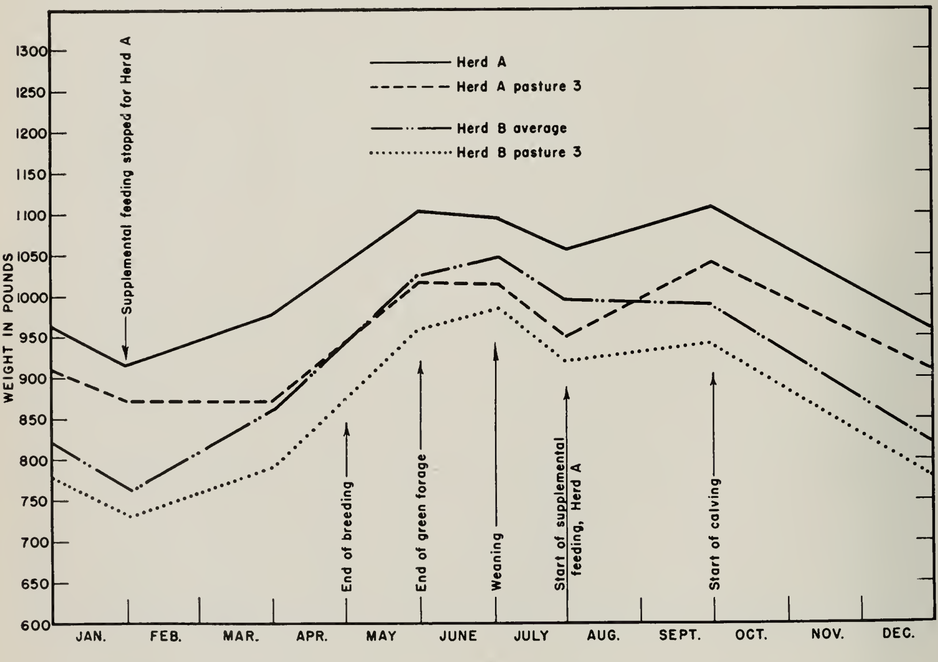

Fig. 7. Average yearlong weight curves of herds A and B with the average weight curves of the A and B herd cows in the most heavily grazed pasture 3.

The reproduction and weaning weights were as follows:

	Percentage calf crop weaned	*Weaning weight, pounds*
Herd A, average	82.9	464
Herd A, pasture 3	83.6	430
Herd B, average	66.4	406
Herd B, pasture 3	61.2	370

The data in the tabulation coupled with the weight curves emphasize again the essentiality of (1) satisfactory conditions and weight gain during the breeding season and (2) gain in weight during the last third of pregnancy. The curve for herd A, pasture 3 cows in figure 7 evidently represents condition and gain that was minimum or above for maximum conceptions during the breeding season since the calving percentage was equal to the average of herd A. These herd A, pasture 3 cows gained significantly during the last of pregnancy and evidently milked about as well as the average of herd A early in lactation. The difference in weaning weight of 34 pounds is largely accounted for by difference in gain while on the pasture and attributable to poorer grazing for the calves as well as for the cows. The weight curve shown for herd A average therefore would appear to be about minimum for maximum calf crop and weaning weight. The curve for herd B average corresponds with 66.4 per cent calf crop and 406-pound weaning weight. Note that during the greater part of the breeding season, the average weight was significantly less than for herd A pasture 3 cows. Only during the last month of the breeding season was the average weight of herd B equal to herd A cows in pasture 3. Extension of the breeding season to the end of the green forage period might have increased the number of pregnancies. The curve for herd B animals on pasture 3 follows the same trend as the average of herd B but at a still lower level of condition, which resulted in further decrease of both calf crop percentage and weaning weight. Thus there was a high correlation of plane of nutrition with reproductive performance.

That the failures to conceive in herd A were not primarily caused by plane of nutrition and that the margin between reproductive success or failure may be comparatively small is shown in figure 8. There was no difference between the average weights of herd A cows four years old and over that calved and rebred and those that failed to rebreed. This indicates that factors other than general plane of nutrition as reflected in body weight were involved with the failures to conceive in this herd. These same factors were also operative in herd B. The differences in percentages of pregnancies and calf crop between herds A and B were attributable to plane of nutrition. Figure 8 shows that herd B cows which calved and failed to rebreed averaged 44 pounds less before calving, 28 pounds less at the beginning of breeding, and 37 pounds less at the end of the breeding season than those that calved and rebred. The weight differences cited are statistically significant or highly significant (0.05 to 0.01 per cent level) and indicate that on the borderline level of nutrition the differences between success and failure may be reflected in comparatively small differences in weight and condition.

As shown in table 2, both herd A and B heifers after dropping their first calves at 3 years of age had lower calf crop percentages at 4 and 5 years than they did initially. Segregation of the weight of those that calved and rebred from those that failed to rebreed showed that, as with the mature cows, the latter were always lighter in weight by 30 to 80 pounds. This again indicates that growing heifers are more sensitive to undernutrition than mature animals and that the nutritional plane was marginal for the 3- and 4-year-old females in herd A. During a greater part of the period under consideration, the heifers were fed

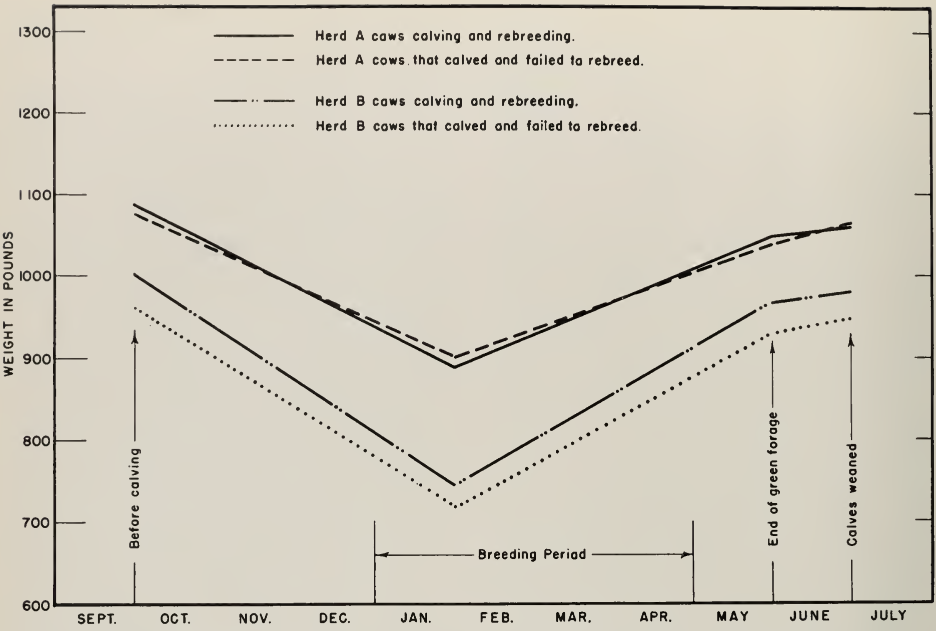

Fig. 8. Average weight curves of herd A and B cows 4 years old and over, calving and rebreeding, as compared with cows calving and failing to rebreed.

supplements with the cows, which militated against their obtaining a fair share of the feed.

Effects on the Range Forage

The details of the effects of rate of stocking on the range forage have been reported by Bentley and Talbot (1945, 1951). The 1951 publication gives detailed accounts not only on effects of rate of stocking, but also of soil sites and types and climatic and ecological factors on forage production, and discusses these in relation to livestock management. These studies were made in conjunction with the present investigation.

EFFECTS OF VARIOUS METHODS OF SUPPLEMENT FEEDING

The concentrate supplements used in this study, for the most part, were handfed in troughs. The use of salt mixed with cottonseed meal as a means of restricting daily consumption of the concentrate when self-fed was attracting the attention of research workers as this study was being terminated.

Daily Versus Alternate-Day Feeding

In ten of the thirteen supplemental feeding periods covered in this study the cows were fed daily. Owing to a shortage of labor at times, it was desired to see if the cows might not be fed on alternate days without detrimental effects. Consequently, in the 1937–38 and 1938–39 supplement periods the animals were fed double daily rations upon alternate days. During the 1944–45 supplement period the cows were not fed on Sundays, because of labor shortage, but received a double daily ration on Mondays. Average calf weaning weights after these supplement periods, for herd A calves, were 481, 487, and 480 pounds, respectively, as compared to the over-all average weaning weight of 464 pounds (herd A, table 1). It was noted that most of the cows would visit the feeding area on nonfeeding days.

Linseed Pellets versus Cottonseed Cake

Cotton being a major crop in the valley farmlands below the San Joaquin Range, cottonseed cake was a logical supplement to use in these experiments. Flax is also grown at times and thus linseed meal was sometimes available. During the 1942–43 and 1943–44 supplement periods herd C was fed linseed pellets instead of cottonseed pellets. Owing to its lower protein content (31 per cent) it was necessary to feed 1⅓ pounds of linseed pellets to furnish the amount of protein furnished by 1 pound of 43 per cent cottonseed cake. Weaning weights of the herd C calves after the above supplement periods were 468 and 386 pounds, respectively, as compared with a 7-year average of 412 pounds (table 1). A direct comparison of these calf crops with those of herd A, which received cottonseed cake, is not feasible because of the lower weaner calf production of the C herd (see page 24). Some difficulty was encountered getting the cows to eat the linseed pellets at the start of the supplement periods.

Hay as a Supplement and for Added Bulk in Dry Years

Since the primary objective of a range-cattle enterprise is the conversion of range forage into meat, it follows that the most efficient use of this forage is one of the first goals of management. Because of their reduced bulk and greater ease of handling, storing, and feeding, concentrates are usually used to supply the deficiencies of range forage. There may at times, however, be special conditions, such as adverse weather, droughts, price differential, or home-produced hay, which may make it more advantageous to use hay as a supplement upon the range. Hay is not produced upon the San Joaquin Range, so that local production is not a factor in its use in this study.

Within the years encompassed in this study hay was only used in the 1944–45 supplement period. Because rainfall was short and poorly distributed, particularly in March and April of the 1943–44 forage growing season, the 1944 forage crop was not only in short supply, but matured and dried early (fig. 4). Before the beginning of the calving period both the A and C herds received daily oil-meal supplementation in the previously described manner. Beginning on October 1 a poor-quality oat hay, at the rate of from 4 to 5½ pounds per head daily, was fed, in addition to the usual concentrate supplementation, for the remainder of the season. Total amount of feed fed per A herd cow was 307 pounds of cottonseed cake, 74 pounds of rolled barley, 135 pounds of alfalfa hay (see below), and 562 pounds of oat hay; and per C herd cow, 307 pounds of cottonseed cake, 74 pounds of rolled barley, and 576 pounds of oat hay. Average weaning weights of the respective calf crops were 480 and 440 pounds. Thus by the use of a cheap poor-quality hay this drought year it was possible to produce weaner calves of a greater than average weaning weight.

Each A herd cow also received a total of 135 pounds of alfalfa hay. Due to the fact that the 1944 forage crop matured and dried so early it was decided to provide the A herd with some vitamin A even though a deficiency of this essential nutrient has not been demonstrated in the diet of our cows. Thus, over 6-day periods in the months of July, August, and September good-quality alfalfa hay of bright green color was fed at the rate of 7½ pounds per head daily. It is interesting to note that in the calving period 38 pregnant cows in the A herd lost 3 calves owing to stillbirths, 3 calves from abortion, and 1 calf died from unknown causes shortly after birth. The 3 abortions occurred between the first and second periods of alfalfa hay feeding. In contrast the C herd, which has a poor record of reproduction (table 1), with a total of 17 pregnant cows lost only 2 calves by stillbirths and one of these was a difficult calving.

This would indicate that vitamin A was not deficient, and that the feeding of alfalfa hay to the A herd had been unnecessary.

SUPPLEMENTED VERSUS UNSUPPLEMENTED RANGE FORAGE FOR CALVES

One of the original objectives was to study the production of yearling feeders. The early breeding and consequent weaning at the beginning of the dry-forage period helps to increase the weaning weight of the calves. This brings up postweaning problems since the weaner calf has high growth potential and can gain 1½ pounds daily under good feed conditions.

Methods

Before weaning each calf was branded with an individual number that also indicated year of birth. During weaning the calves were confined to corral lots and taught to eat supplements before they were fed hay so as to avoid slow acceptance of concentrates at later dates. After weaning the calves were divided into groups according to their herd of origin. Thus, the group A36 calves were the 1936 calf crop weaned from the A herd and the group B36 calves the 1936 calf crop weaned from the B herd. The dams of the 1935 calf crop all received similar treatment until this first calf crop was weaned. These calves were divided into two comparable groups of steers and heifers designated A35 and B35 respectively. Both steers and heifers, of respective A and B groups, were usually pastured together their first supplement period, and individual monthly weights recorded. The weaner groups were placed in various combinations of pastures 7, 8, 9, and 10 (fig. 2) that had not been previously grazed that season.

Feeding for One Half to Two Thirds Pound Daily Gain

In these first experiments it was desired to feed the supplemented weaner calf groups sufficient supplements to maintain ½ to ⅔ pound daily gain through the first supplement period as compared to no supplements for the unsupplemented group. The A35 group were supplemented with 1 pound of pea-sized 43 per cent cottonseed cake for 110 days after weaning, when the first fall rains occurred. At the time of their third monthly weighing (93 days) they had made an average total gain of 91 pounds as compared with 34 pounds for the B35 group. By the fourth weighing in October, substantial rains had occurred (see fig. 4) leaching the old feed and starting the new growth. The transition from a bulky dry forage diet to one of scant green forage caused a marked decrease in rumen contents and consequent loss in body weight averaging 21 pounds in the A35 group and 40 pounds in the B35 group. At this time the ration of the A35 group was increased by the addition of 2 pounds of rolled barley. The last two weighings in this supplement period covered 57 days with green forage increasing, and the A35 group made a 58-pound average gain as compared with 16 pounds for the B35 group. As shown by table 4, the A35 group made a total average gain of 128 pounds, after being fed 311 pounds of supplements per head, as compared with a 10-

Table 4. Comparison of Supplement-fed Weaner Calves with Calves That Received No Supplements

Period and group	Number of steers and heifers	Average weaning age, days	Supplements fed per head, pounds				Average weight, pounds		Average gain or loss, pounds	
			Cotton-seed cake	Rolled barley	Fish-meal	Molasses	Initial	Final	Total	Daily
6/30/36–12/29/36, 182 days										
A35	29	224	191	120	...	...	436	564	+128	+0.70
B35	28	224	0	0	...	...	428	438	+ 10	+ .05
7/7/37–3/7/38, 243 days										
A36	23	211	327	270	...	...	437	578	+141	+ .58
B36	22	202	24	24	...	...	412	354	− 58	− .24
7/6/38–1/27/39, 205 days										
A37	21	242	...	...	163	463	482	621	+139	+ .68
B37	20	249	...	...	0	0	386	393	+ 7	+ .03
6/26/39–2/6/40, 225 days										
A38	33	248	229	57	...	...	487	611	+124	+ .55
B38	26	230	0	0	...	...	418	469	+ 51	+ .22
7/8/40–1/29/41, 205 days										
A39/1	16	237	251	148	...	...	506	594	+ 88	+ .42
A39/2	16	237	399	0	...	...	507	586	+ 79	+ .38
B39	30	242	0	0	...	...	466	422	− 44	−0.21

pound average gain for the unsupplemented group.

For the subsequent supplemented weaner groups the amounts of supplements required are shown in table 4. In the 1937–38 season we had an unusually long supplement period of 243 days, and a total of 597 pounds of supplements per A36-group animal were required to promote average daily gains of 0.58 pounds, with a maximum daily intake of 5 pounds of supplements per head when the most adverse conditions existed in the winter. Marked ill-effects resulted in the B36 group and it was considered necessary to feed them 1 pound of supplements per head daily for 48 days to prevent death losses. They completed the supplement period with an average weight loss of 58 pounds from their weaning weights. As previously stated, the ingestion of live oak acorns before the first fall rains and exposure from the very wet winter contributed to the weight losses of the B36 group.

In contrast to this severe 1937–38 winter situation, the 1939–40 supplement period lasted 225 days and a total of 286 pounds of supplements were required per A38 group animal to produce an average daily gain of 0.55 pound. The B38 group animals finished the period with an average total gain of 51 pounds over their weaning weight. The 1940–41 supplement period was another winter of adverse feed conditions in that live oak acorns were again eaten by the calves. The A39 group calves were fed a total of 399 pounds of supplements per head over a 205-day period but did not reach the goal of ½ pound average daily gain. In feeding the A39 group they were divided into two comparable groups (A39/1 and A39/2) at the beginning of the supplement period. The A39/1 group was supplemented with cottonseed cake and rolled barley in the previously described manner, whereas the A39/2 group received only cottonseed cake in similar total amounts. As shown by table 4, there was no significant difference in their gain.

In the 1938–39 supplement period the A37 group were fed fishmeal and molasses as supplements. Good-quality fishmeal was readily available at the time and there was a desire to investigate the possibility of self-feeding the fishmeal mixed with molasses. The mixture proved quite palatable, and daily consumption increased to about 9.5 pounds per head with resultant poor utilization of dry range feed and some bloating. It was therefore necessary to resort to hand-feeding, and it was found the calves would readily eat the fishmeal alone. Average daily weight gains of 0.68 pound for the A37 group were comparable to what might be expected from feeding cottonseed cake and rolled barley. The B37 group only made average total gains of 7 pounds above their weaning weight, which indicates an about-average supplement period.

These data indicate the necessity of a flexible supplemental feeding program capable of rapid adjustment to meet changes in the nutritive value of the natural range feed during the supplement period.

Feeding for 1 to 1¼ Pounds Daily Gain

In the above studies we have been concerned with promoting average daily gains of ½ to ⅔ pound in weaner calves through their first supplement period. Studies were also conducted to ascertain the supplements required to promote average gains of 1 to 1¼ pounds per head daily. Some of these steers were to be used later in studies on finishing yearling cattle upon the range.

Beginning with the 1940 calf crop all the steer calves were combined to form experimental groups. Combining steer calves from the unsupplemented herd with those from the supplemented herd created greater variation within the

Table 5. Gains of Weaner Steers at Two Levels of Supplement Feeding

Period and group	Number of steers	Average weaning age, days	Supplements fed per head, pounds			Average weight, pounds		Average gain, pounds	
			Cotton-seed cake	Rolled barley	Wheat straw and molasses*	Initial	Final	Total	Daily
7/6/42–2/26/43, 235 days†									
A41/1, A41/2	28	229	310	195	...	449	572	123	0.52
A41/3†	15	226	474	465	...	450	699	249	1.00
6/30/43–3/10/44, 254 days									
A42/1	10	229	307	151	...	468	574	106	0.42
A42/2	11	236	337	501	...	473	674	201	0.79
7/11/45–1/10/46, 183 days†									
A44/1, A44/2	26	239	158	156	...	472	574	102	0.56
A44/3†	13	240	319	496	...	472	715	245	1.06
7/10/46–1/21/47, 195 days									
A45/1	12	208	277	92	366	436	583	147	0.75
A45/2, A45/3†	23	220	409	405	...	436	677	241	1.05
7/1/47–2/3/48, 217 days†									
A46/1	11	207	258	158	...	407	580	173	0.80
A46/2, A46/3†	22	216	413	313‡	...	406	662	256	1.05

* Wheat straw and molasses mixture, control group in a urea-feeding experiment.
† Groups A41–3, A44–3, A45–2 and 3, and A46–2 and 3 had supplement periods of 250, 232, 230, and 244 days respectively.
‡ Includes 20 pounds of beet pulp.

Table 6. Summary of Data on Effect of Supplement Feeding after Weaning

Feeding practice, sex, and number of years of tests	Average length of period, days	Number of animals	Supplements fed per head, pounds		Average weight, pounds		Average gain or loss, pounds	
			Cotton-seed cake	Rolled barley	Initial	Final	Total	Daily
No supplements								
Steers, 4 years	219	53	. . .*	. . .*	424	414	− 10	−0.05
Heifers, 11 years	216	110	. . .*	. . .*	410	399	− 11	−0.05
Fed for ½–⅔ pound daily gain								
Steers, 10 years	218	144	268†	141†	477	601	+124	+0.57
Heifers, 11 years	216	149	283‡	139‡	452	572	+120	+0.56
Fed for 1–1¼ pounds daily gain								
Steers, 4 years	239	73	404	420	441	688	+247	+1.03

* Fed a total of 48 pounds of supplements per head one year. † Eight-year average. ‡ Seven-year average.

groups, as well as lowering average initial weight. Unsupplemented groups of heifers continued to be carried each year to provide replacement heifers for the B herd and also to provide a yardstick of the supplement and grazing periods that followed their weaning (fig. 4). Some steers of the 1940 calf crops were used in an experiment on the importance of continuous growth in beef cattle, which has been reported in detail (Guilbert, Hart, *et al.*, 1944). The remaining steers were supplemented for moderate continuous gains and required a total of 489 pounds of supplements per head for average daily gains of 0.55 pound over a 246-day period.

Weaner steer groups from the 1941, 1942, 1944, 1945, and 1946 calf crops were used to study the amounts of supplements required to promote average daily weight gains of 1 to 1¼ pounds as compared with gains of ½ to ¾ pound. A summation of these data is presented in table 5. (All but a few heifers of the 1943 calf crops were sold at weaning.)

In supplementing for 1 pound average daily gains the initial daily ration was 2 to 2½ pounds of supplements per head. During the most adverse forage conditions of the winter the daily ration was increased to 4 to 5 pounds daily per head. In general the maximum amounts of cottonseed cake fed daily per head varied from 1½ to 2 pounds with the balance of the ration rolled barley. As shown by the data in table 5, not only were the supplement periods longer but also 43 to 61 per cent more feed was fed per pound of gain than for ½ to ¾ pound daily gain. Because of the adverse forage conditions and lack of sufficient animals to furnish the desired steer groups, the 1942 groups were not fed for the gains attained in the other groups (table 5).

Table 6 gives a summation of the data on weight gains or losses with and without supplements for weaner calves for the supplement period after weaning. These data show that with an average supplement period of about 217 days, weaner calves not supplemented had an average weight loss of about 10 pounds, whereas weaner calves fed an average total of about 416 pounds of supplements made total average gains of 122 pounds. On the other hand, when average gains of about a pound daily were aimed for, an average total of 824 pounds of supplements per calf over a 239-day supplement period was required.

Gains during the Grazing Season

The dry-forage and winter seasons are usually the most costly for producing weight gains. Animals in good flesh will gain less on good forage than will thinner cattle that lost weight, or made little gain, in the previous adverse-forage period. Since most cattle are sold at the end of the good-forage period, rather than at the close of the supplement period, the net value of supplemental feeding calves or yearlings is best judged at the close of the good-forage period after the supplement period. The problem is to secure economical gains during the high-cost supplement period without subsequently minimizing cheaper grazing-period gains.

Data used in this discussion are the records of groups of weaners that were supplemented for average daily gains of ½ to ⅔ pound during the supplement period and then carried through the following grazing period on forage alone. Comparably aged unsupplemented groups of weaners that were carried through both forage periods on forage alone are shown for comparative purposes. The data are limited because

Table 7. Weight Gains for Supplemented and Unsupplemented Yearlings on Good Pasture after the Poor-Forage Period

Sex, period, group, and treatment during poor-forage period	Number of animals	Average weight, pounds		Average gain, pounds	
		Initial	Final	Total	Daily
Steers					
12/29/36–8/4/37, 218 days					
A35, supplemented	14	579	890	311	1.43
B35 unsupplemented	14	447	786	339	1.55
2/6/,40–7/31/40, 175 days					
A38, supplemented	15	626	909	283	1.62
B38, unsupplemented	16	450	778	328	1.87
Heifers					
1/29/41–8/12/41, 195 days					
A39, supplemented	10	587	825	238	1.22
B39, unsupplemented	15	415	714	299	1.53
2/26/43–6/28/43, 122 days					
A41, supplemented	13	590	785	195	1.60
B41, unsupplemented	11	403	639	236	1.93
3/10/44–7/11/44, 123 days					
A42, supplemented	15	570	762	192	1.56
B42, unsupplemented	10	360	588	228	1.85
1/20/45–7/10/45, 171 days					
A43, supplemented	5	597	872	275	1.61
B43, unsupplemented	5	382	726	344	2.01

of finishing experiments. The data are presented in table 7. The grazing period varied from 122 to 218 days. In each case the unsupplemented groups outgained the heavier-fleshed animals that had been supplemented the previous period, but in each year they failed to attain the degree of fleshing attained by the latter animals. Since the A35 and B35 groups of steers were of similar fleshing at the time of weaning, a comparison of the weight changes of these two groups through the two major forage periods is representative. The A35 group steers made a total average gain of 124 pounds in the supplement period as compared with 9 pounds for the B35 group steers. In the combined 13-month period the A35 group steers made a total average gain of 435 pounds as compared with 348 pounds for the B35 group steers. Thus, the A35 group steers outgained the B35 group steers by an average 115 pounds in the supplement period; and while the B35 group steers outgained the A35 group steers by 28 pounds in the subsequent grazing period, the A35 group steers still had an 87-pound advantage in total average gain.

FINISHING YEARLING AND TWO-YEAR-OLD CATTLE

Studies in finishing cattle upon the range involved all the calf crops from 1935 through 1945 with the exception of those produced in 1943. The object of these experiments was to ascertain the possibilities of finishing cattle upon this type of range with the animals harvesting their own roughage while being full-fed concentrates. At the start of the finishing period the animals were moved to smaller previously ungrazed pastures, such as 7E and 7W (fig. 2), when the forage upon the hill slopes was beginning to dry.

Two-Year-Old Steers

These experiments involved only two groups (A35 and A38) receiving concentrates for finishing. The unsupplemented groups (B35, B36, B37, and B38) were not finished for slaughter, and were sold as feeders except for the B35 group, which was killed to collect data on their condition and carcass appearance. The data are presented in table 8. Management of these steer groups from weaning through their second grazing period has been presented in the preceding section, "Feeding and Management of Calves after Weaning."

Carrying steers upon the range until they were long 2 years of age entailed the feeding of the supplemented groups through a second supplement period. Supplementing was at the usual rate needed to promote daily gains of ½ to ⅔ pound in weaner calves. As shown by a comparison of the data in tables 4 and 8, the A35 steers were actually fed at a higher rate than the A36 calves but only made 0.22 pound daily gain, as compared with 0.58 pound for the weaner animals. The A38 steers were fed at the same rate as the A39 calves, and their daily gain was 0.11 pound, as compared with about 0.41 pound for the calves. The marked difference in average daily gains of the long yearling steers as compared with the weaner calves is explained by the fact the older animals had passed the age at which they had the greatest stimulation for skeletal and muscular growth and, consequently, did not make as efficient use of their supplements as did the younger animals, which were in this growth phase (Guilbert, Hart, *et al.*, 1944). The supplement periods of the A35 and A38 steers were about a month shorter than those of the A36 and A39 calves, because it is the practice to start supplementing weaner calves immediately after weaning, whereas the supplement periods of the older animals were delayed until

Table 8. Two-Year-Old Steers, Supplemented and Unsupplemented: Gains and Marketing Data

Gains during supplement, grazing, and finishing periods

Period and group	Average weaning age, days	Length of period, days	Supplements fed per head, pounds		Average weight, pounds		Average gain or loss, pounds	
			During period	Total after weaning	At weaning	At end of period	For period	Daily
Supplement period I								
A35, 14 steers	222	182	311	...	455	579	+124	+0.68
B35, 14 steers	223	182	0	...	438	447	+ 9	+0.05
B36, 12 steers	178	243	48	...	396	344	− 52	−0.21
B37, 14 steers	253	205	0	...	411	397*	− 14	−0.06
A38, 15 steers	245	225	286	...	519	626*	+107	+0.47
B38, 16 steers	224	225	0	...	423	450*	+ 27	+0.12
Grazing period I								
A35, 14 steers	...	218	0	...	...	890	+311	+1.43
B35, 14 steers	...	218	0	...	...	785	+338	+1.55
B36, 12 steers	...	152	0	...	...	664	+320	+2.10
B37, 14 steers	...	187	0	...	...	652*	+255	+1.36
A38, 15 steers	...	175	0	...	...	909*	+283	+1.62
B38, 16 steers	...	175	0	...	...	778*	+328	+1.87
Supplement period II								
A35, 14 steers	...	215	746	...	...	937	+ 47	+0.22
B35, 14 steers	...	215	0	...	...	590	−195	−0.91
B36, 12 steers	...	174	0	...	...	662	− 2	−0.01
B37, 14 steers	...	188	0	...	...	681*	+ 29	+0.15
A38, 15 steers	...	176	360	...	...	939*	+ 30	+0.11
B38, 16 steers	...	176	0	...	...	660*	−118	−0.67
Grazing period II								
A35, 14 steers	...	84	0	...	...	1,130	+193	+2.30
B35, 14 steers	...	133	0	0	...	999	+409	+3.07
B36, 12 steers	...	130	0	48	...	905	+243	+1.87
B37, 14 steers	...	120	0	0	...	979	+298	+2.48
A38, 15 steers	...	111	0	...	...	1,133*	+194	+1.75
B38, 16 steers	...	167	0	0	...	1,083	+423	+2.61
Finishing period								
A35, 14 steers	...	49	404	1,461	...	1,208	+ 78	+1.59
A38, 15 steers	...	75	670	1,316	...	1,283	+150	+2.00

Marketing data

Group and disposal	Average weight, pounds			Average shrinkage in shipping, per cent	Average dressing percentage	Selling price per cwt.	Carcass grades, O.P.A.†
	Shipping	Selling	Carcass				
A35, slaughter	1,208	1,141	667	5.55	58.5	$ 8.75	1 AA, 13 A
B35, slaughter	999	910	474	8.91	52.1	7.50	7 B, 7 C
B36, feeder	905	853	...	5.75	...	7.40	....
B37, feeder	979	938	...	4.12	...	8.75	....
A38, slaughter	1,283	1,184	706	7.72	59.6	10.50	15 A
B38, feeder	1,083	1,009	...	6.83	...	8.45	....

* Weighed after all-night shrink in a dry lot.
† AA, Choice; A, Good; B, Medium; C, Common.

gains upon pasture alone had about ceased.

Data presented in figure 4 and table 4 show that feed conditions during the supplement periods of the 1937-38 and 1940-41 seasons were more adverse than most such periods. This is further shown by the 195- and 118-pound average weight losses for the B35 and B38 steer groups, respectively, during their second supplement periods, as compared with a 2-pound loss for the B36 steers and a 29-pound gain for the B37 steers in their respective second supplement periods (table 8). Thus the A35 steers, which had gained an average of 88 pounds more than the B35 steers by the end of the first grazing period, had increased this difference to 330 pounds by the end of the second supplement period, during which they had received an average of 746 pounds of supplements per head. Similarly the A38 steers, which had gained 35 pounds more by the end of the first grazing season, increased the difference in gain to 183 pounds by the end of the second supplement period, during which an average of 360 pounds of supplements per head had been fed the A38 steers.

The second grazing period again found the thin-fleshed unsupplemented groups outgaining their heavier-fleshed supplemented mates. In a 133-day period the B35 steers made an average daily gain of 3.07 pounds and in a 167-day period the B38 steers made a 2.61-pound average gain. The A35 steers were allowed to subsist upon range alone for 85 days of a second grazing period, during which time they made 2.30 pounds average gain. In a similar 111-day period the A38 group steers made 1.75 pounds average gain.

Towards the close of their second grazing periods, when the forage on the slopes was drying, the A35 and A38 groups were moved to smaller ungrazed pastures to be fed concentrates for finishing. Concentrates consisted of 43 per cent cottonseed cake and rolled barley; however, at first a small portion of rolled barley was replaced with beet pulp to increase the palatability of the ration. The daily ration (once a day feeding) was increased as fast as practical until 1 pound of concentrate mixture per 100 pounds live weight was being fed. Cottonseed cake also added palatability to the ration and at full feed comprised from 10 to 15 per cent of the concentrate mixture. At this feeding rate close observation was required in hot weather to detect steers starting to go off feed. When this occurred the daily ration was cut about a third and then returned gradually to full feed. Later, morning feedings were discontinued in favor of evening feedings, as it was thought that the extra heat produced by the ingestion of the concentrates would be more easily eliminated during the cool of the night.

Data in table 8 show the A35 group required an average 404 pounds of concentrates per head over a 48-day finishing period as compared with 670 pounds of concentrates for a 75-day finishing period for the A38 group. The A35 group had an average selling weight of 1,141 pounds and a dressing percentage of 58.5, as compared with a 1,184-pound average selling weight and 59.6 dressing percentage for the A38 group. Only one animal in the A35 group had sufficient covering to grade Choice. All the other steers of both groups finished in the Good grade and the fat was only slightly yellow. There were objections to the heavy carcass weights, and at the time lighter-weight carcasses comparable in grade to the A38 group sold from $1.00 to $1.50 per hundredweight higher.

The B35 group were sold for slaughter at the same time as the A35 group. While they were definitely of the feeder grade, it was desired to secure some slaughter data of this class of animal. Their 910-pound average selling weight was 231 pounds below that of the A35 group and their dressing percentage was only 51.1. The carcasses graded Low, Medium, and Common and were unsatisfactory in that they had practically no fat covering while some were dark-cutting and chilled with an off color.

In none of the 4 years' data given in table 8 did the unsupplemented groups attain sufficient finish for desirable slaughter animals. The data do show however, that by the use of supplements it is possible to finish 2-year-old steers to a Good grade upon this type of range.

Yearlings Previously Supplemented for ½ to ⅔ Pound Daily Gain

Six groups of animals (A36, A37, A39, and B39 steers, and A37 and A38 heifers) were involved in these experiments. The data are given in table 9. All but the B39 steers were finished and the finishing procedure used was the same as previously reported for the finishing of 2-year-old steers except that fishmeal and molasses were the concentrates used in finishing the two A37 groups.

The data show marked variations in length of finishing periods for the yearling steer groups, as well as in selling weights, dressing percentages, and carcass grades. In each case the finishing period was terminated before the steers had reached the desired degree of finish because the range roughage had completely dried and daily weight gains no longer warranted the heavy feeding.

While the A36 group steers were weaned just before the adverse wet winter period of the 1937-38 season, they received adequate supplements to promote average daily weight gains of 0.60 pound for the supplement period. The supplement period did not end until early March, and the new forage growth after that date was so good that the steers made average daily gains of 2.42 pounds in the subsequent grazing period. Then after a 70-day finishing period they sold at the low average weight of 879 pounds. Dressing percentage was 57.0, and the average carcass grade for the group was Good.

The A39 steers, which were similarly supplemented and then finished with cottonseed cake and rolled barley, also had a poorer than average supplement period the 1940-41 season. They did not receive adequate supplements for the usual gain, and their average daily gain for the period was only 0.44 pound. In the following 104-day grazing period their average total weight gain of 166 pounds was markedly below the 203-pound average gain of the A36 group steers for their 70-day grazing period. The finishing period extended over a 104-day period in an attempt to reach the desired degree of finish, but without success. Their average selling weight was 927 pounds with a dressing percentage of 56.2, and the carcasses graded from high Medium to low Good. Total concentrates fed after weaning were an average 1,124 pounds per head with a total average weight gain for the period of 410 pounds, as compared with a total of 1,146 pounds of supplements per A36 steer and a total average weight gain of 414 pounds. The B39 steers, which subsisted upon grass the entire time after weaning, made total average gains of only 251 pounds.

Fishmeal and Molasses as Supplements

As previously stated, the A37 weaners were supplemented with fishmeal and molasses (table 4) the supplement period after their weaning. The average 0.75 pound daily gain of the A37 steers for this period was greater than that of the A36 and A39 groups of steers for their respective supplement periods. While self-feeding the supplements to the A37 group during their supplement period did not prove practical, the A37 steers were self-fed an average 127 pounds of molasses per head over the following

Table 9. Yearling Steers and Heifers Supplemented for ½ to ⅔ Pound Daily Gains as Weaners: Gains and Marketing Data

One group of unsupplemented steers included for comparison

Gains during supplement, grazing, and finishing periods

Period and group	Average weaning age, days	Length of period, days	Supplements fed per head, pounds		Average weight, pounds		Average gain or loss, pounds	
			During period	Total after weaning	At weaning	At end of period	For period	Daily
Supplement period								
A36, 11 steers	218	243	598	...	465	610	+145	+0.60
A37, 8 steers	246	205	626*	...	497	651	+154	+0.75
A39, 18 steers	233	204	399	...	517	607†	+ 90	+0.44
B39, 11 steers	242	204	0	...	467	425†	− 42	−0.21
A37, 7 heifers	253	205	626*	...	470	583	+113	+0.55
A38, 10 heifers	248	225	286	...	455	573	+118	+0.52
Grazing period								
A36, 11 steers	...	84	0	...	...	813	+203	+2.42
A37, 8 steers	...	102	127‡	...	...	842	+191	+1.87
A39, 18 steers	...	104	0	...	...	773†	+166	+1.60
B39, 11 steers	...	161	0	0	...	781	+356	+2.21
A37, 7 heifers	...	102	154‡	...	...	751	+168	+1.65
A38, 10 heifers	...	71	0	...	...	703	+130	+1.83
Finishing period								
A36, 11 steers	...	70	548	1,146	...	929	+116	+1.66
A37, 8 steers	...	89	951*	1,704*	...	934	+ 92	+1.03
A39, 18 steers	...	104	725	1,124	...	979	+206	+1.98
A37, 7 heifers	...	48	403*	1,183	...	810	+ 59	+1.23
A38, 10 heifers	...	60	313	599	...	848	+145	+2.42

Marketing data

Group and disposal	Average weight, pounds			Average shrinkage in shipping, per cent	Average dressing percentage	Selling price per cwt.	Carcass grades, O.P.A.§
	Shipping	Selling	Carcass				
Steers							
A36, slaughter	929	879	501	5.38	57.0	$ 8.50	1 AA, 9 A, 1 B
A37, slaughter	934	888	480	4.92	55.2	8.75	8 B
A39, slaughter	979	927	521	5.31	56.2	10.50	9 A, 9 B
B39, feeders	781	718	...	8.06	...	9.00	....
Heifers							
A37, slaughter	810	758	419	6.42	55.3	8.00	3 A, 3 B, 1 C
A38, slaughter	848	796	444	6.13	55.8	8.50	1 A, 9 B

* Fishmeal and molasses.
† Weighed after all-night shrink in dry lot.
‡ Molasses self-fed.
§ AA, Choice; A, Good; B, Medium; C, Common.

102-day grazing period. Their average daily gain of 1.87 pounds for the period was a little better than that of the A39 group steers for their grazing period but markedly below that of the A36 steers. They were then hand-fed fishmeal daily (2 pounds per head maximum) and self-fed molasses over a 89-day finishing period. Their average daily gain of 1.03 pounds for the period was markedly below the respective gains of the A36 and A39 steers. Average selling weight was 888 pounds with a dressing percentage of 53.2, and all carcasses were in the Medium grade.

All three steer groups fed for finishing were considered, by the buyers, to be lacking in sufficient finish for slaughter, and the consensus was that they should have been placed in a feedlot for further feeding before slaughtering.

Two groups of heifers, A37 and A38, not desired for replacements, were also finished. They were fed in the same manner as the steer groups, with the A37 heifers being fed fishmeal and molasses and the A38 heifers cottonseed cake and rolled barley (table 9). While heifers are easier to fatten at the yearling age than steers, neither of these groups were finished past the Medium grades and had low yields of 55 per cent.

Yearlings Previously Supplemented for 1 to 1¼ Pounds Daily Gains

Since previous experiments at finishing long-yearling steers had not given satisfactory results, new experiments were designed to study the finishing of yearling steers that had been supplemented for daily gains of 1 to 1¼ pounds during the supplement period after weaning, failure in the previous experiments being attributed to the fact the steers had not attained sufficient fleshing before the beginning of the finishing period. In experiments prior to this time (1940 calf crops) the groups being supplement-fed, and then finished for slaughter, were produced by the A herd while the unsupplemented groups were produced by the B herd. In order to have more steers available in future finishing experiments, the steers produced by the B herd were combined with those of the A herd at weaning. The poorer animals of the former group were discarded where possible to decrease variation within the groups.

The first experiment along these lines has already been reported (Guilbert, Hart, *et al.*, 1944). The results are summarized in table 10 (data for A40/1 and A40/2 groups).

After eliminating the five poorest animals, the remainder of the 1940 steers (A40 group), were supplemented in the manner previously described for daily weight gains of ½ to ⅔ pound and then finished in the same way as for the 2-year-old steers. As shown by table 10, their average selling weight of 957 pounds, 58.0 per cent yield, and carcass grades in the Medium to Good grades are comparable to the previous groups finished in a like manner (table 9).

Beginning with the 1941 calf crop, a series of experiments was conducted in which a group of steers were finished after being supplemented for average 1 to 1¼-pounds daily gains as compared with a group fed for the ½ to ⅔ pound average daily gain. Furthermore, all groups finished were fed concentrates twice daily during the finishing period with 1.5 pounds of feed fed per hundred pounds live weight when on full feed. Even though half again as much concentrates were fed daily as in the previous finishing studies, less trouble was encountered with the steers going off feed.

The weaner steers of the 1941 calf crop were divided into two groups of 14 each and one group of 15. These groups were designated as A41/1, A41/2, and A41/3, respectively. One of the A41/2 steers died from a rattlesnake bite before the experiment was completed. During the supplement period after weaning the A41/1 and A41/2 groups were pastured together and supplemented in the usual manner with cottonseed cake and rolled barley to produce average daily gains of ½ to ⅔ pound daily while the A41/3 group was fed at a heavier rate to produce average daily gains of 1 to 1¼ pounds. Because of the heavier fleshing of the heavier-fed steers it was necessary to

Table 10. Effect of Early and Late Supplement Feeding on the Gains and Market Value of Yearlings*

Gains during supplement, grazing, and finishing periods

Period and group	Average weaning age, days	Length of period, days	Supplements fed per head, pounds		Average weight, pounds		Average gain or loss, pounds	
			During period	Total after weaning	At weaning	At end of period	For period	Daily
Supplement period								
A40, 12 steers	246	239	489	...	527	667†	140	0.59
A40/1, 8 steers	237	183	717	...	483	678	195	1.07
A40/2, 8 steers	232	183	0	...	481	461	—20	—0.11
Grazing period								
A40, 12 steers	...	84	0	...	...	761†	94	1.12
A40/1, 8 steers	...	164	0	...	...	906	228	1.39
A40/2, 8 steers	...	164	590	...	...	787	326	1.99
Finishing period								
A40, 12 steers	...	118	937	1,426	...	1,042	281	2.38
A40/1, 8 steers	...	94	1,021	1,738	...	1,036	130	1.38
A40/2, 8 steers	...	94	1,078	1,668	...	923	136	1.45

Disposal data (all groups marketed as slaughter cattle)

Group	Average weight, pounds			Average shrinkage in shipping, per cent	Average dressing percentage	Selling price per cwt.	Carcass grades, O.P.A.†
	Shipping	Selling	Carcass				
A40, 12 steers	1,042	957	555	8.10	58.0	$13.34	7 A, 5 B
A40/1, 8 steers	1,036	969	573	6.4	59.1	13.88	5 A, 3 B
A40/2, 8 steers	923	868	521	5.9	60.0	13.48	4 A, 4 B

* Data on A40/1 and A40/2 are from the experiment reported by Guilbert, et al. (1944), although not given there in this form.
† Weighed after all-night shrink in a dry lot.
‡ AA, Choice; A, Good; B, Medium; C, Common.

extend their supplement period until the new forage growth was more advanced than would be required for thinner-fleshed animals, in order to prevent a regression in weight gains. A summation of the data is given in table 11. These data show the A41/1 and A41/2 steers were each fed a total of 505 pounds of supplements over a 235-day period and made average daily gains of 0.49 and 0.58 pound respectively. The A41/3 steers were each fed a total of 939 pounds of supplements over a 250-day period and made average daily gains of 1.00 pound. The supplement period of the 1942-43 season was more adverse than usual and gains the following grazing period were below average.

In the grazing period the A41/2 and A41/3 groups were moved to the usual small ungrazed fields as the forage began to dry and were fed for finishing. After a 64-day finishing period the A41/3 group sold at an average weight of 931 pounds. They dressed 59.2 per cent with three of the carcasses grading Choice and the remainder Good. Because of their thinner condition it was necessary to feed the A41/2 group over a 98-day period, and they sold at an average weight of 894 pounds. Their dressing percentage was 58.9 with four carcasses

Table 11. Yearling Steers Supplemented for 1 Pound and for ½ to ¾ Pound Daily Gain as Weaners: Gains and Marketing Data

Gains during supplement, grazing, and finishing periods

Period and group	Average weaning age, days	Length of period, days	Supplements fed per head, pounds		Average weight, pounds		Average gain, pounds	
			During period	Total after weaning	At weaning	At end of period	For period	Daily
Supplement period								
A41/1, 14 steers	224	235	505	...	449	565*	116	0.49
A41/2, 13 steers	234	235	505	...	445	581*	136	0.58
A41/3, 15 steers	226	250	939	...	450	699*	249	1.00
A44/1, 13 steers	238	183	314	...	472	568*	96	0.52
A44/2, 13 steers	240	183	314	...	472	581*	109	0.59
A44/3, 13 steers	240	232	815	...	472	715*	245	1.06
A45/1, 12 steers	208	195	735†	...	436	583*	147	0.75
A45/2, 11 steers	226	230	814	...	435	671*	236	1.03
A45/3, 12 steers	213	230	814	...	436	682*	246	1.07
Grazing period								
A41/1, 14 steers	...	131	0	505	...	823	258	1.97
A41/2, 13 steers	...	72	0	...	...	718*	137	1.90
A41/3, 15 steers	...	57	0	...	...	808*	109	1.91
A44/1, 13 steers	...	132	0	314	...	785	217	1.64
A44/2, 13 steers	...	103	0	...	...	727*	146	1.41
A44/3, 13 steers	...	54	0	...	...	799*	84	1.55
A45/1, 12 steers	...	92	0	...	...	734*	151	1.64
A45/2, 11 steers	...	111	0	814	...	827	156	1.40
A45/3, 12 steers	...	57	0	...	...	807*	125	2.19
Finishing period								
A41/2, 13 steers	...	98	1,133	1,638	...	971	253	2.58
A41/3, 15 steers	...	64	719	1,658	...	993	185	2.89
A44/2, 13 steers	...	87	785	1,099	...	915	188	2.16
A44/3, 13 steers	...	55	541	1,356	...	924	125	2.27
A45/1, 12 steers	...	110	1,080	1,815†	...	957	223	2.03
A45/3, 12 steers	...	82	804	1,618	...	979	172	2.10

Marketing data

Group and disposal	Average weight, pounds			Average shrinkage in shipping, per cent	Average dressing percentage	Selling price per cwt.	Carcass grades, O.P.A.‡
	Shipping	Selling	Carcass				
A41/1, feeders	823	783	...	4.86	...	$13.18	....
A41/2, slaughter	971	894	516	7.92	58.9	14.00	4 AA, 8 A, 1 B
A41/3, slaughter	993	931	551	6.24	59.2	15.00	2 AA, 13 A
A44/1, feeders	785	741	...	5.60	...	14.70	....
A44/2, slaughter	915	852	518	6.88	60.7	18.83	13 A
A44/3, slaughter	924	891	519	3.57	58.2	16.51	13 A
A45/1, slaughter	957	893	518	6.60	58.1	24.50	12 A
A45/2, feeders	827	799	...	3.38	...	21.51	....
A45/3, slaughter	979	935	533	7.34	57.0	24.50	10 A, 2 B

* Weighed after all-night shrink in dry lot.
† 366 pounds of total was wheat straw mixed with molasses.
‡ AA, Choice; A, Good; B, Medium; C, Common.

grading Choice, eight Good, and one Medium. As shown by table 11, there was not much difference in total amounts of feed fed or dressing percentage of the A41/2 and A41/3 steers, but the latter had a 37-pound advantage at selling and sold at $1.00 per hundredweight more than the former group. The A41/1 group remained on natural forage until it dried, when they were sold as feeders at an average selling weight of 783 pounds.

Sufficient steers to form three experimental groups were not available in the 1942 calf crop, and the weaning weights of the 1943 calf crop were so low because of the adverse 1943-44 season that only a few weaner heifers were retained for breeding-herd replacements.

The 1944 calf crop was divided into three groups (A44/1, A44/2, and A44/3) of 13 head each, with the groups receiving treatment comparable to the respective 1941 groups. Table 11 shows marked differences in results. Total rainfall for the 1945-46 season was only 13.87 inches and consequently the total forage produced was below average and also matured at an earlier date. The supplement period for the A44 groups was shorter than that required for the A41 groups, with 191 pounds less total supplements per head for the lighter-fed groups and 124 pounds less for the heavier-fed group. Average daily gains of the A44 groups were quite similar to those of the respective A41 groups.

The 1946 grazing period was about the same length as in the 1943 season except for the A44/2 group steers, which were maintained upon pasture about 30 days longer than the A41/2 group steers (table 11). Average daily gains of 1.41 to 1.64 pounds of the A44 groups, for the period, were markedly below the 1.90 to 1.97 pounds average daily gain of the A41 groups. Shortly after mid-April the forage began drying rapidly, and feeding of the A44/2 and A44/3 groups for finishing was started. The steers were fed cottonseed cake and rolled barley in the previously described twice-a-day feeding. Because of drought conditions it was decided to try and finish them to the O.P.A. A grade. Thus, the heavier-fleshed A44/3 group was fed for a 55-day finishing period while the A44/2 group required an 87-day finishing period to reach the same degree of finish. The A44/3 steers' average selling weight was 891 pounds, dressing percentage 58.2, and all carcasses graded A, as compared with an 852-pound average selling weight, 60.7 per cent yield and all grade A carcasses for the A44/2 group. In this experiment the low-fed A44/2 steers received 255 pounds less total feed per head than the A44/3 steers, but had a higher yield and ended with carcass weight almost identical.

The A44/1 group were sold as feeders at the close of the grazing period with a selling weight of 741 pounds.

The steers of the 1945 calf crop were also divided into three groups after weaning (table 11). In contrast with the previous studies, only the A45/1 group was fed for moderate gains while the A45/2 and A45/3 groups were fed for the higher rate of gain during the supplement period after weaning. The supplement period of the 1946-47 season was similar to that of the previous year and the gain and supplements fed the A45/2 and A45/3 groups were quite similar to those of the A44/3 group. The A45/1 group were also used as controls in another experiment during the dry-forage period after weaning. During this period they were fed 3 pounds per head daily of wheat straw that had been sprayed with molasses, in addition to cottonseed cake. Since their feeding rate was higher than the previous moderately fed groups, their average daily gain of 0.75 pound is also above the daily gains attained by the other moderately fed groups (except for the A37 steer group—table 9).

Drought conditions again prevailed the 1947 grazing period with below-average forage production and earlier than usual drying of the forage. As in the previous study, one moderately fed group (A45/1) and one heavily fed group (A45/3) were to be finished for slaughter. The 92-day grazing period for the A45/1 group was between that of the A41/2 and A44/2 groups, and their 1.64-pound average daily gain was below that of the A41/2 group and greater than the A44/2 group. The 57-day grazing period of the A45/3 group was similar to those of the A41/3 and A44/3 groups while their 2.19-pound average daily gain was greater than the two previous corresponding groups.

Both the A45/1 and A45/3 groups were moved to finishing pastures before the close of the grazing period and twice-a-day feeding for finishing initiated. Drought conditions for this period in 1947 were more severe than in the previous year and longer periods were needed to finish the steers to the O.P.A. A grade. After an 82-day finishing period the A45/3 group sold at an average weight of 935 pounds, had a dressing percentage of 57.0 with ten carcasses grading A and two B. The lighter-supplemented A45/1 group were fed over a 110-day period, sold at an average 893-pound weight, had a 58.1 per cent yield, and all carcasses graded A. There was little difference in total amounts of concentrates fed per steer (each A45/1 steer also received 186 pounds wheat straw and molasses mixture during the dry-forage period after weaning), but the A45/3 steers had an average 42-pound advantage in selling weight and an average 15-pound advantage in carcass weight.

The A45/2 group, which had been supplemented to promote an average 1.03-pound daily gain during the supplement period, were sold as feeders with an average selling weight of 799 pounds after a 111-day grazing period.

After weaning, the steers of the 1946 calf crop were divided into three groups with the intention of replicating the study with the A45 steers. Drought conditions continued with resulting poor forage conditions that were unfavorable for finishing steers under the procedure being used. As a consequence this series of finishing studies was discontinued.

The difficulties of attempting to produce finished yearling cattle upon this range under the prevailing conditions are clearly indicated. While these results show that yearling cattle may be satisfactorily finished if the forage conditions are favorable, the climatic hazards are such that the area appears better suited for the production of feeder cattle.

FEEDER-CATTLE PRODUCTION: RECOMMENDATIONS

In their study of ranch management practices, in the "granite area" surrounding this station, Voorhies, *et al.* (1942) found that about half the ranchers ran steers which were sold off the grass at 2 years of age or older. The others ran cow and calf outfits and sold weaners or had no definite yearly marketing plan. Most of the steers from the area, because of the low quality of the forage, were sold as feeders. At this time a considerable proportion of the beef cattle marketed in California were 2 to 4 years of age and had been fattened upon grass or hay. As previously stated, however, the market demand had become more discriminatory with a greater demand for younger and lighter-weight animals with a high degree of finish. Thus range areas were becoming more important for the maintenance of breeding herds and grazing of stocker cattle to produce feeders than for the production of "grass fat" cattle.

Many factors must be considered to determine the best means of marketing the ranch feed supply. Production costs in relation to the selling price of calves, yearlings, and 2-year-olds, and total tonnage of beef produced must be considered for each ranch. Selling weights of the various age classes of feeder cattle, as affected by climatic and managerial factors, are also of great importance in determining a marketing program. Some data on these latter factors have been collected. Data on reproduction and growth of young animals with and without supplements, as well as improvement in quality by the use of good bulls, have been presented and discussed in previous sections.

Weaner Calves

Many ranchers favor a cow and calf enterprise because they are not inclined to carry young growing animals, other than needed replacements, through the costly winter period. Furthermore, this type of setup is favorable to flexibility in management procedure, especially if early calving and weaning around July is practiced. There are times, in areas of mild winters, when favorable climatic conditions produce a surplus of forage and the weaners could be held upon the ranch a few months longer to utilize forage that might otherwise be wasted.

Data in table 1 show that the supplemented A herd produced weaner calves with an average weight of 464 pounds as compared to an average of 406 pounds for the unsupplemented B herd. (The production of the supplemented C herd will not be considered in this discussion because of influence of unknown factors. These are not to be ignored, however, for a rancher confronted with such a problem has cause for concern and need of a management procedure to overcome the difficulties.) The 58-pound difference in A and B herd average weaning weights is of considerable importance because weight and degree of fleshing are important factors in determining the suitability of weaners as feeders to be placed directly in the feedlot. These data also include the heifer calves, from which the best are usually selected for replacement purposes.

Table 12. Average Weaning Weights and Ages of Steers Produced by the A and B Herds

Calf crop	Herd A		Herd B	
	Average weaning weight	Average weaning age	Average weaning weight	Average weaning age
1935	441	221	...	...
1936	465	218	409	182
1937	497	246	411	253
1938	519	245	423	224
1939	507	231	467	242
1940	517	239	445	222
1941	470	231	432	235
1942	445	236	402	221
1943	412	248	363	244
1944	501	256	415	219
1945	473	241	404	205
1946	435	220	362	210
1947	492	247	393	230
1937–1947 Average	479	240	412	228

The average figures presented in table 1 do not show the variations in annual weaning weights and such information is highly important in developing a marketing procedure. Presented in table 12 are the average annual weaning weights and ages for the steers produced by the A and B herds. These data, besides showing the previously discussed differences in the A and B herd total average weaning weights, show marked variations in annual weaning weights and ages resulting from variations in annual forage conditions. Besides the direct influence of variable forage conditions upon calf gains, there is the indirect influence resulting from time and rate of breeding the cows. Thus, if feed conditions are favorable and the cows are bred rapidly at the start of the breeding season the calves will be older than those from cows slow to settle. It is to be noted that variations in annual weaning weights were as much as 100 pounds and occurred in the A herd as well as in the B herd. While the weaner steers from the A herd were heavier and more uniform, it is obvious that some calf crops, such as 1942, 1943, and 1946, did not carry sufficient fleshing for suitable feeders. The use of calf creeps in the below-normal forage years to bolster weaning weights has been suggested, but it was not possible to use them in this study. It is doubtful if any of the B herd steer groups would have been considered suitable as feeders. Not only were the animals thinner fleshed and of lighter weight, but the groups lacked uniformity.

Yearlings

More and more interest is being shown in the production of yearling feeder cattle. Several factors favor the production of this age of animal, as compared with marketing weaner calves, when a breeding herd is being maintained. First, production studies have shown that a greater poundage of beef per acre may be produced. Secondly, a better opportunity for selecting replacement heifers exists because a better insight into the type cow the heifer will develop into is possible at the older age. Thirdly, on ranges of low carrying capacity, and marked annual fluctuations in forage production, in the more adverse years the calves may be sold as weaners and thus leave more acreage for the breeding herd. Fourth, a greater percentage of the total beef produced is from the cheaper range forage, and a shorter period of the more costly feedlot feeding is required to finish the animals for slaughter.

Growth rates of weaner steers during the supplement period (with and without supplemental feed) after weaning and the subsequent grazing period, as well as variations in rate of gain due to fluctuations in forage conditions, have been previously discussed. Presented in figure 9 are the average growth curves for the steers produced in the calf crops from 1935 through 1939, the latter calf crop being the last in which B herd steers were carried past the weaning age. These data show that supplemented steers reached an average weight of 867 pounds, at 600 days in age, at the close of the grazing period, whereas the unsupplemented steers had an average weight of only 735 pounds, or 132 pounds less. Average amount of supplements fed per steer for the supplement period, not including the year fishmeal and molasses were fed, was 396 pounds.

Evidence of variations that may occur in long-yearling steer weights at the close of the first grazing period is shown in tables 8, 9, and 11. These data show that the A35, A38, A41/1, and A44/1 group steers had average final weights of 890, 909, 823, and 785 pounds respectively. In comparison the average final weights of the B35, B36, B37, B38, and B39 group steers were 785, 664, 652, 778, and 781 pounds respectively. In all cases the supplemented groups

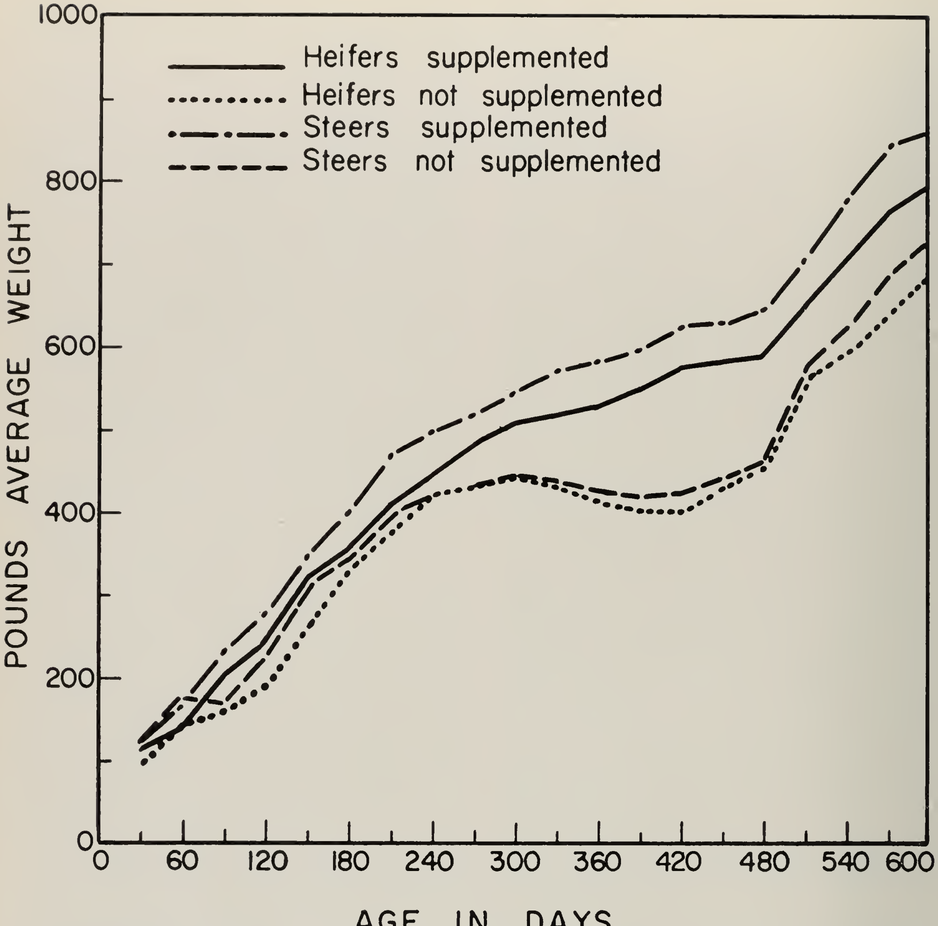

Fig. 9. Average growth curves for steers and heifers being supplemented as compared with similar groups not receiving supplemental feeds.

were of greater uniformity and in good flesh so that they were well suited to go directly to the feedlot. The unsupplemented groups were less uniform and at times (1936 and 1937 calf crops) so lacking in fleshing they were better suited as stocker cattle than feeders.

The data discussed here, for the most part, were produced in years of above-average rainfall (fig. 4) and in the more favorable years it is possible that the final weights of some supplement-fed steers might be heavier (909 pounds for A38 group steers) than the weights desired by feedlot operators. On the other hand, in the more adverse years weaning weights will be down (412 pounds for the A43 group steers—table 12) and the long-yearling weights will be correspondingly light unless the supplemental feeding rate is increased to promote a faster rate of daily gain during the supplement period. This procedure is well illustrated by the A45/2 steer data in table 11. This group of steers had a low weaning weight of 435 pounds, were supplemented for average daily gains of 1.03 pounds, weighed 827 pounds at the close of the following grazing period and had an actual selling weight of 799 pounds.

Growth data of supplemented and unsupplemented heifers (fig. 9) show average weights of 800 and 696 pounds, respectively, at 600 days of age. As previously stated, the top animals of the A and B herd calf crops were selected for replacement purposes at weaning during this period of study. Treatment of those remaining after weaning was not consistent, hence information on long-yearling weights and condition cannot be given. Two groups of surplus heifers from the A herd were finished (table 9).

Two-Year-Olds

Only four groups of feeder steers were carried until they were over two years of age and all were unsupplemented groups. These were the B35, B36, B37, and B38 group steers. Their average shipping weights were 999, 905, 979, and 1,083 pounds respectively (table 8). In all cases their condition lacked suitable finish for slaughter, as illustrated by the slaughter data of the B35 group steers, but because of their age and fleshing only a short period in the feedlot would be required for finishing. As with the other groups, their final weights would be variable in accordance with climatic conditions and in most cases their finished weights would be greater than the best market demands.

HERD IMPROVEMENT THROUGH SELECTIVE BREEDING

An essential of good animal-husbandry practice is improvement of the herd through culling and selection. This was an important part of this enterprise. Excellent opportunity existed for recording information on heredity–environment relations.

Breeding Methods

From January 1 until the herds were placed upon the "grazing intensity" pastures one bull was placed with herd A, one with herd B. These bulls, usually half brothers, were either proven or represented the best available from the standpoint of individuality and ancestry. They were alternated in succeeding years to diminish hereditary differences between the two herds. Being with the cows early in the breeding season, these bulls sired most of the calf crops. When the cattle were placed in pastures 1 to 6 a bull was furnished for each pasture except during 1936, when only five bulls were available, and one had to be rotated between pastures 1 and 2.

Measurements Taken

Recording growth by various body measurements in addition to weight was initiated in 1942. Since variation in measurements as affected by environment may help in understanding the selection problems encountered, the growth data are presented first. Measurement of width of hooks and of cannon bone were not started until 1944. All animals were measured when the calves were weaned. Measurements were taken with the animals standing as naturally as possible in a squeeze chute. At times difficulty was encountered, and considerable patience was required to secure normal posture. Culling of wild and nervous individuals, use of bulls with docile ancestry, and quiet handling in gentle cattle minimized the problem, and measurements were obtained with a degree of accuracy considered to be equal to those for the purebred herd at Davis. Head and cannon bone measurements were recorded to the nearest 0.25 centimeter; all others to the nearest centimeter.

The measurement of the round extends from the point of the stifle (patella) on one side horizontally around the thighs to the point of the stifle on the opposite side. The round measurement is conditioned largely by muscle, and the ratio of round to height $\left(\frac{\text{R.M.}}{\text{H.}} \times 100\right)$ may be considered a muscle: skeletal index and, therefore, an index of conformation (Gregory, 1933; Guilbert and Gregory, 1951).

The D-W (dimension-weight index) (Yapp, 1924) is also an expression of conformation. It expresses the estimated volume of the animal (weight in pounds × an average value of 476 cc per pound) as a percentage of the volume in cubic centimeters of rectangular prism conditioned by height at withers squared times the length:

$$\left(\frac{\text{Weight} \times 476}{\text{Height}^2 \times \text{Length}} \times 100\right)$$

Body length is taken from the point of the shoulder horizontally to a line perpendicular with the pin bone, when the animal is standing squarely with forelegs at right angles with the top line.

Culling and Selection of Replacements

As has been brought out earlier, the intensity-of-grazing study required a definite number of cows in each pasture each season, which necessitated keeping a few extra animals as possible replacements of death losses. A few heifers were kept for this purpose the first few years of the experiment, and some of these were later used as replacements. Later extra animals were maintained for other experimental purposes and were available as temporary fill-ins.

All of the heifers from the first calf crop produced by the foundation heifers were divided between the A and B herds to increase their numbers. Except for the year culling was initiated (1938), the cows culled were removed from their respective breeding herds at the close of the grazing period. This date varied from the fore part of July to the fore part of August. Replacement animals for each herd were from their respective calf crops of the previous year that had been maintained through the supplement period in a manner similar to that for their herd of origin. Actual culling and replacement, therefore, was not initiated until the second calf crop (the first produced by the newly established A and B herds) were long-yearlings.

In the breeding and culling procedure the intent was to maintain hereditary equality between the two breeding herds. Lower percentage calf crops plus poorer development of the B herd heifer calves made this difficult: not only were there usually less heifers to choose from in the B herd calf crops, but also it was often impossible to distinguish genetically inferior animals from those inferior because of improper growth and development. This was particularly true after such extremely severe winters as in the 1937–38 season or drought years as in the 1943-44 season. As a result, culling and replacement proceeded at a slower pace in the A herd than was possible from replacements available, while undesired replacements were used at times in the B herd because no others were available.

Criteria for the culling of cows were poor health, poor reproduction, poor conformation, wildness, and age. A summation of the culling and reproduction data for the A and B herds is given in table 13. The procedure was the same for the C herd except that the foundation animals for this herd were mostly poorer-type cows culled from the A and B herds in 1941.

Animals culled for poor health were those considered a poor risk to carry through another winter and reproductive cycle and were sold while there was something of value to salvage. In culling for poor reproduction, barrenness, low milk production, deformed teats and udders, and a tendency for prolapse were the main considerations. Since the study was concerned with factors causing abortions and stillbirths other than those produced by disease, cows were not usually sold for these reasons. It is to be emphasized, however, that abortions and stillbirths are important reasons for culling in commercial herds. Cows aborting

Table 13. Summation Culling and Replacement Data for A and B Herds

Year and breeding herd	Number cows dying	Number cows culled	Number replacements	Number culled for:					
				Poor reproduction	Poor type	Poor health	Wildness	Age	Other
1936									
A	0	0	0	..	..	..	..	..	..
B	2	0	0	..	..	..	..	..	..
1937									
A	2	0	15	..	..	..	..	..	..
B	4		16	..	..	..	..	..	..
1938									
A	0	10	9	2	8	..	..	..	..
B	0	6	8	..	3	..	3	..	..
1939									
A	0	9	9	1	6	1	..	..	1*
B	0	4	4	1	2	1	..	..	..
1940									
A	2	6	8	1	3	1	1	..	..
B	1	7	7	1	4	1	1	..	..
1941									
A	0	8	7	..	8	..	..	..	..
B	3	10	7	1	8	..	1	..	..
1942									
A	1	6	8	3	2	..	1	..	..
B	0	1	8	1	..	..	..	..	..
1943									
A	0	8	8	..	..	1	..	7	..
B	0	8	8	1	..	..	..	7	..
1944									
A	1	5	5	1	4	..	..	..	..
B	0	5	5	1	4	..	..	..	..
1945									
A	0	3	4	1	..	2	..	..	..
B	1	6	5	..	5	1	..	..	..
1946									
A	1	7	5	4	..	..	..	3	..
B	0	1	3	..	..	..	..	1	..
1947									
A	0	9	12	3	..	3	..	3	..
B	1	7	7	4	..	1	..	2	..
Total									
A	7	71	90	16	31	8	2	13	1
B	12	55	78	10	26	4	5	10	..

* Refused to eat cottonseed cake.

or dropping stillbirths frequently repeat such occurrences in later pregnancies and often apparently pass the trait on to their daughters (fig. 10). Cows failing to conceive in two consecutive years were considered barren and culled.

Cows not producing sufficient milk to raise their calves were culled, as well as those with badly misshapen udders or with teats so enlarged at parturition that

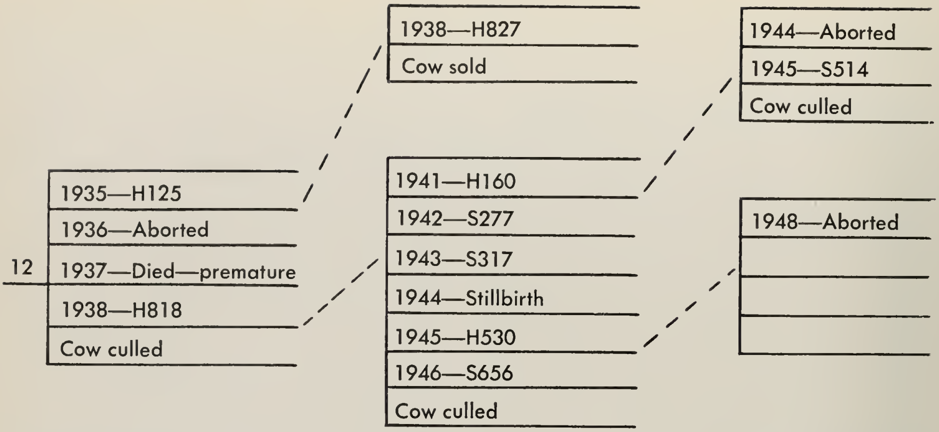

Fig. 10. Summation calving data for foundation cow no. 12, her daughters and granddaughters. All animals maintained in herds receiving supplements.

Table 14. Weaner Calf Data from Two Cows Receiving Identical Treatment in the A Herd

Cow no., calf crop, and calf no.	Weaning age, days	Weaning weight, pounds	Weaning grade
Cow 19			
1935, calf H127	237	330	Good
1936, calf S220	260	400	Medium
1937, calf H703	260	390	Low Good
1938, calf S804	248	410	Low Good
1939, calf H957	267	400	Good
1940, calf H045	233	425	High Good
1941, cow dry	...	...	......
1942,* calf H280	217	327	Low Choice
Total	...	2,682	......
Cow 45			
1935, calf S104	241	465	Choice
1936, calf H225	256	530	High Good
1937, calf H709	246	560	Choice
1938, calf S809	246	545	High Good
1939, calf H959	266	585	Choice
1940, calf S041	259	600	Choice
1941, calf H124	235	511	Low Choice
1942,* calf S275	258	481	Low Choice
Total	...	4,277	......

* Cows culled for age after weaning 1942 calf.

the new-born calf could not nurse without the cow's being first milked out. Adequate milk to supply the needs of the calf is of great importance in the ultimate weaning weight of the calf. This is well illustrated from two cows, nos. 19 and 45, which received identical treatment in the A herd (table 14). No. 19, graded low Choice, always had the appearance of being a good "doer" because she was usually in better flesh than the average of the herd. But it was noted that she was lacking in udder development and usually weaned a below-average calf. The data show that the cow usually bred early in the breeding season. In comparison, no. 45, grading high Good, always looked rougher but had better udder development, and she consistently weaned calves above the average herd weaning weight. In a summation of lifetime production no. 45's calves had a 152-pound greater average weaning weight, with a total of 1,595 pounds more weaner calf production.

As previously stated, herd improvement through the use of better bulls and selection of heifers of best conformation for replacements was a part of the study. Thus, whenever possible, inferior-type cows were replaced by superior-type heifers. Attempts were made to maintain the same rate of culling poor-type cows in both the A and B herds, but this was difficult, as previously mentioned. For the 10-year period, 1938 to 1948, the percentages of heifers used for replacement were 47.4 and 57.7 for the A and B herds respectively.

In herd A the proportion of first- or first- and second-generation females to original cows in different years was as follows: 1937, 15:31; 1938, 25:22; 1939, 30:15; 1940, 35:9; 1941, 35:10; and 1942, 36:8. The corresponding figures for herd B were, 1937, 14:30; 1938, 20:23; 1939, 23:22; 1940, 28:17; 1941, 34:9; and 1942, 38:7. Replacement was thus slower initially for herd B. After 1943 both breeding herds were made up exclusively of first-, second-, and third-generation replacements.

Nervous or "wild" cows were considered a detriment in the herd and cause for culling because they tended to excite other animals when the herds were being fed or worked. In the course of the study it was noted that the exceptionally nervous cow usually produced a nervous calf and that the weaner calves sired by a bull of nervous disposition were usually more nervous than those sired by a bull with a quiet disposition. It must be mentioned, however, that ordinarily quiet-dispositioned cattle may be made wild by rough handling, and this is especially true with calves during the weaning process and immediately after. Supplemental feeding and quiet handling were found to be great aids in quieting a herd of cattle.

In this study the cows were culled after reaching ten years of age. Variations in weaner calf production of different-aged cows has been presented in a previous section.

One herd A animal was culled because she refused to eat cottonseed cake.

Effect of Plane of Nutrition

A summary of data for the various measurements, at different ages, and comparison of herds A and B are given in table 15. Graphical presentation of weight, and selected measurements are shown in figure 11. In figure 11, data for selected measurements for herds A and B are contrasted and both are shown as percentages of the values attained by the parent herd at Davis.

Important differences in growth and development given in table 15 and further illustrated in figure 11 are as follows:

Herd A exceeds B in average weight throughout life. This has already been demonstrated in the section, "Feeding and Management of the Breeding Herds," where seasonal weight variations also are shown.

Table 15. Average Weight and Measurement Data, 1942–1948

Age and herd	Number of animals*	Weight, pounds	Height, cm: At withers	Height, cm: At hooks	Heart girth, cm	Length, cm	Round, cm	Head, cm: Width	Head, cm: Length	Width, hooks, cm	Width, cannon, cm	$\frac{\text{R.M.}^{\dagger}}{\text{H}} \times 100$	D–W‡ index	Grade
8 months														
Herd A	113	437	95	100	130	111	81	17.9	36.4	33	3.8	85	21	86
Herd B	92	390	93	98	124	106	78	17.5	35.7	31	3.6	84	20	84
20 months														
Herd A	84	763	110	115	159	134	92	20.7	44.0	43	4.4	84	23	86
Herd B	64	643	106	111	149	127	87	20.0	42.7	41	4.1	82	21	83
32 months														
Herd A	80	1,016	117	121	177	145	101	21.9	47.1	51	4.6	86	24	87
Herd B	64	882	114	119	168	141	94	21.4	46.1	46	4.2	83	23	85
44 months														
Herd A	59	1,031	118	123	177	149	98	22.4	47.8	52	4.6	83	24	86
Herd B	41	912	116	121	170	144	94	21.8	47.7	49	4.4	81	22	84
56 months														
Herd A	57	1,083	119	123	180	153	98	22.6	48.3	54	4.7	83	24	86
Herd B	41	969	117	122	174	148	97	22.3	47.9	51	4.5	83	23	84
68 months														
Herd A	40	1,120	120	124	183	154	101	22.8	48.7	55	4.7	84	24	86
Herd B	41	999	118	122	175	150	97	22.6	48.5	52	4.6	82	23	84
80 months														
Herd A	50	1,105	120	124	182	154	99	22.9	48.6	55	4.6	83	24	85
Herd B	44	1,017	120	123	177	152	97	22.8	48.8	52	4.6	81	22	84
92–116 months														
Herd A	78	1,082	120	124	180	154	98	23.1	48.8	54	4.7	82	23	86
Herd B	78	1,009	121	124	176	152	97	23.1	49.6	52	4.6	80	22	84
Percentage increase, 8 months to 80 months														
Herd A	...	255	126	124	140	139	122	128	134	167	121	...	...	...
Herd B	...	261	129	126	143	143	124	130	137	168	128	...	...	...

* Width of hooks and width of cannon measurements not taken in 1942 and 1943. Numbers of animals involved, by increasing age group, were 81, 63, 63, 43, 43, 51, 28, and 70, respectively, for herd A, and 67, 45, 27, 28, 32, 33, 30, and 70, respectively, for herd B.

† Round measurement divided by height; see Gregory, 1933.

‡ $\frac{\text{Weight} \times 476}{\text{Height}^2 \times \text{Length}} \times 100$; see Yapp, 1924; and text, p. 52.

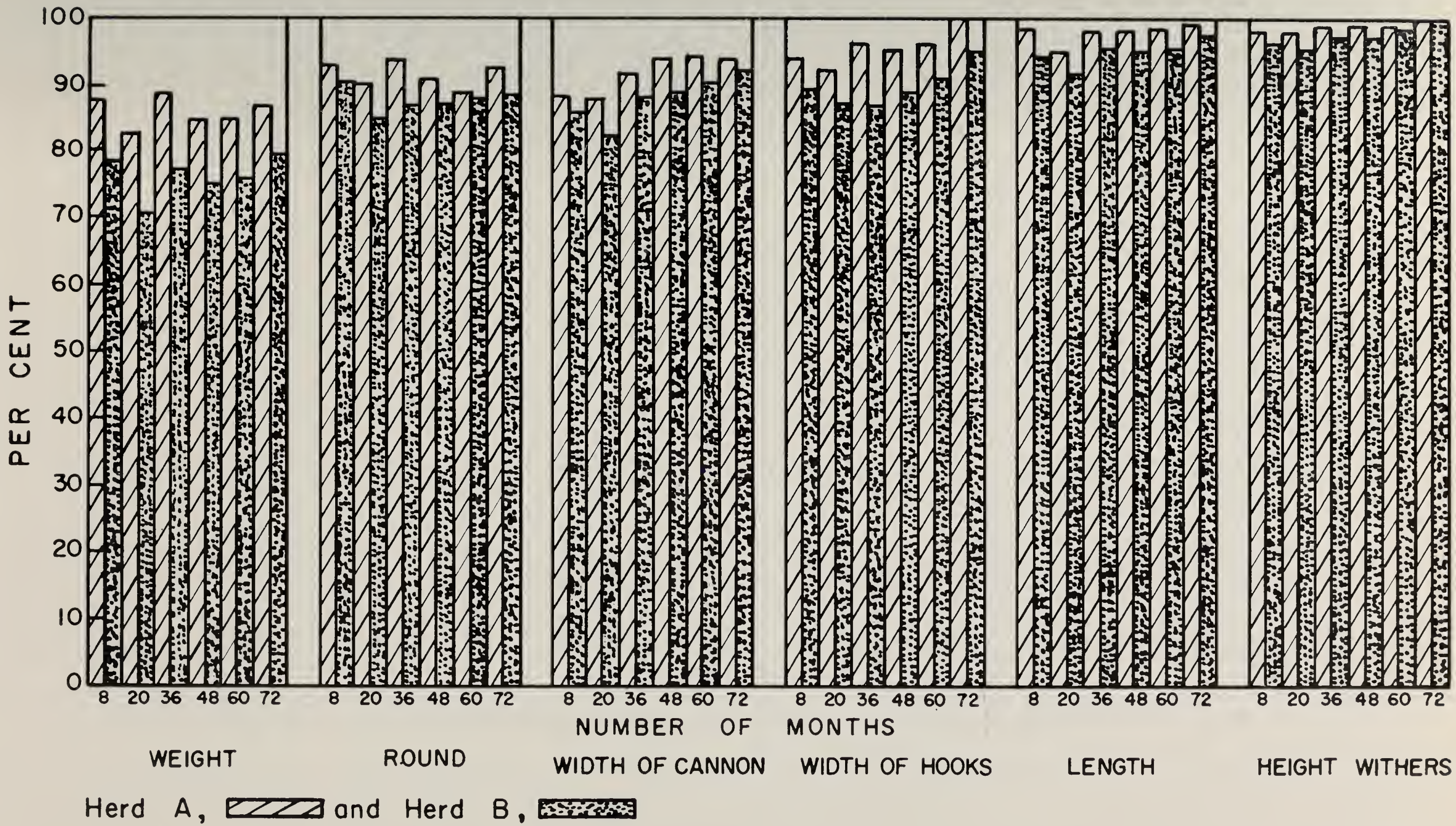

Fig. 11. Herd A and herd B measurements expressed in percentage of the parent herd at Davis.

Heart girth, which is highly correlated with weight, and to a lesser extent, round measurement, show the same general trend of difference between the two groups as weight.

As compared with herd A, *linear* skeletal growth represented by height at withers and hooks was retarded in herd B. The margin of difference gradually decreased with age so that there was no difference at maturity. This probably is true for body length also. The length measurement is less accurate than height because it is affected not only by stance, but also by the estimation of the actual position of the pin bone, which may be covered by a pad of fat. The thickness of this pad averages greater in herd A.

Skeletal *thickness* growth is represented by width of cannon bone and by width of hooks. Undernutrition interfered relatively less with increase in thickness of cannon, one of the earliest-maturing skeletal parts, than with width of hooks, the latest-maturing part of the skeleton.

In contrast with earlier-maturing *linear* skeletal growth, the herd B cattle generally did not quite catch up with herd A in the *thickness* dimensions (width of cannon and hooks). The statistically significant difference in average width of hooks may be biased somewhat by the thicker pad of fatty tissue carried by herd A; this difference, however, was minimal at time of measuring, the calipers were pressed tightly over the points to reduce this source of error.

The mean difference between groups A and B in width of cannon, except for 20 months of age, is less than the smallest calibration of the measuring instrument (0.25 cm). There is nevertheless a consistent retardation of cannon-bone thickness in herd B animals. When groups of animals born in the same year are contrasted at 5½ years old and over, the average cannon-bone width of herd A exceeded herd B in 10 out of 15 comparisons. The average difference including all animals at maturity, about 0.1 cm, is not quite enough for significance at the 5 per cent level. Although there was no difference between some of the groups at maturity, there was a some tendency for herd B animals to be "finer boned." This was particularly striking in the case of the limited number of herd B cows in pasture 3, which were subjected to the most drastic undernutrition (see asterisk, fig. 12).

Percentage increase of the head dimensions from 8 months of age to maturity was in the same order of magnitude as other skeletal measurements with the exception of width of hooks. Herd B had smaller dimensions early in life, but there were no significant differences between the two groups at maturity. Head length tended to increase more than width so that width expressed as a percentage of length decreased slightly with age. This "ratio" of width to length for herd B was slightly but consistently lower than for herd A.

Although effort was made to minimize the influence of condition (fig. 13) on grading, the average grade of the herd B animals was slightly but consistently lower than herd A. This was true also for the muscle-skeletal index and for the dimension-weight index, both of which are expressions of thickness in relation to linear-skeletal dimensions.

In figure 12 the data are arranged in order of the greatest to the least effect of plane of nutrition. Thus the greatest difference between herds A and B and the Davis herd is in body weight and round measure representing general thickness growth and degree of fatness; the least difference was in height and length representing linear skeletal growth.

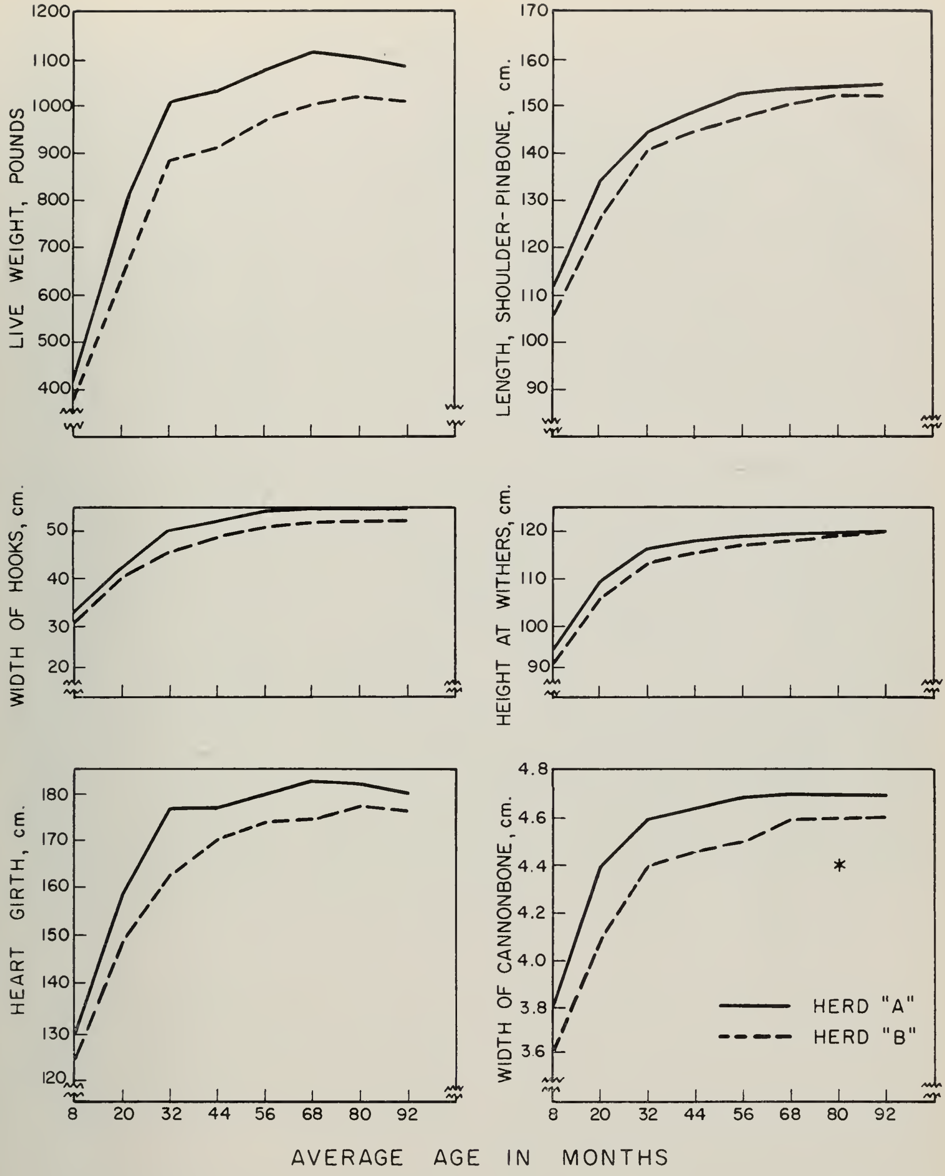

Fig. 12. Variations in some body measurements of herd A and B females from 8 to 92 months of age. The asterisk (*) indicates herd B cows in pasture 3.

Fig. 13. Upper photos, a cow in good flesh, as compared with the same cow in poor flesh in the lower photos. Such differences in fleshing often influence the grading of animals.

At maturity, height of withers was the same for all three herds; the difference in length probably is not significant.

Herd A became equal to the Davis herd in width of hooks at maturity. Herd B never caught up in development of this latest-maturing part of the skeleton.

Length of cannon bone in the Davis herd reaches maximum at about 12 months of age; width at between 20 and 24 months. Herd A cattle apparently increased in cannon-bone diameter to between 4 and 5 years, herd B cattle somewhat later; but neither attained the "size of bone" of the parent herd. Although difference in hereditary size of cannon bone cannot be ruled out, it appears possible that restriction of this early-maturing part of the skeleton through undernutrition at the younger ages may be decisive.

Changes in Proportions during Growth

Each new individual arises from a single cell, differentiates into nervous, glandular, skeletal, muscle, fatty tissues, and into various organs and structures. After these tissues and organs develop, they grow and mature at varying rates so that the proportions change markedly from birth to maturity. Huxley (1932), Thompson (1917), and others, have attempted to generalize these changes in mathematical terms and develop allometric growth equations. Kidwell, Gregory, and Guilbert (1951) reported upon the applicability of the allometric growth equation to measurement data derived from the purebred Hereford herd at Davis. Thus far these highly theoretical mathematical treatments have not contributed much to the problems of relating form and function in farm animals nor in indicating objective ways of measuring conformation. The data of Hammond (1920, 1940) and his students, particularly Vergis (1939) and McMeekan (1940–41), laboriously obtained from detailed anatomical dissection of joints and tissues of animals of different species and ages, have given a clear-cut quantitative picture of the changes in proportions of bone, lean, and fat, and of different parts of the body during growth. These data have clearly demonstrated the following generalizations:

1. All animals follow a similar pattern in changing shape from birth to maturity.

2. Each lower bone of a leg is in turn earlier maturing than the one above. Thus growth gradients extend from the extremities and meet in the loin and pelvic region, the longest-growing and lastest-maturing parts.

3. From the standpoint of tissues, growth proceeds in three overlapping phases: the peak of the bone growth precedes that of muscle; muscle that of fatty tissue.

4. Improving animals for meat production largely has been concerned with the extent of these developmental changes and the *rate* at which they occur. Thus the young of an improved type at birth frequently resembles the mature shape of its wild or unimproved progenitor. The modern hog is heavy in rib, loin, and hams, light in the shoulder and head, whereas the reverse is true in the wild pig—and in the young pig of today. Simultaneous increase in growth rate and maturity rate has increased efficiency of feed use.

5. The above generalizations give a basis of the concept of nutrient priorities. Early-maturing parts and tissues have priority over later ones. Thus when nutrition is limited, growth of fatty tissue is most restricted, followed in turn by muscle and skeleton. Hind quarter and loin will be restricted more than earlier-maturing parts, width or thickness growth more than length growth. Thus undernutrition tends to keep an animal's shape and composition in the immature or unimproved state. The lower the nutritional plane, the less overlapping there is in growth of bone, lean, and fat. A high plane of nutrition increases the overlap and brings the peaks closer together.

6. The composition of the carcass is affected by the shape of the growth curve. Thus at a given age and weight, an animal restricted in nutrition early in life but fed liberally later will have a carcass lower in lean and higher in fat than one fed heavily during the peak of bone and muscle phases and restricted later (McMeekan, 1940–41; Guilbert, Hart, *et al.*, 1944).

The data collected in these investigations on cattle managed under range conditions confirm the generalizations enumerated above. They demonstrate some of the difficulties of distinguishing genetically superior individuals when adverse environment has restricted growth and development. The idea that poor feed and other adverse environment factors will result in "fine-boned" animals is confirmed. Duerst (1931) refers to meat animals as digestive type; to dairy conformation as respiratory type, and summarizes adverse environmental effects on beef conformation as causing reversion to the respiratory type. It appears clear, at any rate, that environmental restriction, prolonged throughout the growing period, affects conformation more than when a normally grown animal is reduced to thin condition.

Commercial producers are more aware of these facts than the purebred breeder, who generally operates under excellent environment—not infrequently carried to artificial extremes. More breeders should see their bulls and follow their progress in commercial herds in order better to understand the mutual problems of breeders and producers.

That the changes in shape with age frequently are not fully appreciated by beef-cattle judges is testified to by the general show-ring preference for calves which have most nearly attained mature shape and conformation. Some of our most respected judges and breeders have even been "taken in" by near monstrosities and by actual dwarfs! More consideration should be given at the younger ages to the conformation and greater "stretch" that is characteristic at these ages of animals that later approach ideal conformation and composition at market weight, age, and condition.

Improvements in Cow Weight, Measurements, and Grade

The grade of all original cows (reconciled with the grading system as more clearly defined in 1940; see Guilbert and Hart, 1946, p. 68) varied from 73 (high Medium) to 85 (low Choice) and averaged 78.3, or slightly under average Good. The first three calf crops from herd A, involving 76 calves all from original cows, averaged 83.0 in grade. The bulls used varied from 88.0 to 91. Thus the average grade of the calves was about midway between the cows and the sires. Variability in type, conformation, and size of the original cows was fairly high. There were some small-boned, light-weight individuals as well as tall, rangy animals. In general the heads, cannon bone, and height at withers averaged greater than subsequent generations. Table 16 shows some comparisons of measurements by generations. The first part of table 16 shows average data on 22 out of 33 original herd A cows at 6 years of age after the poorest third had been culled. First- and second-generation herd A and Davis females at 6 years of age represent selected animals from several calf crops.

The second part of the table represents an attempt to select an age group which permitted comparison of maximum numbers of the different generations on the basis of more complete measurement data. Not only were numbers of third generation limited, but also they were grown out during a series of drought years. There is no evidence that mature body size or weaning weight has been changed significantly. Nearly all the bulls that were kept until maturity and used extensively have weighed over 1,800 pounds in range breeding condition. This would correspond with 1,900 to 2,100 pounds for the same bulls in the condition in which bulls in purebred herds are usually kept.

From available objective comparisons, the cattle were changed in the following manner:

1. Average height at withers was reduced 2 or more centimeters and became identical with the parent herd at Davis.

2. Head length was reduced from about 50 cm (average of a sample of 18 head of the best original cows at maturity was 49.8 cm) to about 48.7 cm in the second generation. Evidence of further reduction in head length in the third generation is indicated in table 17. The range herds were still between 1.5 and 2.0 cm longer in the head than comparably aged cattle in the Davis purebred herd. Difference in head width for the different generations is not significant.

3. There was increase in round measurement and, from observation, general muscle thickness along with reduction in height.

4. These apparently rather moderate

Table 16. Comparison of Weights and Measurements by Generations

Age and generation	Number of animals	Weight, pounds	Height at withers, cm	Heart girth, cm	Length, cm	Round, cm	Head, cm		Width, hooks, cm	Width, cannon, cm	Grade
							Width	Length			
Six years											
Original "A"	22	978*	122	178	...	93	23.0†	49.8†	54	..	80
First "A"	14	1,135	120	184	...	99	22.8	48.6	54	..	83
Second "A"	13	1,116	120	181	...	102	23.2	48.7	54	..	88
Davis	25	1,274	120	192	...	110	22.9	46.9	55	..	91
Three and one-half years											
First	22	1,072	119	182	150	98	22.6	48.0	55‡	4.6‡	84
Second	33	1,078	118	180	150	100	22.4	48.1	55‡	4.8‡	88
Third§	11	973	118	174	147	97	22.4	47.7	52	4.7	86
Davis	40	1,142	118	187	149	108	22.4	46.2	55‡	5.0‡	90

* This low weight was taken in a poor feed year. The same cows averaged 1,070 the previous year at 5 years of age.
† Average of 18 head of A and B cows remaining in 1942.
‡ Mature values were taken for width of hooks and cannon for first and second generation and Davis heifers because of lack of data for first generation. Davis cattle reach maximum cannon-bone width at about 2 years of age. Data beyond 3½ to 4½ was not available in 1948.
§ The lower weight and correlated measurements are considered to be caused by drought years during which the third-generation heifers developed, rather than to genetic decrease in size.

Table 17. Comparison of First-, Second-, and Third-Generation Female Descendants from the Original A Herd Cows Together with Similar Data from the University Purebred Herd, Davis

Average age: Range heifers, 44 mo.; U. C. Davis, about 40 mo.

Generation	Number of animals	Weight, pounds	Height at withers, cm	Heart girth, cm	Length, cm	Round, cm	Head, cm		Width, hooks,* cm	Width, cannon,* cm	Grade
							Width	Length			
First	22	1,072	119	182	150	98.0	22.6	48.0	55	4.6	83.5
Second	33	1,078	118	180	150	99.5	22.4	48.1	55	4.8	87.5
Third	11	973	118	174	147	97.4	22.4	47.7	52	4.7	86.0
Davis herd	40	1,142	118	187	149	108.0	22.4	46.2	55	5.0	90.0

* Mature values were taken for width of hooks and cannon for first- and second-generation heifers and the Davis-herd heifers. Data for first generation at 44 months was not collected. Davis cattle reach maximum cannon width at about 2 years of age. Data beyond 3½ to 4½ years of age was not available for third-generation cattle in 1948.

dimensional changes were associated with improvement in subjective evaluation by grading, from about low Good for the original cows to average Choice for second- and third-generation replacements. Greater uniformity, shorter and thicker cannon bone, and freedom from short, sloping rumps and other asymmetrical conformational characteristics were also obvious.

Improvements in Grade and Weight of Calf Crop

Data for grades and weights of the calf crops weaned for the ten-year period are shown in table 18. The data demonstrate the following points:

1. The average of the first three calf crops and the data in table 18 for 1937 and 1938 show that the first generation averaged about 82, or top Good.

2. After the cow herds consisted of selected first- and second-generation replacements and the top of the original cows, no definite improvement trend was evident from the grades.

3. Average grade of calves from unsupplemented herd B cows generally was significantly lower than their herd A mates. Variation of grade with weaning weight is also apparent in year to year comparisons for both groups. Effort was made to minimize the effect of condition on grading, but restricted growth does more to change conformation than mere change in fatness, and complete allowance is practically impossible.

4. Under optimum conditions, the average grade of second- and third-generation animals was close to 88, or average Choice. This is doubtless somewhat higher than the average of purebred Herefords as a breed and approaches closely the average of the parent herd at Davis.

According to unpublished data from the California Agricultural Experiment Station, there is little or no difference in percentage of wholesale cuts or proportion of lean, bone, and fat in equally fattened animals ranging from Good to Choice in grade. External measurement

Table 18. Average Grade and Weight of Calf Crops at Time of Weaning, 1937–1947

Year born	Grade				Weight, pounds			
	Heifers		Steers		Heifers		Steers	
	Herd A	Herd B	Herd A	Herd B	Herd A	Herd B	Herd A	Herd B
1937	83.6	83.5	85.8	80.7	472	328	497	411
1938	82.5	81.7	84.2	81.8	461	409	519	423
1939	85.0	85.2	85.6	81.1	493	465	507	467
1940	85.5	84.7	86.2	85.5	473	422	517	445
1941	85.3	85.3	87.0	85.6	457	443	470	432
1942	85.7	83.0	84.2	85.6	442	403	445	402
1943	85.9	82.6	84.3	85.0	428	329	412	363
1944	86.7	83.8	87.0	85.2	458	405	501	415
1945	85.0	83.7	86.2	85.0	415	395	473	404
1946	86.2	83.9	86.0	84.8	422	368	435	362
1947	86.7	84.7	85.7	85.8	443	412	492	393

differences likewise are not conspicuous. Even relatively long-legged Brahmans and half-bred Brahmans show little difference from Herefords in these carcass characteristics although shape of rib and some other cuts are conspicuously different in straight Brahmans of good beef quality. These data have focused attention on higher yield at moderate finish and less feed per pound of gain as two variants that at any given price structure most affect value per pound and production cost of animals having acceptable carcass characteristics.

It is probable that no improvement has been made in carcass yield although there are no critical data on this point.

Improvements in Efficiency of Feed Usage

During recent years, some of the bulls used have been subjected to feed-utilization tests after weaning. The bulls used that were sired by California Rover II have, on the average, required less than 700 pounds of feed, consisting of 65 per cent concentrates, for each 100 pounds of gain. The animals were each fed until they would correspond closely with top Choice to low Prime slaughter condition.

Pattengale[3] ran feed-use tests on the steer progeny of three half brothers sired by California Rover II. Those from the San Joaquin Range cows required 691 pounds of feed per 100 pounds' gain, as compared with 797 and 775 respectively for first cross of similar bulls on plainer range cows in a cooperator's herd. Other tests have likewise contributed to the probability that efficiency of feed use has been increased. According to data of Guilbert and Gregory (1952), some of the factors contributing to higher grade are associated with or caused by ability to thrive. Thus high weight for age along with the high rate of maturity required to make higher grade is a good index of efficiency.

[3] Pattengale, P. S. Unpublished data compiled in 1950.

MORTALITY AND MORBIDITY

Accumulated knowledge of occurrence or prevalence of various causes of death or degrees of departure from normal health and well being is valuable in guiding corrective measures or research. During the 13-year period 1935 to 1947 inclusive, there were about 1,270 different case reports recorded — not including the more obvious repetitions of unchanged conditions in individuals. The herd varied from 129 to 269 head in different years, with about a 226-head average. Breeding cows varied from 66 to 110 head; weaner calves from 43 to 78 head; the remainder consisted of varying numbers of yearling and 2-year-old steers and heifers. The approximate number of animal-years from which the 1,270 case reports have been made is 2,950. These figures are given to emphasize the extremely large numbers of abnormalities that detract in small or large degree from optimum well-being and most efficient production. Attention to minor ailments is important, for collectively they exact an enormous toll.

Death Losses in Breeding Cows

The various categories of losses among breeding cows during the 13-year period were as follows, in terms of numbers of cow-years and percentages of total cow-years:

	Number	*Per cent*
Total cow-years	1,122	....
Parturition	8	0.71
Eversion of uterus	3	0.27
Uterine infection (herd B)	3	0.27
Starvation (herd B)	2	0.18
Rattlesnake bite	2	0.18
Other causes	5	0.45
Total loss	23	2.05

Calf Mortality in Utero and Prior to Weaning

At the beginning of the study the foundation heifers purchased were found free from reactors to the agglutination test for infectious abortion, and no reactors have since been detected. A summation of all calf losses for the period 1935 through 1947 for the A, B, and C herds is presented in table 19. The losses of the foundation heifers in 1935 have been included with those of the A herd. These data show total calf losses, prior to weaning, of 9.4, 12.0, and 21.3 per cent for the A, B, and C herds, respectively.

Of a total of 107 calves lost, 40 were due to stillbirths and 19 to abortions. These two sources account for 55 per cent of all the calves lost. Table 19 shows almost identical losses of 5.35 and 5.26 per cent of total pregnancies for the A and B herds, whereas it is 13.11 per cent for the C herd. Factors responsible for these losses are unknown, and the higher percentage of stillbirths in the C herd maintained in one pasture year round with supplemental feeding has already been discussed in the section, "Feeding and Management of the Breeding Herd." A shortage of vitamin A upon the area has not been substantiated, and leptospirosis, a recently discovered disease that may cause abortions and occurs over wide areas, is probably not involved in these cases.

Calf losses caused by dystocia, death of dam, and by starvation were higher in the B herd, especially after drought years, long winters, or other adverse forage conditions. The two calves lost by starvation in the A herd were caused by one cow's having teats too large for the calf to nurse, and another cow's failure

Table 19. Calf Losses and Retained Placentas in the Three Breeding Herds

Item	Total number of animals			Percentage		
	Herd A, 1935–47; supplemented	Herd B, 1936–47; no supplements	Herd C, 1941–47; supplemented	Herd A	Herd B	Herd C
Total pregnancies	467	342	122	...	...	...
Total calves weaned	426*	302*	100	...	...	...
Calf losses:						
Abortions	10	7	2	5.35 (abortions and stillbirths)	5.26	13.11
Stillbirths	15	11	14			
From dystocia	4	5	3	...	...	...
From dam's death	3	6	0	...	...	...
From starvation	2	6	0	...	...	...
From other causes	10	6	3	...	...	...
Total	44	41	22	9.4	12.0	21.3
Retained placentas:						
Cows with retained placentas	80	97	29	17.1	28.4	23.8
Cows kept after retained placentas	62	68	20	...	...	...
Cows rebreeding after retained placentas	46	38	16	74.2	55.9	80.0

* Difference between total pregnancies and calves lost plus calves weaned is due to twins dropped.

to "make bag" at parturition. All starvation losses in the B herd were attributed to impoverished condition of the dams.

Most of the calf losses from "other causes" were due to death from unknown causes a few weeks after birth. Four calves were killed by coyotes in 1935, and 35 coyotes were trapped on the area in 30 days. Regular fall trapping of coyotes was instigated, and no further losses from this source were encountered. Other known causes of death were rattlesnake bite, diarrhea, and pneumonia.

Death Losses from Weaning to Three Years of Age

Losses from weaning to 3 years of age were very low, amounting to only 10 animals out of 1,800, or 0.56 per cent. Rattlesnake bites accounted for 4 deaths, illness 4, and accidents 2.

Retained Placentas and Their Effect on Rebreeding

The data in table 19 show an incidence of 17.1, 28.4, and 23.8 per cent of retained placentas for the A, B, and C herds, respectively. Retained placentas were more prevalent in the B herd in the early favorable-forage years, but when forage conditions were droughty or quite adverse during the calving period, the incidence was equally present in all three herds. During such adverse periods supplementing with cottonseed cake and rolled barley did not alleviate the incidence of retained placentas. Supplemented cows were, however, better able to ward off ill effects of possible uterine infections, whereas some B herd cows were lost from the combined effects of poverty and uterine infection. In the absence of specific infection, future reproduction is not necessarily affected. One herd B cow had a calf each year for four successive years with a retained placenta each year.

Animals with Sore Eyes

Of the various causes of sore eyes, those responsible for inflammation of the eyelids are probably of greatest importance (45.5 per cent of all sore eyes) because of their greater incidence and the possibility that they may lead to eye cancer. The lower eyelid is usually involved, with the afflicted areas just below the eyelash. The condition may be manifested by an irritated or sore spot, but most frequently by a wartlike growth that may extend out from the lower eyelid as much as an inch. These are easily broken off, leaving an ulcerated area on the margin of the lid. Treatment by cutting out the growth and applying silver nitrate styptic has been successful, though the growths often recur. Frequently these growths become progressively worse and may suddenly become malignant. In this study cows with badly inflamed eyelids were culled and sold, only two being completely lost.

Irritation of the haw, though of low incidence, may lead to eye cancer, but is easily treated by cutting out the haw while in early stages of inflammation.

Grass awns, mostly from ripgut brome, were responsible for about 17 per cent of the total eye cases. The greatest incidence of this trouble is in summer after maturity of the forage.

Pinkeye may, at times, cause considerable trouble. During this 13-year period of study, cases of pinkeye were recorded in 1944, 1946, and 1947. The incidence was greater in mid- and late summer, with the newly weaned calves most afflicted.

Abscesses

A total of 48 cases of abscesses were recorded during the study period. Most of the abscesses were about the head and throat and were considered to be mostly the results of penetrating grass awns followed by actinomycosis. These abscesses frequently rupture in the oral cavity or exteriorly and thereby increase the distribution of the causative ray fungus on the feed, with resulting greater incidence.

Fly Strike

This is a general term used to denote maggot infestation of wounds. Open untreated wounds in the summertime frequently become infested with blow-fly maggots, but the greatest difficulties are encountered when myiasis from the screw-worm strike is prevalent. Twenty-five out of the 34 cases occurred in 1940. Most of the screw-worm strikes occurred in the navels of newborn calves and under branding scabs. Treatment of calf navels and wounds with a fly repellent during the period when screw worms are active is effective in reducing the incidence of fly strike.

Snake Bites

Studies by Fitch (1949) have shown the experimental area to have a rattlesnake population of about 1 snake per acre. Forty known cases of animals bitten by rattlesnakes were recorded, and of these 7 died. The cattle are apparently most often bitten while grazing, since 32 of the recorded bites were about the head. Barring asphyxiation from mechanical closing of the respiratory tract or chance deposit of the venom directly into the blood stream, cattle will usually recover without treatment. In some cases an abscess later develops at the site of the bite.

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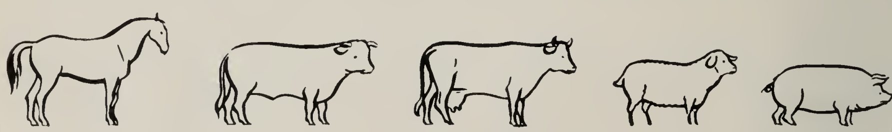

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