

BOTANICAL COMPOSITION OF THE ANNUAL GRASSLAND AS EFFECTED BY  
FERTILIZATION ON TWO SOILS NEAR BERKELEY, CALIFORNIA

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The botanical composition of the annual vegetation was studied on a flat area of generally rolling rangeland near Berkeley where two discrete soil types, Montezuma clay and Laughlin sandy loam are adjacent. Nitrogen and phosphorus were applied at three levels in the fall and spring. Fall fertilization took place after the germination of the annuals.

Remarkable differences in the botanical composition of the untreated soils were observed. The vegetation on the clay soil was composed of annual ryegrass, bur clover, and tarweed. On the sandy loam, the vegetation was more diverse and consisted mostly of annual bromes and fescues, wild oats, quaking grass, hair grass, and perennial weeds like sour dock and plantain. Thinly scattered perennial grasses were found only on the sandy soil and of these the most frequent was California oatgrass.

On the clay soil nitrogen alone was not very effective, though some increase in grasses was evident. Nitrogen and phosphorus in combination stimulated annual ryegrass almost to the exclusion of anything else. Plots treated with phosphorus alone turned into nearly pure stands of bur clover. Tarweed was materially reduced with the increase in the rate of nitrogen applied, while phosphorus controlled the tarweed and a combination of nitrogen and phosphorus resulted in plots clear of the weed.

On the sandy soil nitrogen alone was effective in changing the composition favoring ripgut brome and wild oats. The response to phosphorus on the whole was relatively small. Bur clover and California oatgrass showed no response to either nitrogen or phosphorus fertilization.

The season of application effected the composition relatively little.

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## HISTORICAL BACKGROUNDS OF RANGE LAND USE IN CALIFORNIA

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In July of the year 1769 a group of Spaniards were riding northward from San Diego, through the Coast Ranges, in search of the Port of Monterey. Members of that party, an expedition led by Don Gasper de Portolá, were the first Europeans to gain any extensive, accurate knowledge of California. On Tuesday, July 18, 1769, one of these men, Miguel Costanso, wrote in his diary: "The place where we halted was exceedingly beautiful and pleasant, a valley remarkable for its size, adorned with groves of trees, and covered with the finest pasture..." (Costanso, 1911). Later on he wrote: "We then proceeded over high hills, and through canyons containing very good soil and good pasture..." These statements struck a keynote that was echoed by early travelers throughout California, who uniformly were favorably impressed with the potentialities of the country for livestock grazing.

The Pristine Ranges of California. The early travelers in California were, for the most part, sturdy, experienced, and practical men--explorers, trappers, traders--who viewed the countryside with an eye to its ability to supply their immediate needs, and with regard to its potentialities for settlement. A great many of them had reason to give close attention to the forage resource, either directly, as a source of feed for the animals which transported and fed them, or indirectly as a possible means of livelihood through the grazing of livestock. Almost without exception they were highly impressed with the quantity and quality of the forage, and with the suitability of the country for range use.

The Spaniards, whose activities were confined principally to what we now know as the South Coast--that is, west of the San Joaquin Valley and south of San Francisco--left voluminous records of their first impressions of this country. Of the mission lands at San Diego, Pedro Fages, one of the early provincial governors, said: "For flocks and herds there are excellent places with plenty of water and abundance of pasture" (Fages, 1937). Referring to the country near the mission of San Luis Obispo, he wrote: "Abundant water is found in every direction, and pasture for the cattle, so that no matter how large the mission grows to be...the land promises sustenance" (Fages, 1937). Miguel Costanso concurred with his countryman, as we have seen already, and described the pastoral qualities of several other parts of the South Coast in equally glowing terms (Costanso, 1911). But perhaps none of them excelled the simple eloquence of Fray Juan Crespi, who, in the first letter dated at San Diego, wrote: "...there is much land and good pasture" (Engelhardt, 1920).

The Spaniards did not occupy much of the Great Valley, or the Sierra Nevada-Cascade country. The earliest written records of those regions are in journals of American and Canadian fur trappers, who traveled here extensively after the first quarter of the nineteenth century. Jedediah Smith was interested primarily in trapping beaver, but since he depended upon horses to transport himself and his furs, he had a direct interest in the forage. Of the lower San Joaquin Valley, he wrote, on February 12, 1828: "The winter in this valley is the best season for grass and at the time of which I am now speaking the whole face of the country is a most beautiful green, resembling a flourishing wheat field" (Sullivan, 1934). The journal of Harrison Rogers, a member of Smith's company of trappers, is replete with references to forage conditions along the route which the party traversed across the North Coast Ranges and northward into Oregon (Dale, 1918).

A few years later a party of trappers led by John Work entered California by way of Modoc County and came down the Pit River into the Sacramento Valley. During the winter, Work was marooned at Marysville Buttes by high water of the

Sacramento River. On February 22, 1833, Work noted in his journal: "We have been a month here and we could not have fallen on a better place to pass a part of the dead winter season....There was excellent feeding for the horses..." (Maloney, 1945). This party totaled 163 persons, and must have had in the neighborhood of 400 horses.

Edwin Bryant reached Sutter's Fort (present-day Sacramento) in September, 1846, having traveled overland with a wagon train. He described the country southeast of Sacramento as a level plain covered with luxuriant grasses, and said that in the bottom lands along the Mokelumne the rich soil produced the finest qualities of grasses (Bryant, 1848).

Accounts of contemporary travelers are of great value in giving us an appraisal of the general nature of the forage cover during the time California was being settled, but they afford few details of its botanical composition or floristic characteristics. Fortunately, what may be referred to as the latter part of the period covered by the early travel accounts overlapped the era of the first botanical explorations. It is to them that we must turn for details of the plant cover. They range all the way from fragmentary collections of the Beechey voyage to the more comprehensive work of the Pacific railroad surveys (Hooker and Arnott, 1841; Torrey, 1856). In a sense, early plant collections from California are quite disappointing to a range man. They were made almost wholly to serve special purposes--for medicinal plants, for new horticultural varieties, for identification of rarities, and similar reasons---therefore, they are chiefly records of occurrence, yielding only meager information as to relative abundance and areal distribution of different species. Nor do they ordinarily include introduced species, which shortly had a profound effect on the forage of some localities.

The first settlers in California found a land abundantly provided with natural resources - forage, soils, timber, water, minerals, a considerable array of wildlife--and a climate that since has become fabulous. These resources played a highly significant part in development of the state. The range land of California was the first of her natural resources to be put to beneficial use by settlers, such use dating from the founding of the mission at San Diego, in 1769. Long before the discovery of gold--even before cereals planted by the colonists yielded dependable harvests--the forage on the hills had begun to form the basis of a reliable economy.

The Livestock Industry of California. Ranching had its beginning as the first industry in California in 1769, when the Franciscan missionaries brought 200 head of cattle, a flock of sheep, and some horses from Lower California to the mission being founded at San Diego. Provision for establishing a herd of livestock was an important element in the founding of every mission. Meat was necessary for subsistence of the mission community, while hides and tallow furnished raw materials essential in local economy.

Additional settlements followed San Diego in rapid succession. Finally (by 1823), there was a chain of twenty-one missions stretching from San Diego to Sonoma; presidios had been established at four strategic spots along the coast. As colonizing agents of the Spanish government, missions were not intended to be permanent, nor was their establishment accompanied by any conveyance of land from the crown to the mission. Under both Spanish and Mexican governments, missions were permitted to occupy and use certain lands for the benefit of the Indians. In theory, when the Indians had been Christianized and civilized, mission settlements were to become pueblos (towns) (Robinson, 1948). In California, the missions soon extended their occupation of land so that boundaries of one tended to coincide with those of the next, despite the fact that much of the intervening land was not in actual use for grazing or other purposes. Ultimately, missions asserted



claim to a major part of all lands in the coastal strip from Sonoma southward, embracing about one-sixth of the total area of California. At the height of its activity this mission-dominated pastoral empire probably controlled in excess of 400,000 head of cattle and 300,000 sheep (Gordon, 1883).

Ranching was not a prerogative of the missions. Livestock soon were acquired by soldiers and settlers of the frontier establishment. In 1784, Governor Pedro Fages submitted to his superiors in Mexico the first petition concerning private use of land for ranching in California; it came from one Juan José Domínguez "who was a soldier in the presidio of San Diego and who at this moment has four herds of mares and about 200 head of cattle on the river below San Gabriel" (Cleland, 1941). At least thirty concessions of land for ranching--nearly all to veterans of the army--were made during the Spanish period, ending in 1822 (Robinson, 1948). The Mexican government was more generous in its grants for ranching; but the land grant movement did not become really active until after the years 1834 to 1836, the period during which the vast mission holdings were secularized. From that time until the end of Mexican rule, liberal incentives were offered to persons wishing to engage in ranching. Practically anyone could obtain a grant of a square league of land--usually of much more---if he would put up a house and place a hundred head of cattle on it. More than 500 ranchos existed in California in 1846; all but about thirty had their origin in Mexican grants, mainly from former mission-controlled lands (Robinson, 1948).

For more than half a century after the first Spanish settlement was founded at San Diego, the province of Alta California remained an outpost along the frontier of Spanish possessions in the New World. Its inhabitants pursued a life that was marked by its leisurely manner; a limited contact with the outside world, and the dominance of pastoral pursuits. Livestock raising formed the basis of economic life, almost to the exclusion of all other modes of livelihood, and penetrated deeply into the social life of these people. The change from Spanish to Mexican rule brought a gradual expansion of outside contact, a heightened interest in trade and commerce, a generally increased tempo of living--yet but a faint prelude to the tempestuous era which was to follow so soon.

Acquisition of California by the United States, in 1848, occurred almost simultaneously with the discovery of gold. Previously, livestock had been valued chiefly for hides, tallow, and wool. Almost overnight, a prodigious market for meat was created--on the very doorstep of the California rancher. The spectacular livestock boom which marked the decade that followed was a natural outgrowth of the Gold Rush. The seemingly insatiable demand for meat in mining camps, and in such mushrooming metropolitan centers as San Francisco, Sacramento, and Stockton, furnished the incentive. "The Gold Rush created an enormous and ever expanding demand for beef, raised the price of cattle to levels never before dreamed of in California, destroyed the simple scale of values to which the ranchers had long been accustomed, and transformed the herds of black, slim-bodied cattle into far richer bonanzas than the gold fields of the Sierra yielded to a vast majority of the Argonauts" (Cleland, 1941). Ranchers sent their livestock to markets in northern California in drives that were comparable in economic significance and picturesque detail to those over the Abilene Trail of Kansas (Cleland, 1941). Nor could the demand for meat be satisfied by local production. Large herds of stock were driven to California from Texas, Mexico, Arizona, and New Mexico (Sampson, 1952). Even the Middle West contributed to supply the California market; more than 150,000 head of cattle entered the state from that area during the years 1852 and 1853 alone (Cleland, 1941).

In spite of the enormous demand for meat, and of droughts which created serious shortages of range feed during the late 1850's, the cattle population increased from about a quarter of a million animals in 1850 to nearly one million head by 1860; sheep increased by nearly 1.1 million head (U.S. Census Office, 1853; 1864).

The relatively high livestock population of the early 1860's coincided with a marked slackening in demand for meat. This caused no immediate concern to most ranchers, who thought the situation was temporary. Because there was sale for fewer stock, numbers soared tremendously during 1861 and 1862. Generally accepted estimates place the cattle population at three million head in 1862 (Cleland, 1941; Gordon, 1883). The next two years brought the most critical period of drought in the history of the livestock industry in this state. Great numbers of stock perished from lack of feed and water. William Brewer wrote: "May 27, 1864, we came up the San José Valley...The drought is terrible. In this fertile valley there will not be over a quarter crop, and during the past few days' ride we have seen dead cattle by the hundreds" (Brewer, 1949). Livestock were driven to distant ranges in search of the scant pasturage; some were taken into the Mojave Desert and others into Lower California. It was then that some ranchers began a practice, continued since that time, of driving stock into the mountains to take advantage of seasonal pasturage afforded in the forests. Results of this drought were so drastic that cattle production on a speculative basis was permanently curbed in California. But it had beneficial aspects, too; many ranchers realized they no longer could depend solely on range feed for production of livestock. They began to plant alfalfa and other forage crops to supplement natural vegetation, thus laying a firmer foundation for the range livestock industry. Many ranchers now shifted their interest to sheep, too, in the belief these animals were better suited to the semi-arid climatic conditions. By 1870, cattle numbers had decreased to less than half a million head, while the sheep population had risen above 2.7 million animals.

Since about 1880 the San Joaquin Valley has been a leading area for range cattle production; secondary centers are located in the South Coast, and in the north-eastern counties of Lassen, Modoc, Shasta, and Siskiyou. As permanent settlement of the state proceeded, increased emphasis was placed on farming, large tracts of fertile valley land being diverted from range land to crop production. The pastoral industry shifted to grassland and woodland ranges of the foothills, and to the plateau and mountain areas of the state not generally suitable for agricultural cropland, where it has become relatively stabilized. During the last twenty years the range cattle industry has been marked by two significant developments: (1) a distinct trend toward specialized production within the industry; and (2) the marketing of animals for beef at younger ages. A third development, in progress today, is incorporation of a beef cattle enterprise into other types of farming; for the farmer it provides a great deal of flexibility with comparatively small risks of capital. This practice is having significant effects both in augmenting the meat supply of the state, and in competing directly with ranchers who specialize in beef production only.

Sheep numbers reached a peak in 1876, when California, credited with some six million head, claimed the largest sheep population of any state in the nation (Miller, 1942). Since about 1880 there has been a concentration of the sheep industry in the Sacramento Valley--to a lesser extent in the San Joaquin Valley. Today these areas account for more than 60 percent of the sheep production of the state. The Coast Ranges north of San Francisco constitute a second center of sheep raising--Humboldt, Mendocino, and Sonoma counties each having more than 150,000 head, and together accounting for nearly 25 percent of the sheep in the state. Meat production is the primary interest of the sheep rancher in California--about 65 percent of the annual receipts of the sheep industry are from the sale of spring lambs, and only about 35 percent from wool production.

Major Factors Affecting the Range Resource. More than 185 years of use have vastly altered the range resource of California from the pristine condition seen by the Spanish pioneers. What we see today is the result of interaction of many factors operating during the course of our range use history. In a situation of



this sort the effect of two unfavorable factors is not the simple arithmetic of one plus one equals two. When one adverse factor is added to another under circumstances such as existed here, there is a cumulative effect that assumes aspects of a geometric ratio. When certain factors are singled out for individual inspection, this combined, cumulative effect must be kept in mind.

The major factors affecting California's range resource during the development of the livestock industry have included limited precipitation with irregular distribution, seasonal and long-time variations in temperature, replacement of native vegetation by introduced species, rates of range stocking, increase in size of grazing animals, nutritional deficiencies in the forage, types and patterns of land ownership, changes in land use, and changes within the livestock industry itself.

Only a few of them can be touched upon here. As a whole, California is an area of rainfall deficiency. "About 55 percent of all seasons yield less rainfall than the average rainfall record" (Lynch, 1931). When several such seasons follow one another, as has happened frequently, difficulties arise for the stockman. Deficiencies in precipitation plagued the stockman almost from the moment of his arrival. They were especially severe from 1828 to 1830; in 1840-41; and from 1845 through 1847 (Bryant, 1848; Lynch, 1931; Wentworth, 1948).

Gray demonstrated a downward trend in mean annual precipitation for California, amounting to about eight inches for the 80 years between 1850 and 1930 (Gray, 1934). His conclusion is open to question because his trend line was based on solution of a least squares equation, the results of which may be influenced by the selection of points between which the trend line is calculated.

An analysis of precipitation records from stations located in the primary range area of California, covering more than a century, indicates there has been no pronounced trend in precipitation (Fig. 1). All stations used in this analysis have records of 74 years or longer; three of them extend back well over 100 years. The analysis was based on "seasonal precipitation"--from July 1 through June 30 the following year. The curves show seasonal precipitation as a percentage of total precipitation for the entire period of record, smoothed by use of a ten-year moving average, as follows: For a single station (Fig. 1a); for three stations with records of more than 100 years (Fig. 1b); and for twenty stations in the grassland and woodland range areas of the state (Fig. 1c, solid line). Statistical analysis showed that the curve of Fig. 1c constitutes a homogenous record for the entire period, despite the fact that data from a variable number of stations were used for the seasons prior to 1878-79, and from all twenty stations after that time. It is apparent that while there have been considerable fluctuations of precipitation during the past century, they are rather evenly distributed about the mean, and that there has been no pronounced trend in precipitation within the area, and during the time, included in this study. Precipitation has been below the mean during 52.9 percent of the 104 seasons covered by these data; it has been above the mean during 46.1 percent of them; and during 1.0 percent (just one season) precipitation was equal to the mean. Fluctuations of precipitation greater than one standard deviation from the mean, plus or minus, indicate a condition of surplus, or of deficiency, of precipitation throughout the primary range area of California at the same time; fluctuations of less than that amount were of lesser areal extent.

While there has been no pronounced trend in precipitation in our primary range area during the past century, there is much evidence of wide variation in amounts received in different seasons. The greatest deficiency to appear in the records studied occurred during the twelve-year period from 1853-54 through the season of 1864-65. During eleven of these seasons rainfall was below the mean, and in seven it was less than the mean minus one standard deviation. This deficiency was significant in the major disruptions of the livestock industry occurring at that time.

Today the herbaceous cover of the principal range lands of California is dominated by annual plants, more than half of them species introduced from the Old World (Talbot, et al, 1939). There are no adequate historical records of this occurrence. Apparently, replacement of native vegetation by introduced plants began about the time the first Spanish settlers arrived. Studies of plant remains found in adobe bricks used in construction of the oldest portions of the earliest mission buildings indicate introduced plants such as annual bluegrass (Poa annua), wall barley (Hordeum leporinum), and ryegrass (Lolium multiflorum) became abundant concurrently with the advent of settlers, while red-stem filaree (Erodium cicutarium), curly dock (Rumex crispus), and prickly sow thistle (Sonchus asper) may have preceded the Europeans (Hendry, 1931).

Certain of the introduced annuals achieved virtual dominance of range lands of California at various times. Wild oats (Avena fatua and A. barbata) first became generally widespread (although apparently one of the later introductions), and perhaps captured and maintained a hold on a larger territory than any other of these species. As early as 1833 this was an important element in the plant cover of large areas, including portions of the San Joaquin Valley (Leonard, 1934). According to Brewer: "It was most abundant between 1845 and 1855, when hundreds of thousands of acres were clothed with it thick as a meadow" (Brewer, 1883). By the mid-1860's both Bolander and Perkins recorded that wild oats were fast disappearing (Bolander, 1866; Perkins, 1863). Wild mustards (Brassica spp.) also were important dominants over large areas during this same time (Bryant, 1848; Cleland, 1941). Wild oats and mustard were succeeded by filaree, which increased in abundance until about 1865 to 1870 (Brewer, 1883); it was associated with brome grasses (Bromus), wild barleys (Hordium), and some of the weedier native annuals, such as nitgrass (Gastridium ventricosum) (Bolander, 1866; Brewer, 1883). The third phase in this succession was marked by increased importance of species of comparatively little value for grazing. They include such plants as red brome (Bromus rubens), certain native and introduced wild barleys, and native broad-leaved weeds like tarweed (Hemizonia) and turkey mullein (Eremocarpus setigerus). This phase first became distinct about 1900. At the present time appreciable portions of the California range lands are in this stage. In certain areas there is evidence of a fourth phase of dominance, marked especially by grasses such as medusa-head (Elymus caput-medusae) and barb goatgrass (Aegilops triuncialis) in the Sacramento Valley and North Coast Ranges, and by dogtail (Cynosurus echinatus) in northern Mendocino and Humboldt counties.

It seems significant that this sequence in dominance by the various species has corresponded to the descending scale of annual plant successions on California range lands under different intensities of use. Wild oats, soft chess (Bromus mollis), ripgut grass (Bromus rigidus), and bur clover (Medicago hispida) are typical of the highest stage of succession on ranges dominated by annual plants here; the intermediate stage is characterized by foxtail fescue (Festuca megalura), filaree, and red brome; the low stage of succession is indicated by plants such as tarweed, silver hairgrass (Aira caryophyllea), and turkey mullein (Sampson, 1952). Now, this sequence of succession is intimately related to condition and productivity of the range; therefore, it affords a clear indication of the fact that there has been a steady downward trend in the range resource, and particularly in the soil.

In the early days of California, livestock was valued chiefly for hides and tallow; even after production of meat became more important, animals commonly were bought and sold by the head, instead of by the pound. Under that situation, the stockman placed emphasis on the number of animals he produced. So, he stocked his range with as many head as he thought it would support. This fact, in conjunction with natural factors of climate and plant composition, gave rise to some early difficulties. Evidence of local overgrazing appeared almost at the outset of stock



raising in California. Horses belonging to some of the missions multiplied so rapidly that by 1815 a wholesale slaughter was necessary in order to save forage for sheep and cattle (Westworth, 1948). This occurrence was repeated a number of times before 1850 (Sullivan, 1934); some missions kept men regularly employed to shoot wild horses grazing on their cattle ranges (Engelhardt, 1920; Wentworth, 1948). Actual data on rates of stocking the ranges are sketchy, prior to about 1900 to 1910. Brewer cites a ranch lying east of Pacheco Pass which contained nearly 50,000 acres and ran ten thousand head of cattle---which allowed not more than five acres per cow, for yearlong grazing (Brewer, 1949). Gordon mentioned a ranch in Los Angeles County, which in the fall of 1880 was stocked at a rate of 3.8 acres per animal unit---also on a yearlong basis (Gordon, 1883). In 1880, it was common belief among ranchers that the best grazing lands of the San Joaquin plains would require only ten acres per animal unit on a yearlong basis; that seven acres per head was a sufficient allowance for cattle in Humboldt and Mendocino counties; and it was maintained that as little as three acres per animal unit per year was adequate on certain range lands in Los Angeles County (Gordon, 1883). As late as 1900, practical stockmen in the North Coast believed their ranges would sustain grazing when stocked at the rate of eight acres per head of cattle on a yearlong basis (Davy, 1902). But, as early as 1863, certain members of the livestock industry were cognizant of important changes in range vegetation; and rightly ascribed the cause to overstocking (Perkins, 1863; Bidwell, 1866).

A fact of some significance, not commonly taken into account, is the progressive increase in size of livestock on the range during the past century. Livestock introduced by the Spanish, which were the principal domestic grazing animals in California until late in the 1860's, were significantly smaller than modern animals. The commanding officer of the English ship Sulphur stated, in 1843: "At San Francisco fine fat bullocks, weighing from four to five hundred pounds, hide included, were purchased at five dollars each..." (Belcher, 1843). "Describing a herd of 'large steers' in 1861, Abel Sterns wrote, 'The cattle are large and fat and will weigh from six hundred to eight hundred pounds'" (Cleland, 1941). From this and similar supporting evidence the conclusion has been reached that until after about 1870---when they were largely supplanted by heavier, modern breeds---the vast majority of cattle on California ranges probably averaged about six hundred pounds live weight. The same situation obtained with regard to sheep, too, the common breeds "...weighing from fifty-five to eighty pounds at maturity" (Wentworth, 1948). The significance of this fact is that since the feed requirement of an animal is a function of body weight, these smaller animals required appreciably less range forage. The Spanish steer which averaged approximately 600 pounds live weight, would require only about 75 percent of the feed needed by the 1,000-pound animal of today (Guilbert, et al, 1951). In practical application, this means that a piece of range which was properly stocked with 100 steers in 1855, should carry only about 75 head in 1955---assuming that the range has not deteriorated in the meanwhile!

Today the range livestock industry constitutes an important segment in the agricultural activity of the state. The range lands have an important function in the economy of California. Furthermore, our ranges have significant economic advantages over those of other areas. Whereas grazing regions of other states must look largely to more distant markets, our rancher has within the borders of his own state and relatively close at hand, a market for all the livestock he can produce. "The cattle and sheep industries of California, steeped in tradition and for more than a century concerned chiefly with production problems, are entering in a big way a new, modern era of high powered consumer promotion for their products" (Hintz, 1954).

The stockman has come to a realization that he is producing a commodity in a highly competitive age, and is preparing to meet the competition face to face. The transition to this new promotional era has been preceded by a realization



that the range resource is definitely limited in both quantity and quality; by a growing awareness that this resource is renewable. It is accompanied by an increasing consciousness that ownership of land imposes responsibility for its stewardship. Much constructive work is being initiated to put range management on a practical basis to maintain and increase the productivity of the range lands in our state. The ranchers themselves are in the forefront, making the major contribution to these efforts.

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