THE CALIFORNIA DEER DECLINE AND POSSIBILITIES FOR RESTORATION

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Abstract. The factors which have contributed most to the apparent decline of deer numbers in California which started about 1960 are thought to be primarily a diminishing food supply and loss of habitat. The influences of fire, logging, and livestock grazing starting in the late 1800's altered pristine vegetation on forests and rangelands which originally supported relatively few deer, triggering growth of successional food plants which deer could use.

Changes in the patterns of burning, logging and grazing plus a shift from sheep to cattle on rangelands have all contributed to lowering the production of deer food plants. These changes have been accompanied by unfavorable weather patterns which have apparently augmented the decline. Continued lack of an adequate hunting program to utilize deer effectively has led to overstocked ranges where severe intraspecific competition for existing forage supplies has existed for many years. Deer have contributed importantly to the decline of their own range condition. Changes in land ownership and use objectives, sylvicultural practices, and construction of highways and water projects have all played a part in the loss of deer habitat.

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The relative importance of the major mortality factors was evaluated including highway and railroad kills, accidents, diseases and parasites, predation, legal and illegal hunting, and effects of inadequate nutrition. Losses associated with nutritional deficiencies were considered to be paramount although other loss factors collectively account for a large number of deer.

Restoration of deer numbers will depend upon reversing the down trend in the factors which produce the successional stages of vegetation which deer require. Changing these trends will often be expensive and funds will be largely wasted unless control of deer numbers through hunting can be achieved. An adequate public information program is imperative to convince the public and the legislature of the need to change the hunting program to one of full harvest of both sexes of deer. Controlled burning, modification of reforestation practices, the use of controlled livestock grazing and agricultural planting of deer forage supplements all have potential for improving deer food supplies. It is doubtful if state or federal agencies will have the funds or manpower to restore deer habitat on the necessary scale and private land owners should be encouraged through economic incentives to do the job on their own lands.

Until a workable hunting program is operating, efforts to control deer losses from other causes will serve little purpose except to intensify the level of intraspecific competition for food.

The decline of deer in California has by no means reached its end point and we predict that it will continue if strong measures are not taken to alleviate it.

INTRODUCTION

The decline in deer (*Odocoileus hemionus*) numbers and consequent hunting success in California in recent years has led to increasing public pressure for action by state and federal agencies concerned with deer or public land management in the hope of reversing the trend. Suggestions for improving the deer situation have ranged from burning vast areas of chaparral and removing livestock from public lands to controlling coyotes to reduce predation.

Although there have been no comprehensive censuses of deer in California, a variety of different kinds of evidence attests to the fact that there has actually been a reduction in numbers. However, the magnitude of the reduction as well as the timing has apparently differed in various areas. For example a comparison of the deer tag returns for northcoast blacktail counties compared with data from Rocky Mountain (*O. h. hemionus*) and Inyo mule deer (*O. h. inyoensis*) counties on the east side of the Sierras indicates that the major decline east of the Sierras occurred from 1960-1963 whereas in the northcoastal counties the blacktail decline did not start until 1969 and continued through 1974.

Actually this yearly record of the number of deer taken by hunters in comparison to the number of licenses sold has provided the most direct evidence of the downward trend in deer numbers. However, since a significant but unknown portion of successful hunters do not mail in their deer tag report forms to the Department of Fish and Game as required by law, a mail questionnaire is sent to two percent of the hunters buying licenses in an effort to obtain more reliable deer kill information. On the average the hunter questionnaire survey indicates a buck kill of 2.12 times the number of bucks reported taken according to tag returns. The results of this questionnaire survey too are subject to speculation as to their accuracy, but it is of interest to note that they have a coefficient of correlation of 95 percent with the tag returns. Therefore, even though neither method of assessing deer kill may be entirely accurate, their high degree of correlation indicates consistency. Since both methods show essentially the same pattern of statewide decline in deer kill, there is a good probability that an actual decline in deer numbers has taken place.

For that matter, the decline of deer has by no means been confined to California, but seems to have been a general phenomenon in a number of western states. By 1964 a number of states recognized that Rocky Mountain mule deer populations had started to decline (Macgregor, 1964)-California; (Mohler, 1964)-Idaho; (McKean and Luman, 1964)-Oregon; (Greenly and Humphreys, 1964)-Nevada; and (Hancock, 1964)-Utah. By 1968 even more states were documenting the decline (Russo, 1968)-Arizona; (Macgregor, 1968)-Nevada; (Nielson and Williams, 1968)-Idaho; (Snyder, 1968)-New Mexico; (Stein, 1968)-Oregon; (Lauchhart, 1968)-Washington; (Corsi, 1968)-Wyoming; and (Hancock, 1968)-Utah.

This paper dealing with the possible factors responsible for the decline of deer populations in California is a progress report and a more detailed and comprehensive report is in preparation for later publication. Since a number of California deer populations move seasonally to ranges in Oregon and Nevada, certain inferences drawn from our data would apply to parts of those states as well.

We wish to acknowledge the generous assistance from the California Department of Fish and Game for providing much of the statistical data on deer as well as funding for a substantial portion of the computer study of the relationships of weather and fire to trends in deer numbers. Earl Cummings was especially helpful in designing the computer evaluations.

The U.S. Forest Service, Bureau of Land Management and the California Division of Forestry furnished valuable information on background statistics on fire, livestock grazing, and logging. The U.S. Fish and Wildlife Service kindly furnished information on control of coyotes.

Additionally we appreciate the information given us by Terry Mansfield, California Department of Transportation, on his estimate of deer road kills. James Street and Ted Adams, Cooperative Extension, U.C. Davis, kindly supplied data on supplemental plantings of Sudan grass and alfalfa and brush burning.

Procedure

The decline in deer numbers in California was documented primarily from the trend in deer kill, Figure 1, in comparison with the hunter survey, Figure 2. In order to determine possible reasons for the decline a number of factors were considered which might have either changed the carrying capacity of deer habitat or operated directly on the deer themselves to influence their mortality rate.

It is well accepted that deer belonging to the genus Odocoileus thrive best on rangelands where successional stages of vegetation predominate (Longhurst, 1961). Young brush with a mixture of grasses and forbs appears to be ideal deer habitat. Mature brush, climax forest with little undercover and few openings, and climax grassland without woody plants normally support few deer. A number of factors may upset the normal successional trend of vegetation toward unfavorable conditions for deer. The first three among the various influences listed below have the greatest potential in California to affect large areas of deer range in terms of successional trends in vegetation.

The influences which have the potential to affect deer habitat on a large scale are listed below.

1. Changes in the numbers and sizes of fire on wildlands in the state.
2. Changes in the amount of forest land being logged.
3. Changes in livestock grazing on public and private rangelands.
4. Changes in weather patterns.
5. Changes in agricultural practices.
6. Changes in long-term carrying capacity for deer on rangelands resulting from chronic overstocking by deer themselves.

In addition to the above mentioned factors which have the potential for influencing deer over large areas of their habitat in the state, there are a considerable number of factors which may be of importance but on a more localized or restricted basis. The most significant of these include:

1. Changes in ownership of rangelands or forest properties with consequent shifts to land use objectives which may not favor deer.
2. Changes in forest management practices by federal or state agencies and private timber companies.
3. Changes in deer feeding or movement patterns as consequences of water project developments, road construction, etc.

CHANGES IN DEER MORTALITY FACTORS

1. Changes in deer mortality factors.
   A. Highway and railroad kill.
   B. Other accidents.
   C. Diseases and parasites.
   D. Predation.
   E. Hunting--legal and illegal.
   F. Mortality related to nutrition.

In an attempt to determine the relative importance of these potential influences it was necessary to divide the state into biotic regions and in some cases subregions based primarily on vegetation types of habitat similarities. The data considered had been collected over the years primarily by various state and federal agencies. For these purposes the biotic regions with their associated counties listed in Table 1 have been recognized. Only those counties within these regions where fire data were available were included. In the case of weather data certain of these regions were further divided into subregions restricted to groups of deer management units with closely related biotic characteristics (Table 2).

For these evaluations data were examined mainly for the years from 1947 to 1974, including most of the post World War II period although for certain kinds of data a much longer span of years was covered. In some cases, however, statistics were not yet available for the last year or two of this period.

Fire relationships to deer populations in biotic regions on a county by county basis were analyzed by performing simple correlation and multiple regression analyses of fire and buck kill. Fire data furnished by the California Division of Forestry was used to determine effects by covertype burned and by controlled burns. The CDF wildfire data together with those from the U.S. Forest Service and Bureau of Land Management were combined to appraise the effects of total wildfires in the selected counties.

Simple correlation coefficients (r) were calculated between the acreage burned by region and the buck kill for that region for the period 1949 through 1973. These correlations were determined for 1 to 6 year lag periods following the year of the fires. Using the determinations from these 6 year lags, a stepwise multiple regression was performed (Dixon, 1974) to find the percent of variance in buck kill (r2) explainable by fire (Table 3).

Using an approach analogous to that used for fire, the relationships of buck kill to weather were also investigated. For each deer management unit a U.S. Weather Bureau station was chosen which best represented the geographic region where the unit was located. Monthly temperature and rainfall data were compiled as follows: Mean temperatures and total precipitation; date of last spring freeze and first fall freeze; and cumulative precipitation during the spring and fall. Using 1, 2 and 3 year lag periods, simple correlation coefficients were determined between these weather variables and buck kill data (Table 4). Additionally a stepwise multiple regression was performed to measure the percent of variance in buck kill explained by these variables together.

RESULTS AND DISCUSSION

Because of the complexity of the data evaluated, both results and discussion are covered together for each influence considered. Each of the potential influences was evaluated in respect to its probable effect upon buck kill which in turn is basically dependent upon the reproductive success of the various deer herds in the state. Unfortunately, however, the usable data on fawn survival was limited to a shorter span of years from 1957 onward and was highly variable in terms of annual sampling uniformity for many deer management units. At this time therefore only a few general correlations with deer herd composition data are included.

From the pattern of deer kill statewide it is evident that deer numbers probably peaked between about 1954 and 1959. However, the subsequent decline thereafter was by no means uniform in all parts of the state. Figure 3 shows the pattern of decline in each of the biotic regions.

In addition to the timing of the decline, the relative magnitude differs by region apparently largely in response to the basic carrying capacity and consequent number of deer inhabiting each region. The effects of the various influences which may have contributed to the decline are treated separately here even though it is recognized that there may be important synergistic relationships.

During 1975 the California Department of Fish and Game prepared a draft report entitled "California Deer Management Plan, March 18, 1975" and a supplement "The Deer Situation in California, April 11, 1975." In these reports they summarized most of the essential factors concerned with the rise and fall of deer numbers in California. We wish merely to add some of our thoughts for emphasis and to summarize some of our more detailed analyses of certain relationships.

GENERAL FACTORS

(1) Fire

It is evident that there have been some significant changes in the fire pattern during the period studied. From the standpoint of deer, the pertinent points should logically be number of fires per year and the acreage burned. However, the distribution of fires is also of major importance and an estimate of this relationship can be determined by calculating the average sizes of fires. It is also useful to consider the proportion of total acreage burned by the few largest fires, those exceeding 300 acres.

When fire data from the U.S. Forest Service (USFS), the Bureau of Land Management (BLM), and the California Division of Forestry (CDF) are combined, Figure 4, it is evident that although the acreage burned annually in California has fluctuated widely over the years, the general trend has been downward in total acres burned. Likewise, because of the increased numbers of fire starts in recent years the average size of fires has decreased significantly, Figure 5. The decline of acreage in controlled burns is especially significant. Table 3 gives the correlation between the amount of acres burned, by cover type as well as control burned and burned by all wildfires, with buck kill in the various biotic regions. The lag periods affecting the buck kill were also evaluated from 1-6 years after the fires for relative significance (Table 1).

All of the simple correlations between fire and buck kill are positive so that if fire sizes and frequencies increase, more bucks will be taken. Controlled burns seem to be especially important in this regard and correlations are consistently significant for each region examined. Burns in brush and the total acreage burned by wildfires in general followed in order of importance as shown by the frequency of significant correlations.

Fire data shows high predictive value for anticipating kill rates in the south coast, and of intermediate value in the north coast and west side Sierras, south. Also in the northeast there is good predictive value for the 2nd year following fire. However, in the remaining regions there is low or no predictive value. As in the case of weather analyses, these correlations and associated predictive values must be interpreted with caution because correlation does not necessarily imply causality.

Probably the major cause of the decrease in wildfires is better fire control in spite of the definite trend toward more fire starts. With the advent of an effective force of aerial tankers which were first used in 1958 and increased to the present force of 35 operated by the U.S. Forest Service and State Division of Forestry, fewer wildfires spread over significant acreages in recent years.

Because of the known positive benefits of fires to increased deer food supplies in most covertypes, it seems safe to conclude that decreased acreage of controlled burns and wildfires in California has contributed to the decline of deer numbers.

The exception to the general relationship of benefits to deer food supplies resulting from fires is in the Great Basin range type found east of the Sierras and Siskiyou Mountains. For that covertype the deer browse plants such as bitterbrush, curl-leaf mahogany and sagebrush are killed out by fire in contrast to the chaparral species found in other parts of the state which are adapted to fire and reseed or resprout following a burn. It is therefore puzzling to note that there are significant positive correlations between buck kill and fire in the northeastern part of the state (Table 3).

One possible explanation for this apparently inconsistent relationship is that the Great Basin browse species which are damaged by fire are found mostly at lower elevations on deer winter ranges whereas more of the browse species found in the timber type typical of the higher elevation summer ranges are better adapted to fire. Therefore if most fire data for this area are from higher elevation burns, the positive correlations found in this analysis may be logical. Additionally there is the possibility that fires at higher elevations may improve the supply of forbs which are critical components of deer diets in these areas in spring and summer.

From buck kill data it is difficult to distinguish between the relative effects of increases in deer food supplies resulting from fire and the benefits derived from improved hunter access and greater visibility of deer when dense brush or timber stands are burned. Further analysis will be needed to quantify these effects.

Logging

Even though logging in California did not increase dramatically until after World War II (Figure 7), it did produce positive improvement in deer ranges on localized areas before that time. Dasmann and Dasmann (1963) have shown how logging in the Douglas fir and redwood forests of Humboldt County served to increase the deer population. Maximum benefits from logging in terms of increased deer forage supplies usually occur from 10-20 years later depending upon the timber type, precipitation level, etc. It is therefore clear that the boom in logging which started in the late 1930's in all probability contributed significantly to the peak in deer numbers in the 50's and 60's. However, even though logging has been continued at a high level since the early 50's, deer numbers declined.

Some observers feel that the more intensified reforestation practices which have been increasingly applied in recent years particularly on public lands have tended to depress the regrowth of deer forage species following logging. This may be true on the lands where such practices are applied but collectively they are only applied to a relatively small portion of the deer range in the state. Furthermore as shown in Figure 8 considerably more logs have been produced on private lands than on public lands and as yet we have not obtained sufficient data to evaluate the relative effects on deer forage by reforestation practice on private versus public lands.

Livestock

In order to put the effects which livestock have caused on deer habitat in California into their proper perspective it is necessary to weigh them against the other significant forces which have been at work. With the exception of the impact of Spanish livestock which were primarily confined to the coastal areas of central and southern California, major introductions of cattle, sheep and horses did not reach this state until the latter part of the last century (Figure 9). The impact of livestock on climax vegetation, particularly native perennial grasses and forbs coupled with the introduction of many exotic annual plants served to create what is now known as the California annual range type which dominates most of our coastal grasslands as well as the uncultivated grasslands of the central valley and foothills on the west side of the Sierra and Siskiyou mountain chains. Comparative digestibility studies have shown that many of the introduced annual grasses are more digestible by deer than the native perennials (Longhurst et al., 1968) and many of the introduced forbs are readily utilized as well. The result of this development of the California annual range type produced a significant improvement in the carrying capacity for deer.

It is interesting to observe that this annual type range is maintained in its most productive successional stage for deer through continued livestock grazing. When livestock use is curtailed or withdrawn, deer use of such grasslands decreases because the resulting trend is toward dominance by less palatable annual species or back to native perennials if remnant plants remain for a seed source.

In the high mountains, livestock, especially sheep, produced early impacts on fragile stands of native grasses and forbs reducing them to successional stages which were also more favorable to deer. Fire and logging played a major part in the mountains by opening up climax conifer forests allowing deer populations which had previously been confined to lower elevations to expand upward and take advantage of the changes wrought by livestock in the alpine grasslands (Longhurst et al., 1951).

On ranges east of the Sierra and Siskiyou Mountains, in the Great Basin range type, early cattle and sheep impacts starting in the 1860's were the primary influence which reduced the density of native perennial grasses. This allowed the establishment of browse seedlings of successional browse species which deer could utilize to better advantage than the dominant sagebrush and associated species which formerly existed on these ranges (Vale, 1975).

It has also been shown that digestibility of sagebrush for deer is improved if it is eaten in a mixed diet containing more digestible browse such as bitter brush (Gill, 1972) which is one of the successional species released by early livestock impacts. This synergistic benefit would thereby allow deer to utilize much more of the pristine stands of sagebrush, which when eaten alone does not provide a favorable diet (Nagy et al., 1964; Bissel et al., 1955) because its essential oil contains secondary plant compounds which inhibit rumen function.

In spite of the major benefits which livestock use of rangelands has produced for deer in initiating and maintaining favorable successional food plants, too many cattle, sheep or horses can compete seriously with deer for range forage. This seems to be the pattern which has developed on many Great Basin and high mountain ranges (Tueller and Monroe, 1975). Wet meadows in the mountains, which are especially good fawning grounds if maintained in a favorable successional stage with light livestock use, can be decimated with overuse. Browse supplies on critical Great Basin deer winter ranges can also be depleted by cattle and sheep in late summer before migratory deer herds arrive for the winter. In other parts of California, livestock competition with deer for range forage is usually not as critical as it is on Great Basin ranges and in the high mountains.

Both cattle and sheep contributed to the initial production of successional stages of vegetation favorable to deer. However, over the years there has been a marked reduction of livestock use of California ranges, particularly on public lands (Figures 10, 11). Although cattle numbers have increased this has been primarily on private ranges and improved pastures at low elevations. Sheep, conversely, have declined drastically and have largely been eliminated from public range lands which are also occupied by deer except for a few allotments in the Great Basin range type.

This drastic decline in sheep numbers is largely a result of unfavorable economic factors related to production and marketing, but increased predation by coyotes and dogs in recent years has contributed significantly as well (Nesse et al., 1976). The major shift from sheep to cattle has been common to most of the western states which have experienced deer declines and is potentially one of the most important factors which can have caused long-term reduction of carrying capacity on deer ranges. Thus far it has received remarkably little attention by game managers concerned with declining deer populations.

Space does not permit a full discussion of sheep and cattle relationships to deer range trends at this time, but a few points need emphasis. On Great Basin and mountain ranges sheep probably do a better job than cattle in maintaining the successional grasses, forbs and browse species which are necessary to deer. On such ranges sheep are usually herded and their use of ranges is transitory compared to cattle which, left more to their own devices, tend to be more sedentary in their grazing habits spending much of their time along streams, canyon bottoms and around meadows. Sheep also commonly penetrate rougher country and steeper slopes than do cattle and because more individual animals are usually involved on a given area of range, sheep effects tend to be more uniform and widespread. To a lesser degree this shift from sheep to cattle may have also affected other deer ranges in California.

For these reasons we believe that it is possible to conclude that the general decline in livestock use on much deer range, especially on public lands in California, may well be the basis for unfavorable successional trends in vegetation. However, on some deer wintering areas as well as on certain high mountain ranges the timing and intensity of cattle use may still be excessive for the best production of deer forage.

As noted earlier the deer decline during the 1960's and 70's has been a phenomenon common to a number of western states. In a number of these states logging and fire have not played a significant part in altering deer range capacities. However, the pattern of early livestock build up in the late 1800's and the subsequent shift from sheep to cattle has been common to all of these states. It is logical to expect that livestock effects on the long-term successional trends in range vegetation have also been present in these other states. In fact the livestock grazing pattern is one of the few common denominators which are evident throughout the West which may have profoundly influenced deer range trends.

Weather

As a result of analyzing both the simple correlation coefficients between buck kill and weather as well as the multiple regressions in various regions, certain broad patterns emerge (Table 2). Mean monthly temperatures in October, November and December are positively correlated with the buck harvest 1 to 3 years later. Increased precipitation in December and January is correlated with decreased buck take 1 to 3 years later.

When treated together the weather variables show strong correlation with future buck harvests in the coastal area and the east side of the Sierra and Siskiyou Mountains-north (r^2=average 0.64) and less correlation with future buck kills west of the Sierra and Siskiyou Mountains (r^2 averages 0.52). Least correlation is found in the northeast corner of California (r^2 averages 0.41). The real magnitude of the effects of weather is difficult to determine, however, because correlation and regression procedures of this sort overestimate the real correlation with the independent variables (weather) when other independent variables such as fire, logging and livestock grazing are left out of the equations.

We are currently working to enlarge the analysis and include these variables simultaneously. Also thus far we have only examined the relationships of fire and weather to buck kill but we hope to investigate the effects on fawn production and survival as well.

Agriculture

At this time we do not have detailed data on agricultural trends which may have affected deer, but a few observations are possible. The late 1800's was the time of greatest cultivated acreage in California when much of the foothills around the Central Valley produced dryland grain crops. A sizeable proportion of this land was marginal for cropping and cultivation declined markedly by the mid-1930's.

The major influences which served to produce favorable conditions for deer in California during the late 1800's have been shown to be livestock grazing, logging and fire. Agricultural development should be added to this list and collectively they produced sufficient improvement in deer range carrying capacity so that numbers might have peaked toward the end of the century had not uncontrolled market and hide hunting reduced the herds to low levels in large portions of the state (Longhurst et al., 1951).

Beginning about 1910, grazing, logging, and wildfire came under increasing control but the changes in range plant succession had been triggered to set the stage for continued deer increase. Better enforcement of hunting regulations during this period augmented the buildup of deer herds. By the late 1920's and early 1930's deer numbers began to excede natural food supplies. They then turned increasingly to palatable agricultural crops such as orchards, vineyards and irrigated pastures (True, 1932).

Deer dependence upon agriculture, primarily to supply nutritious, protein rich forage during the dry summer months has been an important aspect of habitat carrying capacity mostly in parts of southern California and the coastal counties from Lake and Mendocino southward over the last 50 years. In total many thousands of deer must have become dependent on agricultural crops.

Because deer caused serious economic losses, more and more crop land has been fenced deer proof through the years. The pace of deer fencing did not accelerate greatly until the boom in wine grapes started in the 1960's. Due to the very high values involved, many thousands of acres have now been fenced effectively and deer carrying capacity in the affected counties, primarily from Mendocino south through Monterey, must have been substantially lowered.

Deer - Intraspecific Competition

In many respects, as has often been stated, deer are their own worst enemies. When a deer population exceeds the carrying capacity of its range, intraspecific competition for the remaining food plants usually increases to a critical level. Competition among deer in a given area is almost invariably greater than between deer and livestock or other big game species. All deer from localized area eat essentially the same diet whereas livestock or other big game animals select different arrays of food plants and as a rule their dietary overlap with deer is only partial. Deer therefore compete with each other to a greater extent than with other ungulates.

Given a free choice deer tend to select the most palatable plants which are usually also the plants that are most digestible and have an adequate nutrient content (Longhurst et al., 1968). With overstocking, supplies of the most palatable plants are exhausted and lower choice plant species are taken. Under extreme conditions deer are forced to rely on plants of such poor quality that starvation ensues. Deer are seldom deprived of sufficient forage to fill their stomachs, but when intraspecific competition is severe, deer are forced to eat plants that are low in nutrient content or contain secondary compounds which are toxic either to the deer themselves or their rumen microbes (Freeland and Janzen, 1974). Disruption of the normal rate of microbial fermentation in a deer's rumen, as a result of being forced to ingest plants with inordinately high levels of these bactericidal secondary chemicals, produces insidious effects that can range from lowered forage digestibility to outright starvation.

Overstocking of deer ranges is manifested by abnormally high rates of loss of deer, particularly fawns and old animals. Ovulation rates, especially those of yearling does decline, and when does are malnourished during gestation, many fawns are born with insufficient energy reserves to ensure early survival.

All of these symptoms of overstocking have been glaringly apparent on California deer ranges throughout most of the state for many years (Longhurst, et al., 1951). From time to time deer receive temporary respites as when fire or logging may produce a local abundance of food, but with the rate of reproduction that deer possess, excess unused food supplies are temporary at best.

The long-term result of chronic overstocking of deer ranges is a selective removal of the preferred forage plants. As a rule, such adverse cumulative impacts of deer are felt least on grass and are only slightly apparent on certain forbs, but in the case of browse species they are widespread and disastrous. In chaparral and mountain brush ranges browse stands can be rejuvenated by fire and sometimes by logging, but on the dry Great Basin ranges, once browse stands are depleted and seed sources are no longer available, recovery is very slow. There can be little doubt that deer themselves have been responsible for a major share of the depletion of their own habitat and in consequence their decline in numbers.

LOCAL FACTORS

1. Changes in Land Use and Ownership

The supplement to the "California Deer Plan" detailing "The Deer Situation in California - 1975" gives a concise account of most of the factors which have operated locally to decrease the quality of deer habitat. Among these, changes in land ownership and use ranks high in importance.

Much good deer habitat formerly in large ownerships devoted to livestock or timber production were divided for second home and recreational subdivisions during the 1960's and early 1970's. In these divided areas brush lands, which formerly were burned periodically to improve livestock or deer range, are no longer managed in this way under the new land use objectives.

Such changes have added to the decline in quality of deer habitat but the effects have been local. Even though changes in ownership have taken place, most of the subdivisions have not yet been built upon and in most cases deer still wander and feed among scattered houses which have been erected. Hunting has been largely curtailed in these areas however.

Although sizeable areas of deer habitat have been involved, the deer declines in these regions were usually already underway before the effects of land subdivision became manifest.

Conversion of brushlands to grassland for livestock range improvement has reduced the deer carrying capacity on many thousands of acres in the coastal part of the state and in the foothills on the east side of the Central Valley. However, this program was largely tied to controlled burning (Figure 6) and has declined drastically since the early 1950's. Even though deer do not readily feed on many of the grasses planted on these converted brush lands, forbs, including some of the planted and many of the weedy species, provide valuable forage in such areas. Likewise many of the brush fields involved were mature and dense before conversion and were not ideal deer habitat. The net effects of these cover type conversions is, therefore, mixed in respect to deer.

2. Forest Management Practices

Production of marketable forest products primarily from conifers has increased in volume and efficiency since World War II (Figure 7). Although logging is one of the primary influences that have improved conditions for deer in the state, intensified sylvicultural practices designed to maximize conifer production on a monocultural basis are often detrimental to deer.

Detrimental practices include certain aspects of brush conversion involving mechanical and chemical means to conifer plantations; removal of hardwoods, especially oaks, to favor conifers; and slash disposal by mechanically piling and burning following logging or wildfires to facilitate planting conifers.

3. Restriction of Deer Movements or Feeding Patterns

Water impoundments, developed largely since the 1930's have inundated many thousands of acres of good deer habitat and in many cases have restricted deer migration or feeding patterns. In situations where key winter ranges of migratory herds have been flooded, loss of carrying capacity has affected deer use of much larger areas. Mitigation measures to compensate for these losses have at best only provided partial rectification.

Water transmission structures such as ditches and canals as well as roads and freeways have all increased in extent through the years. To one degree or another they have all restricted or prevented normal deer movements or feeding patterns. Where such structures have been effective barriers to seasonal movements of migratory deer herds, many more animals can be affected than where resident deer populations are involved.

DEER MORTALITY FACTORS

Changes in mortality

From the standpoint of the general decline of deer numbers in the state it is obvious that mortality from many causes must have exceeded reproduction. Comments on some of the major mortality factors follow:

A. Highway and railroad kill

The proliferation of the highway network and the conversion of many highways to freeways in the last 30 years has greatly increased deer mortality from collisions with vehicles in many parts of the state. Recent estimates by T. Mansfield of the California Department of Transportation (personal communication) indicate that conservatively at least 20,000 deer are being killed annually on our roadways.

Not many new railroads have been constructed during this period in deer habitat so that train mortality has probably not increased significantly and at the most is only a fraction of the highway kill.

B. Other accidents

Deer succumb to a great variety of accidents in varying numbers. One of the most common causes of loss of this kind is entanglement in livestock fences. One survey run for nearly 20 years at the Hopland Field Station of the University of California indicated an average of one deer lost annually per 8 miles of fence. Deer density is high in this area averaging nearly 100 per square mile so that fence mortality rates would be lower where deer are less numerous. At any rate fences must account for several thousand deer per year statewide.

In general losses of deer to other miscellaneous causes have probably not increased sufficiently to count as a major factor in the overall decline.

C. Diseases and Parasites

There is no firm evidence to indicate that loss rates of deer from diseases or parasites have increased significantly compared to years when deer populations were increasing in the state. Deer are afflicted by a great variety of parasites and diseases in California, but relatively few cause major losses (Longhurst *et al*., 1951; Longhurst and Douglas, 1953).

Hoofrot periodically kills large numbers of deer in the coast ranges west of the Central Valley and lung, stomach and intestinal worms account for sporadic losses. Such diseases and parasites operate on a density dependent basis, however, and outbreaks are usually related to situations where deer have become overabundant and exceeded the carrying capacity of their ranges. Severity of effects of these diseases and parasites is closely tied to the nutritional status of deer with well fed animals having much better resistance.

Predation

There is little doubt that predators take substantial numbers of deer in the state. For purposes of this investigation the important point is whether the various carnivores which prey upon deer take a sufficient number to hold herds below the carrying capacity of their ranges and whether predation increased or became more effective during the years of the deer decline.

The relative effectiveness of deer predators in California was rated by Longhurst et al. (1951) with the coyote ranked first by virtue of its numbers in the state. Mountain lions individually take more deer than coyotes, but their numbers are relatively low on much of the deer range.

Figure 12 illustrates the number of coyotes taken by Fish and Wildlife Service animal damage control personnel in California between 1937 and 1975. As indicated by Swick (1974) the take by federal personnel ranging from about 6 to nearly 12,000 per year is only a fraction of the total estimated to be taken per year by county trappers (2000) and sport hunters (80,000) (Swick, 1974). Even with this rate of removal, it is doubtful whether coyote numbers were under effective control over the deer ranges of the state except in local areas. Connolly and Longhurst (1975) have shown that it is necessary to remove at least 75 percent of a coyote population annually to maintain a sustained decline in the breeding populations. Even at this rate of removal it would take over 50 years to achieve extermination.

Since 1972 when the presidential ban on predacides was initiated, coyote control methods have been restricted and the take by county and federal personnel has dropped somewhat. Many observers believe that there has been a general increase in coyote numbers in recent years but this has not been fully substantiated for the state as a whole. At best control is only effective in limited areas where intensive operations are concentrated. Elsewhere food supply, typically mainly rodents and rabbits, seems to be the primary limiting factor.

The moratorium on killing mountain lions in California began in 1972 and only 35 were reported taken by hunters in the 1971-72 season, which was less than half the number killed in previous years. No doubt lions have increased somewhat since 1972, but it is improbable that numbers have even doubled. It is significant to note that the deer population decline started before restrictions on the taking of these two major deer predators were put into effect.

In some areas uncontrolled dogs take a certain number of deer, but again we have not discovered evidence that the rate of dog predation has changed significantly over the years.

E. Hunting - Legal and Illegal

As with our consideration of the relationships between predation and the deer decline, we are concerned here with the question of whether hunting has accelerated the decline or retarded it. To evaluate hunting in its proper context, it must be considered as a type of predation that impinges on the population dynamics of deer herds along with other mortality factors.

For purposes of this analysis we confined our evaluation of hunting essentially to the period from 1947 onward. This is the time when deer herds were building toward their statewide peak, during the years of their apparent peak, and during the decline as far as it has progressed to date.

Reference to the reported take of deer in the state (Figure 1) indicates California hunters have not been very successful through the years. Space in this report does not permit detailed comparison with other western states, but statistics indicate that buck hunting success is usually considerably higher elsewhere than the 10-20 percent level achieved by our hunters.

A survey by Longhurst (1957) of the effectiveness of hunting in controlling big-game throughout North America showed that the only states which felt that they were controlling mule deer numbers by hunting were taking both sexes of deer. Of the 14 states with significant mule deer populations, 8 considered that they were having at least partial success in controlling numbers, and they estimated that they were taking an average of 23 percent of their herds annually.

Various estimates have been made of the percentage of California deer taken by hunters (Longhurst et al., 1951; Anderson et al., 1974; Connolly and Longhurst, 1975; Dasmann, 1952). None of these reports indicate kills of over 7 percent. Dasmann (1952) showed that with hunting mature bucks only, as has been the general practice here for many years, the maximum kill that can be sustained is 9.5 percent. It is doubtful that we are approaching this level. Even if the hunter survey which shows an average kill of slightly over twice the reported kill is correct, the kill is still far short of the 20-25 percent it takes to actually control numbers.

This is especially true in view of the very small percentage of anterless deer taken through the years. The only significant kill of antlerless deer was in 1956 when a general but short (3 days) either sex season was held at the end of the regular buck season. Although considerable numbers of antlerless deer were killed at that time, (38,081 from 34 counties) the bulk of them were taken from a few areas in the northern part of the state. In subsequent years there was no evidence from kill figures that this hunt served to control overall numbers of deer (Dasmann et al., 1958). There is a good possibility, however, that the high fawn ratios counted during several subsequent years from some of the areas where the anterless kill was heaviest may have resulted from reducing forage competition on those ranges.

Crippling loss, those deer shot during regular open season but not recovered by hunters, has been variously estimated to range between 20 and 25 percent of the reported kill. By any measure a sizeable number of deer are involved.

The amount of illegal killing of deer which has occurred in the state through the years is generally an unknown quantity. Some observers believe that the number taken annually may approach the reported kill but no good documentation has been published. Persons familiar with the history of deer and deer hunting in California do generally agree, however, that there were two periods in the past when illegal hunting did exercise significant control of deer numbers. One was during the market hunting days toward the end of the 1800's and early 1900's and the other was during the depression period of the late 1920's and early 30's. Killing during the depression was by all accounts not as intensive and widespread as during the market hunting period. Both of these periods were well before the present decline commenced in the late 1950's and early 1960's. We conclude, therefore, that hunting mortality did not have a direct correlation with the deer decline.

F. Mortality related to nutrition

From all indications deer mortality related in one way or another to inadequate nutrition is the largest category of losses. Neonatal losses of fawns are among the highest of this kind (Verme, 1962; Jones et al., 1964). An indication of the magnitude of this loss can be gained by comparing the numbers of fawns born to those found to be still alive during fall herd composition counts. Although productivity varies in different parts of the state usually averaging below 150 fawns per 100 does in resident herds and over 150 in migratory herds, if an average of 150 is applied statewide, approximately 65 percent do not appear in the fall counts. Through the winter until the spring counts are made, approximately 8 percent more of the number of fawns born the year before disappear. Even though these are not precise figures, they give an indication of the magnitude of fawn losses alone. By comparison, well nourished deer herds should be bringing over 60 percent of the fawns born through their first winter to give spring counts of 90-100 per 100 does instead of the 30-40 per hundred does now commonly counted throughout the state.

Field surveys of deer carcasses reveal that causes of death of many deer found on the range cannot be attributed to predation, accidents or disease, but necropsies do show a high percentage with signs of chronic malnutrition. Neonatal losses are very difficult to document from field data on fawn carcasses recovered, but enough studies on this problem have been carried out under controlled conditions so that we feel confident of our conclusions in this regard.

Published reports and our own experience lead us to the conclusion that after the neonatal losses are finished in the first few hours or days of the fawn's lives, additional losses throughout the rest of the year among deer dying from natural causes will also be predominantly among fawns. Usually 60 to 80 percent of the losses during this period are fawns and the rest older animals.

OVERALL RELATIONSHIP OF MORTALITY TO THE DEER DECLINE

We can see little evidence that, with the exception of nutritionally related mortality, other types of mortality have had significant positive correlations with the deer decline. Rather all forms of mortality collectively have very likely tended to retard and extend the decline. In our estimation the primary cause for the reduction of deer numbers in California has been the declining quantity and quality of food available to them. Deer themselves, through intraspecific competition and consequent depletion of their own food resources, have contributed significantly to the decline.

Mortality in general has worked to reduce the level of intraspecific competition from year to year, but mortality has not been consistently of sufficient magnitude to hold deer below the carrying capacity of their food supply for any length of time. The result, therefore, has been to maintain virtually continuous pressure on the most palatable forage plants giving them little opportunity to rejuvenate. If mortality had been even lower over the years, greater pressure would have been put on the range plants and the decline in carrying capacity and in deer numbers would have been more abrupt.

Without a drastic reversal of some of the habitat trends now in progress we do not believe that the downward trend in deer numbers is anywhere near bottom. It will very likely continue and may even accelerate in some parts of the state.

RESTORATION OF DEER NUMBERS

If our conclusion is correct that the California deer decline has been caused primarily by a diminishing food supply and secondarily from loss of habitat, then it follows that in order for deer to increase these trends will have to be reversed. In many respects it will be impossible to reverse some of the changes which have taken place, but given adequate funding some kinds of restoration are possible. The possibilities which we think can be most fruitful are summarized below:

1. Control of deer numbers

The only practical way to control numbers is through public hunting. Control of numbers is impossible without taking both sexes. Hunting intensity should be controlled and applied to specific management units.

If numbers cannot be controlled, efforts to improve food supplies will be fruitless and money spent for such purposes will be largely wasted. Controlling deer numbers will not reverse many of the long-term successional trends in vegetation which are related to extrinsic factors such as fire, logging, livestock grazing and weather. However, by full utilization of deer populations through hunting, reproductive success will be vastly improved and efficient use will be made of available forage supplies.

2. Public information

Given the present level of general understanding of the technical aspects of deer ecology and management, there is little hope that an adequate hunting program will be accepted by the public or the legislature in California. Therefore the first priority is to mount an effective public information program for this purpose. In view of past efforts by the Department of Fish and Game, which obviously have not achieved the necessary results, outside assistance and vastly more generous budgeting would appear imperative.

3. Improving deer food supplies

A. Fire

The use of controlled burning has been successfully employed to improve deer range for many years, but it is important to review the costs involved. Data compiled by Theodore Adams, Cooperative Extension, U.C. Davis, from literature sources and from consultation with the senior author of this report indicates that in some of the most productive mixed chaparral in the state, between Clear Lake and the Ukiah Valley, the following relationships apply: following burning deer increase from the level of about 20 per square mile which exist in mature chaparral to about 75 (Biswell et al., 1952). Deer hunters take approximately 25 percent of the legal bucks available at the start of the season in this part of the state. Considering average herd composition counts for the area, there are at least 34 deer left on the range for every buck bagged. Burning a square mile of this chaparral would increase the bag by only about 1.6 bucks.

An ideal 10 year rotational burning system would burn about 70 percent of each square mile of chaparral over the 10 year span leaving the other 30 percent for escape cover. This would amount to approximately 45 acres burned per year. Current costs of controlled burning, considering preparation costs, fire guards, etc. average about $20 per acre. At this rate it would cost about $563 annually for each additional buck bagged. If either sex hunting were applied with a 25 percent removal of all deer present, the cost would drop to $64 per head for the increase achieved by burning. Most of the chaparral in the state will not support nearly as many deer as that between Lake and Mendocino Counties, but burning costs would be much the same. Therefore, the cost per deer would rise accordingly.

We seriously question whether state or federal agencies can afford to increase the bag of deer at these rates over the extensive areas required on a monocultural basis. If other benefits can be entered into the equation such as livestock forage increase, improved access, watershed enhancement and fire presuppression costs, then improving deer habitat as part of a "package" may be more feasible economically.

B. Logging

Deer habitat benefits will accrue as a by-product of logging almost automatically. It is in the reforestation and other sylvicultural practices that decisions will have to be made to favor deer. Modification of these established practices in order to favor deer would very likely decrease efficiency of conifer production. It is not logical that federal timberland management agencies should modify their programs to favor deer unless it can be demonstrated that the deer will be harvested efficiently through adequate either sex hunting programs. It is even less logical for private timber companies, which produce the majority of the logs in the state, to become involved in deer production unless a way is found for them to receive economic benefits from the deer.

3. Livestock grazing

Modification of grazing practices seems to us to be one of the best possibilities for improving deer food supplies. In designing grazing systems to achieve this objective, two aspects should be considered. Competition between livestock and deer should be minimized. This can usually be accomplished through adjustments in stocking rates and season of use for critical range areas. Generally the most serious conflicts with livestock in California in recent years tend to be with cattle on migratory deer ranges in the Sierra and Siskiyou Mountains and in Great Basin range type to the east.

The other major aspect of livestock grazing is to use it as a tool to produce the desired successional changes in range vegetation which will improve and maintain deer forage plants. This approach has been considered in the past by some range managers, but thus far has not been put into practice on a significant scale, at least in California.

There are many problems associated with a program of this sort to make it workable on either public or private land. Best results may well be achieved by using a combination of cattle and sheep, but sheep especially when they are herded can be controlled better than cattle. If grazing is properly applied to produce the combination of grasses, forbs and browse needed by deer, this may be detrimental to the best interests of the livestock forage supply and even to the livestock themselves. In all probability the livestock involved will be privately owned and some type of compensation or subsidy will have to be devised to gain the acceptance of the stockman. Likewise an efficient system of coyote control will have to be applied if sheep are to be used for this purpose or predation losses will be prohibitive in many areas.

4. Agricultural practices

There is little chance that private landowners will divert agricultural crop production to feed deer unless they can realize more economic returns from the deer than from the crops marketed for other purposes. However, there is a definite potential for greatly enhancing the deer carrying capacity of much rangeland by actually planting forage crops specifically for deer. The best possibilities for this sort of program undoubtedly lie in the coast ranges from about Mendocino County southward in resident deer areas.

The objective would be to provide small patches of nutritious, protein rich green feed during the dry summer months when protein in native range plants is deficient. Some research will be necessary to determine the best adapted and palatable forage species to plant in each area considering soil characteristics, precipitation patterns, etc. Two which offer promise are sweet sudan and dryland alfalfa. Higher production can be achieved with irrigation, but costs would probably be prohibitive. Forage plantings would have to be fenced deer proof and cross fenced to control use on a rotational basis.

5. Private lands

Because of the substantial costs involved, it does not appear probable that budgetary constraints faced by both state and federal agencies will permit deer range improvement on the massive scale needed to produce significant improvement in the statewide deer picture. To us it, therefore, seems appropriate to consider the potential of private lands where, if the necessary incentives are provided, landowners using their own funds can do the job.

To make a program of this sort practical it is probable that some legislative changes will be necessary. Such changes have been considered from time to time by the legislature but have never received sufficient public support to become law.

Landowners will need considerable freedom to raise deer and harvest them properly by controlled sport hunting at a profit to themselves. They will also need adequate extension advice to make their efforts successful. It is doubtful that the Fish and Game Department has sufficient manpower available to devote to a program of this sort on the scale necessary to produce meaningful results considering the extent of the potential areas which may be involved.

One means which other state game agencies such as those in Colorado and South Dakota have employed to increase their extension efficiency is to fund positions in their universities' cooperative extension services to assist with wildlife programs. A modest expenditure of this sort for extension wildlife coordinators can produce a significant multiplier effect through enlistment of the services of extension staff already on the job in the counties.

6. Reduction of deer losses

Little can be done to restore deer habitat permanently lost to water projects, subdivisions or other land use changes. However, losses of deer themselves from accidents, road kills and other miscellaneous forms of mortality can be alleviated with sufficient effort and adequate funding. To us it seems somewhat incongruous to expend vast sums to prevent these kinds of losses when from a biological standpoint these losses, although wasteful, are serving in lieu of hunting to reduce intraspecific competition for food supplies. The monies might be used to much better advantage for habitat improvement or still better, as a starting point, for a public information program to enable proper control of deer numbers through hunting to be achieved. When hunting is fully harvesting the deer crop, then efforts to reduce other kinds of losses can increase the number of deer available to hunters. At this stage, funds spent to reduce mortality from predators or even illegal hunting are not serving the best purposes.

We believe that it is possible to do much to stem the statewide deer decline but it will take a substantial reordering of established priorities coupled with adequate planning, management and funding to do the job.

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TABLE I. BIOTIC REGIONS OF CALIFORNIA

REGION	COUNTIES EVALUATED FOR BUCK KILL AND FIRE RELATIONSHIPS	
North Coast	Del Norte Humboldt Trinity Mendocino Sonoma Glenn	Lake Napa Colusa Yolo Solano
South Coast	Contra Costa Santa Clara Alameda	Monterey San Benito San Luis Obispo
Southern California	Orange Riverside	San Bernardino San Diego
West Side of Sierra and Siskiyou Mountains - North	Shasta Tehama (East) Yuba Eldorado	Butte Nevada Placer
West Side of Sierra - South	Stanislaus Tuolumne Mariposa Madera Calaveras Amador	Merced Kings San Joaquin Fresno Tulare
East Side of Sierra and Siskiyou Mountains - North	Siskiyou Modoc Lassen	

TABLE 2. DEER MANAGEMENT UNITS EVALUATED FOR BUCK KILL, FAWN SURVIVAL AND WEATHER RELATIONSHIPS

REGION	SUBREGION	DEER MANAGEMENT UNITS	
North Coast	North	Redwood Mattole Smith	Klamath Ruth Mad River
	South	Mendocino Santa Rosa	
	East	Weaverville Tehama (West) Whiskeytown Hayfork	Happy Camp East Park Alder Springs Yolla Bolly
Central Inner Coast	Central	Clear Lake Monticello Capay	Mt. Diablo Mt. Hamilton
West Side of Sierra and Siskiyou Mountains	North	Pit River Cow Creek Bucks Mt. Tehama (East) Camp Beale	Mooretown Nevada City Downieville Sloat
West Side of Sierras	Central	Blue Canyon Placerville Pacific	Grizzley Flat Salt Springs Railroad Flat
West Side of Sierras	South	Raymond Oakhurst San Joaquin Huntington Kings Yosemite Tuolumne Stanislaus	Hume Kawea Porterville Tule Kern Greenhorn Piute Tejon
East Side of Sierra and Siskiyou Mountains	North	Mt. Shasta Glass Mt. Interstate	Warner Adin
East Side of Sierra and Siskiyou Mountains		Eastern Lassen Western Lassen	Doyle Loyalton

TABLE 3
RELATIONSHIPS BETWEEN
BUCK KILL AND FIRE

	LAG PERIOD YEARS	SIGNIFICANT SIMPLE CORRELATIONS (r) TIMBER	WOODLAND	WOODLAND GRASS	GRASS	BRUSH	TOTAL WILDLIFE	CONTROL BURN	MULTIPLE CORRELATION (r^2)
Total State	1		+					++	0.52
	2							++	0.52
	3							++	0.52
	4							++	0.52
	5							++	0.46
	6							++	0.72
Regions									
North Coast	1		++						0.53
	2								0.54
	3								0.20
	4								NS
	5								0.49
	6								0.64
South Coast	1			+		+	++	+	0.61
	2							+	0.41
	3							++	0.73
	4					+			0.72
	5					+			0.52
	6					+			0.38
Southern California	1								N.S.
	2							++	0.31
	3								NS
	4								NS
	5								NS
	6								NS
West Side of Sierras and Siskiyou Mountains North	1							+	0.41
	2								0.40
	3								0.24
	4								NS
	5								NS
	6								0.52
West Side of Sierras South	1							++	0.61
	2								0.20
	3							+	0.45
	4					+			0.50
	5							+	0.53
	6								0.53
East Side of Sierra and Siskiyou Mountains North	1	+							0.25
	2		+	+	+	++	++	+	0.68
	3								NS
	4	++							0.32
	5								NS
	6								NS

++ = Positive correlation coefficient $\alpha < .01$
\+ = Positive correlation coefficient $\alpha < .05$
-- = Negative correlation coefficient $\alpha < .01$
\- = Negative correlation coefficient $\alpha < .05$
NS = No significant correlation

TABLE 4 CORRELATION BETWEEN BUCK KILL AND WEATHER IN SELECTED SUBREGIONS OF CALIFORNIA

SUBREGION	NORTH COAST NORTH			NORTH COAST SOUTH			NORTH COAST EAST			CENTRAL COAST			WEST SIDE SIERRAS AND SISKIYOU MTNS. NORTH			WEST SIDE SIERRAS CENTRAL			WEST SIDE SIERRAS SOUTH			EAST SIDE SIERRAS AND SISKIYOU MTNS. NORTH			NORTHEASTERN CORNER OF CALIFORNIA		
LAG PERIOD	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.	1 yr.	2 yr.	3 yr.
MEAN MONTHLY TEMPERATURE																											
JAN.													+								—	-			+		
FEB.			+										++					+						+			
MAR.		—			-			—															-				
APR.	++	++	++								++	+		+			+		-								
MAY				—			—					-				—						—					
JUNE	—																	++	-			-	-				
JULY									—	+	+								—	-				—			
AUG.							—	+					-									—					
SEPT.																		+				—					+
OCT.	++	++	+	+	++		++	++		++	++	+	++	+		++	++		++	++		++	++		+	++	
NOV.	++																		+								
DEC.		+					+	++			++		+	++	++	+	++	++	++	++			++			+	
LAST SPRING FREEZE											—												+	+			
FIRST FALL FREEZE										+	++																
MONTHLY PRECIPITATION																											
JAN.	—	-	—			—						—			—			-			+						
FEB.			+					++	++				++	++	++		++	++					+	++		++	++
MAR.		++	++			++		+	++																		+
APR.	++		++				++		++						++				++			+		++			+
MAY			++						++			++			++			++			+						
JUNE	—								—						-			—	—								
JULY		++						++			+														+		++
AUG.							++							—		++	-	-				+					
SEPT.	—							+	++	+	+	+	++	+			+		+					+			+
OCT.									+	-				++			++					-		++	-		+
NOV.										—		-		—	—		—	—									-
DEC.	—	—	—			—	—	—	—		—	-	-		—		-	—						—			
SPRING CUMULATIVE PRECIPITATION			++			++			++						++		+	++	++					++			++
FALL CUMULATIVE PRECIPITATION									+														+	+	—		
MULTIPLE CORRELATION r^2	0.73	0.67	0.72	0.56	0.70	0.73	0.53	0.50	0.49	0.71	0.67	0.73	0.55	0.59	0.59	0.53	0.57	0.57	0.38	0.44	0.40	0.61	0.62	0.69	0.36	0.34	0.55

++ = Positive correlation coefficient $\alpha < .01$
\+ = Positive correlation coefficient $\alpha < .05$
— = Negative correlation coefficient $\alpha < .01$
\- = Negative correlation coefficient $\alpha < .05$

Figure 1.

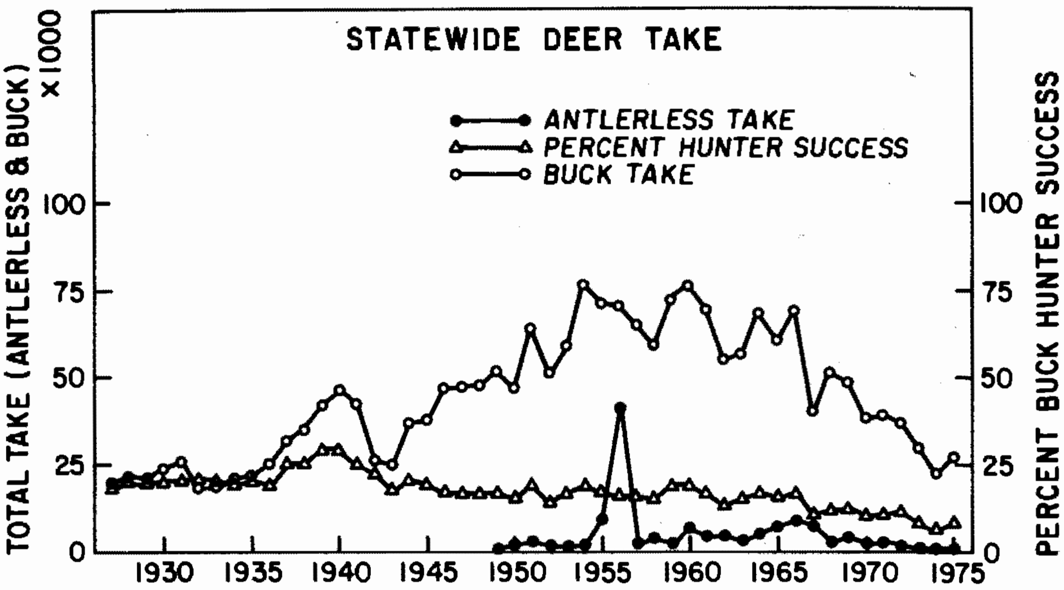

Figure 2.

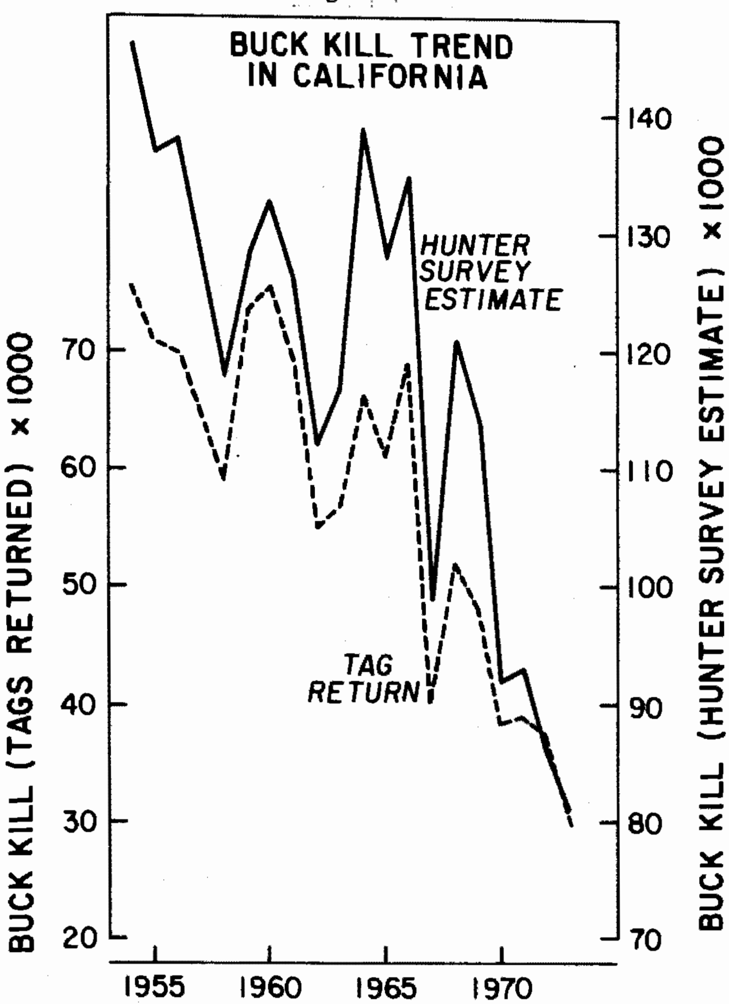

Figure 3. REGIONAL TRENDS IN BUCKS REPORTED KILLED BY HUNTERS

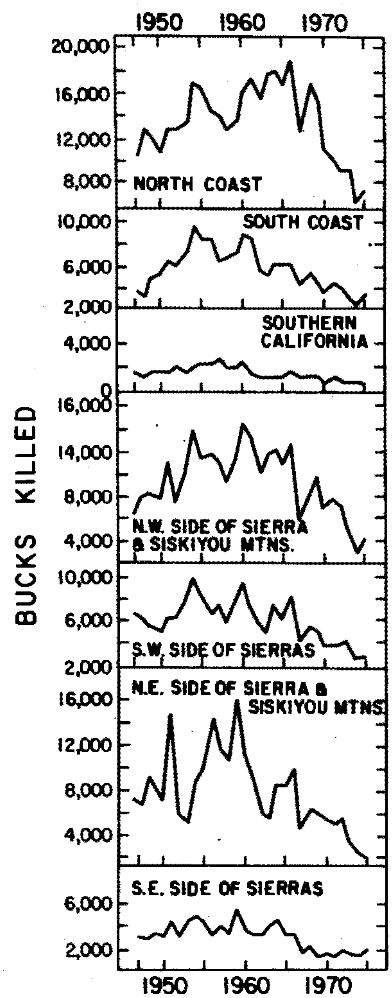

Figure 4. TOTAL ACREAGE BURNED IN CALIFORNIA

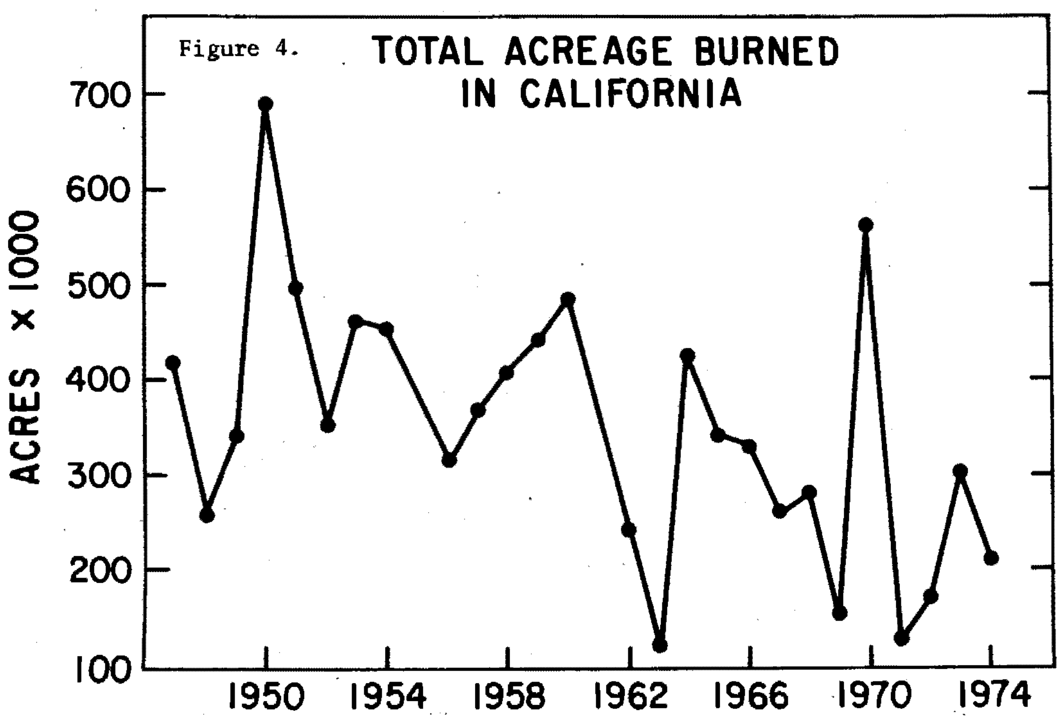

Figure 5.

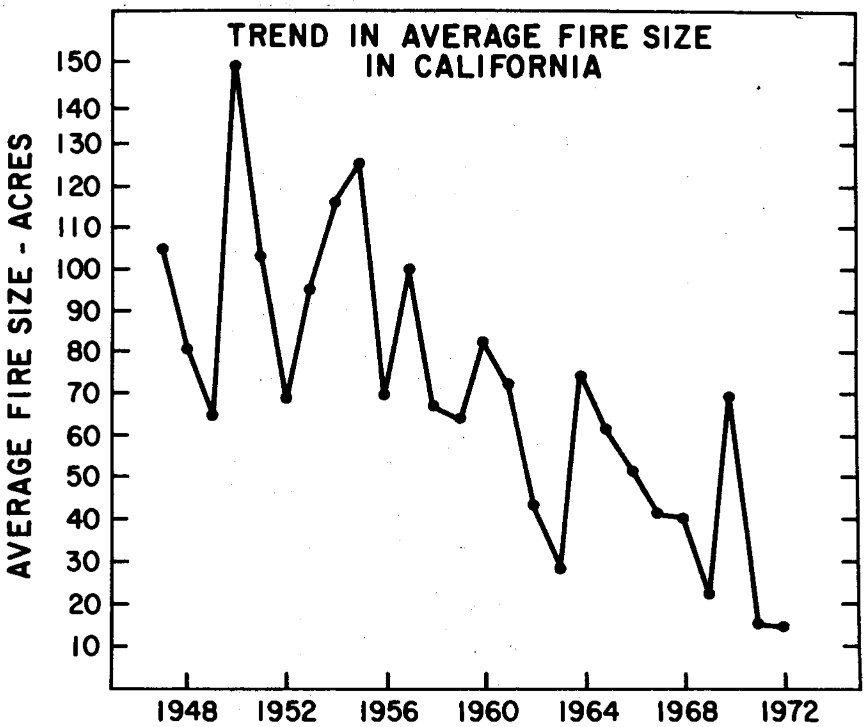

Figure 6.

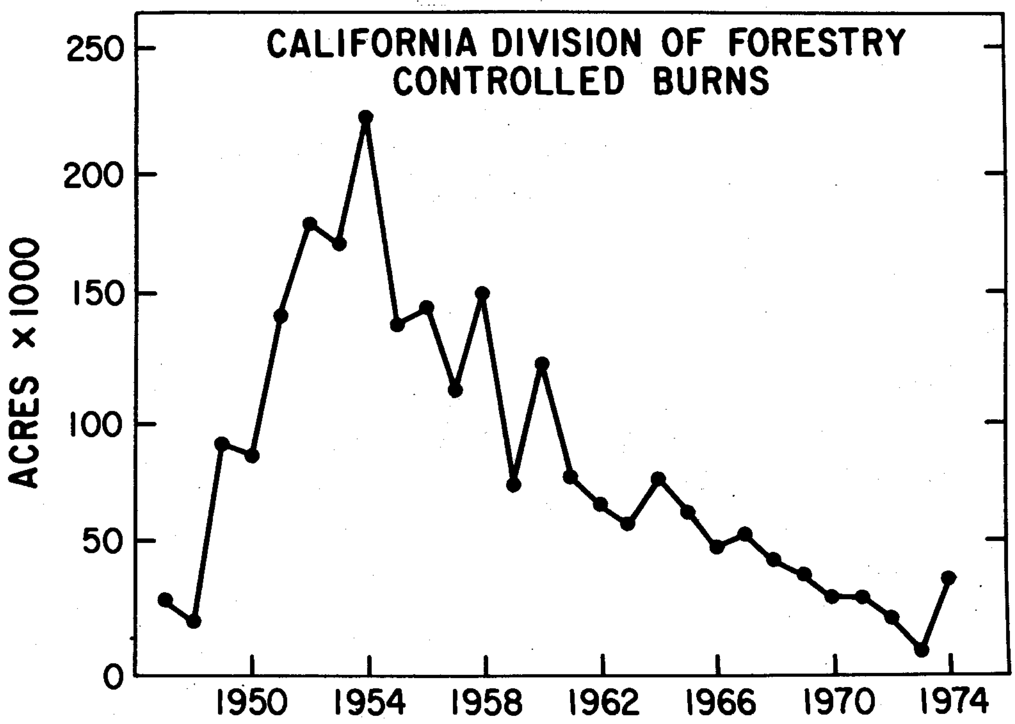

Figure 7.

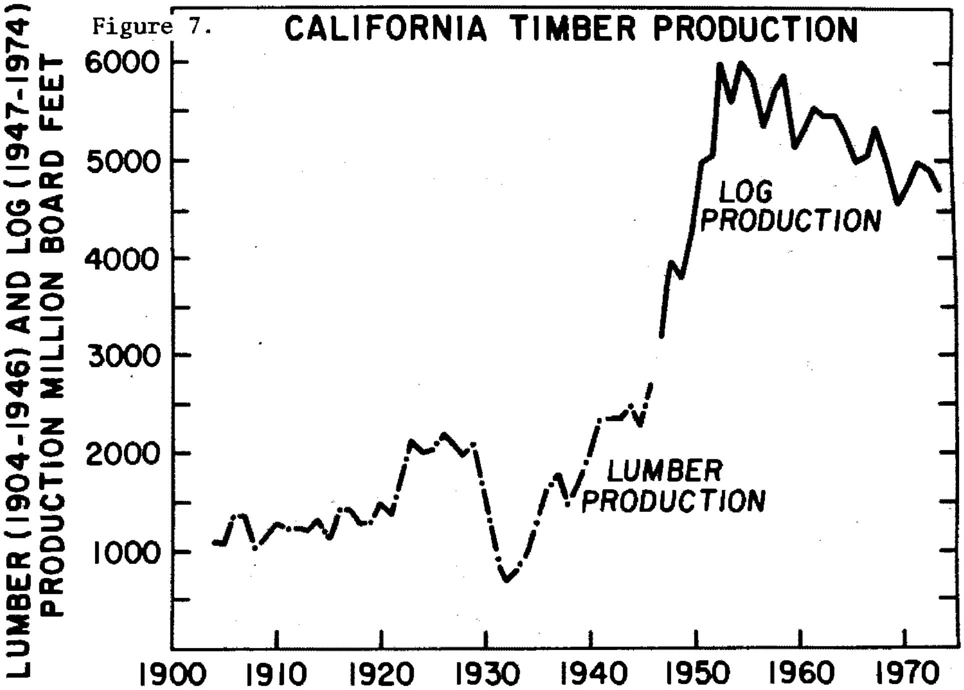

Figure 8.

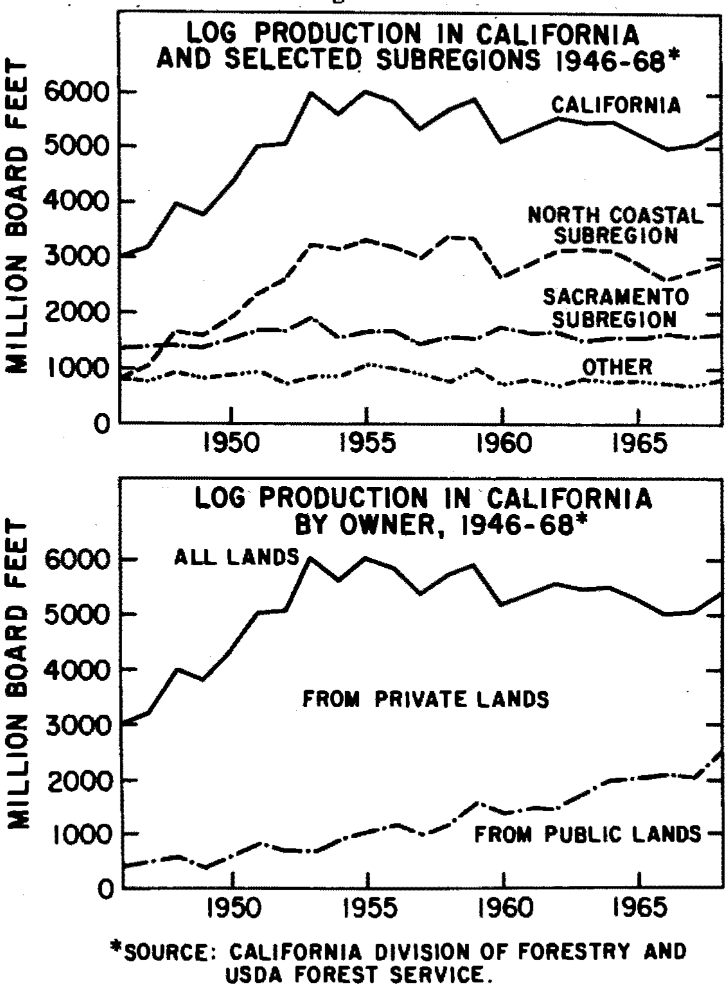

Figure 9.

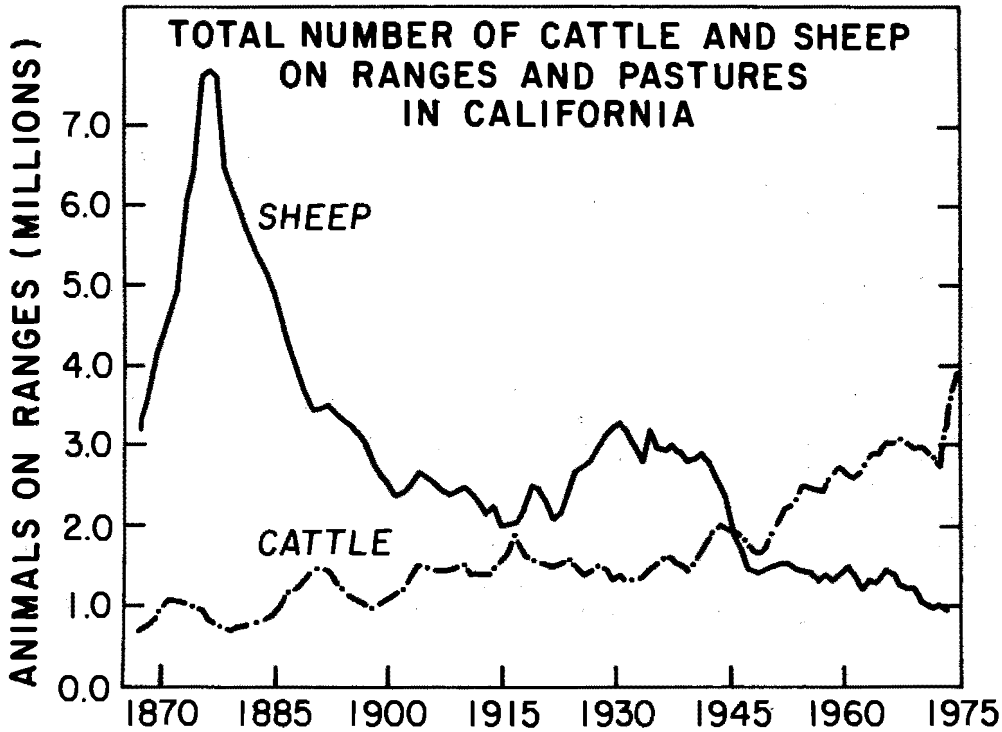

Figure 10.

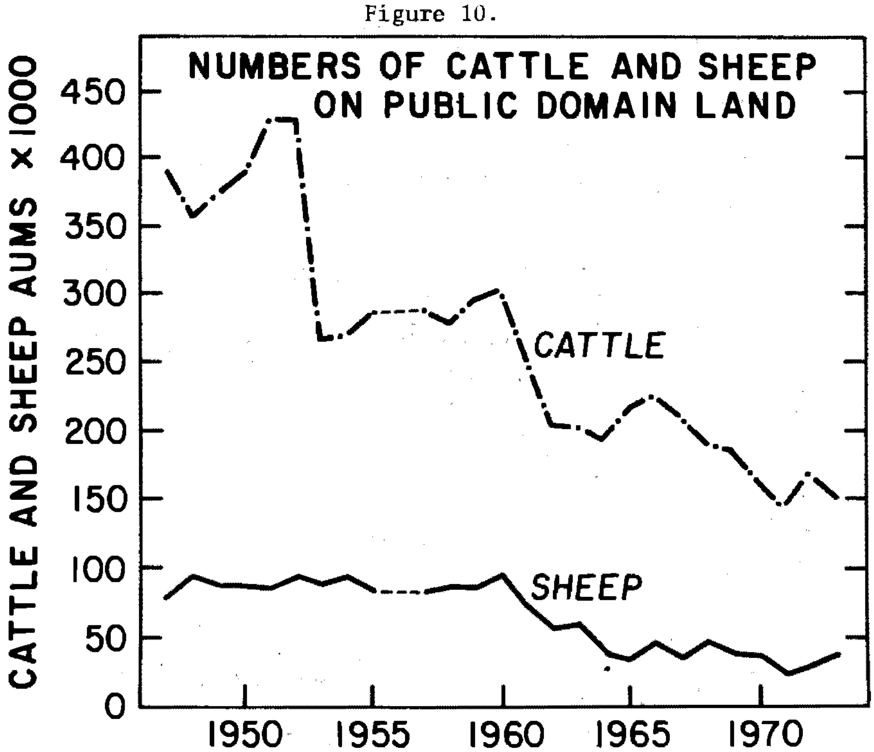

Figure 11.

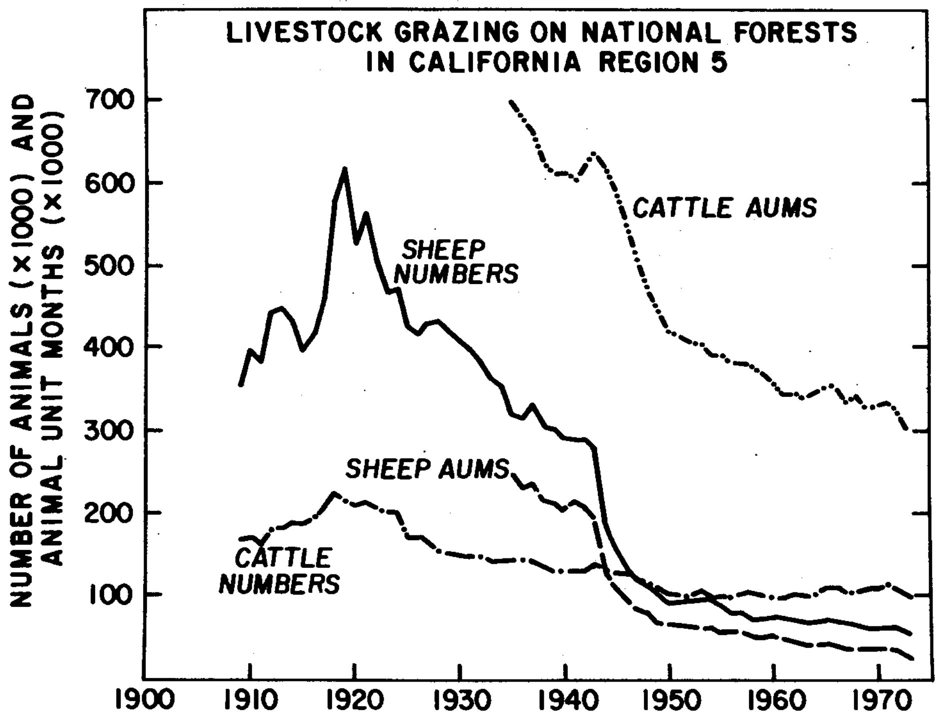

Figure 12.