CATTLE IMPACTS ON MOUNTAIN SHEEP IN THE MOJAVE DESERT: REPORT II.

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INTRODUCTION

Wehausen and Hansen (1986) reported on a one-year pilot study directed at the question of competition between cattle and mountain sheep (Ovis canadensis) in the eastern Mojave Desert of California. The conclusions from that study were: (1) that exploitation competition was not occurring in the areas investigated, (2) interference competition also appeared to be absent, in that minimal range overlap between the two species could be explained more parsimoniously by differences in habitat utilization patterns, rather than avoidance of one by the other, and (3) there was a high probability that viral diseases introduced to the native sheep from the cattle were having a significant effect on population parameters of the sheep, largely through high lamb mortality. The work reported here is the second phase of study of the effects of cattle on mountain sheep populations. While it has continued to consider competition where circumstances have differed from the initial pilot study, its main thrust has been the beginning of an intensive study of the demographic effects of introduced viral diseases.

The Problem

The problem of introduced viral diseases in mountain sheep populations is multifaceted, involving a number of related, but separate questions. For the most part, work on the subject to date has been descriptive in the form of serological surveys and attempts at culturing organisms (Parks and England 1974, Chilelli et al. 1982, DeForge et al. 1982, Turner and Payson 1982, Clark et al. 1985) -- a necessary beginning. Three viruses, parainfluenze-3 (PI-3), bluetongue (BT), and epizootic hemorrhagic disease (EHD), frequently have been found associated with potentially fatal disease processes in mountain sheep, especially lambs in California (DeForge et al. 1982, Clark et al. 1985). Because of the impracticality of medically treating individual sheep in wild populations (Clark et al. 1985), there is a need to approach disease problems from a higher demographic level through the testing of hypotheses that have potential practical management applications.

In looking at the question of demographic impacts of these diseases, it is necessary to separate these viruses to the extent possible. The three disease organisms in question fall into two very different categories. PI-3 is extremely widespread in wild sheep populations throughout North America, and appears to be present wherever ruminant livestock grazing has ever occurred (Wehausen 1987). Once introduced, the wild sheep appear to serve as their own long-term reservoir of infection. It appears that the virus can survive in the host in a non-pathological association, with the virus, but enters a pathological, and presumably infective, phase when the host defenses weaken due to circumstances such as nutrient stress (Wehausen et al. 1987). Transmission of the virus appears to be only by close contact.

In contrast, mountain sheep (and some other north American wild ungulates) appear to contract BT only as an acute disease, and probably carry the virus in an infective state only for a short period until dead or recovered (Robinson et al. 1967, Hoff and Trainer 1981, Thorne 1982, Wehausen et al. 1987). However, cattle commonly carry BT in chronic form, with little influence on their health (Marsh 1965, Bruner and Gillespie 1966, Hoff and Trainer 1981, Thorne 1982); thus, they are the likely long term disease reservoir for the native sheep. EHD is a close relative of BT. Both cause similar pathology, and both require a gnat for transmission between animals (Thorne 1982). As such, close contact between cattle and sheep is not necessary for transmission. BT and EHD are treated here as a single disease complex.

The demographic situation of populations infected with PI-3 varies greatly, from declining trends to rapid increases. It appears that infection with PI-3 is by itself inadequate to explain demographic patterns, although future finer resolution at the level of virus strains may change that conclusion. Wild sheep populations in California's desert region that show evidence of high activity of BT/EHD appear to be more consistently declining or depressed in size.

The research reported here concerns the demographic impacts of the BT/EHD complex. Besides indications that it may be more consistently associated with depressed population status than PI-3, the choice to focus study on BT/EHD results from cattle being the likely long term reservoir for it, and the important management implications therein. It is not clear that any practical management currently is possible relative to PI-3.

Study Approach

Introduced diseases of clinical importance can be expected to reduce population carrying capacity through a higher nutrient requirement of the population to maintain itself. This would occur through (1) additional nutrients used to combat disease organisms in surviving animals, and (2) extra nutrient wastage in animals (mostly juveniles) dying as a result of the disease organisms. How low this carrying capacity will be relative to a situation free of the diseases in question will depend on (1) the influence of population density on disease transmission, (2) the gain in nutrition of individual sheep as population density declines, and (3) the effect of better nutrition in combating the diseases. The basic hypothesis of the research reported here is that high rates of infection with BT/EHD in mountain sheep populations will result in reduced density at carrying capacity. The prediction emenating from this hypothesis is that accurately measured densities of such populations will be lower than nearby populations showing no or low exposure to this virus complex.

As water limited ecosystems, deserts frequently exhibit considerable dynamics due to variation in rainfall (Monson 1960, Beatley 1974, Douglas and Leslie 1986, Wehausen et al. 1987). In such a system, the classical concept of herbivore carrying capacity (e.g. McCullough 1979, Caughley 1976) loses much of its meaning in that effects of environmental variation on individual nutrition may far exceed that of variation in population density (Caughley 1977, Wehausen et al. 1987). To deal with this problem in testing the primary hypothesis of this study, it has been necessary to compare nearby populations in the same time period such that they will all have experienced similar environmental regimes. Nevertheless, no two mountain ranges offer identical habitat quality for sheep inhabiting them. Elevation differences alone may result in substantially different plant communities on neighboring ranges; thus, any demographic differences that might be found and ascribed to disease differences, might equally be ascribed to habitat differences. Consequently, it has been necessary to quantify differences in nutrient availability to sheep in the ranges studied to test this alternative hypothesis in all comparisons.

Because females are (1) the important reproductive base of wild sheep populations, and (2) behaviorally more conservative than males, thus have generally smaller home ranges, ewes are the focus of this study. The goal of this study is to include data from six populations, three with low exposure to BT/EHD, and three with high exposure to BT/EHD. This is an interim report in that it concerns only two populations that have been adequately studied so far: the Old Woman and Marble Mountains.

METHODS

Population density was measured through accurate determination of the population size and the area of range used by ewes. Total range used by ewes was plotted through considerable ground work, aided by some radio collars. This was supplemented by data from regular fixed wing aircraft surveys by the Department of Fish and Game beginning in summer 1986, in which longitude and latitude for the point of strongest radio signal was recorded. Additionally, helicopter flights added further sighting locations. In the Marble Mountains, there were seven helicopter flights in 1986 and two in 1987. Additionally, there was a single flight per year in 1983, 1984, and 1985. In the Old Woman Mountains, there were two helicopter flights in 1986. The range used by ewes in the Old Woman Mountains was mapped in 1985 and previously reported (Wehausen and Hansen 1986); the past two years have turned up few deviations from that original mapping.

Total sizes of ewe populations were determined by mark-recapture methods. Both radio and marking collars were used. In the Old Woman Mountains, ewes were collared in October 1984, March and April 1985, June 1986, and September 1987. The ewes collared in September 1986 have not yet been used in mark-recapture population estimates. Blood samples have been obtained from all animals captured, from which disease exposure has been determined. Prior to 1987, blood samples were obtained from 14 ewes and 2 rams. Disease data for most of these samples have been presented by Clark et al. (1985). Of the 14 ewes marked, one died of capture myopathy before she could be used in mark-recapture sampling. Two others have not been seen since summer 1985, thus were not assumed to be part of the marked population in 1986. Consequently, the highest number of collared ewes used for population estimates was 11.

In the Marble Mountains, 13 adult ewes were collared in June 1986. Three lambs and one yearling ram were also captured and marked at that time. In addition, disease data exist for 55 sheep captured in this range for reintroductions between 1983 and 1985.

With the exception of two counts in the Old Woman Mountains, a radio receiver was not used during or before censuses so as to avoid any bias in the use of radioed ewes as marked animals. In the two exceptions, the two radioed ewes in the Old Woman Mountains were used to find sheep groups in order to increase sample size. In these two cases, these two ewes were eliminated from the population for calculation of mark-recapture estimates, then added to those estimates at the end.

Population estimation calculations included the simple Petersen equation (Overton 1971), as well as those of Bailey (1951), and Seber (1970). A fourth estimate was based on the average percent of ewes collared in large samplings over substantial time periods.

All counts for mark-recapture estimates in both ranges were carried out in a manner that minimized the probability of sheep being seen more than once. In the Old Woman Mountains this was aided by the existence of largely isolated populations of ewes on either side of the range. In the Marble Mountains, counts were made by progressive movement along the range in sequential days. Nevertheless, some collared and uncollared ewes were recognized as being sampled twice during some Marble Mountain counts, and were counted only once in the results. However, for the calculation of the overall percent of ewes collared over larger time periods, all sheep seen (without the aid of a radio receiver) were included.

Fecal collections were made approximately monthly from ewe groups in both ranges and used to produce annual curves of fecal crude protein as a measure of diet quality (Hebert 1973, Wehausen 1980, Hebert et al. 1984). These curves were used to compare habitat quality between ranges, from which qualitative expectations of density differences in the absence of introduced diseases could be generated.

STUDY AREAS

Old Woman Mountains

The Old Woman Mountains are located in eastern San Bernardino County about 40 miles west of Needles, California. Geologically, they mostly consist of granite and metamorphic rocks. Elevations range from 2000 to 5300 feet. Annual precipitation ranges from 3 to 5 inches (Freiwald 1984), occurring as a bimodal distribution (Figure 1) similar to Sonoran Desert ecosystems further south. However, the summer component of this precipitation pattern is highly variable in the ranges under study.

North-facing slopes at higher elevations support pinyon pine, and juniper is present on all slopes above about mid elevation. Otherwise, the vegetation consists of a large variety of Mojave Desert shrub species and an abundance of perennial grass.

Domestic cattle were grazed on the east side of the Old Woman Mountains until the mid-1950's

(R. Weaver, pers. comm.). From that time until the recent episode of cattle grazing began in 1979 (BLM files), no cattle were found in the area. In 1979, the allotment was reopened and expanded to include portions of the western side of the range , where grazing was absent in the previous episode of cattle use. Apparently 200 cattle were on the allotment in 1984 for year-round grazing (BLM files).

For 16 blood samples obtained from mountain sheep in this range during 1984-86, 4 had significant titers to PI-3, 6 were positive for BT, and 13 were positive for EHD (Clark et al. 1985; R. Clark, unpubl. data). This population clearly qualifies as one of high exposure to BT/EHD.

Marble Mountains

The south end of the Marble Mountains lies 11 miles due west of the north end of the Old Woman Mountains. The Marble Mountains are a linear range oriented SE-NW. Total length is about 18 miles, with width varying from 1 to 5 miles.

Except for about a 2-mile length of steep limestone near the south end, the Marble Mountains are almost entirely volcanic. Elevations are lower than the Old Woman Mountains, ranging from 1200 to 3800 feet. It is a hotter and drier range than the Old Woman Mountains, which is clearly reflected in the vegetation. Pinyon pines and juniper are entirely lacking. Relative to the Old Woman Mountains, there is low species diversity in the shrub community, which mostly consists of Larrea divaricata, Encelia farinosa, Ambrosia dumosa, Krameria grayi, and Ephedra sp., with Accacia greggii, Hyptis emoryi, and some other shrub species growing in lower washes. Perennial grass is rare, whereas annual grass is widespread, and barrel cactus (Ferocactus acanthodes) is abundant in many areas.

Significant domestic stock grazing is not known to have ever occurred in the Marble Mountains. In recent years, some cattle have wandered over to the north end of the range in winter and spring from the east. A small population of feral burros was present in the early 1980's, but has disappeared.

For 55 blood samples abtained from Marble Mountains sheep between 1983 and 1985, three had significant titers to PI-3, none was positive for BT, and none of 45 tested for EHD was positive (Clark et al. 1985). Using the equation in Wehausen (1987), this sampling allows a statement with 95% confidence that the rate of exposure to BT at the time of sampling was less than 5%, and less than 6% for EHD. This population clearly qualifies as one of low BT/EHD activity.

RESULTS AND DISCUSSION

Habitat

Nutrition

Differences in the geological and elevational settings of the Old Woman and Marble Mountains are clearly reflected in growth patterns of forage species, with consequences for sheep nutrition. It was clear in both 1986 and 1987 that plant growth in the Marble Mountains peaked in March with the flowering of Encelia farinosa. Peak growths in the Old Woman Mountains have been both later and more luxurient, with many more species involved. This is clearly reflected in the FCP curves for the two populations (Figures 2 and 3). It is noteworthy that the sheep in the Old Woman Mountains began the growing season in both years at a higher nutrient intake level, and peaked considerably higher and later. In 1987, the curves crossed for a significant period of the growing season, a difference that was evident in visual observations of plant phenology. This reflects a long winter dry spell in the Old Woman Mountains due to a storm that missed that range, but hit the Marble Mountains. Nevertheless, if one were to integrate the FCP curves from each range for the growing season in 1987, the Old Woman Mountains would produce a higher value, as was the case the previous year. Additionally, in summer of 1986, the Old Woman Mountains received substantial rainfall that completely missed the Marble Mountains. This moisture initiated major late summer plant growth in the Old Woman Mountains, which is clearly reflected in FCP values (Figure 2). This late season nutrient flush resulted in a visible new dark band of horn growth in the sheep. Overall, it seems a safe conclusion that the Old Woman Mountains offers a better nutrient base for sheep than the Marble Mountains. On this basis one would predict higher sheep densities in the Old Woman Mountains.

When compared between years, the FCP curves for the Marble Mountains show essentially identical spring peak values, but slightly different timings of the growing season and different low values for summer (Figure 4). For the Old Woman Mountains, the wetter growing season of 1984-85 is reflected in substantially higher FCP peak values than in the two subsequent years (Figure 5). Also, the three different patterns for late summer and fall reflect differing amounts of summer greenup due to differences in summer precipitation.

Surface Water

Marble Mountains

The Marble Mountains have only four permanent water sources: three springs on the west side of the range near the north end, and one artificial source involving a catchment and storage tanks on the east side of the range toward the south end. These water sources have persisted unchanged during the course of this study. Additionally, there are numerous potholes throughout the range that hold water for up to about three weeks after summer rain storms. Both perennial and temporary water sources appear to receive some use by the sheep; but overall, this population shows relatively little useage of surface water.

Old Woman Mountains

There are numerous water sources in the Old Woman Mountains, which were previously mapped (Wehausen and Hansen 1986). Unlike the population in the Marble Mountains, the sheep in the Old Woman Mountains exhibit a high reliance on surface water during the hot season. These water sources have been drying down steadily during the course of this study. When this range was first observed from the air in July of 1984, there were streams evident in some washes, such as the Gemco drainage. These were perennial streams rather than short term runoff from summer storms. A couple of these (Upper Bert and Old Woman Statue Wash) were documented to run in the summer of 1985. Since then, the number of water sources that have continued to provide water through the hot season has dropped yearly. Table 1 lists 19 such water sources in or near areas used by sheep that have been monitored from 1985 through 1987. Only about one-third of them continued to provide water in the 1987 hot season.

Summer rains mostly run off the surface, thus do little to recharge aquafers that supply springs. This was evidenced by the continued drying up of springs in 1987 despite substantial summer rains in 1986. In contrast, winter rains soak in deeply. Winter rainfall in this part of the desert was particularly heavy in the 1978-80 period, with a notable peak in 1980 (Figure 6). It is probable that these winters charged springs to their full potential. Since then, 4 out of 7 years have produced average or higher winter precipitation. While it is possible that the surface water trend since 1985 reflects only a short term pattern reflecting winter rainfall in individual years, it seems more probable that this is a longer term pattern of drying since the peak in 1980.

When water sources were mapped in 1985, sheep were using a number of springs in the hot season. In the Dripping Springs section of the range, they used primarily Missing Spring, with less use of Lone Spring. In 1986 and 1987, Missing Spring did not provide water during the hot season, and essenitally all use by sheep shifted to Lone Spring.

In the Sheep Camp section, sheep primarily drank from Upper Sheep Camp Springs #1 and #2, with limited use of the Sheep Camp Drinker and adjacent spring in 1985. In 1986, Upper Sheep Camp Springs #1 and #2 continued to be the primary drinking spots. In 1987, Spring #2 and the drinker both went dry early in the hot season; and Upper Sheep Camp Spring #1 was heavily used by the sheep, despite its limited water holding capacity.

In the Wilhelm Spring section, the sheep used Wilhelm Springs #2 and #3, and Nursery Spring heavily in the summer of 1985. In 1986, both Wilhelm Spring #3 and Nursery Spring provided water through the hot season, and continued to receive heavy use. Wilhelm Spring #3 provided no water in the hot season of 1987 and, although not completely dry, Nursery Spring provided a minimum amount of water, and received only light sheep use in the middle of the hot season. The summer distribution of this portion of the sheep population shifted north in 1987 to the area around and above the Craig Spring drainage, where surface water remained in two locations.

Competition Around Water

Wehausen and Hansen (1986) suggested that any competition between cattle and native sheep that might occur in the Old Woman Mountains probably would involve displacement of sheep from water. This apparently occured in the Wilhelm Spring subpopulation in 1986 and 1987. In the fall of 1985, Marvin Wood Springs were discovered on the west side of this arm of the range. At that time, Lower Marvin Wood Spring held about 200 gallons of water, and had sheep fecal pellets on the immediate slopes around it from the previous season. These included small lamb pellets that were interpreted as dating from late spring. The following winter this spring was colonized by cattle, which continued to use it into July of 1987, when it dried up. Those cattle converted this clear water into a cesspool. At the end of the hot season in both 1986 and 1987, I could find no sign of sheep use of this spring. In both years, the sheep had alternative water to use; thus it is unlikely that this apparent displacement had any significant demographic effect. As such, it cannot be construed as true competition in the strict definition of the term. However, this natural experiment suggests the potential for such displacement. Under different circumstances, the consequences might be more significant. Dunn and Douglas (1982) reported similar displacement of sheep from water due to feral burros.

Demography

Marble Mountains

Home Ranges

The five radio collared ewes in the Marble Mountains each exhibited distinct home ranges, based on aerial and ground locations obtained over an 18 month period (Figures 7-11). None of these ewes exhibited a home range that covered the entire length of the mountain range between highways 66 and I-40, but in combination they do. Plottings on Figures 1-5 were separated into the cool and warm seasons. Four of these five ewes exhibited a general pattern of a more southerly distribution during the cool season and a more northerly distribution during the warm season (Figures 8-11). This is a general pattern that has been apparent from helicopter flights and ground counts. The majority of the ewes appear to use the limestone section that runs south from Iron Hat Mine, and the massif immediately to its north, for lambing. During five helicopter flights in April of 1986, a progressive movement of ewes and lambs to the north was observed. However, some ewes with new lambs have been observed throughout the range, including the most northern section across the pipeline road. Lambing further north in the range appears to be mostly associated with later births.

The general north-south seasonal distribution pattern has a simple explanation in terms of elevation and vegetation greenup. The base of the range drops about 1800 ft elevation from the north end to the south end. The influence of this difference is quite marked in terms of warmer temperatures and an earlier growing season at the south end. During the hot season, sheep are found scattered throughout the Marble Mountains. Thus, the apparent north-south seasonal movement is more a concentration toward the south during the cool growing season and a spreading out during the hot season. There is no evidence of summer concentration around any of the water sources in the range. Use of these water sources is light, especially given the size of the sheep population, and may involve only a small proportion of the sheep. Most of the sheep apparently drink little water during the hot season, instead obtaining moisture from barrel cactus and scattered small tinajas that occasionally have water following summer rains.

All sheep groups sighted in the Marble Mountains during 1986-87 are plotted on Figure 12 along with a line delineating the total range used by ewes. The ewe population in the Marble Mountains exhibits all evidence of being a closed population. None of the radio collared ewes has been recorded to move to neighboring mountain ranges; nor have any of the rams or ewes with radios in the neighboring Clipper Mountains been recorded to move to the Marble Mountains. Apparently ewes occasionally cross Kelbaker Road to use Brown Buttes, as one of a group of three was hit and killed by a car in December of 1986. This is probably a rare occurrence; thus, I have not included Brown Buttes in the range used by ewes. Nor have I included the few aerial fixed-wing locations that are out from the range (Figure 9), as these may be due to signal bounces or the timing of when coordinates were obtained in the aircraft.

Prior to the construction of Highway I-40, Marble Mountain sheep certainly would have used the very northern end of the range now cut off by the highway. Additionally, they probably moved across the short distance separating the Marble and Granite Mountains. On two occasions in summer, we have observed sheep standing at the fence above the freeway onramp at Kelbaker Road gazing north across the freeway.

Current Population Size

Ewes

Estimates of the size of the ewe population in the Marble Mountains have been made on the basis of two helicopter and eight ground counts made since ewes were collared in June 1986. The population being estimated is the ewes, including yearlings, present in 1986. Because yearling ewes rarely are distinguished from a helicopter, the two helicopter surveys in 1987 were not used for population estimates.

The simple Petersen or Lincoln mark-recapture (tag and sample) estimator (Overton 1971), Mn/m (where M is the number marked in the population, n is the size of the sample, and m is the number marked in the sample), yields an upwardly biased estimate on the average, because m is not independent of n (Pielou 1974). Bailey (1951) and Seber (1970) have each provided modified equations that essentially eliminate this bias. For each of the ten counts, I have estimated the ewe population using each of these equations, with average values of 75.2, 63.5, and 67.4 ewes from the Petersen, Bailey, and Seber equations, respectively (Table 2). In addition, I chose a fourth method to try to minimize bias in the m/n ratio. This involved pooling all the data from the ten counts. In so doing, I added back in a number of sheep groups that were thrown out of the original counts as sheep seen earlier in the count, due to recognizable individuals (both collared and uncollared). This approach approximated a sampling with replacement. In this pooled sample, 19.81% of 318 ewes were collared, yielding a simple Petersen equation estimate of 65.6 ewes. This estimate is about the midpoint between the estimates from the Bailey and Seber equations and, henceforth, will be used as the most unbiased estimate.

Mark-Recapture Assumptions

Several assumptions accompany the use of mark-recapture estimation procedures (Pielou 1974, Otis et al. 1978). The first assumption, of a closed population, is satisfied by the Marble Mountain ewe population, as discussed previously. Second, there has been no problem with collars being lost, nor of collars on sheep being missed. The individual identity of collared ewes has sometimes been missed due to long distance or fading of identifying marks on the collars; but this has no consequences in the types of estimates made here.

A third assumption is that if mortality occurs, both marked and unmarked sheep die at the same rate. The extent to which this assumption might not hold probably is slight and inconsequential in the final population estimate made. All collared ewes were documented to have survived through the seven counts made during 1986, and no carcasses of ewes that might have died during those counts was found. Only one collared ewe has not been seen during 1987, but there is no reason to expect her to be dead. Since the 1986 counts, two unmarked ewes are known to have died: the one on Kelbaker Road in December of 1986, and one that died during summer of 1987. Others may not have been found. Thus, the final estimate of the number of ewes is biased to the extent that somewhat fewer unmarked ewes were present during 1987 counts. However, the increase in accuracy from the greater total sample size provided by these 1987 counts probably far outweighs the detriment of this small drop in the number of unmarked ewes. This problem might be circumvented by redefining the population being estimated as the 1986-87 population.

The fourth assumption concerns equal probability of each ewe being observed during any count. A radio receiver was not used during these counts, nor immediately before; thus there is no reason to believe that collared and uncollared ewes had different probabilities of being observed. The sheep exhibit a high mobility and a constant flux of group composition, providing no reason to expect violation of this assumption. Individual marking on collars allowed a rigorous test of this assumption among the collared ewes. This test could not distinguish the pattern of resightings among these ewes from that expected from random sampling (see the Appendix for details of this test).

Rams, Lambs, and Total Population

An estimate of the ram population can be made based on the ratio of rams to ewes during the rutting season when the sexes are mixed. Pooling the data from 7 counts made during the rut provided a ram:ewe ratio of 109.3:100. This high ratio reflects 1983-85 removals for reintroduction that emphasized ewes. When this ratio is applied to the 65.6 ewes estimated, an estimate of 71.7 rams results, thus a total adult population of 137 sheep.

It appears that essentially every ewe has had a lamb each year in 1986 and 1987. However, since the lambing period extends from January into summer, some lambs have died before others have been born. Consequently, the highest spring ratio of lambs to ewes recorded has been 72:100, which dropped to 28:100 in fall of 1986. Thus, the total population in the Marble Mountains varied between 184 and 155 in 1986.

Recent Population Dynamics

Evidence from Age Structures

Collection of demographic data on the population in the Marble Mountains began only in 1983 with helicopter flights. Since recruitment rates were not regularly measured, it has been necessary to make inferences about this parameter from age structure data. These data suggest considerable dynamics since 1978.

The first count to classify rams occurred in 1984, and recorded a predominance of class II rams, followed in importance by class I, and class III+IV. All classifications since then have found low percentages of class I and II rams, with class III and IV rams making up approximately 90% of the classification (Figure 13). The sample size in 1984 was small compared with later years, and may not have accurately represented the older ram cohorts. Also, most of the observers were not experienced and may not have classified rams properly in all cases. However, it is doubtful that these potential problems can completely explain away the virtual disappearance of the I and II classes in subsequent counts. The ram classifications for 1985-87 suggest a population that has experienced very low recruitment for a number of years; and the 1984 classification probably caught the last significant cohort to be recruited before it became unidentifiable in the large III+ class.

Data from 49 ewes aged during yearly captures between 1983 and 1986 provide a more accurate picture of recruitment history that corroborates the findings from rams. When the birth years of these ewes are accumulated, a distinctive distribution with a 1980 peak emerges (Figure 14). Interpretation of this distribution must be cautious because (1) birth years after 1982 have progressively limited opportunities for representation, and (2) interpretation must be made against a background of what would be expected from survivorship curves (Bradley and Baker 1967, Hoefs and Bayer 1983). If recruitment numbers were constant, the distribution of birth years would be expected to decline slowly for a number of years then drop more rapidly. The pattern for 1978-1982 in Figure 14 was derived from ewes aged 1-5 in 1983, 2-6 in 1984, 3-7 in 1985, and 4-8 in 1986, with only 16% of the sampling of age classes older than 6. This is basically a sampling of ewes in high survivorship classes. Thus, the resultant 1978-82 pattern in Figure 14 is probably a reasonable parallel to the number of sheep recruited in those years. This histogram cannot be interpreted as the recruitment rate pattern for 1978-82 because there is good reason to believe that the population was not constant. The 1978-80 exponential increase in Figure 14 is best interpreted as reflecting a combination of increasing recruitement rate and population size. The apparent high recruitments for 1979 and 1980 should have increased the population base of reproductive ewes up to 1982; thus a constant recruitment rate for 1980-82 would be expected to result in increasing numbers in the 1980-82 cohorts. The exponential decline that occurred instead in 1981-83 consequently can be interpreted as an underestimate of the actual degree to which the recruitment rate declined. Restricting the analysis to ewes caught in 1985 and 1986 allows equal representation through 1984, and indicates that recruitment has remained low (Figure 15). This has been documented in 1986 and 1987.

Recent Recruitment Rates

Classification of sheep from above during ground surveys is frequently a problem, and from above in a moving helicopter presents yet further difficulty. This is especially true for the yearling age class of both sexes. During capture operations, what are believed to be ewes sometimes turn out as yearling rams when caught. This has two implications relative to age ratio data. First, ground classifications are likely to be more accurate than those from a helicopter, and second, yearling:adult ewe ratios of captured sheep probably provide a reasonable measure of the composition within the population.

For the sample of 47 adult ewes captured between 1983 and 1986 in the Marble Mountains, a ratio of 17 yearlings of both sexes per 100 adult ewes resulted. This should represent an average for those four years. It is a low figure that suggests just maintenance of the population at best (Wehausen et al. 1987). The average recruitment ratio for five ground surveys totaling 141 ewes in 1986 was 27.7 lambs per 100 adult ewes, considerably above the value for captured sheep. However, when this same cohort was classified as yearlings in 1987 counts, a ratio of only 16.4 yearlings per 100 adult ewes was found for a total sample of 110 ewes (Table 3) -- quite close to the value for captured sheep. It is not clear whether this lower value for yearlings results from further loss of lambs over winter or some bias in the classifications. Two females marked as lambs in 1986 have served to verify the correctness of yearling ewe classification in 1987; but there may remain some misclassification of the largest yearling ewes as adults, as well as bias against yearling rams that are not accompanying ewes. Samplings in future years may answer these questions. The yearling:adult ewe ratio in 1986 was considerably lower than in 1987 (Table 3), suggesting some year-to-year variation in recruitment during this period of low recruitment. This is also indicated by the lower fall lamb:ewe ratio in 1987 compared with 1986 (Table 3).

The first helicopter survey in the Marble Mountains in January 1983 recorded a recruitment rate of 39.5 (1982) lambs per 100 total ewes for 38 ewes sampled. This would have been higher as a ratio to adult ewes. This is well above any of the lamb or yearling ratios discussed above, which supports the earlier interpretation of Figures 14 and 15, that recruitment rates have been low beginning in 1983. It is noteworthy that 1982 has the second lowest representation in Figure 14 for the 1978-82 period. Recruitment rates must have been exceedingly high during the 1979-81 period.

Cause of Recent Population Dynamics

A pattern of recruitment as dramatic as what appears to have occurred between 1978 and 1983 is worthy of exploration as to cause. I investigated the possibility of an environmental cause. This was prompted by findings from another desert ecosystem that variation in November, January, and February precipitation can account for much of the dynamics in recruitment (Wehausen et al. 1987). Precipitation data from the nearby Mitchell Caverns support such an interpretation of the recruitment pattern in the Marble Mountains since 1977. January precipitation in 1978-80 equalled or exceeded all values since 1960, with a notably high peak in 1980 (Figure 16). Similarly, February precipitation in 1980 also was the highest value since 1960, while 1978 and 1979 were both well above normal (Figure 17). Additionally, March precipitation for the entire period 1978-83 equalled or exceeded the highest prior value since 1960, with a notably high peak value in 1983 (Figure 18). March precipitation was not found to influence lamb recruitment in the Santa Rosa Mountains (Wehausen et al. 1987). This appears also to be the case in the Marble Mountains, as 1983 was apparently a year of relatively low recruitment. A rigorous test of correlations with precipitation is not possible since actual recruitment rates are not known for most of the years in question. However, in a general qualitative way, the January and February precipitation data appear to account for the observed dynamics in that they predict (1) a rise in recruitment rate beginning in 1978, (2) a major peak in 1980, and (3) a substantial decline thereafter.

1983 Population Size

Between July 1983 and July 1985, 55 sheep were removed from the Marble Mountains population for reintroductions. Most of these (43) were females, comprised of 35 adult, 2 yearling, and 6 lamb ewes (Table 4). The various recruitment data discussed earlier suggest that recruitment rates from 1983 to present have been at a level likely only to replace natural mortality. At best, any population increase has been slight. This has two implications. First, there is no evidence of a density-dependent response in recruitment to a substantial drop in population density. Second, it is possible to add the sheep removed to the current estimates to arrive at a reasonable estimate of what the population would have been in 1983 before removals began. As a conservative approach, I have added only the yearling and adult sheep. This provides estimates for 1983 of 103 ewes and 82 rams. This results in an adult sex ratio of 80:100. Adding the lambs removed would drop this ratio to 75:100, which is similar to natural sex ratios of other unhunted populations (Wehausen et al. 1987). Including recruited lambs, the total population in 1983 was probably about 200-210 before removals began.

Population Density

The total ewe range outlined in Figure 12 measured 28.33 square miles. For the 1986 population size, this resulted in a density of 2.32 ewes per square mile. For the population size estimated for 1983, this rises to 3.64 ewes per square mile. Given the apparent lack of replacement of sheep removed for reintroduction, this latter density can be construed as the approximate density that would have occurred in 1986 had sheep removals not occurred.

Old Woman Mountains

Home Ranges

Geographically, the Old Woman Mountains are considerably more complex than the Marble Mountains, which is reflected in ewe home ranges. With only 2 radioed ewes, the information of individual home ranges in the Old Woman Mountains is in some regards more limited than for the Marble Mountains. However, a substantial data set on ewes with marking collars has provided considerable additional information on home ranges. The ewe population in the Old Woman Mountains can be divided into two nearly distinct subpopulations: one on the east side of the range in the Wilhelm Spring area, and one inhabiting a considerably larger area on the west side of the range. These ewe ranges, along with sighting locations, are plotted in Figure 19. In three years of study, only a single marked ewe has been documented to be part of both subpopulations, and only briefly, in that she has not been seen since 1985.

Many of the ewes in the westside subpopulation have been documented to use the entire range between Sheep Camp and the Dripping Springs area; however, each shows a clear preference for one end or the other, and this preference reflects the end inhabited during the hot season. All marked ewes have been consistent from year to year in their respective hot season ranges. During the winter of 1985-86, one of the radioed ewes could not be located in the Old Woman Mountains for a substantial time period. The same situation occurred the following winter, at which time she was located south of the Old Woman Mountains in the Iron Mountains during fixed-wing telemetry flights. I located her on the ground in the Iron Mountains, and found her alone with a lamb, and no sign of any other sheep. As occurred the previous year, she reappeared in the Old Woman Mountains in spring. Similarly, the other radioed ewe was documented in telemetry flights to make a short trip to the neighboring Ship Mountains to the west in early spring of 1987. If these two ewes are in any way a representative sample, intermountain movements by this sex are to be expected. The total ewe range mapped on Figure 19 is the range intensively used by that sex, and obviously does not include these distant areas used occasionaly. The two additional radio collars placed on ewes in the Old Woman Mountains in September of 1987 may shed further light on the frequency of long distance movements.

Wehausen and Hansen (1986) suggested that the central section of the range around Old Woman Statue was used only by rams. Data collected since then continue to support that conclusion, although somewhat more of the Gemco Mine drainage below Carbonate Peak is used by ewes than previously recognized. The range use pattern of the single radioed ram is noteworthy. He was collared in the spring of 1985 as a 2-year old in the Wilhelm Spring area. During 1985, he continued to spend time there with what appeared to be his maternal group; but he also began to mix with the ewes in the Sheep Camp area. In the following winter (1985-86), he apparently left the Wilhelm subsection and joined the rams in the center of the range, as his signal could never be picked up in the Wilhelm area. The following winter he was consistently in the central ram area, and has never been documented to return to his natal area since his departure in late 1985. Such a pattern, in which rams always rut outside of their maternal home range, may be the norm among wild sheep, whereby inbreeding is avoided. An opposite pattern among ewes would reinforce such a system. The apparent substructuring of home ranges of ewes found here in the Marble and Old Woman Mountains has also been found in a northern ecosystem (Festa-Bianchet 1986).

Current Population Size

Ewes

Estimates of the size of the ewe population in the Old Woman Mountains were made beginning in spring 1985 after the first marking effort. Three independent estimates were made from three censuses in 1985 (Wehausen and Hansen 1986), and two were made in 1986 following the placement of additional collars. As with the Marble Mountains, the most accurate estimates probably come from the overall percent of ewes collared when measured over long enough time periods to render a substantial sample size. This percent was always based only on groups of sheep found without the use of signals from radio collars on ewes. In two of the censuses used for population estimates, the radio receiver was used to find both radioed ewes. In these cases, population estimates were derived using only marking collars, with the two radioed ewes completely removed from the population being estimated. Two ewes were then added to the resulting estimates to arrive at the final estimates. As with the Marble Mountains, Petersen, Bailey and Seber estimators were used.

The results produced a small range in estimates of the ewe population in the Old Woman Mountains, both within and between years (Table 5). The largest number of estimates is for the population of all ewes (including yearlings) present in 1985 (adult ewes in 1986). For the five censuses, the Petersen estimate ranged from 33 to 38 ewes ($\bar{x}$ = 35.4), the Bailey estimate ranged from 28.8 to 32.6 ($\bar{x}$ = 30.1), and the Seber estimate ranged from 31.4 to 35 ($\bar{x}$ = 32.7). For substantial samples of all ewes in 1985 and adult ewes in 1986, 23.0% were collared in both years, producing two separate population estimates of 34.8. As with the Marble Mountains, this value is considered the most accurate estimate. It lies between the average Petersen estimate and those of the two less biased estimates. However, the Seber estimator is relatively unbiased only where the number of marked animals in samples is seven or greater (Pielou 1974). It is likely that Bailey's estimator suffers similarly. All censuses in the Old Woman Moutains have recorded fewer than seven collared ewes. Consequently, the population estimates based on the percent of ewes collared in larger samples can be expected to be the most accurate. Specifically, the value of 35 (34.8) total ewes in 1985 or adult ewes in 1986 will be used in subsequent discussions.

Mark-Recapture Assumptions

Although both radio-collared ewes were documented to visit neighboring mountain ranges in 1987, there is no reason to believe that the assumption of closed population was violated. Neither of the ranges visited contain permanent sheep populations, and the period of absence did not coincide with the period when counts used for population estimates have been made.

Mark-recapture estimates do not assume that all marked animals are alive when sampling takes place, only that they die at the same rate as unmarked ones. All eight collared ewes used for 1985 estimates were verified to be alive in the summer of 1985. Two of these were never seen in 1986 prior to the two censuses that summer, thus were not used as marked ewes for those two estimates. They have also not been seen subsequently, lending greater support to the assumption that they died. However, the percentage of adult ewes carrying 1985 collars in the 1986 sampling was identical to the percentage in 1985. While this supports the assumption that collared and uncollared ewes died at the same rate, it implies a particularly high mortality rate of about 25% of the ewes, 2-3 times what would be expected. Such a mortality rate would be expected from a population with an age structure heavy in the old age classes due to numerous years of low recruitment.

Previous analysis of resighting frequencies of collared ewes in the three censuses of 1985 using the binomial test suggested the possibility that there was not an equal probability of resighting among them (Wehausen and Hansen 1986). This conclusion was reversed when a reanalysis was made based on a larger data set for the same group of collared ewes, using a more powerful statistical test (see Appendix).

Rams

Samplings from the Old Woman Mountains have consistently exhibited low ram:ewe ratios during the rutting period, when the sexes are most mixed. In 1985, the highest value recorded was 53:100 during fall, whereas the ratio for the whole rutting season was only 42:100 (Wehausen and Hansen

1985). Summer-Fall data for 1986 and 1987 have yielded ratios of 43:100 and 40:100, respectively. All these ratios are well below the sex ratios commonly recorded for unhunted populations (Wehausen et al. 1987). This may reflect a sampling bias. Unlike the Marble Mountains, rams in the Old Woman Mountains occupy a considerable area not used by ewes, and may continue to do so to some extent during the rut. Since sampling of sheep in that period has been entirely within ewe range, some bias may occur against rams. A second possibility is that this may reflect a bias in lamb mortality. Data suggest that this population has suffered from high lamb mortality for some years. Mortality from introduced viral diseases may tend to kill male more than female lambs due to different strategies of growth and metabolism.

When the observed ram:ewe ratios are applied to the estimated total ewe population, an estimate of 15 rams in the population results. Added to the ewes, this results in a total adult population estimate of 50. This is a conservative estimate, given that the actual sex ratio may be higher. However, a sex ratio of 70:100 would raise this only to 59 total adults.

Population Density

Measurement of the ewe ranges delineated in Figure 19 yielded a total area of 40.51 square miles. For the population estimate of 35 ewes, a density of .864 ewes per square mile results. This is about one-third the current population density in the Marble Mountains and less than one-quarter what it would have been had sheep not been removed from that range.

Recruitment

There is a dearth of adequate data on recruitment rates in the Old Woman Mountains prior to the beginning of this study in late 1984. The only useful information comes from one summer waterhole count in 1982. In addition to showing low survivorship of the 1982 lamb crop, this sampling provided some indications of low recruitment the previous year through a low yearling:ewe ratio (Table 6). Data collected during this study show the same pattern for the 1984 and 1985 lamb crops. Thus, it appears that in four out of five years from 1981 to 1985 lamb recruitment was probably too low to effect any population increase. In fact, unless the population began this period with a particularly young age structure, it is probable that the population declined under this recruitment regime (Wehausen et al. 1987). Data collected in 1985 indicated excellent nutritional conditions, from which the opposite population trend would have been projected if the population trends were tied only to nutrition (Wehausen and Hansen 1986).

Recruitment rates in 1986 and 1987 exhibited a departure from the previous regime, with substantial increases in each year from 21:100 in summer 1985 to 39:100 in 1986 and 74:100 in 1987 (Table 6). This trend cannot be explained by yearly differences in nutrition, as growing season nutrition was clearly better in 1985 than in the following two years (Figure 5). Spring lamb:ewe ratios exhibit the same 1985-87 increasing trend. Although data were not adequate to calculate this spring value in 1987, it is clear from the 1987 summer ratio that the spring value had to have been well above the 1986 value (Table 6). These data suggest the hypothesis that this recruitment trend simply reflects changes in actual lamb production. This hypothesis is not supported by 1985 observations that lamb mortality was occurring before the spring surveys (Wehausen and Hansen 1986). Such timing of lamb mortality is typical where populations suffer from the livestock diseases that are present in the Old Woman Mountains (DeForge and Scott 1982, Wehausen et al. 1987). Because of the long lambing period, this mortality has made it impossible to make any empirical estimate of the actual rate of lamb production. Because of the the favorable nutritional regime in this range, it is probable that essentially every ewe older than a yearling bears a lamb every year, as was found for the nutritionally poorer Marble Mountains population.

An alternative hypothesis to explain the 1985-87 recruitment trend is a decreasing trend in transmission of diseases to lambs. This hypothesis is supported by the decreasing surface water trend during that same time period (Table 1). Surface water, especially that contaminated with cattle dung, provides the breeding habitat for the midges that transmit BT and EHD (Hoff and Trainer 1981).

CONCLUSIONS

The basic hypothesis tested in this study is that populations exhibiting high exposure to BT/EHD will have lower densities than equivalent populations of low exposure to these diseases. The results gathered to date support that hypothesis, and provide some idea of the magnitude of the effect; the density in the Old Woman Mountains was less than one-quarter what it would have been in the Marble Mountains had sheep not been removed from the latter. Moreover, the habitat in the Old Woman Mountains is nutritionally superior to that in the Marble Mountains; thus the population density should be higher in the former compared with the latter. This suggests that the approximately 1:4 density ratio for these two populations is an underestimate of the magnitude of what the difference would have been had the two ranges been of equal nutritional value.

Looked at from the standpoint of 1986 and 1987 recruitment values, the observed differences fit the expectations from differences in nutritional quality of the ranges; recruitment in the Old Woman Mountains was better in both years. On the surface, the recruitment and density findings are incompatible. However, this points to the dangers of arriving at conclusions from only two years of recruitment data. In contrast, the density differences represent an integration of many years of population dynamics. The low density of sheep in the Old Woman Mountains apparently has resulted from numerous years of substantially depressed recruitment prior to 1986.

The finding of considerably raised recruitment rates in the Old Woman Mountains in 1986 and 1987 suggests that variation in populations of gnats that transmit BT and EHD may be an important factor in addition to the presence of cattle as the probable reservoir for these viruses. The rising recruitment rates in the Old Woman Mountains correlate with a substantial decline in gnat habitat as springs have dried up. These springs presumably were charged by high rainfall in 1978-80. In the Marble Mountains, this high rainfall led to high recruitment, whereas in the Old Woman Mountains it apparently had the opposite effect due to increased transmission of diseases to the sheep, a pattern that parallels what has happened in the Santa Rosa Mountains (Wehausen et al. 1987). This apparent need for both gnat habitat and a disease reservoir to effect a BT/EHD problem in the wild sheep may explain the low prevalence of these diseases in wild sheep in some areas containing cattle in the samplings by Clark et al. (1985). However, sample sizes from some of these areas were inadequate (Wehausen 1987).

The results of this study so far suggest that cattle in the Old Woman Mountains have been a major adverse factor for the mountain sheep population since this allotment was expanded into the Old Woman Mountains in 1979. While evidence over the past two years indicates that cattle may result in displacement of mountain sheep from water sources, by far the most important finding is the apparent high degree of population depression that can occur from cattle diseases. Continuing studies will look further at this same question in other nearby populations.

Unlike diseases of domestic sheep, which can produce all-age die-offs in native sheep (Foreyt and Jessup 1982, Goodson 1982), diseases contracted from cattle appear to be manifested primarily in excessive lamb mortality leading to long term population declines as recruitment fails to replace adult mortality. If such a pattern was consistent and continued long enough, population extinction would result. The pattern in the Old Woman Mountains suggests that periods of population decline may be broken by ones of gain, depending on the size of the population of gnats needed for transmission of BT and EHD. The limited evidence from the Old Woman Mountains, as well as elsewhere (DeForge and Scott 1982, Wehausen et al. 1987), suggests that the impact of these diseases is most significant in spring, coincident with ideal temperatures for gnats and the loss of colostral immunity in many of the lambs. However, spring and summer rains have the potential to initiate large blooms in the gnat populations; thus a second disease season may occur. As such, a continuation of the surface water drying trend in the Old Woman Mountains may not spare this sheep population from impacts of these livestock diseases.

It is obvious that continuing research on this question of impacts of cattle grazing on mountain sheep populations is necessary. A single comparison of one population with high prevalence of BT/EHD versus one with low prevalence is inadequate to make any generalizations. Secondly, such a study is no more than a study of the demographic impacts of these diseases. The role of cattle in these diseases is a completely separate question. While it is well known that cattle are long term reservoirs of these viruses and that wild sheep, like some other wild ruminants, probably are not (Hoff and Trainer 1981, Thorne 1982, Wehausen et al. 1987), there is a need to test the hypothesis that cattle are the only overwinter reservoir of the BT and EHD viruses (Wehausen et al. 1987). Since vaccination currently is not an option to eliminate the cattle as a reservoir of infection, this can be done only by eliminating cattle for a number of years while determining whether sheep continue to exhibit evidence of exposure to these diseases. However, this must be done in the context of considering the additional variable of transmission by gnats. If exposure of the Old Woman Mountains sheep to BT and EHD naturally declines to low levels with the current drying trend due to reduced gnat populations, cattle removal as an experiment concerning disease reservoirs will lead to ambiguous results.

The Old Woman Mountains would be an appropriate place to carry out such an experiment. The California Desert Conservation Area Plan stated, concerning the Old Woman Mountains, that "Grazing would be eliminated in the Lazy Daisy allotment in bighorn habitat and the allotment would be reduced in size and changed to an ephemeral class (BLM 1980:E-74). That plan also stated, "When bighorn sheep and livestock conflicts are identified, Allotment Management Plans (AMPs) will be developed with the specifid objective to maintain or improve bighorn numbers" (p. P-55). Instead, the allotment was expanded in the Old Woman Mountains in 1981 under Amendment 81-21 to the Plan, which included the stipulation: "At the end of five years (1987), there will be a full reanalysis of bighorn populations and range conditions. If grazing is shown to negatively impact bighorn sheep population, elimination or reduction of cattle range will be considered". This promised "full reanalysis" has not taken place. The study results presented here strongly suggest that grazing, through cattle diseases, has led to a major depression in the sheep population. As such, the appropriate action by BLM would be to honor their written commitment and initiate the process to eliminate this allotment.

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APPENDIX

Test for Equal Observability of Marked Ewes

Tests for equal observability of marked ewes were carried out by a goodness-of-fit test similar to what was done previously for the Old Woman Mountains (Wehausen and Hansen 1986), except that a more powerful statistical test, the Kalmogorov-Smirnov test, was utilized. Goodness-of-fit tests operate by comparing an observed distribution with one expected on the basis of some theoretical assumption. Whether the recorded data meet that assumption is what is tested. In this case, the assumption was that the marked ewes in each population were equally observable; thus the distribution of their resighting frequencies among the various counts should not differ significantly from what would be found from a series of random samplings of the population in which the numbers of marked ewes in each sampling equal the number individually identified in the series of counts in question. This was the null hypothesis being tested in each case.

To arrive at the expected distribution of resighting frequencies, it was necessary to enumerate every permutation by which a ewe could be observed any particular number of times, using the number of marked ewes identified for each count to calculate the probability of being observed, as well as the probability of not being seen. The number of permutations (thus equation terms) for the various resighting frequencies follows Pascal's triangle.

Marble Mountains

Because of the arithmetic intractability of testing this assumption for all ten counts listed in Table 2 without an appropriate computer program (one of the calculations would have 252 terms), it was done for only the seven counts in 1986 using the 13 collared ewes. These provided the following data:

Number of Times Observed:	0	1	2	3	4	5	6	7
Expected Proportion of Ewes:	.020	.115	.264	.308	.202	.075	.014	.001
Observed Proportion of Ewes:	.000	.154	.154	.538	.000	.154	.000	.000

When these data were tested with the Kolmogorov-Smirnov test (Siegel 1956), the observed distribution was not significantly different from the expected distribution ($D = .139$; $P > .20$). Thus, this mark-recapture assumption was met.

Old Woman Mountains

For the Old Woman Mountains, this analysis was made for eight marked ewes present in 1985, using six counts from May 1985 to July 1986, whereby any groups found because of a radioed ewe were excluded. The following data resulted:

Number of Times Observed:	0	1	2	3	4	5	6
Expected Proportion of Ewes:	.014	.090	.236	.318	.240	.090	.014
Observed Proportion of Ewes:	.125	.125	.125	.250	.125	.125	.125

As with the Marble Mountain data, when these were tested with the Kolmogorov-Smirnov test, the observed distribution was not significantly different from the expected distribution (D = .147; P > .20).

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TABLE 1. Water history of nineteen springs monitored in the Old Woman Mountains from 1985 to 1987. Springs were classified as dry if they went dry at any time during the hot season. The locations of these springs can be found in Wehausen and Hansen (1986: Figure 3).

SPRING	1985	1986	1987
Dripping Spring	water	water	water
Upper Dripping Spring	water	dry	dry
Lone Spring	water	water	water
Missing Spring	water	dry	dry
Lower Gemco	water	water	dry
Lower Bert Spring	water	water	dry
Old Woman Statue Wash	water	water	dry
South Scanlon #2	water	water	water
Upper Sheep Camp #1	water	water	water
Upper Sheep Camp #2	water	water	dry
Sheep Camp Drinker Spr.	water	dry	dry
Nursery Spring	water	water	water
Wilhelm #2	water	dry	dry
Wilhelm #3	water	water	dry
Sudmeier Spring	water	dry	dry
Upper Marv Wood Spring	water	dry	dry
Lower Marv Wood Spring	water	water	dry
Upper Craig Spring	water	water	water
Lower Craig Spring	water	water	water
TOTAL with water	19	13	7

TABLE 2. Mark-recapture data and estimates from three different estimators for the ewe population in the Marble Mountains. The total number of ewes collared in the population (M) was 13.

DATE	EWES(n)	COLLARS(m)	Petersen Mn/m	Bailey M(n+1)/(m+1)	Seber [(M+1)(n+1)/(m+1)]-1
7/15/86	26	3	112.7	87.8	93.5
7/28/86	18	3	78.0	61.8	65.5
9/7/86	33	5	85.8	73.7	78.3
9/19/86	29	5	75.4	65.0	69.0
9/28/86	34	7	63.1	56.9	60.2
11/5/86	29	9	41.9	39.0	41.0
12/9/86	32	7	59.4	53.6	56.8
4/7/87	22	3	95.3	74.8	80.5
5/13/87	43	9	62.1	57.2	60.6
11/13/87	24	4	78.0	65.0	69.0
		AVERAGE:	75.2	63.5	67.4

TABLE 3. Recruitment data for the Marble Mountains, 1986-87.

SURVEY TYPE	DATE	LAMBS PER 100 ADULT EWES	YEARLINGS PER 100 ADULT EWES	N (ADULT EWES)
Helicopter	7/15/86	15.4	7.7	26
Helicopter	9/7/86	12.5	6.3	32
Ground	7/28/86	27.8	5.6	18
Ground	9/19/86	25.0	10.7	28
Ground	9/28/86	26.5	5.9	34
Ground	11/5/86	37.9	3.4	29
Ground	12/9/86	21.9	6.3	32
Weighted Average of Ground Counts		27.7	6.4	141
Helicopter	9/28/87	26.9	*	26
Ground	4/7/87	NA	18.2	22
Ground	5/13/87	NA	14.0	43
Ground	Fall 87	15.6	17.8	45
Weighted Average of Ground Counts		15.6	16.4	110

* yearling ewes not classified; some may have been called lambs.

TABLE 4. Inventory of sheep removed from the Marble Mountains for reintroductions, 1983-85.

DATE	ADULT EWES	YEARLING EWES	FEMALE LAMBS	MALE LAMBS	YEARLING RAMS	ADULT RAMS	TOTAL
7/83	9	0	2	0	1	1	13
12/83	7	1	0	0	0	2	10
11/84	8	0	2	1	2	0	13
7/85	11	1	2	1	2	2	19
TOTALS	35	2	6	2	5	5	55

TABLE 5. Mark-recapture data and estimates from four estimators for ewe populations in the Old Woman Mountains, 1985-87. Estimator equations and a key to symbols can be found in TABLE 2.

					EWE	POPULATION	ESTIMATES	
AGE CLASS	DATE	M	n	m	Petersen	Bailey	Seber	Average % Collared
Adult Ewes	5/85	6	16	3	34	27.5	30.8	
	7/85	8	17	4	34	28.8	31.4	
	9/85	8	15	4	<u>30</u>	<u>25.6</u>	<u>27.8</u>	
				$\bar{X}$ =	32.7	27.3	30.0	
	1985	8	77					30.8
Total Ewes	5/85	6	18	3	38	30.5	34.2	
	7/85	8	17	4	34	28.8	31.4	
	9/85	8	17	4	<u>34</u>	<u>28.8</u>	<u>31.4</u>	
				$\bar{X}$ =	35.3	29.4	32.3	
	1985	8	87					34.8
	1986	8	61					34.8
Adult Ewes	7/86	11	18	6	33	29.9	31.6	
	8/86	9	16	4	<u>38</u>	<u>32.6</u>	<u>35.0</u>	
				$\bar{X}$ =	35.5	31.2	33.3	
Total Ewes	7/86	11	18	6	33	29.9	31.6	
	8/86	9	18	4	<u>42.5</u>	<u>36.2</u>	<u>39.0</u>	
				$\bar{X}$ =	37.8	33.0	35.3	
	1986-87	11	69					34.5

TABLE 6. Recruitment data from the Old Woman Mountains for cohorts born 1981-87. The ewe base used in all ratios is ewes two years old and older; thus the yearling ratio in the last column is based on a larger ewe base than the lamb ratios because of the addition of what were previously yearling ewes.

BIRTH YEAR OF LAMBS	SPRING[1] L:100E	N[2]	SUMMER L:100E	N	FALL L:100E	N	WINTER-FALL Y:100E	N
1981							8	24
1982			17	24				
1984							16	80
1985	39	18[3]	21	24	18	28	7	59
1986	67	18[3]	39	36			38	40
1987			74	27				

[1] Spring samplings used were May only in 1985 and April and May in 1986.

[2] Samples sizes are adult ewes in all cases.

[3] Sample used contained only different ewes.

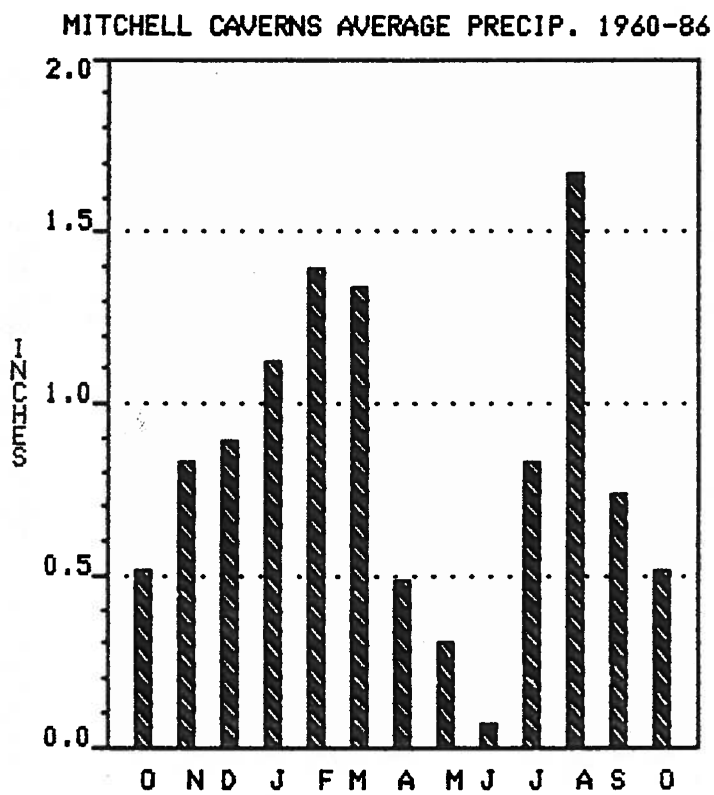


FIGURE 1. Average precipitation by month for 1960-86 from Mitchell Caverns at the south end of the Providence Mountains, California.

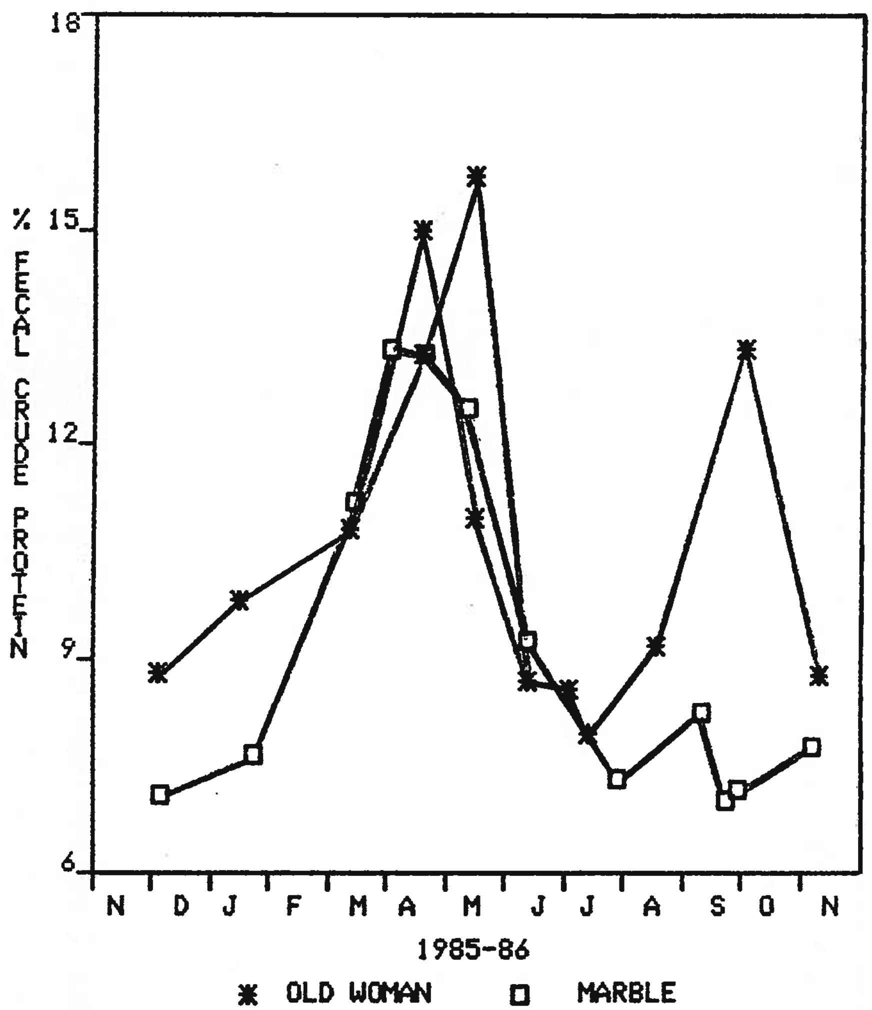


FIGURE 2. Fecal crude protein curves for the mountain sheep populations in the Old Woman and Marble Mountains, 1985-86. The two spring peaks for the Old Woman Mountains represent samplings from different areas in the range which differed in elevation.

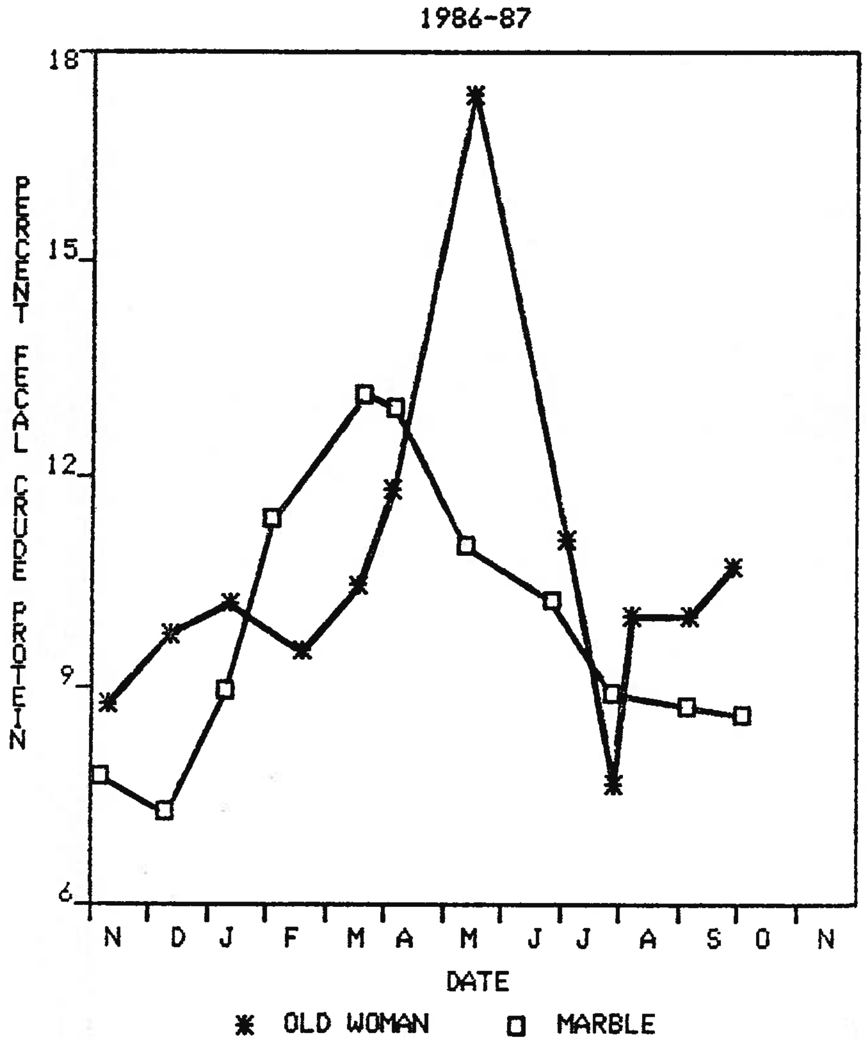


FIGURE 3. Fecal crude protein curves for the mountain sheep populations in the Old Woman and Marble Mountains, 1986-87.

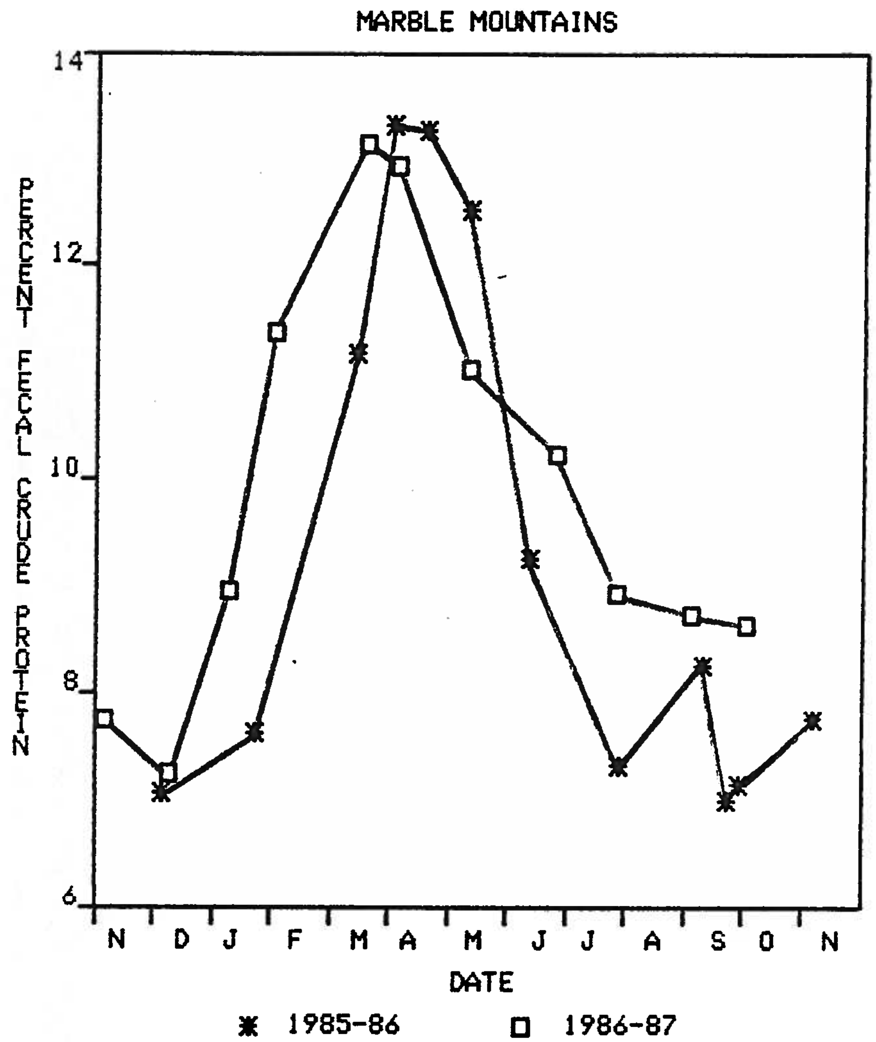


FIGURE 4. Fecal crude protein curves for the mountain sheep population in the Marble Mountains, 1985-86 and 1986-87.

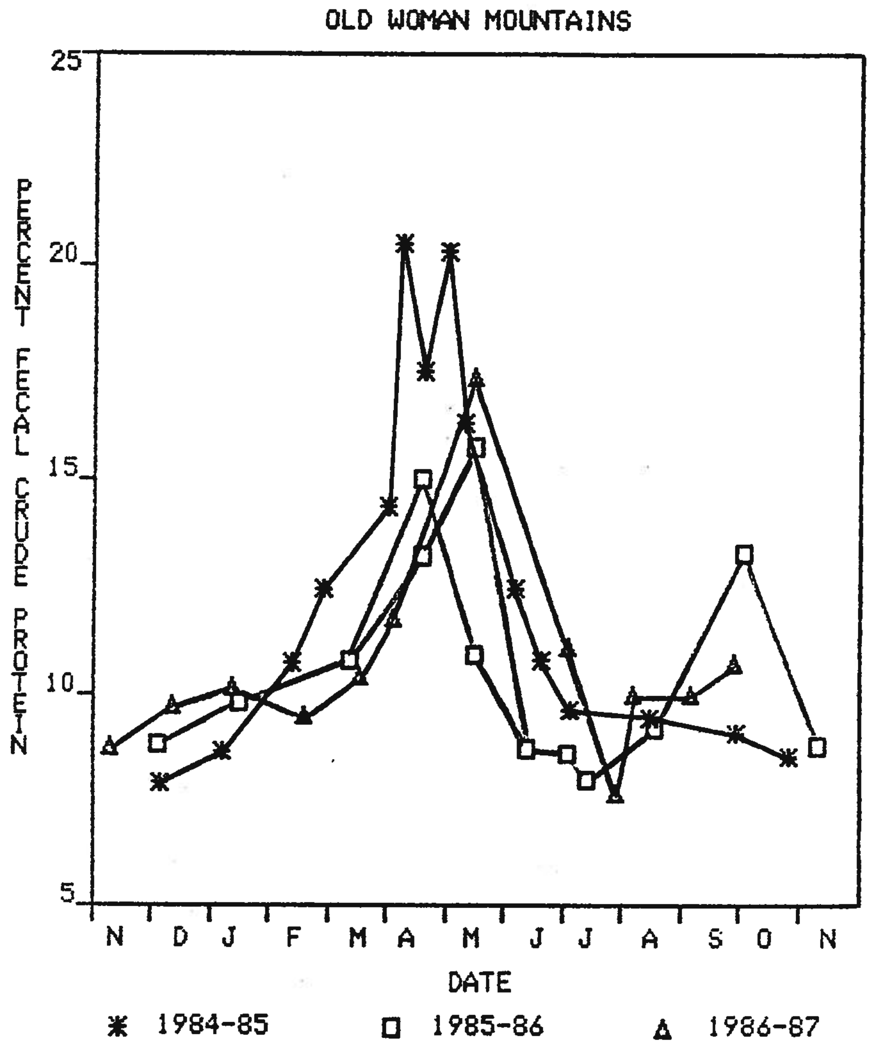


FIGURE 5. Fecal crude protein curves for the mountain sheep population in the Old Woman Mountains, 1984-85, 1985-86, and 1986-87. The two spring peaks in 1985 and 1986 result from samplings of different areas that differed in elevation.

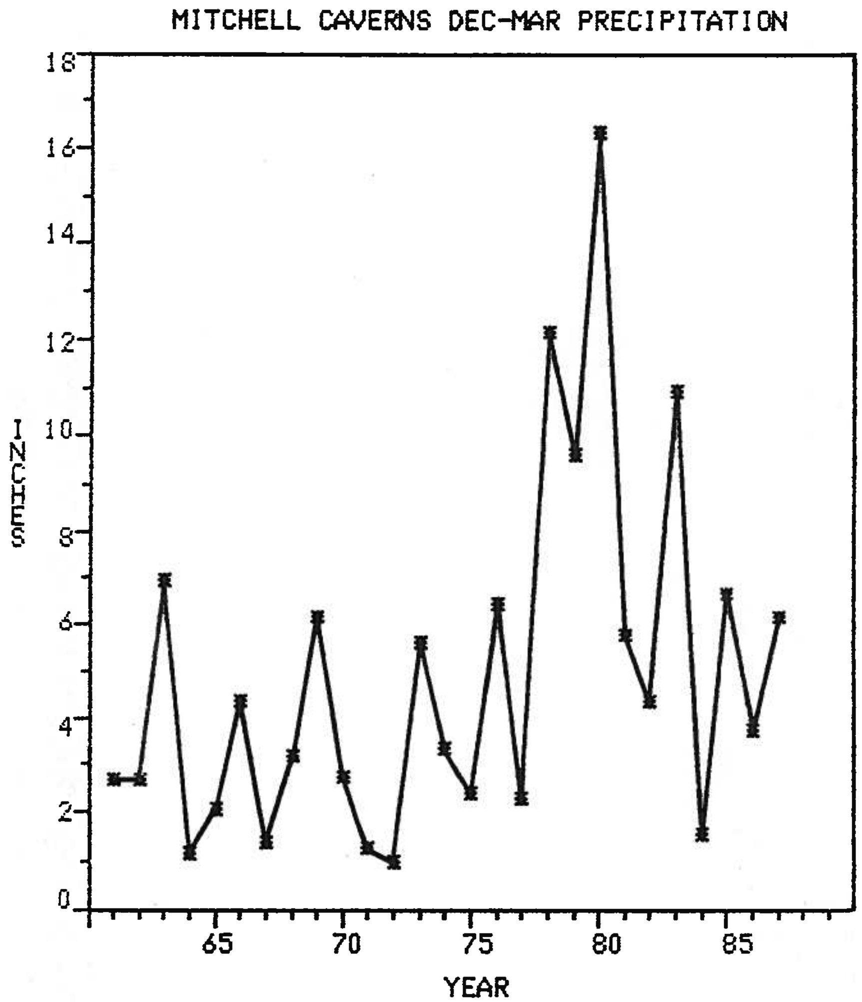
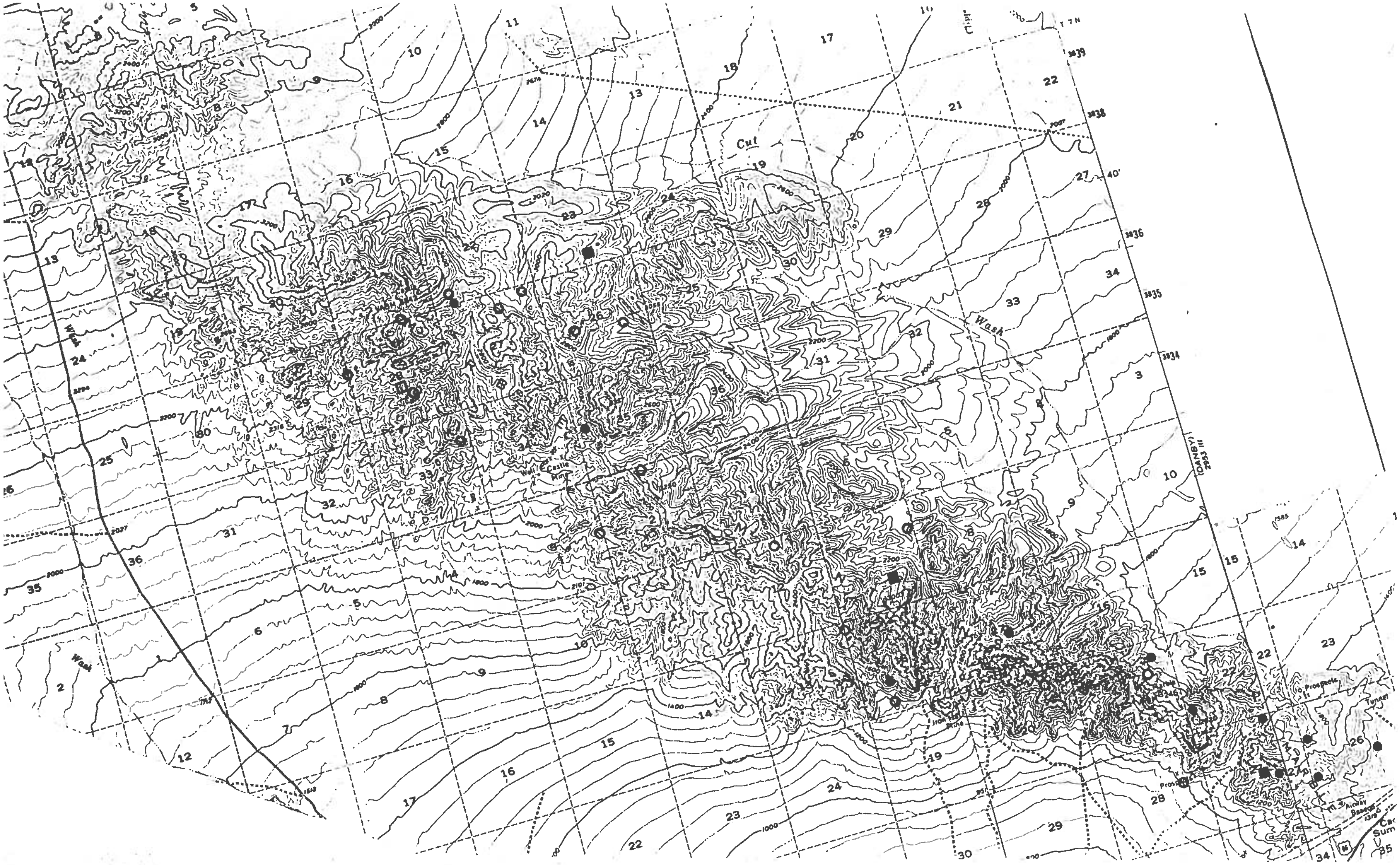


FIGURE 6. December-March precipitation for Mitchell Caverns at the south end of the Providence Mountains, California, 1961-87.

FIGURES 7-11. Location maps for the five telemetered ewes in the Marble Mountains (frequencies .315, .295, .305, .265, and .275, respectively). Open symbols are for the hot season (May-October), and closed symbols for the cool season (November-April). Circular symbols are locations from fixed-wing aerial flights based on point of strongest signal. Square symbols are direct observations from ground or helicopter.


Wash
Cnl
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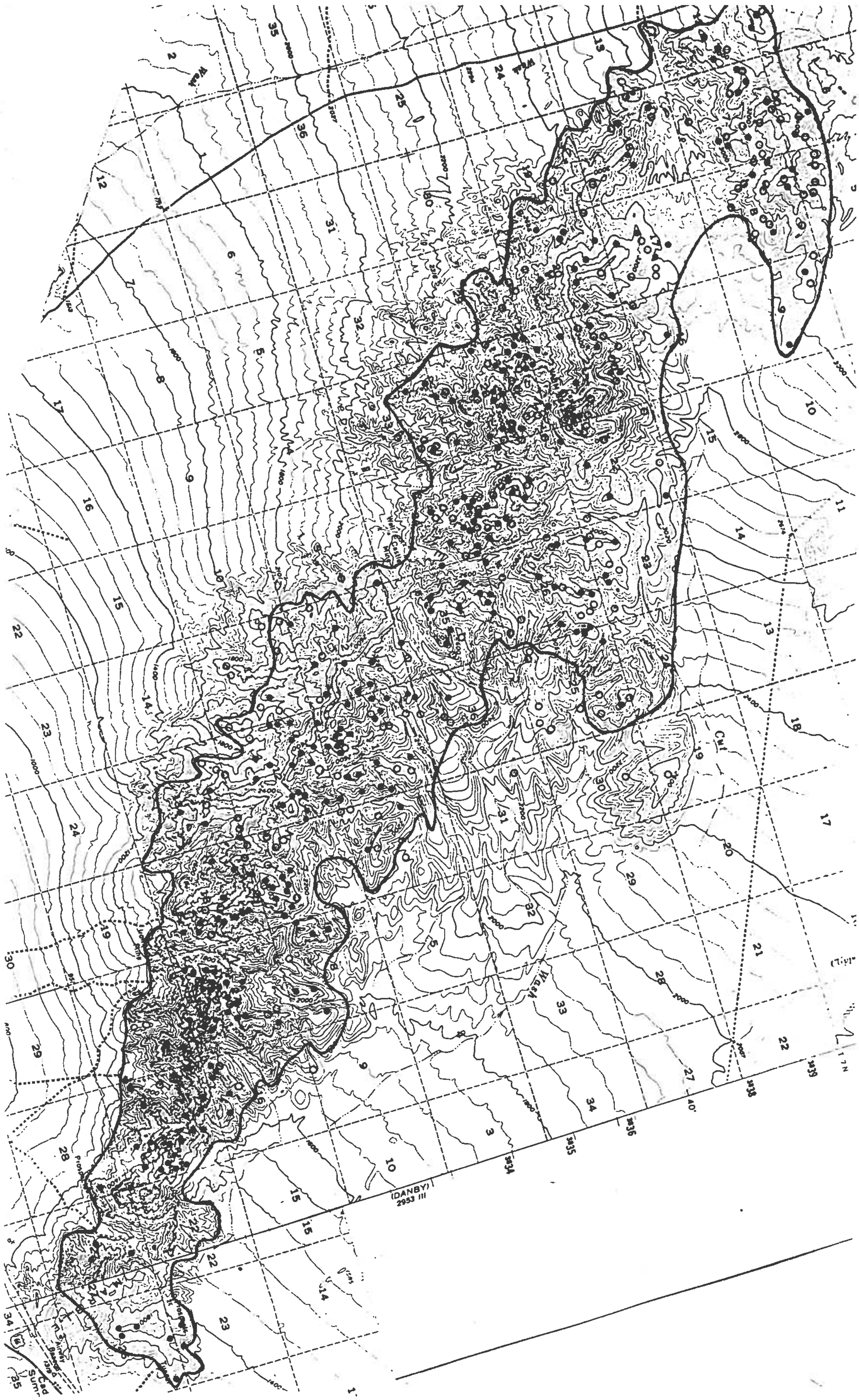
2953 III
Prospects
Tunnel

FIGURE 12. Locations of mountain sheep groups directly observed in the Marble Mountains and the range boundary for ewes. Closed circles are groups containing ewes. Open circles are groups containing only rams.



(DANBY)
2953 III

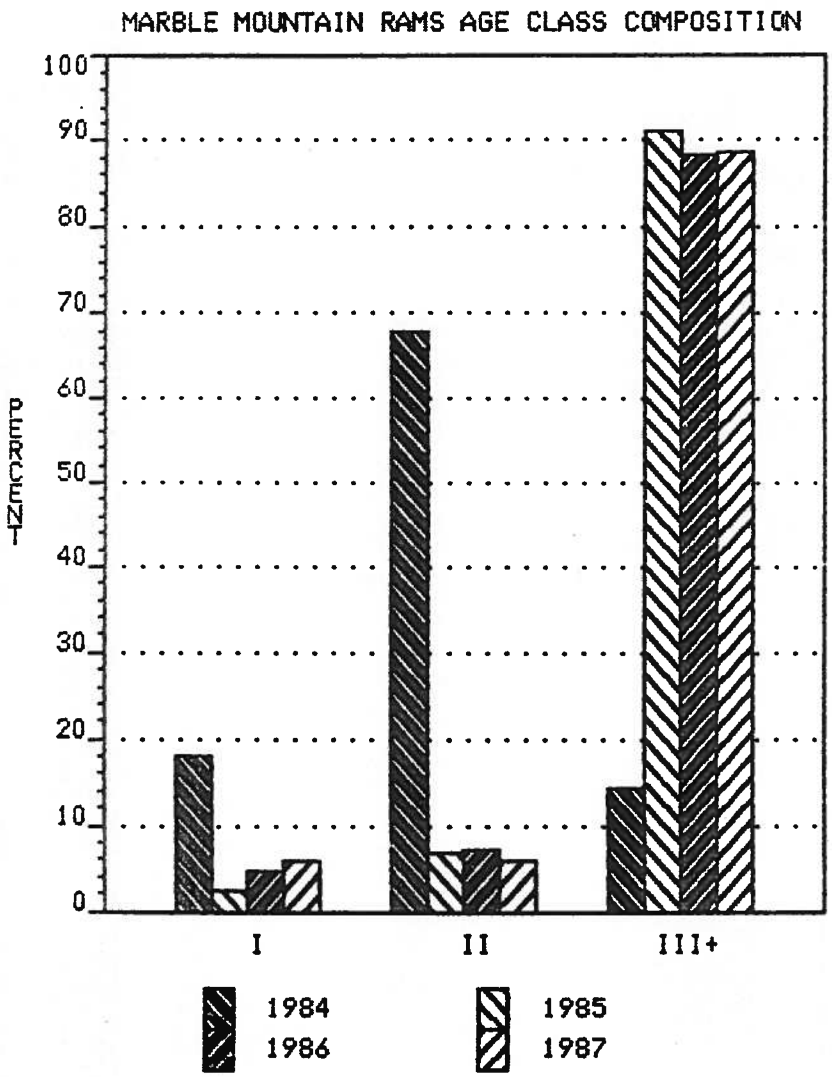


FIGURE 13. Age class composition of rams observed in the Marble Mountains, 1984-87. Sample sizes are 28 in 1984, 45 in 1985, 344 in 1986, and 106 in 1987.

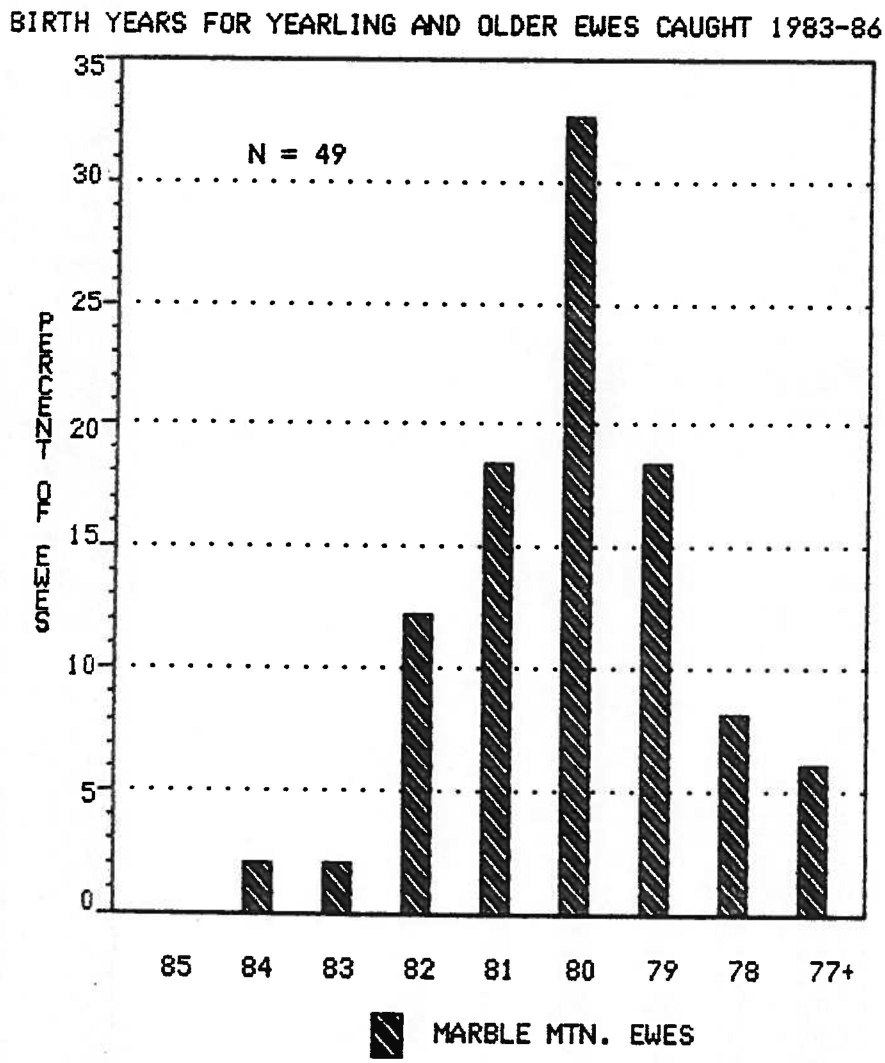


FIGURE 14. Distribution of birth years of yearling and older ewes aged during capture operations in the Marble Mountains, 1983-86.

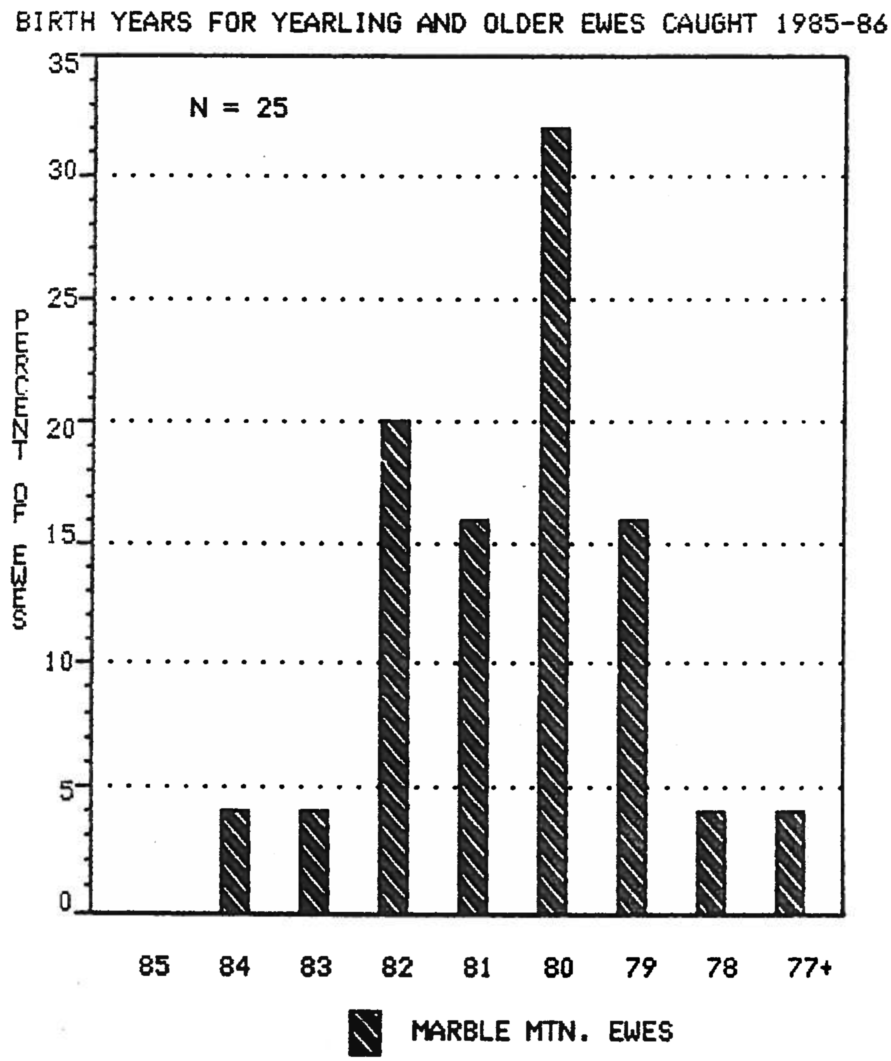


FIGURE 15. Distribution of birth years of yearling and olderewes aged during capture operations in the Marble Mountains, 1985-86.

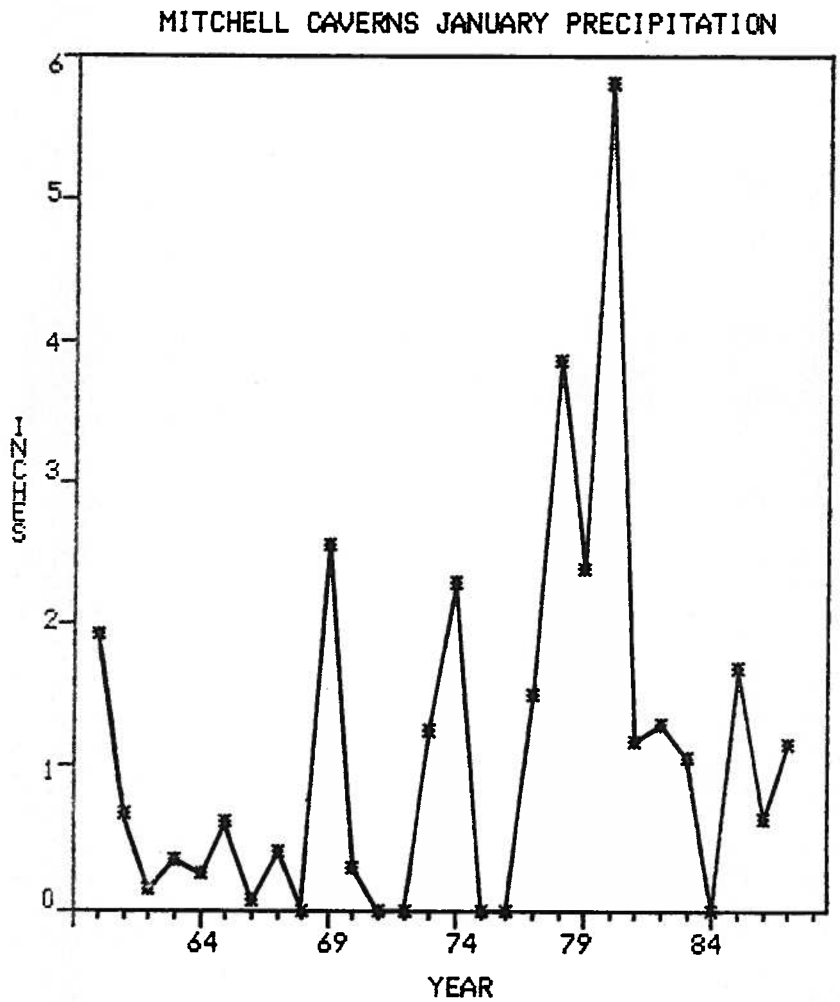


FIGURE 16. January precipitation for Mitchell Caverns at the south end of the Providence Mountains, California, 1960-87.

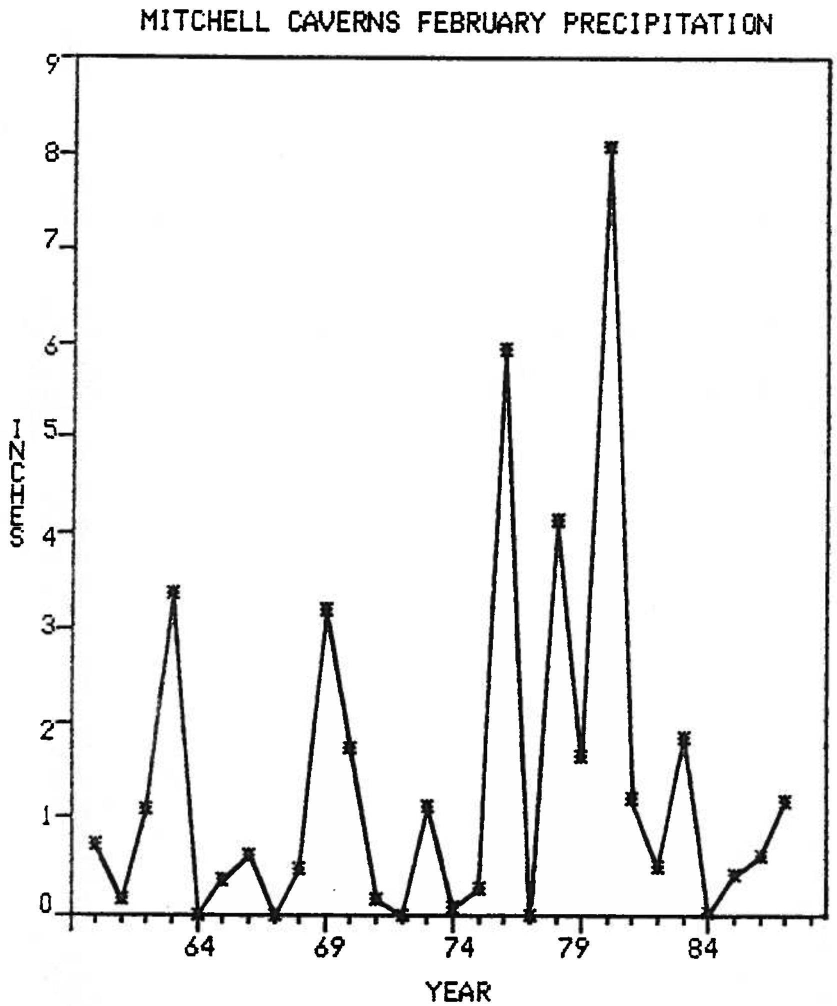


FIGURE 17. February precipitation for Mitchell Caverns at the south end of the Providence Mountains, California, 1960-87.

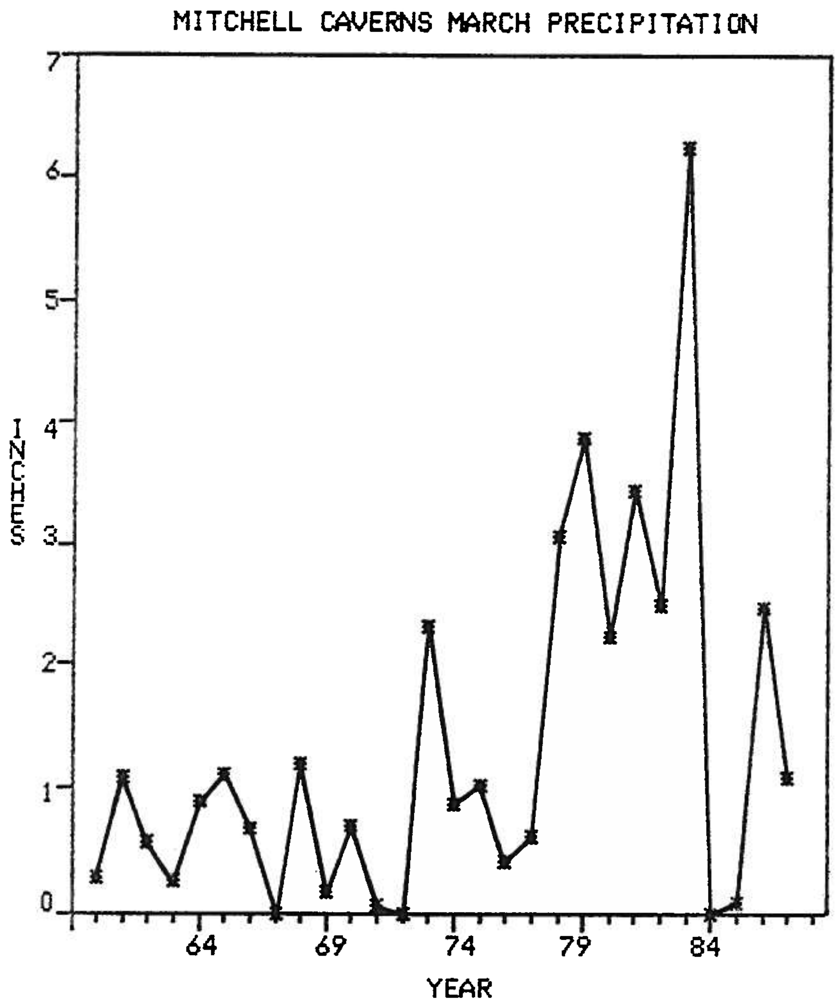


FIGURE 18. March precipitation for Mitchell Caverns at the south end of the Providence Mountains, California, 1960-87.

FIGURES 19. Sheep group locations and the range boundary for ewes in the Old Woman Mountains. Closed circles are for observed groups containing ewes, and open circles are for observed groups containing only rams. Triangles are aerial locations for two radioed ewes from fixed-wing flights based on point of strongest signal. Squares are similar fixed-wing locations for a single 3-4 year old ram.