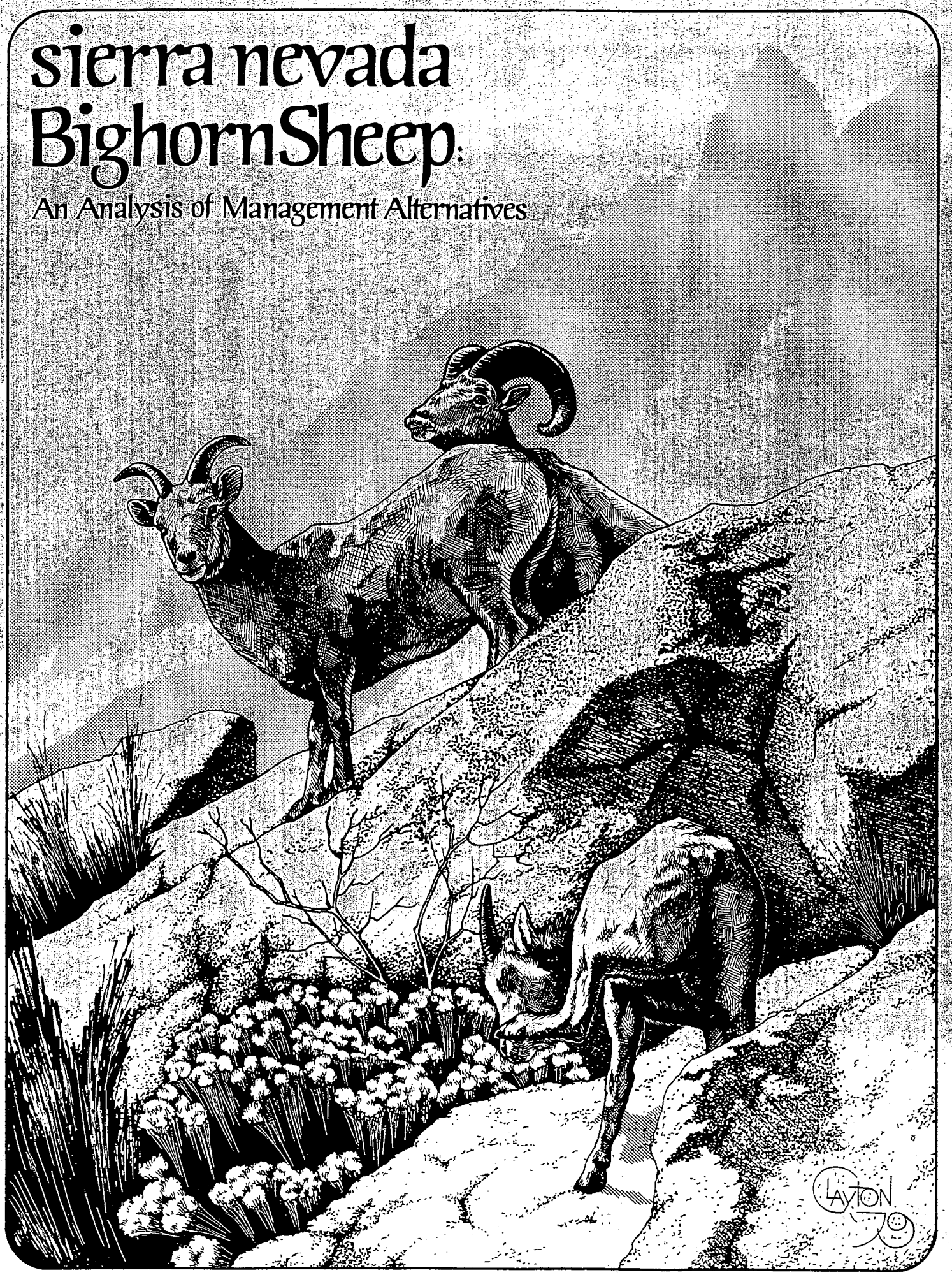
sierra nevada Bighorn Sheep:

An Analysis of Management Alternatives



SIERRA NEVADA BIGHORN SHEEP:
AN ANALYSIS OF MANAGEMENT ALTERNATIVES

Prepared by

John D. Wehausen

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ABSTRACT

Bighorn sheep were studied in the Sierra Nevada for 3½ years from 1975 through 1978. Only two viable bighorn herds remain in the Sierra Nevada. The Mount Williamson herd numbered about 30 in 1978. Its population trend is not known, but is probably close to static. The Mount Baxter herd numbered about 220 in 1978. It has been increasing in size for much of this decade. There is no indication that diseases presently play a significant role in the dynamics of either herd; lungworm infection is much greater in the Williamson herd than in the Baxter herd, but neither level is of clinical significance. Mule deer and tule elk were not found to be forage competitors with bighorn at present population levels. The significance of predation could not be assessed. It is possible that mountain lion predation is of some significance to the Williamson herd, but is unlikely to affect the Baxter herd much due to its large size. Human disturbance was not found to have an adverse effect on the Baxter herd at present use levels. The Williamson herd exhibits greater wariness than the Baxter herd, thus is more readily disturbed. Reductions in its summer range since the 1940's coincide with corridors of increased human use, suggesting a causal relationship.

It is suggested that management objectives give first priority to assuring perpetuation of the two existing herds; second priority should be the expansion of bighorn range in the Sierra Nevada. Potential management actions considered are 1) no change in present management, 2) control of competitors, 3) habitat manipulation, 4) management for lungworms, 5) control of predators, 6) reintroduction, 7) control of human use, 8) possible classification under the 1973 Endangered Species Act, and 9) possible administrative action relative to mining.

Limitations on human use, reintroduction, and habitat manipulation are the management actions most likely to have significant effects on the bighorn herds. Continued limitations on human access to bighorn ranges, especially of the Williamson herd, is considered important insurance of the future of these herds. Reduction in the cover of pinyon pine on wintering areas of the Williamson herd is expected to improve that range as bighorn habitat. It is suggested that this be undertaken on a small scale experimental basis first.

Since natural colonization of new ranges is rare in bighorn sheep, extablishment of additional herds through reintroduction is necessary if expansion of bighorn range in the Sierra Nevada is desired. A discussion of historic bighorn distribution in the Sierra and potential reintroduction sites is included. The Baxter herd is presently capable of serving as stock for reintroduction. Its population status may change. Thus, careful monitoring of this herd should be an integral aspect of reintroduction programs. The Williamson herd should also be monitored until its population trend is clear. Additional information needs are outlined.

INTRODUCTION

This report is the first of two emanating from a 3½ year field study of bighorn sheep in the Sierra Nevada supported cooperatively by the National Park Service and the U. S. Forest Service. The second will be concerned only with scientific aspects of the study. Because this second report remains unwritten at the writing of the present one, it has been necessary to include a considerable body of background information. In order not to encumber the reader, this has been placed in the second half to serve as reference for those interested. The information contained therein is summarized below.

The impetus for intensive study of bighorn is the Sierra Nevada was the apparent disappearance during the third quarter of this century of three of the five herds reputed to have existed in 1950. Human disturbance was implicated in these losses and was suggested to be having an adverse influence on the remaining two herds. Other questions, notably the role of lungworm infection and forage competition from the introduced population of tule elk in Owens Valley were also of concern.

Numerous subjects have been investigated in this study. Formost has been the collection of data on distribution, abundance, and population trends of the sheep. This has entailed intensive work on the two known herds (Baxter and Williamson) as well as extensive work investigating the existence of possible remnant herds in the Sierra Nevada. Coupled with this latter aspect has been an analysis of areas as to their suitability for bighorn reintroduction.

Second has been the investigation of factors likely to influence population parameters. Since it was evident early in the study that the Baxter and Williamson herds differed considerably in their demography, this has taken the form of a comparative study of these two herds in which the following subjects have been investigated: 1) habitat composition, availability, and use, 2) food habits, 3) nutrition, 4) forage utilization and competition, 5) internal parasites, and 6) human disturbance.

This broad-scale approach of investigating the influence of numerous factors on the sheep has been necessary due to a general paucity of adequate information on all aspects of these sheep. As such, this may be viewed largely as a baseline study, against which future information can be compared to detect change, and on which more focused studies may be based. This view is important in that long-term changes necessarily cannot be investigated in a short-term study as this. Conslusions and concerns arising from short-term studies are likely to appear naive when viewed from a long-term perspective; long-term population studies of bighorn are largely lacking.

Field work for this study was carried out by the author continuously from May 1975 to October 1978, in addition to a preliminary study in the summer of 1974. During the summer of 1976, three additional sub-studies were carried out under the supervision of the author, each resulting in a masters's thesis. Two of these (Hicks 1977 and Elder 1977) were concerned with human interactions with the Baxter herd, and the other (Garcia 1979) dealt with habitat selection and range of summer use of the Williamson herd. Numerous other people have

participated in this study as assistants, in some cases taking much responsibility for areas of the research to which I could devote little time. These people have worked variously as volunteers and as paid employees, although none received a decent wage for the work contributed. They are, chronologically, Ben Fisher, Beth Gordon, Scott Stine, Howard Quigley, Henry Elliott, Dan Asay, Steve Sherwood, Tom Andrews, Frances Masland, Susan Baxter, Bill LeDain, Mary Burke, Kane Brightman, and Larry White. Everett Towle and Dave Garber of the U. S. Forest Service, Dave Parsons, Maurice Zardus, Jan Van Wagtendonk, and Dick Riegelhuth of the National Park Service, and Dale McCullough of the University of Michigan have all been instrumental in the study.

I. MANAGEMENT CONSIDERATIONS

HISTORICAL PERSPECTIVE

Prior to the appearance of white man in the Sierra Nevada, bighorn sheep are known to have been distributed from the Jawbone Canyon area in the south to the Sonara Pass area in the north (Jones 1950). Additionally, a substantial population existed in the Truckee River drainage north of Lake Tahoe (Buechner 1960). The distribution from Sonora Pass south was probably discontinuous. Herds would have existed only in those locations providing adequate winter range. As a general rule, winter ranges were found east of the Sierran crest, while summer ranges were located along the crest. The notable exception to this is the area from Kaweah Peaks to Maggie Mountain on the west side of the southern Sierra Nevada. This area apparently provided both summer and winter ranges west of the crest, and supported a substantial population of sheep (Jones 1950). Winter ranges for this population were probably in the Kern River drainage.

Locations of historic east-side winter ranges are not always obvious. In Owens Valley, it is clear from the example of the presently-existing herds that winter ranges were at the base of the escarpment where adequate rocky terrain and vegetation existed. The escarpment base north of Owens Valley is generally about three thousand feet higher, and the substantially higher snow accumulation in this area due to increased elevation and more severe weather patterns has been found to make the escarpment base poor bighorn winter range. It is probable that bighorn in this area wintered in adequate terrain east of the Sierra Nevada proper, such as the Owens River and/or Rock Creek Gorge, the Glass Mountains, Mono Craters, Bodie Hills, Walker River Gorge, and the Sweetwater Mountains. A few bits of evidence exist to support this contention. First, Muir (1894, pg. 306) writes of bighorn in the Sierra:

> "When the winter storms set in, loading their highland pastures with snow, then, like the birds, they gather and go to lower climates, usually descending the eastern flank of the range to the rough, volcanic table-lands and treeless ranges of the Great Basin adjacent to the Sierra."

Second, H. A. Carr of the Museum of Vertebrate Zoology at Berkeley quoted local inhabitants as saying in 1911 that the sheep in the Sierra west of Independence did not leave the escarpment and cross Owens Valley, whereas those north of Owens Valley around McGee Creek (Convict Creek herd) did (Jones 1950). About 1960, Jim Clark of Bishop sighted a ram in the Owens River Gorge, and about 1962, Pat Chesebro of Tom's Place observed a ram along Rock Creek Road, as well as one crossing Highway 395 about a mile north of Tom's Place (D. R. McCullough, field notes 1965). In 1955 a ewe and a ram were observed in winter at the west end of Mono Lake leaving the Sierra and heading toward the Bodie Hills (Forest Service files, Bishop). Other pertinent sightings are a ram and two ewes along Hot Creek in 1953 (Dept. of Fish and Game files, Bishop) and two rams in Rock Creek by Highway 395 in 1943 (Jones 1949).

Lastly, the Sweetwater Mountains north of Bridgeport, where Sierra bighorn from that northern area may have wintered, were known to have

bighorn use prior to the turn of the century (Jones 1950).

Extirpation of bighorn herds in the Sierra Nevada began with the influx of gold miners. By 1880, much extirpation of big game in California had already occurred. Bighorn sheep were given full protection in California by the State Legislature in 1873, which suggests that noticable population changes were known to have occurred by then. Protection of bighorn probably received little effective enforcement until well into the twentieth century.

The first herds to disappear were undoubtedly small localized groups shot for meat on vulnerable winter ranges. The greatest toll on the bighorn probably came with the enormous numbers of livestock, mostly domestic sheep, grazed in the Sierra Nevada late last century and early this century. Domestic sheep devastated bighorn feeding areas through severe overgrazing and spread diseases, notably scabies, to the bighorn population. Also, the livestock operators shot bighorn, as they were considered as competitors with their domestic stock (Jones 1950).

One outbreak of scabies in bighorn is recorded for the Kaweah Peaks area in the 1970's. The population there was so reduced by the epidemic that the few remaining sheep could not survive (Jones 1950). Undoubtedly, other such epidemics have gone unrecorded. This disease has devastated numerous bighorn herds in North America (Buechner 1960).

Disappearance of bighorn herds from the Sierra Nevada spanned a long period, extending well into this century. Grinnell and Storer (1924) felt that bighorn in the Yosemite area had not persisted past the early 1880's, but in 1898 Muir wrote that a few still remained at that time. The latest known records of that period were reports of sheep between Tuolomne Meadows and Matterhorn Peak received by Game Warden Guy Scott in 1914 (Jones 1950). North of Yosemite, in the Sonora Pass region, Manly (1916) believed bighorn had disappeared only a few years prior to 1916. Likewise, the population west of the Sierran crest across the Kern River drainage was believed to have persisted until about 1918 (Jones 1950). Some additional herds, notably the Mount Langley, Taboose Creek, Mount Tom, Pine Creek, and Convict Creek herds apparently disappeared later in the twentieth century.

Of interest regarding most of these herd extirpations is the long period between the time the bulk of a herd disappeared and the time when the last survivors were gone. A good example is the population from the Kern River drainage that suffered a die-off due to scabies in the 1870's; forty years later the last stragglers disappeared. A couple of hypotheses might explain this phenomenon. First, the severe reduction in herd size may have led to progressive inbreeding depression and possibly eventual sterility. Secondly, those that survived the initial decimination may have done so only because they took on different habits, thereby avoiding the cause of decimation. Such changed habits would most likely place the sheep under marginal conditions not particularly favorable to reproduction. Such a group would probably remain small in size, and a series of harsh years could easily spell its end. A good example of changed habits might have been the cessation of migration to winter

ranges east of the Sierra by northern herds, leaving them to winter in deep snow of the Sierra Nevada. The only specific sighting of bighorn in winter in the Yosemite area mentioned by Muir (1894) was such a band snowbound in Bloody Canyon about 1890. It is noteworthy that the three herds believed to have disappeared during the third quarter of this century were all remnant herds of this sort when Jones (1950) identified them, and had apparently already been in this state for many years at that time.

HISTORY OF BIGHORN MANAGEMENT POLICIES

The first management policy affecting bighorn in the Sierra Nevada was the 1873 State Legislature Act giving full protection to all bighorn in California. That this law received relatively little enforcement until well into this century is indicated in the comments by Dixon (1936) Some enforcement did occur, though, as a man was arrested in 1932 for shooting a bighorn in the Alabama Hills in Owens Valley (1932 Inyo National Forest Fish and Game Report) and one was arrested in 1911 by State Fish and Game Warden Ober, for shooting a ram in the Convict Creek herd (Ober 1911).

Domestic stock grazing apparently received minimal management in the early part of the twentieth century, and with no concern for the bighorn until the 1930's, when the Forest Service began cutting permits for domestic sheep from known bighorn ranges (Dixon 1936). By 1947, grazing had been reduced to the levels in Table 1, and by 1950, they had been further reduced an additional 40% of that level (Jones 1950). Jones (1950) points out that the majority of grazing in bighorn areas at that time occurred west of the crest in the Langley area (Table 1) on lower meadows that were not part of the bighorn range. He further notes that "portions of the bighorn range that supports the majority of the sheep population - the ranges of the Baxter and Williamson herds- have been subject to little domestic stock grazing in recent years" (Jones 1950, p. 71). The last domestic sheep grazing allotment adjacent to Sierra bighorn ranges on Inyo National Forest ended in 1961; domestic sheep grazing had been light for quite a few years previous (McCullough and Schneegas 1966). At the end of 1965, domestic cattle grazing in and adjacent to the Baxter herd winter range was eliminated, while moderate cattle grazing at the base of the Williamson herd winter range continued (McCullough and Schneegas 1966). Low levels of cattle grazing currently exist at the base of the Williamson winter range, but appear not to overlap areas of bighorn use. Pack stock use continues at low levels on trails traversing the bighorn ranges.

Dixon's (1936) concern for the future of bighorn in the Sierra Nevada led to a proposal in 1940 to establish a sanctuary for the Baxter herd on the portion of its range lying on Forest Service lands east of the National Park Boundary. Figure 1 is a map of the proposed sanctuary. A meeting on the subject was held in 1941 involving the Sierra Club, National Park Service, California Department of Fish and Game, National Forest Service, and the Fish and Wildlife Service. The proposal was turned down because of opposition from the Forest Service and the

Table 1 - Livestock grazing use on Sierra Nevada bighorn ranges in 1947 (Table 10 from Jones 1950).

Herd range	Cattle and horses	Sheep and goats	Season
Convict Creek	0	0	
Birch Mt.	0	1,800	June
	400		Summer
Baxter		1,200	April 15 - May 31
		810	Spring, Summer, Fall
Williamson	0	0	
Langley, east of crest	250	150	Spring
west of crest	9,515	0	Summer

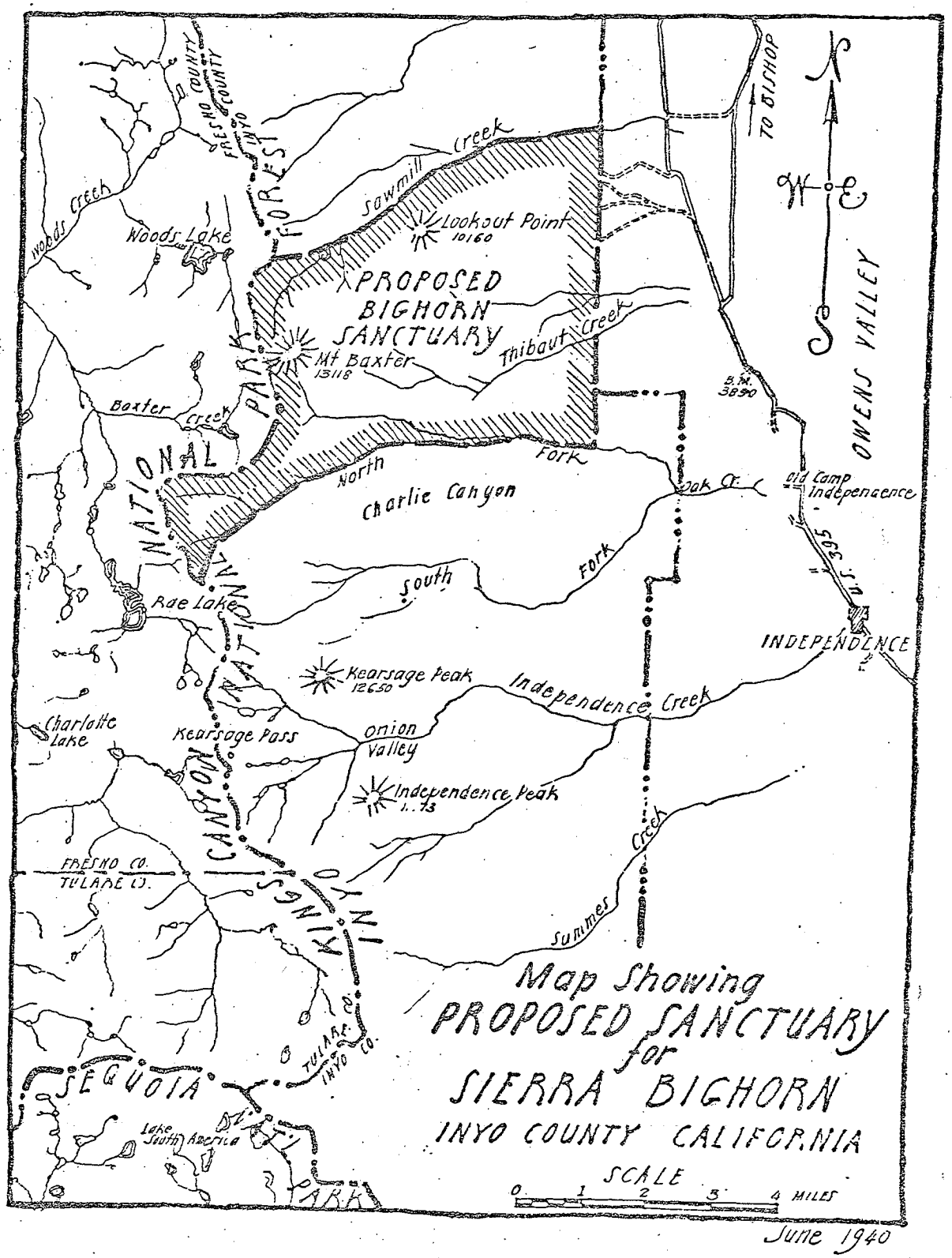

Figure 1 - Map of bighorn sanctuary proposed in 1940 (from Inyo National Forest files)

California Department of Fish and Game on the grounds that 1) more information in the form of a comprehensive study was needed, 2) it was not believed that existing policies were having an adverse effect on the bighorn, 3) it was unclear that a sanctuary would decrease poaching, and 4) the publicity it would create might attract further poaching (April 28, 1941 letter, U. S. Forest Service files, San Francisco; Blake 1940)

A sanctuary was established in 1971 as a result of Dunaway's (1971b) hypothesis on human disturbance. Approximately 41,000 acres of Forest Service land in the ranges of the Baxter and Williamson herds were set aside as The California Bighorn Zoological Area. This classification gave top priority to the requirements of these bighorn through protection and maintenance of their habitat. It also regulated human use in certain sections of their range to minimize disturbance (Dunaway 1971a). A fence was installed along the Forest Service boundary below the winter range of the Baxter herd as insurance against livestock trespass from adjacent range. Maps of the zoological areas are presented in Figures 2 and 3, and the initial regulations were as follows:

1. Permits for entrance will not exceed 25 people per day (per trail).

2. There is no limit on party size except that it meet the requirements for the John Muir Wilderness.

3. Travel and camping will be restricted seasonally according to the maps. (Figures 2 and 3).

4. There will be no new trail construction and trail maintenance will be minimal, however, should be sufficient to permit foot traffic. Livestock use will be terminated when trails become unservicable. Use of chainsaws, blasting, or other disturbing activities should be planned in a manner to minimize effects on bighorn.

5. Firearms will not be discharged in the zoological area and their transportation into the area should be discouraged.

6. Recreation livestock may layover in unrestricted areas but must neither range nor graze.

7. No recreation motor vehicles will be permitted in the zoological area.

8. Recreational developments will not be constructed near the exterior boundaries of the zoological area, including trailhead facilities on Sawmill, Baxter, and Shepherd Pass trails.

9. Wildfire within the area will be controlled utilizing procedures for the John Muir Wilderness.

10. Entrance to restricted areas either for administrative use or special studies will be approved on a case-by-case basis.

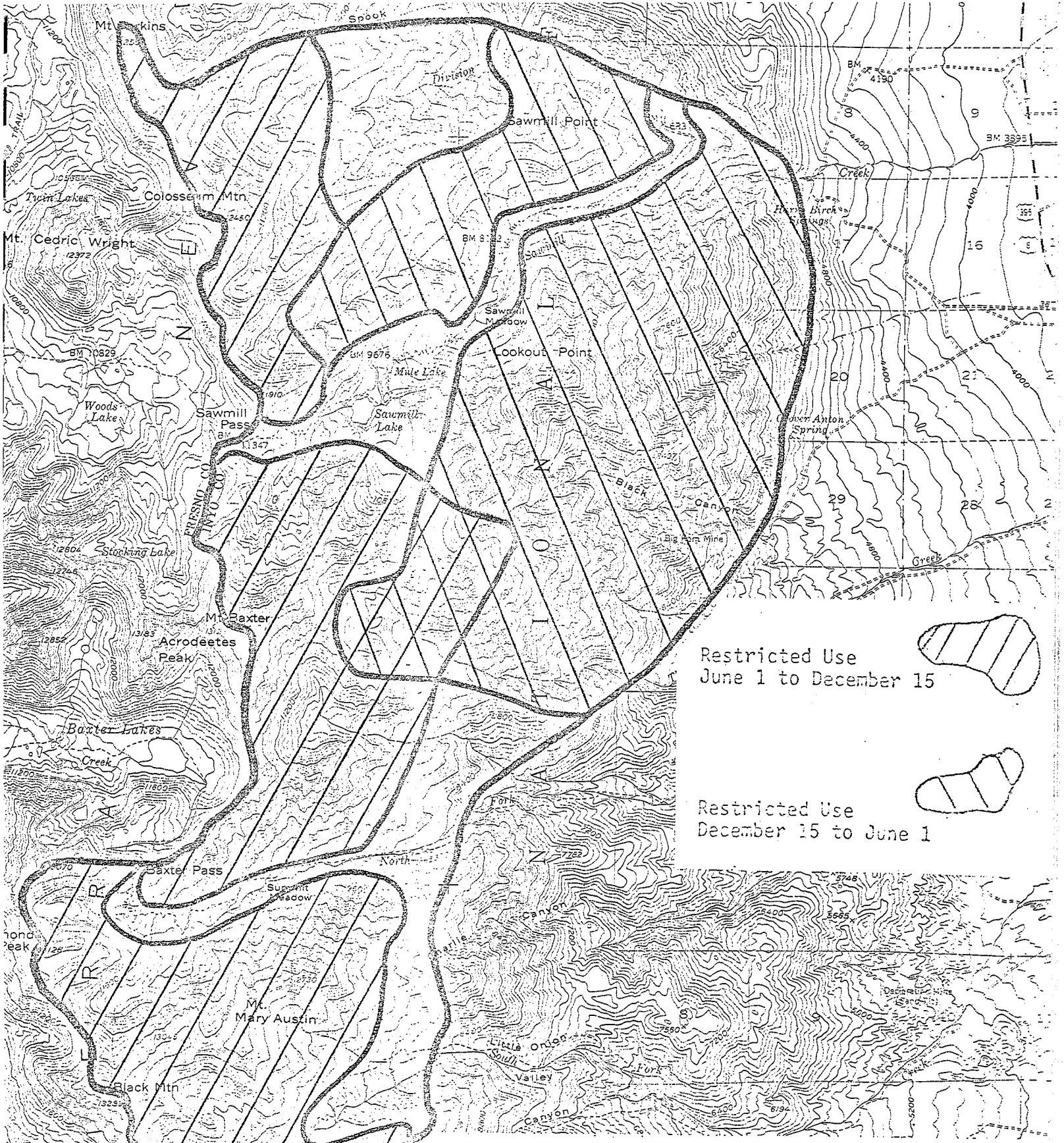

Figure 2 - Inyo National Forest California Bighorn Sheep Zoological Area boundaries - Mount Baxter unit.

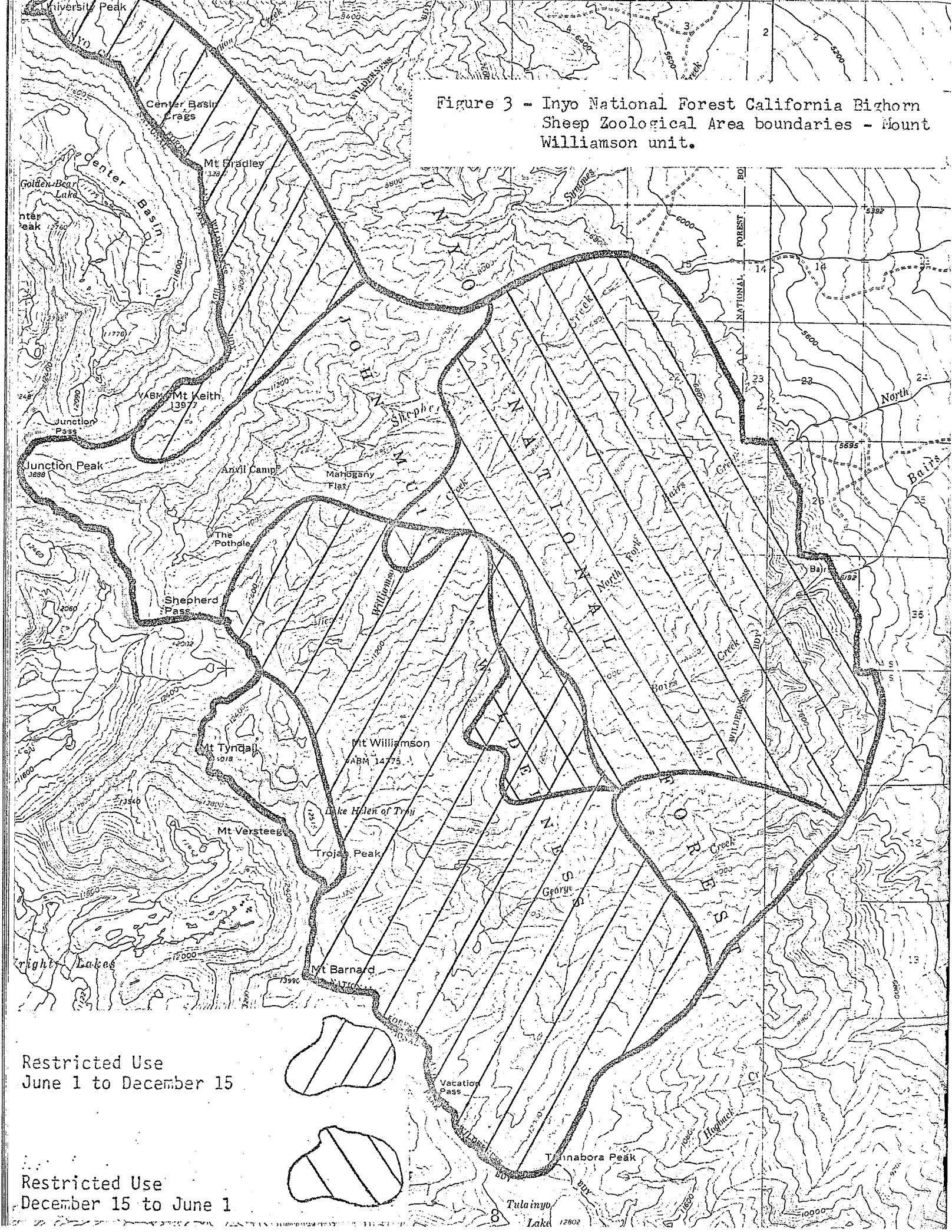

Figure 3 - Inyo National Forest California Bighorn Sheep Zoological Area boundaries - Mount Williamson unit.

In addition, adjacent bighorn summer range west of the crest on Park Service land was designated Class IV by the National Park Service (Dunaway 1971a). This restrictive classification prohibits the existence of man-made facilities, which resulted in the cessation of trail maintenance. However, it did not restrict off-trail human use.

In late 1976, as a result of initial findings on human disturbance, the Zoological Area regulations were relaxed somewhat. Off-trail hiking became permissible below 10,000 feet in summer, and the discharge of firearms was allowed due to indication that there was little or no bighorn use below 10,000 feet during deer hunting season; no enforcement of the previous firearm regulation had been in effect. Sawmill Meadow was also opened to grazing by packstock since this meadow did not and was not expected to receive bighorn use.

In 1977, the Park Service regulations for Baxter herd bighorn ranges west of the crest became more stringent. Off-trail hiking was terminated east of the Rae Lakes drainage, and a one night camping limit was established for the Baxter Lakes Basin. These changes effectively placed summer range regulations on an approximately equal level with those on Forest Service land east of the crest.

In winter of 1978, a trapping program was initiated in the winter range of the Baxter herd with the intention of moving sheep to historic range. This effort was unsuccessful in 1978, but resulted in the relocation of nine sheep to the Wheeler Crest area in early March of 1979 as the first draft of this report was completed. This report treats existing management as those practices in effect prior to the recent transplant program.

SUMMARY OF PRESENT BIGHORN STATUS

Despite considerable effort to find evidence of the existence of suspected remnant herds in the Sierra Nevada, particularly in the Yosemite region, none has been found; only the Baxter and Williamson herds are clearly known to exist.

Both herds exhibit the following general yearly patterns: 1) spring migration up the east side of the range coincident with vegetation greenup, 2) lambing in late April and May at a variety of elevations in this migration depending on area, 3) ewe-lamb group summer use along the crest and ram use largely west of the crest, 4) fall use by both sexes along and east of the crest, and 5) winter use by both sexes along the eastern base of the escarpment following the first major snow storm. Maps of these ranges are found in the second half of this report.

The most complete census results come from the winter of 1978, at which time the Baxter herd numbered about 220, while the Williamson herd numbered 30. The Baxter herd has reached its relatively large size through population increase over the course or most of this decade. This trend was abruptly terminated (or interupted) by a large drop in reproduction in 1978. Reproduction that year was at a level that would only approximately maintain the herd size. Precise knowledge of recent trends in the size of the Williamson herd are not known, but data on rates of reproduction and recruitment during this study suggest that it has not been far from static.

Fecal analysis of levels of parasitism of the Baxter and Williamson herds indicate only three internal parasite species inhabiting these sheep. While the Williamson herd exhibits a substantially higher level of lungworm infection than the Baxter herd, neither of these levels was judged to be clinically significant when compared with values reported from bighorn in the Rocky Mountains. Likewise, levels of thread-necked worm infection were considered insignificant. These findings are consistent with the lack of any clinical signs of disease observed in the field.

Tule elk feed on part of the Baxter herd winter range in spring and early summer, consuming the same seasonal forage growth that the bighorn feed on the following winter. The possibility of resource competition between these two species was investigated by making total utilization measurements on desert needlegrass (Stipa speciosa) and bitterbrush (Purshia glandulosa). These measurements indicated that neither of these species was in short supply in the areas of elk use. Thus, no competition existed under the population levels and weather regimes occurring during this study.

The disturbance of bighorn in the Sierra Nevada by humans was studied by quantifying their reactions to the investigator and by testing hypotheses regarding the significance of this disturbance. Ewe-lamb groups in summer were found to be the most disturbed by human presence. Hikers and ewe-lamb groups in the Baxter herd come into most contact on Baxter Pass. Interactions there indicated that no permanent displacement was occurring. The increase of the Baxter herd this decade suggests that human disturbance has not recently been a significant factor for that herd. The

Williamson herd ewe-lamb groups show more extreme reactions to humans in summer. Portions of their summer range known to receive high use in the 1940's are no longer used. These areas are separated from the central summer range by corridors that have received a large increase in human use in recent decades. It is likely that this human use is a cause of these range losses.

Predators of any significance to bighorn in the Sierra Nevada are coyotes and mountain lions. No evidence of successful coyote predation has been encountered. The vulnerability of lambs to coyote predation in summer is believed to account for the summer habitat separation between sexes, in which ewe-lamb groups occupy the high, safer terrain. Sign of mountain lion occupation has been found only in the winter-spring ranges, where it is abundant. Evidence of lion predation on bighorn has been found in both herds. Its significance is most likely low in the Baxter herd due to the large size of that herd. The small size of the Williamson herd makes this a potentially more significant factor; no assessment of significance can be made due to lack of data on frequency of kills.

MANAGEMENT ALTERNATIVES

Bighorn Management: Principles and Practices

Bighorn sheep are creatures of open areas that use sight as their main sense to detect predators and precipitous rocks to escape them. Two aspects of their biology related to these facts lead the list in terms of importance to their management. First, the requirements of good visibility and rockiness make bighorn habitat very patchy in distribution; most areas between suitable patches are sufficiently unsuitable as to serve as barriers to bighorn movement. Second, locations of suitable patches and routes between them (that sometime cross natural barriers) appear to be learned by younger sheep by following adults (Geist 1967, 1971). Traditional areas of use result from this behavior and dispersal across unsuitable terrain to new areas is apparently an extremely rare event.

Two important management implications result from the biology of North American wild sheep. First, it is necessary for man to move sheep to new areas if extention of their range is desired in the near future. Second, once a sheep herd disappears, along with it go the traditional migration routes between favorable ranges, which in many cases cross what are otherwise barriers to their movement. Once such a herd and its seasonal patterns are lost, it will be, at best, very difficult to replace it (Geist 1975). Consequently, the unit of management of wild sheep must be the herd. With a large percentage of bighorn herds already extirpated in North America from the activities of modern man (Buechner 1960), all efforts should be made to retain the remaining native herds. The following discussion touches on various management practices that have been developed toward that end.

Buechner (1960) discussed various known die-offs of Rocky Mountain bighorn is which the lungworm-pneumonia complex was an important factor. Stelfox (1971) has shown that such die-offs in Rocky Mountain bighorn in Canada result in the loss of 75% or more of the sheep in the herds involved, and are part of a cycle of about a 25-year periodicity. These die-offs occur when the lungworm-pneumonia complex and/or severe winters take their toll on sheep with inadequate physiologic defenses due to poor nutrition. This poor nutrition results from ranges overgrazed by a large bighorn population (Stelfox 1971, 1976).

Unlike population crashes of Rocky Mountain bighorn, in which young and adults alike die (Stelfox 1971, Denny 1976), recent declines in some herds in Colorado have been attributed to very poor lamb survival, such that recruitment has not replaced adult mortality (Hibler et al 1976). This lamb mortality occurs in summer and is again due to a verminous pneumonia with lungworms as the predisposing factor for a secondary bacterial infection (Woodard at at 1974, Hibler at al 1976). What is most striking about this mortality is that it occurs during the least stressful season of the year, and results from lungworm infections of transplacental origin in the lambs (Hibler et al 1972, 1974, 1976).

Successful treatment has been developed for this problem by dosing sheep with a drug against lungworms placed in bait of fermented apple pulp. This treatment has increased lamb survival for 15% to 85% (Hibler at al 1976). It is recognized that this management practice treats the symptoms, but not the source, which is believed to be repeated use of summer bedding areas by ewe-lamb groups where the infection rates of the snail intermediate host of the lungworm become very high, and may persist for many years after the population declines, due to the longevity of lungworm larvae in fecal pellets (Hibler et al 1976, Morris 1976). Two management practices are being tried on the Pikes Peak herd in Colorado in an attempt to deal with the source of the lungworm problem. A small amount of hunting of ewes is hoped to disperse them from favored (infected) bedding areas. In addition, future trapping of sheep from this herd for transplant purposes will be used to keep the herd at about two-thirds the level at which the lungworm problem becomes serious (Morris 1976).

The role of fire and the problems of fire control in maintaining bighorn habitat have received considerable attention of late (Stelfox 1976, Trefethen 1975). Since open habitat is preferred by bighorn, succession in bighorn ranges that leads from open grass or low scrub cover to tall scrub and forest species will ultimately reduce the value of an area as bighorn habitat. Fire or artificial means of keeping the vegetation open may improve habitat for bighorn under such conditions. Controlled burning or a natural fire policy in bighorn ranges is thus an option to be considered in the management of bighorn herds.

Reduction or elimination of competition from other herbivores, native or non-native, has been a bighorn management tool used since early in the century, and continues to be important in some areas. Its most noteworthy application has involved domestic livestock.

Additional bighorn management practices include 1) control of human use where human disturbance is deemed significant, 2) control of major

predators where their effects threaten the persistence of a herd, usually as a result of small herd size, as with transplants or small remnant herds, 3) supplemental feeding, where a nutritional deficiency is clearly demonstrated, 4) purchase of critical habitat that is privately owned and threatened with development, 5) restrictions on development on public lands, such as mineral entry, and 6) development of water sources in desert bighorn habitat.

Much is yet to be understood regarding factors affecting bighorn herds. Some herds appear to have trouble maintaining their numbers and in many cases are declining without any clear cause. The possibility that some small herds decline due to inbreeding depression is a hypothesis that has yet to be investigated (Geist 1975). An increase in homozygosity might be caused by 1) small herd sized and loss of gene flow between herds, both resulting from activities of modern man, and 2) the further decrease in "effective population size" from the polygynous breeding system of bighorn. If evidence comes to light in the future indicating that inbreeding is a significant factor, a management practice of mixing sheep between nearby herds may come into use.

Potential Management Actions and their Projected Effects

The idea that the management practices necessary to fulfill any particular objectives can be precisely prescribed presupposes a complete understanding of cause and effect relationships regarding bighorn in the Sierra Nevada. It also requires tha ability to predict the future, including such parameters as weather. Lacking this ability, management must have a continuing input of information. Consequently, the projected results of potential management actions listed below will be discussed in the context of present knowledge about bighorn in the Sierra Nevada. Additional information required to better address specific points will be identified.

1) No change in the Present Management

Existing Forest Service and Park Service policies (outlined previously) are quite cautious, with a clear emphasis on the bighorn as first priority in the ranges of the Baxter and Williamson herds. These two herds have persisted through time despite previous management policies that gave little consideration to the bighorn. It would thus seem reasonable to predict the continued survival of these herds under the present management policies. While future survival seems likely in the case of the Baxter herd, due to its large range and population size and its lack of concern about man's presence, it is unclear whether the same holds for the Williamson herd. Since known adverse influences of human origin have been largely absent from the Baxter herd range for many years, one might expect an equilibrium situation for that population. Consequently, it is unclear why that herd has increased in size considerably during this decade. Likewise, it is unclear what course the herds will follow under existing management practices. While both may stabilize, it is also conceivable that cyclical fluctuations are the rule, with the two herds presently at different points in the cycle. Only long-term research will elucidate the patterns. Regardless of the

population patterns within the two herds, expansion of bighorn range in the Sierra Nevada is not to be expected without reintroduction attempts, due to the extreme rarity of natural colonization.

2) Control of Competitors

Since no resource competition has been found, there is no evidence that reduction in grazing by other species on bighorn ranges will be of any benefit to either bighorn herd. Increases in the elk and/or sheep populations or conditions during more severe winters may lead to competition between these two species on the Baxter herd winter range. Such circumstances may necessitate consideration of means to alleviate grazing by elk on the Black Canyon winter range.

Interference (spatial) competition caused merely by the presence of another species has not been apparent either. Deer and bighorn mix readily on winter ranges and the timing of the overlap of elk and bighorn on these ranges is slight; no change in patterns of bighorn use of the Sand Mountain area during spring elk use has been apparent. The rare sightings of elk higher in the mountains are believed insignificant due to their rarity and the low probability of habitat overlap between the species at these elevations. The reaction of bighorn to packstock is not known, but might affect bighorn use in the areas of Baxter Lake/Pass, Sawmill Pass, Woods Lake Basin, Rae Lakes, Onion Valley, and the mouth of Sawmill Canyon.

3) Habitat Manipulation

Three components make favorable bighorn habitat in the Sierra Nevada - rockiness, openness, and availability of desirable forage species; water is not a limiting factor in the Sierra as it is in adjacent desert ranges. Openness and composition of forage species are factors over which management can have some control.

Range manipulation to improve forage composition and productivity, and ultimately bighorn nutrition should take place on ranges limiting to the population in this regard in order to significantly affect population size. There is presently no indication that winter ranges are limiting to the Baxter or Williamson herds in terms of quantity of forage available. Sawmill Canyon is the only possible exception due to high utilization levels of desert needle grass. Nevertheless, there is no indication that these levels of utilization are limiting to the sheep wintering there. Of the sheep that remained on the Sawmill Canyon winter range through lambing in 1977, all ten mature ewes produced a lamb. Thus there is no indication that lamb production by ewes wintering in Sawmill Canyon has lagged behind production elsewhere in the Baxter herd.

Population size, through its influence on intraspecific competition, is undoubtedly the principle factor governing lamb production and survival. Abundance and quality of bighorn forage have both been found to be at a minimum on fall ranges in the Sierra. This is reflected in seasonal changes in fecal protein percent. Utilization levels of some preferred forage species have been found to be high on fall range. In addition to

the interaction of population size with fall range forage, yearly differences in the timing of phenological changes of fall vegetation may influence lamb production the following year. Yearly variation in early winter phenology of needlegrass on winter ranges may also have a significant effect on reproduction that spring or the following year. Both winter needlegrass and fall range phenology are influenced by rainfall and temperature, neither of which is amenable to manipulation.

Studies in the Canadian Rockies indicate that the best sheep habitat contains a mixture of browse, forbs, and graminoids (Stelfox 1976). Likewise, ideal winter range in the Sierra Nevada appears to contain a mixture of numerous scrub species with a considerable coverage of grass (desert needlegrass); forb species are uncommon during the winter months. The successional endpoint of this sagebrush scrub vegetation type appears to be a strong domination by blackbrush (Coleogyne ramosissima) (McCullough 1969), a species of minimal forage value (Jones 1954). Fire in this vegetation type eliminates blackbrush, and results in a rich mixture of desert needlegrass, California buckwheat (Eriogonum fasciculatum), desert bitterbrush (Purshia glandulosa), Mormon tea (Ephedra viridis and nevadensis), California lilac (Ceanothus greggii and cordulatus at higher elevation), desert peach (Prunus andersonii), and sagebrush (Artemisia tridentata), and rabbitbrush (Chrysothamnus teretifolius).

On escarpment base south-facing slopes, which are the preferred winter range slopes of the sheep, succession appears to end as an optimal mixture of the above species without the inclusion of blackbrush. Fires on such south-facing slopes do not appear to have much effect on the composition of the vegetation, and thus serve only to rejuvenate various brush species. It is not clear that any manipulation of this habitat will significantly improve it for bighorn in most cases, although fire in areas where brush species such as bitterbrush have passed maturity may be of some benefit in the future. No such senescent brush stands are presently apparent on the bighorn ranges.

Beginning at about 6,300 feet elevation, pinyon pine (Pinus monophylla) becomes a dominant member of the vegetation. The understory of the pinyon woodland is noticably lacking in forage species when compared with adjacent open sites. Also, the pines themselves greatly reduce the openness of the habitat. Fire in pinyon woodland opens up the habitat and increases coverage of forage species, thus greatly improving it as bighorn habitat. This is apparent in a small burn of recent origin in South Bairs Creek at about 9,000 feet, which now supports lush clumps of Indian ricegrass (Oryzopsis hymenoides), as well as Stipa coronata depauperata and a variety of other species used by bighorn as forage. This burned area was observed to be used in 1978 by ewes with new lambs that were strictly avoiding unburned pinyon woodland.

Canyons in the bighorn ranges are glaciated between the pinyon woodland zone and the alpine, resulting in steep sides and wide bottoms. Bighorn use is almost entirely on the side slopes. Fire in the brush and occasional small patches of forest on canyon bottoms will thus be of little significance to bighorn. Side slopes used by bighorn contain occasional sparse forests of varying mixtures of whitebark (Pinus albicaulus),

limber (P. flexilis), foxtail (P. balfouriana), and lodgepole pine (P. contorta ssp. murrayana), and brush patches of mountain mahogany (Cercocarpus ledifolius), currents (Ribes cereum, R. montigenum), cream bush (Holodiscus microhpyllus), manzanita (Arctostaphylus patula), chinquapin (Chrysolepsis sempervirens), sagebrush (Artemisia tridentata), lupine (Lupinus formosa), and rabbitbrush (Chrysothamnus viscidiflorus). While rams readily use forested areas, ewe-lamb groups enter them only if on steep slopes and sufficiently open. Fire in forested areas can be expected to benefit bighorn in many cases; it is unlikely that it will ever be of adverse value. Of the brush species listed above, cream bush, current (R. montigenum) and lupine are important forage species, and mountain mahogany is apparently occasionally eaten in spring. The response of all these brush species to fire is not known. In general, the brush patches that would carry fire well involve the non-palatable species. At worst, fire in this zone would burn a few localized stands of palatable brush, but would burn out at timberline, where these patches of importance occur.

There is no evidence that fire at these upper elevations would be of significant benefit to the bighorn other than opening up occasional forested patches. On the other hand, it is not likely that fire would be of significant detriment; a natural fire management policy would be a viable option. Controlled burning of patches of pinyon woodland in the Williamson herd range on an experimental basis should shed some light on fire as a management tool in that habitat. Optimally, this would occur in South Bairs Creek, although the entire area from Shepherds Creek to Georges Creek may benefit from fire as bighorn habitat.

4) Management for Lungworms

The periodic population crashes of bighorn herds in the Rocky Mountains in which lungworms play a key role (Stelfox 1976) have not been documented for other subspecies of bighorn in North America (Buechner 1960). It was Buechner's (1960) contention that ranges outside of the Rockies did not support sufficient densities of sheep or snail intermediate hosts to allow levels of lungworm infection to reach the epizootic stage. This hypothesis has not been tested, in that studies of the ecology of the snails serving as intermediate hosts are largely lacking, and little study of lungworms in bighorn outside of the Rockies has been made.

The seasonal variation in fecal lungworm larval densities, as found in the Sierra Nevada, seems to be a general phenomenon. Larval output appears always to be highest during the winter-spring period (Uhazy et al. 1973). It appears that the critical period for infection is the spring, when sufficient moisture and high temperatures precipitate snail activity. This is supported by the findings of Forrester and Littell (1976) that the level of lungworm infection in Rocky Mountain bighorn in Montana correlated with the rainfall in the spring period of April through June. In some cases, though, infection may extend on into summer if proper conditions exist (Hibler et at. 1976).

It appears that the infective range is that where the sheep are located when warm moist conditions occur, which may be as early as January in the Sierra Nevada winter ranges. Thus the winter range in the Sierra,

which also serves as much of the spring range, is most probably the infective range. Where on this range the sheep are ingesting snails is unknown. The snails collected by McCullough and Schneegas (1966) in the Baxter winter range were found along streams, where sheep do not feed.

The purpose of the above discussion is to point out that the characteristics of lungworm infection in the Sierra Nevada parallels that reported from the Rockies. The significant difference lies in fecal larval densities in the Sierra being presently relatively low, with no associated clinical signs. It is unlikely that treatment against lungworms by the Colorado technique of Cambendazole in apple pulp bait (Hibler et al. 1976) would have any significant demographic effect on the Baxter herd. It is possible, though, that increase in the size of this herd will lead to more significant lungworm infections in the future.

While the level of lungworm infection in the Williamson herd is a magnitude greater than in the Baxter herd, it is still unlikely that treatment of this herd for lungworms will affect its status, since no clinical signs of lungworm problems are apparent. Substantially higher levels of larvae in fecal samples than found in the Williamson herd are associated with increasing populations of bighorn in the Canadian Rockies (Uhazy et al 1973, Stelfox 1976).

5) Control of Predators

Mountain lion predation on the Williamson herd in winter is the only situation where predation may presently have a significant effect on herd dynamics. While lion predation on this herd has been documented, no information exists on its frequency and consequently on its significance as a mortality factor. Thus no projection can be made of the possible beneficial effects on this herd that control of the mountain lion population in the area might have.

Opening of pinyon pine stands in the Williamson winter range by fire or other means may reduce the susceptibility of members of that herd to lion predation by removing hiding places for lions and increasing visibility for the sheep.

6) Reintroduction

Given that bighorn dispersal to new ranges is rare, expansion of their range must be accomplished by relocation of members of existing herds. In the Sierra Nevada, this is feasible only while sheep are on their winter range.

The source of sheep for relocation should come from the closest herd to the relocation site that is demographically capable of sustaining removal of the required number of animals. The Baxter herd is presently capable of serving that function due to its large and generally increasing size. It is however, essential that the future of this herd not be jeopardized through reintroduction attempts. This can occur only through continual input of sound information on the trend and size of the herd.

It is probable that the Black Canyon, Sand Mountain and Sawmill winter range areas (discussed under background information) are traditional wintering areas, i.e. adults winter in the same area each year. Until information exists to the contrary, each of these areas should be regarded as a separate herd, as decimation of one such area through removal of sheep for reintroduction could severely threaten continued use of that area.

There exist no long-term data necessary for elucidating the degrees of density-dependence and independence governing reproduction and recruitment in the Baxter herd. Consequently, it is impossible to specifically prescribe any program of animal removal for reintroduction that will maintain a predictable productivity of the herd. Given this situation, it is best to err on the safe side until long-term data exist that provide more specific understanding of the population dynamics. It is suggested that sheep not be removed that will reduce the populations on the winter range areas below 60% of the 1978 totals. This would leave a minimum of 55 ewes, lambs and yearlings and 20 rams on the Sand Mountain range, 20 ewes, lambs and yearlings and 15 rams on the Sawmill range, and 16 ewes, lambs and yearlings and 2 or 3 rams on the Black Canyon range. This will ensure a minimum total population of 130 for the Baxter herd distributed as they presently are. A discussion of possible reintroduction sites is presented in Appendix I.

7) Control of Human Use

Rams in the Baxter herd exhibit a relatively undisturbed response to most encounters with man. Little seasonal change is detectable in this response. Such a mild response is also characteristic of other sex-age classes while on the winter range. This changes radically when new lambs appear in the spring. The most wary behavior exhibited is by ewes with new lambs. While this wariness declines somewhat as lambs reach about one month of age, it nevertheless remains at a high level while bighorn are in the high country. Control of human use as a management tool will be most beneficial if directed toward this sex-age class during the spring-summer period when the potential for disturbance is greatest.

A second factor important to management relative to human disturbance is the relative position of people, bighorn and rocky escape terrain. Bighorn exhibit a notably more disturbed response when man separates them from escape terrain. Under most circumstances, this situation occurs when people are above the sheep, causing them to attain an elevation above the people, or to move to a different rock system.

Management of human use in the high country must consider two separate issues: 1) use levels and placement of established trails, and 2) off-trail use, notably peak climbing, since these usually represent different kinds of human-bighorn encounters. The conclusion that human disturbance is presently not of significance to the Baxter herd applies only to the circumstances of human use under which the hypothesis testing took place. Specifically, this refers to 1) the daily quota of 25 people on the Baxter Pass trail, 2) the nature of encounters on the Baxter Pass salt lick, in which people rarely attain elevational positions above the sheep, and 3) recent levels of off-trail use, notably peak climbing. It is not possible

to accurately project the effects of increased human use of Baxter Pass on bighorn use there without actually observing such a situation. The extremely arduous nature of that trail may make this question unimportant, as human use may never significantly increase over present use even if controls were lifted. Presently, the quota of 25 people per day is rarely filled.

Disturbance on Baxter Pass occurs mostly to sheep using the orange colored slope on the west side of the pass as a salt lick. This disturbance could be ameliorated by routing the trail away from the orange slope. Presently the trail traverses the base of this slope, but could be readily moved away from it. Rerouting of the trail could allow an increase in the daily quota without any or a significant increase in disturbance to the sheep use there. At what level of human use significant displacement of the sheep there will occur can only be determined by studies similar to that of Hicks (1977) if and when greater human use is allowed.

Dogs accompanying people heighten the reaction of bighorn. The frequency with which this causes disturbance to sheep which would otherwise tolerate humans in unknown. Frequent association of dogs with people may result in a negative conditioning of bighorn to people. A possible management option is thus the prohibition of dogs in the Zoological Area. This would also serve to help reduce the illegal trespass of dogs across the crest into the park, which is presently common. As no data exist on the effects of pack stock on the sheep, nothing can be said on the effects of a reduction or increase in stock use of Baxter Pass would have.

Peak climbing represents the situation having the greatest potential for disturbance of sheep due to the frequency with which people suddenly encounter sheep from above. I have observed such a situation of a badly frightened ewe running full speed down Black Mountain following an encounter with people near the top. Such circumstances have the potential for injury to sheep due to the loose rocks and steep terrain. Once again, paucity of data on the subject results in the lack of a basis for projection of possible effects of changes in policies regarding peak climbing. Presently, no peak climbing is permitted in the ewe-lamb summer range. Elder (1977) provided data on frequency of peak climbing in the Baxter herd summer range based on records from summit registers. The two peaks showing notably higher use are Mt. Baxter and Black Mountain, both of which have shown significant increases in people use during this decade. Baxter Peak receives frequent summer ewe-lamb use, but the nature of the topography of this plateau topped peak ameliorates the disturbance to bighorn there by people on the peak. The bighorn feel a security in having escape routes (down) in all directions. My own experience with ewe-lamb groups there on a few occasions indicates a considerable tolerance on the part of the sheep, to the extent of their bedding in the middle of the plateau during my presence. The peak records summarized by Elder (1977) indicate an average of about one group per week climbing Mt. Baxter and Black Mountain in recent summers. As this level of use does not appear to have adversely affected the sheep in these areas, a management alternative in this area could be a permit system for peak climbing with a maximum quota of one party per week per peak. Higher levels would require some monitoring to assess effects on the bighorn.

The apparent loss of summer range and greater wariness in summer of ewe-lamb groups of the Williamson herd have been discussed previously. Presently, the only permitted summer human use in the Williamson area is travel over Shepherds Pass and the climbing of Mt. Williamson from the southeast by the Bolton Brown route. Mt. Williamson has a strong attraction for peak climbers, being the second highest peak in California. The easiest route is from the east via Georges Creek, although the west route from the upper Williamson Lakes is not difficult. The Georges Creek route has received regular illegal use in recent years. The indications that human use may have displaced sheep in summer from the region south of and including upper Georges Creek can only lead one to project adverse effects on the bighorn if this area were opened to human use again. Minimally, it may prevent reoccupation of Georges Creek. This projection remains tentative in light of the limited information on which it is based. Further investigations along these lines seem warranted.

While some occasional use of the lower Williamson Lakes area by ewe-lamb groups occurs in summer, the upper part of this basin directly west of the summit of Mt. Williamson receives at most rare bighorn use, and likewise for the west face of Mt. Williamson. Occasional permits for parties to climb Mt. Williamson by this route is not likely to have any adverse effect on the bighorn in that area, provided descent from the summit is not down the east side.

Control of human use of the Baxter winter range while bighorn are present should consider the nature of this use. The great tolerance these animals have for human presence during winter makes viewing from a proper distance an activity of no substantial impact. Rarely will they retreat when the distance from people exceeds 100 yards. Those people, notably photographers, that attempt to get as close as possible to the sheep inevitably displace them, and if persistent may move them quite a bit. While this obviously affects bighorn use patterns, such displacement has not been observed to be of any permanence. Thus a limited amount of this kind of use is tolerable. At what level such use will adversely impact the sheep cannot be known without actually observing such a level and its consequence. Two to three permits per month for close viewing of the sheep is unlikely to cause adverse impact, particularly if such use is spread over different parts of the range. However, this kind of viewing can be a great hinderance to attempts to manipulate bighorn use patterns for trapping purposes, as was demonstrated in 1978.

Human use of the Sawmill Canyon winter range during the lambing period from mid-April to the beginning of June is likely to cause disturbance to the sheep lambing there. Other bighorn in this herd, as well as in the Williamson herd, bear lambs in relatively inaccessible places where disturbance from people is most unlikely.

The initial regulations of the Zoological Areas prohibited the discharge of firearms. This regulation was not enforced and deer hunting was common in the Zoological Areas. In 1977, the firearm regulation was lifted at the same time that cross country travel was opened up below 10,000 feet in the summer range. This was done on the basis of information which suggested that sheep distribution during deer hunting season was entirely

above 10,000 feet. In 1977, exceptions were found to this, and sheep were observed as low as 6,800 feet on the Sawmill Pass trail during deer hunting season.

The sound of a rifle shot does not disturb bighorn, which are accustomed to the similar sound of thunder in the high country. In theory, deer hunting per se should not affect the sheep since they are a fully protected species in California. The issue involved is 1) whether hunters can be trusted not to accidently or maliciously shoot a bighorn encountered during deer season, and to stay below 10,000 feet, and 2) whether the concentrated off-trail use by hunters is of consequence to bighorn. Most off-trail use by deer hunters is in deer habitat not used by sheep. The frequency of bighorn below 10,000 feet in early fall is also unknown. The 1977 observations may have been exceptional due to drought conditions that caused early phenological change in the alpine forage. A specific study during deer hunting season of the behavior of the bighorn as well as hunters in an area like Sawmill Canyon is necessary to make any assessment of the effects of hunting on the sheep.

B) Possible Classification under the 1973 Endangered Species Act

Bighorn in the Sierra Nevada are presently classified as rare by the State of California and the Fish and Wildlife Service, but have not received formal status under the 1973 Federal Endangered Species Act. Classification of separate populations, such as Sierra Nevada bighorn, (as opposed to only at the species and subspecies level) is provided for in the 1978 amendments to the Endangered Species Act by the following paragraph: "The term 'species' includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature".

Endangered is defined as "in danger of extinction throughout all or a significant portion of its range", while threatened "means any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". No formula exists to determine whether any situation fulfills the criteria necessary for endangered or threatened status. Such status is determined by the U. S. Fish and Wildlife Service upon request by a government agency or any individual or group of indivuals. Considering that bighorn in the Sierra Nevada are already extinct over most of their native range, it is likely that one of the two classifications could be considered. As of the 1978 amendments to the Act, classification includes designation of 'critical habitat' for the species in question. The process of classification can be expected to take approximately two years.

Two benefits accrue from threatened or endangered status under the Endangered Species Act. First, this opens avenues for the funding of research and management of the organism in question. Second, this organism receives top management priority in habitat designated as critical, with the possible exception of mining. No legal precedent yet exists as to the power of the Endangered Species Act relative to mining.

Applied to bighorn in the Sierra Nevada, it is not clear that the designation of critical habitat would provide any added protection to the

remaining population, as it already has top priority under the Park Service and Forest Service classifications of its range. Mining is again the exception, as no restriction on mining entry presently exists within the Forest Service lands of the Bighorn Zoological Areas; mining is excluded from Sequoia and Kings Canyon National Parks. In the light of recent decisions relative to the Endangered Species Act, it is likely that a court ruling would favor this act over mining laws. Thus federal classification of bighorn in the Sierra Nevada may effectively protect their entire range from any significant adverse effects of mining.

Some disadvantages would result from the classification of Sierra Nevada bighorn under the Endangered Species Act. Management would take on an additional magnitude of complication and associated paper work. Minimally, the effect would be to lengthen the period between proposal and implementation of any desired management action. Management possibilities might also be more restrictive, depending on the classification status. Lastly, once classification is accomplished, declassification or a shift to a lesser classification may be difficult.

The potentially more restrictive management options under conditions of federal classification could make such classification an advantage to some private or government agency seeking to change or halt existing or proposed management practices considered potentially detrimental to the organism in question. In the case of bighorn in the Sierra Nevada, this is not likely to be the case, considering the extremely protective approach the State has had toward bighorn management, and the restrictive Park Service and Forest Service classifications of its range.

9) Possible Administrative Action Relative to Mining

Mining is a threat of potentially large impact on the remaining bighorn in the Sierra Nevada. Winter range is particularly vulnerable in this regard due to the relatively small area available to bighorn at that time of year. There is presently no limitation on mining on bighorn range lying on Forest Service lands in the Sierra Nevada.

The Rex Montis Mine on Kearsarge Peak in bighorn summer range was in operation up to 1976, but showed no discernable impact on sheep use. Miners commonly observed sheep on the rocks around the mine despite operation of large and noisy diesel generators and other equipment. In this particular instance, the mine location may simply be fortuitous, being at the edge of favorable ewe-lamb summer habitat, as well as having adjacent steep rocks that provide the sheep adequate security to feed nearby. A small amount of habitat was nevertheless probably removed from sheep use by the mine. Other locations could easily impact substantially larger, as well as more critical habitat. Mining activity or roads to mines in certain areas of the winter range could effectively remove large and important bighorn feeding areas.

The only available evaluation of mining potential on bighorn ranges in the Sierra Nevada is the cursory mineral character evaluation under RARE II of winter range areas presently not in wilderness. This evaluation gave a rating of 16 for hard rock mining potential to the Williamson

herd area, which translates as having low potential. The Baxter herd area was rated at 41 as having some, but not a large potential. The Big Ram Mine at Black Canyon in the Baxter herd winter range has been defunct since the 1950's, but serves as an indicator of the existence of extractable minerals in the area.

Under the Wilderness Act, such designated lands will be closed to further mineral entry after 1983. Existing claims will however remain valid. The present boundary of the John Muir Wilderness excludes most of the winter range of the Baxter and Williamson herds. Under the proposed wilderness additions in RARE II, all winter range areas would receive protection. Whether 1983 would be the closing date for the filing of mining claims in these wilderness additions is unknown.

In addition to the wilderness additions under RARE II three alternatives exist to deal with the potential threat of mining to bighorn habitat. The first is classification under the Endangered Species Act, which has been discussed in the previous section. The second is an administrative withdrawal from mineral entry. Such action normally begins with an evaluation of the mineral resources in the area under question, and is usually implemented only if the mineral resource is poor to non-existent. Mineral withdrawal of more than 50,000 acres requires congressional action.

The remaining alternative is the extention of the National Park boundaries to include the entire range of the Sierra Bighorn. It is customary for the government to purchase existing mining claims on land incorporated into the National Park System.

ADDITIONAL RESEARCH NEEDS

The need for continued collection of sound demographic data cannot be overemphasized. As Caughley (1976) has aptly pointed out, all wildlife management is directed toward the manipulation of demography, either directly or indirectly through changes in habitat. Good management depends on the understanding of those factors influencing the dynamics of a population. This is possible only through, first, the acquisition of good information on the population dynamics themselves, and second, the collection of data on factors hypothesized as influencing these dynamics. The ultimate understanding is arrived at through tests for correlations between these two data types.

Sierra bighorn offer an opportunity for collection of complete or close to complete census data for one willing to take on the work involved. Such opportunities are seemingly rare among southern sheep populations. Where they occur, they should be taken advantage of. The herd size data in Table 5 represent little more than baseline data, and leave many questions of dynamics unanswered. The trend of the Williamson herd can not be determined except with additional complete censuses. Considering the apparent loss of part of the summer range of this herd over the last 30 years, it is conceivable that the herd has also declined in size, and could be approaching the level of remnant herd status.

The recent upward trend in the Baxter herd has been clear, but leaves unanswered the question of why this increase has suddenly occurred, as well as where it will lead. Considerably more years of data will be necessary to investigate possible correlations with factors suspected to influence reproduction and recruitment. I recommend that complete herd counts be made as frequently as possible for both herds until long term trends are clear. The necessity of this relative to removal of bighorn from the Baxter herd for relocation purposes cannot be overemphasized.

The question of the separateness of Sawmill Canyon as a winter range could be investigated by tagging bighorn there. Radio collaring of bighorn in the various wintering areas would provide needed information on the distinctness of seasonal home ranges. Information of this nature is required if removal of bighorn for reintroduction is to have minimal impact on any subtle structuring of the population that may exist.

A general insufficiency of information on the Williamson herd is apparent. Further information on the distribution of these bighorn in different seasons and on their reactions to man are needed as a basis for management decisions regarding human use of their range. Some continued monitoring of lungworm infection in this herd, as well as in the Baxter herd is needed to determine whether present demographic differences simply reflect different stages in a long term cycle such as exhibited by bighorn in the Rockies.

Further data on the role of fire as a management tool is needed; comments on the subject in this report have been cursory. Specific attention should be given to pinyon pine habitat in the Williamson range in this regard. The 1979 Georges Creek fire should be studied; additional experimental burn plots may be needed. Information on the response of higher elevation palatable brush species to fire is also needed.

Studies of captive bighorn indicate that percent fecal protein correlates closely with percent dietary protein (Hebert 1973). Fecal protein should thus serve as a good index of nutrition. This index has been used to compare bighorn nutrition between herds and seasons in the Sierra. The results show clearly that the minimum nutrition occurs in the high country during fall months. Also, a considerably lower nutritional plane was evident for the sheep in the higher elevation lambing range of South Bairs Creek compared with Sawmill Canyon. This occurred in mid-May, when lactation and consequent nutritional demands of ewes are at their peak. To further understand the relationships of different habitats to bighorn nutrition in the Sierra, additional lambing ranges of both herds should be compared by this technique. More values for fall and summer ranges may also be revealing.

A small bighorn group including a new lamb was sighted at the beginning of June in 1979 on the switchbacks below Gilbert Lake in Onion Valley. This sighting established that members of the Baxter herd do reach Onion Valley, at least occasionally. Since the beginning of June precedes most human activity in this area, this sighting suggests the hypothesis that bighorn use this area early in the season and are later

displaced by the high level of summer human use. This possibility should be investigated.

A study of the reaction of bighorn to packstock is needed. This study would best be carried out in the Baxter Pass and Lake area by methods similar to those of Hicks (1977). This could be done using packstock on a controlled basis, as well as commercial trips of known timing.

A study of the distribution of bighorn and the behavior of hunters in Sawmill Canyon during deer hunting season should provide information on which to decide whether deer hunting is appropriate in the Bighorn Zoological Areas.

Needlegrass utilization on the Black Canyon winter range should be regularly monitored to test for elk competition. Years of poor needlegrass production are particularly important in this regard.

Areas of possible remnant herds that have received insufficient or no investigation have been mentioned, notably the Hetch Hetchy area of Yosemite, and the Middle Fork of the Kings River. In light of our experience in searching for remnant herds, one has to question the fruitfulness of further investigation along these lines. The problem is further complicated by the question of what can be done to try to restore a remnant herd if evidence of its existence is found. Unless clear and predictable patterns of range use can be detected in a remnant herd, it is not clear that any meaningful management action can be taken on its behalf. Geist (1975) has pointed out that in most cases reintroduction will be more feasible than attempts to rescue remnant herds.

Two possible west side areas of reintroduction have received no attention and therefore warrant investigation. The first is the Middle Fork of the Kings River in the area of the sightings reported in Appendix II B. Such a survey could be coupled with an investigation of some of the sighting locations in that area. The second site is the Kern River drainage where sheep previously inhabiting the Mineral King-Kaweah Peaks area probably wintered. The reintroduction potential of this latter area is believed to be substantial. Additionally, further surveys of Lee Vining Canyon under different winter conditions may lead to its classification as a suitable reintroduction site. Mt. Tom winter range areas also need investigation.

MANAGEMENT OBJECTIVES

Two possible management objectives and my estimation of what their implementation should involve, are considered in this section. They are 1) minimum management necessary to assure perpetuation of existing bighorn herds in the Sierra Nevada, and 2) optimal management to maximize bighorn numbers and range in the Sierra Nevada. These merely represent two points on a management continuum that has at one extreme the extirpation of bighorn from the Sierra Nevada, and at the other extreme the second objective above. The two objectives listed simply provide the end points of the part of the continuum that is considered to be acceptable management under present attitudes regarding rare species. Any management objective representing a position between these two points may be considered acceptable.

In many cases, proper management action is dependent on results of further study and can be specified only as an if/then clause; information input is treated here as an integral part of management procedures where appropriate.

Minimum Management Necessary to Assure Perpetuation of Existing Herds.

The Baxter herd is a relatively large and healthy herd that has persisted despite the many adverse influences of man early this century and late last century that led to the extirpation of most Sierran bighorn herds. It is probable though, that its size was reduced in the past by these influences. Control of human access is not believed to be critical to the survival of the Baxter herd due to the ruggedness of most its range and the general tolerance of human presence exhibited by this herd. The existing management policies with human restrictions deleted would leave what is believed to be the minimum acceptable management of the Baxter herd. Such a management policy might result in some alteration of use patterns of this herd, due to repeated human presence in some areas. A consequent reduction in the resource base available to the herd is probable.

Due to indications of range loss correlated with human use and the small size of the Williamson herd, its perpetuation would be best assured by 1) keeping its range closed to human use, except for west routes up Mt. Williamson, and 2) determine the population trend of this herd; if declining, cause of decline should be investigated and appropriate management action taken.

Optimal Management to Maximize Bighorn Numbers and Range

This management regime would differ from the previous in the following ways:

1. Reintroduction attempts would be made to establish as many herds as possible using the Baxter herd as stock under the guidelines listed previously.

2. Human use in the Baxter herd would be limited using a permit system, not to exceed recent use levels; effects on bighorn of any increases would be monitored.

3. Dogs would be prohibited in the Zoological Areas.

4. The trail would be rerouted away from the salt lick on Baxter Pass.

5. Surveys of mining potential in the Baxter winter range would be carried out and if deemed necessary, appropriate action taken to prevent any potentially detrimental mineral entry.

6. Necessary data would be collected on all facets discussed in the previous section, and management actions taken to alleviate factors detected to have adverse influence on the bighorn. Major

emphasis would be placed on regular censuses, experimental habitat manipulation in the pinyon woodland of the Williamson herd, and surveys of the additional potential reintroduction sites discussed in the previous section.

MANAGEMENT RECOMMENDATIONS

The adoption of any particular management objective is a political decision, while information from studies serves only as the basis for implementation of management objectives. The recommendations in this section are personal views of the author. An attempt is made to provide the rationale behind them. I suggest that final decisions on directions of bighorn management in the Sierra be made by a committee formed for that purpose. Minimally, this committee should be composed of members from the National Park Service, the U. S. Forest Service and the California Department of Fish and Game, since these agencies hold responsibility for the Sierra bighorn. Additional members from private organizations with an interest in bighorn would be desirable.

Some recommendations for management of Sierra bighorn already exist in the State's publication on rare and endangered species. These recommendations are to "develop and implement a recovery plan designated to remove this animal from its rare status" and for "continued programs of field research and reintroduction for the purpose of re-establishing bighorn sheep within their historic range" (Leach et al. 1974,pg. 73). It is also part of the policy of the National Parks to re-establish extirpated native animal populations where feasible.

The first priority in management of Sierra bighorn should be assurrance of the perpetuation of the existing two herds and their native patterns of habitat use. Of first concern in this regard is the Williamson herd, due to its small size, unknown population trend, and recently diminished summer range. Management of this herd should be cautious. Its status should be frequently monitored until either some specific management is deemed necessary to save it, or its trend is clearly stable or increasing.

Perpetuation of the Baxter herd is an issue of less concern. Less protective management of this herd is possible without danger to its future existence. Nevertheless, the Baxter herd is the only remaining Sierran bighorn herd of substantial size, and the only one capable of serving as reintroduction stock. As such, it is appropriate to maintain a margin of safety in its management. It would be undersirable for less cautious management to result in any alteration of native patterns of habitat use of this herd. These patterns serve importantly as examples of native strategies of habitat use by bighorn in the Sierra, on which reintroduction planning can be based. Since repeated human use of an area is the factor most likely to alter bighorn use patterns, the major question in the management of the Baxter herd is the degree to which human access to its range should be controlled.

The second priority of bighorn management in the Sierra should be the expansion of their range through reintroduction attempts. This is presently

feasible using the Baxter herd as stock; it should take place with the first management priority clearly in mind. Specific management recommendations are as follows:

1. Maintain closure of the Williamson range, including the lower Williamson Lakes; Mt. Williamson should be climbed only by its west face on a permit basis.

2. Prohibit dogs from the Zoological Areas.

3. Retain existing trail and camping regulations in the Baxter summer range. Monitor actual use rate of Baxter Pass trail and study the effect on bighorn use of Baxter Pass if it increases.

4. Allow climbing of Black Mountain and Mt. Baxter on a permit basis with at least one week between permits for each. Due to the difficulty of coordination of such permits between the Park Service and Forest Service, it is recommended that these be given only by the Park Service, thus limiting these climbs to western approaches.

5. Relocate the Baxter Pass trail away from the orange salt lick slope.

6. Due to mounting evidence that some bighorn regularly use lower portions of Sawmill Canyon throughout summer and fall, either hunting should be banned in the Zoological Areas, or a study of the situation be made, upon which further recommendations can be based.

7. Maintain closure of the Baxter winter range. Permits to enter for close bighorn viewing (e.g. photography) should be given at no greater frequency than every 15 days. No permits should be given for areas where bighorn trapping attempts are under way. Zoological Area boundaries should be made to coincide with the winter range boundaries provided in this report.

8. Reintroduction to suitable ranges in the Sierra Nevada should be undertaken, within the capacity of the Baxter herd to serve as stock. Each reintroduction should be studied and procedures for further attempts based on the results. Due to its large wintering bighorn population, the Sand Mountatin winter range would be the best source of reintroduction stock. Potential reintroduction sites that have not been surveyed should be investigated.

9. Annual censuses of the Williamson herd should be taken until its population trend is clear. Further information on its seasonal ranges, and reactions to humans should be gathered. The role of fire in improving its range should be investigated.

10. Annual censuses of the Baxter herd should be taken to monitor it as the source of reintroduction stock.

11. Domestic stock should not be allowed in the Sawmill Canyon mouth area.

12. Additional studies outlined previously are desirable, but are not of as high priority as those listed above. These additional studies will serve the purpose of providing information on which more refined management can be based. These studies should be undertaken as funding becomes available.

II. BACKGROUND INFORMATION

SUMMARY OF TAXONOMIC STATUS

Based on a collection of four bighorn from the Sierra Nevada, which he compared with adjacent desert bighorn, Grinnell (1912) classified bighorn in the Sierra Nevada as the subspecies Ovis canadensis sierrae. Cowan (1940), in his extensive and now generally accepted study of the taxonomy of North American wild sheep refuted Grinnel's classification. Cowan (op. cit.) discusses bighorn from the Sierra Nevada under the section on the subspecies californiana. Subsequently, authors have referred to Sierra Nevada bighorn as members of this subspecies (e.g. Jones, 1950; Buechner, 1960). Yet Cowan (1940), in discussing comparisons of skull measurements (on which his taxonomy is largely based) of Sierra Nevada bighorn with those of adjacent desert bighorn (ssp. nelsoni), as well as with ssp. californiana specimens from Washington and British Columbia states the following (p. 556):

> "However, the difference in mean values of the cranial features is small....and not significant in any case. These sheep cannot properly be referred to either named race and yet do not differ from them to a degree that would justify recognition of a separate race 'sierrae' in that area. It seems to me that the sheep of the Sierra Nevada represent a population of intergrades in which can be seen incipient racial characteristics."

It is noteworthy that Cowan had few specimens from the Sierra Nevada with which to work. The taxonomic status of Sierra Nevada bighorn clearly remains in question. That Sierra Nevada bighorn should be the same as those of the ssp. californiana in Washington and British Columbia seems rather unlikely, considering the great distance between locations and that the Sierran-Cascade mountain chain probably never had a continuity of bighorn herds; the entire northern Sierra of California and the Cascades of a southern portion of Oregon are not known to have ever supported bighorn herds (Jones, 1950; Buechner, 1960). The only continuity would have been through desert mountain ranges of Nevada (Jones, 1950). A more likely situation would be that bighorn in the Sierra Nevada are simply an offshoot of the many populations of the subspecies nelsoni in desert mountain ranges immediately to the east, which may or may not have evolved their own characteristics since their establishment in the Sierra Nevada. A couple of points are noteworthy in this regard. First, bighorn (probably all rams) have occasionally crossed between the Sierra and adjacent mountain ranges. A few such animals are recorded to have fallen in the Los Angeles aqueduct in Owens Valley during the first half

of this century, and bighorn were previously known to occasionally cross between the Sierra and the Coso and Argus ranges south of Owens Lake (Jones, 1950). Warden Vernon Burandt was able to plot the course of a ram in the fall of 1973 that started in the Westgard Pass area, moved south in Owens Valley, crossed Highway 395, and was last seen heading toward the Sawmill Canyon-Division Creek area of the Sierra Nevada.

Secondly, the very wide horn flare of existing Sierra Nevada rams is similar to that found on nelsoni rams to the east, but is unlike the relatively tight flare of californiana rams of British Columbia (e.g. pictures in Sugden, 1961; Richard Weaver, Joel Berger, Jim DeForge, pers. comm.). Many more bighorn skulls from the Sierra Nevada are presently available than were forty years ago when Cowan did his work. A new taxonomic evaluation seems worthwhile.

SUMMARY OF PREVIOUS RESEARCH

Although a few short notes on bighorn in the Sierra Nevada were published in the first half of this century (Grinnell 1912, Manly 1916, Ober 1931, Dixon 1936) and others were unpublished (e.g. Annual Fish and Game Reports of Inyo National Forest), the first intensive attempt at systematic data collection was the study of Jones (1950) carried out in the summer and fall of 1948. During the winters of 1963 through 1965, Riegelhuth (1965) conducted winter range surveys, as did McCullough and Schneegas (1966) during the winters of 1964 and 1965. While serving as wildlife biologist on the Inyo National Forest from 1967 through 1973, Dunaway (1970, 1971a, 1971b, 1972) made numerous bighorn studies, mostly on winter range areas. In the summer of 1972, Jorgensen and Schaub (1972) surveyed the summer range of the Mt. Langley herd. The present study was begun in the summer of 1974.

Demography

Some of the early employees of the Forest Service and Department of Fish and Game in Owens Valley made estimates of numbers of bighorn in different areas of the surrounding mountains early this century. These are summarized in Table 2. Such figures were probably based on casual observation rather than any systematic data collection, although the 1937 Inyo National Forest Annual Fish and Game Report states that "The estimate of 200 sheep for the Inyo is based on the reliable data collected in 1936 by Ranger Shellenbarger and J. D. Cassel". It is nevertheless evident from comments made in these early reports that relatively little was known about the bighorn herds in the area. For instance, the Mt. Williamson and Mt. Langley herds were never mentioned, and the Mt. Baxter herd was mentioned only once and was known to winter only in Thibaut Creek.

By 1948, when Jones made his study, herd locations still remained unclear. Thus, Jones began his study by interviewing people familiar with the southern Sierra Nevada, then hiked through some of the areas reputed to have bighorn. He spent five months during the summer and fall of 1948 in the mountains, and concluded from this work that five herds remained

Table 2 - Early size estimated of bighorn herds in the Sierra Nevada

Year	Herd	Size Estimate	Estimater	Source
1870's	Farewell Gap region	75	Hopping	Jones (1949)
1870's	Sawtooth Peak	50	Hopping	Jones (1949)
1910	Rock Cr.-Convict Cr.	40	Joe Smith	Dept. Fish & Game files, Bishop (hand written note)
1911	Mt. Tom - McGee Cr.	40	Ober	Ober (1911)
1911	Taboose Cr.	22	Ober	Ober (1911)
1913	Glen Pass-Sawmill Pass	40	Ober	Ober (1913)
1914	Baxter herd	85-90	Ober	Ober (1914)
1914	Mt. Tom	40-50	Ober	Ober (1914)
1914	Birch Mt. herd	30	Ober	Ober (1914)
1921	Goodale-Birch Mt. band	40		Inyo N. F. Annual Fish & Game Report
1921	Pine Cr.-Rock Cr. band	25		Inyo N. F. Annual Fish & Game Report
1923	Goodale-Birch Mt. band	70		Inyo N. F. Annual Fish & Game Report
1923	Pine Cr.-Rock Cr. band	30		Inyo N. F. Annual Fish & Game Report
1927	Thibaut Cr. band	30		Inyo N. F. Annual Fish & Game Report
1931	Sierra Nevada	230	Bailey	Bailey (1932)
1931	Sierra Nevada	200	Ober	Ober (1931)
1937	Mammoth District	30		Inyo N. F. Annual Fish & Game Report
1940	Sierra Nevada	25-60	Blake	Blake (1940)
1940	Sierra Nevada	140		Inyo N. F. Annual Fish & Game Report
1941	Sierra Nevada	360	Fish & Wildl. Serv.	Jones (1950)
1944	Sierra Nevada	75-100	Clyde	Jones (1950)

in the Sierra Nevada, with an estimated population of 390 (Jones 1950). Table 3 summarizes these findings.

Riegelhuth's (1965) winter survey in 1963-65 was directed toward determining the locations of winter ranges and assessing the status of the southern four of Jones' (1950) five herds. Riegelhuth was quite successfull in identifying winter use areas of the Baxter and Williamson herds through sightings and sign, but could find no evidence of sheep use in potential winter ranges of the Langley and Birch Mountain herds. No population size estimates were made by Riegelhuth (1965) or by McCullough and Schneegas (1966), who also made numerous winter sheep sightings in the Baxter and Williamson areas during that period.

Dunaway (1970, 1971b) made further winter surveys of the ranges of Jones' (1950) five herds, as well as some summer surveys and concluded that neither the Birch Mountain nor the Convict Creek herd existed at that time. Dunaway's (1971b) estimate of 215 (Table 3) sheep in the Sierra Nevada was considerably lower than Jones' estimate 23 years earlier (Table 3).

An additional summer range survey of the Langley herd by Jorgensen and Schaub (1972) failed to uncover any sign of bighorn, thus casting doubt on the existence of that herd.

A summary of past herd composition data obtained in the studies discussed is presented in Table 4. Since not all studies classified yearlings females separately, most ratios are presented only on a ewe+ yearling basis. Furthermore, the authors commonly combined years as well as herds, and the data were not all obtained in the same season. Nevertheless, it is noteworthy that high recruitment occured in both 1969 and 1970, and was at about herd replacement level in most other years represented.

The population estimate figures of Jones (1950) and Dunaway (1971b) presented in Table 3 were essentially guesses, in that they were not based on solid information. As such, it seems invalid to conclude that a population decrease had occurred between 1948 and 1971. Indeed, Jones (1950) himself did no field work in the Convict Creek herd area, and only saw some tracks he believed to be from a bighorn group in the Birch Mountain herd range. It seems questionable whether these two herds existed in 1948. The Birch Mountain herd (=Taboose Creek herd) is not mentioned after 1923 in the Inyo National Forest Annual Fish and Game Reports. That a Mt. Langley herd existed at the time is more likely, in that it is improbable that the seven rams observed by Jones (1950) on Mt. Langley had wandered that far south from the Mt. Williamson herd. At present, the rams in the Williamson herd move north in summer, on a regular basis rather than south.

Based on the demographic information provided by Jones (1950), one can only conclude that in 1948 the Baxter and Williamson herds were both viable herds, and were substantially larger than any other herds that might have existed.

Table 3 - Herd sizes estimated by Jones (1950) and Dunaway (1971b)

Herd	No. of different sheep seen by Jones in 1948	Largest no. of sheep seen by others as reported by Jones (1950)	Population estimate made by Jones (1950)	Population estimate made by Dunaway (1971b)
Convict Creek	0	1948 - 15	25	0
Birch Mountain	tracks of 6	1940 - 1	15	0
Mt. Baxter	22	1938 - 79	135	95
Mt. Williamson	25	1940 - 23+	125	75
Mt. Langley	7 (rams)	1946 - 15	90	45
			390	215

Table 4 - Summary of herd composition data from the Baxter and Williamson herd prior to this study

Year/herd	Season	Lambs per adult ewe	Lambs per ewes plus yearlings	Sample size (ewes + yearlings)	Source
Baxter					
1948	summer		.54	26	Jones (1949)
1963-65	winter		.35	20	Riegelhuth (1965)
1965	winter	.36	.32	76	McCullough & Schneegas (1966)
1968	winter		.36	11	Dunaway (1970)
1969	winter	.66	.56	79	Dunaway (1970)
1970	winter		.48	25	Dunaway (1970)
1972	winter	.38	.32	40	Dunaway (Forest Service files)
1973	winter	.40	.34	143	Dunaway (Forest Service files)
Williamson					
1948	summer		.48	35	Jones (1949)
1971	winter	.30	.23	13	Dunaway (Forest Service files)
1975	winter		.54	11	Burandt (Dept. Fish & Game files)

Diseases

McCullough and Schneegas (1966) used a simple qualitative technique to examine Sierra bighorn fecal pellets for internal parasites. They found that 55% of the adult bighorn were carrying lungworms of the genus Protostrongylus, while none of the lamb samples showed such infection. They also found ova of an intestinal nematode of the genus Nematodirus. Their sample size from the Williamson herd was only four, precluding any interherd comparison of infection rates.

Range Relations

Dixon (1936) expressed concern about winter range competition between the bighorn and domestic sheep in the southern Sierra. He specifically noted that after domestic sheep grazed winter ranges little forage remained for the bighorn to eat the following winter.

Jones (1950) noted that by 1950, the potential for livestock competition with bighorn had been greatly reduced through the control of livestock grazing by the Forest Service, particularly in the Baxter and Williamson herd ranges. He contended that past overgrazing had converted winter ranges from a 'grass-herb association' to one of mostly shrubs, which he felt provided an inferior feed for bighorn, and thus continued to limit their numbers. He further suggested that competition from the high deer population might also contribute to "current winter range shortages of forage" (Jones 1950, p. 71).

As the introduced tule elk population in Owens Valley (McCullough 1969) continued to grow, concern was expressed about its possible role as a competitor on bighorn winter ranges. Riegelhuth (1965) specifically noted that elk were feeding in summer on the Sand Mountain area of the Baxter herd winter range. He contended that utilization of desert bitterbrush (Purshia glandulosa) and needlegrass (Stipa speciosa) was heavy there. He suggested that competition could have a serious effect on the bighorn as the elk population continued to increase. No data were offered on forage utilization. McCullough and Schneegas (1966) tested the contention that forage use was heavy on the Baxter winter range. Their measurements indicated low levels of bitterbrush and needlegrass use, refuting the hypothesis that competition existed between elk and bighorn at that time. Dunaway (1970) repeated the bitterbrush utilization measurements of McCullough and Schneegas (1966) and found higher use following the severe winter of 1968-69, but still well below what may be considered heavy. These higher levels of use were attributed to a deep and prolonged snow pack which concentrated the sheep. Dunaway (1971b) concluded that bighorn ranges in the Sierra were generally in satisfactory condition.

Human Disturbance

Dixon (1936) expressed strong concern about the adverse effects humans had on bighorn in the Sierra Nevada. He specifically cited the problem of sheep poaching by deer hunters. Jones (1950) reiterated the problem, expressing concern about effects of frequent disturbance of bighorn by

by high country users in the Sierra Nevada. He suggested that human use was the cause of the recent disappearance of bighorn from the Humphreys Basin. Dunaway (1971a, b) suggested that human disturbance had had further adverse effects on bighorn herds in the Sierra Nevada since Jones' study in 1948. He based this hypothesis on two apparent correlations. First, human use had substantially increased since 1948 in the areas of the vanished Langley, Birch Mountain and Convict Creek herds, while human use had changed little in the areas of the remaining Baxter and Williamson herds. Second, gaps existing between the Baxter and Williamson herds and between the Williamson and Langley herds fell on heavily-used human trails, namely Kearsarge Pass and the Mt. Whitney trail, respectively.

PRESENT STATUS OF SIERRA BIGHORN

Baxter and Williamson herds

1) Herd Ranges

Maps of the present ranges of the Mt. Baxter and Mt. Williamson herds are presented in Figures 4 through 8. They include a plotting of bighorn sightings made by the author from 1974 through 1979 totaling approximately 8,000 individuals. The range boundaries are by no means firm, as all boundary areas have not been thoroughly investigated. The general sparsity of sightings in the Williamson herd range reflects not only less time alloted to that herd, but also the difficulty of locating members of a herd approximately one-seventh the size of the Baxter herd which inhabit substantially more rugged terrain.

Williamson Herd

All sightings from the Williamson herd are plotted in Figure 4, but only the boundaries of the summer range of ewe-lamb-yearling groups and the winter range of the whole herd are outlined. These range boundaries are based on sighting as well as sign. Although no sightings have been made at the mouth of Georges Creek in the winter range, it was evident in 1978 from their sign that most of the herd spent about three weeks there early in the winter. Previous investigators have observed bighorn in the Shepherds Creek winter range (Riegelhuth 1965, McCullough and Schneegas 1966, Dunaway field notes, Burandt pers. comm.). I have never found bighorn or their sign there, but a ewe was killed by a mountain lion at the mouth of Shepherds Creek in late winter of 1978, indicating some continued use of that area.

Riegelhuth (1965) observed what he believed to be sign of winter bighorn use in the mouth of Pinyon Creek. I have not investigated this possibility, nor have there ever been any reports of bignorn there. On the basis of locations of high country ranges, it is unlikely that this location would receive anything but rare use by rams. In 1962, two rams were sighted in winter by Schneegas and others a mile north of Symmes Creek (Forest Service files, Bishop).

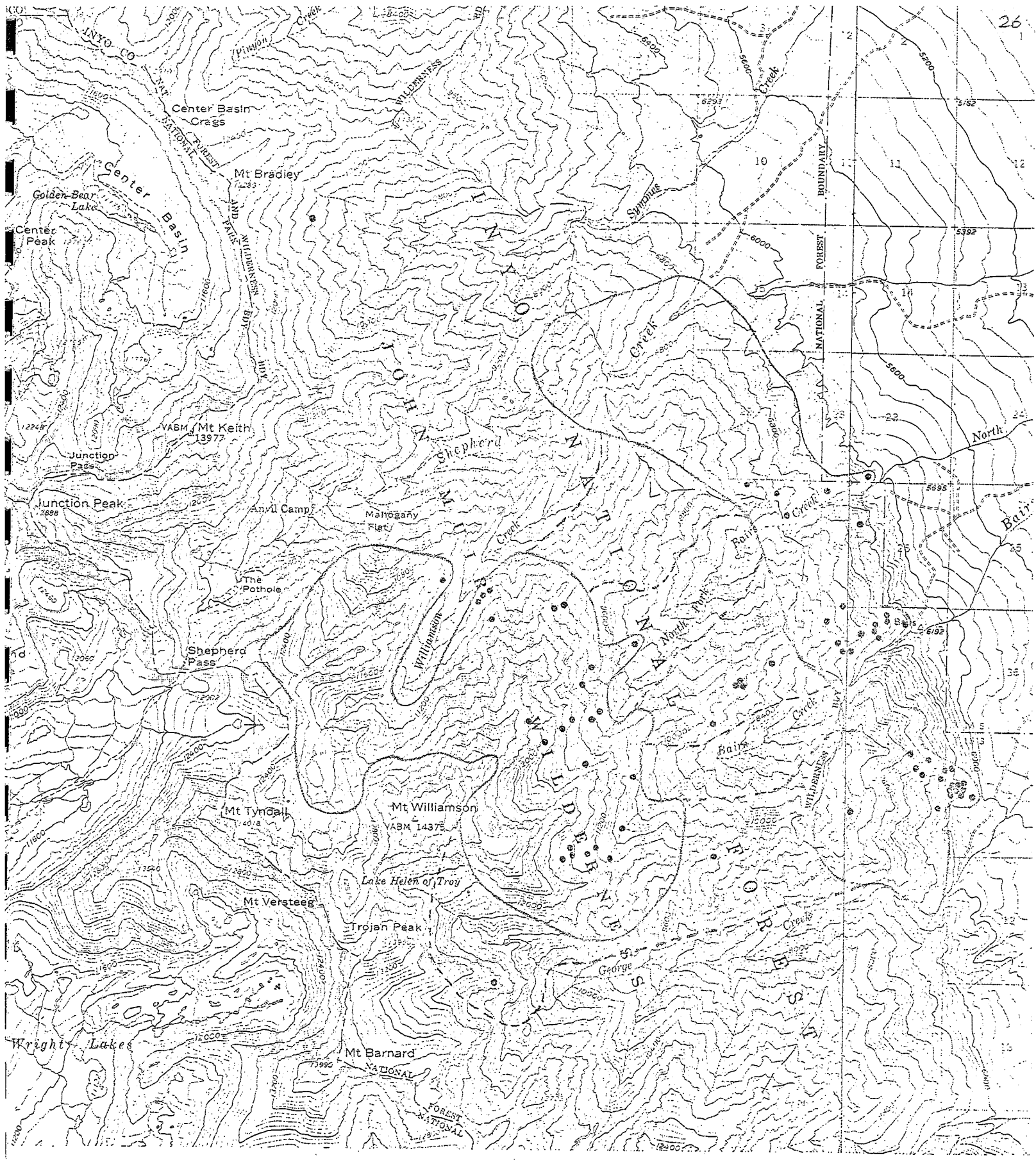

Figure 4 - Sightings and range boundaries for the Williamson herd. Dark lines outline winter range for the entire herd and summer range of ewe-lamb-yearling groups. Dashed lines are areas used in transition, or in fall in the case of upper Georges Creek.

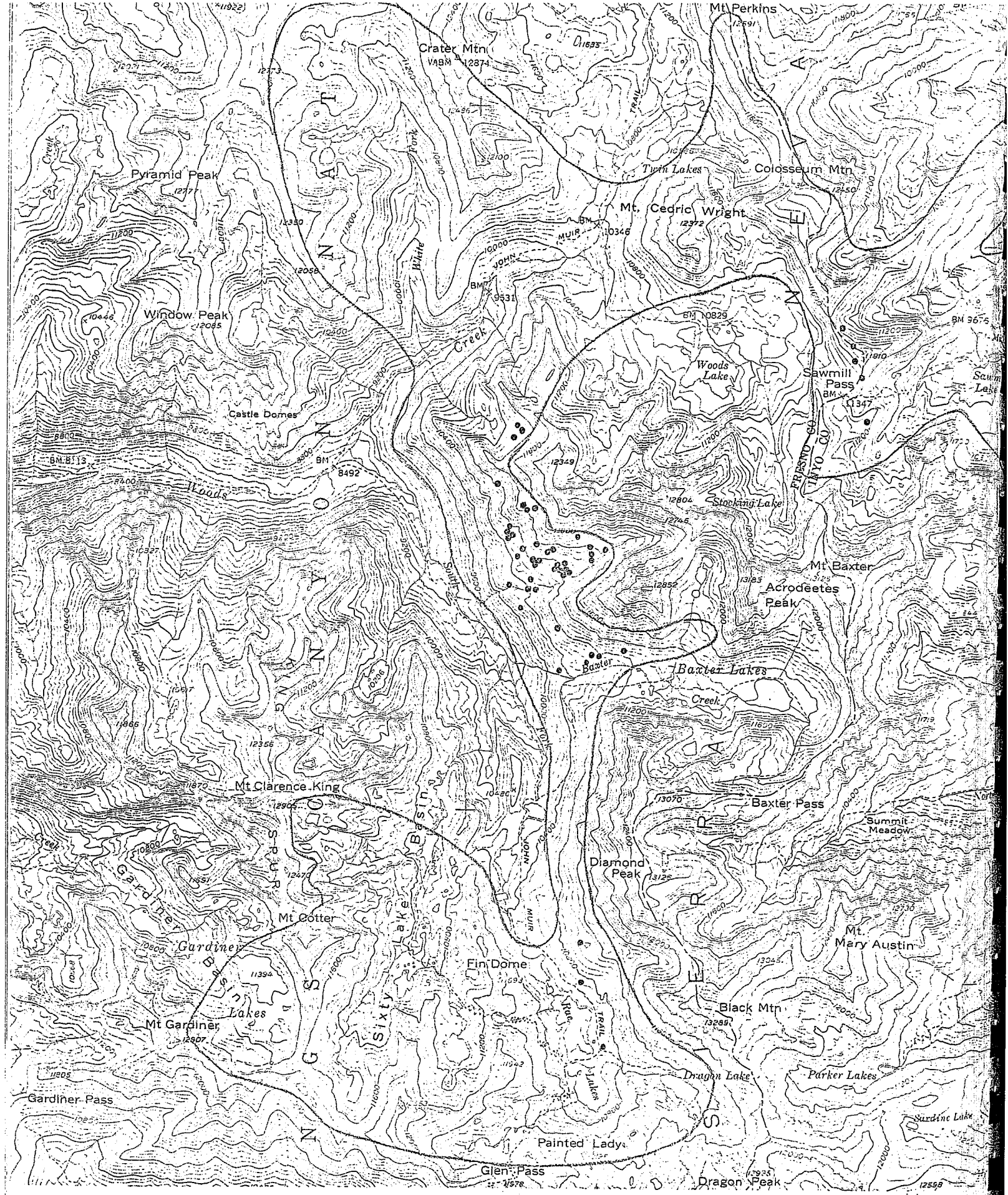

Figure 5 - Summer sightings and range boundaries of rams in the Baxter herd.

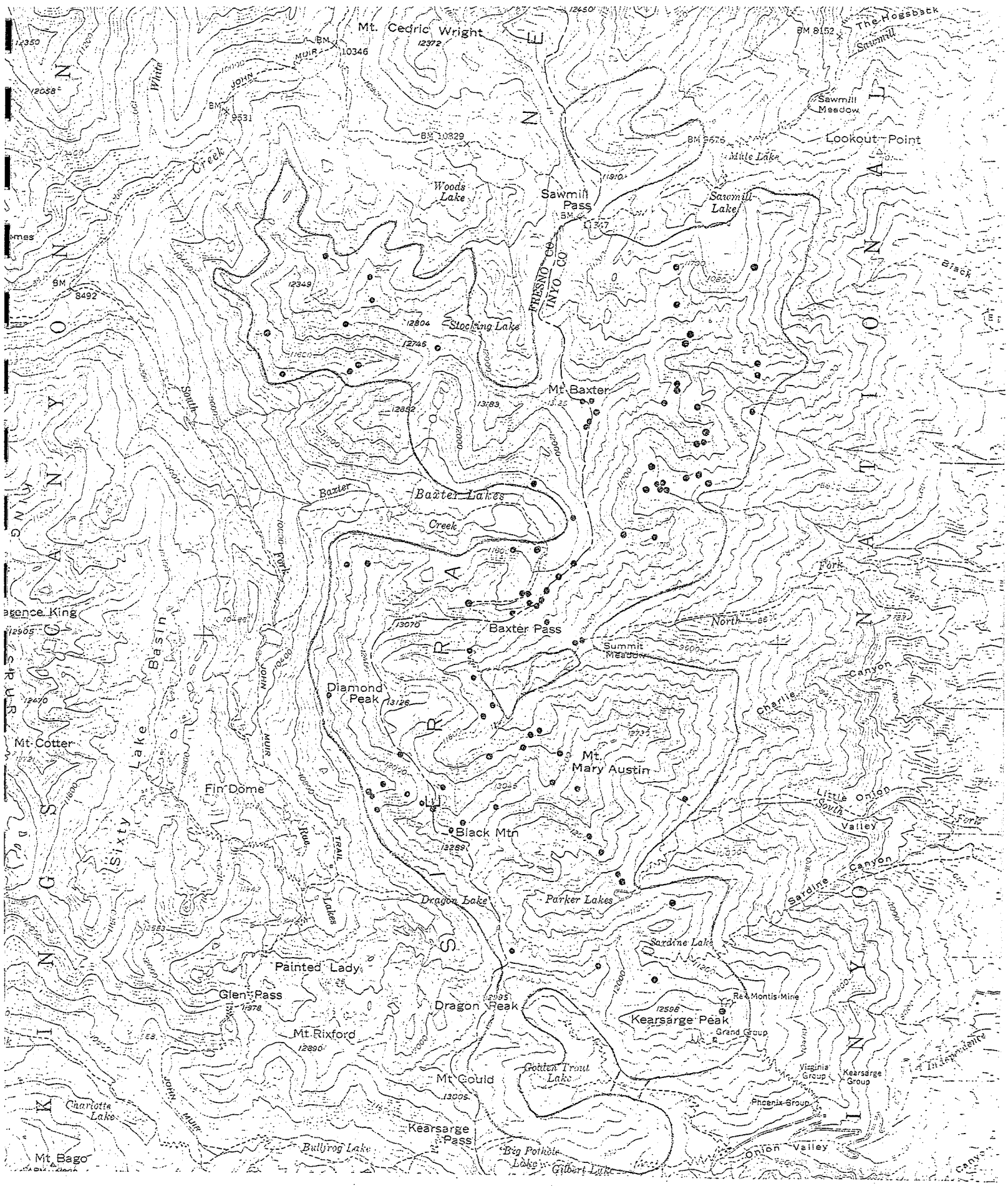

Figure 6 - Summer sightings and range boundaries of ewe-lamb-yearling groups in the Baxter herd. Sightings span the summer period up to October 10. The range boundary represents the summer period up to about mid September.

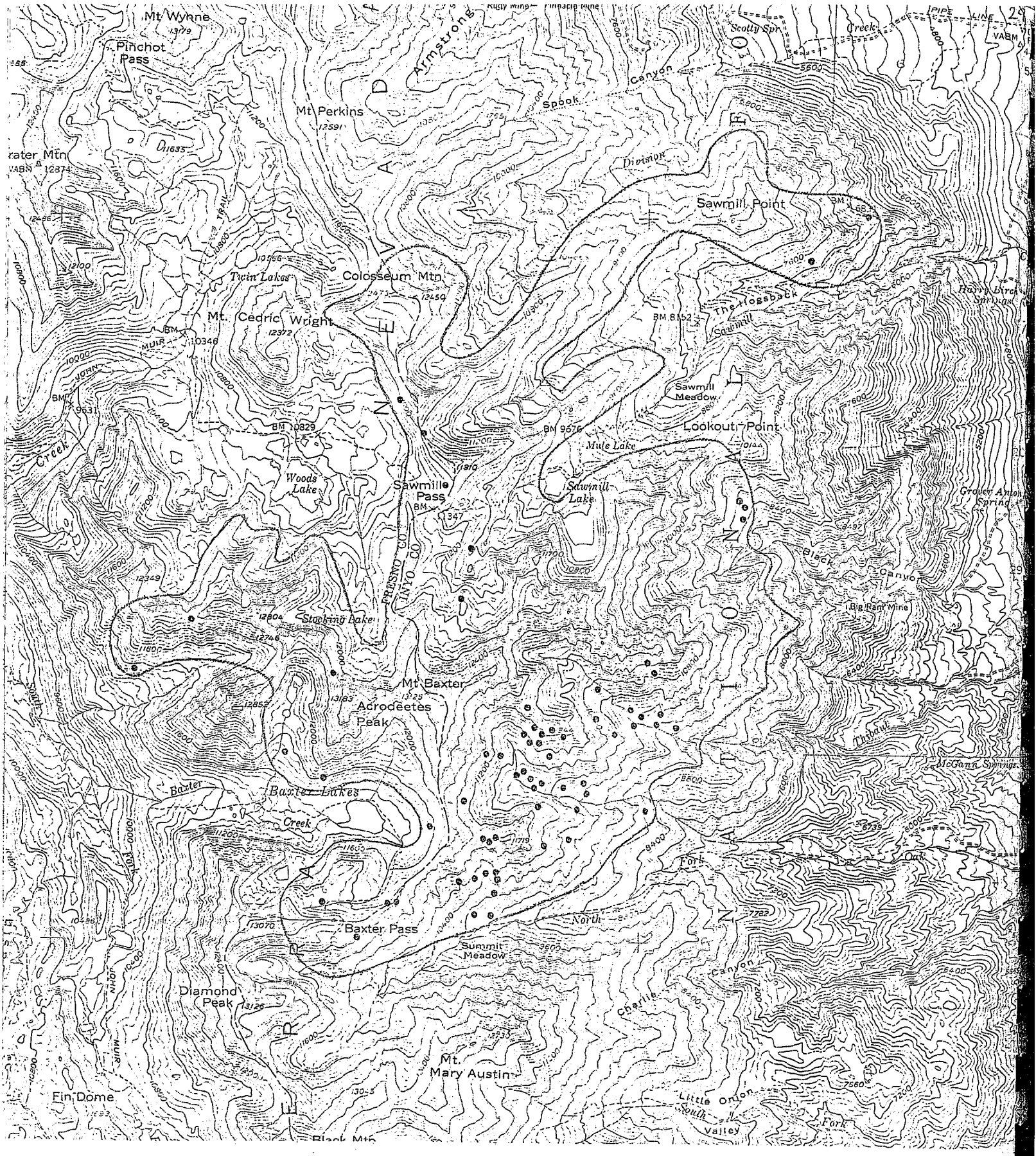

Figure 7 - Sightings and range boundaries of Baxter herd sheep in fall. Sightings span the period from October 10 until the sheep appear on the winter range. The range boundary represents the later fall period beginning about mid November.

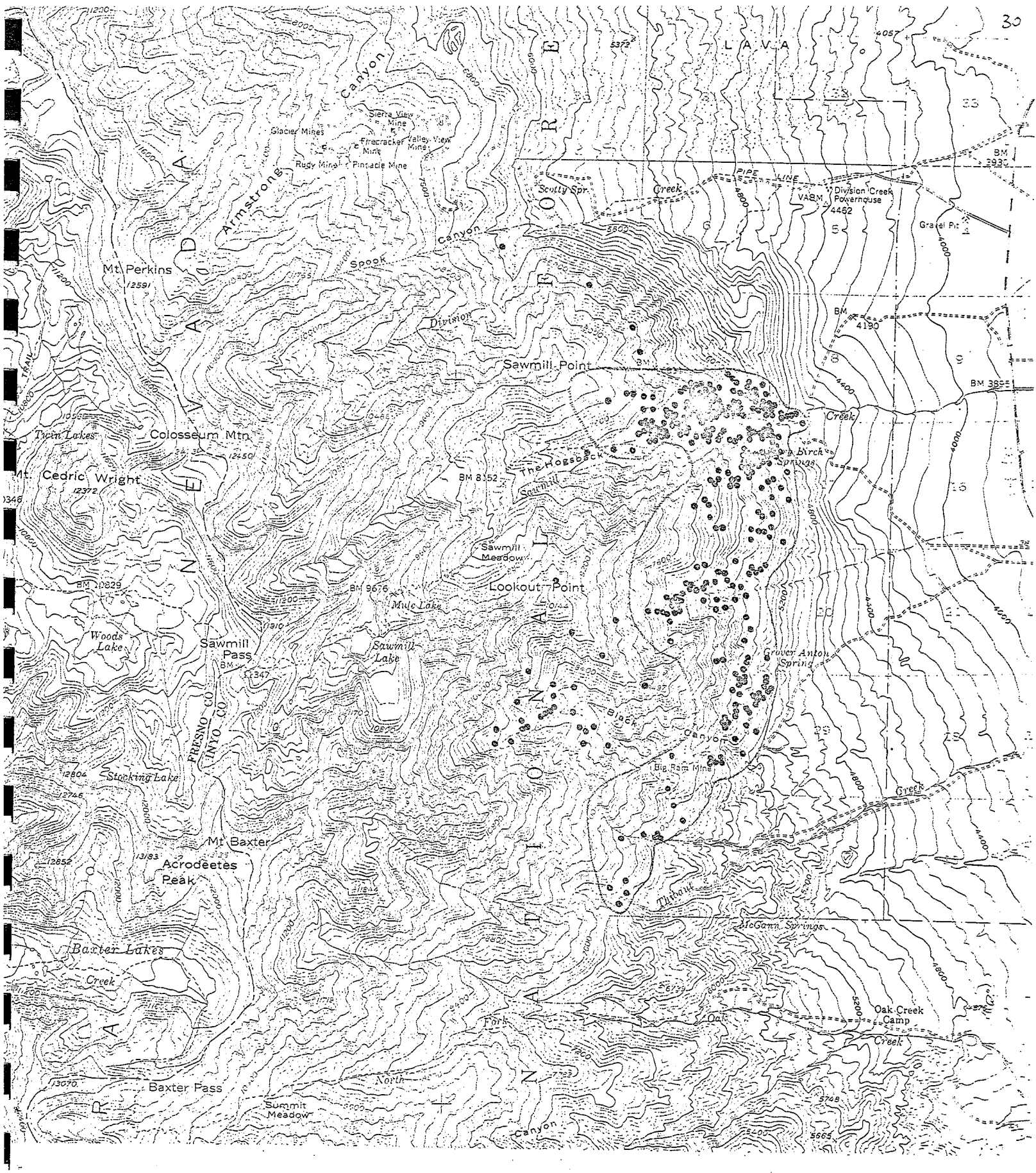

Figure 8 - Winter and Spring sightings and winter range boundary of sheep in the Baxter herd.

The summer range of ewe-lamb use outlined on Figure 4 is based on my observations and those of Garcia (1979) who plotted areas of high country use based on pellet group density. The plateau above Mahogany Flat is included in the ewe-lamb range on the basis of Garcia's (1979) report of ewe-lamb sign there. I found this to be poor habitat due to scant vegetation, with sparse bighorn sign which I interpreted as occasional ram use. The one sighting I have made on the west side of Williamson Creek was a lone two year old ram.

Both the Shepherds Creek and Georges Creek drainages appear presently to act as barriers that ewe-lamb groups will not cross in summer. I have checked upper Georges Creek numerous times in summer without finding evidence of sheep use despite excellent meadows in rocky terrain. The one sighting made there was in fall, as were the sightings of Jones (1949). I interpret this area (dashed line on the map) as presently receiving only fall use. Garcia (1979) made the same suggestion based on the large size of lamb pellets found there. This conclusion remains tentative and warrants further investigation.

The other dashed lines in Figure 4 delineate areas of use between summer and winter ranges, including lambing ranges. I have observed new-born lambs on the south-facing slopes of South Bairs Creek above the winter range. Pellets from very young lambs found in lower Williamson Creek indicate that it too, is a lambing range. Whether any lambing occurs in Georges Creek is unknown. Excellent lambing habitat exists there in the first south-facing side canyon. North Bairs Creek offers less in the way of lambing habitat than the other canyons due to extensive pinyon woodland. However, the top of North Bairs Creek has been found to receive use by ewe-lamb groups as early as June 1.

Ram summer range of the Williamson herd is located north of Shepherds Creek in the upper portion of the Symmes Creek drainage and the top of the south fork of Pinyon Creek. A sighting in 1977 by Vern Clevenger, (pers comm.) of a ram just east of Mt. Genevra and one of an unidentified bighorn (presumably ram) in the same area in 1976 by Bob Kenan (pers. comm.) indicate at least occasional ram movement across the crest. In general, little is known of the activities of the Williamson herd rams in summer.

Garcia (1979) found only very sparse sign south of the north fork of Georges Creek, and noted that it was not always clear whether bighorn or deer were responsible, particularly in the large south tributary of Georges Creek. It is probable that any bighorn use in this southern section is only from occasional rams. This represents a substantial decrease in the range of summer use since Jones' study in 1948. Bighorn (including ewe-lamb groups) and their sign were apparently common along the crest above Georges Creek in the 1940's (Blake 1949, Clyde 1971b, Jones 1949). This appears to no longer be the case, although my sighting of a mixed group at the top of Georges Creek in November of 1975 indicated that bighorn still occasionally use this area.

The area from Mt. Tyndall to Junction Pass, Mt. Keith and Forrester Pass apparently also previously received summer use by ewe-lamb groups

(Blake 1942, 1949, Jones 1949). Further investigation of this is warranted, as this is also apparently no longer the case. The files of Sequoia and Kings Canyon National Parks contain a report of a ewe-lamb group in the Wright Lakes area as recently as 1973. This area has not been investigated by Garcia or myself.

Jones (1950) considered sheep use in the Mt. Russell-Mt. Carillon area to be from the Williamson herd. All past sightings in this area have been of rams (these are reported later in Table 9). Considering that present high country ram use by the Williamson herd is north of Mt. Williamson, it is probable that the Mt. Russell-Mt Carillon area represented the northern boundary of use by the Langley herd.

Baxter Herd

The separation between sexes in summer apparent in the Williamson herd also exists in the Baxter herd (Figures 5 and 6), where the split is essentially between alpine and subalpine, with rams in the latter.

Ewe-lamb groups are strictly tied to slopes with safe rocks. Rams appear to have little restriction on their movement, and will commonly cross wide glaciated canyons that bound the summer range of ewe-lamb groups (Figure 6). Consequently, the Baxter herd rams cover a considerable area in summer, making it necessary to base the summer range map for this sex on reported sightings to a large extent. Lone rams or small groups must occasionally stray out of the boundaries drawn in Figure 5, as evidenced by a sighting reported from Muro Blanco (Sequoia & Kings Canyon National Park files) and a skull found in 1978 at the base of Castle Domes above Woods Creek. However, one can probably expect to find 95% or more of the rams in the herd within these boundaries in summer.

The summer range of the rams lies essentially entirely west of the Sierran crest, but the range on Figure 5 is drawn to show their migration corridor over Sawmill Pass as well. The Sawmill Pass - Colosseum Mountain ridge appears to serve as a holding area for the rams in June and early July prior to crossing to the west side.

It is my impression that there is little ewe-lamb use in the area immediately north and east of Sawmill Pass in summer. It is nevertheless included as part of the range drawn in Figure 6 due to a sighting of three ewes and three new lambs made in the north fork of Sawmill Canyon by Elliott and Garcia in May of 1976. Some uncertainty also exists regarding the exact boundary of ewe-lamb use at the north end of the ridge system lying south and west of the Woods Lake Basin. Likewise, the extent to which ewe-lamb groups cross over the east face of Dragon Peak to Mt. Gould and its eastern ridges above Golden Trout Lake and Onion Valley has not been investigated. No sign could be found in the high lake basin west of Dragon Peak.

As fall progresses, the ewe-lamb range shifts north and somewhat east, placing it largely immediately west of the winter range. Rams join the ewe-lamb groups beginning in October. Bighorn use increases noticably in the Sawmill Pass area during fall, and drops off south of the north fork of Oak Creek. Miners working at the Rex Montis Mine on Kearsarge Peak

stated in 1975 (pers. comm.) that bighorn were commonly seen on the rocks above the mine during summer, ending in the beginning of October. A sighting here by Ernie DeGraff (Forest Service files, Bishop) at the beginning of November indicates occasional use later in fall. Bighorn use continues west of the crest in fall, but tends to concentrate east of the crest following fall snow storms, spreading back west as the snow from these storms melts back. The sightings plotted in Figure 7 are from October 10 on (except for one late September sighting low on the north side of Sawmill Creek), but the range boundary is intended to reflect the distribution a month later; the range boundaries during the fall transition period are not represented.

The first large winter snow storm forces the bighorn down the east side of the Sierra to winter range areas (Figure 8). This usually takes place in the second half of December, but is known to occur as early as the second half of November. In the drought year of 1976, bighorn did not appear on the winter range until mid-February.

The Baxter winter range has been divided into four wintering areas. From Thibaut Creek to Black Canyon mouth is known as the Thibaut winter range. The Black Canyon winter range lies immediately north of Black Canyon mouth for about one mile to the break in the cliffs constituting the mouth of Sand Canyon. From there north to Sawmill Creek is the Sand Mountain winter range, including Sand Canyon, and north of Sawmill Creek is the Sawmill winter range.

Following the first winter snow storm, bighorn appear on all four winter ranges, but with initial concentrations in the Thibaut Canyon area and on the ridge north of Sawmill Creek.

The Thibaut winter range is about 1,000 feet higher and snowier than the Black Canyon range. Most bighorn leave the Thibaut area and slowly move north to the Black Canyon range where there is less or no snow, and better visibility. Many move further north onto Sand Mountain.

Sawmill Creek is thickly choked with water birch and willow along its entire length in the winter range except for one spot outside the mouth of the canyon, which along with the Hogsback back in the canyon (see Figure 8) is the only location where sheep might be expected to cross between the Sand Mountain and Sawmill wintering areas. There is no indication of sheep crossing at either location. It seems safe to assume there is very little or no movement across Sawmill Creek during winter, which is convenient for census purposes.

Between Sawmill Creek and Thibaut Creek the bighorn distribution stabilizes three to four weeks after their arrival on the winter range. Shifts continue, but are mostly within each wintering area. In the drought year of 1977, about 25 bighorn continued to use Thibaut winter range throughout winter. No use was evident in mid-winter of 1978, presumably due to heavy snowfall. In the spring, as vegetation green up rises in elevation, some reoccupation of winter range areas south of Black Canyon probably occurs. It is also at this time that sheep occasionally appear near Division Creek.

The distribution of sightings plotted in Figure 8 does not necessarily represent the relative densities of sheep in the different areas of the Baxter winter range, but rather reflects differentials in time spent investigating different areas, as well as in average group sizes of the sheep in the different areas. In 1977, the population distribution during the most complete census (early April) was 14% on the Thibaut range, 17% on the Black Canyon range, 32% on the Sand Mountain range and 36% on the Sawmill range. In February of 1978 these respective percentages were 0, 17, 55, and 29. The Sand Mountain and Sawmill winter range areas clearly support the majority of the Baxter herd in winter.

The winter range boundary outlined on Figure 8 is intended to cover the winter period through the end of March. In April, most pregnant ewes, followed by lambs of the previous season and yearlings leave the winter range areas south of Sawmill Creek to lamb in the rocks of upper Black Canyon and possibly Thibaut Canyon (see sightings plotted in Black Canyon in Figure 8). Most rams, and some barren ewes, yearlings, and lambs remain in the winter range past the middle of May before moving up. Not all ewes lamb above the winter range. The Sawmill winter range is sufficiently rocky that a large percentage of the ewes there do not leave the winter range until their lambs are two to three weeks old. Ten lambs were born in the Sawmill winter range in 1977 and some ewes remained there that year as late as June 8. In 1976 and 1978 a total of three ewes with new lambs were observed in the rugged rocks on the south side of Sawmill Creek. Thus a few of the Sand Mountain ewes also remain at low elevation to lamb. It is not known where the remaining Sawmill ewes go to lamb, nor whether any lambing occurs in Thibaut Canyon.

2) Herd Sizes and Composition

Deep snow and spring green-up both precipitate the grouping of the Baxter herd into large groups distributed low on the winter range. Under such conditions it is possible to count and classify most of the sheep in the herd. Table 5 summarizes census results from 1977 and 1978. Two population figures are given in Table 5 depending on the assumption regarding sheep movement across Sawmill Creek. The "Minimum" figure is based on counts of Sawmill taken at the time of the census, while the "Probable minimum" figure is based on the maximum counted in Sawmill Canyon during the winter. The reason for the two different figures is that most of the Sawmill winter range is censused from high on the south canyon wall, from which some bighorn are frequently hidden from view behind rocks.

Based on the 1978 census results in Table 5, it is apparent that some sheep were missed in the 1977 Baxter herd census. Considering the "Probable minimum" totals, at least five females and four lambs had to have been missed to make the 1978 ewe and yearling totals; additional bighorn would have to have been missed to account for any mortality between years. It is thus impossible to calculate a precise rate of population increase between years, but based on these data, the increase rate probably lies in the range of 10 to 15%.

Table 5 - Winter census results from 1977 and 1978 for the Baxter and William bighorn herds in the Sierra Nevada

Year/Herd	Ewes	Yearling Ewes	Lambs	Yearling Rams	Rams	Total
1977						
Baxter:						
Minimum	62	15	39	13	38	167
Probable minimum	62	16	39	14	42	173
Williamson:						
Minimum	9	1	5	3	3	21
1978						
Baxter:						
Minimum	78	22	35	16	50	201
Probable minimum	83	25	38	18	50	214
Williamson:						
Minimum	13	1	5	4	7	30

No conditions perticularly optimal for censusing the Williamson herd were found. It has been necessary simply to keep track of different groups of sheep until every group is found. The higher elevation of the Williamson winter range has been beneficial to census attempts due to the ease of finding bighorn by tracking them in the snow. The low 1977 Williamson herd minimum total reflects the small amount of time spent there that season. In contrast, the 1978 total for that herd results from a concerted effort to find every sheep, and is believed to represent the actual total for the herd.

Table 6 summarizes herd composition since 1974. Numerous measures are given for comparative purposes. The ratio of lambs per adult plus yearling ewes is useful for comparison with Table 4. Wherever possible, the compositions reported in Table 6 are based on census totals rather than on samplings, and thus closely represent true population compositions in those cases.

It is evident that lamb production in the Baxter herd was very high from 1974 through 1977. Based on percentages of ewes that were yearlings the previous year, 90 to 95% of the Baxter herd ewes of reproductive age (3 years and older) were bearing lambs. Recruitment of these lamb crops has also been high, as measured by winter ratios (Table 6). Table 4 suggests that there have been other years of high reproduction and recruitment in recent years. With recruitment levels this high, the Baxter herd can only be increasing, as the difference between 1978 and 1977 census totals (Table 5) suggests.

Figure 9 is a plotting of maximum numbers of sheep seen in the Baxter herd in a single day by various investigators over the past 13 years. Most of these data are from days following large winter storms. Although a hand-drawn curve has been fitted to the points in Figure 9, no attempt is made to derive a population increase rate from these data due to a presumed variation in abilities and efforts expended by the different investigators. The relationship between the true population total and this index is not known; it may not be linear. Nevertheless, Figure 9 illustrates a clear upward trend in the Baxter herd over at least the past six years. This is also suggested by a completely pyrimidal age structure obtained by aging all the Baxter herd rams in 1977 by horn rings (Geist 1966).

Insufficient data exist to clearly assess any population trend in the Williamson herd. Recent winter lamb:ewe ratios have been consistently lower than in the Baxter herd (Table 5) suggesting that substantially less, if any population increase has occurred.

Reproduction in the Baxter herd dropped radically in 1978 to 30 lambs per 100 ewes, while that of the Williamson herd remained at its seemingly usual mid-range level (Table 6). A couple of hypotheses as to the cause of the change are worth mention. First, the change may simply reflect a density-dependent response of an increasing population that is approaching or has reached the limits of a limited resource. Secondly, the 1978 reproduction may reflect poor nutrition due to 1) early appearance of fall phenology of forage in the high country in 1977 due to

Table 6 - Herd Composition

Herd/Year	Season	Lambs per Adult Ewe	Yearlings per adult ewe	Lambs per Yearling + Adult Ewes	Lambs per Adult Ewes + all Yearlings	Sample Size (Ewes + Yearlings)
Baxter:						
1974	Summer				.62	29
1975	Summer	.72	.52	.59	.46	90
1976	Winter	.55	.29	.46	.40	246
	Summer	.75	.98	.52	.38	111
1977	Winter*	.63	.48	.50	.42	92
	Summer	.72	.74	.49	.40	114
1978	Winter*	.46	.52	.35	.30	126
	Summer	.30	.36	.26	.22	87
Williamson:						
1976	Winter	.31	.15		.27	15
1977	Winter	.40	.24	.36	.32	31
	Summer*	.54	.27	.50	.43	14
1978	Winter*	.38	.38	.36	.28	18
	Summer	.46	.52	.35	.31	88

*Based on a census or other count in which no animal duplication is possible

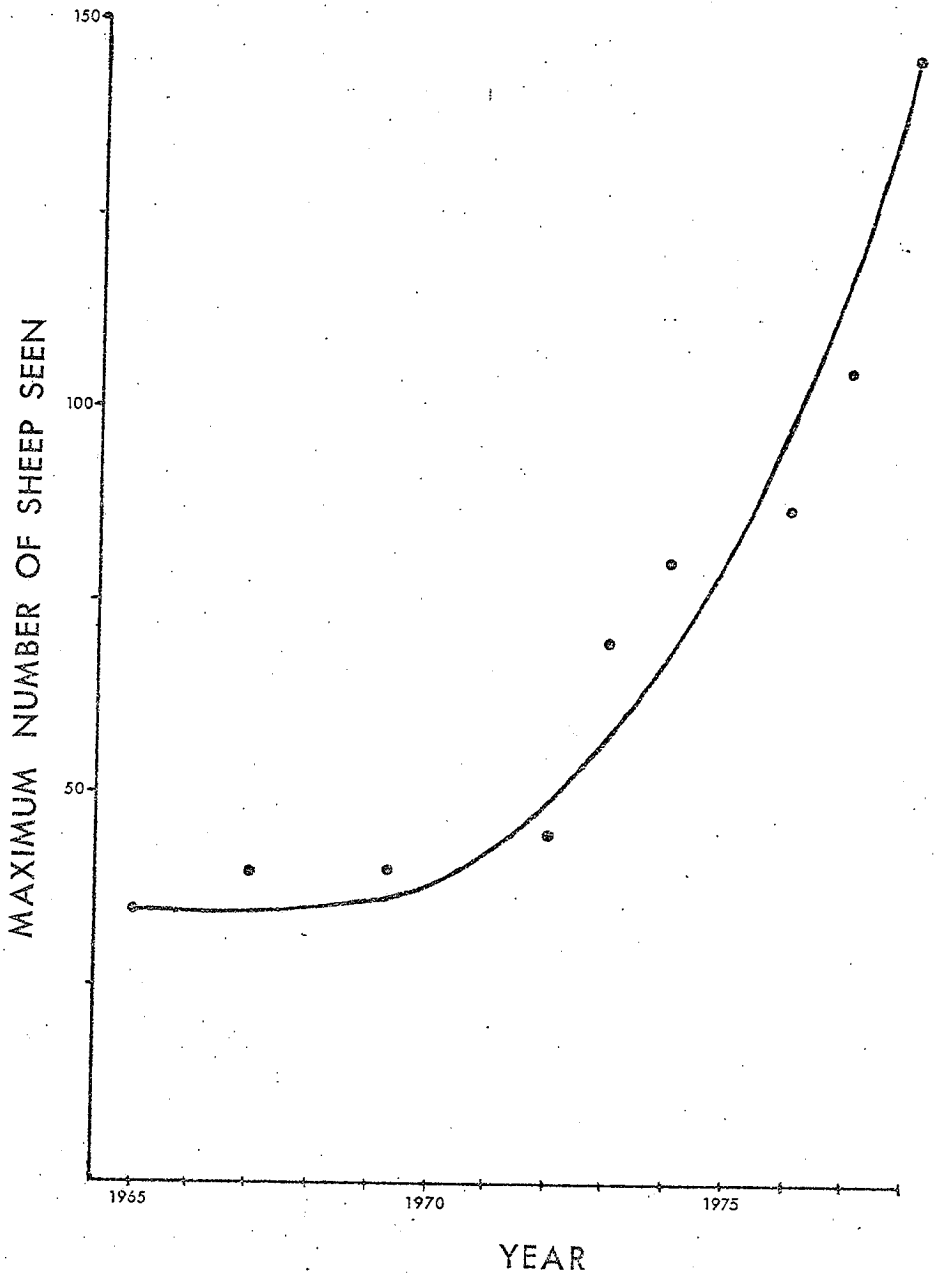

Figure 9 - Maximum numbers of sheep seen on a single day in the Baxter herd winter range by five different investigators between 1965 and 1978.

drought, and/or 2) the low quality of Stipa speciosa in early winter of 1978 as a result of lack of fall rains in 1977. In previous years of the study, Stipa speciosa was already green when the sheep appeared on the winter range. This species makes up the main bulk of the winter diet.

3) Disease

Disease investigations have consisted of analyses of feces by flotation and baermannization using fecal samples collected fresh from bighorn. These analyses have determined that the bighorn in the Sierra Nevada carry a minimum of three internal parasites - threadnecked worms (Nematodirus spathiger), lungworms (Protostrongylus sp.), and pinworms (Skrjabinema ovis).

One adult pinworm was encountered by chance in a fecal pellet of a Williamson herd sheep. Due to the life cycle of pinworms, there is no way of assessing the frequency and level of infection of this parasite. Pinworms are in general, largely non-pathogenic.

Lungworm larval densities in fecal samples exhibited a winter peak and subsequent reduction to near-zero levels in both herds while sheep are in the high country. I have interpreted this to mean that the winter range is the site of infection. Table 7 summarizes winter lungworm data for both herds. The three pellet size classes correspond to the lamb, yearling, and adult age classes, although the latter two are not completely distinct on a pellet weight basis. Pairwise comparisons between herds for each pellet weight class have found them all to be significantly different ($P < .001$ in each case). The level of infection of the Williamson herd is approximately 10 times that of the Baxter herd for adults and 50 times for lambs. Pellets from Baxter herd lambs in summer have not yielded any lungworm larvae, whereas the smallest pellets (from approximately three week old lambs) that could be obtained from Williamson herd lambs already contained Protostrongylus larvae. The most likely explanation for this is prenatal infection, a phenomenon well-decumented elsewhere in bighorn (Forrester and Senger 1964, Hibler et al. 1972, Hibler et al. 1974).

While the differences in lungworm infections between the Baxter and Williamson herds appear great, both are quite low when compared with values reported for other bighorn herds in North America. For instances, Forrester and Senger (1964) report average values ranging from less than 10 to 970 larvae per gram dry feces for 10 Rocky Mountain bighorn herds in Montana, and Uhazy et al. (1973) report average values ranging from 439 to 2,375 larvae per gram dry feces for 6 Rocky Mountain bighorn herds in Canada. In this regard it is noteworthy that clinical signs of lungworm infection and its associated pneumonia (see Forrester 1971) are not apparent in either herd in the Sierra Nevada.

Nematodirus and lungworm larval counts were made simultaneously. Fecal samples were stored six weeks or more after which the Nematodirus eggs have embryonated and the larvae emerge upon soaking along with lungworm larvae. The average densities of Nematodirus found were 2.6 larvae per gram dry feces (n=49) in the Baxter herd and 13.2 (n=47) in the Williamson herd. These two values are significantly different ($P < .001$); both

Table 7 - Winter-spring lungworm (Protostrongylus sp.) levels in the Baxter and Williamson herds. The three pellet size classes correspond to lamb, yearling, and adult. Values are number of larvae per gram dry feces. Analysis was by the Baermann method using air-dried pellets broken in half. All samples were collected fresh.

NUMBER OF LARVAE/GM. DRY FECES

Herd/Pellet Size Class	Mean	Range	S. D.	Sample Size
Baxter:				
≤.15 gm/pellet	1.8	0-6.8	3.325	4
.15-.20 gm/pellet	1.0	0-3.5	1.281	11
≥.20 gm/pellet	15.9	0-59.6	12.956	32
Williamson:				
≤.15 g,/pellet	95.5	4.4-428.0	110.430	16
.15-.20 gm/pellet	124.5	20.5-344.0	97.312	22
≥.20 gm/pellet	157.4	25.8-503.3	103.788	30

represent insignificant infections. In domestic sheep, 50 to 100 Nematodirus per gram wet feces represents a light infection defined as probably having "little or no effect on health or productivity" (Unpublished mimeo, University of California, Davis, School of Veterinary Medicine).

4) Competition

Interspecific competition requires the use by more than one species of a resource in short supply that is a necessary resource for at least one of the species. This may occur as interference competition, where one species physically denies another species access to a resource, or, more commonly, as exploitation competition, where access is uncontrolled. This latter type of competition has been investigated on bighorn winter ranges in the Sierra Nevada.

Ranges of mule deer and tule elk both overlap the bighorn winter range, providing the potential for competition. This overlap occurs in the following way. Mule deer commonly migrate out of the high country in fall six to eight weeks before winter storms force the bighorn down. Many of the deer then spend the fall and early winter at intermediate elevation "holding areas" above the floor of Owens Valley. Sand Mountain, Sand Canyon, and the Black Canyon range have all been found to be such deer ranges. When snows force the bighorn down, they share their winter range with deer until about mid February, at which time the deer move down onto the alluvial fans of the valley floor. Deer spend the remainder of winter there, although occasionally moving onto the lower slopes of the Sand Mountain, Sawmill, and Black Canyon bighorn winter ranges. Beginning about the first of May, deer again occupy the Sand Mountain bighorn range as they move up following spring vegetation green-up. At this time it is mostly rams that remain on the Sand Mountain range. Bighorn and deer readily mix while feeding. Thus no interference competition is apparent.

The first appearance of elk on the bighorn winter range also coincides with spring green-up. While the deer move up in elevation as spring progresses, the elk continue to use the Sand Mountain and Black Canyon ranges. This is particularly true of the latter, due to the availability of water, which is entirely lacking in Sand Canyon and on Sand Mountain. The duration of summer elk use of these ranges has not been determined. Curtis et al. (1977) note that, unlike the other elk herds in Owens Valley, the Goodale herd does not gather at low elevation during the rut, but remains spread out in relatively small groups. Thus some use of the bighorn winter range may continue through summer and possibly into fall. No elk have been observed in the bighorn winter ranges during winter.

In the Williamson herd winter range there is no sign of use by the Mt. Whitney elk herd. Thus the only potential competition would involve deer.

The utilization of two forage species, desert needlegrass (Stipa speciosa) and bitterbrush (Purshia glandulosa and hybrids with P. tridentata) has

been quantified to determine whether either has been in short supply. Needlegrass makes up the bulk of the winter diet of the bighorn while bitterbrush is of lesser importance. Elk feed on both species to a high degree (McCullough 1969, Curtis et al. 1977). Bitterbrush is an important forage species of the deer on the ranges under discussion (Jones 1954, McCullough 1969), while needlegrass may receive a small amount of spring use by deer (Jones 1954).

Green growth of needlegrass dries up in late spring or early summer, depending on the occurrence of spring rains and the onset of summer heat. Fall rain followed by a period of warm weather will initiate the next season's green growth prior to winter. Alternatively, this growth begins sometime in winter or spring after winter precipitation is followed by warm weather. Consequently, the timing of the appearance of green growth on needlegrass can vary greatly from year to year. Competition with elk for needlegrass would involve the dry growth of the previous year, which the sheep must eat first regardless of whether new green growth exists at its base. Such competition would occur if elk were to eat a sufficient quantity of needlegrass during the previous spring and summer that an inadequate supply is left to sustain the bighorn until sufficient new growth exists.

Quantification of needlegrass utilization has been carried out in the spring by noting whether or not clumps received grazing of the previous year's growth, and by measuring the height of the grass. In this way, the percent of plants grazed was measured as well as the percent of the biomass removed, calculated simply as:

$$\% \text{ Utilization} = \% \text{ Plants Grazed} \times \frac{\bar{X}u - \bar{X}g}{\bar{X}u}$$

Where $\bar{X}u$ is the average height of ungrazed clumps, and $\bar{X}g$ is the average height of grazed clumps.

The growth pattern of bitterbrush is much simpler than needlegrass, in that it puts out new leader growth only in the spring for a period depending on moisture availability. Bitterbrush utilization was quantified following winter use, by counting browsed and unbrowsed leaders on one or two randomly-chosen branches per bush.

The data on utilization of needlegrass and bitterbrush are summarized in Table 8 and locations of the measurements are plotted in Figure 10. Total bitterbrush utilization has generally been quite low, and has never exceeded that 60% that Hormay (1943) considered the maximum that plants could withstand without loss of vigor. The relatively high bitterbrush utilization recorded on Sand Mountain in 1976 (Table 8) probably reflects the prolonged use of that area by deer due to the very late arrival of the first winter storms in February. It seems apparent that bitterbrush is not in short supply in the bighorn winter ranges and is thus not a resource over which competition exists.

With one exception, utilization of needlegrass has been found to be heavy only in the Sawmill Canyon range, on which there is no deer or elk

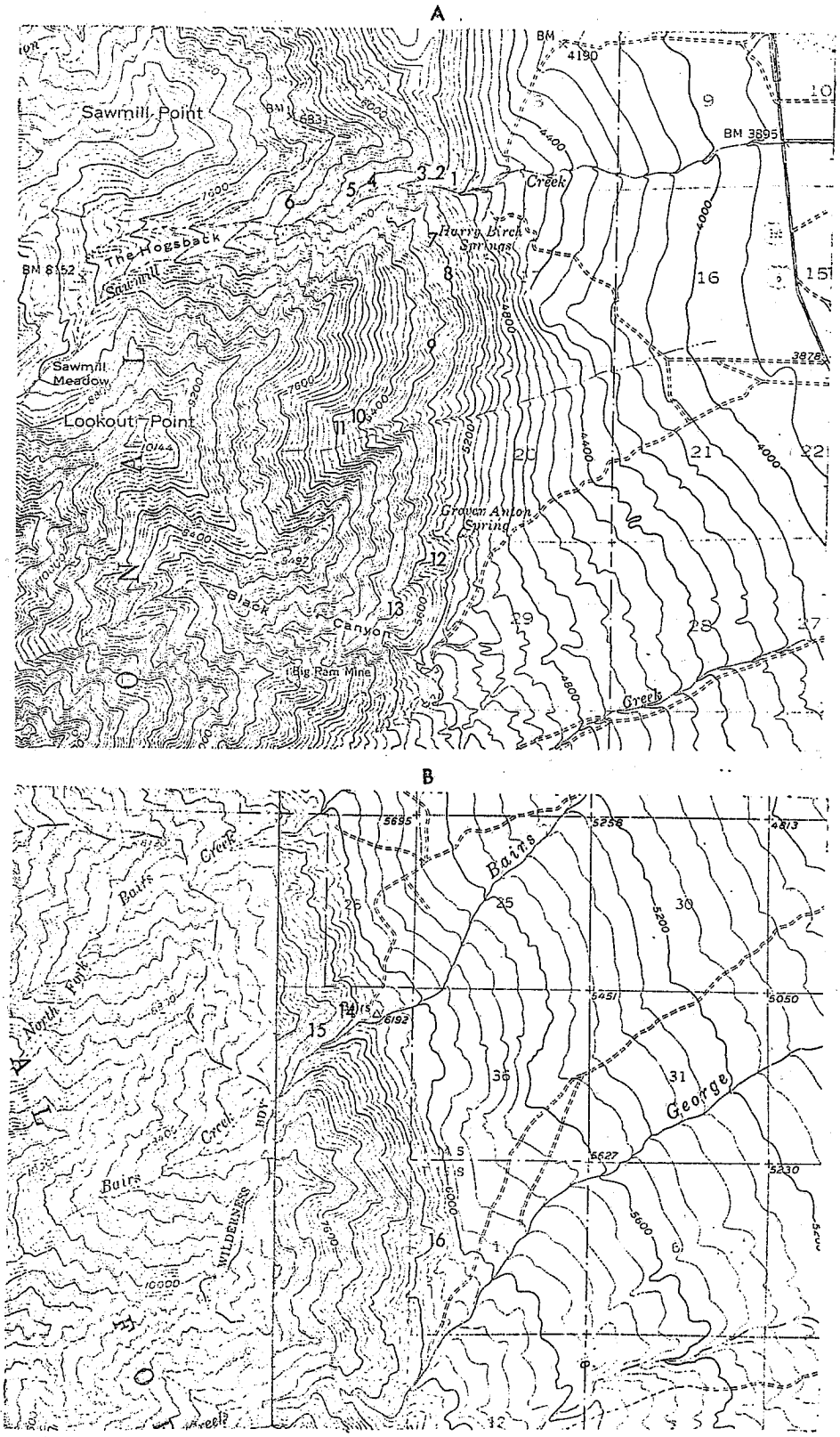

Figure 10 - Locations of forage utilization measurements on bighorn winter ranges in the Sierra Nevada. Map A is the Baxter herd winter range and Map B is the Williamson herd winter range.

Table 8 - Summary of desert needlegrass and bitterbrush utilization measurements on bighorn winter ranges in the Sierra Nevada. Location numbers are plotted on Figure 10

Map Location, Year	Description	Forage Species	% Plants or Leaders Grazed	% Utilization	Sample Size (Plants or Leaders)
1976					
2		Needlegrass	92		40
		Bitterbrush	11		159
3		Needlegrass	84		25
		Bitterbrush	8		400
9		Bitterbrush	53		365
1977					
1	≤10 yds. from rocks	Needlegrass	84	63	84
	20-30 yds. from rocks	Needlegrass	28	15	54
	40-60 yds. from rocks	Needlegrass	12	9	57
2		Needlegrass	79	59	105
		Bitterbrush	27		698
3		Needlegrass	82	73	57
		Bitterbrush	26		1,106
5		Needlegrass	81	68	127
		Bitterbrush	16		976
6		Needlegrass	90	82	89
		Bitterbrush	10		901
9		Needlegrass	54	35	127
		Bitterbrush	18		1,319
10		Needlegrass	48	32	83
		Bitterbrush	5		927
11		Needlegrass	17	13	46
		Bitterbrush	36		912
12		Needlegrass	54	26	109
		Bitterbrush	30		1,108
14		Needlegrass	39	28	107
		Bitterbrush	6		945
15		Needlegrass	29	20	113
		Bitterbrush	1		922

Table 8 (continued)

Map Location, Year	Description	Forage Species	% Plants or Leaders Grazed	% Utilization	Sample Size (Plants or Leaders)
1978					
1	≤ 100 yds. from rocks	Needlegrass	77	62	132
4		Needlegrass	94	92	171
5		Needlegrass	85	78	121
6		Needlegrass	62	60	155
7		Needlegrass	85	80	158
8		Needlegrass	54	43	124
9		Needlegrass	57	47	141
12		Needlegrass	76	48	115
13		Needlegrass	47	37	103
16		Needlegrass	30	26	132

use during the year. The exception is the sand chute above Harry Birch Springs (location 7 in Figure 10). Considerable bighorn use was observed there in 1978, resulting in an overall utilization of 80% of the needlegrass (Table 8). Elk cannot be implicated in this relatively high utilization, as this site is used by elk only as they move up and down Sand Mountain, rather than as a feeding area.

Overall, neither the Sand Mountain nor the Black Canyon ranges have exhibited a shortage of needlegrass during the years of this study. Under different environmental circumstances a shortage may result, leading to a situation of competition. Immediately prior to the appearance of the bighorn on the winter range in December of 1977, the needlegrass utilization was measured at location 12 (Figure 10) on the Black Canyon range and found to be 34%, which increased only to 48% by the end of winter. Under circumstances of poor needlegrass production, these percentages will increase, and may result in a shortage where production is sufficiently low, and/or bighorn utilization increases due to deep snow preventing them from exploiting the Sand Mountain range. Competition is not likely to occur on Sand Mountain or in Sand Canyon since most elk use there occurs in the higher areas, which are normally snow-covered for much of the winter, and thus receive little sheep use.

During the spring of 1976 and 1977, Forest Service horses and mules were pastured at the base of the Baxter herd winter range on an experimental basis. The distribution of these animals was recorded to determine if any overlap of the bighorn winter range occurred. A range overlap occurred at the mouth of Sawmill Canyon. This is the lowest elevation on the winter range, and bighorn on both sides of the canyon regularly make forays out from the rocks here in late winter and early spring to feed on the first green vegetation. The range overlap here was slight during the two years that the stock were present, but in 1978, when stock were absent, the sheep were observed to move considerably further out from the rocks. An untested suggestion would be that the presence of the livestock in the area the previous years affected the behavior of the bighorn in this respect. Minimally, this meant a considerably greater range overlap than was initially apparent.

The horses and mules were noted to feed almost exclusively on green desert needlegrass and cheatgrass (Bromus tectorum), both of which are among the species fed on by the sheep in these locations. That the bighorn will move so far from the rocks (up to 400 yds.) in search of early green vegetation suggests that this is a special and limited resource. The livestock grazed the area heavily. The potential for resource competition (as well as parasite transmission) appears to exist if livestock are permitted to graze the mouth of Sawmill Canyon in the future.

5) Predation

Two predators, the mountain lion and the coyote affect the bighorn in the Sierra Nevada. Mountain lions hunt mostly deer, taking other prey species largely where they occupy deer ranges (Russell 1978). Lion sign

is abundant on bighorn winter ranges in the Sierra, most of which also receive considerable deer use. Except for part of the ram range, high country bighorn ranges have little overlap with those of deer. As would be expected, lion sign has been notably absent in summer bighorn ranges.

Mountain lion tracks and scats are commonly encountered in the Baxter herd winter range, and the droppings occasionally contain sheep hair. In 1978, the remains of two clearly lion-killed sheep were found, one a yearling male killed on Sawmill Ridge, and the other a ewe at the mouth of Shepherds Creek in the Williamson range.

The number of sheep killed by lions in the Baxter herd each year is probably of little significance in relation to the number recruited due to the large population size. In the Williamson herd this may not be the case. The ewe killed in 1978 was one of the 13 ewes in the herd (Table 5), thus represents an 8% reduction in the ewe population. More significant is the fact that only one female had been recruited the previous year. This single killing prevented any increase in the ewe population. Lion predation in the Williamson winter range is potentially a major source of mortility due to the small population size. The Williamson herd is also more vulnerable to lion predation than the Baxter herd because the abundant pinyon pines in their winter range offer more hiding places for lions, whereas the Baxter winter range is entirely open except for parts of the Thibaut range.

Coyotes are widespread throughout the sheep ranges at all times of year, traversing occasionally even some of the more rugged talus slopes. Hicks (pers. comm.) observed a coyote crossing Baxter Pass in July of 1976. Adult sheep are probably not often vulnerable to coyote predation due to their size and defensive behavior (Berger 1978). Subadult sheep, particularly lambs during their first half year or so, though, are certainly vulnerable. It is probably this vulnerability and the abundance of coyotes in the high country that has resulted in ewe-lamb groups in summer religiously staying on safe rocky slopes, while rams roam quite a distance from rocks. I have encountered no evidence of coyotes killing sheep in the Sierra Nevada.

6) Human Disturbance

Bighorn reactions to encounters with the investigator have been classified into five ranked categories varying from unconcerned to an immediate running retreat. These reactions have then been analyzed as to the influence of various parameters. The most important are season, type of sheep group (ram vs. ewe-lamb or mixed), distance from the investigator, distance from safe rocks, and relative elevational position.

In the Baxter herd, ram groups exhibit a mild reaction to humans that does not appear to change seasonally. During winter it is not possible to distinguish reactions of groups of different composition. With the separation of the sexes in late spring and the onset of lambing, a radical change occurs in the reactions of ewe-lamb groups, which take flight at substantially greater distances than during winter. This be-

havior continues until late fall when the sheep reappear on the winter range after the lambs have been weaned.

If disturbance from humans is acting in an adverse way on the population, ewe-lamb groups in summer would be most likely to be affected. Not only do they show the greatest alarm to humans in summer, but it is during that season that they contact the most people.

Two hypotheses regarding disturbance of ewe-lamb groups have been tested. The first suggests that the energy expended in flight and the nutrients lost through the disruption of feeding activities by regular human encounters significantly affect the reproductive performance of the ewes. The second hypothesis suggests that sheep groups are abandoning the use of areas due to repeated human encounters.

Hicks (1977) and Elder (1977) gathered information pertinent to these hypotheses. It was found that on Baxter Pass, where ewe-lamb groups most often encounter hikers (half of the sheep groups encountered hikers), no permanent displacement was occurring. The high reproductive performance during 1974 through 1977 indicates these encounters are not adversely affecting reproductive success. Consequently, it has been concluded that under the present regime of human use, human disturbance is not adversely affecting the Baxter herd (Wehausen et al. 1977).

Dunaway's (1971b) hypothesis on human disturbance was based on the apparent disappearance of the Convict Creek, Birch Mountain and Mt. Langley herds since Jones' (1950) study in 1948. The above conclusion relates only to the present situation in the Mt. Baxter herd and is in no way a test of Dunaway's (1971b) hypothesis. In fact, the correlation between increase in human use and herd disappearance, on which his hypothesis was based implies little or no significant disturbance from humans in the two existing herds.

Three factors are probably important in determining the significance of human disturbance to bighorn herds, as they affect the reactions the bighorn exhibit to human encounters. First is the level of human occupation and its related frequency of human-bighorn encounters. Second is the influence of the nature of human encounters in the past. Wary behavior developed during past episodes of indiscriminate hunting may persist for many generations as learned behavior, and may change only slowly through frequent human encounters of a benign nature. Third is the comfort with which members of a bighorn herd live in any particular habitat. Bighorn forced into forested and/or marginally rocky terrain by snow or other circumstances are likely to be more readily disturbed during these periods. Group size can also be expected to influence behavior in this regard, as herding ungulates appear to find security within the cover of the group (Hamilton 1971, Hirth and McCullough 1977).

While bighorn have shown themselves to be most adaptable to non-threatening human presence, past adverse experiences with humans (e.g. hunting) can make them also one of the least adaptable (Giest 1975). Consequently, one cannot extend reaction curves observed in one herd to another. This appears to be exemplified by the Williamson herd.

Under the present regulations of the California Bighorn Zoological Area, there is no contact between humans and ewe-lamb groups in the high country of the Williamson herd, except occasionally in the Williamson Lakes area (and from hikers climbing Mt. Williamson illegally from the east side). It would nevertheless be useful to know whether their reaction curves differ from those of the Baxter herd, as a measure of their disturbance potential if the area were opened again to hikers. Reaction data have been obtained from only three summer encounters involving Williamson ewe-lamb groups. The impression obtained from these encounters has been that these sheep exhibited greater wariness than Baxter herd sheep would under comparable conditions. This is born out by plotting these three encounters along with those from the Baxter herd (Figure 11). Two of the points fall outside the range of points from the Baxter herd. The sample size is too small to make firm conclusions. However, the data point to the possibility that the Williamson herd does react differently to humans.

Shepherds Creek and Georges Creek have been corridors of recent concentrated human use. These lie between existing summer range and areas of abandoned range of the Williamson ewe-lamb groups, suggesting a causal relationship. Georges Creek has been the major access route for people climbing Mt. Williamson. The peak register on Mt. Williamson serves as an index of human use. Prior to the early 1960's, this peak was climbed only one to a few times per year. This rate increased significantly during the 1960's and peaked on July 4, 1971, when 25 people signed the register. This area was closed to public use shortly thereafter, but illegal use has continued. If the Williamson bighorn are generally as wary as Figure 11 suggests, human use in Georges Creek may explain the apparent loss of habitat to the south. A similar situation may also exist relative to the Shepherds Creek trail. These conclusions remain tentative and warrant further investigations of areas of summer bighorn use and reactions of the Williamson herd to humans.

Dogs accompanying hikers appear to change sheep reactions significantly. In August of 1978 I observed this in what proved to be a natural experiment. A ewe-lamb group of six were all bedded east of Baxter Lake near the base of Baxter Pass. A lone backpacker hiking toward the pass from the lake caused some concern among the sheep, some of which arose to watch him as he passed, then slowly rebedded after he disappeared. Twenty minutes later the sheep were still bedded when two more backpackers with a dog (illegally in the park) came along the same route. This time all sheep arose immediately and moved far upslope onto safe rocks before stopping to watch the people and dog pass. This behavior is what one observes when a coyote appears in the vicinity of ewe-lamb groups in summer. Apparently the sheep regard a dog as they do a coyote and exhibit a more wary reaction to it than to humans alone.

Possible Remnant Herds

Reported sightings of bighorn outside the ranges of the Baxter and Williamson herds have suggested the existence of additional bighorn herds in the Sierra Nevada. For the most part, these sightings fall into discrete concentrations that are indicative of separate remnant herds. All

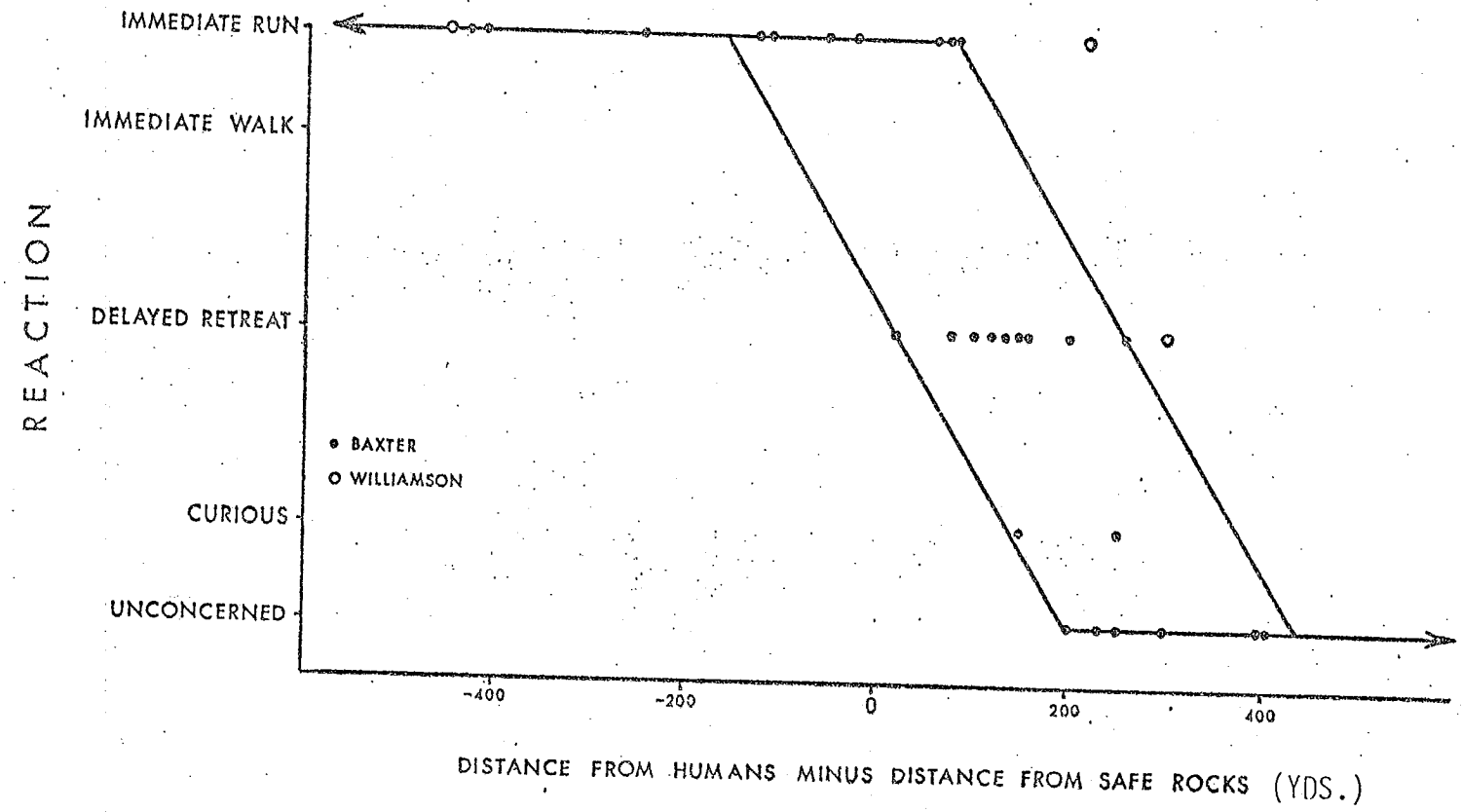

Figure 11 - Reactions of Baxter and Williamson herd ewe-lamb groups to humans in summer. A zero value on the X-axis represents the situation where bighorn are midway between escape terrain and the observer. Negative values represent greater danger (closer to the observer than to escape terrain) and positive values represent less danger. Diagonal lines bound the values recorded for the Baxter herd.

available records have been searched in an attempt to locate all such bighorn sightings since 1900. These have been organized into units that would be reasonably hypothesized to be separate herds. The results are found in Appendix II, which also includes recent evidence in the form of bighorn sign, as well as skull remains. While most of the earlier sightings are not particularly useful in examining the present situation, they are of use to the reader in examining the evidence for the existence of herds Jones (1950) considered to exist in 1948, and are pertinent to discussion of suitable areas for reintroduction found in Appendix I.

Skull remains are in all cases from rams. Due to the great longevity of the skull and horn material of rams, this record indicates only the presence of that sex in the fairly distant past, except for the few cases of skulls of recent origin; ewe-lamb ranges may have been located elsewhere.

The sightings listed are quite sparse in general and not necessarily clear evidence for the existence of permanent herds. Nevertheless, they fall within the habitats in which bighorn would be expected to occur during the summer season when almost all observations have been made.

The sparsity of sightings may be explained in part by the relative inaccessibility of most bighorn habitat due to its ruggedness during the summer season when most people are present in the mountains. This restricts the probability of encounters with humans. The additional probability of encounters being reported and filed on the subject appears to be quite low. A considerable number of the sightings listed in Appendix II, D and E, were obtained by investigators talking with local people. It appears that public input in this regard reflects lack of interest and appreciation of the importance of this information.

This lack of reporting of sightings is very obvious in the area of the Mt. Baxter herd. On Baxter Pass, for instance, it was found in 1976 that approximately one fifth of the groups of backpackers crossing the pass observed bighorn there (Wehausen et al. 1977). Yet, the record of such sightings is scant, and most are from government employees working in the area.

Before any logical steps can be made toward managing remnant herds to help ensure their perpetuation, considerably more information is needed. The first step is to delineate ranges of use during different seasons.

Of the potential herds represented by the information in Appendix II, only three have received concentrated survey work in both summer and winter in attempts to verify the existence of the herds and to delineate ranges of use. Winter sightings have been almost non-existent. Consequently, surveys at that time of year have been based on hypotheses as to where the most likely wintering areas would be. These hypotheses have been individually tested by examining the most likely areas.

Determination of bighorn use on the basis of sign has been complicated by the possibility of confusing deer sign. In much of the Sierra Nevada, deer were found to greatly overlap potential sheep habitat, occasionally

ranging well above timberline. For instance, Clyde (1971b) noted a buck on the summit (14,027') as well as one at 13,000 feet on Mt. Langley. Consequently, verification of bighorn use via sign has required clear pawed-out beds in the open in the manner typical of bighorn, or pellets in terrain too rugged for deer. The possible distinction on the basis of tracks has not proved useful due to the rarity of clear tracks in most bighorn summer habitat in the areas examined. In addition, there exists the possibility of confusing the tracks of large bucks with bighorn. Much of the winter survey work has taken place north of Owens Valley, where deer winter far to the east of the Sierra Nevada and have not been a complicating factor during that season. The possiblility of separating bighorn and deer fecal pellets on the basis of pH was investigated and found not to be a useful tool (Table 9), unlike the finding of Howard and DeLorenzo (1974) in New Mexico.

Most of the survey work outside the Baxter and Williamson herd ranges has been conducted by hired personnel. These people were first trained in the ranges of the Baxter and/or Williamson herds. This consisted of learning to recognize bighorn habitat and sign, particularly beds, and to use a spotting scope to find bighorn. Surveys consisted of covering as much favorable bighorn habitat as possible in the areas of the reported sightings. While covering these areas on foot or skis, all surrounding areas likely to contain bighorn were carefully glassed in a systematic manner with 20X, 25X, 20-45X or 15-60X spotting scopes from optimal vantage points.

1) Mt. Langley Herd

Appendix II A summarizes the known information on the herd Jones (1950) called the Mt. Langley herd. In all probability this should be considered two herds, as the Horseshoe Meadow - Cottonwood Lakes Basin represents a large barrier to bighorn movement, as does the Kern Plateau. Any connection between the high country to the west and north of the Cottonwood Lakes would most likely be reached by bighorn in southern canyons traversing the eastern canyons until north of Cottonwood Creek. It is more likely that a remnant herd south of Cottonwood Creek would never cross the crest to any extent, instead remaining year-round in the eastern canyons there. North of Cottonwood Creek are numerous potential winter range areas with direct access to the high country. A herd wintering there could readily range along both sides of the crest between Cirque Peak and Mt. Russell.

From 1963 to 1965, Riegelhuth (1965) searched potential winter range canyons in the Langley-Olancha Peak area. All canyons from Tuttle Creek in the north, to Olancha Canyon in the south, were investigated except Braley Creek and Carrol Creek. No sign of sheep was found.

In 1972, Jorgensen and Schaub (1972) surveyed potential summer range south of Horseshoe Meadows, notably Diaz Creek and Muah Mountain, both forks of Ash Creek, Cartago Creek and Olancha Peak and Canyon. No positive bighorn sign was found during ten days of survey.

During the summer of 1977, two investigators made two surveys in potential summer range, one from Cottonwood Creek south and one north and

Table 9 - Summary of fecal pH for bighorn and deer. Results were obtained by mashing three grams dried fecal pellets in 45 ml. deionized water and reading the pH 45 minutes later with a Beckman Zeromatic II pH meter. Pellets were all unweathered.

Species	Mean pH	Range	S. D.	Sample Size
Bighorn	7.56	7.05-8.28	.3179	28
Mule Deer	7.59	6.94-8.01	.3043	14

west from the Cottonwood Lakes. The first survey investigated all eastern drainages from Cottonwood Creek south to Olancha Peak, and turned up no positive evidence of the presence of bighorn. The second survey investigated Mt. Langley and its southeast ridge, the top of the South Fork of Tuttle Creek, Cirque Peak, Boreal Plateau, Siberian Outpost, Forgotten Canyon and Peak, upper Rock Creek Basin, Perrin Creek, Crabtree Lakes Basin, Mt. Irvine, Mt. Newcomb, Mt. Pickering, Mt. Chamberlain, and Joe Devel Peak. Again, no positive sign of bighorn use was found.

In early November of 1977, the author surveyed Trail Peak and the southeast ridge of Mt. Langley. Three pellet groups were collected from potential ram beds at about 12,400 feet elevation above the North Fork of Lubkin Creek. These pellet samples were baermannized to investigate the presence of larvae of the bighorn lungworm Protostrongylus sp. Instead, other nematode larvae were found, suggesting that these pellets were from deer. No other potential bighorn sign was encountered.

During the winter of 1976, the author surveyed the mouths of Cartago and Olancha Canyons, and during the winter of 1978, potential wintering areas from Tuttle Creek to the South Fork of Lubkin Creek were surveyed. No sign of bighorn use was encountered.

2) Bishop Creek and Western Sierra Sightings

Appendix II B contains a variety of sightings and recorded bighorn sign that have never been given a herd label. The recent sightings and sign recorded from Mt. Darwin, Darwin Canyon, and upper Bishop Creek may result from no more than a single stray ram that took up residence in this area for some years.

The second set of sightings and sign recorded west of the crest is of considerably more interest, as it suggests the possibility of a small herd wintering along the Middle Fork of the Kings River, possibly below the confluence with the South Fork, and using the White Divide-LeConte Divide area as summer range. The Kings River would appear to offer a great deal of potential steep rugged south facing winter range at low elevation with easy access to the high country along the river gorge.

No investigations have yet been made of the sightings and sign listed in Appendix II B.

3) Convict Creek Herd

Appendix II C lists recorded evidence of bighorn in the herd Jones (1950) labeled the Convict Creek herd. There have been few sightings or reports of fresh sign in this area since Jones' (1950) study. Jones himself apparently spent little or no time in this area in 1948, relying entirely on reports from others, which are included in Appendix II. It may well be that by 1948 this herd had already diminished to a very small size and the few sightings since then represent the very last vestiges of this herd.

Little survey time has been allotted to this area. In the summer of 1977, one investigator made a short trip into the Mt. Morrison area and found

no sign of sheep use. I have examined the base of the escarpment from Highway 395 numerous times during winter to determine whether any escarpment base winter range exists that is sufficiently free of snow. During the winter of 1978, this area was traversed in a fixed-wing aircraft to investigate the existence of adequate high elevation winter range on ridges swept free of snow. Neither of these investigations has elucidated any adequate winter range.

4) Yosemite Area

Locations of sightings in the Yosemite area and north to the Sonora Pass area are listed in Appendix II, D and E. These sightings have been separated into south and north groups as they suggest the possibility of two remnant herds, as hypothesized by Dunaway (1970) and Weaver (1972).

A handout describing the need for, and requesting information about future and past bighorn sightings in the Yosemite area was distributed to backcountry users in this area during the summers of 1977 and 1978. This handout was prepared on the assumption that a small percentage of sightings have been reported in the past. It has so far failed to illicit further sightings.

Although he mentioned a few sightings in the northern Yosemite area, Jones (1950) did not list the area as supporting a bighorn herd, nor did he survey the area.

During 1972 and 1973, a number of aerial surveys were made of the Yosemite area by Charles Hansen of the National Park Service and Richard Weaver of the California Department of Fish and Game. These included two fixed-wing surveys on March 29, 1972 and February 21, 1973, and helicopter surveys on July 25, 26 and 27 in 1972. Except for the 1973 flight, these surveys were all south of Matterhorn Peak. The purpose was to search for any sign of existing bighorn and to assess the terrain for potential reintroduction. No positive sign of recent bighorn use was found.

The present investigation has consisted of both summer and winter surveys. A team of two investigators spent 17 weeks of field time in the high country in the summers of 1976 and 1977. Winter surveys have consisted of one team of two people skiing a total of seven weeks during the winter of 1977 and for nine weeks during the winter of 1978. In addition, a second team of two spent four and a half weeks field time skiing during the winter of 1978. This latter survey began with a flight over the area in a fixed-wing aircraft to locate areas on high wind swept ridges free of snow.

Winter surveys in this area would be expected to provide the most information due to 1) the clear trails that bighorn would leave in snow at a time when deer are not present (the deer in this area winter considerably east of the Sierra Nevada), and 2) the relatively small area of potential winter range that would need surveying since most areas would be unsuitable due to deep snow. This latter consideration has not been as completely borne out due to lack of obvious bighorn

winter range in the area. Also, the winter of 1977 provided less than 20% of the normal snowfall, precluding any reliable judgement of where bighorn might be forced to winter in years of more normal snowfall. Fortunately, the winter of 1978 provided far in excess of normal snowfall, but in this case, winter surveys were often hindered by the continuity of storms.

The lack of obvious wintering areas has made it necessary to formulate alternative hypotheses as to types of wintering areas. Survey work has attempted to eliminate some of these hypotheses to the extent possible. These hypotheses are:

1. Bighorn in this area are wintering at the mouths of eastern canyons on south-facing slopes where rocky terrain exists, as the southern Sierran herds do.

2. Bighorn in this area are wintering on high ridges of the Sierra Nevada that are swept free of snow by wind.

3. Bighorn in this area winter at low elevation west of the Sierran crest along the Tuolumne River drainage and its Piute Creek tributary in the north and/or the drainage of the Middle Fork of the San Joaquin River in the Junction Butte area in the south. The 1974 sighting between Vernon and Wilner Lakes (Appendix II, E) first alerted us to this possibility. Steep rocky south-facing slopes exist as low as 5,000 feet elevation in the Junction Butte area and 4,000 feet in the Hetch Hetchy area.

4. Bighorn in this area are wintering in suitable terrain east of the Sierra Nevada.

Of these four hypotheses, the first two have received intensive investigation, the third has received a small amount of investigation, and the fourth has not been investigated at all. No positive sign of bighorn sheep has been found in these investigations.

Hypothesis 1

The winter survey of 1977 investigated all potential south-facing slopes along the east side of the range from Lundy Canyon to Sonora Junction and the Little Walker River. Little could be concluded from this survey due to the drought conditions that winter. Deer that normally winter to the east across the Nevada border were occasionally sighted in the Sierra due to to the mild winter. This winter, nevertheless, proved useful in delineating the most probable south-facing wintering areas, which were then resurveyed during the heavy winter of 1978. This included the following locations: the West Walker River from Driveway Creek to Pickel Meadow, Driveway Creek, Cowcamp and Poison Creek, Mt. Emma and Peak 10,727, By-Day Creek, Flatiron Ridge from Buckeye Hot Springs to the Roughs, Labrosse Creek, Sawmill and Buckeye Ridges from Bogards Camp to Barney Lake, Monument Ridge from point 8561 to West Lake, Dunderberg Peak, and the full length of Lundy Canyon.

In the south, the 1978 investigation covered Lee Vining Canyon, Bohler Canyon, Williams Butte, Bloody Canyon, Parker Canyon, Rush Creek, Glass Creek, and Deadman Creek. Many locations, south and north, were checked more than once because locations on an adjacent ridge often provided ideal vantage points for glassing slopes investigated earlier that winter. This was particularly true in the north, where a second team skied the ridgetops after a first team had completed a survey of the canyons.

Hypothesis 2

On February 21, 1978 an aerial survey was made to determine the extent of areas at high elevation that were swept free of snow by wind, and on which bighorn might conceivably winter. This flight covered the ridge systems east of the crest as well as much of the crest itself. Few areas showed sufficient snow-free terrain for bighorn to inhabit. These areas were plotted on a map, photographed, and glassed with binoculars from the air. The following high-elevation locations were then investigated by skiers: Mt. Emma, Walker Mountain, Hanging Valley Ridge, Flatiron Ridge, Buckeye Ridge, Sawmill Ridge, Crater Crest, Monument Ridge, Kavanaugh Ridge, Dunderberg Peak, Mt. Warren, Lee Vining Peak, Mono Dome, Dana Plateau, Mono Pass, Mt. Lewis, Gem Pass, and Agnew Pass. Upper Lundy Canyon was glassed from Lake Helen and Tioga Crest from Lee Vining Creek and Saddlebag Lake. Mt. Gibbs, upper Bloody Canyon, and the Kuna Crest were glassed from Mono Pass and the summit of Mt. Lewis, and Koip Peak. Parker Peak, and Mt. Wood were each glassed from both Mt. Lewis and Gem Pass. San Joaquin Mountain and its ridge running south to Minaret Summit were glassed from the upper middle fork of the San Joaquin River to Agnew Pass, from upper Glass Creek, Peak 10,135, and from upper Deadman Creek.

Hypothesis 3

Late winter surveys of the Hetch Hetchy area were made in both 1977 and 1978. In the 1977 investigation, approximately 20 miles of south-facing slope along the Tuolumne River drainage frm O'Shaughnessy Dam to Cathedral Creek, and from Pate Valley to Pleasant Valley on the Piute Creek tributary was surveyed with a spotting scope. The 1978 survey covered the area from the end of Hetch Hetchy Reservoir to Muir Gorge and approximately three miles of Piute Creek. Again, the area was investigated from a distance with a spotting scope, except for one steep slope along Piute Creek which was covered on foot.

Some potential winter range exists on the south-facing slopes from Hetch Hetchy Reservoir to Pleasant Valley and Muir Gorge. Exposed steep rock is abundant throughout this area, providing escape terrain for bighorn. Most of this rock is either steep cliff or glacially polished granite, thus supports little vegetation. Most vegetation consists of either dense patches of oak trees or thick brush, much of which is manzanita. Neither would be of much value to bighorn. The more open vegetation occurs as scattered patches. These include areas of grass and grass-like species as well as brush that could provide suitable bighorn forage. Two areas were noted that contained what appeared to be a mixture of rocks and open vegetation that might be suitable bighorn winter

range. The first is on the hillside just north of Pate Valley on the trail up Piute Creek. The second is about 1½ miles up Piute Creek from Pate Valley.

The two surveys in the Hetch Hetchy area represent only initial investigations as to the possibility of bighorn wintering there. These serve mostly to point out the existence of some potential bighorn habitat there.

No winter surveys have been made along the Middle Fork of the San Joaquin River, where conditions similar to the Hetch Hetchy area exist.

Hypothesis 4

No field investigations have been made of the possibility of bighorn wintering in suitable terrain east of the Sierra Nevada.

Summer Surveys

Summer surveys have concentrated on the general areas of reported sightings. Additionally, a few summer trips have surveyed likely migration routes between the high country and potential west-side winter ranges. Two such trips in 1976 and 1977 have investigated potential routes in the Jack Main Canyon area associated with the 1974 sighting there. Important landmarks covered were Falls Creek Canyon, Mahan Peak, Andrews Peak, Michie Peak, Haystack Peak and Schofield Peak. Deer and their sign were evident over most of the area.

Piute Mountain, Price Peak, and Acker Peak were surveyed in 1977 as more likely areas of migratory use by sheep that might be wintering in the Hetch Hetchy area. Again, deer and their sign were much in evidence over most of the area.

The following landmarks along and east of the crest in the area of northern Yosemite and Toiyabe National Forest were surveyed, some more than once in successive years: Forsyth Peak, Saurian Crest, Snow Peak, Craig Peak, Tower Peak, Ernbeck Peak, Wells Peak, Hawksbeak Peak, Grouse Mountain, Center Mountain, Crown Point, Slide Mountain, Sawtooth Ridge, Matterhorn Peak, Twin Peaks, Excelsior Mountain, Shepherds Crest, Crater Crest, Monument Ridge, Eagle Peak, Victoria Peak, Hunewill Peak and Flatiron Ridge.

Marion Hysell (Fire Control Officer for the Bridgeport Ranger District) has flown the area of Toiyabe National Forest east of northern Yosemite in helicopters and fixed-wing aircraft numerous times every summer for many years. Since his sighting from the air of a ram on Center Mountain in 1963 (Appendix II, E) he has specifically looked for bighorn throughout the area on subsequent flights with no success (M. Hysell, pers. comm.).

In the area of the southern set of sightings, one survey in early June of 1977 examined potential wintering areas along the Middle Fork of the San Joaquin River, and possible routes of migration to the high country. Additional surveys in this southern area investigated the area represented by the following landmarks: Iron Mountain, Volcanic Ridge,

The Minarets, The North Fork of the San Joaquin River drainage, Electra Peak, Mt. Davis, Mt. Ritter, Rodgers Peak, Donahue Peak, Blacktop Peak, Kuna Crest, Koip Peak, Parker Peak, Mt. Lewis, Mt. Gibbs, Mt. Dana, and the Dana Plateau.

Discussion - Remnant Herds

While a great deal of effort directed toward locating signs of possible remnant herds has turned up no positive evidence of their existence, it is not possible to totally discount the existence of any remnant herd. Instead, it is a question of probability, in that as more survey effort is expended without success, the less likely it is that a herd exists in the area.

Summer surveys have commonly dealt with large areas of potential range. Despite a concerted effort in some areas, the possibility of a very small herd ranging over a large area or confined to some isolated pocket of habitat not investigated remains substantial. Nevertheless, it seems unlikely that anything larger than a very small herd would exist.

In the case of winter surveys in the Yosemite area, it is concensus of the investigators involved that the probability of bighorn wintering on ridgetops or south-facing slopes east of the Sierran crest, is very small. In the case of the Langley herd, insufficient field time has been allotted to the area to make as strong a statement.

Bighorn sheep classically have traditional summer and winter ranges on which their appearance is highly predictable (Geist 1971). In this context, it is difficult to explain why no sign of bighorn use can be found in areas of reported sightings. There are several possibilities to account for the evidence and at the same time lack of evidence of these remnant herds.

First, it is possible that the sightings reported have been of deer or stray domestic sheep. Domestic sheep are grazed in many locations east of Yosemite during the summer months, as well as being driven north through Owens Valley in spring. Some of these sheep certainly become feral on occasion, as occurred in 1974 in the Baxter herd range. North of Owens Valley, most feral sheep probably perish in winter, but may first be sighted at a distance in the mountains by hikers who report them as mountain sheep. Feral sheep may occasionally reach high elevations and precipitous terrain, as suggested by a lower jawbone of a domestic sheep found in precipitous rocks off the edge of Dana Plateau during one of the surveys in 1977. While domestic sheep may account for some of the recorded sightings of remnant herds, most appear to be valid bighorn sightings when observers have been further questioned by knowledgeable personnel.

More probable explanations involve deviations from the usual behavior of bighorn. Traditional movement patterns between optimal summering and wintering areas appear to be facilitated by the social nature of bighorn, whereby younger bighorn learn the best areas by following the older bighorn (Geist 1967). Severe and repeated disturbance of bighorn

herds by man early this century and last century may have, in addition to decimating many herds through hunting and livestock grazing, also caused the remaining ones to abandon traditional ranges of use. Such behavior may have been the only successful one in the face of uncontrolled hunting and grazing. The result would likely be a small wandering group of sheep avoiding humans at all costs, and exhibiting no predictable traditions in movement. An example of a group of Dall sheep in Alaska entirely abandoning traditional ranges under severe hunting pressure was documented by Nichols (1976).

Two other factors may be operative in disrupted remnant herds. First, effects from inbreeding resulting from very small "effective population sizes" following human caused decimation may have adversely influenced bighorn herds. Geist (1975) points out that nothing is known on this question. Also, Hansen (1970) noted an apparent genetic linkage between pink tongues and skittish behavior relative to humans in bighorn in Nevada. Geist (1975) has suggested that remnant herds may consist of pink-tongued, wary individuals that were selected for by uncontrolled hunting of the less wary black-tongued individuals. It is also possible that pink tongues and skittish behavior are both products of inbreeding.

Regardless of the causes, it seems likely that once the predictable patterns of an established bighorn herd are seriously disrupted, the habits of the few remaining animals will place them under a considerably more stressful situation in which the intake and expenditure of nutrients leave little extra for reproduction. Such a herd is unlikely to increase and reestablish itself, and more likely is doomed to a slow extinction.

Extreme wariness and relatively unpredictable movement patterns of a small number of sheep using a large area may be the explanation for both the rarity of sightings and the inability of surveys to turn up any sign of sheep use in the areas considered ranges of remnant herds in the Sierra Nevada.

APPENDIX I

POSSIBLE REINTRODUCTION SITES

Although large continuous sections of the Sierran crest may have originally received bighorn use in summer, this was certainly not the case with winter ranges due to the high degree of patchiness of suitable habitat. The following is my assessment from south to north of the pristine locations of bighorn herds along the eastern escarpment of the Sierra Nevada, based on the analysis of suitable habitat as well as the few pertinent historical records. No assessment is made of areas south of Olancha Canyon, although records of sightings compiled by Jones (1949) indicate that bighorn ranges once existed south of Olancha Canyon. Nor is any consideration given to herds wintering on the west side of the range.

Historical bighorn use of an area can be an added assurance of success of reintroduction. This plus the desirability of preservation of rare species in their native habitat rather than as exotic species in non-original habitat is the reason for approaching the question of reintroduction from the angle of pristine distribution.

Some discussion of what constitutes a bighorn herd seems appropriate. Winter range areas that are sufficiently separated that a lamb born to a ewe from one area would be very unlikely to end up wintering in the next winter range, are considered as representing separate herds. It is possible, but improbable, that the sheep wintering in Sawmill Canyon represent a separate herd from the remainder of the Baxter herd by this definition. Lambs are weaned in fall, after which they do not necessarily follow their mothers. It is likely that some lambs follow adults to wintering areas different from those of their mothers, resulting in some exchange of lambs among the Baxter herd wintering areas.

Original Distribution of Herds

The Mt. Langley herd of Jones (1950) was most probably two herds due to the large barrier that the Horseshoe Meadow-Cottonwood Lakes Basin would represent. South of Horseshoe Meadow, much of the relatively gently rolling forested terrain of the Kern Plateau is unsuitable bighorn habitat. Thus bighorn in the canyons south of Horseshoe Meadow would have largely inhabited those east side canyons year round, crossing the crest only to use a few meadows on the eastern edge of the Kern Plateau. Alternatively, they would have traversed north along the east side canyons until north of Little Cottonwood Creek after which they could move into a large area of alpine summer range bounded on the west side by the forests of the Kern River drainage. A migration route to Cirque Peak via Trail Peak is another possibility. This seems less likely due to the large distance of forested terrain largely lacking in adequate rock outcrops that would have to be traversed. It is probable that the early sightings reported by Jones (1949) in meadow areas on the eastern edge of the Kern Plateau represented summer range of this southern herd.

Between Carrol Creek and Lone Pine Creek lie a number of areas of excellent winter range with, in all cases, direct access up to the previously mentioned expanse of summer range, lying essentially between Cirque Peak and Mt. Russell. Due to the large amount of winter range north of Cottonwood Creek, it is unlikely that sheep using this summer range would have reason to winter in more southerly canyons, such as Olancha and Cartago. It is for this reason that the sheep in these southern canyons probably constituted a separate herd.

The pristine range of the Mt. Williamson herd was probably much the same as it is presently, with the possible exception of a somewhat greater range of use in summer. It is also possible that the winter range extended to Pinyon Creek. If this were the case, ewe-lamb groups would have used upper Pinyon and Symmes Creeks in summer, which is where ram summer range is presently located. Such ranges are generally traditional and have developed in such a way that separation between the sexes in summer is complete. This would argue against there having ever been ewe-lamb use of any substantial degree in the Symmes and Pinyon Creek drainages. Nevertheless, it is possible that ram use there has developed as a result of early disturbance to pristine ram summer ranges that were probably located west of the crest.

North of Pinyon Creek, adequate escarpment base winter range terrain is at high elevation and incurs too much snow depth until Thibaut Creek, where the Mt. Baxter herd winter range begins. It is most doubtful that the Baxter herd range has changed since pre-white man times.

Between the Baxter herd winter range and Coyote Flat, lies only one area of suitable winter range, lying in the area of Taboose Creek. The mouth of Taboose Creek and the south facing slope of Shingle Mill Bench have been noted to lose snow quickly following winter storms. Jones (1950) suggested the existence of a herd he labeled the Birch Mountain herd, but provided weak evidence of its existence. However, the existence of this herd earlier this century is indicated by discussion of a 'Goodale-Birch Mountain' herd in the 1921 and 1923 Inyo National Forest Annual Fish and Game Reports. That this herd is not mentioned in any of the later annual reports suggests that it had, at least largely, disappeared prior to Jones' study. Two sources pinpoint the Taboose Creek area as the winter range of this herd. First, the 1921 Inyo National Forest Fish and Game Report states of this herd: "A considerable number ranging from Goodale Mountain to Birch Mountain, and wintering along the foothills in the Black Rock region during heavy snow". Secondly, Ober (1911) writes of the herd: "In the winter season they range low on Taboose Creek and along the snow line to Goodale and Red Mountain Creeks". Of their summer range he states that "this particular herd ranges in summer from Sawmill Pass on over and through the rough ridges and peaks as far as Bench Lake, and then on up north to Split Mountain and the head waters of Red Mountain Creek and even as far as the South Fork of Big Pine Creek".

Somewhat north of Big Pine Creek, the east side of Coyote Flat provides the next suitable low elevation wintering terrain at its base in Shannon, Freeman, and Rawson Canyons. While excellent bighorn terrain exists along the east face of Coyote Flat to the top at 10,000 to 11,000 feet, the top consists of a large high elevation flat, creating a barrier to further movement west to the Inconsolable Range and hence the Sierran crest. Alternatively, sheep

could remain on steep rocky terrain by migrating around the north side of Coyote Ridge via Rawson and Coyote Creeks and up to the crest via the steep west facing slope above the South Fork of Bishop Creek. A considerable amount of summer range both on and west of the crest from the Palisades north would have been available to such a herd. The only historical evidence of bighorn wintering at the base of Coyote Flat is an old horn sheath from the Rawson-Coyote Creek area (Forest Service files), a sighting of a small band in the Coyote Creek area reported to Norman Clyde by an employee at Glacier Lodge on an unrecorded date presumably early this century (Clyde 1971b), and a sighting of a small band about 1935, in the cliffs on the west side of Coyote Ridge a couple of miles north of South Lake (Jones 1949). These two sightings may be one and the same.

North of Coyote Ridge, the next suitable winter range is at the base of Mt. Tom in the Elderberry Canyon area and at the base of Wheeler Crest. The Wheeler Crest winter range is very expansive with elevations as low as 5,600 feet, while suitable winter range on Mt. Tom is very limited at a minimum elevation of 6,400 feet and with less of a southern exposure to melt off snow, except at higher elevation above Horton Creek. Ober (1914) stated that 40 to 50 sheep wintered on Mt. Tom at that time. This would suggest that these sheep did not make the simple crossing of Pine Creek to the less snowy winter range at the base of Wheeler Crest. Whether this was due to human activities there is unknown.

It is also unclear what the extent of summer range of the sheep wintering on Wheeler Crest was, as this may have been the winter range of the Convict Creek herd. To the south, and west, a great expanse of continuous high country was available as summer range, and to the north a matter of only about 12 miles of continuous high country separates the Wheeler Crest from the area of the Convict Creek herd.

Ober (1911) stated of this herd that "they course from Mt. Tom on over the summit to the west and around the headwaters of Pine Creek, venturing even as far north as McGee Creek in Mono County". The 1921 Inyo National Forest Fish and Game Report states "There is also a small band ranging from the head of Convict Creek to the Mt. Tom Divide of East drainage of Pine Creek. These sheep would appear to winter largely on the Alabama Ridge (=Wheeler Ridge) just west of Round Valley". This herd was subsequently referred to as the Pine Creek-Rock Creek band (Table 1). While both these statements suggest that a continuity of sheep use existed along the crest from Mt. Tom to Convict Creek, that they all wintered in the Pine Creek area may well have been assumed. The Convict Creek area herd may have been a separate herd that wintered east of the Sierra Nevada in the Owens River or Rock Creek Gorge, as no suitable winter ranges exists in that area in the Sierra Nevada.

If there was only a single herd that wintered at the base of Wheeler Crest, the comment in the 1948 Inyo National Forest Fish and Game Report regarding Pine Creek, that "there had been no reports of sheep being seen in that section of the Sierra Nevada for many years" suggests that human activity or livestock had forced the sheep to change their wintering habits. This would mean that the Convict Creek herd that Jones (1950) referred to was already a last vestige of a former herd in which, very likely, reproduction no longer replaced mortality due to severe conditions of their new wintering habits.

Between Convict Creek and the Sonora Pass area, it is not clear how many herds existed due to the lack of both apparent suitable winter range in the Sierra

Nevada and records of native wintering areas east of the Sierra. The sheep in the Sonora Pass area probably constituted a herd that wintered along the Walker River or on the slopes of the Sweetwater Mountains. The sheep summering along the Yosemite Crest probably constituted two or more herds - one or two in the north that wintered in the rocky area of the Bodie Hills east of Conway Summit, and/or in the Sweetwater Mountains, and one in the south that wintered east of the Sierra in the Mono Craters or Glass Mountains. It is possible that the southern Yosemite herd wintered along the Middle Fork of the San Joaquin River in the Junction Butte area of the Sierra Nevada, where considerable south facing terrain exists at low elevation.

Locations Suitable for Reintroduction

Of the locations listed above as being known or probable historic bighorn habitat, a number have been selected as suitable for reintroduction. Suitability has been based on the existence of 1) winter range of suitable topography, vegetative composition, and snow cover, 2) direct access via rocky terrain to summer range, and 3) suitable summer range.

The existence of early records of summer range use has been considered the best criterion for evaluating suitability of that range. Additionally, I have looked for the existence of patches of meadow vegetation in or adjacent to rocks in the alpine. Such meadows appear to be important in the summer nutrition of ewe-lamb groups in the Sierra Nevada. Except for canyons south of the Cottonwood Lakes Basin, where bighorn can be expected to be largely confined to the eastern canyons, summer range suitability has not been found to be an important question due to the overall abundance of good summer range.

The criterion for the selection of suitable winter range vegetation has been an abundance of perennial grass with a mixture of palatable shrub species. Snow cover has been a critical factor in the evaluation of potential wintering areas north of Owens Valley.

Of the seven wintering areas believed to have existed historically in the Owens Valley region, two presently contain herds and the remaining five have been judged suitable for reintroduction. North of Owens Valley, reestablishment of bighorn herds is not presently considered feasible. The reason for this is the conclusion that the native herds in this area most probably wintered in suitable ranges east of the Sierra Nevada. Migration routes between such winter ranges and the Sierra Nevada necessitate the crossing of rockless expanses or forested areas that are otherwise natural barriers to sheep movement. The reestablishment of such migratory patterns is not presently feasible, although Geist (1975) suggests an untested method using tame sheep. This situation is further complicated by the existence of Highway 395 that would cut any migratory pathway.

The conclusion that suitable winter range does not exist in the Sierra Nevada north of Owens Valley is based on the 1978 winter surveys. Ridge areas blown free of snow were ruled out as potential wintering sites because 1) the vegetation on such sites is very sparse and to a large extent ungrazable mat vegetation that results from the extreme conditions of dessication that plants in that habitat have to deal with, and 2) such areas were found to be few and small in size.

Lower elevation south-facing wintering sites were found to carry too much snow. Geist (1971) notes that bighorn are practically helpless in snow depths of three feet or more, and two feet makes the finding of food very difficult such that rams will abandon most social interaction (Petocz 1973). Snow conditions in the Sierra Nevada differ from those of northern ranges with their more continental climates in 1) generally having snow of much greater density (% water content), making it more difficult to paw through or move in, and 2) having none of the chinook winds that periodically remove large amounts of snow, and in many cases are the factor making northern areas habitable by sheep (Geist 1971).

During the winter of 1978 snow depths of three to five feet were measured on several occasions on south-facing slopes of potential wintering areas in the Yosemite region. Under these conditions, mountain mahogany (Cercocarpus ledifolius) would have to constitute the majority of forage consumed by sheep wintering in such areas. Whether this species could sustain bighorn through the periods of deep snow is not clear.

Although I have never observed bighorn in the southern Sierra to feed on mountain mahogany, McCullough and Schneegas (1966) and Dunaway (1972) recorded rare use of it; microhistological fecal analysis indicates its use in May in some areas. The general lack of use of this species in winter may not reflect poor palatability, but the overall rarity of this species in the low elevations of southern Sierran winter ranges. A comparison of the nutritional components of mountain mahogany with other shrub species fed on regularly in winter by southern Sierran bighorn is found in Table 10. Although the level of calcium is a bit high relative to phosphorus, resulting in Ca:P ratio in excess of the recommended maximum value of two (Maynard and Loosli 1956), the overall composition of mountain mahogany is not markedly lacking. While the ligin: acid detergent fiber ratio is a good index to the digestibility of the cell wall constituents in the absence of significant levels of rumen-inhibiting essential oils (Van Soest 1967), this sort of analysis cannot sufficiently evaluate a forage without in vitro or in vivo digestibility trials.

Only four south-facing canyon areas in the region east of Yosemite appear to have any possibility of supporting sheep use in winter. These are 1) Lee Vining Canyon from Warren Fork to Peak 9,962, 2) Sawmill Ridge above Robinson Creek in the region between Vicoria and Robinson Peaks, 3) Flatiron Ridge above Buckeye Creek in the area extending one mile either side of Peak 9,345 (about three miles into Buckeye Canyon), and 4) the slopes of Peak 10,727 south of Mt. Emma. Surveys of these slopes during more normal winters might result in more positive evaluation of winter range potential of these areas. Except for the Lee Vining Canyon site, ranges of summer use in these areas would be expected to be quite limited, as drainages that separate these eastern ridge systems from the crest of the Sierra would most probably act as barriers to further westward movement.

Two possible west side wintering areas in the Yosemite region, one in the Hetch Hetchy area and one along the Middle Fork of the San Joaquin River have been previously discussed in the context of remnant herds. The Middle Fork of the San Joaquin River suffers as a reintroduction site from forested areas along the North Fork that would block movement of sheep into the high country. As mentioned relative to possible remnant herd use, the Hetch Hetchy area remains an insufficiently explored possibility for reintroduction. No information exists to suggest that this area was historic bighorn winter range.

Table 10 - Nutritional content of various winter range shrubs. Values are percent dry weight. The Lignin/ADF ratio is an index of digestibility of cell wall contituents.

Species	CWC[1]	Lignin/ADF[2]	Protein	EE[3]	Ca	P	Ca/P
Cercocarpus ledifolius	28.6	.42	9.2	10.4	.98	.13	7.5
Purshia glandulosa	41.8	.51	11.1	8.0	.57	.14	4.1
Penstemon breviflorus	58.7	.38	5.8	2.8	.27	.12	2.2
Ephedra viridis	35.8	.37	11.5	3.8	3.82	.11	34.7
Eriogonum fasciculatum	28.3	.29	13.6	1.8	.76	.18	4.2
Ceanothus cordulatus	26.4	.59	16.9	2.8	.63	.20	3.2
Artemisia tridentata	23.7	.31	11.3		.61	.24	2.5

[1]Cell Wall Constituents

[2]Acid Detergent Fiber

[3]Ether Extract

Potential reintroduction sites have been classified into two categories. The first contains excellent sites containing an abundance of habitat needs, no logistical problems of introduction, and no significant land use conflicts. No relative ranking on sites within this category is made.

The second category contains sites grading from good to marginal. These differ from the first category in having some combination of 1) less than optimal abundance of some resource, 2) land use conflict, or 3) logistic problems of reintroduction. Sites in this category have been subjectively ranked as to their promise of reintroduction success. reintroduction sites lower on the list should be reevaluated later on the basis of information generated from reintroduction sites higher on the list. The following is a brief discussion of each of the areas:

Excellent

1. Pine Creek (Wheeler Crest): The habitat is superb and abundant. An excellent release site exists on the Pine Creek Road. Potential conflict with mining in the area is believed to be low due to considerable habitat free of mining activity.

2. Carrol Creek - North Fork of Lubkin Creek: Carrol Creek, the two forks of Lubkin Creek and a gulley between these two forks all constitute excellent winter range areas. The south fork of Lubkin Creek has the advantage of having a road to its mouth, where sheep could be easily released. Cattle use exists along the base of the range here, but this use rapidly disappears as the slope steepens into the range the sheep would use.

Good to Marginal Areas

1. Taboose Creek: Two excellent wintering areas exist here on the south-facing slopes of Stecker Flat and Shingle Mill Bench. Two drawbacks exist at this site. First, its closeness to the Baxter herd range (about six miles) makes it relatively easy for sheep released there to come back to their native range. This problem can be somewhat alleviated by releasing the sheep in Taboose Creek, where Shingle Mill Bench blocks their view of the Sawmill area, and later taking steps to expend their winter range to the south if necessary. The main problem with this site is the lack of a road into the area. The present road ends about one mile short of the canyon mouth. Cattle grazing in the area exists only along the base of the scarp, below where sheep use would be expected.

2. Falls Creek - Cartago Creek: Summer range is the resource in short supply in this area. Alpine summer range available to sheep elsewhere in the Sierra Nevada is lacking here except for the small area of Olancha Peak. The eastern canyons are quite arid, thus not likely to provide much in the way of areas of lush forbs, sedges, rushes, and grasses. The meadow along the sides of Olancha Peak that are accessible to bighorn due to adjacent rocky ridges may figure importantly in the summer nutrition of sheep in this area. Gomez Meadow is the most important in this regard. Cattle grazing is heavy in these meadows of the Kern Plateau. It is unclear what effect this would have on sheep use of these meadows. Wilson (1969) notes apparent displacement by cattle of desert bighorn on ranges in Utah, but also notes instances reported of the two mixed. Bighorn reaction to cattle is apparently variable with location, similar to their reaction to man.

3. Tuttle Creek: Winter range in this canyon is somewhat high, beginning about 7,000 ft. and consequently contains pinyon pines. The winter range here is limited to this canyon and the next gulley north. Human habitation exists very close to the mouth of the canyon, and excellent access to the canyon mouth makes likely a high level of human use.

4. Pinyon Creek: This site suffers from the limited amount of winter range available. Consequently, introduction here is likely to result in the establishment of only a small herd. Summer range will overlap that of the Williamson herd rams. The access road ends 3/4 of a mile short of the winter range.

5. Shannon Canyon - Rawson Creek: Excellent winter range exists across this entire area. Summer range is limiting. It is unlikely that sheep released here will establish the ten to twelve mile migration route along the top of the Bishop Creek drainage necessary for summer use to occur along the Sierran crest. The opening up of some of the forested areas along this potential migration route by fire or other means might greatly increase the probability of its receiving use by introduced sheep. It is most likely that the east side of Coyote Flat would become the summer range of sheep released in this area. To the south, and including part of Shannon Canyon, summer cattle grazing presently exists, as it does along Coyote Flat. Human habitation exists at the base of the winter range, and the Coyote Flat area receives considerable human use in summer and fall.

6. Ash Creek: This site exhibits the same summer range shortcoming as the Falls Creek - Cartago Creek area, but is more pronounced in that no alpine range exists at its head. Nor is it clear that Ash Meadow would receive use by introduced sheep. The winter range is also of lesser quality than the Olancha Canyon area. This site borders on unsuitability, and should be used for a reintroduction attempt only after success in the Olancha Canyon area has been demonstrated.

Mt. Tom: This site has not been placed in the ranking due to lack of exploration of its winter range. Since it is known as historic range (Ober 1914), it has potential for successful reintroduction. Surveys of snow conditions above Horton Creek and along the eastern base of Mt. Tom are needed to assess its suitability.

Great Western Divide: This historic range on the western drainage of the Kern River has received no attention. Potential reintroduction sites may exist there.

Lee Vining Canyon: Surveys of snow conditions in this canyon during more normal winters than 1978 may find it suitable for reintroduction.

APPENDIX II

REPORTED EVIDENCE OF POSSIBLE REMNANT HERDS

A - Reported sightings of the Mt. Langley herd.

Year	Evidence Seen	Location	Observer	Source
1909	3 reported killed	Whitney Meadows area		Jones (1949)
1914	1 killed	Muah Mountain	Sears	Jones (1949)
1918	2 ewes	foot of Olancha Peak	Stevenson	Jones (1949)
1926	3 sheep	Olancha Canyon mouth	Brown	Jones (1949)
1929-30	29 or 30 sheep	#6 Cottonwood Lake	Urquhart	Burandt
1930	4 sheep	Mt. Whitney west slope		Jones (1949)
1932	6 sheep	Cottonwood Lakes region	Macauley	Jones (1949)
1933	1 ewe carcass	Whitney Portal	Shellenbarger	Jones (1949)
1933	7 sheep	Mt. Langley		Dixon (1936)
1936	3 rams	Mt. Carillon	Clyde	Jones (1949)
1939	4 rams	Mt. Carillon	Clyde	Jones (1949)
1940	5 sheep	Mt. Russel	Murdoch	Jones (1949)
1945	5 rams	Boy Scout Lakes		reported to author
1946	3 sheep	Mt. Langley south side	Treat	Jones (1949)
1946	3 sheep	Mt. Langley, near top	Johnson	Jones (1949)
1946	15 sheep	4,700' in Cottonwood Canyon	Rogers	Jones (1949)
1947	about 12 sheep	Mt. Langley south shoulder	Robinson	Jones (1949)
1947	1 ram	north of Lone Pine Cr. @ 8,000'	Clyde	Jones (1949)
1947	2 rams	7,500' on Whitney Portal Rd.	Clyde	Jones (1949)
1948	7 rams	Mt. Langley	Jones	Jones (1949)
1948	sheep band	Ridge NE of Cottonwood Lakes	Morgan	Jones (1949)
1948	2 rams	Crest above Ash Creeks	Boyer	Jones (1949)
recently before				
1948	1 sheep	Cottonwood Pass	Hall	Jones (1949)
?	4 sheep	Olancha Pk. above Brown Meadow	Shellenbarger	Jones (1949)
1956	sheep	Ash Creek	Bagwell & Barnes	Eliason et al. (1972)
1956	1 ram	upper Ash Creek		Eliason et al. (1972)
1956	2 ewes, 1 lamb	Bell Meadow		Eliason et al. (1972)
1963	1 ram	N. Fork Ash Cr. winter range	Burandt	Eliason et al. (1972)
1965	1 sheep	Forgotten Mountain	Myers	Park Service files

Year	Evidence Seen	Location	Observer	Source
1966	6 sheep	Little Meysan Lake		Forest Service files
1966	2 rams	Cartago Canyon	Zufelt	Forest Service files
1968	1 ewe	SW slope of The Major General	Colliver	Park Service files
1968	1 ewe or young ram	1 mi. below Crabtree Lakes	Moore	Forest Service files
1974	6-7 sheep	Bighorn Park		Foret Service files
1975	2 sheep	SE ridge of Mt. Langley	Hinckley	Forest Service files
1975	2 rams	SE ridge of Mt. Langley		Burandt
1976	1 ram	Whitney Portal	Peck	Forest Service files
1978	1 ram	above Mirror Lake	Bergman	Forest Service files
Bighorn Sign Reported:				
1957		Cottonwood Pass	Burandt	Eliason et al. (1972)
1958		Mesa above Tulainyo Lake	Burandt	Eliason et al. (1972)
1959		N. Fork Ash Creek	Burandt	Eliason et al. (1972)
1960		Crest above Maysan Lake	Burandt	Eliason et al. (1972)
1960		Soldier Lake	Burandt	Eliason et al. (1972)
1961		Cottonwood Pass	Burandt & Whiting	Eliason et al. (1972)
1962		Notch and SE ridge of Mt. Langley	Burandt	Eliason et al. (1972)
1963		North of Hidden Lake	Burandt	Eliason et al. (1972)
1965		betw. Funsten & Rocky Basin Lakes	Burandt	Eliason et al. (1972)
1966		SW of Hidden Lake	Powell	Eliason et al. (1972)
1968		Mesa above Tulainyo Lake	Burandt	Eliason et al. (1972)
1968		betw. Funsten & Rocky Basin Lakes	Burandt	Eliason et al. (1972)
1968		SW slope of The Major General	Meyers	Park Service files
1972		N. Fork Ash Creek	Burandt & Weaver	Eliason et al. (1972)
1973		Pk. 12,758 due north of the Crabtree Ranger Station	ranger	Park Service files
Skull Remains:				
about 1904	20 skulls	Crabtree Creek		Jones (1949)
before 1915	skull	Rocky Basin Lake		Jones (1949)
1925	horn sheath	ridge SE of Mt. Irvine		Jones (1949)
1937	skull	Mt. Langley		Jones (1949)
1974	horn sheath	betw. Muir & Hidden Lakes		Forest Service files
1976	ram carcass reported	betw. Cirque Pk. & Siberian Pass		Burandt
	horn sheath	Tuttle Creek winter range		Forest Service files
	horn sheath	Mt. Corcoran		Forest Service files
		Olancha Peak		Forest Service files
		Olancha Creek		Forest Service files
		Ash Creek		Forest Service files

B - Recent evidence of bighorn in the drainages of Bishop Creek, the Middle Fork of the Kings River, and the South Fork of the San Joaquin River.

Year	Evidence Seen	Location	Observer	Source
1965	1 sheep	Mt. Darwin		Park Service files
1966	1 sheep	Darwin Canyon		Park Service files
1967	fresh beds, pellets tracks of 1-2 sheep	betw. Topsy Turvey and Baboon Lakes	Dunaway	Forest Service files
1969	tracks of 1 sheep	Treasure Lakes	Clyde	Clyde (1971b)
1975	tracks, pellets	Thunder and Lightning Lake	Dr. Staeger	pers. comm.
1965	indefinite no. sheep	Top of Rough Spur (seen from helicopter)	Harry Rogers	Forest Service files
1965	fresh sign including tracks in snow, old horn sheath	Top of Rough Spur	John Parrish	Forest Service files
1965	3/4 curl ram	N. side of S. Fork Kings River on first curve west of Horseshoe Bend		Park Service files
1972	1 sheep	Crown Basin	Cattle permittee	Forest Service files
1972	1 ewe	¼ mile below Chamberlain Lake	Thomas Addison	Forest Service files
1972-73	clear beds and tracks	along LeConte Divide from Mt. Henry to 1 mi. S. of Hell For Sure Pass	Bill Noble	Bill LeDain
1976	complete ram skull	Junction of Goddard and Piute Canyons	Muir Tr. Ranch guest	Forest Service files

C - Reported sightings of the Convict Creek herd.

Year	Evidence seen	Location	Source
1911-12	couple dozen sheep	Head of Fish Creek	Jones (1949)
1913	20 sheep	Silver Divide	Jones (1949)
1935	7 ewes, 5 lambs	betw. heads of McGee and Fish Creeks	Jones (1949)
1936	2 sheep	Convict Lake	Jones (1949)
1936	2 sheep (in winter)	Ski Tow	Forest Service files
1937	small band	Constance Lake area	Jones (1949)
1937	6 sheep	Laurel Lake area	Jones (1949)
1939	3 rams	McGee Mountain	Forest Service files
1940	band of sheep	Head of McGee Creek	Jones (1949)
1943	2 sheep	Head of Convict Creek	Jones (1949)
1943	3 rams	Basin at base of Mt. Hopkins	Jones (1949)
1943	2 rams	Rock Cr., east side of 395 by first bridge north of Sherwin Summit	
1944	1 ram	Pine Creek	Jones (1949)
1947	2 rams	Pincushion Peak	Park Service files
1948	15 sheep	Upper Hilton Lakes	Jones (1949)
1948	1 ram killed	Pine Creek	Jones (1949)
1953	2 ewes, 1 ram	behind Hot Creek Geyser	Jones (1949)
1960	1 ram	Owens River Gorge	Forest Service files
1962	1 ram	395, 1 mi. north of Toms Place	D.R. McCullough (field notes)
1962	1 ram	along Rock Creek Road	D.R. McCullough (field notes)
1970-71	2 sheep	west of Cloverleaf Lake	D.R. McCullough (field notes)
1975	1 ram	near Red Slate Mountain	Steven Kovak
			Forest Service files
Bighorn Sign Reported:			
1966	bedgrounds	NE slope Red Slate	Forest Service files
1966	tracks	East slope of Mt. Baldwin	Forest Service files
1966	bedground	North slope of Mt. Morrison	Forest Service files
1966	fresh sign	about 1 mi. east of McGee Pass	Forest Service files
1968	old bedgrounds	drainage above Mildred Lake	Forest Service files
1968	old bedgrounds	Lava Dome above Bighorn Lake	Forest Service files
Bighorn bones:			
1966	skull with horns	SE of Constance Lake	Forest Service files
1967	skull with horns	Mt. Stanford	Forest Service files
1967	skull with horns	betw. second and third Hilton Lakes	Forest Service files
1967	ram skull	Cascade Valley betw. Purple Cr. & Lake Virginia	Forest Service files
1968	old bones	near Bright Dot Lake	Forest Service files
1968	old jawbone	Canyon above Dorothy Lake	Forest Service files

D - Reported evidence of bighorn in the southern Yosemite area.

Year	Evidence seen	Location	Observer	Source
ca. 1870	3 bighorn killed	Bloody Canyon		Muir (1894)
1954	1 ram	Lee Vining Canyon	Div. Highways	Buechner (1960)
1954	1 ram killed	San Joaquin Mt.	Gauthey	Park Service files
1954	several bighorn	Glass Creek area	F.S. employees	Forest Service files
1955	1 bighorn (in Feb.)	Lee Vining Canyon	Squires	Dept. Fish & Game files
1955	1 ewe, 1 ram (in Feb.)	just north of Mono Lake by 395 headed NE	Donnely	Dept. Fish & Game files
1955-57	single sheep and groups of 3	San Joaquin Ridge (Seen on several occasions from air)	Seybert	Park Service files
1959	1 lamb	Vogelsang Camp		Park Service files
1960	1 ewe	Mt. Conness near McCabe L.	Kelley	Park Service files
1965	1 ewe, 2 lambs, 2 rams	by Rogers Lake	Boy Scouts	Park Service files
1967	10-12 bighorn	south of Mono Pass	Dessle	Park Service files
1967	approx. 10 bighorn	near Parker Pass		Dan Asay
1968	1 ram	Glass Creek Meadow	Roberts	Forest Service files
197?	bighorn	Bloody Canyon		hiker on Baxter trail
1976	1 bighorn	Donahue Pass	Hanson	Park Service files
Skull Remains:				
1901		Mt. Dana near summit		Jones (1949)
1915		Mt. Dana at 13,000 ft.		Grinnell & Storer (1924)
1915		Parsons Pk.		Grinnell & Storer (1924)
1915		Warren Fork of Lee Vining Creek		Grinnell & Storer (1924)
1919		Dana Plateau		Jones (1949)
1923		Parker Pk. at 11,500 ft.		Jones (1949)
1924		Helen Lake cirque		Anonymous (1924)
1927		12,000 ft betw. Mt. Gibbs & Mt. Dana		Jones (1949)
1928		Mt. Dana at 12,500 ft.		Jones (1949)
1928		Mt. Dana at 13,000 ft.		Jones (1949)
1929		Parson Pk.		Jones (1949)
1929		Mt. Lyell		Jones (1949)
1929		Lyell Glacier		Jones (1949)
1930		Mt. Maclure at 12,500 ft.		Jones (1949)
1933	(mumified ram)	Lyell Glacier		Beatty (1933)
1936		head of N. Fork San Joaquin River		Jones (1949)
1946		Simmons Pk. at 12,000 ft.		Jones (1949)
1949		below Dana Glacier		Park Service files
1954		Cathedral Range north of Parsons Pk.		Park Service files
1956		ridge betw. Spillway and Helen Lakes		Park Service files

Year	Evidence Seen	Location	Observer	Source
1966		Slopes of Mt. Lyell		Park Service files
1972		Upper Gaylor Lake at 10,600 ft.		Park Service files
		Bernice Lake at 12,000 ft.		Jones (1949)
		Banner Pk.		Bailey (1931)
		Mt. Ritter		Muir (1894)
		Mt. Ritter		Jones (1949)
		Mt. Gibbs		Bailey (1931)
		Alger Lake		Bailey (1931)
		Mt. Conness		Jones (1949)
		North side of Mt. Warren		Log Cabin Mine Boy Scout Camp caretaker

E - Reported evidence of bighorn in the northern Yosemite area.

Year	Evidence Seen	Location	Observer	Source
1876-78	ca. 12 sheep each year	east slope of Sonora Pass	Smith	Grinnell & Storer (1924)
1929-34	bighorn seen on several occasions	Piute Ridge (near Granite Dome in the Emigrant Basin)	Carry	Jones (1950)
1939	8 rams	Burro Lake	Wane	Forest Service files
1949	bighorn	Summit Creek		Jones (1950)
1955	1 ram	Eagle Peak, east side	Casaus	pers. comm.
1960	1 ewe, 2 lambs, 1 ram	Raymond Pk. @ 8,500 ft.		Dept. Fish & Game files
1963	1 ram, 2 ewes	summit of Lost Cannon Peak (ca. 7 mi. NE of Sonora Pass)	Ziglar	Tom Andrews
1963	1 ram	Center Mt. (seen from air)	Hysell	Park Service files, pers. comm.
1966	mixed group of 11	Center Mt. (seen from air)	Mitchell	Park Service files
1966	1 ram	Eagle Peak (seen from air)	Mitchell	Park Service files
1968	2 ewes, 1 lamb	betw. Center & Grouse Mountains (seen from air)	Mitchell	Weaver (1972)
1968	2-3 bighorn	Tower Peak	Chattin	Park Service files
1972	1 ram	south of Relief Peak	Beck	Park Service files
1974	2 ewes, 1 ram	betw. Vernon & Wilmer Lakes	Nixon	Park Service files
1975	1 ram	toward Emma Lake from Burt Canyon	O'Brian	Henry W. Elliott
1975	3 ewes. 2 lambs, 2 rams	Matterhorn Peak	Crawford	Forest Service files
Skull Remains:				
1911		Sonora Peak summit		Jones (1949)
before 1924		Headwaters of Spiller Creek		Jones (1949)
1926		White Mountain		Jones (1949)
1940		Fish Valley Peak		Jones (1949)
		Shepherds Crest		Jones (1949)
		Matterhorn Peak		Jones (1949)
1964		north side of Matterhorn Peak		Park Service files
1969		Top of Eagle Creek		Henry W. Elliot
1972		12,400 ft. above Onion Lake		Park Service files
1972		upper Matterhorn Canyon		Henry W. Elliot
1977		cirque below Ink Rocks		Tom Andrews

APPENDIX III

HERD MONITORING

Figure 9 suggests that the maximum number of bighorn sighted in a single day by an observer on foot may be a good index of population size. My experience with the Baxter herd indicates that a large variance exists in the ratio of this measure to total population size. The number of bighorn sighted in a day varies greatly with the observer's ability and day to day as well as year to year differences in bighorn distribution. The probability of being in the field on a particular day when conditions are optimal is a function of total field time in any particular winter. In short, maximum bighorn seen in a day is an index that will elucidate large population changes, but appears inadequate for smaller changes.

Total herd counts, as made in this study, also have drawbacks. Nevertheless, they probably correlate more closely with actual herd sizes. It is impossible to know whether every animal has been counted. On the other hand, if numerous census attempts are made in a single season, it is possible to derive a subjective impression as to the completeness of any particular count. This is based to a large extent on comparisons of results of different censuses and on evaluation of the conditions under which they were taken.

Census results will greatly depend on understanding the habits of the animals under the conditions of the census; this dictates where the investigator looks for them. Optimal census conditions exist when the animals are concentrated in the fewest locations. For bighorn in the Sierra, winter is the only time complete counts can be made. Census methods have consisted of first learning the locations of areas favored by bighorn under different conditions; counts were made when conditions limited bighorn to the fewest areas. Bighorn wintering on Sand Mountain have been used as the indicator as to when the best census conditions existed. Snow storms, spring vegetation greenup and other unspecified factors occasionally cause groups of these bighorn to coalesce and drop off Sand Mountain to its base at the mouth of Sawmill Canyon. They often remain there for a number of days. Censuses have normally begun with a complete classification of these bighorn (as many as 120 there at once) followed by careful searches of the Black Canyon and Thibaut wintering areas. Finally, Sawmill Canyon was censused by a complete scanning of its south-facing slope from high on the south canyon wall; the north-facing slope of Sawmill ridge was always glassed from the road before and after searching the interior of the canyon.

A good spotting scope and an observer well experienced in its use are essential for adequate censuses and reliable sex-age classification. Three days are generally needed to census the entire range. Censuses should be repeated until the observer is convinced that more complete counts are unlikely. Since no bighorn movement across Sawmill Creek is apparent in winter, maximum counts for ranges on either side can be added at the end of the season.

The Williamson herd was censused by locating individual bighorn groups. This was continued until no more bighorn could be found. Whenever a new group was found, previous groups were rechecked to be sure they had not moved to the new location. Three groups constituted the 1978 census total of 30.

An investigator can expect to spend most or all of a winter becoming familiar with the bighorn and their winter range before he feels equipped to carry out a census. The winter of 1976 served this function for the author. Census conditions have varied considerably during the three winters (1977-79) in which bighorn were censused. The 1978 census yielded the most complete results because deep snow in the upper winter range prevented bighorn occupation there. Nevertheless, the 1979 total ram count indicated that about six to eight rams were missed in Sawmill Canyon in 1978. A very complete ram count in 1979 was largely fortuitous. Otherwise, census attempts in 1979 yielded incomplete counts. This was due partly to insufficient field time, and partly to wider bighorn distribution. It is believed that more field time could have made up for this latter difficulty. Four to six weeks field time beginning in early February or late January should be expected in order to produce good census results; more or less time may be required depending on winter conditions.

Sex-age classification should be an integral part of census procedures. Yearling females are the most difficult to classify in winter, as they resemble adult ewes. A combination of body proportions and horn characteristics have been used as distinguishing characteristics. It has been necessary to redevelop bighorn classification skills every winter by classifying large numbers of bighorn prior to census attempts.

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