

SIERRA NEVADA BIGHORN SHEEP: 1999 POPULATION STATUS

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Bighorn sheep in the Sierra Nevada have been found to be genetically and morphologically distinct from other bighorn sheep in western North America (Wehausen and Ramey 2000). Following about a century of presumed anthropogenic population losses, the number of surviving populations of bighorn sheep in the Sierra Nevada reached a low of two in the 1970's, the Mount Baxter and Mount Williamson populations (Wehausen 1980). The large size of the former allowed the creation in the late 1970's of a restoration program using reintroductions to restore populations in historic ranges in the Sierra Nevada (Wehausen 1988). Three additional populations were established between 1979 and 1988 (Bleich et al. 1990) before unexpected changes in the behavior of all populations, avoidance of low elevation winter ranges, set off a pattern of population collapses (Wehausen 1996). Large increases in mountain lion predation of these sheep on winter ranges was correlated with these behavioral changes and has provided the only viable explanation for these changes (Wehausen 1996). Below I summarize the current status of each population of bighorn sheep in the Sierra Nevada from south to north, and trace their demographic histories since the 1970's.

I. Mount Langley Population (reintroduced)

Bighorn were first released here in 1980, with subsequent releases in 1982 and 1987. Initial monitoring of this population documented population increases as well as losses to mountain lions on low elevation winter ranges. This population showed sufficient winter range avoidance soon after reintroduction that the best census data have always been obtained in the summer range. Its highest documented population size was 42 in 1990 (Moore and Chow 1990), but possibly as many as 48 in 1987 (Brown and Ramey 1987). Following other documented population collapses during the 1995 winter, monitoring of this population was resumed in 1996. This produced only repeated observations of 3 ewes and a female lamb as the reproductive base during summer and the following winter. In 1997 it was established that 11 rams of widely varying ages also existed in this population. Continued monitoring has documented both population increases and additional sheep not originally accounted for. A yearling ram in 1997 that could not be traced to a male lamb in 1996 indicated the existence of at least one additional adult female. A number of adult ewes consistent with this expectation was finally documented in the summer of 1998, when 4 adult, 1 2-year old, and 3 yearling ewes were seen; but only a single lamb accompanied them. The population had seemingly doubled its number of ewes in two years due to 100% survivorship of ewes and offspring, and a fortuitous sex ratio of lambs: 4 female and 1 male.

Winter range surveys during the 1997 and 1998 winters documented some low elevation use by these sheep ranging from Carroll to Diaz Creeks. The winter of 1999 showed a change in this pattern. Notably more mountain lion sign was observed on or near winter range slopes and only one small group of 3 sheep was briefly found on these slopes. A dead 7-year old ram has since been

found on the North Lubken Creek winter range that was killed by a mountain lion during that winter.

Summer surveys in 1999 nevertheless documented not only high survivorship of the ewes, but also evidence of additional animals not previously accounted for, as well as new expansion of use back to Lone Pine Peak, where use has been lacking since 1995. When the first adult ewes were observed in August this year, they were accompanied by two 2-year old rams that did not correspond with any yearling rams the previous year, nor male lambs two years earlier. At least two additional ewes must have existed, probably in the Tuttle Creek area, bringing the minimum total number of ewes (including yearlings) to 10 in 1998. Summer and fall surveys in 1999 ultimately documented nine ewes, five lambs, and a yearling ram, of which two ewes were classified as 2-year olds. This was one 2-year old fewer than the expected total.

Including the two 2-year old rams, only a total of 6 rams were observed. Similarly, in 1998 only 7 rams were documented. Because survey efforts have been oriented toward females, there is no reason to believe that the other additional rams seen in 1997 have all perished. With known recruitment of 4 rams and the one documented mortality, there could be as many as 14 rams (including the yearling) in this population. The total population could then contain as many as 24 adults and 5 lambs; but the documented minimum population is only 15 adults and 5 lambs.

The lack of winter range use in 1999 was evident during the following summer in the poor body condition of the sheep seen. In mid August, ewes were still showing these effects in poor body condition. This is likely to affect reproductive output next summer. The body conditions observed this past summer contrast notably with those observed the previous few summers.

II. Mount Williamson Population (native)

This population contained consistently 29-31 sheep between 1978 and 1985. Evidence of high turnover rates in the population (high recruitment but no population gains) coupled with scattered documentation of mountain lion kills suggested that predation may have been holding this population at that size during that period. This population abandoned use of its low elevation winter ranges after 1985 and has never been observed using those low elevation areas since. No monitoring of this population occurred between 1985 and 1996. In 1996, a high country summer survey of areas that previously received high use by ewes, yearlings, and lambs (S. Bairs and Williamson Creek drainages) turned up almost no evidence of any sheep remaining and no evidence of ewe-lamb groups. More extensive searches the following summer documented three rams (via observation), as well as a group of three adults (probably ewes) and one lamb on the north ridge of Mount Williamson (via tracks, beds, and feces). All evidence indicated that the range used by these few remaining ewes had shrunk to include only the north ridge of this mountain. A survey of this north ridge in the summer of 1998 turned up similar evidence of a small number of ewes, which included two lambs that year and possibly a yearling.

The South Bairs Creek summer range was not surveyed in 1998, but was again checked this past summer. There was ample sign that the ewes in this population had reestablished use of this range beginning in 1998. One ewe was observed there, and fresh tracks following rain indicated that a yearling had been there earlier in the day. Droppings again indicated two lambs accompanying the ewes and probably as many as 5 adults including yearlings. Five lambs have been documented since

1997, which if added to the initial 6 adults evident in 1997 would set a probable upper limit of 11 in this population, including the current two lambs. Most importantly, all evidence indicates an increasing trend in the population.

III. Mount Baxter Population (native)

This population was the source of all sheep reintroduced in the Sierra Nevada. It was very closely monitored during the period of tranlocations through winter range counts. It numbered as many as 220 sheep then, consisting of two separate ewe populations with divergent home range patterns -- the Sand Mountain and Sawmill Canyon demes. Winter range abandonment by this population occurred beginning in 1987 (Wehausen 1996). With that abandonment developed what appears to be a third independent deme south of Oak Creek, the Black Mountain deme. What characterizes this deme is the lack of any known use of the low elevation winter range at Sand Mountain. Instead, ewes have been seen occasionally in spring at lower elevations near Onion Valley, and may also be using Charlie Canyon in that season.

Previously, the ewes that used this southern end of the summer range used the Sand Mountain winter range. Currently, those that continue to make limited use of that winter range appear to live otherwise only directly above it between Sawmill Canyon and Oak Creek. These three demes are discussed separately.

When the Mount Baxter herd began avoiding winter ranges, it effectively abandoned an entire forage growing season and the associated large nutrient intake. The large population size it had developed was clearly dependent on that winter range nutrition and the population declined steeply during the early 1990's as measured by a "catch-per-unit-effort" index from the summer range (Wehausen 1996). Because of the dispersed nature of the population in a large summer range, attempts to count two of these demes (Black Mountain and Sawmill Canyon) were not possible until they dropped to low numbers. In contrast, yearly counts of sheep using the Sand Mountain winter range have continued to be made this decade. In 1995, the Black Mountain and Sawmill Canyon demes had dropped sufficiently that a concerted effort was made to account for as many females as possible during summer. Similar efforts were not attempted again until this year, but the days allocated there were not as great as in 1995.

A. The Black Mountain Deme.

In 1995 this deme appeared to contain only 6 ewes and 3 lambs, as suggested by repeated sightings of the same animals. In 1998 4 ewes and a yearling ewe were observed on Black Mountain with no lambs. This summer 5 ewes consistent in various external features with those same ewes were again observed on Black Mountain, accompanied by 4 lambs. However, in addition to these, there was clear evidence from droppings of a second group further south in the Kearsarge Peak area that lacked any lambs, but appeared to include two yearlings in addition to about 3 ewes. Thus, this deme may now have as many as 8 ewes and possibly some yearling ewes. Fecal DNA studies should elucidate this.

B. Sand Mountain Deme.

This deme showed winter range use patterns similar to the Mount Langley population -- a notable reduction in use during 1999 following a couple years of increased use. Similarly, evidence of mountain lions was recorded in the two winter range locations preferred by these sheep in recent years -- Black Canyon mouth and the south side of Sawmill Creek. Regular checks of Black Canyon yielded only a brief appearance in late March of a single group of 1 adult ewe, 1 yearling ewe, 1 lamb, and 1 2-year old ram high in rocks above the canyon mouth. These were recognized as 4 of 6 different sheep recorded on Baxter Pass by an automated video camera the previous fall. The other sheep in that video footage were 2 additional ewes. In contrast, in 1998 we recorded 8 different sheep at Black Canyon seen on 6 different days, with one group remaining there about two weeks. In 1997, 5 sheep were observed there on two occasions and remained on that winter range at least one week. The 1997 and 1998 winter range use was very small compared with years prior to winter range avoidance, but represented substantial increases over most earlier years this decade.

The other winter range location used in recent years by ewes from this deme has been the south side of Sawmill Canyon. One ewe has consistently used this area for at least a month each winter. This past winter she was accompanied by a second ewe with a very dark coat that has not been recorded there since 1996. They were first seen on February 27 and remained there until at least April 14. Near the end of April they were gone and recent lion tracks were found along the upper rocks where they had last been seen.

The yearling ewe documented in this deme this past year is the first female known to be recruited there since 1993. The reappearance of the dark colored ewe on the south side of Sawmill Canyon this winter suggests that, while only 4 ewes have been seen every winter, at least 5 have existed. With this year's yearling, this deme appears to contain at least 6 ewes. This deme has shown low reproductive output, with the exception of 1998, when 4 lambs were recorded on the winter range. Over a five year period the total lambs recorded has been only 8, or 35:100 ewes older than yearling.

This deme was large and productive prior to winter range abandonment, and ranks among the very best bighorn ranges in the Sierra Nevada in the potential number of sheep of it can support. Recent demographic patterns suggest that this potential may only be achieved with increased winter range use, as once occurred.

An attempt to obtain further video footage this summer of ewes and lambs from this deme that utilize Baxter Pass was unsuccessful due to camera failure. Signs there indicated probably 3 different lambs had accompanied ewes to this mineral lick slope this past summer.

C. Sawmill Canyon Deme

In the summer of 1995, 7 ewes, 1 lamb, and a 2-year old ram were documented to remain in this deme. In 1997, there was a notable jump in winter range use, with 10 different sheep (6 ewes, 3 lambs, 2 yearling rams, and 1 2-year old ram) found to occupy that range from January 23 through March 25, although not all over that entire time period. In the following winter, only 2 ewes and a lamb used the winter range and were seen first on February 4 and last on March 8, when one ewe was missing. This past winter we found no use of this winter range, and brief surveys in 1998 of preferred summer ranges on the south side of Woods Lake and on Mount Cedric Wright turned up

a paucity of sheep sign.

This fall another summer range survey was conducted and showed that this deme is holding its numbers. Two groups were observed, totaling 6 ewes, 1 lamb, and 2 rams (1 mature and 1 2-yr. old). In addition, fecal pellets were observed that suggested a couple of yearling sheep may exist in this deme as well.

D. Rams

In addition to the 2 rams observed in the Woods Lake area, 8 were seen in the Gardner Basin and a high count of 9 there was reported by reliable sources. Until fecal DNA tests are completed, there is no guarantee that the Woods Lake rams were not among the 9 seen in the Gardner Basin area. The number of rams in the Mount Baxter population is thus at least 9, but possibly at least 11. Of particular note was the finding this summer that ewes and lambs had reached the Gardner Basin. Over the past 25 years only rams have been known to occupy the Gardner and 60 Lakes Basin in summer, i.e. the west side of the Rae Lakes drainage.

E. Mount Baxter Population Totals

The minimum size that can be unquestionably documented for the overall Mount Baxter population this year is 15 ewes, 5 lambs, and 9 rams, for a total of 29. However, other evidence suggests that this figure could be as high as 19 ewes, 5 yearlings, 8 lambs, and 11 rams, for a total of 35 adults and 8 lambs. If so, this appears to be an increase since 1995.

IV. Wheeler Ridge Population (reintroduced)

This population has been monitored yearly in winter and early spring in Pine Creek where these sheep have wintered for many years at elevations as low as 7200 feet. The population dropped to an apparent low of 9 ewes and 6 rams following the winter of 1995, but has shown steady increases since then. A total of at least 14 different lambs have been documented during the 1996-98 winters, which would project a population of at least 30 if survivorship had been 100%. Census opportunities in the winter of 1998 were not ideal and only 20 clearly different sheep could be accounted for. However, following that winter there were reports of at least 3 ewes and a ram that were seen on the low elevation winter range above Round Valley where sheep have not been known since the middle of last decade.

During the past winter a major event occurred that offered better census opportunities. First, large numbers of sheep congregated in upper Pine Creek following a winter storm. Second, about three-quarters of them headed down the canyon to the old low elevation winter range. With the population separated into these two groups, more complete counts were possible. Our total count was 17 ewes (13 adult, 4 yearling), 13 rams (incl. yearlings), and 10 lambs. Thus, the potential of 30 the previous year was verified, and the population had grown by 33% to 40. Seven of these sheep (4 ewes, 1 yearling ram, 1 lamb of each sex) that remained in upper Pine Creek were caught in March under a drop net and the 4 ewes received radio collars.

In a small amount of summer field work in 1999 12 different rams (including 1 yearling)

were observed one day in July and 8 different ewes accompanied by 7 yearlings (2 female, 5 male) and 8 lambs were documented in October. This suggests that all lambs seen in winter are probably now yearlings and that there will again be a large crop of lambs. It is expected that during the coming winter a population of 50-60 will be documented, of which about 40 will be adults.

V. Lee Vining Canyon Population (reintroduced)

This population is treated here as 3 separate demes: Mount Warren, Tioga Crest, and Mount Gibbs. Although there was considerable interchange between ewes on Mount Warren and Tioga Crest in the early 1990's, such interaction has been largely lacking since the population collapsed in 1995.

Following the initial release of sheep into Lee Vining Canyon in 1986, various sources of mortality coupled with the emigration of 3 ewes with their two lambs south to Mount Gibbs reduced the reproductive base to only 5 ewes. Augmentation with 8 ewes and 3 rams in 1988 coupled with 3 years of lion control in winter led to a rapid increase of this population (Chow 1991). A high population count of 80-89 was developed in 1993, of which only 1 ewe and 2 rams were in the Mount Gibbs deme (Chang 1993). Census work by employees hired by Yosemite National Park the following summer produced poor results with a range of 48-72 sheep potentially accounted for in the Mount Warren and Tioga Crest region (Jensen 1994). Consequently, it is not clear whether further population increase occurred following 1993. Since 1995, census work for these demes has been conducted only by experienced individuals, including a group effort every year in early summer. Those results are summarized below by deme.

A. Mount Warren Deme

Only 12 adult ewes, 3 lambs, and 14 rams remained on Mount Warren the summer following the heavy winter of 1995. The following year saw the beginning of population recovery, with 12 adult ewes, 1 yearling ewe, 11 lambs, 2 yearling rams, and 13 older rams counted. In 1997, the ideal census opportunities of the previous 2 years did not occur, and results indicated the existence of at least 9 adult ewes, 3 yearling ewes, 6 lambs, and 12 rams, but probably 12 adult ewes, 6 yearlings of both sexes, 8 lambs, and 12-13 rams. The latter figure suggested continued population recovery.

This recovery proved to be short lived, as a second population collapse occurred over the winter of 1998. Only 6 ewes, 3 lambs, and 9 rams could be found the following summer. Further decline occurred over this past winter even though, unlike 1995 and 1998, it was not a heavy winter. During the past summer and fall all that could be accounted for were 1 adult ewe, 1 lamb (probably female), 2 yearlings (both male), and 10 rams. The sheep sign encountered throughout summer was consistent with this low number of ewes, yearlings, and lambs.

B. Tioga Crest Deme

In the summer of 1995 only 3 ewes and a lamb could be found here. The following summer there were 3 ewes and 2 lambs, and in 1997 there were 3 ewes, 1 lamb, and a yearling of each sex. In 1998 only a single ewe and a 2-year old ram could be found, and lack of sheep sign indicated a population decline. This past summer, however, there were 2 ewes and 2 lambs. While one ewe

may have been missed the previous year, it is also possible that a Mount Warren ewe had joined this group. Fecal DNA tests may answer this question.

C. Mount Gibbs Deme

The initial group that colonized this area in 1986 faltered because the only ram (one of the lambs with them in 1986) was killed by a mountain lion. It was a few years before rams from the Mount Warren area found them. By 1993 this population consisted of only 1 ewe and 2 rams. In 1994, 3 rams but no ewes were found in this area. In 1995, 1 ewe, 1 lamb, 1 yearling ram, and 3 older rams were counted. In 1996, the count increased to 1 ewe, 1 lamb, and 5 rams, of which 1 ram corresponded with the yearling the previous year, and another had apparently joined this group from elsewhere, undoubtedly Mount Warren/Tioga Crest. In 1997 this group consisted of 1 ewe, 1 yearling ewe, 1 lamb (male), and 2 rams (the 1995 yearling then 3 years old, and an older ram). In 1998 there were 2 ewes, 1 yearling ram, and 3 older rams. This summer the two ewes had 1 lamb with them, but no rams were seen.

D. Lee Vining Canyon Population Total

Currently, the Lee Vining Canyon population contains a total reproductive base of only 5 ewes. Additionally, 4 lambs and 12 rams are known to exist, and an additional 4 on Mount Gibbs probably persist for a total of 23. With only a single ewe remaining, the Mount Warren deme is the most endangered deme in the Sierra Nevada. Its decline is striking, considering that prior to 1995 it was the largest remaining population in the Sierra Nevada and continued to be the hope for a future source of translocation stock only two years ago (Sierra Nevada Bighorn Sheep Interagency Advisory Group. 1997). The details of what happened to all the sheep that disappeared on Mount Warren over the 1995, 1998, and 1999 winters remains a mystery, as the remains of only a couple of dead rams have been found in many days of multiple investigators walking across all corners of their range between Lee Vining and Lundy Canyons. It seems clear that they have not died on the high areas blown free of snow in winter, given that these are visually very open and frequently traversed by investigators.

One apparent pattern associated with this decline is a notable drop in use of the Lee Vining Canyon winter range. This range received high use by sheep, especially ewes, in spring during the major population increase in the late 1980's and early 1990's. Beginning in 1995, only a small proportion of the ewes, yearlings, and lambs in the Mount Warren deme have been recorded to use that winter range in spring, reaching a low of zero in 1999.

VI. Synthesis

A. Total Population

A very conservative total count of bighorn sheep actually seen in the Sierra Nevada in 1999 (excluding 1998 lambs seen only in winter) comes to 95 adults and 22 new lambs. This figure is substantially below the actual population level. Adding to it sheep that were not seen but clearly existed based on unambiguous sign, or very probably exist because they were seen a year ago (e.g. 4 rams on Mount Gibbs) brings this figure to 117 adults and 26 new lambs. This is still a

conservative figure. Adding other potential sheep for which there is evidence sets a higher figure of 129 adults (Table 1). A range of 120-129 adults is very unlikely to be an overestimate. Ongoing genotyping from fecal DNA will considerably refine this figure when completed. There are also certainly more than 26 lambs, especially in the Wheeler Ridge population and also probably in the Sand Mount deme. Field work in the coming winter will refine this number. An additional 5-10 lambs is likely, bringing that total to 31-36. There could be as many as 160-165 total bighorn in the Sierra at this time.

Table 1. Summary of population figures for 1999.

Population	BIGHORN SEEN				VERY PROBABLE OTHER SHEEP		POSSIBLE FURTHER SHEEP	
	Ewes	Rams	Adults	1999 Lambs	Adults	1999 Lambs	Adults	1999 Lambs
Langley	9	7	16	5	3		5	
Williamson	1		1		6	2	2	
Baxter	15	9	24	5	6	2	5	1
Wheeler	19	18	37	8	3			4-9
Lee Vining	5	12	17	4	4			
TOTALS	49	46	95	22	22	4	12	5-10

B. Long Term Population Trends

Figure 1 depicts the history of each bighorn sheep population in the Sierra Nevada and the total numbers over the past quarter century beginning with the first reliable population counts. Besides the obvious radical dynamics, a few patterns are noteworthy. First is the fact that the total numbers have been showing recovery since a low point in 1995. This overall recovery has not been continuous because of the further losses to the Mount Warren and Tioga Crest demes in 1998 and 1999, but those losses have now been more than balanced by gains in all other populations.

What this means is that these bighorn sheep populations should currently be placed in two classes: (1) The Lee Vining Canyon population that has demes on the very edge of extinction, and (2) all other populations, where increasing trends are currently apparent. This does not mean that all populations in this second class are equivalent. Clearly, the Mount Williamson population is also close to the brink of extinction. But, recent trends suggest that demographically the Mount Warren deme is considerably more in jeopardy, with but a single adult female remaining. This is not necessarily a hopeless situation. Recent data from the White Mountains on the east side of the Owens Valley for bighorn sheep in Silver Canyon have demonstrated that an entire population can be derived from a single female.

C. Mountain Lion Effects

A second pattern of interest in Figure 1 concerns the different initial trajectories of each of the reintroduced populations. All three incurred mountain lion predation problems shortly after release. Both the Wheeler Ridge and Mount Langley populations showed population increases with no tendency toward initial exponential growth. Instead, they bent to the right and stabilized initially at relatively small population sizes. In contrast, following its initial decline from various causes, and an augmentation in 1988, the Lee Vining Canyon population had a steep increase in numbers and reached a peak size about twice that of the other two reintroduced populations.

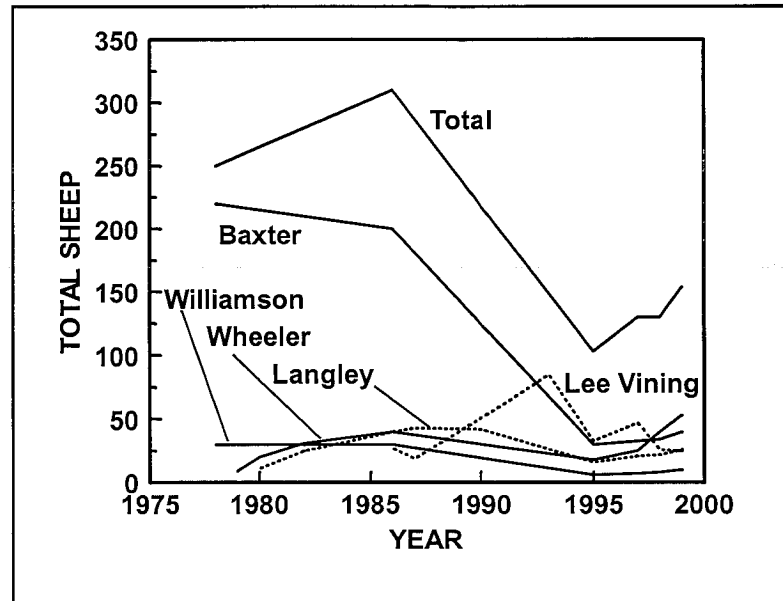


Figure 1. Population sizes, 1978-1999.

One factor stands out as a potential explanation for this difference -- three years of mountain lion control in Lee Vining Canyon beginning in 1988. That the Lee Vining Canyon population continued to increase for a few years following the cessation of that control may have been a carryover effect. With the cessation of lion control, this population developed patterns of winter range avoidance in the critical spring period when ewes most need nutrients at the end of gestation. Two cases of mountain lion predation on ewes in that winter range have been documented since lion control ceased, and others undoubtedly have gone unrecorded because so few radio collars have existed. The total Lee Vining Canyon population is now similar in size to the Mount Langley population. However, its reproductive base is much more precarious, especially given subdivision into three demes.

A third pattern of interest in Figure 1 is the current rapid increase in the Wheeler Ridge population compared with other populations in the Owens Valley region. The mountain lion population utilizing Round Valley and Wheeler Ridge in winter has been studied in great detail since 1992. During that time it exhibited an accelerating decline culminating in virtually no use by mountain lions of the bighorn sheep winter range in Round Valley in 1999. It is unlikely to be a coincidence that the large reoccupation of that winter range by the bighorn sheep coincided with the paucity of lion activity there. A notable drop in mountain lions immigrating to Round Valley accelerated the population decline of lions there in recent years. This suggests that a much larger scale decline in mountain lions was occurring in the Owens Valley region. Thus, it is also not likely to be a coincidence that some increased use by bighorn sheep of other winter ranges in the Owens Valley in recent years have coincided with this apparent decline in lion numbers.

Why has the Wheeler Ridge population recovered so much more rapidly than other populations in the Owens Valley? A possible explanation involves different mortality factors

affecting mountain lions in Round Valley. The Round Valley lion population has incurred human-induced losses, involving depredation, vehicle collision, and apparent poaching. These have hastened its population decline in the face of poor reproductive success (in part due to human-caused deaths of mothers) and a decline to little immigration. The repeated collaring and recollaring of lions in Round Valley may have been an added aversive behavioral effect. Similar human adverse influences on mountain lions have not occurred near the bighorn sheep populations in the southern Owens Valley, where lions may be using bighorn sheep winter ranges to a greater extent than in Round Valley. The development of winter range avoidance by bighorn sheep in the 1980's and consequent population declines were attributed to influences of increased mountain lion populations that decade as the only viable explanation of this widespread phenomenon (Wehausen 1996). The recent increases in winter range use by bighorn sheep associated with an apparent decline in mountain lions lends considerable support to that explanation. The variation in recovery rates of Owens Valley bighorn sheep populations and its apparent association with regional differences in human influences on mountain lions appears to be further support for that explanation, as are the different initial trajectories of the three reintroduced populations.

D. Future Translocations

The recovery of bighorn sheep in the Sierra Nevada since the 1970's has depended on translocations of sheep and will continue to in the future. The Lee Vining Canyon population was considered the hope for a wild source of translocation stock prior to the winter of 1998. The loss of this prospect clearly increased the potential for extinction of these sheep and thereby brought about a heightened urgency concerning this situation. That the Wheeler Ridge population has suddenly exhibited such increased population growth that it can immediately replace the Lee Vining Canyon population as a potential source of sheep to translocate is fortuitous. The mistake made with the Lee Vining Canyon population was that it was not used as a source for translocations before it collapsed. This lesson should be heeded. At its current high rate of increase, the Wheeler Ridge population should be capable of providing regular translocation stock beginning in the winter of 2001. Given all the unexpected population collapses in recent years, this opportunity should not be missed. A particularly effective use of these sheep would be the augmentation of the Sand Mountain deme to help it recover to where it also can again produce translocation stock. Like compounded interest, this will hasten the overall recovery of these sheep and thereby greatly reduce their vulnerability to extinction. The vulnerability of Sierra bighorn sheep has been in part due to the lack of more than one population large and productive enough to be used as stock for translocations. This problem was clearly recognized in the management goals of the 1984 Recovery and Conservation Plan for these sheep (Sierra Nevada Bighorn Interagency Advisory Group 1984). Recovery of the Sand Mountain deme could greatly alleviate that problem.

Similarly, with the Wheeler Ridge population undergoing rapid expansion, it is not clear that a captive breeding program is called for at this time, and the development of a second large population would further alleviate that need. However, changes in the demographic status of the Wheeler Ridge population could suddenly make a captive breeding program a top priority. A second initial fruitful use of some of the sheep from the Wheeler Ridge population would be to supplement some other populations to add radio collars as an aid to monitoring efforts, in addition to increasing numbers.

VII. Literature Cited

- Bleich, V. C., J. D. Wehausen, K. R. Jones, and R. A. Weaver. 1990. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. *Trans. Desert Bighorn Council*. 34:24-26.
- Brown, L. M., and R. R. Ramey II. 1987. The results of the Mount Langley bighorn sheep census, summer 1987. Report to Inyo National Forest, Bishop, CA. 12pp.
- Chang, K. D. 1993. Report on the status of the Lee Vining Canyon bighorn sheep reintroduction, summer 1993. Report submitted to Yosemite National Park. 10pp.
- Chow, L. S. 1991. Population dynamics and movement patterns of bighorn sheep reintroduced in the Sierra Nevada, California. M. S. Thesis, Univ. of Calif., Berkeley. 157pp.
- Jensen, J. 1994. Report on the status of the Lee Vining Canyon bighorn sheep reintroduction, summer 1994. Report submitted to Yosemite National Park. 8pp.
- Moore, P. E., and L. S. Chow. 1990. Results of the 1990 census of the Mt. Langley bighorn sheep. Admin. Report, Inyo Nat. Forest, Bishop, CA. 9pp.
- Sierra Nevada Bighorn Interagency Advisory Group. 1984. Sierra Nevada Bighorn Sheep Recovery and Conservation Plan. Inyo National Forest, Bishop, CA. 17pp.
- Sierra Nevada Bighorn Sheep Interagency Advisory Group. 1997. A conservation strategy for Sierra Nevada bighorn sheep. Inyo National Forest, Bishop, CA. 26pp.
- Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. Ph.D. Thesis, Univ. of Mich., Ann Arbor, MI. 240pp.
- Wehausen, J. D. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite Mountains of California. *Wildlife Soc. Bull.* 24:471-479.
- Wehausen, J. D., and R. R. Ramey II. 2000. Cranial morphometric and evolutionary relationships in the northern range of *Ovis canadensis*. *J. Mammalogy* (in press).

