A CONSERVATION STRATEGY FOR SIERRA NEVADA BIGHORN SHEEP

Prepared by the

Sierra Nevada Bighorn Sheep Interagency Advisory Group

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The Sierra Nevada Bighorn Sheep Interagency Advisory Group includes representatives from federal, state, and local resource management agencies whose jurisdictions include bighorn sheep or their habitat in the Sierra Nevada, the University of California, and the Sierra Nevada Bighorn Sheep Foundation. This group was created by the director of the California Department of Fish and Game in 1981 to fill a need for interagency coordination in the conservation of these bighorn sheep, following a recommendation by Wehausen (1979). This group is not a decision making body, but serves as a clearinghouse for information and recommends actions that are believed to be in the best interest of long term conservation of Sierra Nevada bighorn sheep. This conservation strategy is such a recommendation, as was its predecessor produced in 1984. Major changes in the demographic status of bighorn sheep in the Sierra Nevada and in factors influencing that status prompted the preparation of this new document.

I. EXECUTIVE SUMMARY

Bighorn sheep native to the Sierra Nevada are a unique form of bighorn sheep found only in that mountain range and are listed as threatened by the state of California. A successful reintroduction program during 1979-88 used one of two surviving native populations to create three additional populations and resulted initially in an increase in the overall population. However, steeply increasing mountain lion predation during the 1980's was apparently the cause of a strong reversal in this population trend. In 1996 only 120-125 bighorn sheep remained in the Sierra Nevada with no population large enough to serve as translocation stock. Only one of the reintroduced populations currently shows promise as a source of translocation stock in the near future. This conservation strategy recommends the following actions to achieve recovery of this endangered life form:

1. Control mountain lions in the vicinity of existing bighorn sheep populations where it may help their recovery.

2. Employ prescribed fire in bighorn sheep habitat where it will reduce hunting abilities of mountain lions by increasing visibility.

3. Take all possible steps to prevent contact between domestic sheep or goats and bighorn sheep in the Sierra Nevada.

4. Translocate rams where it will help assure maximum genetic diversity within populations.

5. Develop the Lee Vining Canyon population as a new source of reintroduction stock and use it for translocations at the earliest possible time before unforeseen future factors might preclude such use.

6. Develop a reintroduction plan by 1998 for the most effective use of the limited reintroduction stock that the Lee Vining Canyon population will produce.

7. Upgrade the California status of these bighorn to endangered and consider federal listing as endangered if this status will provide additional tools and/or funding to aid recovery of these sheep.

8. Continue and initiate research critical to achieving the recovery of this resource, including (a) careful monitoring of bighorn populations, (b) assessment of mountain lion populations near bighorn sheep populations, (c) habitat evaluation for future reintroductions, and (d) a detailed analysis of genetic diversity within each of the populations using fecal sources of DNA.

II. OVERVIEW

This conservation strategy attempts to find a way in which the long term future of the unique bighorn sheep in the Sierra Nevada will best be assured. Primary issues of concern are: (1) a recent high level of mountain lion predation that may be historically unprecedented and is the apparent cause of all bighorn sheep populations in the Sierra Nevada abandoning use of low elevation winter ranges, much to the detriment of the overall population; and (2) domestic sheep grazing near some populations, which can result in the loss of the entire bighorn populations to pneumonia if contact between these two sheep species occurs. The 1996 total population of bighorn sheep in the Sierra Nevada (120-125) is less than 40% its level ten years ago, when it was increasing due to the initial success of reintroductions that began in 1979. These reintroductions increased the number of populations from the two surviving native ones to five, but one of the native populations is now on the verge of extinction after avoiding low elevation winter ranges for 10 years, numbering only 6 adults. The other, once large, native, population has dropped to 15% of its former size. Sierra Nevada bighorn sheep are dangerously close to extinction. Because they are a unique form of bighorn sheep, we consider this situation warrants the immediate deployment of all possible tools that might improve this situation.

The fundamental approach of this conservation strategy is that persistence of native bighorn sheep within the Sierra Nevada will be best guaranteed by developing metapopulations (interacting networks of populations) in areas where these sheep can exist in sufficient numbers with the minimum of mountain lion control necessary. There is strong evidence that the local mountain lion population has been declining in the past few years. Whether it will stabilize at a level suitable for reestablishment of existing bighorn sheep populations using low elevation winter ranges is unknown. Although it is possible that mountain lions were previously absent in the eastern Sierra Nevada, it is our assumption that this was not the case. A fundamental premise of this conservation strategy is that the lion densities that drove Sierra Nevada bighorn sheep to the edge of extinction in the 1980's was a very unusual and probably unprecented event, and that these species can coexist under more normal conditions that may currently be developing.

While habitat will be sought where lions may have minimal impact on bighorn populations, we recognize that some focused control of mountain lions to enhance the survival of existing populations is likely to be necessary to ensure the survival of this animal in the wild. Controlled burning is also recommended to open up bighorn habitat, thereby improving it relative to risk of lion predation. Additionally, it is recommended that grazing permits for domestic sheep or goats near bighorn sheep populations be reviewed and altered, with the goal of reducing the probability of domestic sheep or goats contacting any bighorn sheep in the Sierra Nevada to as close to zero as possible. Because of uncertainties about the success of these proposed activities and factors beyond control, we recommend the consideration of the establishment of a captive population. Such a population should serve as an additional source of translocation stock and will be a reservoir for this gene pool in the event of catastrophic losses in the wild.

Key to the success of this conservation strategy will be the development of the Lee Vining Canyon population as a new source of reintroduction stock and very careful management of this population as the only initial source of this stock. The possible success of this conservation strategy will require the collection of some critical data. Among the research projects needed is a new evaluation of the habitat factors that have recently allowed bighorn sheep living year round at high elevations in the Sierra Nevada to thrive in some locations (i.e. Lee Vining Canyon), while others have fared less well. Application of this understanding to the entire central and southern Sierra Nevada will determine whether and where other successful populations similar to Lee Vining Canyon might be established that use high elevation winter range. Such an analysis also will determine whether this habitat factor can be used to develop metapopulations where lions will have least impact.

III. SCOPE OF THE PLAN

This plan covers only the region of the southern and central Sierra Nevada that is believed to have had a relatively continuous distribution of bighorn sheep prior to the appearance of Europeans. The southern limits are Olancha Peak and the Mineral King area and the northern limit is the Sonora Pass area. There is evidence that bighorn sheep occurred historically further south (Jones 1949, 1950) and north (Wistar 1937) in the Sierra Nevada, but these were probably disjunct populations occupying habitats differing somewhat from the primary region of historic distribution covered by this plan. A consistent habitat feature of the region covered by this plan is the presence of alpine environments above timberline.

This plan first provides summaries of background information necessary to understand the current conservation issues concerning these wild sheep. Second, it outlines the nature of the major conservation questions and basic goals. Third, it proposes actions to attain those goals under the current circumstances. Finally, it points to critical studies needed to achieve the stated conservation goals. This is not a decision document. Where it motivates specific actions, these will take place through individual decision documents prepared by the appropriate agencies. This conservation strategy should be followed by an interagency conservation agreement.

IV. THE BIGHORN SHEEP RESOURCE AND ITS PAST MANAGEMENT

Taxonomic Position

Based on only four specimens collected in the Sierra Nevada, none of which was fully mature, Grinnell (1912) designated Sierra Nevada bighorn sheep a distinct subspecies (*Ovis cervina sierrae*). In a more extensive study of all North American wild sheep, Cowan (1940) failed to find support for Grinnell's conclusion, instead including sheep from the Sierra Nevada under his discussion of California Bighorn (*Ovis canadensis californiana*), whose range extended north to British Columbia between the Cascades and Rocky Mountains and extended south to the southern Sierra Nevada. Cowan (1940) considered bighorn sheep immediately east of the southern Sierra Nevada to belong to a different subspecies (*O. c. nelsoni*); however, he noted that he could not statistically distinguish sheep in the Sierra Nevada from those to the east or to the north and suggested that they represented intergrades (Wehausen 1991). Nevertheless, they have been classified as California bighorn sheep for over half a century and have received special status within California as such. Recent genetic research using mitochondrial DNA has found wild sheep from the Sierra Nevada to be allied instead with those occupying the adjacent southwestern desert region. However, Sierra Nevada bighorn sheep were found in that study to be the most unique group in that entire desert region, extending east as far as Utah and New Mexico and south to Baja California (Ramey 1993). New cranial morphometric research has corroborated both of these results, and found bighorn sheep from the Sierra Nevada to be distinguishable from those immediately adjacent to the east (Wehausen and Ramey 1993, Ramey and Wehausen 1996). Ramey and Wehausen (1996) noted that of all bighorn sheep, those in the Sierra Nevada were most deserving of conservation attention because of their uniqueness and rarity. Until a new taxonomic revision is completed, this conservation analysis will follow the most recent research results and treat bighorn from the Sierra Nevada as a unique gene pool, as did the previous conservation plan.

Biology of Bighorn Sheep

Two adaptations of bighorn sheep substantially define basic habitat requirements. First is their agility on precipitous slopes, which is their primary means of escaping predators. Second is their keen eyesight, which is their primary sense for detecting predators. Relatively short legs and a stocky build allow

agility on rocks, but preclude fleetness necessary to outrun coursing predators in less rocky terrain. Consequently, bighorn sheep select open habitats that allow detection of predators at sufficient distances to allow adequate lead time to reach the safety of precipitous terrain. In short, optimal bighorn habitat is visually open and contains steep, generally rocky, slopes. Forests and thick brush usually are avoided to the extent possible, and fire can play an important role in creating bighorn habitat as well as making existing patches safer relative to predators. Also, large expanses lacking precipitous escape terrain, such as Owens Valley, represent substantial barriers to movement. Even within mountain ranges like the Sierra Nevada, bighorn sheep habitat is frequently patchy and the population structure is one of natural fragmentation (Bleich et al. 1990a). Because of conservative behaviors these sheep have developed in the naturally fragmented habitats that they commonly occupy, bighorn sheep are slow colonizers. This has necessitated capturing and moving sheep to locations deemed suitable to speed up and assure reoccupancy of ranges considered lost as a result of human activities since the appearance of Europeans.

Numerous diseases of bighorn sheep have been documented, but most notable is their susceptibility to pneumonias in general (Post 1971). In particular, they die from strains of respiratory bacteria carried by sheep, and occasionally goats, of Old World origin. The history of bighorn sheep is replete with examples of major die-offs following contact with domestic sheep (Goodson 1982). Experiments have repeatedly confirmed that bighorn sheep are not compatible with strains of respiratory bacteria carried normally by domestic sheep (Onderka and Wishart 1988, Foreyt 1989, Callan et al. 1991). It has also been recently documented that domestic goats can similarly carry bacterial strains fatal to bighorn sheep. Bighorn sheep can also develop pneumonias independent of contact with domestic sheep. Lungworms of the genus *Protostrongylus* can be important contributors to this disease process in some situations (Forrester 1971, Woodard et al. 1974) and management strategies to control these parasites have been developed (Schmidt et al. 1979). Bighorn sheep in the Sierra Nevada carry *Protostronglus sp.* lungworms, but the parasite loads have been too low to be considered a management concern (Wehausen 1979, 1980).

Historic Distribution and Early Population Losses

Historically, bighorn sheep populations were scattered along and east of the Sierra Nevada crest from Olancha Peak to the Sonora Pass area. They also occurred west of the Kern River as far south as Maggie Mountain, with concentrated use in the regions of Mineral King, Big Arroyo, and Red Spur (Jones 1950). In some cases, early records provided some detail of area of use by extirpated populations (see map), but this is probably incomplete. Wehausen (1988) postulated some additional areas that might have been used.

Population losses began shortly after the immigration of Europeans to the Sierra Nevada in the mid 1800's, and these losses have continued through the twentieth century (Wehausen et al. 1987). Some populations that existed in 1920 were gone by 1948 when Jones (1950) conducted a survey of bighorn sheep in the Sierra Nevada. He documented three surviving populations in 1948 and postulated the existence of two others based on sign and reported observations. By the 1970's, only two populations remained in the Sierra Nevada (Wehausen 1979, 1980). Specific causes of most population losses are unknown. Market hunting for mining towns may have played a role in the northern portion of the range. A die-off in the 1870's west of the Kern River was attributed to scabies (Jones 1950), presumably contracted from domestic sheep. Die-offs from pneumonia contracted from domestic sheep were probably the most important cause of losses. Large numbers of domestic sheep were grazed seasonally in the Sierra Nevada prior to the turn of the century (Wehausen 1988).

Management and Recent Population History

The first management action for Sierra Nevada bighorn sheep was full protection. Decimation of native sheep in the Sierra Nevada occurred quickly following the influx of gold miners in the mid 1800's. Declines of native game species led the state legislature to enact legal protections beginning in the 1870's. For wild sheep, this first occurred in 1876, when a law of 1872 that provided seasonal protection for elk, deer, and pronghorn was amended to include all bighorn sheep. Two years later this law was further amended to establish a four-year moratorium on the taking of any pronghorn, elk, mountain sheep, or female deer; and in 1883 this moratorium was extended indefinitely for bighorn sheep (Wehausen et al. 1987). Sierra Nevada bighorn remain fully protected.

Concern about bighorn sheep in the Sierra Nevada (Dixon 1936) prompted the National Park Service and Sierra Club in 1940 to jointly propose the creation of a sanctuary on Inyo National Forest land for the Mount Baxter population (Colby 1940a, b; Blake 1940). This proposal was rejected by the U. S. Forest Service and California Department of Fish and Game on grounds that insufficient information existed to justify the need, as well as concern that the publicity of such a sanctuary might exacerbate poaching, rather than having the opposite effect (Blake 1941). Such sanctuaries (Bighorn Sheep Zoological Areas) were eventually created by the U. S. Forest Service in 1971 for the two surviving native populations (Dunaway 1971) to minimize human disturbance to the sheep; similar restrictions were applied to adjacent habitat of these populations under National Park Service management (Wehausen 1985)

In 1972, the California subspecies of Cowan (1940), including surviving native populations in the Sierra Nevada, was listed as rare under the 1970 California Endangered Species Act (California Department of Fish and Game, 1974) and this status was later changed to threatened. This classification recommended the development and implementation of a recovery plan, including field research and reintroductions. Intensive field study began in 1975 and led to a series of reintroductions beginning in 1979. A conservation and recovery plan was completed in 1984. The goals of that plan were: (1) to create two additional populations numbering at least 100 sheep that could serve as reintroduction stock in the event of catastrophic decline of the Mount Baxter herd, and (2) to reestablish bighorn sheep populations throughout historic ranges in the Sierra Nevada where biologically and politically feasible. To date, no reintroduced population has met the first goal, while unforeseen ecosystem level changes have resulted in a major reduction of the Mount Baxter population.

Intensive field studies during 1975-79 provided accurate census data for the two surviving native populations; the Mount Williamson population was found to contain only 30 sheep, while the Mount Baxter population was large (220) and generally increasing (Wehausen 1980). Detailed annual monitoring of the Mount Baxter population up to 1986 repeatedly verified its large size. Similarly, good winter census opportunities in 1983 and 1985 found the Mount Williamson population to be static at 30 sheep. Because of its large size and productivity, the Mount Baxter herd was used as a source of reintroduction stock beginning in 1979, with subsequent removals made in 1980, 1982, 1986, and 1988, totaling 103 sheep. These were used to reestablish populations at Wheeler Crest (1979, 1980, 1982, 1986), Mount Langley (1980, 1982), Lee Vining Canyon (1986, 1988), and the south Warner Mountains in northeastern California (1980; Bleich et al. 1990b). The Warner Mountains population died out in 1988, following contact with domestic sheep, but the others persist.

The Wheeler Crest and Mount Langley populations exhibited increasing populations within a couple of years of reintroduction. In contrast, the Lee Vining Canyon population declined initially due to post-release mortality from particularly inclement weather, followed by limitation from mountain lion predation while on winter-spring range in Lee Vining Canyon (Chow 1991). Following supplementation in 1988 and

removal of one lion from Lee Vining Canyon in each of three consecutive winters (Bleich et al. 1991), this population increased rapidly (Chow 1991).

Mountain lions have come to play an increasing role relative to Sierra Nevada bighorn sheep. Wehausen (1996) reported rapidly increasing evidence of lions and their kills of sheep on the Mount Baxter herd winter range between 1976 and 1988, with kills totaling 49. Reports of mountain lion depredation problems in Inyo and Mono counties also increased sharply during the 1980's, especially in the second half of the decade. Additionally, detailed records of animals drowning in the Los Angeles aqueduct in southern Owens Valley for most year between 1934 and 1988 never recorded a mountain lion, while 12 lions died this way during 1989-93. This is strong evidence of this being an unprecedented event. Following the passage in 1990 of The Mountain Lion Initiative (Proposition 117) by the voters of California, mountain lion control for the sake of Sierra Nevada bighorn sheep ceased due to threats of litigation by environmental groups opposed to the killing of mountain lions.

In addition to the direct effects of predation losses, all bighorn populations in the Sierra Nevada abandoned regular use of low elevation winter ranges during the 1980's, apparently as a response to high mountain lion activity (Wehausen 1996). For the two native populations, the Mount Williamson herd was last recorded using their escarpment base winter range in 1985, while winter range use by the larger Sand Mountain subpopulation of the Mount Baxter herd declined steeply between 1987 and 1991 to negligible use. Lack of low elevation winter range use has occurred at a high cost to populations because of poor nutrition in late winter and spring, exposure to cold conditions throughout winter, and deep snows and avalanches in heavy winters. For the Mount Baxter herd, the results have been later lambing and poor lamb survival, leading to recruitment well below what would be needed to balance adult mortality. This has led to a major population decline, with the population currently at about 15% of its peak level (Wehausen 1996). The Mount Williamson herd now contains only 2-3 ewes and 3 rams.

Reintroduced populations have suffered similarly from occupying high elevations throughout winter. The heavy winter of 1995 took a notable toll. Winter losses in the Wheeler Ridge population, including 12 that died in a single snow avalanche, reduced the population to about 15 from 35-40. It had grown to 21 by the winter of 1997. The Lee Vining Canyon population dropped from ≥85 to 29 during the winter of 1995, but showed very high overwinter survival and reproductive rates a year later. The Mount Langley population persists, but this population appears also to have suffered major reduction in 1995 or prior. Large census efforts during 1996 and 1997 have documented only 4 ewes as the remaining reproductive base of this population, but 11 rams persist, as well as a yearling of each sex. In contrast, 42 bighorn were counted in this population in a similar census effort in the summer of 1990 (Moore and Chow 1990). The total population of bighorn sheep in the Sierra Nevada has declined substantially since the avoidance of low elevation winter ranges began. This decline follows an initial overall population increase that resulted from the reintroduction program; the total population grew from 250 in 1978 to about 310 sheep in 1986, but numbered only 120-125 in 1996. However, all populations are currently showing increases.

V. THE CONSERVATION PROBLEM AND GOALS

From an individual species perspective, the conservation problem of Sierra Nevada bighorn sheep is long term viability of the overall population, and thereby preservation of this unique gene pool. From an ecosystem standpoint, the problem is the absence of a large native herbivore from the regions of the Sierra Nevada that it once occupied. These situations lead to two ultimate conservation goals: (1) the restoration of Sierra Nevada bighorn sheep in a distribution that assures their long term viability as a unique life form; and (2) the reestablishment of these sheep throughout as much of their native range as possible. While methods of reaching these two goals may overlap substantially, they do not coincide entirely. What might

be considered a situation of adequate long term viability may not require reestablishment of bighorn sheep throughout their native range, and might require the establishment of one or more populations outside their native range as a buffer against extinction. Also, from an ecosystem process approach, any bighorn sheep that would adequately assume the former niche of the Sierra Nevada bighorn might be acceptable. However, from a biodiversity standpoint, only Sierra Nevada bighorn sheep are acceptable for restoration within the Sierra Nevada as long as they exist. Given that restriction, the second problem and goal concerning Sierra Nevada ecosystems is subordinate to the problem and goal concerning viability of Sierra Nevada bighorn sheep as a unique life form. Thus, we adopt both goals in the priority order presented: (1) long term viability of Sierra Nevada bighorn as a unique life form; and (2) the restoration of this life form to as much of its former range as is ecologically, economically, and politically possible. These goals are consistent with the mandate of the 1991 California interagency agreement on biological diversity. We consider the maintenance of three populations or metapopulations, each containing at least 100 sheep, as the minimum necessary for the first of these goals. On a more proximate level, the attainment of these two goals is hindered by factors that threaten persistence of populations and those that limit restoration efforts. These are discussed below.

Domestic Sheep and Goats

Domestic sheep and goats can be a threat to both persistence and restoration of bighorn populations through the potential for major die-offs from pneumonia that can extirpate entire populations if contact between these two sheep species occurs. Where stray domestic sheep or goats can enter bighorn sheep habitat, this represents a threat to existing populations, including potential sources of translocation stock. Where domestic sheep or goats occur in or near unoccupied historic ranges of bighorn sheep, they affect the potential for reintroductions. However, other variables may make some of these historic ranges currently undesirable for reintroduction.

While early domestic sheep grazing in the Sierra Nevada probably included all accessible areas at high elevations, it is currently limited primarily to lower elevations immediately east of the mountains. When domestic sheep stray in this region, their natural tendency is to move uphill into the high mountains, putting them potentially in bighorn habitat and leading to the risk of contact between the two sheep species. This threat exists for all current bighorn sheep populations due to a combination of stock driveways on which domestic sheep are driven north through Owens Valley in spring during some years, and summer grazing allotments along the eastern base or slopes of the mountains in other areas (Figure 1).

These threats are more than hypothetical. In 1974, domestic sheep escaped from the driveway through Owens Valley north of Independence and the 25 that remained of this escaped flock were discovered and removed from the Mount Baxter winter range just as bighorn sheep were beginning to descend to that winter range. In 1988, a single stray domestic sheep was discovered in Lee Vining Canyon as it was entering an area used frequently by bighorn sheep. In 1995, 22 domestic sheep from the Bloody Canyon allotment immediately south of Lee Vining Canyon were discovered in late October and removed from Mount Dana in Yosemite National Park, where they overlapped the range of the small population of bighorn sheep that colonized this region in 1986, following their release in Lee Vining Canyon. Undoubtedly, numerous other stray domestic sheep have gone unrecorded.

Domestic sheep have an inherent tendency to stray. While better husbandry may occasionally be possible to help limit this tendency, sheep herders cannot be expected to control it entirely. Consequently, it has been recognized that the safest solution where bighorn sheep are at risk is to provide large buffer distances between the two species. Bureau of Land Management guidelines suggest that buffer distances as great as 9 miles may be necessary for adequate protection in some case. Those guidelines also recommend

that "extraordinary precautions" be taken to protect state-listed taxa, such as Sierra Nevada bighorn, from the threat of contact with domestic sheep (Bureau of Land Management 1992; Appendix B). Potential threats from domestic goats currently concern the use of goats as pack stock in the back country and the possibility of these straying.

Mountain Lions

Mountain lions currently influence both population persistence and restoration efforts and may be at least as important as the threat of domestic sheep diseases. Through their large impact on habitat selection by bighorn sheep in winter, mountain lions have greatly reduced population carrying capacities. Carrying capacities for most populations that winter at high elevations appear to be small. Because small populations have greater probabilities of extinction, mountain lions affect population persistence. Evidence from the Mount Williamson population suggests that in some regions of the Sierra Nevada bighorn populations may not be able to persist while living exclusively at high elevations.

The influence of mountain lions on sizes of bighorn populations also has influenced the potential for restoration of populations because: (1) large populations are needed as sources of stock for translocations; and (2) the capture of sheep for translocation may be difficult, if possible, outside of most winter ranges. The Mount Baxter herd is no longer a source of translocation stock as a result of changed wintering habits; as a consequence there is no longer a restoration program. Therefore, one of the primary conservation problems of Sierra Nevada bighorn sheep is the reestablishment of a source of translocation stock and a program that uses it. How and where control of mountain lion populations might most benefit bighorn sheep, especially toward the development of a new source of reintroduction stock, is a related and important conservation problem.

That mountain lions as a native species have caused the termination of a successful restoration program and a large reduction in overall population of another native species is not easy to reconcile. This situation suggests three possible explanations: (1) recent mountain lion densities have been much higher than was the case prior to changes brought about by Europeans; (2) the situation of the recent past in which some bighorn populations thrived using low elevation winter ranges was an unnatural situation derived from prior mountain lion control practices, including bounties; or (3) this predator-prey system (including deer) undergoes long term fluctuations that may be cyclical in nature. The last of these is not supported by observations of individuals active in earlier decades and the lack of any lions recorded to drown in the Los Angeles aqueduct system in Owens Valley prior to 1989, but 12 such deaths between 1989 and 1993. Also, Ober (1914) reported large numbers of sheep on the winter range of the Mount Baxter population prior to lion control programs, suggesting that mountain lion densities were notably lower then than in the past 10-15 years. Young and Goldman (1964) plotted the historic range of wolves in the Sierra Nevada as no further south than Lake Tahoe. It is not clear why wolves would not have occurred futher south, and this range map may simply reflect an absense of information. If wolves occurred as far south as Owens Valley, they alone could explain the the current problem with mountain lions in that these cats do not coexist well with wolves. Grizzly bears also have negative effects on mountain lions and these bears were documented to exist in the Owens Valley.

Metapopulations of bighorn sheep will persist only if colonization rates exceed extinction rates (Hanski 1991). The naturally slow colonization rate of bighorn sheep means that natural extinction rates must also be low. The rapid decline of the Mount Williamson herd to very small size after abandoning use its low elevation winter range, and the similar rapid decline of the Mount Baxter herd, appear to be inconsistent with the idea that viable metapopulations can persist in that region at recent mountain lion densities. This is particularly concerning given that these are the last native populations that presumably

persisted because habitat in those regions was favorable. That Sierra Nevada bighorn developed into a unique group indicates that metapopulations in this mountain range persisted for a long time prior to the appearance of Europeans, presumably because of low rates of extinction. In short, recent levels of lion predation are probably unprecedented in this ecosystem, as is the case for the Great Basin in general (Berger and Wehausen 1991).

Regardless of what past circumstances might have been, two contrasting facts figure importantly into the solution to this conservation dilemma. First, despite decades of attempts to severely reduce mountain lion populations in California through bounties and professional lion hunters employed by the state, these cats have recently become very abundant throughout California where habitat remains (Torres et al. 1996). Mountain lions are clearly a species whose extinction has very low probability in western United States. They readily colonize vacant habitat and should not be a species of concern. Second, early domestic sheep grazing and other activities of European colonists resulted in extirpation of most of the bighorn sheep populations in the Sierra Nevada. With questionable long term viability of current populations and low natural colonization rates, active management is needed to help ensure their future. Consequently, from an ecosystem perspective, local control of mountain lions to help reestablish bighorn sheep within the Sierra Nevada is a logical and appropriate solution to this conservation problem. Where such control efforts might be focused is a critical question.

Fire

Fire is also a variable in the conservation problem of Sierra Nevada bighorn sheep. Historically, fires may have burned in bighorn sheep habitat much more frequently than has occurred this century because of both fire control and a lack of fires previously set by native Americans. In opening up habitats, fire can decrease the effectiveness of mountain lions as ambush predators of wild sheep, and may allow sheep greater access to areas with high nutrient availability. Consequently, policies to let fires burn in bighorn sheep habitat, as well as prescribed fire in such habitat, offer additional opportunities to solve this conservation problem.

Metapopulations

Inbreeding and Small Populations

The naturally fragmented distribution of bighorn sheep has led to application of a broad landscape approach, known as metapopulation theory, to their demography (Bleich et al. 1990a, 1996). Metapopulations are networks of interacting populations. The importance of this approach is that it considers long term viability not of individual populations within the metapopulation, but the whole metapopulation; both genetic and demographic factors are thereby considered. Below some size threshold, increasing coefficients of inbreeding accompany decreasing population sizes, which may have negative demographic effects through inbreeding depression (Soulé 1980). At some level, inbreeding is likely to be a conservation problem for bighorn sheep, but that level is not known, and will be influenced by their general history of inbreeding. Both lamb survival and horn growth in bighorn sheep may be influenced by levels of inbreeding (Sausman 1982, Stewart and Butts 1982, Fitzsimmons et al. 1995). A small amount of genetic exchange among populations via ram movements will counteract inbreeding and associated increasing levels of homozygosity that might otherwise develop within small, isolated populations (Schwartz et al. 1986). In essence, an entire metapopulation will be a single gene pool, albeit somewhat subdivided. Rams have a much greater tendency than ewes to explore new ranges searching for other sheep populations in which they may breed. If geographic distances between demes of ewes within metapopulations are not great, gene

migration via rams will occur readily. In the absence of such a metapopulation structure, populations will be isolated and some may benefit from induced gene migration via rams translocated between populations.

The Balance between Extinction and Colonization

The other important long term metapopulation process is the balance between rates of natural extinction and colonization of constituent populations. Colonization rates must exceed extinction rates for a metapopulation to persist (Hanski 1991). Certainly this balance has not occurred for Sierra Nevada bighorn since about 1850, due to the high rate of anthropogenic extinctions. Whether metapopulations of long term viability can be created in the Sierra Nevada under current environmental influences is uncertain. While adequate genetic interchange is likely in such systems, rates of colonization and extinction are uncertain. The current situation of high lion densities has resulted in metapopulations of mostly small populations of sheep wintering at high elevations. Regardless of whether this represents the situation 150 years ago, it is the current situation, out of which a conservation strategy must be forged. The most secure future for bighorn sheep in the Sierra Nevada will be found in the development of metapopulations of high elevation demes that have long term stability. Whether and where such stability is possible remains uncertain, and will depend substantially on extinction rates of such demes. Nevertheless, any future reintroduction program for bighorn sheep in the Sierra Nevada should incorporate the idea of high elevation winter refuges and the concept of viable high elevation metapopulations. Close monitoring of populations will be necessary to test whether such metapopulations can exist.

Currently, the Lee Vining and Bloody Canyon populations represent one metapopulation with potential to expand both south and north. The fact that 29 sheep from the Lee Vining Canyon population and the small population to the south on Mount Gibbs survived the extreme winter of 1995 suggests that a metapopulation of long term viability may be possible in that region. The Wheeler Ridge population is small and isolated, but also has potential to be part of a metapopulation. Native sheep were documented immediately to the south up to about 1940 (Wehausen 1988), and Jones (1950) postulated that a population still persisted in 1948 to the north in the McGee/Convict Creek area. The Mount Baxter herd already consists of two subpopulations, and there are indications that the southern of these may have further subdivided into two since they adopted a high elevation wintering habit. Opportunity may exist to extend this metapopulation north to the Taboose Creek area, where a population existed early this century (Ober 1914). However, the imminent extinction of the Mount Williamson population raises the question of whether a metapopulation of high elevation demes can exist in this region of the Sierra Nevada. The population trend of the Mount Baxter herd over the next several years will be critical to answering that question.

VI. CONSERVATION RECOMMENDATIONS

Preservation of Current Populations

Since the current populations are the principle on which any conservation program will build, the first priority of this conservation strategy is to preserve that principle where possible. However, this must be approached from the standpoint of where the greatest return for effort will be found. Existing populations may not always provide this. Two of the three reintroduced populations have shown some resilience in persisting through a variety of environmental fluctuation, including winters of extreme severity, and high predation pressure from mountain lions. However, given the imminent extinction of the native population on Mount Williamson, the continuing decline of the Mount Baxter herd, and the apparent current small size of the Mount Langley population, these populations may not have the same resilience to changes in winter

habitat use. Careful tracking of trends of all existing populations in the Sierra Nevada will be critical to decisions about where to focus future conservation attention.

Predator Control

With the current situation of scarcity of bighorn sheep available for translocation and some populations at dangerously low numbers, every individual sheep is extremely valuable and may prove to be the difference in persistence of a population. While one intent of this conservation strategy is to motivate the search for locations in the Sierra Nevada where bighorn may be ultimately successful with little or no lion control, a lesson from the Lee Vining Canyon population is that some intervention may be necessary, at least initially. It is also not clear whether adequate populations living year round at high elevations can be established. If this proves not to be feasible, the future of Sierra Nevada bighorn sheep may lie in keeping densities of mountain lions low where bighorn populations occur. Given this situation, mountain lion control should be implemented on winter ranges where it might help the future of any existing population. Special attention should be given to areas where bighorn have been translocated and to sources of reintroduction stock in this regard. Such a control program should attempt to remove lions before they kill bighorn. The potential threat posed by mountain lions near low elevation winter ranges of each existing population should be investigated every winter and lion control implemented if it will benefit to the sheep population. Also, actions that might increase the prey base of mountain lions near bighorn sheep populations should be discouraged. Mountain lion control should be very focused. A widespread control program is likely to lead to a large increase in deer, with the possibility of a subsequent large increase in the lion population.

Control of coyotes and bobcats should also be implemented where they may kill sheep. This is particularly important relative to the Lee Vining Canyon population, where losses of two sheep to coyotes and one to a bobcat have been documented during winter in Lee Vining Canyon.

Fire

A "let burn" fire management policy should be established for all bighorn sheep ranges in the Sierra Nevada. Additionally, prescribed fires should be used to open up prime habitat patches in existing sheep ranges to improve lower elevation winter ranges relative to mountain lion predation. The current highest priority in this regard is Lee Vining Canyon, given the potential for that population to serve as reintroduction stock. However, other populations may benefit importantly from such burns, including the Mount Langley and Mount Williamson populations.

Domestic Sheep and Goats

All domestic sheep grazing permits that have potential to result in contact between domestic and bighorn sheep should be reviewed and changes implemented to attain a goal of developing a negligible probability of such contact. This will involve domestic sheep grazing on both Bureau of Land Management and U.S. Forest Service lands, and possibly lands under Los Angeles Department of Water and Power and private ownership. The 1992 Bureau of Land Management guidelines (Appendix A) on this issue should be used. As a list of sites favorable for reintroductions develops, any domestic sheep conflicts should be identified immediately and attempts should be made by the appropriate agencies and permittees to resolve those conflicts. No reintroductions should be made where more than a negligible probability of contact with domestic sheep or goats exists. Current threats of greatest concern involve domestic sheep grazing south of Lee Vining Canyon, and the stock driveway west of Mono Lake. The sheep fencing along the Inyo National Forest boundary below the Mount Baxter herd winter range should be maintained as long as the

Owens Valley domestic sheep driveway has use. Domestic goat packing should not be permitted anywhere in which a stray goat might contact bighorn sheep.

Permit reduction and cancellation are existing responses available to resource management agencies for grazing permittees that violate permit conditions. Given the potential devastating consequences of stray domestic sheep that contact bighorn sheep, a policy should be established to levy the maximum penalty for violations of allotment boundaries in areas near bighorn sheep populations as incentive for responsible herding practices.

Genetic Diversity

The nature and importance of genetic diversity to Sierra Nevada bighorn remains poorly understood. Demographic health may provide for genetic health. However, considerable uncertainty exists on this, especially on a long term basis. For instance, it is not known whether rams move among the three southern populations, thereby linking them a metapopulation. In the absence of thorough studies of genetic diversity in the 5 populations, it would be safest to exchange rams among them at least once per generation (about 7 years). The ultimate goal of this conservation strategy is to conserve the genetic variation in the gene pool of Sierra Nevada bighorn sheep. As such, it would be desirable maximize this diversity within each demographic unit (metapopulation). Until known otherwise, each current population should be treated as an individual demographic unit. The fate of translocated rams should be followed via long lasting radio collars to verify that the effort has been successful. There is a strong need for genetic research on all populations so that decisions on this question can be made on other than guesses. Fecal DNA analysis offers a non invasive means to develop very detailed genetic profiles of populations.

Restoration

Restoration of Sierra Nevada bighorn sheep through reintroductions and augmentations is the second priority of this strategy. This will require first the development of one or more new sources of reintroduction stock and, second, a plan for the use of such stock to most effectively build viable metapopulations.

Sources of Reintroduction Stock

The Lee Vining Canyon population currently holds the most promise as a future source of reintroduction stock. Prior to its large decline during the severe winter of 1995, this population was close to reaching 100 sheep. This population size was a goal of the previous conservation plan that concerned the potential use of reintroduced populations as further reintroduction stock if a catastrophe should occur to the Mount Baxter herd. Census data from 1996 indicated that the Lee Vining population is capable of rapid recovery.

A lesson from the severe winter of 1995 is that initiation of use of this population as reintroduction stock should take place at a population level less than 100, rather than risking the loss of such opportunity in the event of another severe winter. A similar lesson can be gleaned from the failed attempt to use an enclosed population at Lava Beds National Monument to develop reintroduction stock before it died out of pneumonia in 1980 (Blaisdell 1982, Foreyt and Jessup 1982). These historical lessons should be heeded.

In the 1970's, the threat facing the future of Sierra Nevada bighorn was that only a single population existed that could produce reintroduction stock. The major ecosystem change in the 1980's in the form of greatly increased mountain lion predation destroyed the one source of reintroduction stock, and was entirely unanticipated. It is a matter of luck that (1) a reintroduction program for these sheep came into being when

it did, and (2) the third and last location to which these sheep were reintroduced became the one reasonably successful population under the changed wintering patterns brought about by high lion densities. Had those reintroductions not occurred, Sierra Nevada bighorn would undoubtedly now be desperately close to extinction, totaling about 40 animals. What cannot be predicted now is what unforeseen catastrophe might befall the Lee Vining Canyon population, such as one stray domestic sheep. As such, the sooner that population is used to create other populations, the sooner some resolution to this precarious situation will be achieved.

Should an unforeseen calamity occur to the Lee Vining Canyon population that threatens the ability of this population to reach 25 ewes and thereby provide reintroduction stock, immediate capture of some of the remaining sheep should be implemented to place them in a captive breeding facility in order to preserve this gene pool. The capture of a small number of additional sheep from other populations to augment these captive stock should also be considered under such a circumstance.

Sites for Relocations

Establishment of a captive population of Sierra Nevada bighorn sheep should be given strong consideration as (1) a buffer against the possibility that long term viability of metapopulations is no longer possible within the Sierra Nevada, and (2) a potential additional source of reintroduction stock. Establishment of such a population under circumstances in which they retain much of their wildness will may help assure behaviors having better survival potential when caught and translocated to the Sierra Nevada. On the other hand some loss of wildness among captive reared bighorn might be advantageous in trying to redevelop consistent winter range use. A captive facility may offer control of more extraneous factors, but might lead to greater disease threats if located at a zoo.

The previous conservation plan for Sierra Nevada bighorn sheep provided a priority list of sites for reintroductions based on low elevation winter ranges. Despite the fact that this list was based on historic use by bighorn, it should be revised to incorporate (1) consideration of high elevation winter habitat and (2) establishment of metapopulations. This will require a separate translocation plan that cannot be incorporated into this conservation strategy because of research that needs to be undertaken on what constitutes good high elevation winter range and where it exists. To the extent possible, this translocation plan should first develop metapopulations around existing populations, but only where such metapopulations appear to have the potential to be viable. Second, the maintenance of separation between some metapopulations should be addressed as it relates to the possible spread of a disease through populations within the Sierra Nevada. A captive population will provide a buffer against such a situation, and natural breaks between metapopulations will probably provide this buffer without extra planning. This translocation plan also should seek areas in the Sierra Nevada that may be free of mountain lions in winter. In particular, historic ranges west of the Kern River may be free of mountain lions after deer migrate out of the region in fall. If this is the case, this region may have higher habitat value for reintroductions than some high elevation sites. Because of time constraints, it is recommended that research necessary to prepare a reintroduction plan commence immediately.

State and Federal Endangered Status

The Sierra Nevada bighorn sheep is currently an indisputably endangered taxon. Their listing under the California Endangered Species Act should be upgraded from threatened to endangered to reflect this. Listing at the federal level should be pursued only if solutions to problems for the conservation of these sheep cannot be solved by an interagency conservation agreement. This is also the policy of the U.S. Fish and Wildlife Service.

VII. RESEARCH AND MONITORING NEEDS

Population Monitoring

Detailed annual monitoring of demographic trends in all populations will be critical to achieving goals of this conservation plan. The very recent signs of recovery of populations following the devastating winter of 1995 and the beginning of occupation of some low elevation winter ranges is encouraging. However, this could be a false signal if the trend does not continue. Careful monitoring of the Lee Vining Canyon herd is of obvious importance because of the need to use it as translocation stock as soon as possible. Good demographic data on the other populations is equally important because it will be critical in deciding the most effective use of available translocation stock -- augmentation of existing populations to hasten recoveries, or creation of new populations in areas considered to have better potential for success.

Assessment of Mountain Lion Trends

The cause of particularly high mountain lion predation in the 1980's remains uncertain. This pattern fits into a statewide increasing pattern of mountain lion problems during the 1970's and 1980's (Torres 1996). Among the possible explanations for this pattern is that the 1980's represented an overshoot of carrying capacity by the lion population after release in the 1960's from bounty and other hunting. Under this scenario, mountain lion populations might decrease substantially and attain a level compatible with bighorn sheep populations occupying low elevation winter ranges. There are indications that such a decline in mountain lion density has been occurring in the 1990's in one region of the eastern Sierra Nevada adjacent to the Wheeler Ridge population. Consequently, it is recommended that an assessment of lion numbers in the regions of bighorn sheep populations be made to determine the need for lion control measures.

Habitat Evaluation and a Reintroduction Plan

Previous assessments of habitat suitable for reintroductions in the Sierra Nevada (Wehausen 1979, Sierra Nevada Bighorn Interagency Advisory Group 1984) used the Mount Baxter herd winter range as model habitat that supported a large and productive population; high elevation summer ranges were assumed to be sufficient if no barriers between winter and summer ranges existed. The potential reintroduction sites chosen by this approach are not necessarily appropriate to the recent situation of bighorn wintering at high elevations. Consequently, a future reintroduction program will be dependent on a new evaluation of habitat in the Sierra Nevada, that considers also the quality of high elevation winter ranges.

Habitat suitability models developed for bighorn sheep in desert environments have attempted to develop quantitative predictive models. However, these multivariate models have been generated subjectively and have not always predicted habitat quality adequately (Bleich et al. 1992, Andrew 1994). These existing models are not appropriate to the Sierra Nevada, nor is their method of development. Instead, an empirical study is needed that compares characteristics of high elevation winter ranges where sheep have recently developed larger populations (e.g. Lee Vining Canyon) with those where recent densities have been quite limited (e.g. Mount Baxter). Snow patterns will be fundamental in this analysis, since bighorn have been documented using high snow-free slopes in winter. This analysis may be possible using existing digital satellite imagery, but could also be done photographically from an aircraft under appropriate snow conditions. Some assessment of forage conditions in high elevation areas of low snow cover may also be appropriate.

Future mountain lion influences cannot be predicted. The high predation pressure from lions evident in the 1980's was probably an unprecedented circumstance. Recent abatement in lion density may allow

bighorn to reoccupy low elevation winter ranges. Even under high lion densities, lower elevation south-facing slopes have been used by some populations for short periods in April and May and this may be critical for diet quality of females in late gestation. The Use of such slopes in Lee Vining Canyon, for instance, may have been critical to the success of that population, even though these slopes received almost no use in winter and early spring. Consequently, the analysis of high elevation wintering sites should be coupled with an analysis of access to south-facing, lower elevation ranges that might be utilized in winter and spring. Even brief use of such habitats in spring, as occurs in Lee Vining Canyon, may be of crucial importance to these sheep.

Genetic Analyses

Without good genetic data, management actions to preserve overall genetic diversity of the gene pool of Sierra Nevada bighorn sheep and the genetic integrity of individual populations must be made on untested assumptions. In the absence of such information, the safest approach is to assume that some genetic problems may occur. However, a detailed genetic analysis might find that such actions are entirely unnecessary and represent a waste of funds and unnecessary risks to the animals and humans involved. At the other extreme such information might suggest that more or different actions are needed to maximize retention of genetic diversity within to total gene pool. Such genetic analyses can now be done in completely noninvasive ways using DNA extracted from fecal samples. This research should be initiated as quickly as possible.

VIII. TIMING OF ACTIONS

Actions Toward Bighorn Reintroduction or Augmentation

The recovery of Sierra Nevada bighorn sheep will require a well-coordinated series of actions; timing may be critical for some of these. There may be some natural recovery by some populations, but this alone will not adequately assure the future of this resource. Ultimate recovery will revolve primarily around the availability and use of reintroduction stock. The Lee Vining Canyon population contained 15 ewes in 1996 and showed a high reproductive rate. By 1998 this population may exceed 25 ewes and be available as a source of reintroduction stock. A tentative goal should be the capture of some of these sheep for translocation in the fall of 1998 or the following winter. This will require (1) prior completion of research on favorable habitat and reintroduction sites, (2) choice of the next location(s) to receive translocated bighorn, (3) completion of necessary planning documents to make such a translocation, including monitoring of the translocated sheep, and (4) development of a strategy for the capture of these sheep at high elevation. A small trial capture to add collars in 1998 may be of great benefit in developing capture techniques at high elevations. At that time a few rams from Lee Vining Canyon could also be moved to other populations to enhance genetic diversity and provide radio collars to aid monitoring. A critical choice for the use of available translocatable stock will be whether they will be used best to augment existing populations or to establish new populations. Information from detailed monitoring of existing populations will be critical for this decision. A major goal should be the production of a translocation plan in 1998 that will assess the best use of available stock that can be moved. In turn, this plan will depend on continuous population monitoring data and a study of high elevation winter habitat to be combined with traditional and historical lower elevation winter habitat. The sooner detailed genetic data are available, the sooner this information can be used as a basis of decisions on translocations.

Protection and Enhancement of Existing Populations

Efforts to protect existing populations from losses may be equally important. This is especially important for the Lee Vining Canyon population that appears to be the most immediate hope for a source of translocatable stock, but may also be critical to the recovery of other populations. Thus, the following should take place as quickly as possible: (1) controlled burns to make winter habitat more secure relative to predation; (2) assessment of mountain lion densities around remaining bighorn populations and development of a lion control program that can be implemented wherever a potential threat exists; and (3) adjustment of domestic sheep grazing allotments that might lead to contact between domestic and bighorn sheep so as to reduce this threat to a negligible level.

Recommended Timetable of Actions

1997

(1) Detailed monitoring of existing populations (winter and summer).
(2) Begin assessment of high elevation winter habitat (winter).
(3) Begin initial assessment of mountain lion densities near existing bighorn populations (winter).
(4) Implement controlled burns (when conditions appropriate).
(5) Research possible sites for a captive or free-ranging population outside the Sierra Nevada.
(6) Initiate needed grazing permit changes.
(7) Establish the mountain lion control program.

1998

(1) Continue detailed monitoring of existing populations (winter and summer).
(2) Complete assessment of high elevation winter habitat (winter).
(3) Complete plan for population reintroduction and augmentation (spring).
(4) Make assessment of mountain lion densities near existing bighorn populations (winter)
(5) Begin and complete administrative procedures for first bighorn translocation(s) (summer).
(6) Implement small bighorn capture of the Lee Vining Canyon population to add radio collars and begin developing capture methods for this population.

IX. LAND OWNERSHIP AND AGENCY RESPONSIBILITY

Jurisdiction over bighorn sheep within the Sierra Nevada is generally split between the California Department of Fish and Game, which has jurisdiction over the sheep, and land management agencies that control the habitat that these sheep inhabit or once occupied. Land ownership of current and historic bighorn sheep range within the Sierra Nevada is almost entirely split between two federal agencies, the U. S. Forest Service and the National Park Service. Within agencies, these are further divided into different National Forests and Parks. West of the crest are Sequoia/Kings Canyon National Park in the south and Yosemite National Park in the north, separated by Sierra National Forest, with some historic bighorn habitat on Sequoia National Forest in the far south. East of the crest are Inyo and Toiyabe National Forests, and the sheep that once occupied the Sonora Pass area probably also crossed into Stanislaus National Forest. All current bighorn sheep populations in the Sierra Nevada occupy habitat on Inyo National Forest. Seasonally, some of these populations utilize lands under management by the two national parks and Sierra National Forest. Additionally, a small amount of winter range previously used by the Mount Williamson and Wheeler Ridge populations fell on lands administered by the Bureau of Land Management.

Agency responsibilities extend beyond administration of lands previously or currently occupied by bighorn sheep. Domestic sheep grazing allotments that have the potential to affect bighorn sheep are not entirely on lands administered by the U. S. Forest Service. The domestic sheep driveway through Owens Valley is mostly on Bureau of Land Management land, and grazing on Los Angeles Department of Water and Power land may also have the potential to impact bighorn sheep. If Sierra Nevada bighorn sheep become listed under the federal Endangered Species Act, the U. S. Fish and Wildlife Service will become an additional agency with particularly active involvement. They can also play an important role in the absence federal listing.

Because the California Department of Fish and Game has jurisdiction over the bighorn sheep themselves, that agency carries the responsibility for the capture and handling of any sheep for collaring or translocation. Any mountain lion control similarly falls under their jurisdiction. Habitat manipulations, e.g. controlled burns, will be the responsibility of the agency on whose land it takes place. The larger question of responsibility concerns the funding of monitoring, research, and management actions needed to attain the goals of this conservation strategy. The conservation of bighorn sheep in the Sierra Nevada should be approached from an ecosystem perspective and funded on a cooperative basis to the extent possible. Outside funding sources such as private foundations should be solicited to participate to the extent needed.

X. REFERENCES CITED

Andrew, N. G. 1994. Demography and habitat use of desert-dwelling mountain sheep in the East Chocolate Mountains, Imperial County, California. M.S. Thesis, Univ. of Rhode Island, Kingston. 135pp.

Berger, J., and J. D. Wehausen. 1991. Consequences of a mammalian predator-prey disequilibrium in the Great Basin Desert. Conserv. Biol. 5:244-248.

Blaisdell, J. A. 1982. Lava Beds wrap-up, what did we learn? Trans. Desert Bighorn Counc. 26:32-33.

Blake, A. H. 1940. Conference on Sierra bighorn planned. Sierra Club Bull. 25(6):7.

Blake, A. H. 1941. Mountain sheep conference held. Sierra Club Bull. 26(2):3.

Bleich, V. C., J. D. Wehausen, and S. A. Holl. 1990a. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. Conserv. Biol. 4:383-390.

Bleich, V. C., J. D. Wehausen, K. R. Jones, and R. A. Weaver. 1990b. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. Trans. Desert Bighorn Counc. 34:24-26.

Bleich, V. C., C. D. Hargis, J. A. Keay, and J. D. Wehausen. 1991. Interagency coordination and the restoration of wildlife populations. Pages 277-284 *in* J. Edelbrock and S. Carpenter, eds. Natural areas and Yosemite: prospects for the future. U. S. Nat. Park Service, Denver Service Center, Denver, CO.

Bleich, V. C., M. C. Nicholson, A. T. Lombard, and P. V. August. 1992. Preliminary tests of a mountain sheep habitat model using a geographic information system. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 8:256-263.

Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 453-473 *in* D. R. McCullough, ed. Metapopulations and wildlife conservation management. Island Press, Washington, D.C.

Bureau of Land Management. 1992. Guidelines for domestic sheep management in bighorn sheep habitat. Instruction Memorandum No. 92-264.

Callan, R. J., T. D. Bunch, G. W. Workman, and R. E. Mock. 1991. Development of pneumonia in desert bighorn sheep after exposure to a flock of exotic wild and domestic sheep. J. Amer. Vet. Med. Assoc. 198:1052-1056.

California Department of Fish and Game. 1974. At the crossroads, a report on California's endangered and rare fish and wildlife. Calif. Dept. of Fish and Game, Sacramento, CA.

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.

Colby, W. E. 1940a. Sanctuary for bighorn. Sierra Club Bull. 25(3):5-6.

Colby, W. E. 1940b. Sanctuary for mountain sheep. Sierra Club Bull.25(5):3-4.

Cowan, I. McT. 1940. Distribution and variation in the native sheep of North America. Amer. Midl. Natur. 24:505-580.

Dixon, J. S. 1936. The status of the Sierra bighorn sheep. Proc. N. Amer. Wildl. Conf. 1:641-643.

Dunaway, D. J. 1971. Bighorn sheep habitat management on the Inyo National Forest. Trans. Desert Bighorn Counc. 15:18-23.

Fitzsimmons, N. N., S. W. Buskirk, and M. H. Smith. 1995. Population history, genetic variability, and horn growth in bighorn sheep. Conserv. Biol. 9:314-323.

Foreyt, W. J. 1989. Fatal Pasteurella haemolytica pneumonia in bighorn sheep after direct contact with clinically normal domestic sheep. Amer. J. Vet. Res. 50:341-344.

Foreyt, W. J., and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Dis. 18:163-168.

Forrester, D. J. 1971. Bighorn sheep lungworm-pneumonia complex. Pages 158-173 *in* J. W. Davis and R. Anderson, eds. Parasitic diseases of wild mammals. Iowa St. Univ. Press, Ames.

Goodson, N. J. 1982. Effects of domestic sheep grazing on bighorn sheep populations: a review. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:287-313.

Grinnell, J. 1912. The bighorn of the Sierra Nevada. Univ. Calif. Publ. Zool. 10:143-153.

Hanski, I. 1991. Single-species metapopulation dynamics: concepts, models, and observations. Biol. J. Linnean Soc. 42:17-38.

Jones, F. L. 1949. A survey of the Sierra Nevada mountain sheep. M.S. thesis, Univ. Calif., Berkeley. 154pp.

Jones, F. L. 1950. A survey of the Sierra Nevada bighorn. Sierra Club Bull. 35(6):29-76.

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.

Ober, E. 1914. Fish and game conditions in the "land of little rain". Calif. Fish and Game Comm. Bienn. Rep. 23:123-126.

Onderka, D. K., and W. D. Wishart. 1988. Experimental contact transmission of Pasteurella haemolytica from clinically normal domestic sheep causing pneumonia in Rocky Mountain bighorn sheep. J. Wildl. Dis. 24:663-667.

Post, G. 1971. The pneumonia complex in bighorn sheep. Trans. N. Amer. Wild Sheep Conf. 1:98-102.

Ramey, R. R. II. 1993. Evolutionary genetics and systematics of north american mountain sheep. Ph.D. Thesis, Cornell Univ., Ithaca, NY.

Ramey, R. R. II, and J. D. Wehausen. 1996. Morphometric analysis of horn and skull variation in mountain sheep: northern regions of *Ovis canadensis*. Unpub. report to cooperators. Nat. Park Service, Denver Service Center, Colorado.

Sausman, K. 1982. Survival of captive born *Ovis canadensis* in North American zoos. Trans. Desert Bighorn Counc. 26:26-31.

Schmidt, R. L., C. P. Hibler, T. R. Spraker, and W. H. Rutherford. 1979. An evaluation of drug treatment for lungworm in bighorn sheep. J. Wildl. Manage. 43:461-467.

Schwartz, O. A., V. C. Bleich, and S. A. Holl. 1986. Genetics and the conservation of mountain sheep *Ovis canadensis nelsoni*. Biol. Conserv. 37:179-190.

Sierra Nevada Bighorn Interagency Advisory Group. 1984. Sierra Nevada bighorn sheep recovery and conservation plan. Inyo Nat. Forest, Bishop, CA.

Soulé, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 in M. E. Soulé and B. A. Wilcox, eds. Conservation biology, an evolutionary-ecological perspective. Sinauer Assoc., Inc., Sunderland, MA.

Stewart, S. T., and T. W. Butts. 1982. Horn growth as an index to levels of inbreeding in bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:68-82.

Torres, S. G., T. M. Mansfield, J. E. Foley, T. Lupo, and A. Brinkhaus. 1996. Mountain lion and human activity in California: testing speculations. Wildlife Soc. Bull. 24:451-460.

Wehausen, J. D. 1979. Sierra Nevada bighorn sheep: an analysis of management alternatives. Coop. Admin. Report, Inyo Nat. Forest and Sequoia, Kings Canyon, and Yosemite Nat. Parks. 92pp.

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. 1985. A history of bighorn sheep management in the Sierra Nevada. Pages 99-105 *in* D. Bradley, ed. Proc. State of the Sierra Symp. 1985-86. Pacific Publications Co., San Francisco, CA.

Wehausen, J. D. 1988. The historical distribution of mountain sheep populations in the Owens Valley region. Pages 97-105 *in* Mountains to desert; selected Inyo readings. Friends of the Eastern Sierra Museum, Independence, CA.

Wehausen, J. D. 1991. Some potentially adaptive characters of mountain sheep populations in the Owens Valley region. Pages 256-267 *in* C. A. Hall, Jr., V. Doyle-Jones, and B. Widawski, eds. Natural history of eastern California and high-altitude research. White Mountain Research Sta. Symp. Vol. 3., Bishop, CA.

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., V. C. Bleich, and R. A. Weaver. 1987. Mountain sheep in California: a historical perspective on 108 years of full protection. Trans. West. Section Wildl. Soc. 23:65-74.

Wehausen, J. D., and R. R. Ramey II. 1993. A morphometric reevaluation of the peninsular bighorn subspecies. Desert Bighorn Counc. Trans. 37:1-10.

Wilson, L. O., and C. L. Douglas. 1982. Revised guidelines for capturing and re-establishing desert bighorns. Trans. Desert Bighorn Counc. 26:1-7.

Wistar, I. J. 1937. Autobiography of Isaac Jones Wistar. The Wistar Institute of Anat. and Biol., Philadelphia, PA. 528pp.

Woodard, T. N., R. J. Gutierrez, and W. H. Rutherford. 1974. Bighorn lamb production, survival, and mortality in south central Colorado. J. Wildl. Manage. 38:771-774.

Young, S. P., and E. A. Goldman. 1998. The wolves of North America. Dover Publ. Inc., New York.

APPENDIX A

The following individuals were involved in the preparation of this document. Affiliation abbreviations are: Inyo National Forest (INF); Yosemite National Park (YNP); Sequoia/Kings Canyon National Park (SKNP); Bureau of Land Management (BLM); U. S. Geological Service Biological Resources Division, Yosemite Field Station (BRD); U. S. Fish and Wildlife Service (FWS); California Department of Fish and Game (DFG); University of California, White Mountain Research Station (WMRS); Sierra Nevada Bighorn Sheep Foundation (SNBSF).

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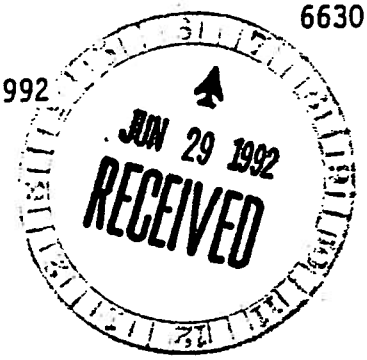
APPENDIX B

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
WASHINGTON, D.C. 20240

IN REPLY REFER TO:
6630 (240/220)

June 18, 1992



EMS Transmission 6/24/92
Instruction Memorandum No. 92-264
Expires 9/30/93

To: AFO's, SCD

From: Director

Subject: Guidelines for Domestic Sheep Management in Bighorn Sheep Habitats

Attached is a copy of the revised guidelines for domestic sheep management in bighorn sheep habitats which replace those issued via Information Bulletin No. 92-212. These guidelines were prepared by representatives of the organizations listed below at a meeting in Denver, Colorado, on May 22-23, 1992. The guidelines represent consensus among the participants and should be followed in current and future bighorn/domestic sheep use areas.

- Foundation for North American Wild Sheep;
- Desert Bighorn Council;
- American Sheep Industry Association;
- Western Association of Fish and Wildlife Agencies;
- Veterinarians from California (Dr. Dave Jessup), Idaho (Dr. Dave Hunter), and Wyoming (Dr. Tom Thorne);
- An Immunobiologist from Idaho (Dr. Alton Ward);
- BLM - Division of Rangeland Resources; and
- BLM - Division of Wildlife and Fisheries.

Please note that these guidelines will be reviewed every 3 years. Should you have any questions on these guidelines, please contact Jim Fox (202/653-9193) or Dave Almand (202/653-9202).

Signed
Mike Penfold
Assistant Director, Land and Renewable Resources

Authenticated
Georgette A. Fogle
Directives (WO 8550

1 Attachment
1 - Guidelines for Domestic Sheep Management in Bighorn Sheep Habitats, (3 pp)

Guidelines
for
Domestic Sheep Management in Bighorn Sheep Habitats

The Bureau of Land Management desires progressive bighorn sheep management compatible with appropriate grazing on public lands by domestic sheep.

It is recognized by State and Federal agencies, bighorn sheep organizations, and the domestic sheep industry that:

- There appears to be some diseases that are shared by domestic and bighorn sheep. There is evidence that if bighorn and domestic sheep are allowed to be in close contact, health problems and die offs may occur. Some diseases may be transmitted between both species;
- There are bighorn sheep die offs that occur with no apparent relationship to contact with domestic sheep;
- The above two observations are both valid and not mutually exclusive;
- Bacterial pneumonias are not the only diseases of concern, although perhaps they are the most catastrophic;
- The risks of disease transmission are often unknown; they may, however, be site specific; and
- Reasonable efforts must be made by domestic sheep permittees and wildlife and land management agencies to minimize the risk of disease transmission, and to optimize preventive medical and management procedures, to ensure healthy populations of bighorn sheep and domestic sheep.

In recognition of the above factors, the guidelines set forth below should be followed in current and future bighorn/domestic sheep use areas.

1. State wildlife and Federal land management agencies, bighorn interests groups, and domestic sheep industry cooperation and consultation are necessary to maintain and/or expand bighorn sheep numbers.

2. When agency and industry agreement has been reached to maintain and/or expand bighorn sheep numbers, the agencies and the domestic sheep industry will be held harmless in the event of disease impacting either bighorns or domestic sheep.

3. Domestic sheep grazing and trailing should be discouraged in the vicinity of bighorn sheep ranges.

4. Bighorn sheep and domestic sheep should be spatially separated to discourage the possibility of coming into physical contact with each other.

5. Buffer strips surrounding bighorn sheep habitat should be encouraged, except where topographic features or other barriers prevent physical contact between bighorn and domestic sheep. Buffer strips could range up to 13.5 kilometers (9 miles), depending upon local conditions and management options.

6. Domestic sheep should be closely managed and carefully herded where necessary to prevent them from straying into bighorn sheep areas.

7. Trailing of domestic sheep near or through occupied bighorn sheep ranges may be permitted when safeguards can be implemented to adequately prevent physical contact between bighorns and domestic sheep.

8. Unless a cooperative agreement has been reached to the contrary, bighorn sheep should only be reintroduced into areas where domestic sheep grazing is not permitted, and the allotment(s) in which bighorns are to be reintroduced should not have been used for domestic sheep grazing for two or more years prior to the bighorn release.

9. In certain special circumstances, extraordinary precautions will be followed to protect federally listed threatened or endangered subspecies; State listed subspecies; federal candidate subspecies; and BLM Category II populations (BLM Rangewide Plan for Managing Habitat of Desert Bighorn Sheep).

10. For desert bighorn sheep, (Ovis canadensis nelsoni, O.c. mexicana, and O.c. cremnobates), the following additional guidelines are recommended:

a. No domestic sheep grazing should be allowed within buffer strips less than 13.5 kilometers (9 miles) surrounding desert bighorn habitat, except where topographic features or other barriers prevent physical contact.

b. Domestic sheep trailed and grazed outside the 13.5 kilometers (9 mile) buffer and in the vicinity of desert bighorn ranges should be closely managed and carefully herded.

c. Unless a cooperative agreement has been reached to the contrary, domestic sheep should be trucked rather than trailed, when trailing would bring domestic sheep closer than 13.5 kilometers (9 miles) to occupied desert bighorn sheep ranges, especially when domestic ewes are in estrus.

11. These guidelines will be reviewed every 3 years by a work group comprised of representatives from the livestock industry, State wildlife agencies, BLM and bighorn sheep organizations.

WO855 for CA910 06:00 PDT 24-Jun-92 Message 864-5010 ⅝5] * Priority *

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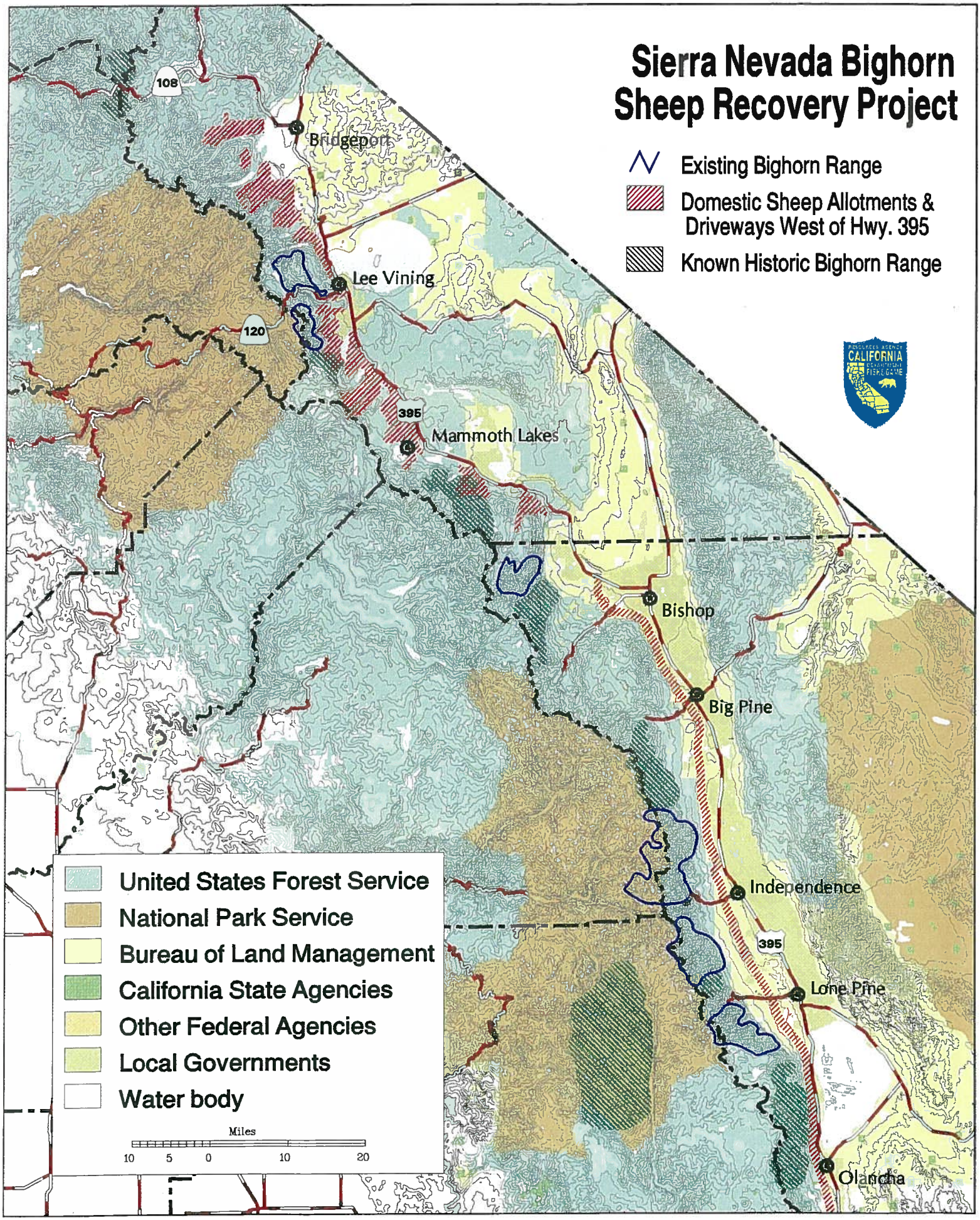
Sierra Nevada Bighorn Sheep Recovery Project
Existing Bighorn Range
Domestic Sheep Allotments & Driveways West of Hwy. 395
Known Historic Bighorn Range
CALIFORNIA
Bridgeport
Lee Vining
Mammoth Lakes
Bishop
Big Pine
Independence
Lone Pine
Olancha
108
120
395
United States Forest Service
National Park Service
Bureau of Land Management
California State Agencies
Other Federal Agencies
Local Governments
Water body
Miles
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