Draft Recovery Plan
for the
Sierra Nevada Bighorn Sheep
(*Ovis canadensis californiana*)

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Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Manager, California/Nevada Operations Office
Region 1, U.S. Fish and Wildlife Service

Date: ___________________________

The *Draft Recovery Plan for the Sierra Nevada Bighorn Sheep* was developed by the State of California, Resources Agency, Department of Fish and Game, and the U.S. Fish and Wildlife Service in cooperation with:

National Park Service
U.S. Bureau of Land Management
U.S. Forest Service

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX Date: ________

Director, California Department of Fish and Game

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX Date: ________

Regional Director, National Park Service

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX Date: ________

Regional Director, U.S. Bureau of Land Management

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX Date: ________

Regional Forester, U.S. Forest Service

Primary Author

The primary author of this recovery plan is:

John D. Wehausen, Ph.D.
University of California
White Mountain Research Station
3000 East Line St.
Bishop, CA 93514

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An electronic version of this recovery plan is also available at http://www.r1.fws.gov/ecoservices/endangered/recovery/default.htm.

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Sierra Nevada Bighorn Sheep Recovery Team

Stakeholder Team Members

Katie Bellomo, People for Mono Basin Preservation, Lee Vining, California
Bob Bissell, Society for the Conservation of Bighorn Sheep
Paula Brown, Sierra Nevada Bighorn Sheep Foundation, Bishop, California
Deirdre E. Flynn, California Wool Growers Association, Sacramento, California
Joe Echenique, Echenique Livestock Company, Bakersfield, California
Gary Guenther, Wilderness Watch, Mammoth Lakes, California
Debbie House, Department of Water and Power, Bishop, California
Mickey Jarvis, California Cattleman's Association, Bishop, California
Ron Keil, Inyo National Forest, U.S. Forest Service, Bishop, California
Brenda Lacey, California Wool Growers Association, Bishop, California
Mike Lawrence, Bridgeport Ranger District, U.S. Forest Service, Bridgeport, California
Ray Lee, Foundation for North American Wild Sheep, Cody, Wyoming
Craig London, Rock Creek Pack Station, Bishop, California
Sally Miller, The Wilderness Society, Lee Vining, California
Paul McFarland, Friends of the Inyo, Lee Vining, California
Kathy Noland, Inyo National Forest, U.S. Forest Service, Bishop, California
Chris Papouchis, Animal Protection Institute, Sacramento, California
Toni Richards, Bishop Paiute Tribe, Bishop, California
Lynn Sadler, Mountain Lion Foundation, Sacramento, California
Steve Thompson, Yosemite National Park, National Park Service, California
Brian Tillemans, Department of Water and Power, Bishop, California
Todd Vogel, Sierra Mountaineering Center, Bishop, California
John Walter, The Sierra Club – Range of Light Chapter, Mammoth Lakes, California
Harold Werner, Sequoia-Kings Canyon National Parks, National Park Service, California

Stakeholder Meetings were facilitated by Dr. John D. Wehausen and Dr. David S. Zezulak.

Science Team Members

Mr. Carl Benz, U.S. Fish and Wildlife Service, Ventura, California

Dr. Vern Bleich, California Department of Fish and Game, Bishop, California

Dr. Walter Boyce, University of California, Davis, California

Ms. Diana Craig, U.S. Forest Service, Pacific Southwest Region, Vallejo, California

Dr. David M. Graber, Sequoia – Kings Canyon National Park, Three Rivers, California

Dr. Howard Quigley, Hornocker Wildlife Institute, Bozeman, Montana

Dr. Peter Stine, Sierra Nevada Research Center, Sacramento, California

Mr. Steve Torres, California Department of Fish and Game, Sacramento, California

Dr. John D. Wehausen, University of California, White Mountains Research Station, Bishop, California

Science Team Meetings were facilitated by Mr. Troy D. Kelly
and Dr. David S. Zezulak.

EXECUTIVE SUMMARY

Current Species Status: The population of bighorn sheep in the Sierra Nevada of California (*Ovis canadensis californiana*) was listed as an endangered species on January 3, 2000, following emergency listing on April 20, 1999. In 1995 these bighorn sheep hit a population low of about 100 total individuals, distributed across 5 separate areas of the southern and central Sierra Nevada, and had increased to about 125 in 1999. Since then conditions have been particularly favorable for population growth, with the total number of individuals reaching about 250 in 2001.

Habitat Requirements and Limiting Factors: These bighorn sheep use habitats ranging from the highest elevations along the crest of the Sierra Nevada (4,000+ meters [13,120+ feet]) to winter ranges at the eastern base of the range as low as 1,450 meters (4,760 feet). These habitats range from Great Basin sagebrush scrub to alpine. Within this range, primary elements of preferred habitats are visual openness and close proximity to steep rocky escape terrain. Forage resources vary greatly across habitats used by these bighorn sheep, and plant species eaten vary accordingly. Of particular importance to population parameters is the nutrient content of forages eaten. Nutrient quality of diets varies greatly with season and elevation and is limited primarily by effects of temperature and soil moisture on plant growth. Because of the relationship between elevation and temperature, low elevation winter ranges provide an important source of high quality forage early in the growing season.

Significant population declines beginning in the late 1980's were associated with these bighorn sheep avoiding low elevation winter ranges. This avoidance behavior has been suggested to be linked to increasing predation pressure from mountain lions on winter ranges during the 1980's. Because of population collapses that have occurred since this winter range avoidance began, some of the herds may now be too small to allow the group sizes necessary to provide bighorn sheep the psychological comfort to make use of winter ranges. Longer-term limiting factors have undoubtedly included contact with domestic sheep leading to pneumonia epizootics in the bighorn sheep; domestic sheep grazing adjacent to bighorn sheep ranges has continued to be a significant threat in recent decades. Because almost all bighorn sheep habitat in the Sierra Nevada is in public ownership, loss of habitat to human use has not been a limiting factor.

Recovery Objective: The objective of this recovery plan is to attain population sizes and geographic distribution of bighorn sheep in the Sierra Nevada that assure long-term viability of the overall population and thereby allow its delisting as an endangered species.

Recovery Priority: The Sierra Nevada bighorn sheep has a recovery priority number of 3. Recovery priorities for listed species range from 1 to 18, with 1 being the highest priority. The priority system uses the criteria of: (1) degree of threat, (2) recovery potential, and (3) taxonomy (level of genetic distinctiveness). A fourth factor, conflict, is a supplementary element characterizing whether or not recovery actions are likely to be in conflict with construction or other development projects. A priority of 3 has been assigned to the Sierra Nevada bighorn sheep for the following reasons: (1) there is a high degree of threat because the population is small in size and its distribution is fragmented; (2) there is a high recovery potential; and (3) the listed entity, as described, is a distinct population (which receives the same rating level as a subspecies).

Downlisting Criteria: Potential bighorn sheep habitat in the Sierra Nevada was divided into 17 herd units, and those herd units were grouped into 4 recovery units on the basis of natural breaks in habitat distribution. Two criteria will be used for downlisting.

Downlisting Criterion A1: A minimum of 50 yearling and adult females exist in the Kern recovery unit (Great Western Divide), 175 in the Southern recovery unit (Olancha Peak to Coyote Ridge), 75 in the Central recovery unit (Mount Tom to Laurel Mountain), and 65 in the Northern recovery unit (Mount Wood to Twin Lakes), for a minimum total of 365 females. These minimum values will be determined by direct count. To achieve these population numbers it is expected that the major threats of excessive predation and avoidance of high-quality low-elevation winter ranges will have substantially diminished.

Downlisting Criterion A2: The threat of domestic sheep or goats contacting bighorn sheep in the Sierra Nevada has been eliminated.

Delisting Criteria: Three delisting criteria were developed based on biological parameters, distribution of the herd units, and research on threats to the population.

Delisting Criterion B1: The minimum numbers of females by recovery units required for downlisting have been maintained as an average for one bighorn sheep generation (6 years) with no intervention. To achieve these population numbers it is expected that the major threats of excessive predation and avoidance of high-quality low-elevation winter ranges will have substantially diminished and remained low over an extended period of time.

Delisting Criterion B2: Bighorn sheep are distributed such that at least 2 herd units are occupied in the Kern recovery unit, 6 in the Southern recovery unit, 3 in the Central recovery unit, and 3 in the Northern recovery unit, for a total of 14 herd units. Currently, seven of these herd units are occupied.

Delisting Criterion B3: Recovery tasks related to monitoring and research goals have been accomplished, allowing the severity of secondary threats (including habitat loss, vegetational succession, recreational disturbance, competition with elk or deer, acid rain, and climate change) to be adequately assessed. Threats have either been ameliorated or have been determined not to pose a significant risk to the population.

Actions Needed: Immediate actions involve helping small herds increase to sizes that allow adequate use of winter ranges in order to achieve positive population growth values. Key elements that may be involved are: (1) predator management; (2) augmentation of small herds with individuals from larger ones; and (3) elimination of the threat of a pneumonia epizootic resulting from contact with domestic sheep or goats.

Longer term actions concern reintroducing bighorn sheep to vacant herd units and maintaining genetic variation. Reintroductions require the development of sufficient sources of translocation stock.

Good monitoring of bighorn sheep herds and some predators are also actions important to the success of this recovery effort, as are some key research projects.

This recovery plan calls for separate implementation plans on the following subjects: (1) bighorn sheep monitoring; (2) bighorn sheep translocation; (3) predator management; (4) genetic management; and (5) how to deal with a pneumonia outbreak.

Recovery Costs: Cost estimates of all recovery (Part II) tasks but task 1.1 are made in the Implementation Schedule (p. 69), totaling $21,730,000 over 20 years. Additional costs to identify and acquire important habitat not in public ownership (Task 1.1) will be determined as parcels are identified and acquired.

Date of Recovery: With optimal population growth rates, recovery criteria might be met to allow downlisting within 10 years (2013) and delisting within another 10 years (2023). Under less than optimal scenarios, including unexpected catastrophes, one or more additional decades may be needed.

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I. INTRODUCTION

A. BRIEF OVERVIEW

1. LISTING OF BIGHORN SHEEP IN THE SIERRA NEVADA

In 1878, State legislation provided temporary protection from hunting for all bighorn sheep in California; in 1883, that protection became permanent, a status that remains for bighorn sheep in the Sierra Nevada (Wehausen *et al.* 1987). In 1972, the California subspecies, as defined by Cowan (1940) and including surviving native herds in the Sierra Nevada, was listed as rare under the 1970 California Endangered Species Act (California Department of Fish and Game 1974); that category was changed to threatened in 1984. In 1999, the California Fish and Game Commission upgraded the status of these bighorn sheep to endangered. On April 20, 1999, we (the U.S. Fish and Wildlife Service) granted emergency endangered status to bighorn sheep inhabiting the central and southern Sierra Nevada of California as a distinct population segment and, simultaneously, published a proposed rule to list the species as endangered (U.S. Fish and Wildlife Service 1999 [64 FR19333]). The final rule granting endangered status to that population segment was published on January 3, 2000 (U.S. Fish and Wildlife Service 2000 [65 FR 20]).

2. ORIGIN, MORPHOLOGY, AND TAXONOMY

Wild sheep crossed the Bering land bridge from Siberia during the Pleistocene and, subsequently, spread through western North America as far south as Baja California and northern mainland Mexico (Cowan 1940). Divergence from their closest Asian ancestor (Siberian snow sheep; *Ovis nivicola*) occurred about 600,000 years ago (Ramey 1993). In North America, wild sheep have diverged into two extant species -- thinhorn sheep (*Ovis dalli*) that occupy Alaska and northwestern Canada, and bighorn sheep (*Ovis canadensis*) that range from southern Canada to Mexico. The seven subspecies of bighorn sheep proposed by Cowan (1940) have come under recent taxonomic scrutiny, and most have not been consistent with new genetic (Ramey 1993, 1995; Boyce *et al.* 1997, Gutierrez-Espeleta *et al.* 1998) or morphological data (Wehausen and Ramey 1993, 2000) or the reanalysis of Cowan's (1940) original data (Ramey 1993).

Lack of support for the traditional taxonomy includes the classification of bighorn sheep from the Sierra Nevada. Based on only four immature specimens collected in the Sierra Nevada, Grinnell (1912) designated Sierra Nevada bighorn sheep a distinct subspecies (*Ovis cervina sierrae*). Cowan (1940) failed, however, to find support for Grinnell's Sierra Nevada subspecies. He included sheep from the Sierra Nevada instead under the California bighorn (*O. canadensis californiana*) subspecies, the distribution of which extended north to British Columbia between the Cascade 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*); he noted, however, that he could not statistically distinguish bighorn sheep in the Sierra Nevada from those to the east or to the north and suggested that they represented intergrades (Wehausen 1991a). Nevertheless, they were classified as California bighorn sheep for over half a century (Shackleton 1985) and have received State rare, threatened and, eventually, endangered status under the California Endangered Species Act as this taxon since 1972.

In contrast to Cowan's (1940) classification, recent genetic research based on mitochondrial DNA has found wild bighorn sheep from the Sierra Nevada to be allied with those occupying the adjacent desert region (Ramey 1993, 1995). However, Sierra Nevada bighorn sheep were found to be the only distinctive group in the desert region that extended eastward to Utah and New Mexico and southward into Baja California, Mexico (Ramey 1993, 1995). They exhibit reciprocal monophyly (no shared mitochondrial haplotypes with desert bighorn sheep), which qualifies them as an "evolutionary significant unit" (Moritz 1994). Recent morphometric analyses (Wehausen and Ramey 2000) have corroborated these genetic results and found bighorn sheep from the Sierra Nevada to be distinguishable from those immediately to the east and north. On that basis, Wehausen and Ramey (2000) determined that *O. c. californiana* was limited to the central and southern Sierra Nevada, and they reassigned more northern populations previously considered to be the same subspecies to other taxa because of an absence of distinguishing characters.

B. ECOLOGY

1. HABITAT

Two adaptations of bighorn sheep substantially define their basic habitat requirements. The first is their agility on precipitous rocky slopes, which is their primary means of evading predators. The second is their keen eyesight, which is their primary means of detecting predators. Relatively short legs and a stocky build allow agility on rocks but preclude the 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 sheep habitat is visually open and contains steep, generally rocky, slopes. Forests and thick brush usually are avoided to the extent possible, but bighorn sheep will use open woodland habitats on rocky slopes. Fire can play an important role in creating or improving bighorn sheep habitat in some ecosystems by increasing the visibility of predators. Large expanses lacking precipitous escape terrain, such as the Owens Valley, can represent substantial barriers to movement. Even within mountain ranges like the Sierra Nevada, bighorn sheep habitat is patchy and the population structure is one of natural fragmentation (Bleich *et al.* 1990a).

Bighorn sheep in the Sierra Nevada utilize a wide range of elevations, from alpine peaks in excess of 4,000 meters (13,120 feet) to the base of the eastern escarpment as low as 1,450 meters (4,760 feet) (Wehausen 1980). Within this elevational range there exists a wide variety of vegetation communities, including (from lowest to highest): (1) Great Basin sagebrush-bitterbrush-bunchgrass scrub; (2) pinyon-juniper woodland and mountain mahogany scrub; (3) mid-elevation and subalpine forests, woodlands, and meadows; and (4) alpine meadows and other alpine habitats varying from cliffs to plateaus. Because of the overall aridity of this region, meadow habitats are patchy in distribution and occur only where the water table is predictably high due to factors like snow accumulation. The Great Basin scrub and alpine communities offer the most desirable habitats for bighorn sheep in terms of visual openness. However, because of the aridity of the eastern slope of the Sierra Nevada, many of the mid-elevation vegetation communities have some locations near precipitous rocks with sufficiently sparse plant cover to allow use by bighorn sheep (Wehausen 1980). Because of their extreme visual openness and steep rocky nature, alpine environments in the Sierra Nevada provide large expanses of habitat broken only by canyons containing forests and willow stands, which bighorn sheep may avoid. In contrast, low elevation winter habitat has been limited to small areas where topographic and visual features are suitable (Riegelhuth 1965; McCullough and Schneegas 1966; Wehausen 1979, 1980). High elevation habitat in the Sierra Nevada has been noted for its aridity relative to other alpine habitats because precipitation is scant and unpredictable during the summer season when temperatures permit plant growth (Major and Bamberg 1967). As a result, the vegetation depends substantially on snow melt for moisture. Snow and resulting soil moisture show great spatial variation (Major 1977). Vegetation patterns vary concomitantly with moisture, ranging from meadow patches to areas almost devoid of plants (Major and Taylor 1977).

2. FOOD HABITS AND NUTRITION

Bighorn sheep are ungulates that possess a large rumen and reticulum relative to body weight (Krausman *et al.* 1993), which permits flexibility in plants consumed and, notably, allows the digestion of graminoids (grasses, sedges, and rushes) in all phenological stages (Hanley 1982). This flexibility in food consumption, in turn, allows flexibility in feeding habitats utilized. Wehausen (1980) and Moore (1991) provided detailed information on the species composition of diets of bighorn sheep on different seasonal ranges in the Sierra Nevada. Those authors found great variation in diets, from those dominated by graminoids to those dominated by non-graminoid species. Wehausen (1980) provided nutritional data on plant species in different phenological stages and noted that bighorn sheep altered their diets on the basis of what provided the best nutrition at the time. Wehausen (1980, 1992), Wehausen and Hansen (1988), and Moore (1991) provided curves of fecal crude protein, which indexes digestibility of the forage consumed and, thus, general diet quality (Wehausen 1995). Analyses of these patterns over 14 years indicated that timing of the first soaking winter storm (2.5 centimeters or about an inch of precipitation) that initiated plant growth most affected winter-spring diet quality for bighorn sheep utilizing low elevation winter ranges. Earlier initiation of plant growth resulted in improved diet quality. In addition, warmer winter temperatures aided plant growth and thereby improved diet quality (Wehausen 1992). Summer range diet quality appeared to be influenced positively by the amount of snowfall the previous winter, presumably through the influence of summer snowpack on soil moisture for alpine plants (Wehausen 1980); overall, summer diet quality was higher following a heavy winter.

Phosphorus may be somewhat lacking in the diets of bighorn sheep in the Sierra Nevada. Klickoff (1965) found alpine soils in the region of Yosemite National Park consistently deficient in this mineral, which may reflect leaching of soils by snowmelt (Major and Bamberg 1967). Wehausen (1983) found notably lower levels of phosphorus relative to crude protein (a covariate correcting for phenological stage) for alpine graminoids in the central and southern Sierra Nevada when compared to the nearby White Mountains. The species analyzed were potential forages of bighorn sheep in the Sierra Nevada, and Wehausen (1980) found bighorn sheep there consistently to select alpine forages of higher phosphorus content, sometimes at the cost of higher protein levels. It is not known if lower phosphorus levels in the Sierra Nevada have population-level effects on bighorn sheep there.

3. BEHAVIOR

Bighorn sheep exhibit a variety of behavioral adaptations to avoid predation. One such adaptation is group living (Hamilton 1971, Alexander 1974); groups provide more eyes and ears, allowing members to spend less time surveying for predators and more time feeding. Studies of this phenomenon have found that increases in group size of up to six (or more) bighorn sheep confer an advantage in the proportion of time allocated to feeding (Berger 1978, Risenhoover and Bailey 1985). The selfish herd concept of Hamilton (1971) suggests that yet greater group sizes may confer further behavioral comfort. Such comfort may be an important factor enabling bighorn sheep to utilize habitats with greater risks of predation, notably low elevation winter ranges in the Sierra Nevada.

Bighorn sheep are primarily diurnal (Krausman *et al.* 1985). Coupled with their strong reliance on keen eyesight to detect predators, diurnal behavior minimizes predation risks. Nights generally are spent on rocky slopes, but bighorn sheep may venture a short distance away from rocky escape terrain to feed during daylight. How far they venture from safer habitat varies and is apparently influenced by visual openness (both habitat and weather influences), wind, gender, season (*e.g.* whether vulnerable young are present), and abundance of predators.

Bighorn sheep commonly exhibit seasonal changes in habitat use that reflect various resource needs. Surface water, although important in many desert ranges, rarely is utilized by bighorn sheep in the Sierra Nevada. Instead, these bighorn sheep obtain needed moisture from forage or occasional consumption of snow. Because of relationships between elevation and temperature (Major 1977) and their influences on plant growth (Wehausen 1980, 1983), altitudinal migration in high mountain ranges like the Sierra Nevada allows bighorn sheep to maximize nutrient intake (Hebert 1973, Wehausen and Hansen 1988, Wehausen 1996). In past years, bighorn sheep in the Sierra Nevada used low elevation ranges extensively in winter and early spring, alpine ranges in summer and fall, and some intermediate ranges during transition periods (Wehausen 1980). During the second half of the 1980's, this seasonal pattern changed to one of avoidance of low elevation winter ranges (Wehausen 1996).

Male and female bighorn sheep commonly live in separate groups during much of the year, and often occupy different habitats (Geist and Petocz 1977, Wehausen 1980, Bleich *et al.* 1997). In the Sierra Nevada, both sexes may share common winter ranges, but they show progressive segregation from winter to spring (Wehausen 1980). During summer, the two sexes utilize different habitats, with females restricted largely to alpine environments along the crest and males often at somewhat lower elevations in subalpine habitats west of the crest (Wehausen 1980). Males again join females during the breeding season in late fall.

Bighorn sheep have developed conservative philopatric behaviors (reluctance to disperse from their home range) that make them slow to colonize unoccupied habitat (Geist 1967, 1971). These behaviors are likely an adaptation to the naturally fragmented habitats that bighorn sheep commonly occupy, but they have necessitated the capture and translocation of bighorn sheep to historic ranges in order to speed up and assure re-occupancy.

4. METAPOPULATION STRUCTURE

a. Inbreeding and Small Populations

The naturally fragmented distribution of bighorn sheep has led to the application of a broad landscape approach to their population ecology. This approach groups geographically distinct herds into metapopulations, which are networks of interacting herds (Schwartz *et al.* 1986, Bleich *et al.* 1990a, 1996, Torres *et al.* 1996). Thus this approach considers long-term viability not of individual herds, *per se*, but rather of entire metapopulations; consequently, both genetic and demographic factors are considered. Increasing coefficients of inbreeding and genetic drift accompany decreasing population sizes and, over time, can lead to decreasing levels of heterozygosity that may have negative demographic effects through inbreeding depression (Soulé 1980) and loss of adaptability. At some level, inbreeding and associated low genetic variation are 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 and other factors that challenge them. Lamb survival and horn growth in bighorn sheep both have been suggested to be influenced by inbreeding (Sausman 1982, Stewart and Butts 1982, Fitzsimmons *et al.* 1995). Moreover, there is growing evidence that disease resistance is related to levels of heterozygosity (Carrington *et al.* 1999, Coltman *et al.* 1999).

A small amount of genetic exchange among herds via movements by males can counteract inbreeding and associated increases in homozygosity that might otherwise develop within small, isolated populations (Schwartz *et al.* 1986). In essence, an entire metapopulation is a single gene pool, albeit somewhat subdivided. Males have a much greater tendency than do females to explore new ranges, which they may do in search of other females to breed with. If geographic distances between groups of females within metapopulations are not great, gene migration via males occurs readily. In the absence of such a metapopulation structure, populations will be isolated and may benefit from genetic enrichment via induced migration by individuals translocated between herds.

Substructuring also can occur within what are often designated as single herds of bighorn sheep (Geist 1971, Holl and Bleich 1983, Festa-Bianchet 1986, Wehausen 1992b, Jaeger 1994, Andrew *et al.* 1997, Rubin *et al.* 1998). Such substructuring is defined by separate home range patterns. Although more evident in females, it can occur in both sexes. Because separate female groups often reflect matrilines (Festa-Bianchet 1986), differences in (maternally inherited) mitochondrial DNA profiles between them may be detectable (Bleich *et al.* 1996, Boyce *et al.* 1999). Population substructuring has been recognized in Sierra Nevada bighorn sheep (Wehausen 1979) and was incorporated in a previous conservation plan for these bighorn sheep (Sierra Nevada Bighorn Interagency Advisory Group 1984). What was once known as the Mount Baxter herd is now recognized as two herds: the Mount Baxter and Sawmill Canyon herds. Bleich *et al.* (1996) suggested that separate female groups are the fundamental building blocks of bighorn sheep metapopulations.

b. The Balance between Extinction and Colonization

The other important long-term process in metapopulation dynamics is the balance between rates of natural extinction and colonization among 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 sheep since about 1850 due to the high rate of anthropogenic extinctions that resulted in an increasingly fragmented distribution. The recent reintroduction program itself added some new isolated herds (Bleich *et al.* 1996). Additionally, the recent collapse of all herds resulted in mostly small groups of bighorn sheep that winter at high elevations and that are more vulnerable to extinction because of small size and more severe winter climates than may be encountered at lower elevations.

5. REPRODUCTION

Bighorn sheep generally give birth to single young, but there is a low incidence of twins (Buechner 1960). Bighorn sheep occupying many desert mountain ranges have protracted lambing seasons covering many months, while those living under colder winter temperature regimes give birth during short periods in late spring and early summer (Thompson and Turner 1982, Bunnell 1982; but, see Rubin *et al.* 2000). Bighorn sheep in the Sierra Nevada fit this latter pattern (Wehausen 1980). The birthing season can begin as early as April 20, and end as late as early July (Wehausen 1991a), with most births occurring in May and June (Wehausen 1996). Timing of births correlates with the nutritional regime of females; later birthing appears to be a consequence of lower annual nutrient intake (Wehausen 1996). The gestation period for bighorn sheep is approximately 174 days (Shackleton *et al.* 1984, Hass 1995). The breeding (rutting) season in the Sierra Nevada, therefore, occurs during late fall and early winter (mostly November and December), when bighorn sheep are usually at high elevations.

Nutrient intake also can influence birth rates (Wehausen 1984), including the frequency with which adult females produce young and the age at which young females first bear offspring. Two years of age is the youngest that females in the Sierra Nevada have been known to give birth. Age at first lambing may be as high as 4 years under poor nutritional circumstances, as has been recorded for Dall sheep (*Ovis dalli*; Bunnell and Olson 1981). Measuring the actual proportion of females producing young is difficult because of possible unrecorded losses soon after birth. The upper range of summer ratios of lambs to females recorded shortly after the birthing season in the Sierra Nevada has been 75 to 83:100 (Wehausen 1980, Chow 1991), while the lowest reported value was 30:100 (Wehausen 1980).

Survivorship of lambs to yearling age also varies with environmental and nutritional factors. For the Mount Baxter and Sawmill Canyon herds in the Sierra Nevada during 1965 to 1979, 73 percent of the variation in winter lamb to female ratios could be explained by variation in precipitation 8 to 12 months prior to conception (Wehausen 1980). That model suggested that variation in the production of young, rather than offspring survival, was the primary variable affecting winter recruitment ratios during that time period. However, with recent winter range avoidance, lamb survival in this population declined considerably (Wehausen 1996); thus, this model does not apply to recent habitat use patterns.

6. MORTALITY FACTORS

Bighorn sheep die from a variety of causes, including disease, predation, and accidents. Of particular interest relative to the conservation of endangered populations are factors that remove animals at younger ages when considerable reproductive potential remains. There is substantial documentation of the devastating effects of various diseases on bighorn sheep populations. Of particular note is pneumonia. Pneumonia epizootics can lead to massive all-ages die-offs that decimate or extirpate entire populations and may have played a major role in early losses of herds in the Sierra Nevada. Mortality resulting from disease is discussed further below in section I.B.7. under "Disease and Parasitism".

Various predators kill wild sheep in North America, including wolves, mountain lions, coyotes, bears, bobcats, wolverines, and eagles (Kelly 1980, Berger 1991, Nichols and Bunnell 1999, Bleich 1999). Wolves are not known to have occurred in the central and southern Sierra Nevada in the original range of bighorn sheep (Young and Goldman 1944). In the Sierra Nevada, mountain lions have been the primary predator of bighorn sheep, accounting for 96 percent of losses attributed to predation (Table 1). Of 147 bighorn sheep deaths recorded in the Sierra Nevada in the past quarter century, 54.5 percent have been attributed to predation (Table 1). That predators take some bighorn sheep does not imply that these losses will limit bighorn sheep populations.

During recent years, bighorn sheep in the Sierra Nevada have incurred major winter losses while avoiding low elevation winter ranges, apparently in response to predation pressure (Wehausen 1996). Those losses have included poor lamb survival over winter (Wehausen 1996), losses of all sex and age classes in snow avalanches, and many undocumented losses during the winter and spring

Table 1. Causes of known bighorn sheep mortalities in the Sierra Nevada by population since 1975. Sources include data in Andaloro and Ramey (1981), Chow *et al.* (1993), Wehausen (1996) and many unpublished records. Data include radio collared individuals and remains of uncollared individuals encountered during field surveys. Baxter includes the Mount Baxter and Sawmill Canyon herd units, and Lee Vining includes the Mount Warren and Mount Gibbs herd units.

Herd	Predation			Avalanche/ Accidents	Post Release Exposure	Highway Collision	Not Known
	Lion	Coyote	Bobcat				
Langley	7						4
Williamson	5						2
Baxter	50			1			27
Wheeler	3			15			2
Lee Vining	12	2	1	3	5	1	7
Totals	77	2	1	19	5	1	42
Percent	52.4	1.4	0.7	12.9	3.4	0.7	28.6

when bighorn sheep failed to use winter ranges. The recent collapse of the Lee Vining Canyon population can be attributed almost entirely to losses at high elevations during certain severe winters. Bighorn sheep accounted for during summer and fall one year have been missing the following summer. A minimum of 77, and possibly as many as 86 bighorn sheep, could be accounted for between Lee Vining and Lundy Canyons in the summer of 1993 (Chang 1993). An apparently less-than-complete count the following summer yielded a minimum of 43 for that area, and a potential maximum of only 69 (Jensen 1994). Following the severe winter of 1995, however, repeated thorough counts of this herd produced consistently only 29 bighorn sheep (Wehausen and Chang 1995), representing a loss of possibly 50, or more, individuals. Additional overwinter declines occurred in 1998 and 1999 (Wehausen and Chang 1998, Wehausen 1999). Somewhat baffling has been a lack of carcasses of these missing individuals; of the dozens of bighorn sheep that disappeared in this area, the remains of only two have been found.

7. DISEASE AND PARASITISM

Numerous diseases of bighorn sheep have been documented (Bunch *et al.* 1999), of which pneumonia and psoroptic scabies have had the greatest population-level effects. Bighorn sheep show a high susceptibility to pneumonia, usually caused by bacteria of the genus *Pasteurella* (Posts 1971). Pneumonia caused by *Pasteurella* alone, or in combination with other pathogens, is the most significant disease threat for Sierra Nevada bighorn sheep (Bunch *et al.* 1999). Exposure of bighorn sheep to some strains of pneumophilic *Pasteurella* commonly carried by healthy domestic sheep usually causes fatal pneumonia in bighorn sheep and constitutes a major management concern (Onderka and Wishart 1988, Foreyt 1989, Callan *et al.* 1991, Foreyt *et al.* 1994, Sweeney *et al.* 1994, Martin *et al.* 1996). The strains of *Pasteurella* that cause disease in bighorn sheep are much more toxic to certain white blood cells in bighorn sheep than they are to those in domestic sheep or domestic goats (Silflow *et al.* 1994). Domestic goats appear not to carry such strains regularly (Foreyt 1994). However, during a *Pasteurella* pneumonia outbreak in bighorn sheep in Hells Canyon (Oregon, Washington, and Idaho border region), a feral goat found with bighorn sheep carried strains of *Pasteurella haemolytica* and *P. multocida* that were genetically identical to those in the bighorn sheep associated with it, including a strain cytotoxic to the bighorn sheep, but not to the goat (Cassirer *et al.* 1996). Whether the feral goat was the source of those strains in the bighorn sheep is not entirely clear (Cassirer *et al.* 1996), but this event demonstrates that domestic goats can carry such strains. Goats may carry strains of *Pasteurella* if they have been in recent contact with domestic sheep.

Domestic sheep once were grazed in very high numbers throughout the southern and central Sierra Nevada (Vankat 1970). While particulars of past population losses for bighorn sheep in the Sierra Nevada are mostly lacking, contact with domestic sheep and consequent disease problems probably played a major role (Wehausen 1985). Domestic sheep and goats in or near bighorn sheep habitat remain the greatest disease threat to the persistence and restoration of bighorn sheep in the Sierra Nevada. The history of bighorn sheep is replete with examples of major die-offs following contact with domestic sheep (Goodson 1982, Foreyt and Jessup 1982), and these pneumonia epizootics can extirpate entire populations (Martin *et al.* 1996). Contact can occur via stray domestic sheep entering bighorn sheep habitat, or when bighorn sheep come into contact with domestic sheep.

While early domestic sheep grazing in the Sierra Nevada probably included all accessible areas at high elevations, it has recently been limited primarily to lower elevations immediately east of the mountains. All current bighorn sheep herds have been at risk of contact in recent decades due to a combination of stock driveways, on which domestic sheep are driven north through the Owens Valley in spring during some years, and summer grazing allotments along the eastern base or slopes of the mountains in other areas. In 1974, a large number of domestic sheep escaped from the driveway through Owens Valley north of Independence, and the 25 that remained were discovered and removed from the Mount Baxter winter range just as bighorn sheep were beginning to occupy that winter range in late December. In 1988, a single stray domestic sheep was discovered in Lee Vining Canyon as it was entering an area frequently used by bighorn sheep. In 1995, 22 domestic sheep from the Bloody Canyon allotment were discovered in late October and removed from Mount Dana in Yosemite National Park, where they overlapped the range of a small group of bighorn sheep near Mount Gibbs. Undoubtedly, numerous other stray domestic sheep have gone unrecorded. Fortunately, no stray domestic sheep have been documented to contact bighorn sheep and cause a pneumonia die-off in the Sierra Nevada in the past quarter century.

Despite their strong herding behavior, history indicates that domestic sheep have an inherent tendency to stray. While better husbandry may help limit this tendency, sheep herders cannot be expected to control it entirely. Bighorn sheep, especially males, have also been known to move into domestic sheep herds. 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. The Bureau of Land Management guidelines for desert regions suggested that buffer distances as great as 13.5 kilometers (9 miles) may be necessary for adequate protection in some cases. Those guidelines also recommended that "extraordinary precautions" be taken to protect listed taxa from the threat of contact with domestic sheep (Bureau of Land Management 1992).

Threats from domestic goats currently concern the use of goats as pack stock in the back country. Pack goats should be assumed to harbor disease organisms of pathogenic consequence to bighorn sheep. Horses, mules, burros, and llamas are not considered disease threats to bighorn sheep (Miller *et al.* 1995, Foreyt and Lagerquist 1996; Appendix A).

Lungworms of the genus *Protostrongylus* can be important contributors to pneumonia in bighorn sheep in the Rocky Mountains (Forrester 1971, Woodard *et al.* 1974), and methods have been developed to control these nematode parasites in some wild populations (Schmidt *et al.* 1979). Bighorn sheep in the Sierra Nevada carry *Protostrongylus* lungworms, but parasite loads have been too low to be considered a management concern (Wehausen 1979, 1980).

Many early die-offs of bighorn sheep, including some in the Sierra Nevada, were attributed to scabies contracted from domestic sheep (Jones 1950, Buechner 1960). Over the past 20 years, this disease has been a significant mortality factor among bighorn sheep in the San Andres Mountains of New Mexico (Lange *et al.* 1980, Hoban 1990, Rominger and Weisenberger 2000). Scabies also has been found recently in bighorn sheep in California east of the Sierra Nevada (Clark *et al.* 1988). In a large sampling of bighorn sheep in the Sierra Nevada during 1979 to 1988, however, no clinical evidence of scabies was noted. Similarly, serum samples from those sheep showed no evidence of exposure to *Psoroptes* (Mazet *et al.* 1992).

Other infectious diseases may be of concern for bighorn sheep in selected instances. For example, bluetongue virus was responsible for die-offs of bighorn sheep in the Lava Beds enclosure in California (Blaisdell 1975) and at the Red Rock facility in New Mexico (Singer *et al.* 1998). For the Red Rock facility, a comparative study of bluetongue exposure in adjacent cattle indicated that those bovids likely were not the source of infection (Singer *et al.* 1998). Similarly, Singer *et al.* (1997), found that neither deer nor cattle were implicated in the Lava Beds die-off.

8. INTERSPECIFIC COMPETITION AND HUMAN DISTURBANCE

Interspecific competition occurs when a resource shared by two species is in short supply for at least one of those species (Krebs 1972). For bighorn sheep exhibiting altitudinal migration, questions of competition commonly have focused on winter ranges, where grazing animals are more concentrated and forage is more limited (Stelfox 1976). Both native deer (*Odocoileus hemionus)* and introduced tule elk (*Cervus canadensis nannodes*) have overlapped winter ranges used by bighorn sheep in the Sierra Nevada (Riegelhuth 1965). Nonetheless, quantitative studies of utilization of key forage species on the Mount Williamson and Mount Baxter winter ranges did not suggest any competition (Wehausen 1979, 1980). Wehausen (1992a) attributed limitations on nutrient intake by bighorn sheep on these ranges to nutritive quality, rather than quantity, of forage. Further, the potential for forage competition has greatly decreased since the studies of the 1960's, 1970's and 1980's due to behavioral changes by the bighorn sheep as well as their potential competitors. The Goodale tule elk population that utilized the Mount Baxter herd winter range abandoned that portion of Owens Valley about 1990, and use of winter ranges by bighorn sheep has declined to a small proportion of what it was when competition studies were carried out.

Leopold (1933) considered bighorn sheep to be a wilderness species because they fail to thrive in contact with urban development. Human disturbance has been suggested to be detrimental to bighorn sheep in a variety of situations (Graham 1980, MacArthur *et al.* 1982, Etchberger *et al.* 1989, Papouchis *et al.* 2001). Similarly, Dunaway (1971) hypothesized that disturbance of bighorn sheep in the Sierra Nevada by humans was a factor limiting populations. Results of subsequent research did not support that hypothesis (Wehausen *et al.* 1977, Hicks and Elder 1979, Wehausen 1980). Bighorn sheep have habituated to human activity in many places in the Rocky Mountains, and occasionally in desert habitats. Any conclusions about the effects of human disturbance, however, must be limited to the situations studied. Thus, the question should be revisited as situations change in a direction that suggests disturbance could be detrimental, such as increased presence of humans in bighorn sheep habitat.

C. ABUNDANCE AND DISTRIBUTION

1. HISTORICAL DISTRIBUTION, ABUNDANCE, AND TRENDS

At one time, bighorn sheep herds were scattered along and east of the alpine crest of the Sierra Nevada from the Sonora Pass area south to Olancha Peak (Figure 1). They also occurred in similar habitat 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). Additional evidence suggested that herds utilized nonalpine habitat farther south near Walker Pass (Jones 1949, Garlinger 1987, Wehausen *et al.* 1987). Whether these southernmost herds were taxonomically the same as those which occurred farther north in the Sierra Nevada is unknown.

The total population in the Sierra Nevada prior to settlement is unknown, but it may have exceeded 1,000 individuals. In some cases, early records provide details on the occurrence of now extirpated populations. However, the overall historical record is incomplete and may lack records of some herds that might have disappeared early in recorded history. Wehausen (1988) postulated some additional areas that might have supported populations of bighorn sheep, but for which records are lacking.

Population losses for bighorn sheep apparently began shortly after the immigration of Europeans to the Sierra Nevada in the mid-1800's, and those losses continued through most of the twentieth century (Wehausen *et al.* 1987). Of 16 areas in the Sierra Nevada that likely had separate bighorn sheep herds (excluding the southernmost nonalpine region), only 9 are known to have persisted to the beginning of the twentieth century (Table 2). Another half century had reduced the number of areas to five by 1948 (Jones 1950). Jones (1950) documented bighorn sheep in 3 areas and postulated their existence in 2 other regions based on sign and reported observations; he also produced a subjective

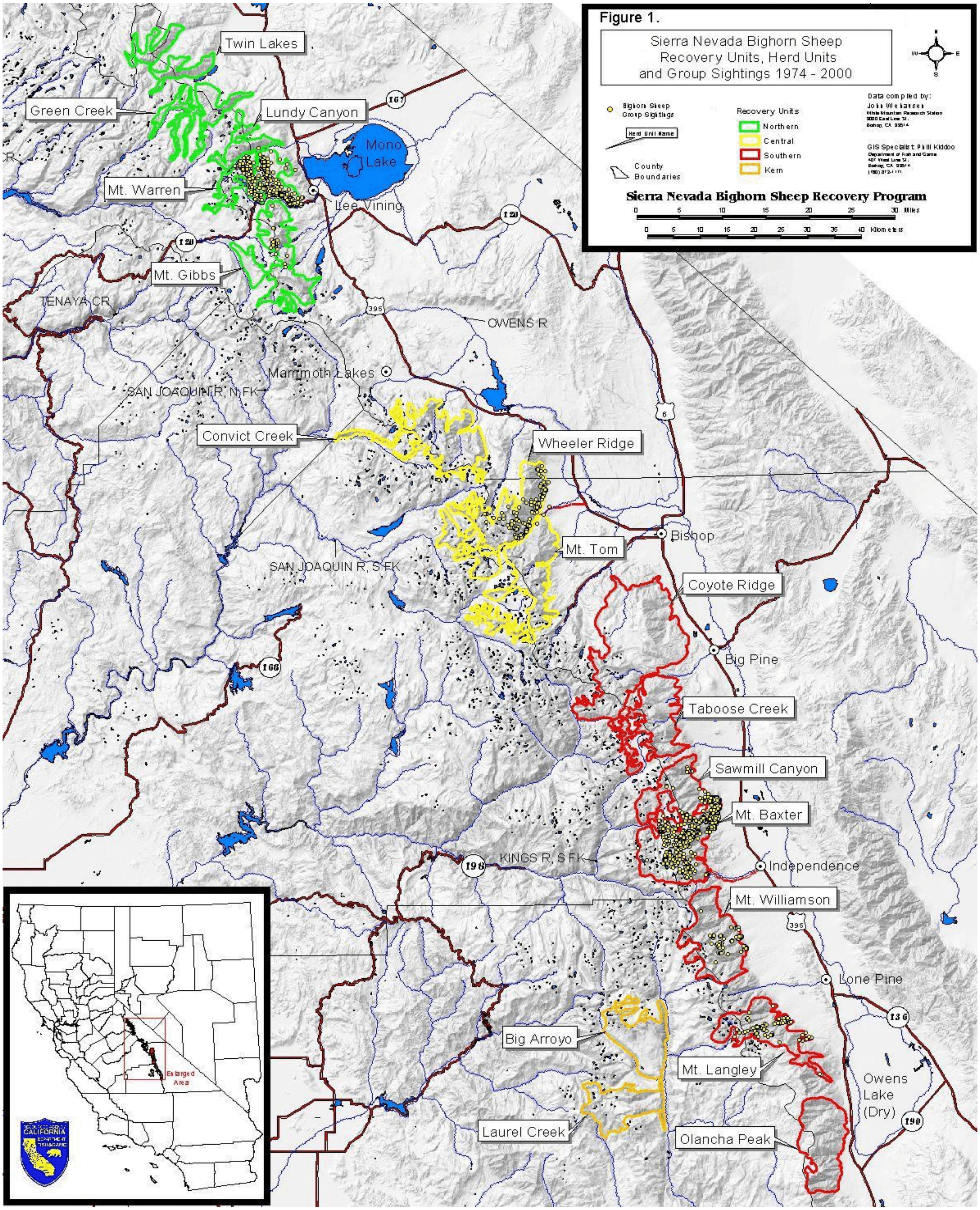

Figure 1.
Sierra Nevada Bighorn Sheep Recovery Units, Herd Units and Group Sightings 1974 - 2000

Table 2. Probable locations of historic bighorn sheep herds in the high Sierra Nevada based on historic records and habitat characteristics.

Region/Population	Last Records of Viable Native Herds	Sources for Sightings, Skulls, or other Data
KERN RIVER		
Mineral King	1800's	Jones 1950
Big Arroyo, Kaweah Peaks	1800's	Jones 1950
SOUTHERN		
Olancha Peak	1920's	Jones 1949
Mount Langley	1960's	Wehausen 1979
Mount Williamson	Extant	Wehausen 1980, 1999
Mount Baxter	Extant	Wehausen 1980, 1999
Sawmill Canyon	Extant	Wehausen 1980, 1999
Taboose Creek, Birch Mountain	1920's	Ober 1914, Jones 1949
CENTRAL		
Mount Tom to Mount Emerson	1920's	Ober 1914, 1931; Wolfe 1979
Pine Creek to Rock Creek	1920's	Jones 1949
McGee Creek to Convict Creek	1940's	Jones 1949
NORTHERN		
Mount Ritter to Dana Plateau	1870's	Muir 1894, Jones 1949
Mount Warren, Tioga Crest, Mount Conness	skulls only	Bailey 1932, Jones 1949
Shepherds Crest	skulls only	Jones 1949
Matterhorn Peak area	skulls only	Jones 1949
Sonora Pass	1878	Grinnell and Storer 1924

estimate of 390 bighorn in those 5 herds. By the 1970's, sheep remained in only two of those areas, but the one known as the Mount Baxter herd was found later to represent two distinct herds (Mount Baxter and Sawmill Canyon in Table 2; Wehausen 1979, 1980).

Specific causes of most population losses in the Sierra Nevada are unknown. Market hunting for mining towns may have played a role in some areas. 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 may have been the most important cause of losses, but have not been documented. Beginning in the 1860's, and extending into the twentieth century, large numbers of domestic sheep were grazed seasonally in the Sierra Nevada (Austin 1906, Vankat 1970). While grazing by domestic sheep has declined greatly and no longer includes ranges occupied by bighorn sheep, the potential for domestic sheep to come into contact with bighorn sheep continued through the twentieth century and persists today.

2. RECENT DISTRIBUTION, ABUNDANCE, AND TRENDS

Bighorn sheep persisted in only two areas in the Sierra Nevada by the 1970's, constituting three herds (Wehausen 1979, 1980). Intensive field studies during 1975 to 1979 provided accurate census data for those herds. The Mount Williamson population was found to contain only 30 bighorn sheep, while the Mount Baxter and Sawmill Canyon herds totaled 220 and generally were increasing (Wehausen 1980). Detailed annual monitoring of the Mount Baxter and Sawmill Canyon herds up to 1986 repeatedly verified large numbers. Good winter census opportunities in 1983 and 1985 found the Mount Williamson population to be static at 30 individuals.

Because of large size and productivity, the Mount Baxter and Sawmill Canyon herds were used as sources of reintroduction stock beginning in 1979, with subsequent removals in 1980, 1982, 1986, 1987, and 1988, totaling 103 individuals. These individuals were used to reestablish populations at Wheeler Ridge (1979, 1980, 1982, 1986), Mount Langley (1980, 1982, 1987), 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 (Weaver and Clark 1988), but the other three persist (Figure 1).

The Wheeler Ridge and Mount Langley herds began increasing soon after they were reintroduced. In contrast, the Lee Vining Canyon population declined initially due to post-release mortality from particularly inclement weather, followed by reductions due to mountain lion predation while on winter-spring range in Lee Vining Canyon (Chow 1991). Following supplementation in 1988 and removal of one mountain lion from Lee Vining Canyon in each of three consecutive winters (Bleich *et al.* 1991), this population increased rapidly (Chow 1991; Figure 2).

Mountain lions have become an increasing source of direct and indirect mortality for Sierra Nevada bighorn sheep populations. Wehausen (1996) reported evidence of rapid increases in mountain lion activity and kills on the winter ranges of the Mount Baxter and Sawmill Canyon herds between 1976 and 1988, with documented kills totaling 49 bighorn sheep. Mountain lion depredation problems along the eastern Sierra Nevada in Inyo and Mono Counties also increased notably during the 1980's, especially beginning in 1986 (Figure 3).

In addition to the direct effects of predation, all bighorn sheep populations in the Sierra Nevada abandoned regular use of low elevation winter ranges during the 1980's, as a possible response to the threat of predation by mountain lions (Wehausen 1996). Of the native herds, the Mount Williamson herd was last recorded using its escarpment base winter range in 1985, while winter range use by the Mount Baxter herd (also sometimes referred to as the Sand Mountain herd) declined steeply between 1987 and 1991 to negligible levels and has remained at these low levels through 2000 (Wehausen 1996, Figure 3). Avoidance of low elevation winter ranges has exacted a high cost from herds throughout the Sierra Nevada due to poor nutrition in late winter and spring, exposure to extreme cold and wind throughout winter, and deep snows and avalanches in heavy winters. For the Mount Baxter and Sawmill Canyon herds, the consequences were manifested in later lambing and poor lamb survival, which led to recruitment well

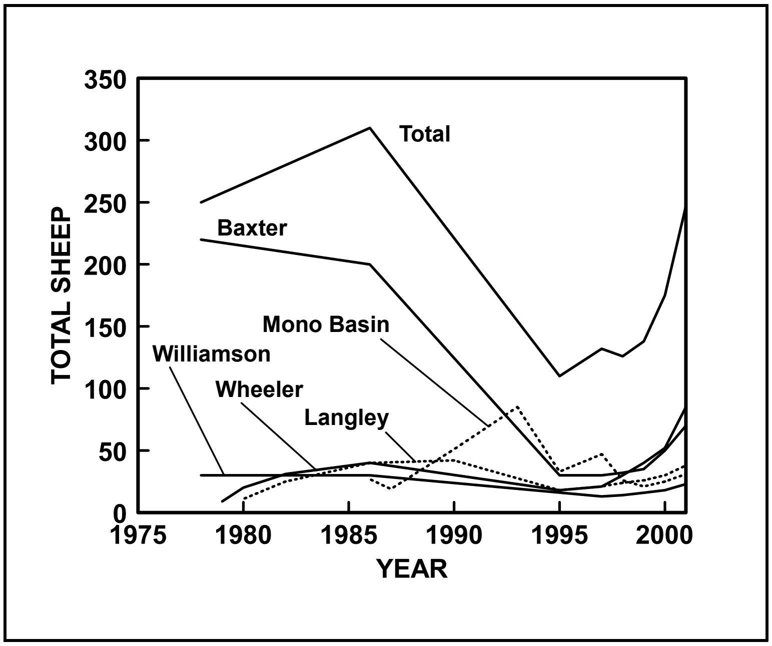

Figure 2. Minimum population sizes, 1978-2001 (from Wehausen 1999, 2001). Baxter includes the Mt. Baxter and Sawmill Canyon herd units, and Mono Basin includes the Mt. Warren and Mt. Gibbs herd units (see Figure 1).

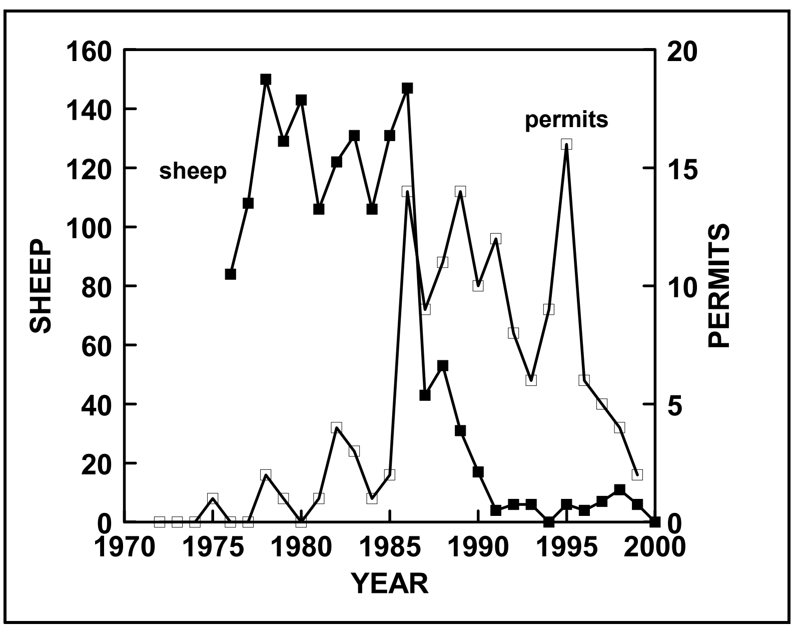

Figure 3. Mountain lion depredation permits issued in Inyo and Mono Counties, 1972-99, and bighorn sheep winter range census results for the Mount Baxter herd (Wehausen 1996, unpubl.).

below that needed to balance adult mortality. This diminished recruitment resulted in a major population decline (Wehausen 1996), with a low of about 17 females in the reproductive base in 1995 (Wehausen and Chang 1995), just 15 percent of its peak level. Summer field surveys in the Mount Williamson herd range since 1996 have suggested that this population may have reached a low of as few as only three to four females and three males. Both of these native populations appear to be increasing slowly (Figure 2).

Reintroduced herds have suffered similarly while avoiding low elevation winter ranges. The heavy winter of 1995 took a notable toll. Winter losses in the Wheeler Ridge herd included 12 individuals that died in a single snow avalanche; only 18 were recorded to have survived that winter. Earlier surveys of that herd (Ramey and Brown 1986, Wehausen 1991b) suggest that it may not have exceeded 40 individuals between the time of its establishment in 1979 and 1998. Since 1995, this herd has been increasing steadily. During 1995 to 1997 the herd remained back in Pine Creek throughout the winter. During the winter of 1999, the majority of the herd was documented to move to low-elevation winter range above Round Valley, and in the winter of 2000, all known females used that low-elevation winter range. Wehausen (2000) suggested that this migratory pattern may have begun in 1998. Numbers of female bighorn sheep counted in Pine Creek declined by two from 1997 to 1998. However, reconstructed population sizes (based on 1999 counts) showed that the number of females actually increased that year, leaving seven females unaccounted for in Pine Creek, at least some of which may have been using low elevation winter ranges that were not surveyed. Correlated with this use of low-elevation winter range, reproductive output was 60 percent higher when compared to the previous 4 years, and the herd subsequently showed a more rapid rate of increase (Figure 2; Wehausen 2000). A minimum of 41 individuals was known to exist in this herd in 1999, and it has continued to grow rapidly; it is now the largest herd in the Sierra Nevada.

The population in Lee Vining Canyon suffered great losses to weather and predation after its introduction, but the herd exhibited strong recovery following supplementation with eight females and three males and the removal of three mountain lions during 1988 to 1990 (Chow 1991). This herd totaled at least 85 individuals in 1993 (Chang 1993). However, beginning in the mid 1990's, a decline in the use of the Lee Vining Canyon winter range became apparent.

During the winter and spring of 1995, few bighorn sheep used low-elevation winter range and many disappeared; the population declined to 29 between Lee Vining and Lundy Canyons, with an additional 4 surviving on Mount Gibbs in a separate herd. Two subsequent years of population recovery were followed by a second major collapse during the winter of 1998. Further mountain lion predation was documented in the spring of 1998. The reproductive base of the two female groups numbered only two females on Mount Gibbs and six on Mount Warren and Tioga Crest in 1998, and the latter further declined to only three females in 1999. Twelve males were confirmed in 1999, with an additional four on Mount Gibbs probably present, but not seen that year (Table 3).

The Mount Langley herd also appears to have suffered a major reduction in 1995. Repeated census efforts have accounted for only 6 females and 11 males that survived that winter (Wehausen 1999), in contrast to 42 bighorn sheep counted there in the summer of 1990 (Moore and Chow 1990). This herd, unlike the one at Mount Warren, has been increasing slowly since 1995. Its reproductive base had increased to at least 10 females in 1998 but only 9 were counted in 1999. Only seven males could be accounted for in 1999, but recent data suggest as many as twice that number exist (Table 3).

A reconstructed population approach has been used for many years to improve minimum population values for Sierra Nevada bighorn sheep (Wehausen 1980). With this method, bighorn sheep of various sex and age classes observed in one year, but not accounted for the previous year, are added to the minimum number known the previous year. For instance, 214 different bighorn sheep could be accounted for in the Mount Baxter and Sawmill Canyon herds in 1978, but counts the following year determined that more males existed in 1978, bringing the total to at least 217 (Wehausen 1980).

The total population of bighorn sheep in the Sierra Nevada increased from 250 in 1978 to about 310 in 1986 during the first phase of the reintroduction program. Since then it has declined substantially. Only about 100 adult bighorn sheep could be accounted for in 1998, but this number increased to 117 to 129 in 1999 (Wehausen 1999). Reconstructed population values indicate that a low point of about 100 total bighorn sheep was reached following the winter of 1995.

Table 3. 1999 population data for Sierra Nevada bighorn sheep (from Wehausen 1999). Baxter includes the Mount Baxter and Sawmill Canyon herd units, and Lee Vining includes the Mount Warren and Mount Gibbs herd units.

	BIGHORN SEEN 1999				VERY PROBABLE OTHER BIGHORN 1999		POSSIBLE ADDITIONAL BIGHORN 1999	
Population	**Ewes**	**Rams**	**Adults**	**Lambs**	**Adults**	**Lambs**	**Adults**	**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			9
Lee Vining	5	12	17	4	4			
TOTALS	49	46	95	22	22	4	12	10

Overall, the total has been increasing since then, despite the recent declines in and near Lee Vining Canyon (Figure 2; Wehausen 1999). Including young-of-the-year, the total population could have been as high as 165 in 1999 (Table 3).

Continued favorable conditions since 1999 have allowed steady high reproductive output and recruitment, resulting in about 250 total sheep in 2001 including young of the year (Wehausen 2001; Figure 2).

D. REASONS FOR LISTING

The following discussion is organized according to the listing criteria under section 4(a)(1) of the Endangered Species Act.

1. THE PRESENT OR THREATENED DESTRUCTION, MODIFICATION, OR CURTAILMENT OF ITS HABITAT OR RANGE

Almost all of the historical and currently occupied habitat of bighorn sheep in the Sierra Nevada is in public ownership and administered by the U.S. Forest Service, National Park Service, or Bureau of Land Management. While there are some small parcels owned by the Los Angeles Department of Water and Power or that are patented mining claims, they amount to a very small fraction of the habitat. Thus, habitat throughout the historic range of Sierra Nevada bighorn sheep remains essentially intact; it is neither fragmented nor degraded. Consequently, habitat loss was not a reason for listing.

2. OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

While unregulated hunting may have played a role in early population declines (Wehausen 1988), there is no evidence that commercial, recreational, scientific, or educational activities currently are significant threats. Further, poaching of these bighorn sheep has not been documented in recent decades. Effects of recreational use should be further evaluated but currently appear to be minor.

3. DISEASE OR PREDATION

The potential for the transfer of virulent disease organisms from domestic sheep to bighorn sheep in the Sierra Nevada was a key factor in listing these bighorn sheep. Diseases transferred through contact with domestic sheep can be particularly devastating to bighorn sheep populations (see section I.B.7), and are suspected to have played a major role in the disappearance of certain bighorn sheep herds in the Sierra Nevada beginning around 1870.

Stray domestic sheep from nearby allotments contacting bighorn sheep has been a continuing threat. Domestic sheep have been known to escape allotments and wander into bighorn sheep habitat in the Sierra Nevada (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1997). Given the susceptibility of bighorn sheep to pathogens contracted from domestic sheep, disease poses a continuing and significant threat to the survival of Sierra Nevada bighorn sheep.

Mountain lion predation of bighorn sheep on winter ranges has accounted for the majority of documented mortalities since the late 1970's. This predation increased from the 1970's to the 1980's and has been hypothesized to be the cause of a coincident and marked decrease in winter range use by bighorn sheep in the Sierra Nevada. Subsequent population declines have been attributed to this change in winter habitat selection. During 1982 to 1990, four mountain lions that preyed on bighorn sheep in two winter ranges were removed to help protect those sheep herds. In 1990 the people of California passed an initiative (Proposition 117) that made mountain lions a specially protected mammal, and thereby removed the authority of the California Department of Fish and Game to control this species for the benefit of bighorn sheep herds. Federal endangered status returned the ability to engage in control of mountain lions to benefit these sheep through Federal law superseding State law.

4. THE INADEQUACY OF EXISTING REGULATORY MECHANISMS

In 1883, an earlier moratorium on the take of bighorn sheep in California was extended indefinitely (Wehausen *et al.* 1987), and bighorn sheep in the Sierra Nevada remain a fully protected species. In 1972, California listed the California bighorn sheep as "rare." The designation was changed to "threatened" in 1984 to standardize the terminology of the amended California Endangered Species Act (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1997), and the California Fish and Game Commission upgraded the species' status to "endangered" in 1999.

In 1971, Inyo National Forest established sanctuaries totaling about 16,500 hectares (41,000 acres) for the Mount Baxter and Mount Williamson herds of Sierra Nevada bighorn sheep and called them the California Bighorn Sheep Zoological Areas (Wehausen 1979; Inyo National Forest Land Management Plan 1988). Those sanctuaries were designated to regulate human use in some areas (Hicks and Elder 1979), and reduce domestic sheep/wild sheep interaction by constructing a fence below the winter range of the Mount Baxter herd along the U.S. Forest Service and Bureau of Land Management boundary (Wehausen 1979). Adjacent summer range on National Park Service land also was designated to reduce human disturbance (Wehausen 1979), and those restrictions continue.

Numerous efforts for the conservation of bighorn sheep in the Sierra Nevada have taken place in recent decades including, but not limited to: (1) intensive field studies; (2) reestablishment of three additional populations in historical habitat; (3) creation, in 1981, of the Sierra Nevada Bighorn Sheep Interagency Advisory Group, including representatives from Federal, State, and local resource management agencies, which has produced the Sierra Nevada Bighorn Sheep Recovery and Conservation Plan (1984) and a Conservation Strategy for Sierra Nevada Bighorn Sheep (1997); and (4) removal of four mountain lions that were taking Sierra Nevada bighorn sheep, which played a significant role in efforts to reestablish the Mount Warren herd (Chow 1991).

Despite these efforts, the bighorn sheep population has shown a significant decline in the past 15 years (Figure 2). This decline has been attributed to mountain lion predation and its hypothesized role in the avoidance of low elevation winter ranges by bighorn sheep (Wehausen 1996). Also, significant threats of contact with domestic sheep persisted. Existing regulatory mechanisms were inadequate to correct those problems. First, although efforts had been underway for many years, the U.S. Forest Service was unable to eliminate, or even reduce, the threat of contact between domestic sheep and Sierra Nevada bighorn sheep by eliminating or modifying grazing allotments. Second, as a result of the passage of Proposition 117 in 1990 by the California Legislature, the California Department of Fish and Game lost the authority to remove mountain lions to protect the Sierra Nevada bighorn sheep. However, between the Federal emergency and final listings, the California State Legislature enacted AB 560, which amended Proposition 117 and allowed the California Department of Fish and Game to remove mountain lions that are a threat to bighorn sheep in California.

5. OTHER NATURAL OR MANMADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

At the time of its listing, the Sierra Nevada bighorn sheep population was very small, with only about 125 adults known to exist among 5 geographic areas, with little probability of interchange among those areas. Additionally, multiple independent groups of females, defined by distinct home range patterns, were known in some of those areas and resulted in yet smaller population units. Evidence has suggested that many of these contained five or fewer females in recent years. Thus, small population effects alone made these bighorn sheep vulnerable to extinction. These effects might be random naturally occurring population fluctuations (see section II.A.1), loss of genetic variation (see section II.A.2), or both.

E. PAST AND CURRENT MANAGEMENT AND CONSERVATION ACTIVITIES

1. FEDERAL AGENCIES

a. U.S. Department of the Interior - Fish and Wildlife Service

The Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 *et seq*.), requires us to identify taxa of wildlife and plants that are endangered or threatened, based on the best available scientific and commercial information. As part of the program to accomplish this purpose, we maintain a list of taxa regarded as candidates for listing. We maintain this list for a variety of reasons, including: to provide advance knowledge of potential listings that could affect decisions of environmental planners and developers; to solicit input from interested parties to identify those candidate taxa that may not require protection under the Act or additional taxa that may require the Act's protections; and to solicit information needed to prioritize the order in which taxa will be proposed for listing.

On September 18, 1985, we published a Notice of Review in which we designated the Sierra Nevada bighorn sheep as a Category 2 candidate and solicited status information (50 FR 37958). Category 2 candidate species include taxa for which we had information indicating that proposing to list as endangered or threatened was possibly appropriate, but for which sufficient data on biological vulnerability and threats were not currently available to support a proposed rule. Category 1 candidates were those species for which we had sufficient information on file to support issuance of proposed listing rules. In our January 6, 1989 (54 FR 554), and November 21, 1991 (56 FR 58804), Notices of Review, we retained the Sierra Nevada bighorn sheep in Category 2. Beginning with our February 28, 1996, Notice of Review (61 FR 235), we discontinued the designation of multiple categories of candidates, and we now consider only species that meet the definition of former Category 1 as candidates for listing. At that point, the Sierra Nevada bighorn sheep was not identified as a candidate.

Nevertheless, we remained in contact with the California Department of Fish and Game and the Sierra Nevada Bighorn Sheep Interagency Advisory Group regarding the status of the species. In 1998, as new information became available regarding the continual decline in the Sierra Nevada bighorn sheep population, we initiated a status review. On April 20, 1999, we published an emergency rule to list the Sierra Nevada distinct population segment of California bighorn sheep as endangered (64 FR 19300), as well as a proposed rule (64 FR 19333) to list the species as endangered. The emergency rule provided Federal protection pursuant to the Act for a period of 240 days. After a thorough review of all comments received on the proposed rule, we published a final rule listing the Sierra Nevada bighorn sheep as endangered in accordance with section 4 of the Act on January 3, 2000 (65 FR 20).

Section 4 further directs us to develop and implement recovery plans for listed species; this recovery plan was developed according to that direction and following "Guidelines for Planning and Coordinating Recovery of Endangered and Threatened Species" (U.S. Fish and Wildlife Service 1990). Once a species has recovered and is removed from the list, we must, in cooperation with State government, "effectively monitor for not less than 5 years" the species' status, and we must be prepared to restore the species to the list if necessary. Section 5 of the Act authorizes the Department of the Interior to acquire habitat essential to preserving listed species, and section 6 directs us to cooperate with the States to maintain adequate programs for their conservation. Through section 7 of the Act, Federal agencies are required to use their authorities to carry out programs for the conservation of listed species and to consult with us when a Federal action may have an effect on listed species. Section 9 of the Act provides for protection of listed species, and section 10 permits exceptions to the protections granted under section 9. The exceptions are permitted in the form of scientific, recovery, and incidental take permits, and other circumstances as detailed in section 10.

During the period of Federal protection provided by the emergency rule, we worked with the Inyo National Forest and the California Department of Fish and Game regarding measures to protect the bighorn sheep. Predation from mountain lions and associated abandonment of winter habitat are thought to be major factors contributing to the decline of the population. We assumed the lead agency role in the development of a Final Environmental Assessment, Predator Damage Management to Protect the Federally Endangered Sierra Nevada Bighorn Sheep (USDA Wildlife Services 1999). This document was prepared by the U.S. Department of Agriculture, Wildlife Services, and identified the cooperating agencies: the California Department of Fish and Game, U.S. Forest Service, and National Park Service. This environmental assessment was for the proposed program to protect the bighorn sheep from predation on and around its current range.

In response to the threat of disease transfer from domestic sheep to Sierra Nevada bighorn sheep and to facilitate a consistent and comprehensive approach to consulting on the taking of Sierra Nevada bighorn sheep under the Act, we organized an interagency team of biologists and rangeland management specialists from the Bureau of Land Management, California Department of Fish and Game, U.S. Forest Service, and Los Angeles Department of Water and Power to develop a grazing strategy for domestic sheep for the Owens Valley. This strategy (U.S. Fish and Wildlife Service 2001) analyzes the risk of disease transmission between domestic sheep and bighorn sheep for each of the allotments/leases within the Owens Valley on the Inyo National Forest (seven allotments and one trail), Humboldt-Toiyabe National Forest (one allotment), Bureau of Land Management (one allotment and one trail), and Los Angeles Department of Water and Power (three leases). Domestic livestock grazing within the Owens Valley has been modified by the Bureau of Land Management, U.S. Forest Service, and Los Angeles Department of Water and Power, including a July 2000 Environmental Assessment and Decision Notice that closed two grazing allotments on the Inyo National Forest.

Pursuant to section 7 of the Act, we have been in formal and informal consultation with the Inyo National Forest, Humboldt-Toiyabe National Forest, and the Bureau of Land Management on their grazing operations. All agencies are working cooperatively throughout the consultation process to identify high risk areas and address unacceptable risks, so that domestic sheep grazing does not threaten the existence of the bighorn sheep.

b. U.S. Department of the Interior - National Park Service

Historical Management

A significant portion of the historic summer range of the Mount Baxter herd occurred, and to some extent still does occur in Kings Canyon National Park. Since reestablishment in 1979, the Mount Langley herd has utilized a limited part of the Sequoia National Park during the summer. Males of the reestablished Lee Vining herd have occasionally visited Yosemite National Park, and it is surmised that should the herd recover fully, parts of the crest in the national park will be included in summer range. Lastly, to replace the herd that once occupied the Great Western Divide, an eventual reintroduction is planned to occur entirely inside Sequoia National Park.

During the early 1960's, biologists from Sequoia and Kings Canyon National Parks conducted surveys along the crest, trying to locate remaining bands of bighorn sheep (Riegelhuth 1965). The National Park Service was a substantial sponsor of the definitive research conducted by Dr. John Wehausen from 1976 through 1979 (Wehausen 1980).

Following the lead of the U.S. Forest Service, Sequoia and Kings Canyon National Parks in the early 1970's closed "the female/lamb range of the Sierra Nevada bighorn sheep . . . to all pack animals and to off-trail travel by humans [in the national park].” This closure was later codified in the Superintendent’s Compendium. The associated map identified an area representing the known range of females and lambs within King Canyon National Park. Because off-trail travel by pack stock is impractical along the crest of the Sierra Nevada and the occasional use by mountaineers and climbers does not pose a significant threat to bighorn sheep, and also because the areas used by bighorn sheep will be in a state of flux for the indefinite future, the permanent closure was terminated in 2001.

Representatives of the National Park Service have participated in the Sierra Nevada Bighorn Sheep Interagency Advisory Group since its inception in 1981. In addition to the Recovery and Conservation Plan authored by that group (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1984), Sequoia and Kings Canyon National Parks produced a “Bighorn Sheep Management Plan” for those parks (National Park Service 1986) that outlined steps to recover populations, such as the Great Western Divide herd, that historically used the national parks.

In 1985, the Yosemite Association solicited funds from the Goldman Fund and the Sacramento Safari Club that were paid to the Lee Vining Canyon grazing allotment holder in exchange for vacating the allotment, which was then later terminated by the U.S. Forest Service. Subsequently, the National Park Service conducted follow-up monitoring and research after bighorn sheep were translocated there in 1986 (Chow 1991, Moore 1991).

During the late 1980's, the National Park Service sponsored and conducted aerial and ground surveys to establish the availability of winter and summer habitat in the Great Western Divide and Kern River as a necessary precursor to eventual translocations there.

<u>Current Management on National Park Service Lands</u>

National Park Service biologists from Sequoia, Kings Canyon, and Yosemite National Parks participated in preparation of this recovery plan and will participate in its implementation, particularly by sponsoring the use of National Park lands by existing herds of Sierra Nevada bighorn sheep and the reestablishment of Sierra Nevada bighorn sheep in the Great Western Divide area of Sequoia National Park.

c. U.S. Department of Agriculture - Forest Service

Historical Management

Much of the historic habitat of the Sierra Nevada bighorn sheep occurs on National Forest System lands within the Pacific Southwest Region (Inyo, Sequoia, Sierra, and Stanislaus National Forests) and the Intermountain Region (Humboldt-Toiyabe National Forest). The current populations primarily occupy the Inyo National Forest, although some of the herds seasonally use Sequoia/Kings Canyon National Park, Yosemite National Park, and the Sierra National Forest.

The U.S. Forest Service is authorized by Acts of Congress and by regulations issued by the Secretary of Agriculture to administer, manage, and protect National Forest System lands for multiple uses, including the provisions of habitat for fish, wildlife, and plants. Typically, the U.S. Forest Service is responsible for managing habitats (*e.g.*, food, water, and cover) on National Forest System lands and coordinates with the appropriate State agency regarding management of the animal populations. 36 CFR 219.19 directs the U.S. Forest Service to manage fish and wildlife habitat to maintain viable populations of existing native and desired nonnative vertebrate species. One way this mandate is met is through the Forest Service Sensitive Species Program, under which each Region establishes a list of sensitive plant and animal species that are given special consideration under the multiple use mandate, with the objectives to ensure the continued existence of viable, well-distributed populations and to prevent a trend toward listing under the Endangered Species Act of 1973. Each National Forest is required to develop a Land and Resource Management Plan, which sets the framework for multiple use management of the Forest and incorporates management strategies to maintain viable populations within the Forest and to promote recovery of federally listed species. In addition, the U.S. Forest Service, like other Federal agencies, has responsibilities under the Federal Endangered Species Act (section 7a). Accordingly, the U.S. Forest Service coordinates and consults with us on activities it conducts, funds, or authorizes that may affect federally listed endangered, threatened, or proposed species and designated or proposed critical habitat.

Concern about bighorn sheep in the Sierra Nevada (Dixon 1936) prompted the National Park Service and Sierra Club in 1940 jointly to 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).

The U.S. Forest Service became active in the management of Sierra Nevada bighorn sheep in 1971, when the Inyo National Forest created two Bighorn Sheep Zoological Areas (Mount Baxter and Mount Williamson Units) for the two surviving native herds (Dunaway 1971). These areas, totaling 1,823 hectares (4,505 acres) outside designated wilderness areas, were created to give top priority to the requirements of the bighorn sheep through protection and maintenance of their habitat and through the regulation of human use in certain sections of the bighorn range to minimize human disturbance; similar restrictions were applied to adjacent habitat of these herds under National Park Service management (Wehausen 1985). The U.S. Forest Service has been a member of the Sierra Nevada Bighorn Sheep Interagency Advisory Group since its inception in 1981, and assisted in the funding and development by that group of a Recovery and Conservation Plan in 1984 and the Conservation Strategy in 1997. California bighorn sheep were classified as a Regional Forester's Sensitive Species in California in 1982. In 1985, the Inyo National Forest facilitated, in cooperation with the California Department of Fish and Game and other members of the Interagency Advisory Group, the reintroduction of bighorn sheep to the Lee Vining Canyon area. On November 25, 1998, due to the rapid decline of Sierra Nevada bighorn sheep, the Pacific Southwest Region Regional Forester issued a letter directing the Forest Supervisors of the National Forests within the historic range of the Sierra Nevada bighorn sheep to take specific actions to provide habitat and other assistance contributing to the viability of the Sierra Nevada bighorn sheep. Various management actions were initiated by this letter; these included providing funding to U.S. Department of Agriculture Wildlife Services to monitor mountain lion activity within occupied bighorn sheep habitat, working with permittees to modify grazing management to eliminate the risk of disease transmission, initiating informal consultation with us, and using prescribed fire to improve winter range.

Current Management on National Forest System Lands

Since the emergency listing of the Sierra Nevada bighorn sheep on April 20, 1999, the U.S. Forest Service, primarily the Inyo National Forest, has been consulting with us on various Federal actions allowed under their Forest Land and Resource Management Plan with the potential to affect Sierra Nevada bighorn sheep or their habitat. These actions include term grazing permits for domestic sheep allotments adjacent to occupied bighorn sheep habitat, recreational use of occupied bighorn sheep habitat, helicopter use within and adjacent to bighorn habitat, prescribed fire, normal fire suppression activities, and special use permits for outfitter guides and packers. In May 2000, a temporary Emergency Forest Order was issued, which prohibited dogs and domestic goats from entering key Sierra Nevada bighorn sheep habitat areas on the Inyo National Forest. The final version of this Forest Order is currently being prepared.

The Inyo National Forest continues to use prescribed fire within bighorn sheep winter range in an attempt to open up habitats, decrease hiding cover for mountain lions, and potentially allow bighorn sheep increased access to areas with highly nutritional food sources.

2. STATE AGENCIES

The first management action for Sierra Nevada bighorn sheep was full protection from hunting. Decimation of native sheep occurred quickly following the influx of gold miners in the mid-1800's, and declines of native game led the State Legislature to enact legal protections beginning in the 1870's. For wild sheep, legal protection 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 4-year moratorium on the taking of any pronghorn, elk, mountain sheep, or female deer; in 1883 the moratorium was extended indefinitely for bighorn sheep (Wehausen *et al.* 1987). Sierra Nevada bighorn sheep remain fully protected.

In 1972, the California subspecies, as defined by Cowan (1940) and 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). This category was changed to threatened in 1984. Through the listing process, the Fish and Game Commission recommended development and implementation of a recovery plan, including field research and reintroductions. Intensive field study began in 1975, and the results of those investigations led to a series of translocations beginning in 1979. A conservation and recovery plan was completed in 1984 (Sierra Bighorn Interagency Advisory Group 1984). The goals of that plan were: (1) to create 2 additional populations numbering at least 100 bighorn sheep that could serve as translocation 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 it was 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.

It is the responsibility of the California Department of Fish and Game (Fish and Game Code Section 1802) to conserve, protect, and manage fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species. It also is the policy of the State to conserve, protect, restore, and enhance endangered or threatened species and their habitats. The role of the California Department of Fish and Game, as trustee for fish and wildlife resources, includes working with other State, Federal, and private entities to further conservation and recovery of threatened and endangered species on their lands. Conservation goals for bighorn sheep (California Department of Fish and Game 1983) are to:

1. Maintain, improve, and expand bighorn sheep habitat where possible or feasible.

2. Reestablish bighorn sheep populations on historic ranges where feasible.

3. Increase bighorn sheep populations so that all races become numerous enough to no longer require classification as rare or fully protected.

4. Provide for aesthetic, educational, and recreational uses of bighorn sheep.

The California Department of Fish and Game supports the concept of regional management for the long-term viability of bighorn sheep populations. In support of this strategy, the California Department of Fish and Game's Bighorn Sheep Conservation Program maintains an inventory of the distribution of bighorn sheep in California. The populations of bighorn sheep in California are grouped into metapopulations, or 'systems' of populations, that best represent logical regions to manage for the long-term viability of the species. This regional approach recognizes the importance of inter-mountain areas that allow movement and exchange of individuals between populations, the recolonization of vacant habitats, and the need for interagency coordination of land management. The concept of regional populations considers not only vegetative and geographic boundaries, but also man-made barriers that define distributions and which have resulted in the fragmentation of habitat. Given the need to understand the status and dynamics of regional populations of bighorn sheep, this type of inventory should provide an index for documenting regional population changes over time and a basis for evaluating the success or failure of management actions at a meaningful level.

Although a metapopulation approach is an important biological principle for understanding the long-term survival of bighorn sheep populations, it is equally important as a management concept that establishes a priority for regional coordination for bighorn sheep population and habitat management. For example, data regarding extinction and recolonization are limited, and we therefore have an incomplete biological justification for considering some regions as true metapopulations. Nevertheless, given the need for regional management of bighorn sheep populations, the California Department of Fish and Game has defined the metapopulations based on the best information available for the regions, and utilizes this regional strategy for the management of bighorn sheep throughout the State.

In 1997, a conservation strategy was produced for bighorn sheep in the Sierra Nevada that reflected the significant changes in the status of those animals (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1997). Unfortunately, funding constraints encountered by the California Department of Fish and Game limited the recovery efforts identified in this conservation strategy. We and the Fish and Game Commission took emergency action in 1999 to list the Sierra Nevada bighorn sheep as endangered under the State and Federal Endangered Species Acts. This action was in response to a significant decline in the population size, from approximately 310 in 1985 to an estimated 125 adults in 1999. With the small population of Sierra Nevada bighorn sheep in decline, the threat of this unique population becoming extinct was great.

Due to the high level of public attention and concern, the California Department of Fish and Game was provided funding (in 1999) through a legislative member's request to implement a population recovery program for bighorn sheep in the Sierra Nevada. This funding resource is needed to meet the mandate of the California Department of Fish and Game, and the public's demand for endangered species recovery. This funding will support the start of a long-term comprehensive population recovery program, and the recovery potential for Sierra Nevada bighorn sheep populations is high if conservation actions are taken immediately. Elements of the recovery program include monitoring the population, intensively reducing mortality, reestablishing additional populations in historic range, and preparing for and potentially implementing captive breeding efforts to increase population size and maintain genetic diversity.

II. RECOVERY

A. CONSERVATION PRINCIPLES USED IN DEVELOPING THIS RECOVERY PLAN

The following sections apply general conservation principles in the context of our current knowledge regarding Sierra Nevada bighorn sheep and outline the relationship of these principles to the recovery criteria for this species. Conservation theory recognizes that population dynamics and genetic issues need to be addressed in species conservation. Although threats to population persistence are of more immediate importance to Sierra Nevada bighorn sheep, potential loss of genetic variation also has implications for the long term conservation of this taxon (Lande 1988). Fundamentally, the recovery strategy revolves around three main conservation issues: population dynamics, genetic variation, and ecosystem integrity.

1. POPULATION DYNAMICS

Demographic processes are especially important considerations in the conservation of small populations (Gilpin and Soulé 1986). Variation in birth, death, immigration, and emigration rates, as well as the age and sex structure of populations, can cause fluctuations in population size that make small populations especially vulnerable to extinction. Lande (1988) noted that a shortcoming of some past recovery plans was an inadequate emphasis on the implications of such population parameters for recovery and cautioned that, for many wild populations, risks concerning population parameters are of more immediate importance than genetic concerns.

Spatial distribution of animals across the landscape is an important consideration. Sierra Nevada bighorn sheep, like other forms of bighorn sheep and many other taxa, are distributed as a collection of subpopulations, each occupying a patch of suitable habitat within a matrix of otherwise less suitable or unsuitable habitat. The complex topography and the vegetation structure of the southern and central Sierra landscape, coupled with the intrinsic biology and behavior of these bighorn sheep, has resulted in a naturally fragmented distribution of animals, a metapopulation (Bleich *et al.* 1990a). This metapopulation is composed of multiple subpopulations that interact intermittently to varying degrees, depending on site-specific geography, movement characteristics of males (occasional) and females (rare), and chance.

Metapopulation structure has profound implications for the conservation of Sierra Nevada bighorn sheep. Conservation objectives for this taxon must simultaneously address all levels of population organization to achieve recovery goals. Recovery units, herd units, and separate female groups within herd units are all relevant to overall recovery of Sierra Nevada bighorn sheep. For further detail on the definitions of these terms refer to the discussion of recovery objectives (section II.C.2).

Metapopulations typically are assumed to exist in a state of balance between population extinctions and colonizations (Hanski and Gilpin 1991). However, bighorn sheep are relatively slow colonizers (Geist 1967, 1971, Bleich *et al.*, 1996) and, therefore, metapopulation extinction-colonization processes must be considered over appropriate time periods. Although bighorn sheep typically have a naturally fragmented distribution (Bleich *et al.* 1990a), any external factor that further fragments existing populations poses a heightened threat to persistence (Schwartz *et al.* 1986, Bleich *et al.* 1996). Hanski and Gilpin (1991) cautioned that species subject to accelerated habitat and/or population fragmentation must be managed carefully, as they may not necessarily be able to function as a metapopulation in equilibrium. This situation may be exacerbated in the Sierra Nevada because the metapopulation is largely linear in geographic distribution, resulting in fewer populations that could serve as sources of colonists.

There is little threat to Sierra Nevada bighorn sheep due to habitat loss. Virtually all land that provides habitat for this taxon is managed by the Federal government and is likely to remain in a wild condition for the indefinite future. Population fragmentation due to random natural fluctuations in population parameters or deleterious effects of disease or predation could, however, affect overall metapopulation dynamics.

The small number of Sierra Nevada bighorn sheep (an estimated 250 individuals in 2001) mandates that population processes be of primary concern in the conservation of this taxon. Furthermore, Sierra Nevada bighorn sheep occur as discrete female groups with significance to the distributional structure of the population (Wehausen 1979). Because these female groups are independent segments of populations, they are the fundamental demographic units and should be treated as the basic conservation units (Soulé 1987). Some of these groups comprise fewer than five females, making them highly vulnerable to chance variation in birth and death events.

In the southern Sierra Nevada, most herds of bighorn sheep have been reduced to such low levels that random natural variation in population and environmental factors pose serious immediate threats. Therefore, recovery efforts for Sierra Nevada bighorn sheep must entail actions that increase the sizes of individual female groups (by decreasing adult mortality rates, increasing recruitment, and possibly augmenting them through translocations) and increasing overall distribution through reintroductions to historic ranges.

2. GENETIC CONSIDERATIONS

The Sierra Nevada bighorn sheep was recently recognized as a unique subspecies (see Section I of this recovery plan). As such, this taxon appears to have distinctive genetic characteristics that may include adaptations to conditions in the Sierra Nevada. One of the fundamental objectives of this recovery program is the conservation of the unique gene pool embodied in the remaining animals of this metapopulation.

Maintaining genetic variation is an important conservation goal because loss of genetic variability can result in inbreeding depression (a loss of fitness) and the inability of populations to respond to long-term environmental changes (Gilpin and Soulé 1986, Ralls *et al.* 1988, Lande 1988, Meffe and Carroll 1994, Fitzsimmons *et al.* 1995). Rate of evolutionary change in a population is proportional to the amount of genetic variation available (Fisher 1958), and loss of genetic diversity reduces future evolutionary options (Meffe 1999). By reducing the fitness of individuals, loss of genetic variation also can reduce the growth rates and resilience of populations (Lacy 1997).

Loss of genetic variation is a special concern among small populations because heterozygosity is lost more quickly in small populations than in large ones (Meffe and Carroll 1994). In the past, movements of males in the Sierra Nevada once maintained gene flow, but it is unclear to what extent such movements now occur. The current, fragmented distribution of populations of these animals likely reduces connectivity among groups. In small herds of bighorn sheep, random natural variability in population parameters can be an overriding determinant of population survival and is mitigated by immigration of both sexes. If small herds become isolated and stay small, they face an increased loss of genetic variability, in addition to the risks to persistence associated with random naturally occurring events.

Even if gene flow is maintained among female groups throughout the Sierra Nevada, the overall small population size (approximately 250 individuals in 2001) is of concern. The effective population size (N_e, the number of individuals actually reproducing; Crow and Kimura 1970), which determines the rate at which heterozygosity is lost, is even smaller than the total number of adults in the population. An effective population of 500 individuals has been suggested as the minimum necessary for genetic variation to ensure future evolutionary change (Franklin 1980, Lande and Barrowclough 1987, Franklin and Frankham 1998), and the actual number may be even higher. Thus, an important goal of this recovery plan is to increase the abundance of Sierra Nevada bighorn sheep to maintain as much of the existing genetic variation as possible.

Although genetic variation among bighorn sheep herds in the Sierra Nevada is not known to confer adaptive advantage in local environments, genetic theory holds that existing genetic variation should be maintained "in as near a natural geographic distribution as possible, so that evolutionary and ecological processes may be allowed to continue" (Meffe and Carroll 1994). Adaptation to future changes in the environment, such as may occur through global climate change, may depend on maintenance of genetic diversity within this taxon.

Because the most immediate problem facing bighorn sheep in the Sierra Nevada concerns depleted population sizes, the potential implications of loss of genetic heterozygosity implied by genetic theory should not override management objectives to maintain and expand the number and size of herds throughout the Sierra Nevada. Nonetheless, as more is learned about the actual genetic diversity in the remaining individuals, it may be necessary to incorporate genetic management, such as moving males between some populations.

3. ECOSYSTEM INTEGRITY

Loss of habitat is recognized as the primary cause of species endangerment and the leading threat to global biodiversity (Groombridge 1992, Noss and Murphy 1995). It is also considered the most significant threat to the viability of many bighorn sheep populations (Bleich *et al.* 1996). However, habitat loss, *per se*, is not considered a proximate threat to the conservation of the Sierra Nevada bighorn sheep. Virtually all habitat used by this taxon is managed by the Federal government.

A stable and functional ecosystem is of paramount concern. For Sierra Nevada bighorn sheep, a primary emphasis is continued access to suitable habitat. Habitat conditions within the range of Sierra Nevada bighorn sheep generally are not subject to obvious human-induced changes. What is primarily at stake for these animals is continuing, safe access to preferred habitats, notably winter ranges. Recent declines in population sizes have been linked to the decreased use of key resources on winter ranges. This change is believed to be the result of predator avoidance by Sierra Nevada bighorn sheep in these locations (Wehausen 1996). A basic premise of the recovery strategy, therefore, is to sufficiently reduce factors that inhibit the ability of Sierra Nevada bighorn sheep to utilize fully all components of their habitat. However, such actions need to take place in the context of all ecosystem components; potential effects of actions to enhance bighorn sheep herds on other components of the ecosystem must be considered.

Maintaining ecosystem integrity for the Sierra Nevada bighorn sheep should revolve around providing suitable habitat conditions and safe access to those habitats. Safe access implies that exposure to exotic diseases and unsustainable levels of predation are prevented. Exposure to lethal diseases carried by domestic sheep is a significant threat that could have catastrophic effects on recovery efforts for this taxon. All habitat, both summer and winter, must be available with no risk of direct contact with domestic sheep or goats. Similarly, predation should be managed within herds that are still at low levels. Biologists suspect that bighorn sheep in the Sierra are especially vulnerable to predation when herds are low in number, and that small group size may preclude the use of important foraging areas. As long as the populations of this taxon remain below viable levels, special predator management actions are warranted to ensure adequate use of important foraging habitat. However, it is also important to recognize that top predators play a crucial and irreplaceable role in maintaining the integrity of a variety of ecosystems (Terborgh *et al.* 1999), including, potentially, the ecosystem inhabited by Sierra Nevada bighorn sheep.

Habitat factors, such as visual openness, that may have been influenced by past management practices, also must be addressed. Since recovery is contingent on full use of the nutritional resources available to these bighorn sheep, the vegetative structure of some winter ranges needs to be considered with respect to the recovery strategy. Fire suppression of lands within some winter ranges has been a common management practice over the last century. The implications of fire suppression for vegetational succession and the loss of visual openness in some winter range habitat are not fully understood. Thus, consideration should be given to how the habitat changes induced by fire suppression might affect use of some winter ranges by bighorn sheep.

B. OBJECTIVES

1. CONSERVATION CHALLENGE AND GOALS

The challenges and objectives of this recovery plan are (1) to define a desired future size and distribution of the overall bighorn sheep population in the Sierra Nevada, at which point continued protection under the Federal and California Endangered Species Acts is no longer needed and, (2) to outline steps necessary to reach that condition. From a species perspective, the conservation challenges of these bighorn sheep concern long-term viability of the overall population and preservation of this unique gene pool. From an ecosystem standpoint, the challenge involves finding the long-term population viability of bighorn sheep relative to other elements of the ecosystems involved, as well as returning this large native herbivore to those regions of the Sierra Nevada from which it has been extirpated. Thus, the conservation goal of this recovery plan is to restore Sierra Nevada bighorn sheep in a geographic distribution throughout their native range with a genetic representation that assures their long-term viability as a unique life form.

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 isolated and protected captive breeding populations as a buffer against extinction or as sources of translocation stock. However, the ultimate goal of this recovery plan is recovery of these bighorn sheep to population sizes and distribution where long-term viability will not require active intervention.

2. RECOVERY CRITERIA

A species is considered to be endangered when it is likely to become extinct in the foreseeable future, and it is considered to be threatened when it is likely to become endangered in the foreseeable future. Downlisting criteria identify the conditions at which point the status of the species has improved such that it is no longer endangered, and may be proposed to be reclassified as threatened. Delisting criteria represent the minimum conditions necessary to propose removing the taxon from the endangered species list.

a. Downlisting Criteria

The taxonomic affinities of bighorn sheep that once inhabited the very southern Sierra Nevada in the vicinity of Walker Pass are unknown. Therefore, this recovery plan concerns the bighorn sheep only in the southern and central Sierra Nevada from near Olancha Peak and the Great Western Divide north to the vicinity of Twin Lakes, near Bridgeport. In this region, 17 herd units have been identified (Table 4, Figure 1). These herd units are areas that are known or

Table 4. Herd Units and Recovery Units used as the basis of recovery goals (see Figure 1).

Herd Units and Recovery Units	Minimum Elevation (ft)
Kern Recovery Unit	
1. Laurel Creek	6800
2. Big Arroyo	6900
Southern Recovery Unit	
3. Olancha Peak	4800
4. Mount Langley	4800
5. Mount Williamson	6200
6. Mount Baxter	4900
7. Sawmill Canyon	4800
8. Taboose Creek	6800
9. Coyote Ridge	5600
Central Recovery Unit	
10. Mount Tom	6400
11. Wheeler Ridge	5600
12. Convict Creek	7900
Northern Recovery Unit	
13. Mount Gibbs	7600
14. Mount Warren	7600
15. Lundy Canyon	8000
16. Green Creek	9000
17. Twin Lakes	7200

suspected to have been occupied historically, and that have a high potential to support herds of these bighorn sheep. These herd units are defined primarily on the basis of the location and abundance of suitable habitat for low elevation winter ranges, because that habitat is considerably more limited than suitable high elevation habitat.

Seven of the herd units currently support bighorn sheep. Herds to be reestablished in the remaining units are expected to support geographically distinct groups of females. It is possible, however, that some may support more than a single group of females exhibiting distinct home range patterns.

There are 3 natural breaks in the distribution of the 17 herd units, which separate them into 4 distinct regions. These four larger regions are termed recovery units, and are treated as the basic units for recovery of this taxon. Within a recovery unit, males are expected to move between herd units, while movement by males between recovery units likely will occur less frequently. Movements by males is likely to be the primary source of gene flow.

The rate at which females in the Sierra Nevada colonize vacant habitat is unknown, but dispersal between adjacent herd units within a recovery unit will occur with considerably higher probability than across the gaps that define the recovery units, and thus has implications for the natural recolonization of herd units that become extirpated. However, movements between herds can also spread diseases (Dobson and May 1986, Bleich *et al.* 1990a, 1996). Unoccupied areas between recovery units are, therefore, potentially important zones of isolation that may limit the spread of epizootics throughout the range of Sierra Nevada bighorn sheep.

> *Downlisting Criterion A1*: Downlisting will require a minimum total of 365 females that are at least 1 year of age. At least 50 of those females must be in the Kern recovery unit, 175 females in the Southern recovery unit, 75 females in the Central recovery unit, and 65 females in the Northern recovery unit (Table 5). To achieve these population numbers it

Table 5. Population criteria for down- and delisting of Sierra Nevada bighorn sheep by recovery units. Minimum total females by recovery units are required for downlisting, while geographic distribution, in terms of herd units occupied by females within recovery units, is a criterion for delisting.

	Herd Units Occupied			
Recovery Unit	**Current**	**Potential**	**Delisting**	**Minimum Total Females**
Kern	0	2	2	50
Southern	4	7	6	175
Central	1	3	3	75
Northern	2	5	3	65

is expected that the major threats of excessive predation and avoidance of high-quality low-elevation winter ranges will have substantially diminished.

Justification: The relative numbers of requisite females for each of the four recovery units are based on differences in habitat quantity and quality among the herd units. Herd units that approached carrying capacity in the past 25 years were used as benchmarks for subjective comparisons with other nearby unoccupied herd units to evaluate overall habitat quality. These comparisons were made largely on the basis of winter ranges because, in most cases, that is the most limited seasonal habitat. Conservative carrying capacities for each herd unit were derived from these comparisons. These were summed for each recovery unit, and that sum was halved to arrive at the number of females needed for downlisting. This 50 percent rule reflected the recognition that: (1) considerable error might exist in these subjective carrying capacities, (2) dynamics of populations may not be synchronous, (3) data used as the basis of downlisting will be minimum counts and will likely be less than actual sizes of some herds, and (4) these criteria need to be realistic and attainable.

Downlisting can occur upon reaching these thresholds, which will minimize extinction risk through: (1) considerable geographic distribution; (2) sufficient numbers to provide multiple sources of bighorn sheep for translocation to help any faltering herds and/or to establish bighorn sheep in unoccupied areas; and (3) minimal loss of genetic variation through drift. Occupation of all four recovery units is necessary to develop sufficient numbers of bighorn sheep, and have bighorn sheep in enough isolated areas to make it highly unlikely that all would go extinct simultaneously. Because of the expectation of natural, independent dynamics among these herds, minimum sizes were set for each of the recovery units, but not for any individual herd units.

Downlisting Criterion A2: The threat of domestic sheep or goats contacting bighorn sheep in the Sierra Nevada has been eliminated.

Justification: Any contact between domestic sheep and bighorn sheep could lead to the loss of entire herds of bighorn sheep in the Sierra Nevada. Hence, potential for contact between bighorn sheep and domestic sheep must be eliminated to avoid the possibility of a catastrophic epizootic. Bighorn sheep and domestic sheep can potentially come into direct contact through the movements of either species. As recovery proceeds, and the numbers and geographic distribution of bighorn sheep increase, the potential for contact will increase. Strong, decisive actions must be taken to prevent contact from occurring now or in the future.

b. Delisting Criteria

Delisting Criterion B1: The number of females required for downlisting by recovery units (Table 5) has been maintained as an average for at least 6 years (one generation) without intervention. Herd status for delisting must entail at least three censuses, one at the beginning of the period (qualifying for downlisting), one at the end of the period, and one intermediate count for each herd unit. To achieve these population numbers it is expected that the major threats of excessive predation and avoidance of high-quality low-elevation winter ranges will have substantially diminished and remained low over an extended period of time.

Delisting Criterion B2: Bighorn sheep of both sexes are present in a minimum of 14 herd units, distributed as follows: 2 in the Kern recovery unit, 6 in the Southern recovery unit, 3 in the Central recovery unit, and 3 in the Northern recovery unit.

Justification: The target number of occupied herd units for delisting (Table 5) was based on realistic expectations. There is uncertainty about whether it will be possible to establish herds of bighorn sheep in three of the herd units (Coyote Ridge, Green Creek, and Twin Lakes; Figure 1, Table 4); thus, those three were not included in the delisting criteria.

These criteria result in a total requirement of 14 occupied herd units and 365 females at least 1 year of age necessary for delisting (Table 5). With a natural adult sex ratio of about 70 males:100 females (Wehausen 1980), the minimum total population at both downlisting and delisting will be about 620 adults. Because this number is based on minimum requirements for each recovery unit, the total population will almost certainly be higher.

The time requirement of one generation will assure the maintenance of these population and distribution conditions across all recovery units while much of the population is replaced through mortality and recruitment. Also, it is recognized that a period of substantial population growth will necessarily precede the initial attainment of conditions necessary for delisting. Thus, a period of favorable population conditions encompassing multiple generations will precede delisting.

Delisting Criterion B3: Recovery tasks related to monitoring and research goals have been accomplished, allowing the severity of secondary threats (including habitat loss, vegetational succession, recreational disturbance, competition with elk or deer, acid rain, and climate change) to be adequately assessed. Threats have either been ameliorated or have been determined not to pose a significant risk to the population.

Justification: Before we determine that the bighorn sheep warrants delisting, additional information is needed regarding which threats significantly endanger the population. Research is needed on the threats noted above, which, although they are not as immediately critical as disease, predation, and winter range usage, may have potential for long-term adverse effects on the population. Research and monitoring tasks should assess which threats are significant and if necessary identify appropriate management actions to be implemented.

c. Recovery Units

The delisting criteria include only 14 of the 17 herd units because of uncertainty as to whether viable bighorn sheep herds can be established in 3 of those units (numbers 9, 16, and 17 in Table 4). The area defined by those 14 core herd units (Figure 1) is considered habitat necessary to the recovery of the species for the following reasons. First, it may be necessary for all 14 herd areas to be occupied to attain the minimum total population size of 365 females. Given the likelihood that the four recovery units will function largely as independent metapopulations, it is important to develop sufficient distribution in each to buffer them against catastrophic losses of individual herds. These recovery units also span a variety of ecological settings. Second, the recovery units may function largely as separate metapopulations. It is, therefore, necessary to have as many bighorn sheep in each as possible to prevent genetic drift from eroding genetic diversity within recovery units. Similarly, there is a need for geographic continuity in the distribution of herds in order to maximize genetic interchange among herds, as well as occasional interchange among recovery units.

C. RECOVERY STRATEGY

Because bighorn sheep are naturally slow to disperse and colonize new habitat, recovery of Sierra Nevada bighorn sheep within a reasonable time frame will ultimately depend on translocations of bighorn sheep to reintroduce them to herd units from which they are absent, or to aid in the recovery of existing herds where necessary. A translocation program will require one or more sources of

Sierra Nevada bighorn sheep. Identifying and developing those sources from the current limited herds is one of the greatest challenges to recovering this subspecies. The rate of recovery will, in part, be tied to the number of herds capable of producing bighorn sheep for translocation. The protection and enhancement of existing herds to maximize population growth is the first step. The major threats to existing herds have been decreased survivorship and reproductive success associated with their avoidance of high-quality winter ranges at low elevations (likely in response to predation by mountain lions) and potential outbreaks of disease contracted from domestic sheep. Therefore, predator management (to reduce direct mortality and encourage use of low-elevation wintering ranges) and changes in domestic sheep grazing practices (to prevent contact and disease transmission) are key aspects of the recovery strategy. The strategy will necessarily be supplemented by habitat management (to promote open habitat where predators are readily visible) and perhaps establishment of a captive breeding facility. A genetic management plan is also necessary because the small size and isolation of existing populations threatens to reduce the variability of their unique gene pool. Because maintaining a viable metapopulation will require a broad, minimally fragmented spatial distribution of subpopulations over the landscape, recovery criteria will be defined on the basis of population sizes and occupied herd units within specified recovery units (section II.C.2).

Monitoring and research are necessary to provide the basis for adaptive management and, as such, are critical aspects of this recovery plan. Recovery actions for the bighorn sheep will depend on regularly updated information on population parameters and habitat use patterns for each herd. Similarly, a detailed assessment of the genetic population structure of each herd will be necessary as the basis of a genetic management plan. Monitoring of mountain lions in the vicinity of bighorn sheep winter ranges will greatly enhance efforts to protect herds. Finally, outreach to enlist public support for recovery efforts will be important to the success of this plan.

D. NARRATIVE OUTLINE OF RECOVERY ACTIONS

1. Protect bighorn sheep habitat.

1.1 Identify and acquire important habitat not in public ownership from willing landowners.

While the vast majority of historic bighorn sheep range in the Sierra Nevada is in public ownership, a small number of in-holdings exist. A list of all private land holdings that might affect bighorn sheep should be developed and prioritized relative to importance to bighorn sheep. Key parcels should be acquired or protected under a conservation easement.

1.2 Maintain and/or enhance integrity of bighorn sheep habitat.

Although the vast majority of bighorn sheep habitat in the Sierra Nevada is under Federal ownership, that does not guarantee maintenance of habitat integrity. Habitat integrity might be compromised by fire suppression that affects vegetation succession (see Task 2.2.3), or a variety of human uses (see Task 2.4). Although these issues are both considered with respect to bighorn sheep behavior and population parameters, they also are important to structural attributes of the habitat. All proposed Federal actions in the vicinity of bighorn sheep habitat should be analyzed relative to influences on that habitat.

2. Increase population growth by enhancing survivorship and reproductive output of bighorn sheep.

Recovery of these bighorn sheep requires an overall population increase. Enhancing survivorship and reproduction wherever possible will speed recovery. To the extent that these parameters are enhanced through increased nutrient intake by more extensive use of habitat, the carrying capacity of herd units also will be increased.

2.1 Prepare and implement a management plan to temporarily protect Sierra Nevada bighorn sheep herds from predation losses, where needed, until viable herd sizes are reached.

The management plan must address the immediate needs for selective predator management while allowing for a long range approach that restores and maintains the health of the larger predator-prey system. Known predation losses have been primarily attributed to mountain lions (Table 1). Thus, efforts to prevent further losses should focus on this predator, but not ignore other potential predators.

Individual mountain lions can vary in behavior, including whether they prey on bighorn sheep and whether immigrating lions become potential threats for each herd when resident lions are removed. Therefore, this management plan should attempt to set up criteria to remove only lions that are a threat. Radio-collaring and careful monitoring of mountain lions in the vicinity of bighorn sheep winter ranges will help with selective removal (see Task 5.2 and Appendix E). Additionally, the need to protect bighorn sheep should be carefully balanced with concerns for the viability of the mountain lion population. Potential effects of mountain lions on winter habitat selection by bighorn sheep should be included in this predator management plan; this aspect is addressed below in Task 2.2.

Predator management should be viewed as a temporary measure. It should be terminated when herd units reach a reproductive base of 25 females, with the possible exception of herd units serving as sources of translocation stock. It should be reinstated if a herd unit subsequently declines below 20 females and predators are preventing recovery of that herd unit.

2.2 Increase use of low elevation winter ranges.

Increased use of low elevation winter ranges will increase nutrient intake and thereby enhance reproductive output and success. Increased low elevation winter range use will also decrease mortality associated with the use of high elevations during severe winters.

2.2.1 Reduce influences of predation on winter habitat selection by Sierra Nevada bighorn sheep.

Adult survivorship and recruitment can be negatively affected when bighorn sheep avoid low elevation winter ranges. Winter habitat selection may influence population dynamics more than direct losses from predation. Reducing influences of predators on winter habitat selection may, therefore, be important. Until some herds build sufficient numbers, it could be necessary to remove mountain lions that frequent key winter range areas or aversively condition mountain lions to cause them to avoid those areas (see Task 6.4). If aversive conditioning is successful, the maintenance of home ranges by conditioned resident lions may discourage immigration of unconditioned lions and thereby reduce the number of lions that need to be removed. Biologists familiar with bighorn sheep have independently arrived at a threshold of 25 females considered a minimum number for herd viability (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1997, Fisher *et al.* 1999, U.S. Fish and Wildlife Service 2000).

2.2.2 Supplement small female groups where appropriate to attain a threshold herd size that will encourage behavioral attributes favorable to winter range use.

Because bighorn sheep find security in groups, habitat selection during winter may be affected by the number of bighorn sheep available to form groups. Adding females to small female groups may produce significant increases in uses of winter ranges and, thereby, increase adult survivorship as well as recruitment rates. Further, behavior of bighorn sheep previously translocated in the Sierra Nevada indicates that females translocated from populations that use low elevations will initially attempt to do the same on new ranges. The ability to augment small herds is currently limited by the lack of sources of bighorn sheep that can be moved. The development of sources of bighorn sheep to move is fundamental to achieving this task and is addressed in task 3.2.

2.2.3 Enhance bighorn sheep winter range habitat to increase visibility where appropriate.

Favorable attributes of bighorn sheep habitat are steepness, rockiness, and visual openness. Although steepness and rockiness cannot be changed, openness can be modified via management of vegetation. In the past, fires may have burned in bighorn sheep habitat much more frequently than has occurred over the past century. In opening up habitats, fire can decrease the effectiveness of mountain lions as ambush predators and, perhaps, allow bighorn sheep greater access to low elevation winter ranges that provide nutritious forage. Policies to let fires burn in bighorn sheep habitat, coupled with prescribed fire or other methods of habitat manipulation, should be used to enhance winter ranges where visibility for bighorn sheep needs to be increased.

2.3 Minimize probability of bighorn sheep contracting diseases causing mortality and morbidity.

Introduced diseases have probably been the primary cause of extirpation of bighorn sheep herds in North America. They represent one of the greatest threats.

2.3.1 Eliminate the risk of contact between bighorn sheep and domestic sheep or goats.

Allotments in the vicinity of bighorn sheep habitat should be reviewed by an expert task force and appropriate actions taken to eliminate the risk of contact between domestic sheep and bighorn sheep. This task force should consist of rangeland managers and independent experts, including at least one veterinarian familiar with bighorn sheep and a scientist versed in mathematical modeling and risk assessment.

The Interagency Domestic Sheep Management Strategy (U.S. Fish and Wildlife Service 2001) provided risk assessment criteria for allotments (see Appendix B for a summary). Reviews of allotments should recognize that management of domestic sheep allotments may not be sufficient to prevent contact between domestic sheep and bighorn sheep over the long term if it is possible for domestic sheep to get to the west side of Highway 395. Allotment reviews should occur in three timeframes. The first should consider existing bighorn sheep herds and lead to immediate actions necessary to eliminate the threat of contact with bighorn sheep. The second should anticipate future conflicts with domestic sheep grazing in relationship to unoccupied bighorn sheep ranges within essential habitat and develop a plan to alleviate those conflicts as needed when bighorn sheep range expands through translocations or natural colonizations. Third should be consideration of domestic sheep allotments that are likely to conflict with bighorn sheep herd units outside of essential habitat. While occupation of some of these herd units by bighorn sheep may prove necessary to meet recovery criteria, attempts to restore bighorn sheep to these herd units outside of essential habitat are unlikely to occur until those within essential habitat are occupied. Consequently, resolution of conflicts with domestic sheep grazing near those herd units will not be necessary until the more distant future, if at all. Because it is not possible to know or control whether domestic goats have recently been in contact with domestic sheep, and thereby carry strains of pneumophilic bacteria that are pathogenic to bighorn sheep, domestic goats should likewise be prevented from utilizing areas near bighorn sheep populations.

2.3.2 Develop an action plan in the event that a pneumonia outbreak occurs.

History is replete with examples of decimation and extirpation of bighorn sheep herds from pneumonia epizootics. Quick and decisive actions may save part of a herd, or other nearby herds, in such an event. The development of an action plan prior to such an occurrence may be critically important to taking timely actions. This plan should include actions needed if a bighorn sheep is found in contact with domestic sheep.

2.4 Manage human use locally where it is found to cause bighorn sheep to avoid important habitat and, thereby, compromises survivorship or reproductive success.

This action will take place only if research (see Task 6.3) results in a recommendation to limit human use in some areas; at present there appear to be few locations where recreational disturbance has the potential to significantly affect bighorn sheep. Focused research on effects of human activities on bighorn sheep will determine whether any limitations on human use are required. If it is concluded that limitations will be beneficial, appropriate actions should be taken to limit human use that is found to be detrimental. Disturbance by humans (or possibly by off-trail domestic dogs) will be significant to bighorn sheep if nutrient intake of a herd is compromised by avoiding key foraging areas because of human activity. Both quality and quantity of forage vary greatly across the landscape, and bighorn sheep visit key locations where more nutritious forage is available. If bighorn sheep are regularly displaced from such areas and cannot procure equivalent nutrient intake at an alternative site, population parameters of the herd will be negatively affected. If they frequently flee encounters with humans, there may also be an unnecessary waste of energy that can have population-level effects.

3. Increase the number of herds, and thereby the number of bighorn sheep.

It will be necessary to increase the geographic distribution and overall numbers of bighorn sheep in the Sierra Nevada to attain criteria necessary for downlisting and delisting. Because of the slow rate of natural colonization of bighorn sheep, this action will require active management.

3.1 Develop and implement a strategy for translocations.

Because of the slow rates of natural colonization by bighorn sheep, recovery can be accelerated by translocations to originate herds in vacant ranges and to augment those in existing ones. It will be important to utilize the limited number of bighorn sheep available for translocations in a way that maximizes recovery of these bighorn sheep in the shortest time period. A strategy is needed that clearly identifies issues, options, and tradeoffs, and analyzes different herd units as potential recipients of translocated bighorn sheep (See Appendix C).

3.2 Develop sources of translocation stock.

Availability of bighorn sheep to be translocated has been, and continues to be, the primary factor limiting recovery of bighorn sheep in the Sierra Nevada. Only one source of stock was available for previous restoration efforts (see section I.C.2). The vulnerability of that situation led to the proposal to develop additional such sources as the primary goal of an earlier conservation plan for these bighorn sheep (Sierra Nevada Bighorn Interagency Advisory Group 1984). Additional sources of translocation stock will continue to be a fundamental need.

3.2.1 Manage wild herds as sources of stock.

Developing sources of translocation stock will depend on sufficient recovery of at least one existing herd to the point where bighorn sheep can be removed. All, or most, of the first available translocation stock should be used to develop one or more additional sources of such stock. This strategy is analogous to compounding interest and will, thereby, increase the rate of recovery of these bighorn sheep.

3.2.2 Develop criteria for and, if appropriate, implement a captive breeding program.

In addition to wild populations as a source of translocation stock, a captive breeding facility should be considered. Such a facility may produce bighorn sheep more rapidly, but it could also pose risks. Aspects of captive breeding as a potential program should be investigated in detail, including criteria that would trigger implementation of such a program (Appendix C).

4. Develop and implement a genetic management plan to maintain genetic diversity of Sierra Nevada bighorn sheep. The plan must use data on genetic variation developed in Task 6.1.

Restoration of bighorn sheep to vacant habitats in the Sierra Nevada will be accomplished largely through translocations. However, translocation may not maximize conservation of the genetic variation that currently exists. There is a need to consider long-term genetic management in conjunction with the translocation strategy to distribute genetic variation throughout the range of these bighorn sheep.

Because translocation will be the primary method of genetic management, a genetic management plan should be developed in conjunction with the translocation strategy to address needs at the level of the population.

5. Monitor status and trends of bighorn sheep herds and their habitat.

Recovery of bighorn sheep in the Sierra Nevada will require an adaptive approach, one in which decisions made will depend on current information about key resources. Consequently, monitoring of those resources is a fundamental component of this recovery plan.

5.1 Develop and implement a monitoring plan for population abundance and distribution of bighorn sheep herds in the Sierra Nevada.

Management actions will be dependent on the best possible data on the population status of each herd. Downlisting and delisting criteria also are dependent on that information and were developed in part with the recognition that minimum counts will be the most conservative data to use as the basis of management decisions. Appendix D considers further details of this monitoring.

Recent population dynamics of Sierra Nevada bighorn sheep indicate that recovery to adequate population levels will occur only with increased use of winter ranges. Trends in the use of winter ranges need to be monitored in conjunction with population monitoring. Trends in winter range use will be useful in projecting future population trends. They will also allow efforts to focus on herds that are reluctant to use winter ranges.

5.2 Monitor key predators in the vicinity of winter ranges.

Efforts toward the recovery of Sierra Nevada bighorn sheep necessarily take place in a larger ecosystem context. Because management of predators, especially mountain lions, is a component of this recovery plan, careful monitoring of these predators near bighorn sheep populations is important. Such monitoring will provide data on how individual mountain lions, and mountain lions in general, use habitat in the vicinity of each population of bighorn sheep, and will allow an assessment of which mountain lions pose the greatest threats to bighorn sheep, and when those threats are greatest (see Appendix E).

5.3 Monitor vegetation structure and composition changes likely to affect bighorn sheep population parameters.

In the absence of regular fires, vegetational succession can slowly decrease openness in bighorn sheep habitat. Vegetation structure and its concomitant effects on visibility should be monitored on a long term basis.

5.4 Monitor exposure to disease organisms of concern.

Exposure to disease organisms can be monitored indirectly by testing blood serum and directly by testing for the organisms. When bighorn sheep in the Sierra Nevada are captured for management operations, appropriate sampling and testing of those animals should take place to develop a continuing database that will potentially detect changes over time. A large database already exists from captures beginning in 1979.

6. Continue or initiate needed research.

An adaptive approach to management will require development or continuation of existing research.

6.1 Investigate genetic population structure of existing herds.

Genetic population structure can play a potentially large role in the long-term viability of bighorn sheep in the Sierra Nevada. The conservation of the gene pool of bighorn sheep in the Sierra Nevada will depend on a detailed understanding of the distribution of genetic variation and the dynamics within that genetic population structure. There is need to develop a genetic database and to use it as the foundation for a genetic management plan (see Task 4). Specific data needs concern: (1) current amount of genetic variation compared with other metapopulations of bighorn sheep; (2) distribution of genetic variation among the different herds; and (3) population genetic changes in each herd to determine if future erosion of genetic diversity is likely to be a problem. These studies are possible with modern laboratory techniques by using a variety of sources of DNA.

6.2 Further investigate habitat use patterns of bighorn sheep herds.

A large database of sightings of bighorn sheep in the Sierra Nevada has been accumulated by researchers over the past 25 years (Figure 1). Population substructuring of female groups also has been identified and hypothesized on the basis of naturally marked bighorn sheep. However, because of sampling limitations, these data do not provide details of habitat use throughout the year or the degree of separation of female groups. Radio telemetry studies can help fill in that detail. Global positioning system collars may provide an efficient method of developing detailed, accurate information on the seasonal distribution and habitat selection patterns of these bighorn sheep.

6.3 Investigate and analyze human use patterns relative to habitat use patterns of bighorn sheep.

Earlier investigations of hypotheses concerning human disturbance (Dunaway 1971) dismissed it as not important for the Mount Baxter herd, but possibly a factor for the Mount Williamson herd (Wehausen *et al.* 1977, Hicks and Elder 1979, Wehausen 1980). Bighorn sheep have been reintroduced to three additional areas since the earlier studies, but these new herds have not been investigated to determine the possible impacts of human disturbance. There is a need to investigate patterns of use by humans and domestic dogs including intensity, trends, and types of use in and near existing bighorn sheep habitat to identify areas of possible conflict. If areas of concern are identified, intensive studies to investigate whether human disturbance may be displacing bighorn sheep from favorable habitat can be initiated. Potential reintroduction sites also should be investigated to identify areas of possible conflict.

6.4 Investigate the potential for altering habitat use patterns of mountain lions on bighorn sheep winter ranges by aversive conditioning.

Altering the behavior or distribution of mountain lions through aversive conditioning may provide an alternative to temporary management involving removal of mountain lions that may kill bighorn sheep. If effective, this approach may allow the recovery of bighorn sheep with less intervention. Aversive conditioning of mountain lions is an untested concept, and it can be investigated in situations that minimize risks to bighorn sheep.

6.5 Investigate future introduction sites relative to predator and domestic sheep problems and other potential conflicts.

Like the genetic management plan, this investigation should be coordinated with the translocation strategy. One product of a translocation strategy (see task 3.1) will be the identification of priority for future reintroduction sites that is based on habitat characteristics and spatial relationship to existing herds. Once this priority is established, sites of top priority should be investigated for potential problems with predators, domestic sheep, or other concerns.

6.6 Investigate and, if appropriate, develop a plan for decreasing the mortality of sheep remaining at high elevations in extreme winters.

The bighorn sheep on Mount Warren have experienced major population declines during recent severe winters while attempting to live at high elevations during that season. While an emphasis of this plan is to attempt to develop more low elevation winter range use, it also is important to maintain numbers of bighorn sheep until such changes in habitat use patterns take place. Supplemental feeding of bighorn sheep at high elevations during severe winters could be crucial to their survival. This subject should be explored in detail and an action plan developed as appropriate.

6.7 Attempt to develop long-term data to elucidate predator-prey dynamics of this ecosystem as they affect bighorn sheep.

During the 1980's, bighorn sheep in the Sierra Nevada began to avoid low elevation winter ranges, a pattern of behavior that has, in turn, led to major declines in the population. This dynamic appears to reflect predator-prey processes that are not fully understood but that clearly can affect the bighorn sheep population. A better understanding of the larger predator-prey system is needed and will require long-term information. Some of the components of this system (bighorn sheep, mountain lions, and possibly other predators) will be tracked as part of the monitoring for this recovery effort. Mule deer, the primary prey of mountain lions, are a key component of this ecosystem. Monitoring the dynamics of the mule deer population is basic to developing an understanding of this predator-prey system. Other potentially important components that are not currently monitored should be identified and efforts should be made to add them to the monitoring scheme to aid future efforts to understand the dynamics of this system.

6.8 Investigate effects of climate change on bighorn sheep habitat and environmental contaminants, such as mining wastes or acid rain, on the health of Sierra Nevada bighorn sheep.

If acid rain increases in the southern Sierra Nevada, profound changes in soil chemistry may occur in bighorn sheep habitat. Such changes can affect plant uptake of minerals, such as selenium, that are important to bighorn sheep. Mining wastes, including pollutants in aerosol form, also have the potential to affect the health of these bighorn sheep. Climate change may cause significant habitat changes.

7. Engage in public outreach and sharing of information.

The overriding purpose of the Sierra Nevada bighorn sheep public information and outreach effort is to build understanding, respect, and concern for this species, and understanding of and support for conservation measures and recovery actions. A number of recovery actions outlined in this recovery plan will directly affect public use in the eastern Sierra Nevada and, conversely, human activities may affect recovery actions. It is therefore imperative that strong public information and awareness programs be implemented. The public needs to be informed of the reasons why specific recovery actions are being taken. Conservation efforts are more likely to succeed if efforts are understood and supported by the populace. Enlisting public support for recovery efforts will require an information and outreach program on the ecology of Sierra Nevada bighorn sheep, the threats this species is currently facing, and how recovery actions will reduce those threats. Imparting that knowledge to the public will help build respect and concern for this species and its larger ecosystem, as well as support for conservation measures. Appendix F contains a detailed plan for developing an effective outreach and information program.

Public information and outreach on Sierra Nevada bighorn sheep has been occurring and is ongoing. The Sierra Nevada Bighorn Sheep Interagency Advisory Group, the Sierra Nevada Bighorn Sheep Foundation, the Inyo National Forest, and the Interagency Domestic Sheep Grazing Strategy Working Group have conducted media interviews and hosted public meetings focused on Sierra Nevada bighorn sheep ecology, management, and threats. However, additional efforts are possible and desirable. In addition, there should be a higher degree of coordination among individual programs and other recovery activities. Increased coordination would not only allow each program to present the most accurate and updated information, but it would also let the general public see that the recovery of Sierra Nevada bighorn sheep is a collaborative effort supported by multiple agencies, organizations, and individuals. Specific recovery actions to accomplish the identified goals are as follows.

7.1 Conduct a survey of public uses of Sierra Nevada bighorn sheep habitat and public attitudes regarding Sierra Nevada bighorn sheep.

Results of the survey will be used to (1) prioritize the public information and outreach action items, (2) determine the best methods to accomplish the action items with the highest likelihood of meeting the recovery plan goals, and (3) establish a baseline from which the success of the action items in meeting the recovery plan goals can be measured by comparing to a resurvey 1 year after implementation.

7.2 Develop and distribute information related to recovery efforts.

The results of the public survey (7.1) should be used to determine the specific topical information and most effective method(s) of disseminating this information to target audiences. This information should be available from the key agencies involved in this recovery effort. A general brochure or information sheet should be developed that contains a brief overview of the status of Sierra Nevada bighorn sheep, as well as specific suggestions on what people can do to help the species. In addition, information on a variety of topics germane to the recovery of Sierra Nevada bighorn sheep should be summarized and made available to the public in booklet form.

During implementation of recovery efforts, the public should be fully informed as early as possible regarding actions required or restricted while in Sierra Nevada bighorn sheep habitat. Further, the finalized recovery plan, along with a cover letter, should be widely distributed to affected and interested people, including hikers and other recreationists, ranchers, ranchette owners with domestic sheep or goats, commercial packers, environmental groups, mountain lion and bighorn sheep advocacy groups, and affected local, State, and Federal agencies. Moreover, the recovery plan should reach people who would not typically be exposed to traditional programs (*i.e.*, individuals who might not frequent visitor's centers or who do not have school-aged children).

7.3 Continue, update, and coordinate existing informational and outreach programs and develop further programs as needed.

The results of the public survey (7.1) should be used to develop the most effective informational and outreach programs. However, there is a more immediate need to update existing programs to provide an accurate view of our current knowledge regarding Sierra Nevada bighorn sheep.

Information should strive to highlight not only how the activities of each individual agency or organization contribute to the recovery of Sierra Nevada bighorn sheep, but how these activities complement those of other agencies or organizations. Further, existing bighorn sheep curricula should be reviewed and modified to be applicable to Sierra Nevada bighorn sheep. Further, a variety of education materials on bighorn sheep exist that target school-aged children and could be incorporated into a Sierra Nevada bighorn sheep curriculum.

8. Establish an implementation advisory team for coordination and communication.

Numerous Federal, State, and private agencies share responsibility for bighorn sheep in the Sierra Nevada along with stakeholders. Efforts to recover these bighorn sheep will require considerable coordination and communication among these different entities. This coordination will be greatly enhanced through the formation of an advisory team that meets at least twice annually. This team should include agency representatives, appropriate specialists, and key stakeholders.

III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions as identified in the Narrative Outline of Recovery Actions (section II.D) and estimates costs for the recovery of Sierra Nevada bighorn sheep. It is a *guide* for meeting the objectives discussed in Part II of this recovery plan. This Schedule indicates task priority, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. The agencies responsible for committing funds are not necessarily the entities that will carry out the tasks. The agency or agencies with the lead responsibility for each task are indicated in the table. Initiation of these actions is subject to the availability of funds.

The Implementation Schedule indicates speculative, future costs (preparation of additional plans, or research programs, etc.) as "to be determined." Indirect costs, such as those incurred by: (1) agencies and groups contributing of time and materials, or (2) public agencies performing administrative or regulatory functions are not included in cost totals. Costs of continuous tasks are estimated assuming a 20-year time to recovery. Though the Implementation Schedule does not distinguish between public and private costs, no identifiable or specific expenditures by the private sector are likely to be necessary, other than voluntary efforts contributed by nonprofit conservation organizations and citizen groups. Priorities (column 1 of the following table) are assigned as follows:

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery of the species.

Abbreviations used in the Implementation Schedule:

TBD	To be determined
cont.	Continuous
†	Continued implementation of task expected to be necessary after delisting.
‡	Task expected to be necessary until delisting of species.
*	Lead responsible agency

Agencies and Organizations

BLM	Bureau of Land Management
CDFG	California Department of Fish and Game
CT	CalTrans
LADWP	Los Angeles Department of Water and Power
FWS	U.S. Fish and Wildlife Service
FS	U.S. Forest Service
NPS	National Park Service
UC	University of California, White Mountain Research Station
USGS	U.S. Geological Survey, Biological Resources Division

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR SIERRA NEVADA BIGHORN SHEEP

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000s)	Estimated Cost ($1,000s)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	2.1	Prepare and implement a management plan that addresses the immediate needs for predator management while developing a long-range approach that concerns the larger predator-prey system.	cont.	CDFG*	7,000	350	350	350	350	350
1	2.2.1	Reduce potential predator influences on winter habitat selection where appropriate	cont.	CDFG*	1,000	50	50	50	50	50
1	2.2.2	Supplement small female groups where appropriate to attain threshold herd sizes that will encourage behavioral attributes favorable to winter range use	cont.	CDFG*	300 (estimated cost $3,000 per animal captured; number captured per year TBD)	TBD	TBD	TBD	TBD	TBD
1	2.3.1	Eliminate risk of contact between bighorn sheep and domestic sheep or goats	cont.[†]	FS*, FWS, BLM, DWP, CDFG	50	2.5	2.5	2.5	2.5	2.5
1	3.1	Develop and implement a strategy for translocations	cont.	FS, NPS, FWS, CDFG*	600	30	30	30	30	30

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000s)	Estimated Cost ($1,000s)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	3.2.1	Manage wild herds as sources of stock	cont.	CDFG*	costs included in other tasks					
1	5.2	Monitor key predators in the vicinity of winter ranges	cont.‡	CDFG*	included in 2.2.1					
2	1.2	Maintain and/or enhance integrity of bighorn sheep habitat	cont.‡	NPS*, FS*, FWS, CDFG	TBD	TBD	TBD	TBD	TBD	TBD
2	2.2.3	Enhance bighorn sheep winter range habitat to increase visibility where appropriate	cont.	FS*, NPS*, CDFG	600	30	30	30	30	30
2	2.3.2	Develop an action plan in the event that a pneumonia outbreak occurs	1	CDFG*	10		10			
2	3.2.2	Develop criteria for and, if appropriate, implement a captive breeding program	cont.	FS, FWS, CDFG*	5,000	250	250	250	250	250
2	5.1	Develop and implement a monitoring plan for population abundance and distribution of bighorn sheep herds in the Sierra Nevada	cont.†	CDFG*, UC*	4,000	200	200	200	200	200
2	5.4	Monitor exposure to disease organisms of concern	cont.‡	CDFG*	75	3.75	3.75	3.75	3.75	3.75
2	6.1	Investigate genetic population structure of existing herds	5	CDFG, UC*	200	40	40	40	40	40

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000s)	Estimated Cost ($1,000s)				
						FY 03	FY 04	FY 05	FY 06	FY 07
2	8.	Establish an implementation advisory team for coordination and communication	cont.[‡]	CDFG*	20	1	1	1	1	1
3	1.1	Identify and acquire important habitat not in public ownership from willing landowners	cont.	FS*, FWS, CT, CDFG	TBD	TBD	TBD	TBD	TBD	TBD
3	2.4	Manage human use locally where it is found to cause bighorn sheep to avoid important habitat and, thereby, compromises survivorship or reproductive success.	1	FS*, NPS*, FWS, CDFG	5					
3	4	Develop and implement a genetic management plan using data on genetic variation developed in Task 6.1	cont.[‡]	CDFG*	20 Implementation costs included in 3.1			20		
3	5.3	Monitor vegetation structure and composition changes likely to affect bighorn sheep population parameters	10	FS*, NPS*, CDFG	100	10	10	10	10	10
3	6.2	Further investigate habitat use patterns of bighorn sheep herds	20	CDFG*	400	20	20	20	20	20
3	6.3	Investigate and analyze human use patterns relative to habitat use patterns of bighorn sheep	cont.	FS, NPS, CDFG*	100	5	5	5	5	5

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000s)	Estimated Cost ($1,000s)				
						FY 03	FY 04	FY 05	FY 06	FY 07
3	6.4	Investigate the potential for altering habitat use patterns of mountain lions on bighorn sheep winter ranges by aversive conditioning	10	CDFG*	100	10	10	10	10	10
3	6.5	Investigate future reintroduction sites relative to potential predator and domestic sheep problems and other potential conflicts	cont.	FS, NPS, CDFG*	200	10	10	10	10	10
3	6.6	Investigate and, if appropriate, develop a plan for decreasing mortality of bighorn sheep remaining at high elevation in extreme winters	1	FS, CDFG*	20			20		
3	6.7	Attempt to develop long term data that will help elucidate predator-prey dynamics of this ecosystem as they affect bighorn sheep	cont.	FS, NPS, UC*, CDFG	1,550	30	80	80	80	80
3	6.8	Investigate effects of climate change on bighorn sheep habitat and environmental contaminants, such as mining wastes or acid rain, on the health of bighorn sheep	TBD	FS, NPS, USGS*, CDFG	120	TBD	TBD	TBD	TBD	TBD
3	7.1	Conduct a survey of public uses of bighorn sheep habitat and public attitudes regarding bighorn sheep	1	FS*, NPS*, FWS, CDFG	30		30			

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000s)	Estimated Cost ($1,000s)				
						FY 03	FY 04	FY 05	FY 06	FY 07
3	7.2	Develop and distribute information related to recovery efforts	cont.[‡]	FS, NPS, FWS*, CDFG*	110	10	10	5	5	5
3	7.3	Continue, update, and coordinate, existing informational and outreach programs and develop further programs as needed	cont.[‡]	FS, NPS, FWS*, CDFG*	100	5	5	5	5	5

Total estimated cost (over 20 year timeframe): $21,730,000 + additional costs that cannot be determined at this time.

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V. APPENDICES

A. Pack llamas as potential sources of diseases for Sierra Nevada bighorn sheep
B. Risk assessment regarding domestic sheep
C. Translocation considerations for Sierra Nevada bighorn sheep
D. Monitoring of bighorn sheep population parameters
E. Monitoring of mountain lions near bighorn sheep winter ranges
F. Public information and outreach plan

APPENDIX A. PACK LLAMAS AS POTENTIAL SOURCES OF DISEASES FOR SIERRA NEVADA BIGHORN SHEEP

Abstract: The interspecies transmission of infectious pathogens is dependent on characteristics of the two species, the disease agents, and the environment and requires effective contact between the host species. The requirements for transmission of diseases potentially shared by pack llamas and Sierra Nevada bighorn sheep are not satisfied in the context of the epidemiology of known diseases of new world camelids in the United States, the management of pack llamas in the back country, and the ecology and natural history of free ranging Sierra Nevada bighorn sheep. Current scientific evidence suggests that llamas utilized as pack animals present minimal risk of transmission of known pathogens to Sierra Nevada bighorn sheep and does not support the exclusion of llamas from Sierra Nevada bighorn sheep habitat due to the risk of disease transmission. Prevention of overuse of trails by llama packers, requirement of evidence of preventive health programs in llama herds for issuance of trail use permits, and good sanitation and husbandry practices by llama packers on the trail will further reduce the already very small risks and further protect the endangered Sierra Nevada bighorn sheep.

Literature Review: The transmission of infectious disease agents from one species to another depends on characteristics of the host species, (susceptibility and infectiousness), characteristics of the pathogen (infectivity, virulence and environmental stability) and effective contact between the host species (Thrusfield 1995). In order for a llama *(Llama glama*) to transmit a pathogenic virus, bacterium or parasite to a bighorn sheep, the agent must be present in the llama in a form and quantity adequate for successful transmission, the disease agent must be infective enough to be passed between species either by direct contact or indirectly via a vector or inanimate physical vehicle, and there must be effective contact with the bighorn sheep adequate to allow transmission. The agent must be able to survive environmental conditions during the transmission and the bighorn sheep must in turn be susceptible to the pathogen.

A review (Thedford and Johnson 1989) and a standard text (Fowler 1998) on the infectious diseases of new world camelids indicated that llamas in the United States are basically healthy and that most medical problems are management or environment related. Many disease agents that are infectious to both new world camelids and bighorn sheep are rare in llamas in the United States, are more easily acquired from the environment or sympatric wildlife than from the llama, are not present at adequate levels in the environment to infect bighorn sheep, or are unlikely to survive environmental conditions during indirect transmission.

Due to their high intrinsic economic value, pack llamas are generally tethered or otherwise kept close to their owners on the trail (Fowler 1998). In the unlikely event that a llama would escape into a free ranging situation, it would be unable to keep up with Sierra Nevada bighorn sheep in the steep, rocky terrain they frequent. Also, Sierra Nevada bighorn sheep naturally keep a wide flight distance from humans, making direct physical contact between pack llamas and bighorn sheep highly unlikely and reducing the opportunity for transmission of infectious disease. Depending on the number and size of llama pack strings and their distribution, indirect transmission of disease agents including common gastrointestinal parasites, contagious ecthyma virus, and others from contaminated pastures, artificial feed, and standing water sources is theoretically possible. A few disease agents warrant individual discussion as they have demonstrated pathogenicity in bighorn sheep: *Pasteurella hemolytic* pneumonia; *Mycobacterium paratuberculosis* (Johne's disease); Contagious ecthyma virus (CE, soremouth); and *Psoroptes* spp. (Scabies).

Pasteurella hemolytica pneumonia

Pasteurella pneumonia is a major cause of epizootic disease outbreaks in captive and free ranging bighorn sheep populations resulting in high adult mortality with poor lamb survivorship in subsequent years. In separate trials, Rocky Mountain bighorn sheep were placed in direct contact with llamas, domestic sheep, exotic mouflon sheep (*Ovis musimon*), domestic goats, mountain goats (*Oreamnos americana*), domestic cattle (Foreyt 1994), elk (*Cervus elaphus*), and deer (*Odocoileus virginianus* and *Odocoileus hemionus hemionus*) (Foreyt 1992) and domestic horses and cattle (Foreyt and Lagerquist 1996) to determine if contact with other wild and domestic ungulate species exposed bighorn sheep to *Pasteurella* pneumonia. Except for the llamas and horses, essentially all the ungulates including the bighorn sheep were phanyngeal carriers of isolates of *Pasteurella hemolytica* when the experiment started. Foreyt tested a total of 17 llamas to use as *Pasteurella* carriers in the trials but found none that were culture positive. All bighorn sheep exposed to the domestic sheep and the mouflon (Foreyt 1994), and one exposed to domestic cattle (Foreyt and Lagerquist 1996), succumbed to *Pasteurella* pneumonia while those exposed to the other ungulates including the llamas remained normal. *Pasteurella multocida* infection can cause a hemorrhagic septicemia-like disease in old world camels (Thedford and Johnson 1989). However, *Pasteurella* pneumonia in new world camelids has not been reported in the literature. Based on available data, there is no scientific evidence that contact with llamas will result in respiratory disease from *Pasteurella spp.* in bighorn sheep (Foreyt 1994).

Mycobacterium paratuberculosis (Johne's Disease)

Much controversy surrounds the potential for transmission of Johne's disease (*Mycobacterium paratuberculosis*) from llamas to free ranging bighorn sheep (Fowler 1998). Johne's disease is considered a disease of confinement, usually requiring intense sustained exposure to feces of infected, shedding animals as seen in domestic livestock and captive wild ungulates. Generally, adult ungulates are much less susceptible to infection and require greater exposure than juveniles. *Mycobacterium paratuberculosis* infection has been documented in several species of free ranging ungulates in the United States (Chiodini *et al.* 1983, Shulaw *et al.* 1986, Riemann *et al.* 1979, Jessup *et al.* 1981). Williams *et al.* (1979) reported on cases of Johne's disease in bighorn sheep and in a mountain goat (*Oreamnos americana*) in the Mount Evans area of Colorado. The source and epizootiology of the disease were not clear in these cases. In a followup study, *M. paratuberculosis* was isolated from tissues and/or feces from nine of nine bighorn sheep/domestic sheep hybrids experimentally inoculated with an *M. paratuberculosis* isolate from the Mount Evans cases and two of three bighorn sheep hybrids exposed to runoff from contaminated animal pens (Williams *et al.* 1983).

Johne's disease has been documented in new world camelids in England (Fowler 1998) and in Australia (Ridge *et al.* 1995) but is rarely diagnosed in llamas in the United States, with only four cases documented in Colorado (2), Oklahoma (1) and Minnesota (1) (Fowler 1998). Casual contact with the feces from a subclinically infected pack llama shedding *Mycobacterium paratuberculosis* is considered unlikely to provide adequate exposure to infect a bighorn sheep. The rare occurrence of this disease in llamas in North America makes it highly unlikely that any exposure will occur. There is no scientific evidence that llamas present a risk of transmission of Johne's disease to bighorn sheep.

Contagious ecthyma virus (CE, soremouth)

Contagious ecthyma is a cause of painful scabs and lesions on the mouths and faces of bighorn lambs and on the teats of bighorn females, and can result in difficulty in nursing and stunted growth of lambs. Clinical cases of contagious ecthyma have been diagnosed in bighorn sheep in Nevada, New Mexico, Colorado, Canada and California (Jessup 1993) and serologic evidence of exposure is not uncommon in desert bighorn (*Ovis canadensis nelsoni*) and Peninsular bighorn sheep (*Ovis canadensis cremnobates*) in California (California Department of Fish and Game, unpublished data). Clark *et al.* (1993) surveyed Sierra Nevada bighorn sheep sera retrospectively for contagious ecthyma exposure and found 2 of 14 (14 percent) seropositive accessions. More recent data from five Pine Creek animals captured in 1999 showed one of five negative and four of five inconclusive results on contagious ecthyma complement fixation tests (California Department of Fish and Game, unpublished data).

Transmission can be direct or indirect, as contagious ecthyma virus can be transmitted by insect vectors and may survive for years in scabs and soil. Contagious ecthyma is seen in camelids in Peru, and at least one case is documented in the United States. The natural reservoir for contagious ecthyma infecting llamas is probably the domestic sheep (Fowler 1998). Direct transmission of contagious ecthyma virus is highly unlikely due to lack of physical contact with bighorn sheep. While the contamination of pastures with contagious ecthyma virus is theoretically possible, the rare occurrence of contagious ecthyma in llamas in the United States makes it highly unlikely. Closely managed pack llamas, kept under good husbandry and sanitation conditions and with no evidence of clinical contagious ecthyma, present little or no risk to Sierra Nevada bighorn sheep.

Psoroptes spp. (Scabies)

Psoroptes scabies is an ectoparasitic disease that has caused declines in bighorn sheep populations throughout the west from the late 19th century to the present. Serologic evidence of exposure is not uncommon in desert bighorn sheep in California (Clark *et al.* 1993), and clinical cases have been observed in several desert mountain ranges in California (California Department of Fish and Game, unpublished data). Of 110 Sierra Nevada bighorn sheep tested retrospectively, none showed evidence of previous exposure to *Psoroptes* spp. (Clark *et al.* 1993). Two llamas, a cria and his dam (offspring and mother), are the only documented cases of *Psoroptes* in new world camelids in the United States. Based on morphological and epidemiological studies, the authors determined that the potential for transmission of *Psoroptes* from llamas to other hosts is present (Foreyt *et al.* 1992). Considering the rarity of this disease in llamas in the U.S. and the unlikely nature of direct contact between llamas and Sierra Nevada bighorn sheep, the risk for interspecies transmission of this disease is extremely low.

Conclusion

Scientific evidence suggests that llamas utilized as pack animals present minimal risk of transmission of known pathogens to Sierra Nevada bighorn sheep. Diseases reported in new world camelids but not discussed here (*e.g.* tuberculosis, brucellosis) are rare or nonexistent in the United States in llamas, are environmentally related (anthrax, clostridial diseases), or require conditions of contact that do not exist in the context of Sierra Nevada bighorn sheep and llama management. Due to the endangered status of the Sierra Nevada bighorn sheep, land managers may desire a conservative approach to further reduce the already small risk of disease introduction from llamas. The following measures could be implemented:

- Prevent overuse by private and commercial llama packers. This measure will limit contamination of pastures, pens, and standing water sources. Limitations placed on numbers due to potential forest and trail impacts may be adequate to address disease considerations.

- Require evidence of adequate herd health care before issuance of permits. Evidence of herd examinations by a licensed veterinarian, regular diagnosis and treatment of gastrointestinal parasites, and exclusion of animals showing signs of infectious disease from the pack string can be reflected in a health certificate that is renewed on a periodic (annual) basis.

These additional precautions impose little if any additional burden on either land managers or llama packers, and will further protect the small and endangered populations of Sierra Nevada bighorn sheep.

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APPENDIX B. RISK ASSESSMENT REGARDING DOMESTIC SHEEP

The probability that stray domestic sheep will contact bighorn sheep might be modeled as the product of three probabilities: (1) the probability of strays occurring near the bighorn sheep population; (2) the probability of those strays entering bighorn sheep habitat; and (3) the probability of those strays that reach bighorn sheep habitat contacting bighorn sheep. The overall probability of contact between a bighorn sheep and a stray domestic sheep in the Sierra Nevada over time will be the product of the above three probabilities for each population summed across years and across populations. Assigning values to the three basic probabilities would be difficult at best. Because probabilities must be summed across many years and populations, it is essential that the product of the three basic probabilities be very close to zero to assure that this larger sum over future years also will be as close to zero as possible. The probabilities that can be influenced by management are the occurrence of strays and the probability of these strays finding bighorn sheep habitat. The second of these will be greatly influenced by the distance between domestic sheep and bighorn sheep habitat, potential barriers to domestic sheep movement toward bighorn ranges, and various aspects of the grazing procedures of each allotment. Detailed monitoring of domestic sheep also may reduce the probability of strays reaching bighorn habitat through the timely knowledge that strays are missing from a flock. While the third probability cannot be altered by management actions, it should be recognized that it will increase as the bighorn sheep herds increase; the more bighorn sheep there are, the more likely it will be that a stray domestic sheep in their habitat contacts one.

The question of contact between bighorn and domestic sheep is further complicated by the possibility that bighorn sheep males might seek out and contact domestic sheep females in estrous and then return to the mountains, thereby serving as the vector of pathogenic strains of pneumophilic bacteria.

Below is a method developed by an interagency team to evaluate the risks to bighorn sheep of nearby domestic sheep grazing operations in the eastern Sierra Nevada. This group included individuals familiar with the behavior and ecology of Sierra Nevada bighorn sheep and the behavior of domestic sheep in wildland grazing situations. Other scientists and specialists were consulted during the development of this method of risk assessment. The group identified nine risk factors associated with the likelihood of interspecies contact (U.S. Fish and Wildlife Service 2001).

The first purpose of this risk assessment approach was to apply it to individual allotments so as to arrive at an overall risk rating (high, medium, or low/insignificant). The second purpose was to investigate key factors responsible for the rating and determine if they could in some way be mitigated to lower the risk rating to an acceptable level. The following risk levels were identified and assigned to each allotment/lease based on a subjective analysis of all the risk factors evaluated, including mitigation measures identified.

- LEVEL 1: Domestic sheep may escape or wander from their permitted grazing area, and at least one contact between stray domestic and bighorn sheep may occur over a 10-year period. This level requires formal consultation with us because the grazing operation is likely to adversely affect the Sierra Nevada bighorn sheep.

- LEVEL 2: It is unlikely that domestic sheep may escape from their permitted grazing area. There is no reasonable risk that they would contact bighorn sheep. This level requires only informal consultation with us because the grazing operation is not likely to adversely affect the Sierra Nevada bighorn sheep.

- LEVEL 3: There is no risk that domestic sheep that stray from their permitted grazing area will contact bighorn sheep. This level represents a no effect determination, which does not require consultation with us.

Risk Factors

a. Distance between grazing area and bighorn sheep habitat and presence or absence of physical barriers to prevent domestic sheep from moving into bighorn sheep range and bighorn sheep moving into domestic sheep areas. For example, barriers that would prevent domestic sheep travel include the following: cliffs, canyons, large bodies of water, and sheep proof fencing. Barriers that would only discourage domestic sheep travel include the following: rocky or broken terrain, dense vegetation (mountain mahogany, thick aspen, coniferous forest), and boundary barbed wire fences. Barriers that would discourage bighorn sheep from moving into domestic sheep areas include the following: large, flat areas without rocky escape cover, large areas of dense vegetation that may harbor predators, large bodies of water, and human settlements.

High: Inconsistent natural and man-made physical barriers

Low: Natural physical barriers continuous with unnatural physical barriers (such as fences)

b. Proximity of bighorn sheep to allotment/lease during time domestic sheep are present.

For example, overlapping seasons of use where bighorn sheep are occupying summer range adjacent to domestic sheep grazing areas being used May-October.

High: Bighorn sheep are known sometimes to be at low elevations during the grazing season (October 10 to June 1)

Medium: It is conceivable that bighorn sheep are at low elevations during the grazing season (September 15 to October 10)

Low: Bighorn sheep are known to be at high elevations during the grazing season (July 1 to September 15)

c. Potential condition of domestic sheep to attract bighorn males.

High: Yes, females in estrus

Low: No females in estrus

d. Physical ability of domestic sheep to move freely

High: Yes, normal physical condition

Low: No, they are in their third trimester of pregnancy

e. Condition of terrain that can hinder: 1) visibility of the entire herd, or 2) detection/capture of escaped domestic sheep.

High: Area includes shrubs, trees, or boulders

Low: Pasture grazed domestic sheep

f. Grazing practices such as "trailing" that require movement to new watering spots/bedgrounds that offer more opportunities for individuals or groups of domestic sheep to wander off.

High: Yes

Low: No

g. Number of domestic sheep each herder must account for. The norm is about 1,000-2,000 animals per herder.

High: Over 1,500 individual animals (including lambs)

Medium: From 800–1,500 individual animals (including lambs)

Low: Fewer than 800 individual animals (including lambs)

h. Length of time when domestic sheep are present within 10 kilometers (6 miles) of bighorn sheep habitat. This factor is important because the longer domestic sheep are on the allotment/lease, the greater risk there is for a stray.

High: Over 2 months

Medium: From 1-2 months

Low: Less than 1 month

i. Known escaped or stray domestic sheep originating from the allotment, lease, or driveway.

High: Yes

Low: No

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APPENDIX C. TRANSLOCATION CONSIDERATIONS FOR SIERRA NEVADA BIGHORN SHEEP

The future of bighorn sheep in the Sierra Nevada hinges on the use of translocations for reintroductions and herd augmentations, and possibly for genetic management. The translocation plan called for in Task 3.1 is therefore critical to the recovery effort for these bighorn sheep. This appendix lays out some of the elements and issues that should be in that plan and a discussion of both occupied and unoccupied bighorn sheep habitat in the southern and central Sierra Nevada.

A. Sources of translocation stock

In the 1970's and 1980's, only a single herd existed in the Sierra Nevada that was large and productive enough to be tapped for reintroduction stock. That vulnerable situation was a primary concern addressed in the Sierra Nevada Bighorn Sheep Recovery and Conservation Plan (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1984). The same vulnerable situation exists today. Solving this problem has to be one of the key elements of the translocation strategy. Among the options that need to be explored are the establishment and maintenance of one or more wild source herds; and the conditions under which a captive herd should be developed in parallel to produce stock for translocation needs to be addressed as well. The advantages of captive breeding lie with being able to control factors affecting survivorship and reproductive output. A captive herd could be managed to have optimum reproduction and survivorship without the environmental variation that is present in wild populations, thereby maximizing production of bighorn sheep.

A captive breeding contingency plan will need to be developed to facilitate decisions relating to the captive breeding of bighorn sheep. The final product of a captive breeding herd should be healthy, behaviorally normal individuals capable of surviving and reproducing in the wild. The concept of captive breeding in general, along with the history of bighorn sheep captive breeding attempts, will need to be reviewed. A theoretical decision tree should be constructed to help facilitate captive breeding decisions and identify the point at which captive breeding is considered essential to prevent extinction and accelerate recovery.

Selection guidelines for a captive breeding site need to be developed, and potential sites should be identified and evaluated. Also, guidelines and recommendations for constructing and maintaining a facility for captive breeding, selection of founder breeding stock, husbandry, veterinary care, and a summary of diseases that may affect a captive herd needs to be carefully developed. Development of this information prior to an actual decision to enter into a captive breeding program will greatly expedite the development of such a facility if and when it is needed.

Population models can help in evaluating how captive breeding may facilitate recovery goals. The integrity of these models will depend on the input of demographic data on age- and cause-specific mortality, reproductive success, and census numbers. Such models also can help assess the effects that the bighorn sheep removal and augmentation associated with captive breeding could have on extinction probabilities in populations. These initial models may help guide decision-making and the construction of future models.

B. Management of wild herds for translocation stock

Issues that should be addressed in a translocation plan are: (1) how such herds are to be managed differently from other herds; (2) what demographic criteria will be used to determine when and how many bighorn sheep will be removed from a herd; (3) what tradeoffs and benefits are associated with waiting until a herd has grown larger before removing bighorn sheep for translocation; and (4) what potential behavioral implications for the source herd may be associated with frequent captures, and how these may relate to logistical difficulties of capturing bighorn sheep.

C. Translocation strategy

The optimal use of bighorn sheep available to translocate is a complex question. While a short term plan can be developed based on current population information, it is important to recognize that it will need to change as the status of herds change, recovery goals are met, and new information on habitat is developed. Ideally, the plan will incorporate needed flexibility. The alternative will be to revise the plan as needed. Below are some of the key issues to be addressed in the plan.

1. Prioritization of locations to receive available stock

- Should available stock be used only for augmentations to assure recovery to all existing herds before unoccupied ranges are considered?

- Should the first bighorn sheep available for translocation be used only to create at least one more source of translocation stock, or should a mixed strategy be considered?

- Should the goal of the translocation strategy be to minimize the time to downlisting? Does such an optimization have any associated risks? In developing a long term strategy, it will be important to estimate the minimum number of bighorn sheep that will need to be moved for reintroductions to meet recovery goals.

2. Translocation group size

Minimum numbers that will be moved for augmentations versus reintroductions need to be established. Moving smaller numbers will risk fewer bighorn sheep and may be desirable for some reintroductions, with the idea that the initial group can be augmented at a later date. Because herd augmentations can generally be accomplished with far fewer individuals than reintroductions, it may be difficult to justify engaging in reintroductions until existing herds have reached sizes that afford some comfort in terms of viability.

It has been recommended that reintroduced herds of bighorn sheep be created with at least 20 individuals (Wilson and Douglas 1982), and this approach has been the common practice, including past reintroductions in the Sierra Nevada. Establishing sufficient genetic variation in isolated herds has been one reason for this approach. In contrast, a new group of females established within a metapopulation where males will find them might be created with a small number of females and perhaps one male to assure breeding until other males discover them. This practice will better mimic natural colonization in bighorn sheep, where new female groups sometimes arise from a single dispersing female (Bleich *et al.* 1996). Males explore nearby habitat considerably more than females and in general find suitable habitat patches before females.

There are other considerations regarding numbers of females to translocate. Regardless of how much research may be allocated to choosing release sites, uncertainties will always remain. Therefore, it will be important to proceed with an experimental approach to translocations so that different scenarios can be evaluated to optimize future efforts. Even for a reintroduction, an initial translocation of a relatively small number of individuals will allow an assessment of site suitability. An augmentation can follow if deemed appropriate to boost numbers and assure sufficient genetic diversity, but the failure of a reintroduction of many bighorn sheep due to unforeseen circumstances will be an irretrievable loss of a rare resource. Also considered should be the advantages that bighorn sheep obtain from group living, including better predator detection and feeding efficiency. Group sizes of five to six are common, and feeding efficiency shows little gain beyond that size (Berger 1978, Risenhoover and Bailey 1985). Thus, releases in new areas should attempt to provide a group of at least five bighorn sheep if possible.

3. <u>Timing of translocations</u>

The intent of most or all translocations will be the establishment or augmentation of herds using low elevation winter ranges. Since the peak in such use of this habitat historically has been in late winter and early spring, this period (especially March) would be the ideal time to translocate bighorn sheep to these sites. There are several reasons for this assessment. First, these bighorn sheep have a natural tendency to descend to such sites at that time of year. Second, forage quality will be high during this period, which may help hold translocated bighorn sheep near the release site. Third, for augmentations, there are likely to be herds present on these winter ranges that translocated animals can join, which should also serve to help hold translocated bighorn sheep near the release site. Finally, bighorn sheep can be caught most readily at this time of year. The translocation strategy should consider whether there is any other time of year at which translocations might be successfully done.

4. Potential areas to receive bighorn sheep

Below is a discussion of locations that might support herds of bighorn sheep. It combines habitat attributes with historical data. These locations are grouped by recovery units and by herd units within recovery units. The following attributes were considered in developing a list of potential areas that might support female groups (Table C-1): (1) known past use by bighorn sheep; (2) extent of high elevation snow-free winter habitat; (3) availability of lower elevation south or east-facing habitat and its lowest elevation and quality in terms of visual openness; and (4) availability of high elevation summer habitat. Winter habitat is the most limited habitat available in general and was the primary focus.

Recent herd histories have indicated that some use of low elevations in late winter and spring is essential for herds to maintain viable sizes. Table C-1 lists minimum elevations for each area. Lower elevations are correlated with warmer temperatures, earlier initiation of forage growth, and potentially higher overall nutrient intake by bighorn sheep. Wehausen (1980) found that each 17.8-meter (58.4-foot) increase in elevation equated to a 1-day delay in initiation of forage growth and associated increases in diet quality. This relationship translates to a 17-day delay per 1,000 feet, or 28 days per 500 meters. The large size attained by the Mount Baxter herd prior to changes in winter habitat use apparently resulted from high nutrient intake obtained on its low elevation winter range; this herd declined to about 15 percent of its former size while avoiding low elevation winter range habitat (Wehausen 1999). While lower minimum elevations allow greater nutrient intake by bighorn sheep herds using them, it is not known what the upper limit of this minimum elevation is relative to supporting a viable herd.

Northern Recovery Unit

Bighorn sheep were recorded historically as far north as the Sonora Pass region (Grinnell and Storer 1924). Some patches blown free of snow exist near and east of Sonora Pass. However, these patches included little rocky escape terrain and were not considered suitable for reintroduction. It is not yet evident what sort of habitat use patterns the native bighorn sheep in this area might have had, but viable habitat may have included the Walker River Gorge and even the Sweetwater

Mountains. It is questionable whether bighorn sheep will ever be returned to this area.

Table C-1. Potential sites for bighorn sheep wintering groups in the central and southern Sierra Nevada grouped by Recovery Unit.

Location	Current Bighorn Sheep Use	Minimum Winter Habitat Elevation (m)	Winter Range Visual Condition
Northern Recovery Unit			
Twin Lakes (Victoria Peak)	no	2,200	open
Green Creek (Crater Crest)	no	2,750	open
Dunderberg Peak	no	3,050	open
Lundy Canyon	males	2,450	mixed
Lee Vining Canyon (Mount Warren)	yes	2,300	mixed
Tioga Crest	yes	2,900	open
Bloody Canyon (Mount Gibbs)	yes	2,775	open
Parker Canyon (Mount Lewis)	males	2,700	open
Alger Creek (Mount Wood)	males	2,300	open
Central Recovery Unit			
Convict Creek (Laurel Mountain)	no	2,400	open
McGee Creek (McGee Mountain)	no	2,450	open
Nevahbe Ridge	no	2,600	open
Wheeler Ridge	yes	1,700	open
Mount Tom	males	1,950	open

Southern Recovery Unit			
Shannon Canyon (Coyote Ridge)	no	1,700	open
Birch Mountain/Kid Mountain	no	2,800	open
Taboose Creek	no	1,950	open
Goodale Creek	no	2,100	open
Sawmill Canyon	yes	1,500	open
Thibaut Canyon-Sand Mountain	yes	1,525	open
Onion Valley (Kearsarge Peak)	yes	2,300	open
Shepherd Creek-Pinyon Creek	yes	2,075	mixed
George Creek - N. Bairs Creek	no	1,900	mixed
Lone Pine Creek-Hogback Creek	no	2,075	mixed
Carroll Creek -Tuttle Creek	yes	1,750	mixed
Cottonwood Creek - Slide Canyon	males	1,450	open
Falls Creek - Ash Creek	no	1,450	open
Kern Recovery Unit			
Big Arroyo	no	2,100	mixed
Rattlesnake Creek	no	2,075	mixed
Laurel Creek	no	2,075	mixed

Nine areas were considered to have potential habitat for bighorn sheep in this recovery unit (Table C-1). Three of these currently are inhabited by both sexes, and three more receive at least occasional use by males.

Mount Warren Herd Unit: The Mount Warren area north of Lee Vining Canyon has a good combination of high elevation and low elevation winter habitat and supported a large concentration of bighorn sheep prior to 1995. Tioga Crest is included in the herd unit because of close connectivity. However, since 1995 data have suggested that a separate female group occupies Tioga Crest.

Lundy Canyon Herd Unit: Immediately north, Lundy Canyon has good low elevation south-facing winter range that rivals Lee Vining Canyon in its lowest elevation (Table C-1). In contrast, Lundy Canyon has very little high elevation winter habitat. Farther north, much of Dunderberg Peak is substantially blown free of snow in winter, but it does not connect to low elevation winter range. It is, however, connected to the Lundy Canyon range in summer.

Green Creek Herd Unit: Farther north is Crater Crest, which has some high areas free of snow in winter and connects to some potential low elevation habitat in Green Creek, but the minimum elevation is somewhat high at 2,743 meters (9,000 feet)

Twin Lakes Herd Unit: Immediately north of Twin Lakes there are south-facing slopes at relatively low elevation that are blown free of snow, as is an area around Victoria Peak. It is not clear whether there would always be a connection between these sites for bighorn sheep except in late winter and spring when snow firms up. The south-facing slopes above Twin Lakes, while steep and open, appear to lack areas of rock outcrops. In contrast, the Crater Crest range provides such outcrops in the Green Creek drainage. Dunderberg Peak, Crater Crest, and Victoria Peak probably all had bighorn sheep use historically, but these areas should be considered for translocations only after all other more suitable areas have been filled. Lundy Canyon is one of those more suitable areas.

Mount Gibbs Herd Unit: South of Lee Vining Canyon, the region from Mount Wood to Mount Dana has high potential for expansion of bighorn sheep range in this recovery unit. There is considerable high elevation habitat blown free in winter, which connects well to south-facing slopes that drop to lower elevations. Males are already known to move between Mount Warren and this area. With the recruitment of a yearling female in the Mount Gibbs herd in 1997, its known reproductive base increased to two females. Beginning in 1999, a third female has been documented in this group (Wehausen 2000). It is possible that, left alone, this little group will grow and eventually expand south to Mount Wood. This process could be greatly accelerated by translocating some females into this area. It is noteworthy that just west of Parker Peak lies Koip Peak, which means bighorn sheep in the Paiute language.

While many details on seasonal habitat use are lacking, the current herd in the region apparently uses only Mount Gibbs and part of Mount Dana during summer. Mount Lewis has habitat that appears to receive use only by males currently. The south-facing side of this mountain is steep and holds little snow in winter. It may be capable of supporting a small group of females. The Mount Wood area appears to be the best habitat in this unit. The slopes above Silver Lake provide low elevation east-facing winter range down to 2,316 meters (7,600 feet) that probably once received use by bighorn sheep, perhaps including birthing in spring in some years.

Central Recovery Unit

Wheeler Ridge Herd Unit: The Central recovery unit currently has one herd on Wheeler Ridge, which had grown to about 70 individuals in 2000. In the winter of 1998, there was a reported sighting of three females above Wells Meadow, the first known use of this low elevation winter range in many years. In subsequent years, this excellent winter range showed a steep increase in use by that herd in late winter. The herd is increasing very rapidly and is the one prospect for a source of translocation stock in the near future.

Mount Tom Herd Unit: Immediately south of Wheeler Ridge is Mount Tom, which had a native herd of bighorn sheep that persisted into the 1930's. Ober (*in litt*. 1911) said of them: "on Mount Tom, twenty miles west of the city of Bishop, there ranges in winter and summer a beautiful herd numbering forty head; they course from Mount Tom on over the summit to the west and around the head waters of Pine

Creek". Three years later Ober also noted that this herd numbered "about forty or fifty head; they follow the snow line in winter, and, as a matter of fact come very close to the little farming community of Round Valley (Ober 1914)." Males from Wheeler Ridge have been known to visit Mount Tom occasionally since they were reintroduced in 1979, and Mount Tom is the likely first site for range expansion in this region via translocation. Mount Tom offers multiple habitat options. Low elevation winter-spring habitat extends down to 1,950 meters (6,400 feet) in Elderberry Canyon. High elevation winter habitat is extensive on the west side of the north ridge of Mount Tom, and there are even some narrow ridges that can be blown free of snow on the south side of the mountain. Further, the summit plateau between Basin Mountain and Mount Humphreys remains snow free in winter and is accessible to bighorn sheep traversing ridge lines from Mount Tom via Four Gables and along the crest. Early sighting records indicate that the bighorn sheep that inhabited this area used the crest in summer at least as far as Mount Emerson, and males certainly ranged farther. Reestablishment of this herd might go a long ways toward increasing total numbers of bighorn sheep in this recovery unit and thereby enhancing its viability.

Convict Creek Herd Unit: Farther north are three areas that were probably all used historically by bighorn sheep to some degree: Nevahbe Ridge, McGee Mountain, and Convict Creek. A native herd inhabited the Convict Creek area into the 1950's (Jones 1950). Traditional south-facing winter-spring habitat that melts off quickly after winter storms occurs above Convict Lake down to 2,407 meters (7,900 feet) This area is connected to extensive high elevation wind swept patches on Laurel and Bloody Mountains. Of these three northern sites, Convict Creek is the most favorable due to this combination. McGee Mountain has excellent south-facing winter habitat down to about 2,438 meters (8,000 feet) that is equivalent to the slope above Convict Lake, but has only a small amount of high elevation winter habitat. Nevahbe Ridge has more windblown habitat than McGee Mountain, but the low elevation habitat is east-facing and occurs down to only 2,590 meters (8,500 feet); thus it is much more delayed in snow melt.

In 1989, 11 males from Wheeler Ridge were photographed by a hiker near Rosy Finch and Laurel Lakes, which is a considerable distance northwest from Wheeler Ridge and indicative of the potential for gene exchange with the northern portion of this recovery unit if it can be established via translocation. There was probably also once some gene exchange between this recovery unit and the Northern recovery unit via San Joaquin Ridge.

Numerous sightings of bighorn sheep on San Joaquin Ridge were recorded between 1954 and 1957 including a male killed by a deer hunter. Connectivity across this region is less likely in the future because of human developments.

Southern Recovery Unit

As many as 13 or more distinct female groups may have once occupied the area from Olancha Canyon to Coyote Flat. Of those areas listed on Table C-1, five currently contain female groups and another four are known to have been visited by males. These areas are discussed below as six general herds.

Coyote Ridge Herd Unit: East above the south fork of Bishop Creek there are multiple high elevation patches of habitat on Coyote Ridge and the Inconsolable Range that remain snow-free in winter. There is a paucity of historical evidence that bighorn sheep occupied this area, but this lack of evidence could reflect an incomplete record. Bighorn sheep using this area might have used low elevation habitat along Bishop Creek and/or crossed over Coyote Flat to excellent south and east-facing winter range as low as 1,706 meters (5,600 feet) in the Shannon Canyon area. Bishop Creek is currently treated as a break between the Central and Southern Recovery Units because of uncertainty about former use of the region of Coyote Ridge and the Big Pine Creek drainage. A Coyote Ridge herd would serve substantially as a link between these two recovery units. It is likely that historically there was gene flow through the bighorn sheep herds along the entire east side of the Sierra Nevada. It is noteworthy that a number of recent reported sightings on Coyote Ridge, the Inconsolable Range, and the west side of the Palisades region suggest the possibility of a small number of bighorn sheep currently occupying this area.

Taboose Creek Herd Unit: Jones (1950) listed a Birch Mountain herd just south of Big Pine that he estimated at 15 bighorn sheep. His evidence for these bighorn sheep was tracks of six animals. Clyde (*in litt.* 1971) noted that he had never seen bighorn sheep sign on Birch Mountain in numerous ascents but had once seen deer (does and fawns) well above timberline on its slopes. Nevertheless, Ober (1914) mentioned bighorn sheep living from Birch Creek to Big Pine Creek, and Clyde (*in litt.* 1971) noted evidence on a variety of occasions of bighorn sheep in the upper Big Pine Creek drainage. Whether females were present is unknown. There are some significant areas of high windblown habitat on Birch and Kid Mountains that might have supported bighorn sheep. However, available low elevation south or east-facing habitat to complement these sites is limited to relatively high elevations unless the animals moved farther south to Red Mountain and Taboose Creeks. Alternatively, they might have dropped as low as 2,194 meters (7,200 feet) on the northeast side of Kid Mountain.

The Inyo National Forest Fish and Game Reports in 1921 and 1923 listed a Goodale-Birch Mountain herd; the 1921 report described it as "A considerable number ranging from Goodale Mountain to Birch Mountain, and wintering along the foothills in the Black Rock region during heavy snow." Ober (*in litt.* 1911) noted, "In the winter season they range low on Taboose Creek and along the snow line to Goodale and Red Mountain." Coincident with increasing mountain lion predation on bighorn sheep in the early 1980's, bighorn sheep were found wintering in Goodale Creek, where they had not been recorded for decades. As numbers of bighorn sheep wintering in Sawmill Canyon declined, the number wintering in Goodale Creek increased to a peak of 25 in 1981 and 24 in 1982, but then declined steadily. It is possible that members of the Sawmill Canyon herd were attempting to find a new safer area to winter. Lion predation on these bighorn sheep was also recorded at Goodale Creek in this period, which may have accounted for the decline in use there also. No use of this winter range has been known for some years. This area offers some patches of high elevation winter habitat, and excellent south-facing low elevation habitat, especially in Taboose Creek, where it occurs as low as 1,950 meters (6,400 feet).

Mount Baxter and Sawmill Canyon Herd Units: What was once referred to as the Mount Baxter herd is now known to be multiple herds. The northernmost is the Sawmill Canyon herd, which ranges as far north as Mount Pinchot. South of Sawmill Canyon is the Mount Baxter herd proper. South of Oak Creek there appears to be a third independent female group that developed after abandonment of winter range use in the late 1980's. Its range extends south to Kearsarge Peak and Mount

Gould. The herd that utilized the ridges and drainages of Mount Baxter in the 1970's and 1980's was large and productive, and it provided most of the reintroduction stock used in the Sierra Nevada. Bighorn sheep removed from the Sawmill Canyon herd made up the remainder. Of existing herds currently existing in the Sierra Nevada, the Mount Baxter herd has the highest prospect for becoming a second wild source of translocation stock in addition to the Wheeler Ridge herd, due to its history. Augmentation of this herd with members of the Wheeler Ridge herd could accelerate that prospect.

Mount Williamson Herd Unit: Females from the Mount Williamson herd ranged from Georges Creek to Shepherd Creek prior to its recent decline (Wehausen 1980) associated with avoidance of winter ranges. Of the four canyons previously used as winter range, only Shepherd Creek is still known to be used. Males were previously known to use the Sambas Creek and Pinyon Creek drainages in addition during summer, as well as areas west of the crest. Clyde (*in litt*. 1971) recorded considerable use farther south on Mount Russell, where he once encountered four males. This greater range of use may have reflected a much larger herd at that time, which Jones (1950) estimated subjectively at 125. Recent surveys of the herd have suggested that its range is currently farther north than it was up to 1985 when all winter range areas were used (Wehausen 2000). Any attempts to expand its current range through augmentation should attempt to reestablish South Bairs Creek as a winter range. Females established there will likely use Georges Creek.

A small amount of historic evidence suggests that females may have once used Sambas and Pinyon Creeks to the north, where only males could be found in the 1970's (Wehausen 1979).

Mount Langley Herd Unit: Prior to its recent decline, females from the Mount Langley herd used the area from Carroll Creek to Lone Pine Peak. It is not clear whether Tuttle Creek currently receives other than occasional use by females. South of Carroll Creek are Slide Canyon, which contains the road to Horseshoe Meadows, and then Cottonwood Creek, the top of which is also traversed by that road. Both of these canyons offer excellent low elevation open winter range, with Cottonwood Canyon notably more extensive. These winter ranges are better than those currently used from Carroll Creek to Diaz Creek, but would require greater distance traveled to connect them to alpine ranges. From Slide Canyon and the top of Cottonwood Canyon, it would be natural for bighorn sheep to cross a short stretch of open south-facing forest via Wonoga Peak to reach the large open plateau country currently used by this herd. It is hard to imagine that Cottonwood Canyon did not once support a large bighorn sheep herd. Males have begun using Cottonwood Canyon. The carrying capacity of this herd could probably increase dramatically if a female group used Cottonwood Canyon every winter. An alternative home range pattern for bighorn sheep using Cottonwood Creek would be a summer range to the south immediately east of the Kern Plateau at top elevations of only about 3,048 meters (10,000 feet). While this habitat would not provide the vast open expanses of higher alpine habitats in the Mount Langley area, it would be nutritionally quite suitable and likely to support a large bighorn sheep herd.

Olancha Peak Herd Unit: South of Cottonwood Creek, from north to south, are Ash, Braley, Cartago, Olancha, and Falls Creeks, all of which are potential bighorn sheep habitat. The southern three of these creeks are more favorable because they readily connect to Olancha Peak, which reaches 3,695 meters (12,123 feet) and provides some alpine summer habitat (the southernmost alpine habitat in the Sierra Nevada). Olancha Canyon is the most direct connection to this alpine habitat. The Olancha Peak herd would be the most southern herd in this recovery unit. Winter range would be traditional low elevation south-facing slopes, of which there is an abundance of excellent habitat reaching low elevations that will ensure high winter and spring diet qualities. Jones (1950) considered this region part of his Mount Langley herd, presumably because of reported sightings in that region at that time.

Kern River Recovery Unit

There is good historical evidence of bighorn sheep on the Great Western Divide. They occurred in the Mineral King and Kaweah Peaks area, with notable concentrations on Red Spur and in Big Arroyo (Jones 1950). A die-off was reported in the Kaweah Peaks in the 1870's that was attributed to scabies (Jones 1950).

Big Arroyo and Laurel Creek Herd Units: Bighorn sheep would have moved readily along the east-facing cliff areas of the Kern River Canyon in winter, but Big

Arroyo, Rattlesnake Creek, and Laurel Creek would have been particularly attractive due to south-facing exposures on which snow melts faster and forage grows earlier. These sites are probably the best ones for reintroductions. Since there are no high elevation wind-swept areas west of the Kern River, the issues in comparing these three winter range sites are: (1) elevation; (2) visual openness; (3) amount of south-facing range; and (4) access to alpine ranges. Minimum elevations differ little among the sites (Table C-1). Big Arroyo may have the largest amount of low open habitat, but there appears to be ample habitat at each site, and all three are substantially open with some scattered trees. The Chagoopa Plateau largely blocks access to alpine habitat from Big Arroyo, but bighorn sheep can be expected to find access to the Kaweah Peaks at the upper end of the drainage. Alternatively, Red Spur can be immediately accessed from the Kern River canyon. In contrast, Rattlesnake and Laurel Creeks provide immediate access to summer ranges. One alternative would be to release bighorn sheep along the Kern River near Red Spur and let them ultimately find Big Arroyo as a preferred winter range. Laurel Creek has the potential advantage of having no trails and, thus, probably the least human use.

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APPENDIX D. MONITORING OF BIGHORN SHEEP POPULATION PARAMETERS

Downlisting and delisting goals (section II.C.2) were formulated in conjunction with monitoring criteria. Those goals recognized that females were key to population success, and monitoring criteria are similarly focused on that sex. Downlisting and delisting goals also recognized that minimum counts were desirable as the basis of management decisions because: (1) there is certainty in the numbers as compared with population estimators of potentially poor precision and (2) minimum counts can have the benefit of a built-in buffer of additional individuals not accounted for.

History of Monitoring Efforts

Monitoring the sizes of bighorn sheep herds in the Sierra Nevada has always posed a challenge because of the difficulty of accessing most of the habitat they inhabit, coupled with the high elevations they occupy much of the year. Prior to the late 1970's, most information consisted of subjective population estimates that used unclear methods to derive estimates from very limited data (Wehausen 1980). A different approach has been used to develop data on population sizes over the past 25 years. These efforts have relied on understanding the behavior of different herds and conducting counts when the bighorn sheep have been most concentrated in regions that are most accessible, either low elevation winter ranges or along the crest in summer, to derive minimum counts that account for a high proportion of the herds. Initially, direct counts were made for the two native herds when bighorn sheep concentrated on low-elevation winter ranges in late winter. This method involved multiple such counts each year when bighorn sheep numbers appeared highest. (Wehausen 1980, 1981, 1982, 1983, 1987, 1996). After those bighorn sheep began avoiding winter ranges beginning in the mid 1980's (Wehausen 1996), data on population sizes became considerably more difficult to obtain and required efforts at high elevations during summer, where bighorn sheep can be more dispersed. Nevertheless, with sufficient persistence, predictable patterns of habitat use in summer also can be used to develop good counts in some situations. For the Mount Langley, Mount Warren, and Mount Gibbs herds, summer counts have always produced the best data (Brown and Ramey 1987, Moore and Chow 1990, Hammett and Thompson 1992, Jensen 1993, Chang 1994). For most herds, attempts to develop regular data on sizes were resumed only beginning in 1995 because of concern about herd declines (Wehausen and Chang 1995, 1997, 1998; Wehausen 1999).

The development of data on minimum numbers at high elevations in summer for some of these herds has been possible only because of a combination of small herd sizes, substructuring into separate female groups, and recognition of some individual bighorn sheep.

All population data on Sierra Nevada bighorn sheep over the past 25 years have been minimum numbers present by sex and distinguishable age classes. Such figures always beg the question of how many were missed. Reconstructed population values have allowed an evaluation of at least some previously uncounted individuals for some herds (see section I.C.2), and consistency from one year to the next has similarly provided a means of assessment. For the Mount Baxter, Sawmill Canyon, and Mount Williamson herds prior to winter range abandonment, counts were notably more complete in winters of heavy snowfall (1978, 1983, and 1986), and only in such winters was it possible that essentially every individual might have been accounted for (Wehausen 1987). During 1977 to 1987, counts of females in the Mount Baxter and Sawmill Canyon herds in years of less snowfall varied from 70 to over 90 percent of numbers expected in the population based on a recruitment model that treated counts in those heavy winters as complete counts (Wehausen 1987). A second major influence on these census results was nutritional level of the winter range forage. Analysis of diet quality data from 14 winters showed that the timing of the first soaking storm had the greatest influence on forage nutritional value for bighorn sheep feeding on the Mount Baxter and Sawmill Canyon herd winter ranges (Wehausen 1992). The lowest winter range counts occurred during years of delayed forage growth, *i.e.* the benefit to risk ratio for these bighorn sheep appears to have influenced their use of winter ranges. A multiple regression analysis using the date of the first soaking storm and April 1 snow pack (inches of water) on Sawmill Pass as independent variables explained 91 percent of the variation in the proportion of expected females counted in the Mount Baxter herd (Wehausen 1987).

Recent herd size information from summer ranges has been supplemented with the interpretation of sign left by bighorn sheep, where it suggested that some individuals had not been counted, to provide an assessment of possible additional individuals present (Wehausen 1999). This method of supplementing counts has been possible also only because of small herd size, and has relied on information such as sizes of lamb fecal pellets to indicate that the sign probably represented additional individuals.

Future Monitoring

Future monitoring of bighorn sheep population dynamics in the Sierra Nevada needs to utilize as many tools as possible to develop the best possible data. Recent direct counts have relied on knowing the habitat use patterns of bighorn sheep, recognizing some individual bighorn sheep, and making usually multiple attempts to find them when they are most accessible and concentrated. Such methods should continue, but they should be augmented to the extent possible with other methods and aids that may supplement these counts, make them easier and more efficient, or serve as an independent check on data.

Helicopter Counts

The remoteness and ruggedness of much of this habitat limit the methods that can be employed. For instance, previous attempts to use a helicopter at high elevations in the Sierra Nevada have found no bighorn sheep or only a small proportion of those known to exist. Because of the atmospheric conditions at high elevations and related high speeds and distances that helicopters must fly for safety, it is unlikely that adequate data will be obtained on sex and age composition of what few bighorn sheep might be found by this method.

In 1981, a helicopter census took place on the low elevation winter ranges of the Mount Baxter and Sawmill Canyon herds. This census was carried out with simultaneous ground observers to produce a double survey estimate (Magnusen *et al.* 1978) and evaluate the use of such helicopter counts (Wehausen 1981). This approach was never repeated because the results were poor compared with data that a single experienced investigator could produce with repeated ground surveys.

Nevertheless, helicopter surveys may prove useful to supplement winter ground data. For instance, under conditions of high snow cover, helicopters may be particularly effective in finding bighorn sheep via tracks. Helicopter surveys will be most effective in late winter (first half of March) when bighorn sheep are most likely to be at low elevations. At this time a helicopter survey can help focus ground efforts by checking locations that are more difficult to access on the ground. Ground work can then focus on areas containing bighorn sheep that had not been recorded in ground work prior to the helicopter survey.

Telemetry Collars

Radio collars have been used to great effect in the past to aid in monitoring the three reintroduced herds in the Sierra Nevada and can similarly aid future population monitoring. Radio collars can be added to herds through capture of existing members or by translocating bighorn sheep to these populations from a larger and more productive herd. Captures will be limited largely to low elevation winter ranges because of logistical constraints. Consequently, the option of translocating bighorn sheep to add radio collars will have the advantage of not putting members of small herds through the major disturbance of capturing them during brief visits to winter ranges that these bighorn sheep are hesitant to utilize. If efforts to capture members of such small groups cause winter range avoidance, these efforts will trade off recovery for easier information. There exist some herds or subgroups of herds in the Sierra Nevada that are not currently known to visit any low elevation winter ranges. For these groups it is likely that the only way to have radio-collared bighorn sheep will be to translocate some to those areas. Because of the fundamental importance of females as the reproductive base of each herd, a greater return in monitoring can be expected by radio collaring that sex.

Radio collars will have the extra benefit of adding data on mortality and habitat use patterns. Such data will be limited by the number of radio collars that can be placed in each herd. Determination of causes of death will require finding dead bighorn sheep a short time following death. Given the remote nature of much of the habitat that Sierra Nevada bighorn sheep occupy, it should be recognized that a significant time lag often will occur between when an animal dies, when the mortality signal is detected (often only from an airplane), and when a biologist can get to the location to investigate the mortality. This time lag may be particularly problematic for winter mortalities that occur at higher elevations. For instance, the death of a radio collared female in the Mount Warren area in 1998 was first detected probably 2 months post-death and then could not be investigated for 4 months until snow had melted. Consequently, radio collars may produce only limited data on cause-specific mortality. The best data will come from low elevation winter ranges where detection of mortality and investigation will be rapid, but these ranges are used for only a small fraction of the year.

Collars might also be used to generate mark-resight population estimates if herds can be sampled in an approximately random manner. Multiple sampling approaches are possible for such estimates (Bailey 1951, Chapman 1951, Caughley 1977, Neal 1993). Such estimates have the advantage of providing measures of precision in the form of confidence limits. However, because of the difficulty of developing large sample sizes and the relatively low proportion of the population likely to be collared, such estimates can be expected to yield confidence limits too large to be of much use. The inefficiency of such sampling compared with a minimum known population approach was demonstrated by Wehausen (1996) for a small population of desert bighorn sheep in the Granite Mountains of California. The requirement of random sampling for such estimation procedures precludes the use of telemetry signals from radio collars to aid in finding bighorn sheep. In the Sierra Nevada, this effect will eliminate the primary benefit of radio telemetry for herd monitoring – greater efficiency in finding bighorn sheep and an aid in finding otherwise missed individuals. Consequently, mark-resight estimation procedures should be used only under sampling conditions that will clearly provide useful results.

Two fundamental question should be asked about radio-collaring bighorn sheep in the Sierra Nevada: (1) what information will be gained with radio collars beyond what has been obtained without them and (2) what tradeoffs may occur in terms of potential adverse behavioral or other effects on the bighorn sheep. The recovery of these bighorn sheep will require many to be captured and moved to new locations. If capture efforts result in undesirable changes in habitat use patterns of the bighorn sheep and make future captures more difficult, it may be preferable to limit capture efforts to the extent possible to translocations.

Genotyping from Feces

Genotyping bighorn sheep from DNA extracted from fecal samples (Taberlet *et al.* 1996, 1997, 1999) is the most promising tool to help assess how many individuals are not accounted for in minimum counts. This procedure can be carried out in conjunction with studies of genetic variation. Sampling can be done in conjunction with field work to develop minimum population values. When field evidence of bighorn sheep is found that is thought to be from individuals not yet seen, this hypothesis can be tested via analysis of fecal samples from those individuals and the ones already seen. There are also sex-specific genes that can be used to determine the sex of the animal from which the sample originated. Because of the major expense of lab work, this approach is currently most appropriate for small herds that are difficult to census directly. As this technology develops further it may have more applications and prove to be an integral part of monitoring these bighorn sheep.

Frequency of Monitoring

A. Herds considered potential sources of translocation stock. Monitor minimum numbers of females, yearlings, and lambs yearly to provide data on recruitment and herd size. Any population to be used as translocation stock will undoubtedly make concentrated use of low elevation winter habitat where the best population data will probably be obtained. Data on population parameters should be developed on winter ranges unless opportunities for better data occur in a different season. Attempt to develop data on the number of males, including age distribution, every 1-2 years.

B. Herds not used as translocation stock containing 1-15 females. Gather yearly data on size and recruitment for each female group. Attempt to count males every 2-3 years.

C. Herds not used as translocation stock containing 15-25 females. Attempt to assess size and recruitment every 1-2 years for each female group. Count males every 2-4 years if possible.

D. Herds not used as translocation stock containing more than 25 females. Attempt to assess size and recruitment every 2-3 years for each female group and every 3-5 years for males if possible until delisting. After delisting, attempt to develop population data every 5 years or more often if severe environmental conditions occur (*e.g.* a very severe winter) that raise concerns for the welfare of the bighorn sheep.

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APPENDIX E. CONSIDERATIONS FOR A PREDATOR MANAGEMENT PLAN

Predators are an integral ecological component of the community occupied by Sierra Nevada bighorn sheep. Sierra Nevada bighorn sheep will not be recovered until population objectives are attained, at which point Sierra Nevada bighorn sheep will be able to withstand naturally occurring predation without intervention. Coyotes and bobcats are known to prey on bighorn sheep; however, mountain lions, because of their larger size, are better adapted to kill larger prey, such as deer and bighorn sheep. Predation is a natural component of the system. But predation, like disease, represents another vehicle of bighorn sheep mortality, and all mortality must be minimized until full recovery is attained. The goal of the predator management plan is to temporarily protect bighorn sheep from adverse effects of predators while preserving an intact ecosystem.

A predator management plan (Task 2.1) should be prepared that ties together the multiple tasks concerning predators called for in section II.D of this recovery plan and lays out specifics of how they will be accomplished and when they will be ended. These tasks include monitoring, research, and selective, humane predator removal where needed. Of potential predators, mountain lions have been implicated as the primary predator of Sierra Nevada bighorn sheep, and they may affect population dynamics of those bighorn sheep through direct losses or by influencing habitat selection by the bighorn sheep. Below is a brief discussion of some of the elements that should be included in this plan.

1. Experimental approaches in an ecosystem context.

The primary objective of the predator management plan should be to protect small herds of bighorn sheep to prevent further extirpations and to restore populations to a level at which the natural predator-prey interactions can be allowed to occur without human intervention. Predators, and their potential direct and indirect effects on these bighorn sheep, are part of the ecosystem inhabited by these bighorn sheep, and management of predators needs to recognize the role of these species in an ecological system.

The one sure way of protecting endangered Sierra Nevada bighorn sheep from the potential negative effects of predation would involve long-term, indiscriminate removal of predators in the vicinity of bighorn sheep herds. There is little question that such a control program would also result in the unnecessary removal of some predators that had little or no influence on the population dynamics of bighorn sheep. Further, such a program would undoubtedly have unforeseen effects on other aspects of the ecosystem that might ultimately negatively affect bighorn sheep. Therefore, this approach is undesirable in that it has unacceptable consequences.

Finding a balance in which the minimum of predator management is practiced will take creative and experimental approaches. Management prescriptions will evolve as they are tried and evaluated and conditions change. Balanced predator management will entail using different approaches for different bighorn sheep herds and will take into account the vulnerability of each herd to extirpation. Finding the optimal prescription(s) for minimal predator management while still recovering bighorn sheep will entail risk to some individual bighorn sheep. At the same time, though, those risks will be allowed only where the bighorn herds are large enough to be able to withstand such a loss.

2. Protection of bighorn sheep translocation stock.

The ultimate success of population recovery hinges on the development and use of sources of translocation stock. Past reintroduction efforts occurred only because of the prior size and productivity of the Mount Baxter and Sawmill Canyon herds. The decline and inability of those herds to serve as further sources of translocation stock was associated with widespread changes in winter habitat use patterns that Wehausen (1996) suggested were linked to increased predation pressure from mountain lions during the 1980's. Predation pressure from mountain lions that developed in the 1980's may have been exceptional, and differed substantially from the current situation of lower lion densities. Nevertheless, the predator management plan should address how herds serving as sources of translocation stock might be treated, given their key role in the recovery of these bighorn sheep.

3. Protection of translocated bighorn sheep.

Bighorn sheep may be translocated to augment existing herds or to create new ones. Translocation stock has been, and will likely continue to be, a rare and precious resource. The predator management plan needs to address questions of how translocated bighorn sheep will be treated relative to predators compared with other herds, and why. Among the tasks to be considered will be investigations of potential predator conflicts at sites considered for reintroductions (Task 6.5). Results of such investigations may influence decisions on where available translocation stock will be used. For instance, reintroduction sites that have higher potentials for predator problems may be a lower priority for translocation projects. Those areas may be stocked later when, presumably, greater numbers of bighorn sheep will be available and that will allow larger initial releases to compensate for potential losses to predators.

4. Monitoring of mountain lions in the vicinity of winter ranges (Task 5.2).

It is well known that mountain lions vary in their behavior toward different prey species. Research in Canada, New Mexico, and California (Ross *et al.* 1997, K. Logan and L. Sweanor 2001, H. Ernest, unpubl.data) indicates that one or a small number of individual mountain lions often are responsible for a disproportionate number of bighorn sheep kills. Radio-collaring of lions in the vicinity of winter ranges will allow the details of habitat use patterns to be elucidated, thereby identifying potential problem animals.

In the Sierra Nevada, mountain lions range long distances as a response to the availability of prey (Pierce *et al.* 1999). Radio-collaring lions will allow predator management teams to monitor their locations precisely in relation to areas used by bighorn sheep. Although physical evidence of the presence of mountain lions is important when evaluating degree of threat to bighorn sheep, tracks of individual lions are not always distinguishable from each other (Grigione *et al.* 1999). Collared lions will remove most guesswork in reading sign (*i.e.*, distinguishing individual lions via track measurements), provide more reliable data on which lions are of concern, and allow predator management specialists to be most efficient in the use of their time. In the absence of the use of radio collars on lions, efforts to protect bighorn sheep in the Sierra Nevada will likely result in the deaths of some lions that might have been spared if telemetry data were available. It is possible to collar most lions near bighorn sheep winter ranges, but it is unlikely that more than a small proportion of the bighorn sheep population can be collared. Monitoring of collared lions can provide considerable data regarding bighorn sheep and predator dynamics. The success of this approach ultimately will lie with the schedule of monitoring of collared and uncollared lions in conjunction with monitoring of populations of bighorn sheep.

Through the collaring of mountain lions, detailed information also can be gathered on lion population dynamics, allowing assessment of the impacts of removals of mountain lions on their populations and, thereby, helping to put recovery efforts for these sheep in a larger ecosystem context.

5. Attempting to alter habitat use patterns of mountain lions on bighorn sheep winter ranges by aversive conditioning (Task 6.4).

Aversive conditioning has not been attempted before with mountain lions. It is a potentially useful tool that, if successful, could afford a reduction of mortality for both Sierra Nevada bighorn sheep and mountain lions. Experiments should be carried out when and/or where they do not jeopardize bighorn sheep. To be effective, these efforts will need to occur during fall and early winter, prior to the usual appearance of bighorn sheep on winter ranges. These experiments will require the development of data on activity patterns of the subject mountain lions that will allow an adequate evaluation of the effectiveness of this intervention.

6. Development of long-term data to elucidate predator-prey dynamics of this ecosystem as they affect bighorn sheep (Task 6.7).

The predator-prey situation that unfolded in the eastern Sierra Nevada during the 1980's was unexpected and is not sufficiently understood. Those dynamics are not likely to be adequately explained unless similar circumstances recur and key elements are monitored over many years. Of primary interest will be the dynamics of deer herds, which are the primary prey of mountain lions, and the distributions and densities of which are important factors determining the abundance of lions (Pierce *et al.* 2000). Monitoring of mesopredators, such as coyote or bobcat, to ascertain population fluctuations relative to mountain lion populations should also be considered. Careful monitoring of key elements of this ecosystem will help elucidate whether the events of the past two decades were simply part of a cyclical phenomenon, or whether these events constitute an exceptional circumstance that is not likely to be repeated; in either situation, however, future efforts to conserve wild sheep will be enhanced through the acquisition of such knowledge.

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APPENDIX F. PUBLIC INFORMATION AND OUTREACH PLAN

Abstract

The Sierra Nevada bighorn sheep Public Information and Outreach Program is based on the overarching principle that understanding and appreciation of the natural history and ecology of the Sierra Nevada bighorn sheep and concern for its future are vital to building public support for conservation measures and recovery actions. A number of recovery actions will directly affect the public using the eastern Sierra Nevada. Conversely, human activities may affect recovery. Knowing how Sierra Nevada bighorn sheep live and survive and the threats they face will help people understand the need for regulatory actions.

Delegating Public Information and Outreach Plan responsibilities to one agency and one or two individuals within that agency will eliminate confusion and ensure that a uniform and timely message gets out to the public.

An initial survey to assess the present level of public understanding of Sierra Nevada bighorn sheep and the situation threatening the survival of the species can be used as a tool to create the most effective public information and outreach program. The survey data will be used to establish and prioritize the steps that are needed to inform the public and build support. The program will not only seek to build an appreciation and understanding of the species, but also to make the public aware that the Sierra Nevada bighorn sheep recovery effort is a collaborative effort supported by multiple agencies, organizations, and individuals.

A second survey will be taken 1 year later and compared to the initial survey in order to measure the success of the program and to identify areas where the program needs to be strengthened or otherwise modified.

Certain information projects should be initiated concurrently with the activities to design a Sierra Nevada bighorn sheep Public Information and Outreach Program. The public needs to be made aware as soon as possible about required actions and restrictions while in Sierra Nevada bighorn sheep habitat. The recovery plan will also be released to the public, and wide distribution should be ensured. Funding to support future programs and broadened public information campaigns should be sought.

1. INCREASING AWARENESS

Using Understanding as a Foundation for Support

The public needs to have a foundation upon which to build concern for the situation facing the Sierra Nevada bighorn sheep and an interest in its recovery. The words "endangered species" frequently carry a negative connotation for a significant segment of the public. In the absence of more information, the public may interpret the words to mean that a rather hopeless situation exists that will limit human activities in order to save a remote species of unknown importance. The Public Information and Outreach Plan should provide information about the unique qualities of the Sierra Nevada bighorn sheep, its historic significance to American Indians, its decline with the settlement of the west, its ecology, and its natural history. This information will offer the public an alternative picture to conceptualize when hearing about the Sierra Nevada bighorn sheep, the threats to the survival of the species, and the recovery program underway.

Assigning Program Duties

To be optimally effective, an information campaign needs to be coordinated, accurate, timely, and consistent in the message it delivers. Deliberate steps need to be taken to ensure that a uniform message reaches the public. Numerous agencies have been and will continue to be involved in the recovery efforts. The responsibility for overseeing the Sierra Nevada bighorn sheep Public Information and Outreach Program should be delegated to one agency or organization and a single or small number or persons within the organization. Restricting oversight of outreach efforts will ensure that a consistent message is delivered to both the public and agency personnel who are not directly involved in the recovery effort. It will also ensure that a message *is* getting out to the public, rather than setting up a situation that could lead to misunderstandings and confusion about which agency is undertaking a given information or outreach activity. Finally, it will provide some assurance that the importance of communicating with the public and building public support will not be forgotten or minimized amid the urgent and intriguing biological questions attendant to the recovery of Sierra Nevada bighorn sheep.

2. DESIGNING A PUBLIC INFORMATION AND OUTREACH PLAN

Objectively Assessing Current Public Perceptions

An objective assessment of current public knowledge and attitudes toward the Sierra Nevada bighorn sheep needs to be made. Identifying the target audience and a baseline use of Sierra Nevada bighorn sheep habitat, key messages, and methods for disseminating information can all be achieved through the use of a survey. The survey should be conducted similarly to the effort currently underway for Peninsular bighorn sheep and could be conducted by one of the partner agencies or a university.

Surveying for Target Audiences

The survey will be used to identify target audiences. Recreationists, commercial packers, local residents, range allotment permittees, and domestic sheep and or goat owners all conduct activities that take place in or near Sierra Nevada bighorn sheep habitat. Other target audiences would need to be identified as part of the process of determining how people receive their information (see Methods of Disseminating Information below). The identification of target audiences would include information about how these individuals and businesses use Sierra Nevada bighorn sheep habitat and important surroundings areas.

Defining and Prioritizing Key Messages

The survey will establish public knowledge of the natural history and ecology of Sierra Nevada bighorn sheep. It will also provide insight into the public perception of the threats to Sierra Nevada bighorn sheep and the seriousness of the situation, as well as attitudes about conservation efforts related to Sierra Nevada bighorn sheep. The data, in turn, will provide direction for defining key messages. Specific information should include: an overview of the ecology of Sierra Nevada bighorn sheep, current threats to population viability, and recovery actions; effects of mountain lion predation on recovery of Sierra Nevada bighorn sheep and the larger role of predators in ecosystems; threats to Sierra Nevada bighorn sheep due to disease transmission from domestic sheep and goats; threats to bighorn sheep recovery from domestic dogs in bighorn sheep habitat; threats to bighorn sheep from disturbance by human recreational activities; actions needed to achieve recovery objectives; and opportunities to learn more about Sierra Nevada bighorn sheep. This approach will encourage the full spectrum of business people, recreationists, students, seniors, and local residents to behave in ways that promote the recovery of Sierra Nevada bighorn sheep populations.

Disseminating Information

The survey will provide data that identify the most effective means of conveying information. The survey could query individuals about how they receive their information and which media outreach efforts could then be channeled through the media that are most effective at delivering the message. The survey will also be used to identify other target audiences, including opinion leaders such as local elected officials and national and local media. The means and methods of distributing information include but are not limited to: printed material (press releases, handouts, brochures, newspaper articles, signage); electronic media (radio and television interviews, public service announcements, web sites); person to person delivery (presentations for service organizations, elected officials, as well as school programs and field trips, interpretive programs, campfire talks); and the merchandising of consumer goods with an educational theme (t-shirts, posters, postcards, notepaper). The information should be updated regularly and kept current regarding the status of Sierra Nevada bighorn sheep and recovery actions.

Distributing Information

Identifying the most effective method of message delivery would also guide the identification and prioritization of points of distribution. Printed matter could be distributed at a variety of locations, including visitor's centers, agency offices, chambers of commerce, web sites, email, and conventional mail. Links to a single web site would assure that the information is up-to-date and would eliminate duplicative efforts.

Information should be specifically distributed to members of the general public that are directly affected by recovery actions, such as hikers, ranchers, ranchette owners with domestic sheep or goats, commercial packers, and off-road vehicle users.

3. ASSESSING THE EFFECTIVENESS OF AND MODIFYING THE PLAN

Second Survey

Approximately 1 year after the initial survey is undertaken and a formal Sierra Nevada bighorn sheep Public Information and Outreach campaign is launched, a second survey should be undertaken. Comparisons of the results with the initial survey would provide the basis for modifying the information and outreach efforts.

Stakeholder and Recovery Team Meeting

A meeting of the Recovery Plan Team and Stakeholders Group should be convened to critique the Sierra Nevada bighorn sheep Public Information and Outreach Plan. Broadening the outreach should also be considered. Interviews on national radio and television should be considered to maximize the number of people reached. Videotapes or audio tapes of the programs could be used as tools for further outreach.

4. USING CONCURRENT INFORMATION PROJECTS

Disseminating Information on Multiple Fronts

Certain information projects should be initiated concurrently with the activities to design a Sierra Nevada bighorn sheep Public Information and Outreach Program. The public needs to be made aware as soon as possible about required actions and restrictions while in Sierra Nevada bighorn sheep habitat. The recovery plan will also be released to the public, and broad distribution should be ensured. Existing outreach programs need to be updated to incorporate the most current information.

During implementation of recovery efforts, the public should be fully informed as early as possible regarding actions required or restricted while in Sierra Nevada bighorn sheep habitat. For example, signs or flyers explaining trail closures (in such places as the Zoological Area) or restrictions (such as areas where dogs or pack goats are not allowed) should be located so that users are aware of these restrictions while planning their trip and/or when they are still able to modify their visit.

Affected members of the public should be contacted in other ways, such as through presentations to commercial packers or campers. Information regarding restrictions and requirements while in Sierra Nevada bighorn sheep habitat should also be included in sources of information that attract visitors to the area, such as commercial advertising, chamber of commerce publications, and web sites.

A master calendar that lists all specific recovery actions requiring public involvement should be developed (such as seasonal trail closures). This calendar should indicate the dates that publicity should begin, as well as the outreach message and method.

Distributing the Recovery Plan

The final recovery plan, along with a cover letter, should be widely distributed to affected and interested people, including hikers and other recreationists, ranchers, ranchette owners with domestic sheep or goats, commercial packers, environmental groups, mountain lion and bighorn sheep advocacy groups, and affected local, State and Federal agencies. Distribution of the recovery plan can be facilitated through the Recovery Plan Stakeholders Working Group. At a minimum, recovery plans should be distributed to everyone on our mailing list of people interested in the Endangered Species Act listing of Sierra Nevada bighorn sheep as well as the local news media.

Updating and Coordinating Existing Informational and Outreach Programs

There is an immediate need to update existing programs to provide an accurate view of our current knowledge regarding Sierra Nevada bighorn sheep. Information should strive to highlight not only each agency’s or organization's contributions to the recovery of Sierra Nevada bighorn sheep, but how these activities complement those of other agencies and organizations.

The bighorn sheep exhibit at the Mono Basin Scenic Area Visitor's Center should be updated and upgraded.

The California Watchable Wildlife Viewing Guide site at Lee Vining/Tioga Lake should include interpretive information on bighorn sheep.

National Park Service, U.S. Forest Service, Bureau of Land Management, and California Department of Fish and Game interpretive talks at visitor centers and campgrounds should include segments on bighorn sheep.

Using Educational Programs for Students

If an educational program targeting local schools is developed, the goals of the program should be for students to: understand the ecology of Sierra Nevada bighorn sheep; develop a respect, appreciation and concern for this species; become aware of the threats this species is currently facing and how recovery actions will reduce these threats; understand the role of Sierra Nevada bighorn sheep within the ecosystem and the value of bighorn sheep recovery to the ecosystem; become aware of specific actions they must take while in Sierra Nevada bighorn sheep habitat and why they are important to recovery; and become aware that the Sierra Nevada bighorn sheep recovery effort is a collaborative effort supported by multiple agencies, organizations, and individuals.

Existing bighorn sheep curricula should be reviewed and modified as needed to be applicable to Sierra Nevada bighorn sheep. Existing activities or curricula include:

- "Murder Ewe Wrote" (level: Grades 6-8) (http://www.sd5.k12.mt.us/glaciereft/wild8-12.htm)

- "Bringing bighorn into the classroom" (Cunningham, S. C. 1993. Desert Bighorn Council Trans. 37:33-36).

In addition, a variety of educational materials on bighorn sheep exist that target school-aged children and could be incorporated into a Sierra Nevada bighorn sheep curriculum. They could be incorporated as is or modified to be made specific to Sierra Nevada bighorn sheep. These materials include:

- National Bighorn Sheep Center's Traveling Trunk Exhibit (http://www.bighorn.org/exhibit.html)
- National Bighorn Sheep Center's **A Year in the Life of the Whiskey Creek Bighorn Sheep** (Level: Grade 6) (http://www.bighorn.org/Exhibit.html)

- Foundation for North American Wild Sheep's **Wild Sheep Journal**

5. IDENTIFYING FUNDING AND PARTNERSHIPS TO SUSTAIN SIERRA NEVADA BIGHORN SHEEP PUBLIC INFORMATION AND OUTREACH PROGRAMS

Finding New Partners and New Funding

An effort should be made to identify new partners in the Sierra Nevada bighorn sheep Public Information and Outreach Plan such as the Paiute Shoshone Tribes, The Independence Civic Club, the Yosemite Association, and others. Funding to support future programs and broaden public outreach campaigns should be sought. In addition to grants, a partnership with the Eastern Sierra Interpretive Association might be explored. As referred to in section 2 above, marketing t-shirts, posters, and other informational consumer goods would not only raise awareness about the Sierra Nevada bighorn sheep program but could also provide a source of income to sustain or augment the program.

Conclusion

An effective Sierra Nevada bighorn sheep Public Information and Outreach Plan will enhance the success of recovery efforts for the Sierra Nevada bighorn sheep. The program needs to celebrate the uniqueness and majesty of the species along with delivering a message about the threats facing the Sierra Nevada bighorn sheep and how recovery efforts are addressing those threats. With opportunities for innovative partnerships, the Sierra Nevada bighorn sheep campaign can be the source of regional pride not only for residents of the eastern Sierra Nevada but also the agencies that are collaborating on the recovery plan.

APPENDIX G. SUMMARY OF THREATS AND RECOMMENDED RECOVERY ACTIONS

LISTING FACTOR	THREAT	RECOVERY CRITERIA	TASK NUMBERS
A	Habitat loss [considered a minor threat]	B3	1.1, 1.2, 6.2
B	Hunting [historical in 19th century; not currently considered a substantial threat]	N/A	N/A
C	Disease (pneumonia and other epizootics contracted from domestic sheep)	A2	2.3.1, 2.3.2, 5.4, 6.5, 7.1, 7.2, 7.3
C	Disease (lungworm infestation) [considered a minor threat]	B3	5.4
C	Direct mortality from predation (by mountain lions and other predators)	A1, B1	2.1, 5.2, 6.4, 6.5, 6.7, 7.1, 7.2, 7.3
C	Reduced nutritional condition and lamb survival due to use of poor-quality winter range at high elevations, perhaps indirectly resulting from excessive predation	A1, B1	2.1, 2.2.1, 2.2.2, 2.2.3, 5.1, 5.2, 5.3, 6.2, 6.4, 6.5, 6.6, 6.7, 7.1, 7.2, 7.3
D	Limited effectiveness of management by State and Federal agencies	B3	1.2, 2.3.1, 2.3.2, 7.1, 7.2, 7.3, 8
E	Random variation in population characteristics (*e.g.*, sex ratio) due to small population size	A1, B1, B2	2.2.2, 3.1, 3.2.1, 3.2.2, 5.1, 6.5, 6.6
E	Loss of genetic variability due to small population size	A1, B1, B2	2.2.2, 3.1, 3.2.1, 3.2.2, 4, 5.1, 6.1, 6.5, 6.6

LISTING FACTOR	THREAT	RECOVERY CRITERIA	TASK NUMBERS
E	Increased vulnerability to naturally occurring environmental events (avalanches, prolonged or severe winters) due to small population size	A1, B1, B2	2.2.2, 3.1, 3.2.1, 3.2.2, 5.1, 6.5, 6.6
E	Competition with elk or deer for winter range resources [considered a minor threat]	B3	6.7
E	Disturbance from recreational use [not currently considered a substantial threat; may be reevaluated if warranted in future]†	B3	1.2, 2.4.1, 2.4.2, 6.3, 7.1, 7.2, 7.3
E	Mortality from automobile strikes	B3	7.3
E	Vegetation succession decreasing openness in habitat†	B3	1.2, 2.2.3, 5.3, 6.2
E	Broad environmental factors (climate change, acid rain, mining wastes)[potential threat, needs research]†	B3	1.2, 6.8

† Not identified as a threat in the original listing rule.

Listing Factors:
A. The Present or Threatened Destruction, Modification, or Curtailment Of Its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, Educational Purposes (not a factor)
C. Disease or Predation
D. The Inadequacy of Existing Regulatory Mechanisms
E. Other Natural or Manmade Factors Affecting Its Continued Existence

Recovery Criteria
Downlisting
A1: A minimum total of 365 females at least 1 year of age, distributed among the Kern (50), Southern (175), Central (75), and Northern (65) Recovery Units.
A2: Threat of domestic goats and sheep contacting bighorn sheep is eliminated.

Delisting

B1: Downlisting population levels maintained for 6 years without intervention.

B2: Bighorn sheep of both sexes present in 14 herd units, distributed among the Kern (2), Southern (6), Central (3), and Northern (3) Recovery Units.