U.S. Fish & Wildlife Service

Recovery Plan for Bighorn Sheep in the Peninsular Ranges, California

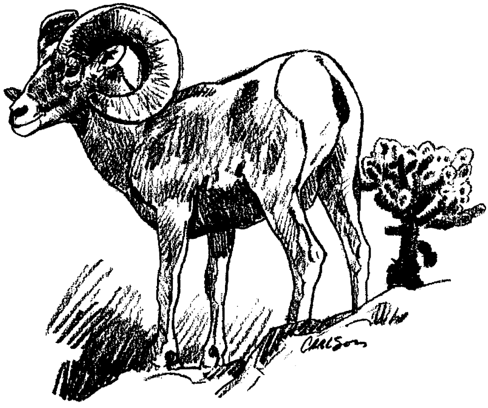

Diagram of bighorn sheep (*Ovis canadensis*) contributed by Ken Carlson for listing of endangered status of Peninsular bighorn sheep. Copyright granted by Mr. Carlson.

Recovery Plan

for

Bighorn Sheep in the Peninsular Ranges,

California

U.S. Fish and Wildlife Service
Region 1

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

Date: 10/25/00

The Recovery Plan for Bighorn Sheep in the Peninsular Ranges, California, was developed in cooperation with:

Bureau of Land Management
U.S. Forest Service
Agua Caliente Band of Cahuilla Indians
California Department of Fish and Game
California Department of Parks and Recreation

____________________ Date: 10/25/00
State Director, Bureau of Land Management

____________________ Date: 10/24/00
Regional Forester, U.S. Forest Service

____________________ Date: 10/17/00
Tribal Chairman, Agua Caliente Band of Cahuilla Indians

for ____________________ Date: 10/23/00
Director, California Department of Fish and Game

for ____________________ Date: 10-17-00
Director, California Department of Parks and Recreation

Primary Author

The primary author of this recovery plan is:

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The plan was written with the assistance of the Peninsular Bighorn Sheep Recovery Team (see Acknowledgments).

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Recovery plans delineate reasonable actions required to recover and/or protect listed species. We, the Fish and Wildlife Service, publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State and other Federal agencies, Tribes, and other affected and interested parties. Recovery teams serve as independent advisors to the Fish and Wildlife Service. Objectives of the plan will be attained and any necessary funds made available, subject to budgetary and other constraints affecting the parties involved. Recovery plans do not obligate cooperating or other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than our own. They represent our official position only after they have been signed by the Director, Regional Director, or Operations Manager as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

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Acknowledgments

This recovery plan was primarily prepared by Esther Rubin, with important contributions from Dr. Vern Bleich, Dr. Walter Boyce, Jim DeForge, Dr. Ben Gonzales, Mark Jorgensen, Stacey Ostermann, Pete Sorensen, Steve Torres, and Dr. John Wehausen. The plan benefitted greatly from numerous discussions with Don Armentrout, Kevin Brennan, Ken Corey, Tom Davis, Diane Freeman, Paul Jorgensen, Jeff Manning, Lilia Martinez, Scott McCarthy, Nancy Nicoli, Dr. Jenny Rechel, Dr. Oliver Ryder, and Gavin Wright. The plan was revised and approved by the Recovery Team and cooperating agencies. Special thanks is extended to Randy Botta for providing telemetry data, and Jim Scrivner, Victoria Smith, Tom Zmudka, and L. Louise Jee for their Geographical Information System support.

An administrative draft of the recovery plan was submitted for technical review; comments were received from Dr. Phil Hedrick, Dr. Dale Toweill, Dr. David Jessup, Dr. Paul Krausman, and Dr. Rob Roy Ramey II. These reviewers also were provided copies of the public review draft for comment. Two of the these technical reviewers also submitted comments on the public review draft. Technical comments deemed not appropriate to incorporate into the public review draft and final recovery plans are addressed as substantive issues in Appendix G. The Fish and Wildlife Service and Recovery Team appreciate the thoughtful review and comments by these colleagues. Preparation of the final recovery plan by the Recovery Team, and incorporation of comments from technical reviewers in the public review and final recovery plans, was conducted in conformance with the peer review process under applicable Fish and Wildlife Service policy.

Mission of the U.S. Fish and Wildlife Service in Recovery Planning

Section 4(f) of the Endangered Species Act of 1973, as amended (the Act), directs the Secretary of the Interior to develop and implement recovery plans for species of animals and plants listed as endangered and threatened unless such recovery plans will not promote the conservation of the species. The Fish and Wildlife Service has been delegated the responsibility of administering the Act. Recovery is the process by which the decline of endangered or threatened species is arrested or reversed, and threats to survival are neutralized, ensuring long-term survival in nature. The goal of recovery is the maintenance of secure, self-sustaining wild populations of species with the minimum necessary investment of resources. A recovery plan delineates, justifies, and schedules the management and research actions necessary to support recovery of listed species. Recovery plans do not, of themselves, commit staffing or funds, but are used in setting regional and national funding priorities and providing direction to local, regional, and State planning efforts. Means within the Act to achieve recovery goals include the responsibility of all Federal agencies to seek to conserve listed species; and the Secretary's ability to designate critical habitat, to enter into cooperative agreements with States, to provide financial assistance to the respective State agencies, to acquire land, and to develop habitat conservation plans with non-Federal applicants.

Peninsular Bighorn Sheep Recovery Team

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EXECUTIVE SUMMARY

Current Species Status: The population of bighorn sheep in the United States' Peninsular Ranges was listed as an endangered species on March 18, 1998. The current population is approximately 334 animals, distributed in 8 known ewe groups (subpopulations) in Riverside, Imperial, and San Diego Counties from the San Jacinto Mountains south to the Mexican border.

Habitat Requirements and Limiting Factors: The Peninsular bighorn sheep is restricted to the east facing, lower elevation slopes [typically below 1,400 meters (4,600 feet)] of the Peninsular Ranges along the northwestern edge of the Sonoran Desert. Bighorn sheep are wide-ranging animals that require a variety of habitat characteristics related to topography, visibility, water availability, and forage quality and quantity. Steep topography is required for lambing and rearing habitat and for escaping from predators. Open terrain with good visibility is critical because bighorn primarily rely on their sense of sight to detect predators. In their hot, arid habitat, water availability in some form is critical, especially during the summer. A wide range of forage resources and vegetation associations is needed to meet annual and drought related variations in forage quality and availability. Limiting factors apparently vary with each ewe group and are not well understood in all cases. The range of factors appear to include predation, urban related sources of mortality, low rates of lamb recruitment, disease, habitat loss, and human related disturbance.

Recovery Objective: The objective of this recovery plan is to secure and manage habitat in order to alleviate threats so that population levels will increase to the point that this species may be reclassified to threatened status, and ultimately delisted.

Recovery Priority: 3C, per criteria published by *Federal Register* Notice (48 FR 43098; September 21, 1983).

Downlisting Criteria: Peninsular bighorn sheep may be considered for downlisting to threatened status as an interim management goal, when all of the following objective, measurable criteria are met:

Downlisting Criterion 1: As determined by a scientifically credible monitoring plan, at least 25 ewes must be present in each of the following 9 regions of the Peninsular Ranges during each of 6 consecutive years (equivalent to approximately 1 bighorn sheep generation), without continued population augmentation:

1) San Jacinto Mountains
2) Santa Rosa Mountains--North of Highway 74
3) Santa Rosa Mountains-- South of Highway 74 through Martinez Canyon
4) Santa Rosa Mountains-- South of Martinez Canyon
5) Coyote Canyon
6) North San Ysidro Mountains (Henderson Canyon to County Road S-22)
7) South San Ysidro Mountains (County Road S-22 to State Highway 78)
8) Vallecito Mountains
9) Carrizo Canyon/Tierra Blanca Mountains/Coyote Mountains Area

Downlisting Criterion 2: Regulatory mechanisms and land management commitments have been established that provide for long-term protection of Peninsular bighorn sheep and all essential habitat as described in section II.D.1 of this recovery plan. Given the major threat of fragmentation to species with metapopulation structures, connectivity among all portions of habitat must be established and assured through land management commitments, such that bighorn sheep are able to move freely throughout all habitat. In preparation for delisting, protection by means other than the Endangered Species Act must be assured. Such protection should include alternative mechanisms for regulation by Federal, State, and local governments, and land management commitments that would provide the protection needed for continued population stability.

Delisting Criteria: Peninsular bighorn sheep may be considered recovered to a status no longer requiring protection under the Endangered Species Act and thereafter removed from the List of Endangered and Threatened Wildlife (50 CFR Part 17) when all of the following criteria are met:

Delisting Criterion 1: As determined by a scientifically credible monitoring plan, at least 25 ewes must be present in each of the 9 regions of the Peninsular Ranges listed under Downlisting Criterion #1 above, during each of 12 consecutive years (approximately 2 bighorn sheep generations) including the 6 years under Downlisting Criterion #1, without continued population augmentation.

Delisting Criterion 2: The range-wide population must average 750 individuals (adults and yearlings) with an overall stable or increasing population trend over the same period of 12 consecutive years (approximately 2 generations) as in delisting criterion 1.

Delisting Criterion 3: Regulatory mechanisms and land management commitments have been established that provide for long-term protection of Peninsular bighorn sheep and all essential habitat as described in section II.D.1 of this recovery plan. Furthermore, connectivity among all portions of habitat must be established, and assured through land management commitments, such that bighorn sheep are able to move freely throughout the Peninsular Ranges. Delisting would result in loss of protection under the Endangered Species Act; therefore continued protection by other means must be assured. This protection should include alternative regulatory mechanisms, land management commitments, or conservation programs that would provide the long-term protection needed for continued population viability.

Actions Needed: In the short-term, improving adult survivorship appears to hold the most benefit to population increase. Over the long-term, the primary actions needed to attain recovery involve conservation of the habitat base upon which Peninsular bighorn sheep depend, and effective management of bighorn sheep and conserved lands. Prevention of further fragmentation, primarily by minimizing adverse effects of human disturbance, will be critical to the persistence of ewe groups bordering the Coachella Valley. Adequate space along the urban interface to absorb anthropogenic effects, and prudent management of human activities within ewe group home ranges, will also be necessary.

Recovery Costs: Total cost of recovery tasks in the Implementation Schedule is estimated at $73,253,000. In addition, costs of certain specific recovery tasks will be determined as information is obtained and/or final actions are undertaken. These items are designated as "to be determined" in the Implementation Schedule.

Date of Recovery: Several to many decades likely will be required before a delisting target date can be accurately estimated. Fecundity (reproductive potential) and rate of population increase is low compared to some ungulates of similar size, such as deer. Periodically depressed recruitment rates and high adult mortality rates also lengthen the time to achieve the population objectives described in this recovery plan. If the population increases sufficiently and all recovery criteria are met, the species could be considered for delisting by approximately 2025. However, this time frame is uncertain and could be substantially extended if population status and protective measures fail to meet criteria.

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I. INTRODUCTION

The purpose of this recovery plan is to (1) establish interim and long-term goals and objectives, (2) describe site-specific management actions to achieve these goals, and (3) establish a schedule and estimate the costs required to reclassify as threatened and ultimately delist the distinct population segment of bighorn sheep (*Ovis canadensis*) in the Peninsular Ranges of California, a northerly extension of the mountainous formations of the Baja California Peninsula. This recovery plan provides guidelines and recommendations to be used in developing and assessing conservation and management activities to achieve recovery.

A. BRIEF OVERVIEW

1. LISTING OF BIGHORN SHEEP IN THE PENINSULAR RANGES

The California Fish and Game Commission listed bighorn sheep inhabiting the Peninsular Ranges as "rare" in 1971. In 1984, the designation was changed to "threatened" by the California Department of Fish and Game to conform with terminology of the amended California Endangered Species Act. We (the Fish and Wildlife Service) listed the distinct vertebrate population segment of bighorn sheep occupying the Peninsular Ranges of southern California (see Appendix A) as endangered on March 18, 1998 (63 FR 13134). For a population to be listed under the Endangered Species Act as a distinct vertebrate population segment, three elements are considered (61 FR 4722, February 7, 1996): (1) the discreteness of the population segment in relation to the remainder of the species to which it belongs; (2) the significance of the population segment to the species to which it belongs, and (3) the population segment's conservation status in relation to the Endangered Species Act's standards for listing (*i.e.*, is the population segment, when treated as if it were a species, endangered or threatened?). The Peninsular Ranges population will hereafter be referred to in this recovery plan as the Peninsular bighorn sheep and will alternatively be referred to as a species, following the definition of "species" in section 3(15) of the Endangered Species Act.

Species Distribution

The population of bighorn sheep addressed in this recovery plan extends along the Peninsular Mountain Ranges from the San Jacinto Mountains of southern California south to the United States - Mexico international border. Though the range extends south to Volcan Tres Virgenes near Santa Rosalia, Baja California, Mexico, only the distinct vertebrate population segment within the United States is listed as endangered and addressed in this recovery plan.

The decision to list the Peninsular bighorn sheep as federally endangered was made because of declining population numbers and continuing habitat loss, degradation, and fragmentation throughout a significant portion of the Peninsular bighorn sheep's range. In addition, periods of depressed recruitment, likely associated with disease, and high predation, coinciding with low population numbers, endanger the continued existence of these animals in southern California. Per recovery planning criteria published in the *Federal Register* (48 FR 43098, September 21, 1983), the Peninsular bighorn sheep has a recovery priority of 3C, indicating that it is a subspecies facing a high degree of threat but has a high potential for recovery if appropriately managed. The "C" indicates that recovery is in conflict with construction or other forms of economic activity.

2. ORIGIN

Wild sheep became established in North America after crossing the Bering land bridge from Eurasia during the late Pleistocene (Geist 1971), which began about 1,000,000 years ago and ended 10,000 years ago at the time of the last Ice Ages and the beginning of the Holocene. The range of bighorn sheep has since spread to include desert habitats as far south as northern Mexico (Manville 1980). In North America, two species of wild sheep currently are recognized: the thinhorn sheep (*Ovis dalli*) and the bighorn sheep (*Ovis canadensis*). Bighorn sheep, originally described by Shaw in 1804 (Wilson and Reeder 1993), were once divided into seven recognized subspecies based on differences in skull measurements (Cowan 1940, Buechner 1960, Shackleton 1985). These subspecies included Audubon bighorn sheep (*Ovis canadensis auduboni*), Peninsular bighorn sheep (*Ovis canadensis cremnobates*), Nelson bighorn sheep (*Ovis canadensis nelsoni*), Mexican bighorn sheep (*Ovis canadensis mexicana*), Weems bighorn sheep (*Ovis canadensis weemsi*), California bighorn sheep (*Ovis canadensis californiana*), and Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). Audubon bighorn sheep are now extinct. As described below, this taxonomy has since been revised.

3. MORPHOLOGY AND TAXONOMY

The term "desert bighorn" is used to describe bighorn sheep that inhabit dry and relatively barren desert environments, and typically includes bighorn sheep subspecies that have, to date, been classified as *nelsoni, mexicana, cremnobates,* and *weemsi* (Manville 1980). The validity of these subspecies delineations has been questioned and reassessed on the basis of additional morphological and genetic analyses (Wehausen and Ramey 1993; Ramey 1993, 1995; Gutierrez-Espeleta *et al.* 1998; refer to section I.A.4). Bighorn sheep in the Peninsular Ranges were once considered a separate subspecies and were one of the four desert subspecies recognized by Cowan (1940) based on cranial measurements. Cowan's (1940) Peninsular subspecies (*Ovis canadensis cremnobates*) did not include the northern end of the Peninsular Ranges in California and extended east across the Imperial Valley north of the Mexican border. Wehausen and Ramey (1993) noted that various authors have arbitrarily changed the geographic boundaries of this subspecies over time based on no additional data or analyses. Ramey (1993) reanalyzed Cowan's (1940) original data using modern statistical methods and found little support for his subspecies of bighorn sheep. In that reanalysis, the apparent distinction of the Peninsular subspecies was found to be an artifact of unequal age distributions among samples. Wehausen and Ramey (1993) conducted a new cranial morphometric analysis using a new and much larger sample and found no statistical support for a Peninsular subspecies. Ramey (1993, 1995) also investigated this question using restriction site polymorphism data for mitochondrial DNA and similarly found no statistical support for description of a subspecies in the Peninsular Ranges. Based on these morphometric and genetic results, Wehausen and Ramey (1993) placed Peninsular bighorn within the Nelson subspecies (*Ovis canadensis nelsoni*), which is the current taxonomy.

4. GENETICS

By analyzing micro-satellite and major histocompatibility complex loci, Boyce *et al.* (1997) found high levels of genetic diversity within and between populations of desert bighorn sheep, including sheep subpopulations within the Peninsular Ranges. Similarly, Gutierrez-Espeleta *et al.* (1998) found significant amounts of variation at microsatellite loci among all bighorn sheep populations studied. However, Ramey (1995) found very little mitochondrial DNA variation between groups of desert bighorn. The results of Ramey (1995), Boyce *et al.* (1997), and Gutierrez-Espeleta *et al.* (1998) differ because various molecular markers and analytical techniques were employed. Different molecular markers (*e.g.*, mitochondrial DNA, microsatellites, allozymes) are subject to various rates of mutation and are likely affected by different evolutionary processes, thereby providing different levels of insight into the genetic variability of a species. One similarity that has been found in all genetic studies of desert bighorn to date is that genetic distance increases with geographic distance. For example, Boyce *et al.* (1997) and Bleich *et al.* (1996) found support for partitioning of genetic variation among metapopulations (*e.g.*, the Mojave and Peninsular metapopulations), with high levels of gene flow within metapopulations, including the Peninsular Ranges, and low levels between metapopulations.

Within the Peninsular Ranges, at least eight subpopulations, or ewe groups, currently exist (Rubin *et al.* 1998, refer to section I.C.1). Based on sampling of about one-third of the animals in the metapopulation, Boyce *et al.* (1999) found that seven haplotypes were distributed in a non-random fashion among these ewe groups and that a significant amount of mitochondrial DNA variation was partitioned among ewe groups, indicating a high level of genetic structure among these subpopulations (Figure 1). The observed structure among ewe groups likely was primarily influenced by differences in founding ewes and their limited movements through the range (W. Boyce, University of California, Davis, pers. comm.). Boyce *et al.* (1999) concluded that the movement of ewes (and therefore

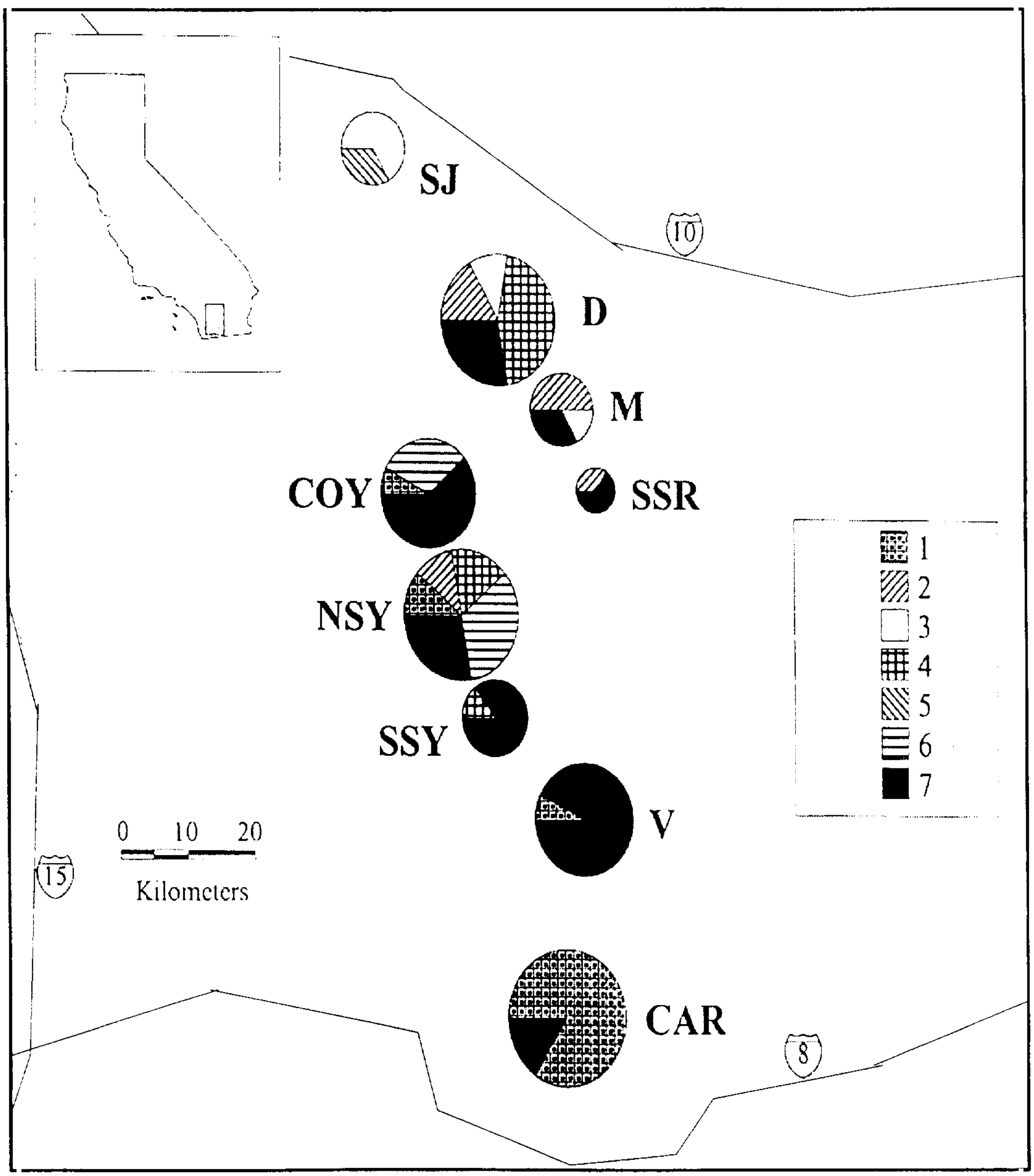


Figure 1. Distribution of seven mitochondrial DNA haplotypes among bighorn sheep ewe home-range groups in the Peninsular Ranges, California (SJ, San Jacinto Mountains, n=6; D, Deep Canyon, n=18; M, Martinez Canyon, n=6; SSR, South Santa Rosa Mountains, n=3; COY, Coyote Canyon, n=13; NSY, North San Ysidro Mountains, n=18; SSY, South San Ysidro Mountains, n=7; V, Vallecito Mountains, n=14; CAR, Carrizo Canyon, n=19). Note that the ewe groups are distributed approximately along a north-south gradient. A ewe group composed primarily of captive-bred animals, located between the Deep Canyon and San Jacinto Mountains groups, was not included in the analysis. (Reprinted with permission from Boyce *et al.* 1999).

the flow of mitochondrial DNA) between ewe groups is limited but has occurred at low levels in the past. This result is in contrast to the greater level of nuclear gene flow (indicated by the analyses of micro-satellite and major histocompatibility complex loci markers discussed above), which is mediated by the movement of rams among ewe groups (refer to section I.B.2).

B. ECOLOGY

1. HABITAT REQUIREMENTS

Bighorn sheep have important habitat requirements that relate to topography, visibility, water availability, and forage quality and quantity. During their evolution, bighorn sheep developed predator evasion behaviors that depend critically on the use of escape terrain, which is generally defined as steep, rugged terrain (Hansen 1980c, Cunningham 1989). Escape terrain is important because bighorn sheep typically do not outrun their predators but, rather, use their climbing abilities to escape their enemies (Geist 1971, McQuivey 1978). When ewes are ready to give birth they will typically seek out the most precipitous terrain, where their lambs will presumably be safest (Geist 1971). The presence of such steep terrain for predator evasion and lambing is, therefore, a crucial component of sheep habitat (see Appendix B). Variation in slope and aspect also help bighorn sheep to survive in a harsh environment. During hot weather, bighorn seek shade under boulders and cliffs, or may move to north facing slopes (Merritt 1974, Andrew 1994). During inclement weather they may again seek protected caves or overhangs, or move to sunny, south facing slopes (Andrew 1994), or slopes that are protected from strong winds.

In addition to mountainous terrain, other types of habitat are crucial to the viability of bighorn sheep populations. M. Jorgensen (California State Parks, pers. comm.) has observed bighorn at various times of the year on numerous alluvial fans and in washes, such as (1) the Borrego Palm Canyon alluvial fan, used for forage during cooler months and for water from May to November; (2) Palm Wash tinajas in the southern Santa Rosa Mountains, a water source in late summer/fall before winter rains; (3) Harper Flat in Anza-Borrego Desert State

Park; and (4) Chino Canyon, most recently in 1982, when seven ewes and lambs were observed. Areas of flat terrain, such as valley floors, serve as important linkages between neighboring mountainous regions, thereby allowing sheep temporary access to resources (*e.g.*, forage, water, or lambing habitat) in neighboring areas, and allowing gene flow to occur between subpopulations (Krausman and Leopold 1986, Schwartz *et al.* 1986, Bleich *et al.* 1990a, Bleich *et al.* 1996).

In the Sierra Nevada and Mojave Desert, the timing of forage green-up in winter is strongly influenced by elevation and mediated through temperature (J. Wehausen, White Mountain Research Station, pers. comm.; Wehausen 1980, 1983). Low rolling terrain and washes seasonally provide an important source of high quality forage, with a greater diversity of browse species than in steeper terrain (Leslie and Douglas 1979). Washes also provide a source of high quality browse for longer in the summer than do other areas (Andrew 1994). Leslie and Douglas (1979) noted that these areas became increasingly important to bighorn sheep not only in summer but during any period of limited forage availability. Bates and Workman (1983) observed bighorn sheep feeding in flat terrain in Canyonlands National Park, and reported that plant production was higher in flatter terrain than in steeper areas. Similarly, Bleich *et al.* (1997) reported that during periods of sexual segregation, rams exploited rolling hills and flat terrain for their superior forage. After localized summer rainfall events, washes and alluvial fans provide the diverse, high quality forage that is especially important to lactating ewes (Turner 1976, Bureau of Land Management 1996). Hansen and Deming (1980) describe the importance of succulent spring foods at lower elevations to lactating ewes.

In the Peninsular Ranges, bighorn sheep use a wide variety of plant species as their food source. Turner (1973) recorded the use of at least 43 species, with browse being the food category most frequently consumed (Turner 1976, Scott 1986). Cunningham and Ohmart (1986) determined that the bighorn sheep diet in Carrizo Canyon (at the south end of the U.S. Peninsular Ranges) consisted of 57 percent shrubs, 32 percent forbs, 8 percent cacti, and 2 percent grasses. Scott (1986) and Turner (1976) reported similar diet compositions at the north end of the range. Plant species eaten by bighorn sheep in the Peninsular Ranges were also reported by Jorgensen and Turner (1973) and Weaver *et al.* (1968). Diet composition varied among seasons (Cunningham and Ohmart 1986, Scott 1986), presumably because of variability in forage availability, selection of specific plant species during different times of the year (Scott 1986), and seasonal movements of bighorn sheep. In Arizona, bighorn sheep also used a wide variety of forage species throughout the year to cope with the changing desert environment (Miller and Gaud 1989).

In ruminants, such as bighorn sheep, fetal growth is relatively slow during the early stages of gestation, with the majority of fetal growth occurring during the final two months of gestation (Robbins 1993). Following lambing, ewes are faced with the costs of lactation, which are typically two to three times higher than the energetic costs of gestation and may range from four to seven times the basal metabolic rate (Robbins 1993). Consequently, the time period surrounding lambing and nursing is very demanding in terms of the energy and protein required by bighorn ewes. Failure to acquire sufficient nutrients during the last two months of gestation and during nursing can adversely affect the survival of newborn ungulates (Thorne *et al.* 1976, Julander *et al.* 1961, Holl *et al.* 1979). Furthermore, females in poor condition may fail to provide adequate maternal care following parturition (Langenau and Lerg 1976, Festa-Bianchet and Jorgenson 1996). Crude protein and digestible energy values of early green-up species, such as annual grasses and forbs, are usually much higher than those of dormant forages during the critical late gestation, lambing, and rearing seasons. With their high nutrient content, even minor volumes of these forages within the overall diet composition may contribute important nutritional value at critical life stages (Wagner 2000). However, during the reproductive season, due to the varied topography of bighorn sheep habitat, these forages typically are concentrated on specific sites, such as alluvial fans and washes, where more productive soils support greater herbaceous growth than steeper, rockier soils. Berbach (1987) found that when ewes were confined to a pen and prevented from using all vegetation associations during late gestation and early lactation, they and their lambs died of malnutrition.

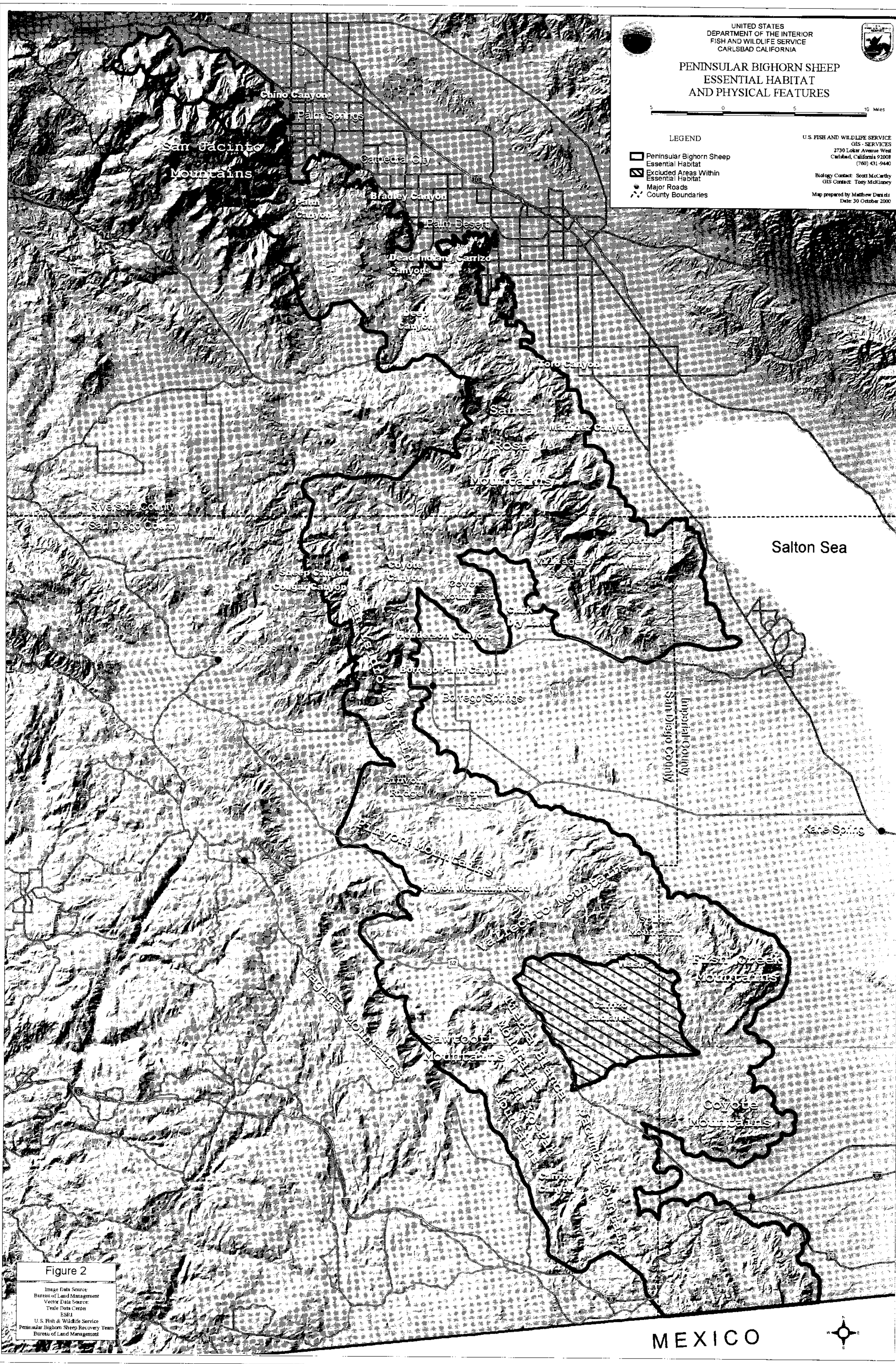
In hot, arid deserts, water is considered to be an important resource for bighorn sheep (Jones *et al.* 1957, Blong and Pollard 1968, Leslie and Douglas 1979, Turner and Weaver 1980, Elenowitz 1984, Cunningham and Ohmart 1986). A number of studies have shown that desert bighorn sheep will concentrate around water sources in the summer, with most animals found within a 3- to 5-kilometer (2- to 3-mile) radius of water (Jones *et al.* 1957, Leslie and Douglas 1979, Cunningham and Ohmart 1986). Lactating ewes and lambs often are more dependent on water and may thus be found closer to water (Blong and Pollard 1968, Leslie and Douglas 1979, Bleich *et al.* 1997). However, these patterns have not been observed in all habitats (summarized by Andrew 1994). Water sources are most valuable to bighorn sheep if they occur in proximity to adequate escape terrain with good visibility. Therefore, the juxtaposition of open escape terrain to water sources will influence drinking patterns (Cunningham 1989, Andrew 1994). During periods of high rainfall, sheep distribution is less coincident with permanent water sources (Leslie and Douglas 1979). The importance of water to bighorn sheep has been questioned (Krausman and Leopold 1986, Broyles 1995), and some small populations apparently exist without standing water (Krausman *et al.* 1985, Krausman and Leopold 1986, and additional examples summarized in Broyles 1995). Furthermore, it has been theorized that the addition of water to bighorn sheep habitat would be detrimental if it attracted competing species to areas of limited forage resources (Smith and Krausman 1988) or expanded the range of mountain lions (Shaw 1993). However, in most populations bighorn sheep will drink regularly when water is available and concentrate near water during summer months, and it is likely that lack of water is a limiting factor for some populations. In the Peninsular Ranges, bighorn sheep have been observed to use areas without known perennial water during some months, including the lambing season (E. Rubin, University of California, Davis, pers. comm.).

The predator evasion behavior of bighorn sheep depends on the ability to visually detect danger at a distance. Visibility has long been recognized as an important characteristic of bighorn sheep habitat (Hansen 1980b). Researchers have found that bighorn sheep will avoid habitat in which dense vegetation reduces visibility (Risenhoover and Bailey 1985, Etchberger *et al.* 1989). This appears to be the case in the Peninsular Ranges, where bighorn sheep usually remain below the elevation of chaparral and other dense vegetation associations.

In the Peninsular Ranges, bighorn sheep habitat occurs along the east-facing desert slopes, typically below approximately 1,400-meter (4,600-foot) elevations (Jorgensen and Turner 1975). In these mountains, bighorn sheep avoid higher elevations, likely because of decreased visibility (and therefore increased predation risk) associated with the denser vegetation found at higher elevations. The elevational patterns of vegetation associations in the Peninsular Ranges, in combination with this predator avoidance behavior, have resulted in habitat use that is more restricted to lower elevations than in most other bighorn sheep populations. Results from helicopter surveys and a 5-year study of radio-collared bighorn in the San Jacinto Mountains found that bighorn sheep in these mountains, where elevations exceed 3,000 meters (9,842 feet), were largely restricted to a narrow band of habitat between 213 and 1,037 meters (700 to 3,400 feet) in elevation (DeForge *et al.* 1997). In the northern Coachella Valley, this lower elevation limit generally coincides with the developed urban interface. At the lowest elevations of their range, bighorn sheep movement onto the valley floor (Coachella Valley, Imperial Valley) is restricted by a tendency to avoid venturing far from escape terrain and by anthropogenic factors that now preclude intermountain movements such as have been recorded elsewhere in the desert. The available habitat of Peninsular bighorn sheep can, therefore, be visualized as a long, narrow band that runs north-south along the lower elevations of the Peninsular Ranges (Figure 2). This pattern of predominantly low elevation habitat use is unique among desert bighorn sheep populations.

2. BEHAVIOR

The social structure of bighorn sheep is matrilineal (based on female associations). Gregarious and philopatric (faithful to natal home range) behaviors confer adaptive advantage to prey species because home range familiarity and group alertness decrease the risk of predation (Boyce *et al.* 1999). The ranging patterns and habits of ewes are learned by their offspring (Geist 1971). By following older animals, young bighorn sheep gather knowledge about escape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FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
PENINSULAR BIGHORN SHEEP
ESSENTIAL HABITAT
AND PHYSICAL FEATURES
5 0 5 10 Miles
LEGEND
Peninsular Bighorn Sheep Essential Habitat
Excluded Areas Within Essential Habitat
Major Roads
County Boundaries
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
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Date: 30 October 2000
Chino Canyon
Palm Springs
San Jacinto Mountains
Cathedral City
Bradley Canyon
Palm Desert
Dead Indian/Carrizo Canyons
Toro Canyon
Santa Rosa Mountains
Salton Sea
Riverside County
San Diego County
Coyote Canyon
Henderson Canyon
Borrego Palm Canyon
Borrego Springs
San Diego County
Imperial County
Kane Spring
Fish Creek Mountains
Sawtooth Mountains
Coyote Mountains
MEXICO
Image Data Source:
Bureau of Land Management
Vector Data Source:
Teale Data Center
ESRI
U.S. Fish & Wildlife Service
Peninsular Bighorn Sheep Recovery Team
Bureau of Land Management

Figure 2

terrain, water sources, and lambing habitat (Geist 1971). Ewes that share the same portion of a range, therefore, are likely to be more closely related to each other than they are to other ewes (Festa-Bianchet 1991, Boyce *et al.* 1999), and the term "home range group" has been used to describe such groups (Geist 1971). These groups are referred to as "ewe groups" in this recovery plan. Rams do not show the same level of philopatry and tend to range more widely, often moving among ewe groups. As young rams reach 2 to 4 years of age, they follow older rams away from their natal group during the fall breeding period, or rut, and often return after this period (Geist 1971, Festa-Bianchet 1991). Rams may follow the same travel routes year after year (Geist 1971, Wehausen 1980, DeForge *et al.* 1997). The sexes tend to loosely segregate during much of the year, coming together primarily during the rut (Geist 1971, Bleich *et al.* 1997), which typically peaks from August through October in the Peninsular Ranges (Rubin *et al.* 2000). During the rut, rams join the ewe groups and compete to breed with receptive ewes. The largest rams presumably are the most successful breeders, but smaller rams have been reported to breed as well (Hogg 1984). During the period of sexual segregation, ewes and their lambs are typically found in steeper, more secure habitat, while rams inhabit less steep or rugged terrain (Geist 1971, Bleich *et al.* 1997).

Bighorn sheep are primarily diurnal (Krausman *et al.* 1985) but may be active at any time of day or night (Miller *et al.* 1984). Their daily activity pattern includes feeding and resting periods that are not synchronous either within or between groups. Forage quality influences activity patterns. When forages are low in digestibility, sheep must spend more time ruminating and digesting forage. Particle size must be reduced sufficiently to pass from the rumen and reticulum to the omasum (Van Soest 1982, Robbins 1993). As forages green-up and digestibility increases, passage rates increase and ruminants can feed more frequently (Risenhoover 1986). Sheep typically increase the number of feeding bouts rather than the length of individual bouts. Consequently, sheep establish a cycle of feeding and ruminating that reflects forage quality and optimizes nutrient intake (Wagner 1999, 2000).

Bighorn sheep rely on vigilance to detect predators. Therefore, they benefit from gregariousness and group alertness (Geist 1971, Berger 1978). Within a ewe home range group, ewes appear to associate with other ewes based on their availability rather than on their matrilineal relationships (Festa-Bianchet 1991, Boyce *et al.* 1999). Within home range groups, these subgroups are dynamic--they may split, reform, or change membership on a daily or hourly basis as animals move through their home ranges.

Burt (1943) defined home range as "...that area traversed by the individual in its normal activities of food gathering, mating, and caring for young". Size of the home range depends on the juxtaposition of required resources (water, forage, escape or lambing habitat) and, therefore, varies geographically. Home range size also is affected by forage quantity and quality, season, sex, and age of the animal (Leslie 1977, McQuivey 1978). In most populations, ram home ranges have been found to be larger than those of ewes (Simmons 1980, DeForge *et al.* 1997). DeForge *et al.* (1997) reported average home range sizes (95 percent utilization distribution) of 25.5 square kilometers (9.8 square miles) and 20.1 square kilometers (7.8 square miles) for rams and ewes, respectively, in the San Jacinto Mountains, using the fixed-kernel method (Seaman and Powell 1996).

Although most desert bighorn sheep do not seasonally migrate along elevational gradients like many populations in higher latitude mountain ranges, they do exhibit seasonal differences in habitat use patterns. In many populations, animals will have a smaller home range in summer (McQuivey 1978, Leslie and Douglas 1979, Elenowitz 1983), presumably due to their limited movement away from permanent water sources. During the cooler or wetter months of the year, bighorn sheep often exhibit an expanded range as animals move farther from water sources (Simmons 1980). In addition, seasonal changes in habitat use are influenced by lambing and rutting behavior (Geist 1971, Bleich *et al.* 1997). Desert sheep also seek the earliest winter green-up of annuals and the first flowering of brittlebush (*Encelia farinosa*), which are elevation dependent (J. Wehausen, pers. comm.).

The gregarious and philopatric behavior of ewes limits their dispersal and exploratory abilities relative to those of rams (Geist 1967, 1971). Geist (1971) theorized, however, that a young ewe might switch to a new ewe group if she encountered neighboring sheep and followed them away from her natal ewe group. In the Peninsular Ranges, movement of radio-collared ewes between ewe groups is rare. During a 3-year study, the most extensive movement documented was by one ewe that moved over 30 kilometers (18.6 miles) and temporarily joined a second ewe group (Rubin *et al.* 1998). No emigration of ewes has been observed even though radio-collared animals have been regularly monitored in the northern Santa Rosa Mountains since 1981 (Ostermann *et al.* in press) and throughout the range since 1993 (E. Rubin, pers. comm.; DeForge *et al.* 1997). Genetic analyses of ewe dispersal suggest that a low rate has occurred in the Peninsular Ranges in the evolutionary past (Boyce *et al.* 1999). Genetic and observational data suggest, however, that ram movements among ewe groups are common (Boyce *et al.* 1997; DeForge *et al.* 1997; Rubin *et al.* 1998; Bighorn Institute 1998, 1999).

An important consideration in the conservation of Peninsular bighorn sheep is their behavioral response to humans and human activity. Bighorn have been considered a wilderness animal because they do not thrive in contact with human development (Leopold 1933). Their response to human activity is highly variable and depends on many factors, including but not limited to: the type of activity, the animal's previous experience with humans, size or composition of the bighorn sheep group, location of bighorn sheep relative to elevation of the activity, distance to escape terrain, and distance to the activity (Weaver 1973; McQuivey 1978; Hicks and Elder 1979; MacArthur *et al.* 1979, 1982; Wehausen 1980; Hamilton *et al.* 1982; Whitacker and Knight 1998; Papouchis *et al.* 1999). Responses can range from cautious curiosity to immediate flight or abandonment of habitat, as well as disruption of normal social patterns and resource use. Though the effect of human activity in bighorn habitat is not always obvious, human presence or activity in many cases has been found to detrimentally alter normal behavioral and habitat use patterns (refer to section I.D.5). For example, bighorn began using urban sources of food and water in the northern Santa Rosa Mountains when development began encroaching on sheep habitat in the 1950's

(Tevis 1959). Though commonly thought to be the result of releasing captive raised bighorn sheep, habituation of wild sheep to urban habitats occurred several decades before the first release of any captive-reared stock in 1985 (DeForge and Scott 1982; Ostermann *et al.* in press; V. Bleich, California Department of Fish and Game, pers. comm.).

3. REPRODUCTION

In the Peninsular Ranges, ewes estimated to be between 2 and 16 years of age have been documented to produce lambs (Rubin *et al.* 2000, Ostermann *et al.* in press). Yearling ewes in captivity also have produced lambs (Bighorn Institute 1999). Some rams are believed to be capable of successful breeding as early as 6 months of age (Turner and Hansen 1980), though the breeding opportunities of young rams are limited by the social pressure of larger rams (Hogg 1984). The breeding period, or rut, occurs in the late summer and fall months. As parturition approaches, ewes seek isolated sites with shelter and unobstructed views (Turner and Hansen 1980), and seclude themselves from other females while finding sites to bear their lambs (Etchberger and Krausman 1999). In the Little Harquahala Mountains, the physical and biological characteristics of lambing sites did not differ from sites used at other times of the year (*ibid*). Lambs are born after a gestation of approximately 6 months--171 to 185 days (Turner and Hansen 1980, Shackleton *et al.* 1984, Hass 1995). During a 4-year (1993 to 1996) study conducted in the Peninsular Ranges south of the San Jacinto Mountains, the lambing season extended from February through August; however, 87 percent of the lambs were born from February to April, and 55 percent of the lambs were born in March (Rubin *et al.* 2000). DeForge *et al.* (1997) and Cunningham (1982) reported a similar onset of the lambing season in the San Jacinto Mountains and in Carrizo Canyon, respectively. In the San Jacinto and northern Santa Rosa Mountains ewe groups, the lambing season begins in January during some years (Bighorn Institute 1997). Lambs usually are weaned by 6 months of age (Hansen and Deming 1980, Wehausen 1980).

From 1993 to 1996, the reproductive patterns of five ewe groups (Carrizo Canyon, south San Ysidro Mountains, north San Ysidro Mountains, Santa Rosa Mountains

[Deep Canyon], and northern Santa Rosa Mountains) were monitored (refer to section I.C.1 for description of ewe groups) and annual lamb production averaged 77 percent (0.77 lambs born per "ewe-year") for the 4-year period (E. Rubin, pers. comm.). Using a fecal-based enzyme immunoassay, Borjesson *et al.* (1996) determined that in the fall of 1992, at least 85 percent of sampled adult ewes were pregnant. Both of these observations suggest that conception rates are not currently limiting population growth in the Peninsular Ranges.

Lamb survival (to 6 months of age) was variable among groups and across years. A good year of lamb survival in one group was not necessarily a good year in another group (Rubin *et al.* 2000, Table 1). Of the four groups studied, the northern Santa Rosa Mountains group typically had the lowest lamb survival, while the neighboring Deep Canyon group, located less than 8 kilometers (5 miles) away, had the highest lamb survival. Researchers working in the northern portion of the Santa Rosa Mountains have expressed concern over the low lamb recruitment average observed in this area since approximately 1977 (DeForge *et al.* 1982, DeForge and Scott 1982, Turner and Payson 1982). Although lamb to ewe ratios observed in the Santa Rosa Mountains have fluctuated across years (Wehausen *et al.* 1987, DeForge *et al.* 1995), fall lamb to ewe ratios were consistently low in the northern Santa Rosa Mountains during 1983 to 1994 (DeForge *et al.* 1995). During 1985 to 1998, recruitment in the northern Santa Rosa Mountains averaged 13 lambs per 100 ewes (Ostermann *et al.* in press, Table 2). Periods of low lamb to ewe ratios, as well as clinical signs of pneumonia among lambs, have occasionally been observed in Anza-Borrego Desert State Park (Jorgensen and Turner 1973, Jorgensen and Turner 1975, Hicks 1978), but years of high lamb to ewe ratios (Cunningham 1982, M. Jorgensen, pers. comm.) and high lamb recruitment to 6 months of age (Rubin *et al.* 2000) have been observed in these areas as well. In the San Jacinto Mountains, low fall lamb to ewe ratios were documented from 1977 to 1983. However, this group exhibited variable recruitment thereafter, with relatively high (greater than or equal to 0.50) fall lamb to ewe ratios from 1994 to 1996 (DeForge *et al.* 1997).

Wehausen (1992) suggested that periods of low recruitment may not warrant alarm because long-lived animals such as bighorn sheep can exist in viable

Table 1. Lamb survival per ewe group in the Peninsular Ranges during 1993 to 1996 (Rubin *et al.* 2000, based on observations of radiocollared ewes).

Ewe Group	Proportion (1.0=100 percent) of lambs living to 6 months of age				
	1993	**1994**	**1995**	**1996**	**1993 to 1996 (# lambs)**
Carrizo Canyon	0.67	0.78	0.50	0.50	0.68 (31)
San Ysidro Mountains-north and south[a]	0.75	0.25	0.57	0.71	0.57 (42)
Deep Canyon	NA	0.80	0.67	0.75	0.74 (23)
N. Santa Rosa Mts.	NA	0.43	0.10	0.40	0.26 (23)

[a]data from the north and south San Ysidro groups were combined because of small sample sizes in the south San Ysidro Mountains when years were considered separately.

populations if periods of low offspring recruitment are interrupted by periodic pulses of high offspring recruitment. Most ewe groups in the Peninsular Ranges appear to have exhibited such pulses of high recruitment but declining population trends (see section I.C.3) suggest that they have not been sufficient to balance adult mortality over longer time periods. Chronically low lamb to ewe ratios observed in the northern Santa Rosa Mountains ewe group (DeForge *et al.* 1995, Ostermann *et al.* in press) are a particular concern. Signs of illness have been observed among lambs in this ewe group (DeForge *et al.* 1982, DeForge and Scott 1982, DeForge and Ostermann 1998a), and it is possible that low lamb survival is associated with disease or disease processes complicated by environmental conditions, such as habitat modification (refer to sections I.B.7 and I.D). This ewe group has been augmented by captive animals since 1985 (see sections I.C.1 and I.E.3), with similar average recruitment rates (to approximately 1 year of age) observed among wild-reared and captive-reared ewes (Ostermann *et al.* in press, Table 2). A 5-year study of radiocollared lambs has been initiated in this population to determine cause-specific mortality (DeForge and Ostermann 1998b).

Table 2. Peninsular bighorn ewe population estimates and recruitment (lamb survival until December) for captive-reared and wild-reared ewes in the northern Santa Rosa Mountains (Ostermann *et al.* in review).

No. of ewes greater than or equal to 2 years of age				Lambs recruited *n* (lambs/100 ewes)		
Year	wild-	captive-	Total	Wild-reared	Captiv	Total
1985	22	0	22	4 (18)	NA	4 (18)
1986	25	0	25	3 (12)	NA	3 (12)
1987	25	5	30	0 (0)	0 (0)	0 (0)
1988	24	9	33	2 (8)	0 (0)	2 (6)
1989	21	11	32	0 (0)	1 (9)	1 (3)
1990	12	12	24	0 (0)	0 (0)	0 (0)
1991	11	10	21	0 (0)	1 (10)	1 (5)
1992	11	13	24	1 (9)	1 (8)	2 (8)
1993	7	10	17	1 (14)	0 (0)	1 (6)
1994	3	8	11	1 (33)	2 (25)	3 (27)
1995	3	7	10	0 (0)	0 (0)	0 (0)
1996	3	7	10	0 (0)	2 (29)	2 (20)
1997	2	7	9	1 (50)	0 (0)	1 (11)
1998	4	6	10	2 (50)	5 (83)	7 (70)
Mean	NA	NA	NA	1 (13.9)	1 (13.7)	2(13.3)

Several studies have documented a positive relationship between winter precipitation and lamb recruitment in the following year (Douglas and Leslie 1986, Wehausen *et al.* 1987). However, the relationship between precipitation and lamb recruitment is not a simple one. Wehausen *et al.* (1987) found that periods of low lamb survival, believed to be a result of a disease epizootic, coincided with periods of increased rainfall. These authors hypothesized that increased standing water caused populations of *Culicoides* midges, a vector of bluetongue and epizootic hemorrhagic disease viruses (Hoff and Trainer 1981), to increase. Another hypothesis involving the presence of livestock as an outside disease reservoir also was presented (Wehausen *et al.* 1987). The relationships between climate, lamb recruitment, and population trends likely differ among different bighorn sheep populations, and are not fully understood (Rubin *et al.* 2000).

In ruminants, reproductive success is related to the mothers body weight, access to resources, quality of home range, and age (Etchberger and Krausman 1999). Survival of offspring also depends on birth weight and date. Festa-Bianchet and Jorgenson (1996) found that female sheep reduce the care of lambs when resources are scarce to favor their own nutritional requirements over their lambs' development. Excessive disturbance also can disrupt nutritional condition by affecting optimum feeding-ruminating cycles (Wagner 2000). Ewes that fail to acquire a minimum level of energy reserves (*i.e.*, body weight) may not conceive (Wehausen 1984) or will produce smaller offspring with a poorer chance of survival (Price and White 1985).

Ewes in the captive herd at the Bighorn Institute had high lamb production (mean 83.6 percent) and recruitment (mean 71.0 percent) during 1985 to 1998. Production and recruitment of individual ewes in captivity ranged from 0 to 108 percent; twins were produced twice. Between 1985 and 1998, 71 lambs (30 males, 41 females) were born to ewes 2 years of age or older, resulting in a sex ratio at birth of 0.73:1. Eleven of 71 lambs (15.5 percent) born in captivity and 6 of 39 lambs (15.4 percent) captured from the wild died in captivity. Lamb mortalities were attributed to disease (n=11), trauma or peritonitis (n=3), and undetermined causes (n=3) (Ostermann *et al.* in press). Lamb survival in the captive herd during 1999 was the lowest recorded for this population, with only two of seven lambs surviving to yearling age. Results from necropsies performed at the California Veterinary Diagnostic Laboratory indicated acute bacterial pneumonia (*Pasteurella* spp.) as the cause of death in all five lambs. Previous studies have implicated severe stress as a factor in pasteurellosis in domestic ruminants (Frank and Smith 1983, Gilmour and Gilmour 1989), and in bighorn pneumonia epizootics (Feuerstein *et al.* 1980, Spraker *et al.* 1984, Festa-Bianchet 1988). During the 1999 lambing season, captive bighorn were observed fleeing from the feeding area in response to construction noise from nearby development projects on multiple occasions. Additionally, helicopters were documented flying over or adjacent to the enclosures and causing alarm responses (*e.g.*, running uphill) among captive bighorn on over 20 occasions between January and July 1999 (Bighorn Institute 1999). Stress resulting from human disturbance may have played a role in predisposing captive lambs to disease.

4. SURVIVORSHIP

In the San Jacinto Mountains, DeForge *et al.* (1997) monitored the survival of adult (2 or more years of age) radiocollared bighorn sheep during 1993 to 1996 and estimated annual adult survival to be 0.75 (1 equals 100 percent). During 1997 and 1998, annual survival in this ewe group was 0.67 and 0.86, respectively (Bighorn Institute 1997, 1998).

In the northern Santa Rosa Mountains ewe group, adult survivorship was monitored during a 14-year period (1985 to 1998), and was found to range between 0.50 and 1.00 annually (Table 3; Ostermann *et al.* in press). Regression analysis did not reveal an increasing or decreasing trend in survivorship during the 14 years. In this ewe group, which has been augmented with captive animals since 1985 (refer to sections I.C.1 and I.E.3), annual survival of captive reared animals (n equals 73, mean 0.80) was not statistically different from that of wild-reared animals (n equals 43, mean 0.81; Ostermann *et al.* in press).

During November 1992 to May 1998, survivorship of 113 adult radio-collared bighorn sheep (97 ewes and 16 rams) was monitored between Highway 74 (in the Santa Rosa Mountains) and the U.S.-Mexico border. During this period, overall annual adult survival was 0.79 (Table 4), with no significant difference among three age classes of adults (Hayes *et al.* 2000). Survivorship varied across years (range: 0.72 to 0.91, Hayes *et al.* 2000), but regression analysis did not reveal a decreasing or increasing trend in survivorship across years. Annual survivorship of individual ewe groups ranged from 0.70 to 0.87, and a year of high survivorship in one group was not necessarily a year of high survivorship in other groups (E. Rubin, pers. comm.).

Survival of adult bighorn sheep has been considered to be high until 10 years of age (Hansen 1980b), or until shortly before the age of ecological longevity (Cowan and Geist 1971). However, observed values of annual adult survivorship in the Peninsular bighorn sheep appear low relative to other reported desert populations: 0.91 or greater in southeastern California (Andrew 1994), 0.86 or greater in northwest Arizona (when highway mortalities were excluded, Cunningham and deVos 1992), 0.82 in New Mexico (Logan *et al.* 1996), and

Table 3. Annual survival estimates[a] for yearling and adult bighorn sheep in the northern Santa Rosa Mountains ewe group for calendar years 1985 to 1998 (excluding captive-reared animals; Ostermann *et al.* in press).

Year	Animal Months	Survival (1.0 = 100 percent)	95 percent Confidence Interval
1985	305	0.70	0.54-0.86
1986	282	0.88	0.76-1.00
1987	264	0.91	0.80-1.00
1988	234	0.90	0.77-1.00
1989	203	0.78	0.59-1.00
1990	145	0.79	0.57-1.00
1991	105	0.80	0.55-1.00
1992	86	0.88	0.65-1.00
1993	73	0.86	0.60-1.00
1994	45	0.50	0.10-0.90
1995	61	0.83	0.54-1.00
1996	52	0.80	0.45-1.00
1997	42	0.75	0.33-1.00
1998	42	1.00	1.00-1.00

[a]Survival calculated using the Kaplan-Meier method modified for a staggered entry design (Pollock *et al.* 1989).

0.85 or greater for four of five populations studied in the Mojave desert (Wehausen 1992). The one exception in the Mojave desert was a small population in the Granite Mountains, which was documented to have low adult annual survival (0.72) resulting from predation by mountain lions (Wehausen 1992).

Survival of Bighorn Institute captive raised yearling and adult bighorn (*n* equals 73, 1985-1998) 12 months after release was 0.61. First year survival for females (0.64) was higher (*p* less than 0.005) than for males (0.55). First year survival for bighorn released as adults (0.75, *n* equals 12) was higher (*p* less than 0.01) than for bighorn released as yearlings ($n = 61$, mean 0.57). After the first year in the wild, survival for captive-reared sheep improved substantially. Average annual survival for captive-reared bighorn excluding the first year after release (0.88) was significantly higher than survival during the first year after release (*p* less than

Table 4. Annual survival of adult bighorn sheep (greater than or equal to 2 years of age)[a], between Highway 74 (in the Santa Rosa Mountains) and the U.S.-Mexico border, 1992 to 1998 (Hayes *et al.* 2000).

Year	Animal Months	Annual Survival (1.0 = 100 percent)	95 percent Confidence Interval
1992-1993[b]	244	0.91	0.79-1.00
1993-1994	758	0.79	0.70-0.89
1994-1995	808	0.79	0.70-0.88
1995-1996	605	0.72	0.62-0.85
1996-1997	368	0.82	0.70-0.96
1997-1998	384	0.83	0.70-0.96
Total	3167	0.79	0.75-0.84

[a] Calculated using the program MICROMORT (Heisey and Fuller 1985).

[b] June 1 of first year through May 31 of second year (except 1992, which started in November).

0.01) and survival for wild-reared bighorn during the same time period (*p* equals 0.05). Mountain lion predation was the primary cause of death for released bighorn, followed by urbanization (Ostermann *et al.* in press).

Between 1985 and 1998, survival for yearling and adult bighorn in the captive population at the Bighorn Institute ranged from 0.89 to 1.0 and averaged 0.98. The only adult bighorn mortality during this time period was the euthanasia of a terminally ill 14-year-old ewe. Three yearlings died in captivity, two from disease and one during transport for release (Ostermann *et al.* in press). In 1999, two adults and a yearling died in captivity: a 15-year-old ram was euthanized after collapsing from a broken humerus; a 14-year-old ram died from complications with old age and bronchopneumonia; and a yearling ram died from an extensive cervical abscess (Bighorn Institute 1999).

5. CAUSES OF MORTALITY

Cause specific mortality in the San Jacinto Mountains was studied from 1992 to 1998. During this period, five mortalities were attributed to mountain lion (*Puma concolor*) predation, two were attributed to bobcat or mountain lion predation, and three died of unknown causes (DeForge *et al.* 1997; Bighorn Institute 1997, 1998).

In the northern Santa Rosa Mountains, artificially irrigated vegetation attracts bighorn sheep and creates a hazard. Though commonly thought to be the product of releasing captive-reared animals into the wild, behavioral habituation to urban sources of food and water began when urbanization started encroaching into bighorn habitat in the 1950's, several decades before population augmentation began in 1985 (Tevis 1959, DeForge and Scott 1982, Ostermann *et al.* in press, V. Bleich, pers. comm.). A study of cause-specific mortality conducted from 1991 to 1996 revealed that predation accounted for 28 percent of 32 adult bighorn sheep mortalities (25 percent due to lion predation and 3 percent due to either lion or bobcat predation) and 34 percent were directly caused by urbanization (DeForge and Ostermann 1998b). The remainder of mortalities were due to disease (3 percent) and undetermined causes (34 percent). Of the 11 adult mortalities attributed to urbanization, 5 were due to automobile collisions, 5 were caused by exotic plant poisoning, and 1 bighorn ram was strangled in a wire fence. An additional four bighorn sheep were struck but not killed by vehicles. Toxic plants causing mortality included oleander (*Nerium oleander*) and laurel cherry (*Prunus* sp.) (Bighorn Institute 1995, 1996). In 1970, a toxic, ornamental nightshade plant may have caused the death of a young ram in Palm Springs (Weaver and Mensch 1970). Due to an absence of comprehensive studies of the toxicity of non-native plants to bighorn sheep, it is unclear how many additional ornamental plant species represent a risk to bighorn sheep in the Peninsular Ranges. Exposure to chemicals, such as fertilizers, herbicides, and insecticides used in developed areas, is also a concern (Turner 1978); however, little is known about the level of exposure or effects on bighorn sheep. Preliminary results from an ongoing study of radiocollared lambs indicate that urbanization is also affecting lamb survival in this ewe group. Of the nine lamb mortalities recorded in 1998 and 1999, five were attributed to coyote or bobcat predation, one to mountain lion predation, and three to the direct and indirect effects of urbanization (automobile collision and drowning in a swimming pool). Dogs also have been observed to chase bighorn ewes and their lambs near residential areas (E. Rubin, pers. comm.). Eight of the nine deaths occurred within 300 meters (980 feet) of the urban interface (Bighorn Institute 1999).

Though mule deer (*Odocoileus hemionus*) are the primary prey of mountain lions in North America (Anderson 1983), and the range of bighorn sheep in the Peninsular Ranges largely avoids overlap with mule deer, lion predation threatens individual ewe groups in the Peninsular Ranges (Hayes *et al.* 2000) and has the potential to affect population recovery. From November 1992 to May 1998, Hayes *et al.* (2000) found the primary cause of death of radio-collared adult bighorn sheep between Highway 74 (in the Santa Rosa Mountains) and the U.S.-Mexico border was predation by mountain lions. Lion predation accounted for at least 69 percent of the 61 adult mortalities and occurred in each of the ewe groups in this portion of the range (Hayes *et al.* 2000). Annually, lion predation accounted for 50 to 100 percent of the bighorn sheep mortality, and did not exhibit a decreasing or increasing trend during 1993 to 1997. Lion predation appeared to show a seasonal pattern, with the majority of incidents occurring during the cooler and wetter months of the year. A bighorn sheep's risk of predation did not appear to be related to its age. In this study, the remainder of mortalities were classified as: 16 percent--causes other than predation and 15 percent--undetermined cause.

It is unknown, however, how current levels of lion predation observed throughout the Peninsular Ranges compare to historic levels. Lions or sign of lion have been observed in the habitat of Peninsular bighorn sheep since the 1950's (Jones *et al.* 1957, Jorgensen and Turner 1973, Gross 1987, Sanchez 1988, Bighorn Institute 1990). However, the literature indicates a lack of agreement on recent mountain lion population trends in California (Smallwood 1994, Smallwood and Fitzhugh 1995, Torres et al. 1996, Wehausen 1996). Past incidents of lion predation were documented by Jorgensen and Turner (1975), Gross (1987), and Bighorn Institute (1998, 1999). Reported incidents of lion predation were not common in the past and predation was not considered to be a serious risk to bighorn sheep (Weaver and Mensch 1970, Jorgensen and Turner 1975, Cunningham 1982), but it is important to note that the increase in the number of radio-collared bighorn sheep since 1993 has greatly increased the detection of such mortalities. Because of the rough desert terrain and the manner in which lions handle their prey (burying or caching under dirt or brush), carcasses of lion-killed bighorn sheep are difficult to find without the aid of telemetry. However, dead bighorn sheep without radiocollars have been found opportunistically during early and recent field work, and it has been suggested that the proportion of these that were killed by lions may have increased. It is possible that other causes of mortality, for example past episodes of diseases, have altered the proportion of mortalities attributed to lion predation.

Past field observations and records in areas far from the Coachella Valley urban interface documented mortalities resulting from predation (of lambs) by coyotes (*Canis latrans*)(Weaver and Mensch 1970, Jorgensen and Turner 1975, DeForge and Scott 1982), train collisions (Jorgensen and Turner 1973), automobile collisions (Turner 1976, Hicks 1978), poaching (Jones *et al.* 1957, Jorgensen and Turner 1973, Cunningham 1982), and accidental falls (Turner 1976). Golden eagles (*Aquila chrysaetos*) and bobcats (*Lynx rufus*) are also potential predators.

6. COMPETITION

In the Peninsular Ranges, bighorn sheep potentially compete for resources with other native ungulates (mule deer), domestic livestock (cattle), feral animals (horses), and humans. Bighorn sheep and deer habitat overlap primarily at the upper elevations of bighorn habitat, with possible geographic and seasonal differences in the degree of overlap. Jones (1980) summarized reports of possible competition for food and water between deer and bighorn sheep in other mountain ranges. Jones *et al.* (1957) and Weaver *et al.* (1968) speculated that competition between the two species may occur but likely was limited in the Peninsular Ranges. The habitat use patterns of deer in the Peninsular Ranges have not been studied; therefore, levels of competition are not known. Recent observations suggest that non-native honey bees (*Apis mellifera*) could affect bighorn sheep use of certain water sources (W. Boyce, pers. comm.).

Numerous reports and observations indicate that cattle grazing can be detrimental to bighorn sheep populations, either through direct competition for forage or water, or through vegetation changes in response to cattle grazing (reviewed by McQuivey 1978 and Jones 1980) and potential disease transmission (*e.g.*, DeForge *et al.* 1982, Clark *et al.* 1985, Jessup 1981, Jessup 1985, Clark *et al.*

1993, refer to section I.B.7 and I.D), although see Singer *et al.*(1997). Historically, large numbers of cattle were grazed in the Peninsular Ranges (Reed 1986; Appendix A). Numbers were greatly reduced when Anza-Borrego Desert State Park was established in 1933 and grazing leases on park lands were terminated in 1970, although cattle have continued to trespass on Park lands from adjacent allotments. Cunningham and Ohmart (1986) found that dietary overlap between cattle and Peninsular bighorn sheep in Carrizo Canyon was low (less than or equal to 18.2 percent) but noted that during their study, the two species used different vegetation associations. These authors cautioned that competition might increase if: 1) cattle were introduced to bighorn sheep habitat (with the impact being most serious at water sources), or 2) drought reduced the availability of annual plants. In 1989, cattle were observed at a water source used by bighorn sheep in Carrizo Canyon (Clark *et al.* 1993), indicating that cattle were using bighorn sheep habitat in the study site of Cunningham and Ohmart (1986). Cattle were also found in bighorn sheep habitat in Coyote Canyon, Rockhouse Canyon, Hellhole Canyon, and Bow Willow Canyon (M. Jorgensen, pers. comm.). During 1987 to 1989, Anza-Borrego Desert State Park personnel removed 117 cattle from park land (M. Jorgensen, pers. comm.); however, cattle (both feral or straying cattle, and those currently grazed legally on grazing allotments) are still found in or near bighorn sheep habitat in the Peninsular Ranges, and represent a potential risk to bighorn sheep.

Domestic sheep present problems similar to cattle with regard to competition; however, their presence represents an even greater threat due to an increased risk of transmitting fatal diseases to bighorn (refer to section I.B.7 and I.D). Domestic goats also are potentially serious competitors because of their ability to maneuver in rough country and their propensity to overgraze forage. Jones *et al.* (1957) found approximately 30 goats in Martinez Canyon in the Santa Rosa Mountains in 1957 and observed that they had heavily used part of this canyon. R. Weaver (California Department of Fish and Game retired, pers. comm.) also observed goats in this area and at the southern edge of the U.S. Peninsular Ranges (south of Highway 8) in the late 1960's. Goats persisted in Martinez and Sumac Canyons (Santa Rosa Mountains) until the early 1980's (Bighorn Institute 1983, 1984a, 1984b, 1985a, 1985b; V. Bleich, pers. comm.; D. Jessup *in litt.* 1999). There are currently no known domestic sheep or goats in the range of the Peninsular bighorn sheep, though transient ram movements, such as along the Sunrise Highway (S1 in San Diego County) could encounter sheep or goats in peripheral areas; reintroduction of these species would create a serious risk to Peninsular bighorn sheep.

Many researchers have documented high levels of competition, both for water and forage, between burros (*Equus asinus*) and bighorn sheep (*e.g.*, Weaver 1959, 1972, 1973; Mensch 1970; Seegmiller and Ohmart 1981; Andrew *et al.* 1997; Jones 1980). Jones *et al.* (1957) reported the presence of burros in Martinez Canyon and speculated that their use of water sources could interfere with bighorn sheep use. Burros also inhabited Rockhouse Canyon (north) from approximately the 1930's to the early 1970's (M. Jorgensen, pers. comm.). No burros are currently known to inhabit the Peninsular Ranges, but they could pose a risk for bighorn sheep if introduced. Feral horses (*Equus caballus*) currently inhabit Coyote Canyon in Anza-Borrego Desert State Park (Anza-Borrego Desert State Park, unpublished data) and Palm Canyon (San Jacinto Mountains). Competition between feral horses and bighorn sheep has not been extensively studied, but increasing horse populations were reported to coincide with decreasing bighorn sheep populations in the Silver Peak Range in Nevada (McQuivey 1978). Similarly, during the 3-day waterhole counts at Anza-Borrego Desert State Park in 1999 and 2000, the continuous presence of 16 and 21 wild horses, respectively, around a traditionally used waterhole coincided with an absence of bighorn coming to water over both census periods (M. Jorgensen, pers. comm.). M. Jorgensen has observed that during periods of poor range forage conditions, horses congregate around water sources more than usual, causing damage similar to that of burros by consuming the best available forage and fouling surface waters.

Competition with domestic livestock, especially domestic sheep (Brigandi 1995), has affected bighorn sheep in the past (refer to Appendix A). Cattle were present in the Peninsular Ranges as early as 1775 (Bolton 1930) and were grazed in large numbers throughout the range (Turner 1976, Reed 1986, Cunningham and Ohmart 1986). Currently, competition with livestock is low in the Peninsular Ranges because of past and current efforts to limit livestock numbers. However, competition may still occur in localized situations. For example, bighorn use of Hellhole Canyon has increased measurably since the removal of over two dozen cattle from the canyon and 117 cattle throughout the park in 1987 (M. Jorgensen, pers. comm.). In Canebrake Canyon, current Bureau of Land Management grazing permits allowing cattle to use water sources located below bighorn sheep lambing areas may be affecting the Carrizo Canyon ewe group. This ewe group also may be affected by cattle that stray out of a grazing allotment in McCain Valley. In addition, the potential risk of disease transmission exists as long as livestock occur in bighorn sheep habitat.

7. DISEASE AND PARASITISM

It has been hypothesized that disease has played an important role in population dynamics of bighorn sheep in the Peninsular Ranges (DeForge *et al.* 1982, DeForge and Scott 1982, Turner and Payson 1982, Wehausen *et al.* 1987). Numerous pathogens have been isolated or detected by serologic assay from bighorn sheep in these ranges. These pathogens include bluetongue virus, contagious ecthyma virus, parainfluenza-3 virus, bovine respiratory syncytial virus, *Anaplasma*, *Chlamydia*, *Leptospira*, *Pasteurella*, *Psoroptes,* and *Dermacentor* (DeForge *et al.*, 1982; Clark *et al.* 1985, 1993; Mazet *et al.* 1992; Elliott *et al.* 1994; Boyce 1995; Crosbie *et al.*, 1997, DeForge *et al.* 1997).

DeForge *et al.* (1982) found multiple pathogens (contagious ecthyma virus, blue tongue, *Pasteurella*, and parainfluenza virus) and low lamb recruitment in association with overall population declines. Between 1982 and 1998, 39 lambs showing signs of illness (lethargy, droopy ears, nasal discharge, and lung consolidation) were collected from the Santa Rosa (northern and southern), Jacumba, and In-Ko-Pah Mountains for disease research and rehabilitation at the Bighorn Institute (Ostermann *et al.* in press). Additionally, DeForge *et al.* (1995) documented a population decline throughout the Santa Rosa Mountains during 1983 to 1994, resulting from inadequate recruitment. Although a cause and effect relationship between disease and population decline has not been clearly established in the Peninsular Ranges, results from several studies provide support for this hypothesis (DeForge *et al.* 1982, Clark *et al.* 1985, Wehausen *et al.* 1987, Clark *et al.* 1993, Elliot *et al.* 1994, DeForge *et al.* 1995). The presence of feral goats in portions of the Santa Rosa Mountains until the late 1970's to early 1980's may have contributed to exposure of wild bighorn to disease during this period of population decline (D. Jessup, *in litt.* 1999).

Analysis of spatial variation in pathogen exposure among bighorn sheep sampled between 1978 to 1990 showed that Peninsular bighorn sheep populations and other populations in southern California have higher levels of pathogen exposure than other populations of bighorn sheep in the State (Elliott *et al.* 1994). However, serological tests have revealed the presence of antibodies to several infectious disease agents in both healthy and clinically-ill animals (Clark *et al.* 1993, Elliott *et al.* 1994; Boyce 1995, DeForge *et al.* 1997), and essentially all of the viruses, bacteria, and parasites that have been reported from Peninsular bighorn sheep appear to be widespread among desert bighorn sheep in the western U. S. (Jessup *et al.* 1990). All evidence indicates that the influence of disease in the Peninsular Ranges has subsided in more recent years. For example, recent sampling and examination of bighorn sheep throughout the range indicate that most animals were clinically normal (Boyce 1995; DeForge *et al.* 1997; Bighorn Institute 1997, 1998, 1999). Several caveats should be kept in mind when interpreting serologic test results of wild animals (Gardner *et al.* 1996). An animal testing positive for a specific pathogen: 1) may or may not be showing clinical signs of the infection and may never have been adversely affected by the infection, 2) may no longer harbor the pathogen, 3) may or may not be resistant to subsequent re-infection, or 4) may have been exposed to a related pathogen that induced the formation of cross-reactive antibodies. On the other hand, an animal testing negative: 1) may never have been exposed to the pathogen, 2) may be recently infected by the pathogen under scrutiny but not yet producing antibodies, or 3) may have been exposed to the pathogen and developed an antibody titer that has subsequently abated. Detection of pathogens does not, in itself, imply a causal relationship between disease and population declines. Additional research is necessary to better understand this relationship. Furthermore, it appears that risk of disease and parasites might differ among ewe groups based on their exposure and their habitat use patterns, so future research should address these questions at the level of the ewe group and the level of the population.

The reduced influence of disease on Peninsular bighorn sheep (as they simultaneously continue to decline) suggests that other factors, such as predation, habitat loss/modification, and human related disturbance currently limit the population. Nonetheless, disease and/or parasites may still threaten bighorn sheep in the northern Santa Rosa Mountains. Bighorn sheep in this group have exhibited low lamb recruitment (refer to section I.B.3), and clinical signs of illness have been observed among adults and lambs (DeForge and Scott 1982; Bighorn Institute 1997; DeForge and Ostermann 1998a; E. Rubin, pers. comm.). In addition, during 1991 to 1998, internal parasites (trichostrongyles) were detected in this ewe group (DeForge and Ostermann 1998b; E. Rubin and W. Boyce, pers. comm.), while similar sampling failed to detect these parasites in bighorn sheep from the remainder of the range (DeForge *et al.* 1997; Bighorn Institute 1998; E. Rubin and W. Boyce, pers. comm.). Habitat modification and altered habitat use patterns may increase the risk of disease and parasites in this group by increasing parasite survival or transmission rates in irrigated landscapes (Bighorn Institute 1997, DeForge and Ostermann 1998b). It has been suggested, for instance, that the density of Rocky Mountain bighorn sheep is important in the transmission of lungworms (*Protostrongylus*) in mesic areas where the snail intermediate hosts are sufficiently common (Uhazy and Holmes 1973). The different ewe groups in the Peninsular Ranges apparently have different pathogen exposure profiles and risks.

C. ABUNDANCE AND DISTRIBUTION

1. HISTORIC ABUNDANCE AND DISTRIBUTION

Bighorn sheep have been documented in the Peninsular Ranges since early explorers such as Anza observed them in the 1700's (Bolton 1930); however, rangewide population estimates were not made until the 1970's. Published estimates were as high as 971 in 1972 (Weaver 1972), and 1,171 in 1974 (Weaver 1975), while more recent estimates were 570 in 1988 (Weaver 1989), 400 in 1992 (U.S. Fish and Wildlife Service 1992), and between 327 to 524 in 1993 (Torres *et al.* 1994). Accuracy of the estimates in the early 1970's (pre-helicopter surveys), especially in the San Jacinto Mountains, has been questioned by several authorities (Wehausen 1999; V. Bleich, pers. comm.) (see section I.C.3 below for more details).

An examination of past records and current data suggests that the distribution of bighorn sheep has been altered during the past 25 years. No new ewe groups have been documented to form, but ewe groups along the Mexican border and in the northern San Jacinto Mountains (north of Chino Canyon) have disappeared since the 1980's. Loss of the border population was poorly documented but the construction of Interstate 8 in the mid-1960's, railroad activity, livestock grazing, poaching, and fire suppression appear to be likely contributing causes (Rubin *et al.* 1998). DeForge *et al.* (1997) suggested that disturbance and habitat fragmentation were the principal causes of changes in distribution in the northern San Jacinto Mountains. In the northern Santa Rosa Mountains, the number and distribution of ewes is substantially reduced from the 1980's, with formerly important use areas, such as Carrizo and Dead Indian Canyons, currently supporting few animals (J. D. Goodman, University of Redlands, unpublished data 1963; DeForge and Scott 1982; DeForge *et al.* 1995; Bighorn Institute 1998, 1999). The Fish Creek Mountains and areas to the west of the Vallecito Mountains (the Sawtooth Range, Oriflamme Mountains, and the lower elevations of the Laguna Mountains) are believed to have supported "transient" use by sheep in the past (Weaver *et al.* 1968, Weaver 1972).

The distribution of ewes has become more fragmented in the recent past, although evidence is not available to suggest that ram use has been curtailed. At the southern distributional limits of the U.S. population, the construction of Interstate 8 preceded the later disappearance of bighorn sheep along the Mexican border, though rams still continue to be found occasionally (Jessup, *in litt.* 2000). At the extreme northern end of their range, ewe group occupation ceased in the northern San Jacinto Mountains about 20 years after construction of the Palm Springs Aerial Tramway in Chino Canyon, though rams still cross Chino Canyon and make use of much of the area formerly occupied by the ewe group. Rubin *et al.* (1998) suggested that in portions of the range, roads or increased traffic have contributed to fragmentation by restricting ewe movement, as evidenced by the distributional limits of four ewe groups currently coinciding with roadways. In the 1970's, ewes were observed to cross Highway 74 in the Santa Rosa Mountains

(V. Bleich, pers. comm.; D. Jessup, *in litt.* 1999) and sheep were struck by cars "where ancestral bighorn trails are bisected by the highway" (Turner 1976). Though a radio-collared ewe crossed Highway 74 in 1982 (DeForge and Scott 1982), no radio-collared ewes were observed to cross this road from 1993 to the present. California Department of Transportation records indicate that traffic on this road has approximately tripled since 1970. Since 1991, at least five rams have been struck by cars while crossing Highway 74; two were killed (Bighorn Institute 1991, 1999). In addition, a significant reduction in bighorn use in portions of the Santa Rosa Mountains has been observed since the construction of the Dunn Road (DeForge *in litt.* 1997).

2. RECENT ABUNDANCE AND DISTRIBUTION

Recent abundance estimates of Peninsular bighorn sheep north of the U.S.-Mexico border were 347, 276, and 334 animals (excluding lambs) in 1994, 1996, and 1998, respectively (Table 5). Currently, at least eight subpopulations (ewe groups) exist in the range (Rubin *et al.* 1998) (Figure 3, Table 6). It is possible that the Santa Rosa Mountains southeast of Highway 74 and the Vallecito Mountains are each inhabited by more than one ewe group, but additional data are required to confirm this. During 1994 to 1998, the largest ewe groups in the Peninsular Ranges typically consisted of less than 30 ewes, while some groups had less than 15 ewes (DeForge *et al.* 1997; Rubin *et al.* 1998, 1999; Ostermann *et al.* in press) (Table 6). The San Jacinto ewe group currently consists of six known ewes (Bighorn Institute 1999). Although permanent emigration of ewes between groups has not been observed, a limited number of temporary moves between some groups were documented in recent years (Bighorn Institute 1998, 1999; Rubin *et al.* 1998), and genetic evidence indicates ewe movement in the past (Boyce *et al.* 1997). Ram movements between ewe groups are more frequent (DeForge *et al.* 1997, Rubin *et al.* 1998, refer to section I.B.2). These observational data are supported by genetic analyses (Boyce *et al.* 1997, Boyce *et al.* 1999, refer to section I.A.3). The existence of distinct ewe groups that are connected by limited movement of bighorn sheep suggests that Peninsular bighorn sheep comprise a metapopulation (Levins 1970, Torres *et al.* 1994, Bleich *et al.* 1996, Boyce *et al.* 1997). Bighorn sheep exhibit a patchy distribution as a result of natural breaks in mountainous habitat (Schwartz *et al.* 1986; Bleich *et al.* 1990a, 1996), and genetic analyses support the hypothesis that discrete ewe

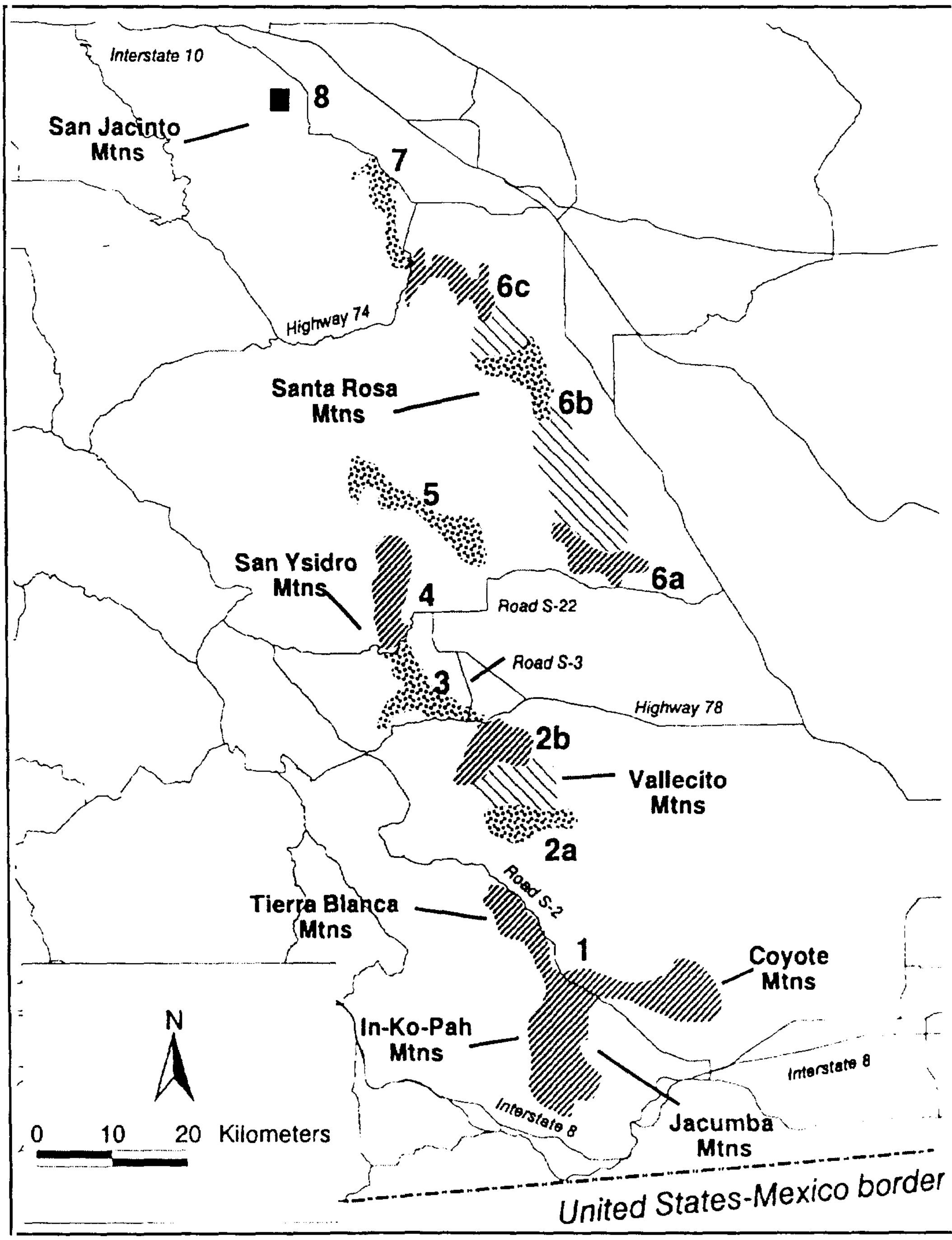


Figure 3. Distribution of bighorn ewes in the Peninsular Ranges, California, 1992-1995. Stippled and shaded areas indicate regions used by home-range groups of ewes identified in this study. 1-Carrizo Canyon, 2a-south Vallecito Mountains, 2b-north Vallecito Mountains, 3-south San Ysidro Mountains, 4-north San Ysidro Mountains, 5-Coyote Canyon, 6a-Santa Rosa Mountains east of Highway 74 (south), 6b-Santa Rosa Mountains east of Highway 74 (Martinez Canyon), 6c-Santa Rosa Mountains east of Highway 74 (Deep Canyon), 7-Santa Rosa Mountains west of Highway 74, 8-San Jacinto. Mountains (■ indicates general location of this group, DeForge *et al.* 1997). Wide hatch marks indicate possible connectivity between ewe groups in the Vallecito Mountains and in the Santa Rosa Mountains. (Reprinted with permission from Rubin *et al.* 1998).

groups existed in the past (Boyce *et al.* 1999). However, it appears that some separations between groups are of anthropogenic origin and movement of ewes has been reduced by human activity (DeForge *et al.* 1997, Rubin *et al.* 1998, refer to section I.C.2).

Two captive populations of Peninsular bighorn sheep currently exist. The Living Desert Museum, an educational and zoo facility in Palm Desert, California, maintains a small group (seven adult females and two adult males) at its facility. These animals are used primarily for educational purposes (Terrie Correll, The Living Desert, pers. comm.). The Bighorn Institute, also in Palm Desert, maintains a small captive herd of approximately 30 animals. This private, nonprofit organization, established in 1982 under the authorization of the California Department of Fish and Game with a Memorandum of Understanding,

Table 5. Abundance estimates (and 95 percent confidence intervals) of bighorn sheep in the Peninsular Ranges north of the U.S.-Mexico border during 1994, 1996, and 1998. Estimates exclude lambs (DeForge *et al.* 1995; Bighorn Institute 1996, 1998).

Region	1994	1996	1998	Source(s)
Anza-Borrego Desert State Park (including all habitat outside of Santa Rosa and San Jacinto Mountains)	214.0 (149.8 to 278.6)	163.0 (131.8 to 194.2)	180.7 (149.5 to 211.9)	Rubin *et al.* 1998, 1999
Santa Rosa Mountains	115.5 (91.5 to 139.5)	93.8 (71.8 to 115.8)	129.0 (91.1 to 166.9)	DeForge *et al.* 1995, Bighorn Institute 1996, 1998
San Jacinto Mountains[a]	17 (NA)	19 (NA)	24 (NA)	DeForge *et al.* 1997, Bighorn Institute 1998
Total	347 (253 to 458)	276 (210 to 439)	334 (262 to 434)	

[a]Minimum number known to be alive, based on absolute counts (intensive field studies of radio-collared animals in combination with annual helicopter surveys). Confidence intervals unavailable.

conducts research and maintains a breeding herd at its facility (refer to section I.E.3). Since 1985, 77 animals from this herd have been released into the wild. Ewe groups in the San Jacinto and northern Santa Rosa Mountains have been augmented with captive-reared sheep (n equals 3 in 1997 and 74 during 1985-1998, respectively) (Ostermann *et al.* in press).

3. POPULATION TRENDS

Although based on different techniques, a comparison of early (pre-1977) and current population estimates suggests a great decline in Peninsular bighorn sheep numbers. Early estimates were based on waterhole counts or foot surveys, whereas helicopter surveys were used to generate population estimates starting in

Table 6. Ewe abundance estimates (and 95 percent confidence intervals) per ewe group generated from helicopter surveys during 1994, 1996, and 1998 (Rubin *et al.* 1998, 1999; DeForge *et al.* 1997; DeForge *et al.* 1995; Bighorn Institute 1996, 1998).

Current ewe group delineation	Year 1994	Year 1996	Year 1998
1. Carrizo Canyon	39.0 (20.9-57.2)	23.5 (17.7-29.3)	19.0 (19.0-19.0)
2. Vallecito Mountains	17.7 (6.7-28.6)	19.0 (19.0-19.0)	30.2 (24.3-36.1)
3. South San Ysidro Mountains	15.3 (9.9-20.6)	12.3 (6.9-17.8)	23.0 (8.3-37.7)
4. North San Ysidro Mountains	32.0 (9.5-54.5)	22.1 (16.2-28.1)	15.3 (6.2-24.5)
5. Coyote Canyon	21.8 (15.4-28.2)	23.0 (5.5-40.5)	22.8 (17.5-28.0)
6. Santa Rosa Mountains east of Hwy. 74	66.2 (42.4-90.0)	83.0 (27.3-138.7)	48.3 (31.6-65.0)
7. Santa Rosa Mts. west of Hwy. 74	15.9 (13.5-18.3)	14 (14.0-14.0)	11.6 (9.7-13.5)
8. San Jacinto Mountains[a]	7 (na)	7 (na)	8 (na)

[a]Minimum number known to be alive, based on absolute population counts (intensive field studies of radiocollared animals in combination with annual helicopter surveys). Confidence intervals are unavailable.

1977. Annual helicopter surveys conducted in the Santa Rosa Mountains since 1977 indicate a regional population decline (DeForge *et al.* 1995, Wehausen *et al.* 1987), with a 69 percent decline observed between 1984 and 1994 (DeForge *et al.* 1995). Rubin *et al.* (1998) examined trends in abundance outside of the Santa Rosa Mountains with the use of a 26-year dataset of annual waterhole count observations in Anza-Borrego Desert State Park. These data indicated that declines had occurred in some, but not all, ewe groups. This result suggests that abundance trends are independent among ewe groups, and is in agreement with field data that show independent differences in lamb recruitment and adult survival among ewe groups (Rubin *et al.* 2000., Hayes *et al.* 2000, refer to sections I.B.3 and I.B.4). Climatic patterns are highly correlated across the Peninsular Ranges, suggesting that other local factors specific to ewe groups play important roles in determining long-term abundance trends (Rubin *et al.* 1998). Independent population trends also were observed among ewe groups in the Mojave Desert (Wehausen 1992).

DeForge *et al.* (1997) found that bighorn sheep in the San Jacinto Mountains declined between 1984 and 1987. Since that time the subpopulation inhabiting these mountains has been stable but precariously small (Table 7). In the Santa Rosa Mountains, mark-recapture estimates generated from helicopter survey data indicated that bighorn sheep numbers appeared to remain stable at low numbers from 1990 to 1995, following a large population decline (DeForge *et al.* 1995). In the northern part of these mountains, the current number of animals is approximately 50 percent of the number present during the 1980's (Table 8). Helicopter surveys south of the Santa Rosa Mountains, encompassing all Peninsular bighorn sheep habitat outside of the Santa Rosa and San Jacinto Mountains, indicated a 28 percent decline in ewe numbers in a recent 2-year period (from an estimate of 141 females in 1994 to 102 females in 1996; Rubin *et al.* 1998), and a statistically non-significant increase (from approximately 102 to 112 females) from 1996 to 1998 (Rubin *et al.* 1999).

Though cause and effect relationships for these population declines among ewe groups have not been documented, likely contributing factors are: high predation rates; disease; and cumulative effects of habitat loss, modification, fragmentation and human-related disturbance.

Table 7. Ewe population estimates[a] for the San Jacinto Mountains from 1993 to 1999 (DeForge *et al.* 1997; Bighorn Institute 1997, 1998, 1999).

Year	Number of ewes (yearlings and adults)
1993	10
1994	7
1995	8
1996	7
1997	9
1998	8
1999	6

Table 8. Fall population estimates[a] of adult (1 year or older) bighorn sheep in the northern Santa Rosa Mountains from 1985 to 1998 (Ostermann *et al.* in press).

Year	Fall population estimate of yearling and adult bighorn (ewes)	Number of captive-reared bighorn in the population
1985	40 (22)	1
1986	46 (25)	5
1987	52 (30)	16
1988	52 (33)	19
1989	50 (32)	20
1990	41 (24)	26
1991	30 (21)	17
1992	35 (24)	20
1993	27 (17)	16
1994	23 (11)	16
1995	24 (10)	16
1996	21 (10)	16
1997	22 (11)	16
1998	22 (10)	15

[a] minimum number known to be alive, based on absolute population count.

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 THEIR HABITAT OR RANGE

Habitat loss is a leading cause of current species extinctions and endangerment (Burgman *et al.* 1993). It represents a particularly serious threat to Peninsular bighorn sheep because they live in a narrow band of lower elevation habitat that represents some of the most desirable real estate in the California desert and is being developed at a rapid pace. At least 7,490 hectares (18,500 acres or about 30 square miles) of suitable habitat has been lost to urbanization and agriculture within the range of the three ewe groups that occur along the urban interface between Palm Springs and La Quinta (see the maps referenced in Appendix B). Within the narrow band of habitat, bighorn sheep need to be able to move daily, seasonally, and annually to make use of sparse and sometimes sporadically available resources found within their home ranges. As humans encroach into this habitat, these resources are eliminated or reduced in value, and the survival of ewe groups is threatened. Bighorn sheep are also sensitive to habitat loss or modification because they are poor dispersers (Geist 1967, 1971), largely learning their ranging patterns from older animals rather than on their own (refer to section I.B.2). When habitat is lost or modified, the affected group is likely to remain within their familiar surroundings but with reduced likelihood of population persistence, due to reduced quantity and/or quality of resources. Habitat fragmentation is a major threat to bighorn sheep (Schwartz *et al.* 1986, Bleich *et al.* 1996) and Peninsular bighorn sheep are particularly vulnerable because of the narrow elevational band of suitable habitat, behavior (use of low elevation habitat and ewe home range fidelity), and population structure. Fragmentation poses a particularly severe threat to species with a metapopulation structure because overall survival depends on interaction among subpopulations. Encroaching urban development and anthropogenic disturbances have the dual effect of restricting animals to a smaller area and severing connections between ewe groups. Movements by rams through downtown Palm Springs (Tevis 1959, Desert Sun, 9/12/1995, DeForge *et al.* 1997) may provide insight into past bighorn movement patterns. Former long-distance movements across the valley floor to the north and east of the Coachella Valley, though never documented, likely occurred as they currently still do between other mountain ranges in the desert southwest (Bleich *et al.* 1996; J. Wehausen, pers. comm.). The potential for such movements now has been eliminated by high density urban development, major freeways, fences, agriculture, and canals. The movement of rams and occasional ewes between ewe groups maintains genetic diversity and augments populations of individual ewe groups (Soulé 1980, Krausman and Leopold 1986, Schwartz *et al.* 1986, Burgman *et al.* 1993, refer to section II.A.2). The occasional movement of ewes can result in a "rescue effect" (Brown and Kodric-Brown 1977) by increasing the number of ewes in a declining ewe group. Temporary moves by females between neighboring ewe groups could also provide new habitat knowledge that facilitates future range expansion (Geist 1971). Increased fragmentation reduces such possibilities.

Beyond physical barriers to movement, fragmentation also can result from less obvious forms of habitat modification. As described above in section I.C.2, increased traffic on roads apparently make bighorn sheep, especially ewes, hesitant to cross these roads (Rubin *et al.* 1998). Animals that do cross suffer an additional risk of mortality (Turner 1976, McQuivey 1978, Cunningham and deVos 1992, DeForge and Ostermann 1998b, Bighorn Institute 1999), with the result that a group whose range is bisected by the road can have reduced viability in the long term (Cunningham and deVos 1992). Human disturbance along roads and trails can cause sheep to avoid those areas (Papouchis *et al.* 1999), potentially affecting bighorn sheep movement and habitat use (refer to section I.B.2), thereby "fragmenting" bighorn sheep distribution although the habitat appears to be intact.

Development and human populations along the eastern slope of the Peninsular Ranges continue to grow at a rapid pace at the lower and upper elevational boundaries of Peninsular bighorn sheep habitat. The Coachella Valley Association of Governments anticipates that by the year 2010, the human population there will increase from 227,000 to over 497,000, not including 165,000 to 200,000 seasonal residents. Bighorn population declines typically have been most pronounced in ewe groups adjoining the urban interface in Coachella Valley. The decline in local bighorn populations in the San Jacinto and northern Santa Rosa Mountains parallels the demise of sheep populations near

Albuquerque and Tucson (Krausman *et al.* in prep.), other major metropolitan areas that have encroached into sheep habitat in the desert southwest. Other cumulative factors caused by human activities within bighorn sheep habitat are discussed in detail below (refer to section I.D.5).

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

There is no regulated hunting season for Peninsular bighorn sheep in the United States, and poaching is rarely documented. Precautions should continue to be taken, however, to prevent poaching. The Bighorn Institute and Living Desert Museum each maintain a captive population of Peninsular bighorn sheep for scientific and educational purposes. This use is thought to have no negative impact on free-ranging bighorn sheep. Researchers are required to obtain State and Federal permits before handling Peninsular bighorn sheep. Although current research techniques are not believed to have a negative impact on bighorn sheep, how research is carried out must always be a consideration (Bleich *et al.* 1994, see Appendix D).

3. DISEASE AND PREDATION

The westward spread of Europeans and their domestic livestock across North America was thought to play a significant role in reducing the distribution and abundance of bighorn sheep due to the introduction of new infectious diseases (Spraker 1977, Onderka and Wishart 1984). In particular, domestic sheep have been repeatedly implicated in *Pasteurella* pneumonia die-offs of bighorn sheep. In the Peninsular Ranges, a number of pathogens have been isolated or detected by serological assay from bighorn sheep (refer to section I.B.7). In the Santa Rosa Mountains, many years of high lamb mortality from an apparent disease epizootic contributed to a population decline from inadequate recruitment (DeForge and Scott 1982, Wehausen *et al.* 1987, DeForge *et al.* 1995). Although diseases do not currently appear to be limiting population growth throughout the range, they pose a potential threat that could occur at any time, especially if disease episodes can be precipitated by chronic levels of disturbance (Geist 1971, Hamilton *et al.* 1982, Spraker *et al.* 1984, King and Workman 1986, Festa-Bianchet 1988, Desert Bighorn Council 1992).

Mountain lion predation is an apparent limiting factor for some ewe groups in the Peninsular Ranges; 69 percent of 61 mortalities of radiocollared sheep from 1992 to 1998 between Highway 74 in the Santa Rosa Mountains and Mexican border are attributed to mountain lions (Hayes *et al.* 2000). The relatively low survivorship of adults (section I.B.4) and associated population declines have recently affected the recovery of most ewe groups.

4. THE INADEQUACY OF EXISTING REGULATORY MECHANISMS

In 1971, the Peninsular bighorn sheep was listed under California State law as a rare species. The designation was changed to "threatened" in 1984 to standardize terminology of the amended California Endangered Species Act. The Peninsular bighorn sheep also is listed by the State as a "fully protected species" under the Fish and Game Code (Section 4700). The California Environmental Quality Act, which allows public comment and generally requires mitigation for significant environmental effects, including adverse impacts to State and federally listed species, has not resulted in conservation benefits sufficient to maintain stable populations.

The Bureau of Land Management and California Department of Fish and Game jointly developed the Santa Rosa Mountains Habitat Management Plan in 1980 and McCain Valley Habitat Management Plan in 1984 to address the needs, as identified at that time, of bighorn sheep in these areas. The Department of Fish and Game also established the Carrizo Canyon and Magnesia Spring Ecological Reserves to protect important watering sites. The effectiveness of these management areas in the Santa Rosa Mountains has been limited because of heavy human use, lack of management presence, and limited funding. The lack of funds also has prevented acquisition of all private lands within the protected areas, resulting in continued fragmentation by development. The existence of private inholdings within the boundaries of Anza-Borrego Desert State Park is also a potential threat to Peninsular bighorn sheep because these lands include prime bighorn sheep habitat, but a lack of funding and/or unwilling sellers have prevented public acquisition to date.

In California, it is Bureau of Land Management policy to conserve State-listed plants and animals and to use its authorities in furtherance of the purposes of the

State of California's rare and endangered species laws. The Bureau of Land Management and California Department of Fish and Game have developed conference procedures to promote cooperation in the application of this policy, although they are inconsistently implemented. Neither State listing nor the proposed Federal listing of bighorn sheep prompted land management agencies to effectively address adverse effects associated with land exchanges, recreational and commercial uses, and livestock grazing programs. Although domestic sheep on Federal lands in the Peninsular Ranges are not a current threat, adverse effects from cattle grazing (including resource competition, degradation of water sources, and disease transmission) require resolution.

A number of development projects with potentially significant adverse effects on bighorn sheep recently have been approved because project proposals and local General Plans for most of the cities in the Coachella Valley inadequately address threats to the long-term conservation of Peninsular bighorn sheep. Though some habitat protection is derived from the presence of the State and federally listed least Bell's vireo (*Vireo bellii pusillus*) and southwestern willow flycatcher (*Empidonax traillii extimus*), benefits are limited due to the specialized habitats (riparian woodland) used by these birds. Section 404 of the Clean Water Act provides protection through the U. S. Army Corps of Engineers' regulation of the discharge of dredged and fill material into certain waters and wetlands of the United States, but Corps' jurisdiction can be avoided under various situations.

5. OTHER NATURAL OR MANMADE FACTORS AFFECTING THEIR CONTINUED EXISTENCE

Drought: Prolonged drought is a natural factor that can have negative impacts on desert bighorn sheep populations, either by limiting water sources or by affecting forage quality (Rosenzweig 1968, Hansen 1980a, Monson 1980, Douglas and Leslie 1986, Wehausen *et al.* 1987, refer to section I.B.1). During drought years, the concentration of bighorn sheep near remaining water sources may increase competition for forage as well as water, thereby limiting population growth through density dependent regulation (Caughley 1977, Gotelli 1995). In addition, increased density potentially renders animals more susceptible to diseases or parasites (Anderson and May 1979, May and Anderson 1979).

Human Disturbance: Human development affects sheep through habitat loss, fragmentation, or other modification (refer to section I.D.1.1), but these impacts also extend into bighorn sheep habitat beyond the urban edge. Though a growing human population and increased activity adjacent to and within bighorn sheep habitat have potential to adversely affect bighorn sheep, accurate mapping of trail locations and quantitative monitoring of recreational trail use have not been conducted. In addition, incremental proliferation of trails has gone largely unaddressed.

Numerous researchers have expressed concern over the impact of human activity on Peninsular bighorn sheep (*e.g.*, Jorgensen and Turner 1973, Hicks 1978, Olech 1979, Cunningham 1982, DeForge and Scott 1982, Gross 1987, Sanchez *et al.* 1988), as well as on sheep in other areas (Graham 1980, Gionfriddo and Krausman 1986, Smith and Krausman 1988). Leopold (1933) considered bighorn sheep a wilderness animal because they fail to thrive in contact with urban development. A variety of human activities such as hiking, mountain biking, hang gliding, horseback riding, camping, hunting, livestock grazing, dog walking, and use of aircraft and off-road-vehicles have the potential to disrupt normal bighorn sheep social behaviors and use of essential resources, or cause bighorn sheep to abandon traditional habitat (McQuivey 1978, MacArthur *et al.* 1979, Olech 1979, Wehausen 1979, Leslie and Douglas 1980, Graham 1980, MacArthur *et al.* 1982, Bates and Workman 1983, Wehausen 1983, Miller and Smith 1985, Krausman and Leopold 1986, Krausman *et al.* 1989, Goodson 1999, Papouchis *et al.* 1999). Attempts to ascribe relative importance, distinguish among, or generalize the effects of different human activities on sheep behavior are not supportable, given the range of potential reactions reported in the literature and the different variables impinging on given situations.

Although cases have been cited in which bighorn sheep populations did not appear to be affected by human activity (*e.g.*, Hicks and Elder 1979, Hamilton *et al.* 1982), numerous researchers, including these authors, have documented altered bighorn sheep behavior in response to anthropogenic disturbance. Even when bighorn sheep appear to be tolerant of a particular activity, continued and frequent use can cause them to avoid an area, eventually interfering with use of resources, such as water, mineral licks, lambing or feeding areas, or use of traditional movement routes (Jorgensen and Turner 1973, McQuivey 1978, Graham 1980, Leslie and Douglas 1980, DeForge and Scott 1982, Hamilton *et al.* 1982, Krausman and Leopold 1986, Rubin *et al.* 1998). In addition, disturbance can result in physiological responses such as elevated heart rate (MacArthur *et al.* 1979, 1982), even when no behavioral response is discernable. It was repeatedly cautioned that human disturbance threatened the viability of a bighorn sheep population in the Santa Catalina Mountains, outside of Tucson, Arizona (Etchberger *et al.* 1989, Krausman *et al.* 1989, Krausman 1993, Krausman *et al.* 1995). In these mountains, Etchberger *et al.* (1989) found that habitat abandoned by bighorn sheep had greater human disturbance than occupied habitat. Today, this population is extinct, or nearly so, and human activities apparently contributed to its demise (Schoenecker 1997; Krausman *et al.* in prep.; P. Krausman, pers. comm.).

A high level of human activity occurs in the habitat of Peninsular bighorn sheep. For example, during a recent 10-hour period in spring, 49 hikers, 2 mountain bikers, and 13 dogs (9 unleashed) were counted in Carrizo Canyon in the northern Santa Rosa Mountains (Bureau of Land Management, unpublished data). This trail bisects a lambing area that has received reduced levels of sheep use in recent years. A ewe and her lamb were observed to wait for over 5 hours to come to water because of continuous off-road vehicle traffic (Jorgensen and Turner 1973). Jorgensen (1974) reported that bighorn sheep use of important waterholes was 50 percent lower on days with off-road vehicle traffic. In Carrizo Canyon, Hicks (1978) observed a group of bighorn sheep flee from a spring area when a Navy helicopter passed overhead, Olech (1979) noted that bighorn sheep did not use waterholes when motorcycles were heard nearby, and Cunningham (1982) speculated that the use of springs by humans (recreationists and persons entering California across the U. S.-Mexico border) reduced use of this resource by bighorn sheep. Sanchez *et al.* (1988) recommended that future management efforts should attempt to reduce human impacts on bighorn sheep in Carrizo Canyon. As the human population of the southern California desert grows, such human activity in bighorn sheep habitat will increase.

Bighorn sheep responses to human activity are difficult to predict (Miller and Smith 1985) and depend on type of activity, season of the activity, elevation of the activity relative to resources (Hicks 1978, Graham 1980), and distance of the activity from resources critical to bighorn sheep (Miller and Smith 1985), among other variables. For instance, ewes with lambs typically are more sensitive to disturbance (Light and Weaver 1973, Wehausen 1980), as are animals that are approached from higher elevations (Hicks 1977, Graham 1980). Papouchis *et al.* (1999) found bighorn sheep to be more sensitive to disturbance during spring and fall, corresponding with the lambing and rutting seasons. Etchberger and Krausman (1999) observed the abandonment of lambing habitat while construction activities were ongoing.

Livestock Grazing and Water Diversion: Human actions also indirectly affect use of resources by bighorn sheep. Domestic livestock and feral animals can reduce the availability and quality of resources (water and forage) required by bighorn sheep (refer to section I.B.6), and can function as potential vectors for diseases such as bluetongue virus. In portions of the range, water has been pumped from aquifers and diverted away from springs for use by ranches and private residences, reducing and eliminating the water sources upon which bighorn sheep depend (Tevis 1961; Blong 1967; Turner 1976; M. Jorgensen, pers. comm.).

Non-native Plants: In the Peninsular Ranges, the presence of tamarisk (*Tamarix* sp.), also known as saltcedar, represents a serious threat to bighorn sheep. This exotic plant was introduced as an ornamental and windbreak but is now a major weed problem (Lovich *et al.* 1994). It consumes large amounts of water and has rapid reproductive and dispersal rates (Sanchez 1975, Lovich *et al.* 1994), enabling it to outcompete native plant species in canyon bottoms and washes. It has the following negative effects on bighorn sheep: 1) it reduces or eliminates standing water that bighorn sheep depend on, 2) it outcompetes plant species that bighorn sheep feed on, and 3) it occurs in thick, often impenetrable stands that block access of bighorn sheep to water sources and provide cover for predators. Tamarisk has also been recognized as a threat to other bighorn sheep populations (Sanchez 1975) and native ecosystems in general (Lovich *et al.* 1994). Effective eradication methods are possible (Barrows 1994) and eradication programs currently are underway by the Agua Caliente Band of Cahuilla Indians, Bureau of Land Management, and Anza-Borrego Desert State Park.

Fire Suppression: As described in section I.B.2 of this recovery plan, bighorn sheep rely on vigilance and visibility to detect and avoid predators. Long-term fire suppression results in taller and more dense stands of vegetation, thereby reducing openness and visibility and in turn making bighorn sheep more susceptible to predation (Sierra Nevada Bighorn Sheep Interagency Advisory Group 1997). In this same manner, fire suppression can influence the distribution and habitat use patterns of bighorn sheep by causing avoidance of areas with low visibility (Risenhoover and Bailey 1985, Wakelyn 1987, Etchberger *et al.* 1989, Etchberger *et al.* 1990, Krausman 1993, Krausman *et al.* 1996). In addition, Graf (1980) suggested that fire suppression reduces forage conditions in some bighorn sheep ranges. In the Peninsular Ranges, changes in vegetation succession are evident in some portions of bighorn sheep range, primarily in higher elevation chaparral and pinyon-juniper habitats, and have apparently influenced bighorn sheep use of certain canyons and springs (M. Jorgensen, pers. comm.). Although temperature and rainfall likely influence the pattern of vegetation associations along the eastern slopes of the Peninsular Ranges more than fire frequency does, a number of researchers have pointed out that fire is an important tool in the management of bighorn sheep habitat (Graf 1980, Smith and Krausman 1988, Krausman *et al.* 1996, Sierra Nevada Bighorn Sheep Interagency Advisory Group 1997).

E. PAST AND CURRENT MANAGEMENT/ CONSERVATION ACTIVITIES

1. FEDERAL AGENCIES

1.1 *United States Fish and Wildlife Service.* We listed the Peninsular bighorn sheep as a Category 2 candidate from September 18, 1985 (50 FR 37958) until May 8, 1992, when it was proposed for Federal listing as an endangered species (57 FR 19837). Between the date of the proposed rule and final listing on March 18, 1998 (63 FR 13134), certain Federal activities were reviewed under the section 7 interagency regulations (50 CFR Part 402) and conference procedures for proposed species. Since Federal listing, the mandatory requirements of sections 7, 9, and 10 of the Endangered Species Act have been in effect, in addition to the allocation of recovery funding to the State under sections 4 and 6 of the Act. On July 5, 2000, we proposed to designate critical habitat throughout the Peninsular Ranges in California (65 FR 41405). This recovery plan is prepared pursuant to section 4(f) of the Endangered Species Act, which requires us to give priority to the preparation and implementation of recovery plans to those species that are most likely to benefit from such recovery plans, particularly those that are, or may be, in conflict with construction or other development projects or other forms of economic activity.

1.2 *Bureau of Land Management*. Approximately 26 percent of bighorn sheep habitat in the Peninsular Ranges is on public lands administered by the Bureau of Land Management (Figure 4). This management was custodial in the Peninsular Ranges until implementation of the California Desert Conservation Area Plan began in 1980. Implementation of this plan included preparation of the Santa Rosa Mountains Habitat Management Plan (1980), McCain Valley Wildlife Habitat Management Plan (1984), and In-Ko-Pah Area of Critical Environmental Concern Management Plan (1988), which identified actions to be taken for the benefit of bighorn sheep in the Peninsular Ranges. From 1988 to the present, using Land and Water Conservation Fund dollars appropriated by Congress and taking advantage of land gifts from private individuals, the Bureau of Land Management acquired about 4,520 hectares (11,165 acres) of bighorn sheep habitat in the Peninsular Ranges, primarily in the Santa Rosa Mountains National Scenic Area. It should be noted that without the help of the Santa Rosa Mountains Conservancy, a group of private citizens concerned with conservation of the Santa Rosa Mountains, the Land and Water Conservation Funds might not have been made available for these purchases. Other conservation activities included:

- Installation of gap fencing to eliminate cattle grazing from steep terrain and from water sources in canyons;
- Reduction in grazing pressure on allotments;
- Closure of most routes of travel east of McCain Valley Road, except to private inholdings, to ranchers, and to Carrizo and Sacatone Overlooks;
- Designation of wilderness study areas and subsequent management for non-impairment of wilderness values;
- Designation of Jacumba, Carrizo Gorge, Coyote Mountains, Sawtooth Mountains, Fish Creek Mountains, and Santa Rosa Wilderness Areas by Congress, with attendant elimination of vehicular access;
- Tamarisk control efforts around water sources;
- Establishment of the Santa Rosa Mountains National Scenic Area Visitors Center to provide public education;

- Financial assistance to the Bighorn Institute during its formative years, as well as land transfer and lease under the Recreation and Public Purposes Act;
- Temporary closure to dogs on most lands in the Santa Rosa Mountains National Scenic Area; and
- Closure of roads into Dead Indian Canyon and Carrizo Canyon.

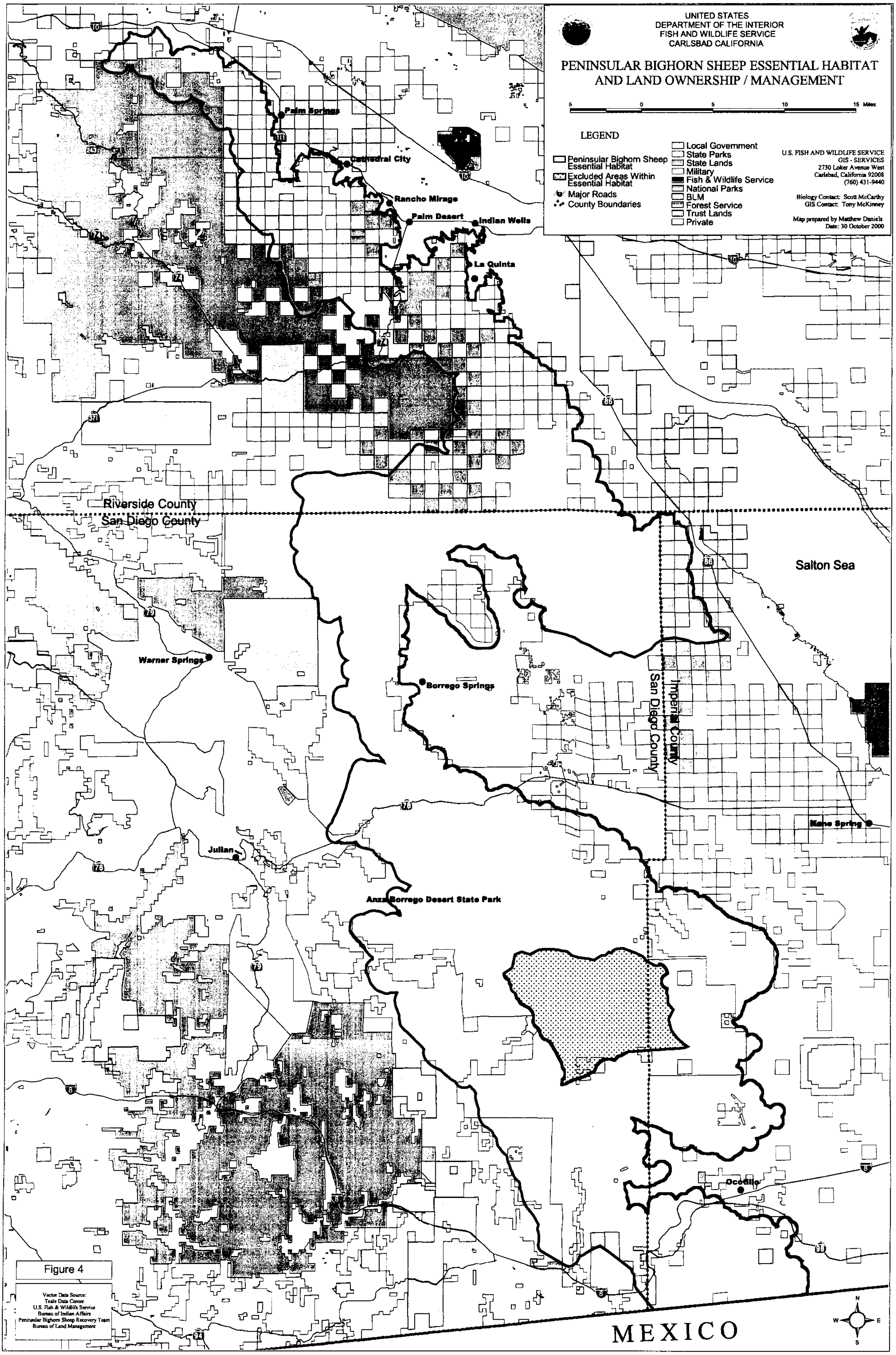
On October 25, 2000, legislation was signed to create the Santa Rosa and San Jacinto Mountains National Monument. The monument covers 110,000 hectares (272,000 acres), including lands administered by the Bureau of Land Management, U.S. Forest Service, California Department of Fish and Game, California Department of Parks and Recreation, Agua Caliente Band of Cahuilla Indians, Coachella Valley Conservancy, and private owners. The designation will prohibit mining and off-road vehicle use on federal lands, support coordinated land management by federal agencies, and increase the area's funding priority.

1.3 *U.S. Forest Service.* The San Bernardino National Forest is responsible for management of bighorn sheep habitat on some public lands. Approximately 3 percent of bighorn sheep habitat in the Peninsular Ranges is on U.S. Forest Service land (Figure 4). Since 1978, the Forest Service has acquired 3,107 hectares (7,680 acres) of land in or within 1.6 kilometers (1 mile) of Peninsular bighorn sheep range. Current management of the San Bernardino National Forest is guided by the Forest Land and Resource Management Plan (Forest Plan) established in 1989. Forest Plan standards and guidelines pertaining to Peninsular bighorn sheep include the following: "coordinate with Bureau of Land Management to manage the Santa Rosa bighorn sheep population in accordance with the (Santa Rosa Mountains Wildlife) habitat management plan"; "establish seasonal closures as necessary to protect important habitat"; "manage domestic sheep and goat grazing to prevent disease transfer to bighorn sheep [a minimum 3.2-kilometer (2-mile) buffer is recommended]"; and "avoid introducing barriers to movement of bighorn sheep." Recent proposed changes in management relative to Peninsular bighorn sheep are discussed in a programmatic Biological Assessment completed by the San Bernardino National Forest (January 27, 1999). This assessment evaluated all ongoing activities occurring in Peninsular bighorn sheep habitat within the San Bernardino National Forest. Specific actions that will be implemented include: 1) cattle will be removed from portions of allotments that overlap bighorn sheep habitat (Wellman allotment), 2) fences within and adjacent to bighorn sheep habitat will comply with specifications listed in section II.D.1.2 of this recovery plan, 3) a barrier will be constructed along the gated closure on Palm Canyon Drive (also known as Dunn Road) to reduce unauthorized vehicular use, and 4) guidelines for management of hiking, biking, and equestrian trails (*e.g.*, seasonal closures) will follow recommendations outlined in section II.D.1.2 of this recovery plan.

Additional actions recommended in the San Bernardino National Forest Biological Assessment include: 1) the Forest Service should not authorize forage use by domestic livestock where they currently do not graze in bighorn sheep habitat, 2) other existing grazing allotments on the San Jacinto Ranger District should not be converted from cattle to domestic sheep or goat use, and 3) the minimum buffer distance between domestic sheep grazing and bighorn sheep habitat should be increased from 3.2 kilometers (2 miles) (the current Forest Plan standard) to 14.5 kilometers (9 miles) throughout the Forest.

2. STATE AGENCIES

2.1 *California Department of Fish and Game.* To designate areas important to bighorn sheep conservation in the Santa Rosa Mountains, the Department of Fish and Game established a State Game Refuge pursuant to Fish and Game Code section 10837. State lands administered by the Department of Fish and Game total about 3 percent of bighorn habitat in the Peninsular Ranges (Figure 4). To further identify and implement management needs, the Department of Fish and Game coordinated with the Bureau of Land Management in the completion of the Santa Rosa Mountains Wildlife Habitat Management Plan (Bureau of Land Management 1980). Currently, the Department of Fish and Game's management activities for bighorn sheep are at the highest level in the State's history. Funds provided through the sale of Environmental License Plates and through the auction of special fund-raising permits have enabled the Department of Fish and Game to support a number of important research efforts concentrating primarily on population characteristics and the disease status of bighorn sheep. The Department of Fish and Game cooperates with several universities, agencies, and non-profit organizations in support of bighorn sheep research and conservation in California. Conservation goals for bighorn sheep, as published in the Statewide Plan for Bighorn Sheep (California Department of Fish and Game 1983), are as follows:


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
PENINSULAR BIGHORN SHEEP ESSENTIAL HABITAT AND LAND OWNERSHIP / MANAGEMENT
5 0 5 10 15 Miles
LEGEND
Peninsular Bighorn Sheep Essential Habitat
Excluded Areas Within Essential Habitat
Major Roads
County Boundaries
Local Government
State Parks
State Lands
Military
Fish & Wildlife Service
National Parks
BLM
Forest Service
Trust Lands
Private
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
2730 Loker Avenue West
Carlsbad, California 92008
(760) 431-9440
Biology Contact: Scott McCarthy
GIS Contact: Tony McKinney
Map prepared by Matthew Daniels
Date: 30 October 2000
Palm Springs
Cathedral City
Rancho Mirage
Palm Desert
Indian Wells
La Quinta
Riverside County
San Diego County
Salton Sea
Warner Springs
Borrego Springs
Imperial County
San Diego County
Kane Spring
Julian
Anza Borrego Desert State Park
Ocotillo
MEXICO
Figure 4
Vector Data Source:
Teale Data Center
U.S. Fish & Wildlife Service
Bureau of Indian Affairs
Peninsular Bighorn Sheep Recovery Team
Bureau of Land Management

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's Bighorn Sheep Management Program maintains an inventory of the distribution of bighorn sheep in California. This assessment of bighorn sheep populations has been conducted as part of a long-term management plan for mountain 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 re-colonization of vacant habitats, and the interagency coordination of land management. The program's definition of regional populations considers not only vegetative and geographic boundaries, but also man-made barriers that define distributions and 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 help evaluate the success or failure of management actions at a meaningful level. Further, this approach may help identify the "missing pieces of the puzzle" for optimizing future reintroduction and management efforts to ensure population viability.

Although a metapopulation approach is an important biological principle for long-term survival of bighorn sheep populations, it is equally important as a management concept that prioritizes regional coordination for bighorn sheep population and habitat management. For example, data regarding extinction and recolonization are limited, and the biological justification for considering some regions as true metapopulations is therefore incomplete. Nevertheless, given the need for regional management of bighorn sheep populations, metapopulations have been defined based on the best understanding of the regions. Several investigations have postulated the importance of population size and genetic diversity to the long-term viability of bighorn sheep populations.

California State law (Assembly Bill 560), which was enacted under an emergency provision in September 1999, allows control of mountain lions to protect threatened, endangered, fully protected, and candidate sheep species. In these cases, selective removal of lions is an alternative short-term emergency measure to facilitate recovery of vulnerable sheep populations, such as in the Peninsular Ranges (refer to section II.D.1.3).

2.2 *California Department of Parks and Recreation.* Two State parks are within the range of the Peninsular bighorn sheep: Anza-Borrego Desert State Park and Mount San Jacinto State Wilderness. Anza-Borrego Desert State Park comprises 243,000 hectares (600,000 acres) along the backbone of the Peninsular Ranges, encompassing approximately 47 percent of this species' existing habitat within the United States (Figure 4). The park also supports a majority of the rangewide sheep population (Rubin *et al.* 1998). Therefore, recovery of the species hinges greatly on the successful management of bighorn sheep habitat in this State park. Anza-Borrego Desert State Park has been actively involved in the conservation of bighorn sheep for 30 years (Table 9).

2.3 *Coachella Valley Mountains Conservancy.* The Conservancy was established by California State legislation in 1990 to "acquire and hold, in perpetual open space, mountainous lands surrounding the Coachella Valley and to provide for the public's enjoyment of and the enhancement of their recreational and educational experiences on those lands in a manner consistent with the protection of the lands and the resource values specified in Section 33500 [Public Resources Code]". The Conservancy has acquired either fee title or a conservation easement on 973 hectares (2,405 acres) in the San Jacinto and Santa Rosa Mountains, and has assisted other entities with additional acquisitions. The Conservancy is preparing the Coachella Valley Multiple Species Habitat Conservation Plan under contract to the Coachella Valley Association of Governments (refer to section I.E.3.2).

3. LOCAL ORGANIZATIONS AND AGENCIES

3.1 *Bighorn Institute.* The Bighorn Institute is a nonprofit, tax-exempt organization that was formed in 1982 to investigate the causes of bighorn sheep declines, particularly Peninsular bighorn sheep. The Institute is located in Riverside County, California, adjacent to the City of Palm Desert. Its facilities, which include an office, laboratory, staff residence, and pens for a captive breeding herd of Peninsular bighorn sheep, are located on 120 hectares (297 acres) of land at the base of the Santa Rosa Mountains.

The Institute began monitoring radio-collared bighorn sheep in the northern Santa Rosa Mountains and the San Jacinto Mountains in 1982 and 1992, respectively. Long-term studies of the population characteristics, distribution, reproductive success, nutrition, movements, and general ecology of these bighorn sheep are ongoing. In the spring of 1998, the Institute initiated a multi-year study of cause-specific mortality of radio-collared lambs in the northern Santa Rosa Mountains. The Bighorn Institute has conducted annual helicopter surveys of bighorn sheep in the Santa Rosa Mountains since 1982 and in the San Jacinto Mountains since 1987, and has also surveyed bighorn sheep throughout the Peninsular Ranges in Mexico. Since 1982, 39 sick lambs have been captured from the U.S. Peninsular Ranges for disease research and rehabilitation at the Institute. In 1985, the Institute began a Captive Breeding and Population Augmentation Program. Although this program began as a by-product of disease research on causes of low lamb survival (DeForge *et al.* 1982, DeForge and Scott 1982), in 1995 it was redirected as a formal captive breeding program with the primary goals of producing stock for augmenting and re-establishing wild populations, and conducting a research program in the Santa Rosa and San Jacinto Mountains. Captive bighorn are maintained in 12-hectare and 3-hectare enclosures encompassing rugged hilltops. Rams and ewes are selectively combined for the breeding season and the parentage of all captive-born animals is recorded. Captive animals are not available for public viewing and a standardized feeding and observation routine is used to limit exposure to humans (Ostermann *et al.* in press).

Before release, all bighorn are health-tested, eartagged, and fitted with mortality-sensing radiocollars. Within the northern Santa Rosa Mountains, bighorn have been released in Bradley Canyon (*n* equals 60), east Magnesia Canyon (*n* equals 6), and west Magnesia Canyon (*n* equals 8). Of the 74 captive-reared bighorn released into the northern Santa Rosa Mountains, 49 (22 males, 27 females) were captive-born and 25 (12 males, 13 females) were wild-born lambs brought into captivity for research and rehabilitation at 1 to 5 months of age (Ostermann *et al.*

Table 9. Past and present conservation activities in Anza-Borrego Desert State Park.

Year	Description of activities
1968	Field studies were conducted in Anza-Borrego as part of a statewide status report on bighorn sheep (Weaver 1972, 1975, 1989; Weaver *et al.* 1968; Weaver and Mensch 1970).
circa 1970	Construction of Blue Spring guzzler in Vallecito Mountains with the Society for the Conservation of Bighorn Sheep.
1971	The annual Anza-Borrego Bighorn Sheep Count began with about 25 volunteers. A waterhole count has been conducted every summer since this time and now involves about 75 volunteers counting 24 watering sites. Over 2,000 volunteers have donated over 60,000 hours to date.
1972-1975	Jorgensen and Turner (1973, 1975) conducted 4 summers of bighorn sheep research and documented over 100 water sources used by bighorn sheep. Russi (1978) continued this work in 1976.
1973-present	Tamarisk removed from riparian areas within bighorn sheep habitat to enhance water availability and native plant community regeneration. Currently, a Riparian Restoration Team works full time to remove tamarisk and other exotic plants. Approximately 208 kilometers (120 miles) of canyons and stream courses have been treated by the team to date.
1975	A seasonal closure of bighorn sheep watering areas in Coyote Canyon during June 15 to September 15 was implemented. This closure was expanded in 1996 from June 1 to October 1.
1982	A bighorn sheep guzzler was constructed in collaboration with California Department of Fish and Game at Limestone Spring in the Santa Rosa Mountains.
1982	163,085 hectares (403,000 acres) of Anza-Borrego Desert State Park were designated as State Wilderness Areas, setting aside a large area of bighorn sheep habitat from development or human disturbance.
1983-present	Park staff assisted in annual helicopter surveys of the entire Santa Rosa and San Jacinto Mountain ranges (DeForge *et al.* 1995, 1997).
1983-1992	Park staff assisted the Bighorn Institute with disease research.
1987	Feral cattle (117) were removed from bighorn sheep habitat by helicopter at a cost of $70,000, culminating 16 years of effort to remove domestic cattle from park lands.
1987	Six bighorn sheep guzzlers were constructed in the Vallecito Mountains to provide water where natural springs and streams had been usurped by human activity. Over 200 volunteers and $30,000 were used and expended respectively, in the project.

Table 9. Continued

1987-1988	Gap fencing [22.5 kilometers (14 miles)] was constructed in the upper elevations of the park to keep stray cattle from entering from neighboring lands. A special Senate appropriation ($200,000) was obtained for this project.
1992-present	Cooperated on Peninsular Ranges Bighorn Sheep Population Health Study with University of California (Davis) and the Zoological Society of San Diego.
1994-1998	Helicopter surveys were conducted in Anza-Borrego Desert State Park, in collaboration with the University of California - Davis and California Dept. of Fish and Game (Rubin *et al.* 1998,1999).
1995-1996	A 15-minute movie "The Bighorn of Anza-Borrego" was produced. This movie is seen by thousands of park visitors each season in the Anza-Borrego Visitor Center.
1996	The Coyote Canyon Public Use Plan was implemented, calling for the closure of Middle Willows and Upper Willows to motor vehicular traffic. This trail segment is 5 kilometers (3.1-miles) long.

in press). In 1997, three captive-reared ewes were released into Tahquitz Canyon in the San Jacinto Mountains. Two of these females were captive-born, and the third was a wild-born ewe captured as a lamb from the northern Santa Rosa Mountains (Ostermann and DeForge 1996, Bighorn Institute 1997).

3.2 *Coachella Valley Multiple Species Habitat Conservation Plan.* This ongoing planning effort is sponsored by the Coachella Valley Association of Governments, with the cooperation of the Fish and Wildlife Service and California Department of Fish and Game, and has been in preparation since 1996. Within the areas at issue in this plan, the Association's membership includes the County of Riverside and all nine cities in the Coachella Valley, as well as the Agua Caliente Band of Cahuilla Indians. Though the plan is not yet complete, it currently proposes to address the conservation needs of bighorn sheep. Lands in the San Jacinto and Santa Rosa Mountains set aside in the past and future by the cities and Riverside County as open space will provide important contributions to bighorn sheep recovery and completion of the habitat conservation plan if those lands are managed appropriately. If the plan is adopted, participating Federal, State, and local governments will cooperate in implementing an agreed upon conservation strategy for bighorn sheep and other species over a large area of the San Jacinto and Santa Rosa Mountains in Riverside County.

4. INDIAN TRIBES

4.1. *Agua Caliente Band of Cahuilla Indians.* The Agua Caliente Band of Cahuilla Indians (Tribe) is a federally recognized Indian Tribe whose reservation was established in 1876 by Executive Order. The Agua Caliente Indian Reservation encompasses 13,000 hectares (32,000 acres) of land in the western Coachella Valley and is encompassed within a checkerboard ownership pattern that supports a significant amount of bighorn sheep habitat.

The Tribe has a long and rich history of land stewardship, particularly in the foothills of the San Jacinto and Santa Rosa Mountain ranges. For decades, the Tribe has managed the area known as the Indian Canyons for cultural resource protection and use by the public as a Tribal park. Protection of the natural resources of the reservation and Indian Canyons has been the foremost priority of the Tribe and has been acknowledged by the Secretary of the Interior.

Currently, the Tribe is preparing a comprehensive Resource Management Plan for the reservation that will protect cultural, wetland, land use, and wildlife resources. The Tribe actively participates and holds seats on the Coachella Valley Association of Governments, Coachella Valley Mountains Conservancy, and Planning Advisory Group of the Coachella Valley Multiple Species Habitat Conservation Plan.

The Tribe's Planning and Environmental Department presently consists of 10 professionals and technicians who, at the direction of the Tribal Council, oversee all land management issues. The Tribal Resource Management Plan will address the management and protection of endangered species, including bighorn sheep. To the extent feasible, the Tribe intends to cooperate with interested and affected agencies who share in the implementation of this recovery plan.

4.2. *Torres-Martinez Desert Cahuilla Indians.* This federally recognized tribe supports approximately six sections (1,554 hectares or 3,840 acres) of bighorn habitat in the extreme southern Santa Rosa Mountains.

4.3. *Morongo Band of Mission Indians.* This federally recognized tribe supports one irregularly shaped section (about 280 hectares or 700 acres) of bighorn habitat at the extreme north end of the San Jacinto Mountains.

II. RECOVERY

A. CONSERVATION PRINCIPLES USED IN THIS RECOVERY PLAN

The following sections discuss general conservation principles in the context of our current knowledge regarding Peninsular bighorn sheep, and outline the relationship of these principles to the recovery criteria for this species. Conservation theory recognizes that population and genetic issues need to be addressed in species conservation (Lande 1988), although population threats pose a greater short-term risk to Peninsular bighorn sheep. The conservation of Peninsular bighorn sheep requires an understanding of habitat use, population dynamics, behavior, and spatial population structure, as well. Ecosystem protection provides an additional important tool in species conservation. The use of models in conservation decision-making for the recovery of bighorn sheep in the Peninsular Ranges also is discussed below.

1. POPULATION CONSIDERATIONS

Population parameters are important to the viability of all populations; however, they are an especially important consideration in the conservation of small populations (Gilpin and Soulé 1986). Variation in population parameters (birth, death, immigration, and emigration rates, as well as population age and sex structure) 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 has been an inadequate emphasis on factors related to population characteristics, and cautioned that for many wild populations, risks related to population parameters are of more immediate importance than genetic concerns.

The small number of Peninsular bighorn sheep (334 adults estimated in 1998) mandates that population dynamics be of concern in their conservation. Furthermore, Peninsular bighorn sheep occur in discrete ewe groups that have ecological significance relative to the genetic and distributional structure of the population (Rubin *et al.* 1998, Boyce *et al.* 1999), and therefore represent an important management and conservation unit (Bleich *et al.* 1996). The persistence of such subgroups are important to the viability of the entire population (Soulé 1987). Some of these groups include less than 20 ewes, making them highly vulnerable to chance variation in birth and death events. The high male to female sex ratio in the San Jacinto Mountains (DeForge *et al.* 1997) provides an example.

Because ewe groups are connected by movements of rams and rarer dispersal by ewes, Peninsular bighorn sheep are considered to comprise a metapopulation (Torres *et al.* 1994, Bleich *et al.* 1996, Boyce *et al.* 1997). Metapopulations typically are assumed to exist in a state of balance between population extinctions and colonizations (Hanski and Gilpin 1991). However, in the case of Peninsular bighorn sheep, the use of a metapopulation approach should not diminish the importance of individual ewe group viability for the following reasons. Bighorn sheep are relatively slow colonizers (Geist 1967, 1971; Bleich *et al.* 1996) and therefore metapopulation extinction-colonization processes would have to function over a very long time period. Recent abandonment of habitat and a lack of known colonizations suggest that Peninsular bighorn sheep comprise a "nonequilibrium metapopulation" (*i.e.*, extinctions are occurring at a faster rate than colonizations) (Harrison 1994, Hanski and Simberloff 1997). Hanski and Gilpin (1991) cautioned that such systems must be managed carefully because they may not necessarily function as a metapopulation. Therefore, extirpations of existing ewe groups should be avoided, while colonization of habitat should be promoted.

In the Peninsular Ranges, a variety of factors have reduced bighorn sheep numbers to levels where random variations in population characteristics and environmental factors have become serious threats. Therefore, this recovery effort should strive to increase the overall population of bighorn sheep by addressing and, where possible, reversing processes that caused the past population decline. This effort will entail implementing actions that increase the size of individual ewe groups by reducing mortality rates, increasing recruitment, and allowing inter-group movements to occur.

2. GENETIC CONSIDERATIONS

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). 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 when dealing with small populations because heterozygosity is lost (through the processes of founder effects, population bottlenecks, genetic drift, and the effects of inbreeding) more quickly in small populations than in large ones (Meffe and Carroll 1994). In the Peninsular Ranges, movement of males apparently has maintained gene flow between ewe groups, resulting in a relatively high level of genetic diversity (Boyce *et al.* 1997). However, increased habitat fragmentation could reduce the connectivity among groups. If ewe groups become isolated, they will face an increased risk of losing genetic variability in addition to vulnerability to natural random fluctuations in the population.

Even if gene flow is maintained among ewe groups in the Peninsular Ranges, the overall population size (approximately 334 adults) is small enough to cause concern. The effective population size (N_e) (Crow and Kimura 1970), which determines the rate at which heterozygosity is lost, is even smaller than the census size. An effective population size of 500 individuals has been suggested as the minimum recommended for maintenance of genetic variation for future evolutionary change (Franklin 1980, Lande and Barrowclough 1987, Franklin and Frankham 1998), while Lande (1995) suggested that this number should be even higher. The current census size of Peninsular bighorn sheep falls far below even the lower recommendation. Because reduced population levels may place Peninsular bighorn sheep at risk, important goals of this recovery effort are to increase the abundance of Peninsular bighorn sheep and maintain as much genetic variation as possible. This recovery plan recommends maintenance of connectivity with populations in Baja California and it may be deemed appropriate in the future to recreate connectivity or induce gene migration with the Mojave Desert metapopulation.

Although the observed genetic variation among ewe groups in the Peninsular Ranges is not known to confer adaptive advantage to 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). In Peninsular bighorn sheep, as in many taxa, genetic variation is partitioned among and within subunits or ewe groups (Meffe and Carroll 1994, Boyce *et al.* 1999, refer to section I.A.3). Although there is no evidence to suggest that bighorn sheep in the Peninsular Ranges lack genetic diversity, a conservative approach to genetic conservation suggests that recovery tasks should recognize and attempt to preserve existing genetic structure whenever possible. This approach will require preservation of multiple ewe groups, maintenance of movement opportunities between groups (Schwartz *et al.* 1986), and judicious protocols for population augmentation, reintroduction, and captive breeding programs (Ryman and Laikre 1991, Elliott and Boyce 1992, see Appendix C). Because the major problems facing bighorn sheep in the Peninsular Ranges relate to population dynamics and viability, genetic theory should not over-ride management objectives to maintain and expand the number and size of ewe groups throughout the Peninsular Ranges. This objective can be accomplished by selecting augmentation and reintroduction stock from the closest available populations (Wehausen 1991, Ramey 1993, Wehausen and Ramey 1993, Gutierrez-Espeleta *et al.* 1998).

3. ECOSYSTEM PROTECTION

Loss of habitat is recognized as the leading 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 bighorn sheep populations (Bleich *et al.* 1996). The potentially negative impacts that habitat loss and degradation have on bighorn sheep are presented in section I.D. Although habitat loss may not directly cause mortality in bighorn sheep, loss of important resources (*e.g.*, water, forage, escape terrain, lambing areas, movement linkages) ultimately reduces carrying capacity, which can affect survival and recruitment rates. In some cases, the cause of death may be documented as disease, malnutrition, or predation, etc., when in fact habitat loss was the underlying cause that resulted in death. In addition, altered land uses that support larger human populations introduce increased levels of anthropogenic disturbance in adjoining habitat. The decline or extirpation of bighorn populations near other metropolitan areas such as Tucson near the Santa Catalina Mountains and Albuquerque near the Sandia Mountains (Krausman *et al.* in prep.), provide case history examples of apparent vulnerability of bighorn to urban influences. This recovery plan will attempt to avoid repeating these scenarios, and accordingly adopts the approach of conserving the larger ecosystem upon which bighorn sheep in the Peninsular Ranges depend, as afforded under section 2(b) of the Endangered Species Act.

Such an ecosystem approach also will benefit numerous other common and uncommon species.

4. THE USE OF POPULATION MODELS TO HELP GUIDE RECOVERY ACTIONS

Models have become an important tool to scientists attempting to understand complex processes because intuition is often not reliable (National Research Council 1995). Conservation biologists frequently use models to gain a better understanding of the many interacting factors (environmental, population, and genetic) that place a species or population at risk. The comprehensive modeling of these factors was christened "population vulnerability analysis" by Gilpin and Soulé (1986). Typically, the goal of a population vulnerability or "viability" analysis is to evaluate the risk of extinction, either in terms of estimated time to extinction or the probability of extinction in a given time interval (Boyce 1992). As such, a population viability analysis is similar, in concept, to risk analyses used to understand issues of public health and safety (Ginzburg *et al.* 1982).

Population viability analyses, like other forms of risk analysis, contain a degree of uncertainty because they attempt to determine the likelihood of future events based on past and present patterns (of population dynamics, environmental conditions, etc.). All models are inherently dependent on underlying assumptions (Starfield and Bleloch 1991) and on the quality of data entered into the model. Therefore, the results of a population viability analysis must be interpreted with caution (Caughley 1994, Beissinger and Westphal 1998). Inclusive population viability analyses may not be appropriate when data are limited (Beissinger and Westphal 1998). This limitation does not mean that the use of models should be discouraged (Akçakaya and Burgman 1995, Starfield 1997, Beissinger and Westphal 1998).

An additional role of modeling in conservation biology is as a decision making tool (Starfield and Bleloch 1991, Walsh 1995, Starfield 1997). Models can be used to compare the relative effects (rather than the absolute outcome) of alternative management strategies or environmental scenarios (Starfield and Bleloch 1991, National Research Council 1995, Walsh 1995, Starfield 1997, Beissinger and Westphal 1998) and can help guide management strategies or focus future research efforts. Smaller, focused models have great potential in guiding conservation decisions (Starfield and Bleloch 1991, Starfield 1997). Use of modeling can help to elucidate several issues related to the recovery of Peninsular bighorn sheep (refer to section II.D.2.2). Models should be designed to ask specific questions (Starfield 1997) that increase our understanding of the ecological processes in the Peninsular Ranges, and should be coupled with field studies of the bighorn sheep (Beissinger and Westphal 1998). It may be useful to simulate shorter time periods, as well as the 100 to 200 year intervals typically used in population viability analyses, so that model predictions (as well as model assumptions) can be evaluated with the use of field study results (Beissinger and Westphal 1998). This type of approach will allow conservation biologists to learn from the models and field studies, and will allow conservation efforts to be adaptive (Minta and Kareiva 1994).

B. OBJECTIVES AND CRITERIA

1. RECOVERY OBJECTIVE

The ultimate objective of this recovery plan is to protect and maintain sufficient individuals and habitat of bighorn sheep in the Peninsular Ranges to eventually delist this species. The recovery of Peninsular bighorn sheep will involve a two-stage process, beginning with an interim goal of downlisting of the species from endangered to threatened status, followed by long-term recovery and removal of threatened status. As new information becomes available, the downlisting and delisting criteria may warrant modification through future revisions to the recovery plan.

2. DOWNLISTING CRITERIA

As an interim management goal, Peninsular bighorn sheep may be considered for downlisting (reclassification to threatened status) when all of the following objective, measurable criteria are met:

> *Downlisting Criterion 1*: As determined by a scientifically credible monitoring plan, at least 25 adult ewes are present in each of the following 9 geographic regions (Figure 5) during each of 6 consecutive years

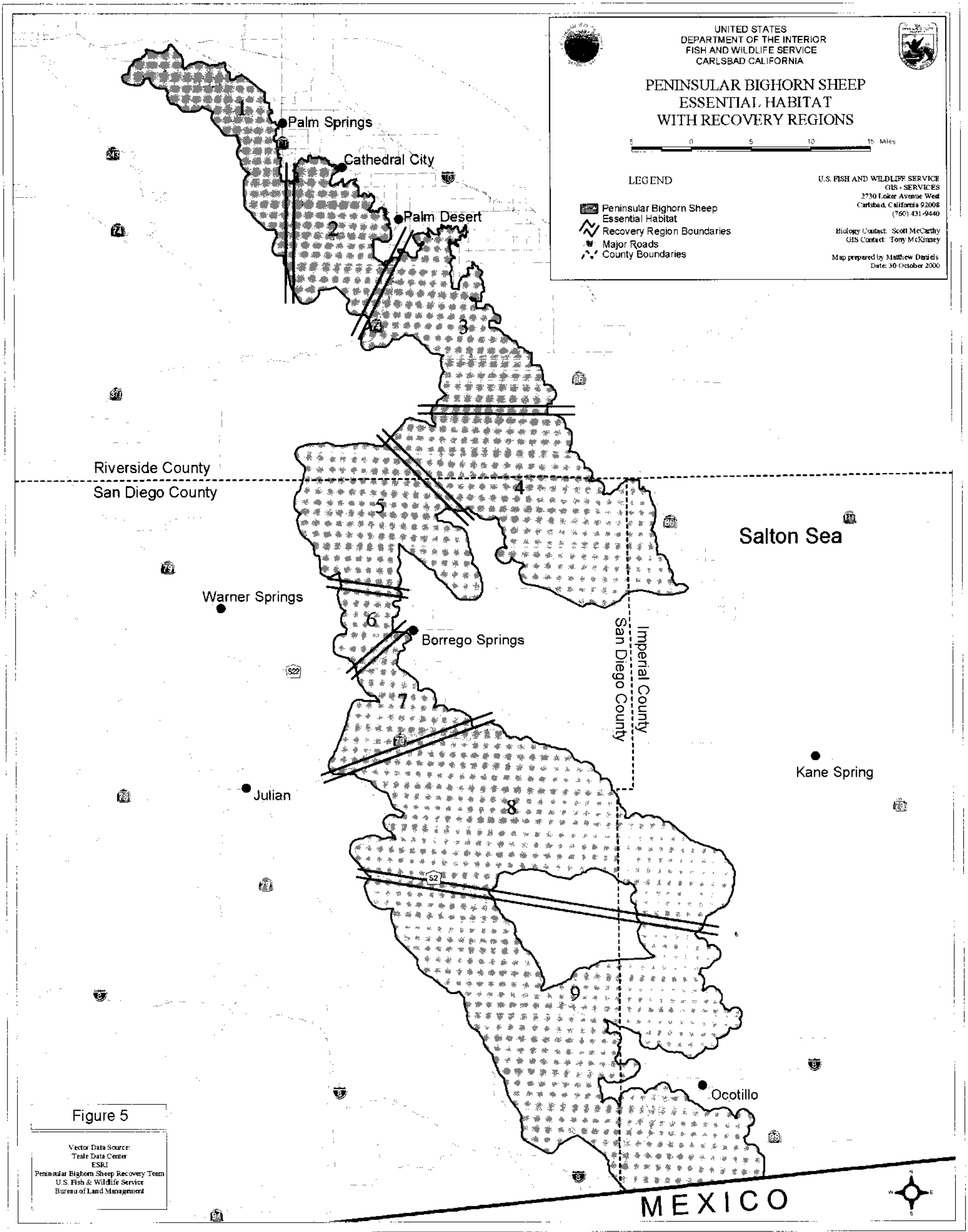


Figure 5

Vector Data Source:
Teale Data Center
ESRI
Peninsular Bighorn Sheep Recovery Team
U.S. Fish & Wildlife Service
Bureau of Land Management

(equivalent to approximately one bighorn sheep generation), without continued population augmentation:

1. San Jacinto Mountains
2. Santa Rosa Mountains--North of Highway 74
3. Santa Rosa Mountains--South of Highway 74 through Martinez Canyon
4. Santa Rosa Mountains--South of Martinez Canyon
5. Coyote Canyon
6. North San Ysidro Mountains (Henderson Canyon to County Road S-22)
7. South San Ysidro Mountains (County Road S-22 to State Highway 78)
8. Vallecito Mountains
9. Carrizo Canyon/Tierra Blanca Mountains/Coyote Mountains Area

Justification: The nine regions were selected on the basis of maintaining: (1) historical distribution, (2) home range herd memory, and (3) connectivity among ewe groups to facilitate re-colonization in the event of localized extirpations. Recovery Team members with knowledge of current and historical conditions judged that each area was capable of supporting at least 25 ewes with associated subadults and rams. Within each of the nine regions, fluctuation in the number of ewe groups, including re-colonization of former habitats, is expected under the metapopulation model. As such, ewe groups may merge, split, and redistribute themselves over time. Although the 9 areas support respective carrying capacities well in excess of 25 adult ewes, a downlisting objective based on maximum attainable population size was not selected because static population levels at full range capacity cannot be maintained in naturally variable environments, even assuming intensive management capability. The minimum group size of 25 adult females was selected by Recovery Team consensus because it:

1. would reduce risk of extirpation from random naturally occurring events to an acceptable level;

2. should be achievable with prudent, population and land management practices;
3. is consistent with management objectives for bighorn sheep in other metapopulations;
4. should maintain ewe group knowledge of a large home range that will minimize the extent of geographic gaps between ewe groups, thereby facilitating interchange of genes and populations within the metapopulation;
5. falls well within known or estimated historical population levels; and
6. should provide, in all but the most catastrophic scenarios, sufficient time for management intervention to prevent extirpation.

Downlisting Criterion 2: Regulatory mechanisms and land management commitments have been established that provide for long-term protection of Peninsular bighorn sheep and all essential habitat as described in section II.D.1 of this plan.

Justification: Given the major threat of fragmentation to species with metapopulation structures, connectivity among all portions of habitat must be established and assured through land management commitments, such that bighorn sheep are able to move freely throughout all habitat. In preparation for delisting, protection by means other than the Endangered Species Act must be assured. Such protection should include alternative regulatory mechanisms by Federal, State, and local governments, and land management commitments that would provide the protection needed for continued population stability.

3. DELISTING CRITERIA

As a long-term management goal of the Peninsular bighorn sheep, three delisting criteria are proposed;

Delisting Criterion 1: As determined by a scientifically credible monitoring plan, at least 25 ewes must be present in each of the 9 regions (Figure 5) listed under Downlisting Criterion #1 above, during each of 12 consecutive years (approximately 2 bighorn sheep generations), including the 6 years under Downlisting Criterion #1, without continued population augmentation.

Delisting Criterion 2: The rangewide population must average 750 individuals (adults and yearlings) with a stable or increasing population trend over 12 consecutive years (same time period as Delisting Criterion #1 above).

Justification: Recovery Team members with knowledge of historic and current population levels evaluated the condition of existing habitat and determined a carrying capacity of approximately 1,000 bighorn sheep in the Peninsular Ranges, which approaches historical population estimates. The required 12-year average population estimate of 750 animals is based on the assumption that achieving the objectives in Downlisting Criterion #1 of at least 25 females in each of the 9 geographic areas likely will result in some areas supporting substantially more than 25 ewes and other sheep. This scenario likely will result in an overall metapopulation size that fluctuates between 600 and 1,000 sheep, averaging about 750 sheep with a normal sex ratio, or approximately 75 percent of estimated carrying capacity. An average population level would allow for natural population fluctuations in a random environment and is believed to be reasonably attainable assuming implementation of the management measures prescribed in this recovery plan.

Delisting Criterion 3: Regulatory mechanisms and land management commitments have been established that provide for long-term protection of Peninsular bighorn sheep and all essential habitat as described in section II.D.1 of this recovery plan. Protection considered long-term can be provided through appropriate institutional practices, such as State Park General Plans, an amended California Desert Conservation Act Plan, an amended Forest Plan, a completed Coachella Valley Multispecies Habitat Conservation Plan, and natural resource management plans on Tribal lands. In addition, connectivity among all portions of habitat must be established and assured through land management commitments such that bighorn sheep are able to move freely throughout the Peninsular Ranges. Delisting would result in loss of protection under the Endangered Species Act; therefore continued protection by other means must be assured.

Justification: This protection should include alternative regulatory mechanisms, land management commitments, or conservation programs that would provide the long-term protection needed for continued population viability.

Recovery of Peninsular bighorn sheep likely will take several decades or longer due to a low reproductive rate (*e.g.*, only one offspring per female per year and reproduction starting usually at 2 years of age). The above criteria will be revised as necessary through a recovery plan amendment or revision if new information becomes available, or if these criteria no longer pass scientific muster or otherwise meet the conservation needs of this species based on the best available information.

C. RECOVERY STRATEGY

This recovery plan describes a strategy to recover and delist bighorn sheep in the Peninsular Ranges. The strategy consists of taking necessary actions to: (1) improve population variables (reproduction, recruitment, survivorship), and (2) secure and effectively manage habitat, including linkages between ewe group home ranges. The recovery actions to implement this strategy are organized in the narrative outline below. This recovery strategy is a synthesis of knowledge accumulated on bighorn sheep in desert environments and elsewhere in North America. Four biological principles of bighorn biology are evident from past research and have been incorporated into management guidelines by various agencies (*e.g.*, McQuivey 1978, Wilson *et al.* 1980, Smith and Krausman 1988, Bureau of Land Management 1996, New Mexico Department of Game and Fish 1995):

1. Bighorn sheep are wide-ranging animals that are spatially dependent on large tracts of habitat that provide a diversity of resources needed to offset seasonal, annual, and longer term cycles of environmental variability and scarcity;

2. Metapopulation structure requires habitat contiguity between/among constituent demes (ewe groups) to allow for long-term shifts in distribution and genetic interchange;

3. Bighorn sheep appear to lack natural or acquired resistance to some diseases and remain highly vulnerable to diseases introduced by domestic sheep; and

4. Behavioral responses to human-related activities can be variable among individuals and populations, which can adversely affect habitat use patterns and population persistence.

In the short term, acquisition and conservation of the relatively narrow band of habitat that still remains is crucial to attaining the population recovery and delisting objectives of this recovery plan. Given the: (1) inability of bighorn sheep to use higher elevation habitats because of excessive shrub and tree cover, (2) incompatible land uses that have encroached into habitat along the lower elevational slopes of the Peninsular Ranges, and (3) pervasive influence of human activities throughout bighorn habitat, the future of bighorn sheep in the Peninsular Ranges will depend on rapid and adequate protection of lower elevational areas that provide critical resources, such as foraging, watering, lambing, and rearing habitats. Short-term management actions to increase population recruitment and adult survivorship are also necessary to effect population increase.

Past studies on bighorn sheep in desert and mountain environments have amassed a wealth of applicable knowledge that guides the management prescriptions of this recovery plan. Much of this work applies to bighorn sheep in general and, therefore, need not be reexamined through further research in the Peninsular Ranges. The monitoring and research tasks recommended in this recovery plan are intended to address the longer-term, more complex environmental relationships that have posed management difficulties in the past. These tasks will require substantial investment by numerous partners if they are to be successfully accomplished. However, only through such a cooperative effort will it be likely that the knowledge requirements for effective management be met.

The success of this recovery plan will also depend on strong education and public awareness programs. A number of recovery actions outlined in this plan will directly affect the general public. Therefore, the general public needs information and outreach on proposed actions being taken, especially in localized areas of action. Programs that include comprehensive and accurate facts about the ecology of Peninsular bighorn sheep and the threats that face them, will be crucial to obtaining public support for conservation measures.

D. NARRATIVE OUTLINE FOR RECOVERY ACTIONS ADDRESSING THREATS

Recovery actions are first described in general below, and then are identified as site-specific tasks, with reference to their appropriate recovery regions, in section II.E. The following tasks consist of interim and long-term management goals and activities that range from single event actions or studies to continuous efforts extending across the entire recovery implementation time line. The task descriptions and the implementation schedule (Part III of this recovery plan) help frame the duration of the respective goals/actions and responsible entities for taking the lead or assisting others in implementation responsibilities.

1. PROMOTE POPULATION INCREASE AND PROTECT HABITAT

1.1 *Protect, acquire, enhance, and restore habitat.* The historic range of Peninsular bighorn sheep has been adversely affected by urban development, agriculture, mining activities, and highways that have led to the destruction, modification, and fragmentation of habitat. Further development can be expected in the future. As pointed out in section I.D of this recovery plan, the viability and, therefore, the recovery of Peninsular bighorn sheep are critically dependent on availability of habitat. Consequently, an important part of this recovery effort is the protection and restoration of remaining habitat essential to Peninsular bighorn sheep conservation.

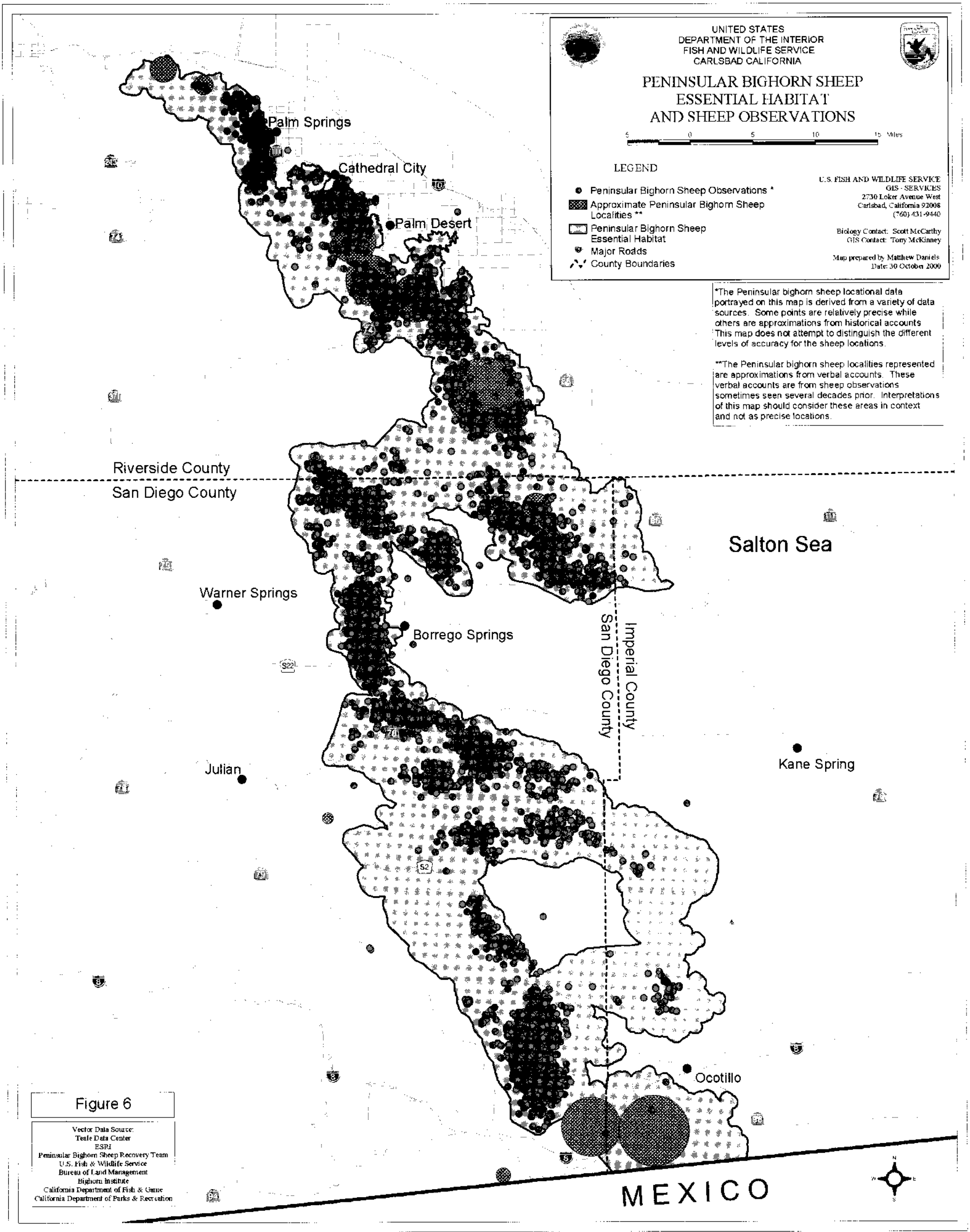
1.1.1 *Protect essential habitat.* Essential habitat is that habitat believed necessary for recovery and should, therefore, be protected from further loss or degradation (Figures 2, 4-9). It is likely that the valley floor to the east and the north of the Peninsular Ranges (*e.g.*, Coachella Valley, Imperial Valley) historically was used by bighorn sheep, for example during long-distance moves to and from other mountain ranges. Exposure to the hazards of high density urban development, major freeways, fences, agriculture, and canals, now would be considered detrimental to bighorn sheep recovery. Therefore, the vast majority of the valley floor to the east of the Peninsular Ranges is not considered essential habitat.

Consequently, "essential habitat" comprises those areas believed to be necessary for a self-sustaining bighorn population with a high probability for long-term survival (recovery) in the Peninsular Ranges of the United States. Essential habitat, therefore, consists of those physical and biological resources (space, food, water, cover) needed for: (1) normal behavior and protection from disturbance, and (2) individual/population growth and movement, including dispersal necessary to support a future population expansion to meet the recovery objective (delisting criteria of approximately 750 animals).

Much of the historical range of the sheep is needed to sustain the larger population levels necessary for recovery because:

a. Habitat may be colonized and inhabited by future ewe groups (Bleich *et al.* 1996), if, for instance, population spatial structure or environmental conditions change, or the population grows as a result of recovery actions. The long-term persistence of a metapopulation depends on the number of habitat patches that are available for colonization (Hanski 1989). An important phenomenon, which is not intuitively obvious, is that destruction of only a fraction of available habitat can drive a metapopulation to extinction by disrupting the balance between colonization and extinction rates (May 1991). Even locally abundant species can sometimes be very close to extinction if the proportion of suitable habitat is near the extinction threshold (Lande 1987).

b. Movement throughout the range is needed to sustain the metapopulation (Bleich *et al.* 1990a).


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
PENINSULAR BIGHORN SHEEP
ESSENTIAL HABITAT
AND SHEEP OBSERVATIONS
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LEGEND
Peninsular Bighorn Sheep Observations *
Approximate Peninsular Bighorn Sheep Localities **
Peninsular Bighorn Sheep Essential Habitat
Major Roads
County Boundaries
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
2730 Loker Avenue West
Carlsbad, California 92008
(760) 431-9440
Biology Contact: Scott McCarthy
GIS Contact: Tony McKinney
Map prepared by Matthew Daniels
Date: 30 October 2000
*The Peninsular bighorn sheep locational data portrayed on this map is derived from a variety of data sources. Some points are relatively precise while others are approximations from historical accounts. This map does not attempt to distinguish the different levels of accuracy for the sheep locations.
**The Peninsular bighorn sheep localities represented are approximations from verbal accounts. These verbal accounts are from sheep observations sometimes seen several decades prior. Interpretations of this map should consider these areas in context and not as precise locations.
Palm Springs
Cathedral City
Palm Desert
Riverside County
San Diego County
Salton Sea
Warner Springs
Borrego Springs
Imperial County
San Diego County
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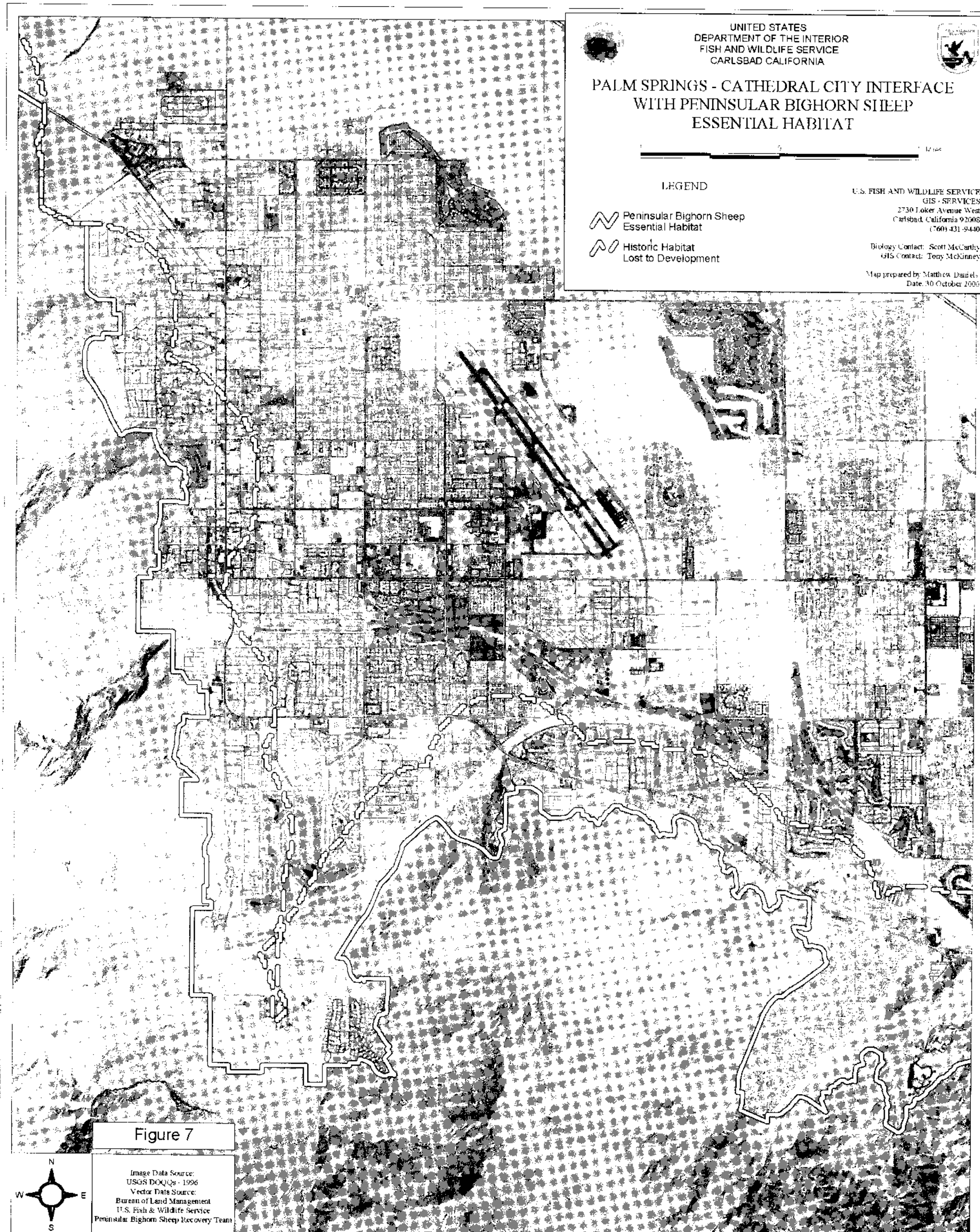
U.S. Fish & Wildlife Service
Bureau of Land Management
Bighorn Institute
California Department of Fish & Game
California Department of Parks & Recreation

Figure 6


UNITED STATES
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FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
PALM SPRINGS - CATHEDRAL CITY INTERFACE
WITH PENINSULAR BIGHORN SHEEP
ESSENTIAL HABITAT
LEGEND
Peninsular Bighorn Sheep
Essential Habitat
Historic Habitat
Lost to Development
U.S. FISH AND WILDLIFE SERVICE
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Map prepared by Matthew Daniels
Date: 30 October 2000
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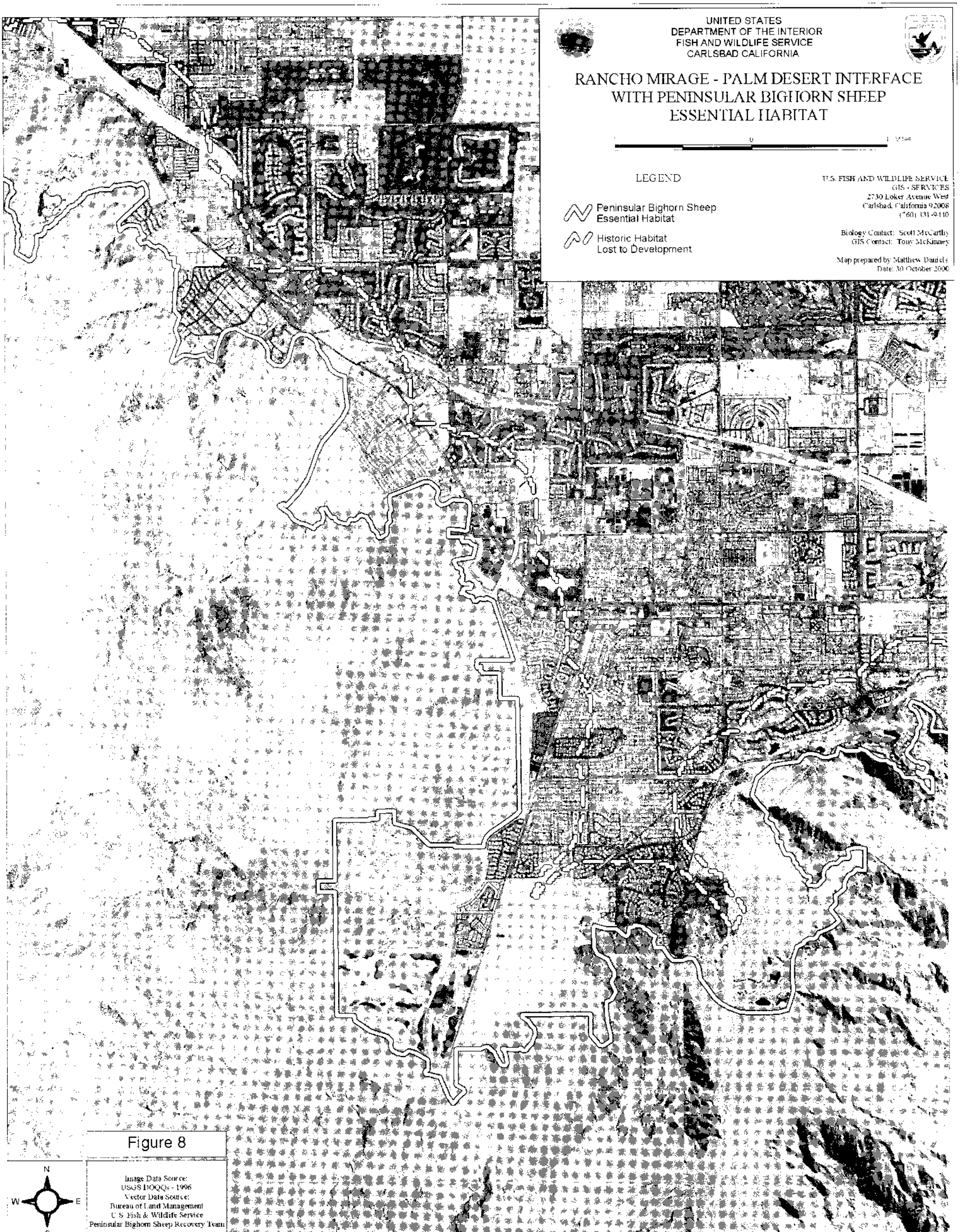
Image Data Source:
USGS DOQQs - 1996
Vector Data Source:
Bureau of Land Management
U.S. Fish & Wildlife Service
Peninsular Bighorn Sheep Recovery Team

Figure 7



UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
RANCHO MIRAGE - PALM DESERT INTERFACE
WITH PENINSULAR BIGHORN SHEEP
ESSENTIAL HABITAT
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Essential Habitat
Historic Habitat
Lost to Development
U.S. FISH AND WILDLIFE SERVICE
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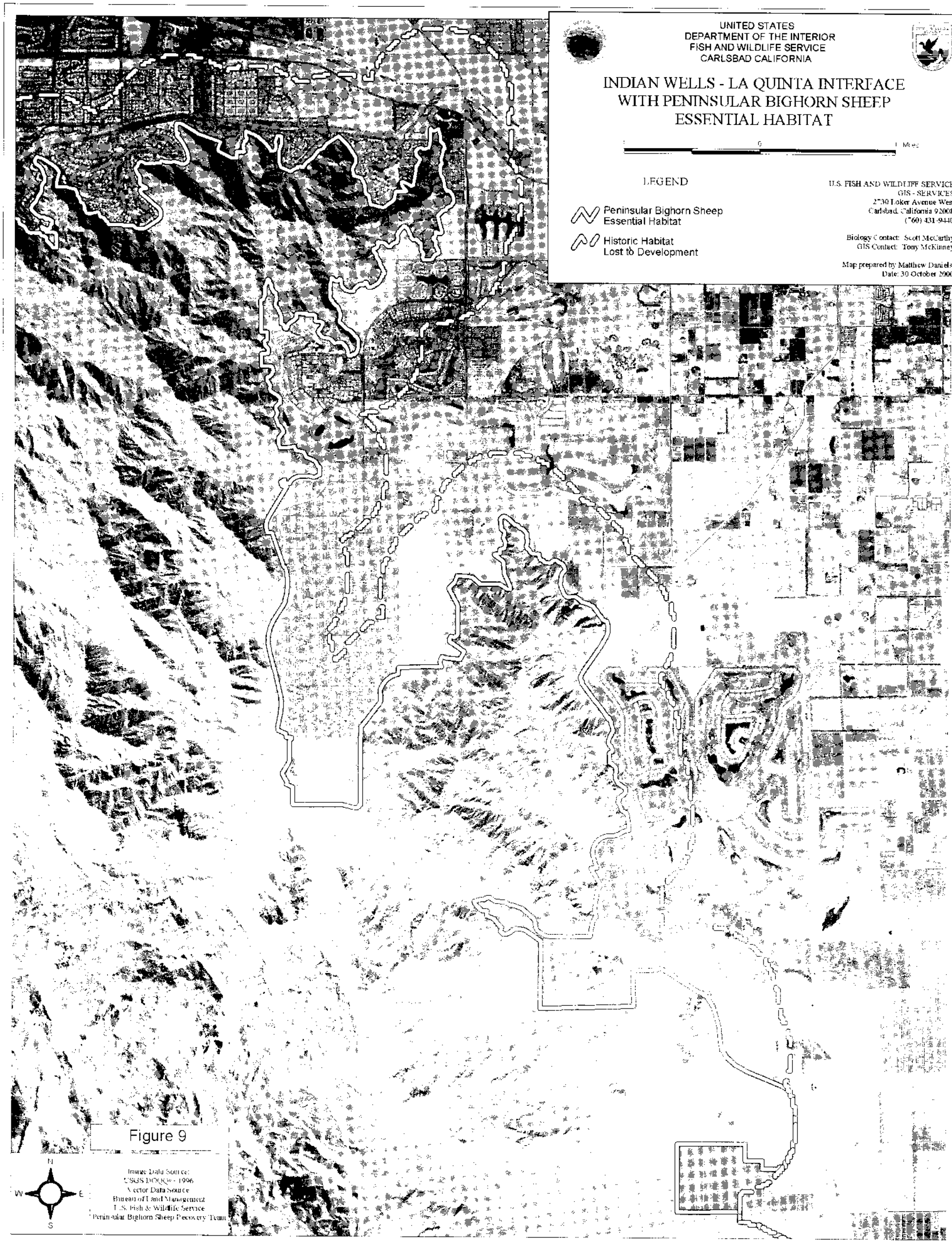
U.S. Fish & Wildlife Service
Peninsular Bighorn Sheep Recovery Team

Figure 8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DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
INDIAN WELLS - LA QUINTA INTERFACE
WITH PENINSULAR BIGHORN SHEEP
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Peninsular Bighorn Sheep Essential Habitat
Historic Habitat Lost to Development
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Image Data Source:
USGS DOQQ's - 1996
Vector Data Source
Bureau of Land Management
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Peninsular Bighorn Sheep Recovery Team

Figure 9

c. The factors limiting the viability of Peninsular bighorn sheep are not yet fully understood and, in general, bighorn sheep habitat use and selection need to be more thoroughly examined (McCarty and Bailey 1994). It is therefore necessary to protect all remaining suitable habitat.

d. The habitat of Peninsular bighorn sheep is restricted to a narrow band along the base of the Peninsular Ranges, from the San Jacinto Mountains south to Mexico. In some areas, this band is less than 6 kilometers (4 miles) wide, so essentially no true "core" habitat exists. Without protection, connectivity could be severed at any point along this narrow band of habitat.

e. Habitat near the eastern edge of this band often coincides with alluvial fans and canyon washes, which provide Peninsular bighorn sheep with important resources (refer to section I.B.1).

f. Unpredictable changes in global climate warrant retention of future options in habitat conservation strategies.

The delineation of essential habitat was based on habitat features known to be important to bighorn sheep, rather than being based solely on current use patterns, because population numbers currently are low and use patterns are known only for a recent short time period. In addition, data collected on radio-collared animals (a sample of the entire population) represent a subset of the total area used. Methods used to delineate essential habitat are outlined in Appendix B. Compiling historical data and conducting recommended ecological research will further understanding of how bighorn sheep use available habitat. See Figures 2, 4-9 for maps of essential habitat.

1.1.2. *Secure habitat.* Bighorn sheep habitat that is currently in private ownership should be secured (*e.g.*, purchased or acquired by exchange on a voluntary basis) by State or Federal agencies and managed compatibly through individual or regional habitat conservation plans or programs (*e.g.*, Coachella Valley Multispecies Habitat Conservation Plan, which will delineate these lands in its planning area), so that proper protection, management, and restoration measures can be implemented. Interagency conservation plans or other potential agreements made with local governments and private land owners should assure: (1) long-term protection of lands under city and county jurisdiction, and (2) appropriate land uses adjoining bighorn sheep habitat to prevent indirect effects from degrading habitat value. Limited funds for land acquisition will require prioritizing parcels; the value of each tract of land should be evaluated according to the following criteria, although not necessarily in the order listed below:

a. At the level of individual ewe groups: how important is this land in supporting a ewe group in this area?

b. Does this land include particularly important resources (*e.g.*, water sources, escape terrain, habitat for lambing, or important forage resources) for the bighorn sheep?

c. Does this land represent important habitat for movement and dispersal necessary for connectivity among ewe groups throughout the Peninsular Ranges?

d. Has this ewe group already experienced habitat loss?

e. Would acquisition of this land reduce the cumulative negative effects of urban growth?

f. Is the habitat imminently threatened?

A list of prioritized parcels should be prepared and updated annually by land management agencies (Bureau of Land Management, U.S. Forest Service, California Department of Fish and Game, Anza-Borrego Desert State Park, Coachella Valley Mountains Conservancy) to facilitate acquisition when opportunities arise. Methods to facilitate public and private cooperation should be pursued, such as: (1) development of land use planning guidelines (*e.g.* the Coachella Valley Multiple Species Habitat Conservation Plan, conservation guidelines in Appendix F), (2) development of a public education and outreach program (refer to II.D.3), and (3) development of supporting maps that better identify and explain bighorn sheep ecology and conservation requirements.

1.1.3 *Maintain, manage, and restore habitat quality and connectivity.* As mentioned in section I.D. of this recovery plan, the recovery of Peninsular bighorn sheep is dependent on the existence of adequate habitat. Maintenance, management, and restoration of essential habitat will allow for geographic expansion when population numbers increase. The ability of bighorn sheep to move freely throughout all parts of the range is critical to recovery because it: (1) facilitates exchange of genes between ewe groups, (2) allows habitat colonization, and (3) allows selection of alternative habitat in response to predation pressure or temporary changes in habitat quality (Schwartz *et al.* 1986, Bleich *et al.* 1996) or human-related disturbance. Shifts in habitat use occur more readily within existing ewe group home ranges but home range boundaries themselves also can change, albeit less frequently and more slowly over time. Therefore, in addition to protection of designated essential habitat, the following measures should be taken to restore and maintain habitat quality and to assure connectivity throughout the range:

1.1.3.1 *Remove exotic vegetation and prevent further invasion by exotic plants.* This item refers primarily to control of tamarisk (*Tamarix* species) along stream courses but also applies to other species such as fountain grass (*Pennisetum setaceum*) in select regions. Additional funding should be secured to continue and expand current tamarisk removal programs throughout the Peninsular Ranges. These programs should include, or be coordinated with, efforts to eradicate tamarisk outside of bighorn sheep habitat, as this will reduce future invasion into bighorn sheep habitat. Tamarisk eradication, such as at Thousand Palms Oasis, can result in immediate reappearance of surface water (Barrows 1994), which can help expand sheep distribution.

1.1.3.2 *Reduce or eliminate wild horse populations from bighorn sheep habitat.* Though burros and goats are currently absent, they also should be eliminated if they become established. The reduction or removal of non-native ungulates would: (1) eliminate potential sources of competition, (2) reduce potential destruction of water sources and vegetation, and (3) benefit other riparian dependant wildlife, such as least Bell's vireo and southwestern willow flycatcher. The involved State and Federal agencies, along with the Agua Caliente Band of Cahuilla Indians, should determine whether wild horse management in Coyote Canyon (Anza-Borrego Desert State Park) and Palm Canyon is consistent with bighorn recovery objectives in these areas. Any continuation of feral horse grazing should be contingent upon the demonstrated ability to implement an effective management and monitoring program to ensure against: (1) the possibility of competition with sheep for food and water, (2) trespass onto other land ownerships, and (3) risks to public safety.

1.1.3.3 *Implement a fire management plan that recognizes fire as a natural disturbance in fire-adapted habitats of the Peninsular Ranges ecosystem and as a process that helps maintain bighorn sheep habitat.* A wildland fire policy should establish fire management areas for natural and management ignited prescribed fires. Further research on the use of fire as a management tool should help guide such a plan (Smith and Krausman 1988, Krausman *et al.* 1996;

and refer to section II.D.2.3). However, fire can represent a serious threat to bighorn habitat quality in Sonoran scrub plant communities, which unlike chaparral are not well adapted to fire disturbance.

1.1.3.4 *Maintain existing water sources and consider providing additional sources on public lands if water is thought to be a limiting factor in particular areas.* Water development should be incorporated into research that investigates the effect that the addition of water has on bighorn sheep and other species (refer to section II.D.2).

1.1.3.5 *Maintain and re-establish connectivity throughout all habitat.* Barriers to movement (roads, fences, increased use of off-road vehicle areas, renewed railroad activity) should be prevented. Potential bighorn sheep crossing areas should be identified and bridged or tunneled to attempt reestablishing connectivity. Typical culverts are not adequate because bighorn sheep are not known to move through dark tunnels. Existing roads appear to represent barriers between four current ewe groups (Rubin *et al.* 1998); solutions to promote connectivity should be attempted. Another important recovery goal is to reestablish connectivity to habitat south of Interstate 8 and, ultimately, to Mexico. This task will require the cooperation of the California Department of Transportation to incorporate bighorn sheep movement opportunities into their future construction plans. Coordination with Border Patrol and the Mexican government will be needed to control human disturbance and the threat of disease transmission from domestic sheep and goats while reestablishing connectivity across the international border.

1.2 *Reduce or eliminate direct and indirect human impacts.* In addition to habitat loss, habitat modification and human activities often directly or indirectly affect Peninsular bighorn sheep habitat use (refer to sections I.B.5 and I..D.5). The following actions, which should all be accompanied by strong educational and public awareness programs (refer to section II.D.3), will reduce these impacts.

1.2.1 *Reduce impacts from existing and future developments and projects.* These recommended actions pertain to any project (residential, recreational, resort, commercial, agricultural, or mining) that has been constructed within bighorn sheep habitat, or any project adjacent to bighorn sheep habitat. Though habitat and opportunities for sheep movement throughout all suitable habitat should be maintained, habitat use along the immediate urban interface should not be encouraged because of risks associated with behavioral habituation.

1.2.1.1 *Construct fences to exclude bighorn sheep from urban areas where they have begun or may begin using urban sources of food and water.* Fences serve several functions including: (1) separating bighorn sheep from potential threats of urbanization (*e.g.*, toxic plants, parasites, accidents, vector-borne diseases, traffic, herbicides, pesticides, behavioral habituation), (2) controlling human and pet access to remaining bighorn sheep habitat, (3) preventing bighorn sheep from becoming habituated to and dependent upon artificial sources of food and water, and (4) modifying habituated behaviors and redirection into remaining native habitat. In the northern Santa Rosa Mountains, ongoing coordination with cities and landowners on a regional fencing strategy will be critical to the long-term health and maintenance of this ewe group. Retrofitting existing developments with fences where sheep currently exploit urban food and water sources is particularly important; cooperation by residential landowners will be critical to the success of excluding the northern Santa Rosa Mountains ewe group from urban habitats. Along the remainder of the urban interface, where sheep have not yet shown indications of habituation to human habitats, future behavioral habituation also may occur. Although fencing may be viewed as a last resort to other potential forms of aversive conditioning, prudent planning dictates that mitigation be required to offset the likelihood of future adverse effects (behavioral habituation and increased mortality rates) when new projects are approved along the urban interface. Though actual fence construction could be contingent upon future use by sheep and the ineffectiveness of other potential deterrents, the wherewithal, responsibilities, and easements for fences should be determined and secured at the time of project approval. Fences should be 2.4 meters (8 feet) high, or functionally equivalent, and should not contain gaps in which bighorn sheep can be entangled. Gaps should be 11 centimeters (4.3 inches) or less. This fence design should only be used at the urban interface. Refer to section II.D.1.2.2 for guidelines for livestock fences within bighorn sheep habitat.

1.2.1.2 *Avoid non-native vegetation along unfenced habitat interfaces where it may attract or concentrate bighorn sheep.* Along fenced sections of the urban interface, ornamental and toxic plants should not extend over or through fences where they may be accessible to browsing bighorn sheep.

1.2.1.3 *Promote the use of native vegetation and limit the planting of exotic species (including grass) in areas accessible to bighorn sheep.* A list of locally native plants should be provided to developers, landscapers, and homeowners. On Bureau of Land Management lands, especially livestock grazing allotments in and near bighorn sheep habitat, utilize only native vegetation in fire rehabilitation and range improvement projects.

1.2.1.4 *Prohibit the use of any known toxic plants where they may be accessible to bighorn sheep or potentially invade bighorn sheep habitat.* A list of known toxic plants should be provided to all developers, landscapers, and homeowners.

1.2.1.5 *Discourage the use of plants known to invade and degrade bighorn sheep habitat (e.g., tamarisk, fountain grass).*

1.2.1.6 *Prohibit intentional enticement of bighorn sheep onto private property.* This item includes, but is not limited to, vegetation, mineral licks, or unfenced swimming pools, ponds, or fountains upon which bighorn sheep may become dependent for water.

1.2.1.7 *In unfenced areas, monitor the use of pesticides, fungicides, herbicides, and fertilizers if sheep are using urban landscapes.* All products used should be warranted by the manufacturer to not be harmful to wildlife when applied at the label rate, and no applications should exceed the label rate. Coordination with landowners and homeowner groups is needed.

1.2.1.8 *Regulate the diversion or procurement of water, whether for human use or irrigation, and whether from springs or aquifers, that would reduce natural water sources used by bighorn sheep.* Coordination with land owners and the State Water Resources Control Board is needed to redress potential water rights conflicts. The Regional Water Quality Control Board's Basin Plan should recognize bighorn sheep as a beneficial use for perennial and seasonal waters within essential habitat.

1.2.1.9 *Prohibit the construction of water bodies in developed areas adjoining sheep habitat that may promote the breeding of midges (*Culicoides *sp.) and monitor/control vectors in existing problematic ponds.* Water features should be designed to eliminate blue-tongue and other vector-borne diseases by providing deeper water (over 0.9 meters [3 feet]), steeper slopes (greater than 30 degrees), and if possible, rapidly fluctuating water levels (see Mullens 1989, Mullens and Rodriquez 1990). Landowners and managers should coordinate with local mosquito and vector control districts to ensure management of existing water bodies that harbor vector species.

1.2.1.10 *Discourage the artificial feeding of coyotes because of the potential for increasing predator abundance and consequent predation on bighorn sheep.*

1.2.1.11 *Establish a method and secure funding to consistently monitor and enforce all actions listed under task 1.2.1.*

1.2.2 *Reduce or eliminate detrimental human activities within bighorn sheep habitat.* A variety of human activities can affect bighorn sheep (refer to section I.D). Bighorn sheep may react in two ways (Papouchis *et al.* 1999): (1) avoidance of disturbance or human encounters (potentially including habitat abandonment), and (2) habituation to sources of disturbance if they are sufficiently predictable. Behavioral habituation can include adjustments to timing of use in certain areas, such as by avoiding the area until the disturbance is gone (Hamilton *et al.* 1982) or fleeing the disturbance and returning when the disturbance is absent. Expansive urban development in and around bighorn sheep in desert habitats has occurred in three metropolitan areas to date--Albuquerque, Tucson, and Coachella Valley–and in all instances, habitat abandonment and population decline has resulted (Gionfriddo and Krausman 1986; Krausman, *in litt.* 1998; Krausman *et al.* In prep.). Bighorn sheep have demonstrated greater resilience to human disturbance in more remote locales such as Alberta (MacArthur *et al.* 1982) and the Sierra Nevada (Hicks and Elder 1979), though bighorn also are known to avoid excessive human disturbance in areas well away from urban centers (Papouchis *et al.* 1999).

Given the potential behavioral vulnerabilities of bighorn sheep to human disturbance (including dogs) and associated risks to the persistence of currently depressed populations in the Coachella Valley, a biologically conservative management approach is appropriate in the Peninsular Ranges. The public should be educated regarding problems associated with human-sheep relationships, and encouraged to continue supporting conservation efforts (Smith and Krausman 1988). A trails management program is currently in place on Anza-Borrego Desert State Park and appears to be providing a level of management that is maintaining relatively stable population levels of bighorn sheep. The success of this program may be attributable to an intensive educational program, along with prohibitions against dogs (on trails) and other disruptive activities, and a strong management presence to ensure adequate compliance. In addition, the most heavily used areas typically are located in steep terrain that limits the number and location of trails to relatively few narrow canyon bottoms. Sheep are better able to coexist with recreational use where human disturbance typically occurs at elevations lower than where sheep spend most of their time (Hicks 1977).

The following section primarily focuses on the northern Coachella Valley though the principles pertain rangewide. The relative remoteness of the Anza-Borrego region renders comparisons with the heavily populated Coachella Valley difficult, but recreation activities could be viewed differently because they are part of a cumulative set of factors affecting the sheep, some of which (*e.g.*, development-related pressures in sheep habitat) are more intense in the Coachella Valley. Though cause and effect relationships have not been established, the proportionally larger population declines in the northern Santa Rosa and San Jacinto Mountains than elsewhere may be related in part to the relatively higher levels of human disturbance associated with the larger metropolitan area. Other contributing factors may include the more extensive and interconnected trail system that is not largely restricted to canyon bottoms. Most of the trails head upslope and intersect other trails at higher elevations, forming an extensive trail network throughout ewe group home ranges, including lambing, rearing, and watering habitat. The patchwork of differing land ownerships has contributed to management difficulties. The types of trail use activities, as well as proliferation of new trails, also have gone largely unregulated. The Dunn Road, constructed illegally in the northern Santa Rosa Mountains in the 1970s, also is considered a trail since much of the use is by recreational pedestrians and bicycles and vehicular access is restricted. Travel in washes by vehicles and on foot also should be considered trail use.

The Agua Caliente Band of Cahuilla Indians currently is preparing a wildlife habitat management plan for the reservation, including a trails management program, which should be coordinated with the larger planning effort to ensure attainment of regional objectives. The Tribe recently banned dog use on its trails system, and will coordinate its efforts with other agencies when a draft plan is complete.

Research should focus on how different kinds and levels of disturbance affect bighorn behavior and habitat use patterns. The prevailing lack of baseline data on location, types, and extent of trail use must be overcome as a prerequisite to studying and better understanding these effects.

1.2.2.1 *Develop and implement a trails management program with affected land management agencies, scientific organizations, and user groups.* A trails program in the San Jacinto and Santa Rosa Mountains necessarily will require interagency cooperation, with specific responsibilities and levels of funding identified. The cities and primary land management agencies, with the Bureau of Land Management in a leadership role, should coordinate with user groups in developing a plan with the Fish and Wildlife Service and the Department of Fish and Game so that it can be effectively implemented on a regional basis. Regular interagency meetings should be scheduled to ensure effective coordination and implementation. The program should consist of the following components:

a. *Public education.* Preparation of a public education and outreach program is needed so that trail users better appreciate and understand bighorn sheep and other biological values associated with the Peninsular Ranges. Also see Section II.D.3. Most members of the public likely will voluntarily refrain from recreating in sensitive habitats during critical seasons if they understand the effects of human related disturbance on bighorn sheep. Nonetheless, monitoring and enforcement will be necessary to provide effective management.

b. *Prohibition of dogs in bighorn sheep habitat.* Dogs should remain in developed or designated areas (campgrounds, picnic areas, on paved roads, etc.) under restraint and prevented from roaming into bighorn sheep habitat.

c. *Lambing and rearing habitat.* Seasonal restrictions are needed on selected trails that bisect lambing habitat. In this Recovery Plan, the lambing season is defined as January 1 to June 30, and lambing and rearing habitat is defined as those areas in which ewes and lambs are observed during this period. These definitions were chosen to provide protection for the majority of lambs during the first 3 months of life and to allow ewes undisturbed access to lambing areas prior to the peak parturition months (February through April). Trails that are currently known to result in disturbance to lambing and rearing habitat are listed in Table 10.

d. *Water sources.* Seasonal restrictions or trail relocations may be appropriate for selected trails that lead to water sources. Trail use should be avoided near critical summer water sources from June 1 through September 30, and other times, as well, if water is scarce. Trail use is prohibited by regulation [see California Government Code, Title 14, Section 630(b)(11)(A) and (30)(A)] at Magnesia Springs and Carrizo Canyon Ecological Reserves. Trails that are currently known to conflict with the summer water requirements are listed in Table 10.

e. *Trail management.* Trails that conflict with lambing, rearing, and water requirements should be addressed through management tools, such as seasonal restrictions or

Table 10. Trails and areas with potential conflicts that should be addressed in an interagency trails management plan.*

Trail	Conflicts with Lambing from January 1 through June 30	Conflicts with Water stress from June 1 though September 30	Comment
N. Lykken trail	X	X	
Skyline trail	X		
Museum trail (Palm Springs)	X	X	Applies above picnic table at Desert Rider's Park.
South Lykken trail	X		
Picnic table trail (south of Tahquitz Canyon)	X		Applies above picnic table.
Tahquitz Canyon	X	X	
Dunn Road	X	X	
Murray Hill trail complex	X	X	
Cathedral Canyon trail	X	X	
Mirage trail (Bump and Grind)	X		Applies above the flat overlook
Art Smith, Schey, and connecting trails	X	X	
Carrizo Canyon trail	X	X	
Bear Creek Canyon trail	X	X	
Boo Hoff trail	X	X	
Guadalupe trail	X	X	
Morrow trail	X	X	

* This list of trails should be updated annually through the interagency trails program, based on the most current information.

relocations. Permanent closures may be necessary where relocation is not possible and seasonal restrictions cannot be effectively monitored or enforced. Trails should be used as a tool to focus human activity away from areas of concern. New trails in bighorn habitat should be avoided, except in select areas along the urban edge, where they could provide two benefits–alleviate pressure on trails that intrude deeper into sheep habitat, and provide a disturbance barrier to discourage potential sheep attraction to urban sources of food and water. Any new trails should minimize adverse impacts to alluvial fans, canyon bottoms, and other areas that may provide essential seasonal forage conditions while still accomplishing the objective of routing use away from the more sensitive areas.

f. *Monitoring, enforcement, and research.* A management presence by uniformed personnel should be deployed during peak use periods to educate the public, monitor compliance with trails rules, and enforce rules against any violations. Monitoring of bighorn sheep habitat use patterns should be designed to detect behavioral responses that can adaptively feedback into revised management measures. Experimental research to further our understanding of human/sheep interactions also should be conducted. See Section II.D.2.7.

1.2.2.2 *Manage activities within bighorn sheep habitat that fragment or interfere with bighorn sheep resource use patterns or other behaviors to reduce or eliminate adverse effects.* This task includes but is not limited to road traffic, trail use, off-trail activity, and aerial activities, such as hang gliders and helicopters, which may have a negative effect on bighorn sheep. For example, the U.S. Navy currently implements a 457-meter (1,500-foot) minimum ceiling for military flights above bighorn sheep habitat in the north end of the Anza-Borrego Desert State Park and a 60-meter (200-foot) minimum ceiling in the remainder of the park. The 457-meter (1,500-foot) minimum ceiling should apply to all flights over any bighorn sheep habitat.

1.2.2.3 *Manage livestock grazing to reduce competition for scarce resources and to minimize the potential for disease transmission.* Existing (Canebrake, with lambing and watering habitat) and currently inactive (Vallecito and Oriflamme) allotments should be evaluated and modified or closed, if necessary to achieve recovery objectives. The McCain Valley allotment should also be assessed to ensure compatibility with adjoining sheep habitat. If the closure of one or more livestock grazing allotments is determined necessary to remove the impediments to recovery described above in Section I.B.6 concerning competition or in Section I.B.7 concerning disease transmission, the Bureau of Land Management should develop proposed land use plan amendments to effect such closure(s). Until decisions are made regarding potential allotment modifications or closures, the current allotment boundaries should be fenced according to Bureau of Land Management fence specifications for cattle and bighorn sheep (Bureau of Land Management 1989). If any allotments, or portions thereof, that overlap with bighorn sheep habitat are subsequently closed through land use plan amendments, the fences around such allotments should be removed following the cessation of livestock grazing.

1.2.2.4 *Prohibit the grazing of domestic sheep within 14.5 kilometers (9 miles) of bighorn sheep habitat to prevent disease transmission.*

1.2.2.5 *Require all cattle grazing allotments adjacent to bighorn sheep habitat to be fenced where cattle straying into bighorn sheep habitat degrades forage or water resources.* Fences should comply with Bureau of Land Management specifications for cattle fences in bighorn sheep habitat (Bureau of Land Management 1989).

1.2.2.6 *Prohibit the use of goats as pack animals in bighorn sheep habitat.* Goats are known to transmit diseases to bighorn sheep. Other pack animals, such as llamas and camels, should be assessed for potential disease risk and prohibited if a risk exists.

1.2.2.7 *Establish a method and secure funding to consistently monitor and enforce all actions listed under task 1.2.2.*

1.3 *Reduce mortality rates.* Low survivorship of adult Peninsular bighorn sheep currently threatens population viability (refer to section I.B.4). Measures to improve survivorship are fundamental to this recovery effort.

1.3.1 *Reduce mortality due to unnatural causes.* A number of mortalities of Peninsular bighorn sheep have been caused directly or indirectly by human activities. Some mortality factors, such as poisoning by plants and vehicular collisions, are a byproduct of urban developments built within or adjoining bighorn sheep habitat, or human presence in bighorn sheep habitat (refer to section II.D.1.2). Additional causes of mortality should be reduced with the following actions:

1.3.1.1 *Prohibit fences in which bighorn sheep may become entangled or strangled, or that interrupt habitat connectivity or block movement of bighorn sheep within remaining habitat.* At the urban interface, fences should not contain gaps larger than 11 centimeters (4.3 inches) (refer to section II.D.1.2.1.1). All other fences should comply with Bureau of Land Management specifications for fences within bighorn sheep habitat (Bureau of Land Management 1989).

1.3.1.2 *Post all movement areas or areas of bighorn sheep concentration near highways with bighorn sheep crossing signs to warn motorists.* Post informational warning signs at the entrance to blind curves. Solutions need to be identified and implemented to reduce the extent of vehicular related mortality along problematic road segments such as Highway 74 above Palm Desert, S-22 west of Borrego Springs, and Highway 78 south of Borrego Springs. If monitoring indicates that more effective warning systems are needed, flashing yellow lights and intensified signage, etc., should be phased in. Coordination with Caltrans and the counties will be required.

1.3.2 *Reduce mortality due to natural causes.* Predation by mountain lions represents a threat to the viability of bighorn sheep in the Peninsular Ranges (refer to sections I.B.4, I.B.5, and I.D). Selective removal of lions may therefore be necessary to facilitate recovery. The goals of reducing predation pressure are to protect small subpopulations from extinction and to stimulate population increases. The following guidelines for implementing predator management were designed to facilitate recovery of Peninsular bighorn sheep in accordance with the recovery criteria established in this recovery plan. The first level of predator control is essentially an emergency action to protect small subpopulations from extinction. This level of management was identified to help the population meet downlisting criterion #1 (the presence of 25 ewes in each of the 9 recovery regions), while the second level of lion control will be conducted, if necessary, to facilitate achievement of delisting criterion #2.

Removal of mountain lions should be selective and only target individual lions known to be, or suspected of, preying on bighorn sheep. Predator management should not be implemented as a mitigation measure for habitat loss because it is a temporary remedy for a potential short-term problem and does not offset the permanent impact of habitat loss. Lion removal must be accompanied by careful monitoring to determine if predator control achieves the desired protection of bighorn sheep (refer to section II.D.2.5). The effects of predator management should be incorporated into ecosystem level research on the predator/prey relationships among bighorn sheep, lions, and deer (refer to section II.D.2.3). The criteria for implementing predator control may need to be changed as knowledge regarding this predator-prey relationship and the balance between predation and population viability are better understood (refer to section II.D.2). The ultimate goal is to restore an ecological system that includes viable predator/prey systems in which no predator removal is necessary.

Predator Removal Level 1. Predator removal should be implemented if there are fewer than 15 adult female bighorn sheep in a given recovery region (refer to the 9 regions in section II.B) and predation is a known mortality factor. In this circumstance, protection of individual bighorn sheep is critical for ensuring bighorn population survival and persistence in the recovery region. Lion removal should be implemented solely in the recovery region of concern, and continue until population growth is reestablished to a trajectory expected to achieve the downlisting threshold of 25 adult ewes in the region.

Predator Removal Level 2. Predator removal may also be implemented if there are greater than 25 ewes in each of the 9 recovery regions, to further facilitate the long-term goals of population recovery. Lion removal should only occur if lion predation is the primary cause of mortality and low survivorship is determined to be limiting population recovery. Careful monitoring, habitat evaluation, and possibly computer simulations should be used to determine if, when, and where predator removal should occur. Predator removal should be discontinued if available evidence indicates that: (1) lion predation no longer limits bighorn sheep population growth, and (2) continued removal would no longer result in a population expansion within the recovery region necessary for the overall recovery of the metapopulation.

1.4 *Develop a long-term strategy and maintain the current capability for captive breeding, reintroduction, and augmentation programs.* A small captive breeding herd (14 animals in 1998) exists at the Bighorn Institute (refer to sections I.C.1 and I.E.3) and is managed according to the guidelines outlined in Appendix C. This herd was established in 1984 to facilitate the study of low lamb survival. Animals born or rehabilitated at the facility have been released into the northern Santa Rosa Mountains (n equals 74) or the San Jacinto Mountains (n equals 3), typically as small groups of yearlings, since 1985 (Ostermann *et al.* in press).

The Recovery Team should develop a long-term strategy that identifies the process and circumstances under which captive breeding, reintroductions, and augmentations may be appropriate and carried out, including the potential introduction of animals from adjoining metapopulations. Reintroduction and augmentation are potential tools to (re)establish ewe groups and restore connectivity among neighboring groups. Augmentation of dwindling groups may serve as a "rescue effect" (Brown and Kodric-Brown 1977), thereby reducing the risks associated with naturally occurring random variations in populations. Augmentation may also play an important role in the conservation of bighorn sheep because habitat use patterns are learned from experienced animals. Once use of a particular area is discontinued by females, it may be more difficult for inexperienced sheep to become established in this area (refer to section I.B.2). Finally, augmentation can be of value to address genetic concerns.

Reintroduction and augmentation programs are recognized conservation tools and have been used extensively to manage bighorn sheep populations (Bleich *et al.* 1990b, Ramey 1993); however, they come with a set of potential problems (Campbell 1980, Kleiman 1989, National Research

Council 1995). Reintroductions and augmentations also must be coordinated with other recovery efforts. That is, they are meant to play supportive roles to other measures that protect Peninsular bighorn sheep and their habitat, they should be supported through public relations and education programs (Kleiman 1989, National Research Council 1995), and they should be preceded or accompanied by other conservation measures to restore population viability (Stanley Price 1991). Finally, decisions regarding reintroductions and augmentation need to consider the genetic, disease, and population structure consequences of such actions.

Although there are advantages to using free-ranging animals in augmentations and reintroductions, captive breeding also can provide animals for releases. In addition, captive propagation can be used as a recovery tool to: 1) conduct recovery related research, 2) maintain genetic diversity or genetic lineages, and 3) maintain refugial populations.

The long-term strategy should specify the goals of reintroduction and augmentation activities, and describe the steps that will be followed to reach these goals. The strategy should be consistent with the guidelines adopted by the Conservation Breeding Specialist and the Reintroduction Specialist Groups of the Species Survival Commission of the International Union for the Conservation of Nature and Natural Resources, The World Conservation Union, and those of the American Zoo and Aquarium Association's Caprinae Taxon Advisory Group. Appendix C outlines additional considerations and a protocol for captive breeding and release of captive animals.

2. INITIATE OR CONTINUE RESEARCH PROGRAMS NECESSARY TO MONITOR AND GUIDE RECOVERY EFFORTS.

This section focuses on research topics with management applicability needed for recovery. The approach is to design management actions so that: (1) results can be measured, (2) efficacy can be evaluated as testable hypotheses, and (3) alternative or refined actions can be formulated and tested again (adaptive management, as defined by Holling 1978). However, adoption of this approach for bighorn sheep recovery likely will be more problematic than for most species. Many results will not become apparent for many years because sheep are long-lived and behavior can be slow to change and difficult to document.

2.1 *Monitor population status*. The status, population dynamics, and population trends of Peninsular bighorn sheep should be monitored so that the success of this recovery effort can be evaluated. Consistent long-term monitoring will allow use of adaptive management approaches that would increase the effectiveness of recovery efforts. Continued monitoring is also a necessary component of future research. Population monitoring (abundance, distribution, recruitment) should be coordinated with other research (*e.g.*, survivorship, habitat selection) to maximize cost efficiency and the data collected per animal collared, as well as to minimize handling and marking animals.

2.1.1 *Monitor abundance*. All bighorn sheep habitat in the Peninsular Ranges should be surveyed by helicopter at least every other year to generate population estimates. Initially, this will require that a known number of radio-collared animals are distributed throughout the range so that mark-recapture abundance estimations can be generated. The number of collared animals should be sufficient to achieve an accuracy of plus or minus 25 percent with a probability of 0.05, following the methods described in Krebs (1989) and Robson and Regier (1964), or approximately 30 percent of the estimated ewe population should be radio-collared. However, a "sightability" estimate may be generated after additional surveys are conducted, thereby eliminating the need to maintain this percentage of radio-collared animals. This approach would be especially beneficial if/when population numbers become large. Where ewe group delineations are known, estimates of abundance should be generated for individual ewe groups as well as for the entire range. Annual waterhole counts should be continued in Anza-Borrego Desert State Park and perhaps reinitiated in the Santa Rosa and San Jacinto Mountains. Data from waterhole counts can be used to potentially provide important information about population characteristics (*e.g.*, lamb to ewe ratios and/or ram to ewe ratios) and to index abundance. Continuation of waterhole counts concurrent with helicopter surveys (for 5 to 10 years) may reveal a relationship between abundance indices and population estimates. This relationship may allow biologists to use historical waterhole count data (collected over 28 years) to estimate historical abundance patterns. Aerial surveys and waterhole counts should be conducted according to the protocols in Appendix E.

2.1.2 *Monitor distribution.* Further data should be collected on distribution of Peninsular bighorn sheep. Ground surveys for bighorn sign should supplement aerial surveys and telemetry studies to further define habitat use patterns. Questions regarding distribution include but are not limited to: (1) how many ewe groups are currently found in the Santa Rosa Mountains and Vallecito Mountains, (2) if augmentation or reintroductions are necessary, where should these occur, and (3) how do the number and distribution of ewe groups change over time as conditions or population numbers change?

Abundance monitoring (see task 2.2.1.1) will initially require that radio-collared animals be distributed throughout the range. The location of each animal should be obtained via visual location or fixed wing aircraft telemetry surveys, at least biweekly. In addition, the locations of all observed animals without collars should be recorded during biennial helicopter surveys.

2.1.3 *Monitor recruitment.* Reproductive success, which includes lamb production and recruitment, should be monitored on a yearly basis in all ewe groups. Tracking and observing individually marked ewes generates the most useful data because lamb survival to specific ages can be determined, and the reproductive success of individual ewes can be tracked. Alternatively, the lamb to ewe ratio of each ewe group could be measured at various times of the year (*e.g.*, during waterhole counts or helicopter surveys). Ground surveys should be organized if feasible. If lamb mortality is found to be high in specific ewe groups, the radio-collaring of lambs may be necessary to identify causes of mortality. Recruitment should be compared among ewe groups, years, and management strategies.

2.1.4 *Monitor survivorship and cause-specific mortality.* Adult survivorship should be monitored annually in all ewe groups. This monitoring would require that radio-collared rams and ewes are present in each area and telemetry signals are monitored on a regular (at least biweekly) basis. It is important that all mortalities be investigated promptly so that cause specific mortality rates can be calculated. A standardized mortality site investigation protocol should be established. Whenever possible, fresh carcasses or tissue samples should be collected and submitted to the California Veterinary Diagnostic Laboratory for pathological examination. Survivorship and cause-specific mortality should be compared among ewe groups, years, and management strategies.

2.2 *Develop population models.* Although a substantial amount of knowledge exists regarding bighorn sheep in the Peninsular Ranges and elsewhere, there is a need for further research regarding their ecology and the factors that influence population viability. Incorporating existing knowledge into models may provide insight into the ecology of Peninsular bighorn sheep and the system to which they belong. Rather than using the absolute results of models to make policy or management decisions, however, the relative outcomes of alternative models should be used to guide management decisions (Beissinger and Westphal 1998) and future research efforts. Models uncover knowledge gaps and thereby guide future research and generate hypotheses that would not otherwise be addressed. The recovery of Peninsular bighorn sheep will benefit from answers to a number of questions. These questions include, but are not limited to: (1) how do the number of ewe groups, size of groups, and level of connectivity among groups affect persistence probabilities of the metapopulation, and (2) what are the relative long-term effects of various levels of adult and juvenile mortality on population viability?

Although the above questions pertain primarily to viability from the perspective of population numbers, future models could also incorporate data to assess genetic diversity. Additional models should explore habitat selection versus availability.

2.3 *Research the relationships between bighorn sheep, mountain lions, mule deer, and habitat.* In the Peninsular Ranges, mountain lions and mule deer are found within bighorn sheep habitat, and are important variables affecting this ecosystem (Hayes *et al.* 2000). To increase our knowledge of the ecology of Peninsular bighorn sheep, a better understanding of predation, interspecies relationships, and habitat selection is needed. Information regarding the relationships will be valuable in making future management decisions to facilitate population recovery, including decisions regarding habitat management, reduction of mortality due to predation, and whether other species should be managed to achieve recovery of Peninsular bighorn sheep. Pertinent research goals include, but are not limited to:

a. Estimate the number of mountain lions preying on bighorn sheep.

b. Examine movement patterns of mountain lions within and adjacent to bighorn sheep habitat, and attempt to identify influencing factors.

c. Examine the spatial and temporal patterns of mountain lion predation on bighorn sheep and mule deer in relation to the distribution of both prey species, season, climate patterns, and habitat characteristics.

d. Describe the habitat use patterns and distribution of mule deer in and near bighorn habitat.

Answering some of these questions requires long-term study (perhaps 10 or more years). Such a study would require extensive monitoring and habitat study of all three species. Experimental approaches involving removal of mountain lions and manipulation of mule deer populations and habitat should be designed to test the outcome in terms of predation rates on bighorn sheep.

2.4 *Investigate the relationships between bighorn sheep and coyotes and bobcats.* Although mountain lions appear to be the primary predator of adult bighorn sheep, predation by coyotes or bobcats also may affect the viability of bighorn sheep populations, primarily through predation on lambs. Factors that put bighorn sheep at risk from these predators should be investigated. Studies should examine what impact expanding urbanization, the use of urban environments, and artificial water sources may have on the relationship between these three species.

2.5 *Investigate the efficacy of temporary suppression of natural predation.* Mountain lion predation currently is the primary cause of death of adult radio-collared bighorn sheep in most ewe groups in the Peninsular Ranges, and threatens population viability (refer to sections I.B.4 and I.B.5). Any measures to intervene should be designed so that the effectiveness of various techniques can be evaluated. The presence of lions and other predators in the area of interest should be monitored as part of the investigation. Because mortality and mountain lion predation rates fluctuate across years (refer to sections I.B.4 and I.B.5), it will be important to evaluate the effectiveness of these actions over multiple years.

2.6 *Research habitat use/selection and dispersal behavior.* Habitat use by sheep has been studied by a number of researchers (refer to section I.B.1), but many questions remain. In the Peninsular Ranges, as in many other bighorn sheep habitats, the specific factors that limit populations are not well understood. A better understanding of habitat use patterns and factors underlying habitat selection will aid our understanding of resource requirements and promote informed management decisions. Selected topics for future research include: (1) water and nutritional requirements and how these factors affect population characteristics and distribution, (2) how and where habitat use and movement are influenced by disturbance barriers and sources of fragmentation, (3) habitat use and how it relates to predator evasion, (4) how habitat quality influences dispersal behavior, and (5) how human disturbance affects habitat use patterns. Documentation of habitat use for essential life functions, such as lambing, rutting, summer water stress, and dispersal, is needed. A detailed vegetation map with sources of fragmentation for the entire Peninsular Ranges would facilitate analyses of these variables on habitat use patterns.

A number of questions exist regarding dispersal behavior. For example, how often do ewes move between groups? Although preliminary data suggest it occurs at a low rate, long-term monitoring (two or more bighorn sheep generations) may be necessary to more accurately estimate the frequency of such moves. Other questions include, but are not limited to: (1) what conditions (population density, forage quality, time of year) are associated with movement of animals between ewe groups; (2) what habitat features are associated with movement paths; (3) how does range expansion occur; and (4) how far (and among how many ewe groups) do rams typically move? The frequency and duration of monitoring will depend on the specific research questions. For example, long-term studies are needed to document dispersal behavior, while frequent or nearly continuous monitoring may be necessary for studying habitat selection and use patterns (Laundre *et al.* 1987). The use of Global Positioning System collars may provide a valuable tool in such studies.

2.7 *Evaluate the effect of human activities on bighorn sheep.* Given the history of bighorn sheep population declines and extirpations in other areas near urban centers, information is needed on how to manage recreational activity in a manner that does not interfere with bighorn habitat use. Because knowledge of the location and extent of human activity is a prerequisite to conducting research and making informed management decisions, responsible land management agencies should place a high priority on obtaining this information. A variety of study designs may be appropriate, such as: (1) experimentally prescribing different management techniques and measuring results, (2) measuring physiological changes in individuals in response to different disturbance regimens, (3) determining the effects of human activities on bighorn population characteristics (*e.g.*, reproduction and recruitment rates), and (4) determining the effects of human activity on bighorn behavioral patterns or activity cycles. It is critical that studies seeking to detect the effects of human disturbance have sufficient sample sizes and statistical power to avoid type II statistical errors (accepting a false null hypothesis).

2.8 *Research disease and preventive measures*. There is a need to provide ongoing screening for pathogens and exposure to infectious diseases to detect and mitigate emerging epizootics. Although infectious diseases do not currently appear to play an important role in population dynamics of bighorn sheep in most of the Peninsular Ranges, it will be important to continue monitoring the presence and impact of infectious diseases in ewe groups because outbreaks could occur at any time. Since it will be essential to radio-collar animals to monitor ewe groups, biological samples should be collected at the time of capture and tested for presence of infectious disease. In particular, whole blood and serum should be analyzed for the presence of specific pathogens and antibodies to those pathogens. A standardized sampling protocol should be developed and the laboratories used by researchers should be identified in all reports so that testing can also be standardized. When feasible, fresh carcasses should be taken immediately to the California Veterinary Diagnostic Laboratory in San Bernardino for necropsy. A standardized necropsy protocol should be developed, and necropsy reports made available to all agencies and researchers.

At this time, preventive measures such as vaccination or anthelmintic treatments do not appear to be warranted in any of the ewe groups with the exception of the northern Santa Rosa Mountains ewe group. Nematode parasites have been documented in this group and nematode treatment may be appropriate. Treatment schemes should be designed so that the effectiveness of each treatment can be evaluated (control animals or groups should be used). Infectious disease data should be re-evaluated periodically or continuously, and recommendations regarding treatment and preventive strategies based on research findings.

Pathogen monitoring should be extended to cattle and mule deer in the Peninsular Ranges. Other ungulates may serve as reservoirs for cross transmission of bluetongue to bighorn sheep.

2.9 *Research genetics of bighorn sheep in the Peninsular Ranges.*
Genetic issues should be considered and re-evaluated during the recovery process, especially as new methods become available. Samples should be used in association with those already collected to more clearly delineate population structure, to estimate gene flow, to identify the most appropriate source stock (free ranging and captive) for translocation, to assess the risk of inbreeding and outbreeding depression, to test if there has been a recent population bottleneck within a subpopulation, and to monitor loss of variation due to changes in breeding structure. Research directed towards the estimation of the effective population size (N_e) should be a priority, and genetic variability should be directly monitored (Lande and Barrowclough 1987). In addition, analyses of samples collected from bighorn sheep within and outside of the Peninsular Ranges would be useful to better estimate the phylogeographic structure of desert bighorn sheep and to further identify management units. DNA samples should be collected from every animal captured in the Peninsular Ranges and from adjacent populations, using a standardized sampling protocol. A DNA bank has been established at the University of California at Davis that consists of over 700 samples from bighorn sheep in the Southwest, including over 100 samples from the Peninsular Ranges. Given recent and

anticipated technological advancements, collection and long-term storage of germinal and somatic cells from captured animals should be initiated for future use.

3. DEVELOP AND IMPLEMENT EDUCATION AND PUBLIC AWARENESS PROGRAMS.

Conservation efforts have a higher chance of success if they are supported by the local community. A number of recovery actions outlined in this recovery plan will directly affect the general public. It is therefore imperative that strong public education and awareness programs be implemented. The public needs to be informed of the reasons why specific recovery actions are being taken. This task will require an education program on the ecology of Peninsular bighorn sheep, what threats this species is currently facing, and how recovery actions will reduce these threats. Coordination with the public and interest groups will be particularly important for controversial issues, such as trails and predator management. This knowledge should translate into a respect and concern for this species, leading to support for conservation measures.

Several programs and sources of information pertaining specifically to Peninsular bighorn sheep already exist. Interpretive displays and materials are found at the Visitor Center in Anza-Borrego Desert State Park, the Bureau of Land Management Visitor Center in Palm Desert, Bighorn Institute, Living Desert in Palm Desert, and Palm Springs Desert Museum. In addition, local interest groups have hosted guest talks by biologists studying bighorn sheep. These programs should be continued and additional programs established, such as information provided to the public through the tourist industry and ecotourism operators. The effectiveness of educational programs would be increased if a higher degree of coordination existed among individual programs and other recovery activities. This coordination would not only allow each program to present the most accurate and updated information, but would also let the general public see that the recovery of Peninsular bighorn sheep is a collaborative effort supported by multiple agencies, organizations, and individuals. Specific recovery actions are:

3.1 *Distribute information related to recovery efforts*. Updated and accurate information should be available to interested individuals, groups, or local governments. This material should be provided by the key agencies involved in the recovery effort and should include information on the ecology of Peninsular bighorn sheep, current threats to population viability, and explain recovery actions. Information dissemination should coordinate with the Coachella Valley Multiple Species Habitat Conservation Plan.

The need for specific recovery actions should be explained to the general public. For example, home owners, land managers, and developers should be provided with information that explains: (1) why restrictions on toxic plants, fences, and pesticides are needed, and (2) why artificial feeding of coyotes could adversely affect bighorn sheep. Recreation groups should be provided with information that explains why certain trail closures are necessary. Interpretive signs should be posted at all trailheads that enter bighorn sheep habitat. Trained docents could be present at popular trailheads during high trail usage periods and during periods of trail closures to provide additional information and answer questions.

3.2 *Continue, update, and coordinate existing education programs*. Existing programs should be expanded and regularly updated to provide an accurate view of our current knowledge regarding Peninsular bighorn sheep. Dynamic displays that feature up-to-date population status and monitoring activities, current research projects, and conservation activities likely will be most effective. Each program should highlight not only how its agency's or organization's activities contribute to the recovery of Peninsular bighorn sheep, but how these activities complement those of other agencies/organizations. An annual meeting of government officials including the Fish and Wildlife Service, the Bureau of Land Management, California Department of Fish and Game, California Department of Parks and Recreation, U.S. Forest Service, researchers from the University of California at Davis, Bighorn Institute, and others, as appropriate (*e.g.* educational facility representatives or public relations directors), should be held to facilitate the exchange of information and ideas for improving and updating education programs.

3.3 *Develop additional educational programs*. An educational program targeting local schools should be developed. This program might include a teaching packet that school teachers can use to introduce their students to Peninsular bighorn sheep and the desert ecosystem in general. Classroom activities could be combined with visits from biologists or tours of bighorn sheep habitat, possibly in conjunction with existing programs (*e.g.*, at Anza-Borrego Desert State Park and The Living Desert). Current conservation issues, population monitoring, and research projects could be incorporated into this type of program, possibly through the use of informative videos or web sites. Cunningham (1993) outlined the use of such an interactive program in Arizona.

The feasibility of additional educational programs should be investigated. Possible sites/organizers are the Zoological Society of San Diego, the Los Angeles Zoo, and museums within Riverside and San Diego Counties.

Additional goals of existing and newly developed programs should be to:

a. Reach people who would not typically be exposed to traditional programs (*i.e.*, individuals who might not frequent visitor centers or who do not have school-aged children). This goal might be accomplished by promoting informative presentations at senior citizen centers, home owner group meetings, tourist centers, or golf clubs. In addition, local and national television programs featuring the Peninsular bighorn sheep should be developed, and press releases should be encouraged.

b. Stress an ecosystem approach in which habitat protection is an integral part of the recovery of Peninsular bighorn sheep.

c. Encourage the public to take part in conservation activities. A prime example is 28 years of waterhole count data that have been collected by volunteer counters in Anza-Borrego Desert State Park. Habitat restoration, such as tamarisk removal or water development also represent ideal volunteer projects. An observation logbook might be established at visitor centers to allow visitors to record bighorn sheep and other species they observed.

d. Conduct public attitude assessments to determine the effectiveness of specific programs and guide future activities.

3.4 *Distribute a protocol to select law enforcement, public health, and safety officials for the humane treatment of injured bighorn sheep.* Injured bighorn sheep are sometimes found by motorists, pedestrians, or hikers who then report the situation to public officials in a variety of agencies. Personnel of these agencies often are not knowledgeable about medical or humane treatment procedures for injured animals. A protocol needs to be developed and distributed to city, county, State, and Federal agencies that are likely to receive reports of injured animals that provides information on appropriate contacts who are qualified to diagnose and treat injured animals. Information from such cases should be collected and maintained by one agency so that a complete data base is available for researchers and managers.

E. SITE SPECIFIC RECOVERY TASKS.

In this section, the recovery actions described in section II.D are further identified as site specific recovery tasks. They are matched with the nine recovery regions listed under the recovery criteria (Table 11). Site specific tasks for each of these areas are indicated in Table 12.

Table 11. Recovery criteria regions.

RECOVERY REGIONS
1. San Jacinto Mountains
2. Santa Rosa Mountains--North of State Highway 74
3. Santa Rosa Mountains--South of Highway 74 through Martinez Canyon
4. Santa Rosa Mountains--South of Martinez Canyon to slopes west of Village Peak
5. Coyote Canyon--east and west sides
6. North San Ysidro Mountains-- Henderson Canyon to County Road S-22
7. South San Ysidro Mountains-- County Road S-22 to State Highway 78
8. Vallecito Mountains/Fish Creek Mountains
9. Carrizo Canyon/Tierra Blanca Mountains/Coyote Mountains A/south of Interstate 8

Table 12. Site specific tasks recommended for each recovery region. Refer to the narrative outline (section II.D) for a complete description of recovery actions.

Recovery Action (abbreviated)	Recovery Region								
	SJ	SR-N74	SR-S74	SR-MCS	CC	SY-N	SY-S	VM/FC	CC/TB/CM
1.1.1 Protect essential habitat	x	x	x	x	x	x	x	x	x
1.1.2 Secure habitat	x	x	x	x	x	x	x	x	x
1.1.3.1 Remove exotic vegetation	x	x	x	x	x	x	x	x	x
1.1.3.2 Reduce/eliminate wild horses	x				x				
1.1.3.3 Implement fire management plan	x	x	x	x	x	x	x	x	x
1.1.3.4 Maintain/provide water sources		x	x	x			x	x	x
1.1.3.5 Maintain/reestablish habitat connectivity	x	x	x	x	x	x	x	x	x
1.2.1.1 Construct fences (at urban interface)	x	x	x						
1.2.1.2 Avoid non-native vegetation	x	x	x						
1.2.1.3 Promote native plants, limit exotic plants	x	x	x						
1.2.1.4 Prohibit use of toxic plants	x	x	x						
1.2.1.5 Discourage use of exotic invasive plants	x	x	x						
1.2.1.6 Prohibit enticement onto private property	x	x	x						
1.2.1.7 Monitor use of pesticide, herbicides, etc.	x	x	x						
1.2.1.8 Regulate water diversion/procurement	x	x	x	x	x	x	x	x	x
1.2.1.9 Prohibit artificial water sources (*Culicoides*)	x	x	x						
1.2.1.10 Discourage feeding coyotes	x	x	x						
1.2.1.11 Secure funds/methods to monitor	x	x	x	x	x	x	x	x	x
1.2.2.1 Develop trails management program	x	x	x	x					
1.2.2.2 Prohibit activities with negative impacts	x	x	x	x	x	x	x	x	x
1.2.2.3 Minimize livestock grazing impacts	x							x	x
1.2.2.4 Prohibit domestic sheep grazing	x	x	x	x	x	x	x	x	x
1.2.2.5 Fence neighboring cattle allotments	x							x	x
1.2.2.6 Prohibit goats as pack animals	x	x	x	x	x	x	x	x	x
1.2.2.7 Secure funds/methods to monitor	x	x	x	x	x	x	x	x	x

Table 12. Continued.

Recovery Action (abbreviated)	Recovery Region								
	SJ	SR-N74	SR-S74	SR-MCS	CC	SY-N	SY-S	VM/FC	CC/TB/CM
1.3.1.1 Regulate fence construction and design	x	x	x					x	x
1.3.1.2 Post/monitor highway crossing areas		x	x			x	x	x	x
1.3.2 Reduce mortality due to natural causes	x	x			x	x	x	x	
1.4 Develop reintro./augment. strategy	x	x							x
2.1.1 Monitor abundance	x	x	x	x	x	x	x	x	x
2.1.2 Monitor distribution	x	x	x	x	x	x	x	x	x
2.1.3 Monitor recruitment	x	x	x	x	x	x	x	x	x
2.1.4 Monitor survivorship/causes of mortality	x	x	x	x	x	x	x	x	x
2.2 Develop population models	x	x	x	x	x	x	x	x	x
2.3 Research bighorn/lions/deer/habitat	x	x			x	x	x	x	
2.4 Research impact of coyotes/bobcats	x	x	x		x	x	x	x	
2.5 Research methods to decrease predation	x	x			x	x	x	x	
2.6 Research habitat use/dispersal	x	x	x	x	x	x	x	x	x
2.7 Monitor human impacts	x	x	x		x	x	x	x	x
2.8 Research disease/prevention	x	x	x	x	x	x	x	x	x
2.9 Research genetics	x	x	x	x	x	x	x	x	x
3.1 Distribute recovery information	x	x	x	x	x	x	x	x	x
3.2 Cont./update public education programs	x	x	x	x	x	x	x	x	x
3.3 Develop new public education programs	x	x	x	x	x	x	x	x	x
3.4 Distribute protocol for injured sheep treatment	x	x	x	x	x	x	x	x	x

SJ: San Jacinto Mountains
SR-N74: Santa Rosa Mountains - north of Highway 74
SR-S74: Santa Rosa Mountains - south of Highway 74
SR-MCS: Santa Rosa Mountains--South of Martinez Canyon
CC: Coyote Canyon--east and west side
SY-N: North San Ysidro Mountains
SY-S: South San Ysidro Mountains
VM/FC: Vallecito/Fish Creek Mountains
CC/TB/CM : Carrizo Canyon/Tierra Blanca Mountains/Coyote Mountains

III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs for the Peninsular bighorn sheep recovery program, as set forth in this recovery plan. It is a *guide* for meeting the objectives discussed in part II of this 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 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". Some costs appear as zero because indirect costs, such as those incurred by: (1) contributions of time and materials by agencies and other groups, and (2) administrative or regulatory costs by public agencies, are not included in cost totals. Costs of continuous tasks are estimated assuming a 25-year time to recovery. Though the Implementation Schedule does not distinguish between public and private costs, no identifiable or specific expenditures are likely to be needed by the private sector, other than voluntary efforts contributed by nonprofit 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.

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
MSHCP	Coachella Valley Multiple Species Habitat Conservation Plan, which includes participating cities, County of Riverside, and landowners
Cities	Palm Springs, Cathedral City, Rancho Mirage, Palm Desert, Indian Wells, and La Quinta
Counties	San Diego, Imperial, and Riverside Counties

AGENCIES AND ORGANIZATIONS

ACBCI	Agua Caliente Band of Cahuilla Indians
BI	Bighorn Institute
BLM	Bureau of Land Management
CALTRANS	California Department of Transportation
CDFG	California Department of Fish and Game
CDPR	California Department of Parks and Recreation
CVMVCD	Coachella Valley Mosquito and Vector Control District
CVMC	Coachella Valley Mountains Conservancy
CVWD	Coachella Valley Water District
DoD	Department of Defense
FWS	U.S. Fish and Wildlife Service
RWQCB	Regional Water Quality Control Board
RC	Riverside County
RCFCWCD	Riverside County Flood Control and Water Conservation District
SDZS	San Diego Zoological Society
UCD	University of California - Davis
USFS	U.S. Forest Service
*	Lead Agency

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR PENINSULAR BIGHORN SHEEP

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's) FY 01	FY 02	FY 03	FY 04	FY 05
1	1.1.1	Protect essential habitat	cont.	ACBCI*, BLM*, FWS*, CVMC*, MSHCP*, CDFG*, CDPR*, CVWD*	0	0	0	0	0	0
1	1.1.2	Secure habitat	cont.	BLM*, CDFG*, CVMC*, CDPR*, MSHCP*	70,000	TBD	TBD	TBD	TBD	TBD
1	1.1.3.1	Remove exotic vegetation and prevent invasion by exotic plants	cont.	ACBCI*, BLM*, CDFG*, CDPR*, CVWD*, RCFCWCD*	250	10	10	10	10	10
1	1.1.3.2	Reduce/eliminate wild horses	5	ACBCI*, BLM*, CDPR*	TBD	TBD	TBD	TBD	TBD	TBD
1	1.1.3.4	Maintain/provide water sources	5	BLM*, CDFG*, CDPR*	50	20	20	10	0	0
1	1.1.3.5	Maintain/re-establish habitat connectivity	cont.	BLM* , FWS*, CDFG*, CDPR*, Caltrans*, MSHCP*	TBD	TBD	TBD	TBD	TBD	TBD
1	1.2.1.1	Construct fences to exclude bighorn sheep from urban areas	5	MSHCP*, CDFG, FWS	500	100	100	100	100	100
1	1.2.1.4	Prohibit use of toxic plants	cont.	MSHCP*	0	0	0	0	0	0
1	1.2.1.8	Regulate water diversion/procurement	cont.	RWQCB*, CVWD*	0	0	0	0	0	0

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR PENINSULAR BIGHORN SHEEP										
Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
1	1.2.1.11	Secure funding to implement measures	cont.	MSHCP*	0	0	0	0	0	0
1	1.2.2.1	Develop and implement a trails management program	cont.	BLM*, CDFG, USFS, FWS, MSHCP	TBD	TBD	TBD	TBD	TBD	TBD
1	1.2.2.2	Prohibit fragmenting and interfering activities	cont.	BLM*, USFS*, FWS*, DoD*, CDFG*, CDPR* Counties*, Cities*	TBD	TBD	TBD	TBD	TBD	TBD
1	1.2.2.3	Minimize livestock grazing impacts	5	BLM*, USFS*	25	5	5	5	5	5
1	1.2.2.4	Prohibit grazing by domestic sheep	5	BLM*, USFS*	0	0	0	0	0	0
1	1.2.2.7	Secure funding to implement measures	cont.	BLM*, USFS*, FWS*, CDFG*, MSHCP*	0	0	0	0	0	0
1	1.3.2	Reduce mortality due to natural causes	cont.	CDFG*, CDPR, FWS, BLM	TBD	TBD	TBD	TBD	TBD	TBD
1	2.1.1	Monitor abundance	cont.	CDFG*, CDPR, BLM, FWS, BI	323	11	15	11	15	11
1	2.1.2	Monitor distribution	cont.	CDFG*, CDPR, BLM, FWS, BI	323	11	15	11	15	11
1	2.1.3	Monitor recruitment	cont.	CDFG*, CDPR, BLM, FWS, BI	323	11	15	11	15	11
1	2.1.4	Monitor survivorship and cause-specific mortality	cont.	CDFG*, CDPR, BLM, FWS, BI	125	5	5	5	5	5
2	1.1.3.3	Implement fire management plan	5	USFS*, BLM, CDFG, CDPR	TBD	TBD	TBD	TBD	TBD	TBD
2	1.2.1.2	Avoid non-native vegetation	cont.	MSHCP*	0	0	0	0	0	0

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR PENINSULAR BIGHORN SHEEP

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's) FY 01	FY 02	FY 03	FY 04	FY 05
2	1.2.1.9	Prohibit *Culicoides* water sources	cont.	MSHCP*	0	0	0	0	0	0
2	1.2.2.5	Fence cattle allotments adjoining habitat	3	BLM*	TBD	TBD	TBD	TBD	0	0
2	1.2.2.6	Prohibit goats as pack animals	cont.	BLM*, USFS*, CDFG*, CDPR*	0	0	0	0	0	0
2	1.3.1.1	Regulate fence design/construction	cont.	BLM*, USFS*, MSHCP*	0	0	0	0	0	0
2	1.4	Develop captive breeding, reintroduction, augmentation strategy	cont.	BI,* CDFG,* FWS*	TBD	TBD	TBD	TBD	TBD	TBD
2	2.2	Develop population models	3	TBD	30	10	10	10		
2	2.3	Research the relationships between bighorn, mountain lions, mule deer, and habitat characteristics	5	FWS,* CDFG,* CDPR*, SDZS*, UCD*	650	130	130	130	130	130
2	2.5	Investigate the efficacy of temporary suppression of natural predation	5	CDFG*, FWS, CDPR	150	30	30	30	30	30
2	2.6	Research habitat use/selection and dispersal behavior	10	TBD	150	15	15	15	15	15
2	2.7	Monitor the effects of human disturbance	3	CDFG*, BLM, CDPR, USFS, FWS	TBD	TBD	TBD	TBD		
2	2.8	Research disease and preventive measures	3	TBD	TBD	TBD	TBD	TBD		
2	2.9	Research genetics	3	TBD	TBD	TBD	TBD	TBD		

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost ($1,000's)	Cost ($1,000's) FY 01	FY 02	FY 03	FY 04	FY 05
2	3.1	Distribute information on recovery efforts	cont.	FWS*, BLM, CDFG, BI, MSHCP, CDPR, USFS	50	2	2	2	2	2
2	3.2	Continue, update, and coordinate existing programs	cont.	FWS*, BLM, USFS, CDFG, BI, CDPR, MSHCP	50	2	2	2	2	2
2	3.3	Develop educational programs	cont.	FWS*, BLM, USFS, CDFG, MSHCP,CDPR, BI	50	2	2	2	2	2
3	1.2.1.3	Promote native plants	cont.	MSHCP*	29	5	1	1	1	1
3	1.2.1.5	Discourage use of exotic invasive plants	cont.	MSHCP*	0	0	0	0	0	0
3	1.2.1.6	Prohibit enticement on private property	cont.	MSHCP*	25	1	1	1	1	1
3	1.2.1.7	Monitor use of pesticide, herbicides	5	MSHCP*	25	5	5	5	5	5
3	1.2.1.10	Discourage feeding coyotes	cont.	MSHCP*	0	0	0	0	0	0
3	1.3.1.2	Post/monitor highway crossing areas	cont.	Caltrans*, BLM, CDPR, CDFG	25	TBD	TBD	TBD	TBD	TBD
3	2.4	Investigate the relationships between bighorn, coyote, and bobcat	10	TBD	100	10	10	10	10	10
3	3.4	Injured sheep treatment protocol	cont.	CDFG*, FWS, BLM, MSHCP	0	0	0	0	0	0

Total estimated cost of recovery: $73,253,000 +

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V. APPENDICES

APPENDIX A. AN OVERVIEW OF THE PENINSULAR RANGES

The Peninsular Ranges are located in southern California and Mexico, in the Colorado Desert division of the Sonoran Desert (Ryan 1968). On the north, the Peninsular Ranges are bordered by the Transverse Ranges. From this point, they extend south into Mexico, forming the backbone of Baja California. In California, the ranges form a prominent natural province (Sharp 1976) that is bounded on the east by the Salton Trough. To the west, the province extends to the Pacific Ocean, as a 130-kilometer-wide (80-mile-wide) series of northwesterly trending basins and ranges. The basins form channels below sea level and the ranges form the islands of San Nicolas, Santa Barbara, Santa Catalina, and San Clemente.

The highest peak in the San Jacinto Mountains is the 3,292-meter (10,800-foot) high San Jacinto Peak. Toro Peak, at 2,655 meters (8,700 feet), is the highest peak in the Santa Rosa Mountains (Oakeshott 1978). The Salton Sea, located to the east of the Peninsular Ranges, is found in the largest land mass below sea level in the Western Hemisphere (Ting and Jennings 1976). Historically, the Salton Sea has alternated between a freshwater lake fed with waters from the Colorado River, and a dying brackish pond when the waters of the Colorado River flowed instead to the Gulf of Mexico. When filled, the Salton Sea lapped at the foothills of the Santa Rosa Mountains. Since approximately 1907, however, the sea has been an increasingly salty depository for agricultural wastes of the Coachella and Imperial Valleys (Ting and Jennings 1976).

Bighorn sheep inhabit the eastern slopes of the Peninsular Ranges in habitat characterized by steep slopes and cliffs, canyons, washes, and alluvial fans. The remainder of this appendix will, therefore, provide an overview of the eastern slopes of the Peninsular Ranges.

Within bighorn sheep habitat, annual rainfall is variable with maxima of 35 to 470 millimeters (1.3 to 18.5 inches) during the past 36 years (National Oceanic and

Atmospheric Administration, 1962 to 1997). Rainfall exhibits a bimodal distribution pattern with most (approximately 70 percent) occurring in the winter months and a lesser amount in the late summer months. Winter rains are of the Pacific marine type, characterized by steady long rain showers, which promote the spring peak in plant productivity. Summer showers are of the Gulf marine type, which result in localized and sometimes fierce thunderstorms (Lindsay and Lindsay 1991). Maximum temperature in bighorn sheep habitat often reaches 46 degrees Celsius (115 degrees Fahrenheit) in summer, while winters are mild, with temperatures occasionally reaching freezing (National Oceanic and Atmospheric Administration, 1962 to 1997).

On the eastern slopes of the Peninsular ranges, vegetation associations are coniferous forest, primarily ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), Coulter pine (*Pinus coulteri*), and white fir (*Abies concolor*) above approximately 1,800 meters (5,905 feet), chaparral above approximately 1,500 meters (4,920 feet), and pinyon pine (*P. monophylla*)-juniper (*Juniperus californica*) above approximately 1,200 meters (3940 feet). Lower elevations are dominated by agave (*Agave deserti*), ocotillo (*Fouquieria splendens*), cholla (*Opuntia* spp.) and palo verde (*Cercidium floridum*), creosote (*Larrea tridentata*), palo verde-mesquite (*Prosopis* spp.) associations (Ryan 1968). Bighorn sheep typically are found at elevations less than 1,400 meters (4,600 feet) (Jorgensen and Turner 1975), usually staying at elevations below the chaparral and pinyon pine-juniper vegetation associations. These associations can represent visual obstruction because of denser and taller structures, and therefore make bighorn sheep more susceptible to predation (refer to section I.B.1 and I.B.2).

The Peninsular Ranges are inhabited by a large number of mammalian species (reviewed by Ryan 1968). The only native sympatric ungulate is the mule deer (*Odocoileus hemionus*). Bighorn sheep and deer distributions overlap at the upper elevations of bighorn sheep habitat, with possible geographic and seasonal differences in the degree of overlap. Deer are observed more frequently at lower elevations during the winter months. Potential native predators of bighorn sheep are mountain lions *(Puma concolor)*, bobcats *(Lynx rufus)*, coyotes *(Canis latrans)*, and golden eagles *(Aquila chrysaetos)*. These species are found throughout bighorn sheep habitat in the Peninsular Ranges.

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APPENDIX B. DELINEATION OF ESSENTIAL HABITAT FOR BIGHORN SHEEP IN THE PENINSULAR RANGES

Intended use of the map (Figures 2, 4-9)

A number of habitat models have been developed to rate bighorn sheep habitat (*e.g.*, Hansen 1980b, Holl 1982, Armentrout and Brigham 1988, Cunningham 1989, Dunn 1996) and components of bighorn sheep habitat have been examined or discussed by numerous researchers (*e.g.*, Hansen 1980a, McCarty and Bailey 1994). It has been suggested that some of these models be used to rate bighorn habitat in the Peninsular Ranges. However, application of these models here is inappropriate because they were developed in other areas and life zones where bighorn sheep exhibit different habitat requirements. For example, the Hansen model has been shown to be of limited value in measuring habitat quality in areas outside the habitats in which it was derived (Andrew and Bleich 1999) and is no longer used by the California Department of Fish and Game (S. Torres, California Department of Fish and Game, pers. comm.). Cunningham (1989) suggested that such habitat models need to be modified before being applied to novel bighorn sheep habitat.

The purpose of mapping bighorn sheep habitat in this recovery plan is not to rate the relative value of habitat types and areas within the Peninsular Ranges, but to identify those lands in need of protection, restoration, and management that are essential to bighorn sheep recovery (refer to section II.D.1). Rating the quality of sheep habitat would require a more thorough understanding of habitat selection versus habitat availability; studies that address this topic in the Peninsular Ranges have not been conducted to date but are recommended under section II.D.2.6. Though bighorn sheep habitat sometimes can be described by its function (*e.g.*, habitat for escape or lambing), Wilson *et al.* (1980) and Bleich *et al.* (1996) concluded that all habitat types used by bighorn sheep in desert environments are necessary for their population viability. The Santa Rosa Mountains Wildlife Habitat Management Plan (Bureau of Land Management 1980), a long-standing plan developed and implemented under the Sikes Act (16 USC 670a *et seq.*, Public Law 86-797) also recognized this, stating "(e)ach acre of bighorn habitat is important in maintaining the present population".

The purpose of this mapping effort is to delineate those areas believed to be necessary for a self-sustaining bighorn population with a high probability for long-term survival and recovery in the Peninsular Ranges of the United States. "Essential habitat", therefore, consists of those areas that provide bighorn sheep with the various physical and biological resources (*e.g.*, space, food, water, cover) potentially needed for: (1) individual/population growth and movement, and (2) normal behavior with protection from disturbance. Essential habitat should be protected from further loss or degradation (refer to section II.D.1.1). The valley floor to the east and the north of the Peninsular Ranges (*e.g.*, Coachella Valley, Imperial Valley) likely was used historically by bighorn sheep during rare, long-distance moves to and from other mountain ranges. However, no such moves have been documented. Furthermore, the chance of such moves has essentially been eliminated by high density urban development, major freeways, fences, and canals. Consequently, the vast majority of the valley floor to the east of the Peninsular Ranges is not included as essential habitat and is now detrimental to future use by sheep.

Approach used

The delineation of essential habitat was based on physical and biological features known to be important to bighorn sheep. These features were identified by reviewing pertinent literature and by drawing on the collective knowledge and experience of the Recovery Team and other biologists who have studied bighorn sheep in the Peninsular Ranges. The knowledge of such biologists played an important role in the mapping exercise because Peninsular bighorn sheep occupy a habitat that has marked climate and vegetational differences compared to habitat of most other bighorn sheep populations. The Peninsular Ranges are located in the Colorado Desert, a division of the Sonoran Desert, which experiences different precipitation patterns (timing and intensity of rainfall) than the Mojave or other Sonoran deserts and contains a somewhat different flora (Jaeger 1957, MacMahon 1985). These differences appear to cause Peninsular bighorn sheep to use habitat differently than bighorn sheep in other areas. For example, dense vegetation at higher elevations of the Peninsular Ranges restricts bighorn sheep to the more open desert slopes at lower elevations. For this reason, researchers familiar with bighorn sheep in the Peninsular Ranges have referred to these mountains as the "upside-down mountain ranges" (R. Weaver, California Department of Fish and Game retired, pers. comm.). Therefore, published information regarding habitat use patterns of bighorn sheep, in general, was supplemented with knowledge regarding habitat use patterns of Peninsular bighorn sheep, to identify habitat features that determine the distribution of bighorn sheep in these ranges.

Delineation of essential habitat is not based solely on known use patterns because: (1) population numbers currently are low and small populations use less habitat than larger populations, such as will be needed for recovery; (2) bighorn sheep are difficult to detect; (3) use patterns are only known for a recent short time period; (4) telemetry data on radio-collared animals (a sampled subset of the entire population) represents only the area used by marked animals, not the entire herd; and (5) habitat loss and human disturbance likely inhibits use of some lower elevation habitat. However, the delineated habitat boundaries were reviewed by Recovery Team biologists studying bighorn sheep in the Peninsular Ranges to verify that the mapped habitat encompassed most areas known to be used by animals currently or in the recent (25 to 30-year) past. However, numerous documented locations of sheep fell outside the essential habitat boundaries (Figure 6). The resulting map also was compared against a previous modeling effort (Bureau of Land Management 1980) as part of the validation and refinement process (see below).

Choice of habitat components

Habitat requirements have been examined by numerous researchers in the past (*e.g.*, Cunningham 1989, McCarty and Bailey 1994). Topographic cover, water, and forage appear to be the most consistently recognized habitat requirements, although other components such as mineral availability, thermal cover, as well as absence of competition with other ungulates and disturbance from human activities also have been suggested to be important (Cunningham 1989, McCarty and Bailey 1994).

Because these habitat components and characteristics largely determine how bighorn sheep use their habitat in the Peninsular Ranges, information available on these potential model parameters were compiled for analysis. Data that are available consisted of: (1) a fairly comprehensive inventory of water sources for Anza-Borrego Desert State Park, (2) a water source survey by the Bureau of Land Management for the northern parts of the range, (3) vegetation community maps, and (4) topographic relief.

In desert environments, water is a known limiting factor for many species of plants and wildlife. However, some populations of bighorn sheep are known to exist in areas without sources of perennial water (summarized in Broyles 1995), as is known to be the case in parts of the Peninsular Ranges for at least some parts of the year (refer to section I.B.1). In the Peninsular Ranges, the presence of perennial water is known to be a limiting factor only during prolonged droughts or summers without significant thunderstorm activity. However, given the numerous dependable water sources in the San Jacinto Mountains and other portions of the range (*e.g.* central Santa Rosa Mountains), water likely does not limit sheep distribution in these regions, even under drought conditions. The variable quality and lack of reliable water source data in some portions of the Peninsular Ranges, and the fact that water availability does not limit habitat use in much of these ranges, resulted in the decision to not use water sources to delineate bighorn sheep habitat. Available observational records (Figure 6) indicate that sheep range at least 16 kilometers (10 miles) from known perennial water sources. Given the existing distribution of water, sheep are capable of using, and therefore can be expected to use, all areas mapped as essential habitat.

Generalized plant community mapping has been completed within bighorn habitat throughout Riverside County, and detailed mapping has been completed in Anza-Borrego Desert State Park. However, bighorn sheep are generalist foragers and plants known to be eaten are broadly distributed across habitat types in the Peninsular Ranges. Extreme topographic relief provides a diversity of interdigitated habitats and plant communities across the mountainous slopes, canyons, washes, and alluvial fans within the home range of each ewe group. Consequently, the distribution of forage plants does not appear to limit sheep distribution, though it can influence seasonal habitat use patterns.

The primary habitat components that limit the distribution of bighorn sheep in the Peninsular Ranges may be those associated with predator evasion. Unobstructed visibility is recognized as an important habitat characteristic by many researchers (*e.g.*, Geist 1971, Risenhoover and Bailey 1985, Fairbanks *et al.* 1987, Etchberger *et al.* 1989). Bighorn sheep rely on their keen vision and climbing ability to detect and evade their predators (Geist 1971). The presence of escape terrain and an unobstructed view are, therefore, key habitat requirements (Geist 1971).

All bighorn sheep habitat models recognize escape terrain as a key habitat component. However, the definition of "escape terrain" varies widely (McCarty and Bailey 1994). Some researchers defined it by a minimum slope (*e.g.*, Andrew *et al.* 1999, Dunn 1996) or slope plus a qualitative measure of ruggedness (*e.g.*, Holl 1982, Risenhoover and Bailey 1985, Armentrout and Brigham 1988), while others have described escape terrain with word models that incorporate a qualitative description of slope and ruggedness (*e.g.*, Hansen 1980b, Elenowitz 1983, Gionfriddo and Krausman 1986, Fairbanks *et al.* 1987, Cunningham 1989). The difficulty in determining a universal definition may be because bighorn sheep in different mountain ranges have access to different habitat (in terms of slope and ruggedness), and/or because use of escape terrain varies with group size (Risenhoover and Bailey 1985), group composition, and season (Cunningham and Ohmart 1986, Bleich *et al.* 1997). Furthermore, escape terrain has been described as habitat used "for escape from perceived danger" (Van Dyke *et al.* 1983). This definition recognizes that escape terrain is based on a bighorn sheep's perception, something that apparently differs among individuals and populations. Desert bighorn sheep frequently have been found at slopes of 21 to 50 percent (Elenowitz 1983), slopes greater than or equal to 20 percent (Andrew *et al.* 1999), and slopes averaging 13 to 34 percent (Bleich *et al.* 1997). A minimum slope of 20 percent was used (in combination with canopy cover) to define bighorn sheep habitat in New Mexico (Dunn 1996). A slope of greater than or equal to 20 percent was adopted as the minimum required as escape terrain for bighorn sheep in the Peninsular Ranges. The first step of the habitat mapping process was, therefore, to identify all patches of land having a slope of greater than or equal to 20 percent (see following methods).

Bighorn sheep are closely associated with mountainous habitat and often are hesitant to venture far from escape terrain (Geist 1971). Although they have been documented to move great distances from escape terrain on rare occasions (Schwartz *et al.* 1986), it is not uncommon to observe animals moving a short distance from escape terrain in search of forage or water sources, or moving between neighboring mountain masses. Washes and alluvial fans often support a higher diversity, quality, and quantity of forage species than less productive rocky slopes (Leslie and Douglas 1979), seasonal and perennial water sources (Wilson *et al.* 1980, Holland and Keil 1989), bedding and thermal cover (Andrew 1994), alternative forage sources in times of drought, resource scarcity, and stress (Leslie and Douglas 1979, Bleich *et al.* 1997), and a source of forage with higher nutritional value during the lambing and rearing season (Hansen and Deming 1980). Also refer to section I.B.1. Since temperature varies inversely with elevation, the earliest winter forage growth occurs at lower elevations (Wehausen 1980, 1983), and sheep often seek this early source of nutrients. The critical importance to bighorn of access to a variety of feeding habitats was demonstrated in the Whipple Mountains when reintroduced sheep were confined to an enclosure containing what was considered ample forage. At lambing time, both ewes and their new lambs began dying of malnutrition (Berbach 1987), apparently because they were not free to seek out habitats containing more nutritious forage. Researchers have documented animals ranging at a variety of distances from mountainous terrain, *e.g.*, 1.6 kilometers (0.80 mile) (Denniston 1965), 0.8 kilometer (0.50 mile) (McQuivey 1978), 1.3 kilometers (0.70 mile) (Leslie and Douglas 1979), greater than 1 kilometer (1.6 miles) (Burger 1985), greater than 1.6 kilometers (1 mile) (Bleich *et al.* 1992), and greater than 2.5 kilometers (1.6 miles) (Andrew *et al.* 1997). Jones *et al.* (1957) reported bighorn sheep foraging as far as 2 kilometers (1.2 miles) from the base of the Santa Rosa Mountains. Elsewhere in the Peninsular Ranges, bighorn sheep were frequently observed within 0.8 kilometer (0.5 mile) from mountainous habitat feeding in or moving across washes and alluvial fans (DeForge and Scott 1982; E. Rubin and M. Jorgensen, pers. comm.). Accordingly, the second step of the mapping process was to include habitat within 0.8 kilometers (0.50 mile) of slopes greater than or equal to 20 percent.

To identify slopes of 20 percent or greater, 7.5' digital elevation models (DEMs) were merged together over the entire study area. These digital elevation models are 30-meter by 30-meter (98-foot by 98-foot) cell grids with a vertical accuracy of 7 meters (23 feet). All grid cells were then aggregated into slope classes. Next, the slope classes were analyzed to select habitat within 0.8 kilometer (0.5 mile) of slopes of greater than or equal to 20 percent. This selection was accomplished by first lumping slopes greater than or equal to 20 percent into one class in a derivative grid. A buffer of 0.8 kilometer (0.5 mile) was then applied to the perimeter of all areas of slope in the derivative grid.

In the Peninsular Ranges, bighorn sheep habitat is delimited at upper boundaries by dense vegetation associations (primarily chaparral) that reduce visibility and likely increase susceptibility to mountain lion predation. Measuring visibility (by actual field measurements) to delineate the upper boundary of habitat would require study because it is currently not known what visibility threshold is acceptable to bighorn sheep in the Peninsular Ranges. Fire frequency and its effect on plant succession changes visibility thresholds over time (refer to section I.D). Therefore, to determine the upper boundary of bighorn sheep habitat, the westernmost areas used by bighorn sheep within the past 25 to 30 years were identified and the vegetation associations in these areas were applied rangewide where detailed vegetation analyses were available. Because a detailed vegetation map was not available rangewide, a team of biologists experienced with Peninsular bighorn sheep flew the entire upper/western boundary line in a helicopter and visually assessed vegetation associations. The path of the flight was determined by consensus among the biologists and was recorded via a Global Positioning System (GPS). The antenna of a Trimble Navigation, LTD., Global Positioning System was mounted in the helicopter and position data were recorded every 10 seconds. A total of 228 kilometers (142 miles) were flown. A base station Global Positioning System, located in the Anza-Borrego Desert State Park, was run during the entire flight. Trimble Navigation Pathfinder Office software was used to post process the collected Global Positioning System data using base station information. Trimble Navigation Pathfinder Office (IM) was then used to export the data as an ESRI ARC/INFO Geographic Information Systems (GIS) readable file. Only corrected data were used to build the resulting Geographic Information System layer. Because this line is dynamic in response to fire frequency and likely has shifted to a lower elevation with the advent of fire suppression, a 0.8 kilometer (0.5 mile) extension was added to the west side of this line.

The resulting line in Anza-Borrego Desert State Park was checked against detailed Geographic Information System mapping of vegetation associations within the park (Keeler-Wolf *et al.* 1998). Vegetation associations not typically used by bighorn sheep in the Peninsular Ranges were excluded from essential habitat. These associations primarily included Muller's oak (*Quercus cornelius-mulleri*), sugarbush (*Rhus ovata*), chamise (*Adenostoma fasciculatum*), and manzanita (*Arctostaphylos* spp.) associations. Associations encompassed within bighorn sheep habitat included brittlebush (*Encelia farinosa*), desert lavender (*Hyptis emoryi*), cholla (*Opuntia* spp.), burro-weed (*Ambrosia dumosa*) and creosote (*Larrea tridentata*), and other creosote associations. The resulting line supported the habitat boundary that was derived during the helicopter flight along the western margin of current bighorn sheep habitat.

To validate the choice of greater than or equal to 20 percent slope and 0.8 kilometer (0.5 mile) distance from this slope as model parameters, Recovery Team members experienced with Peninsular bighorn sheep flew the easternmost line of bighorn sheep habitat in a northern portion of the range (San Jacinto Mountains and Santa Rosa Mountains). The path of this flight was determined by consensus among the team members, based on their observations of bighorn sheep in these ranges, and was believed to represent the low elevation (easternmost) boundary of habitat commonly used by Peninsular bighorn sheep. The path of this flight, which was recorded via Global Positioning System, supported the choice of the greater than or equal to 20 percent slope plus 0.8 kilometer (0.5 mile) distance from this slope as the eastern, lower elevation habitat boundary.

The resulting habitat boundaries were reviewed by Recovery Team members who have studied bighorn sheep in the Peninsular Ranges to verify whether those areas known to be used by sheep in the recent past (within the past 25 to 30 years) were included within the modeled habitat boundaries. This review included a comparison of bighorn sheep sighting locations against the map and verified that most areas used by sheep within the past 25 to 30 years were included within the modeled habitat boundaries (Figure 6).

Mapping Refinement

Upon further review by Recovery Team members, it was determined that the modeled habitat included a habitat type not likely to be used by Peninsular bighorn sheep. This habitat type, classified as mud hills (Augustine and Ward 1995) was found in the Borrego Badlands and Carrizo Badlands of Anza-Borrego Desert State Park. Much of this soil type was removed from the delineated map because it did not correspond with known bighorn sheep habitat use patterns. Conversely, the preliminary habitat boundaries excluded several small islands of "nonhabitat" (defined by the modeling of slope and distance from slope). Because Recovery Team members familiar with the areas considered these islands to be bighorn sheep habitat on the basis of known sightings in nearby or comparable areas, these islands were included in delineated habitat.

A small number of known observations fell outside the delineated boundaries at lower elevations on relatively flat terrain, such as Clark Dry Lake and Coyote Canyon. These observations support previously published reports of bighorn sheep occasionally moving away from mountainous areas. However, the relative rarity of records beyond the 0.8 kilometer (0.5 mile) distance from slope was judged to indicate that such habitat was not essential to population recovery if the habitat delineated within the 0.8 kilometer (0.5 mile) distance from slope were protected. In other areas, the opposite process was required to minimize the habitat edge to area ratio consistent with sound tenets of resource management and preserve design. Along some segments, the 0.8 kilometer (0.5 mile) distance from slope was expanded slightly to capture "nonhabitat" areas that would have represented deep but narrow intrusions into an otherwise stable and manageable essential habitat boundary.

Further modifications were deemed necessary along the urban interface in the Coachella Valley. The 0.8 kilometer (0.5 mile) distance from slope largely has been lost to urban development. Much of the remaining valley floor and alluvial habitat within the 0.8 kilometer (0.5 mile) distance is highly fragmented and degraded with marginal or detrimental value to bighorn conservation (*e.g.*, vacant lots along Highway 111, parcels bordered on three sides by urban development). A series of meetings with affected jurisdictions and major land owners was convened under the auspices of the Coachella Valley multiple-species planning effort to discuss and refine the delineation of essential habitat along the urban interface. Lands without long-term conservation value were excluded from essential habitat (Figures 7, 8, 9). The larger fragments that still remain were included within essential habitat where they were contiguous with mountain slope habitat and of a configuration amenable to effective management. Subject to implementation of required conservation measures, the essential habitat boundary does not include development projects previously reviewed and approved by us.

Finally, pursuant to Secretarial Order 3206 June 5, 1997, we have entered into government to government discussions with the various American Indian tribes that possess lands in bighorn sheep habitat. We coordinated with the tribes to encourage their participation in delineating essential habitat and developing the Peninsular bighorn sheep Recovery Plan in a way that promotes recovery of the species and minimizes the social, cultural, and economic impacts on tribal communities. We worked with and supported the efforts of the Torres-Martinez Desert Cahuilla Indians to obtain data on the value of Reservation lands to bighorn sheep conservation but the Tribe has not agreed that sufficient information is available to demonstrate that their lands are essential to recovery. Based on coordination with the Morongo Band of Mission Indians, tribal lands within the essential habitat boundary will be included for sheep conservation. The Agua Caliente Band of Cahuilla Indians has coordinated with us in the delineation and have agreed that a reservation-wide habitat conservation planning effort will determine appropriate land management issues at a finer scale within the essential habitat boundary.

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APPENDIX C. GUIDELINES FOR DEVELOPING A LONG-TERM STRATEGY FOR REINTRODUCTION, AUGMENTATION, AND CAPTIVE BREEDING OF BIGHORN SHEEP IN THE PENINSULAR RANGES

The purpose of this appendix is to provide guidelines for developing a long-term strategy for reintroduction, augmentation, and captive breeding of bighorn sheep in the Peninsular Ranges, as identified in the recovery plan (task 1.4). This appendix is organized into two sections. The first section outlines some of the preliminary steps needed to identify cases in which reintroductions, augmentations, and captive breeding may be appropriate, and highlights some important considerations in the development of a long-term strategy. The second section presents protocols for captive breeding and release of captive animals, and represents guidelines prepared by the Bighorn Institute for an existing captive breeding and release program. This section addresses many of the issues identified in our Policy Regarding the Controlled Propagation of Species Listed Under the Endangered Species Act (65 FR 56916; September 20, 2000).

I. Considerations in developing a long-term strategy for reintroductions and augmentations

A number of decisions must be made when developing a long-term strategy for augmentation and reintroduction of bighorn sheep in the Peninsular Ranges. Important preliminary steps are presented here in outline form:

1) Identify the general goals of the long-term strategy in relation to the overall recovery effort. These goals should consider the viability of the population with respect to population dynamics and genetics.

2) Determine if existing ewe groups should be augmented or new groups established. A population model, using estimated population parameters (*e.g.*, abundance, recruitment, survivorship, dispersal), should be used to evaluate the effectiveness of various options (including the option of no augmentation or reintroductions) on the viability of the metapopulation.

3) Identify and prioritize sites for augmentations and reintroductions. This assessment must evaluate not only the site's importance to the viability of the entire population, but also must address the following questions:
   a) What is/was the cause of extinction or endangerment in this location?
   b) Has this cause been minimized or removed?
   c) Is reintroduction or augmentation the best conservation option for this particular situation? Have other necessary measures, such as habitat restoration or protection, been taken?

4) Determine augmentation and reintroduction techniques. The success of previous bighorn sheep augmentation and reintroduction projects has been mixed, and a number of questions remain (Desert Bighorn Council 1996). In reintroducing or augmenting Peninsular bighorn sheep, the following issues need to be evaluated:

   a) Determine whether to use captive or free-ranging animals. For the following reasons, caution should be exercised when using captive animals:
      i) If multiple, consecutive generations of animals are bred in captivity, they may undergo "domestication selection"; that is, captive individuals may have behavioral or morphological phenotypes that perform well in captivity but not in the wild. In addition, captive animals may have been raised in an overly protective environment where selection against deleterious genes was relaxed (Brambell 1977, Campbell 1980, Elliott and Boyce 1992, Bush *et al.* 1993).
      ii) Captive animals may be disease vectors to wild populations if they have been exposed to novel diseases during *ex situ* (outside the original site, or captive) propagation (Campbell 1980, Woodford and Kock 1991, Bush *et al.* 1993), or if they have continued to harbor pathogens that have been "purged" from wild populations.
      iii) The use of captive animals during augmentations can reduce or increase the effective population size of the wild population (Ryman and Laikre 1990, Elliott and Boyce 1992).

      Part II of this appendix provides protocols by which these concerns may be minimized. Releases of free-ranging animals are typically more successful than are those of captive animals (Griffith *et al.* 1989, Gordon 1991, Stanley Price 1991); however, an advantage of using captive animals is that their genetic profiles typically are known. In addition, the potential effects on population (Stevens and Goodson 1993) and genetics of removing animals from the wild population must be considered. Currently the small size of ewe groups within the Peninsular Ranges limits the availability of free-ranging animals for translocation. Additional genetic studies may help identify sources within the Peninsular Ranges or elsewhere. Future projects could involve both captive and free-ranging bighorn sheep.

b) If captive animals are to be used in reintroductions and augmentations, determine the desired size of the captive herd, and optimum facilities and management techniques. One alternative is to establish a large captive herd that is housed in a larger enclosure and managed less intensely than the existing captive herd. An approach similar to this is used by the New Mexico Department of Game and Fish (1997) at their Red Rock Wildlife Area, where bighorn sheep are housed in a fenced area of over 500 hectares (1,235 acres). Potential advantages of such a facility are that released animals may have traits more characteristic of free-ranging animals (as opposed to animals raised in a more confined environment), and a larger captive population may lessen genetic concerns associated with small founder populations. As with any captive breeding program, however, the source of animals for this captive population would have to be considered, and both population and genetic management guidelines would have to be addressed (see part II of this appendix).

c) Determine the best population composition of released groups. This consideration applies whether captive or free-ranging animals are used. The number, age/sex composition, and experience of released animals are important considerations (Lenarz and Conley 1980, Wilson and Douglas 1982, Kleiman 1989). The gregarious behavior of bighorn sheep suggests that larger groups are desirable (Wilson and Douglas 1982). However, smaller group sizes more likely mimic natural re-colonization events. The sex ratio should maximize the reproductive potential of the released group or the wild population during reintroductions and augmentations respectively. For bighorn sheep, this typically means a low ram to ewe ratio (Lenarz and Conley 1980). Young animals have high reproductive value (Gotelli 1995) and have a strong tendency to integrate with existing herds when used as release stock (Ostermann *et al.* in press), and thus are desirable for augmentation programs. Lenarz and Conley (1980) suggested that the optimum age for released bighorn sheep is 3 years. However, inclusion of a small number of older or free-ranging, and presumably more experienced, individuals increases the likelihood of success of a reintroduction. The effect of these variables needs to be considered not only with respect to how they will influence success of the release, but also how the removal of these animals will affect the source stock from which they came (Stevens and Goodson 1993).

d) Identify appropriate release animals based on pedigree and proximity to the intended release area. Though based solely on genetic theory, this approach is conservatively designed to: (1) preserve the potential for genetic adaptations to local conditions, (2) prevent outbreeding depression, and (3) maintain the existing genetic structure currently found among Peninsular bighorn ewe groups (Brambell 1977, Boyce *et al.* 1999). However, other options are available to prevent loss of heterozygosity in the wild population (May 1991). In general, the preservation of the gene pool of the entire metapopulation (wild and captive populations included) should be the primary concern (Foose 1991). Therefore, when reintroducing or augmenting animals, care must be taken to avoid genetic swamping of native populations (Kleiman 1989, Ryman and Laikre 1991, Foose 1991, Elliott and Boyce 1992). Furthermore, during any reintroduction or augmentation, the number and sex ratio of released animals must be considered, as it will affect effective population size (Crow and Kimura 1970, FitzSimmons *et al.* 1997). The second section of this appendix discusses the genetic considerations of captive breeding and release of captive animals in detail.

e) Determine the most effective means of releasing animals. These considerations, which apply to both the release of captive and free-ranging animals, should include:
   i) Whether to use a 'soft' or 'hard' release (Berbach 1987, Moore and Smith 1991).
   ii) How far to move free-ranging animals during reintroductions and augmentations. The philopatric behavior of bighorn sheep may result in animals attempting to return to their natal home range. Research on dispersal and movement patterns may guide these decisions (refer to section II.D.2 of this recovery plan).
   iii) During which time of year to conduct releases.
   iv) What specific release site to use. For instance, how far should release sites be from other bighorn sheep (Bleich *et al.* 1996) or from human development? This question may be assessed by releasing and monitoring a small number of sentinel animals during a feasibility study (Kleiman 1989, Chivers 1991).

5) Determine methods for monitoring and assessing the success of reintroduction or augmentation programs, in relation to the goals of this recovery effort (Stanley Price 1991), and identify a specific schedule for future review and possible revision of the long-term strategy.

II. Captive breeding and release of captive bighorn sheep

While it is not a long-term solution (Snyder *et al.* 1996), captive breeding is a powerful tool for rescuing species threatened with extinction (Caughley 1994, Philippart 1995, Caughley and Gunn 1996). Captive breeding can also be used to delay extinction while the agents of a decline are investigated (Caughley and Gunn 1996). Other advantages of captive propagation include the ability to moderate environmental variance, manage genetic diversity, increase the effective population size, and expand animal numbers to provide stock for wild populations (Foose *et al.* 1995). Releasing captive-born animals into the wild to support weak populations is an increasingly common practice (Griffith *et al.* 1989, Kleiman 1989, Snyder *et al.* 1996).

Although there are benefits of captive propagation programs for releasing animals into the wild (Griffith *et al.* 1989, Kleiman 1989, Caughley 1994, Foose *et al.* 1995), these programs can be costly, labor intensive, and their effectiveness has been questioned (Campbell 1980, Philippart 1995, Caughley and Gunn 1996, Snyder *et al.* 1996). Additionally, there are a number of potential risks associated with captive breeding and release programs. Our Policy Regarding Controlled Propagation of Species Listed Under the Endangered Species Act (65 FR 56916; September 20, 2000) identified the following risks that must be addressed when planning controlled propagation and reintroduction programs: (1) removal of natural parental stock that may result in an increased risk of extinction by reducing the abundance of wild individuals and reducing genetic variability within naturally occurring populations; (2) catastrophic events that can cause the loss of some or all of the captive population; (3) potential for inbreeding or other adverse genetic effects that may result from increasing only a portion of the gene pool; (4) potential erosion of genetic differences between populations; (5) exposure to new selection regimes in controlled environments that may diminish capacity to survive and reproduce in the wild; (6) genetic introgression; (7) increased predation or competition for food, space, and/or mates; and (8) disease transfer.

Adhering to established criteria and upholding standardized protocols will contribute to the success of reintroduction and augmentation programs and reduce the accompanying risks. In this appendix, generalized criteria and guidelines for reintroduction and augmentation programs are combined with knowledge of desert bighorn sheep ecology to create more specific guidelines for Peninsular bighorn sheep captive breeding and release programs.

In this appendix, reintroduction is defined as the movement of wild or captive animals into formerly occupied habitat, while the release of animals into currently occupied habitat is termed "augmentation" or "restocking." The ultimate objective of these guidelines is to establish wild, free-ranging herds that no longer rely on captive breeding. Separate guidelines should be developed for captive breeding programs with other primary goals.

Feasibility Study

Before commencing a captive breeding program, a feasibility study should be conducted to determine its necessity and potential for success. The following general criteria should be considered (Kleiman *et al.* 1994): the wild population's need for support with respect to genetic diversity and population structure, the availability of stock, removal of the original cause of decline, protection of sufficient habitat, local politics, governmental and nongovernmental agency support, reintroduction/augmentation technology, knowledge of species biology, and sufficient financial resources. A summary of these criteria, which are grouped into four categories, is provided below.

Need for population and/or genetic support

Because captive breeding and reintroduction/augmentation programs require large financial and logistical commitments, the need for population and/or genetic support must first be clearly established (Kleiman 1989, Phillipart 1995, Snyder *et al.* 1996). The International Union for the Conservation of Nature and Natural Resources (1995) guidelines for reintroduction and augmentations recommend conducting a population and habitat viability workshop before initiating a program. A population viability analysis may also facilitate the design and objectives of the program by providing direction on the number of animals needed, and hence the size of the facility needed, and whether restocking (augmenting populations) or reintroduction (establishing new groups) is preferred. Captive breeding is often expensive and not always the most cost-efficient conservation strategy (Kleiman 1989, Kleiman *et al.* 1991, Snyder *et al.* 1996). It must be conducted in conjunction with other conservation measures, and should be based on specific recommendations within a recovery or management plan so that it does not unjustly preempt other recovery techniques (Snyder *et al.* 1996).

Environmental conditions

Captive breeding should only be undertaken if suitable, unsaturated habitat is available (Brambell 1977, Kleiman 1989, Ounsted 1991) and release sites have sufficient carrying capacity to support the expansion of the reintroduced or augmented population. Ideally, release sites should be legally protected (Kleiman *et al.* 1994). Removing or controlling the original cause(s) of decline is an essential step, as failure to do so is a primary reason that reintroduction and augmentation efforts are unsuccessful (Brambell 1977, Ounsted 1991, Kleiman *et al.* 1994). However, in some situations, augmenting a population while investigating the cause of decline is an acceptable practice (Caughley and Gunn 1996). The philopatric behavior of bighorn sheep (Geist 1971) suggests there are advantages to augmenting a population to retain traditional herd knowledge, rather than reintroducing animals after extirpation, particularly if this would allow research into the cause of decline.

Biopolitical conditions and funding

Although no breeding program can be successful without knowledge of the species' biology or reintroduction/augmentation technology, non-biological factors such as long-term funding, project administration, and communication among participating organizations have been found to be important determinants for program success (Stanley Price 1991, Beck *et al.* 1994, Kleiman *et al.* 1994). Feasibility studies should include investigating prospects for long-term funding and obtaining the support of all relevant governmental and non-governmental agencies. Inadequate funding could severely limit the progress and success of the program. Therefore, programs should not be initiated until funding is secured to ensure that all phases (disease testing, research, post-release monitoring, etc.) will be accomplished. Because captive breeding programs are a multidisciplinary undertaking involving people drawn from a variety of backgrounds (International Union for the Conservation of Nature and Natural Resources 1995), the decision making structure, as well as the authority and responsibility of each group involved should be clearly delineated (Kleiman *et al.* 1994).

Knowledge of the species and reintroduction/augmentation technology

Knowing the ecological requirements of a species is necessary for a successful breeding and release program. For many species, the lack of basic information and release technology necessitates detailed studies examining the species behavior and biological needs before establishing a breeding program (Kleiman 1989, Stanley Price 1991). However, past and ongoing captive propagation programs for desert bighorn sheep (Calkins 1993, New Mexico Department of Game and Fish 1997, Ostermann *et al.* in press) have demonstrated the potential for establishing self-sustaining captive populations and the techniques developed for translocations (Rowland and Schmidt 1981, Wilson and Douglas 1982) provide information that can be applied to releasing captive-reared animals into the wild.

Husbandry

Large, predator-proof enclosures with native vegetation, natural habitat features, and adequate food, salt, mineral, and water resources are needed. Native vegetation should be retained in the enclosure, and supplemental feed may be required to prevent over-browsing. An enclosure that contains a variety of habitat types and topographic relief will allow captive animals to exhibit natural behavior, such as using escape terrain in response to disturbance. Presumably, housing captive animals in conditions as similar to the release site as possible will ease their transition to a wild environment. During the nonbreeding season, adult males and females should be separated or have ample room to naturally segregate. To reduce disease transmission risks, captive populations should be maintained within the natural range of the animal, in single-species facilities that do not regularly exchange stock (Snyder *et al.* 1996). The design of the enclosure should allow for the safe capture of animals for sampling and/or release. Enclosure fencing should be greater than or equal to 3 meters (10 feet) in height above ground and extend a minimum of 0.61 meter (2 feet) underground, or employ other options to exclude predators. Mountain lions have entered enclosures and killed captive bighorn sheep on several occasions (Blaisdell 1971, Sandovol 1979, Winkler 1977). Monitoring consisting of at least daily checks of the enclosure and animals is necessary for detecting health concerns, causes of mortalities, and disturbances.

Disease prevention and screening

Disease prevention is of primary importance for desert bighorn sheep captive breeding programs. Of all North American wild ungulate species, wild sheep are possibly the most sensitive to common livestock diseases and parasites (Jessup

1985). Disease outbreaks terminated reintroduction efforts at both the Lava Beds National Monument in California (Blaisdell 1982) and the Sierra Diablo pens in Texas (Brewer 1997), two initially successful desert bighorn sheep breeding operations. Disease in the captive animals and poor reintroduction success led to the release of all bighorn sheep from the Zion National Park captive propagation enclosure (McCutchen 1978). Outbreaks of blue-tongue reduced the Red Rock population by approximately 18 animals in 1985 and 25 animals 1991 (New Mexico Department of Game and Fish 1997). See section I.E.3 for information on the captive population at Bighorn Institute.

Disease considerations for augmentation programs include the potential of introducing disease to the wild population when releasing captive-reared stock and the impact of diseases endemic in the wild population on released animals (Viggers *et al.* 1993). The prevalence of disease in the wild and captive population will determine the need to eradicate pathogens in animals brought into or released from captivity and whether to release or breed certain animals. Elimination of all pathogens from captive animals is not expected or recommended (Bush *et al.* 1993, Viggers *et al.* 1993), as this may reduce their immunity to disease and place them at risk of diseases endemic in the wild population. Regular, standardized disease monitoring of both the wild and captive populations is strongly recommended.

Disease prevention measures

Captive breeding facilities should be closed to the public and the staff should practice rigorous disease prevention measures, including avoidance of potential disease transmission from other captive stocks as well as between wild and captive bighorn sheep. All potential routes for disease transmission from domestic livestock should be anticipated and avoided. For example, when purchasing hay, care should be taken to avoid dealers who rotate their crops with domestic livestock grazing.

Separate quarantine facilities should be available to house incoming stock; however, animals known to be sick should not be brought into captivity. It is important to determine the cause of death for all animals that die in captivity or soon after release into the wild. Fresh carcasses should be refrigerated and transported to a veterinary diagnostic laboratory for full necropsy.

Disease-free certification

Disease screening (hematology, serum chemistry, serology, virus isolation, ova and parasite tests, and bacterial culture) should be performed on greater than or equal to 25 percent of the captive animals at least annually, and on all pre-release animals within 30 days prior to their release into the wild. Health screening of pre-release bighorn sheep helps prevent the introduction of disease into the free-ranging population and optimize the released animal's chances for survival in the wild. Screening of wild-caught breedstock reduces the chance of introducing disease to the captive population. All bighorn sheep entering or leaving the captive breeding program should be certified as "disease-free." Disease-free certification requires that within 30 days prior to release: (1) the animals appear healthy and shows no signs of active infection upon visual examination by an U.S. Department of Agriculture accredited veterinarian familiar with bighorn sheep, (2) recent laboratory results (from testing described above) do not indicate active infection or other health concerns, (3) the animal tests negative for Ovine Progressive Pneumonia (AGID test), and (4) the animals have not been exposed to diseased animals in the captive breeding facility.

Treatment of sick animals in captivity

Animals showing signs of illness (*e.g.*, drooping ears, nasal discharge, coughing, lethargy, weight loss) should be closely observed and biologically sampled to attempt to determine the cause of illness. Bighorn sheep in poor condition, needing frequent treatment, or exhibiting signs of infectious or contagious disease should be placed in quarantine. Treatment should be provided under veterinary supervision if the condition is life threatening, unless research needs dictate otherwise.

Principles guiding genetic management

Genetic management strives to minimize the loss of naturally occurring genetic variability by preserving genes of founders who represent a gene pool of interest

(Ballou and Lacy 1995). Goals for the genetic management of captive populations usually include retaining genetic variation for future evolutionary potential, minimizing genetic changes that may occur while a species is in captivity, and avoiding inbreeding (Foose and Ballou 1988, Hedrick and Miller 1992, Foose 1991, Foose *et al.* 1995). Concerns about the fitness, evolutionary potential, and locally adapted gene pools of natural populations require that conservation efforts also consider intraspecific genetic variation (Soulé 1986, Millar and Libby 1991, Hedrick and Miller 1992, Cronin 1993). Molecular markers (allozymes, restriction fragment length polymorphisms, microsatellites, mitochondrial DNA) can aid in identifying current and historic levels of population subdivision, gene flow, and population characteristics (Milligan *et al.* 1994, Avise 1995). However, it is important to note that molecular markers identify only a small portion of the genome and are not specifically or necessarily tied to traits involved in either adaptation or fitness.

Identifying the genetic structure of the population being augmented is considered a first step towards assuring that appropriate subpopulations are targeted for propagation and release (Brambell 1977, Lyles and May 1987). Peninsular bighorn sheep are distributed in a metapopulation comprising approximately eight subpopulations, although the degree to which this structure reflects anthropogenic forces is unknown (Torres *et al.* 1994, Boyce *et al.* 1997, Rubin *et al.* 1998, Boyce *et al.* 1999).

The genetic effects of population subdivision are quantified by the fixation index (F_{ST}; Wright 1951), which describes the proportion of genetic variation within bighorn sheep subpopulations relative to the total variation in the population. The fixation index can also be used as an index of genetic differentiation among populations. A high fixation index value indicates significant genetic substructuring of the population. Moderate values (defined as F_{ST} of 0.05 to 0.15, Wright 1978) for mean F_{ST} were found for six populations within the Peninsular Ranges using nuclear DNA markers (micro-satellite loci [F_{ST} equals 0.113] and the major histocompatibility complex loci [F_{ST} equals 0.120]). They suggest there are relatively high levels of male-mediated gene flow among populations (Boyce *et al.* 1997). When managing a group of closely related subpopulations migration should be maintained while also allowing for genetic differentiation among demes in response to local selective pressure (Nelson and Soulé 1987, Ryman *et al.* 1995).

Other factors to consider in reintroduction or augmentation programs are effects to the native gene pool, including introgression, and an increase in the variance in family size or the number of offspring per individual (Ryman *et al.* 1995). Introgression occurs when populations with different genetic characteristics are mixed. It may cause the loss of locally adapted genes through interbreeding, loss of entire gene pools as a result of displacement, and/or homogenization of a previously genetically structured population through swamping with a common gene pool. Factors relating to introgression that should be considered include: the amount of genetic divergence between the captive and wild populations, the genetic population structure of the wild population, and the number of animals to be released relative to the size of the recipient population (Ryman *et al.* 1995). Without knowledge of the genetic characteristics of the natural population, it is nearly impossible to predict the occurrence or importance of changes in the genetic structure of the augmented population. Although problems with outbreeding depression usually involve populations that are distinct subspecies, the effects of genetic mixing are difficult to predict, ranging from no effect to outbreeding depression even within the same species under similar circumstances (Ryman *et al.* 1995). There are some circumstances when introgression can be beneficial, for example, when a natural population has been genetically depleted over an extended period due to small population size (Ryman *et al.* 1995).

A second problem with captive or supportive breeding programs is the potential to increase the variance in family size or number of offspring produced per individual (Ryman *et al.* 1995). Taking a fraction of the wild population into captivity for enhanced reproduction and survival may increase population numbers, but it can reduce genetic variation by inflating the variance in family size, a parameter that is inversely related to the genetically effective size of the population (Ryman and Laikre 1991). Pedigree analysis, rotation of breeding stock, and genetic management of the captive and wild populations can help lessen concerns associated with introgression and variance in family size. For example, in the northern Santa Rosa Mountains, the origin (captive or wild-born) of all animals in this herd is known and the sire and/or dam of most individuals is known (Ostermann and DeForge 1996). In this case, particular wild-born bighorn sheep native to the gene pool can be targeted for captive propagation if necessary. This situation presents a unique opportunity to use high intensity genetic management (Lacy *et al.* 1995) to improve or maintain the genetic variability in a free-ranging population.

Selection of breeding stock

Even when the main goal of an augmentation project is to provide population support, Kleiman (1989) recommended first considering the genetic characteristics of potential release animals. Animals released into the wild should be similar to the native animals of the region because over evolutionary time, successful populations are expected to become morphologically, physiologically, and behaviorally adapted to the local environment (Brambell 1977, Kleiman 1989, Lynch 1996). Obtaining locally adapted stock for captive breeding and release into the wild is proposed as a method to approximate the correct, locally adapted genotype, although this may add relatively little genetic variability to the wild population (Lyles and May 1987). However, given the habitat fragmentation and small size of several demes in the Peninsular Ranges, genetic exchange to avoid inbreeding depression should be considered.

Only bighorn sheep less than 1 year of age are recommended for capture for breeding stock if animals are to be placed in small enclosures (approximately less than 2 hectares [5 acres]) for quarantine. Young bighorn sheep adjust more readily to a captive environment than adult bighorn sheep (J. DeForge, pers. comm.), which have died from colliding with fences while in captivity (Montoya 1973, Sandoval 1981). Larger enclosures would reduce this risk.

Mating strategies

Appropriate level of genetic management of captive populations depends on the information available, intended intensity of management, and goals of the program (Lacy *et al.* 1995). Breeding programs for bighorn sheep vary from small populations receiving high-intensity genetic management to large herds where only low-intensity genetic management is possible. Several low-intensity mating strategies based on maximizing the effective population size and maximum avoidance of inbreeding have been developed (Princee 1995). This document focuses on concepts for intensive genetic management, which applies mainly to small captive populations.

The genetic importance of an animal is defined as a measure of the probability that it carries founder genes that are currently at risk of being lost (MacCluer *et al.* 1986, Ballou and Lacy 1995, Thompson 1995), though this value may be compromised by the presence of deleterious genes. Although animals with many living relatives in a population may be less genetically valuable than animals with few relatives, this larger group of relatives may be more successful due to superior fitness. "Mean kinship", one of several methods used to identify genetically important individuals, is defined as the average of the kinship coefficients between an individual and all living individuals including itself (Ballou and Lacy 1995). Animals with low mean kinship values are genetically important. Because mean kinship is insensitive to the age structure of a population, the concept of kinship value was introduced. "Kinship value" considers the age and reproductive value of animals when calculating mean kinship (Ballou and Lacy 1995). Kinship values will exceed mean kinship for animals whose relatives are of prime reproductive age.

Both theory and computer simulation studies suggest that mating strategies based on mean kinship (and therefore kinship value) retain the highest level of gene and allele diversity (Ballou and Lacy 1995, Miller 1995). To the extent possible, a strategy based on kinship value (Ballou and Lacy 1995) should be used to arrange matings in the captive population, precluding matings between relatives. Target founder representation and kinship value can be used to assess the genetic importance of animals and help direct rotation of breeding stock. Rams will generally contribute genes faster than ewes and will therefore need to be rotated more frequently than ewes.

Genetic evaluation

Captive breeding programs should include provisions for genetic testing, including mitochondrial DNA sequence analysis and microsatellite typing on all founders in the captive population. Genetic testing of captive-born offspring is particularly important in populations with low intensity genetic management or in cases where paternity is unknown. Molecular genetic analyses can be used to determine the genetic similarity between captive-reared and free-ranging sheep, as well as to construct pedigrees for captive or wild populations.

Population management

General objectives for population management of large captive populations with multiple generations in captivity are: (1) establishment of a self-sustaining captive population, (2) expansion of the population to a predetermined carrying capacity as quickly as possible within genetic management guidelines, (3) stabilization of the population at a given capacity, with an age and sex ratio that will achieve the goals of the program (such as production of surplus stock for release) (Foose and Ballou 1988). For small captive breeding programs, population management is most relevant to the behavioral stability of the captive population and minimizing the impact of stock rotation. In most cases bighorn sheep should be released into the wild by 10 years of age, to prevent an accumulation of old-age animals. Ewes that fail to recruit a lamb for 3 consecutive years should be considered for release because they are not contributing to the goal of producing stock for release into the wild.

Surplus or unfit animals

Healthy animals displaying abnormal behavioral or physiological characteristics should be evaluated. Preferably, if the characteristic has potential to be altered to allow release into the wild, the animal should be retained in captivity until suitable for release. If an animal's genetic characteristics cause it to be unfit for release into target populations, that animal can be released into a nontarget subpopulation so long as deleterious traits are not introduced to the wild. Because the primary goal of captive propagation is reintroduction or augmentation, bighorn sheep should be released into the wild whenever possible. As a last resort, animals may be transferred to a zoo facility in cooperation with the American Zoological and Aquarium Association.

Research and data collection on the captive population

Captive populations can provide an ideal control population for experimental or developmental studies. Data on the population characteristics, behavior, physiology, nutrition, and diseases of the captive population should be collected to the extent possible without risking the animals' survival or ability to be released into the wild. Handling or continuous observation at close range should be minimized to avoid habituation. The captive population at Bighorn Institute has been used in several studies (Castro *et al.* 1989, Jessup *et al.* 1990, Borjesson *et al.* 1996) that required little or no additional handling.

A SPARKS (Single Population Analysis and Records Keeping System; International Species Information System [ISIS] 1989) or similar format studbook should be maintained to record the identification, sex, parentage, date of birth, release date, release location, and date as well as cause of death for each individual born or brought into captivity. Marking of animals to facilitate data collection may be necessary in large captive populations. Locations of births within enclosures and individual ewe reproductive success should also be recorded. Notes recording the feeding rations, general health, and behavior of captive animals, and unusual environmental conditions should be collected at least once daily.

Research and data collection on released bighorn sheep

Each release should be designed as an experiment to test various techniques related to factors such as release site and time (May 1991). Monitoring post-release animals is one of the most critical components of a reintroduction or augmentation program because it allows for the assessment of methods, use of adaptive management, and can provide a framework for theoretical studies. All released bighorn sheep should be fitted with a radiocollar and eartag and monitored as frequently as possible (more than weekly) to record their integration process, habitat use, behavior, health, survivorship, and reproductive success. At a minimum, monitoring should be designed to document survival and reproductive rates, cause-specific mortality, habitat use of released bighorn sheep though their first year in the wild, and key biotic and abiotic factors, such as habitat quality and weather. Most importantly, post-release studies should provide data to evaluate the success of the program. Long-term (greater than or equal to 3 years) monitoring on at least a monthly basis of greater than or equal to 50 percent of released animals in a subpopulation should be included in all programs. Monitoring of post-release animals should include planned studies comparing captive-reared and wild-reared sheep (*e.g.*, reproductive success, survivorship, vigilance, maternal behavior, reactions to disturbance, etc.), and theoretical studies (May 1991, Sarrazin and Barbault 1996).

Peer-reviewed Program Assessment

Guidelines for reintroductions (Kleiman 1989, Stanley Price 1991, Chivers 1991) suggest an assessment phase in which the experiences, results, and conclusions of a reintroduction or augmentation program would be published at intervals or at the completion of the study. Short-term success of such programs can be evaluated by: 1) the survival and/or reproductive rates of released animals, or 2) the amount of genetic diversity retained and/or habitat preserved, or 3) public education and research interest generated, or 4) the time gained to allow continued research into the problems suppressing the population (Kleiman 1989; Caughley and Gunn 1996). The multi-faceted nature of captive breeding and release programs requires that assessments examine both the captive breeding and release phases, as well as the indirect benefits generated from the program. Reporting failures encountered in captive breeding and release programs is of equal or greater value than reporting successes, although it is done much less frequently.

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APPENDIX D. GUIDELINES FOR SAFELY CAPTURING, HANDLING, AND MONITORING BIGHORN SHEEP

Standard research methods, including surveys (foot, helicopter, and fixed wing aircraft), field capture, biological sampling, and radiotelemetry monitoring have been used for assessing abundance and abundance trends (DeForge *et al.* 1995, 1997; Rubin *et al.* 1998), recruitment patterns (Wehausen *et al.* 1987, DeForge *et al.* 1995, DeForge *et al.* 1997, Rubin *et al.* 2000, Ostermann *et al.* in press), adult survivorship and cause-specific mortality (Hayes *et al.* 2000, DeForge *et al.* 1997, DeForge and Ostermann 1998b, Ostermann *et al.* in press), health status and disease exposure (DeForge *et al.* 1982; Clark *et al.* 1985, 1993; Jessup and Boyce 1993; Elliott *et al.* 1994; Boyce 1995; Crosbie *et al.* 1997), genetic profiles (Boyce *et al.* 1997, Boyce *et al.* 1999), and spatial distribution of the population (Rubin *et al.* 1998) in specific subpopulations of bighorn sheep within the Peninsular Ranges. Adaptive management (Holling 1978) will require the continued use of these field research methods to achieve recovery of Peninsular bighorn sheep.

As with any human intervention, these research methods are not without risks and consequences for free ranging bighorn sheep. Low-level helicopter surveys provide an effective method for estimating population size and distribution. However, alterations in behavior, movement, and distribution of bighorn sheep resulting from helicopter disturbance (Bleich *et al.* 1990a) could potentially introduce bias into those estimates or adversely affect survivorship and reproduction in bighorn sheep populations (Bleich *et al.* 1994). Jessup *et al.* (1984) compared the relative risks and benefits of different capture methods, including drop-netting, drive-netting, darting from helicopters, stationary corral-trapping and the use of a hand-held net gun operated from a helicopter. Some methods were found to be inherently safer than others. All methods presented some risk to individual animals, and no single method of capture was best for all situations. Bleich *et al.* (1990b) documented chronic injuries to the mandibles and necks of bighorn rams from ill-fitting radiotelemetry collars and proposed potential adverse effects on foraging behavior and decreased fitness of these otherwise dominant males.

Through constant critical re-assessment of research activities, risks can be recognized and addressed to minimize the impact of these activities on bighorn sheep populations. In the past, epidemiological analysis of capture data documented the relative safety of drop net and helicopter net gun capture of bighorn sheep over other methods including drive-net, chemical immobilization, and corral trapping (Jessup *et al.* 1988). Recommendations on collar tightness (Bleich *et al.* 1990b) have reduced jaw and neck injuries in bighorn rams in recent years. Risks associated with future research activities can be minimized by requiring: (1) adequate justification for the activity, (2) thorough planning, (3) selection of appropriate survey and capture methods, experienced personnel, and proper equipment for the activity, and (4) constant critical re-assessment of research activities to recognize and address problems arising from these activities.

Guidelines for specific research activities

Surveys

Fixed-wing aerial surveys have a very low probability of affecting bighorn sheep because aircraft are typically flown at high altitude. During these flights, telemetry locations of radio-collared animals are obtained but visual observations are not usually attempted. The risk of disturbance to bighorn sheep is greater during helicopter and foot surveys.

Helicopter surveys may temporarily disrupt normal bighorn sheep behavior and may negatively affect bighorn sheep if not conducted properly. Helicopter surveys should be avoided during periods when bighorn sheep may be especially sensitive to disturbance. These periods include the late winter through early summer months, when the majority of ewes give birth, and the summer months, when bighorn sheep are dependent on scant water sources. During surveys, the helicopter should only remain above a group of animals long enough to determine group size and composition. If the group appears to be running excessively, if terrain conditions are potentially dangerous for the animals, or if young lambs are observed in a group, the safety of the animals should take priority over data collection, and the survey crew should continue moving to the next portion of the survey area. During surveys, the location of roads should be considered, and flight paths should proceed from roads into habitat, so as to avoid driving animals towards automobile traffic.

Foot surveys are not typically considered a risky research activity but the following considerations will further reduce any negative impact on bighorn sheep. Bighorn sheep appear to be more comfortable when they are able to remain higher than their human observers and watch them from a distance. Observers should approach bighorn sheep from below and avoid approaching too closely. Care should be taken to avoid startling bighorn sheep by appearing suddenly around a corner or over a ridge. Time near springs and guzzlers should be kept to a minimum to avoid displacement of animals from water sources, especially during the summer.

Capture

The active management of bighorn sheep may require: (1) marking or tagging to determine population numbers, range usage, movement patterns, behavior, reproduction, survival, and cause-specific mortality; (2) treating or sampling diseased individuals; (3) sampling of healthy bighorn sheep for research; and (4) relocation (Jessup *et al.* 1984). In skilled, experienced hands, the use of a net gun from a helicopter has been shown to be a safe method of capture, with fewer stress related complications and lower injury and mortality rates than other methods (Jessup *et al.* 1988). Due to the steep, rough terrain and the scattered distribution of bighorn sheep found in the Peninsular Ranges, net gun capture appears to be the most practical and cost-effective capture technique. The use of drop nets and tangle nets may also be necessary on the rare occasion when an animal has to be captured within or on the fringes of the urban environment. The safe use of these techniques requires careful planning and adequate numbers of experienced personnel trained in handling net-captured bighorn sheep. Thorough discussions of capture methods and veterinary medical concerns can be found in *The Wildlife Restraint Handbook* (California Department of Fish and Game 1996), and the *Wildlife Restraint Series* (International Wildlife Veterinary Services 1996).

The most common veterinary problems occurring during the helicopter net gun capture of bighorn sheep are physical injury, capture stress/capture myopathy (disorder of muscle tissue or muscles) and hyperthermia. Physical injury can occur when a netted animal tumbles on rough, rocky terrain, takes a fall down a steep slope, or when the net tangles around the animal's neck and compromises respiration. The risk of physical injury can be minimized by netting the animal as it runs uphill or capturing animals on relatively flat saddles or in flat sandy canyon bottoms. Capture stress/capture myopathy occurs when an animal severely overexerts itself, resulting in pathologic metabolic changes and cellular damage in muscle tissue and internal organs. Hyperthermia occurs when an animal's heat production from muscle activity exceeds its ability to dissipate that heat. Due to the physical exertion experienced during helicopter pursuit, the rectal temperature of most bighorn sheep at capture will be higher than 38.9 degrees Celsius (102 degrees Fahrenheit), considered normal for resting domestic sheep (California Department of Fish and Game 1996), and will often reach 39.4 to 40.6 degrees Celsius (103 to 105 degrees Fahrenheit) or greater. These animals are susceptible to hyperthermia regardless of the ambient temperature. Dousing with water around the flanks, inguinal region, thorax, head, and neck at capture to cool the animal should be routine during warm weather and anytime an animal shows an increasing trend in rectal temperature. Animals with heavy winter pelage also may have a problem dissipating heat even in cold weather and may require efforts to cool them. Keeping chase times within conservative limits will prevent most problems with capture stress/capture myopathy and hyperthermia. A "safe" chase time will vary with the condition of the animal, terrain, environmental conditions, and the intensity of pursuit. Most individual chase times during California Department of Fish and Game bighorn sheep captures are under 3 minutes. Pursuit of a running animal should not exceed 5 minutes. Attention must be paid to total chase time as animals in a group may be run repeatedly as individual herd members are captured. Pursuit should be called off if the animal appears disoriented, exhausted, or injured, or anytime a member of the capture crew determines that there is excessive risk in continuing the capture effort.

Prolonged restraint can also contribute to capture stress/capture myopathy and hyperthermia. Most bighorn sheep cease struggling when eye covers and hobbles are applied. Positioning the animal in a normal resting position with its head up will allow the sheep to belch ruminal gas and minimize bloat and regurgitation. Vital signs should be taken immediately and monitored continuously to monitor the need/effectiveness of cooling treatment or to determine if a severely distressed animal should be released. A severely compromised animal that is not ambulatory requires aggressive therapy. Jessup (1999) recommended that wild sheep with rectal temperatures greater than 41.7 degrees Celsius (107 degrees Fahrenheit), respiration rates of 75 per minute, and/or heart rates greater than 200 per minute receive intensive treatment for capture stress/myopathy including cooling baths, balanced intravenous fluids, anti-inflammatory drugs (fast acting corticosteroids), vitamin and mineral supplements, and possibly intraperitoneal bicarbonate. Medical treatment of a moderately compromised animal that is ambulatory involves the trade-off of continued stress during the treatment period with the benefits of medication. Some medications themselves may have adverse effects when administered. For example, pharmacologic doses of corticosteroids used in treating shock may induce parturition in ewes in late stages of pregnancy (Plumb 1995). In a field situation, the decision to treat or release is a judgement call made by capture personnel in consultation with an experienced wildlife veterinarian.

Air transport of bighorn sheep to base camps should be accomplished in "sheep bags" (heavy weave plastic mesh bags custom designed for this purpose), which support the animal in a sternal position. "Air transport of mountain sheep upside down suspended by their hobbled legs.....is inappropriate and unnecessary" (Jessup 1999). During captures using base camp processing, the capture crew should be prepared to process animals exhibiting capture stress at the capture site to reduce the handling time.

Processing (application of tags and collars, collection of biological specimens, administration of prophylactic medications) should be carried out in a quick, efficient manner with minimal disturbance to the animal. Prior to release, the animal should be positioned so that release occurs in the direction with the fewest physical hazards and that allows the animal to move toward the area from which it was captured.

Other issues to consider when capturing and handling bighorn sheep include:

> Pregnancy status - capture of ewes in the last two months of pregnancy should be avoided whenever possible (December through early summer).

Caution should be used when capturing ewes with very young lambs (spring through late summer) due to possible abandonment of the lamb or exposure of the lamb to predation in the absence of the mother. These ewes should be processed at the capture site, and should not be transported to a base camp.

Extreme caution should be used when capturing young lambs. Lambs should be processed and released at the capture site whenever possible.

Whenever possible, processing at the capture site is preferred to minimize stress on the animal, However, for adult animals, the choice of processing at the capture site or transport to a base camp will vary with local conditions. Very important for ewes and less so for rams, the location and distance of base camps from the capture site should allow direct access back into the area in which the animal was captured. A general guideline is that the release site should be within the home range of the ewe group and within 5 kilometers (3.1 miles) of the capture location with no insurmountable or dangerous obstacles separating the animal from its home range.

Capture personnel should be made aware of human safety and zoonotic disease concerns.

Key points to consider before capture of bighorn sheep:

A detailed capture plan must be prepared in advance of the capture that outlines goals, methods, potential problems, personnel and safety procedures (California Department of Fish and Game 1988).

A pre-capture meeting should be mandatory for all participating personnel.

All personnel must be trained in proper animal handling techniques.

Experienced veterinary assistance and emergency medical supplies and equipment should be readily available to treat a physically distressed or injured animal. Frequent post-capture monitoring of individual bighorn sheep is mandatory to determine effects of capture, tags, and collars on survivorship, reproduction, and well being.

A written report should be prepared after each capture that documents the activity, provides a critical assessment of the capture, and suggests improvements for future capture activities.

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APPENDIX E. PROTOCOLS FOR MONITORING POPULATION ABUNDANCE

This appendix presents protocols for two methods of monitoring the abundance and population trends of Peninsular bighorn sheep. These two methods are: (1) waterhole counts and (2) aerial helicopter surveys. For explanations of terminology (*e.g.*, ewe group) or reference to specific names of locations, please refer to the main body of the recovery plan and papers cited therein.

Waterhole counts have been conducted in selected parts of Anza-Borrego Desert State Park since 1971 (M. Jorgensen, pers. comm.) and have been used to assess abundance trends of Peninsular bighorn sheep (Rubin *et al.* 1998). Prior to 1993, no marked animals were present in the areas in which counts were conducted. Count data were, therefore, only appropriate for use as an index of abundance rather than for calculation of an absolute population estimate. Since 1993, however, collared animals have been present and waterhole count data can be used to generate population estimates for some ewe groups in Anza-Borrego Desert State Park.

Waterhole counts are organized and conducted by volunteers under the direction of Park staff. Although helicopter surveys provide a more comprehensive population estimation tool, waterhole counts should be continued. Continuation for at least 10 more years will allow investigators to determine the correlation between waterhole count and aerial survey population estimates, which may make it possible to generate historical population estimates using early waterhole count data. In addition, waterhole counts provide data that are difficult to determine from a helicopter (*e.g.*, reproductive status of individually marked ewes; refer to section II.D.2.1 of the recovery plan), and provide an opportunity for the community to participate in Peninsular bighorn sheep conservation projects (refer to section II.D.3).

Helicopter surveys have been conducted in the Santa Rosa Mountains annually since 1977 (Wehausen *et al.* 1987, DeForge *et al.* 1995), the San Jacinto Mountains in 1983, 1984, and annually since 1987 (DeForge *et al.* 1997), and in some parts of Anza-Borrego Desert State Park in the early 1980's (M. Jorgensen, pers. comm.). Radio-collared animals have been present in the northern Santa Rosa Mountains since the early 1980's (DeForge *et al.* 1995) and in the San Jacinto Mountains since 1992 (DeForge *et al.* 1997). In 1994, 1996, and 1998, radio-collared animals were present throughout the Peninsular Ranges and surveys covered all parts of the ranges for the first time, making it possible to generate population estimates for the entire range as well as for subregions (Rubin *et al.* 1998). Currently, helicopter surveys in the San Jacinto Mountains and the Santa Rosa Mountains are conducted by California Department of Fish and Game and the Bighorn Institute, while surveys of the remainder of the range are conducted by California Department of Fish and Game and Anza-Borrego Desert State Park. The following sections outline specific protocols for each monitoring technique.

Aerial Helicopter Surveys

Frequency of surveys

Helicopter surveys covering the entire range should be conducted at least every other year. Recently, the San Jacinto Mountains and Santa Rosa Mountains have been surveyed annually, while the remainder of the range has been surveyed every other year (1994, 1996, 1998).

Time of survey

Helicopter surveys should be conducted ideally between late September and early November. This method reduces the risk to bighorn sheep by avoiding periods when young lambs are present, periods when ewes reach late gestation, and months of high summer temperatures. In addition, this time period coincides with part of the rut, or breeding season. This approach allows the most accurate estimate of the sex ratio because bighorn tend to congregate during this time.

Areas to be surveyed

All bighorn sheep habitat in the Peninsular Ranges should be surveyed. For consistency among years, the same predetermined areas should be flown every year, with the same amount of time (effort) spent per area during each year. Flight areas and associated approximate survey times are included in this appendix (Tables E-1 and E-2). Maps are not included here because the geographic references in the Tables below accurately describe the survey areas and this plan is

Table E-1. Approximate polygons flown by Bighorn Institute in annual helicopter surveys of the San Jacinto and Santa Rosa Mountains. Topography and sheep sign influenced the amount of time spent per area. Flight polygons were developed while the population was at a low, and some areas where sheep sign (trailing, bed sites, etc.) has not been noted for several consecutive years are flown less intensely than areas with sign. If the population increases, more time may be needed to thoroughly survey areas that are only cursorily surveyed now. Flight times are actual time within the polygon.

Polygon Number	Area/Canyons	Approx. flight time (hours)	Notes
1	San Jacinto Mountains: west fork of Palm Canyon north to Blaisdell Canyon	2.25	Areas south of Andreas and north of Chino have been flown less intensely in recent years due to lack of bighorn sheep sign. It will be necessary to add survey time if distribution expands.
2	Santa Rosa Mountains: Calcite Mine west to Rattlesnake Canyon	2.25	
3	Santa Rosa Mountains: western Santa Rosa Mountains, west of Rattlesnake Canyon to Buck Ridge and Rockhouse Canyon	2.25	Buck Ridge flown cursorily.
4	Santa Rosa Mountains: Big Wash north, Wonderstone Wash, Travertine Palms, and Barton, Alamo, and southern Sheep Canyons.	1.75	Barton, Alamo, and Sheep Canyons flown cursorily due to lack of sign.
5	Santa Rosa Mountains: north Sheep Canyon, Martinez Canyon	1.25	
6	Santa Rosa Mountains: Agua Alta and Toro Canyons	2.00	
7	Santa Rosa Mountains: Guadalupe, Devil, and Bear Canyons	2.25	Polygon should include Indio and Eisenhower Mountains.
8	Santa Rosa Mountains: Coyote, Sheep, Deep, Carrizo, and Dead Indian Canyons.	2.25	
9	Santa Rosa Mountains: Magnesia, Bradley, and Cathedral Canyons.	2.00	Western Cathedral Canyon appears to have been abandoned recently – minimal flight time spent west of Cathedral Canyon. Surveys may need to intensify west of Cathedral Canyon proper if the population increases.

Table E-2. Survey polygons flown in bighorn sheep habitat outside of the Santa Rosa and San Jacinto Mountains. Flight times are actual time within the polygon.

Polygon Number	Area	Polygon Description	Approx. flight time (hours)
10	Coyote Canyon	Coyote Peak	1.25
11	" "	NE side of Coyote Canyon	3.00
12	" "	SW side of Coyote Canyon	2.25
13	N. San Ysidro Mts	N of County Rd 22 (Montezuma Grade)	2.75
14	S. San Ysidro Mts	S of County Rd 22 and Yaqui Ridge	2.00
15	" "	Pinyon Ridge and N side of Sentenac Canyon	1.00
16	Vallecito Mountains	Pinyon Mts to Pinyon Canyon	2.25
17	" "	Sunset Mtn, Harper Flats, to Harper Canyon	1.50
18	" "	Harper Canyon to Hapaha Flats to Alma Canyon	1.75
19	" "	Alma Canyon to Fish Creek Wash to Split Mtn	1.25
20	" "	Whale Peak (Fish Creek Wash to Smuggler Cyn)	1.25
21	Carrizo Canyon area	Tierra Blanca Mts to Rockhouse Canyon	2.00
22	" "	W side Carrizo Wash (to Blackwater Canyon)	1.25
23	" "	Carrizo Gorge to Tule Cyn, E. to Dos Cabezas	2.00
24	" "	E side of Carrizo Wash (N of railroad tracks)	1.25
25	Fish Creek Mountains	Fish Creek Mountains	1.75
26	Coyote Mountains	Coyote Mountains	1.75
27	S. of Interstate 8	Dos Cabezas to U.S.-Mexico border	2.00

not intended to represent a comprehensive compendium of information related to bighorn conservation activities.

Survey techniques

The survey crew consists of three observers in addition to the pilot. When possible, the same pilot and pool of experienced observers should be used each year. The doors of the helicopter should be removed for optimum visibility. Each polygon should be flown systematically at 40 to 60 kilometers per hour (25 to 35 miles per hour), following topographic contours of 100 to 150-meter (330 to 490-foot) intervals. The pilot and the observers should not be aware of the locations of radio-collared sheep, and telemetry should not be used to locate groups or individuals. The number of radio-collared animals in each survey polygon should be determined immediately before or during the helicopter survey, by additional personnel, using aerial fixed-wing or ground monitoring. These animals serve as "marked" animals in the calculation of abundance estimates using mark-recapture methods (see below). The Global Positioning System base station at Anza-Borrego Desert State Park headquarters should be run during the entire survey so that Global Positioning System location data can be corrected by staff at their General Plan office. All four individuals in the flight crew are considered observers, and each of the three passengers is assigned one of the following additional tasks: (1) to monitor the progress of the flight on a topographical map, advise the pilot of polygon boundaries, and record the location of each observed sheep on the map, (2) maintain a data sheet onto which the date, time, elevation, group size and composition, number of collared animals, and, possibly, identification of collared animal is recorded for each group of animals, or (3) record the flight of the survey and the location of each observed animal using a Global Positioning System unit. All observed animals should be classified as yearling ewe, adult ewe, yearling ram, Class II ram, Class III ram, Class IV ram, or lamb (classifications modified slightly from those used by Geist 1971). When possible, simultaneous double-counts should be conducted during each survey, following the methods of Graham and Bell (1989), to provide an additional abundance estimate. All sightings of feral animals and deer should be recorded during surveys. The location and condition of springs, tinajas, and other water sources also should be recorded.

Data Analyses

Population estimates should be generated using estimators such as Chapman's (1951) modification of the Peterson estimator (Seber 1982), or the joint hypergeometric estimator (*e.g.*, Neal *et al.* 1993). Estimates should be calculated separately for each sex and for the total population (rams and ewes combined). In the event that low numbers of collared rams prevent the estimation of ram numbers, the ram to ewe ratio and the estimated number of ewes can be used to generate an estimate of adult numbers. Confidence intervals (95 percent) should be calculated using methods such as those of Seber (1982). Simultaneous double-count data should be used to estimate the number of groups missed and to generate an additional estimate of the minimum number of animals present within the surveyed areas (Graham and Bell 1989). All reported results (*e.g.*, lamb to ewe or ram to ewe ratios) should clearly state whether or not yearlings are included.

Estimates should be generated for the entire range, as well as for individual ewe groups. It is important to note that ewe group distribution may change slowly over time. Monitoring of radio-collared ewes to determine ewe group structure will therefore, have to be continued, and stratification of survey data may have to be modified slightly. Furthermore, ewe group delineations in the Santa Rosa Mountains south of Highway 74 and in the Vallecito Mountains still need to be more clearly resolved.

Further considerations

Initially, a sufficient number of active radio-collared animals must be present in each portion of the range for use in mark-recapture estimate calculations. The number of collared animals should be sufficient to achieve an accuracy of plus or minus 25 percent with probability of 0.05, following the methods described in Krebs (1989) and Robson and Regier (1964), or approximately 30 percent of the estimated ewe population should be radio-collared. However, a "sightability" estimate may be generated after additional multiple surveys are conducted, thereby eliminating the need to maintain this percentage of radio-collared animals. This approach would be especially beneficial if/when population numbers become large.

As batteries expire, collars become non-functional and the actual number of marked animals present in the survey area becomes difficult to know. Only those bighorn sheep with functional collars should be used as marked animals. This approach will require that bighorn sheep with "functional" collars be distinguishable from those with "nonfunctional" collars at a glance, from the helicopter. Therefore, an accurate inventory of all collared animals must be maintained and the choice of collar and eartag color combinations must be considered during collaring efforts. No newly collared animal should match (in collar and eartag color combination) an animal that is possibly still present in the field.

Within a polygon, an attempt should be made to "sweep" across the survey area, rather than flying over an area more than once. This method will reduce the chance of double counting animals. Helicopter activity at times cause bighorn sheep to move (Bleich *et al.* 1994); therefore, adjacent polygons should, when possible, be flown consecutively so that groups can be recognized and possible double counts eliminated. The flight polygons delineated in this document were chosen, in part, so that natural breaks in topography or roadways coincided with polygon boundaries.

Data should be maintained in an electronic data set that can be used by investigators in the future. All raw data should be retained. That is, data should not be summarized before being entered into a data set.

Waterhole Counts

Frequency of Counts
Waterhole counts should be conducted annually.

Time of Counts
Counts should be conducted at the same time every year so that yearly comparisons of ram:ewe ratios, lamb:ewe ratios, group size, and number of sheep observed at water sources are most meaningful. In addition, counts should be conducted during the hottest and driest time of the year to maximize the number of animals coming to drink at water sources. Counts have typically been conducted during the July 4th weekend, and should continue to be held between mid June and the first week of July.

Areas to be Counted
Annual counts have been conducted in the southern part of the park (Carrizo Canyon area) during 1973 to 1982, and in the northern part of the park (San Ysidro Mountains, Coyote Canyon, and one site in the south Santa Rosa Mountains) since 1971. Counts in the southern portion of the park were discontinued after 1982 because of the large number of volunteers that were needed to conduct counts at both ends of the State park, and the complex logistics of organizing and getting teams set up in fairly remote count sites.

In the past, the number of sites counted in each area has varied slightly across years because of variation in the number of available volunteers or unexpected problems (for example, a fire near count sites). The number of sites did not significantly influence the number of sheep counted in each portion of the range (Rubin *et al.* 1998). However, an attempt should be made to keep the number and locations of count sites constant during future years. Priority sites should be those that have been counted most consistently in the past. Additional or "secondary" sites should be counted when additional volunteers are available. Data analyses can then focus on data collected at "priority" sites, while "secondary" sites can be used for more cursory monitoring of sheep presence.

Count Techniques

Teams of three to five observers should be assigned to each count site. Each team should include at least two individuals who are experienced at classifying bighorn sheep by age and sex. At each count site, the entire team should be stationed at a location that allows observation of animals coming to a water source, while minimizing disturbance of the animals or interference with their use of the water source. These locations have been identified by Anza-Borrego Desert State Park personnel. While at these sites, observers should minimize noise and movement. Observations should be made during 7 a.m. to 5 p.m. on 2 consecutive days and 7 a.m. to 2 p.m. on the third day. During these periods, observers should systematically scan all areas within view and record all sheep observations on the supplied data sheet. Data to be recorded include date, time, temperature, group size and composition, the presence of collared animals, and, if possible, the identification of collared animals. Additionally, interactions among individuals (*e.g.*, breeding behavior, lamb nursing bouts) and observations of other species (*e.g.*, deer, coyotes, birds) should be recorded. The location of each group of bighorn sheep should be noted on a topographic map.

Repeat sightings of individual sheep should be recorded as such, but they should not be counted. At the end of each day, each team should review and discuss their observations with neighboring teams so that repeat observations can be identified and eliminated from the final tally.

Data Analysis

The primary use of data collected during waterhole counts is to monitor abundance trends. Rubin *et al.* (1998) used count data to assess long-term trends. In this case, linear regression analysis was used to determine if the number of ewes observed per day showed an increasing or decreasing trend over a period of 10 to 26 years. If a sufficient number of collared animals are present in each ewe group area, abundance estimates can be generated for some ewe groups, using mark-recapture techniques. Lamb to ewe ratios can be calculated to monitor reproductive success of ewe groups. Most lambs are 3 to 5 months old during waterhole counts and these ratios will not be directly comparable to ratios generated from helicopter surveys, which represent lamb recruitment to an older (approximately 6 to 8 months) age. The reproductive status (lamb present versus not present) of individual radio-collared ewes can supplement observational data collected by biologists monitoring reproductive patterns of Peninsular bighorn sheep. Ram to ewe ratios should be generated for comparison among years. The rut typically peaks after July, so these ratios may underestimate the actual ram to ewe ratios since some rams may not have joined ewe groups yet.

Further Considerations

To make waterhole count data as useful as possible for future investigators, it is important for teams to determine the composition of each group as accurately as possible. Given the great distances sometimes involved, an effort should be made to equip each team with a spotting scope and at least one individual should be experienced at using it to observe and classify bighorn sheep.

All new observers must complete a one day orientation and training session led by Anza-Borrego Desert State Park personnel. In addition, all new observers must be paired with individuals experienced at classifying bighorn sheep in the Peninsular Ranges (Bleich 1998).

Data should be maintained in an electronic dataset for use in the future. All raw data should be retained. That is, data should not be summarized before being entered into a primary data set.

Reinitiation of waterhole counts in the Santa Rosa Mountains should be considered. This approach may enhance the probability of detecting relationships between aerial helicopter data and water hole count data, thereby facilitating a retrospective interpretation of numbers of sheep in the Santa Rosa Mountains in the past.

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APPENDIX F. RECOMMENDED CONSERVATION GUIDELINES

BACKGROUND

Bighorn sheep in the Peninsular Ranges are afforded protection pursuant to the California Fish and Game Code (sections 4700 as a fully protected species and 2050 as a threatened species). Section 4700 of the Fish and Game Code does not allow for issuance of permits or licenses to take fully protected mammals, except for scientific research, notwithstanding any other provision of law; therefore, a California Endangered Species Act section 2081 permit that would authorize incidental take of Peninsular bighorn sheep cannot be issued. This take prohibition in turn limits the type of mitigation that can be required pursuant to the California Environmental Quality Act. The sheep also is listed at 50 CFR § 17.11 by the U.S. Fish and Wildlife Service as an endangered species and protected against take at 50 CFR § 17.21. Regulations that authorize take under prescribed circumstances are found at 50 CFR Parts 17 and 402.

The California Environmental Quality Act requires that mitigation measures be identified and implemented for any significant impacts unless a finding of over-riding considerations is adopted. Section 15370 of the California Environmental Quality Act Guidelines provide five categories of mitigation measures: "...avoid, minimize, rectify, reduce or compensate." These forms of mitigation are appropriate for bighorn sheep only to the extent that they avoid take of the species, pursuant to Section 4700 of the Fish and Game Code, and avoid take under 50 CFR § 17.21, unless otherwise authorized by the U.S. Fish and Wildlife Service under 50 CFR § 17.22. Accordingly, the Fish and Wildlife Service and California Department of Fish and Game work with lead agencies and project proponents on a case by case basis to identify which forms of mitigation would be appropriate.

OBJECTIVES

The objective of these guidelines is to provide a set of consistent mitigation measures for project proposals that do not otherwise threaten sustainable bighorn sheep populations needed for recovery. These mitigation measures are not intended for projects proposed in locations that would fragment habitat or preclude effective reserve design and management of the species because those adverse effects cannot be offset. In such instances, the Fish and Wildlife Service and California Department of Fish and Game may recommend additional avoidance, minimization, and mitigation measures to ensure against the likelihood of significant adverse effects that would impinge on take and jeopardy thresholds. Through proper coordination, our agencies will assist local, State, and Federal governments in identifying whether the adverse effects of project proposals can be mitigated to a level of insignificance, based on project location, size, and potential for indirect effects, which typically are the primary criteria influencing the type and severity of impact. These guidelines may require future modification based on the availability of new information on threats, ecological requirements, species status, etc.

CONSERVATION MEASURES

I. HABITAT COMPENSATION: Acquisition of off-site habitat may be appropriate to offset any residual effects after application of appropriate avoidance and minimization measures. For projects adjacent to bighorn sheep habitat that provide infrastructure to support larger human populations, habitat compensation is generally appropriate because of the consequent increased levels of human-related disturbance in adjoining open space. The cumulative effects of human disturbance may be mitigated by acquisition of sheep habitat that would otherwise be vulnerable to future development. Projects adjacent to sheep habitat that do not result in indirect effects to adjoining sheep habitat generally lack a mitigation nexus.

To maintain sustainable subpopulations (ewe groups), compensation habitat should be acquired within the range of the affected ewe group and at an elevation comparable to the impact. Bighorn sheep in the Peninsular Ranges are mainly threatened by habitat loss at lower elevations that provide unique resources unavailable farther up the mountain slopes. Therefore, loss of unique or limiting resources at lower elevations can not be offset by conservation of different resources associated with habitats at higher elevations.

Habitat acquisition promotes survival and recovery by reducing the potential future loss of bighorn sheep habitat through permanent protection of land currently available for development. Amount of compensation will be determined on a case by case basis because the effects of individual projects are variable. A management endowment should accompany all acquired lands so that the responsible public agency has the ability to effectively manage conserved lands.

II. FENCING: Fencing along the urban interface provides a barrier that separates bighorn sheep from urbanization threats (e.g., disease and mortality associated with toxic plants, traffic, parasites, irrigated landscapes, pesticides, etc.). Fencing also can help mitigate the adverse effects of incompatible land uses adjoining sheep habitat. For example, fencing controls human access into habitat that may otherwise conflict with management objectives to minimize human disturbance, especially during sensitive time periods, such as lambing. Land uses along the habitat edge should be designed to not introduce additional human disturbance. Recreational access should be provided only where access is coordinated with natural resource agencies and is consistent with management objectives in the regional trails plan. Fencing does not offset the effects of habitat loss and should be located along the edge and not within sheep habitat.

A. Fencing should be mandatory for any new development in or adjacent to sheep habitat, where bighorn sheep have begun or may begin using urban sources of food and water.

B. Fences should be 2.4 meters (8 feet) high, chain-link or functional equivalent.

C. Fences should not contain gaps in which sheep can be entangled [gaps should not be larger than 11 centimeters (4.3 inches)].

III. TOXIC PLANTS: Landscape plants can cause sickness or death. Only local native plants should be used along the wildland interface. Known and potential toxic plants should not be used in areas accessible to bighorn sheep. Ornamental plants currently known to be toxic to sheep include oleander, *Prunus* species, and plants in the nightshade (Solanaceae) family.

IV. LAMBING SEASON AND HABITAT RESTRICTIONS: Seasonal restrictions during this period minimize impacts to bighorn sheep at a critical stage of their life cycle. Lambing habitat is often emphasized because of the sensitive nature and behavior of ewes and lambs. Lambing habitat comprises those areas used for breeding, sheltering, and nurturing of lambs up to the time of weaning, including those areas occupied by ewes 1 month before giving birth. Though the lambing season can span the majority of the calendar year--from late winter through summer, January 1 through June 30 encompasses the majority of the lambing season. Trails that traverse lambing habitat should be managed during this period or relocated outside of sensitive habitat areas.

V. SUMMER WATER SEASON: Available water sources during summer months are highly restricted and bighorn sheep are vulnerable to disturbance in these areas. If summer rains fail, water may remain scarce until the first winter rains. Accordingly, interagency cooperation will be needed to adapt trails management prescriptions to the water requirements of bighorn sheep. Public education, signage, rangers, and other forms of management should be provided at appropriate locations to control access during this period.

Title 14 of the Public Resources Code, Section 550(b)(1) and Sections 630(b)(11) and (30) restricts access to water holes on State lands in the Santa Rosa Mountains. Closure periods are from June 15 to September 15.

VI. WATER FEATURE DESIGN SPECIFICATIONS: Any artificial water features (*e.g.* ponds, lakes) in areas adjoining bighorn habitat should be designed to preclude shallow, vegetated edges that provide breeding habitat for *Culicoides* midges, an invertebrate disease vector for bluetongue virus. Water bodies should be designed with steep sides and depths at least 0.6 to 0.9 meters (2 to 3 feet) along the edge [see: Mullens, B. A. 1989. A quantitative survey of *Culicoides variipennis* (Diptera: Ceratopogonidae) in dairy wastewater ponds in southern California. J. of Medical Entomology 26(6):559-565; and Mullens, B. A. and J. L. Rodriquez. 1990. Cultural management of bluetongue virus vectors. Calif. Agriculture 44(1):30-32].

WILDLIFE AGENCY RECOVERY AND MANAGEMENT RESPONSIBILITIES

AUGMENTATION: Augmentation is a potential recovery tool that is addressed within the context of the recovery plan and would be used until a self-sustaining population is established. The release of captive reared or translocated wild animals to establish new populations or supplement small populations are not acceptable mitigation measures because they do not compensate for the permanent loss of habitat or ensure the continued viability of habitat to support self-sustaining, wild populations.

PREDATOR CONTROL: Predator control is a potential management tool available to the Fish and Wildlife Service and California Department of Fish and Game to address specific situations. Bighorn sheep are adapted to survive natural levels of predation, drought, disease, competition, etc., which do not pose problems in properly functioning ecosystems. Because predator control is a temporary solution to remedy a short-term problem, it does not constitute mitigation for the permanent loss of sheep habitat.

APPENDIX G. RESPONSE TO COMMENTS

The following issues are a compilation of all substantive comments received by the Fish and Wildlife Service from technical reviewers, agencies, and the public, which were not otherwise responded to by directly incorporating changes into the text of the final recovery plan. The issues are organized by general subject matter.

LEGAL ISSUES

Issue: Designation of essential habitat illegally usurps authority over local land use planning by imposing prohibitions on private property and mandating erection of fences. Identifying private lands for protection without committing Federal funding or conservation incentives exposes local government to property taking lawsuits because cities and counties lack the wherewithal to cooperate in implementation of the plan. To avoid representing a moratorium on future development, can some development in essential habitat go forward if adequately mitigated, and if so, what criteria or standards would be used?

Response: Essential habitat (in contrast to critical habitat, discussed below) is a nonregulatory indication of those areas we believe to be important to the conservation of bighorn sheep. The map is intended to provide information that can advance conservation efforts through the activities of other agencies and the public. By sharing biological information, we intend to promote public policy decisions that balance the conservation needs of bighorn sheep with other competing land uses. As such, the designation of essential habitat does not affect the discretion of local and State governments or private land owners over land use decisions. Given the biological importance of the habitat to recovery, limited development could occur in essential habitat if adequately mitigated and designed to be compatible with bighorn sheep recovery. Furthermore, the identification of areas with biological importance can provide a wider range of potential land uses that generate economic opportunity. For example, local governments and private landowners can structure economic incentives to conserve bighorn habitat by creating programs whereby developments in other areas can provide a source of income to land owners with habitat of higher conservation value. This mitigation bank concept has gained widespread acceptance in numerous other areas where local government has created a mitigation nexus that avoids property taking lawsuits and promotes regional habitat conservation planning.

Issue: Membership of the Recovery Team and peer review team consists of individuals whose livelihood depends on funding, permits, and recommendations from the State and Federal government. Therefore, these individuals are reluctant to voice criticisms with the recovery planning process for fear of retribution. In addition, authors of the draft recovery plan stand to gain financially by creating an open checkbook/cash cow with questionable research projects having no accountability.

Response: At our invitation, members agreed to participate on the Recovery Team for the purpose of providing scientific advice to the Fish and Wildlife Service and cooperating agencies, including assistance in developing and implementing the recovery plan. The draft recovery plan was largely written by team members who provided the information and opinions needed to complete a draft plan. Though consensus was achieved on most issues addressed by the team, we and cooperating agencies judged how best to incorporate various views where full agreement was not reached. Many of the research topics recommended in the recovery plan are a reflection of scientific questions that remain unresolved. Any funding to address these research needs will be directed on a competitive basis to the best qualified individuals available. Funding and permitting actions by us and cooperating agencies have and will follow applicable laws and regulations that ensure against preferential treatment and capricious behavior. Recovery Team members are not dependent upon the Fish and Wildlife Service or the listing of bighorn sheep for their continued livelihood. Members are under no obligation whatsoever and do not enjoy economic benefit for their voluntary participation on the Recovery Team.

Issue: Undue reliance on unpublished information fails to justify the spending of $16M every 5 years for several decades. The conclusions, recovery criteria, and habitat mapping lack credibility due to their reliance on over 100 unsupported citations and that underlying data were intentionally withheld from public review. The public has a right to inspect all the unpublished information cited in the draft plan as an aid to provide informed comments; therefore, the public comment *period should be extended until after these data have been made available. Following the response to all comments and correction of many deficiencies, the draft recovery plan should be circulated again for public review.*

Response: The draft recovery plan was based on the best available data, which includes personal experience of credible researchers. Unpublished information cited in the draft recovery plan was documented and compiled prior to completion of the final recovery plan and has been available along with published papers, for public inspection. Any facts or interpretations based on unpublished information cited in the draft recovery plan for which documentation could not be obtained have not been included in the final recovery plan. Justification for research recommended in the recovery plan was not based on cited unpublished information but on consensus recommendations of the Recovery Team and concurrence by the cooperating agencies. Upon reassessing the relative importance of the unpublished information cited in the draft recovery plan to the findings and conclusions in the recovery plan, we have determined that the unpublished information unavailable for review in the draft recovery plan did not materially affect any significant findings or recommendations in the final recovery plan. As a result, we elected to not reopen the public comment period. In response to any substantive comments received after review of the unpublished information, the recovery plan may be appended, revised or updated.

Issue: The recovery plan is too general to meet the specific criteria at 16 U.S.C. 1533(f). The unusable scale of the essential habitat map was intentionally vague and fails to meet the site specific standards for describing management actions necessary for recovery.

Response: Section 4(f) of the Act requires that recovery criteria be measurable and site specific, with estimates of associated time frames and costs. We believe that these requirements have been satisfied. The scale of the draft essential habitat map in the draft recovery plan was designed to portray a specific concept outside and along the urban interface based on bighorn habitat requirements and principles of conservation biology. The draft map was designed to elicit input from interested parties so that the final map could best reflect the concerns of local interests. We elected not to depict draft essential habitat in the draft recovery plan at a parcel specific scale because it would have engendered unnecessary and unproductive controversy and suggested a predetermined outcome. We scheduled numerous meetings with all local jurisdictions and major landowners to refine the boundaries along the urban interface. As described below under the Essential/Critical Habitat section, consensus among Federal, State, and local governments was achieved along the majority of the urban boundary.

Issue: A recovery plan is unnecessary if bighorn sheep in the Peninsular Ranges are synonymous with the Nelson's subspecies.

Response: Section 4(f) of the Act requires preparation of recovery plans for listed species whenever prudent. This comment implies that bighorn sheep in the Peninsular Ranges do not comprise an entity that can be listed under the Act. Please refer to the *Federal Register* Notice, dated March 18, 1998, as well as section I.A.1. of the recovery plan, for a discussion of the applicability of our policy on implementing the Act's provisions for listing distinct vertebrate population segments.

Issue: The Fish and Wildlife Service's authority and intended use of the "Recommended Conservation Guidelines" in Appendix F is not apparent. Furthermore, the guidelines appear intended to restrict the power and override the legislative authority of lead agencies.

Response: The Fish and Wildlife Service and Department of Fish and Game prepared these guidelines to assist local governments in their implementation of the California Environmental Quality Act and land use decision making, not to usurp the discretion of other governmental agencies. It is our intention to provide consistent guidance as early as possible in the decision making process so that (1) our recommendations do not come as a surprise later on in the planning process, and (2) projects can be designed to accommodate the habitat requirements of bighorn sheep.

PROCEDURAL ISSUES

Issue: The bibliography contains many blanks for the authors names, indicating that such information cannot be relied upon.

Response: The blank lines in place of the name of an author is a bibliographic convention that indicates the same author as for the preceding reference. In the final plan the bibliographic format has been revised to show full references.

Issue: The recovery plan should describe how the public will track agency implementation of recovery tasks, be involved in prioritizing lands to be acquired, be involved in future modifications to recovery criteria, comment on land exchanges, etc. Similarly, the draft recovery plan did not identify how entities, such as local government, were expected to fulfill assigned task responsibilities in the Implementation Schedule. The recovery tasks often lack site specificity and do not identify applicable mechanisms or responsible entities for implementing the tasks. For example, the habitat protection objective for task 1.1 does not describe who, how, or where the action would be completed. As a result, affected parties have been prevented from providing meaningful review of the recovery plan.

Response: The public can track implementation by communicating directly with the agencies assigned to implement specific tasks. Progress and updates should be incorporated into the public education and outreach programs recommended in the recovery plan. The public may also track the extent of appropriations allocated by legislative bodies as an indication of agency capability for implementing the recovery plan. Local governments should interpret the recovery plan as guidance for contributing to the recovery process. Many of the provisions in the recovery plan should be implemented through the regional habitat conservation plan sponsored by the Coachella Valley Association of Governments. This plan represents a stakeholders group that provides an opportunity for involvement by all interests. Any of the recovery tasks that apply to respective jurisdictions should be viewed as an opportunity to cooperatively participate with other agencies in the common goal of bighorn sheep recovery. We encourage local governments to use their applicable authorities for conservation/management of open space in the furtherance of bighorn recovery.

Participating agencies can provide more detailed guidance on the roles and responsibilities of local government as case specific questions arise. If the recovery plan is updated or revised in the future, the public will be given another opportunity to comment on the plan.

Issue: The recovery plan should contain an economic impact analysis to estimate the costs of recovery. The total estimated costs of recovery implementation should be determined and provided to the public for comment before the recovery plan is approved. Projected funding levels for monitoring appear inadequate; if a long-term monitoring program is needed, why are costs projected for only 5 years.

Response: Though an economic impact analysis is not required by law or regulation, section 4(f) of the Act requires an estimate of costs to achieve recovery. We have projected total costs based on a rough estimate of 25 years to recovery, with more detailed cost estimates for the first five years. Certain costs are difficult to estimate accurately without detailed scopes of work, real estate appraisals, etc. As a result, cost estimates in the Implementation Schedule should be viewed as approximations that inform the public and participating agencies about the resource estimates necessary to achieve the recovery objectives of the recovery plan.

Issue: *The recovery plan should describe the study areas for all research conducted in the Peninsular Ranges.*

Response: The reader should refer to the references cited to obtain more detailed information on the study methods of literature cited in the recovery plan. The purpose of this recovery plan is not to compile and summarize all research conducted in the area at issue.

Issue: Reliance upon forthcoming planning efforts, such as the Coachella Valley multispecies plan to address immediate bighorn sheep conservation needs, unnecessarily defers actions needed to avert the near-term risk of extinction.

Response: We are not aware of any such deferrals and intend to use our legal authorities under sections 4 (designation of critical habitat), 7 (interagency consultation), and 10 (habitat conservation planning) whenever appropriate during the interim period while the Coachella Valley plan is in preparation.

Issue: The recovery plan should critically examine past management mistakes so that they are not repeated in the future.

Response: Much of the recovery plan reflects on the past (*e.g.*, section I.D) and looks to the future (*e.g.*, section II.D). Many of the Recovery Team members have many years of experience in the Peninsular Ranges and, therefore, have a solid historical perspective. A focused, intensive historical inquiry likely would result in arguable conclusions of dubious merit that could adversely affect current interagency cooperation. The purpose of recovery plans is to assess the current situation with a view towards future feasibility of implementing needed conservation actions.

Issue: Many of the tables were not as descriptive as they could have been because (1) the tables excluded potentially available data, such as from years before or after those presented in the tables, and (2) statistical analyses were not conducted.

Response: In some instances, more recent data were not available; in other cases, data from earlier years were not comparable because of different data collection methodologies; and in other circumstances, available data have not yet been compiled and analyzed. In most instances, statistical analyses were not included because this information was provided in the references cited and because the purpose of recovery plans is more informative and prescriptive than analytical and quantitative.

Issue: The recovery plan should discuss the financial situation of the Bighorn Institute, along with a detailed critique of overall operations.

Response: Financial issues associated with the Bighorn Institute are not a concern of the Fish and Wildlife Service or cooperating agencies. Overall operations regarding research and captive rearing have been the subject of annual reviews by the California Department of Fish and Game prior to Federal listing and now fall under the purview of section 10(a)(1)(A), not section 4(f) of the Act.

Issue: A repository for all data collected on bighorn sheep should be created and made available to the public at large.

Response: Creation of such a repository would not be possible unless agencies and researchers donated proprietary information and personal property. The concept poses numerous legal, economic, and administrative issues that exceed our authorities and those of cooperating agencies.

Issue: Numerous comments requested the Fish and Wildlife Service and cooperating agencies to conduct additional research and further analyze data not in their possession before issuing a recovery plan.

Response: The Act's mandate to use the best available information does not require us to conduct additional research or obtain unavailable data as a prerequisite to preparing and completing recovery plans. A court stipulated settlement agreement required completion of the recovery plan under an established schedule.

Issue: The draft recovery plan focuses excessively on habitat conservation instead of population recovery; the various problems should be dealt with in order of importance.

Response: As described in the draft and final recovery plans, multiple, apparently cumulative factors are depressing population levels, with contributing causes differing among ewe groups. The relative importance of factors affecting reproduction, recruitment, and adult survival are poorly understood in some ewe groups, though intensively studied in others. These complexities make it difficult to determine relative importance and management priority. Therefore, we have and will address concurrently all probable factors affecting individual ewe groups to the extent possible. If the habitat base upon which bighorn sheep depend is not protected, sufficient space will not be available to support "recovered" population levels.

Issue: The Fish and Wildlife Service should list credentials of Recovery Team members.

Response: By practice and for consistency, we do not provide this information regarding team members. Members were selected for a variety of skills and experiences that may not be apparent from brief synopses.

Issue: The Fish and Wildlife Service rejected, without explanation, many comments provided by Recovery Team members themselves. Disagreements within the team should be discussed in the recovery plan.

Response: The various views held by members of the team were discussed openly at team meetings until a consensus emerged. Various iterations, including the final recovery plan, have been reviewed multiple times by team members, and all comments have been incorporated into the recovery plan directly or after group discussion where further consideration was warranted. We are unaware of any significant scientific disagreement within the team regarding the content of the recovery plan. Regardless, the Fish and Wildlife Service and cooperating agencies assume ultimate responsibility for the recovery plan, inasmuch as Recovery Teams function as expert advisors to the Fish and Wildlife Service.

Issue: The peer review process of the draft recovery plan was flawed, failed to address all the issues raised and to follow academic protocol, and therefore, should not be referred to as peer review. The draft recovery plan misleads the public into thinking that the peer reviewers endorse the draft plan.

Response: The peer review process referred to in the draft recovery plan represented separate technical and agency reviews prior to public release and was not intended to follow academic protocols. Though most of the comments received by the technical (peer) reviewers were addressed in the draft recovery plan, the draft recovery plan did not claim that the reviewers necessarily agreed with or endorsed the plan. The Recovery Team and Fish and Wildlife Service have included and addressed in this list of issues and responses all substantive comments submitted by technical reviewers not otherwise incorporated into the draft or final recovery plans.

Issue: Research tasks in the recovery plan should identify testable hypotheses.

Response: The Recovery Team is not a research team; therefore, this recovery plan represents a general strategy for recovery that identifies major research topics that should be pursued. It would not be appropriate to propose various experimental designs and hypotheses at this time because the additional level of analysis required should more properly occur when detailed research proposals by individual researchers are prepared.

Issue: The Recovery Team should include a trained land use planner to improve the effectiveness of coordinating conservation activities with local jurisdictions, such as the cities and counties.

Response: One of the current Recovery Team members has an extensive background in land use planning, having worked in that capacity for numerous jurisdictions for many years. In addition, several other members work routinely with local government in land use planning matters and have a thorough understanding of legal and procedural requirements needed to coordinate effective interagency conservation programs.

ESSENTIAL/CRITICAL HABITAT ISSUES

Issue: All local jurisdictions should be extended the same opportunity as the Indian tribes in determining essential habitat boundaries. Failure to do so will doom the recovery planning effort.

Response: Federally recognized Indian tribes enjoy a special relationship and trust privileges under numerous executive, legislative, and judicial mandates not extended to non-Tribal entities. Nonetheless, within the context of the Coachella Valley multispecies planning program, the Fish and Wildlife Service and California Department of Fish and Game convened numerous meetings with city and county governments to discuss and refine essential habitat boundaries in a process similar to that used with the tribes. The Fish and Wildlife Service, Department of Fish and Game, and local jurisdictions achieved agreement along virtually the entire urban boundary except for about six proposed project sites. The Fish and Wildlife Service and Department of Fish and Game will attempt to resolve residual differences for each of the proposed developments through individual regulatory actions.

Issue: The suggested 20 percent slope delimiting lower elevational boundaries in most cases lies below the 213-meter (700-foot) lower elevation limit described elsewhere in the recovery plan as the lower elevational limit of sheep distribution. The essential habitat line should be set along the 213-meter (700-foot) elevation contour from Palm Springs to La Quinta, which would avoid lambing and watering areas and provide opportunities for unrestricted hiking. Essential habitat should not extend onto the valley floor farther than existing wilderness or the proposed National Monument boundary. The map appears to represent a no growth effort that would extort extreme mitigation from developers.

Response: The 213-meter (700-foot) lower elevational limit of sheep distribution typically corresponds to the urban interface at the northern end of the Coachella Valley, whereas in the southern end of the valley, the urban interface occurs along lower elevational contours. As described elsewhere, sheep in the Peninsular Ranges are adapted to survive at lower elevations and depend on lower elevational slopes and alluvial habitats for important resources. The extent of suitable habitat is influenced by soils, aspect, and other topographic features that do not necessarily correspond with fixed elevation contour lines, or wilderness and proposed monument boundaries, which were established for a variety of reasons apart from the habitat needs of bighorn sheep.

Issue: Habitat compensation should not be required for development adjacent to sheep habitat because development of these fragmented areas would not affect sheep.

Response: Most of the proposed development along the urban interface occurs within, rather than adjacent to, sheep habitat. As discussed in the recovery plan, bighorn sheep in the Peninsular Ranges spend much of their time at lower elevations, where otherwise scarce resources, such as food and water, commonly occur. Flatter topography contains more productive alluvial soils that support more diverse and nutritional food sources than occurs on steeper, rockier slopes. Though alluvial habitats are more fragmented by urban development, these smaller patches still support habitat value, though much reduced from historical conditions. Development of habitat fragments also indirectly affects sheep by supporting a larger human population that increases the amount of disturbance in adjoining sheep habitat. As long as suitable habitat conditions exist within the historical range of the species and development results in indirect adverse effects to sheep in nearby habitat, local governments have a mitigation nexus under the California Environmental Quality Act. Mitigation measures can be designed to conserve larger patches of comparable value habitat by requiring offsite habitat replacement, thereby contributing to the conservation of sheep even if smaller habitat fragments are permitted for development. To contribute to recovery, we recommend that local governments consider offsite habitat replacement for permitted development of residual habitats between the essential habitat boundary and 800 meters (2,624 feet) from toe of 20 percent slope.

Issue: Proposed designation of essential habitat requires adequate legal notice to landowners in the vicinity of habitat proposed for conservation so that an opportunity to comment on the proposal is provided. The public comment period should be opened indefinitely until essential habitat is displayed on detailed aerial photography and has been made available for public comment. A more detailed map of essential habitat then should be provided for public comment before the recovery plan is completed.

Response: The Fish and Wildlife Service broadly announced a 45-day public comment period on the draft recovery plan (64 FR 73057; December 29, 1999), which was extended an additional week as a convenience to the public. This noticing process fulfilled all legal requirements. As described above, the Fish and Wildlife Service coordinated with affected interests in soliciting input and promoting discussion to achieve consensus on the essential habitat boundary.

Issue: The draft recovery plan does not adequately describe the importance of the Mount San Jacinto State Park to sheep recovery.

Response: The park is largely located above the elevation where bighorn sheep normally occur.

Issue: The essential habitat map should model food and water resources as was done for physiography.

Response: Food and water resources generally are too dynamic to quantify because their distribution is a function of unpredictably variable rainfall patterns. For example, randomly occurring thunderstorms do not provide uniformly distributed moisture regimens throughout sheep habitat but rather result in localized green-up following high intensity, short duration precipitation events. Sheep typically respond to these sporadic events by exploiting ephemeral sources of food and water. Patterns of sheep distribution relative to perennial water sources have been analyzed and discussed in Appendix B.

Issue: The draft recovery plan did not identify the specific projects previously approved by the Fish and Wildlife Service that would be excluded from areas mapped as essential habitat. Essential habitat should be designated on areas previously approved by the Fish and Wildlife Service for development if scientific data indicate these areas should be part of critical habitat for recovery. Essential habitat should include not yet constructed projects that have been previously approved by the Fish and Wildlife Service because these areas are needed for sheep recovery.

Response: The Fish and Wildlife Service completed section 7 consultation on the Ritz-Carlton Golf Course and Mirada development prior to release of the draft recovery plan, and completed section 7 conferences on the Jimenez Pit, Cahuilla Zone Reservoir, and Shadowrock projects prior to listing. The Fish and Wildlife Service and project proponents agreed to reconfiguration of project designs and other conservation measures on the former four projects. Agreement on the latter project has not been achieved and the affected area is considered essential habitat unless the project is reconfigured to be consistent with the section 7 conference opinion.

Issue: Critical habitat should be designated even if it divulges locations and consequently exposes sheep to harm.

Response: On July 5, 2000, the Fish and Wildlife Service published a proposed rule (65 FR 41405) to designate critical habitat under a separate process pursuant to a recent settlement agreement with the plaintiffs who challenged our not prudent finding that accompanied the listing. This topic was discussed in the proposed rule.

Issue: The recovery plan should describe the relationship of essential habitat and critical habitat from a regulatory and procedural perspective.

Response: Though the two designations are similar in their focus on defining future survival and recovery needs, they differ significantly from a regulatory perspective. For purposes of this plan, essential habitat is an informative designation intended to provide scientific guidance to cooperating agencies and the public, while critical habitat is statutorily defined with implementing regulations that govern Federal agency activity. Critical habitat receives protection under the Act through the prohibition against destruction or adverse modification of critical habitat as set forth under section 7 of the Act with regard to actions carried out, funded, or authorized by a Federal agency. Aside from the protection that may be provided under section 7, the Act does not provide other forms of protection to lands designated as critical habitat. Critical habitat designation does not impose any restrictions to activities on private or other non-Federal lands that do not involve a Federal permit, authorization, or funding. The process for designating critical habitat is distinct from the process for completing the recovery plan. A proposal to designate critical habitat for the Peninsular bighorn sheep was published in the Federal Register on July 5, 2000 (65 FR 41405). The essential habitat mapped in the recovery plan has the same boundary as the proposed critical habitat, with slight discrepancies introduced by a legal description for critical habitat along boundaries imposed by a township/range/section coordinate grid.

Issue: Undeveloped but fenced property should not be mapped as essential habitat.

Response: Areas that can be enhanced or restored are included as essential habitat if they are necessary for recovery. Fencing often does not establish an effective movement barrier to sheep, though it can cause entanglement, injury, and death. The Fish and Wildlife Service advises that fences constructed to exclude bighorn sheep could result in take if built at the wrong location or improperly designed.

Issue: The recovery plan should provide more specific guidelines to local jurisdictions for conserving habitat and reducing the effects of urbanization. For essential habitat to be effective, the recovery plan should provide guidance on future regulation of take under sections 7 and 10 of the Act, which should specifically prohibit authorization of future take if ewe group population levels drop below predetermined thresholds and/or populations increase to a point suggesting progress towards recovery. For example, the threshold approach used for predator management also could be applied to habitat loss.

Response: Appendix F was designed to provide general guidelines that would fit most projects in or adjacent to sheep habitat. More specific guidelines would be difficult without a case by case analysis of individual projects. The Fish and Wildlife Service can not use recovery plans to predetermine future regulatory decisions under sections 7 and 10 because the Act did not envision recovery plans as a regulatory mechanism.

Issue: The draft recovery plan places inordinate importance on land use controls and too little emphasis on reducing predation pressure. By failing to manage threats under its control, such as predation, the Fish and Wildlife Service unfairly shifts onerous regulatory impositions onto private property owners. Another commenter claimed that the acknowledged lack of understanding concerning factors limiting population viability undermines the credibility of the proposed land use controls, and that the uncertainty over adverse effects of urban development eliminates any nexus for governmental regulation.

Response: The Fish and Wildlife Service intends on concurrent implementation of numerous recovery tasks commensurate with available funding. Completion of the recovery plan provides a basis for increased funding allocations to cooperating agencies. Because numerous factors are depressing population growth, it would not be appropriate for the Fish and Wildlife Service and cooperating agencies to attempt to prioritize threats and address only one at a time. Focusing solely on predator control and allowing continued loss of valuable habitat would be based on a theory that habitat loss does not adversely affect bighorn sheep. The available evidence suggests the opposite. The ewe groups adjoining metropolitan areas historically have declined to a greater degree and currently are more severely threatened with extirpation than more southerly and remote ewe groups that have not sustained substantial loss of habitat in the past.

Issue: The draft recovery plan does not adequately identify the specific lands mapped as essential habitat and targets all available habitat without scientifically analyzing whether portions of the area support any suitable habitat at all.

Response: Appendix B presents a habitat model that analyzed a variety of habitat characteristics based on information in the scientific literature and distributional data throughout the Peninsular Ranges. Areas with unsuitable soils and topography were excluded, as were areas greater than 800 meters (2,624 feet) from toe of 20 percent slope, though sheep are known to use these areas. Based on the wide-ranging movements of sheep in the Peninsular and other ranges throughout the desert southwest, sheep are known to use a broad range of habitats in desert environments. None of the areas mapped as essential habitat contains soils, vegetation, or topography that is unsuitable for use by sheep. Though sheep may not use or occur in certain areas as frequently when population sizes are small and distribution is more constrained, it is sometimes difficult to track sheep movements, especially when only a small percentage of certain subpopulations have radio collars. Thus, the known distribution is always an underestimate of actual distribution.

Issue: The designation of "essential habitat" is an illegal subterfuge for avoiding the statutory requirement for designating critical habitat and analyzing consequent economic effects.

Response: A proposal to designate critical habitat for the Peninsular bighorn sheep was published in the Federal Register on July 5, 2000 (65 FR 41405), under terms of the settlement agreement referenced above. A notice of availability for the draft economic analysis on proposed critical habitat designation was published in the Federal Register on October 19, 2000 (65 FR 62691).

Issue: Numerous land owners requested that their lands be specifically removed from areas designated as essential habitat because of the significant social and economic impacts that should be minimized per existing Fish and Wildlife Service policy on recovery planning.

Response: As discussed above, the Fish and Wildlife Service has met with many landowners and agencies in an effort to refine the essential habitat boundary so that social and economic impacts are minimized to the extent that the potential for recovery is not compromised. These discussions resulted in substantial agreement with all parties involved over the vast majority of the urban interface. The resulting essential habitat boundary was designed to minimize economic conflict to the extent consistent with maintaining the likelihood of future recovery. Essential habitat differs significantly from critical habitat. Under critical habitat, exclusions are a procedural outcome of applying section 4(b)(2) and/or "special management" under the Endangered Species Act. Under 4(b)(2), economic and social impacts are evaluated. However, there is no such process identified for exclusions for essential habitat because recovery plans are nonregulatory documents designed to guide, not dictate, recovery of the species.

Issue: *The draft recovery plan was deficient because it did not quantify the acreage of different landownerships, historical distribution, and extent of proposed essential habitat.*

Response: Acreages were not calculated in the draft recovery plan because an updated landownership map was not available and a precise boundary along the urban interface was not delineated. In the final recovery plan, land ownership is delineated with respect to essential habitat in Figure 4; however, the land ownership map is somewhat outdated and any acreage figures would be approximate. Approximate land ownership percentages are summarized in

Section I.E. of the plan. Historical trends along the urban interfaces are summarized in Section D.1.

Issue: Lands that historically never were used by sheep should be identified. The term "unoccupied habitat" is scientifically undefined and inappropriately used to describe unsuitable habitat from which bighorn sheep are absent.

Response: Historical information prior to the use of aerial surveys and radio telemetry is of limited utility because the rugged topography and lack of roads throughout the Peninsular Ranges greatly restricted the extent of access on the ground. Therefore, it is not possible to reliably conclude that certain areas were not used historically. Similarly, given the relatively small sample size of radio-collared sheep at present, especially rams (which are far more wide ranging than ewes), more recent data cannot be properly interpreted to conclude that sheep are absent from certain areas. Therefore, the remaining undeveloped portions of historical range constitute the current distribution of bighorn sheep in the Peninsular Ranges. Use of the terms "occupied", "unoccupied", "suitable", and "unsuitable", are more conceptual than empirical. Thus, these terms add little to our understanding of sheep biology, and as a result, the final recovery plan avoids use of this terminology.

Issue: *Given the tendency of sheep to not venture far from escape terrain, justification in the recovery plan is not adequate to support the need for habitat up to 0.8 kilometer (0.5 mile) from toe of 20 percent slope. Twenty percent slope does not represent effective escape terrain; therefore, a steeper slope should be used for identifying habitat in need of conservation. The recovery plan does not adequately describe what constitutes a movement corridor on the desert floor. If sheep avoid human disturbance, the fragmented habitat patches on the desert floor within the urban matrix would appear to have low habitat value for sheep.*

Response: Though sheep typically are found in steeper terrain, numerous records exist in the Peninsular Ranges and elsewhere of occurrences over 0.8 kilometer (0.5 mile) from escape terrain. The 0.8 kilometer (0.5-mile) distance was selected to capture the more typical movements onto the alluvial slopes. The 20 percent slope for escape terrain was taken from the published literature. As discussed in

Appendix B, a range of slopes have been recognized by various authors as escape habitat. Flatter topography encompasses more productive soils that support more diverse and nutritious forage that is seasonally critical to sheep. Flatter topography also can be important for dispersal and for sources of seasonal water. Sheep in other areas of the desert southwest have been known to move many kilometers across the desert floor to reach neighboring mountain ranges. Given the limited number of documented movements of this kind, not enough is known to delimit linkage dimensions. Rams are especially prone to use flatter areas farther removed from escape terrain. Ruggedness on flatter topography can function as escape habitat but has been difficult to measure and account for in studies published to date. The essential habitat map excludes the less frequently used and lower value habitats characterized by small patch size and proximity to human disturbance.

Issue: Designation of essential habitat as proposed would restrict access for construction and maintenance of infrastructural facilities like flood control and water supply. Flood control facilities should not be included in essential habitat because any use by sheep is incidental to the primary purpose of these lands.

Response: Case by case project reviews under the regulatory provisions of sections 7 and 10 of the Act will determine whether construction of infrastructural facilities are compatible with sheep survival and recovery. Based on discussions with Riverside County Flood Control and Water Conservation District and Coachella Valley Water District, normal operations and maintenance of existing facilities would not conflict with the management objectives for essential habitat. Flood control facilities typically occur in washes and alluvial habitat that have been most affected by historical habitat losses and often still support the same important habitat values as the surrounding areas. As such, these facilities are not *de facto* unsuitable or detrimental to sheep use. If reasonably managed, these areas can fulfill their intended function while at the same time not conflicting with sheep use in the area.

Issue: The recovery plan does not discuss the possibility that past habitat loss from urbanization in the San Jacinto and northern Santa Rosa Mountains may *have resulted in irreversible population declines, rendering essential habitat designation in this area potentially useless.*

Response: The recovery plan strives to intensify management efforts to offset the loss of historic habitat, and thereby maintain functional population levels in the future. If populations become extirpated and the Recovery Team and cooperating agencies determine that habitat areas are no longer capable of supporting self-sustaining populations, future revisions of the recovery plan may delete essential habitat and management objectives for those areas.

BIOLOGICAL ISSUES

Issue: One commenter thought that the eyesight of bighorn equaling that of humans aided by 8-power binoculars should be emphasized.

Response: According to Geist (1971), scientific evidence is not available to support this popular myth, which probably originated with the experiences of hunters with the species.

Issue: The regular sightings of bighorn sheep in Chino Canyon and Tachevah Canyon alleged by Fish and Wildlife Service biologists appear inconsistent with portions of the draft recovery plan that state bighorn sheep vanished from the northern San Jacinto Mountains after construction of the Palm Springs Aerial Tramway.

Response: Though rams still range north of Chino Canyon, ewes have not been documented in the northern San Jacintos (north of Chino Canyon) since the late 1980's. The tramway was constructed in the early to mid-1960's.

Issue: *The high number of undetermined causes of death indicates that a better explanation is needed of how the deaths were discovered and how the causes were diagnosed.*

Response: Most deaths were discovered from radiocollared animals because the fate of uncollared animals is far more difficult to ascertain. When dead animals are found, the cause of death is sometimes difficult to determine because in many cases, coyotes and other scavengers have consumed the carcass so thoroughly that the original cause of death (whether predation or not) can not be determined.

Issue: Some commenters thought the recovery criteria of 25 ewes per 9 identified regions and an average of 750 adults for delisting is too low to assure survival and recovery, and that the estimated rangewide carrying capacity of 1,000 sheep appears low. Another commenter thought the criteria requiring a minimum of 25 ewes in each ewe group would be too difficult to achieve.

Response: The team and agencies decided that it would be difficult to justify a higher population level than was known historically, especially given the extensive habitat loss and fragmentation, and other factors that likely have reduced carrying capacity over time. Team members most familiar with the Peninsular Ranges assessed current and historic habitat quality, and made regional comparisons with other bighorn sheep habitats in estimating current conditions and carrying capacity. The 9 regions were deemed capable of supporting in excess of 25 ewes, with the carrying capacity in most of the regions substantially exceeding the minimum. Because 750 is an average figure, it would be necessary for the population to rise above that level for some period of time, likely in response to changing carrying capacity. The averaging criterion was selected because it allows natural population fluctuations and management flexibility. If the long-term carrying capacity exceeds 750 animals, the population likely would exceed the 750 minimum established in the recovery plan.

Issue: The operations by the Bighorn Institute are contributing to the decline instead of the recovery of bighorn sheep. Alternative methods, such as on-the-ground surveys, should be used for estimating population size and distribution, instead of more highly disruptive helicopter flights. Helicopter censuses and captures are far more stressful to sheep than researchers, hikers, and riders quietly moving through sheep habitat.

Response: The Bighorn Institute conducts hundreds of days of on-the-ground work and only about 6 days of helicopter work each year. Conducting on-the-ground studies is often not feasible on private property and could result in significant disruption to sheep if implemented at a level needed to estimate population distribution and abundance at precision levels comparable to aerial techniques. Even at current levels, on-the-ground disturbance associated with research activities could be detrimental if not for rigorous safeguards. For example, Bighorn Institute biologists regularly document through radio telemetry that their presence "bumps" or "pushes" sheep in flight away from them, at which point the field methodology requires backing off, which often prevents the recording of field data.

Issue: Why is agricultural use adjoining bighorn sheep habitat considered a more compatible use, whereas residential and resort developments are not?

Response: Agricultural activities do not generate the high levels of secondary impacts, such as human recreation in adjoining habitat, as is typically associated with urban land uses. In addition, agricultural lands can be restored to sheep habitat, whereas urban land uses can not. Though agricultural lands were excluded from delineated essential habitat, several Recovery Team members recommended they be included because of their restoration potential.

Issue: Numerous commenters inquired whether studies have been conducted and evidence exists for the presence of bighorn sheep on their lands.

Response: We have included a map with known locality records to provide a better indication of bighorn sheep distribution. References cited throughout the recovery plan should be perused to determine study areas and methods. The lack of records for certain areas does not necessarily indicate that sheep are absent, only that their presence has not been documented.

Issue: The slow reproductive rate and long-term estimates for recovery should be accelerated by importing sheep to increase population levels.

Response: Unless the factors that limit population growth in the Peninsular Ranges are addressed, it is unlikely that a program to introduce animals from outside areas would be successful. However, alleviating *in situ* decimating factors would allow the resident population to expand on its own, which would forego the need for translocation. Importing animals also poses risks of disease transmission. Regardless, bighorn sheep populations throughout the Mojave Desert are currently depressed to the extent that surplus animals are not available for importation.

Issue: Given the history of population declines in regions adjoining urban areas, it does not seem plausible for the recovery plan to claim that Peninsular bighorn sheep have a high potential for recovery.

Response: The recovery plan attempts to build on past examples and taking action soon enough to reverse the decline of sheep in our mountains. The Recovery Team and cooperating agencies believe that the recovery potential is high if the management recommendations in the recovery plan are implemented.

Issue: *The further research and planning required through the captive rearing and augmentation guidelines in Appendix C does not recognize or expedite the immediate recovery needs and issues that must be addressed in the short-term. After many years of operation, these issues should already have been addressed and a plan ready to implement.*

Response: The existing operations of the Bighorn Institute are reviewed annually by the agencies and adjustments made if needed. Captive breeding for population augmentation, population monitoring, and research have been and continue to be the primary emphases until changes in direction are agreed to by the Institute, agencies, and Recovery Team.

Issue: *One commenter suggested that the draft recovery plan was deficient because a recent discovery of a desert bighorn sheep population in Ventura County was not addressed.*

Response: Sheep populations in Ventura County are not included in the distinct population segment listed in the Peninsular Ranges and, therefore, are not relevant to the recovery plan.

Issue: Because bighorn sheep are wilderness animals, more emphasis should be place on conservation efforts in Anza-Borrego Desert State Park, instead of urbanizing Coachella Valley, where prospects for success are less than in more remote areas.

Response: Numerous subpopulations are necessary to maintain the larger Peninsular Ranges metapopulation. Therefore, recovery will require protection of all areas needed to maintain the constituent subpopulations. This protection will require increased management emphasis and cooperation among land managers in urbanized areas.

Issue: The limited dispersal and colonization capabilities contradict statements elsewhere in the recovery plan that bighorn sheep are wide ranging animals dependant upon large tracks of habitat.

Response: True, each individual is a wide-ranging animal with a relatively large home range. This behavior and knowledge of these areas is learned by the offspring, which is transmitted across generations. Though colonizations of new habitat are known to occur, they are not a common event. Rams are more wide-ranging than ewes and are known to move between mountain ranges and ewe groups.

Issue: The draft recovery plan does not clearly indicate how or whether models would be used to assist in gaining a better understanding of the interacting factors that place sheep at risk.

Response: Models are a tool that help assimilate knowledge and understand factors that place bighorn sheep at risk, for later application through management prescriptions. Models should be used anytime they can help us to better understand bighorn sheep population dynamics, genetics, or ecosystems. Though the recovery plan provides examples of high priority issues that should be examined with models, the points at which a model would be appropriate are difficult to predict. Modeling is included in the section on research because it is an ongoing process that will have to be applied and modified as questions arise and more data become available.

Issue: The recovery plan is biologically inconsistent, arguing on the one hand that human disturbance in wild areas causes them to avoid otherwise important habitat but on the hand arguing that fences are needed to prevent sheep from being attracted to urban areas.

Response: Bighorn sheep react differently to various kinds of disturbance depending on numerous factors, including location. The northern Santa Rosa Mountains ewe group is the only herd that has habituated to using the urban interface, yet when in wild habitat distant from the urban edge, these same sheep react similarly to nonhabituated herds–that is, individuals revert to normal wild behavior when away from the urban edge. The reaction is perhaps most pronounced during the lambing season, when ewes with lambs are frequently displaced by human disturbance. This effect has been repeatedly documented through radio telemetry research, where sheep are sometimes inadvertently "bumped" or "pushed" farther away by researchers, even though the sheep are still hundreds of meters distant and not visible to the researchers. In other words, behavioral reactions often depend on geographical and seasonal context, with the spectrum of contrasting responses to human stimuli most clearly evident within this ewe group.

PREDATOR CONTROL ISSUES

Issue: Radiocollars may render sheep more vulnerable to predation and therefore should not be used as prevalently as they are today.

Response: We are not aware of data that indicates radiocollared animals are at greater risk of predation than uncollared animals. Nonetheless, cooperating agencies have attempted to balance the number of radiocollars to minimize potential risk without compromising information needed to achieve population recovery.

Issue: Whereas one commenter asserted that the proposed predator management measures were too lax and should be more aggressive in terms of moving predators from the area before they become an issue, another commenter claimed *that scientific evidence was sufficient to indicate that mountain lion predation was not a problem and that management measures, therefore, were not warranted.*

Response: This issue was discussed vigorously by the team and agencies. Because documented mortalities were particularly high in certain ewe groups, the team and agencies decided the prudent course of action dictated a measured management response, which would be modified as more data became available.

Issue: Predator management should be given higher priority than land management restriction because mortality to predators is the more likely limiting factor on bighorn populations.

Response: The draft recovery plan and available evidence indicate that individual subpopulations are affected by a variety of influences that affect population levels and that the combinations and relative strength of these influences typically differ among ewe groups and change over time. Therefore, the recovery plan focuses on the range of threats facing bighorn sheep. The recovery plan prescribes predetermined criteria for initiating predator management and recognizes the importance of habitat protection so that recovered populations have sufficient space to inhabit.

Issue: The long-term decline in habitat quality and deer populations in the Santa Rosa Mountains should be identified as a cause of high levels of mountain lion predation on bighorn sheep, with a strategy to reverse the situation. The recovery plan should more clearly establish the relationship of bighorn sheep to mule deer by superimposing a deer distribution map.

Response: Mule deer typically occur at higher elevations than bighorn sheep, though ranges may overlap regionally and seasonally, such as during the winter when deer in some areas move to lower elevations. Traditional predator/prey theory holds that predator populations increase and decrease in response to fluctuating prey populations. However, there are no data indicating that high levels of predation are due to declines in habitat quality or deer populations, or whether prey switching may be occurring in the Peninsular Ranges. Because data on habitat quality, as well as deer and mountain lion populations in the Peninsular

Ranges are not sufficiently robust to provide insight into these questions, the draft and final recovery plans propose focused research to address this ecological issue.

Issue: The recovery plan does not provide compelling evidence that the predator/prey system is not viable, and therefore, predators should not be managed unless a cause and effect relationship with bighorn population declines is established.

Response: The high incidence of predation, comparatively lower adult survivorship rates than in other regions, and long-term population declines suggest to land managers that predation is a limiting factor to population growth in some areas of the Peninsular Ranges. The cooperating agencies have agreed that this evidence is sufficient to prompt responsible but cautious management intervention.

Issue: One commenter argued that counter to claims in the draft recovery plan, the only available scientific evidence indicates a declining trend in statewide mountain lion populations.

Response: The evidence presented by the commenter lacked associated statistical analysis; therefore, the statistical resolution of the data cannot be evaluated and no conclusion on population trend is possible.

TRAIL ISSUES

Issue: The constant presence of bighorn sheep along Highway 111 in Rancho Mirage indicates human activities, such as hiking and jeep use, may not create movement barriers, as suggested in the draft recovery plan. Further information is requested to support why back roads and trails are detrimental to sheep when they are known to cross 6-lane highways (e.g. Highway 111 in Rancho Mirage).

Response: The recovery plan cites numerous studies that have documented avoidance behavior to human related disturbance (see Papouchis *et al.* 1999 for example). Numerous records of vehicular related mortality provide further evidence of adverse effects. The recovery plan seeks to remedy the maladaptive behavior of habituation to urban sources of food and water so that sheep are better able to survive in the wild.

Issue: A trails map to clarify and accompany Table 10 is needed.

Response: Though a good idea, an accurate trails map is not currently available. The cooperating agencies are pursing the development of such a map.

Issue: Detailed maps of lambing, rearing, and watering habitat are needed to justify any decisions to close trails.

Response: The distribution of lambing, rearing, and watering habitat is incompletely known and, therefore, cannot be accurately mapped. The final recovery plan has been modified to include a more complete set of information upon which trails decisions should be based.

Issue: A permit system should be used for controlling trail use on all trails for which conflicts were identified in the recovery plan.

Response: The cooperating agencies are working with interest groups in the formulation of a range of alternative trails strategies that include this option.

Issue: The recovery plan should consider that in the San Jacinto Mountains, the existing trails network appears to provide a passive disturbance boundary that may control sheep access to the urban interface and prevent exposure to the urban hazards experienced in the northern Santa Rosa Mountains. Consequently, seasonal or permanent trail closures could have unintended adverse effects.

Response: A trails management plan prepared by the land management agencies and interest groups will consider the merits of this comment. Certain adjustments to the existing trails network and associated monitoring could be implemented to improve upon this concept.

Issue: More specificity is needed in describing where human disturbance and other indirect effects of urbanization is conflicting with sheep conservation.

Response: Human intrusion and associated disturbance has the potential to extend wherever access into habitat is provided. Though lambing and watering habitats are particularly vulnerable, excessive human use throughout the year may also affect bighorn persistence.

Issue: Will mitigation credits be given for the eradication of invasive non-native plants?

Response: Conservation measures for proposed projects will be determined on a case by case basis through regulatory processes of local, State, and Federal agencies.

Issue: The January through June trail conflicts in the San Jacinto Mountains appear excessive if the lambing season there extends only through mid-March.

Response: The draft recovery plan stated on page 12 that DeForge *et al.* (1997) found a similar onset to the lambing season in February in the San Jacintos. Cunningham found that lambing in Carrizo Gorge extended only to mid-March. Lambs are critically dependent upon their mothers for several months after birth.

Issue: Rather than monitoring to ensure compliance with seasonal trail closures before allowing construction of trail reroutes out of lambing habitat, the recovery plan should allow simultaneous construction of alternative trail routes to enhance the effectiveness of seasonal closures on existing trails in lambing habitat.

Response: The final recovery plan has been modified to incorporate flexible approaches that will be provided in more detail in the trails management plan prepared by the cooperating agencies and interests. Without adequate management and monitoring, this approach could result in more trails and no reduction in use of problematic trails.

FENCING ISSUES

Issue: The draft recovery plan does not provide evidence for the effectiveness of the proposed fencing as a mitigation measure and fails to address the associated *financial and visual burdens. Except in areas with vehicular related mortalities, the need for fencing is questionable, considering the potentially detrimental effects of severing habitat, restricting sheep movement, and rendering sheep more vulnerable to predation against fences. Alternatives to fences, such as nonmotorized trails adjoining development, which would provide a deterrent to sheep movement into urban areas, warrant more analysis. By imposing the mandate for fencing on private property without adequate justification, the draft recovery plan acted in an arbitrary manner in excess of statutory authority.*

Response: The cooperating agencies are open to alternative means of controlling sheep movements into urban areas. However, some landowners and jurisdictions have chosen fencing as an affordable and reliable solution to the problem of behavioral habituation. When installed, fences have proven effective and aesthetic concerns have been addressed through alternative designs and alignments. Fencing along the urban interface is intended to benefit sheep by curtailing movement into areas with unnatural sources of mortality and help reduce herd mortality rates to sustainable levels. The demonstrated loss of animals to vehicular related mortality, poisoning from landscaping plants, drownings, etc., establish a legal nexus to warrant measures to prevent these adverse effects.

NON-NATIVE ANIMAL ISSUES

Issue: The recovery plan needs to establish a buffer zone between bighorn sheep habitat and cattle grazing, as was done for domestic sheep grazing, so that the risk of disease transmission is minimized.

Response: There is no conclusive evidence to support a buffer zone for disease protection from cattle as there is for domestic sheep. The recovery plan recommends research on disease transmission between livestock and bighorn, and if a buffer zone is shown to be warranted, future iterations of the recovery plan will be amended accordingly.

Issue: Cattle grazing and associated fencing should not be allowed for various reasons, including disease hazards and risk of physical injury to bighorn sheep.

Response: We agree that fencing should be minimized and eliminated if possible. If fencing is necessary, design guidelines have been developed that minimize and prevent the risk of injury. The recovery plan establishes the need to thoroughly review the appropriateness of cattle grazing in sheep habitat and take action if prudent.

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