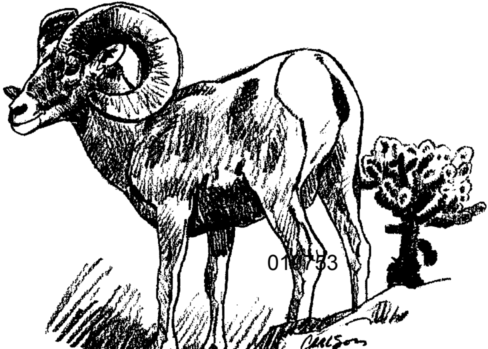
U.S. Fish & Wildlife Service

Recovery Plan for Bighorn Sheep in the Peninsular Ranges, California



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

010754

010210

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:

Esther Rubin
University of California, Davis
Davis, California

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

Disclaimer

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.

Literature citation should read as follows:

U.S. Fish and Wildlife Service. 2000. Recovery plan for bighorn sheep in the Peninsular Ranges, California. U.S. Fish and Wildlife Service, Portland, OR. xv + 251 pp.

Additional copies may be purchased from:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814-2158
(301)492-6403 or 1-800-582-3421
FAX: 301-564-4059
E-mail: fwrs@mail.fws.gov
http://fa.r9.fws.gov/r9fwrs/

The fee for the plan varies depending on the number of pages of the plan.

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

Don Armentrout, Bureau of Land Management, Susanville, California
Dr. Vern Bleich, California Department of Fish and Game, Bishop, California
Dr. Walter Boyce, University of California, Davis, California
Tom Davis, Agua Caliente Band of Cahuilla Indians, Palm Springs, California
James DeForge, Bighorn Institute, Palm Desert, California
Diane Freeman, U.S. Forest Service, Idyllwild, California
Mark Jorgensen, California State Parks, Colorado Desert District, Borrego Springs, California
Stacey Ostermann, Bighorn Institute, Palm Desert, California
Esther Rubin, University of California, Davis, California
Dr. Oliver A. Ryder, Zoological Society of San Diego, San Diego, California
Pete Sorensen, U.S. Fish and Wildlife Service, Carlsbad, California
Steve Torres, California Department of Fish and Game, Sacramento, California
Dr. John Wehausen, University of California, White Mountain Research Station, Bishop, California

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.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

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

010773

010229

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

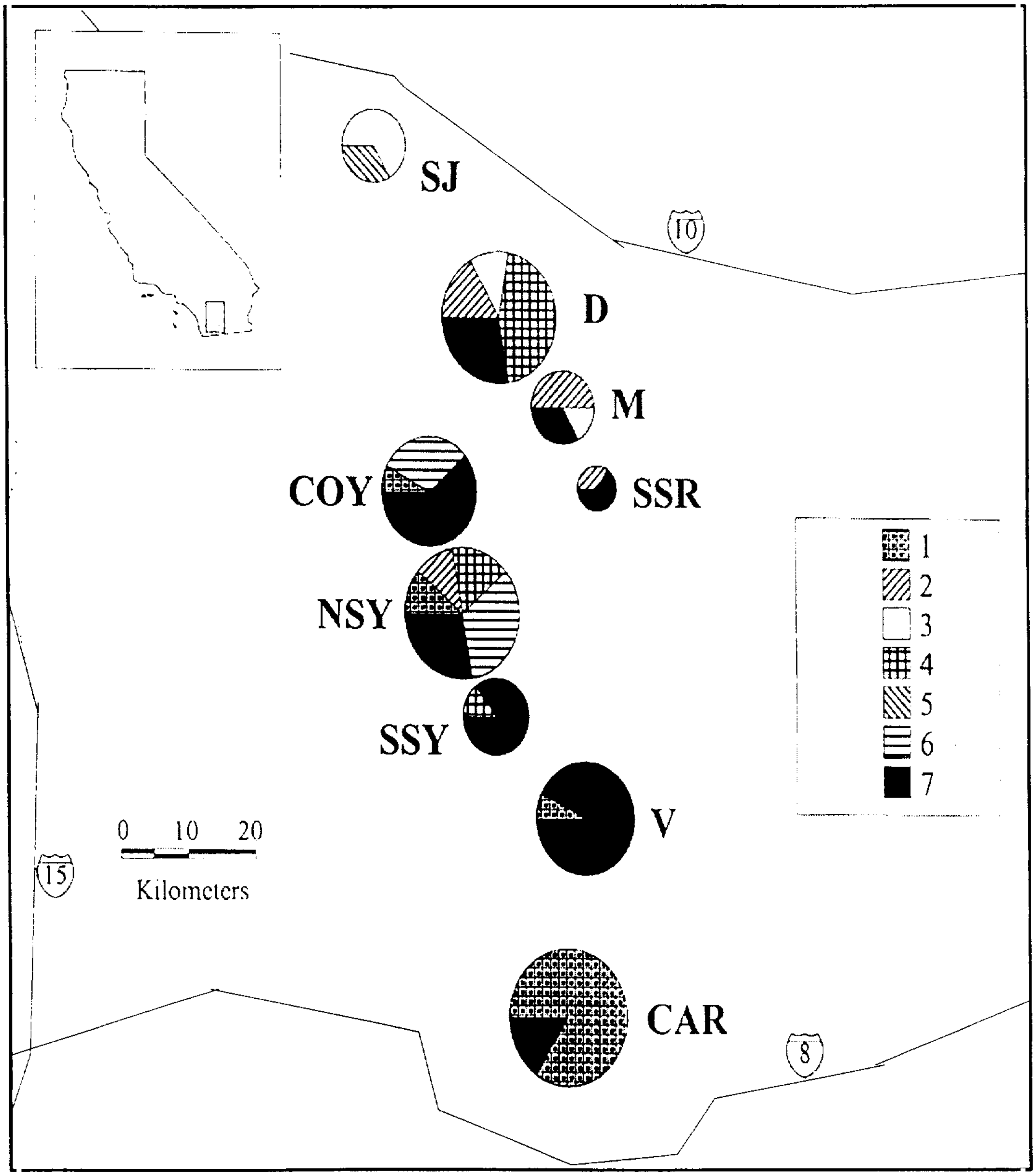


Figure 1. Distribution of seven mitochondrial DNA haplotypes among bighorn sheep ewe home-range groups in the Peninsular Ranges, California (SJ, San Jacinto Mountains, n=6; D, Deep Canyon, n=18; M, Martinez Canyon, n=6; SSR, South Santa Rosa Mountains, n=3; COY, Coyote Canyon, n=13; NSY, North San Ysidro 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

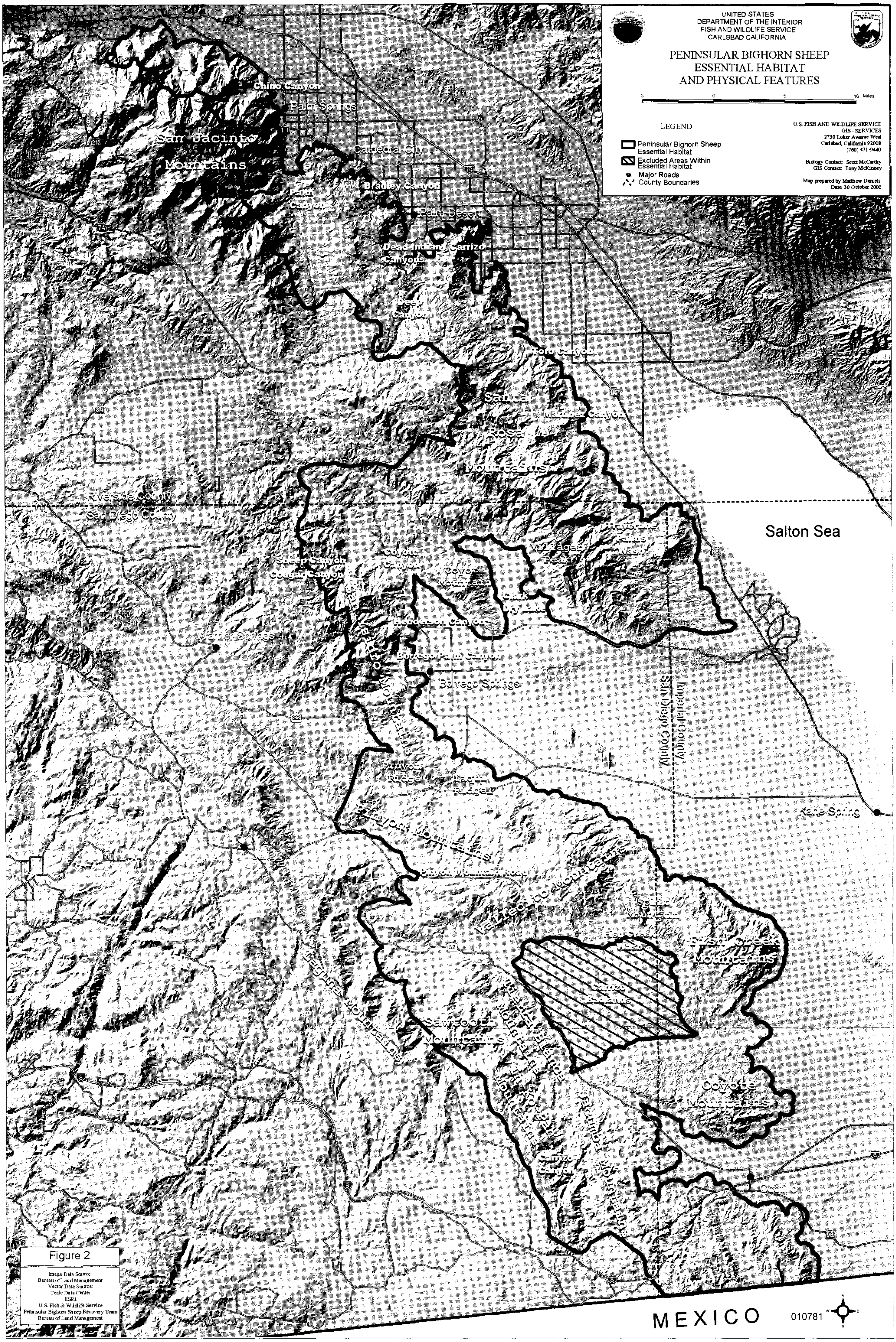

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
PENINSULAR BIGHORN SHEEP
ESSENTIAL HABITAT
AND PHYSICAL FEATURES
5 0 5 10 Miles
LEGEND
Peninsular Bighorn Sheep Essential Habitat
Excluded Areas Within Essential Habitat
Major Roads
County Boundaries
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
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
Chino Canyon
Palm Springs
San Jacinto Mountains
Cathedral City
Palm Canyon
Bradley Canyon
Palm Desert
Dead Indian/ Carrizo Canyons
Deep Canyon
Toro Canyon
Santa Rosa Mountains
Martinez Canyon
Riverside County
San Diego County
Salton Sea
Sheep Canyon
Cougar Canyon
Coyote Canyon
Coyote Mountain
Clark Dry Lake
Henderson Canyon
Borrego Palm Canyon
Borrego Springs
Imperial County
San Diego County
Pinyon Ridge
Pinyon Mountains
Kane Spring
Sawtooth Mountains
Fish Creek Mountains
Coyote Mountains
Carrizo Canyon
MEXICO
010781
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

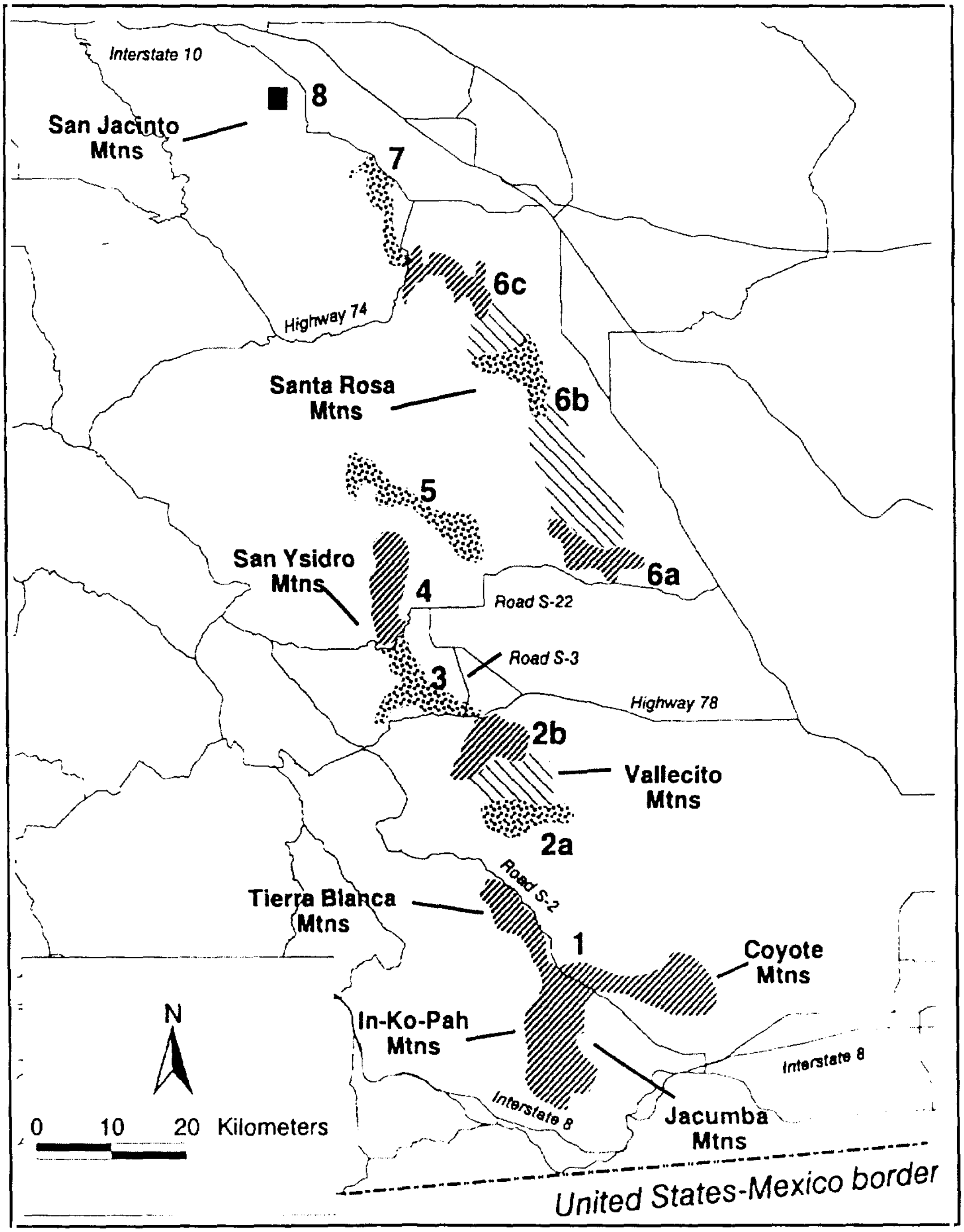


Figure 3. Distribution of bighorn ewes in the Peninsular Ranges, California, 1992-1995. Stippled and shaded areas indicate regions used by home-range groups of ewes identified in this study. 1-Carrizo Canyon, 2a-south Vallecito Mountains, 2b-north Vallecito Mountains, 3-south San Ysidro Mountains, 4-north 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.

010805

010261

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.

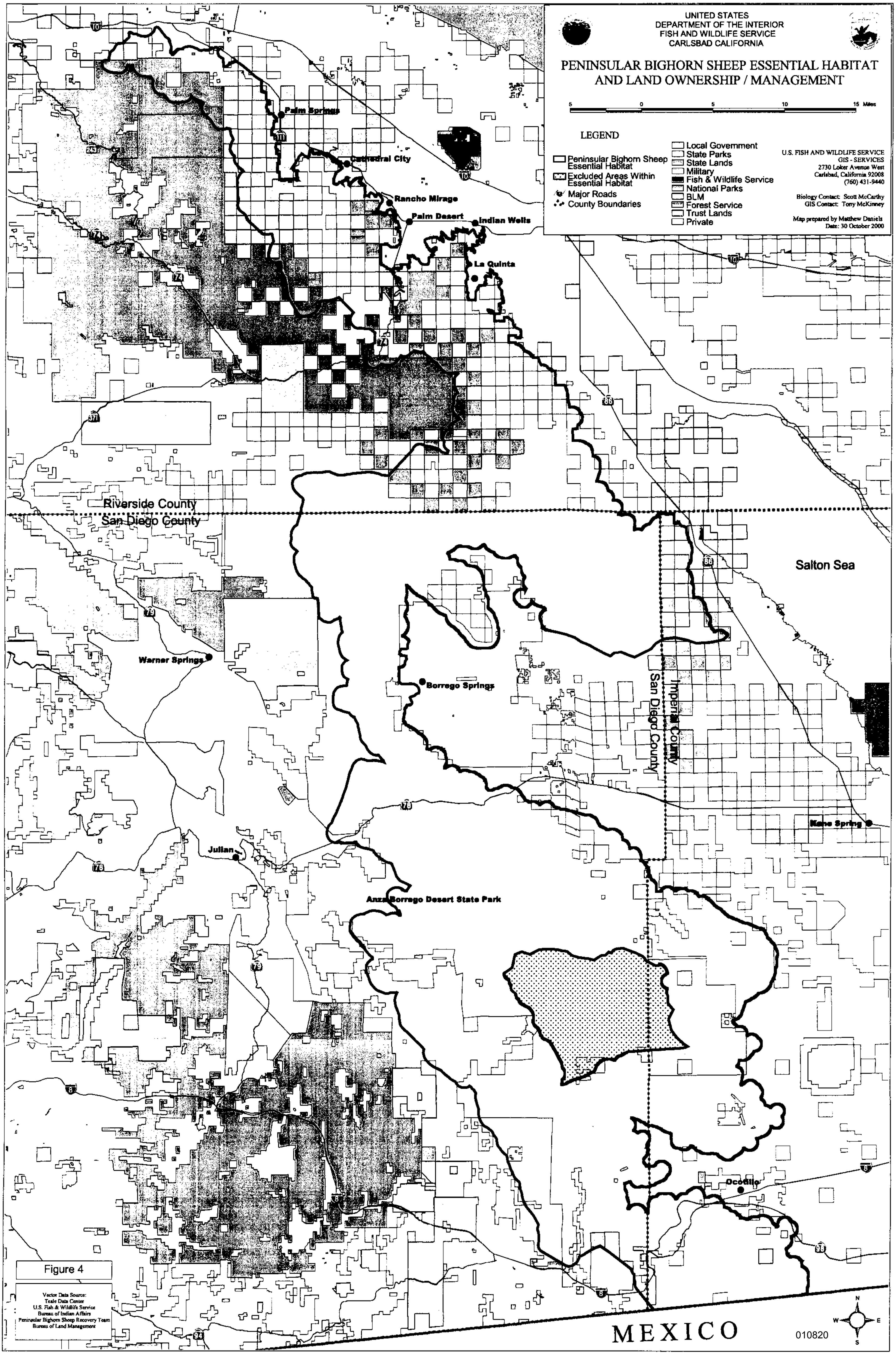
On October 25, 2000, legislation was signed to create the Santa Rosa and San Jacinto Mountains National Monument. The monument covers 110,000 hectares (272,000 acres), including lands administered by the Bureau of Land Management, U.S. Forest Service, California Department of Fish and Game, California 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
010820
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

010822

010278

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

010827

010283

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