

focus future research efforts. Smaller, focused models have great potential in guiding conservation decisions (Starfield and Bleloch 1991, Starfield 1997). Use of modeling can help to elucidate several issues related to the recovery of Peninsular bighorn sheep (refer to section II.D.2.2). Models should be designed to ask specific questions (Starfield 1997) that increase our understanding of the ecological processes in the Peninsular Ranges, and should be coupled with field studies of the bighorn sheep (Beissinger and Westphal 1998). It may be useful to simulate shorter time periods, as well as the 100 to 200 year intervals typically used in population viability analyses, so that model predictions (as well as model assumptions) can be evaluated with the use of field study results (Beissinger and Westphal 1998). This type of approach will allow conservation biologists to learn from the models and field studies, and will allow conservation efforts to be adaptive (Minta and Kareiva 1994).

B. OBJECTIVES AND CRITERIA

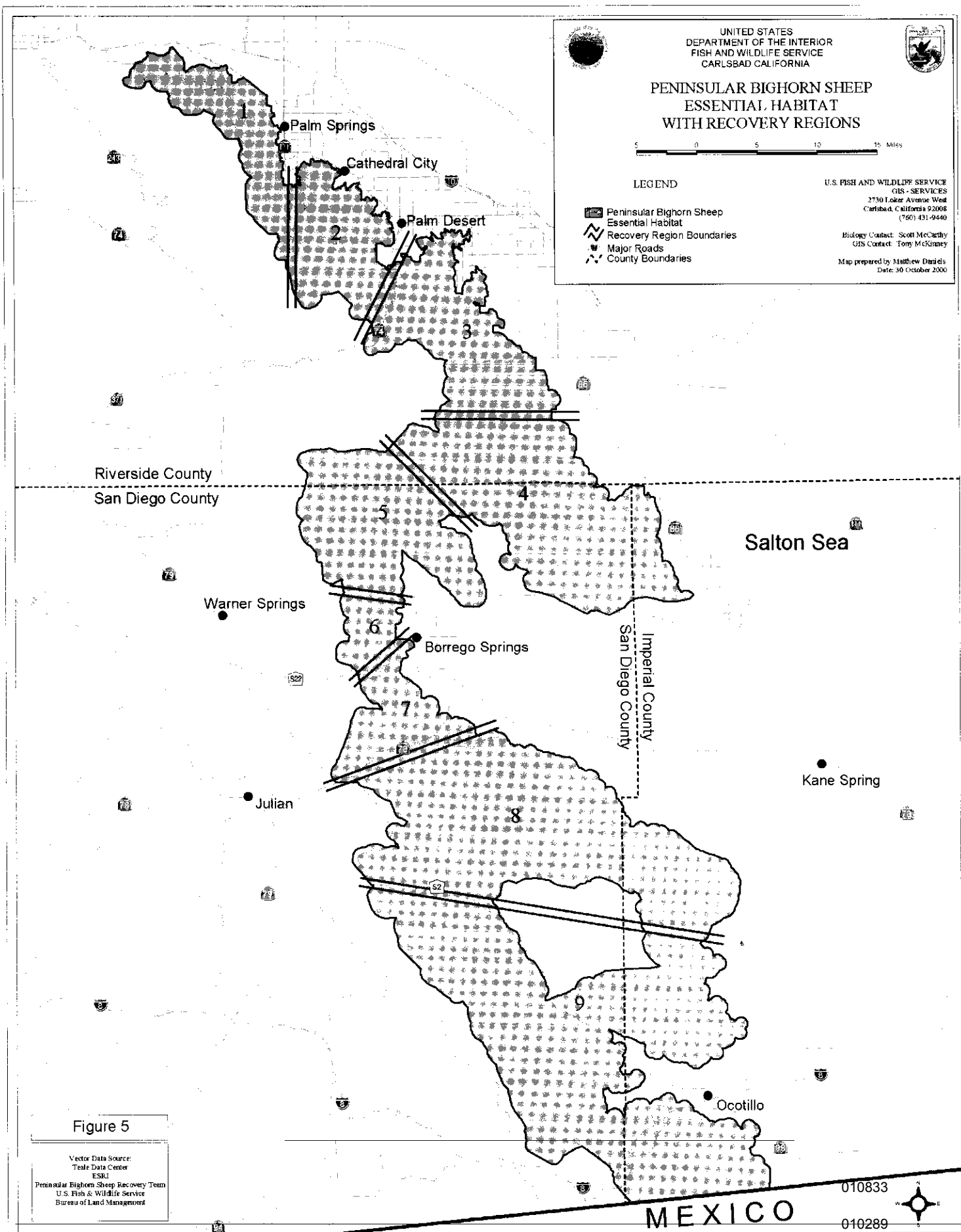
1. RECOVERY OBJECTIVE

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

2. DOWNLISTING CRITERIA

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

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



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

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

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

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

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

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

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

3. DELISTING CRITERIA

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

Delisting Criterion 1: As determined by a scientifically credible monitoring plan, at least 25 ewes must be present in each of the 9 regions (Figure 5) listed under Downlisting Criterion #1 above, during each of 12 consecutive years (approximately 2 bighorn sheep generations), including

010835

the 6 years under Downlisting Criterion #1, without continued population augmentation.

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

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

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

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

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

C. RECOVERY STRATEGY

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

1. Bighorn sheep are wide-ranging animals that are spatially dependent on large tracts of habitat that provide a diversity of resources needed to offset seasonal, annual, and longer term cycles of environmental variability and scarcity;
2. Metapopulation structure requires habitat contiguity between/among constituent demes (ewe groups) to allow for long-term shifts in distribution and genetic interchange;

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

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

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

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

The success of this recovery plan will also depend on strong education and public awareness programs. A number of recovery actions outlined in this plan will directly affect the general public. Therefore, the general public needs information and outreach on proposed actions being taken, especially in localized areas of action. Programs that include comprehensive and accurate facts about the ecology

010838

010294

of Peninsular bighorn sheep and the threats that face them, will be crucial to obtaining public support for conservation measures.

D. NARRATIVE OUTLINE FOR RECOVERY ACTIONS ADDRESSING THREATS

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

1. PROMOTE POPULATION INCREASE AND PROTECT HABITAT

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

1.1.1 Protect essential habitat. Essential habitat is that habitat believed necessary for recovery and should, therefore, be protected from further loss or degradation (Figures 2, 4-9). It is likely that the valley floor to the east and the north of the Peninsular Ranges (e.g., Coachella Valley, Imperial Valley) historically was used by bighorn sheep, for example during long-distance moves to and from other mountain ranges. Exposure to the hazards of high density urban development, major freeways, fences, agriculture, and canals, now would be considered detrimental to bighorn sheep

recovery. Therefore, the vast majority of the valley floor to the east of the Peninsular Ranges is not considered essential habitat.

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

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

- a. Habitat may be colonized and inhabited by future ewe groups (Bleich *et al.* 1996), if, for instance, population spatial structure or environmental conditions change, or the population grows as a result of recovery actions. The long-term persistence of a metapopulation depends on the number of habitat patches that are available for colonization (Hanski 1989). An important phenomenon, which is not intuitively obvious, is that destruction of only a fraction of available habitat can drive a metapopulation to extinction by disrupting the balance between colonization and extinction rates (May 1991). Even locally abundant species can sometimes be very close to extinction if the proportion of suitable habitat is near the extinction threshold (Lande 1987).
- b. Movement throughout the range is needed to sustain the metapopulation (Bleich *et al.* 1990a).

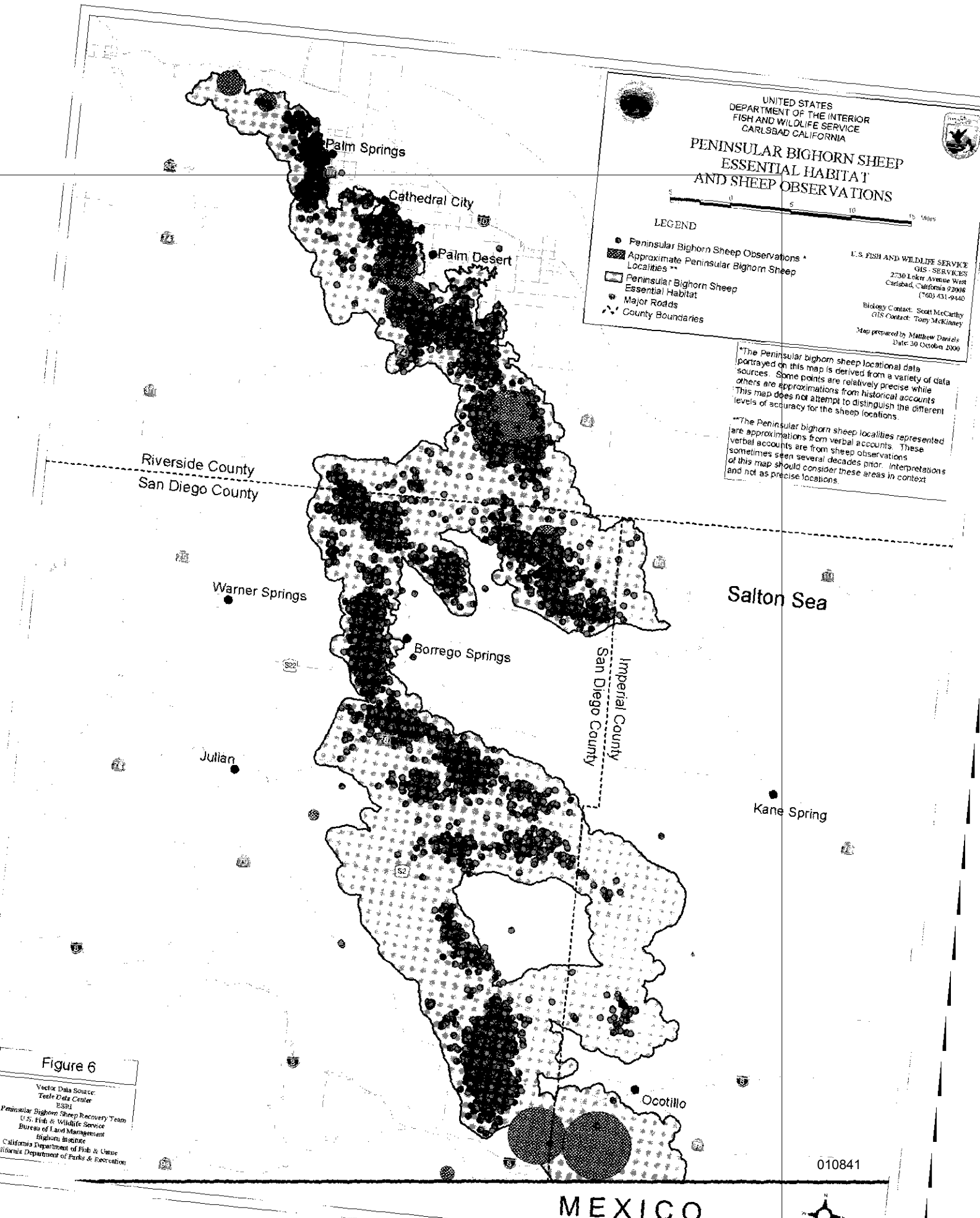


Figure 6

Vector Data Source:
Teale Data Center
ESRI
Peninsular Bighorn Sheep Recovery Team
U.S. Fish & Wildlife Service
Bureau of Land Management
Bighorn Biologist
California Department of Fish & Game
California Department of Parks & Recreation

010841

MEXICO



UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA



PALM SPRINGS - CATHEDRAL CITY INTERFACE WITH PENINSULAR BIGHORN SHEEP ESSENTIAL HABITAT

LEGEND

-  Peninsular Bighorn Sheep
Essential Habitat
-  Historic Habitat
Lost to Development

U.S. FISH AND WILDLIFE SERVICE
GIS SERVICES
2730 Loker Avenue West
Carlsbad, California 92008
(760) 431-9440

Biology Contact: Scott McCarthy
GIS Contact: Tony McConney

Map prepared by Matthew Daniels
Date: 30 October 2005

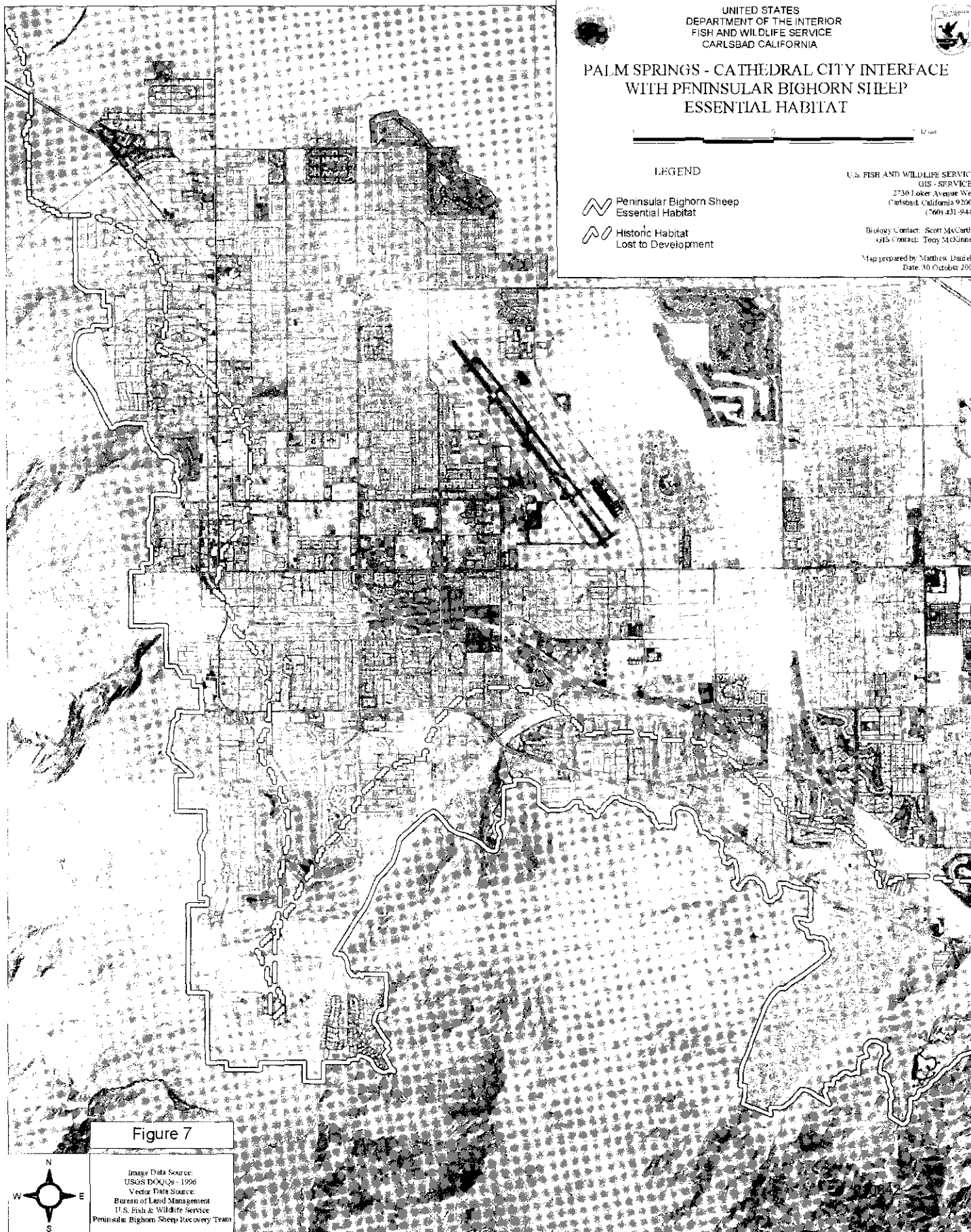


Figure 7

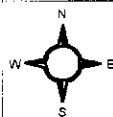
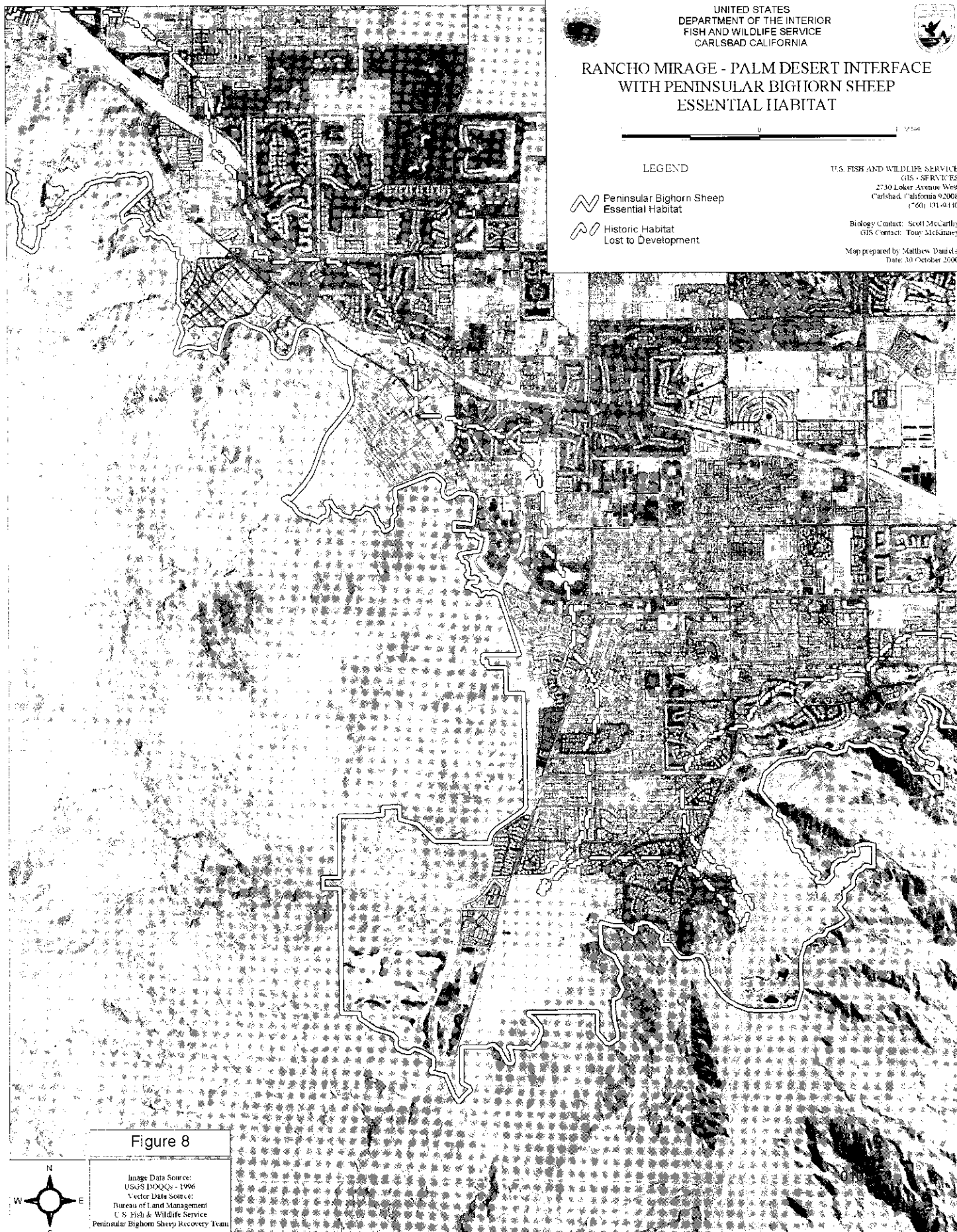
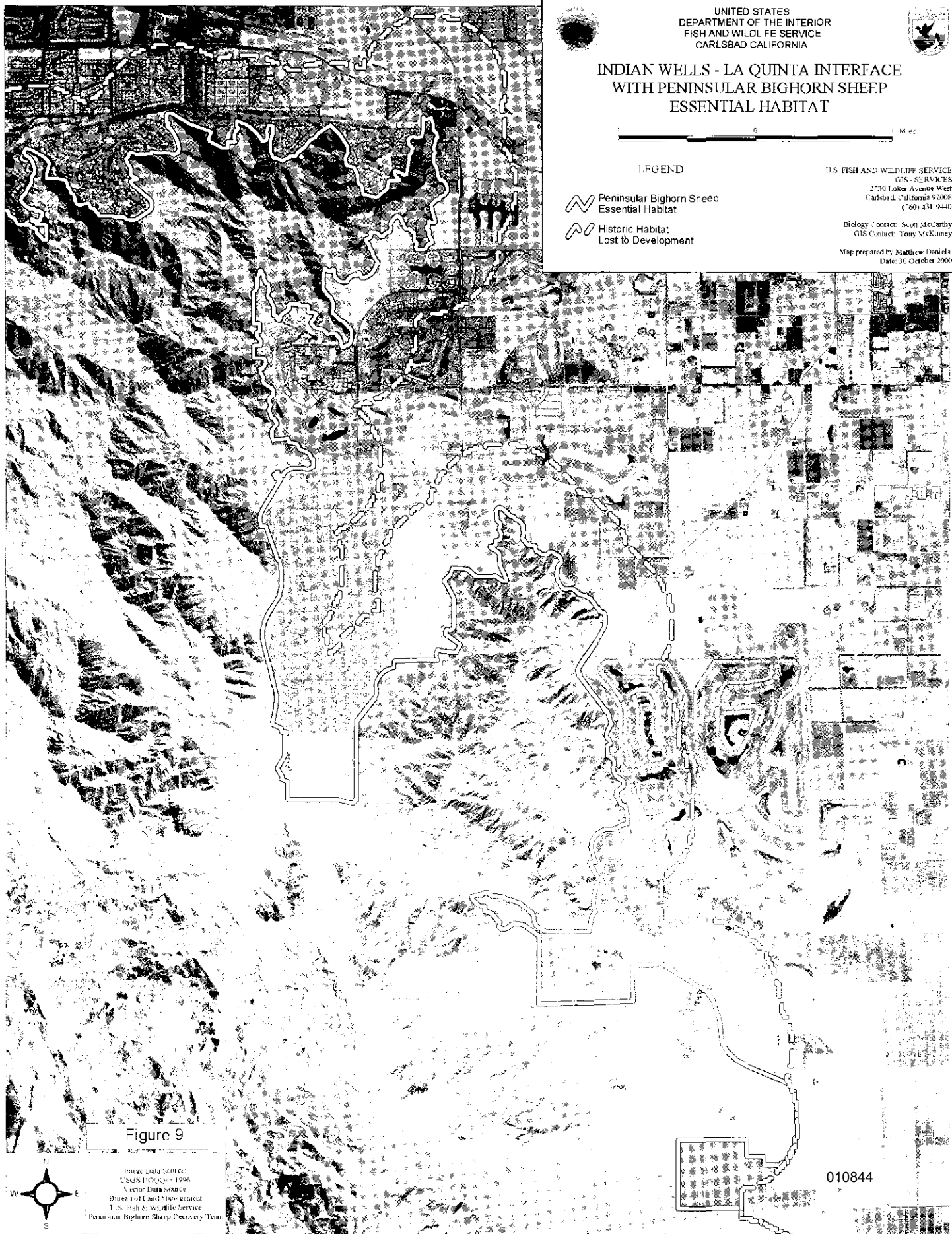


Image Data Source:
USGS DOQs - 1996
Vector Data Source:
Bureau of Land Management
U.S. Fish & Wildlife Service
Peninsular Bighorn Sheep Recovery Team





- c. The factors limiting the viability of Peninsular bighorn sheep are not yet fully understood and, in general, bighorn sheep habitat use and selection need to be more thoroughly examined (McCarty and Bailey 1994). It is therefore necessary to protect all remaining suitable habitat.
- d. The habitat of Peninsular bighorn sheep is restricted to a narrow band along the base of the Peninsular Ranges, from the San Jacinto Mountains south to Mexico. In some areas, this band is less than 6 kilometers (4 miles) wide, so essentially no true "core" habitat exists. Without protection, connectivity could be severed at any point along this narrow band of habitat.
- e. Habitat near the eastern edge of this band often coincides with alluvial fans and canyon washes, which provide Peninsular bighorn sheep with important resources (refer to section I.B.1).
- f. Unpredictable changes in global climate warrant retention of future options in habitat conservation strategies.

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

1.1.2. *Secure habitat.* Bighorn sheep habitat that is currently in private ownership should be secured (*e.g.*, purchased or acquired by exchange on a voluntary basis) by State or Federal agencies and

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

- a. At the level of individual ewe groups: how important is this land in supporting a ewe group in this area?
- b. Does this land include particularly important resources (*e.g.*, water sources, escape terrain, habitat for lambing, or important forage resources) for the bighorn sheep?
- c. Does this land represent important habitat for movement and dispersal necessary for connectivity among ewe groups throughout the Peninsular Ranges?
- d. Has this ewe group already experienced habitat loss?
- e. Would acquisition of this land reduce the cumulative negative effects of urban growth?
- f. Is the habitat imminently threatened?

A list of prioritized parcels should be prepared and updated annually by land management agencies (Bureau of Land Management, U.S. Forest Service, California Department of Fish and Game, Anza-Borrego Desert State Park, Coachella Valley Mountains Conservancy) to facilitate acquisition when

opportunities arise. Methods to facilitate public and private cooperation should be pursued, such as: (1) development of land use planning guidelines (e.g. the Coachella Valley Multiple Species Habitat Conservation Plan, conservation guidelines in Appendix F), (2) development of a public education and outreach program (refer to II.D.3), and (3) development of supporting maps that better identify and explain bighorn sheep ecology and conservation requirements.

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

1.1.3.1 *Remove exotic vegetation and prevent further invasion by exotic plants.* This item refers primarily to control of tamarisk (*Tamarix* species) along stream courses but also applies to other species such as fountain grass (*Pennisetum setaceum*) in select regions. Additional funding should be secured to continue and expand current tamarisk removal programs throughout the Peninsular Ranges. These programs should include, or be coordinated with, efforts to eradicate tamarisk outside of bighorn sheep

habitat, as this will reduce future invasion into bighorn sheep habitat. Tamarisk eradication, such as at Thousand Palms Oasis, can result in immediate reappearance of surface water (Barrows 1994), which can help expand sheep distribution.

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

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

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

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

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

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

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

1.2.1.1 *Construct fences to exclude bighorn sheep from urban areas where they have begun or may begin using urban sources of food and water.* Fences serve several functions including: (1) separating bighorn sheep from potential threats of urbanization (*e.g.*, toxic plants, parasites, accidents, vector-borne diseases, traffic, herbicides, pesticides, behavioral habituation), (2) controlling human and pet access to remaining bighorn sheep habitat, (3) preventing bighorn sheep from becoming habituated to and dependent upon artificial sources of food and water, and (4) modifying habituated behaviors and redirection into remaining native habitat. In the northern Santa Rosa Mountains, ongoing coordination with cities and landowners on a regional fencing strategy will be critical to the long-term health and maintenance of this ewe group. Retrofitting existing developments with fences where sheep currently exploit urban food and water sources

is particularly important; cooperation by residential landowners will be critical to the success of excluding the northern Santa Rosa Mountains ewe group from urban habitats. Along the remainder of the urban interface, where sheep have not yet shown indications of habituation to human habitats, future behavioral habituation also may occur. Although fencing may be viewed as a last resort to other potential forms of aversive conditioning, prudent planning dictates that mitigation be required to offset the likelihood of future adverse effects (behavioral habituation and increased mortality rates) when new projects are approved along the urban interface. Though actual fence construction could be contingent upon future use by sheep and the ineffectiveness of other potential deterrents, the wherewithal, responsibilities, and easements for fences should be determined and secured at the time of project approval. Fences should be 2.4 meters (8 feet) high, or functionally equivalent, and should not contain gaps in which bighorn sheep can be entangled. Gaps should be 11 centimeters (4.3 inches) or less. This fence design should only be used at the urban interface. Refer to section II.D.1.2.2 for guidelines for livestock fences within bighorn sheep habitat.

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

1.2.1.3 Promote the use of native vegetation and limit the planting of exotic species (including grass) in areas accessible to bighorn sheep. A list of locally native plants

should be provided to developers, landscapers, and homeowners. On Bureau of Land Management lands, especially livestock grazing allotments in and near bighorn sheep habitat, utilize only native vegetation in fire rehabilitation and range improvement projects.

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

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

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

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

1.2.1.8 *Regulate the diversion or procurement of water, whether for human use or irrigation, and whether from springs or aquifers, that would reduce natural water sources used by bighorn sheep.* Coordination with land

owners and the State Water Resources Control Board is needed to redress potential water rights conflicts. The Regional Water Quality Control Board's Basin Plan should recognize bighorn sheep as a beneficial use for perennial and seasonal waters within essential habitat.

1.2.1.9 Prohibit the construction of water bodies in developed areas adjoining sheep habitat that may promote the breeding of midges (Culicoides sp.) and monitor/control vectors in existing problematic ponds.

Water features should be designed to eliminate blue-tongue and other vector-borne diseases by providing deeper water (over 0.9 meters [3 feet]), steeper slopes (greater than 30 degrees), and if possible, rapidly fluctuating water levels (see Mullens 1989, Mullens and Rodriguez 1990).

Landowners and managers should coordinate with local mosquito and vector control districts to ensure management of existing water bodies that harbor vector species.

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

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

1.2.2 Reduce or eliminate detrimental human activities within bighorn sheep habitat. A variety of human activities can affect bighorn sheep (refer to section I.D). Bighorn sheep may react in two ways (Papouchis *et al.* 1999): (1) avoidance of disturbance or human encounters (potentially including habitat abandonment), and (2) habituation to sources of disturbance if they are sufficiently predictable. Behavioral habituation can include adjustments to

timing of use in certain areas, such as by avoiding the area until the disturbance is gone (Hamilton *et al.* 1982) or fleeing the disturbance and returning when the disturbance is absent. Expansive urban development in and around bighorn sheep in desert habitats has occurred in three metropolitan areas to date--Albuquerque, Tucson, and Coachella Valley--and in all instances, habitat abandonment and population decline has resulted (Gionfriddo and Krausman 1986; Krausman, *in litt.* 1998; Krausman *et al.* In prep.). Bighorn sheep have demonstrated greater resilience to human disturbance in more remote locales such as Alberta (MacArthur *et al.* 1982) and the Sierra Nevada (Hicks and Elder 1979), though bighorn also are known to avoid excessive human disturbance in areas well away from urban centers (Papouchis *et al.* 1999).

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

disturbance typically occurs at elevations lower than where sheep spend most of their time (Hicks 1977).

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

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

coordinate its efforts with other agencies when a draft plan is complete.

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

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

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

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

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

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

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

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

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

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

relocations. Permanent closures may be necessary where relocation is not possible and seasonal restrictions cannot be effectively monitored or enforced. Trails should be used as a tool to focus human activity away from areas of concern. New trails in bighorn habitat should be avoided,

except in select areas along the urban edge, where they could provide two benefits—alleviate pressure on trails that intrude deeper into sheep habitat, and provide a disturbance barrier to discourage potential sheep attraction to urban sources of food and water. Any new trails should minimize adverse impacts to alluvial fans, canyon bottoms, and other areas that may provide essential seasonal forage conditions while still accomplishing the objective of routing use away from the more sensitive areas.

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

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

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

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

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

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

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

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

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

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

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

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

Removal of mountain lions should be selective and only target individual lions known to be, or suspected of, preying on bighorn sheep. Predator management should not be implemented as a mitigation measure for habitat loss because it is a temporary

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

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

Predator Removal Level 2. Predator removal may also be implemented if there are greater than 25 ewes in each of the 9 recovery regions, to further facilitate the long-term goals of population recovery. Lion removal should only occur if lion predation is the primary cause of mortality and low survivorship is determined to be limiting population recovery. Careful monitoring, habitat evaluation, and possibly computer simulations should be used to determine if, when, and where predator removal should occur. Predator removal should be discontinued if available

evidence indicates that: (1) lion predation no longer limits bighorn sheep population growth, and (2) continued removal would no longer result in a population expansion within the recovery region necessary for the overall recovery of the metapopulation.

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

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

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

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

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

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

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

This section focuses on research topics with management applicability needed for recovery. The approach is to design management actions so that: (1) results can be measured, (2) efficacy can be evaluated as testable hypotheses, and (3) alternative or refined actions can be formulated and tested again (adaptive

management, as defined by Holling 1978). However, adoption of this approach for bighorn sheep recovery likely will be more problematic than for most species. Many results will not become apparent for many years because sheep are long-lived and behavior can be slow to change and difficult to document.

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

2.1.1 Monitor abundance. All bighorn sheep habitat in the Peninsular Ranges should be surveyed by helicopter at least every other year to generate population estimates. Initially, this will require that a known number of radio-collared animals are distributed throughout the range so that mark-recapture abundance estimations can be generated. The number of collared animals should be sufficient to achieve an accuracy of plus or minus 25 percent with a probability of 0.05, following the methods described in Krebs (1989) and Robson and Regier (1964), or approximately 30 percent of the estimated ewe population should be radio-collared. However, a “sightability” estimate may be generated after additional surveys are conducted, thereby eliminating the need to maintain this percentage of radio-collared animals. This approach would be especially beneficial if/when population numbers become large. Where ewe group delineations are known, estimates of abundance should be generated for individual ewe groups as well as for the entire range. Annual waterhole counts should be continued in Anza-Borrego Desert State Park and

perhaps reinitiated in the Santa Rosa and San Jacinto Mountains. Data from waterhole counts can be used to potentially provide important information about population characteristics (*e.g.*, lamb to ewe ratios and/or ram to ewe ratios) and to index abundance. Continuation of waterhole counts concurrent with helicopter surveys (for 5 to 10 years) may reveal a relationship between abundance indices and population estimates. This relationship may allow biologists to use historical waterhole count data (collected over 28 years) to estimate historical abundance patterns. Aerial surveys and waterhole counts should be conducted according to the protocols in Appendix E.

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

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

2.1.3 Monitor recruitment. Reproductive success, which includes lamb production and recruitment, should be monitored on a yearly basis in all ewe groups. Tracking and observing individually marked ewes generates the most useful data because lamb survival

to specific ages can be determined, and the reproductive success of individual ewes can be tracked. Alternatively, the lamb to ewe ratio of each ewe group could be measured at various times of the year (*e.g.*, during waterhole counts or helicopter surveys). Ground surveys should be organized if feasible. If lamb mortality is found to be high in specific ewe groups, the radio-collaring of lambs may be necessary to identify causes of mortality. Recruitment should be compared among ewe groups, years, and management strategies.

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

2.2 Develop population models. Although a substantial amount of knowledge exists regarding bighorn sheep in the Peninsular Ranges and elsewhere, there is a need for further research regarding their ecology and the factors that influence population viability. Incorporating existing knowledge into models may provide insight into the ecology of Peninsular bighorn sheep and the system to which they belong. Rather than using the absolute results of models to make policy or management decisions, however, the relative outcomes of alternative models should be used to guide management decisions (Beissinger and Westphal 1998) and future research efforts. Models uncover knowledge gaps and thereby guide future research and generate hypotheses that would not otherwise be addressed. The recovery of Peninsular bighorn sheep will benefit from

answers to a number of questions. These questions include, but are not limited to: (1) how do the number of ewe groups, size of groups, and level of connectivity among groups affect persistence probabilities of the metapopulation, and (2) what are the relative long-term effects of various levels of adult and juvenile mortality on population viability?

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

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

- a. Estimate the number of mountain lions preying on bighorn sheep.
- b. Examine movement patterns of mountain lions within and adjacent to bighorn sheep habitat, and attempt to identify influencing factors.
- c. Examine the spatial and temporal patterns of mountain lion predation on bighorn sheep and mule deer in relation to the distribution of both prey species, season, climate patterns, and habitat characteristics.

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

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

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

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

2.6 Research habitat use/selection and dispersal behavior. Habitat use by sheep has been studied by a number of researchers (refer to section I.B.1), but many questions remain. In the Peninsular Ranges, as in many other

bighorn sheep habitats, the specific factors that limit populations are not well understood. A better understanding of habitat use patterns and factors underlying habitat selection will aid our understanding of resource requirements and promote informed management decisions. Selected topics for future research include: (1) water and nutritional requirements and how these factors affect population characteristics and distribution, (2) how and where habitat use and movement are influenced by disturbance barriers and sources of fragmentation, (3) habitat use and how it relates to predator evasion, (4) how habitat quality influences dispersal behavior, and (5) how human disturbance affects habitat use patterns.

Documentation of habitat use for essential life functions, such as lambing, rutting, summer water stress, and dispersal, is needed. A detailed vegetation map with sources of fragmentation for the entire Peninsular Ranges would facilitate analyses of these variables on habitat use patterns.

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

2.7 Evaluate the effect of human activities on bighorn sheep. Given the history of bighorn sheep population declines and extirpations in other areas near urban centers, information is needed on how to manage

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

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

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

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

2.9 Research genetics of bighorn sheep in the Peninsular Ranges.

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

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

3. DEVELOP AND IMPLEMENT EDUCATION AND PUBLIC AWARENESS PROGRAMS.

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

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

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

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

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

held to facilitate the exchange of information and ideas for improving and updating education programs.

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

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

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

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

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

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

E. SITE SPECIFIC RECOVERY TASKS.

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

Table 11. Recovery criteria regions.

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

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

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

Table 12. Continued.

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

SJ: San Jacinto Mountains

SR-N74: Santa Rosa Mountains - north of Highway 74

SR-S74: Santa Rosa Mountains - south of Highway 74

SR-MCS: Santa Rosa Mountains--South of Martinez Canyon

CC: Coyote Canyon--east and west side

SY-N: North San Ysidro Mountains

SY-S: South San Ysidro Mountains

VM/FC: Vallecito/Fish Creek Mountains

CC/TB/CM : Carrizo Canyon/Tierra Blanca
Mountains/Coyote Mountains

III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated costs for the Peninsular bighorn sheep recovery program, as set forth in this recovery plan. It is a *guide* for meeting the objectives discussed in part II of this plan. This schedule indicates task priority, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. The agencies responsible for committing funds are not necessarily the entities that will carry out the tasks. The agency or agencies with lead responsibility for each task are indicated in the table. Initiation of these actions is subject to the availability of funds.

The Implementation Schedule indicates speculative, future costs (preparation of additional plans, or research programs, etc.) as “to be determined”. Some costs appear as zero because indirect costs, such as those incurred by: (1) contributions of time and materials by agencies and other groups, and (2) administrative or regulatory costs by public agencies, are not included in cost totals. Costs of continuous tasks are estimated assuming a 25-year time to recovery. Though the Implementation Schedule does not distinguish between public and private costs, no identifiable or specific expenditures are likely to be needed by the private sector, other than voluntary efforts contributed by nonprofit organizations and citizen groups. Priorities (Column 1 of the following table) are assigned as follows:

- Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.
- Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.
- Priority 3 - All other actions necessary to provide for full recovery of the species.

Abbreviations used in the Implementation Schedule:

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

AGENCIES AND ORGANIZATIONS

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

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR PENINSULAR BIGHORN SHEEP

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

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR PENINSULAR BIGHORN SHEEP

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Agencies	Total Estimated Cost (\$1,000's)	Cost (\$1,000's)				
						FY 01	FY 02	FY 03	FY 04	FY 05
1	1.2.1.1	Secure funding to implement measures	cont.	MSHCP*	0	0	0	0	0	0
1	1.2.2.1	Develop and implement a trails management program	cont.	BLM*, CDFG, USFS, FWS, MSHCP	TBD	TBD	TBD	TBD	TBD	TBD
1	1.2.2.2	Prohibit fragmenting and interfering activities	cont.	BLM*, USFS*, FWS*, DoD*, CDFG*, CDPR* Counties*, Cities*	TBD	TBD	TBD	TBD	TBD	TBD
1	1.2.2.3	Minimize livestock grazing impacts	5	BLM*, USFS*	25	5	5	5	5	5
1	1.2.2.4	Prohibit grazing by domestic sheep	5	BLM*, USFS*	0	0	0	0	0	0
1	1.2.2.7	Secure funding to implement measures	cont.	BLM*, USFS*, FWS*, CDFG*, MSHCP*	0	0	0	0	0	0
1	1.3.2	Reduce mortality due to natural causes	cont.	CDFG*, CDPR, FWS, BLM	TBD	TBD	TBD	TBD	TBD	TBD
1	2.1.1	Monitor abundance	cont.	CDFG*, CDPR, BLM, FWS, BI	323	11	15	11	15	11
1	2.1.2	Monitor distribution	cont.	CDFG*, CDPR, BLM, FWS, BI	323	11	15	11	15	11
1	2.1.3	Monitor recruitment	cont.	CDFG*, CDPR, BLM, FWS, BI	323	11	15	11	15	11
1	2.1.4	Monitor survivorship and cause-specific mortality	cont.	CDFG*, CDPR, BLM, FWS, BI	125	5	5	5	5	5
2	1.1.3.3	Implement fire management plan	5	USFS*, BLM, CDFG, CDPR	TBD	TBD	TBD	TBD	TBD	TBD
2	1.2.1.2	Avoid non-native vegetation	cont.	MSHCP*	0	0	0	0	0	0

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR PENINSULAR BIGHORN SHEEP

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

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

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

IV. LITERATURE CITED

A. References

- Akçakaya, H. R. and M. Burgman. 1995. PVA in theory and practice. *Conservation Biology* 9(4):705-707.
- Anderson, A. E. 1983. A critical review of literature on puma (*Felis concolor*). Special Report Number 54. Colorado Division of Wildlife, Wildlife Research Section. 92pp.
- Anderson, R. M. and R. M. May. 1979. Population biology of infectious diseases: part I. *Nature* 280(2):361-367.
- Andrew, N. G. 1994. Demography and habitat use of desert-dwelling mountain sheep in the east Chocolate Mountains, Imperial County, California. MS thesis. University of Rhode Island. 135pp.
- Andrew, N. G., L. M. Lesicka, and V. C. Bleich. 1997. An improved fence design to protect water sources for native ungulates. *Wildlife Society Bulletin* 25(4):823-825.
- Barrows, C. 1994. Tamarisk: a success story. *Fremontia* 22(3):20-22.
- Bates, J. W., Jr. and G. W. Workman. 1983. Desert bighorn sheep habitat utilization in Canyonlands National Park. *Desert Bighorn Council Transactions* 27:25-28.
- Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. *Conservation Biology* 7(1):94-108.
- Beissinger, S. R. and M. I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. *Journal of Wildlife Management* 62(3):821-841.

- Berbach, M. W. 1987. The behavior, nutrition, and ecology of a population of reintroduced desert mountain sheep in the Whipple Mountains, San Bernardino County, California. M.S. Thesis, Calif, State Polytechnic University, Pomona, 135pp.
- Berger, J. 1978. Group size, foraging, and antipredator ploys: an analysis of bighorn sheep decisions. Behavioral Ecology and Sociobiology 4:91-99.
- Bighorn Institute. 1983. Helicopter Survey Data; Oct. 27-28, 1983. Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1984a. Helicopter Survey Data; Oct. 29-30, 1984. Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1984b. Helicopter Survey Data; May 14-15, 1984. Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1985a. Helicopter Survey Data; Oct. 21-22, 1984. Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1985b. Progress report Santa Rosa Mountain bighorn study; Oct. 31, 1985. Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1990. Summary of 1990 accomplishments, as per points of memorandum of understanding (Calif. Dept. Fish and Game). Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1991. Summary of 1991 accomplishments, as per points of memorandum of understanding (Calif. Dept. Fish and Game). Bighorn Institute, Palm Desert, Calif.
- Bighorn Institute. 1995. Bighorn Institute Year-end Report. Report to the California Department of Fish and Game, Sacramento.

- Bighorn Institute. 1996. Bighorn Institute Year-end Report. Report to the California Department of Fish and Game, Sacramento.
- Bighorn Institute. 1997. Bighorn Institute Year-end Report. Report to the California Department of Fish and Game, Sacramento.
- Bighorn Institute. 1998. Bighorn Institute Year-end Report. Report to the California Department of Fish and Game, Sacramento.
- Bighorn Institute. 1999. Bighorn Institute Year-end Report. Report to the California Department of Fish and Game, Sacramento.
- Bleich, V. C., J. D. Wehausen, and S. A. Holl. 1990a. Desert-dwelling mountain sheep: conservation implications of a naturally fragmented distribution. *Conservation Biology* 4(4):383-390.
- Bleich, V. C., J. D. Wehausen, K. R. Jones, and R. A. Weaver. 1990b. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. *Desert Bighorn Council Transactions* 34:24-26.
- Bleich, V. C., R. T. Bowyer, A. M. Pauli, M. C. Nicholson, and R. W. Anthes. 1994. Mountain sheep *Ovis canadensis* and helicopter surveys: ramifications for conservation of large mammals. *Biological Conservation* 70:1-7.
- Bleich, V. C., J. D. Wehausen, R. R. Ramey II, and J. L. Rechel. 1996. Metapopulation theory and mountain sheep: implications for conservation. Pages 353-373 in *Metapopulations and Wildlife Conservation*. D. R. McCullough, ed. Island Press, Washington, D.C. 429pp.
- Bleich, V. C., R. T. Bowyer, and J. D. Wehausen. 1997. Sexual segregation in mountain sheep: resources or predation? *Wildlife Monographs*. No. 134. The Wildlife Society. 50pp.

- Blong, B. 1967. Desert bighorn and people in the Santa Rosa Mountains. The Wildlife Society Transactions. California-Nevada Section. Pages 66-70.
- Blong, B. and W. Pollard. 1968. Summer water requirements of desert bighorn in the Santa Rosa Mtns., Calif., in 1965. California Fish and Game 54:289-296.
- Bolton, H. E. 1930. Anza's California expeditions. Vol. IV. Font's complete diary of the second Anza expedition. University of California Press, Berkeley. 552pp.
- Borjesson, D. L., W. M. Boyce, I. A. Gardner, J. DeForge, and B. Lasley. 1996. Pregnancy detection in bighorn sheep (*Ovis canadensis*) using a fecal-based enzyme immunoassay. Journal of Wildlife Diseases 32(1):67-74.
- Boyce, M. S. 1992. Population viability analysis. Annu. Rev. Ecol. Syst. 23:481-506.
- Boyce, W. M. 1995. Peninsular bighorn sheep population health and demography study. Final Progress Report. California Department of Fish and Game, Sacramento.
- Boyce, W. M., P. W. Hedrick, N. E. Muggli-Cockett, S. Kalinowski, M. C. T. Penedo, and R. R. Ramey II. 1997. Genetic variation of major histocompatibility complex and microsatellite loci: a comparison in bighorn sheep. Genetics 145:421-433.
- Boyce, W. M., R. R. Ramey II, T. C. Rodwell, E. S. Rubin, and R. S. Singer. 1999. Population subdivision among desert bighorn sheep (*Ovis canadensis*) ewes revealed by mitochondrial DNA analysis. Molecular Ecology 8:99-106.
- Bradley, W. G. and L. R. Baker. 1967. Range of variation in Nelson bighorn sheep from the desert game range and its taxonomic significance. Desert Bighorn Council Transactions 11:114-140.

- Brigandi, P. 1995. The livestock industry on the Anza-Borrego desert. A report for the Anza-Borrego Desert State Park. Contract No. C4532007.
- Brown, J. H. and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. *Ecology* 58:445-449.
- Broyles, B. 1995. Desert wildlife water developments: questioning use in the southwest. *Wildlife Society Bulletin* 23:663-675.
- Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present, and future. *Wildlife Monographs*, No. 4, The Wildlife Society. 174pp.
- Bureau of Land Management. 1980. Santa Rosa Mountains Wildlife Habitat Management Plan: a Sikes Act plan. Prepared by BLM and Calif. Dpt. Fish and Game.
- Bureau of Land Management. 1989. Fences, BLM Manual Handbook H-1741-1. BLM Manual Supplemental Handbook Release 1-1572. BLM, Washington, D.C. 56pp.
- Bureau of Land Management. 1996. Peninsular ranges desert bighorn sheep interagency recovery plan. Bureau of Land Management, California Department of Parks and Recreation, U.S. Forest Service, California Department of Fish and Game. Unpubl. Rept.
- Burgman, M. A., S. Ferson, and H. R. Akçakaya. 1993. Risk assessment in conservation biology. Chapman and Hall, New York. 314pp.
- Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy* 24:346-352.
- California Department of Fish and Game. 1983. A plan for bighorn sheep. CDFG, Sacramento, California.

- California Department of Fish and Game. 1992. Annual report on the status of California State listed threatened and endangered animals and plants. State of California, The Resource Agency, Sacramento.
- Campbell, S. 1980. Is reintroduction a realistic goal? Pages 263-269 in Conservation biology: an evolutionary-ecological perspective. Soule, M. E. and B. A. Wilcox, eds. Sinauer Associates, Inc. Sunderland, Massachusetts. 395pp.
- Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York. 234 pp.
- Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63:215-244.
- Clark, R. K., D. A. Jessup, M. D. Kock, and R. A. Weaver. 1985. Survey of desert bighorn sheep in California for exposure to selected infectious diseases. Journal of the American Veterinary Medicine Association 187:1175-1179.
- Clark, R. K., C. A. Whetstone, A. E. Castro, M. C. Jorgensen, J. F. Jensen, and D. A. Jessup. 1993. Restriction endonuclease analysis of herpesviruses isolated from two Peninsular bighorn sheep (*Ovis canadensis cremnobates*). Journal of Wildlife Diseases 29(1):50-56.
- Cowan, I. McT. 1940. Distribution and variation in the native sheep of North America. American Midland Naturalist 24:505-580.
- Cowan, I. McT. and V. Geist. 1971. The north American wild sheep. Pages 58-63 in R. C. Albers, ed. North American big game. Boone and Crockett Club, Pittsburgh, Pennsylvania.
- Crosbie, P. R., W. L. Goff, D. Stiller, D. A. Jessup, and W. M. Boyce. 1997. The distribution of *Dermacentor hunteri* and *Anaplasma* sp. in desert bighorn sheep (*Ovis canadensis*). Journal of Parasitology 83(1):31-37.

- Crow, J. F. and M. Kimura. 1970. An introduction to population genetics theory. Burgess Publishing Company, Minneapolis, Minnesota. 591pp.
- Cunningham, S. C. 1982. Aspects of the ecology of Peninsular desert bighorn sheep (*Ovis canadensis cremnobates*) in Carrizo Canyon, California. M. S. thesis. Arizona State University, Tempe. 76 pp.
- Cunningham, S. C. 1989. Evaluation of bighorn sheep habitat. Pages 135-160 in R. M. Lee, ed. The desert bighorn sheep in Arizona. Arizona Game and Fish Dept. Phoenix. 129pp.
- Cunningham, S. C. 1993. Bringing bighorn into the classroom. Desert Bighorn Council Transactions 37:33-36.
- Cunningham, S. C. and R. D. Ohmart. 1986. Aspects of the ecology of desert bighorn sheep in Carrizo Canyon, California. Desert Bighorn Council Transactions 30:14-19.
- Cunningham, S. C. and J. C. deVos. 1992. Mortality of mountain sheep in the Black Canyon area of northwest Arizona. Desert Bighorn Council Transactions 36:27-29.
- DeForge, J. R. 1972. Man's invasion into the bighorn's habitat. Desert Bighorn Council 16:112-116.
- DeForge, J. R. 1980. Ecology, behavior and population dynamics of desert bighorn sheep (*Ovis canadensis nelsoni*) in the San Gabriel Mountains of California. Masters Thesis. 133pp.
- DeForge, J. R. and J. E. Scott. 1982. Ecological investigations into high lamb mortality. Desert Bighorn Council Transactions 26:65-76.
- DeForge, J. R., D. A. Jessup, C. W. Jenner, and J. E. Scott. 1982. Disease investigations into high lamb mortality of desert bighorn in the Santa Rosa Mountains, California. Desert Bighorn Council Transactions 26:76-81.

- DeForge, J. R., S. D. Ostermann, D. E. Toweill, P. E. Cyrog, and E. M. Barrett. 1993. Helicopter survey of Peninsular bighorn sheep in northern Baja California. *Desert Bighorn Council Transactions* 37:24-28.
- DeForge, J. R., E. M Barrett, S. D. Ostermann, M. C. Jorgensen, and S. G. Torres. 1995. Population dynamics of Peninsular bighorn sheep in the Santa Rosa Mountains, California, 1983-1994. *Desert Bighorn Council Transactions* 39:50-67.
- DeForge, J. R., S. D. Ostermann, C. W. Willmott, K. B. Brennan, and S. G. Torres. 1997. The ecology of Peninsular bighorn sheep in the San Jacinto Mountains, California. *Desert Bighorn Council Transactions* 41:8-25.
- DeForge, J. R. and S. D. Ostermann. 1998a. Survival and cause-specific mortality of Peninsular bighorn lambs in the northern Santa Rosa Mountains, California. Proposal to the California Department of Fish and Game and U. S. Fish and Wildlife Service, March 1998.
- DeForge, J. R. and S. D. Ostermann. 1998b. The effects of urbanization on a population of desert bighorn sheep. Abstract for the 5th Annual Conference of Wildlife Society, Buffalo, New York.
- Desert Bighorn Council. 1992. Stress and bighorn sheep. Panel discussion from 1991 Desert Bighorn Council Meeting. W. Boyce, moderator. *Desert Bighorn Council*.
- Doak, D. F., P. Kareiva, and B. Klepetka. 1994. Modeling population viability for the desert tortoise in the Mojave Desert. *Ecological Applications* 4:446-460.
- Douglas, C. L. and D. M. Leslie, Jr. 1986. Influence of weather and density on lamb survival of desert mountain sheep. *Journal of Wildlife Management* 50(1):153-156.

- Elenowitz, A. S. 1983. Habitat use and population dynamics of transplanted desert bighorn sheep in the Peloncillo Mountains, New Mexico. M. S. thesis. New Mexico State University, Las Cruces. 158pp.
- Elenowitz, A. S. 1984. Group dynamics and habitat use of transplanted desert bighorn sheep in the Peloncillo Mountains, New Mexico. Desert Bighorn Council Transactions 28:1-7.
- Elliott, L. F. and W. M. Boyce. 1992. Implications of captive breeding programs for the conservation of desert bighorn sheep. Desert Bighorn Council Transactions 36:54-57.
- Elliott, L. F., W. M. Boyce, R. K. Clark, and D. A. Jessup. 1994. Geographic analysis of pathogen exposure in bighorn sheep (*Ovis canadensis*). Journal of Wildlife Diseases 30:315-318.
- Etchberger, R. C., P. R. Krausman, and R. Mazaika. 1989. Mountain sheep habitat characteristics in the Pusch Ridge Wilderness, Arizona. Journal of Wildlife Management 53:902-907.
- Etchberger, R. C., P. R. Krausman, and R. Mazaika. 1990. Effects of fire on desert bighorn sheep habitat. Pages 53-57 in P. R. Krausman and N. S. Smith, eds. Managing wildlife in the southwest: proceedings of the symposium. Arizona Chapter of the Wildlife Society, Phoenix. 262 pp.
- Etchberger, R. C. and P. R. Krausman. 1999. Frequency of birth and lambing sites of a small population of mountain sheep. Southwest. Nat. 44(3):354-360.
- Festa-Bianchet, M. 1988. A pneumonia epizootic in bighorn sheep with comments on preventive management. N. Am. Wild Sheep and Goat Council 6:66-76.
- Festa-Bianchet, M. 1991. The social system of bighorn sheep: grouping patterns, kinship and female dominance rank. Animal Behavior 42:71-82.

- Festa-Bianchet, M., and J. T. Jorgenson. 1996. Selfish mothers: reproductive expenditure and resource availability in bighorn ewes. *Behav. Ecol.* 9:144-150.
- Feuerstein, V. R., L. Schmidt, C. P. Hibler, and W. H. Rutherford. 1980. Bighorn sheep mortality in the Taylor River-Almont Triangle area, 1978-1979: a case study. Special Report Number 48, Colorado Division of Wildlife. Denver, Colorado, 19 pp.
- FitzSimmons, N. N. and S. W. Buskirk. 1992. Effective population sizes for bighorn sheep. *Biennial Symposium of the Northern Wild Sheep and Goat Council* 8:1-7.
- FitzSimmons, N. N., S. W. Buskirk, and M. H. Smith. 1995. Population history, genetic variability, and horn growth in bighorn sheep. *Conservation Biology* 9(2):314-323.
- FitzSimmons, N. N., S. W. Buskirk, and M. H. Smith. 1997. Genetic changes in reintroduced Rocky Mountain bighorn sheep populations. *Journal of Wildlife Management* 61(3):863-872.
- Foin, T. C. and J. L. Brenchley-Jackson. 1991. Simulation model evaluation of potential recovery of endangered light-footed clapper rail populations. *Biological Conservation* 58:123-148.
- Frank, G. H., and P. C. Smith. 1983. Prevalence of *Pasteurella haemolytica* in transported calves. *American Journal of Veterinary Research* 44:981-985.
- Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135-150 *in Conservation biology: an evolutionary-ecological perspective*. M. E. Soulé and B. A. Wilcox, eds. Sinauer Associates, Inc. Sunderland, Massachusetts. 395pp.
- Franklin, I. R. and R. Frankham. 1998. How large must populations be to retain evolutionary potential? *Animal Conservation* 1:69-73.

- Gardner, I. A., S. Hietala, and W. M. Boyce. 1996. Validity of using serologic tests for diagnosis of diseases in wild animals. *Reviews of Science and Technology Office of International Epizootics*. 15:323-335.
- Geist, V. 1967. A consequence of togetherness. *Natural History* 76(8):24-31.
- Geist, V. 1971. Mountain sheep: a study in behavior and evolution. The University of Chicago Press. Chicago and London. 383pp.
- Gilmour, N. J. L. and J. S. Gilmour. 1989. Pasteurellosis of sheep. Pp. 223-262 in C Adlaman and J. M. Rutter, editors. *Pasteurella* and pasteurellosis. Academic Press Ltd., San Diego, California.
- Gionfriddo, J.P. and P.R. Krausman. 1986. Summer habitat use by mountain sheep. *J. Wildl. Manage.* 50:331-336.
- Gilpin, M. E. and M. E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19-34 in *Conservation biology: the science of scarcity and diversity*. M. E. Soulé, ed. Sinauer Associates, Inc., Sunderland, Massachusetts. 584pp.
- Ginzburg, L., L. B. Slobodkin, K. Johnson, and A. G. Bindman. 1982. Quasiextinction probabilities as a measure of impact on population growth. *Risk Analysis* 2:171-181.
- Gonzalez, P. D. 1976. Skull measurement of male desert bighorns from Baja California, Mexico. *Desert Bighorn Council Transactions* 20:27-29.
- Goodson, N. 1999. Effects of river based recreation and livestock grazing on desert bighorn sheep on the Navajo Nation. Desert Bighorn Council, Trans. Sec. N. American Wild Sheep Conf. Cohosted with N. Am. Wild Sheep and Goat Council. April 6-9: Reno, NV.
- Gotelli, N. J. 1995. A primer of ecology. Sinauer Associates, Inc. Sunderland, Massachusetts. 206pp.

- Graf, W. 1980. Habitat protection and improvement. Pages 310-319 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Graham, H. 1980. The impacts of modern man. Pages 288-309 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Groombridge, B. (editor). 1992. Global biodiversity: state of the earth's living resources. Chapman and Hall, New York, N.Y. 585pp.
- Gross, R. 1987. Peninsular bighorn sheep of the Jacumba Mountains and Carrizo Canyon, San Diego, California, 1986. Report to the Anza-Borrego Desert Natural History Association, Borrego Springs, California. 36pp.
- Gutierrez-Espeleta, G. A., S. T. Kalinowski, W. M. Boyce, and P. W. Hedrick. 1998. Genetic variation in desert bighorn sheep. Desert Bighorn Council Transactions 42:1-10.
- Hamilton, K., S. A. Holl, C. L. Douglas. 1982. An evaluation of the effects of recreational activity on bighorn sheep in the San Gabriel Mountains, California. Desert Bighorn Council Transactions 26:50-55.
- Hansen, C. G. 1980a. Habitat. Pages 64-79 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Hansen, C. G. 1980b. Population dynamics. Pages 217-235 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Hansen, C. G. 1980c. Habitat evaluation. Pages 320-325 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.

- Hansen, C. G., and O. V. Deming. 1980. Growth and development. Pages 152-171 *in* G. Monson and L. Sumner eds. The desert bighorn: its life history ecology and management. Univ. Arizona Press, Tucson.
- Hanski, I. 1989. Metapopulation dynamics: does it help to have more of the same? *Trends in Ecology and Evolution* 4(4):113-114.
- Hanski, I. and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. *Biological Journal of the Linnean Society* 42:3-16.
- Hanski, I. and D. Simberloff. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. Pages 5-26 *in* Metapopulation biology: ecology, genetics, and evolution. I. Hanski and M. E. Gilpin, eds. Academic Press, Inc., San Diego, California.
- Harrison, S. 1994. Metapopulations and conservation. Pages 111-128 *in* Large-scale ecology and conservation. P.J. Edwards, N. R. Webb, and R. M. May, eds. Blackwell Scientific Publications, Oxford, England.
- Hass, C. C. 1995. Gestation periods and birth weights of desert bighorn sheep in relation to other Caprinae. *Southwestern Nat.* (40):139-147.
- Hayes, C. L., E. S. Rubin, M.C. Jorgensen, R. A. Botta, and W. M. Boyce. 2000. Mountain lion predation on bighorn sheep in the Peninsular Ranges, California. *J. of Wild. Manag.* 64(4):954-9.
- Hedrick, P. W., R. C. Lacy, F. W. Allendorf, and M. E. Soulé. 1996. Directions in conservation biology: comments on Caughley. *Conservation Biology* 10(5):1312-1320.
- Heisey, D. M. and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. *Journal of Wildlife Management* 49:668-674.

- Hicks, L. L. 1978. The status and distribution of Peninsular bighorn sheep in the In-Koh-Pah Mountains, California. Bureau of Land Management, Riverside District, El Centro, California. 63pp.
- Hicks, L. L. and J. M. Elder. 1979. Human disturbance of Sierra Nevada bighorn sheep. *Journal of Wildlife Management* 43(4):909-915.
- Hoff, G. L. and D. O. Trainer. 1981. Hemorrhagic diseases of wild ruminants. Pages 45-53 *in* Infectious diseases of wild mammals. 2nd ed. J. W. Davis, L. H. Karstad, and D. O. Trainer, eds. Iowa State University Press, Ames.
- Hogg, J. T. 1984. Mating in bighorn sheep: multiple creative male strategies. *Science* 225:526-529.
- Holl, S. A., H. Salwasser, and B. Browning. 1979. The diet composition and energy reserves of California mule deer during pregnancy. *Calif. Fish and Game*. 65:68- 79.
- Holling, C. S. 1978. Adaptive environmental assessment and management. Wiley International Series on Applied Systems Analysis. Vol. 3. Wiley Publ. Co., Chichester, UK.
- Jessup, D. A. 1981. Pneumonia in bighorn sheep: effects on populations. *California-Nevada Wildlife Transactions* 1981:72-78.
- Jessup, D. A. 1985. Diseases of domestic livestock which threaten bighorn sheep populations. *Desert Bighorn Council Transactions* 29:29-33.
- Jessup, D. A., W. M. Boyce, and R. K. Clark. 1990. Diseases shared by wild, exotic, and domestic sheep. Pages 44-51 *in* the Proceedings of the Second International Wildlife Ranching Symposium, Edmonton, Alberta, Canada.
- Jessup, D. A., J. R. DeForge, and Sandberg. 1991. Biobullet vaccination of captive and freeranging bighorn sheep. Pages 428-434 *in* Wildlife

Production: Conservation and Sustainable Development. L.A. Reneker and R.J. Hudson. Univ. Alaska, Fairbanks.

Jones, F. L. 1980. Competition. Pages 197-216 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.

Jones, F. L., G. Flittner, and R. Gard. 1957. Report on a survey of bighorn sheep in the Santa Rosa Mountains, Riverside County. California Fish and Game 43:179-191.

Jorgensen, M. C. and R. E. Turner, Jr. 1973. The desert bighorn sheep of Anza-Borrego Desert State Park. Desert Bighorn Council Transactions 17:81-88.

Jorgensen, M.C. and R.E. Turner. 1975. Desert bighorn of the Anza-Borrego Desert State Park. Desert Bighorn Council Transactions 19:51-53.

Jorgensen, M. C. 1989. Feral cattle removal: Anza-Borrego Desert State Park. California State Park Rangers Association Newsletter 6(9):1-4.

Jorgensen, P. 1974. Vehicle use at a desert bighorn watering site. Desert Bighorn Council Transactions 18:18-24.

Julander, O., W. L. Robinette, and D. A. Jones. 1961. Relation of summer range condition to mule deer herd productivity. J. Wildl. Manage. 25:54-60.

King, M. M. and G. W. Workman. 1986. Response of desert bighorn sheep to human harassment: management implications. Trans. 51st N. A. Wildl. And Nat. Res. Conf.

Kleiman, D. G. 1989. Reintroduction of captive mammals for conservation. BioScience 39(3):152-161.

- Krausman, P. R., S. Torres, L. L. Ordway, J. J. Herver, and M. Brown. 1985. Diel activity of ewes in the Little Harquahala Mountains, Arizona. *Desert Bighorn Council Transactions* 29:24-26.
- Krausman, P. R. and B. D. Leopold. 1986. The importance of small populations of desert bighorn sheep. Pages 52-61 *in* Transactions of the 51st North American Wildlife and Natural Resources Conference, Reno, Nevada. Wildlife Management Institute, Washington, D.C.
- Krausman, P. R., B. D. Leopold, R. F. Seegmiller and S. G. Torres. 1989. Relationships between desert bighorn sheep and habitat in western Arizona. *Wildl. Monogr.* 102:1-66.
- Krausman, P. R. 1993. Exit of the last wild mountain sheep. Pages 242-250 *in* Counting sheep: 20 ways of seeing desert bighorn. G. P. Nabhan, ed. The University of Arizona Press, Tucson. 261pp.
- Krausman, P. R., W. W. Shaw, R. C. Etchberger, and L. K. Harris. 1995. The decline of bighorn sheep in the Santa Catalina Mountains, Arizona. Pages 245-250 *in* Biodiversity and management of the madrean archipelago: the sky islands of southwestern United States and northwestern Mexico. DeBano, L. F., P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, tech. coords. September 19-23 1994; Tucson, Arizona. General Technical Report RM-GTR-264. United States Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 669pp.
- Krausman, P. R., G. Long, and L. Tarango. 1996. Desert bighorn sheep and fire, Santa Catalina Mountains, Arizona. Pages 162-168 *in* Effects of fire on Madrean Province ecosystems: a symposium proceedings. USDA Forest Service General Technical Report RM-GTR-289.
- Krausman, P. R., W. C. Dunn, L. K. Harris, W. W. Shaw, and W. M. Boyce. Can mountain sheep and humans coexist? In prep.

- Krebs, C. J. 1989. *Ecological Methodology*. Harper Collins Publishers. New York, N.Y. 654pp.
- Lacy, R. C. 1997. Importance of genetic variation to the viability of mammalian populations. *Journal of Mammalogy* 78(2):320-335.
- Langenau, E. E., Jr., and J. M. Lerg. 1976. The effects of winter nutritional stress on maternal and neonatal behavior in penned white-tailed deer. *Appl. Anim. Ethology* 2:207-223.
- Lande, R. 1987. Extinction thresholds in demographic models of territorial populations. *American Naturalist* 130:624-635.
- Lande, R. 1988. Genetics and demography in biological conservation. *Science* 241:1455-1460.
- Lande, R. 1995. Mutation and conservation. *Conservation Biology* 9:782-791.
- Lande, R. and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 *in* *Viable populations for conservation*. M. E. Soulé, ed. Cambridge University Press, Cambridge, England. 189pp.
- Laundre, J. W., T. D. Reynolds, and S. T. Knick. 1987. Accuracy of daily point relocations in assessing real movement of radio-marked animals. *Journal of Wildlife Management* 51(4):937-940.
- Leopold, A. 1933. *Game management*. Charles Scribner's Sons, New York, NY.
- Lesica, P. and F. W. Allendorf. 1995. When are peripheral populations valuable for conservation? *Conservation Biology* 9(4):753-760.
- Leslie, D. M. Jr. 1977. Home range, group size, and group integrity of the desert bighorn sheep in the River Mountains, Nevada. *Desert Bighorn Council Transactions* 21:25-28.

- Leslie, D. M., Jr., and C. L. Douglas. 1979. Desert bighorn of the River Mountains, Nevada. *Wildlife Monographs* 66:1-55.
- Leslie, D. M., Jr., and C. L. Douglas. 1980. Human disturbance at water sources of desert bighorn sheep. *Wildlife Society Bulletin* 8:284-290.
- Levins, R. 1970. Extinction. *In: Some mathematical questions in biology.* Am. Math. Society, Providence, RI. 1970.
- Light, J. T., and R. Weaver. 1973. Report on bighorn sheep habitat study in the area for which an application was made to expand the Mt. Baldy winter sports facility. U. S. For. Serv., Cajon Ranger District, San Bernadino National Forest. 39pp.
- Lindenmayer, D. B. and R. C. Lacy. 1995. A simulation study of the impacts of population subdivision on the mountain brushtail possum *Trichosurus caninus* Ogilby (Phalangeridae: Marsupialia) in south-eastern Australia. I. Demographic stability and population persistence. *Biological Conservation* 73:119-129.
- Logan, K. A., L. L. Sweaner, T. K. Ruth, and M. G. Hornocker. 1996. Cougars of the San Andres Mountains, New Mexico. Final Report, Federal Aid in Wildlife Restoration Project W-128-R. New Mexico Department of Game and Fish, Santa Fe, New Mexico.
- Lovich, J. E., T. B. Egan, and R. C. De Gouvenain. 1994. Tamarisk control on public lands in the desert of southern California: two case studies. *Calif. Weed Sci. Society. Proceedings of the 46th annual meeting.* San Jose, Calif.
- MacArthur, R.A. R.H. Johnston, and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. *Canadian J. of Zoology* 57:2010-2021.

- MacArthur, R. A. , V. Geist, and R. H. Johnston. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. *Journal of Wildlife Management* 46:351-358.
- Manville, R. H. 1980. The origin and relationships of American wild sheep. Pages 1-6 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- May, R. M. 1991. The role of ecological theory in planning re-introduction of endangered species. *Beyond captive breeding: reintroducing endangered mammals to the wild. Symposia of the Zoological Society of London* 62:145-163.
- May, R. M. and R. M. Anderson. 1979. Population biology of infectious diseases: part II. *Nature* 280(9):455-461.
- Mazet, J. A. K., W. M. Boyce, J. Mellies, I. A. Gardner, R. K. Clark, and D. A. Jessup. 1992. Exposure to *Psoroptes* sp. is common among bighorn sheep (*Ovis canadensis*) in California. *Journal of Wildlife Diseases* 28:542-547.
- McCarty, C. W. and J. A. Bailey. 1994. Habitat requirements of desert bighorn sheep. Special Report Number 69, Colorado Division of Wildlife. 27pp.
- McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nevada Dept. of Fish and Game, Biological Bulletin No. 6. 81pp.
- Meffe, G. K. and C. R. Carroll. 1994. Principles of conservation biology. Sinauer Associates, Inc. Sunderland, Massachusetts. 600pp.
- Mensch, J. L. 1970. Survey of bighorn sheep in California. *Desert Bighorn Council Transactions* 14:123-126.

- Merritt, M.F. 1974. Measurement of utilization of bighorn sheep habitat in the Santa Rosa Mountains. Desert Bighorn Council Transactions 18:4-17.
- Miller, G.D., M.H. Cochran and E.L. Smith. 1984. Nighttime activity of desert bighorn sheep. Desert Bighorn Council 1984 Transactions. Pp. 23-25.
- Miller, G. D. and E. L. Smith. 1985. Human activity in desert bighorn habitat: what disturbs sheep? Desert Bighorn Council Transactions 1985:4-7.
- Miller, G. D. and W.S. Gaud. 1989. Composition and variability of desert bighorn sheep diets. J. Wildlife Management 53:597-606.
- Minta, S. C. and P. M. Kareiva. 1994. A conservation science perspective: conceptual and experimental improvements. Pages 275-304 in Endangered Species Recovery: finding the lessons, improving the process. T. W. Clark, R. P. Reading and A. L. Clarke, eds. Island Press, Washington, D. C. 450pp.
- Monson, G. 1980. Distribution and abundance. Pages 40-51 in G. Monson and L. Sumner, editors. The Desert Bighorn Sheep. University of Arizona Press, Tucson, Arizona.
- Mullens, B. A. 1989. A quantitative survey of *Culicoides variipennis* (Diptera: Ceratopogonidae) in dairy wastewater ponds in southern California. J. of Medical Entomology 26(6):559-565.
- Mullens, B. A. and J. L. Rodriquez. 1990. Cultural management of bluetongue virus vectors. Calif. Agriculture 44(1):30-32.
- National Research Council. 1995. Science and The Endangered Species Act. National Academy Press. Washington, D.C. 271pp.
- Neal, A. K., G. C. White, R. B. Gill, D. F. Reed, and J. H. Olterman. 1993. Evaluation of mark-resight model assumptions for estimating mountain sheep numbers. J. Wildlife Management 57(3):436-450.

- New Mexico Department of Game and Fish. 1995. New Mexico's long-range plan for desert bighorn sheep management, 1995-2002. Final Rep. Fed. Aid in Wildlife Restor. Proj. W-127-R10, Job 1. New Mexico Dept. Game and Fish, Santa Fe. 40pp.
- Noss, R. and D. Murphy. 1995. Endangered species left homeless in Sweet Home. *Conservation biology* 9:229-231.
- Olech, L. A. 1979. Summer activity rhythms of Peninsular bighorn sheep in Anza-Borrego Desert State Park, San Diego County, California. *Desert Bighorn Council Transactions* 23:33-36.
- Onderka, D. K. and W. D. Wishart. 1984. A major sheep die-off from pneumonia in southern Alberta. *Biennial Symposium Northern Wild Sheep and Goat Council* 4:356-363.
- Ostermann, S. D., and J. R. DeForge. 1996. Pedigree Analysis and Breedstock Selection Criteria.
- Ostermann, S. D., J. R. DeForge, and W. D. Edge. Captive breeding and reintroduction evaluation criteria: a case study of Peninsular bighorn sheep. *Conservation Biology*. In press.
- Papouchis, C. M., F. J. Singer, and W. Sloan. 1999. Effects of increasing recreational activity on desert bighorn sheep in Canyonlands National Park, Utah. Pages 364-391 *in*: Singer, F. J. and M. A. Gudorf. Restoration of bighorn sheep metapopulations in and near 15 national parks: conservation of a severely fragmented species. USGS Open File Report 99-102, Midcontinent Ecological Science Center, Fort Collins, CO.
- Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. *Journal of Wildlife Management* 53:7-15.

- Price, M. A., and R. G. White. 1985. Growth and development. Pages 183-213
in R. J. Hudson and R. G. White, eds. Bioenergetics of wild herbivores.
CRC Press, Boca Raton, Fla.
- Ralls, K., J. D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents
and the cost of inbreeding in mammals. *Conservation Biology* 2:185-193.
- Ramey, R. R. II. 1993. Evolutionary genetics and systematics of American
mountain sheep: implications for conservation. PhD dissertation. Cornell
University, Ithaca, New York. 212pp.
- Ramey, R. R. II. 1995. Mitochondrial DNA variation, population structure, and
evolution of mountain sheep in the southwestern United States and
Mexico. *Molecular Ecology* 4(4):429-439.
- Reed, L. 1986. Old Time Cattlemen and Other Pioneers of the Anza-Borrego
Area. Third Edition. Anza-Borrego Desert Natural History Association,
Borrego Springs, California. 149pp.
- Risenhoover, K. L. and J. A. Bailey. 1985. Foraging ecology of mountain sheep:
implications for habitat management. *Journal of Wildlife Management*
49:797-804.
- Risenhoover, K. L. 1986. Winter-activity patterns of moose in interior Alaska. *J.*
Wildl. Manage. 50:727-734.
- Robbins C. T. 1993. Wildlife feeding and nutrition. Second ed. Academic
Press, New York, N. Y. 352pp.
- Robson, D. S. and H. A. Regier. 1964. Sample size in Peterson mark-recapture
experiments. *Transactions of the American Fisheries Society* 93:215-226.
- Rosenzweig, M. L. 1968. Net primary production of terrestrial communities:
prediction from climatological data. *American Naturalist* 102:67-74.

- Rubin, E. S., W. M. Boyce, M. C. Jorgensen, S. G. Torres, C. L. Hayes, C. S. O'Brien, and D. A. Jessup. 1998. Distribution and abundance of bighorn sheep in the Peninsular Ranges, California. *The Wildlife Society Bulletin* 26(3):539-551.
- Rubin, E., R. Botta, and S. Torres. 1999. Results of the 1998 bighorn sheep helicopter survey in the Peninsular Ranges south of the Santa Rosa Mountains. California Department of Fish and Game, Sacramento.
- Rubin, E. S., W. M. Boyce, and V. C. Bleich. 2000. Reproductive strategies of desert bighorn sheep. *J. of Mammalogy* 81(3): 769-786.
- Russi, T. L. 1978. Notes on a group of Peninsular bighorn. *Desert Bighorn Council Transactions* 22:43-44.
- Ryder, O. A. 1986. Species conservation and systematics: the dilemma of subspecies. *Trends in Ecology and Evolution* 1:9-10.
- Ryman, N. and L. Laikre. 1991. Effects of supportive breeding on the genetically effective population size. *Conservation Biology* 5(3):325-329.
- Sanchez, P. G. 1975. A tamarisk fact sheet. *Desert Bighorn Council Transactions* 19:12-14.
- Sanchez, J. E. 1988. Decline of the Carrizo Canyon Peninsular desert bighorn population. M. S. thesis. New Mexico State University, Las Cruces. 81pp.
- Sanchez, J. E., R. Valdez, V. W. Howard, M. C. Jorgensen, J. R. DeForge, and D. A. Jessup. 1988. Decline of the Carrizo Canyon Peninsular desert bighorn population. *Desert Bighorn Council Transactions* 32:31-33.
- Schoenecker, K. A. 1997. Human disturbance in bighorn sheep habitat, Pusch Ridge Wilderness, Arizona. M. S. thesis. University of Arizona, Tucson. 41pp.

- Schwartz, O. A., V. C. Bleich, and S. A. Holl. 1986. Genetics and the conservation of mountain sheep *Ovis canadensis nelsoni*. *Biological Conservation* 37:179-190.
- Scott, J. E. 1986. Food habits and nutrition of desert bighorn sheep (*Ovis canadensis cremnobates*) in the Santa Rosa Mountains, California. M. S. thesis. California State Polytechnic University, Pomona. 81pp.
- Seaman, D. E. and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77:2075-2085.
- Seegmiller, R. F. and R. D. Ohmart. 1981. Ecological relationships of feral burros and desert bighorn sheep. *Wildlife Monographs* 78:1-58.
- Shackleton, D. M. 1985. *Ovis canadensis*. *Mammalian species* 230:1-9.
- Shackleton, D. M., R. G. Peterson, J. Haywood, and A. Bottrell. 1984. Gestation period in *Ovis canadensis*. *Journal of Mammalogy* 65:337-338.
- Shaw, H. G. 1993. Only prey. Pages 221-241 in *Counting sheep: 20 ways of seeing desert bighorn*. G. P. Nabhan, ed. The University of Arizona Press, Tucson. 261pp.
- Sierra Nevada Bighorn Sheep Interagency Advisory Group. 1997. A conservation strategy for Sierra Nevada bighorn sheep.
- Simmons, N. M. 1980. Behavior. Pages 124-144 in *The desert bighorn: its life history, ecology, and management*. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Sinclair, A. R. E., R. P. Pech, C. R. Dickman, D. Hik, P. Mahon, and A. E. Newsome. 1998. Predicting effects of predation on conservation of endangered prey. *Conservation Biology* 12(3):564-575.

- Singer, R. S., D. A. Jessup, I. A. Gardner, and W. M. Boyce. 1997. Pathogen exposure patterns among sympatric populations of bighorn sheep, mule deer, and cattle. *Journal of Wildlife Diseases* 33(2):377-382.
- Smallwood, K. S. 1994. Trends in California mountain lion populations. *The Southwestern Naturalist* 39(1):67-72.
- Smallwood, K. S. and E. Lee Fitzhugh. 1995. A track count for estimating mountain lion *Felis concolor californica* population trend. *Biological Conservation* 71:251-259.
- Smith, N. S. and Krausman, P. R. 1988. Desert bighorn sheep: a guide to selected management practices. Biological Report 88(35). U. S. Department of the Interior, Fish and Wildlife Service, Washington, D. C. 20240.
- Soulé, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 *in* Conservation biology: an evolutionary-ecological perspective. M. E. Soulé and B. A. Wilcox, eds. Sinauer Associates, Inc. Sunderland, Massachusetts. 395pp.
- Soulé, M. E. 1987. Introduction. Pages 1-10 *in* Viable populations for conservation. M. E. Soulé, ed. Cambridge University Press. 189pp.
- Spraker, T. R. 1977. Fibrinous pneumonia of bighorn sheep. *Desert Bighorn Council Transactions* 21:17-18.
- Spraker, T. R., C. P. Hibler, G. G. Schoonveld and W. S. Adney. 1984. Pathologic changes and micro-organisms found in bighorn sheep during a stress-related die-off. *J. Wildl. Disease* 20(4):319-327.
- Stanley Price, M. R. 1991. A review of mammal re-introductions, and the role of the Re-introduction Specialist Group of IUCN/SSC. Beyond captive breeding: reintroducing endangered mammals to the wild. *Symposia of the Zoological Society of London* 62:9-25.

- Starfield, A. M. 1997. A pragmatic approach to modeling for wildlife management. *Journal of Wildlife Management* 61(2):261-270.
- Starfield, A. M. and A. L. Bleloch. 1991. Building models for conservation and wildlife management. 2nd ed. Burgess International. Edina, Minnesota. 253pp.
- Steidl, R. J., J. P. Hayes, and E. Schaubert. 1997. Statistical power analysis in wildlife research. *Journal of Wildlife Management* 61:270-279.
- Stevens, D. R. and N. J. Goodson. 1993. Assessing effects of removals for transplanting on a high elevation bighorn sheep population. *Conservation Biology* 7(4):908-915.
- Tevis, L. Jr. 1959. Man's effect on bighorn in the San Jacinto-Santa Rosa Mountains. *Desert Bighorn Council Transaction* 3:69-76.
- Tevis, L. Jr. 1961. Battle to save the bighorn range in Santa Rosa Mountains of California. *Desert Bighorn Council Transactions* 5:103-107.
- Thorne, E. T., R. E. Dean, and W. G. Hepworth. 1976. Nutrition during gestation in relation to successful reproduction in elk. *J. Wildl. Manage.* 40:330-335.
- Torres, S. G., V. C. Bleich, and J. D. Wehausen. 1994. Status of bighorn sheep in California, 1993. *Desert Bighorn Council Transactions* 38:17-28.
- Torres, S. G., T. M. Mansfield, J. E. Foley, T. Lupo, and A. Brinkhaus. 1996. Mountain lion and human activity in California: testing speculations. *Wildlife Society Bulletin* 24(3):451-460.
- Turner, J. C. 1973. Water energy and electrolytic balance in the desert bighorn sheep (*Ovis canadensis cremnobates* Elliot). PhD dissertation. University of California, Riverside. 150pp.

- Turner, J. C. 1976. Bighorns. *In* I. P. Ting and B. Jennings, eds., Deep Canyon, a desert wilderness for science. Philip L. Boyd Deep Canyon Desert Research Center, University of California, Riverside, CA. Pp. 167-173.
- Turner, J. C. 1978. Chlorinated hydrocarbon residues in perianal fat of desert bighorn sheep. *Bulletin of Environmental Contamination and Toxicology*:23-31.
- Turner, J. C. and C. G. Hansen. 1980. Reproduction. Pages 145-151 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Turner, J. C. and R. A. Weaver. 1980. Water. Pages 100-112 *in* The desert bighorn: its life history, ecology, and management. G. Monson and L. Sumner, eds. University of Arizona Press, Tucson. 370pp.
- Turner, J. C. and J. B. Payson. 1982. The occurrence of selected infectious diseases in the desert bighorn sheep, *Ovis canadensis cremnobates*, of the Santa Rosa Mountains, California. *California Fish and Game* 68(4):235-243.
- U. S. Fish and Wildlife Service. 1992. Endangered and Threatened Wildlife and Plants; Proposed rule to list the Peninsular Ranges population of the desert bighorn sheep as endangered. *Federal Register* 57(90):19837-19843.
- Uhazy, L. S. and J. C. Holmes. 1973. Lungworms in the Rocky Mountain bighorn sheep of western Canada. *Canadian Journal of Zoology* 51:817-824.
- Van Soest, P. J. 1982. Nutritional ecology of the ruminant. O & B Books Inc., Corvallis, Oreg. 374pp.
- Wagner, G. D. 1999. Activity patterns of Rocky Mountain bighorn ewes in central Idaho. *Trans. Second North American Wild Sheep Conf.*; Reno, Nev. 2:103-121.

- Wagner, G. D. 2000. Diet selection, activity patterns, and bioenergetics of bighorn ewes in central Idaho. Ph. D. Thesis, Univ. of Idaho, Moscow. 165 pp.
- Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. *Journal of Wildlife Management* 51:904-912.
- Walsh, P. D. 1995. PVA in theory and practice. *Conservation Biology* 9(4):704-705.
- Weaver, R. A. 1959. Effects of wild burros on desert water supplies. *Desert Bighorn Council Transactions* 3:1-3.
- Weaver, R. A. 1972. Conclusions of the bighorn investigation in California. *Desert Bighorn Council Transactions* 16:56-65.
- Weaver, R. A. 1973. Burro vs. bighorn. *Desert Bighorn Council Transactions* 17:90-97.
- Weaver, R. A. 1975. Status of the bighorn sheep in California. Pages 58-64 in *The Wild Sheep in Modern America*. J. B. Trefethen, ed. Boone and Crockett Club. Alexandria, Virginia.
- Weaver, R. A. 1989. Status of bighorn sheep in California, 1988. *Desert Bighorn Council Transactions* 33: 11-12.
- Weaver, R. A., J. L. Mensch, and W. V. Fait. 1968. A survey of the California desert bighorn (*Ovis canadensis*) in San Diego County. California Department of Fish and Game. PR Project W-51-R-14. 26pp.
- Weaver, R. A. and J. L. Mensch. 1970. Bighorn sheep in southern Riverside County. California Department of Fish and Game, Wildlife Management Administration Report No. 70-5. 36pp.

- Wehausen, J. D. 1979. Sierra Nevada bighorn sheep: an analysis of management alternatives. Coop. Admin. Report, Inyo Nat. For., Sequoia Nat. Park, Kings Canyon Nat. Park, and Yosemite Nat. Park. 92pp.
- Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: history and population ecology. PhD dissertation. Univ. Michigan. 243pp.
- Wehausen, J. D. 1983. White Mountain bighorn sheep: an analysis of current knowledge and management alternatives. U. S. For. Serv. Adm.. Rep., Inyo Nat. Forest Contract No. 53- 9JC9-0-32.
- Wehausen, J. D. 1991. Some potentially adaptive characters of mountain sheep populations in the Owens Valley Region. Pages 1-12 *in* C. A. Hall, Jr., V. Doyle-Jones, and B. Widawski, eds. White Mountain Res. Symp 3.
- Wehausen, J. D. 1992. Demographic studies of mountain sheep in the Mojave Desert: Report IV. Unpublished report. California Department of Fish and Game, Bishop, California.
- Wehausen, J. D. 1996. Effects of mountain lion predation on bighorn sheep in the Sierra Nevada and Granite Mountains of California. *Wildlife Society Bulletin* 24(3):471-47.
- Wehausen, J.D. 1999. Rapid extinction of mountain sheep populations revisited. *Conservation Biology* 13(2):378-384.
- Wehausen, J. D., V. C. Bleich, B. Blong, and T. L. Russi. 1987. Recruitment dynamics in a southern California mountain sheep population. *Journal of Wildlife Management* 51:86-98.
- Wehausen, J. D. and R.R. Ramey II. 1993. A morphometric reevaluation of the Peninsular bighorn subspecies. *Desert Bighorn Council Transactions* 37:1-10.

- Whitacker, D. and R. L. Knight. 1998. Understanding wildlife responses to humans. *Wildlife Society Bulletin* 26:312-317.
- The Wildlife Society. 1995. Journal news. *Journal of Wildlife Management* 59:196-198.
- Wilson, L. O., J. Blaisdell, G. Walsh, R. Weaver, R. Brigham, W. Kelly, J. Yoakum, M. Hinks, J. Turner, and J. DeForge. 1980. Desert bighorn habitat requirements and management recommendations. *Desert bighorn Council Transactions* 24:3-7.
- Wilson, D. E. and D. M. Reeder, eds. 1993. *Mammal species of the world: a taxonomic and geographic reference*, 2nd edition. Smithsonian Institution Press. Pp. 408-409.
- Wootton, J. T. and D. A. Bell. 1992. A metapopulation model of the Peregrine falcon in California: viability and management strategies. *Ecological Applications* 2(3):307-321.

B. Personal Communications

- Bleich, V. C. California Department of Fish and Game, Bishop, Calif.
- Boyce, W. M. University of California, Davis, Calif.
- Correll, T. The Living Desert Museum, Palm Desert, Calif.
- DeForge, J. R. Bighorn Institute, Palm Desert, Calif.
- Jorgensen, M. C. California State Parks, Colorado Desert Dist., Borrego Springs, Calif.
- Krausman, P. R. University of Arizona, Tucson, Arizona

Rubin, E. S. University of California, Davis, Calif.

Weaver, R. A. California Department of Fish and Game, retired

Wehausen, J. D. University of California, White Mountain Research Station,
Bishop, California

C. *In Litt.* References

DeForge, J. R. 1997. Letter to Gavin Wright, Bureau of Land Management,
North Palm Springs, California. Oct. 22, 1997. Bighorn Institute, Palm
Desert Calif. 2pp.

Jessup, D. A. 1999. Letter to Sheryl Barrett, U. S. Fish and Wildlife Service,
Carlsbad, Calif. Aug. 28, 1999. Calif. Dept. of Fish and Game, Santa
Cruz. 2pp.

Jessup, D. A. 2000. Letter to Scott McCarthy, U. S. Fish and Wildlife Service,
Carlsbad, Calif. June 23, 2000. Calif. Dept. of Fish and Game, Santa
Cruz. 1p.

Krausman, P. R. 1998. E-mail to Esther Rubin. Oct. 19, 1998. Univ. of
Arizona, Tucson. 1p.

V. APPENDICES

APPENDIX A. AN OVERVIEW OF THE PENINSULAR RANGES

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

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

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

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

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

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

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

References

- Bolton, H. E. 1930. Anza's California expeditions. Vol. IV. Fonts complete diary of the second Anza expedition. University of California Press, Berkeley. 552pp.
- Brigandi, P. 1995. The livestock industry on the Anza-Borrego desert. A report for the Anza-Borrego Desert State Park. Contract No. C4532007.
- Cunningham, S. C. and R. D. Ohmart. 1986. Aspects of the ecology of desert bighorn sheep in Carrizo Canyon, California. Desert Bighorn Council Transactions 30:14-19.
- Jorgensen, M. C. and R. E. Turner. 1975. Desert bighorn of the Anza-Borrego Desert State Park. Desert Bighorn Council Transactions 19:51-53.
- Lindsay, L. and D. Lindsay. 1991. The Anza-Borrego Desert Region. Third Edition. Wilderness Press, Berkeley, California. 179pp.
- National Oceanic and Atmospheric Administration. 1962-1997. Climatological data: California. National Climate Data Center, Asheville, North Carolina.
- Oakeshott, G. B. 1978. California's changing landscape: a guide to the geology of the state. McGraw-Hill, New York, New York. 379pp.
- Reed, L. 1986. Old Time Cattlemen and Other Pioneers of the Anza-Borrego Area. Third Edition. Anza-Borrego Desert Natural History Association, Borrego Springs, California. 146pp.
- Ryan, R. M. 1968. Mammals of Deep Canyon. The Desert Museum, Palm Springs, California.
- Sharp, R. P. 1976. A field guide to southern California. Kendall/Hunt Publishing Company, Dubuque, Iowa. 301pp.

References

- Bolton, H. E. 1930. Anza's California expeditions. Vol. IV. Font's complete diary of the second Anza expedition. University of California Press, Berkeley. 552pp.
- Brigandi, P. 1995. The livestock industry on the Anza-Borrego desert. A report for the Anza-Borrego Desert State Park. Contract No. C4532007.
- Cunningham, S. C. and R. D. Ohmart. 1986. Aspects of the ecology of desert bighorn sheep in Carrizo Canyon, California. Desert Bighorn Council Transactions 30:14-19.
- Jorgensen, M. C. and R. E. Turner. 1975. Desert bighorn of the Anza-Borrego Desert State Park. Desert Bighorn Council Transactions 19:51-53.
- Lindsay, L. and D. Lindsay. 1991. The Anza-Borrego Desert Region. Third Edition. Wilderness Press, Berkeley, California. 179pp.
- National Oceanic and Atmospheric Administration. 1962-1997. Climatological data: California. National Climate Data Center, Asheville, North Carolina.
- Oakeshott, G. B. 1978. California's changing landscape: a guide to the geology of the state. McGraw-Hill, New York, New York. 379pp.
- Reed, L. 1986. Old Time Cattlemen and Other Pioneers of the Anza-Borrego Area. Third Edition. Anza-Borrego Desert Natural History Association, Borrego Springs, California. 146pp.
- Ryan, R. M. 1968. Mammals of Deep Canyon. The Desert Museum, Palm Springs, California.
- Sharp, R. P. 1976. A field guide to southern California. Kendall/Hunt Publishing Company, Dubuque, Iowa. 301pp.

Ting, I. P. and B. Jennings. 1976. Deep Canyon's past. Pages 1-6 *in* Deep Canyon, a desert wilderness for science. I. P. Ting and B. Jennings, eds. University of California, Riverside. 177pp.

Turner, J. C. 1976. Bighorns. Pages 167-173 *in* Deep Canyon, a desert wilderness for science. I. P. Ting and B. Jennings, eds. Univ. of California, Riverside. 177pp.

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

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

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

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

The purpose of this mapping effort is to delineate those areas believed to be necessary for a self-sustaining bighorn population with a high probability for long-term survival and recovery in the Peninsular Ranges of the United States.

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

Approach used

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

mountains as the “upside-down mountain ranges” (R. Weaver, California Department of Fish and Game retired, pers. comm.). Therefore, published information regarding habitat use patterns of bighorn sheep, in general, was supplemented with knowledge regarding habitat use patterns of Peninsular bighorn sheep, to identify habitat features that determine the distribution of bighorn sheep in these ranges.

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

Choice of habitat components

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

Because these habitat components and characteristics largely determine how bighorn sheep use their habitat in the Peninsular Ranges, information available on