Desert Bighorn Sheep (*Ovis canadensis nelsoni*)

Legal Status

Photo by Dee E. Warenycia.

State: None for subspecies *Ovis canadensis nelsoni* (Nelson's bighorn sheep); Peninsular bighorn sheep distinct population segment (DPS) is Threatened, Fully Protected

Federal: Peninsular bighorn sheep DPS is Endangered; Nelson's bighorn sheep is Bureau of Land Management Sensitive, U.S. Forest Service Sensitive

Critical Habitat: Designated for Peninsular bighorn sheep DPS occupying the Peninsular Ranges of Southern California on April 14, 2009 (74 FR 17288–17365).

Recovery Planning: A Recovery Plan for Peninsular bighorn sheep in the Peninsular Ranges of California was approved October 25, 2000 (USFWS 2000).

Taxonomy

The subspecific taxonomy of bighorn sheep (*Ovis canadensis*) at the subspecies level in the southwest desert region has been uncertain. Earlier studies had placed desert bighorn sheep in one of four subspecies occurring in the southwest desert region (Cowan 1940). For populations within the Desert Renewable Energy Conservation Plan (DRECP) Area, based on cranial measurements, desert bighorn sheep in the Peninsular Ranges were considered a separate subspecies, *O. c. cremnobates,* and northerly populations were designated *O. c. nelsoni* (Nelson's bighorn sheep). More recent genetic and morphometric information does not support the distinct subspecific delineation of *O. c. cremnobates* and the current classification has Nelson's bighorn sheep as the only bighorn subspecies occurring in the Plan Area. Research has found north-south and elevational variation in life history patterns of Nelson's bighorn sheep that tracks differences in temperature regimes in California and on a larger geographic scale (Wehausen 2005, 2006) but with no clear boundaries that might be used to define subspecies. This clinal variation supports Ramey's (1995) suggestion that all desert bighorn sheep be recognized as one polytypic subspecies. Wehausen (2006) suggested that such regional variation be recognized and considered in conservation planning.

In the 2009 federal critical habitat designation, desert bighorn sheep in the Peninsular Ranges are treated as a DPS of the Nelson's bighorn sheep, and are no longer referred to as a separate subspecies (74 FR 17288–17365). This DPS is federally listed as endangered and state-listed threatened and fully protected. Consistent with the federal critical habitat designation, the common name Peninsular bighorn sheep is retained in this species profile where the information pertains specifically to the federally and state-listed DPS. The common name desert bighorn sheep is used elsewhere where this distinction is not made, but this information for desert bighorn sheep would also apply to the Peninsular bighorn sheep DPS.

Distribution

General

Desert bighorn sheep occur in the desert mountain ranges from the White Mountains in Mono and Inyo counties, south to the San Bernardino Mountains, then southeast to Mexico (Wehausen 2006; Shackleton 1985) (Figure SP-M01). An isolated population occurs in the San Gabriel Mountains (Zeiner et al. 1990). Beyond California, its range extends into southern Nevada, southern Utah, southwestern Arizona, and northwestern Mexico and Baja California, Mexico (Shackleton 1985). Although desert bighorn sheep has a broad overall geographic range, actual populations within the range are scattered and discrete (Shackleton 1985).

The Peninsular bighorn sheep DPS generally occurs in the Peninsular Ranges from the San Jacinto and Santa Rosa ranges south into Mexico. The DPS critical habitat is located in Riverside, San Diego, and Imperial counties (74 FR 17288–17365). The bighorn sheep in this region are restricted to the east-facing, lower elevation slopes below about 1,400 meters (4,593 feet), and most occur at elevations between 91 and 1,219 meters (300 and 4,000 feet) (63 FR 13135).

Distribution and Occurrences within the Plan Area

Historical

All of the California Natural Diversity Database (CNDDB) occurrences of desert bighorn sheep, excluding the Peninsular bighorn sheep DPS, within 5 miles of the Plan Area are historical (i.e., before 1990). These occurrences range from the Last Chance Range near the northeastern portion of the Plan Area south to the Chocolate Mountains in the southeastern portion of the Plan Area. Records marking the eastern boundary of the CNDDB records are from near Straw Peak, the Newberry Mountains, and the San Bernardino Mountains east of Joshua Tree National Monument (CDFW 2013).

Five of the six CNDDB records for Peninsular bighorn sheep within 5 miles of the Plan Area are historical. All of these records lie west of the southern portion of the Plan Area, three are within Anza-Borrego Desert State Park, one is near In-Ko-Pah Gorge, and one is east of San Bernardino National Forest (CDFW 2013).

Recent

The California Department of Fish and Game (CDFG)(2010a) prepared the *Biennial Report to the Legislature Regarding Desert Bighorn Sheep Management* pursuant to Section 4094 of the California Fish and Game Code. This report summarizes census information related to long-term management of desert bighorn sheep (including the authorization of hunting tags) and includes sheep counts in specific management units in 2009 and 2010. The distribution of desert bighorn sheep is grouped by a regional system of subpopulations (or metapopulations) based on natural physical features such as geography and vegetation that affect species occurrence, as well as manmade obstacles that affect distribution, such as freeways (CDFG 2010a). Aerial surveys in 2009 and 2010 documented 1,022 desert bighorn sheep, including ewes, lambs, and rams, in the following mountain ranges: Marble Mountains; Clipper Mountains; Kelso Peak and Old Dad Peak; Clark, Kingston, and Mesquite Mountains; Orocopia Mountains; Sheephole Mountains; South Bristol Mountains; Cady Mountains; White Mountains; and San Gorgonio Mountains. The 1,022 individuals represent minimum populations in these areas because they were the only animals actually observed; population size is assumed to be larger (CDFG 2010a). The CDFG (2010a) report included the Peninsular bighorn sheep metapopulation, with an estimate of about 950 adults and recruited lambs among the nine distinct subpopulations as of December 2010. Population sizes and trends throughout the species' range in the Plan Area are discussed in more detail in the "Population Status and Trends" subsection.

There are 35 recent occurrences of the Peninsular bighorn sheep DPS in the Plan Area and 13 occurrences just west of the Plan Area (Dudek 2013). These occurrences are clustered in the extreme southwestern portion of the Plan Area (Figure SP-M01).

Natural History

Habitat Requirements

Desert bighorn sheep are mobile and wide-ranging and require a variety of habitat characteristics related to topography, visibility, forage quality and quantity, and water availability (USFWS 2000). Desert bighorn sheep prefer areas on or near mountainous terrain that are visually open, as well as steep and rocky (Wehausen 2006). Steep, rugged terrain is used for escape and lambing. Alluvial fans and washes in flatter terrain are also used for forage and water and as connectivity habitat between more rugged areas. However, based on an assessment of radiotelemetry data, Epps et al. (2007) found that desert bighorn sheep mainly used slopes greater than 10% in intermountain habitats. They used 15% slope as a cutoff value in a model for 'effective geographical distance', or EGD, where cells with slopes less than 15% were considered 10 times more costly to cross than cells with slopes greater than 15%. Because desert bighorn sheep predator avoidance is based on vigilance and visual contact, they tend to avoid dense vegetation (USFWS 2000). Peninsular bighorn sheep in particular avoid higher elevations that support chaparral.

Desert bighorn sheep occur in the following habitats (see Table 1): alpine dwarf-shrub, low sage, sagebrush, bitterbrush, pinyon-juniper, palm oasis, desert riparian, desert succulent shrub, desert scrub, subalpine conifer, perennial grassland, montane chaparral, and montane riparian (Zeiner et al. 1990). A wide range of forage resources and vegetation associations is needed to meet annual and drought-related variations in forage quality and availability (USFWS 2000). Seasonal forage available in alluvial fans and in washes provides a diversity of browse during warmer periods that support lactation and thus is important for reproduction and recruitment of lambs. Foraging behavior is described in more detail herein.

Surface water is an important habitat element for desert bighorn sheep, although individuals can survive without drinking surface water (Wehausen 2006). While desert bighorn sheep may drink water in the cool season, in years of poor forage growth, surface water is most important during the May through October hot season, when most females and associated lambs and yearlings live largely within 2 to 3 miles of water. Males join them at these water sources as the hot season progresses with the onset of the breeding season (Wehausen, pers. comm. 2012). In populations in the eastern Mojave Desert (Old Dad Peak, Kelso Mountains, and Marl Mountains), females occur in areas closer to water and more rugged terrain than males (Bleich et al. 1997). Water sources adjacent to escape terrain are preferred and a lack of water may be a limiting factor in the distribution of desert bighorn sheep populations; there are no known large populations in regions lacking water (Wehausen 2006).

Outside the breeding season, males and females commonly occupy different habitats and usually only come together during the rut period (USFWS 2000). Females prefer particularly steep, safe areas for bearing and initial rearing of lambs (Bleich et al. 1997), especially areas of steep limestone if available (Wehausen 2006). Steep topography is not only important for lambing and rearing, but also helps desert bighorn sheep escape from predators (USFWS 2000). Because desert bighorn sheep primarily rely on their sense of sight to detect predators, open terrain with good visibility is critical for protection from predation (USFWS 2000). Males tend to occupy much less rugged habitat during the lambing season (Wehausen 2006).

Table 1. Habitat Associations for Desert Bighorn Sheep

Land Cover Type	Land Cover Use	Habitat Designation	Habitat Parameters	Supporting Information
Alpine dwarf-shrub, Low sage, Sagebrush, Bitterbrush, Pinyon-juniper, Palm oasis, Desert riparian, Desert succulent shrub, Desert scrub, Subalpine conifer, Perennial grassland, Montane chaparral, Montane riparian,	Primary habitat	Year-round	Desert bighorn sheep prefer areas on or near mountainous terrain that are visually open and steep and rocky and that support surface water. Males tend to occupy much less rugged habitat during the lambing season.	Zeiner et al. 1990; USFWS 2000; Wehausen 2006
Alluvial fans and washes	Foraging	During warmer periods/ lambing		

Foraging Requirements

Bighorn sheep are generalist foragers and feed on a wide variety of plant species (Miller and Gaud 1989; Shackleton 1985). For example, Miller and Gaud (1989) documented 121 plant taxa in fecal samples and through direct observations of desert bighorn sheep in a Sonoran Desert habitat in Western Arizona over an 11-year period. However, the composition of their diet varies with season and location (Bleich et al. 1997; Miller and Gaud 1989; Shackleton 1985; Wehausen 2006; 74 FR 17288–17365). They must be able to access the seasonal abundance of plants at various elevations in various habitat types to maximize resources. Desert bighorn sheep adjust their feeding ranges to exploit areas with more nutritive resources, such as within bajadas, early in the season as high-protein grasses emerge. The relationship between nutritive resources, reproductive success, and optimal timing of birth is complex. Lamb survival is strongly related to spring body growth, so the earlier they are born the more they can grow before forage quality quickly declines in late spring (Wehausen 2005). However, the earlier the birth, the more likely that ewes will have inadequate food quality during late gestation and early lactation (Wehausen 2005.) The factor that controls this relationship is the body condition of the ewes coming into the reproductive season, with ewes in better condition ovulating earlier in the season because they have the condition to withstand the period with lower nutrient resources (Wehausen 2005).

During the reproductive season, nutritious forage is typically concentrated on alluvial fans and bajadas, and in washes where more productive, wetter soils support more herbaceous forage than steeper, drier, rockier soils. These areas, therefore, are especially important food sources during the heat of summer months and in drought conditions (74 FR 17288–17365). For example, Peninsular bighorn sheep browse year-round on shrubs such as burro bush (*Ambrosia dumosa*), small-leaved hoffmannseggia (*Hoffmannseggia microphylla*), desert lavender (*Hyptis emoryi*), globemallows (*Sphaeralcea* spp.), and jojoba (*Simmondsia chinensis*). Grasses such as six weeks threeawn (*Aristida adscensionis*) and red brome (*Bromus rubens*), as well as cacti (*Opuntia* spp.), are primary food sources in the fall (74 FR 17288–17365). Forbs such as native plantains (*Plantago* spp.) and common ditaxis (*Ditaxis neomexicana*) are primary food sources in the spring (74 FR 17288–17365). The Peninsular bighorn sheep diet is about 57% shrub, 32% forbs, 8% cacti, and 2% grasses (USFWS 2000).

Desert bighorn sheep typically stay close (i.e., within 2 to 3 miles) to reliable sources of water during hot summer months and drink large quantities at each visit (USFWS 2000). Desert bighorn sheep have been known to travel at least 10 miles from perennial water sources and typically visit a water source every 2 to 3 days. Sources of water for desert bighorn sheep include rainwater accumulated in natural collection tanks and potholes in rock, natural springs, and vegetation with high water content, such as cacti (74 FR 17288–17365).

Reproduction

The primary desert bighorn breeding season, or rut period, is between August and October in the Peninsular Range (USFWS 2000) and August and November in west Mojave Desert (Wehausen 2006). The gestation period is about 6 months (range of 171 to 178 days (Shackleton et al. 1984). Desert bighorn sheep tend to have relatively high conception rates, with a reported rate of 77% to 85% (USFWS 2000). The lambing period depends on location and resources available, but generally desert bighorn sheep have a long lambing season (see Table 2 for key seasonal periods). The reported lambing period for desert bighorn sheep generally occurs between January and June, with most lambs born February to April. In the Mojave Desert, lambing occurs somewhat later than more southerly areas and may begin in December and end in June, with a small percentage of births commonly occurring in summer as well (Wehausen 2006). In a study in the Peninsular Ranges, the lambing season extended from February through August, with 87% of the lambs born from February to April (Rubin et al. 2000). Lambs usually are weaned by 6 months of age.

In the Peninsular Ranges, the reproductive age of ewes ranges from approximately 2 to 16 years of age. As the birthing time approaches, ewes seek isolated sites with shelter and unobstructed views to bear their lambs, secluding themselves from other females (USFWS 2000).

Mortality rates are highest in the first year of life and lamb survival (to 6 months of age) varies by group and year (Shackleton 1985; USFWS 2000) and is related to several factors. Reproductive success in ruminants such as desert bighorn sheep is associated with the mother's body weight, access to resources, quality of home range, and age. As discussed above, lamb survival to summer is strongly related to body growth during the spring (Wehausen 2005). Rubin et al. (2000) found that lamb survival in a Peninsular desert bighorn sheep population was related to the time of year that lambs are born, with the highest survival rate for lambs born in February through April, compared to lambs born later. Lamb mortality may also be caused by disease or disease processes complicated by environmental conditions, including habitat modification (USFWS 2000).

Winter precipitation, which is tied to plant phenology and nutrient availability for desert bighorn sheep, is an important factor in lamb survival (Wehausen 2005). In the eastern Mojave Wehausen (2005) found that rainfall in the months of October and February has the greatest effect on diet quality. Fall rainfall is important for initiating the growth of cold-tolerant species, including annuals, herbaceous perennials, and perennial grasses, and February is important for both the continued growth of cold-tolerant species, but also the growth of cold-intolerant perennial species. Timing of birthing coincides with peak nutrient availability and the amount of rainfall in the October through April period has a strong effect on lamb survival and recruitment rate (Wehausen 2005). A similar pattern was reported by Wehausen et al. (1987) for a Peninsular Range population in the Santa Rosa Mountains where rainfall in November, January and February was significantly positively correlated with lamb recruitment. Elsewhere in the desert bighorn sheep's range, similar patterns have been observed. Douglas and Leslie (1986) found a positive relationship between fall and winter precipitation and lamb recruitment the following year. Douglas and Leslie (1986) determined that 52% of the variability in lamb survival in desert bighorn population in the River Mountains in Nevada over a 12-year period was accounted for by autumn precipitation during gestation.

While precipitation patterns are strongly associated with lamb survival, lower lamb survival has also been associated periods of increased rainfall, complicating the relationship between rainfall patterns and lamb survival. Wehausen (2005) noted that declining survivorship occurs with rainfall over about 23 centimeters (about 9 inches). It has been hypothesized that increased rainfall may be associated with disease; increased standing water causes an increase in populations of *Culicoides* midges, which are a vector for bluetongue and epizootic hemorrhagic disease viruses (USFWS 2000), but Wehausen (2005) indicates that more research is needed to understand this relationship.

Table 2. Key Seasonal Periods for Desert Bighorn Sheep

	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Breeding	X	X	X	X	X	X	X	X			X	X
Lambing	X	X	X	X	X	X						X

Source: Wehausen 2006.

Spatial Behavior

Desert bighorn sheep exhibit seasonal differences in habitat use patterns (USFWS 2000), and some populations of females may migrate seasonally between mountain ranges (Jaeger 1994). Seasonal migration by desert bighorn sheep may be more common than previously thought (Wehausen, pers. comm. 2012). They tend to concentrate in areas with water during the hot summer months and expand their ranges away from water sources in the cooler, wetter season (USFWS 2000). They also alter their ranges during rutting and lambing seasons (USFWS 2000). Home range size depends on the availability of required resources, such as water, forage, and lambing habitat, and, thus, varies geographically (USFWS 2000). Forage quantity and quality, season, sex, and age also influence home range sizes. Generally, ram home ranges are larger than those of ewes. In the San Jacinto Mountains, based on a fixed kernel method for estimating home range (95% utilization distribution), the average estimated home range size was approximately 9.8 square miles for rams and 7.8 square miles for ewes (USFWS 2000).

The social structure of desert bighorn sheep is matrilineal (based on female associations). They exhibit gregarious and philopatric (remaining in natal area) behaviors (USFWS 2000). However, rams do not show the same level of philopatry as females and tend to range more widely, often moving among groups of ewes (USFWS 2000). At 2 to 4 years of age, young rams follow older rams away from their natal group during the fall breeding period, often returning after this period. Rams may use the same travel routes year after year (USFWS 2000).

Long-distance inter-mountain range dispersal movements are important for desert bighorn sheep, primarily by rams, but also by ewes (Wehausen 2006). Using radiotelemetry, Bleich et al. (1990) documented substantial intermountain movement between mountains in southeastern California. Epps et al. (2004, p. 103) state that "Three apparent natural recolonizations have been observed in recent years. It is possible that additional extinctions and subsequent recolonizations were undetected between survey years," but they do not provide more detail about these recolonizations. Nonetheless, recent information indicates that intermountain movements and natural recolonizations are not rare occurrences (Bleich et al. 1996; Epps et al. 2010). Epps et al. (2010) analyzed DNA information and found that both native and translocated desert bighorn sheep have colonized "empty habitats." Wehausen (pers. comm. 2102) reports that additional natural colonizations have occurred in several ranges, including Deep Springs, Coso, South Soda, South Bristol, Iron, Little Maria, and Cushenbury (San Bernardino Mountains). Further, ewe movements to new groups once thought be rare (e.g., USFWS 2000) are now known to be much more common (Wehausen, pers. comm. 2012). For example, 3 of 10 radio-collared females moved from the Marble Mountains to the South Bristol Mountains in 1992 when that vacant range was colonized (Wehausen, pers. comm. 2012). The available information now indicates that over the past 25 years recolonizations have exceeded the extinctions that occurred in the mid-20th Century during a 30-year drought period and during a period when desert bighorn sheep were being adversely affected by human activities (Wehausen, pers. comm. 2012).

Ecological Relationships

Access to forage and water resources in proximity to rugged escape habitat is critical for desert bighorn sheep (USFWS 2000). Because of the nutritive requirements for supporting reproduction and body growth, the quality of forage during these periods is important (e.g., USFWS 2000, Wehausen 2005). As noted previously, lambing recruitment is generally positively correlated with high winter precipitation. Poor quality forage may adversely affect maternal care if ewes are in poor condition and lamb mortality may be increased through malnutrition, thus adversely affecting recruitment (USFWS 2000). Although lack of water may adversely affect lactation, water sources may also attract natural predators such as mountain lion (*Puma concolor*) that prey on all age classes, and coyote (*Canis latrans*) and bobcat (*Lynx rufus*) that prey on lambs (USFWS 2000). Predation may be an important loss in very small populations, including recent transplants (Zeiner et al. 1990). For this reason, it is important to have rugged escape habitat near water sources.

In addition to being sensitive to natural predators, desert bighorn sheep may be in competition with both native and non-native animals such as mule deer (*Odocoileus hemionus*), livestock, and feral burros for water and food sources (USFWS 2000). Competition with mule deer may occur in the more northern bighorn populations, but may not be as great in the Peninsular bighorn population (USFWS 2000). Cattle, sheep, and goats may be serious direct and indirect competitors for food and water sources, and may also sources of disease (USFWS 2000). Goats in particular can forage in rugged terrain favored by desert bighorn sheep and tend to overgraze, reducing or eliminating available forage for desert bighorn sheep (USFWS 2000). Cattle and desert bighorn sheep use different habitat types for grazing/browsing (Shackleton 1985), but may compete at water sites. Sheep and goats are an issue for the northern bighorn populations due to risk of disease (Wehausen 2006; Wehausen et al. 2011), but are not currently present in the Peninsular bighorn range (USFWS 2000). Present competition with cattle in the Peninsular ranges is also limited due to general absence of cattle from bighorn habitat (USFWS 2000).

Competition with cattle and feral burros in the Mojave Desert for water and food resources may occur, but a true competition between burros and desert bighorn sheep has not been demonstrated (Wehausen 2006). It is also possible that bighorn use of water sources is affected by the presence of the non-native honeybee (*Apis mellifera*) (USFWS 2000).

Domestic sheep are the major disease source for the northern bighorn populations, and sheep contact has been associated with major bighorn die-offs (Wehausen 2006). Goats also may be a disease source for desert bighorn sheep (USFWS 2000). Diseases contracted from domestic sheep and goats are described subsequently in the Threats and Environmental Stressors Section.

Population Status and Trends

Global: Subspecies *O. c. nelsoni* is apparently secure; Peninsular bighorn DPS is vulnerable (NatureServe 2010)
State: Subspecies *O. c. nelsoni* is vulnerable; Peninsular bighorn DPS is critically imperiled (NatureServe 2010)
Within Plan Area: Same as above for Peninsular bighorn DPS.

The 2009 estimate for the northern populations of Nelson's desert bighorn sheep is a population of approximately 4,800 individuals (CDFG 2010a). This compares with an estimated population of 3,737 individuals in 1972 and 4,500 individuals in 2003 (CDFG 2010a). Although the broad estimate indicates an increasing or at least stable population, local populations have shown more variability, with some local population declines (CDFG 2010a). The most recent CDFW aerial survey counts for the northern populations of the desert bighorn sheep are shown in Table 3. The large majority of the counts are within the Plan Area, with only the White Mountains Management Unit wholly outside of the Plan Area.

Table 3. Aerial Counts of Desert Bighorn Sheep in Specified Management Units for 2009–2010.

Mountain Range	Survey Date	Ewes	Lambs	Rams	Total
Management Units Within Plan Area					
Marble Mountains	October 2009	88	34	65	187
Clipper Mountains	October 2009	13	4	16	33
Kelso Peak and Old Dad Peak	October 2009	95	15	69	179
Clark, Kingston, and Mesquite Mountains	October 2009	45	6	28	79
Orocopia Mountains	September 2009	39	7	21	67
Sheephole Mountains	May 2009	22	3	17	42
South Bristol Mountains	October 2009	44	13	26	83
South Bristol Mountains	October 2010	33	9	30	72

Table 3. Aerial Counts of Desert Bighorn Sheep in Specified Management Units for 2009–2010.

Mountain Range	Survey Date	Ewes	Lambs	Rams	Total
Cady Mountains	September 2009	92	37	38	167
Cady Mountains	October 2010	102	23	49	174
San Gorgonio Wilderness Area[1]	May 2009	48	15	20	83
Subtotal Within Plan Area[2]		**485**	**116**	**315**	**916**
Management Unit Outside Plan Area					
White Mountains	March 2009	59	16	31	106
Grand Totals		**544**	**132**	**346**	**1,022**

[1] The eastern portion of the San Gorgonio Wilderness Area is within the Plan Area. The counts may include desert bighorn using areas west of the Plan Area.
[2] Subtotal excludes the 2009 counts for the South Bristol and Cady mountains to avoid double-counting.

Source: CDFG 2010a.
Note that counts are minimum population sizes because they are based on individuals actually observed during aerial surveys. Population size is assumed to be larger.

For the Peninsular bighorn sheep, as of December 2010, there were about 950 adults in nine distinct subpopulations north of the Mexican border, which indicates an upward trend since the mid-1990s (CDFG 2010a). The highest population estimate for the Peninsular bighorn was 1,170 individuals in 1974 (CDFG 2010a). Since that time, population estimates north of the Mexican border for adults have been 570 in 1988, 400 in 1992, between 327 and 524 in 1993, 347 in 1994, 276 in 1996, and 334 in 1998 (USFWS 2000).

Threats and Environmental Stressors

The potential impacts of threats and stressors are closely related to the metapopulation population structure of desert bighorn sheep in the Plan Area. Metapopulations are characterized by groups of partially isolated populations (or subpopulations) that are typically connected by emigration and immigration pathways that allow for exchange of individuals (and genetic material) and for colonizations after local extinctions. Desert bighorn sheep exhibit such a metapopulation structure in the Plan Area in that small local populations are largely restricted to steep, isolated rocky mountain ranges that are scattered across the desert landscape and which are separated by substantial expanses of unsuitable habitat (Bleich et al. 1990; Epps et al. 2010). Based on Epps et al. (2003), there are 13 metapopulations in California, of which approximately 8 occur in the Plan Area. Within each metapopulation in the Plan Area, there are separate population groups ranging from 1 population in the San Gabriel metapopulation to 18 populations in the South Mojave metapopulation (see Table 1 in Epps et al. 2003). In the 2004 population inventory, of the most frequent population size classes in the Plan Area were either 0 or 25-100 (see Table 2 in Epps et al. 2003). As discussed in Spatial Behavior, inter-mountain movements are not rare, but conservation of the species in the Plan Area depends on maintaining intermountain habitat connectivity that allows for dispersal and migrations between populations, and recolonizations of empty habitats (Bleich et al. 1990). This intermountain habitat includes "stepping stones" within movement corridors that are not permanent habitat, but which facilitate movement (Bleich et al. 1990).

Desert bighorn sheep are threatened by loss and fragmentation of important habitats (e.g., lambing and feeding areas, escape terrain, water, travel, and dispersal routes), disease (mostly livestock derived), predation, drought, potential resource competition, and negative interactions with humans (63 FR 13136; USFWS 2000; Wehausen 2006). In addition, some of these threats are interrelated and interactive. For example, habitat fragmentation has resulted in loss of genetic diversity (Epps et al. 2005), which can result in reduced fitness and vigor and make desert bighorn sheep more vulnerable to other threat factors or stressors such as disease, drought, and predation. These kinds of threats or stressors to desert bighorn sheep are magnified in the Peninsular bighorn DPS due to reduced population numbers and consequent higher risk of extinction.

Habitat loss and fragmentation as a result of highways and aboveground canals (e.g., portions of the California aqueduct from the Colorado River to western Riverside County) and high densities of human habitation present obstacles to movement of desert bighorn sheep between mountain ranges that can interfere with the natural metapopulation structure of desert bighorn in the Plan Area. There is essentially no migration across the Interstate highways (Wehausen, pers. comm. 2012). These physical obstacles limit the potential for natural colonization of vacant areas and gene exchange among subpopulations, which are critical to metapopulation viability (CDFG 2010a; Epps et al. 2005; Wehausen 2006). Epps et al. (2005) examined 27 separate bighorn populations in the central and southern Mojave Desert and northern Sonoran Desert had a rapid reduction in genetic diversity (up to 15%) in the 40 years or less of anthropogenic isolation. They concluded that these barriers have eliminated gene flow among populations, and that isolated populations could lose up to 40% of their pre-isolation genetic diversity over the next 60 years.

Historically, disease contracted from domestic sheep has probably been the greatest factor in desert bighorn sheep population declines throughout its range in North America (USFWS 2000; Wehausen 2006). Extensive domestic sheep grazing in northeastern California, northern Nevada, southwestern Idaho, Oregon, and Washington, likely lead to the extirpation of all native populations in these regions. In contrast, where domestic sheep grazing has not been economical, such as Canada and Alaska, little change has occurred in the distribution of native sheep (Wehausen 2006).

Wehausen et al. (2011) provide a comprehensive review of experimental research on the risk of respiratory disease transmission from domestic sheep to bighorn sheep (the so-called "contact hypothesis), including (1) contact trials between bighorn sheep, domestic sheep and other native and domestic animals; (2) inoculation experiments with no animal contact; (3) studies to isolate and identify specific organism (i.e., bacterial strains and other pathogens) that may be responsible for pneumonia in bighorn sheep; and (4) vaccination experiments. Their review found that the experimental evidence supports the contact hypothesis. Contact between domestic sheep and bighorn sheep, as well as inoculation with certain strains of the bacteria *Mannheimia haemolytica* cultured from the respiratory tracts of domestic sheep, has a high probability of causing fatal pneumonia in the bighorn sheep. At least one study also found that *Pasturella multicoda* cultured from a flock of wild and domestic sheep cause fatal pneumonia in bighorn sheep (Callan et al.

1991). As a test of the domestic sheep-bighorn sheep contact hypothesis, contact trials between bighorn sheep and other native and domestic animals produce low disease and mortality rates, indicating that the high disease and mortality rates of bighorn sheep in contact with domestic sheep are not an artifact of captivity (which was an alternative hypothesis) (Wehausen et al. 2011). The studies of specific organisms responsible for pneumonia in bighorn sheep after contact with domestic sheep failed to clearly identify specific causes (possibly due to the complexity of the disease and/or the sensitivity of culturing methods in identifying the sampled microbial community); nonetheless, the research has clearly demonstrated a negative effect of direct contact between bighorn sheep and domestic sheep despite uncertainty of the nature of the pathogen. Finally, vaccinations failed to reduce the spread of respiratory disease and vaccination is probably not an effective management tool, both because it apparent lack of effectiveness and the logistical challenges in treating wild populations (Wehausen et al. 2011).

Predation is also a significant factor in desert bighorn sheep mortality, with mountain lion being the major predator. In the Kingston, Clark, and Granite mountains, considerable predation by mountain lion has been documented (Jaeger 1994; Wehausen 1996). In the Granite Mountains, mountain lion predation caused a steep population decline in the desert bighorn sheep population, with the population reduced to 8 ewes for a period of 3 years (Wehausen 1996). In this study all mortalities in the first 3 years of the study were from mountain lion predation (Wehausen 1996). Predation abated after the first 3 years of the study and the population rebounded at 15% annually the next 3 years (Wehausen 1996). Areas of the Mojave Desert where mountain lion predation is a threat to desert bighorn sheep also support populations of native or introduced deer, which is the mountain lion's primary prey (Wehausen 2006). At least four radio-collared male desert bighorn sheep in the eastern Mojave Desert were killed by mountain lions; predation of females was not confirmed and only males tended to use habitats with mountain lions (Bleich et al. 1997). In the Peninsular Ranges, predation is also a frequent cause of mortality. Of 61 documented mortalities of radio-collared sheep from 1992 to 1998 between Highway 74 in the Santa Rosa Mountains and the Mexican border, 42 were attributed to mountain lion (USFWS 2000). Another study of mortality conducted from 1991 to 1996 in the northern Santa Rosa Mountains found that predation accounted for 9 of 32 adult desert bighorn sheep mortalities, of which, 8 were due to mountain lion predation and 1 due to either mountain lion or bobcat predation (USFWS 2000). Coyote and bobcat also prey on desert bighorn sheep, but are more likely to take lambs; a study showed that of nine lamb mortalities recorded in 1998 and 1999, five were attributed to coyote or bobcat predation (USFWS 2000).

Prolonged drought periods can also cause population declines (USFWS 2000; Wehausen 2006). As discussed previously, high-quality forage associated with winter precipitation and water sources are important to support reproduction (e.g., USFWS 2000; Wehausen 2005, 2006). Lamb recruitment is reduced during periods of drought because gestation or lactation is disrupted or maternal care by ewes in poor condition is reduced, leaving the lambs vulnerable to malnutrition and predation. Drought can increase competition with native and non-native species, such as livestock, for food and water sources (Wehausen 2006). Competition for water sources can also increase congregations around water, thus increasing the risk of disease transmission (USFWS 2000). Epps et al. (2004) examined whether local extinctions of historical desert bighorn sheep populations are correlated with regional climate patterns and found that elevation, precipitation, and availability of dependable springs are strongly related to population persistence. They concluded that climate has already affected local extinction patterns and that desert bighorn sheep are vulnerable to the effects of future climate change, especially if precipitation is reduced in association with climate change. However, while observations of local extinctions are consistent with directional climate change, Epps et al. (2004) also noted that natural climate stochasticity cannot be ruled out as a factor, with population expansions during cooler wetter periods and retreats during periods of increase drought frequency and intensity. It is unknown long-term climate change is the cause of current population trends (Epps et al. 2004).

Within the Peninsular Ranges, negative interactions with humans and pets, and other urban-related factors, are a threat to the Peninsular bighorn sheep (USFWS 2000). In addition to loss and fragmentation of habitat due to urban and rural development, more than 30% of mortalities in one study were directly attributable to human activities, including vehicle collisions, poisoning, and entanglement in fences (USFWS 2000). Humans, pets, off-road vehicles, construction activities, and aircraft also can affect desert bighorn sheep behavior (Leslie and Douglas 1980; USFWS 2000). These factors can affect desert bighorn sheep to the extent that essential activities, such as foraging or the use of important areas (e.g., water sources, mineral licks, lambing areas, traditional movement routes), are disrupted, which can affect the viability of populations through reduced lamb recruitment (USFWS 2000). Human activities may also induce physiological stress such as increased heart rate, which can affect the health of desert bighorn sheep individuals and lamb recruitment (USFWS 2000). Impacts related to human activities may also occur in the northern populations. However, with the exception of livestock grazing and some recreational activities, impacts would be expected to be less frequent or severe due to reduced human activity in the more remote areas occupied by desert bighorn sheep.

Non-native plants used for landscaping, such as oleander (*Nerium oleander*) and laurel cherry (*Prunus laurocerasus*), have been implicated in the poisoning of desert bighorn sheep (USFWS 2000). Tamarisk (*Tamarix* spp.) is highly consumptive of water, reducing critical surface water sources for desert bighorn sheep (USFWS 2000).

Mortality in a desert bighorn sheep population in the vicinity of Old Dad Peak was linked to type C botulinum (*Clostridium botulinum*) poisoning near two artificial water catchments (guzzlers) (Swift et al. 2000). The investigators reconstructed the probable cause of the poisoning as 13 lambs that fell into and drowned in one guzzler tank while attempting to drink from the top of the tank. A hatch cover had become dislodged when the drinker trough was dry because the tank valve was closed. The decaying lamb carcasses served as the substrate for the growth of *Clostridium botulinum*, which other individuals ingested after a rain increased water levels and allowed sheep to drink from the source (Swift et al. 2000).

Conservation and Management Activities

The Bureau of Land Management (BLM), CDFG, state parks, National Park Service, and private non-profit organizations (the Bighorn

Institute, the Anza-Borrego Foundation, Society for the Conservation of Bighorn Sheep, and Desert Wildlife Unlimited, Inc.) have planned implemented and/or participated in numerous conservation and management actions that benefit the desert bighorn sheep.

Conservation and management activities undertaken by the BLM to benefit the Peninsular desert bighorn sheep include the following actions identified in the Recovery Plan (USFWS 2000):

- Installation of gap fencing to eliminate cattle grazing from steep terrain and from water sources in canyons
- Reduction in grazing pressure on allotments
- Closure of most routes of travel east of McCain Valley Road, except to private inholdings, to ranchers, and to Carrizo and Sacatone overlooks
- Designation of wilderness study areas and subsequent management for non-impairment of wilderness values
- Designation of Jacumba, Carrizo Gorge, Coyote Mountains, Sawtooth Mountains, Fish Creek Mountains, and Santa Rosa wilderness areas by Congress, with attendant elimination of vehicular access
- Tamarisk control efforts around water sources
- Establishment of the Santa Rosa Mountains National Scenic Area Visitors Center to provide public education
- Financial assistance to the Bighorn Institute during its formative years, as well as land transfer and lease under the Recreation and Public Purposes Act
- Temporary closure to dogs on most lands in the Santa Rosa Mountains National Scenic Area
- Closure of roads into Dead Indian Canyon and Carrizo Canyon
- Designation of Santa Rosa and San Jacinto Mountains National Monument, which will prohibit mining and off-road vehicle use on federal lands, support coordinated land management by federal agencies, and increase the area's funding priority.

The BLM also issued an Instruction Memorandum in 1992 regarding domestic sheep grazing, such that domestic sheep should not be allowed within 9 miles of desert bighorn habitat, except where topographic features or other barriers prevent physical contact. Also, domestic sheep trailed and grazed outside the 9-mile zone in the vicinity of desert bighorn sheep habitat should be closely managed and carefully herded (Wehausen 2006).

CDFG manages desert bighorn sheep populations throughout much of the state through the Desert Bighorn Sheep Conservation Program (CDFG 2010a). In accordance with Section 1801 of the California Fish and Game Code, the state policy is to preserve, restore, utilize, and manage the desert bighorn sheep population. Limited harvest of desert bighorn sheep (excluding the Peninsular DPS and the Sierra Nevada bighorn sheep (*O. c. sierra*) which are fully protected) in selected areas is provided by state law for biologically sound management (CDFG 2010a). Management of desert bighorn sheep includes sport hunting of rams, with a limit on hunting tags for no more than 15% of the ram population in a single year (CDFG 2010a). As part of the management program, CDFG is required to report the status of management units; summarize counts of individuals in specified management units (see Table 3); report the number of hunting tags issued; summarize unlawful take of desert bighorn sheep; report the number of individuals translocated; and track the environmental impacts of hunting (CDFG 2010a).

CDFG conducts periodic inventories of the distribution of desert bighorn sheep in California in specific management units to assess population trends and provide the basis for issuance of hunting tags (see Table 3 for the 2009–2010 counts).

CDFG has also prepared management plans for a number of the major herds in California. The CDFG Desert Bighorn Sheep Management Program is currently preparing a range-wide management program that will provide a strategy to conserve populations throughout the state (CDFG 2010a). In 2010, draft regional management plans were prepared and submitted for approval for the Cady Mountains and South Bristol Mountains management units (CDFG 2010a). These plans address the following issues (CDFG 2010b, 2010c):

1. The numbers, age, sex ratios, and distribution of desert bighorn sheep within the management unit

2. Range conditions and a report on the competition that may exist as a result of human, livestock, wild burro, or any other mammal encroachment
3. The need to relocate or reestablish bighorn populations
4. The prevalence of disease or parasites within the population
5. Recommendations for achieving the policy objective of Section 4900, which addresses the potential for limited hunting opportunities for desert bighorn sheep.

A management objective of the state conservation program is to re-establish desert bighorn sheep on historical ranges (CDFG 2010a). Since 1983, CDFG has translocated almost 500 individuals (including the Sierra Nevada subspecies *O. c. sierrae*).

CDFG also conducts capture-sample-radio collar-release studies for research purposes. In 2010, 10 individuals were captured-collared-released in the Santa Rosa and Vallecito mountains, including 9 ewes and 1 ram (CDFG 2010a).

Anza-Borrego Desert State Park supports a majority of the range-wide Peninsular bighorn sheep population in California. Anza-Borrego Desert State Park has been actively involved in the conservation of Peninsular bighorn sheep for 30 years. Specific activities relevant to the DRECP that were identified in the Recovery Plan (USFWS 2000) are as follows:

- Construction of guzzlers to supplement water supplies
- Annual monitoring (conducted for 40 consecutive years; California Department of Parks and Recreation 2009)
- Research into bighorn sheep ecology and threats
- Tamarisk removal from riparian areas within bighorn sheep habitat to enhance water availability and native plant community regeneration (approximately 120 miles of canyons and stream courses had been treated by 2000)
- Seasonal access closure of bighorn sheep watering areas from June 1 to October 1
- Remove feral cattle from bighorn sheep habitat

- Construct gap fencing to keep stray cattle from entering bighorn sheep habitat
- Public outreach, including production of a 15-minute movie "The Bighorn of Anza-Borrego"
- Closure of some areas to vehicular traffic.

The National Park Service has conducted burro removal from their lands in the Mojave Desert, with the goal of removing all approximately 1,300 burros from the Mojave National Preserve between 1998 and 2001. (http://www.nature.nps.gov/yearinreview/yir98/chapter06/chapter06pg2.html). Although true competition between desert bighorn sheep and burros has not been demonstrated (Wehausen 2006), burros have caused adverse impacts on native plant communities, wildlife, soils, water quality (http://www.nature.nps.gov/yearinreview/yir98/chapter06/chapter06pg2.html).

The Bighorn Institute is a nonprofit organization formed in 1982 that investigates the causes of desert bighorn sheep declines, particularly among Peninsular bighorn sheep. The institute began monitoring radio-collared desert bighorn sheep in the northern Santa Rosa Mountains in 1982 and the San Jacinto Mountains in 1992. Research activities conducted by the institute include the ecology of bighorn populations in the Santa Rosa and San Jacinto mountains, lamb ecology, captive breeding and wild population augments, annual population surveys, and disease research (Bighorn Institute 2011).

The Anza-Borrego Foundation is the nonprofit cooperating association for the Anza-Borrego Desert State Park and is a sponsor for the annual desert bighorn sheep count, which has been conducted from 1971 through 2010.

The Society for Conservation of the Bighorn Sheep (SCBS) is a nonprofit organization established in 1964 that has several programs for restoring desert bighorn sheep (http://sheepsociety.com/) in coordination with CDFG and BLM. The SCBS provides labor to help conduct censuses and to establish "drinker" sites and also conducts water monitoring (including remote water monitoring stations that record available water at drinkers and precipitation) and water hauling to supplement water at some sites. SCBS maintains remote trail cameras to monitor wildlife use of water sites. SCBS also has "Area Captains" that volunteer under the auspice of CDFG and conduct inspections of the drinkers twice a year and "Hot Shot Crews" that conduct repair and maintenance at drinkers.

Desert Wildlife Unlimited, Inc. is also involved in providing and maintaining Drinkers for desert wildlife, including desert bighorn sheep (http://www.desertwildlifeunlimited.com/home/). They employ 12,000 gallon fiberglass tanks with a step drinker attached, which require relatively little maintenance.

Data Characterization

Data availability for desert bighorn sheep is excellent and represents one of the best population datasets for any managed species in California. In particular, the Peninsular bighorn sheep DPS has been monitored annually since 1971. Furthermore, extensive research on the ecology of the desert bighorn sheep has yielded an excellent understanding of its habitat and ecological relationships.

The CDFG, State Parks, Anza-Borrego Foundation, and the Bighorn Institute conduct periodic assessments of the desert bighorn sheep populations in California, including portions of the Peninsular bighorn DPS. CDFG assessments are based on historical and current data from ground, waterhole, and aerial surveys that are suitable for estimating population size classes (CDFG 2010a). The Bighorn Institute conducts annual assessments of bighorn populations in the Northern Santa Rosa and San Jacinto mountains, and includes radiotemeletry data to study habitat use, reproduction, survival, mortality, and general ecology (Bighorn Institute 2011). The annual desert bighorn sheep count in Anza-Borrego Desert State Park has been conducted annually since 1971 and includes mid-summer counts of ewes, lambs, male and female yearlings, and rams in about 21 different locations in the park (California Department of Parks and Recreation 2009).

Management and Monitoring Considerations

The CDFG (2010b, 2010c) identified several management and monitoring considerations for desert bighorn sheep, including demography (numbers, age, sex ratios, and distribution of desert bighorn sheep within management units); range conditions; relocation or reestablishment of populations; and the prevalence of disease or parasites.

The BLM West Mojave Plan determined that the best way to ensure the long-term viability of desert bighorn sheep metapopulations would be by preventing further population losses and fragmentation and restoring populations in vacant historical habitat. Natural and induced colonization may require artificial enhancement of populations, such as water developments (Wehausen 2006). Contact between domestic sheep and desert bighorn sheep should be prevented by eliminating or carefully managing sheep grazing in the vicinity of desert bighorn sheep habitat (Wehausen 2006). To ensure reliable water supply during the summer months, key water sources within current and historical desert bighorn sheep habitat should be closely monitored and potentially enhanced. Water enhancement may promote development of large desert bighorn sheep populations that may produce natural colonists to reestablish populations in vacant habitat (Wehausen 2006). However, because water sources may also enhance the populations of desert bighorn sheep predators, such as mountain lion, coyote, and bobcat, water enhancement should be limited.

The federal *Recovery Plan for Bighorn Sheep in the Peninsular Ranges, California* (USFWS 2000) identified improving adult survivorship as likely the strongest positive influence on Peninsular bighorn population dynamics in the short term. Over the long term, conservation and effective management of conserved lands are needed to recover the Peninsular bighorn sheep. Minimizing adverse effects of human disturbance by preventing further fragmentation is critical to the persistence of ewe groups bordering the Coachella Valley. Maintaining adequate buffers between urban development and Peninsular bighorn sheep habitat, and effective management of human activities within ewe group home ranges is needed (USFWS 2000).

Habitat fragmentation and population isolation has led to decreased genetic diversity in small isolated populations (Epps et al. 2005). Fragmentation of metapopulations from fenced highways, aqueducts, and losses of some populations should not be permitted. Epps et al.

(2005) recommend that existing barriers to movement should be mitigated and new highways in desert bighorn sheep habitat should be designed to minimize disruption of connectivity. Fencing near existing drainage undercrossings should be modified to allow access to the undercrossings and construction of overpasses should be considered to reestablish connectivity (Epps et al. 2005).

When reintroduction stock is available, historical habitat should be restocked to maximize connectivity and the number of populations in remaining metapopulations. Although evidence suggests that existing metapopulations can remain viable if adequately managed and intermountain travel corridors are maintained, opportunities to reestablish connections across recent artificial barriers that now define metapopulations should be considered (Wehausen 2006).

Species Modeled Habitat Distribution

The habitat model used for the Plan Area was provided by BLM and depicts mountain ranges and intermountain habitat for desert bighorn sheep suitable for both supporting local populations (i.e., mountain habitat) and movement (i.e., intermountain habitat). There are 12,872,136 acres of modeled suitable habitat for desert bighorn sheep in the Plan Area, including 7,976,800 acres of mountain habitat and 4,893,423 acres of intermountain habitat.

Literature Cited

63 FR 13135. Final rule: "Endangered and Threatened Wildlife and Plants; Endangered Status for the Peninsular Ranges Population Segment of the Desert bighorn sheep in Southern California." March 18, 1998.

74 FR 17288–17365. Final rule: "Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Peninsular Bighorn Sheep and Determination of a Distinct Population Segment of Desert Bighorn Sheep (*Ovis canadensis nelsoni*)." April 14, 2009.

Bighorn Institute. 2011. "Facts About Bighorn Sheep," "Our Mission," and "Research Projects." Accessed March 8, 2011. http://www.bighorninstitute.org/index.htm.

Bleich, V.C., J.D. Wehausen, and S.A. Holl. 1990. "Desert-Dwelling Mountain Sheep: Conservation Implications of a Naturally Fragmented Distribution." *Conservation Biology* 4:383-390.

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 D.R. McCullough, editor. Metapopulations and wildlife conservation. Island Press, Covelo, California, USA.

Bleich, V.C., R.T. Bowyer, and J.D. Wehausen. 1997. "Sexual Segregation in Mountain Sheep: Resources or Predation?" *Wildlife Monographs* 134:1-50.

CDFG (California Department of Fish and Game). 2010a. *Biennial Report to the Legislature Regarding Bighorn Sheep Management.* December 2010. Accessed March 9, 2011. http://www.dfg.ca.gov/wildlife/hunting/sheep/docs/BighornReporttoLegislature2010.pdf.

CDFG. 2010b. *Bighorn Sheep Management Plan: Cady Mountains Management Unit*. Sacramento, California: California Department of Fish and Game. 16 pp.

CDFG. 2010c. *Bighorn Sheep Management Plan: South Bristol Mountains Management Unit*. Sacramento, California: California Department of Fish and Game. 15 pp.

CDFW (California Department of Fish and Wildlife). 2013. *"Ovis canadensis nelsoni*." And Element Occurrence Query. California Natural Diversity Database (CNDDB). RareFind, Version 4.0 (Commercial Subscription). Sacramento, California: CDFW, Biogeographic Data Branch. Accessed September 2013. http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp.

California Department of Parks and Recreation. 2009. "Sheep Counters: July 5, 2009." Borrego Springs, California: Anza-Borrego Desert State Park. Accessed March 8, 2011. http://theabf.org/files/images/2009_SheepCount.pdf.

Callan, R.J., T.D. Bunch, G.W. Workman, and R.E. Mock. 1991. "Development of Pneumonia in Desert Bighorn Sheep After Exposure to a Flock of Exotic Wild and Domestic Sheep." *Journal of the American Veterinary Medical Association* 198:1052-1056.

Cowan, I. Mc T. 1940. "Distribution and Variation in the Native Sheep of North America." *American Midland Naturalist* 24:505-580.

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* 50:153-156.

Dudek. 2013. "Species Occurrences– *Ovis canadensis nelsoni*." DRECP Species Occurrence Database. Updated September 2013.

Epps, C.W., V.C. Bleich, J.D. Wehausen and S.G. Torres. 2003 "Status of Bighorn Sheep in California, 2004." *Desert Bighorn Council Transactions* 47:20–35.

Epps, C.W., D.R. McCollough, J.D. Wehausen, V.C. Bleich, and J.L. Rechels. 2004. "Effects of Climate Change on Population Persistence of Desert-Dwelling Mountain Sheep in California. *Conservation Biology* 18:102-113.

Epps, C.W., P.J. Palsbøll, J.D. Wehausen, G.K. Roderick, R.R. Ramey II, and D.R. McCullough. 2005. "Highways Block Gene Flow and Cause a Rapid Decline of Desert Bighorn Sheep." *Ecology Letters* 8:1029-1038.

Epps, C.W., J.D. Wehausen, V.C. Bleich, S.G. Torres, and J.S. Brashares. 2007. "Optimizing Dispersal and Corridor Models Using Landscape Genetics." Journal of Applied Ecology 44:714-724.

Epps, C.W., J.D. Wehausen, P.J. Palsbøll, and D.R. McCullough. 2010. "Using Genetic Tools to Track Desert Bighorn Sheep Colonizations." *Journal of Wildlife Management* 74(3):522-531.

Jaeger, J. 1994. "Demography and movements of mountain sheep (*Ovis canadensis nelsoni*) in the Kingston and Clark Mountain ranges, California." M.S. Thesis; University of Nevada, Las Vegas. 64 pp.

Leslie, D.M. Jr. and C.L. Douglas. 1980. "Human Disturbance at Water Sources of Desert Bighorn Sheep." *Wildlife Society Bulletin* 84:284-290.

Miller, G.D. and W.S. Gaud. 1989. "Composition and Variability of Desert Bighorn Sheep Diets." *Journal of Wildlife Management* 53:597-606.

NatureServe. 2010. "Bighorn Sheep." "NatureServe Explorer: An Online Encyclopedia of Life" [web application]. Version 7.1. Arlington, Virginia: NatureServe. Accessed March 2011. http://www.natureserve.org/explorer.

Ramey, R. R. II. 1995. "Mitochondrial DNA Variation, Population Structure, and Evolution of Mountain Sheep in the South-Western United States and Mexico." *Molecular Ecology* 4:429-439.

Rubin, E.S., W.M. Boyce, and V.C. Bleich. 2000. "Reproductive Strategies of Desert Bighorn Sheep." *Journal of Mammalogy* 81:769-786.

Shackleton, D. M. 1985. "*Ovis Canadensis.*" *Mammalian Species* 230: 1–9.

Shackleton, D. M., R.G. Petersen, J. Haywood, and A. Bottrell. 1984. "Gestation Period in *Ovis canadensis*." *Journal of Mammalogy* 65:337-338.

Swift, P.K., J.D. Wehausen, H.B. Earnest, R.S. Singer, A.M. Pauli, H. Kinde, T.E. Rocke, and V.C. Bleich. 2000. "Desert Bighorn Sheep Mortality Due to Presumptive Type C Botulism in California." *Journal of Wildlife Diseases* 36:184-189.

USFWS (U.S. Fish and Wildlife Service). 2000. *Recovery plan for bighorn sheep in the Peninsular Ranges, California*. Portland, Oregon: U.S. Fish and Wildlife Service. xv+251 pp.

Wehausen, J.D. 2012. Personal communication (email and profile review comments) from J.D. Wehausen to M. Unyi (ICF). May 10, 2012.

Wehausen, J.D. 1996. "Effects of Mountain Lion Predation on Bighorn Sheep in the Sierra Nevada and Granite Mountains of California." *Wildlife Society Bulletin* 24:471-479.

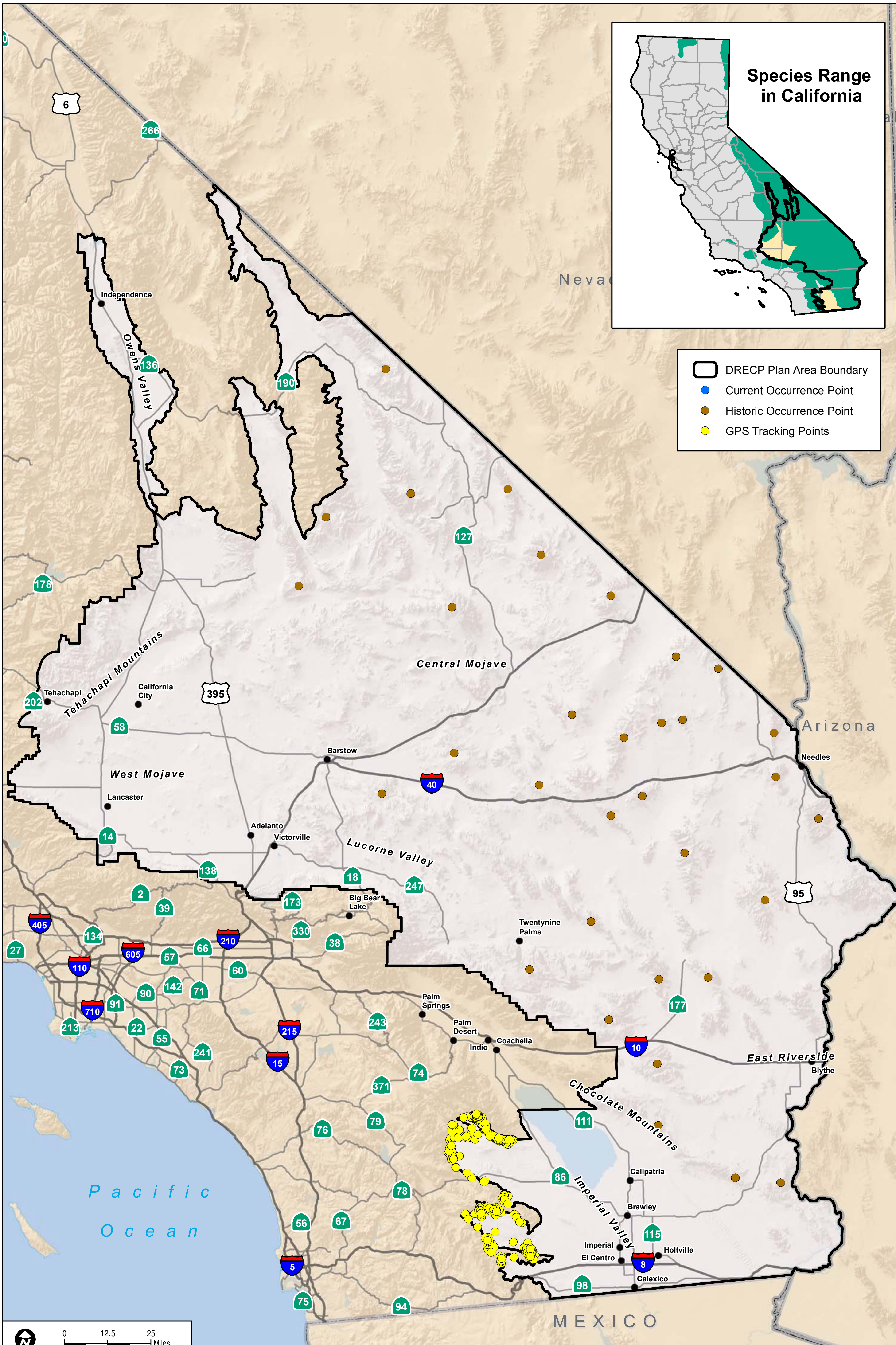
Wehausen, J.D. 2005. "Nutrient Predictability, Birthing Season, and Lamb Recruitment for Desert Bighorn Sheep. Pages 37-50 in J. Goerrissen and J. M André, eds. Sweeney Granite Mountains Desert Research Center 1978-2003: A Quarter Century of Research and Teaching. University of California Natural Reserve Program, Riverside, CA 2005.

Wehausen, J.D. 2006. "Nelson Bighorn Sheep." West Mojave Plan Species Accounts. U.S. Department of the Interior, Bureau of Land Management. January 2006. Accessed March 3, 2011. http://www.blm.gov/ca/pdfs/cdd_pdfs/Bighorn1.PDF.

Wehausen, J.D., S.T. Kelley, and R.R. Ramey II. 2011. "Domestic Sheep, Bighorn Sheep, and Respiratory Disease: A Review of the Experimental Evidence. California Fish and Wildlife 97:7-24.

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.

Zeiner, D.C., W.F. Laudenslayer Jr., K.E. Mayer, and M. White, eds. 1990. "CWHR: Life History Accounts and Range Maps." Originally published in *California's Wildlife, Volume III: Mammals*. Accessed online October 5, 2010. http://www.dfg.ca.gov/biogeodata/cwhr/awildlife.aspx.



Sources: ESRI (2014); DRECP Species Occurrence Database (2013), CDFW (2013); CWHR (2008)

FIGURE SP-M01

Bighorn Sheep Species Occurrences in the Plan Area