California Department of Fish and Wildlife
Region 6

# Desert Bighorn Sheep Status Report

## November 2013 to October 2016

A summary of desert bighorn sheep population monitoring and management by the California Department of Fish and Wildlife

Authors: Paige Prentice, Ashley Evans, Danielle Glass, Richard Ianniello, and Tom Stephenson

*Inland Deserts Region*

**California Department of Fish and Wildlife**
**Inland Deserts Region**
**787 N. Main Street Ste. 220**
**Bishop, CA 93514**
**www.wildlife.ca.gov**

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Cover photo: A chocolate-brown ram photographed by Regina Abella during helicopter surveys in the Chuckwalla Mountains in October 2016.

## Executive Summary

Desert bighorn sheep (*Ovis canadensis nelsoni*) historically occupied more than 60 mountain ranges in California (Figure 1). This report documents data collection and management actions performed by California Department of Fish and Wildlife's (CDFW) Bishop Field Office between November 1, 2013 and October 31, 2016. The Bishop Field Office monitors desert bighorn populations within Region 6. This includes the White Mountains in the north to Highway 62 in the south, the Nevada border in the east, and California's Highway 395 in the west.

In California, desert bighorn monitoring has been conducted since early in the second half of the twentieth century, but starting in 2013 CDFW entered an era of renewed emphasis on data collection due to the outbreak of respiratory disease, first documented at Old Dad Peak. That disease epizootic was, and continues to be, the largest documented disease outbreak in California's Nelson bighorn sheep populations. This report summarizes monitoring efforts and management actions from November 1, 2013 through October 31, 2016; it also includes survey work conducted from May 2015 through the end of October 2016. May 2015 marked the hiring of field personnel dedicated to desert bighorn in the Bishop Field Office. During 2013-2016, CDFW conducted eight ground surveys, flew the first helicopter surveys in five years, captured and collared over 170 bighorn across thirteen mountain ranges, recovered 25 mortalities, and helped repair and bring water into bighorn drinker systems, as needed.

One of CDFW's management goals is to prevent further fragmentation of desert bighorn populations and to re-connect the four focal metapopulation fragments into a single functional metapopulation (CDFW, draft Desert Bighorn Sheep Management Plan). We monitor demography and habitat use at the herd and metapopulation level. We rely on collared animals to monitor survival, cause-specific mortality, habitat use, and range connectivity. Desert bighorn are captured and collared with global positioning system (GPS) and very high frequency (VHF) telemetry collars. Additionally, ground, helicopter, and water-source surveys are conducted for the following data: minimum counts, population size estimates (mark-resight, simultaneous double count), and reproductive success (lamb:ewe ratios). We also occasionally use remote cameras and fecal DNA to produce mark-recapture estimates. Management actions include: disease risk management, monitoring and maintenance of water developments, and hunting.

The current surge of research in the desert and the work carried out as part of this effort could not have been completed without the help and collaboration of Oregon State University, the National Park Service, the Bureau of Land Management, and the volunteers that work with the Society for the Conservation of Bighorn Sheep and the California Chapter of the Wild Sheep Foundation.

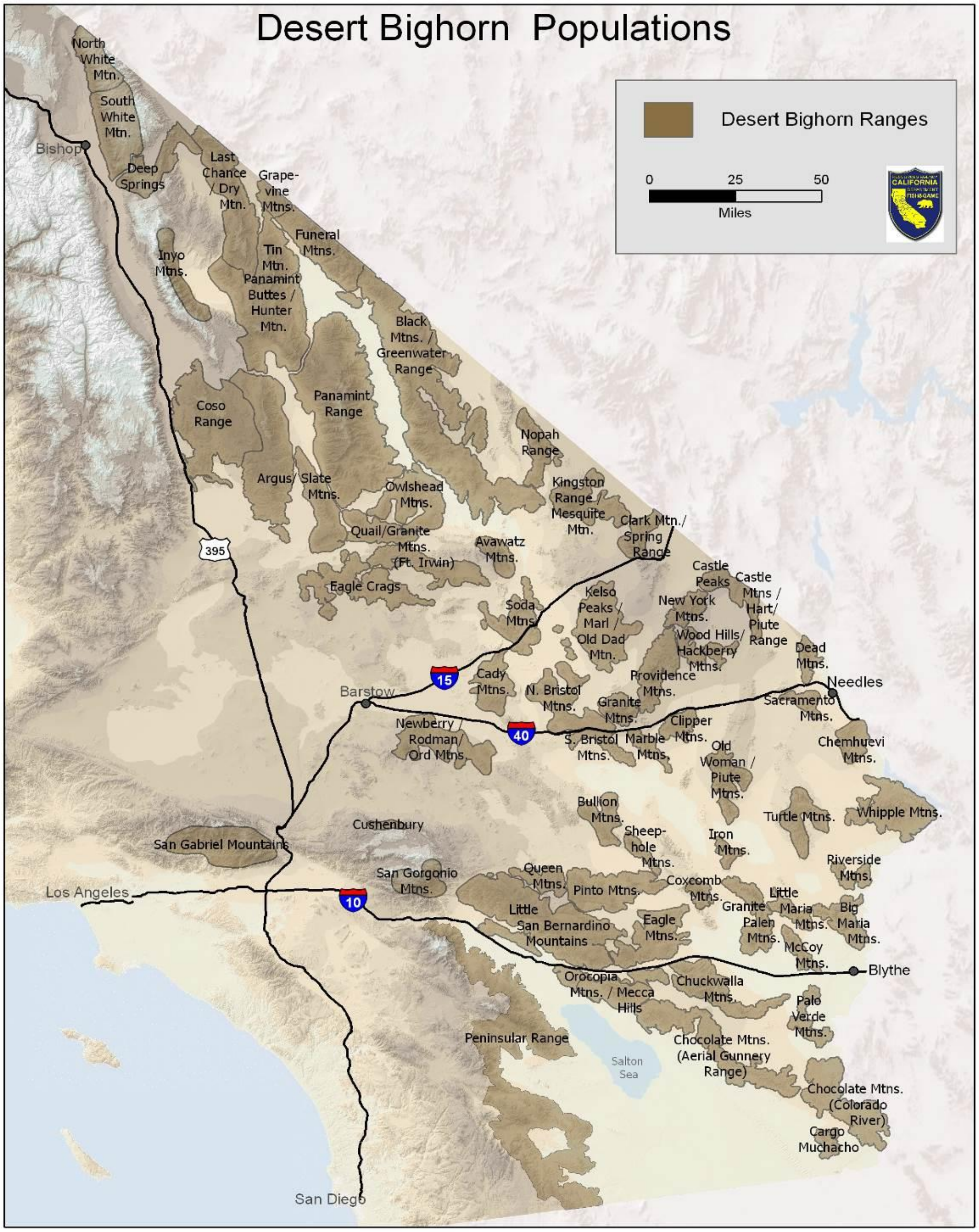


*Figure 1. Historically occupied ranges of desert bighorn sheep (Ovis canadensis nelsoni) in Southern California.*

# Desert Bighorn Sheep Status Report

November 2013 to October 2016

Region 6

The purpose of this status report is to summarize desert bighorn sheep (*Ovis canadensis nelsoni*) work done by the California Department of Fish and Wildlife (CDFW) Bishop Field Office between November 2013 and October 2016. The bulk of this document describes data collection, including methods and results. The results are primarily raw data. Subsequent data analyses will be presented in other reports and publications, with some including collaborators. The Bishop Field Office monitors desert bighorn populations within Region 6. This includes the White Mountains in the north to Highway 62 in the south, the Nevada border in the east, and California's Highway 395 in the west.

Ranges south of Highway 62 and the San Gorgonio, San Gabriel, and Sespe ranges are managed by CDFW Regional offices nearer those ranges. Bighorn sheep in the Peninsular Ranges are geographically isolated from the rest of the population of desert bighorn in California and are listed as an endangered population segment of *Ovis canadensis nelsoni* at both state and federal levels. The Peninsular Ranges bighorn are primarily managed by Region 5 under a specific recovery program.

# I. Monitoring

CDFW considers the monitoring of desert bighorn populations at both the herd and metapopulation levels essential for the management of this species. Individual herds are monitored by collecting data on population size, recruitment, survival, movement, and herd health; whereas, the metapopulation is monitored by documenting extinctions, colonizations, range connectivity, and gene flow. The overarching management goals for desert bighorn in California are outlined in CDFW's draft "Desert Bighorn Management Plan." Similarly, the specific long term goals for the individual management units will be outlined in subsequent range-specific documents.

Due to limited personnel and the large geographic area, it is currently not possible for CDFW to monitor all occupied and unoccupied mountain ranges. Consequently, there are different intensity levels of population monitoring: occupancy (presence/absence), rotational (data collected every 3-7 years), biennial, and annual (Figure 5, page 13). The annual and biennial population monitoring efforts are implemented in current hunt zones, potential hunt zones, and other ranges that are considered critical to the connectivity of a region. Furthermore the ranges that are surveyed annually are considered "core index populations" and were chosen as potential representatives of the ranges around them. If a major change is detected within a population then additional effort will be directed to the surrounding populations to investigate the potential of a region-wide phenomenon, and to attempt to identify and/or address the potential cause. Other ranges that are known to have bighorn, but are not currently prioritized to be surveyed annually, or biennially, are scheduled to be surveyed via ground, helicopter, or camera every 3-7 years. Finally, ranges that are currently believed to be extirpated will be checked every 3-7 years for signs of occupancy. All ranges are subject to shifts between the different intensity levels of population monitoring.

## *A. Data Collection Methods*

We monitor population size, annual rate of population change, fecundity, survival, resource selection, habitat use, and disease status. Individuals are monitored using global positioning system (GPS) and very high frequency (VHF) collars. In addition, we conduct walking-ground surveys, helicopter surveys, cameras surveys at water sources in the hot season, and we systematically collect fecal samples for genotyping.

### 1. Capture Methods

During this reporting period, desert bighorn were captured by experienced helicopter capture specialists from Leading Edge Aviation. Bighorn were captured using a net gun fired from the helicopter at close range (Krausman et al. 1985). After firing the net, one or two crew members exited the aircraft and manually restrained the bighorn sheep, which were blindfolded and hobbled for processing. No chemical immobilization was required for this technique. Captured bighorn sheep were then either processed in the field or transported via helicopter to a base camp.

*Figure 2: A collared ewe with a unique combination of ear tags. Collared animals were used in mark-resight analyses to estimate population size.*

During processing, blood was collected by jugular venipuncture in serum and EDTA tubes. Blood was later assayed for trace minerals and tested for exposure to a variety of disease pathogens. Age was estimated by horn rings and tooth replacement. Nasal swabs, hair, and fecal samples were collected for disease testing and archived. Samples were processed as per the methods and locations identified by the CDFW Wildlife Investigations Lab (WIL). For animals processed at base camp, morphometric measurements were recorded and ultrasonography was used to measure maximum subcutaneous fat thickness on the rump and to determine a body condition score. Total body fat was estimated using predictive equations similar to those developed for deer (Stephenson et al. 2002, Cook et al. 2010). Pregnancy was determined by ultrasonography in base camp, and by serum assay for pregnancy-specific protein B for ewes processed in the field (Stephenson et al. 1995). A CDFW veterinarian was present at base camp to ensure the health of each individual and to attend to any injuries or concerns. Disease testing included serologic testing for the following antibodies: bluetongue virus, bovine herpes virus, bovine respiratory syncytial virus (BRSV), border disease virus, contagious ecthyma, epizootic hemorrhagic disease virus, parainfluenza virus 3 (PI-3), and *Mycoplasma ovipneumoniae (M. ovi.).*

Captured bighorn sheep were fitted with VHF and GPS collars and all bighorn were marked with numbered and colored ear tags (Figure 2). VHF collars stay on the animals for the remainder of their lives and have a battery life of 4-8 years. GPS collars have a battery life of 3-5 years. Care was taken to ensure that all collars fit snugly and did not slide up and down the animal's neck. After handling was complete, bighorn sheep were transported via helicopter to their initial capture location and the capture crew released the animal. The handling of each animal, from capture to release, took approximately 60 minutes.

## 2. Survey Methods

### Ground Surveys

Ground surveys were conducted by a group of trained observers hiking through bighorn habitat in a mountain range over the course of one to several days. Observers worked in teams of 1-3 and were equipped with spotting scopes, binoculars, and a map of their survey route. Each team also carried a radio or cell phone in order to communicate with other teams to avoid double counting and to aid one another in classifying and counting sheep potentially visible to multiple groups. Bighorn groups seen by more than one team were recorded by both groups but later identified and removed from the data for one group to produce a minimum count. In addition to developing a minimum count, ground surveys also provided data on population composition, notably lamb:ewe, yearling:ewe, and ram:ewe ratios. Surveys were usually conducted without the use of telemetry which allowed the development of a mark-resight population estimate with confidence intervals using marked sheep recorded during the survey. Mark-resight estimates use the proportion of animals seen that are collared, together with the total number of animals that are seen, and the total number of collars in the population to estimate the total population size. To meet the assumptions for a mark-resight survey, it is important not to use telemetry or have knowledge of GPS collar locations so that collared and uncollared animals have an equal chance of being observed. Marked individuals are thereby identified visually by their unique ear tag and collar color combinations.

Helicopter Surveys

Helicopter surveys became one of the main methods for monitoring desert bighorn populations in California during the early 1980s. Due to the rugged terrain that bighorn tend to inhabit and the limited ground access to many ranges, helicopter surveys have proven to be a useful, albeit expensive, sampling method. In the fall of 2015 and 2016, helicopter surveys were conducted with four people: pilot (front right), data recorder (front left), observer and photographer (rear right), and observer (rear left). Surveys were flown over typical desert bighorn habitat within predetermined polygons designed to be representative of all potential habitat across the range. In an effort to allow the greatest opportunity of spotting a bighorn, transects were flown across each polygon with the spacing of transects and flight speed varying by visibility and complexity of the terrain. Contour-based transects were tracked during flights using the Gaia GPS app on an iPad to ensure full coverage of each polygon, and the amount of survey time allocated was designed to allow for future survey replication and comparisons. Photographs were taken of each group of bighorn (Figure 3) using a Canon EOS Rebel T3i camera and a Canon ET-83C image stabilizer 100-400mm lens. All photos were reviewed post-flight to verify or correct group composition and to compare with GPS tracks to check for double counts. Double counts were corrected in the final data set.

*Figure 3. A group of bighorn photographed during the 2015 helicopter survey in the Kingston Range.*

To estimate a population within an area surveyed by helicopter, we used the simultaneous double-count methodology described by Graham and Bell (1989). In this method, all four people in the helicopter are independent observers and wait until an observed group of sheep has passed beyond the midway horizontal axis of the helicopter (directions 3 o'clock and 9 o'clock) before "calling" a group of sheep. The data recorder then marks which of the four observers made independent observations of the group before it was called. This method allows for a sightability estimate to be calculated for each range. The observations from the left side observers were used in this analysis. The resulting bighorn estimate is the predicted number of bighorn that were available to be seen from the helicopter within the area flown. It is important to recognize that this method does not estimate the total population, but does supply an estimate well above the minimum count obtained.

Waterhole and Camera Surveys

During the hot summer months we used waterhole surveys and remote cameras to monitor desert bighorn. In some cases, if enough marked animals were present or natural marks could be identified, these data were used to estimate population size through mark-resight analyses. Camera data also provided information on population composition (lamb:ewe, yearling:ewe, and ram:ewe ratios), disease presence (nasal discharge or coughing), behavior (rutting), and collar-fit.

Waterhole surveys consisted of one or more observers sitting in a discrete location that allowed them to watch bighorn approach and leave the water source. Waterhole sits tended to be most productive after a series of 3-5 hot (>105°F) days and at least a week after the last rainfall/monsoon. From a vantage point, the observers recorded the time and group composition (sex, age, marked) of all the bighorn sheep that visited the water or were within view. For this reporting period, waterhole sits were usually for a period of 4 hours and the results were primarily used to confirm lamb:ewe ratios and to monitor lamb health (look for active signs of respiratory disease).

Remote cameras were used to complement and/or verify data collected via other methods. For CDFW purposes, cameras were strategically positioned at point-source water in the attempt to capture every individual that came to drink on camera. The photos were then used to check for signs of disease, assure correct collar fit, calculate lamb:ewe and ram:ewe ratios (Dekelaita and Epps 2017), and identify individuals with either ear tags or natural horn markings. In order to do the latter, it was important to take up-close, high-resolution, head-on photos of individuals (Figure 4). CDFW is working with Dr. John Wehausen in developing and testing a method for identifying bighorn with unique, repetitively-recognizable identifying marks on their horns and to use them as marked individuals for a mark-resight analysis (2017 Desert Bighorn Council presentation). Lighting, camera angles, and crowding of bighorn around water sources often make a mark-resight analysis difficult. The methods involved in this process are still being finalized; therefore, we report only minimum counts here. Although photo analyses were time-intensive, cameras successfully determined use of a water source, population composition, and general health of the animals. Daniella Dekelaita (Oregon State University) is also currently developing an alternate method for estimating population sizes in the South Bristols, and multiple other ranges in the Mojave, based on camera work she conducted in 2014-2016 with assistance and funding from CDFW.

## *B. Results and Discussion*

### 1. Capture Data

Between November 2013 and November 2016, CDFW conducted three desert bighorn captures in collaboration with the NPS, the BLM, and Oregon State University. Another capture was planned for the fall of 2016 but was cancelled due to contract delays. The three captures resulted in 176 desert bighorn collared across 13 mountain ranges (Table 1). The captures primarily focused on ewes, 146 ewes were collared across 12 ranges, because they are the primary drivers of population dynamics. However, in an effort to better understand ram movements and address broader connectivity questions, we collared 30 rams across 8 ranges. See the "Notable Movement" section below for some additional information on data collected from the GPS collars.

*Table 1: Desert bighorn sheep captured in the south-eastern deserts of California during 2013-2016. All individuals were collared with GPS and VHF collars and were marked with one or two colored ear tags. In addition, nasal swabs and blood serum samples were collected for disease testing.*

| | 2013 | | 2014 | | 2015 | | |
|---|---|---|---|---|---|---|---|
| **Range** | Ewe | Ram | Ewe | Ram | Ewe | Ram | **Total** |
| **Black Mtn./ Greenwater** | --- | --- | 2 | --- | --- | --- | **2** |
| **North Bristol** | 6 | --- | --- | --- | 9 | 4 | **19** |
| **South Bristol** | 13 | --- | 3 | 4 | 4 | 3 | **27** |
| **Cady** | --- | --- | 10 | --- | --- | --- | **10** |
| **Clipper** | 4 | --- | --- | --- | 8 | 3 | **15** |
| **Granite** | 4 | 1 | --- | --- | --- | --- | **5** |
| **Hackberry/Wood** | 5 | 1 | 1 | --- | 7 | 1 | **15** |
| **Marble** | 15 | --- | 3 | 6 | 5 | 3 | **32** |
| **Old Dad/Kelso/Marl** | 19 | --- | --- | --- | 4 | 3 | **26** |
| **Newberry/Rodman/Ord** | --- | --- | 4 | --- | --- | --- | **4** |
| **Orocopia** | --- | --- | 10 | --- | --- | --- | **10** |
| **Old Woman** | --- | --- | --- | 1 | --- | --- | **1** |
| **South Soda** | 4 | --- | --- | --- | 6 | --- | **10** |
| **Total** | **70** | **2** | **33** | **11** | **43** | **17** | **176** |

As described above, various types of data are collected both during captures and post-capture. Given the outbreak of pneumonia in the desert bighorn populations, a few of the critical samples collected during captures were for disease testing. Although we tested for a variety of pathogens, *M. ovi*. was the main bacterium we were looking for during those captures. It has been associated with countless other respiratory disease outbreaks, as well as major die-offs in bighorn populations throughout the western states (WAFWA Wild Sheep Working Group). We used two different tests for exposure to *M. ovi*: polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA). The PCR test is performed on nasal swabs or tissues from the respiratory tract and detects *M. ovi*. DNA. If DNA is detected, multi-locus sequence typing (MLST) can be used to determine specific strain-types (Cassirer et al. 2017). The ELISA test screens for antibodies and a positive result indicates exposure to *M. ovi*. The percentage of bighorn that tested positive for *M. ovi* via PCR and ELISA varied between herds and years (Table 2). Of the 13 ranges sampled, the Black Mountain and Greenwater ranges in southern Death Valley National park and the Newberry, Ord and Rodman ranges south-east of Barstow, Ca were the only ranges to test negative. However, it is important to note that there were only 2 ewes and 4 ewes sampled, respectively, in 2014 and further samples are needed to confirm whether those herds have been exposed or not.

*Table 2: The percent of desert bighorn captured that tested positive for Mycoplasma ovipneumoniae (M. ovi.) in the Mojave Desert in the years 2013, 2014, and 2015. Sample sizes are in parenthesis and vary depending on if samples were viable upon testing. The PCR assay screens for M. ovi. DNA and if positive suggests an "active" infection while the ELISA test screens for antibodies to M. ovi and if considered positive suggests prior exposure to the pathogen..*

| | **2013** | | **2014** | | **2015** | |
|---|---|---|---|---|---|---|
| **Range** | PCR | ELISA | PCR | ELISA | PCR | ELISA |
| **Black Mtn./ Greenwater** | --- | --- | 0% (2) | 0% (2) | --- | --- |
| **North Bristol** | 17% (6) | 33% (6) | --- | --- | 8% (12) | 8% (12) |
| **South Bristol** | 100% (13) | 92% (13) | 14% (7) | 83% (6) | 14% (7) | 86% (7) |
| **Cady** | --- | --- | 30% (10) | 70% (10) | --- | --- |
| **Clipper** | 100% (4) | 100% (4) | --- | --- | 17% (12) | 75% (12) |
| **Granite** | 40% (5) | 40% (5) | --- | --- | --- | --- |
| **Hackberry/Wood** | 60% (5) | 50% (6) | 0% (1) | 0% (1) | 25% (8) | 25% (8) |
| **Marble** | 57% (14) | 100% (15) | 11% (9) | 78% (9) | 38% (8) | 75% (8) |
| **Newberry/Rodman/Ord** | --- | --- | 0% (4) | 0% (3) | --- | --- |
| **Old Dad/Kelso/Marl** | 58% (19) | 68% (19) | --- | --- | 0% (7) | 43% (7) |
| **Orocopia** | --- | --- | 30% (10) | 80% (10) | --- | --- |
| **Old Woman** | --- | --- | 0% (1) | 100% (1) | --- | --- |
| **South Soda** | 0% (4) | 50% (4) | --- | --- | 0% (6) | 50% (6) |

In 2014, Daniella Dekelaita, and advisor Dr. Clint Epps at Oregon State University, started a doctoral project focused on the various impacts of a disease outbreak on bighorn populations in the Mojave region. More specifically, she is focused on adult survival, cause specific mortality, lamb survival, recruitment, and intra- and inter- population movement. Dekelaita's dissertation research concluded field work in the fall of 2016; data analysis is currently underway and publications will follow.

## 2. Demographic Data by Range

The following section summarizes the data collected and results obtained in each mountain range or region of the study. Data were collected annually (core index populations), biennially (remaining hunt zones or populations of interest), or at least once during the reporting period (Figure 5). During 2015 and 2016 CDFW conducted ground surveys in the Marble, White, South Bristol, and Old Woman Mountains. Ground surveys were designed to sample ewe groups, with survey routes tending to follow ridgelines from which the most ewe habitat could be seen. The number of rams recorded during ground surveys were likely under-representations because rams tend to range over larger areas not included in the surveys. Sexual segregation in habitat use, coupled with the fact that more ewes were marked during captures, are why mark-resight population estimates were calculated only for ewes. Monitoring focused on ewes because they drive population dynamics. All lamb to ewe ratios are calculated using adult ewe counts (yearling ewes are not included).

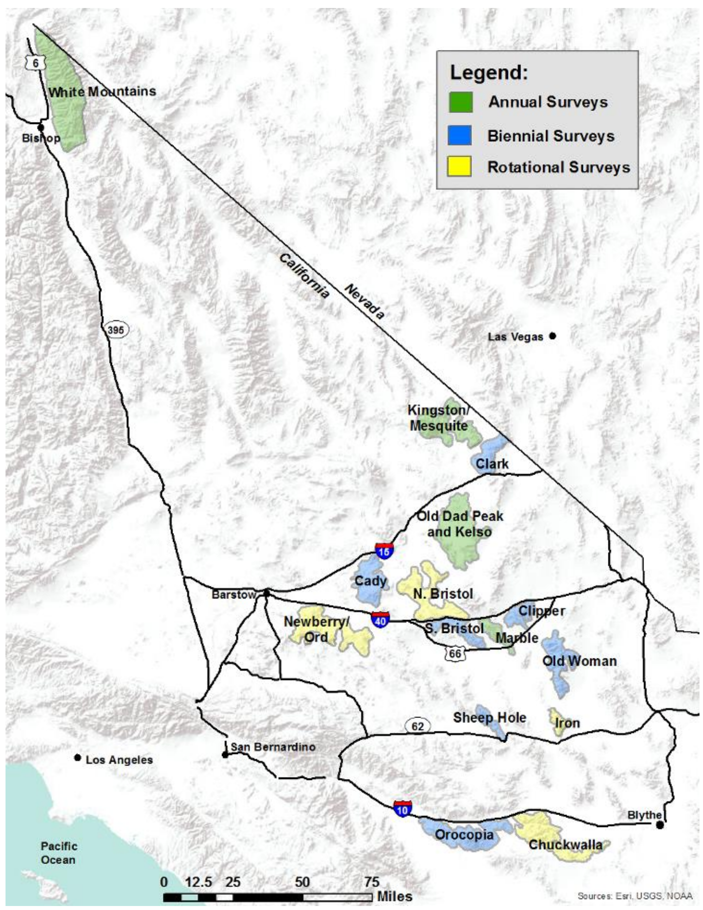


*Figure 5. Desert bighorn sheep ranges surveyed between October 2015 and November 2016. Colors delineate which ranges CDFW plans to survey annually (green), biennially (blue), or rotationally (yellow).*

September 2015 marked the first CDFW helicopter surveys of desert bighorn in five years. A pilot from Air Shasta Rotor and Wing flew the surveys with three CDFW personnel. In 2015, helicopter surveys were conducted in the Clark, Mesquite, Kingston, Cady, Old Dad, South Bristol, Clipper, Orocopia, Marble, and Sheep Hole ranges. In 2016, helicopter surveys were conducted in the Clark, Mesquite, Kingston, North Bristol, Old Dad, Newberry, Rodman, Ord, Sheep Hole, and Chuckwalla ranges.

### Survey Results by Range

<u>White Mountains</u>

The White Mountains are the northernmost and highest elevation range with desert bighorn sheep in California (Figure 5). The White Mountains are located on the eastern side of the Highway 6. With elevations ranging from 4,000 to over 14,000 feet above sea level, this range runs north to south mostly just west of the

California-Nevada border, with the northernmost section crossing into Nevada. For this report, data reported as being from "White Mountains," covers the portion of the range from Sheep Mountain in the south to Montgomery Peak in the North. Information for "Silver Canyon," a translocated low-elevation subpopulation south of Sheep Mountain is reported separately. In 2015 CDFW counted a total of 217 bighorn in these two regions. In 2016, the count was much lower at 138 individuals (Table 3). Due to a lack of collared animals in this population it was not possible to calculate mark-resight population estimates.

Bighorn sheep in the White Mountains have a history of respiratory disease outbreaks, with the most recent documented episode in 2008. As of this reporting period, this herd has not tested positive for the same *M. ovi* strain associated with the respiratory disease epizootic currently ongoing in the central Mojave Desert. However, a ram that was legally harvested in August of 2016 tested positive for the *M. ovi* strain currently found in neighboring ranges in Nevada. Additionally, both ewes and lambs were reported to be coughing and lethargic in the Silver Canyon subpopulation during the summer of 2016. CDFW has worked with the U.S. Forest Service to complete the necessary compliance to conduct future helicopter captures in the White Mountain Wilderness. Annual monitoring of this population, including efforts to detect any signs of disease and possible die-offs, will continue.

*Table 3: Age and sex classification of bighorn observed, minimum counts, and lamb:ewe ratios of bighorn seen during ground surveys in the White Mountains in the summers of 2015 and 2016, and Silver Canyon in the summer of 2016. There were very few marked animals at the time of these surveys; thus no mark-resight estimates were calculated.*

| Region | Year | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Unclassified | Minimum Count | Lamb:Ewe Ratio |
|---|---|---|---|---|---|---|---|---|---|
| White Mountain | 2015 | 65 | 4 | 78 | 4 | 46 | 20 | 217 | 0.72 |
| White Mountain | 2016 | 40 | 3 | 13 | 2 | 26 | 22 | 106 | 0.65 |
| Silver Canyon | 2016 | 16 | 2 | 0 | 1 | 13 | - | 32 | 0.81 |

<u>Clark Mountain, Kingston and Mesquite Ranges</u>

The Clark Mountain, Kingston and Mesquite Ranges are located in northeastern San Bernardino County near the Nevada border (Figure 5). Helicopter surveys were conducted in these ranges in the fall of 2015 and 2016. This large area varies in elevation from the high summits of Clark Mountain and the Kingston Range, exceeding 7,000 feet, to surrounding lower desert terrain at 3,500 feet.

Those ranges consist of vast and complex terrain. Two days of flying was not enough to cover all suitable bighorn habitat. Therefore, as with most helicopter surveys, the "population" estimates and confidence intervals (CI) in Table 4 are only for the areas flown and are not for the entirety of the range. In October 2016, we counted >100 individual sheep during the 2 days of surveys; however, the low number of lambs spotted (Table 4), particularly on Clark Mountain, suggests the possible presence of disease. This is of concern. We will continue to monitor those populations and attempt to capture some desert bighorn for disease testing.

*Table 4: Age and sex classification of bighorn observed, minimum counts, and lamb:ewe ratios of bighorn seen during 2015 and 2016 helicopter surveys in Clark Mountain, Kingston and Mesquite Ranges. The simultaneous double count method was used to calculate population estimates with 95% confidence intervals (CI) for the areas surveyed.*

| Year | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Unclassified | Min Count | Lamb:Ewe | Pop Estimate | CI |
|---|---|---|---|---|---|---|---|---|---|---|
| 2015 Kingston | 24 | 1 | 2 | 2 | 9 | - | 38 | 38:100 | 52 | 38-61 |
| 2016 Kingston | 31 | - | 17 | 2 | 3 | 2 | 55 | 10:100 | 76 | 55-116 |
| 2015 Clark | 1 | - | 2 | 1 | - | - | 4 | - | - | - |
| 2016 Clark | 29 | 2 | 13 | 1 | 1 | 4 | 50 | 3:100 | 83 | 50-148 |

Cady Mountains

The Cady Mountains are located in the central Mojave Desert, approximately 30 miles east of Barstow (Figure 5). The range is bounded by Interstate Highways 15 and 40 to the north and south, respectively, and Crucero and Zzyzx Roads in the east. The Cady Mountains were surveyed by helicopter in September 2015. The minimum population count was 67 individuals and a simultaneous double count provided an estimate of 130 bighorn sheep, but with a wide 95% confidence interval of 67-223 (Table 5). Because the Cady Mountains stretch over a fairly vast area with varying habitat suitability, the helicopter survey was not able to cover all potential habitat; once again, the population estimate is only applicable to the area surveyed.

*Table 5: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn seen during the 2015 Cady Mountains helicopter survey. The simultaneous double count method was used to calculate a population estimate with 95% confidence intervals (CI) for the area surveyed.*

| Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe | Pop Estimate | CI |
|---|---|---|---|---|---|---|---|---|
| 31 | 6 | 20 | 2 | 8 | 67 | 26:100 | 130 | 67-223 |

Newberry and Ord Mountains

The Newberry and Ord Mountains are located in the central Mojave Desert and are approximately 20 miles southeast of Barstow (Figure 5). Historically, this has been a relatively small and genetically isolated population. In 2003, it was estimated that only 25-50 bighorn occupied this complex of mountains (Epps et al. 2003) and in 1974 this range was documented as not having any bighorn (Weaver 1975). However, in the past ten years, reports have documented a steady increase in bighorn sign and markedly higher water use in the summer months. After a volunteer with the Society for the Conservation of Bighorn Sheep (SCBS) reported seeing over fifty bighorn utilizing the Newberry Drinker early in the summer of 2016, a trail camera was placed there and confirmed this high usage. The results were overwhelming, with tens of thousands of photos documenting numerous bighorn. The large number of bighorn in the photos made it impractical to determine counts or composition from the pictures; but the data were enough to confirm the need to fly a helicopter survey.

*Table 6: Age and sex classification of bighorn observed, minimum counts, and lamb:ewe ratios of bighorn seen during the 2016 Newberry and Ord Mountain helicopter surveys. The simultaneous double count method was used to calculate population estimates with 95% confidence intervals (CI) for the areas surveyed.*

| Range | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe | Pop Estimate | CI |
|---|---|---|---|---|---|---|---|---|---|
| Newberry | 41 | 4 | 10 | 7 | 33 | 95 | 80:100 | 107 | 99-135 |
| Ord | 23 | 2 | 35 | 4 | 16 | 80 | 70:100 | 82 | 79-95 |
| Total | 64 | 6 | 45 | 11 | 49 | 175 | 77:100 | 189 | 174-239 |

In October 2016 CDFW counted 175 individuals from a day and a half of helicopter surveys that covered a large swath of suitable habitat in all three ranges (Table 6). Rodman Mountain is located south-east of Newberry and Ord mountains and was the only polygon flown where bighorn were not seen. The small sample of three collars deployed in 2014 have shown that there is movement between the Newberry and Ord Mountains, but Rodman Mountain appears to be used only as intermittent winter habitat and as a connectivity corridor between the Newberry and Ord Mountains and the Bullion Mountains (see the Movement Data section for more details).

Old Dad Peak and Kelso Mountains

The Old Dad Peak and Kelso Mountains complex is located in central San Bernardino County approximately mid-way between the cities of Barstow and Las Vegas, Nevada (Figure 5). Since the early 1980's, Old Dad Peak and Kelso Mountain have supported a healthy and productive population of bighorn sheep from which more than 200 individuals were transplanted to other mountain ranges throughout the Mojave Desert.

The first bighorn sheep documented to have died from *M. ovi* in the Mojave Desert were found near Old Dad Peak in the spring of 2013. This is the only range where CDFW documented an all-age-class die-off. Preliminary analyses of camera data by John Wehausen estimated that there were 137 ewes in the Old Dad Peak area during the summer of 2012 but only 57 ewes during the summer of 2014 (Desert Bighorn Council 2017, presentation). Helicopter surveys flown during the fall of 2015 and 2016 counted 15 and 22 ewes, respectively. There was a sufficient number of collared animals at the time of the surveys that mark-resight (Chapman estimator) was used to calculate ewe estimates with confidence intervals (Table 7). Additionally, the low lamb:ewe ratios and lack of yearlings suggest that this population is still heavily affected by respiratory disease. We will continue to monitor this population closely.

*Table 7: Age and sex classification of bighorn observed, minimum counts, and lamb:ewe ratios of bighorn seen during the 2015 and 2016 Old Dad Peak and Kelso Mountains helicopter surveys. Mark-resight was used to calculate ewe estimates with confidence intervals (CI) for the areas surveyed.*

| Year | Adlt Ewes | Yrlg Ewes | Lambs | Adlt Rams | Yrlg Rams | Min Count | Lamb:Ewe | Marks | Re-sights | Ewe Estimate | CI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 15 | - | 5 | 11 | - | 31 | 33:100 | 15 | 5 | 52 | 24-80 |
| 2016 | 22 | - | 1 | 6 | - | 29 | 5:100 | 15 | 5 | 62 | 31-93 |

Marble Mountains

The Marble Mountains are located in the south-central Mojave Desert (Figure 5). This range lies immediately south of Interstate-40 and the Mojave National Preserve, north of Route 66, and east of Kelbaker Road. Annual ground counts conducted in May and June of 2015 and 2016 consistently produced minimum counts of over 100 animals (Table 8). One objective of those surveys was to monitor changes in the lamb:ewe ratio in late spring. May and June were an ideal time to conduct these counts because it was hot enough for bighorn to be concentrated near water, yet females still maintained the larger group sizes seen in spring. This range was of particular interest because of the long-term data set that has been developed by CDFW and its collaborators. Additionally, respiratory disease was documented in this range in 2013, and following the disease outbreak a high rate of lamb mortality has led to low recruitment.

*Table 8: Age and sex classification of bighorn observed, minimum counts, and lamb:ewe ratios of bighorn seen during the 2015 and 2016 Marble Mountain helicopter and ground surveys. Mark-resight (Chapman's estimator) was used to calculate ewe estimates with confidence intervals (CI) for the areas surveyed.*

| Survey Date | Survey Type | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Unclassified | Min Count | Lamb:Ewe | Ewe Est | CI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| May 20th 2015 | Ground | 72 | 1 | 20 | 1 | 45 | - | 139 | 63:100 | 108 | 75-141 |
| June 11th 2015 | Ground | 82 | 3 | 17 | 1 | 41 | - | 144 | 50:100 | 118 | 82-155 |
| Sept 26th 2015 | Helicopter | 45 | 3 | 23 | 1 | 8 | 5 | 85 | 18:100 | 133 | 70-196 |
| May 12th 2016 | Ground | 60 | 2 | 24 | 0 | 26 | - | 112 | 43:100 | 159 | 67-251 |
| June 14th 2016 | Ground | 73 | 2 | 35 | 0 | 42 | 1 | 153 | 58:100 | 98 | 73-123 |

During the helicopter survey in September of 2015, 85 bighorn sheep were spotted. That survey showed a notably lower lamb:ewe ratio in early fall compared to early summer (Table 8). This difference may be indicative of high lamb mortality as a result of persistent disease in the Marble Mountains. With this range, and others affected by disease, one of the main concerns is that continually low lamb survival will ultimately lead to a declining trend in population size because adult mortality will exceed recruitment. The five surveys produced mark-resight estimates (Chapman estimator) of the ewe population in the Marble Mountains ranging from 98 to 159 (Table 8, Figure 6).

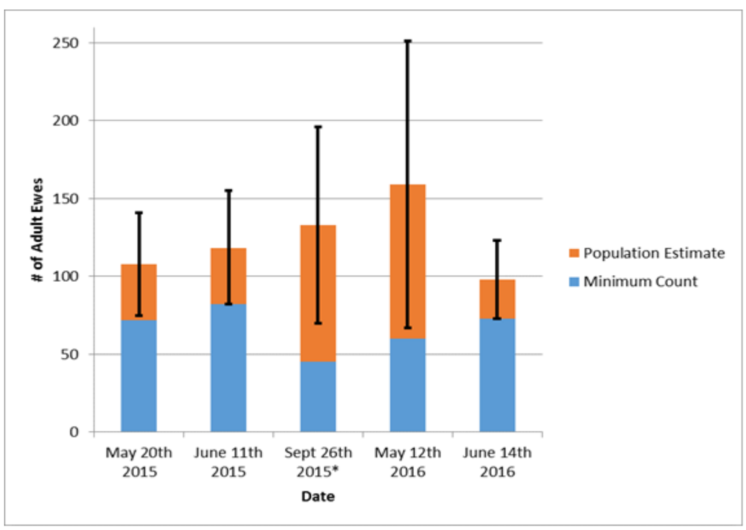


*Figure 6. Marble Mountains ewe population estimates via two ground counts and one helicopter survey (*) in 2015 and two ground counts in 2016.*

Clipper Mountains

The Clipper Mountains are located in the south-central Mojave Desert (Figure 5), due east of the Marble Mountains. Although there has been some ram movement documented between these two ranges, no ewes have been documented moving between the two ranges and consequently these are considered to be separate populations. A helicopter survey of the Clipper Mountains was conducted in September 2015. The simultaneous double count estimated 125 desert bighorn, but with a very wide 95% confidence interval (Table 9).

*Table 9: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn seen during the 2015 Clipper Mountains helicopter survey. The simultaneous double count method was used to calculate a population estimate with 95% confidence intervals (CI) for the area surveyed.*

| Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe | Pop Estimate | CI |
|---|---|---|---|---|---|---|---|---|
| 20 | - | 21 | 3 | 4 | 48 | 20:100 | 125 | 48-308 |

South Bristol Mountains

The South Bristol Mountains are located just west of Kelbaker Road and the Marble Mountains, and are separated from the North Bristol Mountains by Interstate 40. The current South Bristol population stems from a natural colonization in the 1990s. During the early 1990s John Wehausen documented three radio-collared ewes moving between the Marble and S. Bristol Mountains, and by the late 1990s, there was an established and growing population (Epps et al. 2010). Abella et al. (2011) estimated the population in 2011 at 101-150 sheep. While only eight bighorn sheep were spotted in a 2015 helicopter survey of the South Bristol Mountains, a ground survey in January of 2016 counted 54 individuals (Table 10). While this range is substantially more difficult to survey on the ground than its eastern neighbor, the Marble Mountains, the ground surveys have provided useful information. However, due to the fact that we used telemetry to help us locate collared animals while surveying, we are not able to calculate a mark-resight estimate. We plan to test the use of automated cameras placed at water in summer for population estimates in this range.

*Table 10: Age and sex classification of bighorn observed, minimum counts, and lamb-to-ewe ratios of bighorn seen during the 2015 helicopter survey and the 2016 ground survey. The * denotes that a lamb:ewe ratio was not included for the 2016 ground survey because it was conducted during lambing season.*

| Year | Adlt Ewe | Yrlg Ewe | Adlt Ram | Yrlg Ram | Unknown Yrlg | Lamb | Min Count | Lamb:Ewe |
|---|---|---|---|---|---|---|---|---|
| 2015 | 7 | 0 | 6 | 1 | - | 1 | 15 | 14:100 |
| 2016 | 36 | - | 13 | - | 3 | 2 | 54 | * |

North Bristol Mountains

The North Bristol Mountains are located in central San Bernardino County (Figure 5), north of Interstate-40 (I-40), east of the Cady Mountains, and west of the Mojave National Preserve. Prior to the construction of I-15, there was presumably continuous habitat from the North Bristol Mountains to the South Bristols, but the North Bristol Mountains are also closely connected with the Cady and Granite Mountains. The North and South Bristol Mountains were both classified as having only transient bighorn present in 1974 (Weaver 1975). In 1992 bighorn sheep from Old Dad Peak were translocated to the North Bristol Mountains. Attempts to sample this population in the early 2000s using fecal DNA found only evidence of rams, and the population was classified as extirpated (Epps et al. 2003). However, in recent years evidence of a population has emerged, and it is now a key connector between populations north of I-40 including the Cady, Old Dad/Kelso, and Granite Mountains, forming a network of populations that now interacts with populations south of I-40 (see Movement Data section below). In October 2016 we conducted a helicopter survey of part of the North Bristol Mountains; the simultaneous double count yielded an estimate of 73 bighorn for the area surveyed (Table 11).

*Table 11: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn seen during the 2016 North Bristol helicopter survey. The simultaneous double count method was used to calculate a population estimate with 95% confidence intervals (CI) for the area surveyed.*

| Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Unclassified | Min Count | Lamb:Ewe Ratio | Pop Est | CI |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 2 | 15 | 1 | 8 | 2 | 58 | 27:100 | 73 | 60-98 |

Old Woman Mountains

The Old Woman Mountains are located in the southern Mojave Desert (Figure 5). Compared with the surrounding mountains, they are higher elevation, have more surface water sources, and are considered to have some of the best forage resources in the southern Mojave Desert (John Wehausen, *personal communication*). Analyses conducted by Epps et al. (2004) found that this range should have a low extinction probability; however, it also has a long history of cattle grazing and has experienced multiple recorded disease episodes. Currently it appears that this population may be struggling to persist and has not shown evidence of reaching its population potential since intensive research began there in 1985. Great concern for this population emerged in 2013 when the helicopter capture crew only observed a single bighorn sheep, a mature ram (captured and collared at that time).

A ground survey conducted in April 2016 on the west side of the Old Woman Mountains counted 17 bighorn (Table 12) and found little to no bighorn sign at the water sources that have previously had heavy bighorn use. Additionally, several of the springs that were known to have perennial water were dry. This suggests this range may be suffering from recent drought years, and the bighorn may have shifted their habitat use patterns as a result. This is a population of great concern, and we are actively working to develop reliable demographic data.

*Table 12: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn seen during the 2016 Old Woman Mountains ground survey.*

| Date | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Unclassified | Min Count | Lamb:Ewe |
|---|---|---|---|---|---|---|---|---|
| April 2016 | 3 | 1 | 1 | 0 | 2 | 10 | 17 | 67:100 |

During our scouting efforts we identified two reliable water sources in the Old Woman Mountains and placed an automated trail camera at each one during the summer of 2016. Only one of these sources proved to be utilized by bighorn. Pictures from the trail cameras showed a minimum count of 28 bighorn sheep (Table 13). Lamb:ewe ratios were determined by dividing the sum of each ewe sighting instance, by the sum of each lamb sighting instance when ewes were also identified in the group. In addition to the camera increasing the minimum count for this range, the photos also revealed that most of the lambs appeared to be infected with contagious ecthyma in May, but by the end of the summer there was no sign of the disease.

*Table 13: Age and sex classification of bighorn observed, minimum counts, and lamb-to-ewe ratios of bighorn observed at a water source during the summer of 2016. Observations were made from photos taken by a remote camera installed at Surveyor Spring in the Old Woman Mountains.*

| Dates | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe |
|---|---|---|---|---|---|---|---|
| May 14-18 | 13 | 0 | 1 | 1 | 6 | 17 | 42:100 |
| August 17-26 | 7 | 1 | 4 | 1 | 8 | 21 | 85:100 |
| Aug 26- Sept 12 | 6 | 1 | 5 | 1 | 4 | 17 | 64:100 |
| Total Min Count | 13 | 1 | 5 | 1 | 8 | 28 | 64:100 |

<u>Iron Mountains</u>

The Iron Mountains are located in the southern Mojave Desert (Figure 5), north of Highway 62, south of the Old Woman Mountains, and east of the Sheep Hole Mountains and were classified as a transient population in 1974 (Weaver 1975). In the summer of 2016 we conducted a scouting trip in this range to check for occupancy and sign. Although there was not a large quantity of sign, it was clear there were bighorn in this range. In an effort to better understand the population size we placed a remote camera near a large tenaja, a natural rock basin that fills with water during rain events.

*Table 14: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn recorded at a tenaja in the Iron Mountains in 2016. Observations were made from photos taken by a remote camera. The minimum count is based strictly on maximum counts from each age and sex class group.*

| Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Minimum Count | Lamb: Ewe Ratio |
|---|---|---|---|---|---|---|
| 6 | 2 | 5 | 1 | 3 | 17 | 74:100 |

The camera location did not offer a close up view of animals coming to water (Figure 7); therefore, the minimum count is based strictly on maximum counts from each age/sex group for a total of 17 individuals (Table 14). The lamb:ewe ratio of 74:100 was calculated using the same methods as at Surveyor Spring in the Old Woman Mountains. During the fall of 2016, it was our intention to fly the Iron Mountains during our helicopter surveys, but that flight did not occur.


*Figure 7: A remote camera captures a group of desert bighorn sheep coming into drink at a natural rock pool, tenaja, in the Iron Mountains. Summer 2016.*

<u>Sheep Hole Mountains</u>

The Sheep Hole Mountains are located in the southern Mojave Desert north of Highway 62 and Joshua Tree National Park and east of Twenty-nine Palms (Figure 5). This range was surveyed by helicopter in the fall of 2015 and 2016. Simultaneous double counts resulted in a low population estimate in this range each year (Table 15). In 2016, a brief survey of the adjacent Calumet Mountains did not find any sheep, and showed little sign.

*Table 15: Age and sex classification of bighorn observed, minimum counts, and lamb-to-ewe ratios of bighorn seen during the 2015 and 2016 Sheep Hole Mountain helicopter surveys. The simultaneous double count method was used to calculate population estimates with 95% confidence intervals (CI) for the areas surveyed.*

| Year | Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe Ratio | Population Est | CI |
|---|---|---|---|---|---|---|---|---|---|
| 2015 | 16 | 0 | 5 | 0 | 4 | 25 | 25:100 | 42 | 25-89 |
| 2016 | 14 | 0 | 4 | 2 | 5 | 25 | 36:100 | 32 | 25-50 |

Orocopia Mountains

The Orocopia Mountains are located south of Interstate 10, north of the Salton Sea, and east of Palm Springs (Figure 5). This range was surveyed by helicopter in September 2015. Using the simultaneous double count method the population estimate for the area surveys was 56 bighorn (Table 16).

*Table 16: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn seen during the 2015 Orocopia Mountains helicopter survey. The simultaneous double count method was used to calculate population estimates with 95% confidence intervals (CI) for the areas surveyed.*

| Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe | Population Est | CI |
|---|---|---|---|---|---|---|---|---|
| 30 | 0 | 9 | 0 | 10 | 49 | 33:100 | 56 | 50-65 |

Chuckwalla Mountains

The Chuckwalla Mountains are located south of Interstate 10, east of the Orocopia Mountains, and west of Blythe, Ca (Figure 5). In October of 2016 we conducted a helicopter survey of the Chuckwalla Mountains. A simultaneous double count yielded a population estimate of 74 bighorn for the area surveyed (Table 17).

*Table 17: Age and sex classification of bighorn observed, minimum count, and lamb-to-ewe ratio of bighorn seen during the 2016 Chuckwalla Mountain helicopter survey. The simultaneous double count method was used to calculate population estimates with 95% confidence intervals (CI) for the areas surveyed.*

| Adlt Ewes | Yrlg Ewes | Adlt Rams | Yrlg Rams | Lambs | Min Count | Lamb:Ewe | Population Est | CI |
|---|---|---|---|---|---|---|---|---|
| 22 | 1 | 17 | 0 | 7 | 47 | 32:100 | 74 | 49-115 |

**Survival Data**

The monitoring of desert bighorn sheep fitted with GPS and VHF collars allowed for the study of adult survival using a known fate model. Using Program MARK, we estimated the survival probability of collared sheep under the assumption that the status (alive or dead) of each animal was known for every sampling occasion. Through the combination of GPS collar data and telemetry flights for VHF collars, we determined if an individual was present or detectable during the sampling occasion, and if so, whether or not that bighorn was alive. Sampling occasions were assessed on both quarterly and annual timeframes from 2013-2016.

We estimated survival rates in herds in the central Mojave Desert, including the Mojave National Preserve and bordering ranges. Because of differences in behaviors, we calculated ewe and ram survival rates separately. Also, in order to represent newly captured animals throughout each year, the year is based on capture dates. For this analysis, each year began on October 25$^{th}$ of the previous calendar year, and ends on October 24$^{th}$.

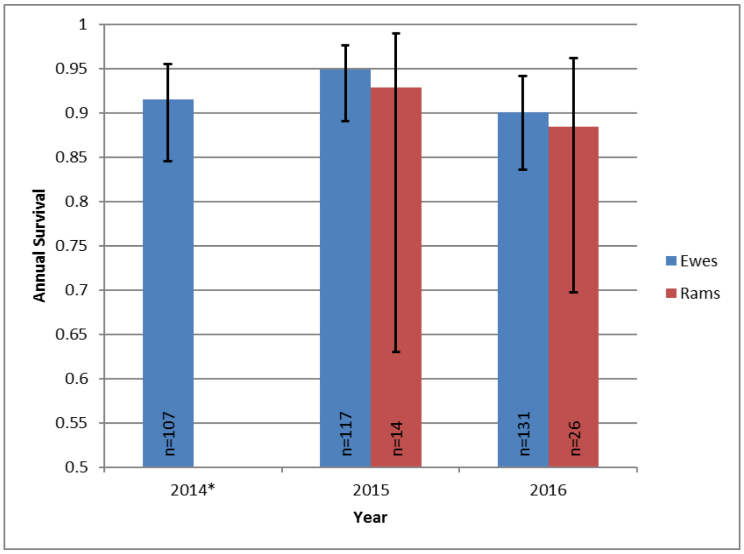


*Figure 8. Mojave Desert bighorn sheep annual survival rates by sex, calculated using a known fate analysis in Program MARK. Error bars are 95% confidence intervals. Sample size (n) is given in each bar. *With only 3 collared rams in 2014, there weres not enough survival data to do a meaninaful calculation.*

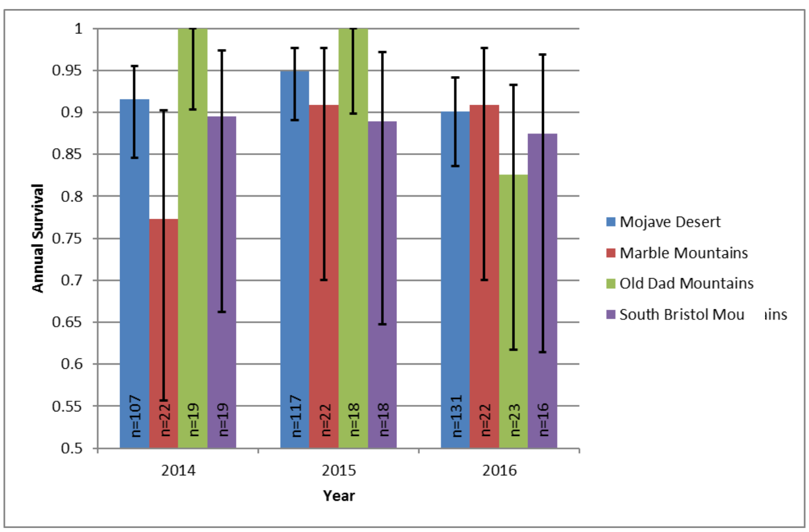


*Figure 9. Annual survival of Mojave Desert bighorn ewes by mountain range, calculated using a known fate analysis in Program MARK. Error bars are 95% confidence intervals. Sample size (n) is given in each bar. Please note that Old Dad Mountain consists of the herd unit formed by the Old Dad Peak, Kelso, and Marl Mountains.*

The annual survival estimates for ewes in the Mojave Desert was at least 0.9, indicating that over 90% of ewes were expected to survive each year (Figure 8). The estimates for rams were slightly, but not significantly, lower—the small sample size for rams resulted in wider confidence intervals than for the ewes. The Marble Mountains, South Bristol Mountains, and Old Dad/ Kelso/Marl complex, each had a large enough sample size of collared ewes to estimate annual survival by range (Figure 9). Annual survival estimates between mountain ranges showed small and insignificant variation. To examine seasonal survival, we divided the year into four quarters: Winter (October 25th to January 24th), Spring (January 25th to March 24th), Summer (March 25th to July 24th), and Fall (July 25th to October 24th) (Figure 10).

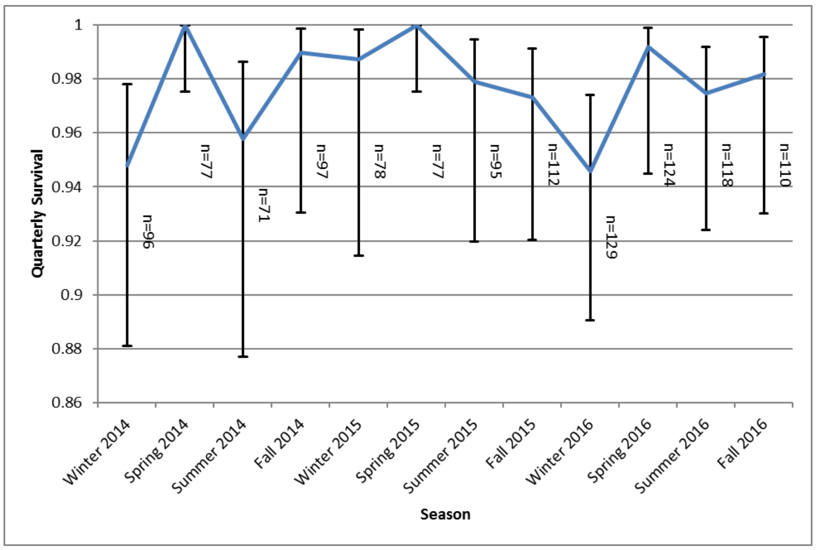


*Figure 10. Quarterly survival of desert bighorn ewes in the Mojave Desert of California during 2014-2016. Survival was calculated using a known fate analysis in Program MARK. Error bars are 95% confidence intervals. Sample size (n) is given next to each bar.*

## 3. Notable Movements by Range

The dynamics of immigration, emigration, extinction, and recolonization are core processes influencing wildlife populations, and we study these interactions in order to gain a better understanding of metapopulation dynamics. These biological principles are especially important in smaller populations where extinction risks are higher and in isolated habitats where gene flow may be less frequent. Having small herd sizes living in isolated mountain ranges, desert bighorn sheep populations meet these conditions. Over the years, various methods have been developed to better understand gene flow and movement patterns of bighorn between ranges in the California desert. Using DNA from bighorn fecal samples, Epps et al. mapped gene flow across ranges throughout the Mojave Desert (Epps et al. 2005, 2006, 2010, and 2018). In addition, radio telemetry and ground observations have been used for decades to track the movements of individually marked animals. However, with the increased reliability and decreased cost of GPS collars, the resolution of data we attain has drastically increased. We use GPS data to calculate home ranges, document the details of intermountain movements, and better understand key corridors. In 2014, Clint Epps and Daniella Dekelaita (Oregon State University) introduced the study of ram movements to the CDFW monitoring effort as part of Dekelaita's PhD research project.

Although bighorn sheep prefer mountainous escape terrain, intermountain movements and colonization events have been documented during various studies. It has also been shown that human barriers, such as highways, have created substantial genetic barriers between populations (Epps et al. 2005). The GPS data that were collected during this reporting period generally supports this research; however, the data also captured some exceptions (Figure 11) and support more recent genetic findings (Epps et al. 2016).

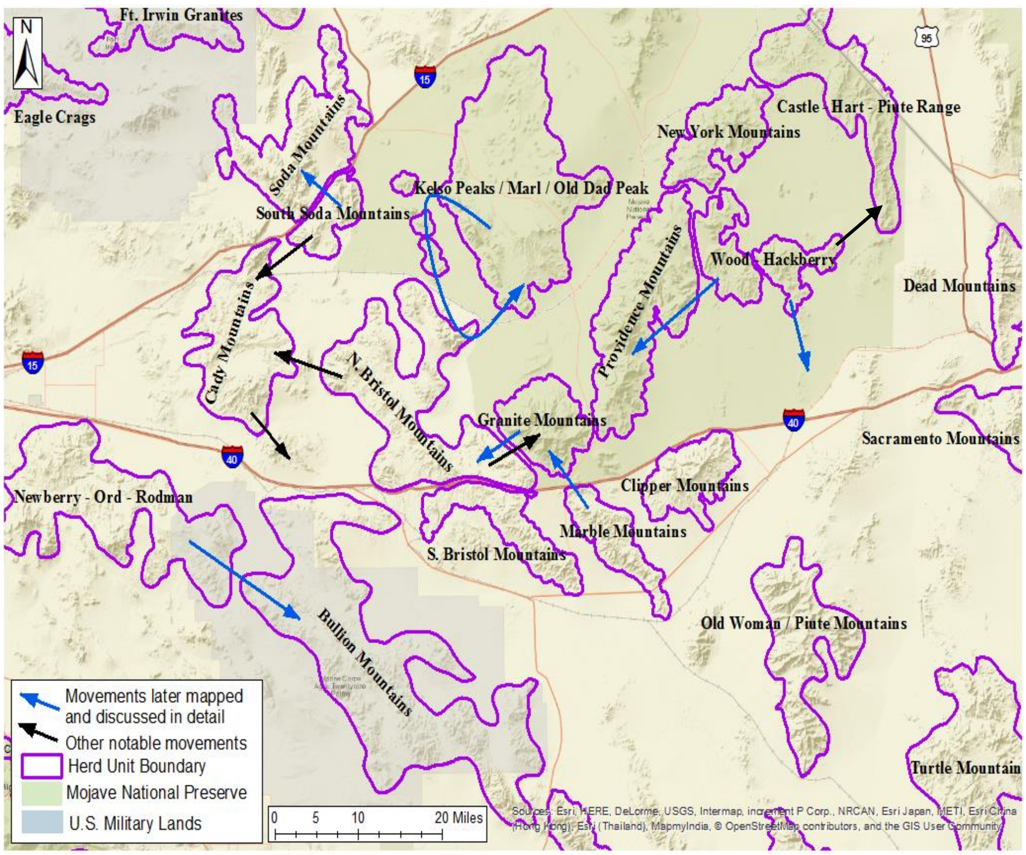


*Figure 11. Desert bighorn sheep (Ovis canadensis nelsoni) movements across herd unit boundaries in the Mojave desert, CA (November 2013 – October 2016. Movements indicated in blue are mapped and discussed in greater detail.*

<u>Hackberry Mountains:</u>

On October 19, 2014, ewe 1346 left the herd unit boundary of the Hackberry Mountains and, over the following eight days, traveled 6 miles south over the chain of the Fenner Hills. After spending two days in the southernmost hills, 1346 turned back north and retraced her 6 mile journey over the next two days. Overall, she traveled over 15 miles in 13 days, much of it in relatively poor escape terrain (Figure 12).

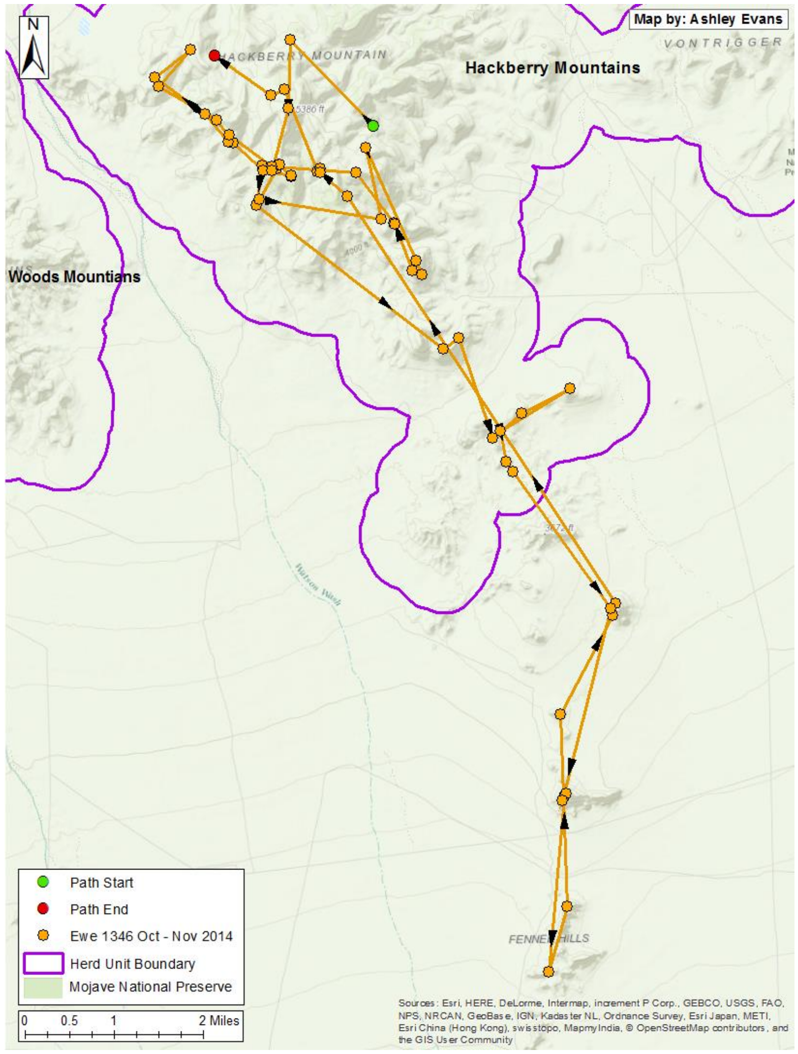


*Figure 12. Notable movement of a desert bighorn ewe across the Fenner Hills to the south of the Hackberry Mountains between October and November 2014.*

<u>Kelso Mountains/Old Dad Peak:</u>

Genetic data collected in the early 2000's demonstrated that the Old Dad complex was isolated from neighboring ranges (Epps et al. 2004). However, the recolonization of the North Bristols and access to GPS data confirms that connectivity between ranges has increased over the last 20 years. In late November 2015, nine-year-old ram 1532 traveled 3.5 miles through an area known as Devil's Playground, across the alluvial fan to the west of Old Dad Mountain to Cowhole Mountain (Figure 13). After spending two days around Cowhole Mountain, 1532 traveled south along a chain of hills and sand dunes before entering the northeastern spur of the North Bristol Mountains herd unit, traveling 8.5 miles in eight hours. After five days of traveling through the North Bristols, he crossed 5 miles of sandy flatland to return to his home herd unit of the Kelso Peaks/Marl/Old Dad Mountain complex.

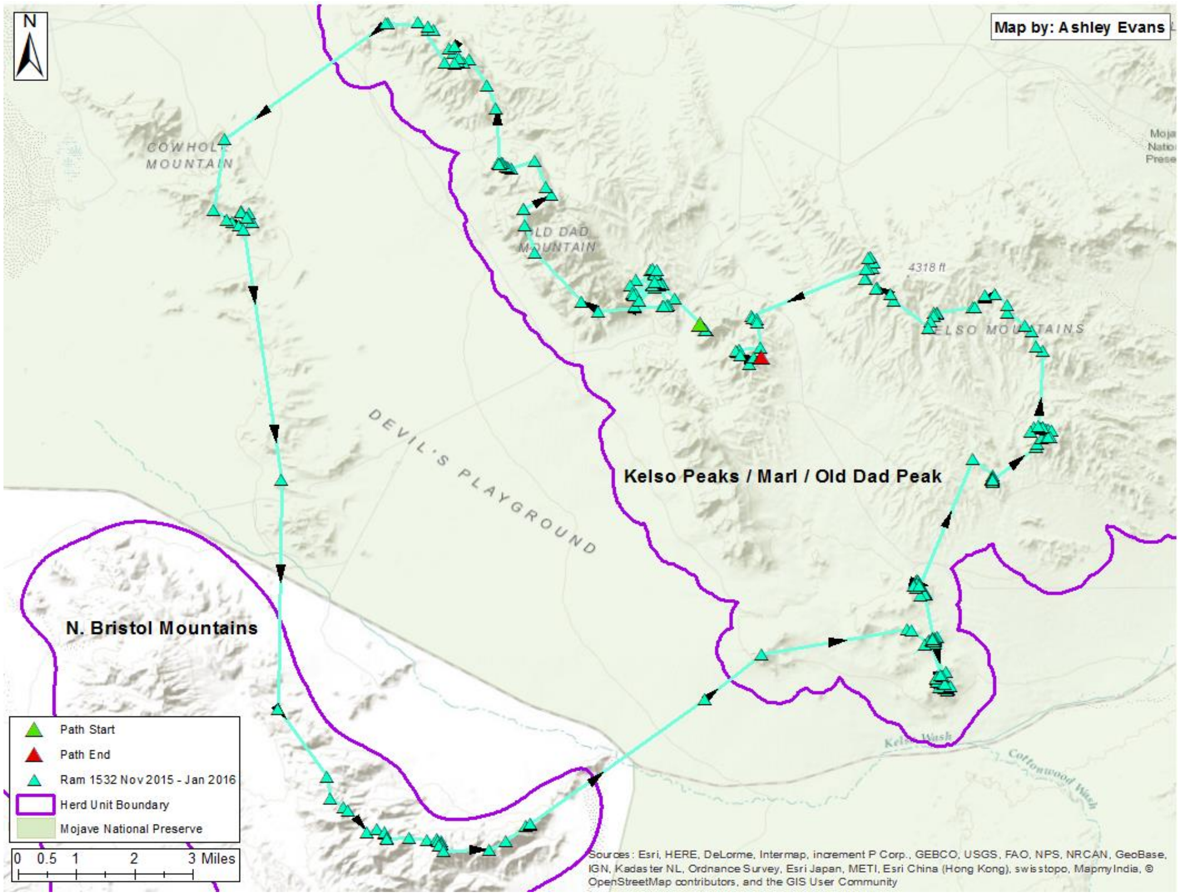


*Figure 13. Notable movement of a desert bighorn ram from Old Dad Peak, to Cowhole Mountain, south to the North Bristols, and back to the original herd unit over the course of three months.*

Marble Mountains: Interstate 40 (I-40) was constructed in the 1960's and for the last 50 years has proven to be a significant barrier to bighorn sheep populations to both the north and the south (Epps et al. 2005). However, in the Marble Mountains, a recent increase in movement across this barrier has been documented using data from GPS collars. Although movements have been documented, some of which are described below, resolution of the data is not at a fine enough scale to determine whether bighorn are crossing over or under I-40. Movement across I-40 has yet to be documented between the South and North Bristol Mountains to the west.

After crossing Kelbaker Road the previous day, six-year-old ram 1417 crossed I-40 on the morning of January 14, 2015 (Figure 14). Over the next four hours, he traveled 4 miles northwest across the alluvial fan to the south of the Granite Mountains to arrive in the North Bristol Mountains herd unit. The following day, 1417 crossed the 2 mile flat separating the North Bristol Mountains and the Granite Mountains where he remained until September, 2015. Over the course of this trek, 1417 traveled at least 19 miles in 4 days, much of it over flat land with little to no escape terrain.

On September 14, 2015, ram 1417 left the Granite Mountains and crossed 1.5 miles of flat land and Kelbaker Rd before reaching the low hills directly north of I-40 and the Marble Mountains. 1417 crossed I-40 on September 16 and stayed in the northern part of the Marble Mountains before returning north, crossing I-40, over 1.5 miles of flat plains, and Kelbaker Road, to return to the Granite Mountains. Following a very similar route to his previous trek, ram 1417 returned to the Marble Mountains one month later, on October 19, 1417. He retraced his path back to the Granite Mountains on October 27 where he remained until his death in April 2016. Between September 14 and October 28, this ram traveled a minimum of 95 miles and crossed I-40 on four separate occasions.

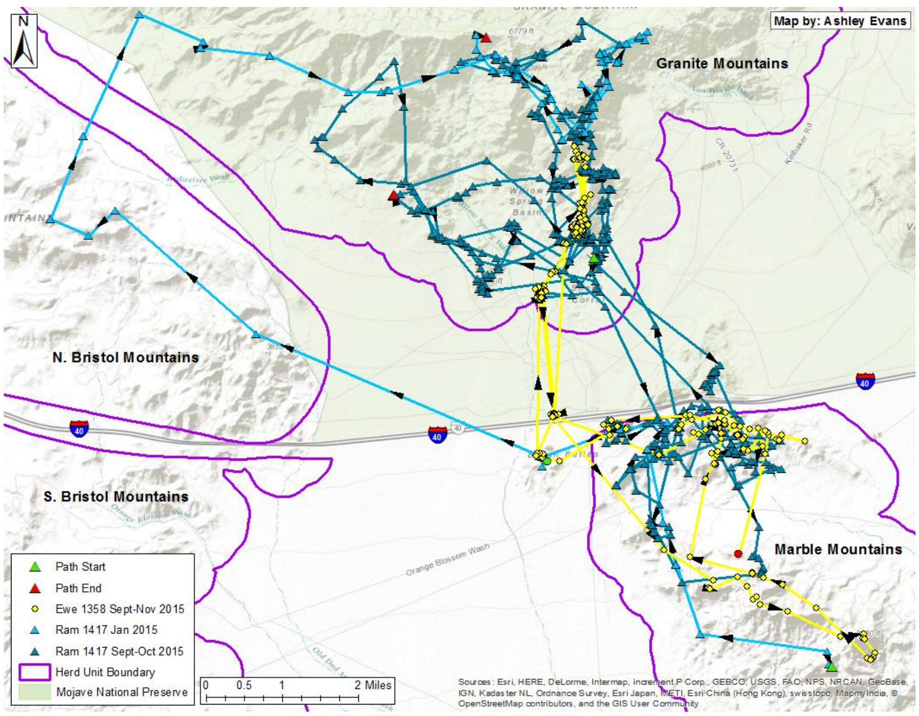


*Figure 14. Three movement events, two by ram 1417 and one by ewe 1358, of desert bighorn sheep between the Marble, North Bristol, and Granite Mountains herd units and across Interstate 40 in 2015.*

Ewe 1358 also made treks to the Granite Mountains during the fall of 2015 (Figure 14). On September 1, 2015, she crossed I-40 and 2 miles of the alluvial fan to the south of the Granite Mountains before arriving in the low hills to the southeast of Willow Spring Basin. She remained in these low hills for 13 days, and then walked 4 miles south, across I-40 and Kelbaker Road, before arriving back in the Marble Mountains. On September 25, she crossed north over I-40 again and spent five days on a single small hill next to the Interstate. 1358 then returned north to the hills to the east of Willow Spring Basin where she spent her time until October 18 when she traveled south and returned to the same small hill next to I-40. The next morning she crossed I-

40 and returned to the northern portion of the Marble Mountains where she remained through fall of 2016.

<u>South Soda Mountains:</u> On May 21, 2016, ewe 1525 ventured to the edge of Interstate 15 (I-15) at the base of the northern portion of the South Soda Mountains (Figure 15). She approached the edge of I-15 on two consecutive evenings before crossing on May 23 and then spent two days in the foothills on the southeastern edge of the North Soda herd unit. 1525 then crossed 3 miles of the sandy alluvial fan to the west and entered the North Soda Mountains directly north of Interstate 15. After staying in the area for four days, 1525 crossed back over I-15 to return to the South Soda Mountains. On May 29, her GPS collar transmitted a mortality alert. Investigation of the site and a necropsy of the ewe revealed a bullet wound to the chest with no other blunt force trauma. It is unknown who shot the ewe. The presence of milk in the ewe's udder, and later discovery of lamb pellets and small bed sites at the ewe's bed sites in the North Soda Mountains, indicate 1525 crossed I-15 and traveled through the North Sodas with a lamb.

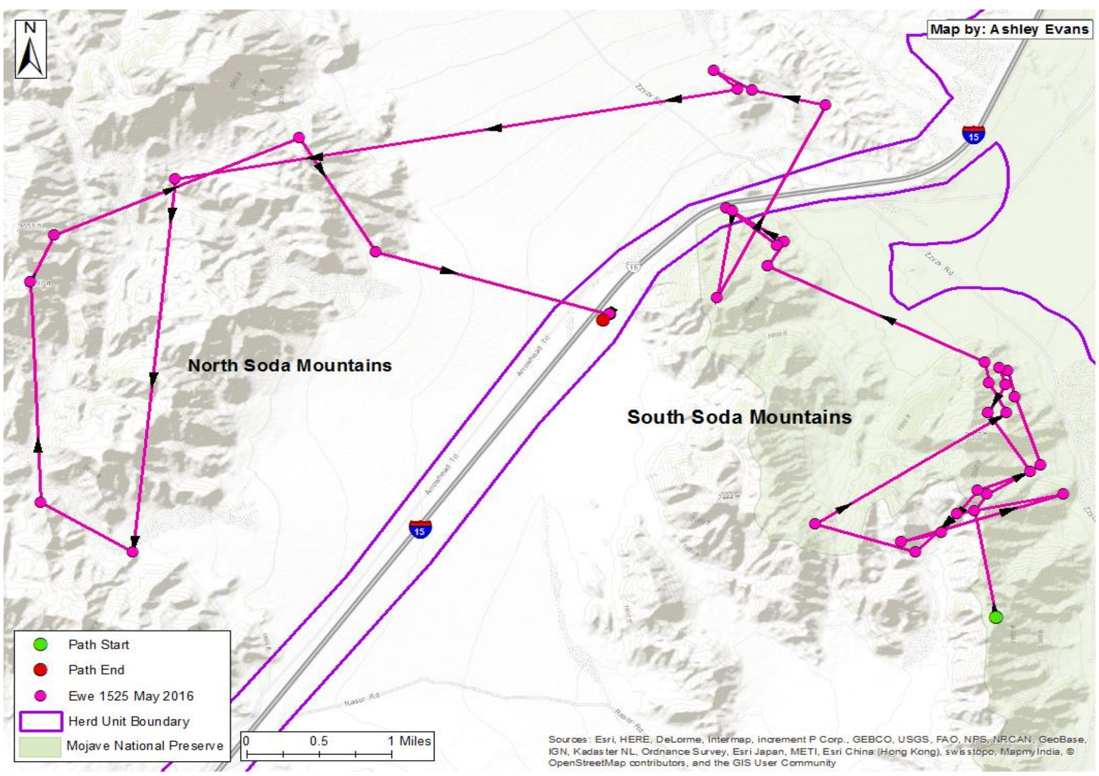


*Figure 15. Movements of desert bighorn ewe in May 2016 from the South Soda Mountains, across Interstate 40 to the North Soda Mountains, and back. The ewe was found dead after she crossed back over the interstate.*

North Bristol Mountains: Immediately after his capture in the southeast portion of the North Bristol Mountains herd unit in November 2015, yearling ram 1511 traveled northeast, crossing 1.5 miles of flat wash and entered the Granite Mountains herd unit (Figure 16). He remained there until the end of November, when he returned to the North Bristols where he traveled extensively for the next month, covering over 75 miles in 24 days.

After spending the following months in the southern half of the North Bristols, 1511 returned to the Granite Mountains in late March 2016. In October 2016 he crossed the wash to make a circuit of the North Bristols before heading back to the Granites, traveling a minimum of 65 miles in 13 days, 55 miles of which he traversed in only eight days.

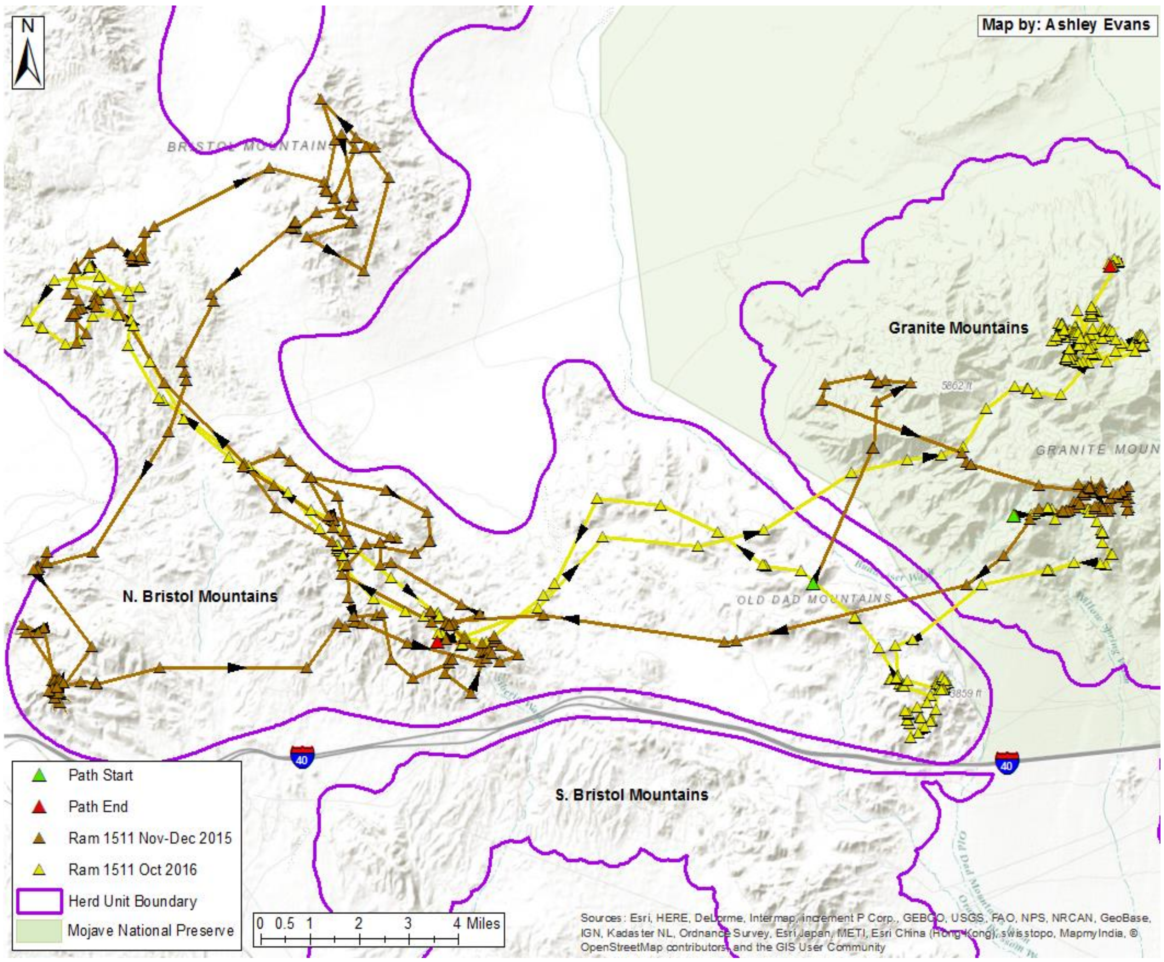


*Figure 16. Movements of a desert bighorn ram between the North Bristol and Granite Mountains herd units. In October 2016 he traveled 55 miles in only eight days.*

Wood-Providence Mountains: Ewe 1541, collared in November 2015 in the Woods Mountains, traveled extensively between the Woods Mountains and the neighboring Providence Mountains from November 2015 to September 2016, a distance of over 16 miles between the area she primarily utilized in the Woods Mountains and the area west Fountain Peak in the Providence range (Figure 17). Over the course of 10 months, 1541 made four treks of at least 10 miles through the Providence Mountains in a few days before turning around and returning to the mountains west of Fountain Peak. After her trip back to the Woods Mountains in September 2016, 1541 remained in the Woods Mountains herd unit.

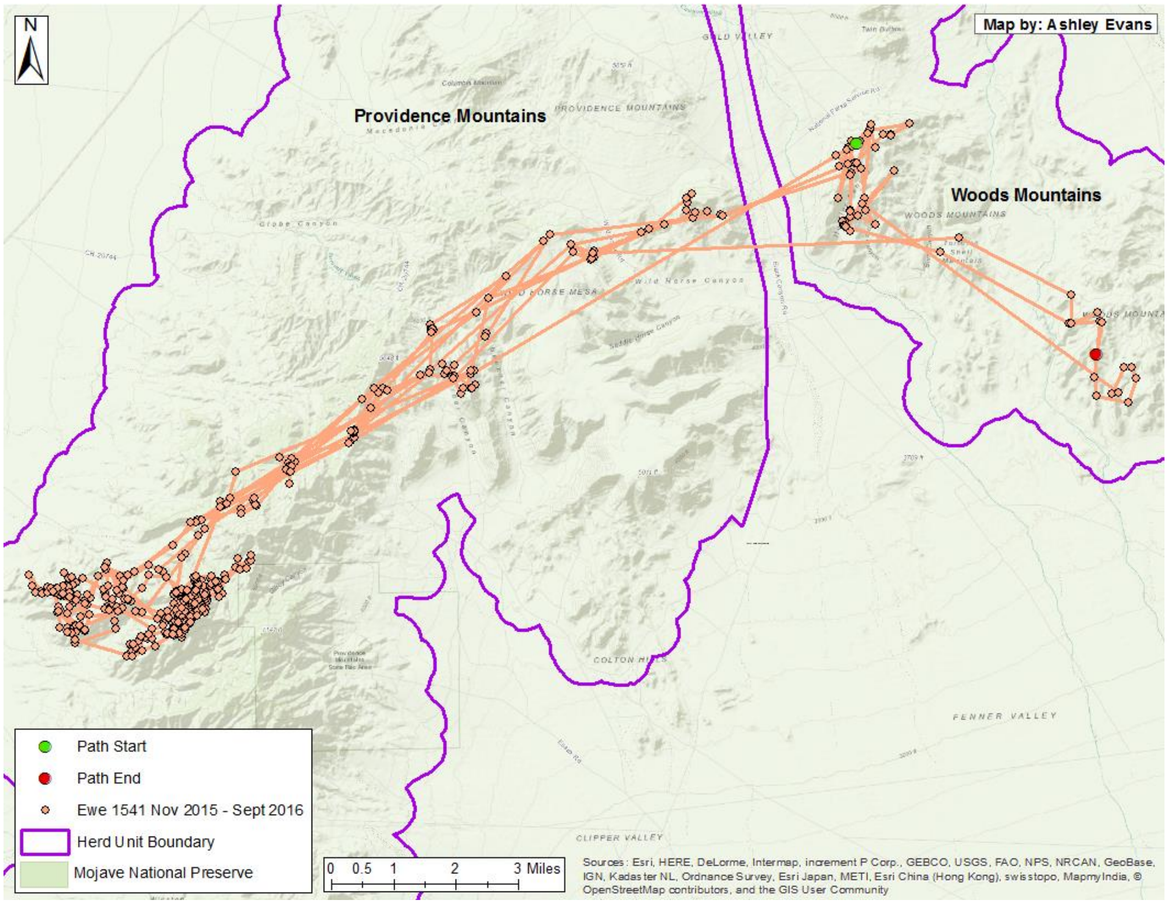


*Figure 17. Movements of a desert bighorn ewe (Ovis canadensis nelsoni) between the Woods and Providence Mountains herd units. She traveled extensively through the Providence Mountains over the course of 10 months.*

<u>Newberry, Ord, and Bullion Mountains:</u> Collared in 2014, ewes 1441 and 1442 migrated long distances from the Newberry-Rodman-Ord herd unit complex to the Bullion Mountains in two consecutive years (Figure 18). Their GPS collar data reveal that 1411 and 1442 left their summer/fall home ranges in the Ord and Newberry Mountains respectively in early December (or as early as mid-October in the case of 1441 in 2015). They then spent the following weeks traveling at least 50 miles southeast through the mountainous corridor and entered their winter/spring home ranges in the Bullion Mountains. The ewes remained in the Bullion Mountains until late March (1442 in 2015) or early June (1442 in 2016) when they began their 50 mile migration back to their respective summer home ranges.

The locations of these ewes reveal that they encountered each other in the Bullions, and even traveled together for days; however, the ewes migrated back to the northwest and to their own summer home ranges independently of the other. It is possible these ewes migrated with other animals as well.

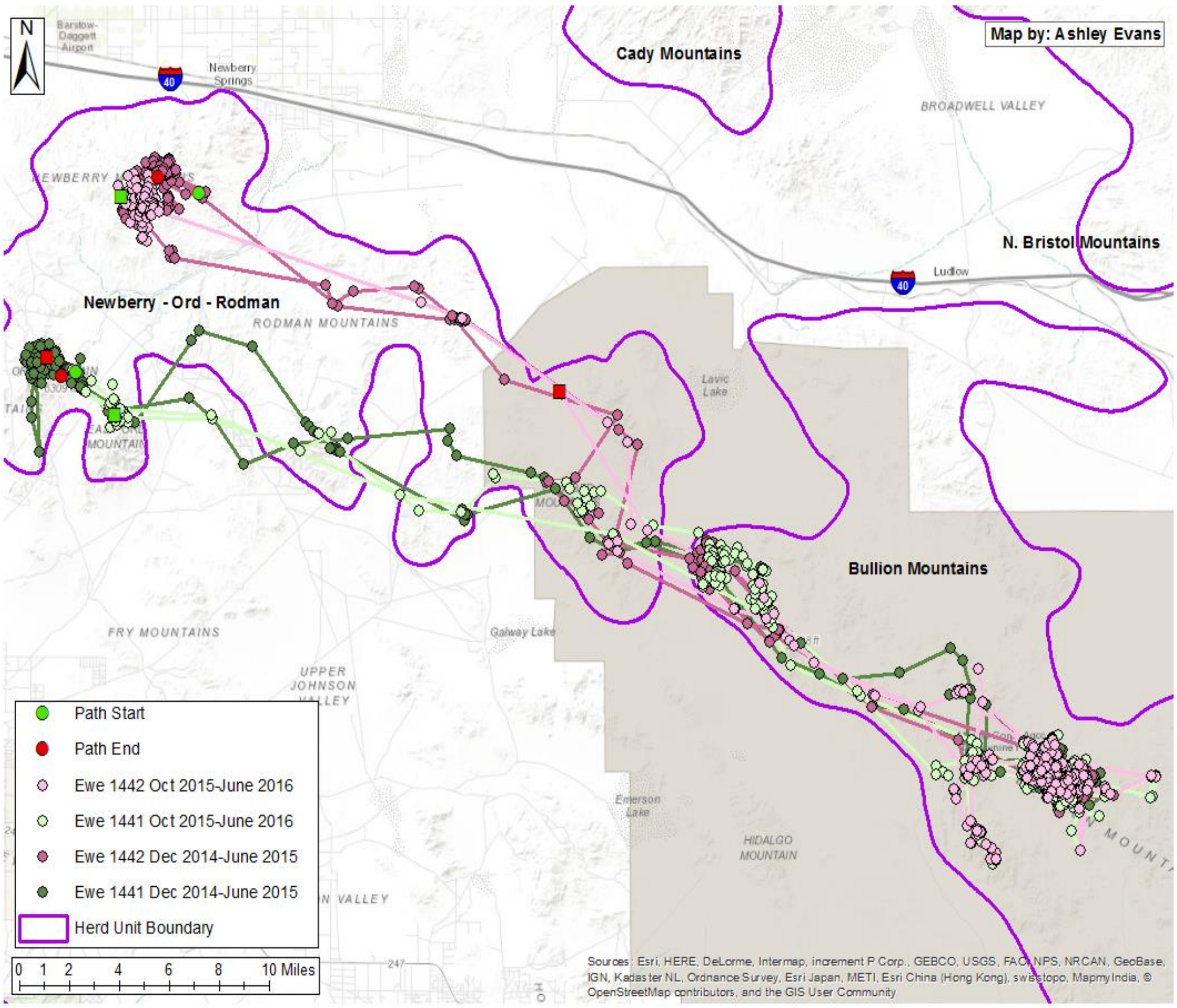


*Figure 18. The migratory movements of desert bighorn ewes 1441 and 1442 between the Newberry-Rodman-Ord complex and the Bullion Mountains herd units. Two ewes travel over 50 miles from their individual summer ranges in the Newberry and Ord Mountains to the Bullion Mountains to spend the winter.*

# II. Management Actions

## A. Disease Management

Domestic sheep and goats are the primary concern when considering potential disease vectors threatening desert bighorn sheep, specifically epizootic pneumonia (Wehausen et al. 2011). Recent studies suggest that the bacterial respiratory pathogen *Mycoplasma ovipneumoniae (M. ovi)* plays a key role in many bighorn sheep die offs (Besser et al. 2012). *M. ovi* is known to be associated with the 2013 outbreak of pneumonia in the Mojave Desert and the resultant all ages die-off in the Old Dad Mountains (Epps et al. 2016). Identifying individuals and populations in the Mojave Desert that are carriers of the bacteria is a priority for the Department. To date we have found animals with antibodies to *M. ovi.* in 11 of 13 mountain ranges (Table 2). Additional sampling is needed in the two ranges that tested negative to further test that status.


*Figure 19. Game cameras at water sources can show physical indicators of disease within the population such as the contagious ecthyma visible on this lamb's muzzle.*

There are several different methods used to monitor the presence of potentially disease causing pathogens in desert bighorn populations. Swabs of nasal, oropharyngeal, and tonsillar membranes of captured animals, fresh carcasses, and hunter-harvested animals, as well as blood samples collected during captures, can be used to test for active infection as well as previous exposure to various pathogens. Observing physiological and behavioral changes via direct observation or from remote camera photos, may indicate the presence of clinical disease (Figure 19). Investigation of mortalities yields useful information on histopathology, virology, toxicology, bacteriology, as well as an animal's body condition prior to death. We have performed serology to assess antibodies to the following pathogens: bluetongue virus, bovine herpes virus, bovine respiratory syncytial virus (BRSV), border disease virus, contagious ecthyma, epizootic hemorrhagic disease virus, parainfluenza virus 3 (PI-3), and *M. ovi*. We are focused on collecting data to gain a better understanding of these potential pathogens and their effects on both individuals and populations. This critical information will help guide management options and plans for the future.

## *B. Water Management*

Desert bighorn acquire water from forage, natural water sources including springs and tenajas, and man-made water developments (also known as big game guzzlers or wildlife drinkers). In years with adequate precipitation, desert bighorn may stay hydrated from forage alone (Gedir et al. 2016). However, in years of drought, desert bighorn require surface water for hydration (Dolan 2006, Gedir et al. 2016).

Historical Trends in Water Availability & Population Size

In the last century, natural water sources in the Mojave Desert have become increasingly unreliable. Joshua Tree National Park and Mojave National Preserve have noted both a decline in the number of springs with reliable surface water and a decrease in discharge from springs with surface water (Douglas & White 1975, Dekker & Hughson 2014). Forage availability and quality have also declined (McAuliffe & Hamerlynck 2010). Climate change and long-term groundwater pumping have been implicated as contributing factors to these drought conditions (Galloway et al. 1998, Cook et al. 2004).


*Figure 20. Desert bighorn gather around a drinker in the Old Dad Mountains during the hot summer months.*

Epps et al. (2004) found that the persistence of bighorn in desert mountain ranges directly correlated to the climatic factors of elevation, precipitation, and the presence of dependable springs. The Mojave Desert bighorn populations have been impacted by the decreased water availability and increased aridity of their desert habitat. In the twentieth century, bighorn populations inhabiting lower and drier mountain ranges were more likely to go extinct (Epps et al. 2004). Furthermore, expanding human settlements have led to desert bighorn habitat fragmentation—thus reducing the number of movement corridors and/or access to perennial water sources.

Artificial Water Sources

Artificial water sources have been used in the Mojave Desert since the 1950's (CDFW unpublished records, Figure 20). At that time, the impact of water development in the desert was not investigated, but development was assumed to positively impact wildlife. Since then, water development has become controversial, with many stakeholders questioning both the need for artificial water in areas maintained as wilderness, and the economic efficacy of building and maintaining guzzlers (Krausman et al. 2006). However, an alternative perspective is to use artificial water sources as a means to mitigate the human-caused decrease in surface water availability and the predicted rise in climatic temperature (Dolan 2006, Longshore et al. 2009).

Predicted Trends in Climate and Desert Bighorn Populations

Recent climatic modeling predicts the Southwestern United States will become increasing arid (Cook et al. 2004, Seager et al. 2007). Analyzing the 19 climate models in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Seager et al. (2007) found that precipitation is predicted to average 0.1 mm/day in the Southwest by the midcentury – approximately the equivalent of the Dust Bowl Drought.


*Figure 21. Ewes drink from a wildlife drinker in the Newberry Mountains, August 2016.*

Based on the forecasts of a more arid Southwest, several studies have analyzed the desert bighorn population's future size and stability (Epps et al. 2004, Dolan 2006, Longshore et al. 2009). When modeling a scenario with decreased precipitation, Epps et al. (2004) predicted that desert bighorn would exhibit a greater dependence on water sources. Longshore et al. (2009) found that desert bighorn summer habitat has and would continue to decrease in area, but that artificial water sources could increase the size of summer habitat. Dolan (2006) concluded that desert bighorn benefit from artificial water development, and that most criticism fails to consider the anthropogenic factors already influencing desert bighorn populations. During population monitoring, CDFW has found that many desert bighorn hydrate from big-game guzzlers during the hot summer months (Figure 21).

<u>CDFW's Active Management</u>

Over the past three years, CDFW reaffirmed its commitment to assist in the maintenance of artificial big-game guzzlers. Given the predicted increased aridity of the bighorn's habitat, CDFW believes that artificial guzzlers are an important conservation tool to prevent a decline in the desert bighorn population. CDFW also views artificial water developments as a way to actively mitigate the human-caused decline in surface water availability in the Mojave Desert. As such, department personnel have worked, and will continue to work, in collaboration with the Bureau of Land Management (BLM), the National Park Service (NPS), Water for Wildlife (WFW), and the Society for the Conservation of Bighorn Sheep (SCBS) to ensure the functionality of the artificial water developments found in bighorn habitat.

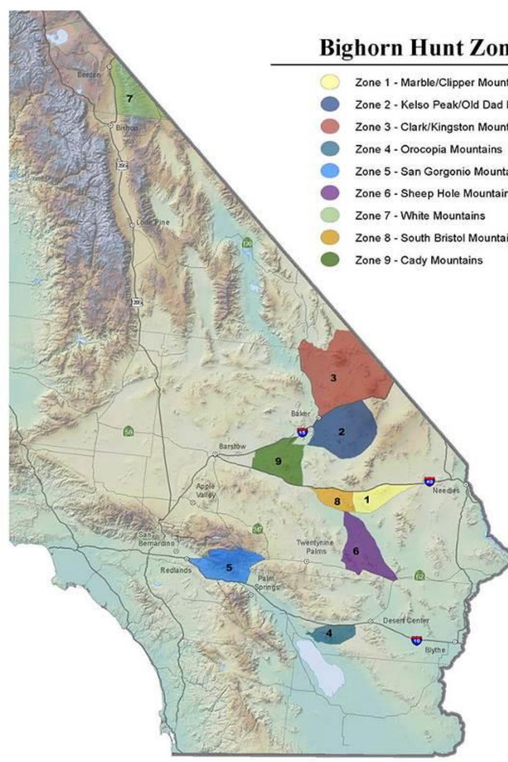


*Figure 22. Designated desert bighorn sheep hunt zones in California.*

During this reporting period, CDFW helped haul water to several artificial water sources, dug out multiple catchment dams, helped SCBS on a few major repair projects, and documented future work and repairs that are needed.

## *C. Hunting Program*

<u>Desert Bighorn Ram Harvest</u>

The hunting of desert bighorn rams was authorized by the California Legislature in 1986 for adult rams with at least a ¾ curl.

Since that date, nine separate hunt zones have been established (Figure 22).

The number of tags for each zone is adjusted annually based upon population surveys in each range. The harvesting of rams is only allowed in Fish & Game Commission approved hunt zones and the allowable number of rams harvested is set at no more than 15% of the total mature rams in a population, and up to the number of total tags allotted by the Fish & Game Commission.

For the 2011 to 2016 hunt seasons, 91 tags for desert bighorn sheep were issued (Table 18). Of those tags, 82 were filled by a successful ram harvest. While most hunt zones yield high rates of success for hunters, the White Mountains have proven to be the most challenging, accounting for over half of the unsuccessful hunts in the last six years.

*Table 18: Desert bighorn hunting tags purchased, rams harvested, and success rate by range for 2011-2016 hunt seasons.*

| Hunt Zone | Ranges | Tags | Rams Harvested | Success Rate |
|---|---|---|---|---|
| 1 | Marble, Clipper | 24 | 24 | 100% |
| 2 | Old Dad, Kelso Marl | 12 | 10 | 83% |
| 3 | Clark, Kingston, Mesquite | 8 | 7 | 88% |
| 4 | Orocopia, Mecca Hills | 6 | 5 | 83% |
| 5 | San Gorgonio | 10 | 10 | 100% |
| 6 | Sheep Hole | 4 | 3 | 75% |
| 7 | White | 6 | 2 | 33% |
| 8 | South Bristol | 8 | 8 | 100% |
| 9 | Cady | 13 | 13 | 100% |
| Total | California | 91 | 82 | 90% |

During the 2013 hunt season, an outbreak of pneumonia in the Mojave Desert began to have substantial effects on populations of desert bighorn. Hunt Zone 2 in the Mojave National Preserve was especially affected, which likely influenced the poor success rate of hunts in that zone for that season. This outbreak necessitated a decline in the number of tags available the following two years. Subsequent to the outbreak, the monitoring of desert bighorn sheep populations was increased. Evidence of some recovery from the initial outbreak allowed the number of tags to be increased in 2016.

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