

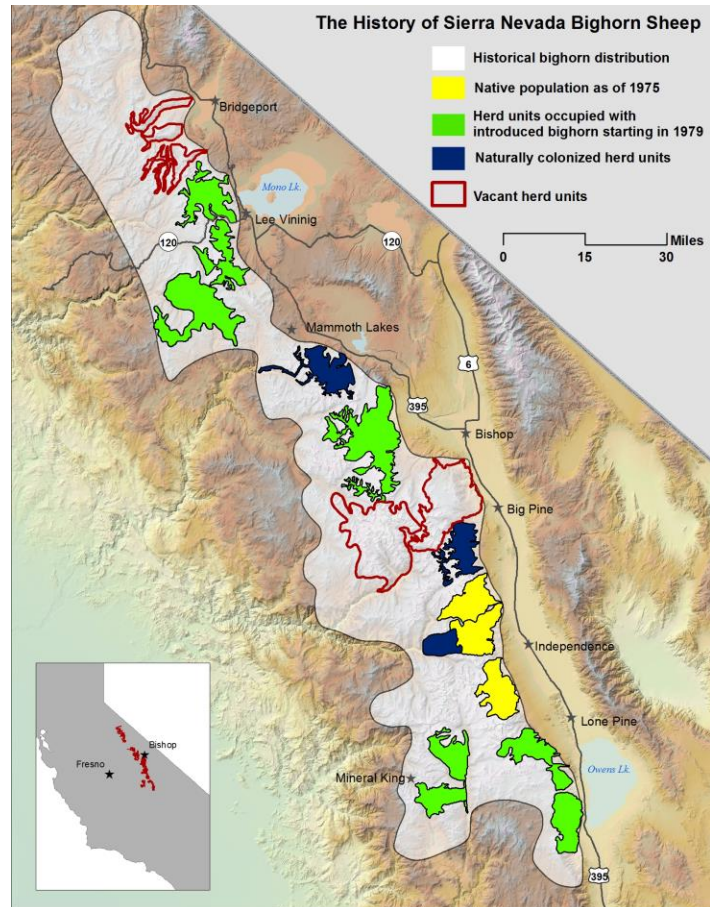


## 2014-2015 Annual Report of the Sierra Nevada Bighorn Sheep Recovery Program

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### Summary of Progress

This report documents conservation and monitoring activities carried out between May 1, 2014 and April 30, 2015 by California Department of Fish and Wildlife's (CDFW) Sierra Nevada Bighorn Sheep Recovery Program (the Recovery Program). The Recovery Program works to return the population of Sierra Nevada bighorn sheep (*Ovis canadensis sierrae*; hereafter Sierra bighorn) to a stable level through adaptive management based on an understanding of their distribution and demographics following the guidelines established by the *Recovery Plan for Sierra Nevada Bighorn Sheep* (the Recovery Plan, USFW 2007). Chief among the Recovery Program's activities are regular population counts, cause-specific mortality investigations, habitat and demographic modeling, captures to deploy radio collars, and translocations to increase the distribution of bighorn throughout the range.



**Figure 1.** Distribution of Sierra bighorn herd units, April 30, 2015. All herd units considered essential for recovery are occupied.

As a result of the translocations completed in March and April 2015 and the recent natural colonization of the Taboose Creek herd unit, Sierra bighorn have now met the distribution requirements identified in the Recovery Plan, occupying 14 herd units (Figure 1). Survey data from this season indicate that there are now at least 288 adult and yearling ewes in the Sierra; the Recovery Plan identifies a minimum target population size of 305 females distributed among 4 recovery units. We project that the Sierra bighorn population may reach all demographic criteria required for downlisting of the species within the next 5 years.

## **Conservation Activities**

### ***Translocations***

In March and April 2015, we captured and translocated 31 animals, reintroducing herds to the Laurel Creek area of the Kern Recovery Unit in Sequoia National Park and to the Cathedral Range of the Northern Recovery Unit in Yosemite National Park. A new deme in the Mt. Gibbs herd unit was created, and the Olancha Peak herd unit was augmented.

The Kern Recovery Unit is the most remote area currently occupied by Sierra bighorn; though limited connectivity exists with the Olancha Peak and Mt. Langley herds, we expect that this recovery unit could serve as a refuge for Sierra bighorn in the event of a disease outbreak in the more connected herds along the Sierra Crest. We reintroduced bighorn to the Big Arroyo drainage of the Kern Recovery Unit in March 2014; the recent addition of 7 ewes and 4 rams to the Laurel Creek drainage will speed the growth and increase the genetic diversity present in this recovery unit.

The Northern Recovery Unit contains two of the smallest herds in the Sierra (Mt. Gibbs and Mt. Warren). Both have exhibited slow population growth, and the Mt. Warren herd has recently experienced a high rate of mortality (Few et al. 2013, Runcie et al. 2014). In September 2012, biologists from the Recovery Program and Yosemite National Park began discussing the possibility that the Northern Recovery Unit may require an additional herd to reach its recovery goal of 50 females. The Washburn Lake area of the Merced drainage and the adjacent Cathedral Range were identified as suitable habitat (Few et al. 2015), and in March and April 2015 we introduced 10 ewes and 3 rams to this area to initiate the Cathedral Range herd. We also augmented the Mt. Gibbs herd with 5 collared ewes known to have high genetic diversity; these ewes were placed in the Alger Creek drainage below Mt. Wood, an area of high-quality habitat south of the currently-occupied Mt. Gibbs range.

The Olancha Peak herd unit was created in March 2013 with 10 ewes and 4 rams, and augmented with an additional 4 ewes in March 2014. Two of the rams introduced to the herd have since died. In March 2015 we captured 2 high-heterozygosity rams from the Mt. Baxter herd unit and translocated them to Olancha Peak in an effort to maintain high genetic diversity and reproductive success within this herd unit.

### ***Disease Management***

Domestic sheep and goats carry respiratory pathogens that can cause fatal pneumonia when transmitted to wild bighorn (Lawrence et al. 2010, Wehausen et al. 2011). The only effective means to prevent disease transmission is to prevent contact by maintaining separation both in time and space (Wild Sheep Working Group 2012). Domestic sheep grazing that occurs in proximity to bighorn habitat can pose a significant threat to Sierra bighorn recovery, and the Recovery Plan stipulates that measures to prevent contact must be implemented and be successful before the subspecies can be

downlisted (USFWS 2007). For decades, CDFW has worked closely with land management agencies, landowners and permit-holders to mitigate this threat by vacating high risk allotments and performing actions like double-fencing and scheduled grazing to minimize the possibility of contact between bighorn and domestic animals.

During this reporting period we applied a disease risk model, combining a resource selection function model based on ram occurrences with a cost distance analysis to quantify the proximity of domestic sheep and goat grazing to bighorn core home ranges and the risk of contact of bighorn with domestic sheep and goats. We then examined the robustness of this model to the expanding distribution of Sierra bighorn. This model will directly inform translocation efforts, allowing identification of suitable areas for future Sierra bighorn reintroductions.

Some of the highest risk grazing occurs on the Conway and Mattly Ranches, which are owned and managed by Mono County and abut the Mt. Warren herd unit. Recovery Program leaders met with Mono County to continue discussing the risk that grazing on the Conway and Mattly Ranches poses to Sierra bighorn. In 2015, CDFW will monitor domestic sheep grazing operations on the Mattly Ranch at the mouth of Lundy Canyon.

## **Sierra Bighorn Population Monitoring**

### ***Herd Unit Surveys***

Demographic data provide a foundation for the Recovery Program's adaptive management strategy, shaping our understanding of the health and growth of the Sierra bighorn population. Each year we focus on obtaining ground surveys from multiple populations and comparing these results with data from previous years. Certain herds (specifically Mt. Baxter and Wheeler Ridge) provide better survey opportunities in the winter, when animals congregate on low-elevation range; however surveys of most herds are more feasible in the summer. When possible, we compare minimum counts with mark-resight (MR) estimates, in which the total population is estimated from the ratio of marked to unmarked animals in an unbiased sample. During this reporting period we attempted surveys of all occupied herd units except Bubbs Creek (see Table 1 for survey results).

### ***Olancho Peak***

We surveyed Olancho Peak in June and September 2014 and April 2015 and accounted for 14 adult ewes, 2 yearling ewes, 6 lambs, 2 adult rams, and 2 yearling rams. One ram (S196) died of unknown causes before these surveys, and 3 ewes (S273, S206, and S272) died between November and April. S272 was seen in very poor condition in September 2014 and was nursing a late lamb. Her poor condition likely led to her death. We classified S273's death as a probable mountain lion kill, but were unable to determine the cause of death for S206. During the March 2015 capture we augmented this herd with two collared rams (S358 and S197) from the Mt. Baxter herd. At the end of this

reporting period, we estimate that this population contained 11 adult ewes, 2 yearling ewes, 2 yearling rams, 6 lambs, and 4 adult rams. All adult ewes and rams are collared.

### ***Laurel Creek***

In March 2015 we introduced 6 adult ewes, 1 yearling ewe, and 4 adult rams to the previously-vacant Laurel Creek herd unit in the Kern Recovery Unit. All of the ewes were pregnant. One ram (S364, originally from Mt. Baxter) left Laurel Creek on April 2 and traveled to Cartago Creek at the north end of the Olancho Peak herd unit. On April 28 he left Olancho Peak and started a return journey toward the Kern River; at the time of this report he was on the Boreal Plateau. Another ram (S311, originally from Sawmill Canyon) left the herd unit boundary on April 13 and traveled to the Mt. Langley herd unit, where he remained for several weeks before joining S364 on the Boreal Plateau. Ram S322 also left Laurel Creek for the Boreal Plateau in May 2015, leaving only 1 ram, S204, in the Laurel Creek herd unit.

### ***Big Arroyo***

We introduced 10 Sierra bighorn ewes and 4 rams to the Big Arroyo herd unit in March 2014. One adult ewe (S281) and one adult ram (S233) died of unknown causes during this reporting period. Summer surveys and subsequent genotyping of lamb pellets confirmed the survival of 5 lambs; therefore the population of the Big Arroyo in May 2015 was 9 adult ewes, 5 lambs, and 3 adult rams.

### ***Mt. Langley***

Surveys of the Mt. Langley herd in August 2014 accounted for 45 adult ewes, 10 yearling ewes, 18 lambs, 57 adult rams, and 8 yearling rams. One collared adult ewe (S86) was censored (due to collar failure) during this reporting period and so was not included in this count. During a capture in October 2014, 3 adult ewes and 2 yearling ewes were collared and 1 previously-collared adult ewe was recaptured and her collar replaced. In March 2015, we removed 8 uncollared adult ewes, 1 uncollared yearling ewe, and 3 previously-collared adult ewes for translocations. We also collared 1 adult ewe who was re-released at Mt. Langley. Three collared adult rams (S179, S189, and S220) and 1 collared adult ewe (S341) died during this reporting period. S179's cause of death was unknown, S189 died from rockfall, S220 was classified as a probable lion kill, and S341 was determined to be a certain lion kill. As of May 2015, we estimate that this population contained 34 adult ewes, 9 yearling ewes, 18 lambs, 54 adult rams, and 8 yearling rams. Twenty-four percent of adult ewes and nine percent of adult rams have functional telemetry collars.

### ***Mt. Williamson***

In October 2014 we conducted the first survey of the Mt. Williamson herd unit since 2010. Our observations resulted in a minimum count of 11 adult ewes, 2 yearling ewes, 4 lambs, 8 adult rams, and 2 yearling rams. This is likely a significant undercount. One adult ram (S135) was killed by rockfall in June 2014.

***Bubbs Creek***

We did not survey the Bubbs Creek herd during this reporting period.

***Mt. Baxter***

In spring 2015, ground surveys led us to a minimum count of 46 adult ewes, 6 yearling ewes, 29 lambs, 25 adult rams, and 8 yearling rams. In October 2014 we collared 7 adult ewes, 1 yearling ewe, and 7 adult rams in this herd unit. In February 2015 we collared an additional 4 adult rams and 1 yearling ram. One 5 year old collared adult ram, S318, died of malnutrition in February 2015. In March 2015 we removed 6 uncollared adult ewes and 1 uncollared yearling ewe for translocation to Laurel Creek; we also removed 5 previously-collared rams for translocation to Laurel Creek, the Cathedral Range, and Olancho Peak. We estimate that at the end of this reporting period the Mt. Baxter population contained a minimum of 40 adult ewes, 5 yearling ewes, 29 lambs, 19 adult rams, and 8 yearling rams. Based on these minimum figures, a maximum of 38% of adult ewes and 26% of adult rams carry functional collars. Rams were probably significantly undercounted in 2015; thus the percent collared is likely considerably lower than 26%.

***Sawmill Canyon***

A survey in August 2014 resulted in a minimum count of 77 bighorn: 38 adult ewes, 6 yearling ewes, 17 lambs, 8 adult rams (2 seen and 6 collars not seen), and 8 yearling rams. Because our survey efforts focused on ewe groups, we expect that many adult rams were missed in this count. We collared 9 adult ewes, 8 adult rams, and 1 yearling ram in October 2014. One collared ewe (S231) and 1 collared ram (S313) died during this capture. In February 2015 we collared 4 more adult rams. In March and April 2015 we removed 3 collared adult ewes for translocation to Alger Creek in the Mt. Gibbs herd unit, and 3 collared adult rams for translocation to Laurel Creek. We estimate that at the end of this reporting period the Sawmill Canyon herd contained 34 adult ewes (of which 41% wear functional collars). Without a reasonable count of adult rams we cannot estimate the percentage of rams collared, but there are currently 13 functional collars on rams in this population.

***Taboose Creek***

On April 24, 2014, 2 biologists saw a group of 12 bighorn in this herd unit consisting of 11 adult rams and 1 yearling ewe. This was the first occasion on which Recovery Program staff made a confirmed observation of a female in the Taboose Creek herd unit. Subsequent observations were made in July, August of 2014, and February, and April of 2015. To date, the maximum numbers of each class of animal seen at one time has been 2 adult ewes, 1 yearling ewe, 15 adult rams, and 2 yearling rams. In October and February 2015 we collared 3 rams in this herd unit; 1 on Split Mountain and 2 on Birch Mountain in the northern end of the herd unit. All 3 have since traveled between the Taboose Creek and Sawmill Canyon herd units. In addition, 3 rams collared in Sawmill Canyon have made forays into Taboose Creek. We cannot yet provide estimates of the size or composition of the population that uses the Taboose Creek herd unit, nor

can we confidently describe the relationship between this population and the Sawmill Canyon bighorn.

### ***Wheeler Ridge***

During the exceptionally dry winter of 2014-2015 bighorn did not congregate on the low-elevation winter range at Wheeler Ridge; several attempts to survey this herd during the winter months were unsuccessful. However, numerous yearlings (4 female and 9 male) were observed suggesting good recruitment. We will attempt a summer survey in 2015 to obtain better population data.

### ***Convict Creek***

June 2014 surveys counted a minimum of 13 adult ewes, 8 lambs, 2 adult rams, 1 yearling ram, and 1 unclassified yearling in the Convict Creek herd unit. One 2-year-old ram was observed in 2013 and 1 in 2012, so the adult rams seen may be the 3- and 4-year-old rams produced by this population. While it is possible there are only 2 adult rams in this herd, it seems unlikely. On December 17, 2014, a group containing 1 yearling ewe and 2 yearling rams was observed, which added 1 yearling to the summer's count. In October 2015 we collared 2 adult females, 1 adult male, and 1 male lamb in this herd unit. The collared adult male, S337, was killed by a mountain lion on April 15, 2015. Based on our counts we estimate a maximum of 38% of ewes and 0% of rams have functional telemetry collars.

### ***Cathedral Range***

In March and April 2015 we introduced 9 adult ewes, 1 yearling ewe, and 3 adult rams to this newly-designated herd unit in Yosemite National Park. The ewes were moved from the Mt. Langley herd unit and all but the yearling were pregnant. Two rams were from Mt. Baxter and 1 was from Wheeler Ridge. On April 12, 14 days after translocation, 1 ram (S359) died of unknown causes. A mortality investigation noted that he had been scavenged by a black bear. He was 12 years old which is close to the maximum age for rams. Prior to his translocation, we recognized that he might be close to the end of his life. Nevertheless, because of his high genetic diversity and that it was unlikely for him to be competitive for mates in his native herd; we opted to give him a chance to breed in a new herd.

### ***Mt. Gibbs***

Biologists surveyed the Mt. Gibbs herd unit in July and September 2014 and accounted for 10 adult ewes, 3 yearling ewes, 8 lambs, 4 adult rams, and 1 yearling ram. Preliminary analyses of fecal samples from Mt. Gibbs rams in combination with observational data indicate that there may be as many as 9 adult rams in this herd. In October 2014 we replaced 1 nonfunctional ewe collar and 2 ram collars; we also captured and collared 1 yearling ewe. In April 2015 we introduced 5 adult ewes from the Sawmill Canyon and Mt. Langley herds to the Alger Creek area of the Mt. Gibbs herd unit with the intention of creating a new deme in that habitat and continuing genetic

rescue efforts for that population. Sixty-seven percent of adult ewes in this herd unit now wear functional collars, and 3 adult rams have working collars.

Herd	Ewes				Lambs	Rams			Total
	Adult	Yearling	Total	MR Est.		Adult	Yearling	Total	
Olancho	14	2	16		6	2	2	4	26
Laurel	6	1	7		0	4	0	4	11
Big Arroyo	9	0	9		5	4	0	4	18
Langley	45	10	55	68 (50-91)	18	57	8	65	138
Williamson	11	2	13		4	8	2	10	27
Baxter	46	6	52		29	25	8	33	114
Sawmill	38	6	44		17	8	8	16	77
Taboose	2	1	3		0	15	2	17	20
Convict	13	1	14		8	2	2	4	26
Cathedral	9	1	10		0	3	0	3	13
Gibbs	10	3	13*		8	4	1	5	26
Warren	11	0	11		8	7	3	10	29

**Table 1.** Minimum count data and mark-resight estimates (MR Est.) from surveys conducted during the 2014-2015 reporting period. Lambs are not identified by sex. Because translocations occurred after surveys were completed, translocated animals are shown both in their original herd units and in the herd units to which they were translocated.

\*These data do not include ewes translocated into this population in March 2015.

### ***Mt. Warren***

Our usual early summer survey of this herd unit in July of 2014 identified 8 adult ewes, 6 lambs, and 3 yearling rams in this herd unit. Those yearlings were consistent with 3 lambs identified during counts in 2013 and 3 male lamb genotypes identified from lamb fecal samples that year; however, the count of 8 ewes was 3 lower than expected from 2013 data. During subsequent field work in 2014, three ewes and 2 lambs were sighted unexpectedly from a long distance on the top of the Dore Cliffs south of Lundy Canyon, where no ewes have been known since a small female deme that resided in that area perished during the heavy winter of 2010-2011. Genotyping of lamb fecal pellets identified two lambs from samples collected below the Dore cliffs which were different from 6 lambs similarly sampled and identified genetically from the opposite side of Lundy Canyon. This brought the total minimum count for this herd unit to 11 ewes, 8 lambs, and 3 yearling rams. The origin of the 3 ewes seen on the Dore Cliffs in 2014 has not yet been determined.

In October 2014, a biologist observed a group of 7 adult rams including all the collared rams known to be alive (S65, S239, and S185). This observation likely accounted for all of the adult rams in the Mt. Warren herd, bringing the total population size at that time to at least 29.

At the end of October we collared 2 adult ewes, 2 adult rams, and 1 yearling ram in the Mt. Warren herd unit, and replaced 2 adult ram collars. Genetic analysis showed that the yearling ram did not match any of the 3 male lamb genotypes from the 2013 season. This indicates the existence of at least one more ewe than was counted in 2013. One adult ewe died during capture. One collared adult ram was killed by a mountain lion in January 2015. At the end of this reporting period we estimate that the Mt. Warren herd unit contained 10 adult ewes of which 3 have functional telemetry collars, 8 lambs, 3 yearling rams, and 6 adult rams, 5 of which have functional telemetry collars.

### ***Geographic Distribution***

Sierra bighorn now occupy 14 herd units in 4 recovery units spanning a nearly 150-mile stretch of the Sierra Nevada (Figure 1). The Recovery Plan designates 16 herd units historically occupied by Sierra bighorn (USFWS 2007); the recently-completed Translocation Plan demarcates 2 additional herd units identified as suitable for reintroductions (Few et al. 2015). Of these 18 areas, 12 are included in recovery goals for the subspecies. All 12 of these herd units are now inhabited. Over the next few years, continued population monitoring and augmentation of recently-introduced herds will be essential to confirm that bighorn are persisting and flourishing in these areas.

### ***Collaring Efforts***

The Recovery Program strives to maintain a high proportion (30-35%) of marked animals within each herd to facilitate accurate population surveys, monitoring of reproductive success, and cause-specific mortality investigations (Table 2). The data we collect from GPS collars are central to our ongoing studies of habitat selection, seasonal migration, home range use, and survival. We conduct annual captures to create new marks, replace nonfunctional collars, and translocate animals to new habitat in accordance with the Translocation Plan (Few et al. 2015). Captures also give us the opportunity to assess the health and reproductive status of captured animals and to collect samples for genetic analysis.

We carried out 3 captures during this reporting period. Wildlife capture specialists from Leading Edge Aviation captured Sierra bighorn from 8 herds (Mt. Langley, Mt. Baxter, Sawmill Canyon, Bubbs Creek, Taboose Creek, Convict Creek, Mt. Gibbs, and Mt. Warren) using a net-gun fired from a helicopter. During October 18-28, 2014, we captured 62 Sierra bighorn (33 ewes, 27 rams, and 2 lambs) in order to increase the percentage and distribution of collared animals in each herd to aid us in obtaining accurate counts and survival data and to obtain genetic data on rams to allow selection of members of that sex for translocations based on genetic diversity. Three mortalities occurred as a result of this capture. A previously-collared Sawmill Canyon ewe, S231, died of spinal cord trauma when she was caught in the net with another animal. A previously-uncollared Mt. Warren ewe was captured alive under ordinary circumstances but was dead on arrival at basecamp; a field necropsy revealed that the pericardium and the bottom portions of the lungs were filled with blood. S313, a newly-collared Sawmill Canyon ram, moved about half a mile after his release on October 19 and died the next



day; although no injuries or unusual behaviors were evident during his capture, the timing of his death indicates it was probably capture-related.

	Langley		Williamson		Baxter		Sawmill		Taboose		Bubbs		Wheeler		Convict		Gibbs		Warren	
Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
<b>5/1/2014</b>	<b>7</b>	<b>7</b>	<b>5</b>	<b>3</b>	<b>11</b>	<b>3</b>	<b>12</b>	<b>4</b>	<b>0</b>	<b>0</b>	<b>4</b>	<b>3</b>	<b>12</b>	<b>7</b>	<b>3</b>	<b>0</b>	<b>4</b>	<b>4</b>	<b>1</b>	<b>4</b>
Additions	+7	0	0	0	+6	+11	+6	+13	0	+3	+2	+2	0	+6	+2	+1	+6	0	+2	+3
Subtractions	-6	-2	-1	-2	-2	-9	-4	-4	0	0	-1	-1	-1	-2	0	-1	0	-1	0	-2
<b>4/30/2015</b>	<b>8</b>	<b>5</b>	<b>4</b>	<b>1</b>	<b>15</b>	<b>5</b>	<b>14</b>	<b>13</b>	<b>0</b>	<b>3</b>	<b>5</b>	<b>4</b>	<b>11</b>	<b>11</b>	<b>5</b>	<b>0</b>	<b>10</b>	<b>3</b>	<b>3</b>	<b>5</b>
% Collared	<b>24</b>	<b>9</b>	<b>36</b>	<b>13</b>	<b>38</b>	<b>26</b>	<b>41</b>	<b>*</b>	<b>0</b>	<b>20</b>	<b>50</b>	<b>*</b>	<b>26</b>	<b>55</b>	<b>38</b>	<b>0</b>	<b>67</b>	<b>33</b>	<b>30</b>	<b>83</b>

**Table 2.** Distribution of radio collars by herd unit; new herd units created with introduced animals are not included because 100% of adults are collared. Additions include new captures, recaptures where nonfunctional collars were replaced, and augmentations. Subtractions include removals for translocation, mortalities, censors, and nonfunctional collars. The percent of the population collared is based on functional collars and adult population size from the most recent complete minimum counts. Because the number of collars is always known, but the population data are the minima, what is presented is the maximum %.

\* Indicates a population from which the minimum number of rams is not known; thus, a maximum % collared cannot be determined.

On February 19, 2015 and February 20, 2015, we captured 18 Sierra bighorn rams in an effort to gain a larger pool of individuals known to have high genetic diversity; the Translocation Plan calls for selecting rams with high heterozygosity when initiating new herds (Few et al. 2015).

Over 5 days in March and April 2015 we translocated 31 Sierra bighorn. We reintroduced bighorn to 2 previously-vacant areas of historic habitat by moving 10 ewes and 3 rams to the Cathedral Range in Yosemite National Park and 7 ewes and 4 rams to the Laurel Creek area in Sequoia National Park. We supplemented the Olancha Peak herd, which was reintroduced in 2013, with 2 rams to maximize genetic diversity. We augmented the Mt. Gibbs herd with 5 ewes to increase genetic diversity while also creating a new deme in the Alger Creek basin south of Mt. Wood.

## Sierra Bighorn Population Dynamics

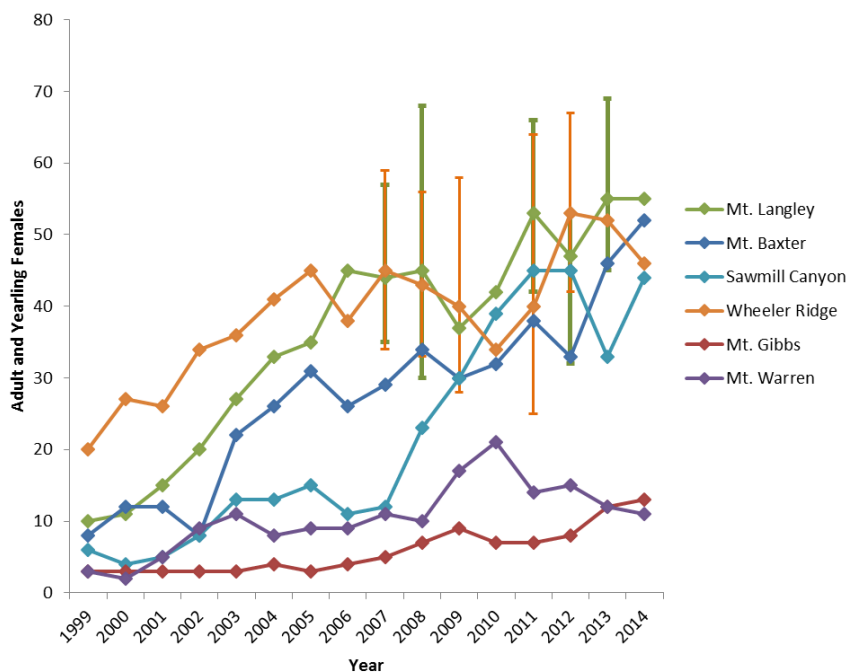
### *Population Size*

When Sierra bighorn were listed as an endangered species in 1999, only about 125 animals were known to exist in the range. We now estimate the total population size at over 600 bighorn (Few et al. 2015); the largest herds contain more than 40 adult and yearling females (Figure 2).

Because we did not obtain a complete survey of the Wheeler Ridge herd this year, the estimate shown was derived from the total females found in the previous year's surveys minus 10 removals for translocation to Big Arroyo and including the 4 yearling ewes

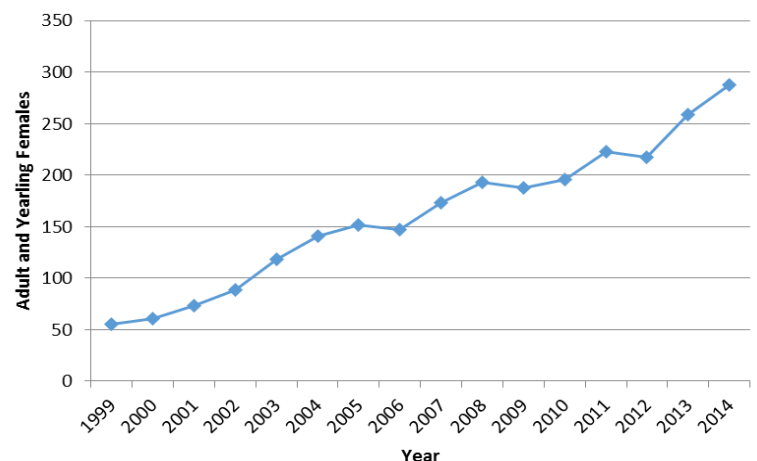
observed during our December survey attempts. The apparent increase in the Sawmill Canyon population is likely the result of a more complete count this year.

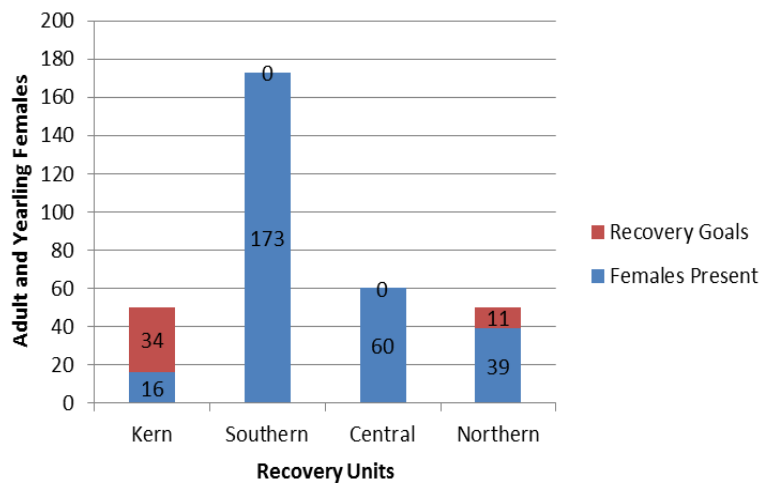
At the end of the 2014-2015 survey season we estimate that there were at least 288 female bighorn in the Sierra (Figure 3). The Recovery Plan recommends downlisting when the female population reaches 305 animals distributed throughout the recovery units (50 in the Kern Recovery Unit, 155 in the Southern Recovery Unit, 50 in the Central Recovery Unit, and 50 in the Northern Recovery Unit; USFWS 2007). We anticipate reaching this goal within 5 years. The Southern and Central Recovery Units exceed the number needed for recovery. The Northern and Kern Recovery Units are 11 and 34 females, respectively, under their recovery goals.



**Figure 3.** Combined population trajectories for adult and yearling ewes from all occupied herds (Olancho Peak, Big Arroyo, Mt. Langley, Mt. Williamson, Bubbs Creek, Mt. Baxter, Sawmill Canyon, Taboose Creek, Wheeler Ridge, Convict Creek, Mt. Gibbs, and Mt. Warren) from 1999-2014 surveys. Population estimates in earlier years lack data for some herds. Some of the significant increases have been due to better data and cannot be construed as population gains; for example, the increase between 2012 and 2013 is the result of more complete counts in 2013.

**Figure 2.** Population trajectories for adult and yearling females from 1999-2014 based on a combination of minimum counts, mark-resight estimates, and reconstructed data for 6 herds in the Sierra Nevada with annual population data. In years when no data were available or when surveys were incomplete, survey totals from the most recent complete count were used. Data from mark-resight estimates are plotted with error bars representing 95% confidence intervals. In all figures, years are defined from May 1 to April 30 of the following year.

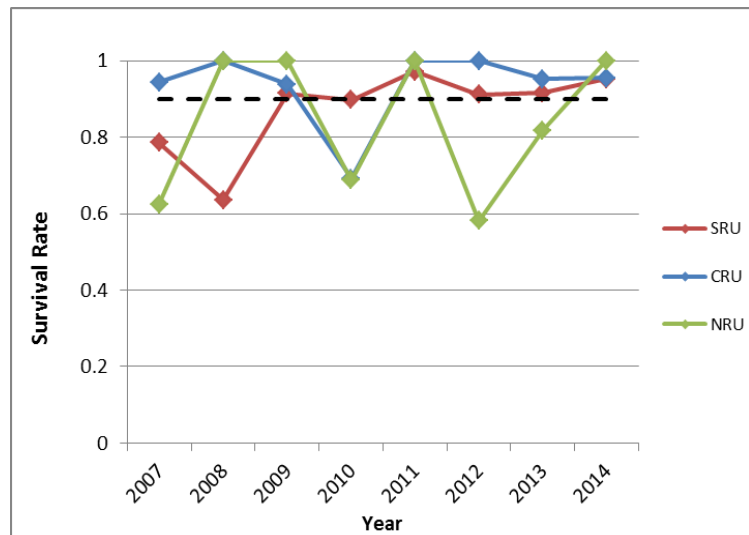




**Figure 4.** Adult and yearling females present in each recovery unit at the end of the 2014-2015 reporting period relative to the distribution of females specified in recovery goals.

### ***Survival and Cause-Specific Mortality***

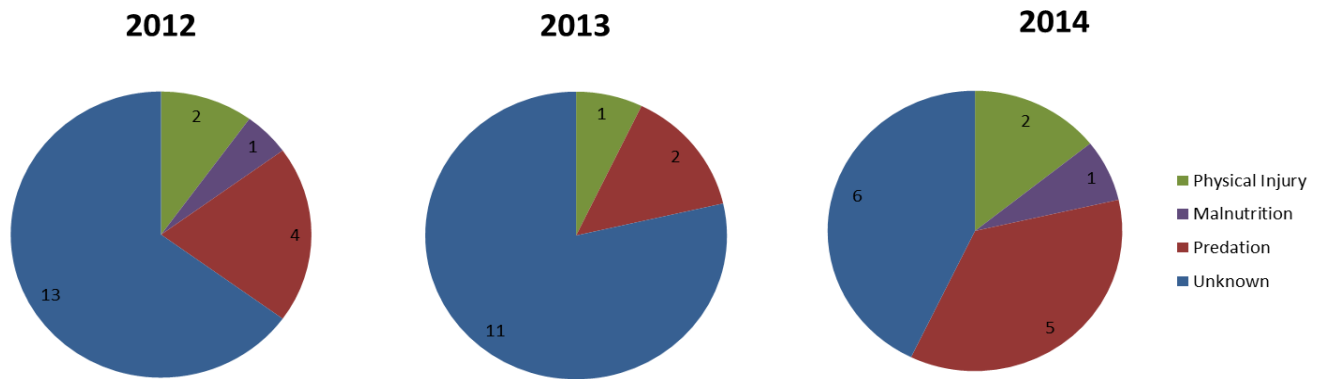
Demographic rates are important tools for evaluating population health and growth. Adult female survival is the primary factor driving population growth or decline in Sierra bighorn herds (Johnson et al. 2010). Maintaining radio collars on 30-35% of females in each herd unit allows us to detect and investigate mortalities; we use this information to calculate annual Kaplan-Meier survival rates of radio-collared ewes (Kaplan and Meier 1958). Following these rates over time gives us an understanding of the year-to-year variation in adult ewe survival and the general trend of this metric in different populations.



**Figure 5.** Annual Kaplan-Meier survival rates of radio-collared ewes in the Northern, Central, and Southern Recovery Units for 2007-2014. The dashed line represents 90% survival.

Between 2007 and 2014, survival rates varied from 0.58 to 1.0 (Figure 5). The lowest survival rates occurred in the Northern Recovery Unit in 2012, in the Central Recovery Unit in 2010, and in the Southern Recovery Unit in 2008. In 2014 survival rates were high in all herd units; survival rates above 90% are associated with population growth (unpublished data).

The Recovery Program prioritizes prompt mortality investigations. Understanding the predominant causes of bighorn mortality can help develop conservation measures that may increase survival and population growth. During this reporting period we detected 14 natural mortalities of collared bighorn (5 female, 9 male; Figure 6). We were unable to determine the cause of 6 of these mortalities. One ram at Mt. Baxter died of malnutrition. One ram at Mt. Langley and one ram at Mt. Williamson died of physical injury (the former due to a fall from a cliff, the latter due to rockfall). We determined that 3 Sierra bighorn (1 ewe at Mt. Langley, 1 ram at Mt. Warren, and 1 ram at Convict Creek) were killed by mountain lions; 2 additional mortalities (1 ram at Mt. Langley and 1 ewe at Olancho Peak) were considered probable mountain lion kills.



**Figure 6.** Cause-specific natural mortalities of radio-collared bighorn from May 1 to April 30 of the following year.

### ***Reproduction and Recruitment***

Recruitment, the proportion of females that reach reproductive age, can be measured by comparing the number of adult and yearling females observed in each herd unit in one year with the total number of adult females observed there the following year. Assuming accurate minimum counts in both years and 100% survival, the two numbers would be equal. This is rarely the case; yet, in 4 herd units, Olancho Peak, Mt. Langley,

<b><i>Herd</i></b>	<b>2013</b>				<b>2014</b>
	Adult Ewes	Yearling Ewes	Total Ewes	Known Gains/Losses	Adult Ewes
<b>Olancho</b>	14	0	<b>14</b>		<b>14</b>
<b>Langley</b>	38	9	<b>47</b>	-2	<b>45</b>
<b>Baxter</b>	40	6	<b>46</b>		<b>46</b>
<b>Convict</b>	12	1	<b>13</b>		<b>13</b>
<b>Gibbs</b>	11	1	<b>12</b>	-1	<b>10</b>
<b>Warren</b>	7	4	<b>11</b>		<b>11</b>

**Table 3.** Comparison of the number of adult ewes in 2014 to the total number of ewes in 2013 after accounting for recruitment of yearlings and known losses or gains from mortalities or translocations. Populations with poor minimum counts in either year are not included.

Mt. Baxter and Convict Creek (Table 3) the 2014 totals of adult ewes corresponded exactly to the number of adult and yearling ewes observed in 2013 after known losses were subtracted. 2014 totals in the two remaining herd units, Mt. Gibbs and Mt. Warren (Table 3), are only one ewe short of projected totals based on 2013 data. These findings suggest high adult survival and yearling recruitment in all of those herd units.

Additional metrics to assess herd health are the observed ratio of yearlings to ewes and the ratio of lambs to ewes which indicate recruitment and fecundity (reproductive output depending on the age at which lambs are observed), respectively. Yearling to ewe ratios vary from 0.23 to 0.44 in 2014 (Table 4) which indicate positive or stable population growth assuming high adult survival. Lamb to ewe ratios vary from 0.33 to 0.8 in 2014 (Table 4) which are within the healthy range for these populations indicating good reproductive success.

<i><b>Herd</b></i>	<i><b>Lamb:Ewe</b></i>	<i><b>Total Yearling:Ewe</b></i>
<b>Olancho</b>	0.33	0.44
<b>Langley</b>	0.42	0.42
<b>Baxter</b>	0.74	0.36
<b>Convict</b>	0.62	0.23
<b>Gibbs</b>	0.8	0.40
<b>Warren</b>	0.72	0.27

**Table 4.** Ratios of juvenile age classes to ewes from 2014. Populations with poor minimum counts in either year are not included.

Another way to assess lamb survival is to compare the total number of yearlings observed in each herd unit with the number of lambs observed there in the previous survey season. Observed lamb survival between 2013 and 2014 varied from 0.5 to 1.0 (Table 5). These values represent lamb survival between annual surveys, which occur months after lambs are born. Thus these estimates of lamb survival do not include survival rates of neonatal lambs. While a 50% survival rate may seem low compared to adult survival, it is not unusual for juvenile age classes.

<i><b>Herd</b></i>	<i><b>2013 Lambs</b></i>	<i><b>2014 Yearlings</b></i>	<i><b>Lamb Survival</b></i>
<b>Olancho</b>	8	4	0.50
<b>Baxter</b>	24	14	0.58
<b>Convict</b>	5	3	0.60
<b>Gibbs</b>	7	4	0.57
<b>Warren</b>	3	3	1.00

**Table 5.** Lamb survival estimated by comparing the number of yearlings in 2013 to the number of lambs in 2012. All data are from minimum counts. Populations with incomplete minimum counts in either year are not included.

## **New Findings**

### ***Taboose Creek Occupation***

For several years, the Recovery Program has suspected that a natural colonization of the Taboose Creek herd unit by Sawmill Canyon bighorn was underway (Stephenson et al. 2012). Observations made during this reporting period and collars deployed in these 2

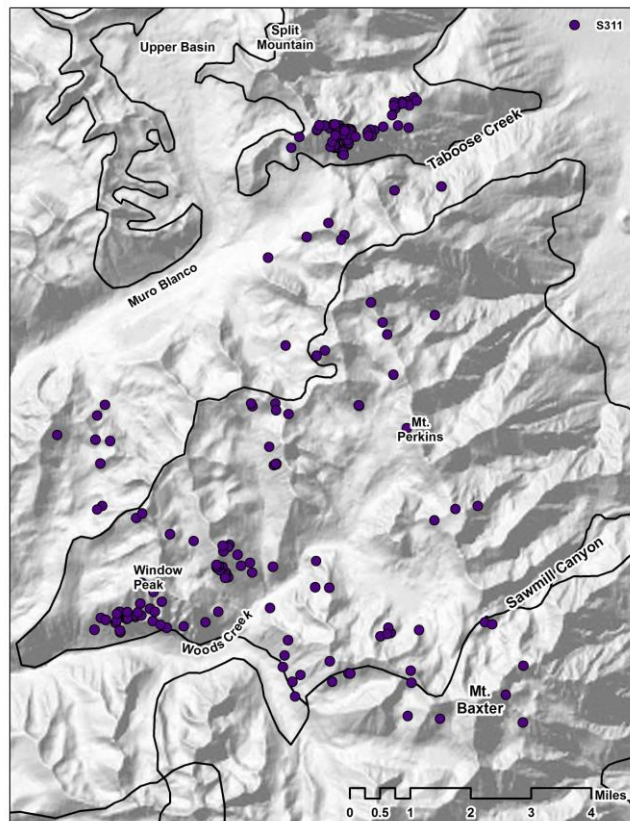
herd units confirm that numerous rams make regular use of both areas. It is likely that a population of rams also resides permanently in the Taboose Creek herd unit, and several recent sightings of adult and yearling ewes strongly suggest that a reproductive population exists here as well. The Recovery Program will continue to make investigation of this herd unit a priority in 2015-2016.

#### ***New Habitat Use, Possible Range Expansions, and Long-Distance Movements***

Deployed GPS collars provide insight into habitat use and long-distance movements by Sierra bighorn. In the Mt. Warren herd unit, a small ewe group has continued to use the Camiaca Peak area, where collared ewe S89 moved in November 2013. A summer survey also located 3 adult ewes and 2 lambs on Dore Peak, an area south of Lundy Canyon where no bighorn have been seen since avalanches during the heavy winter of 2010-2011 killed all animals known to use that habitat. It is possible that this small ewe group has persisted undetected in the area since 2010; an alternative explanation is that occupation of this area represents a recent range expansion or repossession for ewes in the Mt. Warren herd.

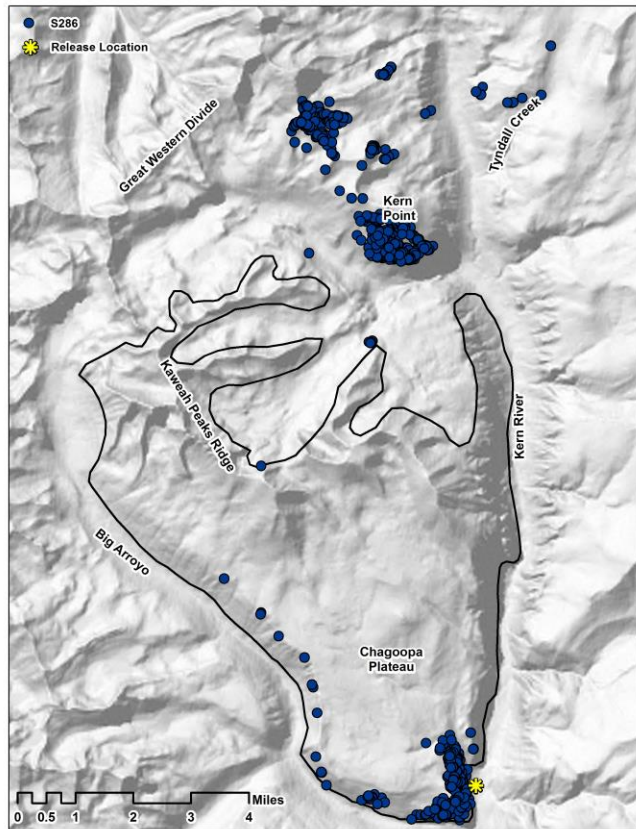
Studies of bighorn rams have often documented long-range movements, particularly during the rut (Geist 1971, Leslie and Douglas 1979, O'Brien et al. 2014). Deploying collars on Sierra bighorn rams allows us to document the significant distances that specific individuals travel. S311, a 9-year-old ram first captured in October 2014 in the Window Peak area of the Sawmill Canyon herd unit, traveled throughout the Sawmill Canyon herd unit and into the northern end of the Mt. Baxter herd unit before spending most of the winter on Cardinal Peak in the southern Taboose Creek herd unit (Figure 7).

These movements suggest the Sawmill Canyon, Mt. Baxter, and Taboose Creek herds function as a metapopulation with gene flow occurring between herds.



**Figure 7.** Movements of S311, a 9-year-old Sawmill Canyon ram, between October 2014 and March 2015.



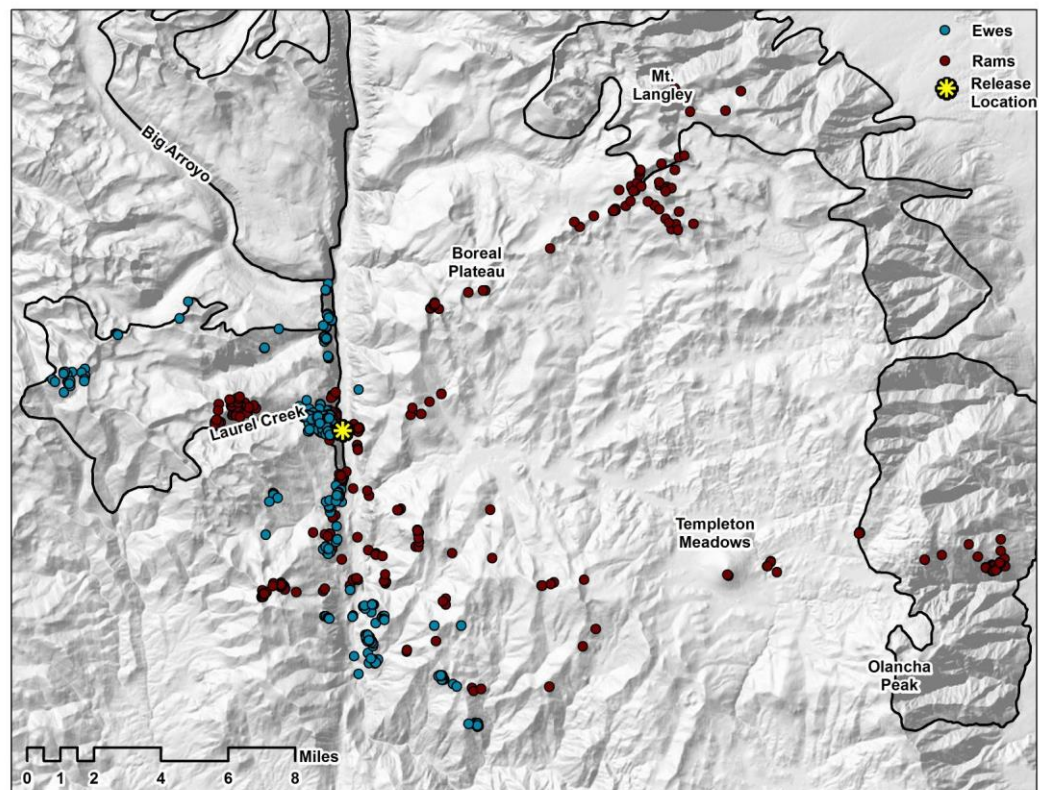


**Figure 8.** Movements of Big Arroyo ewe S286 since her translocation in March 2014.

### ***Habitat Exploration by Naïve Animals***

Translocating Sierra bighorn often results in unanticipated movements by the naïve animals as they explore their new habitat. S286, a Wheeler Ridge ewe who was translocated to the Big Arroyo in March 2014, left that drainage on June 30, 2014 and traveled north, accompanied only by her lamb. She briefly crossed the Kern River north of Tyndall Creek, then crossed back to the Kern Ridge and eventually settled on Kern Point, where she has remained since late July 2014 (Figure 8). No other collared ewe has ever traveled to her location.

The 11 bighorn translocated to the Laurel Creek herd unit in March 2014 have since dispersed widely (Figure 9). Some traveled over 6 miles south to Coyote Peaks while others crossed the Kern River to the east, and 3 rams left the herd unit boundary for the Boreal



**Figure 9.** Movements of Laurel Creek animals after translocation in March 2015.

Plateau, just west of the Mt. Langley herd unit. Three ewes, S377, S378, and S382, have remained east of the Kern River near the Hell-For-Sure drainage for several weeks. We will continue to monitor these animals over the 2015 summer, when the search for high-elevation habitat may draw them back within the Laurel Creek herd unit boundary.

By contrast, the animals translocated to the Cathedral Range herd unit in Yosemite National Park have all remained in the immediate vicinity of their release site, on the slopes above Washburn Lake.

## **Research Priorities**

### ***Genetic Research***

Sierra bighorn are recognized for their genetic uniqueness as a separate subspecies; therefore, recovery efforts for this taxon are ultimately about conserving and enhancing this unique gene pool. Sierra bighorn survived epizootics caused by past domestic sheep grazing only in three herds in the southern Owens Valley, but they did not survive without genetic scars. They exhibit signatures of a genetic bottleneck and have the lowest genetic diversity measured for free-ranging native populations in the desert region. Genetic diversity in Sierra bighorn herds is sufficiently low that individuals at the lowest end of the heterozygosity (individual genetic diversity) spectrum may be less fit (Johnson et al. 2011). This presents a potential opportunity to increase genetic diversity in small and reintroduced populations to enhance population fitness and success.

Various authors have recommended that large numbers of bighorn sheep (more than 20) be used in reintroductions to maximize the representation of genetic diversity in new herds and to minimize founder effects (Fitzsimmons et al. 1997, Griffiths et al. 1982, and Wolf et al. 1996). However, Sierra bighorn translocation stock is both limited in the numbers of animals available and in the genetic diversity of those animals. With careful genetic planning including selective captures of individual bighorn, it might be possible to initiate highly diverse herds with fewer animals by maximizing genetic diversity in the founding gene pool.

To explore different genetic management options, we employed sampling experiments of existing data to examine the genetic consequences of three different approaches that might be used for founding populations: 1) all individuals selected for higher heterozygosity, 2) all individuals selected at random, and 3) all ewes selected randomly but rams selected individually for higher heterozygosity. In our sampling experiments, we measured average heterozygosity at 17 microsatellite loci and interpreted this as a direct measurement of genetic diversity. However, we did not look at allele structure or loss at the individual loci.

These sampling experiments revealed that (1) the first approach can produce founding gene pools with notably higher heterozygosity than any existing population, but that there are too few alleles remaining in the Sierra bighorn gene pool to support that level of genetic diversity over time (heterozygosity excess); (2) the third approach of selecting



only high heterozygosity rams provides a significant genetic improvement over random selection of bighorn, does not produce a large heterozygosity excess, and minimizes the number of sheep that need to be selectively recaptured; (3) genetic diversity is improved for this third approach if the rams are selected from multiple populations; and (4) random selection of ewes from a single population mating with selected rams resulted in genetic diversity similar to the remaining native populations. As a result of these findings, all recent reintroductions (Olancho Peak, Laurel Creek, Big Arroyo, and the Cathedral Range) initially translocated 7-10 pregnant females randomly captured from a single herd and 3-4 specific males selected for high individual heterozygosity from multiple source herds.

Greater selectivity in the individuals used to initiate a population should allow for fewer animals to represent variation in the gene pool. However, a downside of a smaller founding population is that matings between close relatives are more likely to occur, and such inbreeding will work against the advantages of the initial selectivity. The Olancho Peak herd was reintroduced in 2013 and augmented in 2014. This is the only recently-reintroduced herd where bighorn have been present long enough that rams now have the potential opportunity to breed their daughters. Of 6 lambs that were born in 2014 and survived to be sampled in late summer, genetic and observational studies found that 3 belonged to pregnant ewes moved there in 2014. Of the other 3, 2 are females that have the potential to be bred by their fathers. One of these was born very late, thus is very unlikely to breed in 2015 as a yearling. In 2015 we added 2 high heterozygosity rams to this population to dilute the probability of a father-daughter mating. We will consider this strategy in our other newly created populations as well.

It is at small population sizes that we can have the greatest influence on genetic population structure by adding high heterozygosity individuals. Within Sierra bighorn, the Mt. Gibbs herd unit stands out in showing clear signs of low genetic diversity, which is consistent with its demographic history and substantial isolation (Stephenson et al. 2012). This has raised the question of whether the population's growth rate might be improved by increasing genetic diversity through a genetic rescue by selective augmentation with high heterozygosity individuals. To increase the genetic diversity of this herd we have implemented two approaches, both of which used translocated ewes selected for high genetic diversity. First, in 2013, we augmented the existing ewe group (7 ewes) on Mt. Gibbs with 3 high heterozygosity ewes, two of which were pregnant. Second in 2015, we created a new deme of high heterozygosity ewes in the Alger Creek area on the south side of Mt. Wood, an area Mt. Gibbs rams have used regularly. This new deme was founded with 3 ewes translocated from the Sawmill Canyon herd and 2 ewes from the Mt. Langley herd, all of which were pregnant. This results in the current total 15 adult ewes of which 8 (>50%) are ewes selected for high genetic diversity.

### ***Pine Creek Recreation Study***

Over the last ten years, the Pine Creek area of the Wheeler Ridge herd unit has become an increasingly popular destination for hikers, sightseers, and rock climbers. Pine Creek

Canyon is also routinely used as lambing habitat by Wheeler Ridge ewes. In 2014-2015 the Recovery Program began a study to develop a baseline estimate of current recreational use of this canyon. Tracking recreation over time will allow us to quantify this trend and detect any relationship between increased recreation and Sierra bighorn use of Pine Creek.

### ***Home Range Analysis***

Recovery Program staff used a dataset containing a decade's worth of GPS collar locations to define the home ranges of Sierra bighorn both at the individual and at the population level. They examined variation in home range size from year to year and in different seasons, as well as the relationship between home range size and population size. The results of this study may contribute to a better understanding of habitat selection and availability. Results will be summarized in next year's report.

### ***Resource Selection Function***

Species distribution models (SDMs) provide a measure of the importance of ecological variables that correlate with species occurrence. These models can provide a framework for the implementation of adaptive management in the recovery of Sierra bighorn. Model results can be applied to spatial data to produce maps representing the likelihood of species occurrence. In a study currently underway, we used one type of SDM, a resource selection function (RSF) generated by logistic regression, to examine how species rarity affects model predictions of the likelihood of occurrence.

This model and a winter RSF that accounts for altitudinal migration identified two large patches of bighorn habitat unrecognized by the Recovery Plan in remote geographic areas where there is a paucity of historic occurrence data (the Cathedral Range and Black Divide herd units) compared to more easily accessible areas east of the Sierra crest (Wehausen and Jones 2014). By quantifying habitat quality, these models will directly inform translocation efforts, allowing the Recovery Program to identify suitable areas for future Sierra bighorn reintroductions.

## **Public Outreach**

### ***Educating the Community***

Community support is crucial to the success of conservation efforts for the recovery of Sierra bighorn. Because these animals are rare and occupy remote areas, most residents of the Eastern Sierra have never seen a Sierra bighorn in the wild and know very little about them. The Recovery Program partners with the Sierra Nevada Bighorn Sheep Foundation (SNBSF) to increase public awareness of this endangered subspecies and conservation work on its behalf.

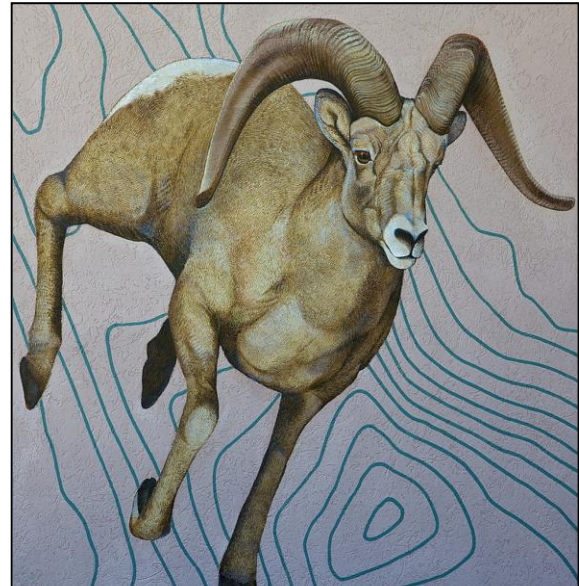
The SNBSF continues to expand its educational programs. Since May 2014, the SNBSF has planned and carried out 23 public events, reaching over 1,500 people throughout the region. The events range from booths at local celebrations like Bishop Earth Day, CDFW's Trout Fest, and the Tri-County Fair, to school programs in which children

simulate the capture and processing of a toy bighorn sheep, entering the animal's measurements into a datasheet, fitting it with a radio collar, and using its heterozygosity score to determine its suitability for translocation.

In conjunction with the SNBSF, the Recovery Program also led 2 free public field trips in February and March 2015. Over 60 participants were given the opportunity to observe groups of Sierra bighorn on winter ranges, while Recovery Program staff members and SNBSF volunteers answered questions and provided historical and biological context.

### ***Permanent Outreach Displays***

The Migrating Mural, created by scientific illustrator Jane Kim, is a series of paintings depicting life-size Sierra bighorn on buildings along the Highway 395 corridor. Kim hopes the murals will bring public attention to the plight of Sierra bighorn and raise support for recovery efforts. The final mural in the series, painted on the Forest Service Visitor Center in Lee Vining, was completed in May 2014. Other Migrating Mural scenes appear at the Bishop Gun Club, Sage to Summit running store in Bishop, the Mt. Williamson Motel in Independence, and the Lone Pine Airport, spanning most of the north-south range of bighorn in the Sierra.



**Figure 10.** Detail from Jane Kim's Migrating Mural in Lee Vining; photograph courtesy of Jane Kim, [www.inkdwell.com](http://www.inkdwell.com).

### **Future Recovery Actions**

The Translocation Plan completed in 2015 outlines the augmentations and reintroductions the Recovery Program may carry out within the next 10 to 20 years. These translocations are a means of recreating the population distribution that characterized the subspecies before endangerment, while also increasing the genetic diversity and long-term viability of smaller herd units (Few et al. 2015). No translocations or augmentations are scheduled during the next reporting period.

Downlisting to threatened status will not occur until the risk of contact between wild bighorn and domestic sheep is eliminated. The Recovery Program will increase its focus on reducing the risk of contact between wild bighorn and domestic sheep. Program leaders will continue working to mitigate this risk in cooperation with land management agencies, landowners, and grazing permittees.

Since its inception in 2000, the Recovery Program has helped to catalyze and document significant increases in the size and distribution of the Sierra bighorn population. The 2014-2015 reporting period witnessed the realization of a major objective: all 12 herd units included in recovery goals for the subspecies are now occupied. With additional translocations, continued population growth, and further steps taken to mitigate disease risk, Sierra bighorn may achieve Recovery Plan goals for downlisting to threatened status within the next 5 years.

### **Literature Cited**

Few, A.P., J.M. Runcie, D.W. German, J.D. Wehausen, and T.R. Stephenson. 2013. 2012-2013 Annual Report of the Sierra Nevada Bighorn Sheep Recovery Program. California Department of Fish and Wildlife. 19pp.

Few, A.P., K. Knox, D. W. German, J. D. Wehausen, and T. R. Stephenson. 2015. 2015 Translocation Plan for Sierra Nevada Bighorn Sheep: A Focus on Strategic Planning. California Department of Fish and Wildlife. 54pp.

Geist, V. 1971. Mountain Sheep: A Study in Behavior and Evolution. The University of Chicago Press, Illinois, USA.

Johnson, H. E., L. S. Mills, T. R. Stephenson, and J. D. Wehausen. 2010. Population-specific vital rate contributions influence management of an endangered ungulate. *Ecological Applications* 20: 1753-1765.

Kaplan, E. L. and P. Meier. 1958. Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association* 53: 457–481.

Lawrence, P. K., S. Shanthalingam, R. P. Dassanayake, R. Subramaniam, C. N. Herndon, D. P. Knowles, F. R. Rurangirwa, W. J. Foreyt, G. Wayman, A. M. Marciel, S. K. Highlander, and S. Srikumaran. 2010. Transmission of *Mannheimia haemolytica* from domestic sheep (*Ovis aries*) to bighorn sheep (*Ovis canadensis*): unequivocal demonstration with green fluorescent protein-tagged organisms. *Journal of Wildlife Diseases* 46:706-717, and erratum 46: 1346-1347.

Leslie, D. M., and C. L. Douglas. 1979. Desert bighorn sheep of the River Mountains, Nevada. *Wildlife Monographs* 66:1-56.

O'Brien, J. M., C. S. O'Brien, C. McCarthy, and T. E. Carpenter. Incorporating foray behavior into models estimating contact risk between bighorn sheep and areas occupied by domestic sheep. *Wildlife Society Bulletin* 38:321-331.

Runcie, J. M., A. P. Few, D. W. German, J. D. Wehausen, and T. R. Stephenson. 2014. 2013-2014 Annual Report of the Sierra Nevada Bighorn Sheep Recovery Program. California Department of Fish and Wildlife. 19pp.

Stephenson, T. R., J.D. Wehausen, A.P. Few, D.W. German, D.F. Jensen, D. Spitz, K. Knox, B.M. Pierce, J.L. Davis, J. Ostergard, and J. Fusaro. 2012. Annual Report of the Sierra Nevada Bighorn Sheep Recovery Program: A Decade in Review. California Department of Fish and Game. 57 pp.

Wehausen, J. D. and F. L. Jones. 2014. The historic distribution of bighorn sheep in the Sierra Nevada, California. California Fish and Game 100:417-435.

Wehausen, J. D., R. R. Ramey II, and S. T. Kelley. 2011. Domestic sheep, bighorn sheep, and respiratory disease: a review of experimental evidence. California Fish and Game 97: 7-24.

Wild Sheep Working Group. 2012. Recommendations for Domestic Sheep and Goat Management in Wild Sheep Habitat. Western Association of Fish and Wildlife Agencies.

U.S. Fish and Wildlife Service. 2007. Recovery Plan for the Sierra Nevada Bighorn Sheep. Sacramento, California. 199 pp.

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