2015-2016 Annual Report

# Sierra Nevada Bighorn Sheep Recovery Program

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Photo Credit: Steve Yeager

## Executive Summary

During the 2015-16 year, the Sierra Nevada bighorn sheep (*Ovis canadensis sierrae;* bighorn) population continued to increase. We estimated 320 adult and yearling females in the Sierra Nevada dispersed among 14 herds. These numbers surpass the downlisting goal of 305 females and the distribution includes occupancy in all required herd units. However, we are still working toward the more specific numeric goals for each area to fully meet the downlisting distribution requirements (U.S. Fish and Wildlife Service 2007). In the last three years, we have successfully repopulated four herd units through reintroduction.

Field crews worked diligently to count adults, yearlings and lambs in 10 of the 14 herds. This year we captured and collared 62 bighorn from seven herds, which should improve our ability to track herd sizes and measure demographic rates. Although most herds increased in abundance, there was also a notable increase in the number of bighorn killed by mountain lions. Within herds, annual collared ewe survival averaged above 90% and estimated lamb survival ranged from 15-100%.

In general, Sierra bighorn function as a metapopulation, or a group of interconnected herds. This connectivity was demonstrated by several long distance movements between herds from both translocated and local animals, particularly within the southern recovery unit. Research on bighorn migration highlighted the importance of high elevation winter habitat. Some bighorn migrate to low elevation winter ranges while other resident animals spend their winter on windswept slopes at high elevation, within their summer ranges. Some herds are entirely migratory, some entirely non-migratory and some are a mixture of both strategies. In addition, individuals switch between migratory and resident strategies. Unexpectedly, females that stayed at high elevation during the winter contributed more per capita to population growth than migratory animals, indicating the value of this habitat.

The majority of our public outreach was done in collaboration with the Sierra Nevada Bighorn Sheep Foundation (SNBSF). This included tabling at local events, field trips and Sierra bighorn specific educational programs in local schools. In addition, we are continuing to work with local climbing groups to proactively prevent and minimize any potential conflicts between bighorn and recreationists.

# Introduction

This report covers monitoring, management and conservation activities carried out between May 1, 2015 and April 30, 2016 by the California Department of Fish and Wildlife's (CDFW) Sierra Nevada Bighorn Sheep Recovery Program (hereafter Recovery Program). We monitor population sizes, demographic rates, and habitat use to inform management decisions on translocations, augmentations and predator management. In addition, we work to reduce the potential for disease transmission from domestic sheep and we promote bighorn recovery through public outreach. For brevity, we refer to herds and herd units using single keywords such as 'Olancha' for Olancha Peak herd unit; we refer to Sierra Nevada bighorn sheep as 'bighorn;' and we use '2015' to represent the animal year May 1, 2015 thru April 30, 2016.

# Population Monitoring

*Herd Unit Surveys*

Each year we perform ground surveys to estimate the female population size of various herds. Although we also count rams, our focus is on females because they drive population trajectories. Roughly two thirds of all known female bighorn are in larger herds (>40 individuals), so we try to survey these herds annually. Smaller herds are surveyed as conditions and resources allow. Here we report the survey results for this year but also include the most recent surveys for Bubbs, which was in 2013, and Taboose, which was done in 2014 (Table 1). Survey results from the last ten years are summarized in Appendix B.

**Table 1. Minimum counts and mark-resight estimates (MR Est) of Sierra Nevada bighorn sheep from May 1, 2015 – April 30, 2016. MR Est is for adult and yearling females combined. Best MR Est here based on lowest coefficient of variation. Lamb sex not determined. MR estimates tend to be more accurate for larger herds (>20) in which we are unlikely to have complete census minimum counts.**

| Herd | EWES | | | | LAMBS | RAMS | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| | **Adult** | **Yrlng** | **Total** | **MR Est** | | **Adult** | **Yrlng** | **Total** | |
| Olancha | 13 | 3 | 16 | | 4 (5) | 6 | 2 | 8 | 28 |
| Laurel | 7 | 0 | 7 | - | 1 | 4 | 0 | 4 | 12 |
| Big Arroyo | 9 | 1 | 10 | | 2 | 3 | 2 | 5 | 17 |
| Langley | 33 | 4 | 37 | 57 (41-80) | 20 | 29 | 7 | 36 | 93 |
| Williamson (2014) | 11 | 2 | 13 | - | 4 | 8 | 2 | 10 | 27 |
| Baxter | 34 | 7 | 41 | - | 16 | 27 | 6 | 33 | 90 |
| Sawmill | 41 | 4 | 45 | - | 11 | 16 | 4 | 20 | 76 |
| Bubbs (2013) | 10 | 1 | 12* | - | 9 | 5 | 1 | 6 | 27 |
| Taboose (2014) | 2 | 1 | 3 | - | 0 | 15 | 2 | 17 | 20 |
| Wheeler | 50 | 5 | 58^ | | 20 | 28 | 8 | 36 | 114 |
| Convict | 12 | 1 | 14* | | 8 | 9 | 3 | 12 | 34 |
| Cathedral | 10 | 0 | 10 | | 2 | 2 | - | 2 | 14 |
| Gibbs | 19 | 3 | 22 | - | 10 | 10 | 4 | 14 | 46 |
| Warren | 10 | 2 | 12 | - | 4 | 7 | 2 | 9 | 25 |
| **Totals** | **261** | **34** | **300** | **320** | **107** | **169** | **43** | **212** | **623** |

Lamb genotyping estimate in parentheses after count. *These counts each included one female of unclassified age so the overall count is one higher than the sum of adults and yearlings. ^Wheeler total count includes 3 uncollared ewes seen by a reliable observer that was not part of the survey.

We use 'survey' to refer to a systematic effort to cover the known range of female habitat use within a given herd. Surveys result in a minimum count or a mark-resight (MR) estimate. Minimum counts make use of telemetry and satellite collar locations. MR population estimates are derived from the ratio of marked to unmarked individuals and are developed from observations in which telemetry was not used. In addition to surveys, we also make opportunistic observations. A collared animal is censored after two years without visual or radiotelemetry observation; censor date is one month after the last observation. Our reported minimum counts are our highest count for the given class and sex, taking into account and often combining different survey efforts and opportunistic observations.

**Table 2. Sierra Nevada bighorn sheep population estimates for April 30th, 2016, accounting for all translocations and known mortalities.**

| Herd | EWES | | | LAMBS | RAMS | | | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | **Adult** | **Yrlng** | **Total** | | **Adult** | **Yrlng** | **Total** | |
| Olancha | 13 | 3 | 16 | 4 (5) | 6 | 2 | 8 | 28 |
| Laurel | 6 | 0 | 6 | 1 | 1 | 0 | 1 | 8 |
| Big Arroyo | 8 | 1 | 9 | 2 | 3 | 2 | 5 | 16 |
| Langley | 32 | 4 | 36 | 20 | 29 | 7 | 36 | 92 |
| Williamson | 11 | 2 | 13 | 4 | 8 | 2 | 10 | 27 |
| Baxter | 33 | 7 | 40 | 16 | 27 | 6 | 33 | 89 |
| Sawmill | 40 | 4 | 44 | 11 | 16 | 4 | 20 | 74 |
| Bubbs (2013)* | 10 | 1 | 12 | 9 | 5 | 1 | 6 | 27 |
| Taboose (2014) | 2 | 1 | 3 | 0 | 15 | 2 | 17 | 20 |
| Wheeler^ | 50 | 5 | 58 | 20 | 27 | 8 | 35 | 113 |
| Convict* | 10 | 1 | 12 | 8 | 9 | 3 | 12 | 32 |
| Cathedral | 10 | 0 | 10 | 2 | 2 | 0 | 2 | 14 |
| Gibbs | 19 | 3 | 22 | 10 | 10 | 4 | 14 | 46 |
| Warren | 9 | 2 | 11 | 4 | 4 | 2 | 6 | 21 |
| **Totals** | **253** | **34** | **292** | **107** | **162** | **43** | **205** | **607** |

Lamb genotyping estimate in parentheses after count. *These counts each included one female of unclassified age so the overall count is one higher than the sum of adults and yearlings. ^Wheeler total count includes 3 uncollared ewes seen by a reliable observer that was not part of the survey.

Survey timing varies between herds. The best survey results for Baxter and Wheeler tend to occur in winter, when animals tend to congregate at lower-elevations. Most other herds are surveyed in the summer, although big snow winters can provide unique winter survey opportunities. In some herds, such as Olancha, we are still figuring out the best survey season. Survey success is partially driven by luck. For example, sometimes we get lucky and the bighorn congregate in an area where it is easy to count and identify them. Other times, just as an observer sees a group, it may be spooked and scatter, not to be seen again during the survey. For this reason, it sometimes takes multiple attempts to get a good count of a given herd, and in fact some years we are unable to get a good count (detailed summaries of survey attempts in Appendix A). Because our surveys occur at different times of year for different herds, our best estimates for each herd (Table 1) do not represent a single snapshot in time. Therefore, we also tabulate all known animals at the end of the reporting period including all translocations and known mortalities (Table 2).

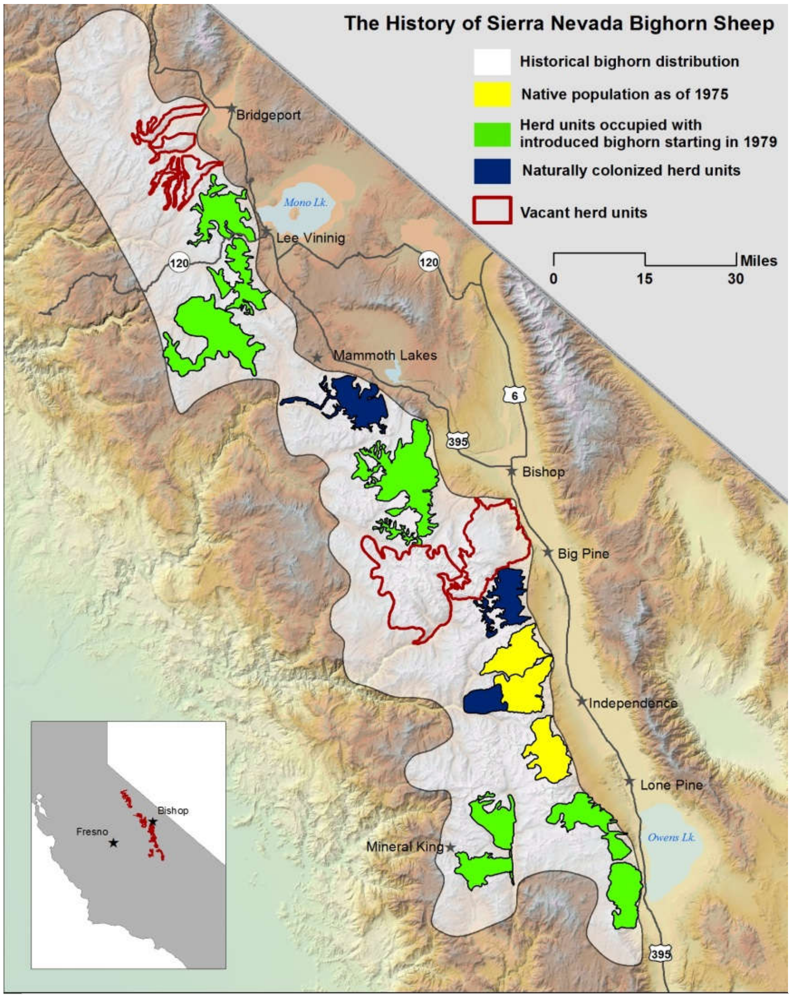



**Figure 1. Distribution of Sierra Nevada Bighorn Sheep on April 30, 2016.**

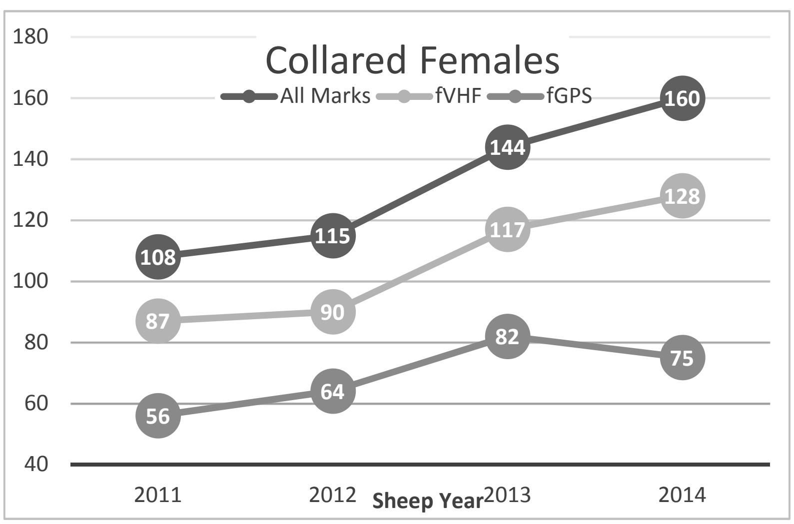



**Figure 2. Number of female Sierra bighorn wearing any collar (AllMarks), functional VHF collar (fVHF), or functional GPS collar (fGPS).**

## Geographic Distribution

Bighorn now occupy 14 of 18 identified herd units, spanning nearly 250 km of the Sierra Nevada (Figure 1). The Recovery Plan designates 16 herd units historically occupied by bighorn and the Translocation Plan demarcates two additional herd units identified as suitable for reintroductions (Few et al. 2015). Of those 18 herd units, 12 are considered essential for downlisting. All 12 essential herd units are now inhabited, although specific numeric goals for each recovery unit have not yet been met (see section on Population Dynamics and Figure 4).

## Translocations

There were no translocations during the 2015 animal year. This deviates slightly from our translocation plan which projected translocating up to 25 individuals (Few et al. 2015). This less aggressive approach will give our source populations an opportunity to rebuild from the spring translocations that occurred during the 2012-2014 animal years.

## Collaring Efforts

The Recovery Program strives to maintain collars on 30-35% of females within each herd to facilitate accurate population surveys, monitor reproductive success, and identify cause-specific mortality (Figure 2 and Table 3; collar details in Appendix C). We focus on females because they drive bighorn population dynamics. However, males are also collared in order to monitor disease risk and genetics. The data we collect from GPS collars are central to understanding habitat selection, seasonal migration, home range use, and survival. We conduct annual captures to add new collars, replace nonfunctional collars, and translocate animals to new habitat. Captures also give us the opportunity to assess the health and reproductive status of captured animals and to collect samples for genetic analysis.

Wildlife capture specialists from Leading Edge Aviation captured 62 bighorn from seven herds: Wheeler, Sawmill, Baxter, Langley, Convict, Williamson, and Taboose. The majority of captures occurred in the fall from October 21-

25, 2015, when 41 bighorn were captured within seven herds including 17 rams and 24 ewes; 18 of the animals captured were lambs (4 months of age). During March 19-24, twenty-one adult bighorn were captured in five herds (Wheeler, Sawmill, Baxter, Langley, and Convict), including 7 rams and 14 ewes. All capture related injuries such as lacerations and abrasions were minor and there were no capture related mortalities. All bighorn captured were known to be alive at least two weeks after capture. However, there was one capture-related mortality (Cathedral ram S359) in the last reporting period that was not included in the 2014 Annual Report.

Table 3. Count and percent of total marks and functioning (f) VHF and GPS collars by herd and sex on April 30, 2016.

| Herd | Females | | | | | Males | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | End Count | fGPS | fVHF | Total Marks | % fVHF | End Count | fGPS | fVHF | Total Marks | % fVHF |
| Olancha | 16 | 1 | 12 | 12 | 75% | 8 | 2 | 4 | 4 | 50% |
| Laurel | 6 | 6 | 6 | 6 | 100% | 1 | 1 | 1 | 1 | 100% |
| Big Arroyo | 9 | 6 | 8 | 9 | 89% | 5 | 0 | 3 | 3 | 60% |
| Langley* | 56 | 11 | 15 | 19 | 27% | 36 | 4 | 5 | 9 | 14% |
| Williamson | 13 | 1 | 5 | 7 | 38% | 10 | 1 | 1 | 2 | 10% |
| Baxter | 40 | 8 | 14 | 19 | 35% | 33 | 5 | 8 | 13 | 24% |
| Sawmill | 44 | 4 | 14 | 16 | 32% | 20 | 7 | 12 | 19 | 60% |
| Bubbs | 12 | 2 | 5 | 7 | 42% | 6 | 1 | 4 | 4 | 67% |
| Taboose | 3 | 2 | 2 | 2 | 67% | 17 | 2 | 3 | 3 | 18% |
| Wheeler | 58 | 9 | 16 | 24 | 28% | 35 | 8 | 11 | 22 | 31% |
| Convict | 12 | 11 | 8 | 12 | 67% | 12 | 2 | 2 | 3 | 17% |
| Cathedral | 10 | 9 | 10 | 10 | 100% | 2 | 2 | 2 | 2 | 100% |
| Gibbs | 22 | 4 | 10 | 13 | 45% | 14 | 1 | 4 | 4 | 29% |
| Warren | 11 | 1 | 2 | 3 | 18% | 6 | 1 | 3 | 3 | 50% |
| Total | 312 | 75 | 127 | 159 | 41% | 205 | 37 | 63 | 92 | 31% |

End counts are the best count from the season (minimum, reconstructed or mark-resight) adjusted for any known mortalities or translocations. * Mark-resight estimated adjusted for known mortalities

# Population Dynamics

*Population Size*

When bighorn were listed as an endangered species in 1999, the entire range-wide population was estimated to be 95-129 adults including at least 49 adult females (Wehausen 1999). In 2015-2016, we estimated a total population size of 667. This includes 320 yearling and adult ewes, 107 lambs, and an estimate of 240 rams based on a ram:ewe ratio of 0.75. We rely on a ram:ewe ratio instead of our minimum count of rams (n=212) because our survey and collaring efforts are directed toward females. Although we have observed a ram:ewe ratio as high as 1, in general we observe a higher ram mortality rate and

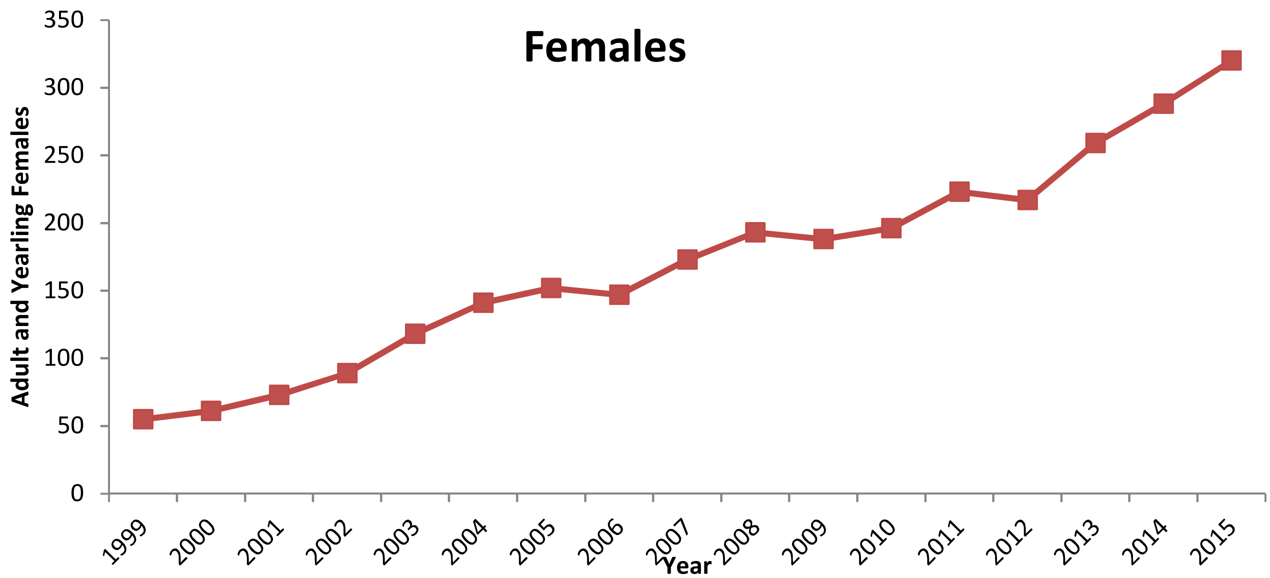



**Figure 3. Population abundance for adult and yearling female Sierra bighorn. Data include minimum counts, mark-resight estimates and reconstructed data. Data gaps were filled with the most recent best estimate for each herd.**

therefore use 0.75 as a conservative and realistic estimate of ram numbers. In addition, some of our population increases are a result of better survey data and may not represent actual population gains. Although some changes in population estimates, particularly within a few years, may be due to survey methods, the overall trends likely represent true population trajectories. The largest two herds, Langley and Wheeler each contain more than 50 adult and yearling females (Figure 4).

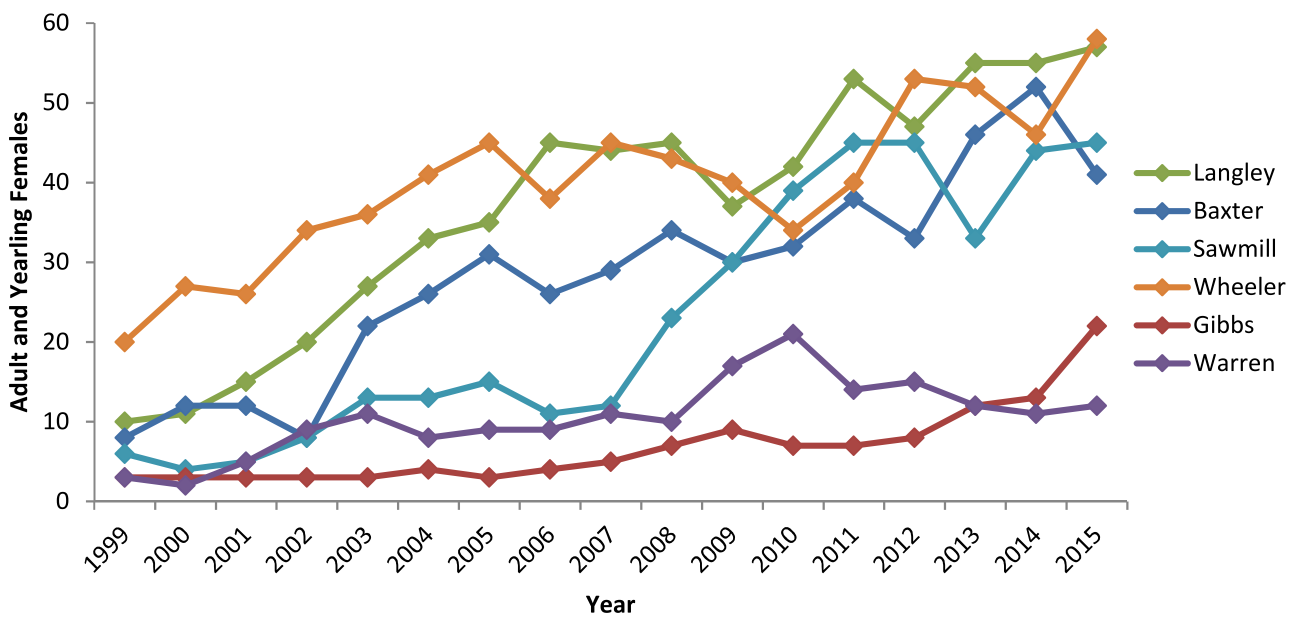



**Figure 4. Abundance of adult and yearling female Sierra bighorn from 1999-2015. Data include minimum counts, mark-resight estimates, and reconstructed data from all herds with long-term datasets. Data gaps were filled with the most recent complete survey.**

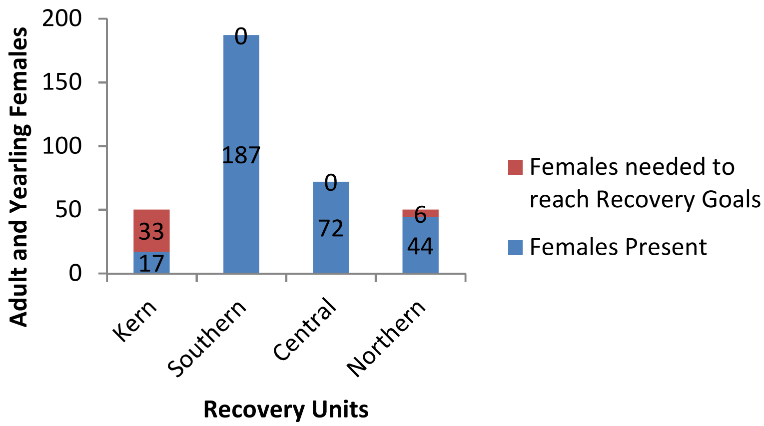



**Figure 5. Adult and yearling female Sierra bighorn present in each recovery unit on April 30, 2016, relative to the females needed to reach recovery goals.**

The Recovery Plan (U.S. Fish and Wildlife Service 2007) recommends downlisting when the female population reaches 305 animals distributed throughout the recovery units: specifically 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. Currently the Southern and Central Recovery Units exceed the number needed for downlisting. However, the Northern and Kern Recovery Units are below target levels at 17 and 44 females respectively (Figure 5).

*Survival and Cause-Specific Mortality*

Bighorn population trajectories are usually driven by adult female survival (Johnson et al. 2010). During 2006-2015, Kaplan Meier (Kaplan and Meier 1958) survival rates of collared females within recovery units varied from 0.58 to 1.0 (Figure 6). We try to maintain radio collars on 30-40% of the female population in order to detect a 10% change in survival over five years (German 2010). We are not always able to maintain this proportion of collared females which results in large confidence intervals and less than ideal precision (Figure 6). In addition, some of the variation in collared female survival is driven by the discrete nature of small numbers which can lead to large, but not necessarily meaningful, increases or decreases to the percent change. For example, the decline in survival in the Northern Recovery Unit from 89% in 2006 to 63% in 2007 was calculated based on 1 collared female mortality in 2006 and 3 collared female mortalities in 2007. This demonstrates the challenge of obtaining accurate and precise survival estimates in small populations. This problem is slightly reduced in the larger central and southern recovery units. In general, the trend over time is that survival estimates have become less variable and have reduced confidence intervals, as both the proportion of collared females and the overall population sizes increase.

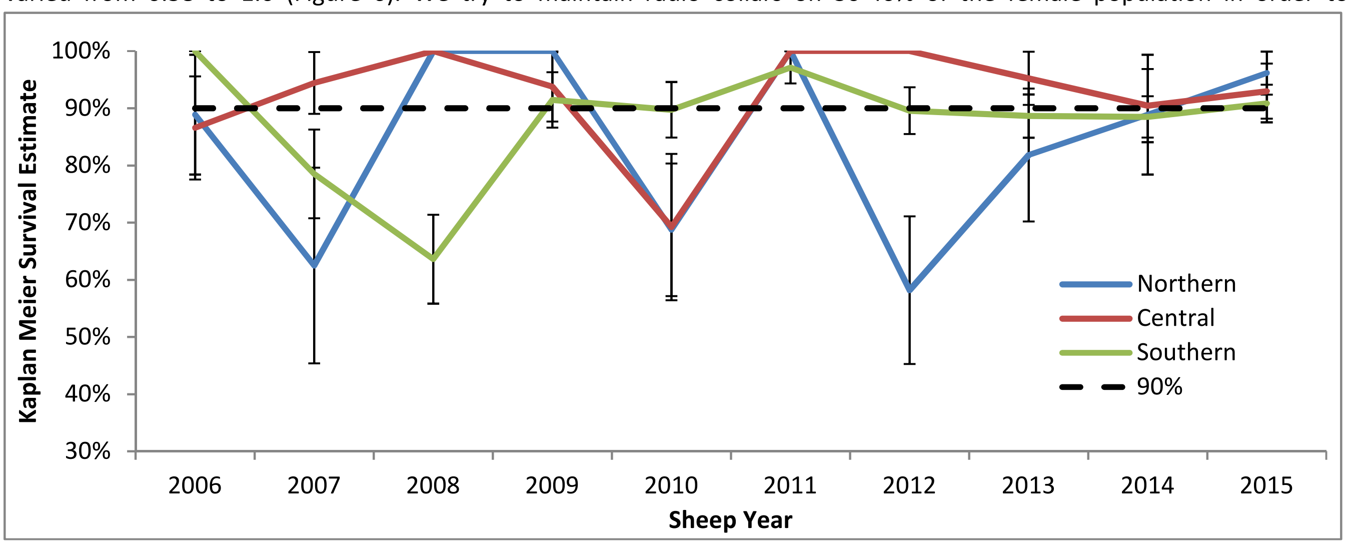



**Figure 6. Annual Kaplan-Meier survival rates of collared ewes by Recovery unit for 2006-2015. Dashed line at 90% survival. Error bars show one SE, or 67% CI. When there is 100% marked animal survival, the SE cannot be estimated.**

In addition to calculating survival rates, having collared animals allows us to track cause-specific mortality. It is often difficult to determine the cause of death because critical evidence can be quickly destroyed by scavengers, often within 48 hours. We use GPS collars as well as VHF collars to determine cause-specific mortality. Modern GPS collars that are capable of sending a mortality signal via satellite in real time have further increased our ability to identify cause specific mortality. In the last ten years we have determined the cause of death with 70% certainty in 47% of mortalities detected using GPS collars and in 29% of mortalities detected with only VHF collars. However, the benefit of VHF collars, which require monitoring via ground or fixed-wing aircraft, is that their batteries can last several years longer. We try to monitor VHF collars monthly, or at least quarterly, for any mortalities.

During the 2015 animal year, we detected 28 mortalities of collared bighorn (13 female, 15 male; Figure 7). We were unable to determine cause of death for 10 animals (36%). One Wheeler ram (S384; 4%) died of physical injury; sixteen animals (57%) died of certain or probable mountain lion predation; and one Wheeler ram lamb (S387) was killed by a bobcat in February on the mining road above Pine Creek Mill.

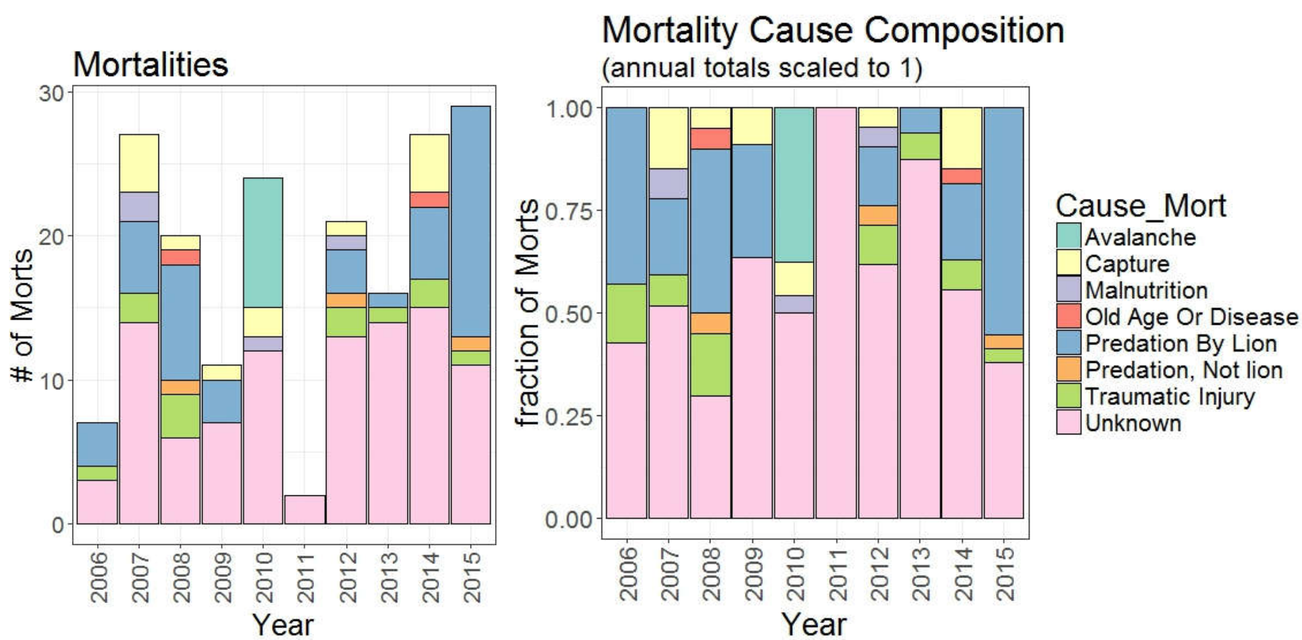
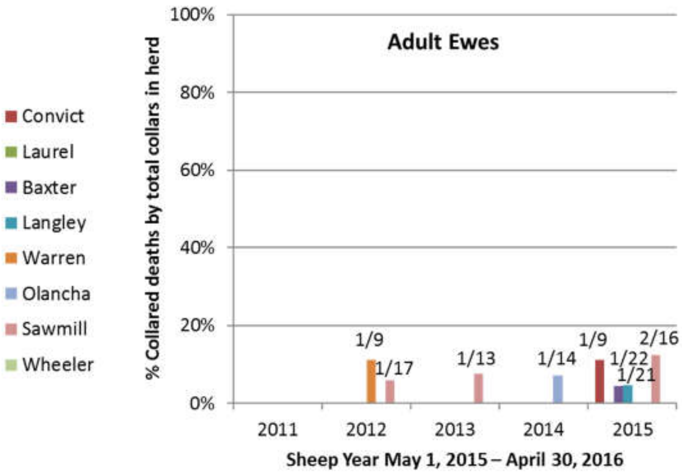



**Figure 7. Cause-specific mortalities of radio-collared Sierra bighorn (both males and females) from 2006-2015. Cause was determined at a minimum of 70% certainty.**

During 2006-2015 we determined the cause of death for 50% of our collared animal mortalities. Death from avalanche varied from 0%, to 38% in the big winter of 2010 (Figure 7). Mortality of collared animals from predation varied from 6 to 61%. Mountain lions were responsible for 94% of the predation mortality, followed by 4% from bobcat and 2% from coyote. Some types of mortalities may be easier to detect and access than others. For example, predation tends to occur at lower elevations with easier access compared to avalanches, which tend to occur in areas that are inaccessible for months during winter and spring. Therefore, it is unlikely the unknown mortalities are well represented by the known mortalities, and determining the cause of death remains top priority.

There was both a higher number and a higher proportion of bighorn killed by mountain lions than we have documented in the last ten years (Figure 6). However, collaring efforts have increased over this time period increasing our ability to detect predation events (Figure 2). In 2015, mountain lions killed both male and female bighorn in seven different herds at higher numbers than we have seen since 2010. (Figure 8).



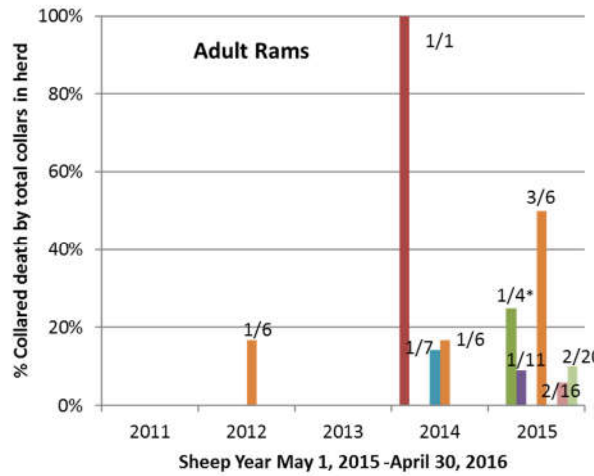




**Figure 8. Lion kills of collared adult Sierra bighorn ewes and rams. Numbers above or beside bars represent the number of adult animals killed by lions out of the total number of collared adult animals in that herd. * Laurel Ram was killed in Olancha.**

*Reproduction and Recruitment*

We project an expected number of adult ewes based on the number of adult and yearling females observed the year before. Assuming minimum counts are actually true censuses for two consecutive years and all mortality is known, our projected and counted ewes should be equal (Table 4) which occurred in 5 out of 11 herds including Olancha, Laurel, Big Arroyo, Cathedral and Warren. Complete census data is more likely in smaller or newly reintroduced herds. For larger herds (>20) it is unlikely that our minimum counts represent exact population totals. In Gibbs, where our projection was one less than we counted,

**Table 4. Sierra Nevada bighorn sheep females in 2014 and 2015, including recruitment of yearlings and losses or gains from mortalities or translocations.**

| *Herd* | 2014 | | | | 2015 |
|---|---|---|---|---|---|
| | Adult Ewes | Yearling Ewes | Total Ewes | Known Gains/Losses | Adult Ewes Projected/Counted |
| Olancha | 14 | 2 | 16 | -3 | 13/13 |
| Laurel | 6 | 1 | 7 | 0 | 7/7 |
| Big Arroyo | 9 | 0 | 9 | 0 | 9/9 |
| Langley* | 45 | 10 | 55 | -13 | 42/34 |
| Baxter* | 46 | 6 | 52 | -7 | 45/34 |
| Sawmill* | 38 | 6 | 44 | -4 | 40/41 |
| Wheeler* | ^ | ^ | ^ | | 50 |
| Convict | 13 | 0 | 13 | 0 | 13/12 |
| Cathedral | 9 | 1 | 10 | 0 | 10/10 |
| Gibbs | 10 | 3 | 13 | +5 | 18/19 |
| Warren | 11 | 0 | 11 | -1 | 10/10 |

*** Due to larger population sizes, these minimum counts are not likely censuses. ^ We were unable to get a good count in Wheeler 2014.**

and where we have had census data for many years, we will use this year's count to correct or reconstruct last year's count by adding a yearling ewe. We clearly document these types of changes within the database for easy traceability. In Convict, where our projection was one greater than our count, this may represent an undetected female mortality. However, because Convict surveys in 2014 and 2015 included animals of unclassified sex and age, we are unable to precisely reconcile this data.

The observed ratio of lambs to ewes is one way to estimate fecundity, or reproductive success. During spring captures, pregnancy rates are 90-95% in adult bighorn, but observed lamb to ewe ratios are much lower and more variable (21-86%; Table 5). The reason for this discrepancy is uncertain, but neonatal lambs may be dying before they are detected (Gilbert et al. 2014).

**Table 5. Estimated Sierra Nevada Bighorn Sheep lamb survival based on observed juvenile age class ratios in 2014 and 2015.**

| Herd | 2015 Lamb:Ewe | | 2014 Lamb:Ewe | | 2014 Female Lamb:Ewe | 2015 Female Yrlng:Ewe | | Est. Female Lamb Survival |
|---|---|---|---|---|---|---|---|---|
| **Olancha** | 4/9 | 0.44 | 3/9 | 0.33 | 0.17 | 3/9 | 0.33 | 1.00 |
| **Big Arroyo**[e] | 2/5 | 0.4 | 4/7 | 0.57 | 0.29 | 1/5 | 0.20 | 0.35 |
| **Langley** | 20/26 | 0.77 | 18/43 | 0.42 | 0.21 | 4/26 | 0.15 | 0.37 |
| **Baxter**[w] | 15/26 | 0.58 | 17/35 | 0.49 | 0.24 | 7/26 | 0.27 | 0.55 |
| **Sawmill**[w] | 7/33 | 0.21 | 17/38 | 0.45 | 0.22 | 4/33 | 0.12 | 0.27 |
| **Wheeler**[w] | 19/46 | 0.41 | 6/13 | 0.46 | 0.23 | 5/46 | 0.11 | 0.23 |
| **Convict** | 8/11 | 0.73 | 8/13 | 0.62 | 0.31 | 1/11 | 0.09 | 0.15 |
| **Cathedral**[t] | 2/9 | 0.22 | -- | -- | -- | -- | -- | -- |
| **Gibbs**[t] | 10/18 | 0.55 | 8/10 | 0.80 | 0.40 | 4/13 | 0.31 | 0.38 |
| **Warren** | 4/10 | 0.4 | 6/7 | 0.86 | 0.43 | 2/10 | 0.20 | 0.23 |

[e] Early survey may have missed some lambs. [w] Winter surveys include at least 6 months of lamb survival. [t] Ewes translocated the previous year have been removed from yearling:ewe ratios. Female lamb:ewe ratio is calculated as one half of the lamb:ewe ratio assuming an equal sex ratio as lamb sex cannot be consistently determined in the field.

We used two different methods to estimate female lamb to yearling survival. First, we divide the observed female yearling:ewe ratio by female lamb:ewe ratio of the previous year (Table 5). With this method, we do not need to have complete census counts, but we assume that our observations of lamb:ewe and yearling:ewe ratios represent the whole population. However, it can be difficult to differentiate yearling from adult ewes and incorrectly classifying yearling ewes as adult ewes would result in an underestimate of true lamb survival. Also, these data are not directly comparable among all herds because of the differences in survey seasons. For example lamb survival in Olancha is from ~3 to ~15 months of age because surveys occur in the summer. In contrast lamb survival at Wheeler is from ~9 months to 21 months of age because the surveys occur in the winter.

**Table 6. Estimated Sierra Nevada bighorn sheep lamb survival based on comparing the minimum count of yearlings in 2015 to lambs in 2014.**

| Herd | 2014 All Lambs | 2015 All Yearlings | All Lamb Survival | 2014 Female Lambs est. | 2015 Female Yrlngs | Female Lamb Survival |
|---|---|---|---|---|---|---|
| **Olancha** | 6 | 5 | 0.83 | 3 | 3 | 1.0 |
| **Big Arroyo[e]** | 5 | 3 | 0.60 | 2.5 | 1 | 0.4 |
| **Langley** | 18 | 11 | 0.61 | 9 | 4 | 0.44 |
| **Baxter[w]** | 29 | 13 | 0.45 | 14.5 | 7 | 0.48 |
| **Sawmill[w]** | 17 | 8 | 0.47 | 8.5 | 4 | 0.47 |
| **Wheeler[w]** | 6 | 13 | 2.16* | 3 | 5 | 1.67* |
| **Convict** | 8 | 4 | 0.50 | 4 | 1 | 0.25 |
| **Gibbs[t]** | 8 | 7 | 0.88 | 4 | 3 | 0.75 |
| **Warren** | 8 | 4 | 0.50 | 4 | 2 | 0.50 |

*Lamb survival >1 indicates that the 2014 Wheeler minimum missed some lambs. [e] Early survey may have missed some lambs. [w] Winter surveys include at least 6 months of lamb survival. [t] Ewes translocated the previous year have been removed from yearling:ewe ratios. Female lambs are calculated as one half of the total lambs assuming an equal sex raio because lamb sex cannot be consistently determined in the field.

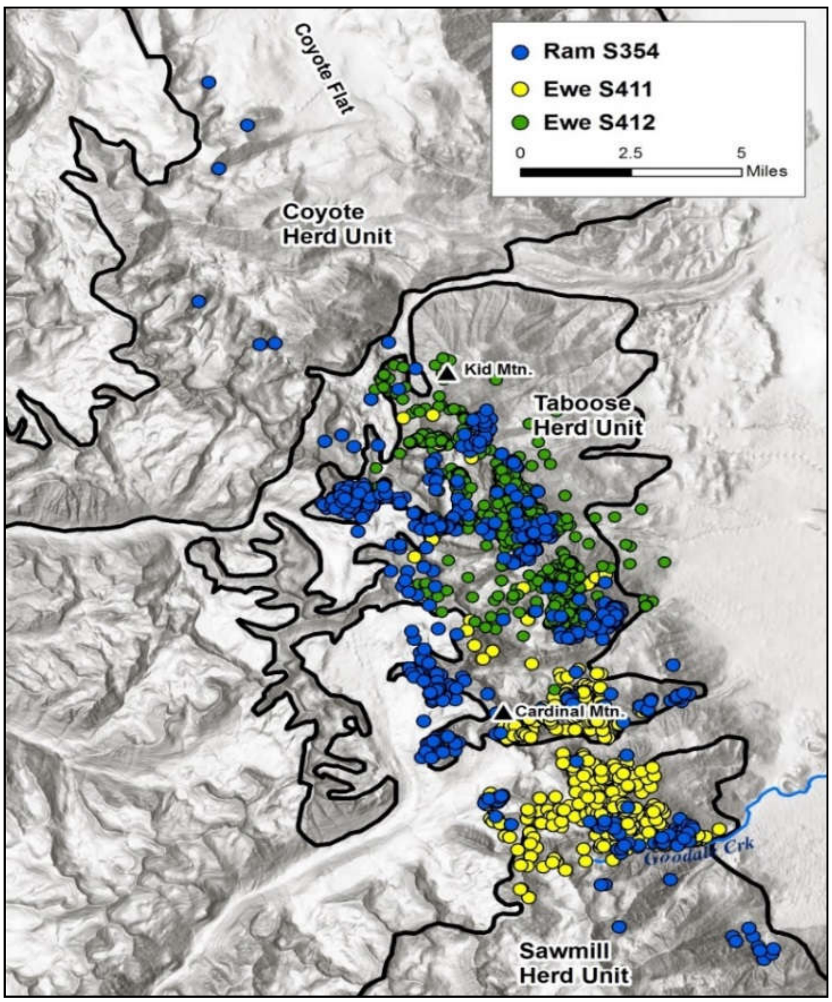



**Figure 9. GPS collar locations of three Taboose Sierra bighorn in 2015-16.**

## Movement and Habitat Use

*Taboose Creek Herd Unit*

In the fall of 2015, we put radio collars on two ewes (S411 and S412) in the Taboose herd unit (Figure 9). These were the first females to be radio-collared in this herd unit. During winter, the ewes primarily used the area between Kid and Cardinal Mountains. In March 2016, ewe S411 travelled south to the Goodale Creek drainage located within the Sawmill herd unit. Previously both rams and ewes that were captured within the Sawmill herd unit, traveled between Sawmill and Taboose herd units. Bighorn rams have traveled great distances, particularly during the rut; for example, Taboose ram S354 moved a straight line distance of 26 km from Birch Mountain to Coyote Flat and then returned back to the Taboose creek drainage between late October and early November 2015. The only other confirmed record of bighorn in the Coyote Flat vicinity was a ground sighting of two ewes in 2009. Since that sighting, we have surveyed the Coyote Flat area and have not detected any bighorn. Those movements represent the potential for bighorn to colonize new areas. Natural recolonization or movement into new habitat can be very difficult to detect, but it is an important recovery process for bighorn.

*Taboose, Sawmill, Baxter, Bubbs Overlap*

In addition to the movement between Taboose and Sawmill, rams have moved between the Sawmill, Baxter and Bubbs herd units (Figure 10). During the summer, both ewes and rams were known to cross the boundary between the Sawmill and Baxter herds. However, during the winter, bighorn ewes rarely crossed Sawmill Canyon. Our last sighting of a ewe crossing Sawmill Canyon was in 2009 when Baxter ewe S108 moved north across Sawmill Canyon and stayed on the north side for one month. This movement correlated with a fire that may have removed or reduced barriers that previously limited dispersal between the two herds (Wehausen et al. 2009). On the other hand, rams frequently cross between Sawmill and Baxter herd units during the winter. For example, Sawmill rams S165 and S254 were seen during winter south of Sawmill Canyon on the Baxter winter range. Together those movement data indicate likely genetic mixing and metapopulation dynamics between the Baxter, Sawmill, Taboose and Bubbs herd units.

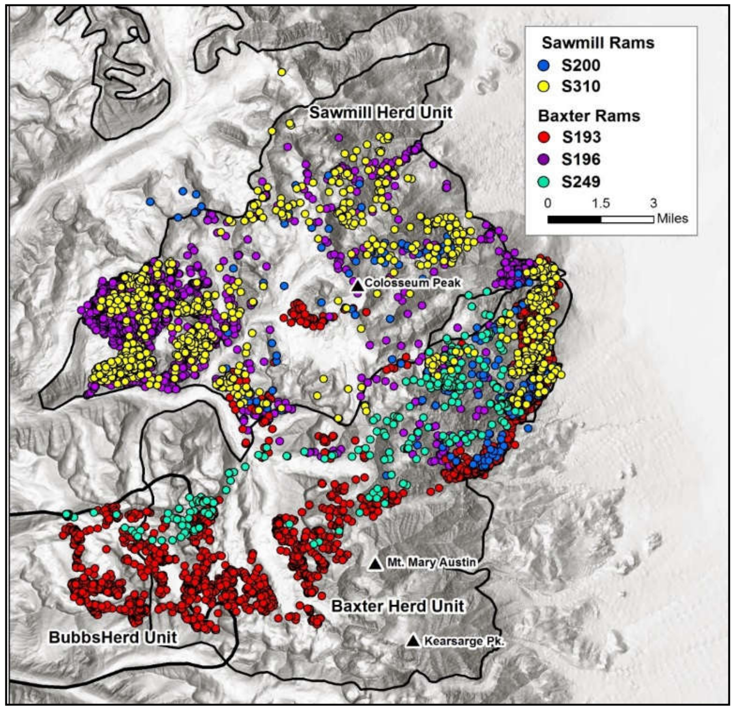



**Figure 10. Select GPS collar locations showing Sawmill and Baxter ram use within and between three herd units between 2011-2017.**

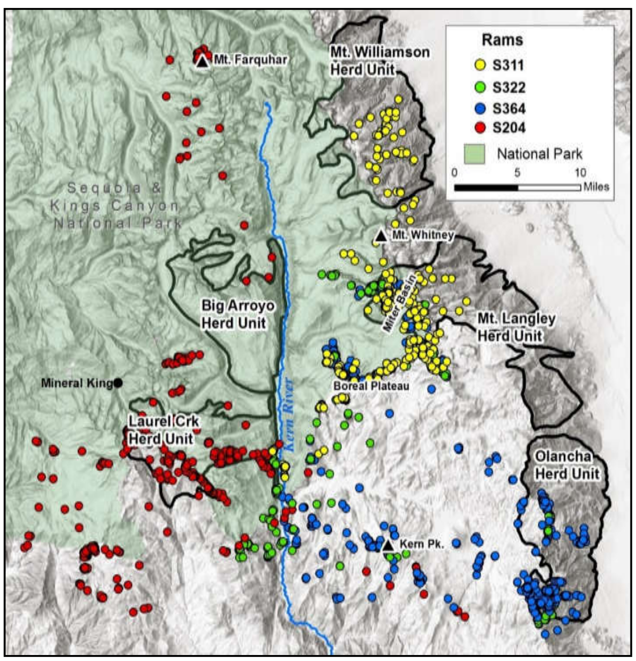



**Figure 11. GPS collar locations of four Sierra bighorn rams translocated to the Laurel Creek herd since their translocation in spring 2015 – April 30, 2016.**

*Habitat Use by Naïve Animals at Laurel Creek*

In the spring of 2015, 11 bighorn were reintroduced to the Laurel Creek herd unit. Three of the four rams that were moved to Laurel crossed the Kern drainage to the east soon after translocation. Once on the east side of the Kern drainage, S311 travelled between the Boreal Plateau, Cirque Peak, the Miter Basin, and the Williamson herd unit (Figure 11). Two other rams (S322 and S364) made exploratory movements to Kern Peak, the Boreal Plateau, and Mt. Langley. While within the Langley herd unit, those two rams used the western portion of the Miter Basin, an area that is not typically used by Langley animals. Ram S322 has resided in the Olancha herd unit since November 2015. Ram S364 died in January 2016 near Olancha Creek. In December 2015, S204 left the Laurel Creek herd unit and travelled a straight line distance of 48 km north to Mt. Farquhar where he remained for much of the winter (Figure 11).

*Gibbs Herd Unit*

Five ewes were translocated in the spring of 2015 to the Alger Creek drainage to establish a new deme, or population subdivision, in the southern portion of the Mt. Gibbs herd unit. Two ewes (S253 and S250) travelled from the Alger lakes release site west to Kuna Crest (an area frequently used by rams) and then continued south to Donohue Peak where they remained for much of the year. Another ewe (S339) remained within a mile of the Alger Lakes basin release site for the entirety of 2015. GPS data of these bighorn ewes demonstrate the variability in movements after translocation to a new area.

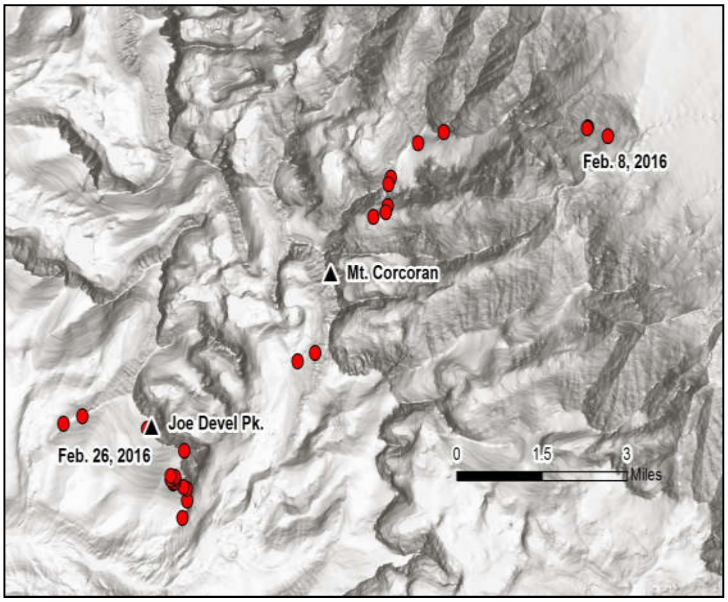



**Figure 12. GPS collar locations of Sierra bighorn ram lamb at Langley during February 2016.**

*Unexpected Lamb Movements at Langley*

Previous GPS collar data from the Langley herd has shown that ewes, and presumably their current lambs, primarily use habitat from the Sierra crest to the east side canyons. By collaring three 6-month old lambs in the Langley, we were able to see how they travel across the landscape. At 9-10 months of age, male lamb S414 was documented as far west as Joe Devel Peak, west of the Sierra crest (Figure 12). Because it was a midwinter movement, there was no visual observation of this lamb and we do not know whether the lamb was with his mother, as she was uncollared. However, in the past only rams have been documented to use the more western terrain of Joe Devel, Chamberlin and Newcomb peaks. This movement could represent an early separation of lamb and mother or possibly new ewe movement into that area.

*Cathedral Herd Unit*

After being reintroduced in March 2015 to the Cathedral Range, all bighorn remained within the designated herd unit boundaries. For the remainder of spring, the ewes travelled to the south facing slopes near Washburn Lake. During the summer months 9 of the 10 ewes explored the ridges between Mt. Maclure and Mt. Lyell, while S371 moved alone between Washburn Lake and Mt. Florence. Ewe S371 wintered on the low elevation slopes of Washburn Lake, again separate from the main ewe group on the Parson's plateau.

**Figure 13. All but one of the newly created Cathedral Range ewes including two female lambs on Parson's Peak where they over wintered. Photo by L&R Pilewski 4/20/16.**

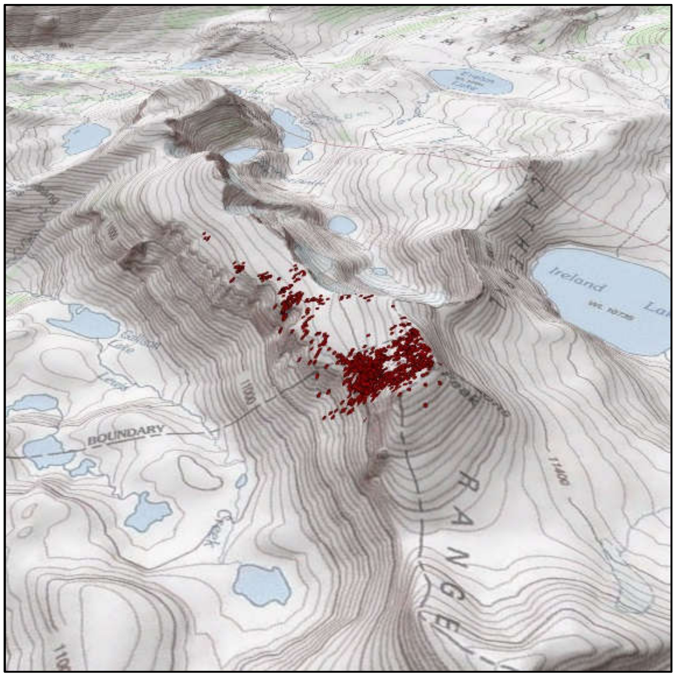



**Figure 14. Select Sierra bighorn ewe locations from January - March 2016 on the Parson's Plateau in Yosemite National Park.**

It was long thought that Sierra bighorn could only survive winters by migrating to low elevations where snow melted earlier. By deploying GPS collars in the Sierra Nevada, we learned that many bighorn actually remained at high elevations year-round. During their first full winter after being reintroduced to the Cathedral Range, ewes wintered above tree-line on the Parson's Plateau. Their high elevation winter range is about 5 km from the alpine habitat near Mt. Lyell where they spent much of the summer. The lush summer range in Yosemite National Park provides optimal forage for bighorn to fatten in preparation for winter. The winter of 2015-16 exhibited average snowfall following four years of drought and the 9 ewes and 2 lambs that wintered on the Plateau appeared to use a pattern of energy conservation to survive the harsh, snowy conditions. They remained within a relatively small area of only 0.33 km$^2$ during the months of January – March where high winds scoured away deep snow. The ewes moved little and relied on stored fat reserves to meet their energetic needs for survival.

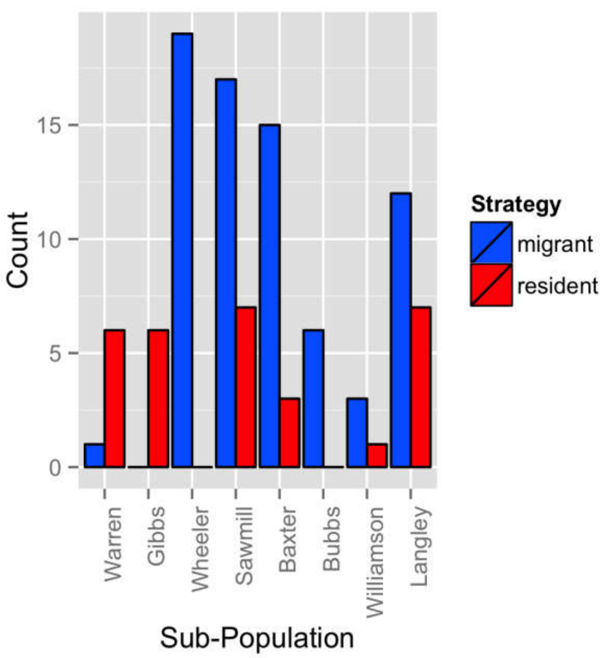



**Figure 15. Migrant and resident classification of Sierra bighorn by sub-population (ordered north to south). We observed both strategies in all but three of the sub-populations: Gibbs, Wheeler, and Bubbs (resident, migrant and migrant, respectively).**

# Research

*Migration*

Like most migratory animals, bighorn are actually only partially migratory in that not all animals migrate every year (Figure 13; Spitz et al. 2017). Bighorn showed extremely flexible migratory behavior in both tactics (e.g. timing, duration of movements) and status (migrant v. resident), with individuals frequently switching migratory status between years. Fall migration to lower elevations was more variable but averaged to be around December 28. Spring migration to higher summer ranges was a more synchronous process with an average date of May 9. Animals switched migratory strategy (from resident to migrant or vice versa) 33% of the time (Spitz et al. n.d.).

Spitz (2015) evaluated winter resource use and selection by migrants and residents using resource selection functions across three scales from 2005 to 2013. Previous work that focused only on low elevation winter range, and therefore migrants, found selection for forage at large spatial scales and avoidance of predation risk by selecting for escape terrain at finer scales (Johnson et al. 2013). Recent analyses corroborated this previous finding and in addition, found that in contrast to migrants, residents avoided predation risk at large scales and focused on forage in fine- scale selection

(Spitz 2015). These selection processes resulted in migrants gaining better access to forage. In addition, the amount of low elevation habitat predicted differences in the prevalence of migration across eight populations (Spitz 2015).

As expected, bighorn migration to lower elevation winter habitat was positively correlated with winter severity. In addition, bighorn ewes that raised lambs into the fall were likely to migrate, but the strength of this effect declined with body mass. Somewhat unexpectedly, winter elevation had no effect on adult female survival. Bighorn were more likely to be observed with a lamb following residency than following migration. These results suggest that where residency is viable, residents make greater per-capita contributions to population growth than do migrants, highlighting the importance of high elevation winter habitat. However, because more animals migrate, migrants contribute more overall to bighorn populations (Spitz 2015). Further investigation is needed to better understand these tradeoffs and apply them to future augmentations and translocations (Spitz 2015).

*Pine Creek Recreation Monitoring*

In October of 2014 the Recovery Program initiated a study in Pine Creek Canyon to address concerns of increased recreational use. 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 in particular, rock climbers. Pine Creek Canyon is also routinely used as lambing habitat by Wheeler Ridge ewes. The overall goal of this study is to determine if there are any detectable effects from changes in human recreational use on bighorn at Wheeler. To do this, daily use was monitored using three Trafx infrared trail counters at three popular climbing trailheads: Barf Canyon, Lamb Canyon and the Palisades School of Mountaineering (PSOM) slabs. These sites were selected because they experience the highest use in proximity to parturition and lambing sites, as well as for ease of access for checking and maintaining trail counters. We discovered these sites were visited frequently, more than 500 visits/month, during lambing season in April and May of 2015. In addition, recreationists and bighorn overlapped throughout the winter of 2014-15 in Pine Creek, but this was likely driven by the drought conditions allowing above average winter use by humans. In more average weather years overlapping use of recreationists will likely be reduced, as the same weather that tends to push bighorn down to wintering grounds also halts recreational use in the canyon. By continuing to collect this data we hope to gain a further understanding of interannual variation to identify the most likely periods of overlap between bighorn and recreationists. In addition, this study supplies critical baseline data of both human and bighorn use of the area that may be used to determine if increased recreation causes bighorn to shift their habitat use in the future.

## 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 in both time and space (Wild Sheep Working Group 2012). Measures to prevent contact must be implemented and be successful before the subspecies can be downlisted (U.S. Fish and Wildlife Service 2007).

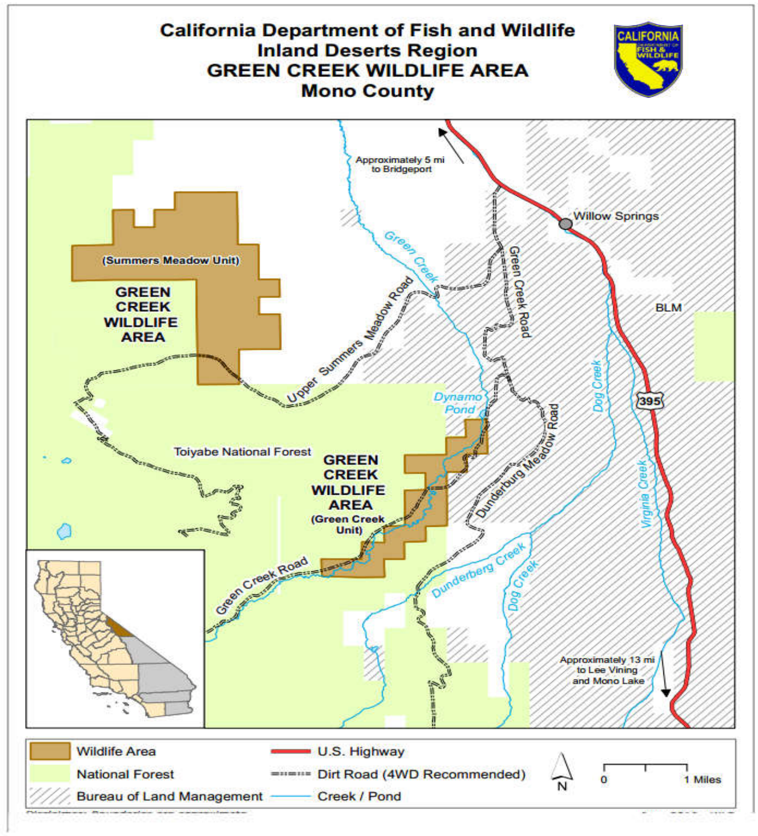



**Figure 16. Land acquisition that will minimize threat of disease to Sierra bighorn.**

*Land Conservation Reduces Disease Threat*

In January, 2016, CDFW's lands department acquired a 2,036 acre property from private owners. This acquisition, now called the Green Creek Wildlife Area, includes sagebrush-bitterbrush uplands of the Hunewill Hills, as well as a reach of Summers Creek and associated montane riparian habitat, including areas of wet meadow (Figure 16). Historically this property had been grazed seasonally by domestic sheep, but it will no longer be grazed by domestic sheep because of the high risk of respiratory disease transfer to endangered bighorn. Domestic sheep grazing is already no longer permitted on adjacent public land allotments in order to support bighorn recovery. A documented observation of a ram from the Mt. Warren herd traveling through the property underscores the likelihood of contact if domestic sheep were present. In addition to buffering bighorn from domestic sheep grazing, this property provides key habitat for greater sage grouse as well as summer range and migration habitat for mule deer.

*Disease Risk Model Updated*

Our disease risk model was updated by combining a resource selection function based on our most recent ram occurrences with a cost distance analysis to quantify the proximity and the risk of contact of bighorn with domestic sheep and goats. This newest model identified Conway Ranch as public land being grazed that poses the highest risk. Conway Ranch consists of two parcels (Conway and Mattly) and is owned by Mono County. The Mattly parcel is within 1.5 miles of known bighorn ram use in the Mt. Warren herd. Additional grazing concerns include LADWP property in Little Round Valley, as well as hobby farms at the mouth of McGee Canyon, in the Pine Creek area, and at Carroll Creek adjacent to the Langley herd.

## Public Outreach

Community support is crucial to the success of conservation efforts for the recovery of bighorn. The Recovery Program often partners with the SNBSF to increase public awareness and outreach. This year public outreach included tabling at many local events including: Endangered Species Day, Bishop Earth Day, Mule Days, CDFW's Trout Fest, Banff Mountain Film Festival and the Tri-County Fair. In addition there were three free bighorn viewing field trips in January, February and April. At these field trips over 80 participants were given the opportunity to observe groups of bighorn on winter ranges, while Recovery Program staff and SNBSF volunteers answered questions and provided historical and biological context.

The SNBSF has developed and implemented an excellent school program in which children simulate the capture and processing of toy bighorn, 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. SNBSF staff and volunteers have brought this program to Lone Pine Elementary, Palisade High School in Big Pine, Bishop Elementary, Round Valley Elementary, Edna Beamon Elementary in Benton, Mammoth Middle School, Mammoth Elementary, Lee Vining Elementary, Minden Elementary and Gardnerville Elementary.

## Acknowledgments

Numerous personnel contributed to recovery efforts, data collection, and public outreach including Recovery Program Staff, SNBSF volunteers, and many others. Recovery Program staff include: Julia Runcie, Ellen Brandell, Alex Few, Todd Calfee, Vicki Davis, Brian Hatfield, Dennis Jensen, and Jon Weissman. Additional CDFW staff include: Jonathan Fusaro, Jane McKeever, and Mike Morrison. SNBSF volunteers include: Virginia Chadwick, Jora Fogg, and Julie Rolfe. In addition, helicopter pilot Jim Pope, fixed-wing pilot Geoff Pope, as well as CDFW warden pilots Michael Breiling and Gary Shales contributed to this effort.

The recovery effort is funded primarily by the California Department of Fish and Wildlife. Funding was also acquired through U.S. Fish and Wildlife Service Section 6 grants to support recovery activities. The Bureau of Land Management, Inyo National Forest, Humboldt-Toiyabe National Forest, Yosemite National Park, and Sequoia-Kings Canyon National Parks are partners in the recovery effort. The Yosemite Conservancy, the Sierra Nevada Bighorn Sheep Foundation, and the Wild Sheep Foundation provided important supplemental funding when needed. The SNBSF also contributed significantly to field monitoring efforts and has provided all genetic data used for monitoring and translocation decisions.

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# Appendix A
# Summaries of Population Monitoring Activities by Herd for SNBS During May 2015-April 2016.

*Olancha Peak*

We surveyed Olancha at high elevation in August 2015 and we obtained various observations at low elevation from January-February 2016. Based on combining observed bighorn and known collared bighorn not seen, the best minimum count for females occurred in the winter: 13 adult ewes, 3 yearling ewes, and 4 lambs. The best minimum count for males occurred in the summer: 6 adult rams and 2 yearling rams (Table 1). Genotyping of lamb fecal pellets identified 5 unique genotypes, but we observed only 4 lambs, indicating minimum counts may have missed some bighorn. There were no known adult mortalities during the year. All collared animals were seen except for ewe S279 and ram S259. Ewe S279 was last heard alive on May 25, 2016 and last seen June 18, 2014 with a lamb. Her collar signal is intermittently on mortality and also seems to change pitch. Ram S259 was last heard alive in February 2016 and has not been seen since he was released in 2013. Ram S322 was released along the Kern River near Laurel Creek in 2015, but has been included in this Olancha minimum population count because he seems to be most associated with Olancha despite some wandering movements. There were no capture activities or mortalities at Olancha. At the end of the reporting period we can account for 13 adult ewes, 3 yearling ewes, 5 lambs, 6 adult rams and 2 yearling rams (Table 2). Up to 75% of the ewes are collared in this population but only one has a functioning GPS collar. Up to 50% of rams are collared including two functioning GPS collars that are scheduled to drop off in March 2017 (Table 3).

*Laurel Creek*

There was no systematic survey at Laurel. However, on August 19, ewe S376 was observed with her lamb at Rattlesnake Creek / Soda Creek Ridge. Laurel ewe S380 died of unknown cause in October 2015. Laurel ram S364 made exploratory movements in Langley and Olancha since release and died in Olancha in January 2016 from probable lion predation. Laurel ram S311 made exploratory movements to Langley and Williamson since release and died in Williamson in November 2015 of unknown cause. In December, Laurel ram S204 made exploratory movements north through Big Arroyo to Mt. Farquhar. In addition, Laurel ram S322 moved in to the Olancha herd in November 2015. More permanent moves are considered separate from exploratory movements based on the persistent use within a new herd unit for 1 year. There were no capture activities in Laurel. Based on those limited observations, we estimate a minimum count for Laurel at the end of the year to be 6 adult ewes, 0 yearling ewes, 1 lamb, and 1 adult ram (Table 2). Up to 100% of the ewes have functional VHF collars and 86% have functional GPS collars. The one known ram has functional VHF and GPS collars (Table 3).

*Big Arroyo*

Based on combining observations from May and July, our minimum count is 9 adult ewes, 1 yearling ewe, 2 lambs, 3 adult rams and 2 yearling rams (Table 1). Ewe S282 died in March 2016 but was not recovered until June due to access limitations and the cause of death was unknown. This reduces the total count at the end of the year by 1 ewe (Table 2). There were no capture activities. We estimate 80% of ewes in this population have functional VHF collars and 60% have functional GPS collars. Up to 60% of the rams in this population have functional VHF collars and none have functional GPS collars (Table 3).

*Mt. Langley*

Langley was surveyed twice, Sept. 1-3 and Sept. 29-Oct. 1. Based on combining observed bighorn and known collared bighorn not seen, the best minimum count for all age classes occurred during the first survey: 33 adult ewes, 4 yearling ewes, 20 lambs, 29 adult rams and 7 yearling rams (Table 1). This is likely an underestimate as only 50% of marked animals were seen during the minimum count (7/14) and our mark-resight estimate was 57 (41-80). Collared ewe S86 was censored as of January 5, 2014. Past minimum counts or MR estimates were adjusted as necessary. During a capture in October 2015, 3 adult females, 1 female lamb and 1 male lamb were collared. During a capture in March 2016, vaginal implant transmitters (VITs) were placed in 3 adult females along with collars, 3 adult males were collared and one adult female was recaptured and re-collared. Two collared adult ewes (S374 and S342) as well as one uncollared lamb died. Langley ewe S342 was observed with an injured leg two months prior to her mortality in May of 2015, but the proximate cause of death was determined to be predation by mountain lion. Ewe S342's lamb was located within 10 feet of S342 and also identified as a certain lion kill. Langley ram S374 was missing a hoof at capture in 2015, but the proximate cause of death in April 2016 was unknown. As of

May 2016, we can account for 32 adult ewes, 4 yearling ewes, 20 lambs, 29 adult rams, and 7 yearling rams (Table 2). We estimate a maximum of 51% of ewes have marks: 41% have functional VHF collars and 30% have functional GPS collars. We estimate at most 25% of rams have marks: 14% have functional VHF collars and 11% have functional GPS collars (Table 3).

*Mt. Williamson*

We made no ground observations of the Williamson herd during this period. Ewe S270 was captured in October. There were no collar mortalities. Our general population estimate for Mt. Williamson is derived from a minimum count in 2014: 11 adult ewes, 2 yearling ewes, 4 lambs, 8 adult rams, and 2 yearling rams (Table 1). Based on this estimate we have up to 54% of ewes marked, 38% with functional VHF collars and a single functional GPS collar (8%). Up to 20% of rams are marked and 10% have functioning VHF and GPS collars (Table 3).

*Mt. Baxter*

Based on our March 9 survey, we had a minimum count of 34 adult ewes, 7 yearling ewes, 16 lambs, 27 adult rams and 6 yearling rams (Table 1). This count includes 2 collared Sawmill rams (see movement section for discussion on overlapping herds). This minimum count is likely an underestimate, as 60% (12/20) of females were observed during the count. In October 2015 we collared 3 ram lambs (S390, S391, S392). In March 2016, we collared 2 adult rams. Genetic heterozygosity of these rams will be determined in order to identify if these individuals should be targeted in future translocation efforts. There were five mortalities: 3 ewes (S213, S304, S302) and 2 rams (S362, S392). One ewe (S302) and ram (S392) were certain and probable lion kills respectively and the other three bighorn died from unknown causes. All mortalities except S302 occurred before the minimum count. Taking into account all known mortalities we ended the season with a minimum count of 40 ewes (all ages) and with at least 33 rams (Table 2). Up to 46% of the ewes are marked: 34% have functional VHF collars and 20% have functional GPS collars. There are up to 39% of rams marked, 24% with functional VHF collars, and 15% with functional GPS collars (Table 3).

*Sawmill Canyon*

An opportunistic observation of Sawmill on March 10, 2016 provided our best minimum count of 41 adult ewes, 4 yearling ewes, 11 lambs, 16 adult rams, and 4 yearling rams (Table 1). This likely represents an underestimate as only 38% (6/16) of collared females were observed. In October 2015 we collared 3 ram lambs, 1 ewe lamb, and recaptured one adult ewe (S327). There were no spring captures in Sawmill. All 3 mortalities were lion kills: ewes S327 and S262 as well as ram S230. One ewe mortality (S327) occurred after the minimum count so the estimate at the end of the reporting period is reduced by one. We ended the season with a minimum count of 44 ewes, 11 lambs, and 20 rams, although this is likely a significant underestimate of rams (Table 2). Up to 36% of ewes are marked; 31% have functional VHF collars and 9% have functional GPS collars. Although our minimum ram count is an underestimate, 16 of the 20 counted rams were marked (80%): 12 have functional VHF collars (60%), and 7 have functional GPS collars (35%; Table 3).

*Bubbs Creek*

We made no ground observations in Bubbs. A hiker reported a group of 4 rams east of Gardiner Lakes on Aug. 13, which included S198 (dropped GPS collar) and S316. Ram S316 died in December and was not investigated until the following June. Cause of death was not determined. Our general population estimate for Bubbs creek is derived from the most recent minimum count in September 2014: 10 adult ewes, 1 yearling ewe, 1 ewe of unknown age, 9 lambs, 5 adult rams and 1 yearling ram (Table 1). Up to 58% of the ewes are marked: 42% have functional VHF collars and 17% have functional GPS collars (Table 3). There are up to 67% marked rams: 67% have functional VHF collars and 17% functional GPS collars (Table 3).

*Taboose Creek*

There was no systematic survey of Taboose. In October 2015, 2 ewes were collared and in March 2016, 1 ram was collared. Opportunistic observations confirmed the presence of at least 7 uncollared rams but no lambs or additional uncollared ewes were observed. Our best estimate for this population comes from maximum numbers of each class of animal observed in 2014: 2 adult ewes, 1 yearling ewe, 15 adult rams and 2 yearling rams (Table 1). We cannot confidently describe population size or the relationship between this population and the Sawmill Canyon bighorn. There are 2 ewes with functional VHF and GPS collars and 3 marked rams, 2 of which have functional GPS and VHF collars (Table 3).

*Wheeler Ridge*
Wheeler was surveyed July 27-29, 2015 and February 9-10, 2016. Our highest minimum count occurred in February, in which 74% (14/19) of collared ewes and 22% (4/18) of collared rams were observed. In addition 3 uncollared ewes of unknown age were observed. The total minimum count was 58 total ewes (50 adult ewes, 5 yearling ewes, 3 unknown aged ewes), 20 lambs, 28 adult rams and 8 yearling rams (Table 1). In October we collared 16 animals: 6 adult ewes, 1 yearling ewe, 1 lamb ewe, 3 adult rams, 2 yearling rams and 3 lamb rams. This included 4 recaptured ewes (S143, S241, S244, S248). In March we captured an additional 6 ewes including 1 recapture (S240) and placed VITs in 4 of them (S240, S417, S419, S420). There were 5 collar mortalities: 4 rams and 1 ewe. A ram lamb (S387) was killed by a bobcat, 2 rams were probable lion kills (S348, S72), one ram (S384) died of physical injury and the ewe's (S144) cause of death is unknown. In addition there was one uncollared carcass opportunistically encountered of unknown sex and unknown cause, as well as one censored ram (S294) that had dropped its lamb collar and is no longer uniquely identifiable. One adult ram loss (S348) occurred after the February survey (Table 2). We estimate a maximum of 41% of ewes have marks: 28% with functional VHF collars and 16% with functional GPS collars (Table 3). We estimate a maximum of 61% of rams have marks with 31% functional vhf and 22% functional GPS (Table 3).

*Convict Creek*
Convict was surveyed on May 7 and September 16-23, 2015. The highest minimum ewe, lamb and yearling ram count came from September and the highest minimum adult ram count came from May: 12 adult ewes, 1 unclassified ewe, 1 yearling ewe, 8 lambs, 9 adults rams, and 3 yearling rams (Table 1). In the spring, 2 collared Convict ewes died (S404, S148) of probable and certain lion predation respectively. A total of 13 Convict animals were captured. In October we captured 7 ewes, including 1 yearling and 4 lambs, as well as 1 yearling and 1 adult ram. This included 1 ewe recapture (S336). In March 4 adult ewes were caught including 1 recapture (S222) and VITs were placed in all but one (S422). At the end of the year we accounted for 12 females, 8 lambs and 12 rams (Table 2). Based on our counts we estimate a maximum of 92% of ewes are collared: 62% have functional VHF collars and 85% have functional GPS collars. A maximum of 25% of rams are collared: 17% have both functional VHF and GPS collars (Table 3).

*Cathedral Range*
In July, all but 1 of the newly created Cathedral ewes were observed on the Parson's plateau, including 2 lambs. There were no capture events in this herd. Ram S349 died in January 2016 but was not investigated until June and was determined to be possible lion predation. We were able to get a complete a census of the Cathedral Range: 10 adult ewes, 2 ewe lambs, and 2 adult rams (Table 1). All adults in the Cathedral Range have functional VHF collars and 90% of adult ewes have functional GPS collars due to the failure of 1 GPS collar (Table 3).

*Mt. Gibbs*
Gibbs was surveyed July 1, 2015. In combination with additional observations of the augmented Alger ewes betweem May – August, we accounted for 19 adult ewes, 3 yearling ewes, 10 lambs, 10 adult rams, and 4 yearling rams (Table 1). All but one (S100) of the Mt. Gibbs collared animals were seen. There were no capture activities or mortalities in the Mt. Gibbs herd. Up to 59% of Mt. Gibbs ewes are marked: 45% have functional VHF and 18% have functional GPS collars (Table 3). Up to 29% of Gibbs rams are marked: 29% have functional VHF collars and 7% have functional GPS collars (Table 3).

*Mt. Warren*
Warren was surveyed June 30 – July 1, 2015 by an interagency cooperative group; there were 10 adult ewes, 2 yearling ewes, 4 lambs, 7 adult rams and 2 yearling rams (Table 1). All collared animals were seen. No animals were observed in the Dore Cliffs area. There were 4 collared animal mortalities: 3 rams (S65, S329, S333) all of which were probable (S329) or certain lion predation, and 1 ewe (S332) whose cause of death on a windswept slope of Excelsior mountain in the winter is unknown. All mortalities occurred after the survey, so the end of the season minimum count is reduced to: 9 adult ewes, 2 yearling ewes, 4 lambs, 4 adult rams and 2 yearling rams (Table 2). Up to 25% of the ewes in this population have marks: 17% have functional VHF collars and 8% have functional GPS collars. Up to 33% of the rams are marked: 33% with functional VHF collars and 11% have functional GPS collars (Table 3). It is important to maintain functional collars on rams in Warren because of the disease threat from domestic sheep grazing nearby.

# Appendix B
## Reconstructed Sierra Nevada bighorn sheep abundance estimates during 2006-2016.

| Herd Unit | Year | Adult Ewes | Yrlng Ewes | Min Total Ewes | Est Total Ewes | Lambs | Adult Rams | Yrlng Rams | Min Total Rams | Est Total Rams | Min Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Olancha | 12-13 | (+10) | 0 | 10 | | 0 | (+4) | 0 | 4 | - | 14 |
| | 13-14 | 10(+4) | 0 | 14 | | 8 | 3 | 0 | 3 | - | 25 |
| | 14-15 | 14 | 2 | 16 | | 6 | (+2) | 2 | 4 | - | 26 |
| | 15-16 | 13 | 3 | 16 | | 5 | 6 | 2 | 8 | - | 29 |
| Laurel | 14-15 | (+6) | (+1) | 7 | | 0 | (+4) | 0 | 4 | - | 11 |
| | 15-16 | 7 | 0 | 7 | - | 1 | 4 | 0 | 4 | - | 12 |
| Big Arroyo | 13-14 | (+8) | (+2) | 10 | | 0 | (+4) | 0 | 4 | - | 14 |
| | 14-15 | 9 | 0 | 9 | | 5 | 4 | 0 | 4 | - | 18 |
| | 15-16 | 9 | 1 | 10 | | 2 | 3 | 2 | 5 | - | 17 |
| Langley | 06-07 | 34 | 11 | 45 | 38 (35-47) | 18 | 21 | 7 | 28 | | 91 |
| | 07-08 | 34 | 10 | 44 | 47 (38-60) | 17 | 16 | 6 | 22 | | 83 |
| | 08-09 | 35(-2) | 3(-1) | 35 | 46 (33-65) | 8 | 19 | 5 | 24 | | 67 |
| | 09-10 | 29 | 4 | 33 | 48 (32-71) | 15 | 15 | 4 | 19 | | 67 |
| | 10-11 | 36 | 6 | 42 | 41 (30-56) | 11 | 32 | 7 | 39 | | 92 |
| | 11-12 | 41 | 6 | 47 | 53(42-66) | 15 | 42 | 3 | 45 | - | 107 |
| | 12-13 | 42(-5) | 5(-1) | 41 | 41 (32-53) | 27 | 31(-2) | 5 | 34 | - | 102 |
| | 13-14 | 39 | 9 | 48 | 59(46-76) | 22 | 34 | 9 | 47 | - | 117 |
| | 14-15 | 45(-11) | 10(-1) | 43 | 63(49-81) | 18 | 59 | 8 | 67 | - | 128 |
| | 15-16 | 33 | 4 | 37 | 57 (41-80) | 20 | 29 | 7 | 36 | - | 93 |
| Williamson | 07-08 | 10 | 3 | 13 | | 7 | 7 | 1 | 8 | | 28 |
| | 08-09 | 11 | 3 | 14 | | 4 | 8 | 2 | 10 | | 28 |
| | 09-10 | 8 | 0 | 8 | | 2 | 6 | 0 | 6 | | 16 |
| | 10-11 | 9 | 1 | 10 | | 3 | 3 | 1 | 4 | | 17 |
| | 11-12 | - | - | - | - | - | - | - | - | - | |
| | 12-13 | - | - | - | - | - | - | - | - | - | |
| | 13-14 | - | - | - | - | - | - | - | - | - | |
| | 14-15 | 11 | 2 | 13 | | 4 | 8 | 2 | 10 | - | 27 |
| | 15-16 | - | - | - | - | - | - | - | - | - | |
| Bubbs | 06-07 | - | - | - | - | - | - | - | - | | |
| | 07-08 | 13 | 1 | 14 | | 6 | 6 | 1 | 7 | | 27 |
| | 08-09 | 14 | 3 | 17 | | 1 | 4 | 1 | 5 | | 23 |
| | 09-10 | - | - | - | | - | - | - | - | | |
| | 10-11 | 6 | 3 | 9 | | 2 | 11 | 1 | 12 | | 23 |
| | 11-12 | - | - | - | - | - | - | - | - | - | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12-13 | 8 | 1 | 9 | | 5 | 7 | 1 | 8 | - | 22 |
| | 13-14 | 11 | 2 | 14 | | 9 | 4 | 1 | 5 | - | 28 |
| | 14-15 | - | - | - | - | - | - | - | - | - | 0 |
| | 15-16 | - | - | - | - | - | - | - | - | - | 0 |
| Baxter | 07-08 | 26 | 5 | 31 | | 13 | 9 | 4 | 13 | | 57 |
| | 08-09 | 29 | 5 | 34 | 27(18-40) | 13 | 12 | 5 | 17 | | 64 |
| | 09-10 | 24 | 6 | 30 | 27(24-32) | 20 | 21 | 1 | 22 | | 72 |
| | 10-11 | 30 | 6 | 36 | 32(27-38) | 21 | 26 | 8 | 34 | | 91 |
| | 11-12 | 30 | 8 | 38 | 20(17-24) | 19 | 25 | 5 | 30 | - | 87 |
| | 12-13 | 28 | 6 | 34 | 32 (27-37) | 23 | 32(-1) | 10 | 41 | - | 98 |
| | 13-14 | 40 | 6 | 46 | | 34 | 33(-3) | 7 | 37 | - | 117 |
| | 14-15 | 46(-6) | 6(-1) | 45 | | 17 | 29 | 5 | 34 | - | 96 |
| | 15-16 | 34 | 7 | 41 | - | 16 | 27(-4) | 6 | 29 | - | 86 |
| Sawmill | 07-08 | 11 | 1 | 12 | | 4 | 3 | 2 | 5 | | 21 |
| | 08-09 | 22 | 1 | 23 | | 9 | 8 | 3 | 11 | | 43 |
| | 09-10 | 29 | 1 | 30 | | 10 | 13 | 2 | 15 | | 55 |
| | 10-11 | 33 | 6 | 39 | | 16 | 12 | 6 | 18 | | 73 |
| | 11-12 | 41 | 4 | 45 | | 12 | 9 | 2 | 11 | 1 | 68 |
| | 12-13 | 22(-10) | 2 | 12 | | 8 | 5(-1) | 2 | 6 | - | 26 |
| | 13-14 | 26(-4) | 7 | 29 | | 9 | 7 | 3 | 10 | - | 48 |
| | 14-15 | 38(-3) | 6 | 41 | | 17 | 8(-1) | 8 | 15 | - | 73 |
| | 15-16 | 41 | 4 | 45 | - | 11 | 16(-1) | 4 | 19 | - | 75 |
| Wheeler | 06-07 | 34 | 4 | 38 | 49 (37-61) | 11 | 26 | 4 | 30 | 59 (26-92) | 79 |
| | 07-08 | 36 | 6 | 42 | 55 (43-70) | 15 | 35 | 4 | 39 | | 96 |
| | 08-09 | 36(-3) | 2 | 35 | 43 (33-56) | 14 | 20 | 2 | 22 | 33 (21-55) | 71 |
| | 09-10 | 36 | 3 | 39 | 43 (31-59) | 12 | 31 | 2 | 33 | 35 (29-42) | 84 |
| | 10-11 | 29 | 4 | 34 | 40 (32-51) | 21 | 23 | 10 | 33 | | 88 |
| | 11-12 | 31 | 4 | 35 | 40(25-64) | 15 | 31 | 5 | 36 | - | 86 |
| | 12-13 | 29 | 10 | 39 | 53 (42-67) | 15 | 32 | 4 | 36 | - | 90 |
| | 13-14 | 39(-8) | 7(-2) | 36 | | 20 | 23(-1) | 8 | 30 | - | 86 |
| | 14-15 | - | - | - | - | - | -(-1) | - | - | - | |
| | 15-16 | 50 | 5 | 58 | | 20 | 28(-4) | 8 | 36 | - | 114 |
| Taboose | 14-15 | 2 | 1 | 3 | | 0 | 15 | 2 | 17 | - | 20 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15-16 | - | - | - | - | - | - | - | - | - | |
| Convict | 11-12 | 3 | 2 | 5 | | 2 | 0 | 1 | 1 | - | 8 |
| | 12-13 | 1(+2) | (+1) | 4 | | 3 | 1 | 0 | 1 | - | 8 |
| | 13-14 | 12 | 1 | 13 | | 5 | 1 | 2 | 3 | - | 21 |
| | 14-15 | 13 | 1 | 14 | | 8 | 2 | 2 | 4 | - | 26 |
| | 15-16 | 12 | 1 | 14 | | 8 | 9 | 3 | 12 | - | 34 |
| Cathedral | 14-15 | (+9) | (+1) | 10 | | 0 | (+3) | 0 | 3 | - | 13 |
| | 15-16 | 10 | 0 | 10 | | 2 | 2 | - | 2 | - | 14 |
| Gibbs | 06-07 | 3 | 1 | 4 | | 2 | 3 | 0 | 3 | - | 9 |
| | 07-08 | 4 | 1 | 5 | | 4 | 3 | 1 | 4 | - | 13 |
| | 08-09 | 5 | 2 | 7 | | 3 | 3 | 2 | 5 | - | 15 |
| | 09-10 | 8 | 1 | 9 | | 2 | 5 | 1 | 6 | - | 17 |
| | 10-11 | 7 | 0 | 7 | | 1 | 6 | 0 | 6 | - | 14 |
| | 11-12 | 7 | 0 | 7 | | 4 | - | 1 | 1 | - | 12 |
| | 12-13 | 7(+3) | 1 | 8 | | 2 | 9 | 2 | 11 | - | 21 |
| | 13-14 | 11 | 1 | 12 | | 6 | 7 | 1 | 8 | - | 26 |
| | 14-15 | 10 | 3 | 13 | | 8 | 4 | 1 | 5 | - | 26 |
| | 15-16 | 14(+5) | 3 | 22 | - | 10 | 10 | 4 | 14 | - | 46 |
| Warren | 06-07 | 7 | 2 | 9 | | 4 | 10 | 0 | 10 | | 23 |
| | 07-08 | 9 | 2 | 11 | | 4 | 13 | 0 | 13 | | 28 |
| | 08-09 | 7(+5) | 2(+1) | 16 | | 5 | 7 | 0 | 7 | | 28 |
| | 09-10 | 16 | 1 | 17 | | 12 | 6 | 2 | 8 | | 37 |
| | 10-11 | 16 | 5 | 21 | | 11 | 5 | 3 | 8 | | 40 |
| | 11-12 | 12 | 2 | 14 | | 4 | 7 | 2 | 9 | - | 27 |
| | 12-13 | 12 | 3 | 15 | | 11 | 9 | 1 | 10 | - | 36 |
| | 13-14 | 7 | 4 | 11 | | 4 | 6 | 2 | 8 | - | 23 |
| | 14-15 | 10 | 0 | 11 | | 8 | 7 | 3 | 10 | - | 29 |
| | 15-16 | 10 | 2 | 12 | - | 4 | 7 | 2 | 9 | - | 25 |

This represents the Recovery Program's best estimate of the population by herd. Reconstructions include counting marked animals not seen, counting genetic evidence of individuals, as well as using the best count of each age class from any given season in the year. Total ewes or rams may not always equal the sum of yearlings ands adults when animals of unclassified age are encountered.

# Appendix C
## Collar Details by Herd and Function for SNBS during May 2015 – June 2016

Identification of each animal wearing a collar by April 30, 2016. Collar status is functional VHF (fVHF), functional GPS (fGPS), non-functional VHF (IDnonfVHF), non-functional GPS (IDnonfGPS). IDVHF_old are animals who currently have a functional VHF but the VHF is > 5 years old. IDRecentMorts are animals we believe are dead but have not yet investigated or recovered. fMarkNew are the functional collars we project to have for that herd for the next animal year (fVHF+fGPS-oldVHF-RecentMorts).

| Herd | Sex | ID All Marks | IDfVHF | IDfGPS | IDnonfGPS | IDnonfVHF | IDVHF_old | IDRecentMorts | fMarkNew |
|---|---|---|---|---|---|---|---|---|---|
| Gibbs | F | s100,s101,s145,s160,s172,s191,s218,s219,s250,s253,s324,s334,s339 | s160,s172,s191,s218,s219,s250,s253,s324,s334,s339 | s250,s253,s334,s339 | s160 | s100,s101,s145 | s100,s101,s145 | | s250,s253,s334,s339,s160,s172,s191,s218,s219,s324 |
| Gibbs | M | s159,s161,s186,s215 | s159,s161,s186,s215 | s186 | s159 | | s159,s215 | | s186,s161 |
| Baxter | F | s108,s123,s138,s139,s140,s162,s167,s180,s214,s223,s228,s229,s260,s263,s298,s299,s301,s306,s307 | s108,s167,s180,s214,s223,s228,s229,s260,s263,s298,s299,s301,s306,s307 | s223,s229,s263,s298,s299,s301,s306,s307 | s162,s180,s214 | s123,s138,s139,s140,s162 | s108,s123,s138,s139,s140,s162,s180,s214 | s392,s362 | s223,s229,s263,s298,s299,s301,s306,s307,s167,s228,s260 |
| Baxter | M | s163,s199,s296,s297,s300,s303,s305,s363,s390,s391,s392,s432,s433 | s296,s297,s303,s305,s363,s392,s432,s433 | s199,s297,s300,s390,s391 | | s163,s199,s300 | s163,s199 | s162,s302,s304,s213 | s297,s300,s390,s391,s296,s303,s305,s363,s392,s432,s433 |
| Wheeler | F | s142,s143,s17,s182,s236,s240,s241,s242,s243,s244,s246,s248,s386,s388,s409,s413,s417,s418,s419,s420,s421,s62,s82,s84 | s143,s182,s240,s241,s242,s243,s244,s246,s248,s386,s413,s417,s418,s419,s420,s421 | s240,s241,s244,s248,s388,s413,s417,s419,s420 | s182,s243,s246,s386,s409,s62,s84 | s142,s17,s236,s62,s82,s84 | s142,s17,s182,s62,s82,s84 | s348,s387,s384,s72 | s240,s241,s244,s248,s388,s413,s417,s419,s420,s143,s242,s243,s246,s386,s418,s421 |
| Wheeler | M | s112,s116,s150,s152,s181,s234,s245,s247,s294,s347,s350,s351,s352,s353,s383,s385,s389,s405,s410,s416,s63 | s234,s247,s347,s350,s351,s352,s353,s383,s385,s405 | s247,s347,s353,s383,s385,s389,s410 | s116,s416 | s112,s116,s150,s152,s181,s63 | s112,s116,s150,s152,s181,s63 | s144 | s247,s347,s353,s383,s385,s389,s410,s234,s350,s351,s352,s405 |
| Williamson | F | s114,s115,s166,s170,s171,s269,s270 | s166,s170,s171,s269,s270 | s270 | s170,s171 | s114,s115 | s114,s115,s170,s171 | | s270,s166,s269 |
| Williamson | M | s113,s268 | s268 | s268 | | s113 | s113 | s166 | s268 |
| Sawmill | F | s126,s128,s165,s203,s205,s232,s251,s252,s254,s255,s308,s314,s319,s323,s326,s396 | s165,s203,s205,s232,s251,s252,s254,s255,s308,s314,s319,s323,s326,s396 | s254,s314,s319,s326 | s205,s232,s308 | s126,s128 | s126,s128,s203,s205 | s230 | s254,s314,s319,s326,s165,s232,s251,s252,s255,s308,s323,s396 |
| Sawmill | M | s130,s207,s257,s258,s309,s310,s312,s320,s321,s325,s356,s357,s360,s361,s393,s394,s395,s430,s431 | s207,s258,s309,s310,s312,s320,s321,s325,s356,s357,s360,s361 | s207,s310,s312,s360,s393,s395,s431 | s357,s394 | s130 | s130,s207 | s327,s262 | s310,s312,s360,s393,s395,s431,s258,s309,s320,s321,s325,s356,s357,s361 |
| Warren | F | s155,s330,s89 | s330,s89 | s330 | s155 | s155 | s155 | s333,s329,s65 | s330,s89 |
| Warren | M | s239,s328,s331 | s239,s328,s331 | s331 | | | | s332 | s331,s239,s328 |
| Bubbs | F | s168,s169,s194,s226,s227,s315,s317 | s168,s194,s226,s315,s317 | s315,s317 | | s169,s227 | s168,s169,s194 | s316 | s315,s317,s226 |
| Bubbs | M | s192,s198,s249,s316 | s192,s198,s249,s316 | s316 | s198 | | s198 | | s316,s192,s249 |
| Langley | F | s173,s174,s177,s209,s221,s264,s265,s266,s340,s343,s406,s407,s408,s415,s425,s426,s70,s81,s92 | s173,s177,s209,s221,s264,s265,s266,s340,s343,s406,s407,s408,s425,s426,s70 | s177,s266,s340,s343,s406,s407,s408,s415,s425,s426,s70 | s174,s81 | s174,s81,s92 | s174,s209,s81,s92 | | s177,s266,s340,s343,s406,s407,s408,s415,s425,s426,s70,s173,s221,s264,s265 |
| Langley | M | s178,s190,s211,s217,s369,s414,s427,s428,s429 | s190,s211,s217,s428,s429 | s414,s427,s428,s429 | | s178 | s178,s190,s211 | s374,s342 | s414,s427,s428,s429,s217 |
| Convict | F | s175,s222,s336,s345,s397,s398,s400,s402,s403,s422,s423,s424 | s175,s222,s336,s345,s397,s398,s423,s424 | s222,s336,s345,s397,s398,s400,s402,s403,s422,s423,s424 | | | | | s222,s336,s345,s397,s398,s400,s402,s403,s422,s423,s424,s175 |
| Convict | M | s335,s399,s401 | s335,s401 | s399,s401 | | | | s148,s404 | s399,s401,s335 |
| Big Arroyo | F | s282,s283,s284,s285,s286,s287,s288,s289,s290 | s282,s283,s284,s285,s286,s287,s288,s290 | s282,s283,s284,s285,s288,s290 | s286,s287,s289 | s289 | | | s282,s283,s284,s285,s288,s290,s286,s287 |
| Big Arroyo | M | s193,s200,s202 | s193,s200,s202 | | s193,s200,s202 | | | s282 | s193,s200,s202 |
| Olancha | F | s206,s271,s274,s275,s276,s277,s278,s279,s280,s291,s292,s293 | s206,s271,s274,s275,s276,s277,s278,s279,s280,s291,s292,s293 | s291 | s206,s271,s279,s280,s292 | | | | s291,s206,s271,s274,s275,s276,s277,s278,s279,s280,s292,s293 |
| Olancha | M | s197,s210,s259,s358 | s197,s210,s259,s358 | s197,s358 | | | | | s197,s358,s210,s259 |
| Laurel | F | s376,s377,s378,s379,s380,s381,s382 | s376,s377,s378,s379,s380,s381,s382 | s376,s377,s378,s379,s381,s382 | s380 | | | s364,s311 | s376,s377,s378,s379,s381,s382,s380 |
| Laurel | M | s204,s311,s322 | s204,s311,s322 | s204 | s311 | | | s380 | s204,s311,s322 |
| Cathedral | F | s344,s365,s366,s367,s368,s370,s371,s372,s373,s375 | s344,s365,s366,s367,s368,s370,s371,s372,s373,s375 | s365,s366,s367,s368,s370,s371,s372,s373,s375 | s344 | | | s349 | s365,s366,s367,s368,s370,s371,s372,s373,s375,s344 |
| Cathedral | M | s295,s349 | s295,s349 | s295,s349 | | | | | s295,s349 |
| Taboose | F | s411,s412 | s411,s412 | s411,s412 | | | | s430 | s411,s412 |
| Taboose | M | s338,s354,s355 | s338,s354,s355 | s354,s355 | | | | | s354,s355,s338 |