2020-21 Annual Report
Sierra Nevada Bighorn Sheep Recovery Program

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Executive Summary

A worldwide pandemic and catastrophic extreme wildfires in California appeared to be of no consequence to the Sierra Nevada bighorn sheep population, which grew slightly from 258 females in 2019 to 260 females in 2020. This is a welcome trend after the decline of the last three years, which included dramatic losses associated with the snowy winters of 2016-17 and 2018-19. Given that this was the second consecutive mild winter, the Sierra bighorn population growth rate was lower than expected; with survival at 86% it is low enough to prevent levels of growth desired for recovery. Recruitment based on observed lamb:ewe ratios was only slightly above average. With the exception of Olancha, most of the larger and moderate sized herds showed declines, while smaller herds tended to increase in size. The newly established Olancha herd continues to be a highlight, growing to 30 females this year.

The Sierra Nevada Bighorn Sheep Recovery Program implemented measures to keep staff safe and healthy while continuing field and capture work. Due to smoky conditions, we were unable to perform summer surveys of Baxter, Olancha, and Williamson. However, we were able to get a good count at Olancha in the subsequent winter. In October, 56 animals were captured from 8 different herds, which will greatly increase our ability to monitor habitat use and vital rates. This was a particularly important capture as we were unable to capture in fall 2019 due to contract limitations. No bighorn translocations occurred.

Figure 1. *Rattlesnake fire near the Big Arroyo herd. Photo credit: Tony Caprio, Sequoia and Kings Canyon National Park.*

The role of mountain lion monitoring and management within the Recovery Program has grown dramatically and is showing substantial results. Within proximity to the eastern Sierra, 54 lions were counted, which is the highest count to date. This included high counts within the northern and central zones, but lower counts in the southern and Olancha zones. Lion predation was generally low, but was detrimental in Baxter and Wheeler, two critical source herds. Thirty mountain lions were collared, and lion GPS data were vital in identifying three predation events.

Five lions that threatened Sierra bighorn populations were translocated. These lions included 2 adult males and 1 adult female who was moved with 2 subadults. The females and subadults were translocated to Slinkard Valley and the family unit showed signs of cohesion, but unfortunately the adult female subsequently died from vehicle collision. Both males displayed intense homing movements and required secondary translocation before eventually dying. Future translocations will benefit from many lessons learned in these cases.

Introduction – 2020 Wildfires and Drought

This was the first full year of operations during the COVID19 pandemic, which came with a variety of health safety restrictions, including forest closures to the public, and the year also included massive wildfires (Figures 1 and 2). Despite these challenges, we were able to survey most bighorn herds and expanded our mountain lion monitoring and management. However, we were not able to host any public field trips, and public outreach was limited. This report summarizes the activities of the Sierra Nevada Bighorn Sheep Recovery Program (hereafter Recovery Program) from May 1, 2020 to April 30, 2021. A brief background on the program and Sierra bighorn is provided in Appendix B.

California experienced a record-breaking number of large wildfires (Keeley and Syphard 2021), including the Castle, Rattlesnake, Shotgun, and Iris fires, within or near Sierra Nevada bighorn sheep habitat (Figures 1 and 2). Although only a small portion of occupied Sierra bighorn habitat burned, these fires, in addition to other large fires in California (including the Creek, SCU Complex, Hennessey, and August fires) produced widespread smoke throughout Sierra bighorn occupied habitat. We did not detect changes in movements to avoid fires or smoke. However, we were unable to complete summer surveys in Baxter, Williamson, and Olancha due to smoky conditions. The removal of forest canopy by the fires may enhance habitat for Sierra bighorn in the coming years.

The 2021 water year was the second driest year on record in California, with 50% of statewide average precipitation, following the fifth driest year on record in 2020. Emergency proclamations related to drought were issued in 50 counties in California (California Department of Water Resources 2021), and temperatures were generally above average. However, it is snowy winters that tend to negatively impact Sierra bighorn (Greene et al. 2017, 2019), while populations are resilient to, or even thrive, during drought, including the recent five year drought (2012-2016, Figure 3). Because Sierra bighorn are likely well below their historical maximum abundance and below nutritional carrying capacity, they may experience minimal competition for forage under drought conditions. The snowpack during drought years appears to continue to provide high quality forage for Sierra bighorn at their current population levels.

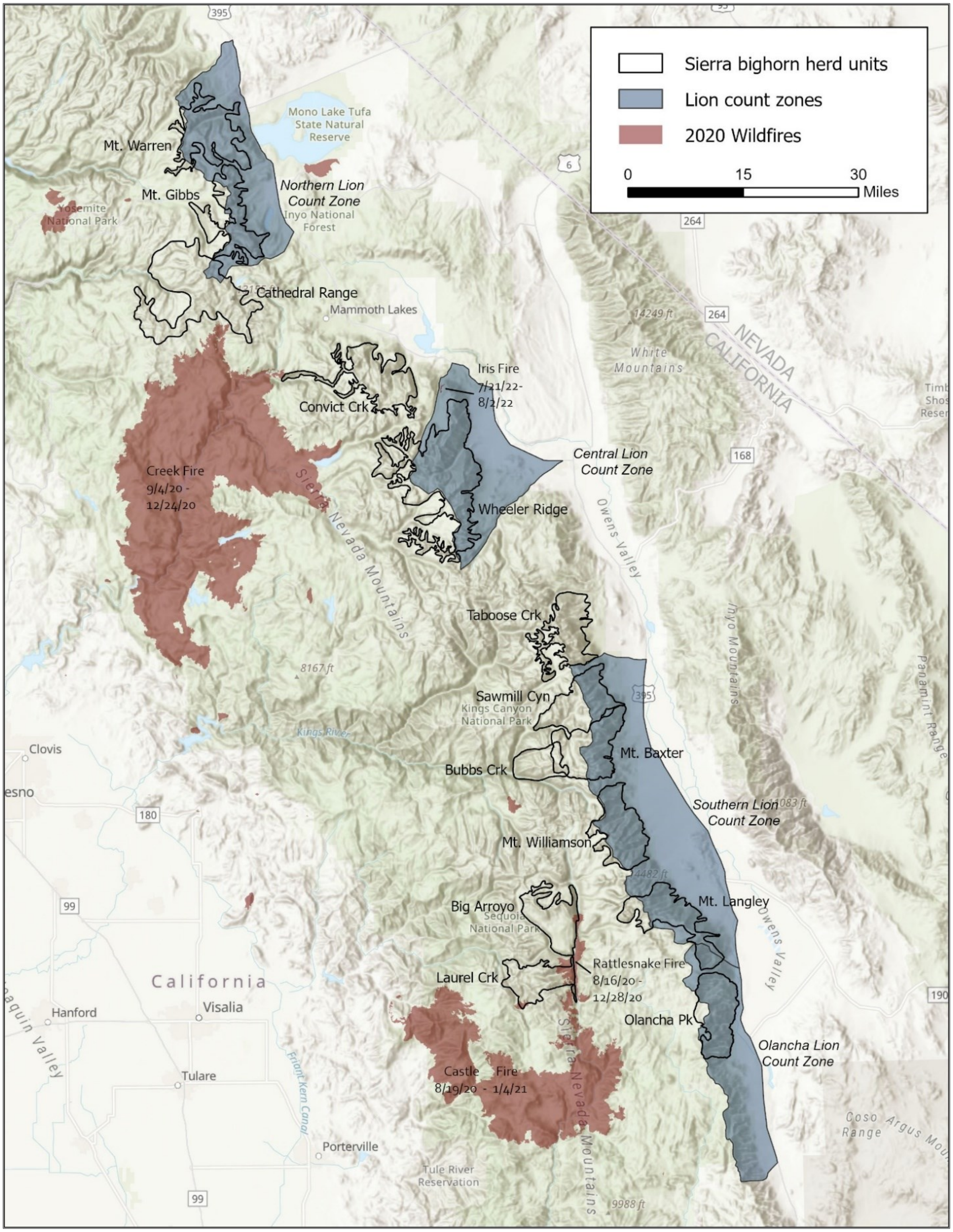

__Figure 2__. Overview map of major wildfires in the summer of 2020, Sierra bighorn herd units, and mountain lion count zones in the eastern Sierra.

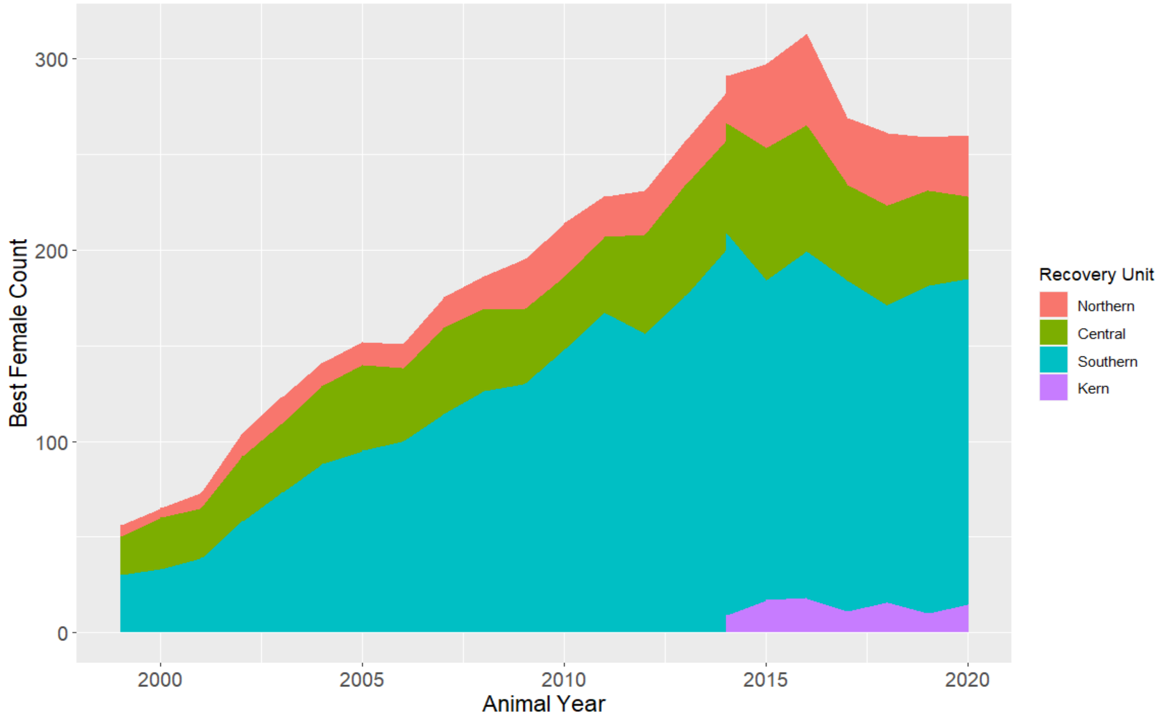

Figure 3. *Range-wide female Sierra bighorn population abundance since 1999. Range-wide numbers are calculated using annual herd values based on reconstructed minimum counts and mark-resight estimates, as well as the most recent survey results for herds not surveyed annually. Herd counts are combined across the animal year (May 1 – April 30). Because some herds are counted before winter in summer and others are counted during or after winter in the spring, the complete impacts of a given winter are not shown in this graph.*

Population Monitoring and Recovery Goals

This year we documented a slight increase of 2 females in the range-wide population of Sierra bighorn, counting 260 females (including 29 yearlings), 117 lambs, and an estimated 173 males (including 21 yearlings; Table 1, Figure 3). This is a welcome change from the declining trend of the last three years. Previously, the highest count of 317 females occurred in 2016, prior to the snowy winters of 2016-17 and 2018-19, from which the population has not yet rebounded. These range-wide estimates are largely based on minimum counts in combination with some mark-resight estimates at the herd level with males estimated based on a 2:3 male:female ratio (Appendix B, Methods).

Annual range-wide counts are an incomplete metric to evaluate the impact of a given winter (Figure 3) because surveys occur throughout the animal year – with some occurring before, and others after winter impacts. For example, we estimate up to 30% of females, ~100, were lost in 2016-17 winter, and up to 25% of females, ~75, were lost in the 2018-19 winter (Greene et al. 2017, 2019), but these losses are not clearly seen in our range-wide estimates because our annual range-wide estimate combines herd counts from summer (before winter) and the following spring (after winter impacts). We get more complete counts in some herds in the summer while other herds are more successfully counted in the spring, but when these counts are combined into an annual range-wide count, the impact of a given winter is diluted. This year, however, was a mild winter with minimal losses.

Table 1. Reconstructed minimum counts (MC) of Sierra bighorn during May 1, 2020 - April 30, 2021. Lambs not identified by sex. Female and lamb estimates are likely more accurate than male estimates because there is a higher proportion of marked females and survey routes are designed to detect females. However, all minimum counts are underestimates. Year-end population is reduced by all known mortality that occurred after the survey.

Herd	Female Adult	Female Yrlng	Female Total	Lambs	Male Adult	Male Yrlng	Male Total	MC Population	Year End Females	Mortality post survey	Notes
Olancha	24	5	**30**	16	10	2	12	**58**	30	none	Includes 1 unknown aged female
Laurel	2	0	**2**	2	0	2	2	**6**	2	none	Only 1 collared female, S382
Big Arroyo	12	1	**13**	7	8	0	8	**28**	12	1 (S287)	Mort is from capture
Langley	15	2	**17**	8	10	1	11	**36**	17	none	
Williamson[W] (2019)	14	0	**14**	4	5	0	5	**23**	NA	none	Not surveyed annually
Baxter[W]	(31)	(5)	**(36)**	(14)	(27)	(4)	(31)	**(81)**	(33)	3 (S227, S585, S214)	Low winter count
Baxter (2019)	46	10	**56**	15	28	5	33	**104**	NA	NA	2019 count--better estimate because 2020 count was inaccurate
Sawmill	33	2	**35**	17	6	1	7	**59**	35	none	
Bubbs	12	2	**14**	8	14	3	17	**39**	14	none	No collars
Taboose	4	0	**4**	2	5	1	6	**14**	4	none	Males from 2018 count. Total includes 2 unclassified animals. Early count may underestimate lambs
Wheeler	32	5	**37**	14	11	3	14	**65**	36	S547	
Convict[C]	6	0	**6**	4	4	2	6	**16**	6	none	Possibly another yearling but not confirmed
Cathedral	2	0	**4**	1	1	0	1	**6**	4	none	Includes S365 but not Gibbs male S488. 2 females added as reconstruction from 2021 count
Gibbs	19	2	**21**	14	16	1	17	**52**	18	S521, S485, S565	
Warren	7	0	**7**	5	2	0	2	**15**	7	none	Includes 1 unclassified animal from hiker video. All females collared
Totals	**228**	**29**	**260**	**117**	**120**	**21**	**141**	**518**			

[W] Winter counts, other surveys conducted in summer [C] Data combined from winter and summer surveys

The Recovery Plan (U.S. Fish and Wildlife Service 2007) specifies minimum counts are used to evaluate progress toward downlisting goals, requiring at least 305 females with specific geographic targets in four Recovery Units (Figure 4). Each Recovery Unit consists of 2-7 herd units. Currently only the Southern Recovery Unit meets the numerical downlisting goal. However, we recognize that our counts represent a minimum number of bighorn in herds and the true number is likely higher in most herds.

We report the highest count for each herd which typically occurs in the summer for most herds, but sometimes occurs in the following winter or early spring (Table 1 and Figure 5). Olancha had its highest count to date with 30 females. However, most of the other larger and moderate-sized herds have shown declining trends in the last five years (Figure 5).

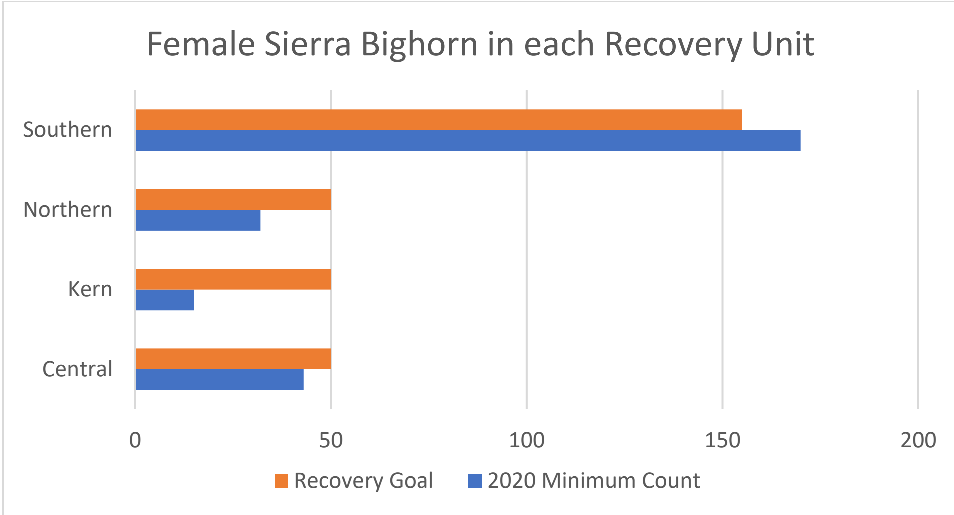

Figure 4. *Abundance and distribution of female Sierra bighorn across Recovery Units compared to downlisting goals.*

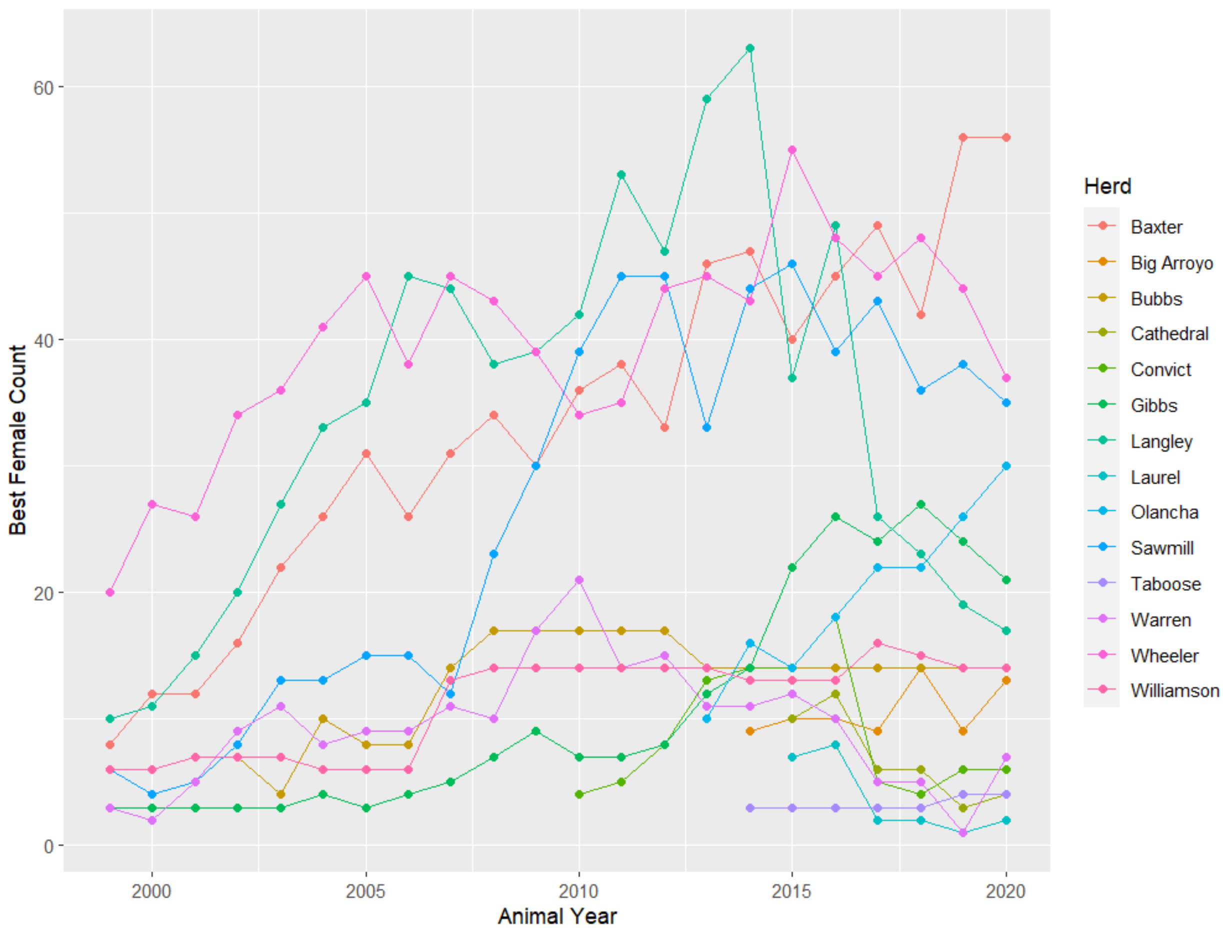

Figure 5. *Range-wide female Sierra bighorn population abundance since 1999. Range-wide numbers are calculated using annual herd values based on the most recent survey results for each herd as reconstructed minimum counts or mark-resight estimates. Herd counts are combined across summer and spring (post winter; May 1 - April 30), and therefore do not show the impacts of a given winter.*

Capture, Collaring, and Translocation Efforts

This fall we captured 56 animals (40 females, 16 males) across 8 herds: 3 at Big Arroyo, 4 at Convict, 13 at Baxter, 7 at Gibbs, 3 at Williamson, 8 at Olancha, 1 at Taboose, and 17 at Wheeler. Most captures occurred in the fall, but 5 animals (4 females, 1 male) were captured in Baxter in the spring. All captures were performed with a net gun fired from a helicopter by Leading Edge Aviation and pilot Jim Pope. There was one capture mortality, female S581 at Big Arroyo. All 55 animals released had a VHF collar, and additionally 47 animals also had GPS collars. Three camera collars were deployed on females at Baxter in the spring (S544, S585, S587). No bighorn translocations occurred.

Capturing Sierra bighorn provides the opportunity to determine body condition, pregnancy status, test for disease, measure genetic diversity, and deploy collars. Capturing animals is critical for translocations, and collaring animals enables us to monitor habitat use, disease risk, vital rates, and estimate herd size. Power analyses indicate we need to maintain collars on 35% of the female population in order to detect 10% change in survival per year over five years using a known fate survival analysis (German 2010). Functional collars have proven essential for tracking survival and cause-specific mortality. Collared bighorn and collared lions provide complimentary information on predation by mountain lions and one or the other has proven essential in cases where keeping both species collared in any given herd is challenging. We try to maintain this ratio for source herds with >20 females and in newly established herds. We focus capture and collaring efforts on females, as they tend to drive population dynamics. However, collared males can help identify patterns of habitat use and identify and quantify disease risk from contact with domestic sheep, so we also try to maintain some collars on males, particularly in herds near domestic sheep (e.g., Warren, Convict, and Wheeler).

On April 20, a camera collar on Sawmill female S541 detected a lambing event. It was quite challenging to interpret the footage (Figure 6), but it appears that a lamb was born. Occasionally the lamb can be seen lifting its head and breathing rapidly. Unfortunately, after this footage the lamb was never seen again, so it is unknown if the lamb was truly viable, if it was quickly preyed upon, or if it met some other fate.

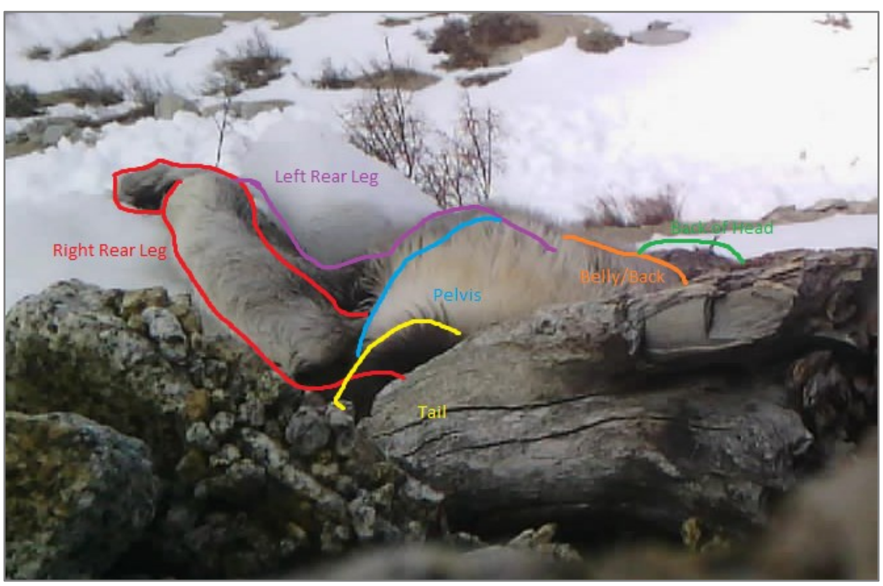

Figure 6. *Still shot from camera collar deployed on Sawmill female S541 showing a believed birthing event on April 20, 2020. After this footage the lamb was never seen again by either the camera collar or by observers during summer surveys.*

2020 Demographic Rates

In 2020, we accounted for 260 females distributed across 14 herds; herd size ranged from 2 to 56 (Table 1 and Figure 7). Currently only Baxter exceeds the 40 female threshold to be able to provide females for translocation, although Wheeler and Sawmill are close. Olancha remains the highlight of the new herds as it continued to grow to 30 females. None of the herds appear to be growing or declining quickly at this time. Range-wide collared female survival was 86%, ranging from 67% to 100% between herds (Figures 8 and 10). Range-wide female lamb survival calculated from observed ratios of lambs, yearlings, and adults was 52% ranging from 35% to 83% (Figures 8-10). We are unable to calculate survival for very small herds or herds with few collared females.

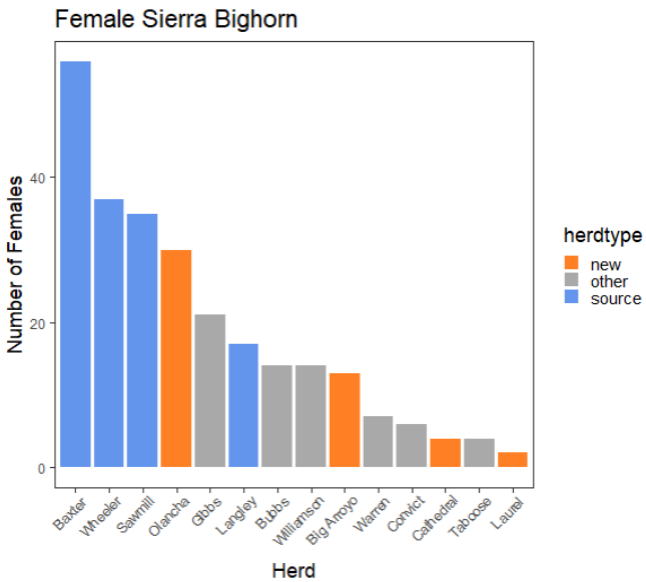

Figure 7. *2020 Reconstructed minimum counts of female Sierra bighorn.*

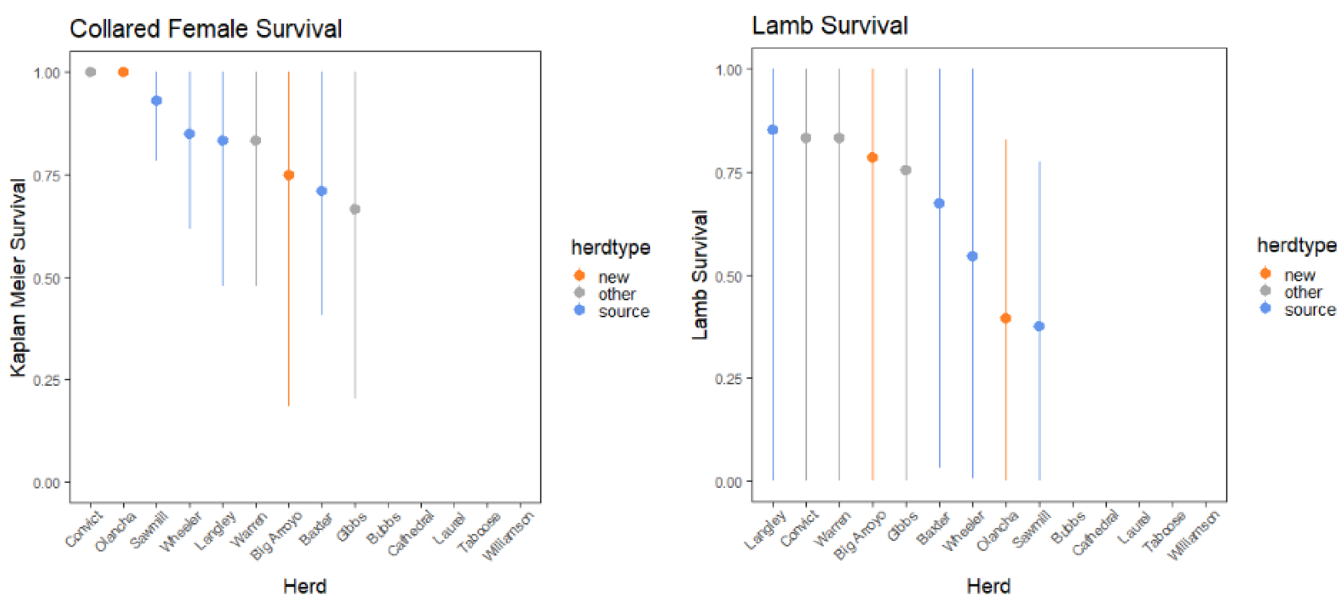

Figure 8*. 2020 collared female and lamb survival with 95% confidence intervals, for herds with >3 collared females. Female survival estimated using Kaplan Meier, and lamb survival estimated using age ratios.*

Collared female survival was low (<0.75) in Big Arroyo, Baxter, and Gibbs. While Big Arroyo and Gibbs may simply be artifacts of having a small number of collared females, Baxter mortality was representative and almost entirely due to mountain lion predation. Lamb:ewe ratios tended to be highest in smaller and newer herds and yearling:ewe ratios tend to be about half of lamb:ewe ratios (Figure 9). With a few exceptions discussed here, herd based vital rates tend to be at or slightly below average, which is not particularly concerning, but we would expect herds to be growing robustly after two consecutive mild winters.

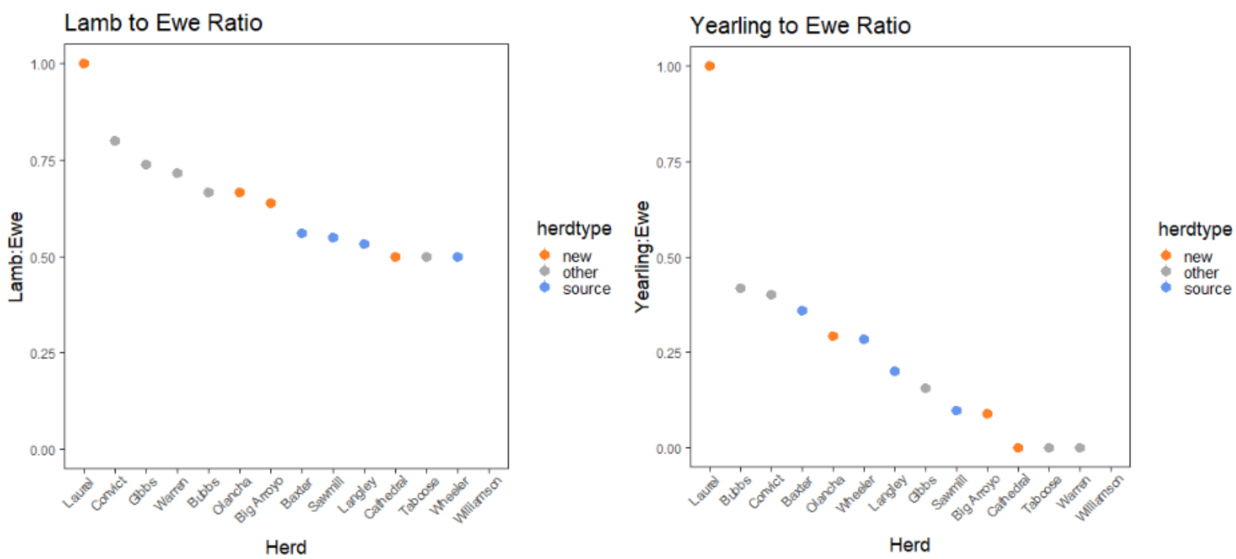

Figure 9. *Observed ratios of lambs and yearlings (males and females combined) to adult females by herd in 2020.*

Baxter was the largest herd with an estimated 56 females. However, this count is from 2019, because smoky conditions prevented a summer count in 2020. This may be an overestimate for Baxter because collared female survival was low at 71% compared to the long-term average for Baxter of 92%. Meanwhile recruitment measures at Baxter were near average. A good count in 2021 would provide useful insight into how this herd is performing.

The second largest herd, Wheeler, declined from 44 to 37 females, but this decline was expected as 6 females were removed for translocation. Additionally, the count at Wheeler was given a poor rating based on the proportion of collared animals seen, indicating animals may have been missed. Wheeler survival and recruitment were either slightly below or about average. Sawmill declined slightly from 38 to 35 females but had slightly higher survival, 93%, compared to the long-term average of 85%. Recruitment measures were near average.

Olancha has continued to grow, reaching 30 females, and is the most successful of the new herds. This is likely due to the fact that it is the southernmost herd with abundant low elevation snow-free habitat even in snowy winters. While recruitment at Olancha tends to be average or slightly lower than other herds, survival tends to be high, as it was this year with 100% collared female survival. High female survival is likely the key to Olancha's growth.

Although Langley was previously a source population and the largest herd in the range for several years, it now has only 17 females, which is the lowest count since 2001. The peak minimum count of 56 females at Langley occurred in 2014. Subsequently in 2015, 10 Langley females were translocated to start the Cathedral herd and 2 were translocated to augment the Gibbs herd. The population appeared to be steady after these removals, with 49 females counted in 2016, but then it experienced an extreme predation event which reduced the population to 26 by 2017. Predation rates decreased after two lions were lethally removed in 2016, but low levels of lion predation are still present in this herd, including the loss of one collared female (S408) in 2020.

Big Arroyo appears to be rebounding from the 2018-19 winter, increasing from 9 to 13 females, although it is also possible that some animals were missed in 2019, as this was considered a poor-quality survey. The low survival of 75% at Big Arroyo is concerning, but with such a small sample size it is hard to know if this is natural stochasticity or a trend. Similarly, although Gibbs had the lowest collared female survival at 67%, there were only 3 collared females at Gibbs this year. Recruitment measures at Gibbs were above average.

There are several herds for which there is limited data or, due to their small size, it is difficult to identify population trends at this time. The Laurel herd persists with 2 females, Cathedral and Taboose each with 4, Convict with 6, and Bubbs with 14. With the help of a recent augmentation, Warren has increased from 1 to 7 females. We also do not know much about the status of Williamson because it has limited collars and was not counted this year (see Appendix A for survey information).

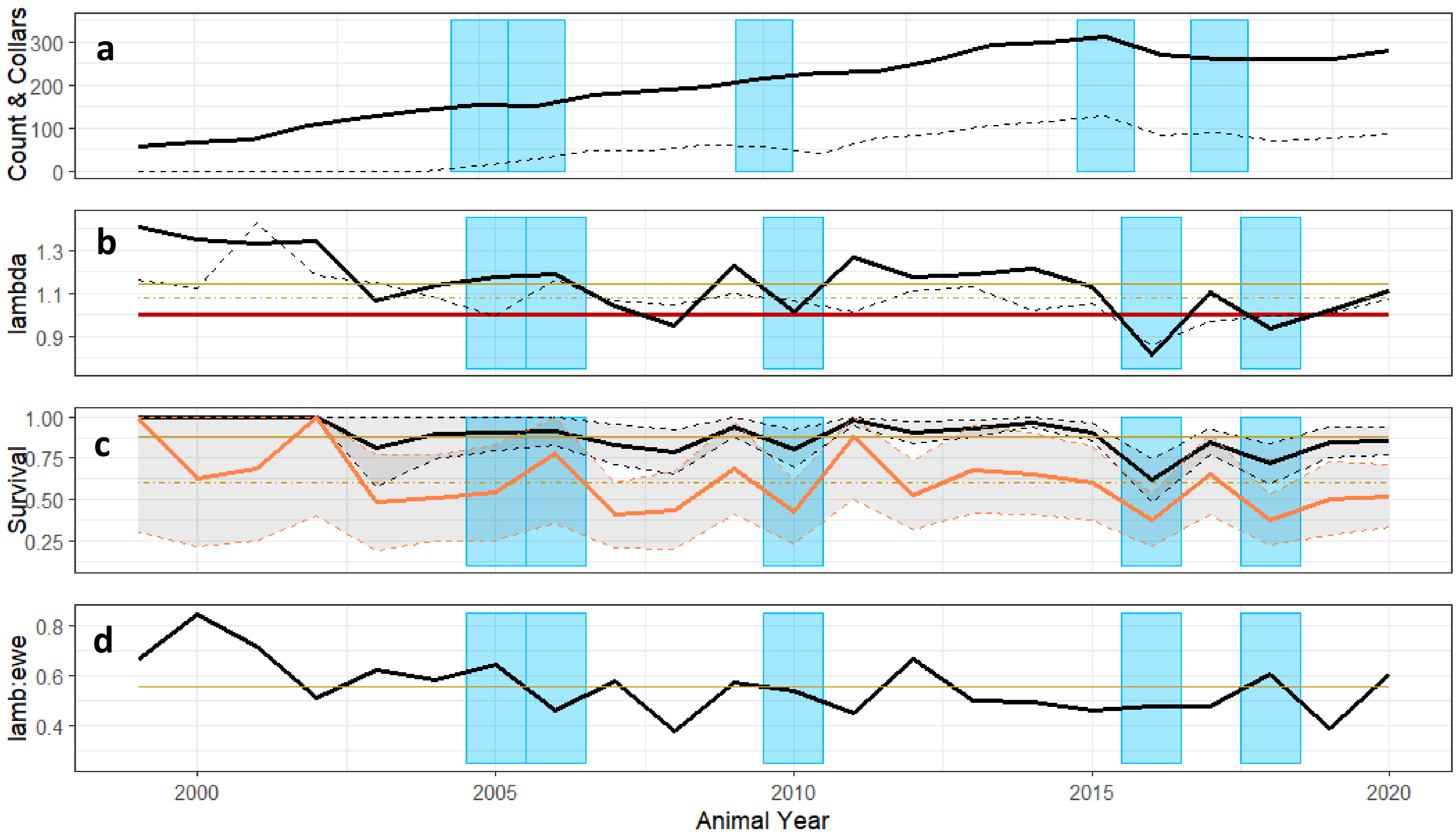

Figure 10. *Long-term and range-wide female Sierra bighorn population estimates and vital rates, 1999-2020; winters with >150% average snow depth are highlighted in blue.*

a) *Total female population estimate (solid line) and number of collared females (dashed line)*

b) *Lambda calculated from eigenvalues derived from vital rates and lambda from minimum counts (dashed line). Averages shown in yellow and dashed yellow respectively. Red line at 1 differentiates growing vs. declining population.*

c) *Adult survival (black line) and lamb to yearling survival (orange line) with 95% confidence intervals. Averages in yellow and dotted yellow respectively.*

d) *Lamb:ewe ratios as a measure of fecundity; long-term average in yellow.*

Range-wide and Long-term Demographic Rates

We focus on female vital rates because Sierra bighorn population growth tends to be driven by female survival (Johnson et al. 2010). This year the population growth rate was slightly below average, but still >1, indicating the population is increasing. Adult survival was average and increased slightly from last year; lamb survival was below average and decreased slightly from last year. In general, lamb survival is lower and more variable than collared female survival. Lamb:ewe ratios were higher than last year and higher than long-term averages indicating good recruitment. In general, vital rates were similar to long-term averages, but survival was lower than what we would expect after two consecutively mild winters (Figure 10).

Cause-Specific Mortality

We detected 19 mortalities in 2020, including 16 collared animals (12 females, Figure 11). Seven collared animals died from lion predation: 5 at Baxter, 1 at Langley, and 1 at Wheeler. Six collared animals died from unknown cause: 3 at Gibbs, 2 at Wheeler, and 1 at Sawmill. Additionally, 1 individual died from rock fall at Gibbs. We also detected 3 uncollared animals at Baxter that were killed by lions and had one capture mortality at Big Arroyo. Four animals were censored after not being detected for two years.

Mortalities in 2020 were similar to what we have detected in other years with mild winters, although with slightly higher predation than the 2011-2015 drought years. In general, collared female mortality was relatively low and not localized, but with notable losses at Baxter and Gibbs. While typically most Sierra bighorn mortality occurs in the winter, this year <10% of all mortalities occurred in the winter, and higher losses were in the spring and fall. In terms of collared females, we detected more predation range-wide than the snowy 2018-19 winter, but less than in the snowy 2016-17 when there was an extreme predation event at Langley. Low to moderate levels of predation on females can limit population growth sufficiently to eliminate the availability of translocation stock (Gammons et al. 2021).

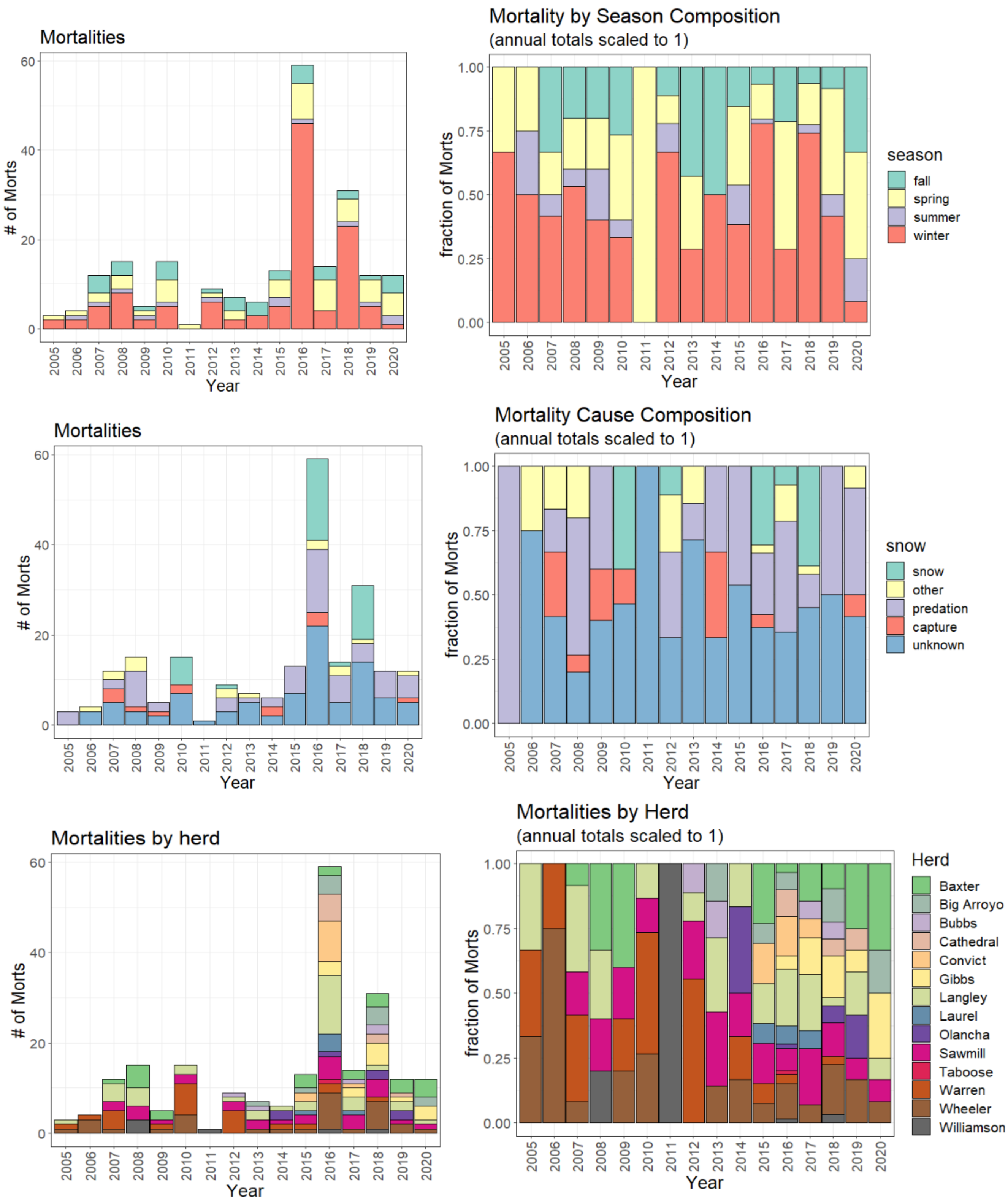

Figure 11. *Collared female Sierra bighorn mortality 2005-2020 by cause of death and herd. The category snow includes death by avalanche and starvation during winter and spring. The number of mortalities (left) is influenced by the number of collared females at a given time which trends with the overall population size. The number of herds has increased with time. This does not include censored animals because their cause and date of death are unknown.*

Sierra Bighorn Movements

Mixing of Sawmill and Taboose bighorn

There is not clear differentiation between the northern Goodale deme of the Sawmill herd and the Taboose herd, with mixed-use from both males and females. Taboose is north and adjacent to Sawmill, and female bighorn were first observed in Taboose by a hiker in 2012 who reported four females near Taboose Pass. We assume these females originated from Sawmill. This year, 2 GPS-collared females from Sawmill (S542, S543), along with 1 collared Taboose female (S578) used Cardinal Mountain, which is technically within the Taboose herd unit (Figure 12). Use of Cardinal Mountain had previously been documented by GPS-collared males in 2015 as well as Taboose females (S411 and S512) in 2015 and 2016. Additionally, "Sawmill" female S543 does not seem to fit in either Taboose or Sawmill; she visited Tinemaha and Birch mountains, traveling as far north as the south fork of Big Pine basin and then traveling as far south as Goodale Plateau and Creek, within the Sawmill herd.

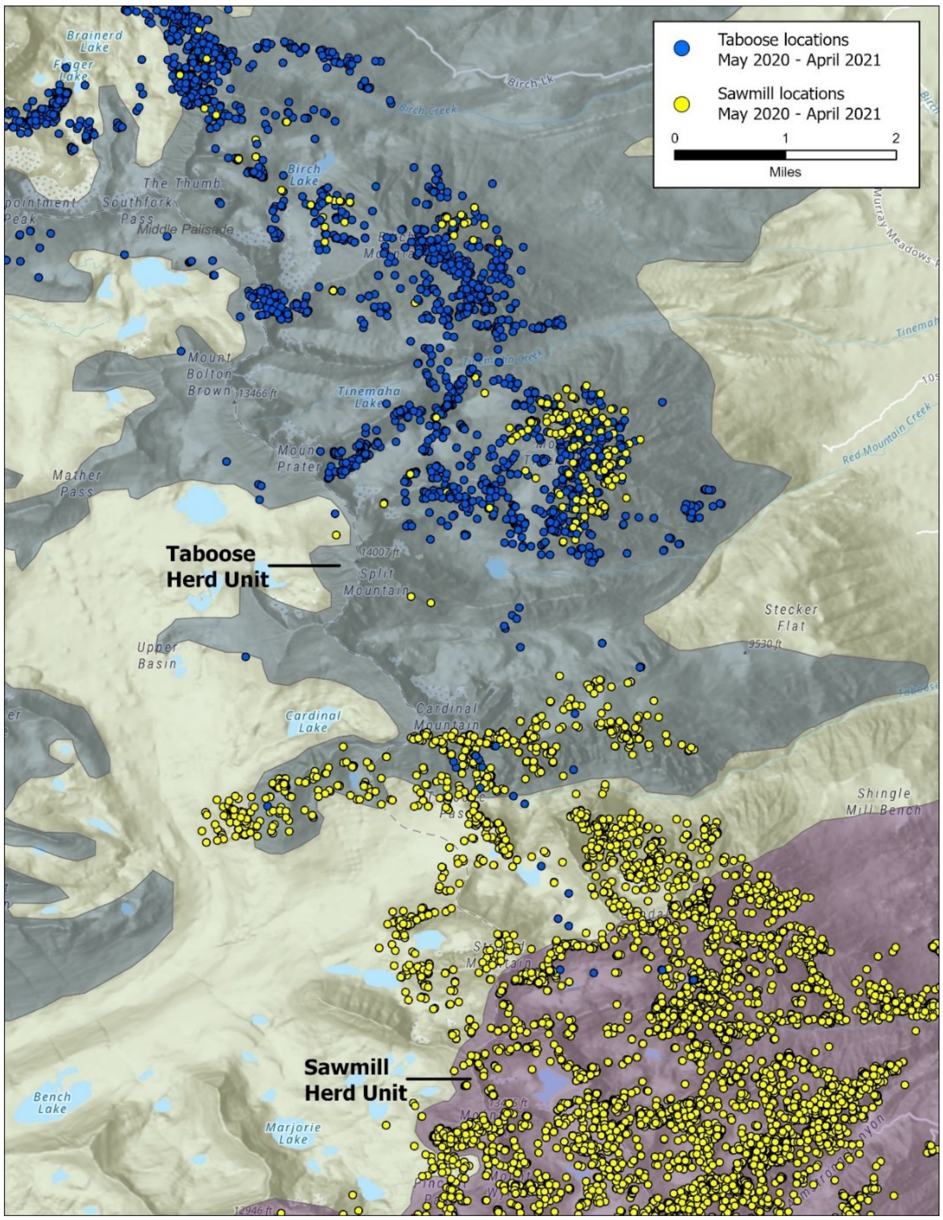

Figure 12. *Females from the Taboose and Sawmill herd units both visited Cardinal Mountain.*

Post Capture Movements at Wheeler

Several animals at Wheeler moved into novel habitat after fall capture (Figure 13). Female S242 was released near Four Gables Peak in an area previously not used by Sierra bighorn. She stayed there for about two months before moving to Seven Gables Lakes and eventually Mt. Hilgard. Male S502 appeared to circumnavigate Seven Gables Peak, and then visited the Seven Gables Lakes, along with four collared animals (S242, S502, S553, S554). By winter these animals returned to previously used habitat within the Wheeler herd.

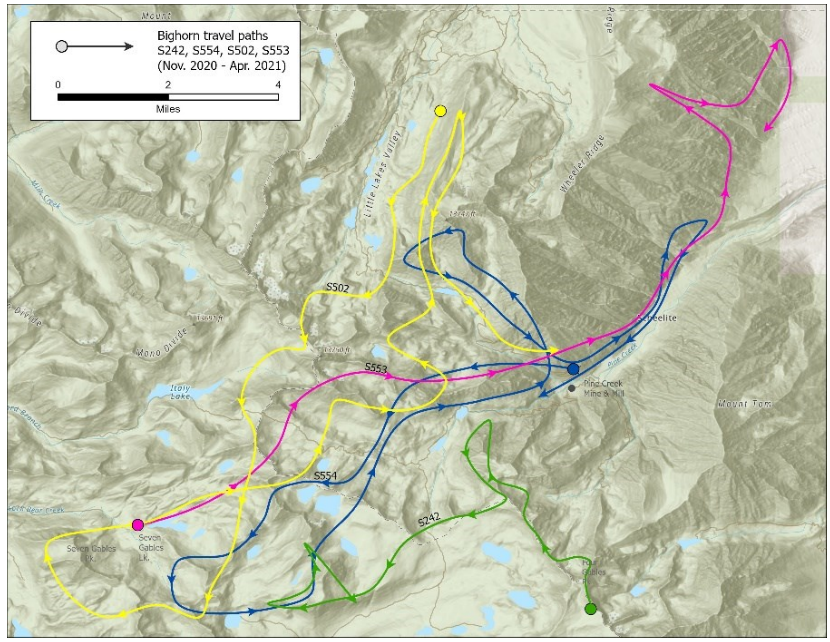

Figure 13. *Post-capture movements at Wheeler in the Granite Park deme.*

Mountain Lion Monitoring and Management

Minimum Counts

We monitor mountain lions throughout the range of Sierra bighorn to understand which herds experience impacts from predation and the degree to which these impacts may hinder recovery. We use all available evidence to create minimum counts of mountain lions in each count zone, following techniques described in McBride et al. (2008, Appendix B). Minimum counts encompass the total number of collared animals, the number of uncollared mortalities documented, and the number of distinct unmarked animals that can be identified. Minimum counts are conducted within four separate count zones: northern, central, southern, and Olancha. We also create a minimum count for mountain lions in the eastern Sierra outside of the count zones, but within the count zones we attempt to count every animal present when possible. Lion minimum counts reported in this section reflect animals counted July 1, 2020 - June 30, 2021.

In the 2020 lion count year we documented a minimum of 54 mountain lions in the eastern Sierra population: 21 adult females, 12 adult males, and 21 subadults. This is the highest lion minimum count our program has ever produced, exceeding last year's high of 50 mountain lions. Ten lions were detected in the northern count zone, 19 in the central, 7 in the southern, and 2 in the Olancha count zone (Figure 14). Twenty-four additional lions were detected in the eastern Sierra population outside of any count zone. Minimum counts summed across zones exceed the total minimum count for the eastern Sierra because individual lions detected in multiple count zones are included in the tally for each zone but are only counted once in the range-wide count of 54 lions. 37 of the 54 lions detected were collared. The 17 uncollared lions were identified by physical evidence including unique markings, unique tracks, photographs, visual observations, and ages and sexes of dependent sub-adults (see Appendix C).

Identifying unmarked individual lions becomes increasingly difficult as the density of unmarked animals rises. In cases where detections of unmarked, indistinguishable lions vastly outnumber detections of marked or uniquely featured lions we infer that our minimum count is likely an underestimate. This was the case in the central count zone in 2019 and triggered an increased survey effort in the 2020 count year, resulting in higher accuracy and an increased count. This effort detected 3 adult mountain lions in the central count zone who were not being tracked with GPS collars: L148 (adult male with failed collar), L225 (uncollared adult female), and L229 (uncollared adult female). These 3 uncollared lions were captured in a subsequent year and identified based on unique markings.

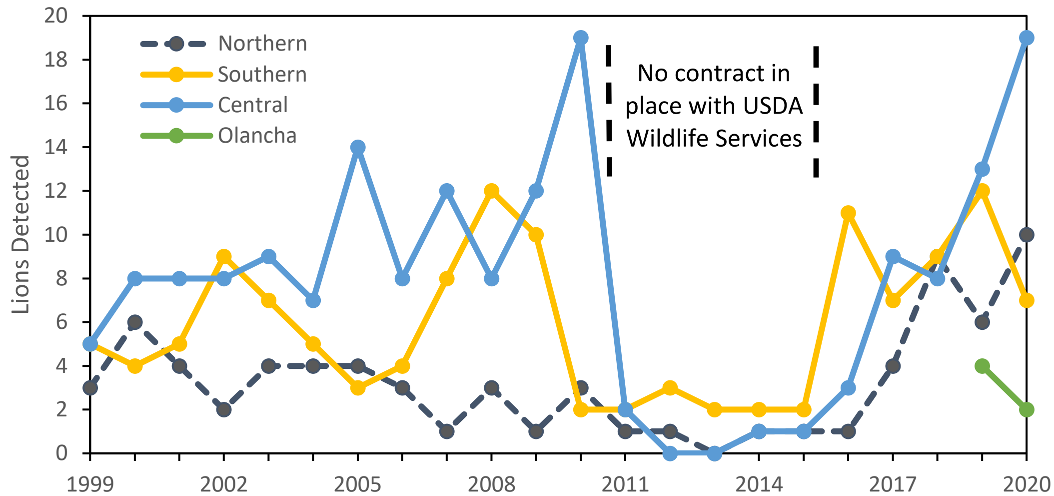

Figure 14. *Minimum counts of mountain lions in eastern Sierra count zones, 1999-2020. Efforts to monitor lions have varied over time.*

Captures

We captured 30 lions, including 19 females (13 adults and 6 subadults) and 12 males (4 adults and 8 subadults), which is significantly higher than the 17 animals captured the previous year and the annual average of 10.1 lions per year from 1999-2017 (excluding 2012-2015 when no captures occurred).

Predation on Sierra Bighorn

We identified a minimum of 10 Sierra bighorn killed by mountain lions in the 2020 sheep year (5 adult females, 4 adult males, and 1 lamb of unknown sex). This is a decrease from the previous year when we documented a minimum of 20 Sierra bighorn killed, but it is a slight increase from the annual average from 1999-2019 of 8.52 (Figure 15). The decrease in detected predation may be due to several factors, including the translocation and subsequent mortality of 2 resident male bighorn-predators, the emigration of 1 subadult male and 1 adult female away from Sawmill/Baxter, and another subadult bighorn-predator being lethally removed on a depredation permit by a citizen in the Sawmill/Baxter area. Alternatively, it is possible that we are simply detecting a smaller proportion of the predation that is occurring due to circumstances of lion collar distribution. In 2019 our ability to detect mountain lion predation on Sierra bighorn in the Baxter herd was almost entirely dependent on identifying GPS clusters indicating feeding sites from collared lions, rather than mortality alerts from collared bighorn or opportunistic investigations. Changes in the mountain lion population due to immigration, mortality, and home range shifting can result in sudden localized increases in lion predation on Sierra bighorn, which may not be detected if the lions responsible are not collared. Additionally, resident lions utilizing areas of rugged terrain are more difficult to detect in camera and track surveys, and once they are detected these individuals may be extremely difficult to capture and collar. Therefore, given that we know collaring lions increases our detection of predation on Sierra bighorn, the lower predation levels reported here should be considered a minimum estimate.

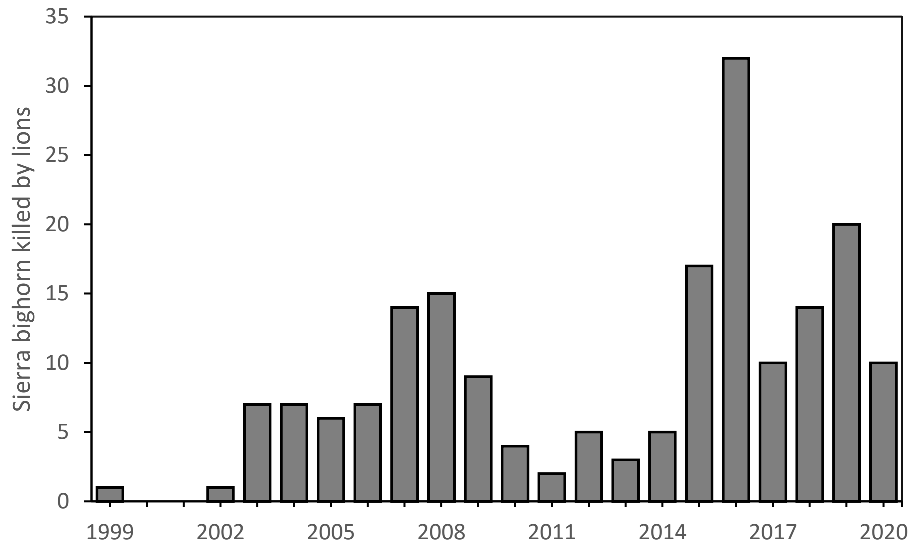

Figure 15. *Sierra bighorn mortalities caused by mountain lions from 1999-2020. Efforts to detect predation events (both in staff hours and collars on lions and bighorn) have varied over time, as has the population size of Sierra bighorn.*

Similar to 2019, mountain lion predation was largely detected in the southern count zone, with 8 of 10 documented predation events occurring in the Sawmill and Baxter herds. The remaining two predation events occurred in the Wheeler herd. A minimum of 3 lions were documented preying on the Sawmill and Baxter bighorn: 2 collared adult males and 1 uncollared adult female. L147 (collared adult male) preyed on one adult ewe in the Sawmill herd, L176 (collared adult male) killed one adult ewe, one adult ram, and one lamb of unknown sex in the Baxter herd, and uncollared lions preyed on 3 adult ewes and one adult ram in the Baxter herd. On 5/8/2021 we collared an adult female lion on the Sawmill/Baxter winter range, L200, who we believe was responsible for some or all of the predation attributed to uncollared lions in the Baxter herd documented this winter. L200 was documented with 2 dependent female subadults, L209 and L210.

Mountain lion predation in the Wheeler herd was detected via collared bighorn mortality signals from two adult rams, who were killed by an unknown lion. Adult male L148 was collared on 3/29/2018 and killed an adult ram in the Wheeler herd on 5/28/2018. Shortly after that, L148's collar failed and his movements and predation on Sierra bighorn were largely undocumented. Our central count zone camera survey detected L148 on 36 separate occasions between 7/1/2020 and 6/30/2021, all near the Wheeler herd unit. Additionally, our intensive Round Valley lion survey detected 2 uncollared adult females (L225 and L229) whose home ranges and predation habits were unknown to us (Appendix C). We suspect that the collared ram mortalities in the Wheeler herd documented this year were the result of predation by 1 or more of the 3 adult lions which were detected in our survey but were not being tracked by GPS collars. At this time, we are focusing our capture and collaring efforts on these animals.

Reproduction

We documented 21 adult females, and 14 of them were confirmed to have at least 1 offspring. Seven of the 14 females with confirmed offspring were documented with at least 2 young, and 1 of the 7 was confirmed with three.

Predation Management – Lion Translocations

Since April 2017 there have been no lethal removals of mountain lions for the protection of Sierra bighorn, but in 2019 we began translocating predating lions as a means of mitigating the impact of predation on vulnerable herds.

L172 was a subadult female mountain lion who was translocated to the Slinkard/Little Antelope Wildlife Area in 2019 after predating sheep (see Greene et al. 2019). L172's ability to survive translocation, establish a home range, and refrain from further predation of Sierra bighorn demonstrated the viability of translocation as an alternative to lethal removal of mountain lions for the protection of Sierra bighorn.

In January 2021 we captured L147 and translocated him away from the Sawmill herd after he killed an adult ewe. L147 was released at the Slinkard/Little Antelope Wildlife Area approximately 130 air-miles north of his former home range (Figure 17). L147's movements following his release on 1/18/2021 showed typical homing behavior, as he headed south in a direct line towards his former home range. On 2/25/2021 he was captured again near Bishop, CA, approximately 107 air-miles south of his release site and only 24 miles from where he was captured on 1/17/2021. It was deemed that a mountain lion translocation to the south of I-15 in the Mojave Desert may provide valuable data that could inform the placement of wildlife crossing corridors, and on February 26, L147 was released in the Mescal Range approximately 210 miles southeast of Bishop Creek where he was captured. After release in the Mescal Range L147 again showed typical homing behavior, traveling in a straight line northwest towards his former home range. Subsequently, adult male L176 was captured on the Sawmill winter range in March, after preying on 3 Sierra bighorn in the Baxter herd, and he was translocated to the Mescal Range as well, where he was released on 3/27/2021 (Figure 18).

The decision to release L147 and L176 in the Mescal Range was primarily motivated by interest in gathering data on wildlife corridors crossing I-15, and more important and practical factors which should influence mountain lion release sites, such as prey availability and habitat familiarity, received less consideration. Consequently, both L147 and L176 struggled to find prey in an unfamiliar environment. L147 was found dead on 3/29/2021 in an emaciated condition, suggesting starvation as the cause of mortality. L176 also exhibited homing behavior and was recaptured on the China Lake Naval Air Weapons Station on 5/5/2021 (Figure 18). L176 was in an extremely emaciated condition and had to be euthanized on 5/12/2021 after being translocated again to the San Bernardino National Forest. Both L147 and L176 used separate underpasses to cross I-15, demonstrating the importance of wildlife crossing corridors on major roadways.

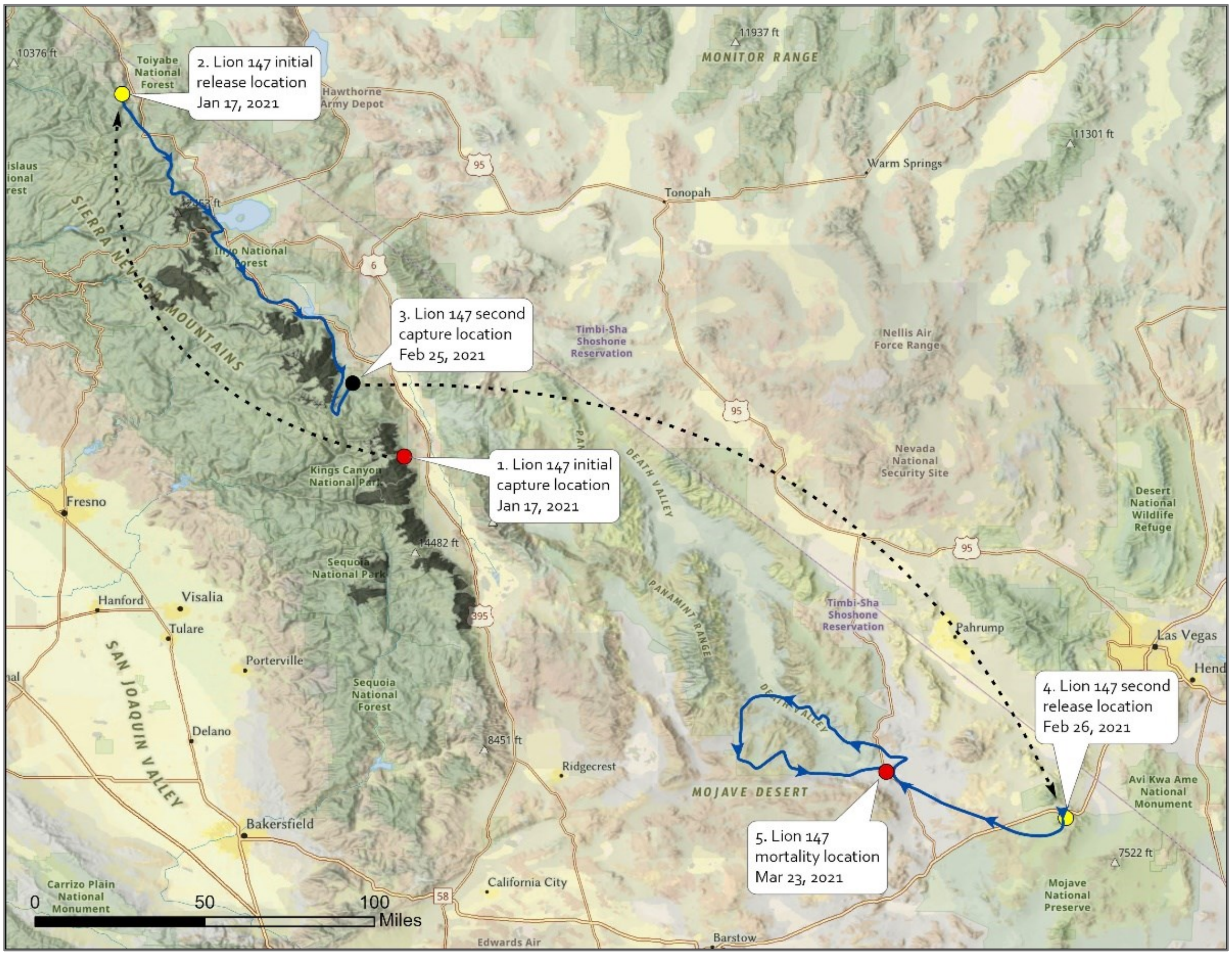

__Figure 17.__ Adult male lion L147's movements following translocation out of Sierra bighorn habitat.

L168 and her two 6-month-old subadults, L198 and L199, were captured at Oak Creek on the Baxter winter range and translocated as a group 4/3/2021 to the Slinkard/Little Antelope Wildlife Area, approximately 140 air-miles north of their capture site. L168 was a resident female who overlapped with Sierra bighorn in the Sawmill, Baxter, and Williamson herds and had preyed on at least 1 bighorn. She was also suspected of raising previous bighorn-predating lions. On 5/28/2021, L198 and L199 were observed with their mother near a kill-site on the Walker River, demonstrating that family group cohesion had been maintained after translocation. Unfortunately, on 6/14/2021, L168 was killed by a vehicle collision on CA-395 near Sonora Junction. L198 and L199 were too small to be safely fitted with tracking collars so their fates remain unknown. CA-395 bisected L168's former home range, and in fact that section of the freeway is 4-lanes and more heavily trafficked than the section on which she was killed. While the translocation of L168 may have played a role in her mortality, CA-395 represents the largest single source of mortality for all mountain lions in the eastern Sierra, and that risk was present in her former home range as well as her new one. Concentration of major roadways is a factor that should be considered in mountain lion release-site selection, but there are no places in California that offer complete safety from this anthropogenic source of mortality.

Figure 18. *Adult male lion L176's movements following translocation out of Sierra bighorn habitat.*

The unfortunate outcome of the translocation of the 2 adult males highlights two important factors that must be considered in future mountain lion translocations: 1) homing behavior in adult males, and 2) prey availability in release locations. The reproductive biology of male mountain lions dictates that they defend a group of females within their home range from the advances of other males, thereby creating a region in which their genes may be propagated. Males removed from their home ranges are compelled by instinct to return. Perhaps even more critical for consideration is prey availability, as even subadults or females who are not motivated by homing behavior will be compelled to leave an area that does not offer sufficient prey to sustain them. These lessons are currently being applied and are yielding better outcomes in lion translocations that have occurred since the time period of this report.

Lion Survival and Mortality

The estimated annual survival rate for the 37 collared lions was 0.80 for females (±0.13 SE) and 0.56 for males (±0.29 SE), both of which are slightly lower than the 1999-2017 annual average of 0.83 (±0.16 SE) and 0.68 (±0.30 SE) for females and males, respectively. Surprisingly, of 10 subadults monitored we documented only one mortality in the 2020 year resulting in an annual survival rate of 0.86 (±0.15 SE). The prior year's survival rate was 0.35, a more typical rate for subadult mountain lions. Among the 54 lions detected in the eastern Sierra this year we documented 10 mortalities, due to depredation (n=3), predation by other mountain lions (n=2), legal Nevada harvest (n=1), vehicle collision (n=1), starvation (n=1), physical injury (n=1), and unknown cause (n=1).

Disease Management

Recent bighorn die-offs throughout the west have been associated with the bacterium *Mycoplasma ovipneumoniae* (*M. ovi*), and it is thought that respiratory disease likely drove earlier declines in the distribution and abundance in Sierra bighorn (Wehausen et al. 2011). Fortunately, *M. ovi* has not been detected in the Sierra Nevada based on testing beginning in 2001, and we have observed no clinical signs of respiratory disease, such as coughing or lung lesions, since monitoring began in 1974. In 2020, the Sierra Nevada Bighorn Sheep Foundation worked successfully with the De La Cour Ranch outside of Lone Pine, California to remove domestic sheep adjacent to Langley winter range (Sierra Nevada Bighorn Sheep Foundation Newsletter, December 2020).

Future Management

Sierra bighorn population dynamics appear to be largely driven by adult female survival (Johnson et al. 2010), and over the last twenty years, the top two causes of mortality are predation by mountain lions and snow-related death in the form of starvation and avalanche. Reaching recovery requires continual monitoring and persistent management. We must be flexible in adapting our management as needed given the high variability in factors driving population change. We cannot prevent heavy snow, but we can manage predation to ensure high survival and the availability of translocation stock. Augmenting herds until they reach optimal sizes will enhance their viability as migratory patterns are restored, habitat selection is optimized, and vigilance towards predation improves demographic rates. Typical levels of predation in many herds continues to stall population growth in multiple source herds and will hamper translocation efforts (Gammons et al. 2021). Gammons et al. (2021) also noted that management actions to reduce lion predation likely will be needed to ensure the availability of translocation stock and to meet recovery goals.

A changing food web has the potential to alter predator-prey dynamics in the eastern Sierra. During February 2021 a GPS-collared wolf traveled from northern California into Mono County. The wolf spent about 2 weeks in Mono County before crossing over the Sierra Nevada and heading toward the coast. The colonization of northern California by wolves allows for the possibility of wolf recolonization in the eastern Sierra in the coming years. The presence of wolves would alter trophic relationships among predators and prey in and adjacent to the Recovery Area. Mule deer populations in the eastern Sierra are currently declining. The addition of wolves into a system with mountain lions and black bears would likely reduce the deer populations further. The reduction in deer prey, along with direct killing by wolves, would then reduce the lion population. Under such a scenario, Sierra bighorn could experience reduced predation by lions. They would be less likely to be preyed upon by wolves given the abundance of escape terrain. Thus, the return of wolves may more closely represent historical conditions in the Sierra Nevada that favored Sierra bighorn over mule deer.

Johnson et al. (2013) identified apparent competition as a factor contributing to predation on Sierra bighorn, whereby larger deer populations support lion populations that also prey on Sierra bighorn. As multiple predators and other factors reduce the deer population in the eastern Sierra, lion numbers may decline and pose less of a threat to Sierra bighorn. Until that happens, we need to prevent lion predation from hampering recovery.

Acknowledgements

Numerous personnel contributed to recovery efforts and data collection this year. Recovery Program staff included: Todd Calfee, Vicki Davis, Jeff Davis, Jackie Leary, Sonya Maple, Bradyn O'Connor, Elsbeth Otto, Ben Regan, and Elizabeth Siemion. Additional CDFW staff included: Michael Brown, Marisa Christopher, Justin Dellinger, Shannon Fusaro, Lily Harrison, Brian Hatfield, Rick Ianniello, Emma Lantz, Art Lawrence, Mike Morrison, Julia Runcie, Nicholas Shirkey, Dan Taylor, and Jon Weissman. Sierra Nevada Bighorn Sheep Foundation volunteers included: John Wehausen, Virginia Chadwick, and Julie Rolfe. In addition, helicopter pilot Jim Pope and fixed-wing pilot Geoff Pope provided many hours of safe flying. Additional collaborators include: Sarah Stock (Yosemite National Park), Tyler Coleman (SEKI National Park), Mary Conner (Utah State University), Kristin Denryter (University of Wyoming), Kevin Monteith (University of Wyoming, Erin Nordin (USFWS), Marcy Haworth (USFWS), Sherri Lisius (BLM), Sheena Waters (BLM), and Kary Schlick (USFS).

The recovery effort is funded primarily by the California Department of Fish and Wildlife. Funding was also provided by Federal Aid in Wildlife Restoration Grants, the Yosemite Conservancy, and the Sierra Nevada Bighorn Sheep Foundation. 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 Sierra Nevada Bighorn Sheep Foundation also contributed significantly to field monitoring efforts and provided all genetic analyses used for monitoring and translocation decisions.

Correction:

Annual Report 2019 claimed a rangewide total of 249 females, but this should be corrected to 258. Specifically, 5 females were counted in Bubbs in 2019, but as there are no collars in Bubbs, and mortality range-wide is low, it is assumed animals were missed and this count was low. Instead, an estimate of 14 females should be used which aligns with counts from 2007, 2013, and 2020, and is likely more accurate.

Literature Citation Should Read as Follows:

Greene, L. E., P. Johnston, C. P. Massing, D. W. German, K. Anderson, and T. R. Stephenson. 2021. Sierra Nevada Bighorn Sheep Recovery Program Annual Report 2020-21.

This report is available at: https://wildlife.ca.gov/Conservation/Mammals/Bighorn-Sheep/Sierra-Nevada/Recovery-Program/Literature. Data and summaries in this report are preliminary and are subject to change contingent upon further interpretation, analyses, and review.

Literature Cited *(Includes citations in Appendices)*

Bleich, V. C., J. D. Wehausen, K. R. Jones, and R. A. Weaver. 1990. Status of bighorn sheep in California, 1989 and translocations from 1971 through 1989. Desert Bighorn Council Transactions.

Buchalski, M. R., B. N. Sacks, D. A. Gille, M. C. T. Penedo, H. B. Ernest, S. A. Morrison, and W. M. Boyce. 2016. Phylogeographic and population genetic structure of bighorn sheep (*Ovis canadensis*) in North American deserts. Journal of Mammalogy 97:823-838.

Cahn, M. L., M. M. Conner, O. J. Schmitz, T. R. Stephenson, J. D. Wehausen, and H. E. Johnson. 2011. Disease, population viability, and recovery of endangered Sierra Nevada bighorn sheep. Journal of Wildlife Management 75:1753–1766.

California Department of Water Resources. 2021. Water Year 2021: An Extreme Year.

Conner, M. M., T. R. Stephenson, D. W. German, K. L. Monteith, A. P. Few, and E. H. Bair. 2018. Survival analysis: Informing recovery of Sierra Nevada bighorn sheep. Journal of Wildlife Management 82:1442–1458.

Cougar Management Guidelines Working Group. 2005. Cougar Management Guidelines. WildFutures.

Gammons, D. J., J. L. Davis, D. W. German, K. Denryter, J. D. Wehausen, and T. R. Stephenson. 2021. Predation impedes recovery of Sierra Nevada bighorn sheep. California Fish and Wildlife Journal 444–470.

German, D. 2010. Sample sizes for estimation of population size, recruitment, and adult female survival of Sierra Nevada bighorn sheep. California Department of Fish and Wildlife Memo.

Greene, L. E., P. Johnston, D. J. Gammons, C. P. Massing, D. W. German, K. Anderson, and T. R. Stephenson. 2020. Sierra Nevada Bighorn Sheep Recovery Program Annual Report 2019-20.

Greene, L. E., C. P. Massing, D. W. German, D. Gammons, K. Anderson, E. A. Siemion, and T. R. Stephenson. 2019. 2018-19 Annual Report: Sierra Nevada Bighorn Sheep Recovery Program.

Greene, L. E., C. P. Massing, D. W. German, A. C. Sturgill, K. Anderson, E. A. Siemion, J. Davis, D. Gammons, and T. R. Stephenson. 2017. 2016-17 Annual Report: Sierra Nevada Bighorn Sheep Recovery Program.

Johnson, H. E. 2010. Escaping the Extinction Vortex: Identifying factors affecting population performance and recovery in endangered Sierra Nevada Bighorn Sheep. University of Montana.

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.

Johnson, H. E., M. Hebblewhite, T. R. Stephenson, D. W. German, B. M. Pierce, and V. C. Bleich. 2013. Evaluating apparent competition in limiting the recovery of an endangered ungulate. Oecologia 171:295–307.

Keeley, J. E., and A. D. Syphard. 2021. Large California wildfires: 2020 fires in historical context. Fire Ecology 17. Fire Ecology.

McClintock, B. T., G. C. White, M. F. Antolin, and D. W. Tripp. 2009. Estimating abundance using mark-resight when sampling is with replacement or the number of marked individuals is unknown. Biometrics 65:237–246.

Schroeder, C. A., R. T. Bowyer, V. C. Bleich, and T. R. Stephenson. 2010. Sexual segregation in Sierra Nevada bighorn sheep, *Ovis canadensis sierrae*: Ramifications for conservation. Arctic, Antarctic, and Alpine Research 42:476–489.

Sierra Nevada Bighorn Sheep Foundation Newsletter, December 2020. 2020.

U.S. Fish and Wildlife Service. 2007. Recovery Plan for the Sierra Nevada Bighorn Sheep. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=27634 215.

Valdez, R., and P. R. Krausman, editors. 1999. Mountain Sheep of North America. University of Arizona, Tucson.

Wehausen, J. D. 1980. Sierra Nevada bighorn sheep: History and population ecology. University of Michigan.

Wehausen, J. D., V. C. Bleich, and R. R. Ramey II. 2005. Correct nomenclature for Sierra Nevada bighorn sheep. California Department of Fish and Game 91:216–218.

Wehausen, J. D., and R. R. Ramey II. 2000. Cranial morphometric and evolutionary relationship in the northern range of *Ovis canadensis*. Journal of Mammalogy 81:145–161.

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

White, G. C., A. F. Reeve, F. G. Lindzey, and K. P. Burnham. 1996. Estimation of mule deer winter mortality from age ratios. The Journal of Wildlife Management 60:37–44.

Appendix A. Herd Unit Summaries

Olancha

Olancha was not surveyed in the summer due to smoky conditions created by various large wildfires throughout California. In the fall, 8 animals were captured including 4 females (1 yearling) and 4 males. This included recaptures of 1 male (S210) who was relieved of a tight VHF collar, and 2 females (S271 and S494). All 15 collared animals (10 females, 5 males) were seen in a survey on January 20-21. This resulted in the highest minimum count for Olancha to date of 24 adult females, 5 yearling females, 1 female of unclassified age, 16 lambs, 10 adult males, and 2 yearling males. No mortalities were detected. GPS collar data shows Olancha animals predominantly using Olancha Peak, Falls Canyon, Olancha Canyon, and several smaller gullies north of Olancha Canyon. Few novel movements or areas of use were detected from GPS collars, but 2 males did make a brief foray into frontage hills south of Walker Creek at 5,200 feet in March 2021.

Laurel

Two females (S382) and two lambs were observed on May 30, 2020 and may compose the entire Laurel herd. The presence of lambs also indicates that a male was present during the rut, although none were seen. The lambs could have been sired by male S352 before he died in December 2019, or there may be an uncollared male in Laurel. The group was located on the east side of the Kern River above Funston meadow. It was intended that Laurel sheep would stay in the general vicinity of Laurel Creek (west side of Kern River) but none of them have settled into that area exclusively. No mortalities were detected. Since reintroduction in 2014 of 7 females and 4 males, this population has generally been declining.

Big Arroyo

Big Arroyo animals were seen throughout the summer resulting in a minimum count of 12 adult females, 1 yearling female, 7 lambs and 8 adult males. All collared animals were seen (4 females, 2 males). This could indicate that the 2019 count of 9 females was an underestimate, or that Big Arroyo is rebounding well from the snowy winter of 2018-19. Female S287 was found dead in the summer from unknown cause (not included in count) and one yearling female (S581) died during capture in the fall after the count. Three previously uncollared females were caught and given new collars during fall capture. GPS collar data indicates limited use of high elevation summer habitat from Black Kaweah to Red Spur and extensive use of lower elevation habitat along the Big Arroyo and Kern River (west side only) year-round.

Langley

Langley bighorn were observed throughout the summer. The best survey occurred August 12-13 when we accounted for 36 animals: 15 adult females, 2 yearling females, 8 lambs, 10 adult males, and 1 yearling male. We detected 2 mortalities: female S408 on Lone Pine Peak from mountain lion predation prior to the survey, and an old uncollared male M187 near Iridescent Lake whose timing and cause of death could not be determined. There are no functional GPS collars in Langley this year. Captures have not occurred since 2017 when the population began declining. No novel habitat use was detected from flights or ground observations.

Williamson

Due to wildfires and smoke limiting our summer survey opportunities, we did not perform a summer Williamson survey. Three animals, including 2 females and 1 male, were captured in the fall. During capture efforts at least 2 adult females, 1 lamb and 3 adult males, were detected. However, we assume our 2019 count of 14 adult females, 4 lambs, and 5 adult males is a better representation of bighorn present in Williamson than this small count. Female S166 was censored at the beginning of the year; she had previously made movements between Williamson and Baxter (Greene et al. 2017). This was the second time she had been censored because previously two years had passed without any detection of her. Both collared females appear to be in the southern Barnard 'deme' within Williamson but also used lower elevation habitat in Williamson, Bairs, George, and Hogback creeks. No particularly novel habitat use was detected with GPS collars this year.

Baxter

There was no comprehensive summer survey due to smoky conditions. The winter minimum count at Baxter was 81 animals: 31 adult females, 5 yearling females, 14 lambs, 27 adult males, and 4 yearling males. This winter count is known to be low and inaccurate, so we will use the 2019 count as the best estimate for 2020.

In the fall, 7 females were captured including 3 new captures and 4 recaptures. One of the newly collared animals (S545) died 11 days after capture, but the cause of death was determined to be mountain lion predation and did not seem to be related to capture. In the spring, 5 animals were captured including 4 females (1 recapture) and 1 male. Camera collars were deployed on 3 animals to determine if they could be used to detect lambing events and possibly lamb predation.

We detected 7 lion predation mortalities: 3 from lion clusters, 3 from collared sheep, and 1 opportunistically. One female was censored (S140). After the fall capture, a group of 10 uncollared individuals (5 females, 2 lambs, 3 males) was seen on the east side of Mt. Gould. Additionally, GPS data showed that S228 traveled south around Dragon Lake and Peak.

Sawmill Canyon

In the spring we tried to detect young lambs based on GPS clusters. Our first lamb was detected May 28 above Sawmill Lake and then two additional lambs were seen on Colosseum Mountain on May 29. No additional detections were made until our survey July 19-24. It frequently can take two tries to get a good Sawmill survey, but this year we were successful on the first try, accounting for 33 adult females, 2 yearling females, 17 lambs, 6 adult males, and 1 yearling male. Most (13/15) collared females were seen, but neither of the 2 collared males were seen. Prior to the survey, we detected a single female mortality from unknown cause (S511). GPS collar data showed summer use by females of both Taboose (S542 and S512) and Sawmill (S543) on Cardinal Mountain. The Goodale deme of Sawmill and the Taboose herd sometimes mix and overlap in this area.

Bubbs Creek

Despite having no collars, there was a great minimum count July 15-17, including 12 adult females, 2 yearling females, 8 lambs, 14 adult males, and 3 yearling males for a total of 39 animals. This is a large increase from our last count of 5 females in 2018, and similar to counts of 14 females in 2007 and 2013. The highest count at Bubbs was 17 females in 2008. The 2020 count indicates animals were missed in 2018. We try to capture animals in this herd to help with monitoring, but with no collars as lead-ins it has been very challenging. This fall, however, we thought we had successfully captured a Bubbs male (S563), but after collaring he predominantly used habitat within Baxter, mostly east of the crest, before he died the following spring from mountain lion predation.

Taboose

On May 5 we observed 4 adult females, 2 lambs, and 2 unclassified yearlings. This included both female collars in the herd (S412, S512), and it is possible that more lambs could have been born after this observation. In the fall we captured an uncollared female (S578). This new collar along with S512 showed the majority of the area used by these animals was east of the crest, with a foray to Middle Palisade. Female S578 also visited Cardinal and Goodale mountains, mixing with the Goodale deme of Sawmill in the fall.

Wheeler

The highest minimum count at Wheeler occurred from September 1-3 of 65 animals: 32 adult females, 5 yearling females, 14 lambs, 11 adult males, and 3 yearling males. Only 4 out of 9 collared females were seen. This is the third year with a poor count at Wheeler and likely an underestimate. In the fall, 17 animals were captured including 11 females and 6 males, as well as 3 recaptures (female S242, S468 and male S350). The new collars are distributed throughout the Wheeler herd and will hopefully improve counts. We detected 3 mortalities including 2 from mountain lion predation (male S549 and female S547) and one from unknown cause (male S551). This male (S551) was captured on October 17 as a lamb, and due to his young age only given a VHF collar. After capture he was not detected until a flight in November heard him on mortality. Based on a field investigation, he was determined to have died before November 8, because snowfall on November 8 buried the carcass. Although he had been fed on by a bobcat, it was not clear if the bobcat had killed him, and it is also not clear how soon after capture he may have died, so we were unable to identify the cause of death. Post-capture, there was some novel habitat use including recaptured female S242 at Four Gables Peak and females S553 and S554 near V lake in Bear Creek as well as Merriam and Royce Peaks.

Convict

Through a compilation of observations from June - November, we determined there were at least 6 adult females, 4 lambs, 4 adult males, and 2 yearling males. Most collared animals (5 females, 2 males) were seen except 1 female that was presumed alive. In the fall, 4 animals were captured, including 3 females and 1 male. No mortalities were detected. GPS collars indicated no unique movements, and Convict animals continued to cross to the north side of McGee Creek.

Gibbs

During July 6-8, we accounted for 52 individuals including 19 adult females, 2 yearling females, 14 lambs, 16 adult males, and 1 yearling male. This included all collared animals (3 males and 7 females). We documented 3 mortalities in Gibbs, female S521 died from rockfall in July, and females S485, and S565 died from unknown cause in November. In the fall, 7 animals were captured including 5 females (2 recaptures) and 2 males. No unusual or unique movements were detected. Gibbs male S487 visited the Cathedral herd unit as he had done in the past.

Warren

Based on observations in June and July, we documented 7 adult females (all collared), 5 lambs, 2 adult males, and 1 unclassified animal. The one resident female (S522) was seen with a lamb. The additional 4 lambs were associated with newly introduced animals. In March 2020, 5 of the 6 introduced females were pregnant when they were captured and translocated. No mortalities were detected. GPS collars indicated use on Shepherd's Crest, but no unusual movements or habitat use was detected. No bighorn use around Camiaca Peak was detected.

Cathedral

Based on a single observation in June from Parson's Plateau, we counted 2 adult females, 1 lamb, and 1 adult male. This included the 1 collared female in Cathedral (S365). The lamb was associated with the uncollared female. GPS-collared Gibbs male S487 spent most of the winter in the Cathedral herd unit. There were no further observations at Cathedral.

Appendix B: Background and Methods

BACKGROUND

Sierra Nevada bighorn sheep (*Ovis canadensis sierrae*) are a unique subspecies native to the Sierra Nevada in California (Grinnell 1912, Wehausen and Ramey II 2000, Wehausen et al. 2005). They have distinctly wide splayed horns and have been genetically isolated from other bighorn sheep subspecies for roughly 100-300,0000 years (Buchalski et al. 2016). Conservation management has included hunting regulations beginning in 1878, as well as a series of translocations beginning in 1979 (Bleich et al. 1990). The early translocations established the Warren, Wheeler, and Langley herds, and also unintentionally created Gibbs (Figure 2). Despite these efforts, the range-wide population was estimated to be only ~100 individuals in 1995 (U.S. Fish and Wildlife Service 2007).

In 1999, Sierra bighorn were placed on the federal endangered species list and the California Department of Fish and Wildlife was selected to be the lead agency in the implementation of recovery efforts. Many bighorn die-offs throughout the west have been associated with the bacterium *Mycoplasma ovipneumoniae* (*M. ovi*), and it is thought that respiratory disease likely drove earlier declines in the distribution and abundance of Sierra bighorn (Wehausen et al. 2011). Fortunately, we have observed no clinical signs of respiratory disease, such as coughing or lung lesions, since Sierra bighorn monitoring began in 1974. Additionally, testing for *M. ovi* in captured animals began in 2001, and *M. ovi* has not been detected. Sierra bighorn population dynamics appear to be largely driven by adult female survival (Johnson 2010), and over the last twenty years, the top two causes of mortality are predation by mountain lion (*Puma concolor*) and snow-related death in the form of starvation or avalanche.

The Recovery Program monitors Sierra bighorn abundance, demography, and habitat use to inform management decisions regarding translocation, predator management, and disease risk. We monitor mountain lion abundance, demography, and habitat use because they are the main predator and largest known cause of mortality for Sierra bighorn. Monitoring of Sierra bighorn and lions requires the capture and collaring of animals, ground counts, and the investigation of mortalities and mountain lion kills. Our two main conservation activities are translocation and predator management. Additionally, we work to reduce the potential for disease transmission between Sierra bighorn and domestic sheep, and we promote bighorn recovery through public outreach. We also support and direct academic research.

For brevity we refer to herd units using single word names, for example ‘Olancha’ for the Olancha Peak herd unit. We refer to Sierra Nevada bighorn sheep as ‘bighorn’ or ‘Sierra bighorn’ and mountain lions as ‘lions’. Each animal ID number has a prefix: “S” for collared Sierra bighorn, “M” for uncollared Sierra bighorn, and “L” for mountain lions. For bighorn, we use ‘2020’ to represent the animal year May 1, 2020 - April 30, 2021, beginning with lambing season and including the winter of 2020-21. For lions, the 2020 year is from July 1, 2020 - June 30, 2021. Climatologists refer to the water year 2021 as October 1, 2020 - September 30, 2021, which is most clearly associated with bighorn year 2020. “Source” herds (Wheeler, Sawmill, Baxter, and Langley) have contributed to recent reintroductions (starting in 2013) that have supplied animals for “new” herds (Cathedral, Big Arroyo, Laurel, and Olancha).

METHODS

Sierra Bighorn Population Estimation

Although minimum counts are not technically a statistical estimation with confidence intervals, we consider them an “estimate” of the population size. Without confidence intervals it is not possible to know if a low count is indicative of a shrinking population or simply a bad or incomplete count. For this reason, we also developed our own metric of minimum count quality based on the proportion of females that have marks and the proportion of marks seen. “Census” minimum counts are where we think, based on the previous year’s count and our familiarity with the herd, as well as known mortalities and recruitment, that we have accounted for every female and lamb in the herd. “Good” minimum counts have at least 20% of females collared and at least 80% of collared females seen. “Poor” minimum counts either have <20% of females collared or <80% of collared females seen during the survey. It is possible that a poor survey may be accurate, particularly in the case of a herd with few marks but in which all of the animals were seen. However, these categories allow us to be more confident that a population trend is real if the minimum counts are consistently at the “census” or “good” level.

Minimum counts are “reconstructed” to include animals that were not seen during the survey but subsequently determined to have been present based on additional information. All reconstructions are carefully tracked. The most common way minimum counts are reconstructed is to add collared individuals known to be alive but not seen during the survey. A collared animal is censored after two years without visual, GPS collar, or radio telemetry observation; censor date is one month after the last detection. In addition, for herds with near census counts, a count from a given year can often indicate that there must have been more animals present in the previous year than were counted. In this case, additional animals may be added to a previous year’s count. Even with reconstructions, minimum counts tend to underestimate true abundance, particularly in herds with >20 individuals, as it becomes more difficult to locate every individual.

Mark-resight (MR) estimates were calculated for females using Bowden’s estimator (McClintock et al. 2009). Within a season, we evaluated each survey individually and also considered combining multiple surveys to identify the MR estimate with the lowest CV. We only report MR estimates with a coefficient of variation (CV) < 0.15.

Our range-wide abundance represents our best estimate of female population size (Figure 3) and is compiled from herd unit survey data. However, these range-wide counts are somewhat confounded by seasonal differences in herd surveys. To prevent double-counting translocated animals, we only include translocated animals in summer counts of receiving herds and remove them from winter counts of source herds. Wheeler and Baxter tend to be surveyed after most winter mortality has occurred, but before lambing. Therefore, the total female count for these herds includes winter impacts on adult and yearling survival but does not include the addition of recruiting lambs or their survival (lamb to yearling). Most other herds are surveyed in summer, prior to any winter mortality. For these herds, the total count of females does not include the impact of winter. Because of this, more complex vital rate analyses based on count data requires separating the data based on survey timing, or alternatively, focusing on data not associated with count data, such as collar survival (e.g., Conner et al. 2018).

We generally estimate that there are 2 males for every 3 females based on past counts in the Sierra Nevada (Wehausen 1980) and various studies on bighorn sheep (e.g., Valdez and Krausman 1999). We believe this ratio is more accurate than our male minimum count because we have so few males collared, and survey effort is focused on finding females. Our collaring efforts focus on females because they tend to drive population dynamics, but we have enough males collared to know that male survival tends to be lower than female survival (Conner et al. 2018). Our more recent ground counts target female home ranges and therefore produce low counts of males because males tend to use different habitat (Schroeder et al. 2010).

Sierra Bighorn Survival Estimation

We estimate herd-specific annual survival rates using the Kaplan Meier staggered-entry estimator (Pollock et al. 1989). Survival rates are based on collared individuals and only use herds with >3 collars. Survival estimates from herds with few collars may show large changes that do not necessarily reflect the underlying population, as well as higher levels of uncertainty caused by stochastic variation among collared animals, rather than correctly representing survival of the underlying population.

Sierra Bighorn Lamb Survival

We estimate lamb survival using the age ratio approach (White et al. 1996). We modified this approach using Kaplan Meier estimates of survival from collared females instead of measuring adult survival from carcasses on winter range. The age ratio approach assumes that the proportion of lambs counted in a given survey relative to the proportion of adults counted is constant across all surveys. In other words, the likelihood of seeing a lamb is the same as the likelihood of seeing a female. This seems reasonable for Sierra bighorn survey observations. We bounded adult and lamb survival at 0 and 1. Similar to the variances calculated by White (1996) we used sequential applications of the delta method to calculate the variance of the ratios. Since our adult survival is not based on a ratio calculation, but on the Kaplan Meier method, our calculations are expected to have a somewhat lower variance for similar survey effort.

Sierra Bighorn Pregnancy Rates

Pregnancy rate was determined from ultrasound during spring capture. Proportion of pregnant females observed with lambs was estimated using the range-wide pregnancy rates for adults (85%) and yearlings (55%) combined with the average proportion of yearling females (21%).

Sierra Bighorn Eigenvalue Lambda Estimation

We estimate the annual population growth rate λ by constructing a three stage (lamb, yearling, adult) matrix model to describe the population dynamics of Sierra bighorn of the following form (Johnson 2010, Johnson et al. 2010, Cahn et al. 2011). Equations are formulated based on the timing of the annual population survey:

Summer survey equation matrix Fecundity = lamb/ewe ratio (Jul-Aug)

$$N(t+1) = \begin{vmatrix} N_L(t+1) \\ N_Y(t+1) \\ N_A(t+1) \end{vmatrix} = \begin{bmatrix} 0 & S_A F(0.5) & S_A F \\ S_Y & 0 & 0 \\ 0 & S_A & S_A p \end{bmatrix} \begin{vmatrix} N_L(t) \\ N_Y(t) \\ N_A(t) \end{vmatrix}$$

Winter survey equation matrix Recruitment = lamb/ewe ratio (Mar-Apr)

$$N(t+1) = \begin{bmatrix} 0 & R(0.5) & R \\ S_Y & 0 & 0 \\ 0 & S_A & S_A p \end{bmatrix} \begin{vmatrix} N_L(t) \\ N_Y(t) \\ N_A(t) \end{vmatrix}$$

Where N = number of individuals, F = fecundity, S = survival, R = recruitment, p = 1% senescent

We then solve this linear series of simultaneous equations using eigenvectors and eigenvalues to get the ratio of N(t+1)/N(t), or λ, the annual population growth rate.

Mountain Lion Population Estimation

Mountain lion minimum counts are determined by summing the number of marked individuals, unmarked individuals reported dead (e.g., vehicle collisions, depredation killing), and uniquely identifiable unmarked individuals documented via detection at collared Sierra bighorn mortalities as well as through extensive track and trail camera surveys. We use methods adapted from McBride et al. (2008) and further described in Davis et al. (2012) to distinguish unmarked individual lions from each other and avoid double-counting, considering detections of unmarked individuals to be distinct if they occurred >9.6 linear km apart for females and >16.1 linear km for males within a 24-hour period. When track observations are used to distinguish between unmarked individuals, only tracks <24 hours old are used. Track age is verified by wind, rain, or snow events, or evidence that tracks occurred the night prior to a survey, such as those occurring over vehicle tracks from the previous day. To avoid overestimating lion abundance, we do not reconstruct presumed incomplete counts by assuming that females initially captured when ≥30 months old were born within the study area (e.g., Logan and Sweanor 2001; Robinson et al. 2008). Individuals are only counted when there is direct physical evidence of their presence. Minimum counts may include transient animals. If the same individual is identified in multiple count zones, it is added to the count for each zone, but only as a single individual in the range-wide count. The range-wide count is lower than adding the individual count zones together when known individuals move through multiple count zones.

While counts conducted in this manner can be used to determine that there were at least a certain number of individuals present, we currently do not have a quantitative procedure for determining how close minimum counts are to true abundance. Instead, we rely on a subjective measure of completeness, based on (1) the rate at which previously undetected lions within a year are found (i.e., this rate should decline as counts approach a census), and (2) whether counts of animals in subsequent years reveal that a substantial number of animals were potentially undetected in previous years. So, while including transients could result in an over-estimate of abundance, we think it is more likely that the true abundance is often higher than the minimum count, and there is some possibility that if survey effort is not intense enough, true abundance could be substantially higher than minimum counts. Despite these concerns, such counts are considered the most reliable method to monitor lion population density and demography (Cougar Management Guidelines Working Group 2005).

To have confidence in minimum counts and make comparisons of count data between years within the same area or within years between areas, it is critical to obtain counts in the same area over multiple years, maintain a high proportion of collared lions in the area being counted, and survey consistently to the point at which by the end of a count period, detections are only of individuals that have been previously identified.

Appendix C: 2020-2021 Round Valley Mountain Lion Population Assessment

Prepared for California Department of Fish and Wildlife – Sierra Nevada Bighorn Sheep Recovery Program

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INTRODUCTION

Monitoring mountain lion populations is notoriously difficult due to the low densities at which they occur and the lack of identifying pelage characteristics. Population estimates derived from camera trap data often rely on statistical modeling with parameters bounded by assumptions about lion populations and behavior that present a risk when analyzing small sample sizes. The ability of mountain lion biologists to identify individual lions in photographs has been shown to be unreliable (Alexander and Gese 2018), but McBride and Sensor (2015) developed a method to objectively identify individual lions from photos based on gender, ear notches, age of dependent young, and time and distance. Our goal was to count all lions in Round Valley, 10 miles west of Bishop, CA, using the objective metrics set forth by McBride and Sensor (2015) as well as GPS data from collared lions.

METHODS

We used GPS locations from collared lions in conjunction with remote cameras to monitor mountain lions in the central mountain lion count zone in the eastern Sierra. We used photographs from 18 remote cameras to count the minimum number of collared and uncollared mountain lions in Round Valley, an area of 65 square-miles just west of Bishop. Our survey period was 7/1/2020 - 6/30/2021, however 14 of the 18 cameras used in the survey were not deployed until the end of January or later, representing an intensive survey period during 2/13/2021-6/30/2021 (henceforth ISP) with increased lion detections. Fifteen of the 18 cameras were placed on game trails and/or mountain lion scent-marking areas. Of the 4 remaining cameras, 2 were sites baited with deer carcasses for the purpose of capturing lions, and the other 2 camera locations were deer killed by uncollared lions. Our cameras were placed with two objectives; 1) capture photographs of every lion in Round Valley, and 2) obtain photos of proper angle and quality to discern unique marks on individual lions. Cameras were not placed in accordance with a grid or any other sampling scheme. We used scent-lure and/or naturally occurring mountain lion scent at scrape sites as an attractant to entice lions to linger in front of the camera and offer multiple angles of view as they turn their heads and bodies (McBride and Sensor 2015). Lions in photographs were identified as individuals by 1) GPS collar location data, 2) GPS collar make, model, and other unique collar features, 3) unique ear shapes due to healed lacerations, and 4) age of dependent subadults. GPS-collared animals were identified by GPS locations placing animals in proximity to cameras at the time of camera detections, and by unique features of collars such as model, color, unit symmetry, and spacer modifications.

Collared lions were classified as adults if they were greater than 24 months of age and traveling independently of their mother and siblings. A detection was defined by a lion visiting a camera site yielding any number of photos. A new detection was counted if any one of the following criteria were met: 1) greater than two hours elapsed between photos, 2) different individual lions sequentially triggered a camera regardless of elapsed time, 3) different camera sites triggered by lion regardless of elapsed time or distance between cameras. Detections of adult females with dependent subadults were classified as one detection of a family group rather than multiple detections for the individual lions.

Uncollared Lion Identification

Identification of uncollared lions was based entirely on unique scar patterns on ears and age of sub-adults. It is also possible to distinguish uncollared lions based on simultaneous detections separated by sufficient distance such that it would have been impossible for one lion to trigger the two distant cameras within the timespan between the detections. Tears, notches, holes, and missing parts of ears are common in mountain lions and while the bleeding edges will heal, they do not regrow missing flesh. A lion may accumulate these scars as time goes on, but they do not lose them. If a lion passes a remote camera in January with no ear scars, then a lion passes the same camera in February with many ear scars, this is counted as one lion because the scars could have been accumulated between the detections. However, if a lion passes a camera in January with many ear scars, then a lion passes the same camera in February with no ear scars, these photographs represent two individual lions. All lions within a gender with no ear scars are counted as one individual. Female lions with no ear scars or other unique marks can be identified by the age of their dependent young that appear in photos with them. For example, if a camera detects a female lion with a group of 4-month old subadults and the following week the same camera detects a female lion with a group of 12-month old subadults then that would yield a count of two adult females. Uncollared subadult lions were classified as individuals by the adult female with which they were photographed, by the number of animals visible in a single frame, and by the gender of those animals. Subadults photographed by themselves with no adult female present were counted as one of the known subadults belonging to a known adult female unless the age of the unknown animal was clearly not consistent with that of the known animals.

Uncollared lions were classified as adults if they were photographed with dependent young, or if they met all the following criteria: 1) had no juvenile pelage or morphological characteristics, 2) had unique ear notches which distinguished them from all known lions, and 3) were photographed repeatedly over a period of months indicating residency. Collared and uncollared lions that could not be identified as individuals by the methods described above were classified as unknown.

RESULTS

Using GPS data and remote cameras, we identified a minimum of 19 individual lions present in Round Valley during the survey period, 13 adults and 6 sub-adults (Table 1c). Nineteen camera traps yielded 121 lion detections with a mean 5.89 detections per individual lion (Table 3c).

Fourteen GPS-collared lions were known to be present in Round Valley during the survey period and 11 of those lions were detected by the cameras (72.72%). Ninety-eight of the 121 lion detections (80.99%) occurred during the 4.5 month ISP and every individual lion that was detected before the ISP was detected again during the ISP, with a mean 7 detections per individual lion (Table 4c). Eleven collared lions were known to be present in Round Valley during the ISP and all these lions were detected by the cameras. Eighty-five of the 121 lion detections were of collared lions and 36 were of uncollared lions. 95.29% of the collared lion detections and 72.22% of the uncollared lion detections were identified to individual (Table 2c). GPS-data placing individual collared lions near cameras at the time of detection allowed for individual identifications to be made from blurry or partial photographs which would not be usable for identifying uncollared lions, and accounts for the difference in identification rates.

Collared Lion Detections

Of the fourteen GPS-collared lions known to be present during the survey period, one lion (L148) has not transmitted GPS data since 2/15/2019. Three lions with functional GPS-collars were in the survey area during the survey and were not detected by the cameras, but each of these lions either died or their collars failed before the ISP began. Lion 165M was killed on a depredation permit for depredating domestic livestock on 1/6/2021, 5 weeks before the ISP began. Lion 177M's GPS collar failed on 1/25/2021, 19 days before the ISP began, and Lion 178F's GPS collar failed on 2/8/2021, 5 days before the ISP began. Lion 178F was a resident adult female however and it is likely that she was present in the survey area during the ISP, despite the failure of her GPS collar on 2/8/2021. However, her home range straddles the southern border of the survey area and only 2 cameras were deployed in this area. Additionally, these 2 cameras were not deployed until the week of 4/1/2021, resulting in a shorter survey period for this area. Lion 177M was Lion 178F's dependent male subadult and was approximately 12 months old when his collar failed on 1/25/2021 after which time his fate and location were unknown.

All of the 10 lions with functional GPS-collars in Round Valley during the ISP were detected by cameras with a mean of 4.7 detections per lion. Lion 148M whose collar has not functioned since 2/15/2019 was detected 36 times. Lion 147M traveled through Round Valley after being translocated from his home range in the southern mountain lion count zone and during his 48- hour trip through the survey area was detected by one camera.

Uncollared Lion Detections

Our 18 cameras captured 36 uncollared lion detections, 26 of which yielded individual identifications for a minimum of 5 individual lions. Two of these 5 uncollared lions are resident adult females (HCFG-1 and RVF-1). HCFG-1 has no ear notches or other distinguishing marks and was repeatedly photographed with two uncollared dependent subadults (HCFG-2 and HCFG-3) whose growth throughout the survey period was chronologically consistent (Figure 1c). RVF-1 was detected 13 times and bears a small nick in the tip of left her (Figure 2c). The nick in RVF-1's left ear is visible in photos dating both before and after photos in which HCFG-1's left ear is clearly visible and free of damage, separating the identity of these two adult female lions. Lion 141F was photographed with an uncollared dependent subadult (141-S) on 4/25/2021.

Resident and Non-resident Lions

Of the 13 adult lions identified in Round Valley via GPS locations and camera data, 11 of them can be classified as resident animals. Two of these resident adult lions are uncollared, Lion HCFG-1 and Lion RVF-1. Lion 147M traveled through Round Valley after being translocated from his former home range in the southern mountain lion count zone and spent roughly 48 hours in the survey area. Lion 147M was detected by one camera in that 48 hours but is excluded from the count of 11 resident adult animals. Lion 165M was estimated to be 23 months of age at the beginning of the survey period, but his independent movements through Round Valley consisted of two large and temporary trips, comprising less than 10 total days. Lion 165M was killed in Round Valley (on a depredation permit for depredating domestic livestock) on 1/6/2021 at an estimated age of 29 months. We considered Lion 165M's movements in Round Valley to be part of a dispersal pattern that resulted in his death, and therefore he was excluded from the count of 11 resident adult animals. Lion 174M was estimated to be 23 months of age at the start of the survey period and made a dispersal-type movement far to the north of Round Valley during the survey period but returned to Round Valley after this movement and is counted as a resident adult based on his age of greater than 24 months for the majority of the survey period and his independent movements.

DISCUSSION

During the ISP 100% of the collared lions known to be present in Round Valley from GPS locations were detected by the 18 cameras, including Lion 147M who spent less than 48 hours in the survey area. This demonstrates the ability of this method to capture images of a large, if not entire, proportion of the individual lions present in a given survey area. Additionally, during the ISP the proportion of uncollared and collared lion camera detections (23 and 70 respectively, 24.73% uncollared) was very near the proportion of the minimum number of individual uncollared and collared lions detected (5 and 11 respectively, 31.25% uncollared). The fact that collared lions are over-represented in the camera detections in relation to the known minimum number of uncollared lions lends support to the idea that our minimum number is not an underestimate and may be the actual number of uncollared lions present in the survey area.

Capture efforts in the 2021-2022 season should be aimed at collaring RVF-1 and HCFG-1 as this will provide a means to test whether our minimum uncollared lion count is an underestimation or not. If the minimum uncollared adult lion count is the same as the actual number, then there should be no more detections of uncollared adult females after Lion HCFG-1 and Lion RVF-1 are collared. Future efforts should be focused on maintaining a more even survey effort throughout the year, expanding the survey method employed in Round Valley to the other mountain lion count zones, and capturing uncollared animals identified by cameras. The latter will provide a means of continuously assessing the degree of population under-estimation associated with the minimum count methodology and the risk posed by mountain lion to Sierra Nevada bighorn sheep.

LITERATURE CITED

McBride, R. and R. Sensor. 2015. Efficacy of trail cameras to identify individual Florida panthers. Southeastern Naturalist 14:351-360.

Alexander, P. D. and E. M. Gese, 2018. Identifying individual cougars (*Puma concolor*) in remote camera images – implications for population estimates. Wildlife Research 45:274-281.

Table 1c. Lions detected in Round Valley by age class, sex, and collar status during 7/1/2020 - 6/30/2021.

	Adults			Sub-adults		
Sex	**M**	**F**	**U**	**M**	**F**	**U**
Collared	5	6	0	2	1	0
Un-collared	0	2	0	1		2
Sub-Total	5	8	0	3	1	2
Total	**13**			**6**		

Table 2c. Collared and uncollared lion detections, and proportion of detections that yielded an individual identification during 7/1/2020 - 6/30/2021.

	Collared Lions	Uncollared Lions
Detections	85	36
Detections Identified	81	26
Detections Un-identified	4	10
% Identified	**95.29%**	**72.22%**

Table 3c. Lions detected in Round Valley during the entire survey period, 7/1/2020 - 6/30/2021.

Lion ID	Sex	Age	Residency Status	Collared?	Collar Functional During Survey?	Status	Camera Detections
141	F	Adult	Resident	Yes	No	presumed alive	4
141-S	U	Subadult	Natal Range	No	N/A	presumed alive	1
147	M	Adult	Non-resident	Yes	Yes	dead	1
148	M	Adult	Resident	Yes	No	presumed alive	36
166	M	Adult	Resident	Yes	Yes	presumed alive	11
174	M	Adult	Resident	Yes	Yes	presumed alive	16
180	F	Adult	Resident	Yes	Yes	presumed alive	6
185	F	Adult	Resident	Yes	Yes	presumed alive	2
194	F	Adult	Resident	Yes	Yes	presumed alive	2
195	M	Subadult	Natal Range	Yes	Yes	presumed alive	1
196	F	Subadult	Natal Range	Yes	Yes	dead	2
173	F	Adult	Resident	Yes	Yes	presumed alive	2
177*	M	Subadult	Natal Range	Yes	No	unknown 1/26/2021	0
178*	F	Adult	Resident	Yes	No	unknown 2/8/2021	0
165*	M	Subadult	Non-resident	Yes	N/A	dead	0
HCFG-1	F	Adult	Resident	No	N/A	presumed alive	5
HCFG-2	U	Subadult	Natal Range	No	N/A	presumed alive	4
HCFG-3	M	Subadult	Natal Range	No	N/A	presumed alive	6
RVF-1	F	Adult	Resident	No	N/A	presumed alive	13
						mean detections per lion	**5.894736842**
						Percentage of collared lions known to be present detected by cameras	**72.72%**

Table 4c. Lions detected in Round Valley during the Intensive Survey Period (ISP) 2/13/21 - 6/30/21.

Lion ID	Sex	Age	Residency Status	Collared?	Collar Functional During Survey?	Status	Camera Detections
141	F	Adult	Resident	Yes	No	presumed alive	4
141-S	U	Subadult	Natal Range	No	N/A	presumed alive	1
147	M	Adult	Non-resident	Yes	Yes	dead	1
148	M	Adult	Resident	Yes	No	presumed alive	36
166	M	Adult	Resident	Yes	Yes	presumed alive	11
174	M	Adult	Resident	Yes	Yes	presumed alive	16
180	F	Adult	Resident	Yes	Yes	presumed alive	6
185	F	Adult	Resident	Yes	Yes	presumed alive	2
194	F	Adult	Resident	Yes	Yes	presumed alive	2
195	M	Subadult	Natal Range	Yes	Yes	presumed alive	1
196	F	Subadult	Natal Range	Yes	Yes	dead	2
173	F	Adult	Resident	Yes	Yes	presumed alive	2
HCFG-1	F	Adult	Resident	No	N/A	presumed alive	5
HCFG-2	U	Subadult	Natal Range	No	N/A	presumed alive	4
HCFG-3	M	Subadult	Natal Range	No	N/A	presumed alive	6
RVF-1	F	Adult	Resident	No	N/A	presumed alive	13
						mean detections per lion	**7**
						Percentage of collared lions known to be present detected by cameras	**100.00%**

Figure 1c. *Uncollared adult female HCFG-1, with no notches in ears. Note sub-adults in background left.*

Figure 2c. *Uncollared adult female RVF-1, with distinct ear notch at tip of left ear.*