2017-18 Annual Report
Sierra Nevada Bighorn Sheep Recovery Program

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Figure 1. Fourteen Sierra bighorn photographed on Mt. Gibbs in April 2018.

Executive Summary

Sierra Nevada bighorn sheep (*Ovis canadensis sierrae*, hereafter Sierra bighorn) survival rebounded quickly from the record lows during the heavy snow winter of 2016-17. Both milder winter conditions this year (2017-18, Figure 1) and last year's mountain lion (*Puma concolor*, hereafter lion) management likely influenced survival rates. Although survival has returned to more average values, the overall population of female bighorn is taking longer to recover. We found a slight decrease in the total number of females this year, possibly due to poor recruitment during the 2016-17 winter; the total population is now 552 animals, which includes 266 adult and yearling females. While some of the herds remain small (female N<5), there was no loss of herd unit occupation. Bighorn movements documented this year demonstrate connectivity between herds (Mt. Baxter and Mt. Williamson as well as Mt. Gibbs and Cathedral Range). Along with our robust capture and monitoring program for Sierra bighorn, we expanded our efforts to focus on their main predator, lions. We documented a minimum of 19 lions in eastern Sierra Nevada count zones, which is the greatest number of individuals ever counted for this area. Research published on Sierra bighorn this year included analyses of migration, female survival, and the effects of nutrition on ram horn size. The highlight of our public outreach for the year was 'Project Bighorn,' developed by members of Girl Scout Troop 580 which included the development of an original game, internet quizzes, and a Sierra bighorn rap song.

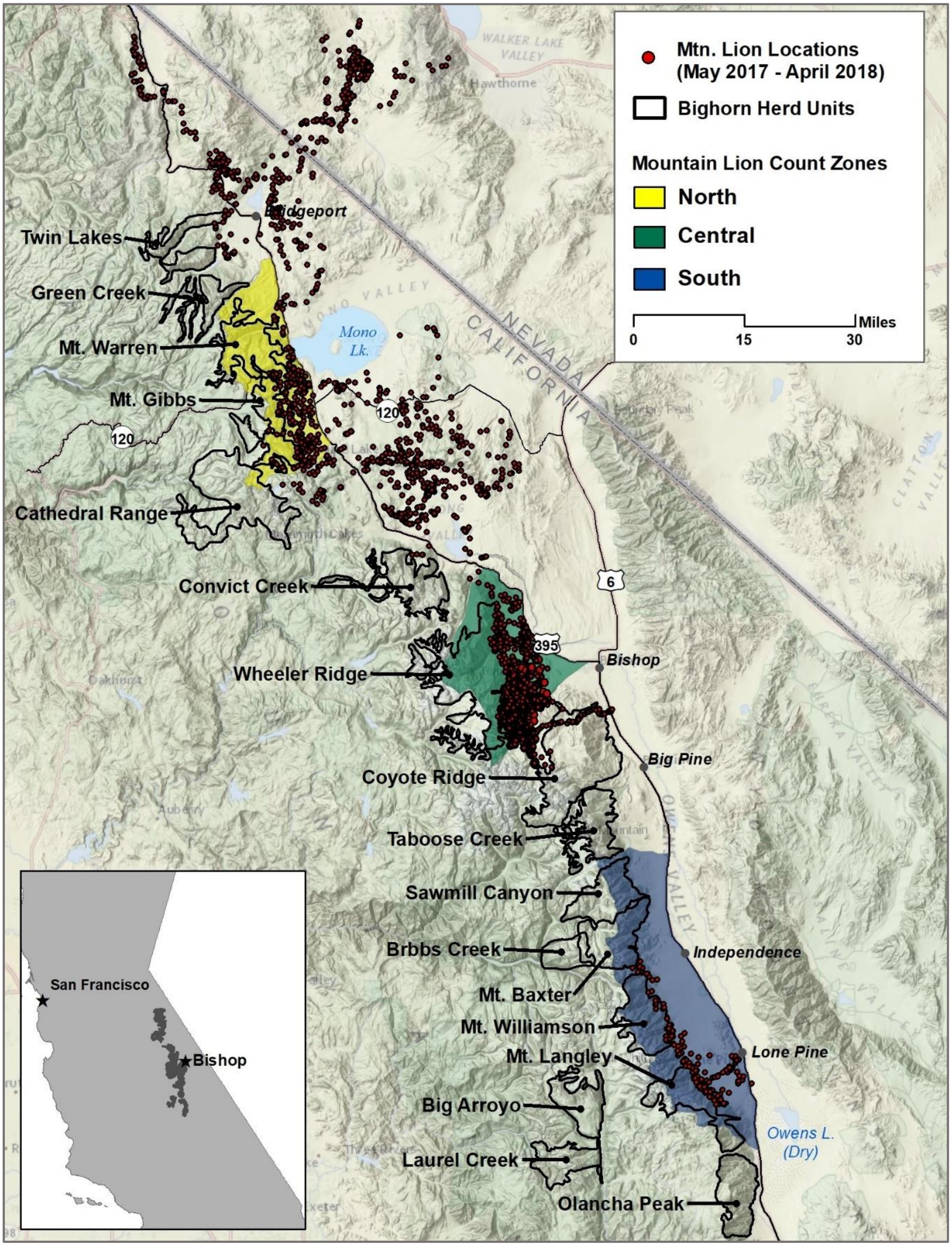


Figure 2. Sierra bighorn herd units and mountain lion count zones in the eastern Sierra Nevada. Map includes locations of collared mountain lions during May 2017-April 2018.

Introduction

We monitor Sierra bighorn herd abundance, demography and habitat use to inform management decisions on translocations, predator management, and disease risk. We also monitor mountain lion abundance, demography, and habitat use because they are the main predator of Sierra bighorn. In addition, we work to reduce the potential for disease transmission between Sierra bighorn and domestic sheep and we promote bighorn recovery through public outreach. Here we summarize the activities of the Sierra Nevada Bighorn Sheep Recovery Program for May 1, 2017 – April 30, 2018. We report our progress toward recovery goals and we also summarize climatic data as well as demographic and movement data for bighorn and lions.

For brevity we refer to herds and herd units using single descriptive keywords such as 'Olancha' for Olancha Peak herd unit; we refer to Sierra Nevada bighorn sheep as 'bighorn;' and we use '2017' to represent the animal year May 1, 2017 – April 30, 2018. The animal year begins in May because most Sierra bighorn are born in May. Because additional information may be obtained after publication, data summaries are subject to change. Data analyses and summaries presented in this report may differ from previously published information, and interpretations may be subject to change contingent upon future analyses and the peer review process.

Recovery Goals: Abundance and Distribution

Sierra bighorn were listed as federally endangered in 1999; at that time the range-wide population was estimated to be 95-129 adults including at least 49 adult females (Wehausen 1999). Based on minimum counts conducted mostly within 2017 (see Appendix A for survey details and Appendix B for methods details), we estimated a total population size of 552 including 266 females, 109 lambs, and 177 males (Table 1). The male estimate is calculated from a ram:ewe ratio of 2:3, based on the first systematic surveys for Sierra bighorn which targeted both males and females (Wehausen 1980), as well as general ratios commonly reported in the literature (Valdez and Krausman 1999).

Downlisting criteria specifies 50 females in the Kern recovery unit (RU), 155 females in the southern RU, 50 females in the central RU, and 50 females in the northern RU, based on minimum counts (U.S. Fish and Wildlife Service 2007). At this time, Sierra bighorn exceed the abundance goal for the southern RU, meet the goal for the central RU, and have not achieved the goals for the northern and Kern RUs (Figure 3). Within recovery units, Sierra bighorn are currently distributed across 14 herd units (from south to north): Olancha, Laurel, Big Arroyo, Langley, Williamson, Baxter, Sawmill, Bubbs, Taboose, Wheeler, Convict, Cathedral, Gibbs, and Warren (Figure 2). The current distribution includes all 12 essential herd units identified in the Recovery Plan (Criteria B2, SNBS Recovery Plan 2007). Bighorn also occupy two additional herd units, Bubbs and Cathedral.

Table 1. Reconstructed minimum counts of Sierra bighorn during May 1, 2017 – April 30, 2018. Lambs not identified by sex.

	EWES			LAMBS	RAMS			TOTAL	
Herd	**Adult**	**Yrlng**	**Total**		**Adult**	**Yrlng**	**Total**		**Notes**
Olancha	21	1	22	6	7	3	10	38	
Laurel	2	0	2	1	1	0	1	4	
Big Arroyo[C]	7	2	9	5	2	1	3	17	Ram observations split between seasons
Langley	21	5	26	3	30	5	35	64	
Williamson[C]	13	2	15	6	5	2	7	28	Females from winter count, males from summer count
Baxter[W]	41	8	49	22	29	11	40	112	Total includes 1 unclassified animal
Sawmill	38	5	43	22	9	3	12	77	
Bubbs (2013)	12	1	14	9	5	1	6	29	Female count includes 1 unclassified age. Last good count of Bubbs occurred in 2013
Taboose	1	0	1	0	3	0	3	4	May be missing lambs, observations from mid-May
Wheeler[W]	38	7	45	20	17	1	18	83	
Convict	5	0	5	0	3	0	3	8	
Cathedral	6	0	6	0	0	0	0	6	
Gibbs	21	3	24	13	2	3	5	42	
Warren	5	0	5	2	5	1	6	13	
Totals	**231**	**34**	**266**	**109**	**118**	**31**	**149**	**525**	
Most surveys conducted in summer; W = winter surveys; C = data combined from winter and summer surveys.									

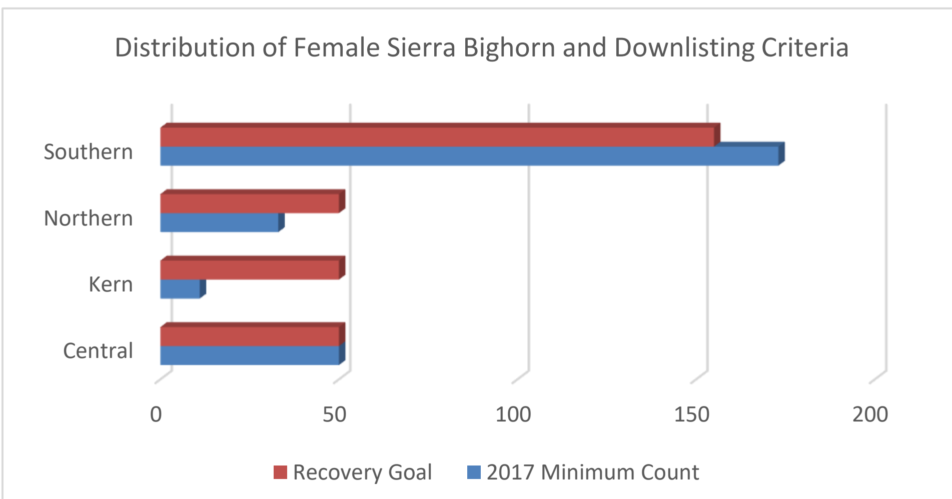


Figure 3. Abundance and distribution of female Sierra bighorn across recovery units compared to downlisting recovery goals.

Although the Recovery Plan specifies that minimum counts be used to evaluate progress toward recovery goals, these counts are known to underestimate populations (U.S. Fish and Wildlife Service 2007). We categorize our minimum counts as ‘census’, ‘good’, or ‘poor’ (Table 2, Appendix B). Some herds tend to consistently have ‘good’ surveys (e.g. Big Arroyo and Langley), while there is rarely a good survey in other herds (e.g. Sawmill, Table 2). The quality of a survey is likely the result of the difficulty of the area being surveyed, as well as luck: luck that most, or ideally all, bighorn present will be observed.

Based on female minimum counts (adults and yearlings combined) the largest herds are Baxter, Sawmill, and Wheeler, each with more than 40 females (Table 1). The mid-size herds are Langley, Gibbs, and Olancha, each with more than 20 females (Table 1). The majority of all females are in larger herds (60%, N=137), with 31% (N=72) in mid-size herds, and 10% (N=22) in small herds. Langley’s population has declined from 49 females in 2016 to 26 in 2017, based on ‘good’ minimum counts. Previously Langley was one of our larger herds and one of the main sources for translocation (Few et al. 2015). Bighorn are periodically removed from ‘source’ herds to augment existing herds or reestablish herds in historical locations following translocation plans (Few et al. 2013, 2015). To be considered a ‘source’ herd for translocation, a herd must have at least 40 females (Few et al. 2013). Until Langley rebounds, we will not consider removing animals from this herd. Both Gibbs and Olancha have been increasing and may become source herds in the future. We also calculated the year-end populations including known mortalities as of April 30, 2018 (Table 3).

Table 2. Sierra bighorn minimum count quality evaluation. “Census” surveys are thought to include every animal in the herd. This tends to occur in the first few years after translocation when most females are collared, or at Gibbs. “Good” surveys 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. Williamson, Bubbs, and Taboose herds are not listed here because they were not surveyed in every year.

Herd	Total Females 2016 year-end	Known Gains/Losses before survey	Projected Adult Females 2017	Adult Females Counted in 2017	Difference	Proportion Females Collared	Proportion Collared Females Seen	2015 Survey Quality	2016 Survey Quality	2017 Survey Quality	Notes
Olancha*	18	0	18	21	3	0.41	1	poor	poor	good	3 more females than projected indicated 2016 not a census
Laurel	3	0	3	2	-1	0.5	1	good	good	good	Could be census if 1 uncollared female died. Limited opportunistic observation.
Big Arroyo	6	0	6	7	1	0.44	1	good	good	good	Missed at least 1 female in 2016 count
Langley	34	-2	32	21	-11	0.23	1	poor	good	good	No evidence there were animals missed in 2016, but 2017 is low--either bad count or more mortality than observed
Baxter[W]	47	-5	42	48	6	0.28	1	poor	good	good	Higher count in 2017 indicates 2016 not census
Sawmill[C]	37	-1	36	38	2	0.37	0.75	poor	poor	poor	Higher count in 2017 indicates 2016 not census
Wheeler[W]	48	-1	47	38	-9	0.29	0.85	good	poor	good	It's possible 9 animals died undetected but more likely 2017 was not a census, only 1 collared female was lost during that time
Convict	10	0	10	5	-5	0.4	0.5	poor	good	poor	Could be census if 5 uncollared animals died
Cathedral	6	0	6	6	0	0.67	1	census	census	census	No mortality, all animals accounted for
Gibbs	24	0	24	21	-3	0.38	0.89	census	census	census	Could be census if 3 uncollared females died
Warren	9	0	9	5	-4	0	NA	good	good	unknown	Unable to assess quality because no collared females remain. Could be census if 4 uncollared females died.
Totals	**242**			**212**							

W = winter surveys; C = data combined from winter and summer surveys. * One female was translocated in to Olancha in spring after the count, so it is not added to the projection.

Table 3. Best estimate of Sierra bighorn present in each herd unit as of April 30, 2018 based on reconstructed minimum counts and known mortalities and translocations. Lambs are not identified by sex.

	EWES			LAMBS	RAMS			TOTAL	
Herd	**Adult**	**Yrlng**	**Total**		**Adult**	**Yrlng**	**Total**		**Notes**
Olancha	23	1	24	6	7	3	10	40	Ram S322 died; ram S493 and ewe S494 translocated in
Laurel	2	0	2	1	1	0	1	4	Ram S352 moved to Big Arroyo Nov. 2017, but later returned to Laurel
Big Arroyo	9	3	12	5	3	2	5	22	
Langley	19	5	24	3	29	4	33	60	
Williamson	13	2	15	6	5	2	7	28	Combined spring females and summer males. Not surveyed annually
Baxter	38	7	45	22	27	10	37	105	Includes 1 unclassified animal
Sawmill	36	5	41	22	8	3	11	74	
Bubbs (2013)	12	1	13	9	5	1	6	28	Not surveyed annually
Taboose (2016)	1	0	1	0	3	0	3	4	Not surveyed annually
Wheeler	37	7	44	20	16	1	17	81	1 male and 1 female translocated to Olancha
Convict	4	0	4	0	3	0	3	7	
Cathedral	6	0	6	0	1	0	1	7	
Gibbs	19	3	22	13	2	3	5	40	
Warren	5	0	5	2	5	1	6	13	
Totals	**224**	**34**	**258**	**109**	**115**	**30**	**145**	**513**	

Weather and Climate

Compared to the snowy winter of 2016-17, which was the second wettest winter on record in California, the winter of 2017-18 had below average precipitation with 58% of average snowpack statewide (Figure 4). The 2017-18 winter followed a general statewide warming trend (California Department of Water Resources 2018). These dry conditions, following the snowy winter of 2016-17, fueled many large destructive wildfires throughout California, although none occurred within Sierra bighorn habitat. While overall conditions were dry, there were sporadic periods of significant precipitation; in April an atmospheric river event flooded the Merced River impacting Yosemite National Park.

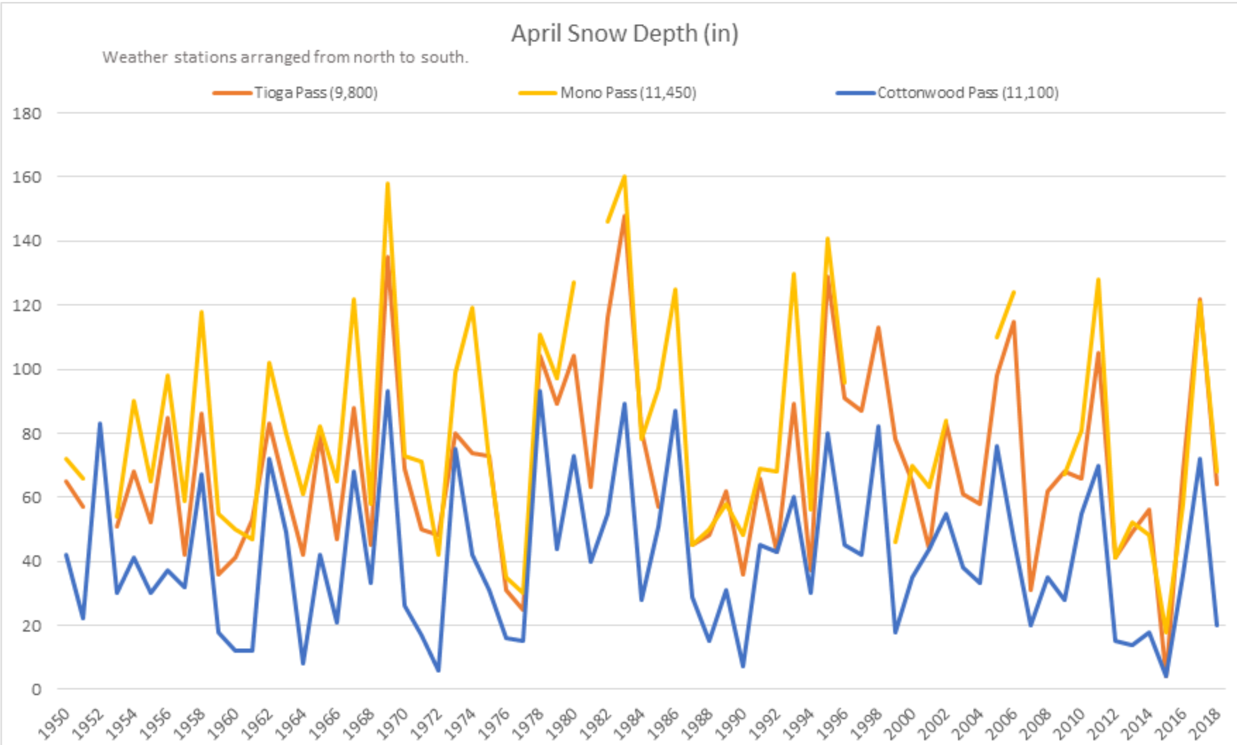


Figure 4. April snow depth (in) since 1950 at 3 high elevation sites in the Sierra Nevada within the historic range of Sierra bighorn. Weather stations are within recovery units (RU): Tioga Pass = northern RU, Mono Pass (Rock Creek drainage) = central RU, and Cottonwood Pass = southern RU. Data compiled from California Data Exchange Center Department of Water Resources (https://cdec.water.ca.gov/).

Across the Sierra Nevada, snow depth and weather patterns vary on small scales, with some significant differences among basins (Figure 4, 5). To understand conditions for a given herd, it is useful to have local weather and snow data. The Department of Water Resources maintains several weather stations throughout the Sierra Nevada. However, these stations do not always occur near Sierra bighorn herd units. Between 2006-2010 the Recovery Program maintained five weather stations within bighorn herds: high and low elevation stations at Warren and Wheeler, and a low elevation station at Baxter. We have recently upgraded the weather station components and software at the high elevation stations, but they are not yet transmitting data in real time. The low elevation Warren weather station is functional, but the other low elevation stations need to be fully upgraded. Localized weather data are critical to understand winter impacts on herds.

Figure 5. Two Sierra bighorn rams photographed in blowing snow on Mt. Gibbs, February 2018.

Population Dynamics

In addition to minimum counts at the herd level, we calculated range-wide female abundance for each calendar year by combining both minimum counts and mark-resight (MR) estimates (Figure 6). For herds with >20 females, it is likely our minimum counts were incomplete, so when possible, we used MR estimates (Appendix B). We combined spring and summer counts and estimates, in order to evaluate the impact of each winter on female population (Figures 6, 7). For example, the 2018 estimate included 2018 winter/spring estimates from Baxter and Wheeler (technically collected during the 2017 animal year) and 2018 summer survey estimates for the other herds. These abundance estimates represent our best evaluation of female population size post-winter (Figures 6, 7).

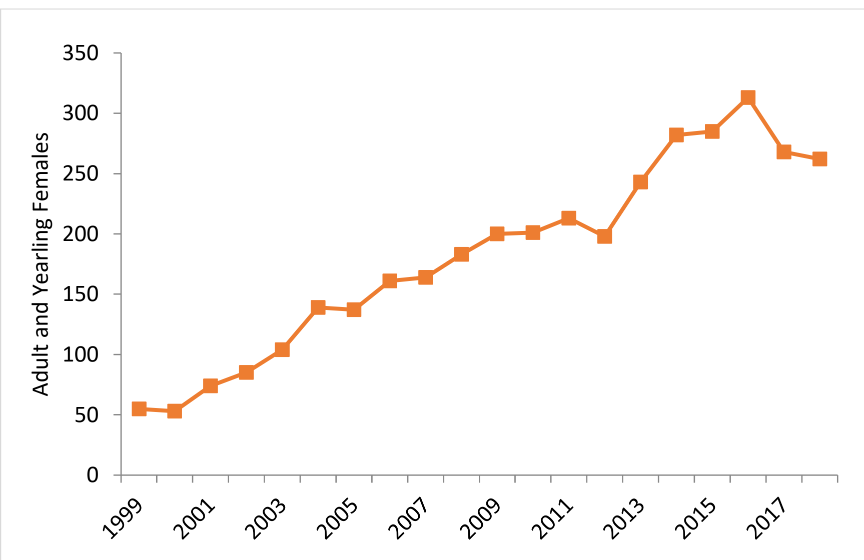


Figure 6. Range-wide Sierra bighorn female population estimates since 1999. Data include reconstructed minimum counts and mark-resight estimates (CV < 0.15). Data are compiled post winter (spring and summer counts combined for a given year) so that the impact of a given winter can be easily interpreted. For example, the decline in 2017 represents the impact of heavy snowfall in the 2016-17 winter.

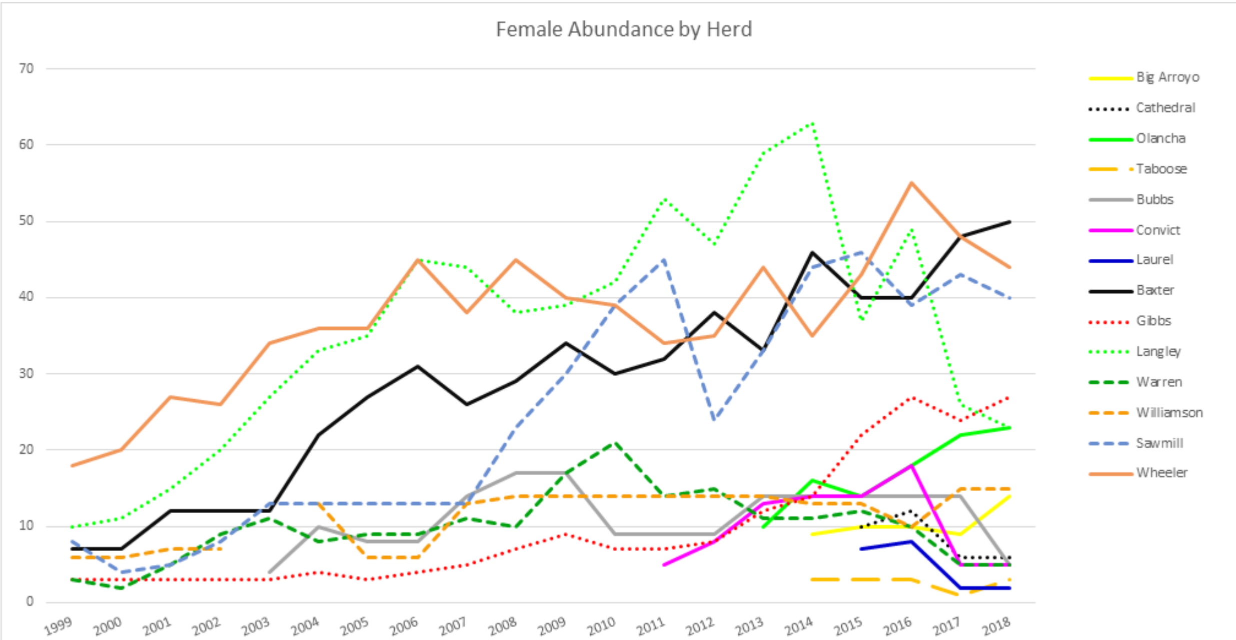


Figure 7. Estimated female Sierra bighorn within each herd since 1999. This includes reconstructed minimum counts and mark-resight estimates (CV < 0.15). For herds not surveyed annually, population estimates may rely on previous years' counts.

Our range-wide estimate of female abundance shows a slight decline after the 2017-18 winter (N=6, Figure 6). Although the decline itself is within the error of our estimation, the stagnation in the overall population is likely due to high lamb mortality during the 2016-17 winter, which limited recruitment of yearlings in 2017-18. The mild 2017-18 winter (Figure 4) had similar collared female mortality (N=14) to 2015 (N=15). Mountain lion predation was the most frequent cause of mortality for collared females (N=6, Figure 8a). Collared female mortality was distributed across eight herds, with the highest mortality at Langley and Sawmill (N=3 each, Figure 8b). This is the first year in which the majority of collared female mortalities occurred in spring (April – May) rather than winter (January – March, Figure 8c). We could not determine the cause of death for 36% of collared female mortalities (N=5), often due to the inaccessibility of the carcass and the limited availability of staff. Because predation typically occurs in more accessible low elevation areas, it is likely that predation occurs at a smaller proportion in the unknown mortalities than in the known mortalities. We determined the cause of death for all carcasses investigated within one week of the mortality.

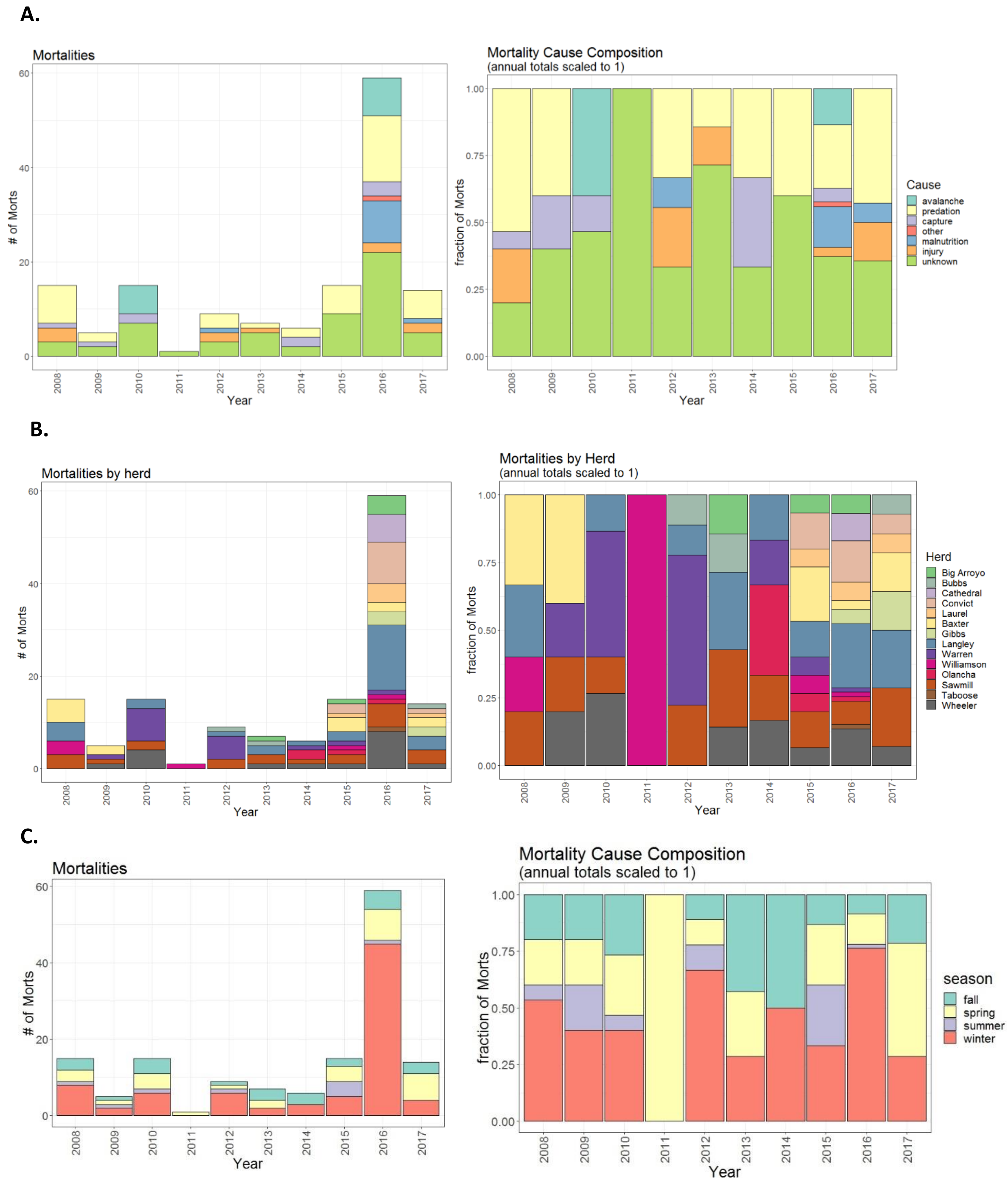


Figure 8. Collared female Sierra bighorn mortality 2008-2017 by A) cause of death B) herd, and C) season. The overall population size has increased, as have the number of collared females and the distribution of collars across herds (e.g. Olancha was created in 2013). This does not include censored animals because their cause and date of death are unknown.

Sierra bighorn population trajectories are typically driven by female survival (Johnson et al. 2010). Here we report Kaplan-Meier survival rates (Kaplan and Meier 1958) for females in herds that had a minimum of 3 collars within a year. There were averages of 13.5 collars per year (Figure 9) within source herds, 9 collars per year within new herds, (Figure 10), and 7 collars per year within northern RU herds (Figure 11). Survival rates varied substantially within source herds, ranging from 100% to 37% (Figure 9). Despite their close proximity (Figure 2), Baxter and Sawmill survival rates do not appear to be closely synchronized. With the exception of Baxter, which appears to be robust during heavy snow winters, the survival rates of all other source herds decreased during previous snowy winters in 2010 and 2016.

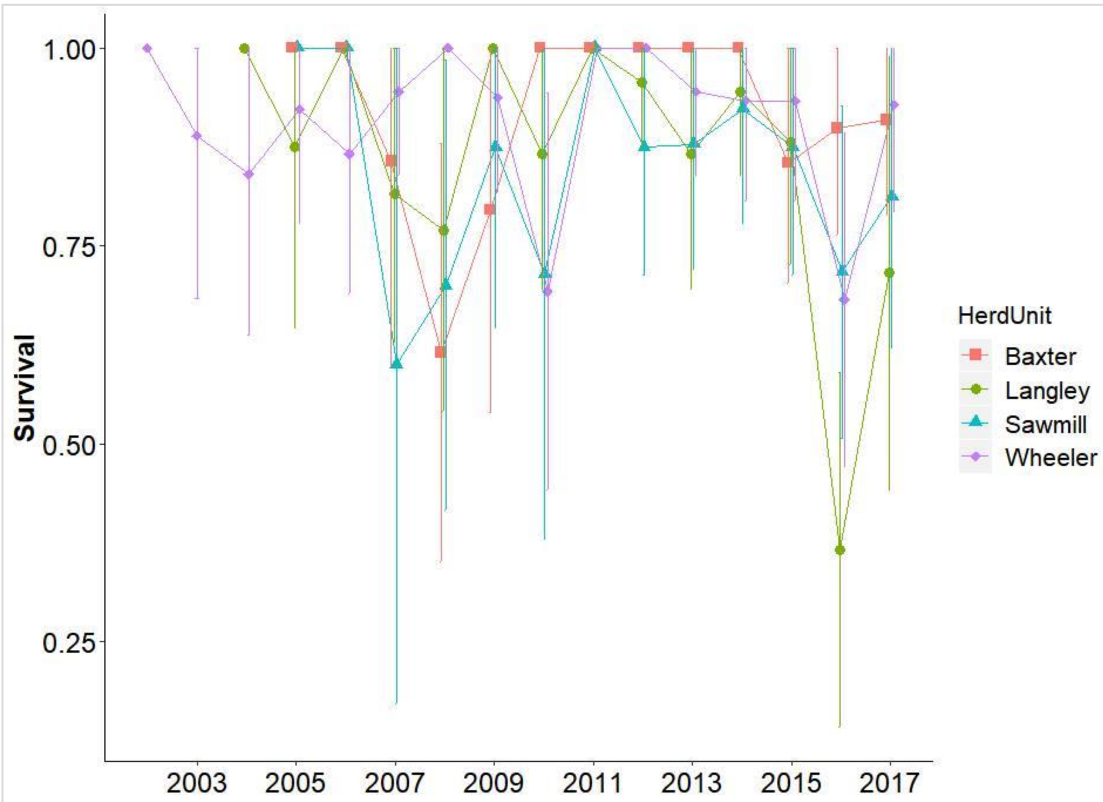
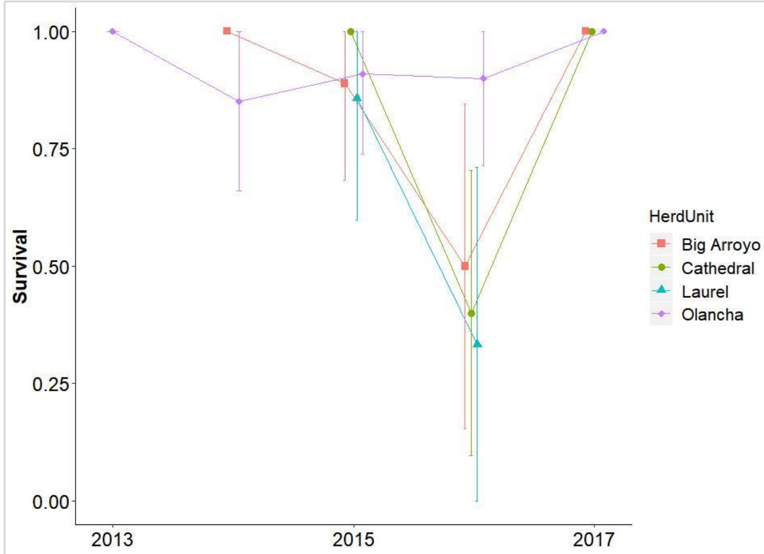


Figure 9. Annual Kaplan-Meier survival for collared yearling and adult female Sierra bighorn with 95% confidence intervals, bounded at 1 and 0. These were source herds that provided animals for translocation.

Survival in newly established herds rebounded from low values in 2016 to 100% for all new herds in 2017 (Figure 10). In other words, no collared females died in these herds. We were unable to report an official survival rate at Laurel because there was only one live collared female remaining in that herd.

Figure 10. Annual Kaplan-Meier survival for collared yearling and adult female Sierra bighorn with 95% confidence intervals, bounded at 1 and 0. These are recently reintroduced herds, and each herd had a minimum of 3 collars in it at some point during the year. There is no estimate of Laurel in 2017 because there was only 1 collared female that year.



The three herds within the northern RU (Warren, Gibbs, and Cathedral) exhibit asynchronous survival rates despite their close proximity (Figure 11). The only exception was during the 2016-17 snowy winter, when survival rates for all herds was reduced. The lower survival at Warren in both 2010 and 2016 suggest that large snowpacks may consistently negatively impact survival of Warren bighorn, while Gibbs survival appears less sensitive to large snowpacks (Figure 11). Poor survival at Warren may be due to an Allee effect associated with small populations. We have not augmented this herd in more than a decade because disease risk was not reduced until 2017.

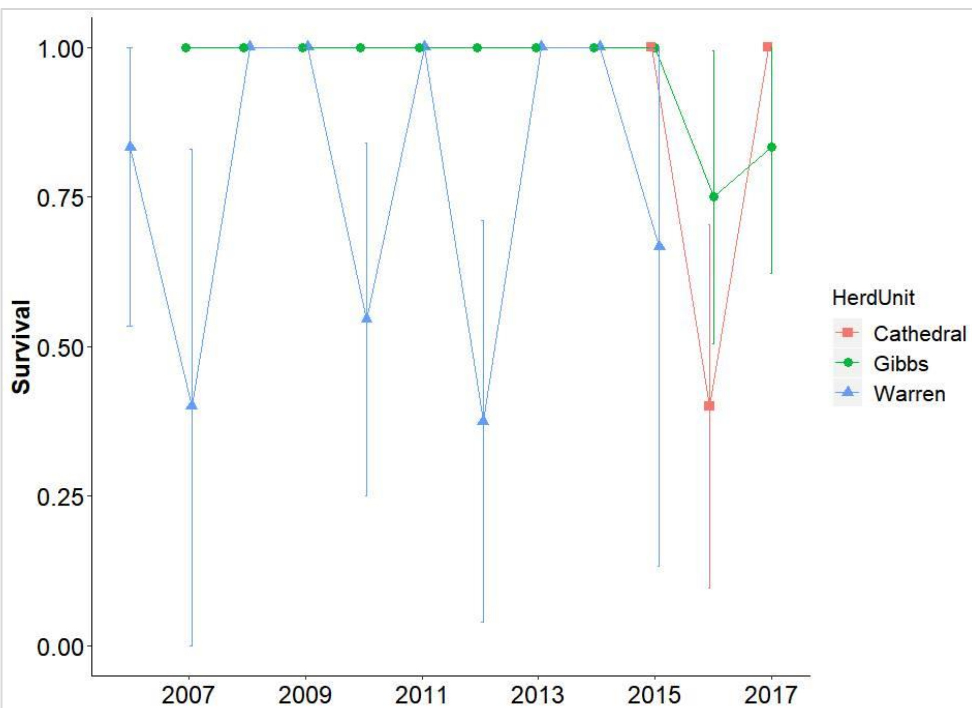


Figure 11. Annual Kaplan-Meier survival for collared yearling and adult female Sierra bighorn in the northern recovery unit with 95% confidence intervals, bounded at 1 and 0.

Reproduction and Recruitment

During spring capture 2017, the pregnancy rate for adult females was 82% (14/17) using ultrasonography. We estimated annual reproductive success from the observed ratio of lambs to adult ewes (Table 4). For herds surveyed in the summer, the lamb:ewe ratios reflect a combination of the likelihood of having a lamb combined with the lamb surviving through summer (~3 months). For herds surveyed in winter, lamb:ewe ratios reflect the likelihood of having a lamb combined with the lamb surviving for 9 months, which includes over winter survival. Lamb:ewe ratios ranged from 0 to 71%. Lamb:ewe ratios were highest in Big Arroyo, Sawmill, and Gibbs; lamb:ewe ratios were low in Langley and Olancha; no lambs were observed in Convict and Cathedral (Table 4). We expected that there would be no lambs in Cathedral, as the rams we translocated during the previous fall had limited overlap with the Cathedral ewes (based on GPS collar locations) and then died during the 2016-17 winter. There were 4 adult females observed in Convict, and none of them had lambs.

Table 4. Observed lamb:ewe ratios for all Sierra bighorn herds surveyed annually. Female lamb survival estimated as the ratio of [2017 female yearling:ewe]/[2016 female lamb:ewe]. Lamb survival for herds surveyed in the summer is from 3-15 months and for herds surveyed in winter is from 9-18 months.

	2017 Lamb:Ewe			2016 Lamb:Ewe			2016 Female Lamb:Ewe	2017 Female Yrlng:Ewe		Est. Female Lamb Survival
Herd	**Date**	**N**	**%**	**Date**	**N**	**%**	**%**	**N**	**%**	**%**
Olancha	8/15-8/16/17	6:21	29%	9/27-9/28/16	6:12	50%	25%	1:21	5%	19%
Laurel	6/8/17	1:2	50%	8/18-10/12/16	3:6	50%	25%	0:2	0%	0%
Big Arroyo	9/2-9/9/17	5:7	71%	6/8-7/20/16	5:8	63%	31%	2:7	29%	91%
Langley	8/29-9/8/17	3:20	15%	9/5-9/8/16	16:40	40%	20%	5:20	25%	100%
Baxter[W]	2/28-3/6/18	22:41	54%	1/17/17	20:37	54%	27%	8:41	20%	72%
Sawmill	7/11-7/12/17	22:35	63%	9/13-9/15/16	16:30	53%	27%	5:35	14%	54%
Wheeler[W]	3/12-3/19/18	20:36	56%	2/14/17	17:41	41%	21%	7:36	19%	94%
Convict	6/28/17	0:4	0%	7/13/16	8:12	67%	33%	0:6	0%	0%
Cathedral	7/19/17	0:6	0%	6/23-7/12/16	0:10	0%	0%	0:10	0%	NA
Gibbs	7/7-8/27/17	13:20	65%	7/8/16	11:22	50%	25%	3:20	15%	60%
Warren	6/14-7/6/17	2:5	40%	8/24-8/26/16	5:9	56%	28%	0:5	0%	NA
Totals			**40%**			**48%**	**24%**		**12%**	**61%**

W = winter counts. 2017 year is May 1, 2017- April 30, 2018. 2016 year is May 1, 2016 - April 30,2017.

Bounded survival at 100. Lamb survival estimates may be >100 because animals were missed or because sex ratio of lambs was not exactly equal.

Although lamb production declined in some herds after the large 2016-17 snowpack, the pattern is not consistent across all herds. For herds surveyed in the summer (i.e., after the 2016-17 winter), we expected snowy 2016-17 winter conditions would result in lower lamb:ewe ratios in 2017 compared to 2016. This occurred in four out of nine herds (Olancha, Langley, Convict, and Warren). Due to the difference in survey timing, for herds surveyed in the winter, we expected lamb:ewe ratios to be lower in animal year 2016 compared to 2017 if the 2016-17 winter impacted lamb production. However, there was no difference in lamb:ewe ratios at Baxter and only a slight reduction in 2016 lamb:ewe ratios at Wheeler (41% in 2016, 56% in 2017). This indicates lamb mortality may have been equal to and not greater than adult mortality.

In addition to annual reproductive success, we estimated lamb survival based on the ratio of observed age classes across two years ([2017 yearling:ewe]/[2016 lamb:ewe], Table 4). For small herds with annual minimum counts, we also calculated lamb survival directly from minimum counts in consecutive years ([2017 yearlings/2016 lambs], Table 5). Using these measures, lamb survival for herds surveyed in the summer is from 3-15 months and for herds surveyed in winter is from 9-18 months. Lamb survival varied from 0-100% (Table 4). Lamb survival was highest at Langley, Wheeler, and Big Arroyo and lowest at Laurel, Olancha, Convict, and Warren (Table 4). However, all lamb survival estimates should be considered cautiously because with small herd sizes (N<100), unrepresentative observations and/or unequal sex ratios may contribute to biased estimates.

Table 5. Sierra bighorn lamb survival (3-15 months) estimated from small herds with annual counts. Cathedral is not included because no lambs were born there in 2016 or 2017; no rams were present to breed the ewes.

Herd	2016 All Lambs	2017 All Yearlings	All Lamb Survival	2016 Female Lambs	2017 Female Yearlings	Female Lamb Survival
Olancha	6	4	67%	3	1	33%
Big Arroyo	5	3	60%	2.5	2	80%
Convict	8	0	0%	4	0	0%
Gibbs	11	6	55%	5.5	3	55%
Warren	5	1	20%	2.5	0	0%
Totals	**35**	**14**	**40%**	**17.5**	**6**	**34%**

This was the second and final year of a lambing study designed to understand why pregnancy rates (average 85%) are higher than observed lamb:ewe ratios (42% averaged by herd in 2017, summer observations only). In March 2017, 13 vaginal implant transmitters (VITs) were placed in pregnant ewes at Baxter, Sawmill, Wheeler, and Langley. These ewes and their lambs were monitored for several months after birth (Table 6). The lamb:ewe ratio within this project was 81%, which is higher than our observed ratios (Table 4). When a VIT is expelled, it sends a signal via the satellite collar on the female that expulsion has occurred so staff can investigate the site. Just over half (7/13, 54%) of VIT expulsion sites were investigated, due to limited staff availability and heavy snow conditions that made access difficult. None of the Baxter VIT expulsion sites were investigated (N=5), while all Sawmill (N=4) and Langley (N=1) and all but one of the Wheeler (N=2/3) site were investigated. Although VITs are designed to be expelled during the birthing process, they are also occasionally expelled before birth, sometimes more than a month early. Of the 7 VIT expulsion sites investigated, 3 were clearly not birth sites, 1 lamb was not approachable, 1 lamb was stillborn, and 2 lambs were captured by hand. One collared lamb is presumed alive and the other died the day after capture from rockfall (Table 6).

Table 6. Results from Sierra bighorn lamb project that tracked 13 pregnant females with vaginal implant transmitters (VITs) and their lambs. VITs were placed in March 2017. ID refers to the female with the VIT implant.

Herd	ID	VIT Drop	Outcome	Lamb ID	Lamb Status
Baxter	S465	4/14/2017	No capture attempt: staff not available. VIT site not investigated. Lamb observed 4/15 and 4/26/17.	NA	presumed alive
	S464	5/5/2017	No capture attempt: bad weather. Repeatedly observed with lamb summer and winter.	NA	presumed alive
	S463	5/6/2017	No capture attempt: bad weather. Observed lamb suckle 6/21/17.	NA	presumed alive
	S462	5/27/2017	No capture attempt: steep terrain and snow conditions. Ewe not observed until winter, lamb status not identified.	NA	unknown
	S323	Not Recorded	Not investigated. Animal observed 6/8/17 with lamb.	NA	presumed alive
Sawmill	S457	5/16/2017	Lamb present and captured. Observed with lamb 7/11/17.	S472	presumed alive
	S458	Not Recorded	VIT expelled early. No capture attempt. Observed with lamb through summer. Ewe died 4/4/18 from lion kill.	NA	presumed alive
	S460	4/12/2017	VIT investigation found no evidence of birth. GPS cluster indicates lambing on 5/12/17. Lamb observed 6/8 and 7/11/17.	NA	presumed alive
	S323	5/16/2017	Lamb present, not able to approach without being seen. Lamb seen 6/8/17.	NA	presumed alive
Wheeler	S466	5/5/2017	VIT investigation found no evidence of birth. GPS cluster indicates lambing on 5/16/17. Seen 5/22 and 6/15 with lamb.	NA	presumed alive
	S468	4/24/2017	Lamb present and captured.	S471	died from rockfall 4/26/17
	S417	5/29/2017	Not investigated, not conducive to capture. Observed with lamb 6/15/17.	NA	presumed alive
Langley	S470	4/4/2017	Stillborn. S470 found dead 4/10/17 from capture-related aspiration pneumonia.	NA	stillborn
Summary	**13 VITs**	**13 VIT Drops**	**2 collared lambs (15%), 8 uncollared lambs (62%), 1 unknown lamb status (7.5%), 1 stillborn (7.5%).**	**9 lambs alive (81%, includes S472), 1 died rockfall (11%), 1 stillborn (11%)**	

Collaring and Translocation Efforts

Capturing Sierra bighorn provides the opportunity to determine body condition and pregnancy status, test for disease, measure genetic diversity, and deploy collars. Collared animals are critical for monitoring habitat use, disease risk, vital rates, and for estimating herd size. As of May 1, 2018, there were 104 collared females, 41 with functional GPS collars, and 51 collared males, 15 with functional GPS collars. Most capture and collaring efforts focus on females, as they tend to drive population dynamics. However, collared males can help identify patterns of habitat use and identify disease risk from contact with domestic sheep. Power analyses indicate we need to maintain radio collars on 35% of the female population in order to detect a 10% change in survival over 10 years (German 2010). We currently estimate 39% of females are collared, but collars are not distributed equally across herds (Figure 12, Appendix C).

During October 21-26, we captured 27 adult female and 7 adult male (N=34) bighorn across eight herds (Olancha, Gibbs, Bubbs, Williamson, Sawmill, Baxter, Big Arroyo, and Langley). We translocated 2 of the males to Cathedral: 1 from Sawmill and 1 from Baxter. During March 24-25, we translocated 7 Sierra bighorn: 3 females and 2 males to Big Arroyo from Baxter, and 1 male and 1 female to Olancha from Wheeler. We brought all captured animals into a central handling area, processed them, and then held them until the helicopter could transport them back to their capture location. If they were to be translocated, animals were placed in transport boxes to be moved by truck to a release location (for Olancha) or helicopter pick up location (for Cathedral and Big Arroyo). Leading Edge Aviation conducted all captures using a net-gun fired from a helicopter. All animals were alive two weeks post capture based on GPS collar locations and telemetry. In addition, we captured two neonatal lambs by hand as part of the lamb survival study (both males, S471 and S472). On April 25, we caught the lamb of Wheeler female S468 near Lion Kill Canyon and on May 17, we caught the lamb of Sawmill female S457 in Armstrong Canyon. For all captures, we did not detect *Mycoplasma ovipneumoniae* (*M. ovi*) by PCR, and ELISA results from blood serum indicated no previous exposure to *M. ovi*.

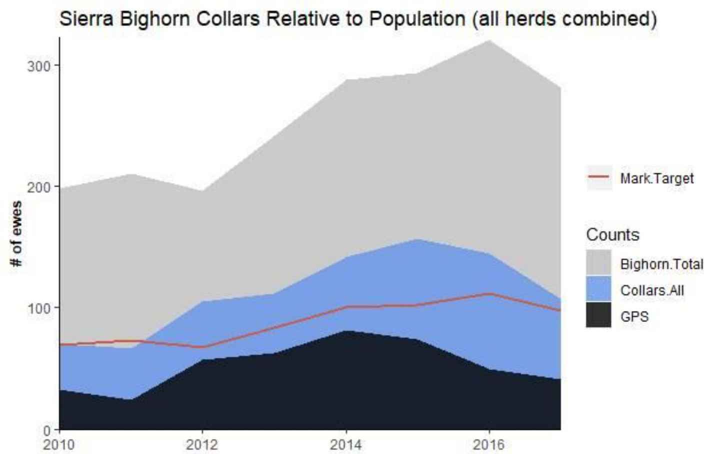
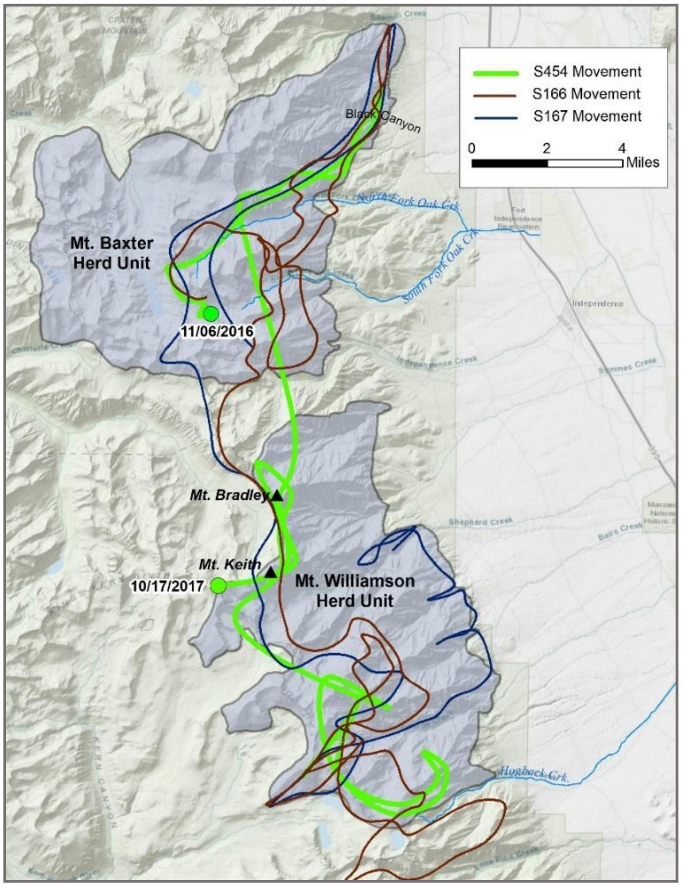


Figure 12. Proportion of female Sierra bighorn collared as a proportion of the population estimate. The target for monitoring herds is 35% collared (red line).

Sierra Bighorn Movements

After capture in October 2016, Baxter ram lamb S454 initially used the core area of Baxter, moving to low elevation range near Black Canyon in the winter and to upper Oak Creek in the spring (Figure 13). However, from June 18-21, 2017, S454 left Oak Creek and traveled south to Mt. Bradley, outside the Baxter herd unit, as a yearling. He stayed in the Mt. Bradley and Mt. Keith region for one month before continuing south to upper Hogback Creek in the Williamson herd unit where he was observed with five other adult rams. Genetic data was not collected to determine if the other rams were from Baxter or Williamson, which may have indicated whether S454 traveled alone or within a group. This movement is similar to movements from Baxter ewes S166 and S167 that moved to Williamson in 2010 (Few et al. 2011). These ewes moved independently from one another, with S166 establishing permanent residence



in Williamson, and S167 moving back to Baxter in August 2011. All three took a similar travel path by moving along the Sierra crest to Mt. Keith, Junction Pass, and then Shepherd Pass (Figure 13).

Figure 13. Movements of Sierra bighorn ram S454, and ewes S166 and S167 between Baxter and Williamson. Ram S454 movements are from November 2016 - October 2017. Movements of females took place from 2009 - 2012.

Post-Translocation Movements

Translocation often yields unexpected results as released animals respond to novel terrain. Post-translocation movements are often larger or more directional than movements of bighorn in established herds (see Appendix D for Sierra bighorn translocation history).

Cathedral Range

In October 2017, rams S488 and S489 were translocated from Baxter and Sawmill to Parsons Plateau in Cathedral because all Cathedral rams had died the previous winter (N=6). In 2017, rams released at Parsons Plateau moved less than those released in the Lyell Basin during previous translocations (Greene et al. 2017, Figure 14). Ram S488 stayed in Cathedral while ram S489 moved immediately north to the Kuna Crest in the Gibbs herd unit. Based on GPS collar locations, S489 encountered ewe S250 near Kuna Pass and spent the winter around Blacktop Peak with the Alger deem, a subunit of Gibbs. Ram S489 developed a home range that extended to Mt. Lewis and Bloody Canyon in the summer. After release, S488 travelled southeast to the Lyell

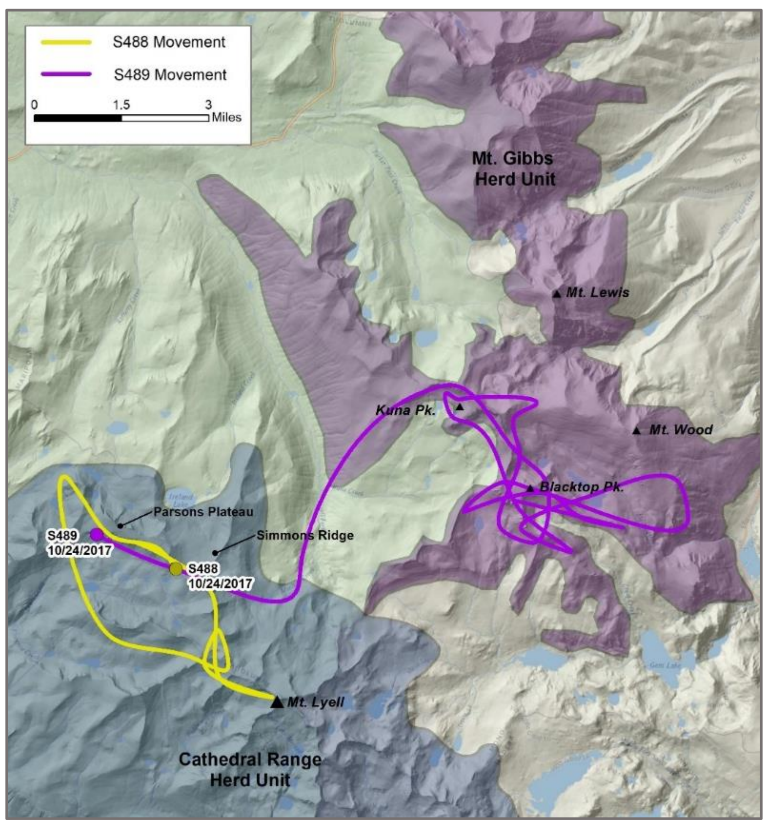


Figure 14. Post translocation movements of 2 Sierra bighorn rams in Cathedral from October 2017 to April 2018.

basin and then back to Parsons Plateau in early November, where ewe S375 was located (Figure 14). If any lambs are born in 2018 in Cathedral they will likely have been sired by S488, or by Gibbs rams that moved to Cathedral undetected. For the remainder of the winter, S488 used the Parsons Plateau and the Simmons Ridge within the Cathedral herd unit.

Big Arroyo

In March 2018, we translocated 3 ewes (2 pregnant), and 2 rams to Funston Meadow along the Kern River in the Big Arroyo herd from Baxter. On April 6, the first interaction occurred between resident ewe S289 and newly translocated ewe S497 above Funston meadow based on GPS collar locations. Three days later, resident ram S490 moved to Funston creek and likely interacted with the entire group of newly translocated bighorn. He moved back to the resident group after five days. On April 20, newly translocated ewe S497 joined the resident bighorn in the Big Arroyo and remained with this group for the rest of the month. Although these interactions occurred almost immediately after translocation, it does not appear that the augmented animals have fully integrated with the resident Big Arroyo animals. The two groups have remained mostly divided, with resident bighorn in the Big Arroyo and newly translocated bighorn at Funston Creek. Poirier and Festa-Bianchet (2018) observed that for translocated bighorn sheep in Alberta Canada, social integration into the resident population took about a year. Due to high rates of received aggression, translocated bighorn initially avoided resident conspecifics, but were able to create social networks and gradually assimilate into the population over time.

Olancha Creek

Since Olancha was established in 2013, 8 bighorn have been added to the population via subsequent trans-locations (Appendix D). In March 2018, one ewe (S494) and one 3-year-old ram (S493) were translocated to Olancha from Wheeler. The animals were released at Falls Creek, one drainage south of Olancha Canyon. This release site has vehicle access, which makes translocation more feasible due to helicopter time limitations. After release, ram S493 immediately moved into Olancha Canyon while ewe S494 moved south of Round Mountain, outside of the herd unit boundaries, where there were no known Sierra bighorn (Figure 15).

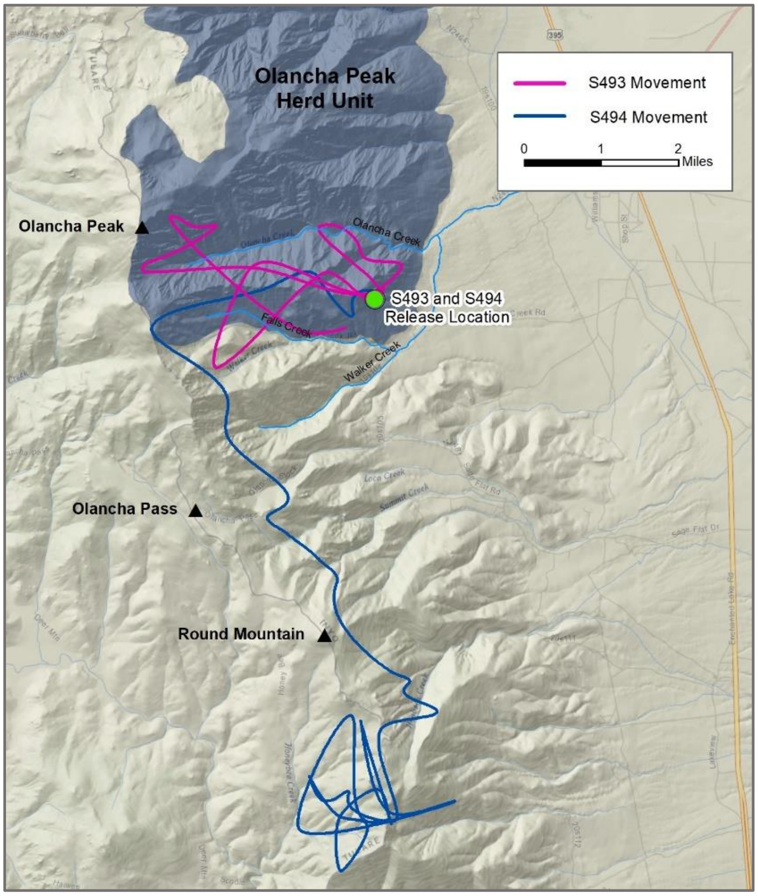


Figure 15. Sierra bighorn movements of ewe S494 and ram S493 after translocation in to Olancha from March – April 2018. Since the timeframe of this report, she has integrated with the Olancha herd.

Movement outside the intended herd unit is not uncommon for animals released at Falls Creek, where bighorn have been released on 6 separate occasions. During the initial reintroduction in 2013, there were 3 release events. During the first event, all 11 bighorn (10 ewes and 1 ram) remained north of Falls Creek. On the second event, 2 rams were released. While both moved initially to Olancha Creek, S196 made a transient movement to Olancha Pass before returning after 3 days. On the last release for reintroduction, only 1 ram was released, and he remained between Walker and Falls Creek. In 2014, 4 translocated individuals were released together and moved north to Olancha with no explorations south. In 2015, 2 rams were released and went in opposite directions. Ram S358 moved north and ram S197 remained between Falls and Walker Creek until late April where he moved farther south to Round Mountain. During the last release in 2018, S494 moved south while S493 moved immediately to Olancha. Four of the six release events resulted in individuals moving south of Falls Creek within one month of release. All southern movements were associated with releases involving two or fewer individuals. This suggests that group size may affect movements of translocated animals.

Predator Monitoring and Management

During 1999-2011, we captured, collared, and intensively monitored individual lions that potentially used Sierra bighorn habitat (Davis et al. 2012). We monitored lion abundance by conducting systematic surveys to identify uncollared lions within 3 count zones (Figure 2) and developed minimum counts. Over this period, we captured 97 individual lions (52 males, 42 females, 3 unknown sex) on 158 occasions. The minimum number of resident adults inhabiting these count zones averaged 11 annually[1] (range = 8-15). We documented a minimum of 71 Sierra bighorn killed by lion predation and we lethally removed (hereafter, removed) 24 lions (13 males, 9 females, 2 unknown sex) to minimize additional predation losses of Sierra bighorn.

During 2012-2015, lion monitoring efforts were largely discontinued. Track surveys were sporadic, limited to the south count zone, and capture efforts did not resume until March 2017 when 2 lions (140 and 141) were captured and collared. Two others (142 and 143) were removed April 2017 in response to a substantial predation episode that occurred within the Langley herd. During this episode, at least 18 Sierra bighorn were killed by lions over a 4-month period, including 13 of the estimated 51 adult ewes (25%) in the herd. In the fall of 2017, lion monitoring efforts resumed in earnest, but with ~25% of the staffing that was available during 1999-2011[2].

Figure 16. Female mountain lion at a cage trap near the Sierra bighorn Wheeler herd unit, February 2018.

[1] Minimum count data is for 1999-2010. Monitoring efforts in 2011 were insufficient for producing a count.

[2] During 1999-2011, there were generally 4 personnel (2 USDA Wildlife Services lion capture specialists and 2 assistants) conducting lion captures and monitoring throughout the year. When monitoring resumed in 2017, lion capture efforts were reduced to ~6 mos/yr with 1 lion capture specialist and 1-2 assistants. Track survey efforts were reduced, and remote camera surveys were more important than in the past.

This section summarizes lion monitoring for the bighorn animal year 2017 (May 1, 2017-April 30, 2018), the first complete year after the 2012-2015 hiatus in which substantial effort was made to monitor lions.

Lions are categorized by age class throughout the report. Age classes are defined as:

- adult: >24 months of age
- subadult: <24 months of age

Lion Captures

During 2017 we captured 6 individual lions on 6 occasions, including 1 subadult female and 5 males (Figure 16 and Table 7). Compared to previous years, the number of lions captured in 2017 was below average ($\overline{x}$ = 10.8 unique lions captured annually, 1999-2011) (Table 8). All 6 lions handled in 2017, as well as 3 of the 4 handled in 2016 were previously unmarked (one was previously marked by the Nevada Department of Wildlife in Nevada, and then traveled into California). This was expected given the lack of capture effort during 2012-2015.

Table 7. Mountain lion captures in the eastern Sierra Nevada during 2017.

Lion	Sex	Age	Capture Date	Count Zone[a]	Location	Capture Method	Collared?
144	M	adult	10/13/2017	North	Williams Butte	hounds	Yes
145	M	subadult	10/27/2017	North	Williams Bute	hounds	Yes
146	F	subadult	2/2/2018	Central	Pine Creek	cage trap	Yes
147	M	adult	3/5/2018	South	North Lubkin	cage trap	Yes
148	M	adult	3/29/2018	Central	Wells Meadow	cage trap	Yes
149	M	adult	4/12/2018	South	Sawmill Canyon	cage trap	Yes

[a]Refers to the primary count zone in which the lion resided, see Figure 2 for map

Table 8. Age and sex (male, female, and unknown) distribution of mountain lions captured in the eastern Sierra Nevada, 1999-2017. If individuals were captured >1 time in a year, age and sex at the initial capture is recorded.

	Adult		Subadult			
Year	M	F	M	F	U	Total
1999	2	1	0	0	0	3
2000	4	4	1	0	0	9
2001	3	2	4	2	0	11
2002	3	5	2	1	0	11
2003	4	5	4	4	0	17
2004	4	3	1	0	0	8
2005	4	6	3	1	0	14
2006	2	1	1	1	0	5
2007	3	5	2	2	0	12
2008	6	5	2	1	0	14
2009	2	2	2	6	0	12
2010	4	6	4	3	2	19
2011	1	2	1	1	0	5
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	1	2	1	0	0	4
2017	5	0	0	1	0	6

Lion Mortalities and Emigration

We documented 3 lion mortalities during 2017, including 1 subadult female and 2 subadult males, all of which were human-caused (Table 9). Notably, lion 140, who died after a vehicle collision on 12/9/2017 along highway 395 in Round Valley, had been previously struck by a vehicle earlier in the year. He survived the initial collision, moving very little over the course of several weeks while taking shelter in a culvert. We did not detect losses in the population due to emigration during 2017 (Table 10).

Table 9. Documented mountain lion mortalities in the eastern Sierra Nevada 2017.

Lion	Sex	Age	Date	Collared?	Count Zone	Location	Cause
140	M	subadult	12/9/17	Yes	Central	Round Valley	vehicle collision
N47	M	subadult	1/25/17	No	NA[a]	Nine Mile Canyon	vehicle collision
150	F	subadult	4/23/18	No	NA[a]	Haiwee Canyon	vehicle collision

[a]Location was not within one of the 3 count zones

Excluding capture-related mortalities (N=6), since 1999 we have documented the deaths of 58 collared lions (Table 10) and 28 uncollared lions (Table 11). In both cases, the dominant causes of mortality were human-related, which is typical for most lion populations, whether they are hunted (as in most of the western U.S.) or whether hunting is prohibited, such as in California and Florida (California lions are protected from hunting by the state government and considered a "specially protected mammal," and the Florida panther is protected from hunting by the federal government under the Endangered Species Act).

Table 10. Causes of collared lion population loss (mortalities and emigration) in the eastern Sierra Nevada, 1999-2017, excluding capture-related mortalities. Zero mortalities were documented during 2013-2015 because no lions were collared during this period.

Year	Sierra bighorn management[a]	Depredation[b]	Vehicle-collision	Emigration	Intra-specific killing	Other[c]	Unknown	Total
1999	1	0	0	1	0	0	0	2
2000	1	0	0	0	0	0	1	2
2001	0	0	1	1	1	1	0	4
2002	0	0	0	3	1	0	1	5
2003	2	2	1	0	0	0	0	5
2004	1	1	0	1	0	0	0	3
2005	0	0	1	0	1	0	1	3
2006	1	1	0	1	0	1	1	5
2007	1	0	0	0	1	0	0	2
2008	1	2	0	0	1	1	3	8
2009	5	0	0	0	0	0	0	5
2010	2	3	0	0	0	1	2	8
2011	0	1	1	0	0	0	0	2
2012	0	0	2	0	0	0	0	2
2016	1	0	0	0	0	0	0	1
2017	0	0	1	0	0	0	0	1
Total	**16**	**10**	**7**	**7**	**5**	**4**	**9**	**58**

[a]Lethally removed to reduce predation on Sierra bighorn
[b]Lethally removed for depredation upon domestic livestock/pets (N=9) or due to public safety threat (N=1)
[c]Includes natural causes (N=2), starvation (N=1), and poaching (N=1)

Table 11. Causes of uncollared lion mortalities in the eastern Sierra Nevada, 1999-2017.

Year	Sierra bighorn management[a]	Depredation[b]	Vehicle-collision	Other[c]	Unknown	Total
1999	1	2	0	1	0	4
2000	0	2	0	1	0	3
2001	0	0	0	0	0	0
2002	0	0	1	0	0	1
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	1	3	1	0	0	5
2006	0	0	0	0	0	0
2007	0	1	0	0	0	1
2008	2	0	1	0	1	4
2009	3	0	0	0	0	3
2010	2	0	0	0	0	2
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	1	0	0	0	1
2014	0	0	0	0	0	0
2015	0	0	0	0	0	0
2016	1	0	0	0	1	2
2017	0	0	2	0	0	2
Total	10	9	5	2	2	28

[a]Lethally removed to reduce predation on Sierra bighorn

[b]Lethally removed for depredation upon domestic livestock/pets (N=8) or due to public safety threat (N=1)

[c]Includes natural causes (N=2), starvation (N=1), and poaching (N=1)

The most common cause of lion mortality, lethal removals for Sierra bighorn protection, peaked in 2009 (N=8, Tables 10 and 11). In total, 26 lions were removed for Sierra bighorn protection, an average of 1.4/year, although in 8 years no lions were removed (Tables 10 and 11). Depredations and vehicle collisions were the second and third most common causes of mortality, respectively, and remained relatively low, with mean values of 0.9/year and 0.6/year, respectively. Despite having few collars deployed during 2011-2017, it is unlikely that there were many additional deaths due to depredation and vehicle collisions, because depredation permits are issued and recorded by CDFW and vehicle collisions are routinely reported by the California Department of Transportation or members of the public.

We used telemetry to monitor 8 individual lions during 2017. Each lion was fitted with a GPS collar programmed to obtain 6 fixes/day. Some lions were fitted with a secondary VHF collar. The mean duration of monitoring was 145 days (11-365 days). Six of these lions (75%) remained active at the end of the reporting period (Table 12).

Table 12. Radio-monitored lions in the eastern Sierra Nevada during 2017.

Lion	Sex	Age	Days Monitored	Status[a]
140	M	subadult	223	Killed
141	F	adult	365	Active
144	M	adult	200	Active
145	M	subadult	186	Active
146	F	subadult	88	Active
147	M	adult	57	Active
148	M	adult	33	Active
149	M	adult	11	Lost collar

[a]As of the end of the reporting period

Lion Population Monitoring

We monitored trends in lion abundance annually by conducting minimum counts of lions known to have been alive, following McBride et al. 2008 (Appendix B). During 2017, we documented a minimum of 19 lions in the eastern Sierra lion population, 17 of which occurred within the 3 count zones. Collared lions accounted for 8 individuals (2 that were collared in 2016 and 6 that were collared in 2017). Unmarked lions were discerned from each other by mortalities (N=2) and categorizing physical evidence based on sex, time, and distance rules (Davis et al. 2013, Table 13).

Table 13. Individual lions documented to be alive during 2017 in the eastern Sierra Nevada.

Count Zone[a]	Lion ID	Sex	Age	Reason Counted
North	144	M	adult	collared
	145	M	subadult	collared
Central	140	M	subadult	collared
	141	F	adult	collared
	NA	U	subadult	observed with mother (141)
	146	F	subadult	collared
	148	M	adult	collared
	NA	F	adult	incidental photograph (mother and 3 subadults)
	NA	U	subadult	incidental photograph (mother and 3 subadults)
	NA	U	subadult	incidental photograph (mother and 3 subadults)
	NA	U	subadult	incidental photograph (mother and 3 subadults)
South	133	F	adult	trail camera photo
	147	M	adult	collared
	149	M	adult	collared
	NA	M	adult	track
	NA	U	adult	trail camera photo
	NA	F	adult	trail camera photo
Outside of count zone	N47	M	adult	mortality-vehicle collision
	150	F	subadult	mortality-vehicle collision

[a]For collared lions, refers to the primary count zone in which the lion resided. For uncollared lions, refers to count zone in which the most observations occurred (which may be as few as 1).

In 2017 we documented the greatest number of individual lions since the lion monitoring program for Sierra bighorn began, which is especially noteworthy given that survey effort was a fraction of what it was during 1999-2011. In addition, while we consider counts in the north and south zones to be reasonably complete, we did not conduct track surveys in the central zone in 2017. As the central zone typically has higher lion densities than the other two zones, due to a higher mule deer concentration, it can be reasonably assumed that the true abundance of lions in the central zone in 2017 exceeded our count of 2 adult females, 1 adult male, and 6 subadults. It is likely that at least 1-2 undetected adult females were present, considering previous occupancy rates. Ideally, minimum counts from 1999-2016 would be provided with this report to help contextualize the 2017 count, but these data are currently being analyzed. We anticipate providing the results in future annual reports.

Lion Reproduction and Recruitment

In 2017, 2 of the 3 adult females (67%) detected had at least one offspring (Table 14). Ideally, we would compare reproductive parameters, such as the proportion of females with offspring and litter sizes, across years, but currently these data are not available. While we have minimum counts for all age classes and can derive population level subadult:adult ratios, it is not always clear, even with our marked sample of adult females, which individuals had offspring and how many each female had. We hope to review our records and present this data in future annual reports.

Table 14. Known resident adult female mountain lions and minimum litter sizes in the eastern Sierra Nevada during 2017.

Lion	Minimum Litter Size	Notes
133	NA	No evidence of reproduction
141	1	1 kitten observed during a kill investigation
Unmarked	3	Family group photographed in Swall Meadows
Unmarked	NA	No evidence of reproduction

Predator-Prey Interactions

We documented 11 Sierra bighorn killed by lions in 2017 (7 adult females, 2 adult males, 1 yearling male, and 1 bighorn of unknown age and sex). Lion 149 was responsible for one of these kills; the identities of the lions responsible for the remaining 10 kills could not be determined. Lion predation was documented in 6 herds: 4 in Langley, 3 in Sawmill, and 1 each in Taboose, Baxter, Wheeler, and Gibbs. It is noteworthy that this much predation was documented at Langley because it represents the second year in a row of elevated predation relative to historic levels. For example, during 1999 and 2015, an average of only 0.6 lion-killed Sierra bighorn were detected annually at Langley.

Research

To better understand the factors driving adult female Sierra bighorn survival, we used a known fate survival analysis to assess the role of age, sex, climate, habitat, population size, and predation (Conner et al. 2018). Sierra bighorn survival declined continuously with age and varied between males and females by location. Top models for both males and females included spatial separation between southern and central recovery units as well as between Warren and Gibbs within the northern recovery unit (Conner et al. 2018). Warren and Gibbs are known to have asynchronous vital rates (Johnson et al. 2010). For females, top models included a measure of predation risk, avalanche danger, and forage availability. For males, top models included a measure of forage, climate, and avalanche risk. Predation measures were not in the top models for males. Publication of this work was possible through a contract with Utah State University.

In 2018, the Journal of Wildlife Management had a special section on Mountain Sheep Management. In an invited paper, Monteith et al. (2018) included a new case study on Sierra bighorn horn growth. Based on 175 measurements of ram horn size, as well as body condition and weight measurements from captured female Sierra bighorn (115 from spring and 118 from fall), Monteith et al. (2018) found differences between herds, indicating the nutritional conditions of these herds varied, with the largest and fattest animals at Gibbs, and the thinnest, smallest animals in Warren. In addition, Monteith et al.

(2018) found a strong relationship between male horn size (projected for age 7) and female body size in spring (R^2=0.93). There was also a strong relationship between male horn size (projected to age 7) and ingesta-free body fat in females in spring (R^2=0.80) and fall (R^2=0.86, Monteith et al. 2018). This demonstrates the importance of nutrition, and possibly maternal condition, on horn size (Monteith et al. 2018). Collaboration with the University of Wyoming facilitated this publication.

Derek Spitz published one of his dissertation chapters (University of Montana) on the plasticity of Sierra bighorn migratory behavior (Spitz et al. 2018). Sierra bighorn are partially migratory because some 'resident' animals stay at high elevations during the winter while other 'migrant' animals move to lower elevations. Analyzing data from 2005 to 2016, Spitz et al. (2018) found that two herds were entirely migratory (Wheeler and Laurel) and Gibbs was the only herd that was entirely resident, while all other herds had a mixture of resident and migrant behavior. In addition, on average, any given individual switches tactics every four years (Spitz et al. 2018).

Public Outreach

We hosted two joint field trips with the Sierra Nevada Bighorn Sheep Foundation (SNBSF) in February and April with a total of 62 participants. The SNBSF also added a high school program in Lee Vining that included a population board game developed by Recovery Program staff Alex Few, Dave German, and Derek Spitz. In addition, SNBSF supported Girl Scout Troop 580 Bronze Award team's "Project Bighorn". Fifth grade troop members Kaihla Halferty, Katherine Truax, Ellie Crall, Lucy Perry, and Sage Harper, under the supervision of leader, Drea Perry, helped with multiple classroom presentations and hosted the Project Bighorn open house March 10 in Mammoth Lakes (Figure 17). These five girls designed a scavenger hunt, made a quiz on the internet site Kahoot, made art for young children to color, took photos with trail cameras, made brochures about Sierra bighorn, presented a skit about disease passage between domestic and bighorn sheep, sold refreshments and Girl Scout cookies, read stories, and supported John Wehausen in his demonstration of tracking collared bighorn. They also inspired a rap song about bighorn. Steve Yeager provided a slide show of his incredible bighorn sheep photos and Julie Rolfe stenciled shirts and bags for Project Bighorn.

Figure 17. Bronze Award Team from Girl Scout troop 580 with Sierra Nevada Bighorn Sheep Foundation members. Clockwise from upper right: Dr. John Wehausen (SNBSF), Sage Harper, Katherine Truax, Lucy Perry, Ellie Crall, Kaihla Hafferty, Ginnie Chadwick (SNBSF) and troop leader Drea Perry.

Acknowledgments

Numerous personnel contributed to recovery efforts, data collection, and public outreach this year. Recovery Program staff include: Elsbeth Otto, Jackie Leary, Todd Calfee, Vicki Davis, Brian Hatfield, Dennis Jensen, Jon Weissman, and Shannon Forshee. Additional CDFW staff include: Paige Prentice, Ashley Evans, Danielle Glass, Rick Ianniello, Jonathan Fusaro, Jane McKeever, and Mike Morrison. SNBSF volunteers include: John D. Wehausen, Virginia Chadwick, Jora Fogg, and Julie Rolfe. In addition, helicopter pilot Jim Pope, fixed-wing pilot Geoff Pope, as well as CDFW warden pilot Michael Breiling provided many hours of safe flying. Additional collaborators include: Sarah Stock (Yosemite National Park), Erin Nordin (USFWS), Sherri Lisius (BLM), Sheena Girner (BLM), and Carrie Schlick (USFS).

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Literature Cited

California Department of Water Resources. 2018. Water Year 2018 : Hot and Dry Conditions Return.

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.

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

Davis, J. L., S. W. Carlson, C. C. Coolahan, and D. L. Orthmeyer. 2012. Sierra Nevada Bighorn Sheep Recovery Program: The Role Of USDA Wildlife Services, 1999-2011. Sacramento.

Doak, D. F., and K. Cutler. 2014. Re-evaluating evidence for past population trends and present dyanmics of Yellowstone grizzly bears. Conservation Letters 7:312–322.

Few, A. P., K. Knox, D. W. German, J. D. Wehausen, and T. R. Stephenson. 2013. 2013 Translocation Plan for Sierra Nevada Bighorn Sheep: <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=117097>.

Few, A. P., K. Knox, D. W. German, J. D. Wehausen, and T. R. Stephenson. 2015. 2015 Translocation plan for Sierra Nevada bighorn sheep : A focus on strategic planning. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=117097&inline.

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

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:457–481. <http://www.jstor.org/stable/2281868>.

McBride, R. T., R. M. McBride, R. M. McBride, and C. E. McBrdie. 2008. Counting pumas by categorizing physical evidence. Southeastern Naturalist 7.

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.

Monteith, K. L., R. A. Long, T. R. Stephenson, V. C. Bleich, R. T. Bowyer, and T. N. Lasharr. 2018. Horn size and nutrition in mountain sheep: Can ewe handle the truth? Journal of Wildlife Management 82:67–84.

Poirier, M. A., and M. Festa-Bianchet. 2018. Social integration and acclimation of translocated bighorn sheep (Ovis canadensis). Biological Conservation 218:1–9. Elsevier. <https://doi.org/10.1016/j.biocon.2017.11.031>.

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.

Spitz, D. B., M. Hebblewhite, T. R. Stephenson, and D. W. German. 2018. How plastic is migratory behavior? Quantifying elevational movement in a partially migratory alpine ungulate, the Sierra Nevada bighorn sheep (Ovis canadensis sierrae) . Canadian Journal of Zoology 96:1385–1394.

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.

Appendix A: Herd Unit Summaries

Summaries of herd units monitored between May 1, 2017 and April 30, 2018

Olancha Peak

We surveyed Olancha August 15-16, 2017. All collared females were seen and 2 of the 3 collared males (S358, S322) were not seen. The reconstructed minimum count was 21 adult females, 1 yearling female, 6 lambs, 7 adult males, and 3 yearling males. This included 3 more uncollared females than the 2016 count, in which not every collared female was observed, indicating our 2016 count was not a census. The only collared mortality was male S322, which was first detected during a survival flight in March and not yet investigated. Male S322 was translocated from Sawmill to Laurel in March 2015 and then emigrated to Olancha around November 2015. In October 2017, 4 females (S271, S274, S278, S292) were recaptured and an additional 2 uncollared adult females (SS473, S474), 1 uncollared female yearling (S475), and 1 uncollared male (S476) were also captured. Three females had neck sores from their old Televilt Tellus Iridium 2D GPS collars (S292, S271, S274) deployed in 2013 and 2014. Female S292 had the most severe sores on the back of her neck and was released without any collars. Female S271 was given a new VHF collar but no GPS collar, and female S274 was deemed ok for new VHF and GPS collars. All other bighorn received both a VHF and a GPS collar per normal practice. Groups of Olancha bighorn were twice observed at lower elevation during the winter: on January 24, north of Olancha Canyon, and on February 3, south of Olancha Canyon. In March 2018, we translocated an adult female (S494) and a three-year-old male (S493) from Wheeler to Olancha. Post translocation the male stayed within the occupied Olancha herd unit, but the female moved south along the crest near Round Mountain outside of the herd unit. We hope these new collars will help us track this herd as it continues to grow and expand. As of May 1, 2018, we estimated 59% of females were marked (N=13/22), 55% with functional VHF (fVHF) collars and 27% with functional GPS (fGPS) collars. We estimated 40% of known males (N=4/10) were marked, all with fVHF collars, and 20% with fGPS collars.

Laurel Creek

We did not perform a systematic survey of Laurel in 2017. Instead, during recovery of winter mortalities in June, we opportunistically observed 2 adult females and 1 lamb. This included the only remaining collared female (S382). The other collared female (S377) had been heard consistently on live during survival flights from January - May but was heard on mortality June 8th from the ground. When investigated, all that remained were collars. We estimated the date of death for S377 to be May 10 2017, the last flight with a live signal. The one collared male (S352) moved to the Big Arroyo herd in December 2017. It is unknown at this time whether this represents a seasonal movement or a permanent emigration. Until more time has passed, we will continue to consider this animal as part of the Laurel herd. Based on our observations from this animal year, 50% of females (N=1, S382) were collared and 100% of males were collared (N=1, S352).

Big Arroyo

In Big Arroyo, we counted 7 adult females, 2 yearling females, and 5 lambs during a survey September 2-4, 2017. All collared females were observed and no males were seen. In October 2017, we captured 4 animals using a remote basecamp in upper Funston Meadow. This included 2 recaptured females (S285, S289) and 2 new captures, including 1 adult female (S490) and 1 adult male (S491). In March 2018, 5 animals were translocated from Baxter to Big Arroyo including 2 adult females (S496, S497), 1 yearling female (S499), 1 adult male (S495), and 1 yearling male (S498). All were newly captured animals from Baxter. In December, male S352, that was initially translocated into Laurel, moved to Big Arroyo and began traveling with animals there. No collared animals died in Big Arroyo, so we ended the year with 9 adult females, 1 yearling female, 5 lambs, 3 adult males, and 1 yearling male. This herd was well marked: 89% of adult females were marked with fVHF collars and 67% had fGPS collars. As no uncollared males were observed this year we assumed 100% of males were collared.

Langley

Our best reconstructed minimum count for Langley included two surveys: August 29-30 and September 7-8, 2017. We accounted for 21 adult females, 5 yearling females, 3 lambs, 30 adult males, and 5 yearling males. We did not see 1 collared female (S173). In July 2017, a hiker photographed 2 uncollared males on Mt. Anna Mills. Mt. Anna Mills is between the Langley and Laurel herd units. In 2015, 3 Laurel males (S322, S311, S364) visited Mt. Anna Mills, but these individuals were either dead or known to be in a different area in July 2017. In 2012, a Langley male (S188) visited a nearby feature, the Boreal Plateau. We designated these males as Langley animals because at the time of the observation, GPS collared Langley animals were slightly closer (8 km) than Laurel animals (11 km). In October 2017, we captured 5 adult females (S477, S478, S480, S264, S343) and 1 yearling female (S479). We wanted to add collars in order to increase our ability to document mortality causes, particularly given that lion predation had increased dramatically during the 2016-17 winter. We documented 5 mortalities: 1 collared female (S340) died of unknown cause and the rest were killed by lions, including 2 uncollared adult males, 1 collared yearling male (S447), and 1 collared adult female (S70). In addition, 1 collared female (S173) was censored (see Appendix B for methods details). At the end of the year we estimated 40% of females were marked, 32% with fVHF collars (N=8), and 28% with fGPS collars (N=7). For males, 17% were collared, 11% with fVHF (N=4) collars, and 6% with fGPS (N=2) collars.

Williamson

This year we had the highest female count ever recorded for the Williamson herd. It occurred, not during the summer survey attempt in August, but from a series of opportunistic observations during March 9-14, 2018. There were 13 adult females, 2 yearling females, and 6 lambs. The highest male count of 5 adults and 1 yearling male occurred on August 11, 2017. All collared animals were seen. Included in the summer male group, although not counted here, was Baxter male S454, who has moved between Baxter and Williamson, but is still considered a Baxter animal at this time. An animal has to spend one full year in a new herd before we consider it to have emigrated. In October, we captured 3 previously uncollared animals including 2 adult females (S481, S482) and 1 adult male (S492). There were no mortalities and at the end of the year we estimated 29% of females were marked (N=5), 11% with fVHF collars (N=2) and 5% with fGPS collars (N=1). We also estimated 29% (N=2) of males were marked and 14% (N=1) had fVHF and fGPS collars.

Baxter

Our best survey for Baxter occurred during February 28 – March 6, 2018. We documented 41 adult females, 8 yearling females, 22 lambs, 29 adult males, 11 yearling males, and 1 unclassified animal. There were 2 collared males not seen but known to be present, and all collared females were seen. In the fall we captured 1 previously uncollared adult male from Baxter (S488) and moved it to Cathedral (along with Sawmill male S489). Throughout the year we documented 4 collared animal mortalities: 1 yearling female died from rockfall (S437), 2 adult males died of unknown causes (S432, S303), and one adult female (S229) was killed by a lion. At the end of the year, we estimated 36% of females were collared (N=20), 25% with fVHF collars (N=14), and 14% with fGPS collars (N=8). For males, we estimated 16% had collars (N=7), 2% with fVHF (N=1), and 5% with fGPS (N=2) collars.

Sawmill

Our best count occurred during July 11-12, 2017, which resulted in a minimum count of 38 adult females, 5 yearling females, 22 lambs, 9 adult males, and 3 yearling males. This count includes 3 collared females and 6 collared males not seen but known to be alive. In the spring of 2018, we hand-captured 1 male lamb (S472) from female S457. In the fall we captured 1 previously uncollared adult male (S489) and translocated him to Cathedral (along with Baxter male S488). We documented 3 collared adult females killed by lion (S319, S458, S449). No other mortalities were detected. At the end of the year we estimate 31% of females are marked (N=14), 13% with fVHF (N=6), 11% with fGPS (N=5) collars. We did not have a good male count for Sawmill, but we estimated there were up to 69% of males marked (N=11), 25% with fVHF (N=4), and none with fGPS collars.

Bubbs

There were no ground observations in Bubbs Creek. During the fall capture, we collared 3 adult females (S315, S317, S226). The capture crew observed a group of 12, including 3 adult females, 3 lambs, 3 males, and 3 animals of unknown sex and age. We still rely on our helicopter observation from 2003 as a baseline population size for Bubbs of 10 adult females, 1 yearling female, 9 lambs, 5 adult males, 1 yearling male, and 1 unknown aged female, for a total of 27 bighorn. We detected 1 collared female mortality (S315) in March, but were unable to get to it until June, so cause of death was undetermined. Based on our 2003 count, we estimated 17% of females were marked with fVHF (N=2) and 8% with fGPS (N=1) collars. We estimated up to 20% of the males were marked (N=1) and none of their collars were functioning.

Taboose

In spring 2017 we had three ground observations in Taboose that when combined resulted in a minimum count of 1 adult female and 3 adult males. The female is the only collared animal in Taboose (S412). The males were seen with a known Sawmill male (S357) who is excluded from the Taboose count to avoid double counting. We documented 1 uncollared male mortality from a lion in April. There were no captures in Taboose. At the end of the period, we estimated 100% of females were collared with a fVHF and GPS collar (N=1, S412), and no males were marked.

Wheeler

Our best count of Wheeler came from combining surveys from March 12 and March 19, 2018. We accounted for 38 adult females, 7 yearling females, 20 lambs, 17 adult males, and 1 yearling male for a total of 83 animals. This count includes 2 collared females and 5 collared males not seen but known to be alive. We documented 2 mortalities: 1 adult female (S240) from physical injury, and 1 adult male (S353) was killed by a lion. In the spring we captured an adult female (S494) and male (S493) and translocated them to Olancha. At the end of the period, we estimated 31% of females were marked

(N=14), 18% with fVHF (N=8), and 2% with fGPS (N=1) collars. In addition, there were up to 42% of males marked (N=8) – 21% with fVHF (N=4) and 5% with fGPS (N=1) collars.

Convict

We had a difficult time finding bighorn in Convict, despite multiple survey attempts. From a single observation on June 28, 2017, our best count of Convict was 5 adult females and 3 adult males. This includes 1 collared female (S175) and 1 collared male not seen. Female S175's collar has been intermittently on mortality, and plane locations indicate she was still moving until December 2018, when we estimate she died in Pioneer Basin, based on an investigation in July 2019. At the end of the period, we estimated 40% of females were marked (N=2), 20% with fVHF (N=1) collars, and 67% of males were marked (N=2). No animals in Convict had fGPS collars.

Cathedral

Throughout the summer we documented 6 females at Cathedral, which was a census of the population and included 4 collared females. In the fall we translocated 2 adult males to Cathedral: 1 from Baxter (S488) and 1 from Sawmill (S489). Based on GPS locations, male S489 moved to the Gibbs herd unit, and S488 appeared to join the Cathedral females. We detected no mortalities in Cathedral. At the end of the period 67% of females were collared (N=4), 50% with fVHF (N=3) and 17% with fGPS (N=1) collars. The 1 male had fGPS and fVHF collars.

Gibbs

Our best minimum count resulted from a combination of observations in July and August, 2017. We accounted for 21 adult females, 3 yearling females, 13 lambs, 2 adult males, and 3 yearling males. These totals include 1 collared female not seen but known to be alive (Alger female S250). The group that started as a translocation to Algers in spring 2015 is still relatively separate from the main herd associated with Mt. Gibbs. In the fall we captured 8 animals: 4 adult females (S334, S483, S172, S250), 1 yearling female (S485), 1 adult male (S487), and 1 yearling male (S484). In addition, male S489 that was initially translocated to Cathedral moved to the Gibbs area almost immediately after translocation in October 2017. We documented 2 adult female mortalities: S483 of malnutrition, and S172 was killed by a lion at low elevation in an area not typically used by bighorn. At the end of the period, we estimated 44% of females were marked (N=11), 28% with fVHF (N=7) and 12% with fGPS (N=3) collars. Although our male count was likely underestimated, up to 50% of males were marked (N=3), 33% with fVHF (N=2) and 17% with fGPS (N=1) collars.

Warren

By combining observations in June and July 2017 we accounted for 5 adult females, 2 lambs, 5 adult males, and 1 yearling male. The 1 collared female S89 was censored because she had not been observed for 2 years. We were unable to account for any cause specific mortality because we lacked any functioning collars. Compared to 2016, this count represents a loss of 9 uncollared individuals (2 males, 3 females, and 4 yearlings) in addition to the 5 collared animals that were known to have died in 2016. During spring capture, we briefly surveyed the area by helicopter but were unable to locate any females. A small group of males (<5) were observed, but they were in an area that was not conducive to capture. At the end of the 2017 animal year, there were no functioning collars despite several capture attempts in fall and spring.

Appendix B: Methods Details

Sierra Bighorn Minimum Counts

Minimum counts are "reconstructed" to include animals that were not observed during the survey but subsequently determined to have been present based on additional information. The most common way minimum counts are reconstructed is to add collared individuals known to be alive but not seen during the survey. 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. The previous year count will then be reconstructed. All reconstructions are carefully tracked in our database. Even with reconstructions, minimum counts are almost always a fraction of the true abundance, particularly as herds get above 20 individuals (SNBS unpublished data), as it is generally not possible to count every individual. We use a ratio to estimate male numbers because surveys target females and males tend to be in different areas (Schroeder et al. 2010). A collared animal is censored after two years without visual or radio telemetry observation; censor date is one month after the last observation (visual, telemetry, or GPS collar update).

Sierra Bighorn Population Dynamics

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. In addition, to prevent double counting in the case of translocations, which occur in the spring following winter counts, translocated animals were only included in summer counts and were removed from winter counts. Our range-wide abundance represents our best estimate of female population size post winter (Figure 6).

Mountain Lion Minimum Counts

Mountain lion minimum counts are the sum of the number of collared individuals, mortalities of unmarked individuals, distinct unmarked individuals present that can be identified, and adult females that must have been missed in a given year if such individuals were captured or found dead in subsequent years. Unmarked individuals are distinguished from each other by categorizing physical evidence (e.g., tracks, photographs, and GPS collar data) in a manner that uses sex (determined by track size or photographic evidence), time (determined for sign by known events such rain or recently dragged roads and for photographs by a timestamp), and distance between observations to avoid counting the same unmarked individual more than once (McBride et al. 2008, Davis et al. 2012). For example, the presence of an unmarked female could be determined if a fresh (i.e., from the previous night) female track is found greater than 6 miles (the maximum an eastern Sierra female lion is likely to travel in 24 hours) from the nearest collared female at the time the track was made. For males, this distance is 10 miles.

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 whether counts of animals in subsequent years reveal that a substantial number of animals were undetected in previous years. So, while there is little danger of overestimating abundance, the true abundance will almost always be 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).

The primary reasons that, despite being the best method available, minimum counts are potentially problematic are that (1) it is unknown what proportion of unmarked individuals present have been accounted for and (2) the ability to account for unmarked individuals is dependent on survey effort. For example, if a given area actually has 5 adult females present, one might determine with a small amount of survey effort that 2 of them exist. The true abundance in that case would be 60% greater than the minimum count, which may lead to inappropriate management recommendations. However, with additional survey effort, perhaps the remaining 3 could be accounted for, and the minimum count would equal the true abundance. In either case, one does not actually know what the true abundance is—the amount of survey effort required to count all individuals present is unknown. Given that survey effort varies annually, both in the amount of person-days devoted and in the skill-set of the individual surveyors, making comparisons of count data between years within the same area or within years between areas becomes problematic.

One method that could potentially be used to facilitate these needed comparisons is to determine catch-per-unit-effort (CPUE) ratios, with each unmarked lion counted being considered a "catch." CPUE ratios should increase as lion density increases and decrease with increasing search effort (See Doak and Cutler 2014, where the importance of considering survey effort is discussed in the context of grizzly bear management). Unfortunately, survey effort (i.e., person-days of track surveys, and number of camera-trap nights) has not been systematically documented in the past. In the future this information will be recorded (and an attempt will be made to reconstruct past survey effort) in the event CPUE data could prove useful.

Appendix C: Collar Number and Proportion by Herd

Total number and proportion of Sierra bighorn collared by herd based on minimum counts in 2017-18. Collars includes any type of collar, functional or not, which provide marks within the population for MR estimates. Because minimum counts (“MinCnt” in table) underestimate the true population size, these are likely over estimations of the proportion collared, particularly of males.

Herd	Sex	MinCnt	Collars	GPS	VHF	% All Collars	% GPS	% VHF
Olancha	F	22	13	6	12	59%	27%	55%
Olancha	M	10	4	2	4	40%	20%	40%
Laurel	F	2	1	1	1	50%	50%	50%
Laurel	M	1	2	1	2	200%	100%	200%
Big Arroyo	F	9	8	6	8	89%	67%	89%
Big Arroyo	M	3	3	3	3	100%	100%	100%
Langley	F	26	9	7	7	38%	27%	31%
Langley	M	35	6	2	4	17%	6%	11%
Williamson	F	15	4	1	2	27%	7%	13%
Williamson	M	7	2	1	1	29%	14%	14%
Baxter	F	49	20	8	14	41%	16%	29%
Baxter	M	42	7	2	1	17%	5%	2%
Sawmill	F	43	14	5	6	33%	12%	14%
Sawmill	M	12	11	0	4	92%	0%	33%
Bubbs	F	14	2	1	2	14%	7%	14%
Bubbs	M	5	1	0	0	20%	0%	0%
Taboose	F	1	1	1	1	100%	100%	100%
Taboose	M	3	0	0	0	0%	0%	0%
Wheeler	F	45	13	1	7	29%	2%	16%
Wheeler	M	18	8	1	4	44%	6%	22%
Convict	F	5	3	0	1	60%	0%	20%
Convict	M	3	2	0	1	67%	0%	33%
Cathedral	F	6	4	1	3	67%	17%	50%
Cathedral	M	0	2	2	2	0%	0%	0%
Gibbs	F	24	11	3	7	46%	12%	29%
Gibbs	M	5	3	1	2	60%	20%	40%
Warren	F	5	1	0	0	20%	0%	0%
Warren	M	6	0	0	0	0%	0%	0%

Appendix D: Translocation History of Sierra bighorn

Sierra bighorn translocations from 2001-2018, color-coded by calendar year.

Calendar Year	Release Location	Season	Females-Source	Males-Source
2001	Williamson	Spring		1-Wheeler
2003	Warren	Spring		2-Wheeler
2005	Baxter	Spring	5-Wheeler	
2009	Warren	Spring	3-Wheeler 3-Langley	
2013	Olancha	Spring	10-Sawmill	1-Sawmill 1-Baxter 2-Langley
2013	Convict	Spring	3-Langley	
2013	Gibbs	Spring	3-Langley	
2014	Big Arroyo	Spring	10-Wheeler	1-Wheeler 3-Baxter
2014	Olancha	Spring	4-Sawmill	
2015	Cathedral	Spring	10-Langley	2-Baxter 1-Wheeler
2015	Laurel	Spring	7-Baxter	3-Sawmill 1-Baxter
2015	Olancha	Spring		2-Baxter
2015	Gibbs (Alger)	Spring	3-Sawmill 2-Langley	
2016	Cathedral	Fall		4-Baxter 1-Sawmill
2016	Laurel	Fall		4-Wheeler
2017	Cathedral	Fall		1-Baxter 1-Sawmill
2018	Olancha	Spring	1-Wheeler	1-Wheeler
2018	Big Arroyo	Spring	3-Baxter	2-Baxter