CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

PENINSULAR BIGHORN SHEEP 2018-19 ANNUAL REPORT

AND RECOVERY PROGRAM REVIEW 1992 - 2019

This report presents information on the status, distribution, and management of Peninsular bighorn sheep from 1 June 1992 to 31 May 2019

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South Coast Region

California Department of Fish and Wildlife Peninsular Bighorn Sheep 2018-19 Annual Report and Recovery Program Review 1992 - 2019

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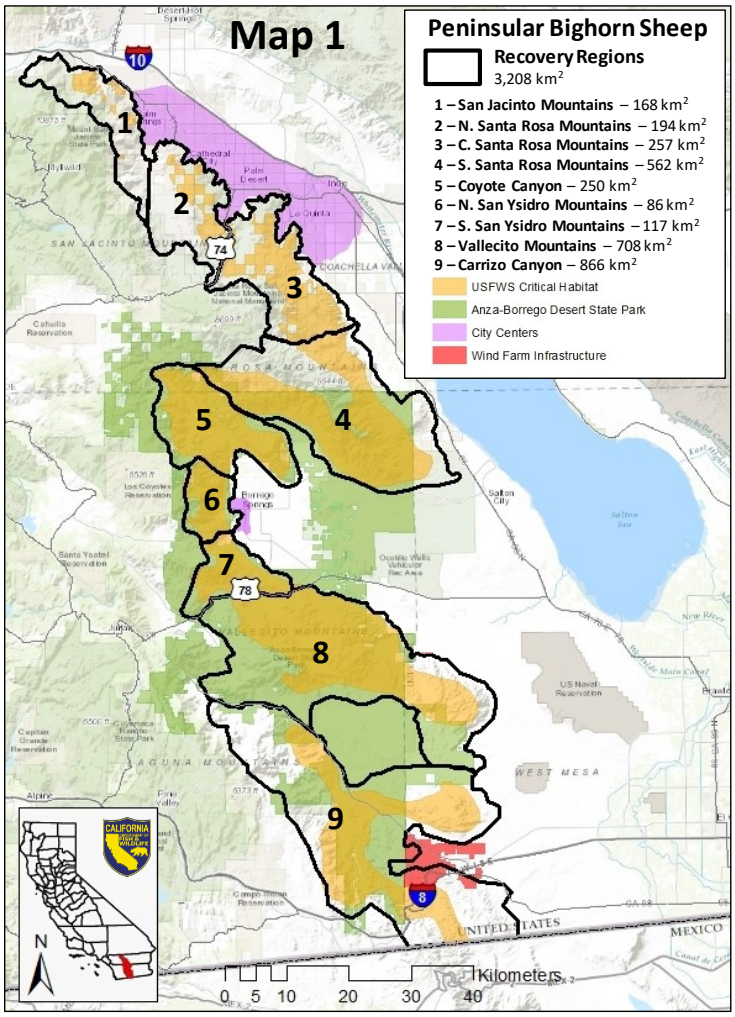
BACKGROUND



Peninsular bighorn sheep (*Ovis canadensis nelsoni*) inhabiting the Peninsular Ranges of southern California are a federally listed endangered species. The California Department of Fish and Wildlife (CDFW) carries out population monitoring and recovery under U.S. Fish and Wildlife Service (USFWS) Endangered Species Permit TE163017-1. This report summarizes peninsular bighorn sheep (PBS) radio-collar monitoring, disease surveillance, and cause-specific mortality investigations undertaken by CDFW from 1 June 2018 to 31 May 2019. In addition, PBS data collected by CDFW over the past 27 years is reviewed.

The Peninsular Mountain Ranges contain 9 designated bighorn sheep recovery regions occupying portions of southern Riverside, western Imperial, and eastern San Diego Counties (Map 1). The 9 recovery regions are: 1) San Jacinto Mountains (SJM), 2) Northern Santa Rosa Mountains (NSRM), 3) Central Santa Rosa Mountains (CSRM), 4) Southern Santa Rosa Mountains (SSRM), 5) Coyote Canyon (CoC), 6) Northern San Ysidro Mountains (NSYM), 7) Southern San Ysidro Mountains (SSYM), 8) Vallecito Mountains (VM), and 9) Carrizo Canyon (CC).

CDFW monitored all Very High Frequency (VHF) and Global Positioning System (GPS) radio-collared sheep range-wide using a combination of ground, satellite, remote-download, and aerial telemetry. Ground monitoring efforts focused on the following: 1) radio-collared sheep status (alive/dead), 2) mortality investigations, 3) observations of sheep group composition, health, and status, and 4) spatial and temporal movements. Satellite-collared sheep were monitored every 5 to 10 days with the Iridium satellite Network that delivers messages and location data via the internet. A Cessna 185 fixed-wing aircraft was used to conduct aerial telemetry monitoring of radio-collared sheep status; however, flight availability was limited during this reporting period and the bulk of monitoring was done from the ground.

CDFW Wildlife Management Program Staff

Mr. Randy Botta, Senior Environmental Scientist (Specialist) for the South Coast Region provides oversight for range-wide population monitoring activities, manages all capture and survey activities, assists with aerial telemetry flights, and supervises one field position. Ms. Janene Colby, Environmental Scientist with the South Coast Region conducts all field monitoring, mortality investigations, GIS mapping, data analysis and reporting, and assists with aerial telemetry flights and capture and survey activities.

RADIO-COLLAR STATUS PAST AND PRESENT

This report will review CDFW data for radio-collared Peninsular bighorn sheep range-wide over the past 27 years. A reporting period spans a 12-month period from 1 June of one year to 31 May of the following year. For example, reporting period 1 started on 1 June 1992 and ended on 31 May 1993 and reporting period 27 started on 1 June 2018 and ended on 31 May 2019 (Table 1). Hereafter reporting period 27 will be referred to as the "current reporting period". On average,

Table 1. CDFW raw data for the number of bighorn sheep (ewes and rams combined) with radio-collars at the beginning of each reporting period, number captured, total number radio-collared over each reporting period, number of collars censored (due to dead batteries or collar drop-off), and number and percentages of mortalities by cause. A reporting period is 12 months starting 1 June of one year and ending on 31 May of the following year.

Years	Report-ing period	Collars at start of period	Cap-tured	Total Collared	Censor-ed	Predat-ion	Non-predat-ion	Un-known	Capture related	Urban related	Total Mortal-ities	% Predat-ion	% Non-predat-ion	% Un-known	% Capture related	% Urban related	Total % Mortalities
1992-93	1	0	43	43	1	1					1	2%					2%
1993-94	2	41	27	68		8	2	2	3		15	12%	3%	3%	4%		22%
1994-95	3	53		53	4	11	3				14	21%	6%				26%
1995-96	4	35		35		8					8	23%					23%
1996-97	5	27		27	5	3					3	11%					11%
1997-98	6	19	21	40	6	6					6	15%					15%
1998-99	7	28	12	40	3	4		1			5	10%		3%			13%
1999-00	8	32	17	49		3	2	2			7	6%	4%	4%			14%
2000-01	9	42		42		2	1				3	5%	2%				7%
2001-02	10	39	37	76	1	9	1	1	2		13	12%	1%	1%	3%		17%
2002-03	11	62	4	66	6	4		2			6	6%		3%			9%
2003-04	12	54	24	78	25	8		3			11	10%		4%			14%
2004-05	13	42		42	2			1			1			2%			2%
2005-06	14	39	21	60	1	5	2	2	1		10	8%	3%	3%	2%		17%
2006-07	15	49		49			1	2			3		2%	4%			6%
2007-08	16	46	18	64		3	1	1	1	2	8	5%	2%	2%	2%	3%	13%
2008-09	17	56		56	4	2	2			1	5	4%	4%			2%	9%
2009-10	18	47	36	83		4	2	3	1		10	5%	2%	4%	1%		12%
2010-11	19	73	8	81	3	2		1		1	4	2%		1%		1%	5%
2011-12	20	74		74	10	1		1			2	1%		1%			3%
2012-13	21	62	12	74	9	4	3	5			12	5%	4%	7%			16%
2013-14	22	53	18	71	15	4	5	2	1	1	13	6%	7%	3%	1%	1%	18%
2014-15	23	43	49	92		5	3	2	1		11	5%	3%	2%	1%		12%
2015-16	24	81	89	170		12	1	6		1	20	7%	1%	4%		1%	12%
2016-17	25	150	1	151	2	15	1	5		1	22	10%	1%	3%		1%	15%
2017-18	26	127	36	163	24	16	1	3	1	1	22	10%	1%	2%	1%	1%	13%
2018-19	27	117		117	9	8	5	5			18	7%	4%	4%			15%
27-year total & Ave.		**1491**	**473**	**1964**	**130**	**148**	**36**	**50**	**11**	**8**	**253**	**7.5%**	**1.8%**	**2.5%**	**0.6%**	**0.4%**	**12.8%**

approximately 19% of radio-collars are lost each year due to a combination of expired batteries (6%) and sheep deaths (13%); therefore, radio-collars must be purchased, and captures conducted on a regular basis. Between 2009 and 2017, CDFW focused on placing GPS collars within recovery regions that lacked information on sheep movement and distribution

(Figure 1). The recovery plan (USFWS 2000) recommends maintaining active radio-collars on approximately 25-30% of the adult ewes (females) in each recovery region. Maintaining at least 25% is important for generating reliable mark-resight population estimates based on helicopter surveys. Furthermore, maintaining a representative sample of radio-collared PBS is necessary to accurately describe distribution and movement patterns, adult survivorship, cause- specific mortality, and health status. The cost associated with radio-collars and capture operations are extremely high, and it has become increasingly difficult for CDFW to procure funds on a regular basis. Without consistent funding to maintain active radio-collars on at least 25% of the adult ewes into the future, it will be impossible to accurately estimate population abundance and trends. Regular and accurate population estimates are crucial to assess if recovery goals can be met. With limited funds available, CDFW has focused efforts on radio-collaring ewes since they are the reproductive base of the population.

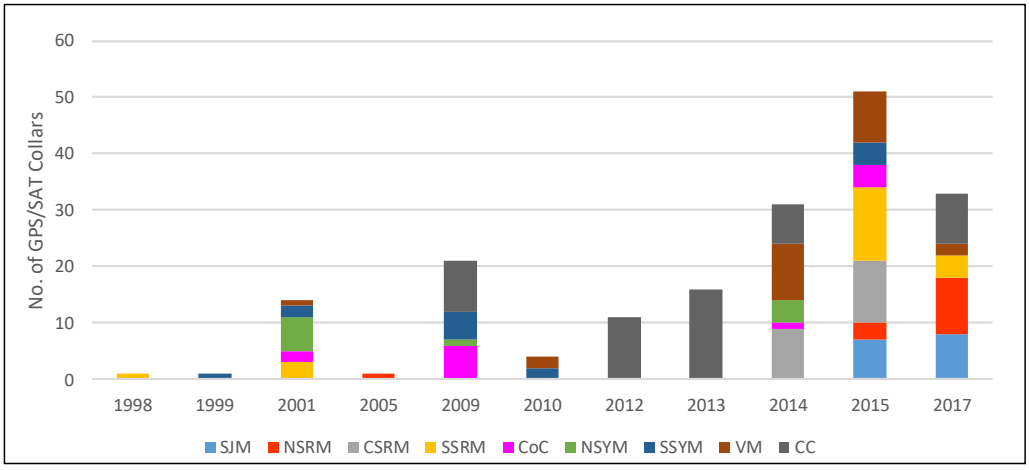


Figure 1. Number of GPS collars placed on bighorn sheep each capture year by recovery region.

At the beginning of the current reporting period (1 June 2018), the 9 recovery regions contained 117 (115F, 2M) active radio-collared bighorn sheep (Table 2). Over the reporting period, 18 radio-collared sheep died (17F, 1M) and radio-collars on 9 ewes became nonfunctional (censored). At the end of the reporting period (31 May 2019), there were 90 (89F, 1M) active radio-collared bighorn sheep. Range-wide, approximately 21% of the estimated ewe population was radio-collared at the beginning of the reporting period compared to 16% at the end of the reporting period (based on 2016 generalized ewe population abundance estimate of 552). Presently, the only recovery regions that are well represented with radio-collared ewes are the NSRM (54%) and the NSYM (28%). All other recovery regions are poorly represented with CC and CoC having only 11% and 4% of the estimated ewe population radio-collared, respectively. A capture to radio-collar additional PBS is tentatively planned for fall 2019; however, due to limited CDFW funding, capture activities are only being planned for the VM and CC recovery regions.

Table 2. Distribution and numbers of active radio-collared female (F) and male (M) bighorn sheep within the 9 recovery regions starting on 1 June 2018 and ending on 31 May 2019. The estimated percentage of females' radio-collared (% F Collared) at the end of May 2019 is based on the generalized ewe abundance estimate of 552 obtained from the 2016 helicopter survey. Mortalities are the number of bighorn sheep that died during the reporting period. Censored is the number of bighorn sheep that wore radio-collars that became nonfunctional during the reporting period.

Cate-gory	SJM F	SJM M	NSRM F	NSRM M	CSRM F	CSRM M	SSRM F	SSRM M	CoC F	CoC M	NSYM F	NSYM M	SSYM F	SSYM M	VM F	VM M	CC F	CC M	Sub-total F	Sub-total M	Grand Total
6/1/ 2018	10	1	17	0	12	0	14	0	3	0	11	0	9	0	19	1	20	0	115	2	117
mortal-ities	3		2		1		3		1				3		2	1	2		17	1	18
censor-ed	1				1		2				3		2						9		9
5/31/ 2019	6	1	15	0	10	0	9	0	2	0	8	0	4	0	17	0	18	0	89	1	90
% F Collared	19%		54%		15%		17%		4%		28%		14%		17%		11%		16%		

POPULATION ABUNDANCE REVIEW

CDFW conducted helicopter surveys to estimate PBS population abundance in recovery regions 5-9 from 1994-2008, and range-wide surveys in recovery regions 1-9 in 2010 and 2016 (Table 3). Bighorn Institute conducted helicopter surveys in recovery regions 1-4 from 1994-2008. CDFW did not conduct helicopter surveys in 2012, 2014 and 2018 due to lack of a state-wide helicopter contract and/or funding limitations. Generalized range-wide population abundance estimates were

derived by summing the estimates for each recovery region; however, a range-wide estimate was not possible in 2004 because surveys were not conducted in recovery region 3 & 4. A range-wide helicopter survey is anticipated for fall 2020. From 1994 to 2010, the range-wide PBS population steadily increased from an estimated 335 to 955 (Figure 2). The most recent 2016 range-wide PBS population estimate of 884 demonstrated a stable population. Whether the population has remained stable, increased, or decreased is not known since surveys were not conducted in 2018; therefore, the importance of regular surveys cannot be overstated. The bulk of the range-wide increases since 2002 were contributed by recovery regions 9 and 8 respectively (Table 3). These 2 recovery regions are the largest by area (Map 1) and each contain 4 ewe groups (Maps 13 & 15). Recovery region 4 is the third largest by area (Map 1) and consists of 3.5 ewe groups (Maps 4 & 8). This recovery region reached an estimated population of 179 in 2006, slightly decreased over the next 2 surveys and substantially decreased for the 2016 survey (Table 3). Similarly, recovery region 2 increased steadily until the 2016 survey when the estimate was considerably lower than in the previous 5 survey efforts; however, the survey number was likely underestimated based on direct observations of sheep throughout the year. Recovery region 5 has consistently increased since survey efforts started. Recovery regions 6 and 7 reached a peak in the 2010 survey and slightly decreased in the 2016 survey. Most notably, the population in recovery region 1 has lagged far behind all other recovery regions and was consistently low until 2016 when the population estimate dramatically increased threefold.

Table 3. Population abundance estimates (adult rams + adult ewes + yearlings) per Recovery Region (RR) for Peninsular bighorn sheep from 1994 to 2016 based on helicopter surveys. Bighorn Institute (BI) conducted helicopter surveys in RR 1-4 from 1994-2008 and used a variety of statistical methods to generate population abundance estimates (Green italic numbers). CDFW conducted helicopter surveys in RR 5-9 from 1994-2008, and RR 1-9 in 2010 and 2016: population abundance estimates (blue bold numbers) were generated using Chapman's (1951) modification of the Peterson estimator (Seber 1982) unless otherwise noted. Due to a lack of a CDFW helicopter contract, surveys were not conducted in 2012 and 2014.

Recovery Region	1994	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018	2020
RR 1 - San Jacinto Mtns.	*17*	*19*	*23*	*17*	*22*	*32*	*21*	*26*	**16**	No Range-wide Survey	No Range-wide Survey	**56**	No Range-wide Survey	No Range-wide Survey
RR 2 - N. Santa Rosa Mtns.	*117*[a]	*94*[a]	*22*	*32*	*40*	*57*	*49*	*77*	**90**	No Range-wide Survey	No Range-wide Survey	**37**	No Range-wide Survey	No Range-wide Survey
RR 3 - C. Santa Rosa Mtns.	*117*[a]	*94*[a]	*72*	*53*	*115*	*No Surveys*	*163*	*122*	**133**	No Range-wide Survey	No Range-wide Survey	**119**	No Range-wide Survey	No Range-wide Survey
RR 4 - S. Santa Rosa Mtns.	*117*[a]	*94*[a]	*35*	*51*	*84*	*No Surveys*	*179*	*155*	**149**	No Range-wide Survey	No Range-wide Survey	**83**	No Range-wide Survey	No Range-wide Survey
RR 5 - Coyote Canyon	**29**	**37**	**35**	**35**	**35**	**47**	**42**	**52**	**66**	No Range-wide Survey	No Range-wide Survey	**69**	No Range-wide Survey	No Range-wide Survey
RR 6 - N. San Ysidro Mtns.	**68**	**39**	**34**	**33**	**47**	**50**	**79**	**82**	**72**	No Range-wide Survey	No Range-wide Survey	**59**	No Range-wide Survey	No Range-wide Survey
RR 7 - S. San Ysidro Mtns.	**19**	**26**	**41**	**39**	**41**	**47**	**38**	**53**	**55**	No Range-wide Survey	No Range-wide Survey	**42**	No Range-wide Survey	No Range-wide Survey
RR 8 - Vallecito Mtns.	**29**	**28**	**45**	**64**	**155**[b]	**150**[b]	**77**	**123**[b]	**142**	No Range-wide Survey	No Range-wide Survey	**163**	No Range-wide Survey	No Range-wide Survey
RR 9 - Carrizo Canyon	**58**	**34**	**28**	**82**	**127**	**101**[b]	**145**	**186**[b]	**232**	No Range-wide Survey	No Range-wide Survey	**256**	No Range-wide Survey	No Range-wide Survey
Total*	**339**	**277**	**335**	**406**	**511**	**Un-known**	**793**	**567**	**955**	**Unknown**	**Unknown**	**884**	**Unknown**	**Unknown**

*This is the sum of recovery regions (Generalized) rather than a range-wide population abundance estimate.

[a]BI reported 1 helicopter survey estimate for all recovery regions combined (RR 1-4) in the Santa Rosa Mountains in 1994 and 1998.

[b]Due to the low proportion of radio-collared animals observed a "markless" population estimator was used.

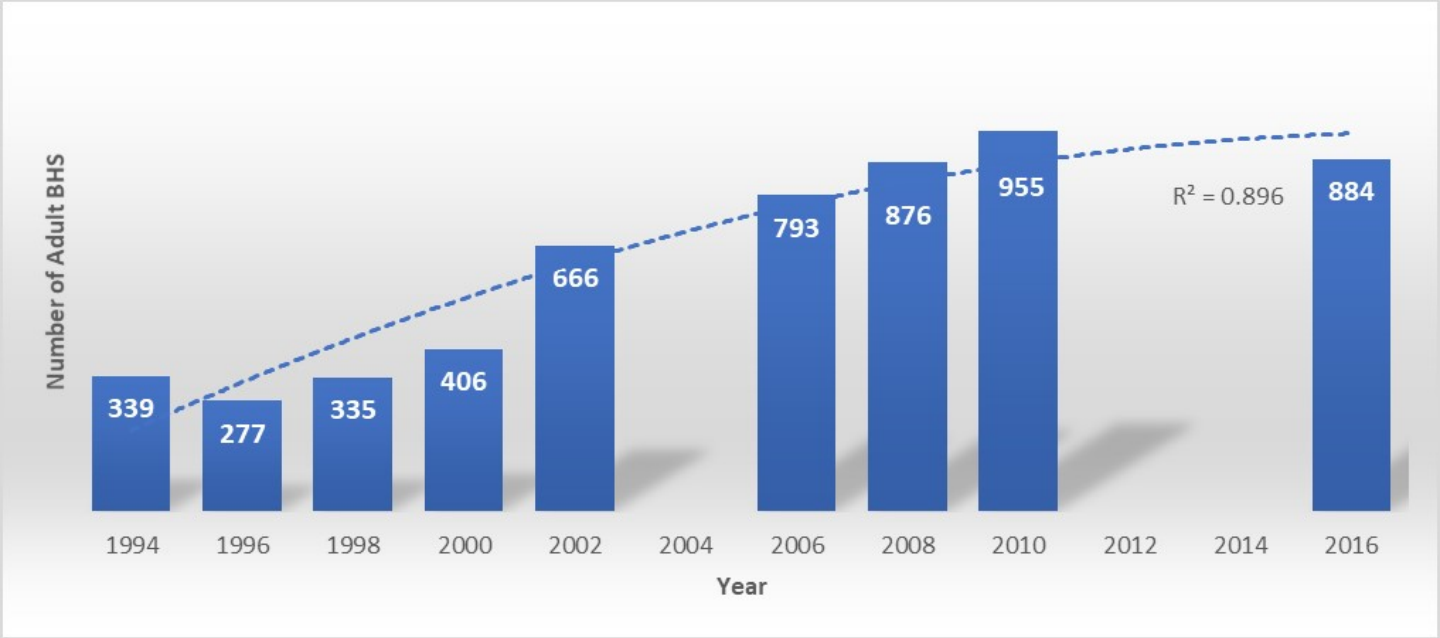


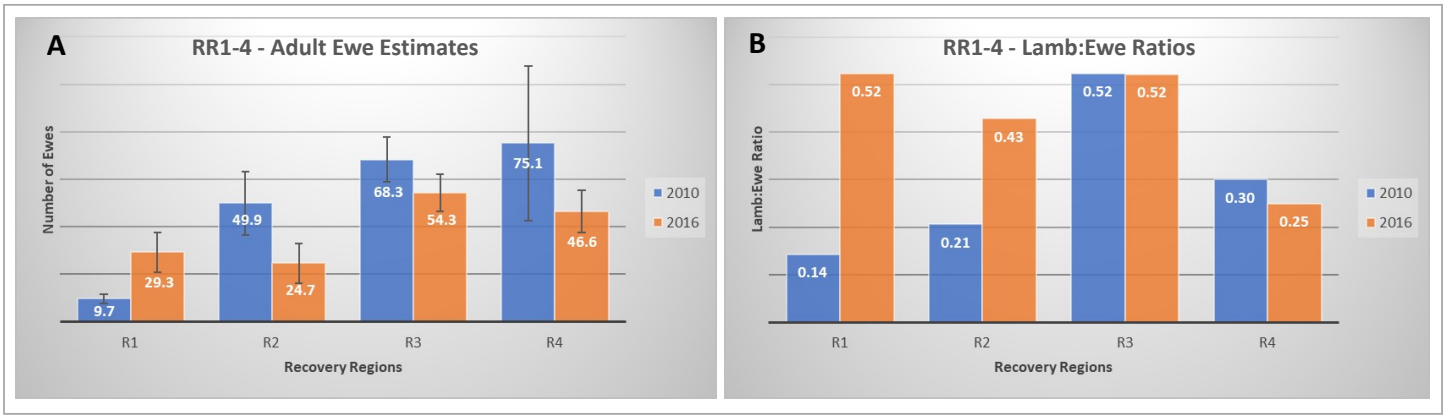
Figure 2. Generalized range-wide (RR 1-9) peninsular bighorn sheep population estimates from 1994 to 2016 based on helicopter surveys. There were no surveys conducted in RR 3 & 4 in 2004 and no range-wide surveys in 2012 & 2014.

Examining trends in ewe abundance estimates are important as ewes are the reproductive base of the population. Furthermore, recovery goals focus on maintaining 25 ewes within each recovery region for 12 consecutive years before PBS can be removed from the endangered species list. Lamb:ewe ratios derived from survey results are used as an index of lamb survival to approximately 9 months of age (based on a peak parturition in February and surveys conducted in November). Ewe abundance trends and lamb survival indices based on CDFW helicopter surveys are summarized below for recovery regions 1-9:

1. **SJM** – 10 ewes were estimated in 2010; 6 years later the population estimate met and exceeded 25 ewes for the first time since recovery efforts started (Figure 3A). Lamb survival was very poor in 2010 but reached a high of 52% in 2016 (Figure 3B).
2. **NSRM** – 47 ewes were estimated in 2010 but barely 25 ewes were estimated in 2016 (Figure 3A). The estimate in 2016 was likely underestimated based on field observations. Lamb survival was exceptionally low in 2010 but was well above 30% in 2016 (Figure 3B).
3. **CSRM** – Ewe abundance estimates were well above 25 in 2010 and 2016 (Figure 3A). Lamb survival for both survey efforts were high at 52% (Figure 3B).
4. **SSRM** – Ewe abundance decreased from 75 in 2010 to 47 in 2016; however, the confidence interval in 2010 was exceedingly large (Figure 3A). Lamb survival in 2010 and 2016 was 30% and 25% respectively (Figure 3B).
5. **CoC** - Except for low counts in 1998 and 2006, ewe abundance estimates have slowly increased to above 30 ewes for the last 3 surveys efforts (Figure 4A). Lamb survival has been above 30% except in 2002 and 2010 (Figure 4B).
6. **NSYM** - Ewe abundance estimates reached a low of only 15 ewes in 1998 and 2000 after which the population steadily increased to a high of 47 in 2008 (Figure 4C). Since 2008, ewe abundance decreased to an estimate of 28 ewes in 2016. Confidence intervals were large in 1994 and 2004-2010 and thus the ewe population may either have been over or underestimated for those years. Prior to the 2002 survey, there were extreme fluctuations in lamb survival indices that ranged between 50% and 13% (Figure 4D). Lamb survival reached a high of 53% in 2002 but steadily declined each survey to a low of less than 1% in 2010. Low lamb survival within this recovery region has been linked to pneumonia based on direct observations and lab necropsy results. Lamb survival rebounded to 39% in 2016.
7. **SSYM** – Ewe abundance estimates did not exceed 25 ewes until 2002 (Figure 5E). Ewe abundance has been maintained at over 25 ewes since 2002 except in 2006 when it was estimated at only 21. While the declining trend

in lamb survival since 1994 is concerning (Figure 5F), indices have remained above 30% survival except in 1996 and 2010.

8. **VM** – The trend in ewe abundance estimates has steadily increased since 1996 and have remained above 25 ewes since 1998 (Figure 5G). Lamb survival indices show no trend with fluctuations equally above and below 30% survival (Figure 5H).
9. **CC** –Ewe abundance estimates decreased from 39 in 1994 to only 18 ewes in 1998 (Figure 5I). Since 1998 the ewe population trend has increased with all survey estimates well above 25 ewes. However, confidence intervals have been notoriously large within this recovery region and likely due to the difficulties in maintaining a representative sample of radio-collared ewes in such a large recovery region. There is not a discernable trend in lamb survival with 7 out of 10 surveys above 30% survival (Figure 5J).



Figures 3A & B. CDFW population abundance estimates for adult ewes (A) and Lamb:Ewe ratios (B) per Recovery Regions 1-4 (RR 1-4) based on 2010 and 2016 helicopter surveys. Population abundance estimates were generated using Chapman's (1951) modification of the Peterson estimator (Seber 1982). Error bars represent the upper and lower 95% confidence intervals.

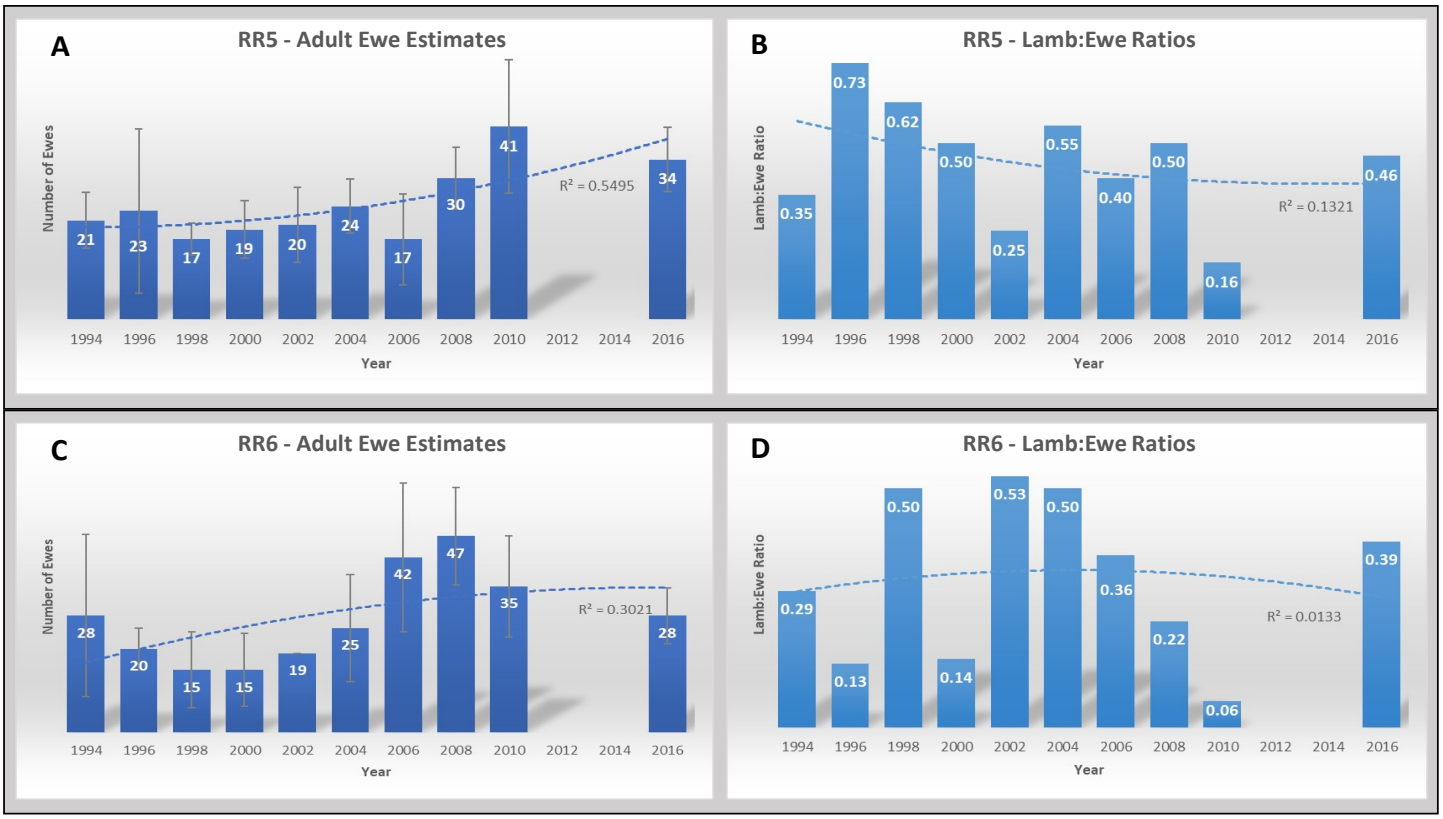


Figure 4A-D. CDFW population abundance estimates for adult ewes and Lamb:Ewe ratios in Recovery Regions 5 & 6 (RR 5 & 6) from 1994 to 2016 based on helicopter surveys. Population abundance estimates were generated using Chapman's (1951) modification of the Peterson estimator (Seber 1982). Due to a lack of a CDFW helicopter contract, surveys were not conducted in 2012 and 2014. Error bars represent the upper and lower 95% confidence intervals.

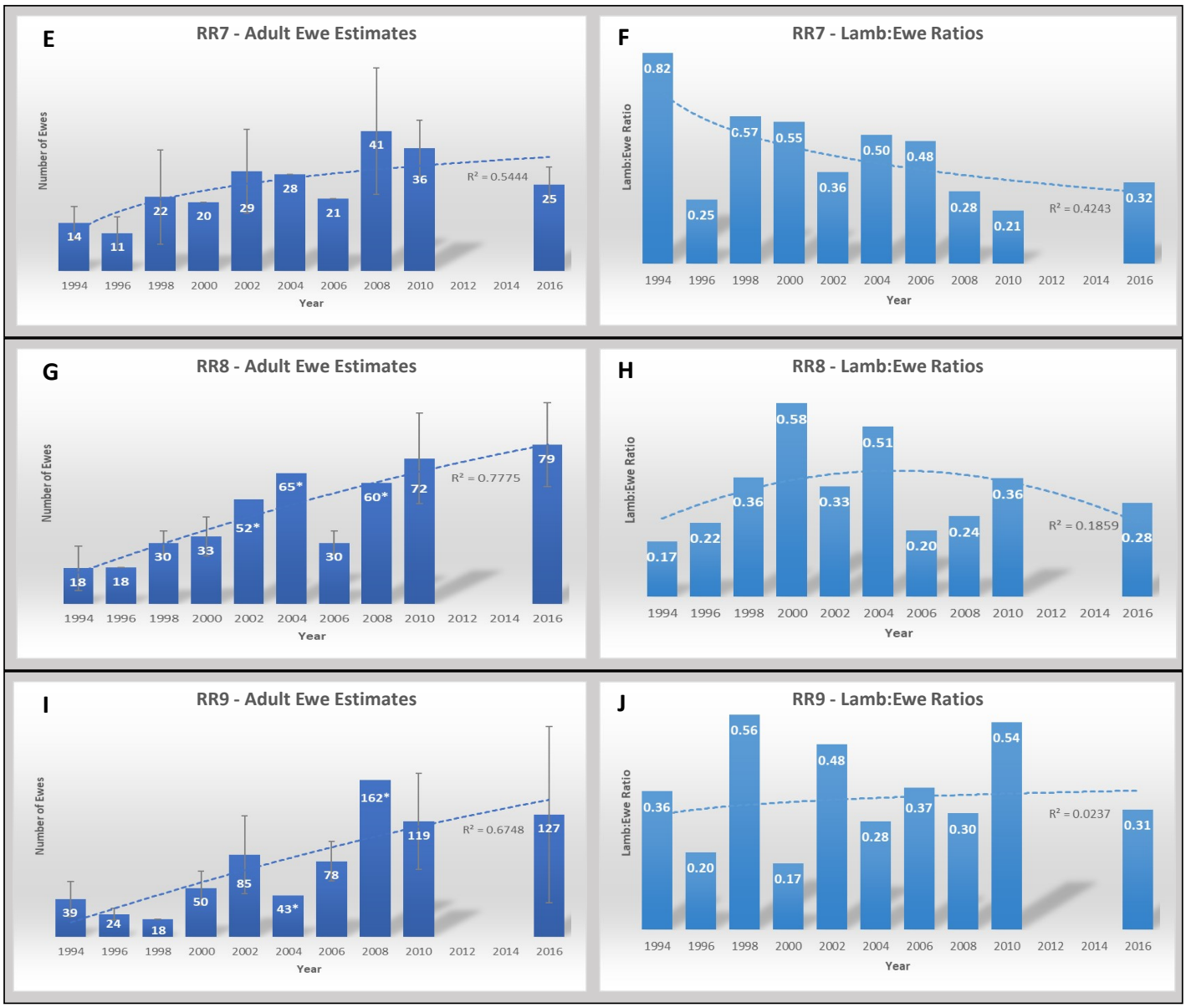


Figure 5E-J. CDFW population abundance estimates for adult ewes and Lamb:Ewe ratios in Recovery Regions 7-9 (RR 7-9) from 1994 to 2016 based on helicopter surveys. Population abundance estimates were generated using Chapman's (1951) modification of the Peterson estimator (Seber 1982) unless otherwise noted. Due to a lack of a CDFW helicopter contract, surveys were not conducted in 2012 and 2014. *Markless method was used to generate ewe abundance estimate due to the small number of marked ewes observed in 2002, 2004, and 2008 in RR 8 and in 2004 and 2008 in RR9. Error bars represent the upper and lower 95% confidence intervals.

CAUSE-SPECIFIC MORTALITY PAST AND PRESENT

CDFW attempts to investigate all radio-collared sheep mortalities in a timely manner to accurately assess cause of death. The following descriptive statistics on cause-specific mortality were obtained from CDFW mortality reports from 1993 through 2019 in recovery region 4 through 9 and from 2010 to 2019 in recovery regions 1 through 3. In 2006, CDFW developed a detailed protocol for conducting mortality investigations and criteria for categorizing cause of death. Once a specific cause of a sheep's death is determined, it is placed in one of the following general categories:

1. **Predation** - the primary cause of a sheep's death is due to a predator (typically mountain lion and occasionally coyote). There are 3 levels of confidence categorized under the umbrella of predation that are based on the amount of direct evidence (predation) and indirect evidence (probable and possible predation) found during the mortality investigation.

2. **Nonpredation** - when the cause of death is clearly not due to predation but to some other cause such as age-related disease, injury, fall, dystocia, etc.
3. **Unknown** - cause of death cannot be determined due to scavenging of the carcass or advanced stage of decomposition. Predation versus nonpredation cannot be ruled out or in.
4. **Capture related** - any death that occurs while a sheep is being captured or that occurs within the first month after capture.
5. **Urban related** - any cause of death associated with the urban environment such as vehicle collisions, drowning, injury, or plant poisoning.

Over the past 27 years, on average, 12.8% of all active radio-collared sheep die each year with predation (hereafter includes possible lion, probable lion and lion predation combined) accounting for 7.5%, nonpredation 1.8%, unknown causes 2.5%, capture related 0.6% and urban related accounting for 0.4% (Table 1). The percentage of radio-collared mortalities for reporting periods 2, 3 & 4 were from 22 to 26%—considerably higher than for any other reporting period mainly due to predation (Table 1, Figure 6). Since reporting period 11, the percentage of radio-collared mortalities due to predation has not exceeded 10% (Table 1, Figure 6). Small numbers of radio-collared PBS can have a greater influence on percentages and fluctuations in mortality among years due to chance alone. There was little fluctuation in the percentage of mortality among years for reporting periods 23-27 when there were greater than 90 radio-collared PBS maintained each year throughout the range (Figure 6).

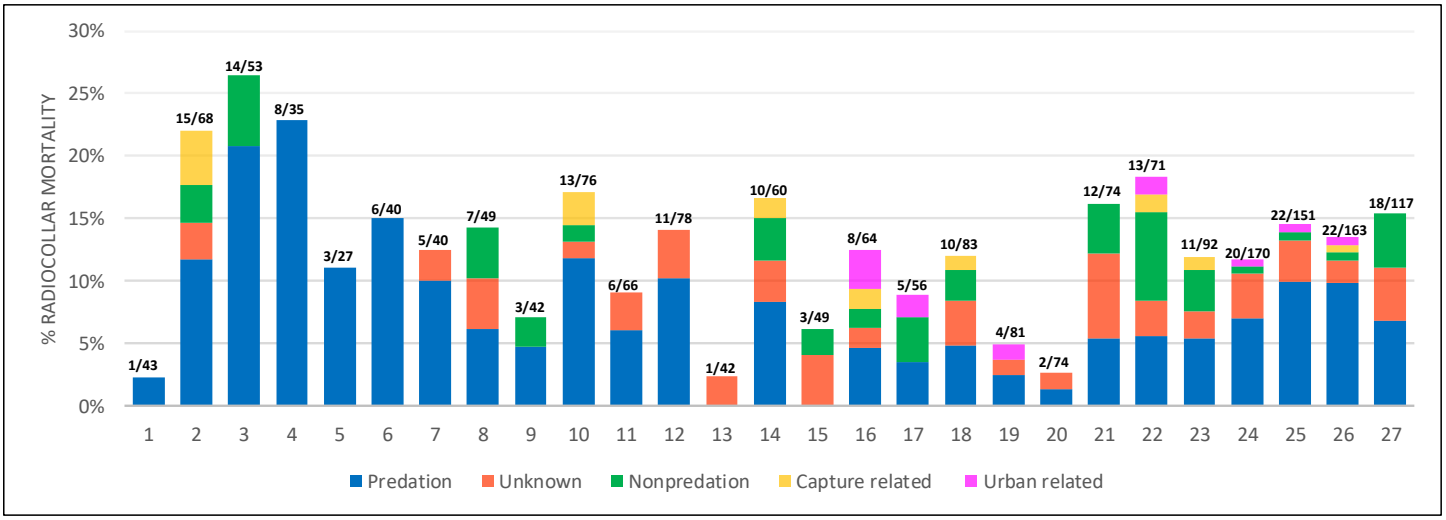


Figure 6. Percentage of radio-collared bighorn sheep mortality due to predation, unknown, nonpredation, capture related, and urban related causes for all radio-collared bighorn sheep over 27 reporting periods. Numbers above bar: n = radio-collared mortalities/radio-collared sheep. A reporting period is 12 months starting on June 1 of one year and ending 31 May of the following year. First reporting period: 1 June 1992 to 31 May 1993. Current reporting period 27: 1 June 2018 to 31 May 2019.

Predation accounts for 58% (n = 147) of all PBS radio-collared deaths (n = 253). When examined by sex (ewe mortalities = 206, ram mortalities = 47), predation accounts for 62% (n = 127) of ewe deaths and 43% (n = 20) of ram deaths (Figure 7). The caveat being mortality statistics for rams are not well represented since the majority of PBS radio-collared over the past 27 years have been ewes. The majority (54%, n = 69) of radio-collared ewes killed by predators were between 9 and 16 years old, 40% (n = 51) were middle-aged (≥ 4 and ≤ 8 years old), and 6% (n = 7) were young (≤ 3 years old). Similarly, the majority (65%, n = 13) of radio-collared rams killed by predators were between 9 and 13 years old, 30%

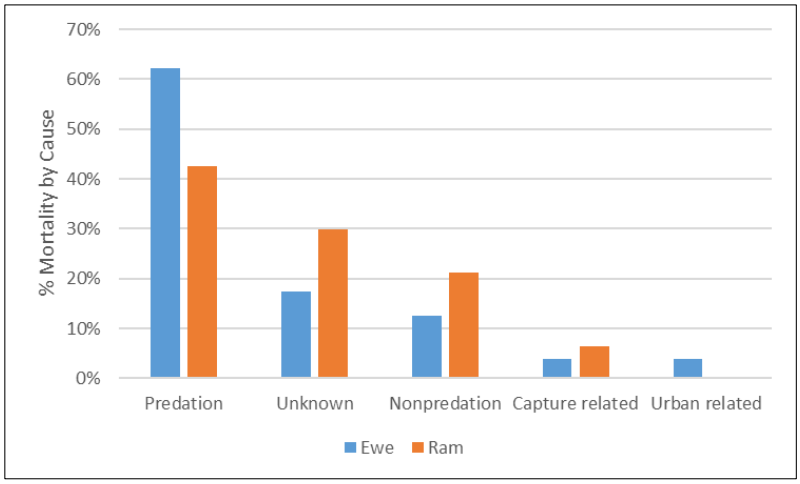


Figure 7. Comparison of the average percentage of mortalities by cause for radio-collared ewes and rams over 27 years. Ewe mortalities = 206, Ram mortalities = 47.

(n = 6) were middle-aged (≥ 4 and ≤ 8 years old), and 5% (n = 1) were young (≤ 3 years old). The long-term data indicates that predation risk increases from December through March and is lowest in June and July (Figure 8). In contrast, there is no seasonal pattern for deaths attributed to all other causes combined except for a slight increase in July and March (Figure 8). Peer-reviewed research on mountain lion predation in the Peninsular Ranges was last conducted in the 1990s with data spanning a maximum of 6 years (Hayes et al. 2000, Ernest et al. 2002). Current research by Washington State University in collaboration with CDFW is analyzing all mortality data and associated GPS data collected over the past 27 years to produce a peer-reviewed publication on predicting the landscape of PBS predation risk by mountain lions.

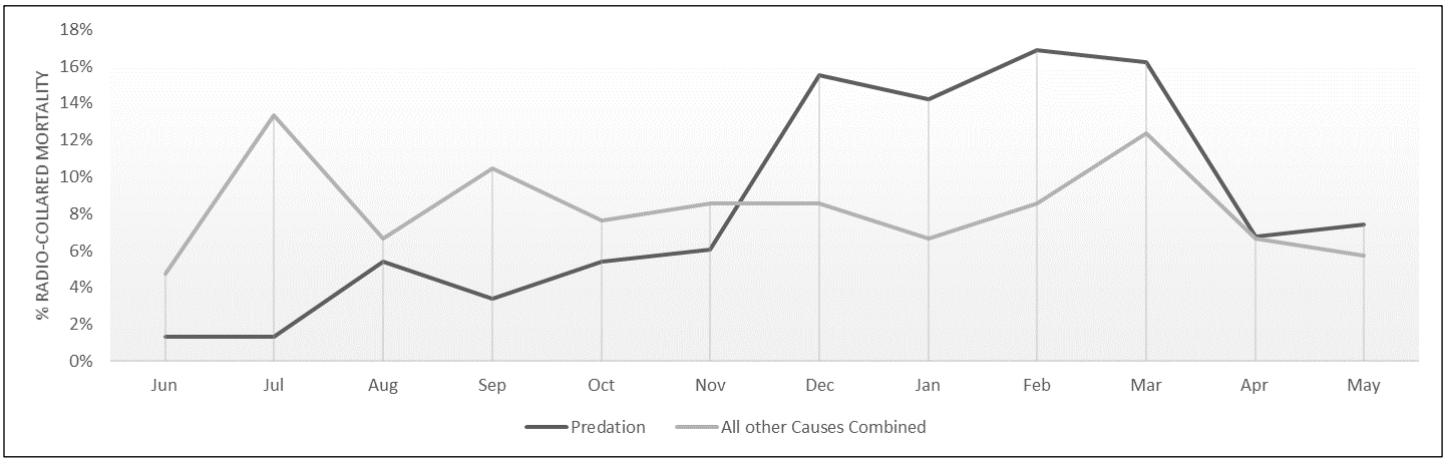


Figure 8. Average monthly percentage of mortalities due to predation (n = 148) and due to all other causes combined (n = 105) for all radio-collared bighorn sheep (n = 1964) over 27 years (1 June 1993 to 31 May 2019).

In recovery regions 3 through 9, predation is the leading cause of death with predation highest (76%) in recovery region 8 and lowest (53%) in recovery region 7 (Figure 9). In recovery regions 1 through 3, sample size with respect to the number of mortalities and number of years data were collected is relatively small and thus may not necessarily be representative of the population. Urban related causes of death have been documented in recovery regions 3, 6, 7 and 9 (Figure 9). Figure 10 shows the yearly percentage of radio-collared ewe mortalities (number of radio-collar deaths ÷ number of radio-collars) due to predation and all other causes combined for each recovery region.

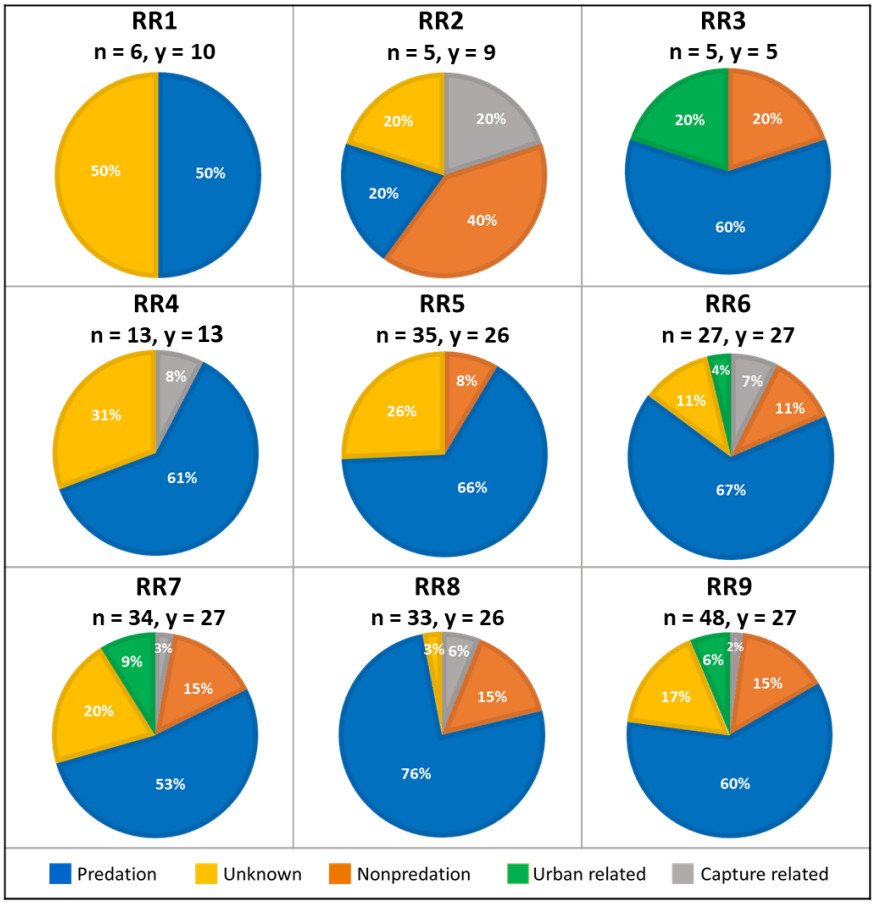


Figure 9. Overall percentage by cause of death for radio-collared ewes within each of 9 recovery regions (RR1-9). n = the total number of mortalities within each recovery region, and y = number of years data were collected.

For the current reporting period, there were 18 (17F, 1M) radio-collared sheep mortalities (Table 4). Mortalities by recovery region were SJM = 3F, NSRM = 2F, CSRM = 1F, SSRM = 3F, CoC = 1F, SSYM = 3F, VM = 2F, 1M, and CC = 2F. The percentage of radio-collared mortalities (number of radio-collar deaths ÷ number of radio-collars) was slightly above average at 15% with predation accounting for 7%, nonpredation 4% and unknown causes accounting for another 4% (reporting period

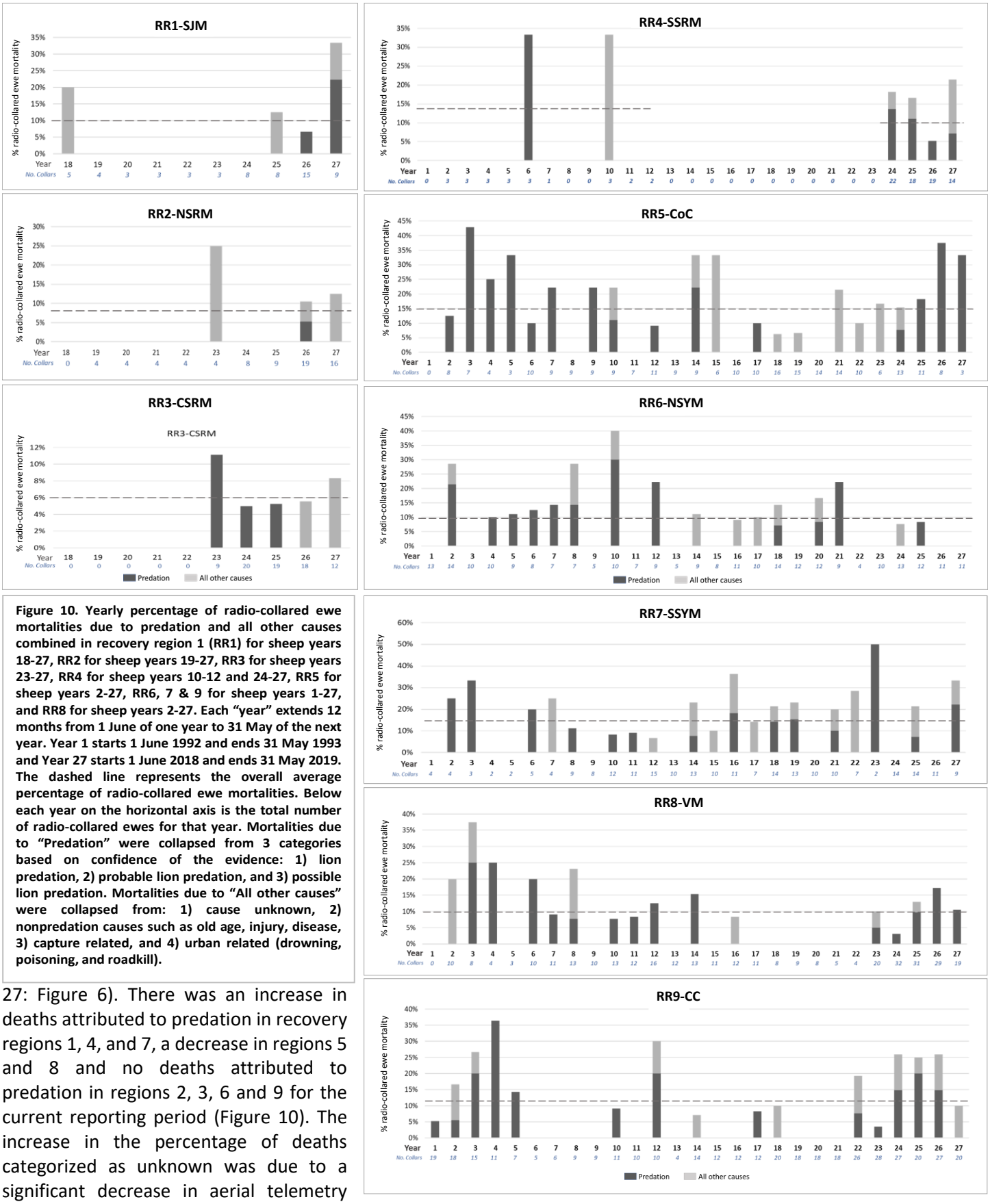


Figure 10. Yearly percentage of radio-collared ewe mortalities due to predation and all other causes combined in recovery region 1 (RR1) for sheep years 18-27, RR2 for sheep years 19-27, RR3 for sheep years 23-27, RR4 for sheep years 10-12 and 24-27, RR5 for sheep years 2-27, RR6, 7 & 9 for sheep years 1-27, and RR8 for sheep years 2-27. Each "year" extends 12 months from 1 June of one year to 31 May of the next year. Year 1 starts 1 June 1992 and ends 31 May 1993 and Year 27 starts 1 June 2018 and ends 31 May 2019. The dashed line represents the overall average percentage of radio-collared ewe mortalities. Below each year on the horizontal axis is the total number of radio-collared ewes for that year. Mortalities due to "Predation" were collapsed from 3 categories based on confidence of the evidence: 1) lion predation, 2) probable lion predation, and 3) possible lion predation. Mortalities due to "All other causes" were collapsed from: 1) cause unknown, 2) nonpredation causes such as old age, injury, disease, 3) capture related, and 4) urban related (drowning, poisoning, and roadkill).

27: Figure 6). There was an increase in deaths attributed to predation in recovery regions 1, 4, and 7, a decrease in regions 5 and 8 and no deaths attributed to predation in regions 2, 3, 6 and 9 for the current reporting period (Figure 10). The increase in the percentage of deaths categorized as unknown was due to a significant decrease in aerial telemetry monitoring over the past year that resulted in delayed detection and response times for investigations in extremely remote areas such as the SSRM and CC recovery regions. The average age of radio-collared PBS at death was 9 years (n =

18). The average age of ewes at death attributed to predation was 10 years (n = 8) of which 50% were middle-aged (≥ 4 and ≤ 8 years old) and 50% were between 11 and 16 years old. Additionally, 5 out of 7 ewe deaths attributed to predation showed signs of chronic disease at time of death (the condition of ewe 236 was not determined). Ewes 342, 346, and 443 had severe chronic sinusitis, ewe 395 had an active tooth infection, and ewe 234 had mandibular osteomyelitis, likely the result of a chronic tooth infection. Additionally, ewe 346 was pregnant at the time of her death and ewe 234 and her newborn lamb were both killed.

Table 4. Cause of death for 18 radio-collared bighorn sheep by recovery region within the Peninsular Ranges of Southern California from 1 June 2018 to 31 May 2019. All mortalities were investigated by CDFW unless otherwise noted.

Region	Animal ID	Sex	Age	Mortality Date	Mortality Cause
SJM	234	F	11	2/4/2019	Probable lion predation
SJM	236	F	16	2/11/2019	[a]Probable lion predation
SJM	481	F	4	3/15/2019	Unknown
NSRM	421	F	11	9/1/2018	Unknown nonpredation
NSRM	268	F	11	10/23/2018	[a]Unknown
CSRM	410	F	9	9/14/2018	Fall/broken neck
SSRM	468	F	3	7/22/2018	Unknown
SSRM	436	F	8	10/9/2018	Unknown
SSRM	437	F	11	10/25/2018	Possible lion predation
CoC	397	F	5	10/19/2018	Possible lion predation
SSYM	394	F	9	7/15/2018	Unknown nonpredation
SSYM	443	F	7	10/5/2018	Probable lion predation
SSYM	395	F	8	5/10/2019	Lion predation
VM	375	M	7	7/20/2018	Unknown nonpredation
VM	342	F	13	1/23/2019	Probable lion predation
VM	346	F	8	3/14/2019	Probable lion predation
CC	230	F	10	7/7/2018	Unknown nonpredation
CC	335	F	11	1/14/2019	Unknown

[a]Investigated by Bighorn Institute and cause of death re-evaluated based on CDFW criteria.

Table 5. Cause of death for 9 non-collared bighorn sheep by recovery region within the Peninsular Ranges of Southern California from 1 June 2018 to 31 May 2019. All mortalities were investigated by CDFW unless otherwise noted.

Region	Location	Date	Age	Sex	Cause
NSRM/CSRM	Highway 74	6/30/2018	lamb	Ram	[a]Killed by vehicle
NSRM/CSRM	Highway 74	7/20/2018	2	Ram	[a]Killed by vehicle
NSRM/CSRM	Highway 74	9/24/2018	3	Ewe	Killed by vehicle
NSRM/CSRM	Highway 74	10/27/2018	4	Ewe	Killed by vehicle
CSRM	PGA West	9/22/2018	11	Ram	Drowned
CSRM	PGA West	12/8/2018	4	Ewe	Drowned
SSYM	Pinyon Ridge	1/14/2019	9	Ram	Lion Predation
Carrizo	County Road S2	8/28/2018	3	Ram	Killed by vehicle
Carrizo	Interstate 8	12/15/2018	6	Ram	Killed by vehicle

[a]Investigated by Bighorn Institute.

Table 6. Cause of death for non-collared bighorn sheep by recovery region within the Peninsular Ranges of Southern California from 2002 to 31 May 2019.

Recovery Region	Vehicle Collision	Disease	Predation	Non-predation	Unknown	Drowned	Oleander Poisoning	Grand Total
NSRM/CSRM	28							28
CSRM	1	13				7	2	23
SSRM		2		2				4
CoC			4		2			6
NSYM	5	11	6	5	1		1	29
SSYM	2	1	2	1	1			7
SSYM/VM	2							2
VM			5	4	1			10
CC	16	3	5	1	3			28
Grand Total	54	30	22	13	8	7	3	137

Mortality investigations of non-collared PBS deaths were undertaken opportunistically by CDFW personnel when discovered during field monitoring or when reported by the public, land management agencies, or other organizations. Most non-collared sheep deaths are discovered within or adjacent to the urban environment, or in areas heavily used by

recreational hikers; therefore, they are not necessarily representative of the range-wide PBS population but rather the populations adjacent to urban areas or roadways that bisect PBS habitat. For the current reporting period, there were 9 non-collared bighorn sheep deaths reported with vehicle collisions responsible for 6 deaths, followed by 2 deaths due to drowning and 1 death due to lion predation (Table 5). Since 2002, CDFW has documented 137 non-collared PBS deaths across all recovery regions except for the SJM (Table 6). The majority (39%) of non-collared mortalities reported were due to vehicle collisions followed by disease 22%, predation 16%, nonpredation 10%, unknown causes 6%, drowning 5%, and oleander poisoning 2%.

Bacterial pneumonia in lambs accounted for all but one of the 30 non-collared PBS deaths attributed to disease with most occurring in the CSRM and NSYM recovery regions (Table 6). Lambs with pneumonia have been observed in all recovery regions; however, the chance of opportunistically finding dead lambs in remote areas is virtually impossible. In contrast, lambs that have died in golf communities and popular hiking areas within lamb-rearing habitat are more likely to be discovered and reported.

Since 2012, 7 non-collared PBS (Table 6) and 1 radio-collared ewe have drowned in the un-fenced section of the Coachella Canal that runs through the PGA West golf course within the city of La Quinta. All but one of the drownings occurred from August to December with the peak in August. The cement sides of the canal are covered in a thick layer of mud that are exposed when water levels are low. Bighorn sheep that walk down to drink can slip in the mud and fall into the canal. The mud-covered cement is too slick for sheep to gain traction to exit the canal and they eventually drown. Furthermore, numerous plants that are attractive to sheep grow within the cracks in the cement sides, further attracting sheep to the water's edge. Likely, the number of PBS that drown in the canal will continue to increase until the canal is fenced.

Highway 74 impedes sheep movement between the NSRM and CSRM and each year more sheep are struck and killed by vehicles while attempting to cross the highway (Table 7 & Map 2). Between 2007 and the current reporting period, the majority of PBS killed on Highway 74 were rams with peak months for collisions in April and July through September (Figure 11). Peak months for ewes killed on Highway 74 were April and October (Figure 11). Interstate 8 has the second highest number of PBS killed by vehicles; however, data were not available prior to 2012 (Table 7 & Map 3). The core lamb-rearing habitat for this ewe group is within the island created by the divergence of the west and east-bound lanes of the Interstate (Map 3). As a result, most of the PBS killed on Interstate 8 are ewes with peak months for collision occurring during the lamb-rearing season from January through May when ewes will often cross the east-bound lanes several times each day (Figure 11).

Table 7. Documented road-killed bighorn sheep within the Peninsular Ranges. Data for road-killed sheep on Highway 74 and Jefferson were provided by Bighorn Institute. ǂData are from January 2019 to 31 May 2019. *No data are available on Interstate 8 prior to 2012.

Road and Region	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	ǂ2019	Total by road
Highway 74 - NSRM/CSRM		2	2	1	1	1	1	1	3	4	4	2	6		**28**
Interstate 8 - CC	*	*	*	*	*	*	1		[a]1	2	[b]5	[c]4	2		**15**
County Rd S22 - NSYM		[d]1			[e]2		2						1		**6**
County Rd S3 - SSYM	1			[f]1		[g]1						1			**4**
County Rd S2 - CC											1		3		**4**
Highway 78 - SSYM/VM		1	[h]1									1			**3**
Jefferson Street - CSRM										1					**1**
Total by year	**1**	**4**	**3**	**2**	**3**	**2**	**4**	**1**	**4**	**7**	**10**	**8**	**12**	**0**	**61**

[a]Ewe 284 killed on 3/27/2014; [b]Ewe 277 killed on 5/14/2016; and [c]Ewe 225 killed on 2/2/2017
[d]Ewe 184 killed on 12/14/2007; [e]Lamb of ewe 137 killed on 2/9/2010
[f]Ewe167 killed on 3/7/2009; and [g]Ewe 201 killed on 1/26/2011
[h]Ewe 164 killed on 2/16/2008

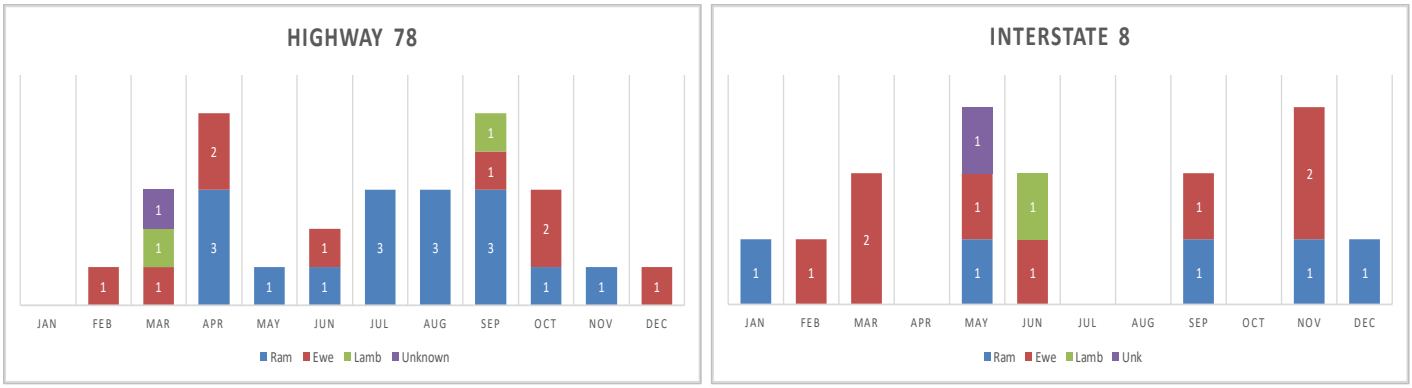
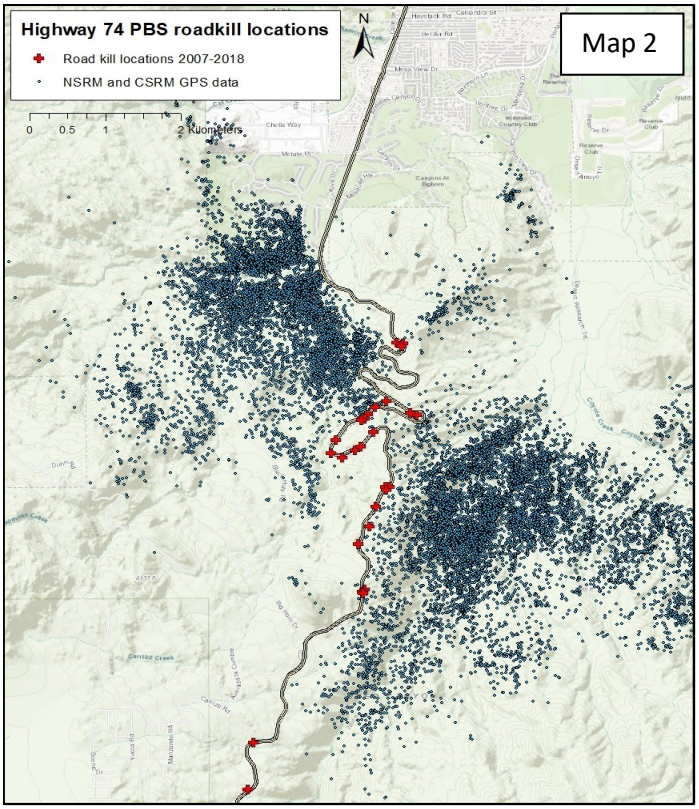
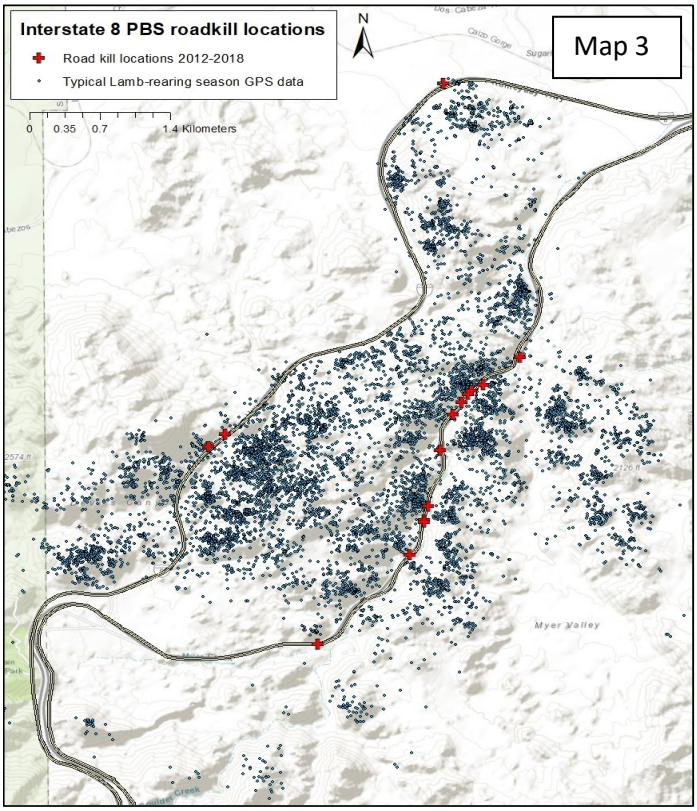


Figure 11. Number of Peninsular bighorn sheep (rams, ewes, and lambs) killed by month on Highway 74 from 2007 through 2018 and on Interstate 8 from 2012 to 2018.





EWE SURVIVAL PAST AND PRESENT

Population viability is most sensitive to changes in ewe survival (Ruben et al. 2002); therefore, it is important to document ewe survival within the Peninsular Ranges to make cogent management decisions.

Ewe survival rates vary by recovery region, year and month and the reliability of survival rates is influenced by the percentage of radio-collared sheep within each recovery region and the number of years data were collected. Over the past 27 years, the average range-wide survival of radio-collared ewes was 88.4% ± 5% (annual Kaplan-Meir survival rates reported as mean percent survival ± 95% Confidence Interval). Average ewe survival by recovery region from highest to lowest was: CSRM 93.5% ± 5%, NSRM 93.0 ± 6%, SJM 91.2% ± 7%, VM 90.1% ± 3%, NSYM 89.6% ± 4%, CC 88.1% ± 3%, SSRM 85.5% ± 8%, SSYM 85.4% ± 5% and CoC 85.4% ± 4%. It should be noted that the number of years ewe survival data were collected in the SJM, NSRM, and CSRM (Figure 12) was relatively small in comparison to all other recovery regions (Figure 13).

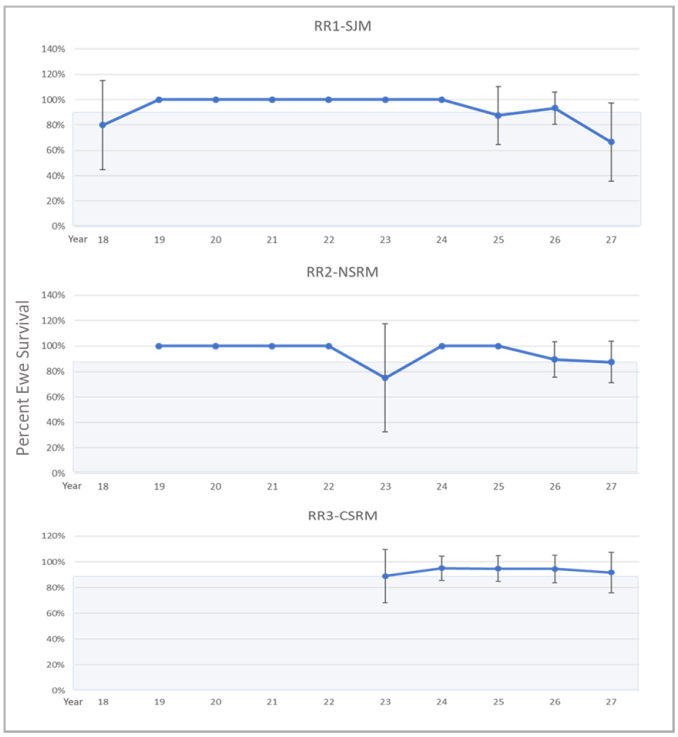


Figure 12. Annual Kaplan-Meier estimates (modified to allow for staggered entry of new animals) of adult radio-collared ewe survival (± 95% Confidence Intervals) for Recovery Regions 1-3 (RR1-3). Each "year" is 12 months from 1 June of one year to 31 May of the next year. Year 1 starts 1 June 1992 and ends 31 May 1993 and Year 27 starts 1 June 2018 and ends 31 May 2019. CDFW did not start collecting survival data in RR1 until year 18, year 19 in RR2, and year 23 in RR3. For comparison, blue background height set at range-wide average ewe survival of 88.4%.

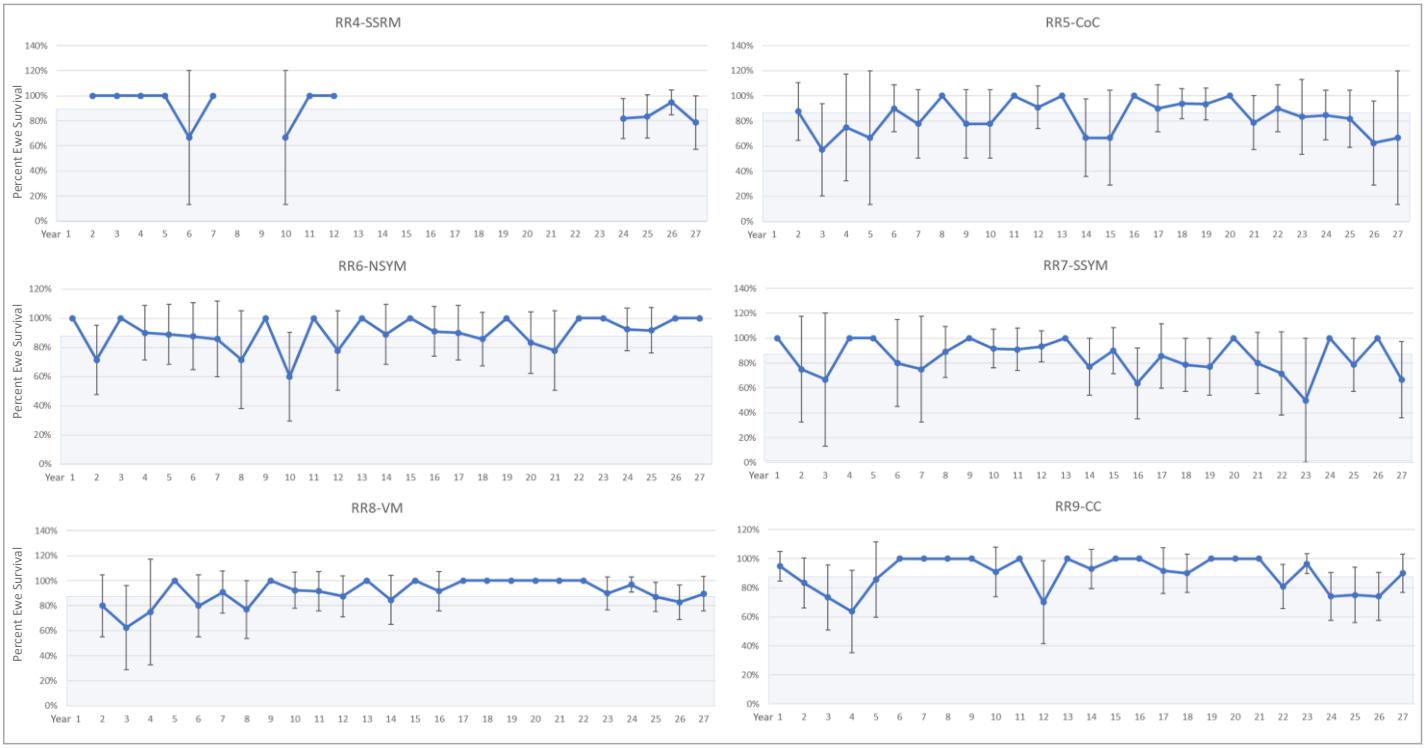


Figure 13. Annual Kaplan-Meier estimates (modified to allow for staggered entry of new animals) of adult radio-collared ewe survival (± 95% Confidence Intervals) for Recovery Regions 4-9 (RR4-9) over 27 years. Each "year" is 12 months from 1 June of one year to 31 May of the next year. Year 1 starts 1 June 1992 and ends 31 May 1993 and Year 27 starts 1 June 2018 and ends 31 May 2019. For comparison, blue background height is set at range-wide ewe survival average of 88.4%.

LAMB SURVIVAL, RECRUITMENT AND LAMB-REARING HABITAT

Pneumonia has been identified as a major cause of lamb deaths throughout the Peninsular Ranges. Poor lamb survival to approximately 4 months of age is considered the most sensitive indicator of pneumonia-induced mortality in lambs (Cassirer et al. 2017). Furthermore, persistently low recruitment below 30% may pose a significant obstacle in population recovery (Cassirer et al. 2013). Due to concerns of disease in lambs, CDFW initiated monitoring of lamb survival (survival to ~ 3 to 4 months) and recruitment (survival to 1 year) in CoC, NSYM and SSYM in 2008. Lamb monitoring was extended into the In-Ko-Pah (IKP) ewe group (within CC recovery region) in 2010 and in the CSRM in 2015. Lamb:ewe ratios and yearling:ewe ratios, based on group observations obtained during field monitoring, are used as indices of lamb survival and recruitment. Clinical signs of lamb pneumonia have been documented in all recovery regions; however, rates of lamb survival and recruitment have varied by ewe group, season, and year. In the past 11 years, recruitment has only been above 30% twice in the CoC and 3 times each in the NSYM and SSYM (Table 8). In all areas monitored, lamb recruitment in 2018 was well below 30% and lamb survival for the first half of 2019 was extremely low; therefore 2019 recruitment is expected to be even lower than for 2018 (Table 8). Additionally, during this reporting period, lamb recruitment and survival data were obtained in the SJM recovery region and the Tierra Blanca ewe group of recovery region 9. In the SJM, 2018 lamb recruitment was only 13% and lamb survival for the first half of 2019 was only 4%. In the Tierra Blanca ewe group, 2018 lamb recruitment was 19% and lamb survival for the first half of 2019 was 59%.

Table 8. Index of lamb survival to approximately 3 to 4 months old (Survival) and recruitment of lambs to yearlings (Recruited) in Coyote Canyon (CoC), NSYM (North San Ysidro Mountains), SSYM (South San Ysidro Mountains), In-Ko-Pah (IKP) ewe group in Carrizo Canyon, Urban ewe group in CSRM (Central Santa Rosa Mountains) and Wild ewe group in CSRM. Lamb survival was calculated from lamb:ewe ratios from group observations obtained in the field from May-June of the year lambs were born and matched with yearling:ewe ratios (recruited) from January - June of the following year. For example in 2018 in CoC, 31% of lambs survived to 4 months old (Survival), and only 18% survived to yearlings (Recruited).

Year	CoC Survival	CoC Recruited	NSYM Survival	NSYM Recruited	SSYM Survival	SSYM Recruited	IKP-CC Survival	IKP-CC Recruited	Urban CSRM Survival	Urban CSRM Recruited	Wild CSRM Survival	Wild CSRM Recruited
2008	66%	21%	43%	21%	64%	29%	*	*	*	*	*	*
2009	51%	31%	30%	24%	41%	18%	*	*	*	*	*	*
2010	37%	24%	14%	19%	61%	28%	79%	39%	*	*	*	*
2011	56%	4%	21%	3%	58%	17%	63%	20%	*	*	*	*
2012	36%	7%	13%	13%	63%	38%	70%	45%	*	*	*	*
2013	26%	7%	7%	18%	93%	*	51%	26%	*	*	*	*
2014	25%	22%	38%	34%	*	27%	10%	8%	*	*	*	38%
2015	35%	27%	19%	11%	47%	23%	86%	35%	53%	11%	66%	36%
2016	73%	52%	66%	43%	94%	42%	75%	33%	86%	67%	65%	43%
2017	[a]41%	24%	77%	34%	83%	32%	b	26%	77%	19%	61%	b
2018	31%	18%	33%	22%	22%	11%	41%	13%	83%	*	38%	28%
2019	[a]43%		20%		5%		16%		*		29%	

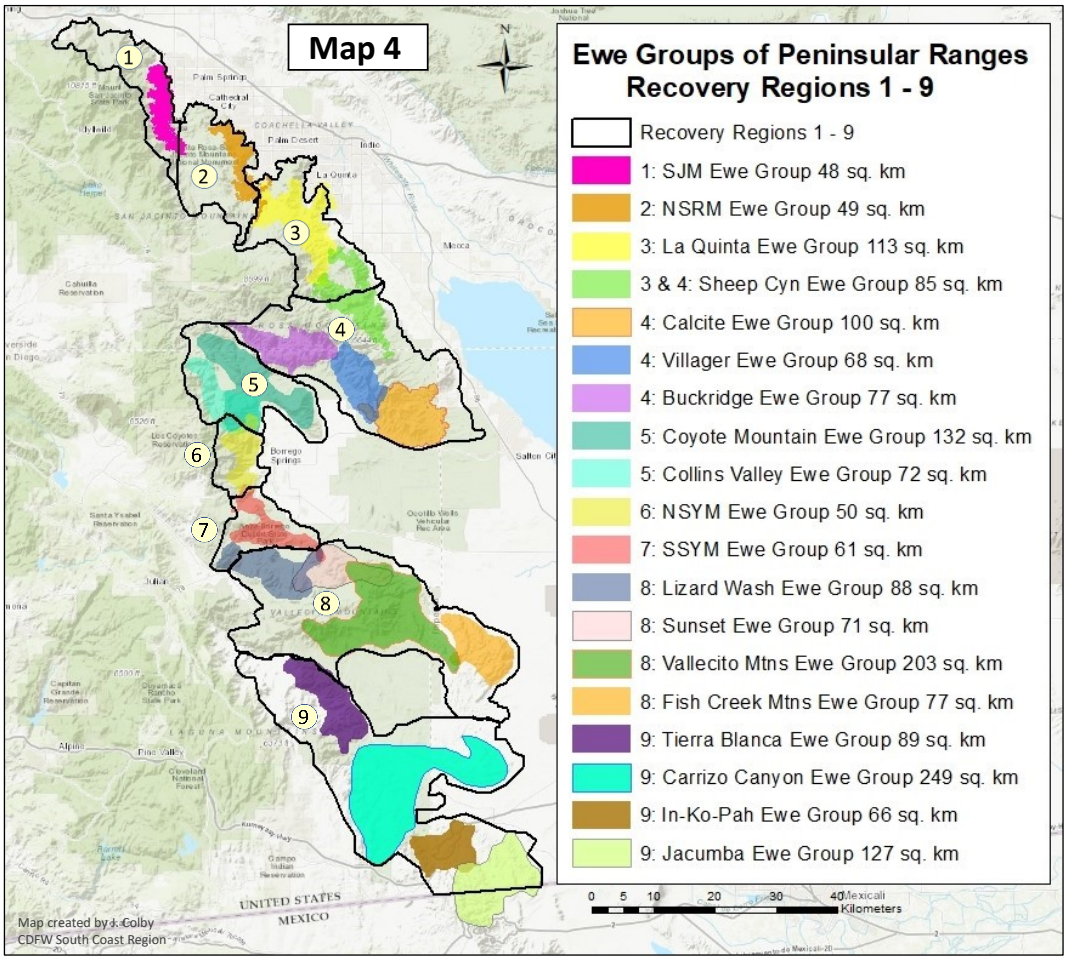
[a]Lamb:ewe ratio obtained from ABDSP annual sheep count for CoC
[b]Not enough observation data were obtained for lamb:ewe ratios.
*Observation data were not collected.

A primary pathogen associated with bighorn sheep pneumonia outbreaks across the western United States, is the bacteria *Mycoplasma ovipneumoniae* (*M. ovi*). Research conducted by the University of California at Davis (UCD), in collaboration with CDFW, has demonstrated that *M. ovi* (via enzyme-linked immunosorbent assay) has been persistently present in all PBS recovery regions since the early 1990s. Moreover, increases in *M. ovi* PCR (polymerase chain reaction) prevalence were associated with lower recovery region survival rates and recruitment (Sanchez et al. 2019). Current research by UCD will focus on describing the spatial and temporal exposure of PBS to multiple pathogens, explore the role of bighorn sheep habitat use in pathogen transmission and how these dynamics have changed over time, and estimate the impact of disease on bighorn sheep survival and reproduction range-wide. Results from this research will be shared with stakeholders involved in bighorn sheep management and submitted for peer-reviewed publication.

Since 2009, CDFW has documented lamb-rearing habitat used by GPS-collared ewes throughout the Peninsular Ranges. In collaboration with CDFW, California State University, San Marcos (CSUSM) recently completed a study that quantitatively described postpartum habitat use of 28 ewes in 4 ewe groups (CoC, SSYM, Carrizo Canyon, and IKP ewe groups) from 2009-2017 (Hines 2019). Hines' study found that ewes in CoC, Carrizo Canyon and IKP (but not SSYM) moved farther from water and predator corridors while moving closer to alluvial fans when choosing lamb-rearing habitat. Vegetation and water-rich cactus are more abundant in alluvial fans than in steep terrain and may be an important source of nutrition and water during lactation. The results for the SSYM may have differed with respect to water and predator corridors due to an artificial water source that was installed near the lamb-rearing habitat. Ewes have high site fidelity for lamb-rearing areas and may not respond quickly enough to anthropogenic changes within traditional nursery grounds such as artificial water sources that may attract predators, roads that may result in collisions, and housing and energy developments that may reduce available foraging habitat. Interestingly, while ewes in CoC moved to higher elevation habitat during the lamb-rearing season, ewes in the Carrizo and IKP ewe groups moved to lower elevation habitat during the lamb-rearing season. Ewes in SSYM were found at slightly higher elevations during the lamb-rearing season but the pre and postpartum difference was not found to be biologically significant. Most importantly, this study demonstrated that while several trends tracked across all ewe groups, most had unique patterns of change between the pre- and postpartum periods. To preserve and protect lamb-rearing habitat, it is essential to understand not only the similarities but the differences among ewe groups within the Peninsular Ranges.

DISTRIBUTION AND MOVEMENT

Since 2009, CDFW has deployed GPS collars on PBS range-wide in order to build a foundation of knowledge concerning distribution, movement, and ewe group structure. All ewes with similar patterns of habitat use are grouped together into a ewe group and, if appropriate, those individuals displaying distinct patterns of habitat use into sub-ewe groups (Map 4). As we build a foundation of knowledge concerning ewe group structure, data will be analyzed and compared among ewe groups rather than among recovery regions. Furthermore, these data will be used to help predict changes in seasonal movement patterns and habitat requirements in an increasingly dry climate. Currently, there are 19 ewe groups identified in the Peninsular Ranges (Map 4); additionally, within almost every ewe group, several sub-ewe groups have been identified. The information within this section is a brief review on current understanding of ewe group home ranges within each recovery region. For more detailed information, refer to CDFW 2016-17 Annual Report.



San Jacinto Mountains

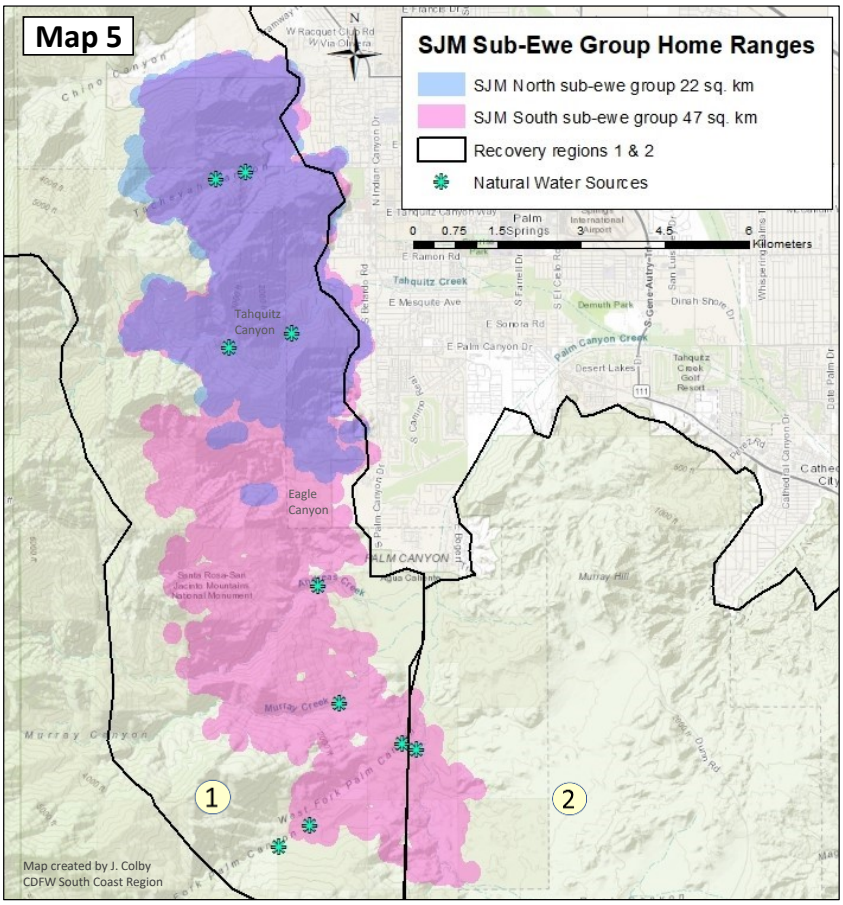
Currently, the SJM ewe group encompasses approximately 48 km^2 and consists of 2 sub-ewe groups that share some lamb-rearing areas but in general use different water sources during the summer months at the north and south ends of the recovery region (Map 5). The north sub-ewe group home range encompasses approximately 22 km^2 and extends 8 km from the south side of Chino Canyon to Eagle Canyon. The south sub-ewe group home range is much larger at approximately 47 km^2 and extends 15 km from the south side of Chino Canyon down into Palm Canyon.

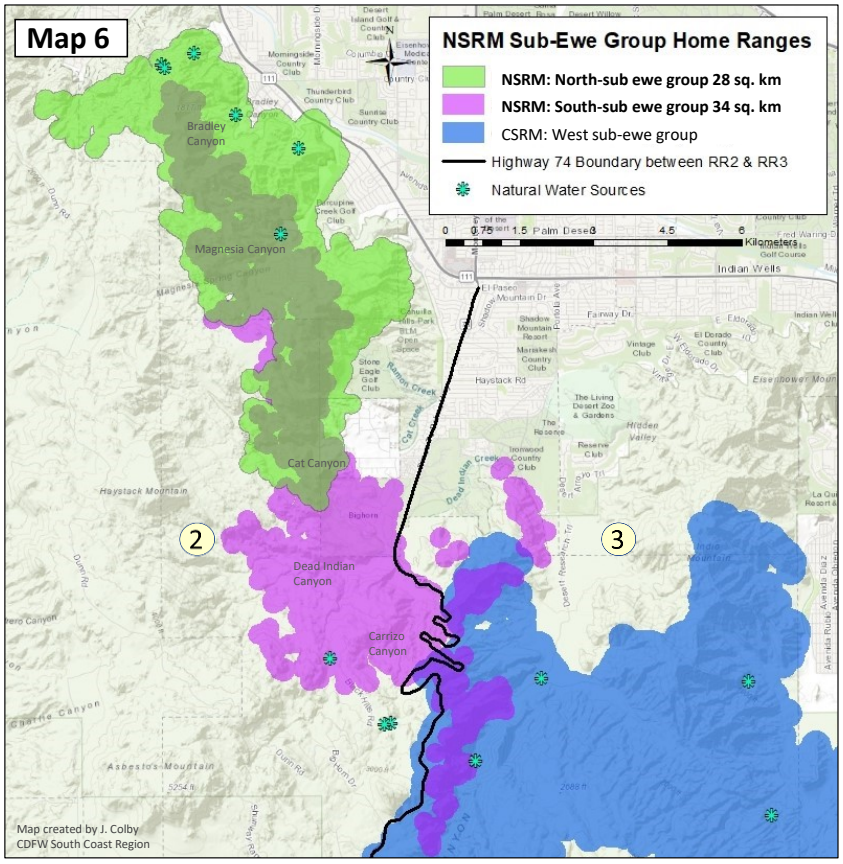
Northern Santa Rosa Mountains

Currently, the NSRM ewe group encompasses approximately 49 km^2 and consists of 2 sub-ewe groups (Map 6) that in general use different lamb-rearing areas and different water sources during the summer months at the north and south ends of the recovery region.

The north sub-ewe group home range is approximately 28 km^2 and extends 10 km from Cathedral Canyon to Cat Canyon with core areas on the slopes surrounding Bradley and Magnesia Canyons. The south sub-ewe group home range is approximately 34 km^2 and extends 16 km from Bradley Canyon to the east side of Highway 74 with core areas surrounding Dead Indian and Carrizo Canyons.

Prior to 2019, NSRM radio-collared ewes occasionally crossed to the east side of Highway 74 into the CSRM and typically stayed for only a few days before returning. However, starting in 2019 the number of road crossing events and the amount of time spent within the CSRM both increased. For example, ewe 470 crossed to the east side of Highway 74 for only 2 days in September of 2018; whereas in 2019, the ewe spent the majority of February and March and the first week of April on the east side of the Highway. Ewe 471 spent several days in February, September and November of 2018 on the east side of Highway 74 but in 2019 spent most of March on the east side of the Highway.



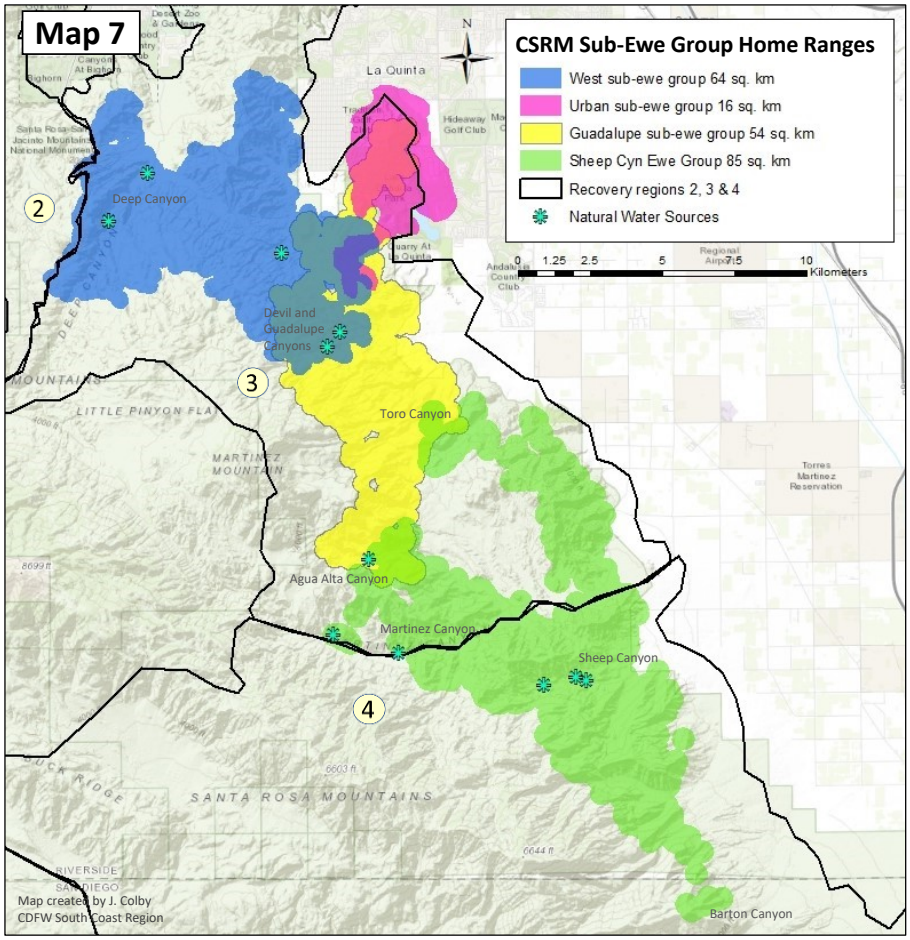


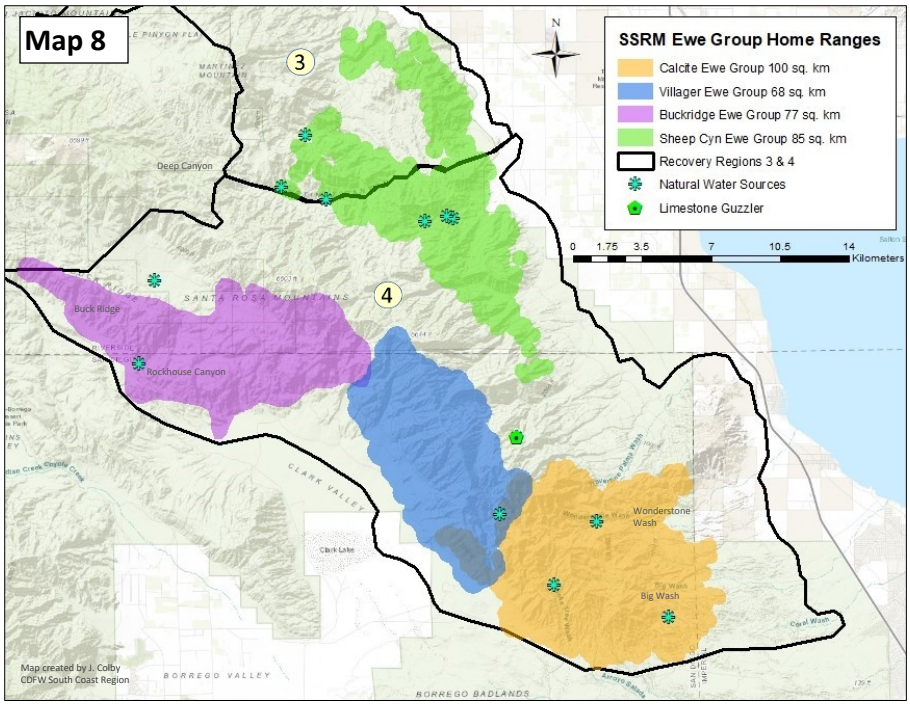
Ewe 424 may have also increased her use of the east side of Highway 74 in 2019; however, the GPS collar stopped functioning in mid-March of 2019.

Each year the south sub-ewe group increases their use at the Bighorn Golf Club course in Palm Desert, particularly during the summer and fall months. In contrast, the north sub-ewe group has not yet used the Bighorn Golf Club course but do visit the lawns of single-family homes at the base of the slopes in the Cahuilla Hills community north of the Bighorn Golf Club.

Central Santa Rosa Mountains

Currently, the CSRM consists of 2 ewe groups—Sheep Canyon ewe group and the La Quinta ewe group (Map 7). However, the Sheep Canyon ewe group home range is bisected by the boundary between the CSRM and SSRM recovery regions (Map 7). The Sheep Canyon home range encompasses approximately 85 km^2 and extends 20 km from Toro Canyon to Barton Canyon with the core use area within Sheep Canyon and the south side of Martinez Canyon.

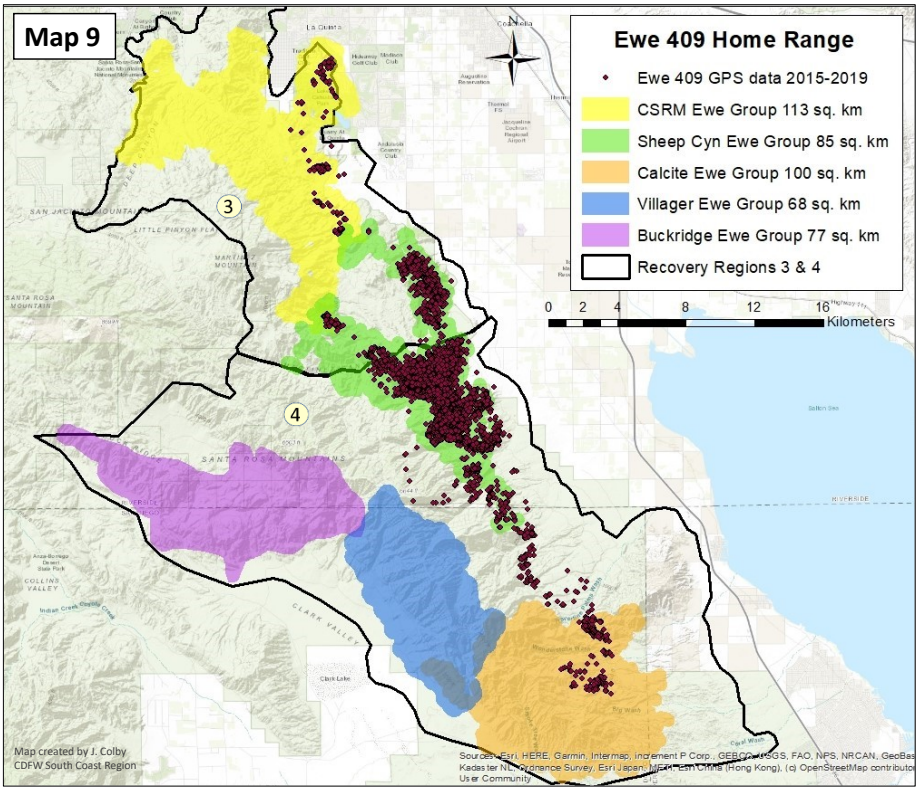




The La Quinta ewe group encompasses approximately 113 km^2 and consists of 3 sub-ewe groups—West, Guadalupe, and Urban (Map 7). The West sub-ewe group home range is approximately 64 km^2 and extends 11 km from the east side of Highway 74 to Guadalupe Canyon with the core use area surrounding Deep Canyon. Thus far, the GPS-collared ewes within this ewe group have remained on the east side of Highway 74. The Guadalupe sub-ewe group home range encompasses approximately 54 km^2 and extends 17 km from the slopes above SilverRock Golf Course to Agua Alta Canyon with the core area surrounding Guadalupe Canyon. Based on GPS location data, the West and Guadalupe sub-ewe groups have not utilized the urban landscape for water or forage and thus are referred to as "wild" sub-ewe groups. The Urban sub-ewe group home range encompasses approximately 16 km^2 and extends 7 km from the slopes above SilverRock Golf Course to Devil Canyon with core use at PGA West Golf Course and community.

Southern Santa Rosa Mountains

The SSRM consists of 3 ewe groups (not including the Sheep Canyon ewe group)—Calcite, Villager, and Buck Ridge (Map 8).

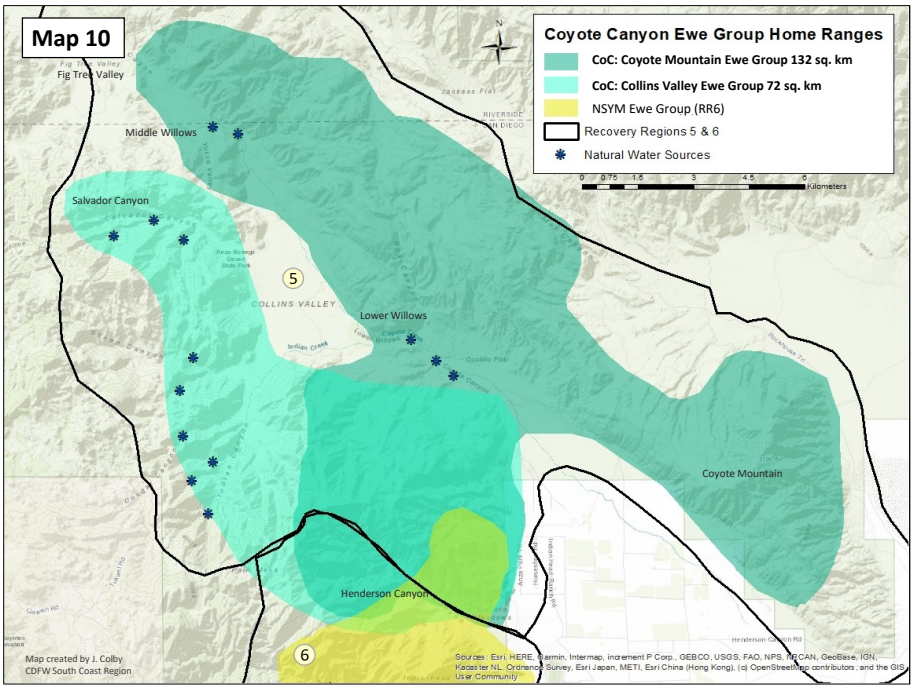


The Calcite ewe group home range is approximately 100 km^2 and is 13 km long from west to east and 10 km wide from north to south. The Calcite ewe group core use area is between Wonderstone, Smoke Tree and Big Washes.

The Villager ewe group home range is approximately 68 km^2 and is 16 km long from north to south and 6 km wide from west to east. The Villager ewe group core use area is the west-facing slopes of Rattlesnake Ridge overlooking Clark Dry Lake.

The Buck Ridge ewe group home range is approximately 77 km^2 and is 19 km long from west to east and 7 km wide from north to south. The Buck Ridge ewe group core use areas are the southwest facing slopes of Buck Ridge and Rockhouse Canyon.

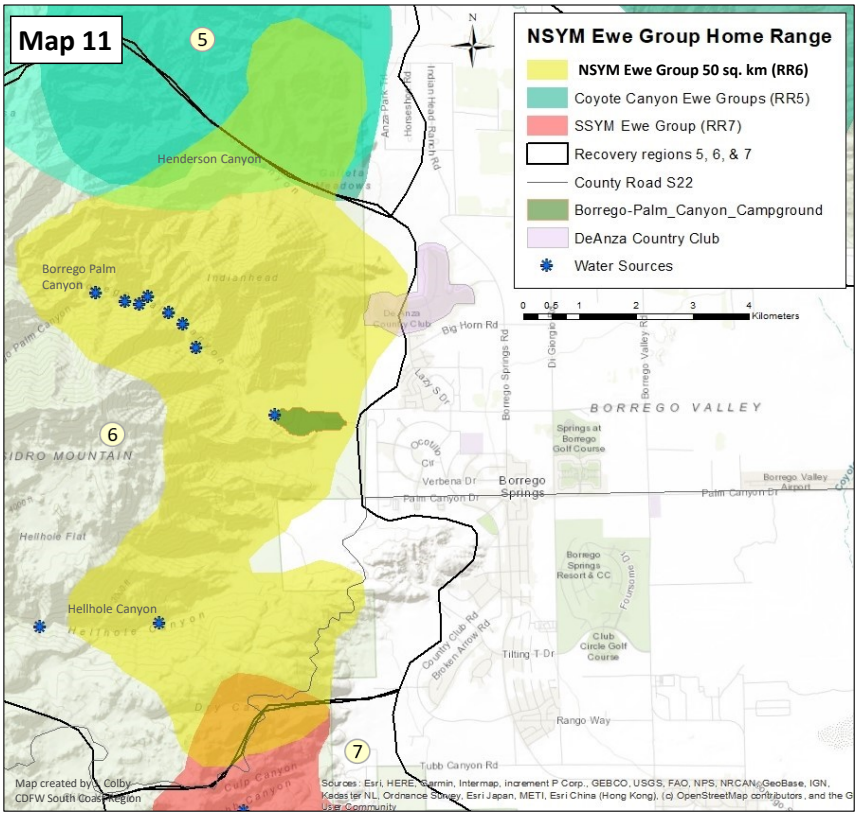
There are a few ewes within each ewe group that move between multiple ewe groups on a regular basis. These ewes often bridge the social and physical gaps between ewe groups within a region or across regions. As an example, 11-year-old ewe 409 mainly associates with the Sheep Canyon ewe group but also spends time with the Guadalupe sub-ewe group to the north in the CSRM and the Calcite ewe group to the south in the SSRM (Map 9). This ewe has the largest home range compared to any other ewe documented thus far in the Peninsular Ranges with an overall home range of approximately 150 km^2 that extends 42 km from the slopes above SilverRock Golf Course in the CSRM to Wonderstone Wash in the SSRM.



Coyote Canyon

There are 2 ewe groups within this recovery region exhibiting a fair amount of ewe group sub-structuring most likely due to the multitude of water sources throughout the region (Map 10). The Coyote Mountain ewe group home range is approximately 132 km^2 and extends 23 km from Fig Tree Valley in the northwest to

almost the terminus of Coyote Mountain to the southeast. The Collins Valley ewe group home range is approximately 72 km^2 and extends 16 km from Salvador Canyon in the north to Henderson Canyon in the south.

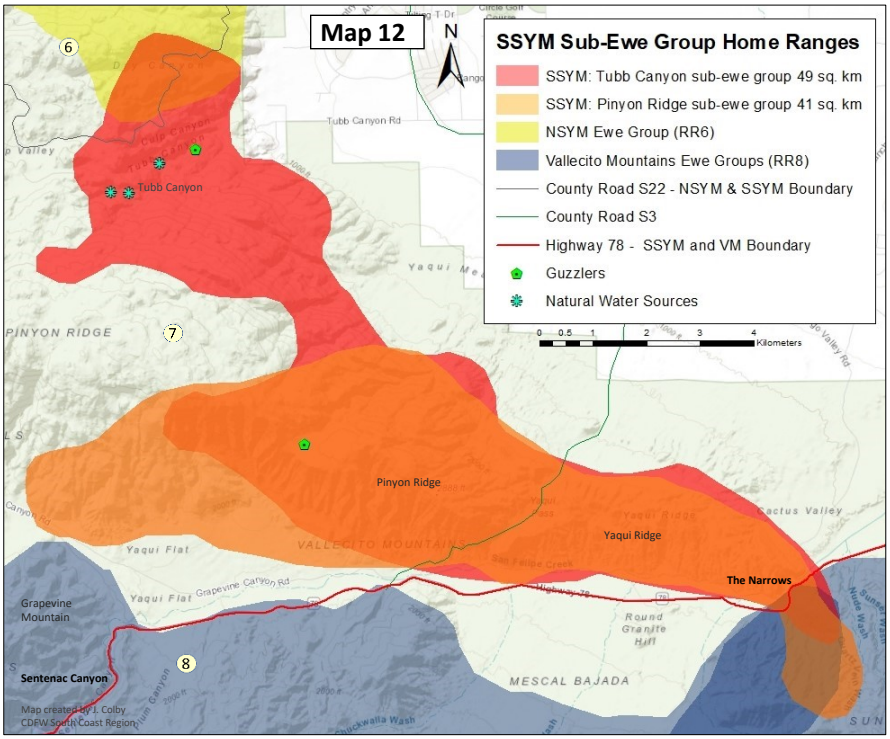


The recovery region lost a significant number of radio-collared ewes to mortality (3) and nonfunctioning collars (2) during the last reporting period. Unfortunately, during the current reporting period 1 of 2 remaining GPS-collared ewes died leaving only 1 GPS-collared ewe and 1 VHF-collared ewe within the Coyote Mountain ewe group. Because there were no GPS-collared ewes within the Collins Valley ewe group during this reporting period, current information on habitat use is lacking.

Northern San Ysidro Mountains

The NSYM ewe group home range is approximately 50 km^2 and extends 13 km from Henderson Canyon in the north to County Road S22 to the south (Map 11). Most radio-collared ewes spend all 3 seasons within the area surrounding Borrego-Palm Canyon. A subset of ewes spends much of their time between Hellhole Canyon and the slopes above County Road S22 just north of Tubb Canyon; however, these ewes also use Borrego-Palm Canyon during the summer and/or lamb-rearing seasons.

Henderson Canyon serves as the dividing line between the CoC and NSYM recovery regions; however, Henderson is used by the NSYM, Collins Valley, and Coyote Mountain ewe groups. Dry Canyon located at the south end of the NSYM recovery region is used by the NSYM ewe group and a subset of ewes from the SSYM ewe group (Map 11).



Over the past few years, the NSYM ewe group has increased its use of low elevation habitat within the Anza Borrego Desert State Park's (ABDSP) Borrego Palm Canyon campground during July and August. The NSYM ewe group's use of de Anza Country Club community from September through December has also increased each year.

Southern San Ysidro Mountains

The SSYM ewe group encompasses approximately 61 km^2 and consists of 2 sub-ewe groups that share the same lamb-rearing area but use different areas during the summer months (Map 12). The Tubb Canyon sub-ewe group home range

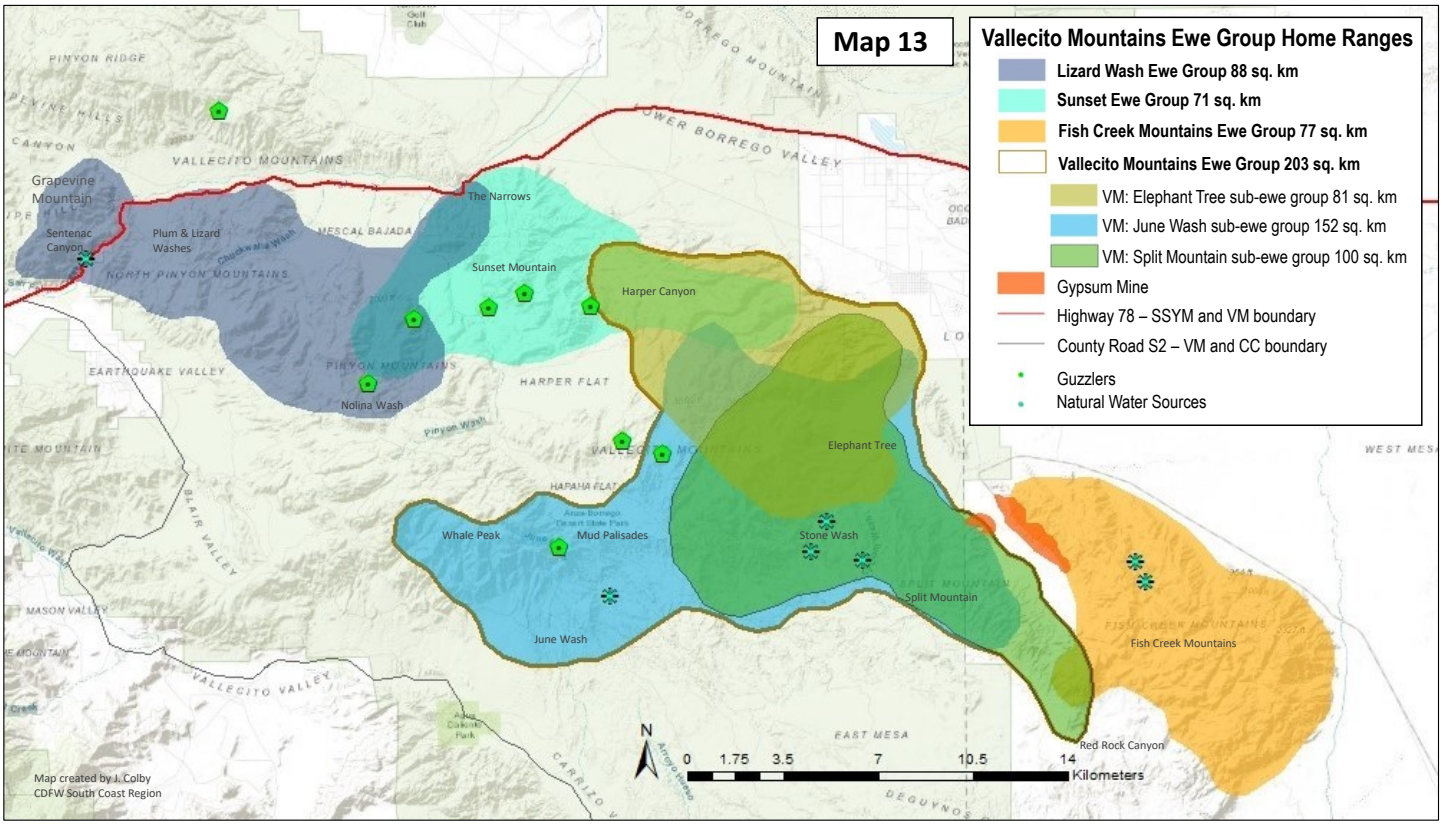
encompasses approximately 49 km^2 and extends 17 km from Dry Canyon in the SSYM recovery region to Quartz Vein Wash in the VM recovery region. Summer months are spent in the area surrounding Tubb Canyon that has several natural water sources and 1 guzzler. The Pinyon Ridge sub-ewe group home range encompasses approximately 41 km^2 and extends 15 km from the Grapevine Hills to Quartz Vein Wash. The Pinyon Ridge sub-ewe group spends summer months on the south-facing slopes of Pinyon Ridge: there is one guzzler in this area, but remote camera photos show that sheep seldom use it. Grapevine Mountain within the SSYM recovery region is not included in the home range map for the Pinyon Ridge sub-ewe group due to lack of current GPS data for this area; however, two VHF-collared ewes have been observed using Grapevine Mountain during the fall months.

County Road S3 between Pinyon Ridge and Yaqui Ridge bisects the SSYM ewe group. On Highway 78, both The Narrows and Sentenac Canyon serve as movement corridors between the SSYM and VM recovery regions. Sheep are most often struck and killed by vehicles during the early spring when ewes are moving between lambing and nursery grounds. Unfortunately, this coincides with an increase in traffic during peak visitation to ABDSP and Ocotillo Wells State Vehicular Recreational Area.

Vallecito Mountains

There are 4 ewe groups in the Vallecito Mountains—Sunset, Vallecito, Fish Creek Mountains, and Lizard Wash (Map 13). Due to lack of winter rains, in the summer of 2018 almost all the guzzlers and many of the natural water sources were dry in the Vallecito recovery region. Despite this fact, GPS-collared ewes did not change their patterns of habitat use in these areas; however, VHF-collared ewes are not monitored on a frequent basis.

The Sunset ewe group home range encompasses approximately 71 km^2 and extends 10 km from Nolina Wash in the west to Harper Canyon in the east (Map 13). It is bound by Highway 78 in the north and extends 7 km to Harper Flats at the southern boundary. Currently, there are only 2 VHF-collared ewes in this area and no functioning GPS collars. Our understanding of the Sunset ewe group is based on GPS data collected from 2010 to 2012 and 2014, from remote camera data and from VHF-collared sheep observations.

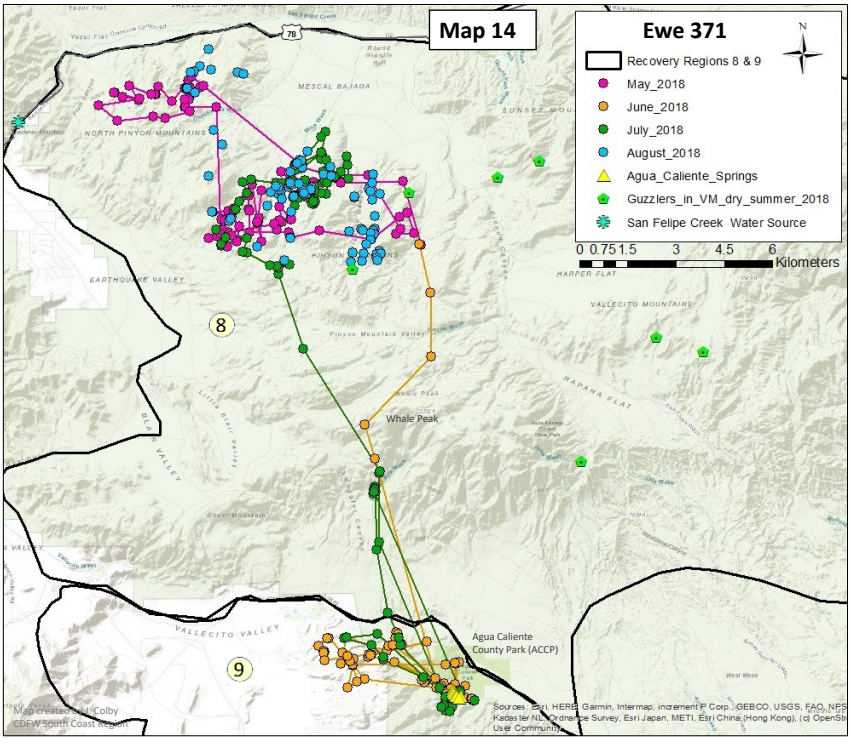


The Vallecito ewe group home range encompasses approximately 203 km^2 and extends 24 km from the southern slopes of Whale Peak in the west to the Split Mountain area in the east (Map 13). The northern boundary extends 14 km in width from Harper Canyon to Fish Creek Wash drainage. The Vallecito ewe group consists of 3 sub-ewe groups—Elephant Tree, June Wash, and Split Mountain. The Elephant Tree sub-ewe group home range encompasses approximately 81 km^2 with the core use areas within the alluvial fan of Elephant Tree and in the mountains to the west and north of the Elephant Tree area. The June Wash sub-ewe group home range encompasses approximately 152 km^2 with core use areas on the slopes between June Wash and the Mud Palisades. The Split Mountain sub-ewe group home range encompasses approximately 100 km^2 with core use areas around Stone Wash and the eastern side of Split Mountain down to Red Rock Canyon.

The Fish Creek Mountains (FCM) ewe group home range encompasses approximately 77 km^2 and extends 14 km in length from the Gypsum Quarry in the north to Carrizo Wash in the south and 8 km in width from Red Rock Canyon to the Mining Railroad (Map 13). There are only a few known ephemeral water sources within a north/south trending canyon at the northeast end of their home range.

The Lizard Wash ewe group home range encompasses approximately 88 km^2, extends 16 km from Grapevine Mountain to Nolina Wash with the core use area between Plum and Lizard Washes (Map 13). While Nolina Wash defines the eastern boundary for this ewe group, a few radio-collared ewes move to Sunset Mountain for 3 to 4 days each lamb-rearing season. Each fall, several radio-collared ewes cross Highway 78 through Sentenac Canyon and spend time on Grapevine Mountain. No radio-collared ewes have been killed on this portion of Highway 78 to date but there have been occasional reports of sheep being hit by vehicles in this area. Ewe 371 serves as a bridge between the Lizard Wash ewe group in the VM recovery region and the Tierra Blanca ewe group within the CC recovery region.

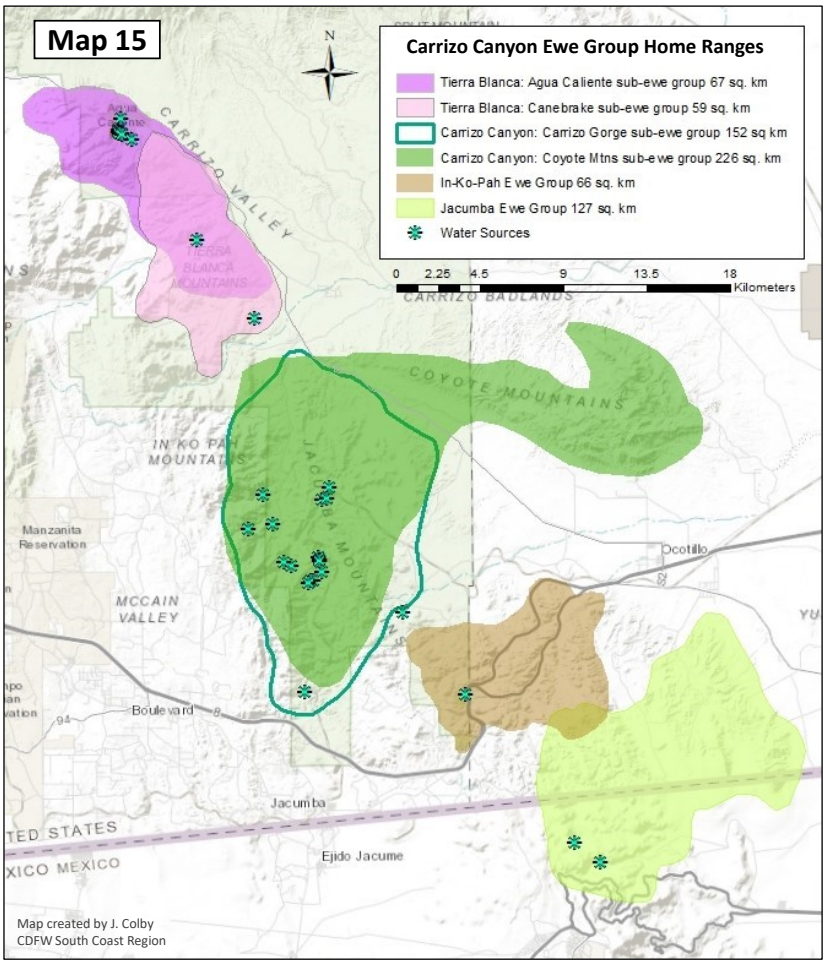
Ewe 371 was originally captured in Lizard Wash in October 2015 and fitted with a VHF-radio collar. The ewe was frequently observed in the Lizard Wash area but in August of 2017 was observed at Agua Caliente County Park (ACCP) in the Tierra Blanca Mountains. This was the first documented movement by a radio-collared ewe from the VM to CC recovery regions. To understand the connectivity between the two recovery regions, Ewe 371 was recaptured in Lizard Wash in November 2017 and fitted with a satellite collar. According to satellite data, ewe 371 stayed in the Lizard Wash area until June 2018 when she moved down to the Tierra Blanca Mountains. The route south started from Nolina Wash, skirted around the west side of Whale Peak, down through Bisnaga Alta Wash, across County Road S3 and ended at ACCP (Map 14). On the return trip in mid-July, ewe 371 went back up Bisnaga Alta Wash but contoured across the lower western slopes of Whale Peak and ended at Mine Wash.



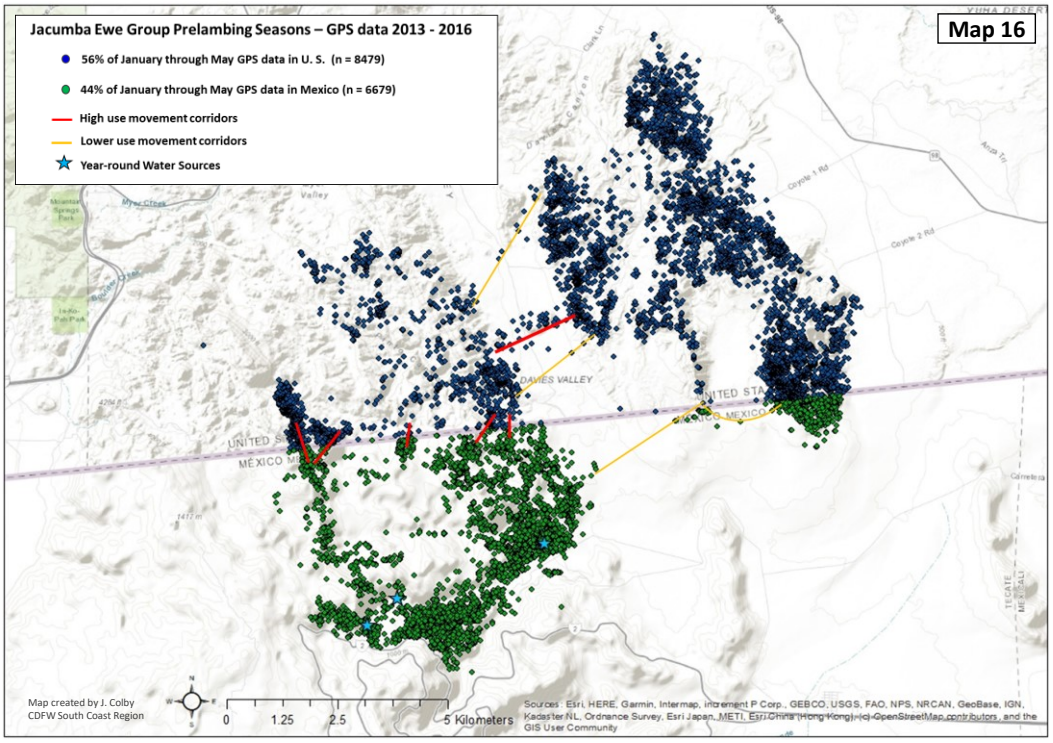
Carrizo Canyon

There are 4 ewe groups in the CC recovery region—Tierra Blanca, Carrizo Canyon, In-Ko-Pah (IKP), and Jacumba (Map 15). From 2009 to present, GPS collars have been maintained within all 4 ewe groups in this recovery region. Detailed information concerning the IKP and Jacumba ewe groups can be found in the CDFW 2014 Annual Report.

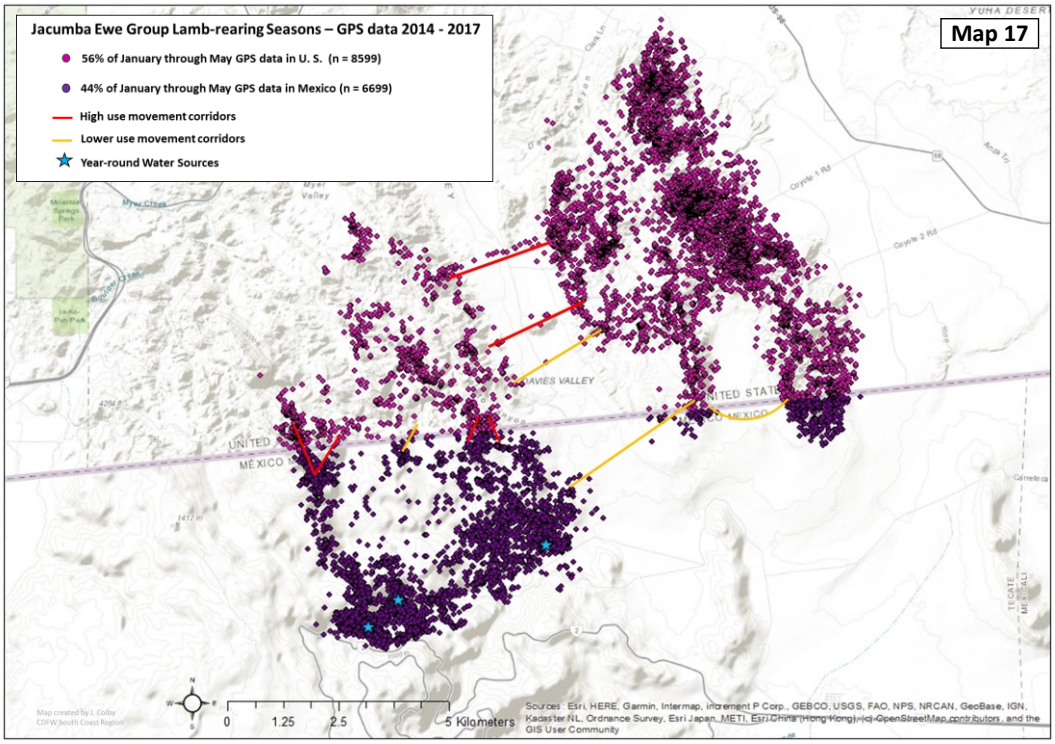
The Tierra Blanca ewe group encompasses approximately 89 km^2 and consists of 2 sub-ewe groups—Agua Caliente and Canebrake (Map 15). The Agua Caliente sub-ewe group home range encompasses approximately 67 km^2 and extends 16 km from the Sawtooth Mountains to Indian Gorge with the core use area on the slopes surrounding ACCP. The Canebrake sub-ewe group home range encompasses approximately 59 km^2 and extends 14 km from the mountains south of Moonlight Canyon to the north side of Bow Willow Canyon with core uses areas surrounding Canebrake and Indian Gorge. Thus far, GPS-collared Canebrake ewes have not used the springs surrounding ACCP as a water source during the summer months. Both sub-ewe groups have increased their use of low elevation habitat during the late summer and fall months which include the community of Canebrake and the area surrounding county road S2.



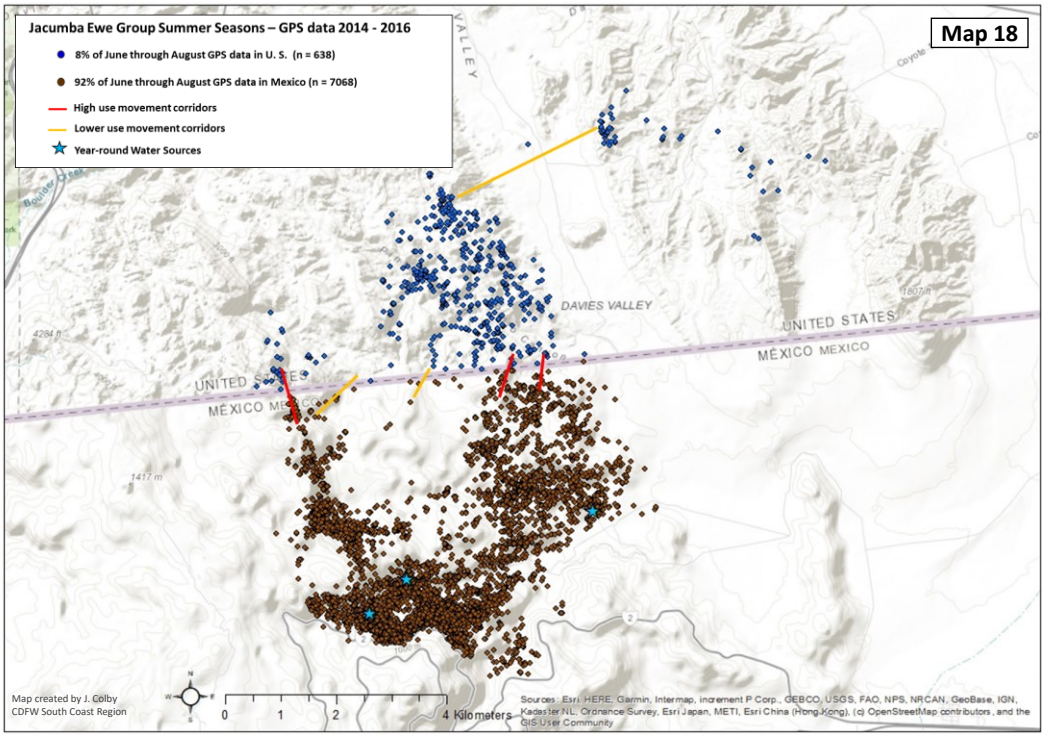
The Carrizo Canyon ewe group encompasses approximately 152 km^2 and consists of 2 sub-ewe groups—Carrizo Gorge and Coyote Mountains (Map 15). The Carrizo Gorge sub-ewe group home range encompasses approximately 152 km^2 and extends 18 km from the entrance to Carrizo Canyon to Tule Canyon near Interstate 8. Core use areas are on both the west and east slopes of Carrizo Gorge; however, there is some use east of Carrizo Canyon within the area surrounding Jojoba Wash and the Volcanic Hills. The Coyote Mountains sub-ewe group (not to be confused with the Coyote Mountain ewe group in CoC) encompasses approximately 226 km^2 and extends 17 km through Carrizo Canyon and another 19 km along the length of the Coyote Mountains (Map 15). Typically, from June through November, the Coyote Mountains sub-ewe group uses almost the same home range as the Carrizo Gorge sub-ewe group. However, from December through May, the Coyote Mountains sub-ewe group moves east across County Road S2 into the Coyote Mountains for the lamb-rearing season while the Carrizo Gorge sub-ewe group remains within Carrizo Canyon and its tributaries.



The In-Ko-Pah ewe group home range encompasses approximately 66 km^2 in the areas surrounding Mountain Springs, Devils Canyon, In-Ko-Pah Gorge, Myers Valley and within the island created by the divergence of the eastbound and westbound lanes of Interstate 8. Core use areas are surrounding Mountain Spring during the summer and in the Interstate 8 Island during the lamb-rearing season. Use of Myers Valley, south of Interstate 8, during the early half of lamb-rearing season has increased over the past few years, which has increased road crossing events.



Lastly, the Jacumba ewe group home range encompasses approximately 127 km^2 and extends 16 km from the Jacumba Wilderness in the United States to Highway 2 in Mexico and is 13 km wide from west to east (Map 15). The Jacumba ewe group is dependent on resources both within the United States and Mexico. A fence along the US-Mexico border would prohibit movement to, and use of, pre-lambing and lamb-rearing habitat in the United States and summer water sources in Mexico (Maps 16-18). Furthermore, the core lamb-rearing habitat in the east Jacumba Mountains is not within USFWS-designated critical sheep habitat and further development of energy projects within or adjacent to these areas, combined with disturbance by border security activities, will have significant adverse impacts on this ewe group.



THREATS TO RECOVERY

Section II.D.1.1-1.4 of the Peninsular Ranges bighorn sheep recovery plan (USFWS 2000) describes a series of interim and long-term actions that, if implemented, would eliminate, or significantly reduce threats to population recovery. Actions

described in the recovery plan address a broad range of known and potential threats to recovery. These threats (generally described) include but may not be limited to the following: 1) habitat loss and fragmentation, 2) loss of habitat connectivity, 3) loss of habitat quality due to natural (fire) and human causes (introduction of exotic/toxic vegetation), 4) loss, reduction or diversion of water sources, 4) use of the urban interface, 5) livestock grazing, 6) road and highway crossing, and 7) human activities known or found to be directly or indirectly detrimental to sheep. Because bighorn sheep in the Peninsular Ranges reside in a network of state, federal, private, and tribal government lands which lie adjacent to large human urban populations, reaching recovery goals and assuring long-term protections for sheep will require an understanding of and commitment to eliminating threats within and among recovery regions. For a review of the current threats and concerns within each recovery region refer to CDFW 2017-2018 Annual Report.

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Photo by Tyler Webb

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Photo by Jeff Young