2011-2012 Annual Report
of the Sierra Nevada Bighorn Sheep Recovery Program

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Summary of Progress

This report documents conservation and monitoring activities carried out by the Sierra Nevada Bighorn Sheep Recovery Program (the Recovery Program) between May 1, 2011 and April 30, 2012. The purpose of the Recovery Program is to conserve and restore state and federally endangered Sierra Nevada bighorn sheep (Sierra bighorn) to reach delisting goals specified in the Recovery Plan (USFWS, 2007) in as timely a manner as possible. When these bighorn were listed as endangered in 1999 there were about 125 bighorn sheep throughout the Sierra Nevada (USFWS, 2007). At the end of this reporting period we estimate there are more than 480 bighorn using habitat from the Cottonwood Lakes Basin in the Mt. Langley herd unit to Virginia Lakes in the Mt. Warren herd unit. While Sierra bighorn numbers have grown in recent years, these bighorn remain the rarest mountain sheep in North America.

Progress towards delisting is measured both in the geographic distribution of Sierra bighorn and in the number of females in each of 4 recovery units. Currently, 8 of 12 herd units necessary for delisting are occupied (Figure 1). Minimum counts over the last year documented 191 females (Table 2), but additional information suggests that there are at least 220 ewes. With continued support for conservation activities, Sierra bighorn are poised to reach the recovery goal of 305 females in 12 herd units within a decade.

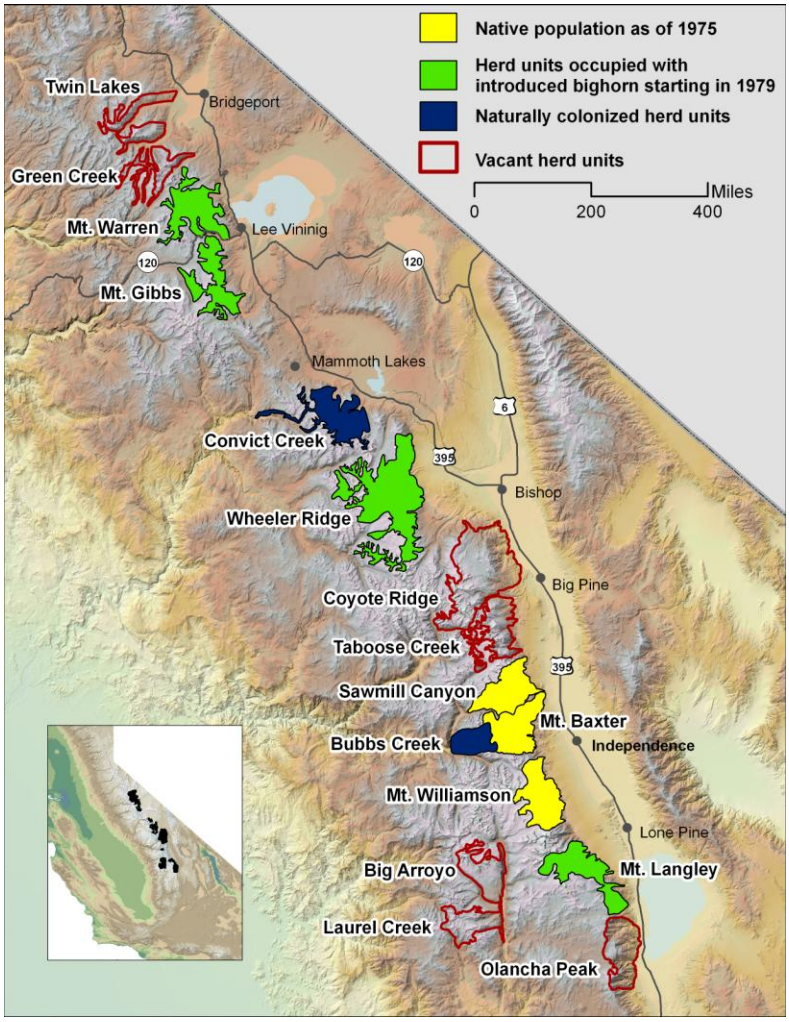


Figure 1. Locations of 16 historic herds of Sierra bighorn. All occupied herd units (filled polygons) are required for recovery except Bubbs Creek. Four vacant herd units: Olancha Peak, Laurel Creek, Big Arroyo, and Taboose Creek, must be occupied to delist Sierra bighorn.

Conservation Activities

Translocations

No translocations occurred during this reporting period; however preparations for large-scale reintroductions are underway. Preparations are underway to transport bighorn from large source populations east of the Sierra Crest to unoccupied habitat. We expect to begin the first of a series of reintroductions in spring 2013. This will be the first reintroduction of these bighorn to a vacant herd unit in 25 years.

Habitat Enhancement

Bighorn sheep rely on visually open habitat to detect predators with sufficient lead time to flee to nearby escape terrain. Predators, specifically mountain lions, pose the greatest threat to bighorn sheep during winter. This occurs when bighorn sheep use low-elevation winter ranges that are often adjacent the winter ranges of mule deer, the primary prey of mountain lions. Since 1990, the Inyo National Forest has worked with the Department of Fish and Wildlife (DFW) to use controlled burns to reduce pinyon forest for Sierra bighorn conservation. This decreases risk of predation by reducing visual obstruction, while also increasing forage availability.

Bighorn sheep in the Mt. Langley herd have exhibited increasing use of low-elevation winter range (Figure 2). While bighorn in this herd have regularly used the area above

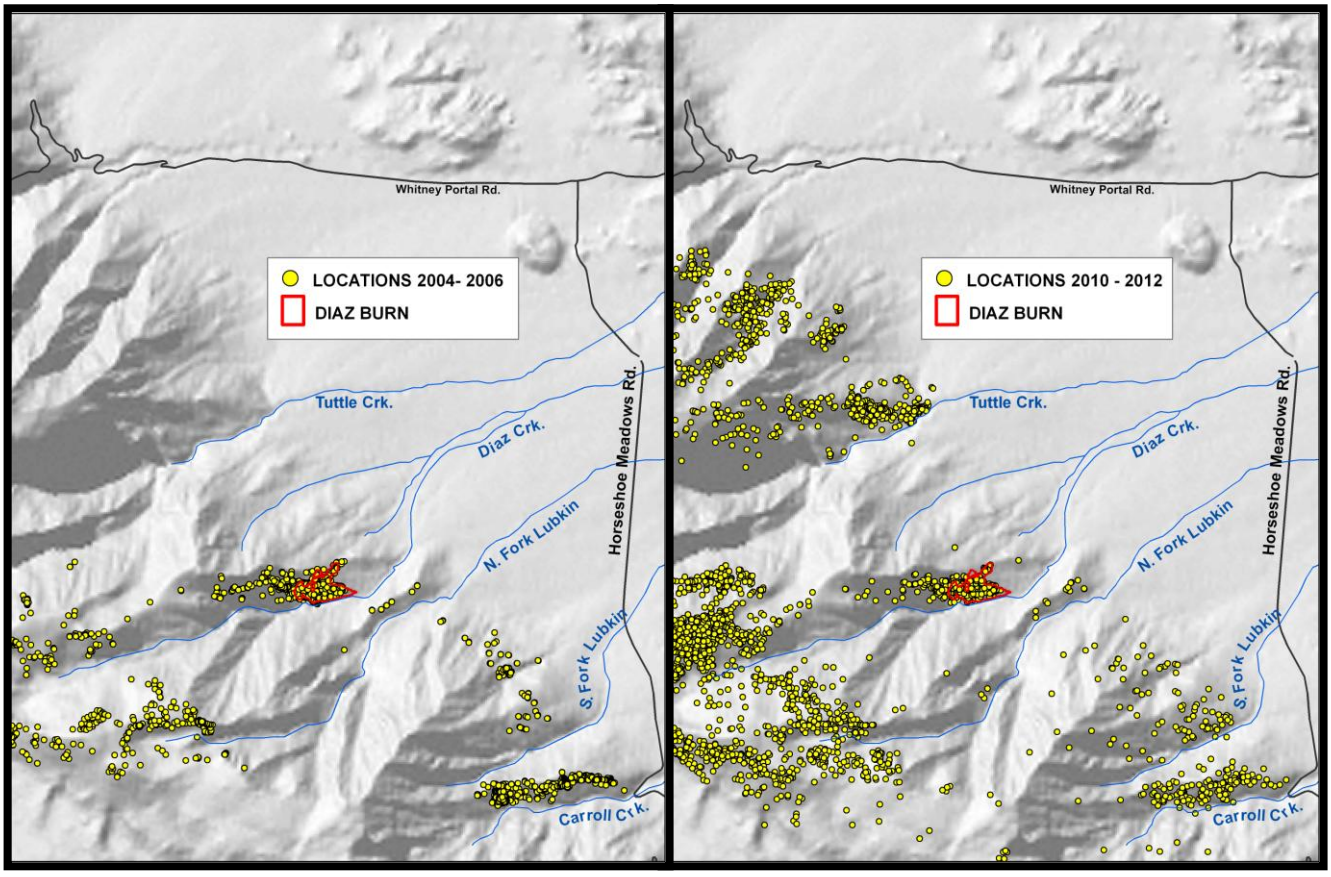


Figure 2. GPS collar locations from bighorn in the Mt. Langley herd document increasing use of low-elevation winter range.

Diaz Creek, which was burned in 1990 and 2001 to improve habitat for bighorn, increasing use of winter range outside of the Diaz burn suggests this herd would benefit from additional habitat enhancement efforts.

Disease Management

Domestic sheep grazing near bighorn sheep habitat continues to threaten the recovery of Sierra bighorn. The normal respiratory flora of domestic sheep can cause devastating pneumonia in bighorn following nose-to-nose contact with just 1 animal (Wehausen et al. 2011, Lawrence et al. 2010). The risk of contact between domestic and wild sheep and subsequent disease transmission is particularly high during the rut when bighorn rams travel large distances in search of ewes that may include domestic sheep. The BLM is currently performing an environmental assessment that analyzes impacts of 4 different alternatives for 2 different domestic sheep grazing allotments. These allotments, Dog Creek and Green Creek, are at the northern end of the range of Sierra bighorn between the towns of Lee Vining and Bridgeport. Four different alternatives are being considered in the environmental assessment: a modified grazing permit, no action, no grazing, and a crossing permit only. The outcome of this environmental assessment will determine how these 2 allotments are grazed over the next 10 years.

While DFW has worked successfully with land management agencies to address the risk of disease transmission from large scale grazing operations on public lands, small sheep and goat operations on private lands also constitute a growing potential threat to Sierra bighorn recovery. DFW is working with local area ranchers to identify funding for double fences for smaller operations to provide a reliable contact barrier (Western Association of Fish and Wildlife Agencies, 2012).

Predator Management

Monitoring predation is an important component of the Recovery Program. Predation has been a leading cause of mortality in some herd units in most years (Stephenson et al. 2012). Mountain lion capture and monitoring was significantly limited in the last year due to political and fiscal constraints (see Mountain Lion Ecology section below). Understanding the relationship between predation and Sierra bighorn should be 1 of the highest priorities of the Recovery Program as DFW strives to increase the use of science as the basis for management.

Predation by mountain lions was documented for a single ewe near Sawmill Lake from May 1, 2011 to April 30, 2012 (Table 1). No mountain lions were removed for the protection of bighorn sheep and the identity of the mountain lion responsible for the kill in Sawmill Canyon is not known. The decrease in mountain lion predation on Sierra bighorn may be related to the limited snowfall occurring during this period or the culling in previous years of mountain lions that preyed on bighorn. A number of reliable sightings and reports of mountain lion sign since 2011 suggest that, as expected, there is still a healthy population of mountain lions in the Sierra bighorn recovery area.

Table 1. Documented lion kills of ewes and rams (collared or uncollared) between May 1 and April 30 of the following year.

Year	Langley	Williamson	Baxter	Sawmill	Wheeler
2008-09	2	2	9	1	1
2009-10	2	0	3	0	3
2010-11	0	0	0	0	2
2011-12	0	0	0	1	0

Sierra Bighorn Population Monitoring

Demographic Data

Most herds of Sierra bighorn are surveyed annually, in part to measure progress toward recovery goals. These counts focus on females and associated lambs and yearlings because reproduction and population growth are most likely to be limited by this segment of the population. Bighorn sheep are polygynous (Geist, 1971) and exhibit sexual segregation, where males live separately from females for much of the year, and thus are not viewed as readily in areas that are surveyed for ewes. Demographic data, including reproduction and recruitment, are collected during surveys to track population trends.

Population data are generated using 2 different approaches: minimum counts and mark-resight (MR) estimates. Both methods provide better data when VHF or GPS collars are distributed in all sub-populations in a herd. Relatively complete minimum counts can be obtained for herds with 30-35 total ewes with focused effort at the right time. This method requires prior knowledge of habitat use patterns most easily obtained from collared animals. Collars also help with finding the most sheep during minimum counts. MR estimators use the ratio of marked to unmarked (i.e. collared to uncollared) animals observed in an unbiased sample to extrapolate the total number of animals from the total number of marks in the population. These estimates, which produce confidence intervals, are becoming increasingly important as the sizes of Sierra bighorn herds increase, and minimum count techniques become less efficient and less feasible.

The season that produces the best population data differs among herd units. Typically the best demographic data are collected from the Mt. Baxter and Wheeler Ridge herds in winter. Historically the Sawmill Canyon herd also was surveyed in winter, but since the addition of collars into the population in 2007, summer surveys have produced much better counts. The best population data for the Mt. Langley, Convict Creek, Mt. Gibbs, and Mt. Warren herd units come from summer surveys, while attempts to survey the Mt. Williamson and Bubbs Creek herds have produced inconsistent results.

Mt. Langley

After repeated failed attempts at a minimum count, we successfully counted the Mt. Langley herd on September 28-29, 2011 just before the first snow of the season. The count totaled 47 adult and yearling ewes, including 1 collar that was not seen. A prior count from August produced an excellent count of rams totaling 42 adults and 3

yearlings. Combining these 2 counts with the lambs counted at the end of September yielded a total of 107 animals (41 adult ewes, 6 yearling ewes, 15 lambs, 3 yearling rams, and 42 adult rams; Table 2). This was the most complete total count ever obtained for this herd.

The total of 9 yearlings indicates high lamb recruitment given the 11 lambs counted the previous summer. The count of 41 adult ewes was also consistent with data from the previous year when 42 adult and yearling ewes were counted. One collared ewe was known to die between those 2 counts. Together these counts in successive years suggest that both may have approached total counts. The mark-resight estimate of 53 adult and yearling females (Table 2) generated from the late September count data produced a narrow confidence interval (42-66) which included the minimum count.

Mt. Williamson

Bad weather spoiled the single survey attempt made at Mt. Williamson in August 2011. One adult ewe, a yearling ewe, and a lamb were observed before weather caused staff to end the survey early.

Mt. Baxter

We made repeated trips to the Mt. Baxter winter range south of Sawmill Canyon including Charlie Canyon between February 23 and April 9, 2012 to develop the best possible count for that herd. The final minimum count was 87 animals: 30 adult females, 8 yearling females, 19 lambs (9 females and 10 males), 5 yearling males, and 25 adult males (Table 2). These minima represent a compilation of repeated group observations. This count excludes S166 who emigrated to Mt. Williamson in May 2010 and includes S167 who migrated to Mt. Williamson in September 2010. In contrast to S166, S167 returned to Mt. Baxter prior to the 2011-12 winter, but did not return to the winter range where counts were made. Instead, she remained at high elevations at the southern end of the Mount Baxter herd summer range. Repeated attempts to find her in winter failed.

A mark-resight estimate of 20 adult and yearling ewes (Table 2) made from all observations on winter range had narrow confidence intervals (17-24), but is clearly a significant underestimate reflecting unequal sighting probability among marked and unmarked ewes in this population (See discussion below in Mark-Resight Estimates).

Survey efforts from the winter of 2010-11 identified 13 lambs on the winter range. The presence of 13 yearlings (8 female and 5 male) this winter indicates that all lambs counted on the low-elevation winter range during the heavy winter of 2010-11 survived.

Sawmill Canyon

The mid-July survey of Sawmill Canyon produced the highest female count of this population to date at 45 total ewes (41 adult ewes, 4 yearling ewes), 12 lambs, 2 yearling rams, 9 adult rams, and 1 unclassified animal (Table 2). This minimum count

includes 1 collared ewe and 1 collared ram that were not seen. Many rams clearly were not seen.

Since radio collars were added to this population in 2007, the known minimum population size has increased from 12 total ewes in the winter of 2007-08 to 45 total ewes in this reporting period. This huge increase in population size is largely a reflection of more complete minimum counts rather than of population growth. During the past 4 years the average ratio of yearling ewes to adult ewes in this herd has been only 0.084, which is about the amount of recruitment needed to replace the annual mortality of adult ewes. With more than 40 ewes in this population, reintroductions and augmentations using animals from this herd can now be planned.

Wheeler Ridge

Changes to wilderness boundaries have prevented captures in this herd for several years. One result was a limited ability to monitor this herd during the past winter because only 4 ewes remained with functional collars. There were multiple attempts to survey Wheeler Ridge in the winter of 2011-12. These produced an estimated total population of 86 bighorn: 31 adult females, 4 yearling females, 15 lambs, 5 yearling males, and 31 adult males (Table 2). This estimate is a compilation of repeated group observations over several months. This minimum of 35 adult and yearling females is slightly less than a mark-resight estimate of 40 adult and yearling females (Table 2) generated from the best minimum count obtained February 5-9, 2012.

Bubbs Creek

No ground or aerial count was attempted at Bubbs Creek this reporting period. A helicopter was not available for surveys.

Convict Creek

Hiker observations and genetic analyses from fecal pellets collected in summer 2009 suggested that a few ewes from the Wheeler Ridge herd had colonized the region east of Pioneer Basin in the Convict Creek herd unit. Our first direct sightings were 1 adult ewe, 1 yearling ewe, 1 yearling ram, and 1 lamb on Esha Peak in June 2010. On January 6, 2011 local skiers observed and photographed a group of 7 bighorn sheep on Esha Peak that consisted of 3 adult ewes, 1 yearling ram, and 3 lambs. We surveyed this herd on June 20, 2011, and observed a group containing 3 adult ewes, 2 yearling ewes, 1 yearling ram, and 2 lambs in Esha Canyon. The presence of 3 yearlings in June 2011 indicates that all 3 lambs observed in January 2011 survived that heavy winter. With continuing reproduction documented, we now consider this herd unit occupied.

Mt. Gibbs

After multiple failed summer surveys, on September 16, 2011 we observed a group with all of the collared ewes consisting of 7 adult females, 1 yearling male, and 4 lambs. This is only the second time since 1986 that there have been 4 lambs in this herd. This minimum count is entirely consistent with count data from the previous year when we

observed 7 adult females and 1 lamb. During the October 2011 capture, the helicopter was unable to find more than 1 uncollared ram. While we did not survey rams in 2011, we believe that this indicates a total of 6 rams that include 5 that wear radio collars. This puts the total Mt. Gibbs herd at 18 bighorn in 2011.

Mt. Warren

Coordinated summer counts in 2011 totaled 11 adult ewes and 2 yearling ewes for a total of 13 ewes in the Mount Warren herd unit. Each of the 2 survey attempts (7/7/2011 and 8/4/2011) missed at least 1 collared adult ewe, suggesting the possibility of another group. This raises the minimum count to 12 adult ewes and 14 total ewes. We counted 2 yearling rams during July, while in August we counted 1 yearling ram, providing further evidence that an additional group exists. Both surveys counted 4 lambs and 2 yearling ewes.

In 2010 there were 8 total rams (5 adults and 3 yearlings) in the Mt. Warren population. In 2011, we counted 7 adult rams (3 at least 3 years old and 4 2-year-olds) on both survey attempts. We know that 2 collared males died in the previous winter. The only inconsistency between these counts is the appearance of an additional 2-year-old ram this year. This suggests that we missed a yearling male in 2010.

In 2010 there were 21 total ewes in the Mt. Warren population (16 adults and 5 yearlings) including the population on Mt. Scowden. This year (2011), we accounted for only 12 adult ewes, and we know of 7 ewe mortalities (19 ewes total). Thus, there are 2 ewes missing from this year's count. We suspect these are the uncollared ewes on Mt. Scowden. Based on last year's count we would not expect more than 2 uncollared adult ewes in this sub-population. Multiple visits to the Mt. Scowden area indicated this area is no longer used. It is likely that these 2 uncollared ewes died along with all of the collars in this sub-population at Mt. Scowden during the extreme winter conditions of 2010-2011.

Geographic Distribution

The Recovery Plan for Sierra bighorn identifies 16 areas of habitat across the Sierra Nevada that were likely occupied by bighorn herds historically (Figure 1). These habitat patches stretch from west of the Bridgeport Valley to Olancha Peak. Of these 16 herd units, occupation of 12 is included in recovery goals for Sierra bighorn. Extensive translocation efforts by DFW during 1979-88 resulted in the reintroduction of 4 herds (Figure 1, green) using the Mount Baxter and Sawmill Canyon native herds (Figure 1, yellow) as translocation stock. Those efforts increased the geographic distribution and thereby protected this unique subspecies should 1 population experience a catastrophic decline. Since listing in 1999, natural range expansions have resulted in the occupation of an additional 2 herd units, Bubbs Creek and Convict Creek (Figure 1, blue), the latter of which is included in recovery goals. The herd units at Olancha Peak, Laurel Creek, Big Arroyo, and Taboose Creek are the remaining vacant herd units listed in recovery goals. Reintroductions to at least 1 of those herd units are being planned for spring 2013.

Given recent explorations into Taboose Creek by bighorn from the Sawmill Canyon herd unit (Stephenson et al. 2012), reintroductions may not be required there; natural colonization of Taboose Creek is likely.

Table 2. Minimum count data and mark-resight estimates (M.R. Est) for populations surveyed during the 2011-2012 reporting period. Lambs are not identified by sex. Unclassified describes animals for which sex and age class could not be determined.

	♀ - Ewes				Lambs	♂ - Rams			Unclassified	Total
Herd	**Adult**	**Yearling**	**Total**	**M.R. Est**		**Adult**	**Yearling**	**Total**		
Langley	41	6	47	53 (42-66)	15	42	3	45	-	107
Baxter	30	8	38	20 (17-24)~	19	25	5	30	-	87
Sawmill	41	4	45		12	9	2	11	1	69*
Wheeler	31	4	35	40 (25-64)	15	31	5	36	-	86
Convict	3	2	5		2	0	1	1	-	8
Gibbs	7	0	7		4	-	1	1	-	12*
Warren	12	2	14		4	7	2	9	-	27

*Total includes a significant undercount of adult rams.
~Estimate is a significant underestimate of total ewes

Collaring Efforts

As the Recovery Plan recognizes, the capture of Sierra bighorn and the deployment of collars are necessary actions to implement recovery (USFWS 2007). Collared bighorn are needed to track population sizes, examine threats to survival and potential contact with domestic sheep, and thereby evaluate the success of management actions. Helicopter net-gunning is the only method feasible for capturing and collaring bighorn sheep throughout most of the Sierra Nevada. Data collected from VHF and GPS collars allow greater understanding of population dynamics and of spatial patterns of habitat use. Spatial information on habitat use has made it possible to document population sub-structuring (different home range patterns), seasonal migratory patterns, and occasional extreme movements that have brought bighorn close to domestic sheep allotments, increasing the risk of disease. Obtaining population estimates and monitoring demographic parameters such as adult and lamb survival and cause-specific mortality ensures a greater understanding of factors that influence population dynamics, including density-dependence and predation. In addition to gathering data from collars, we determine genetic diversity, body condition, health/disease status, and pregnancy status by handling bighorn sheep during captures.

During October 24-29, 2011, 34 Sierra bighorn from 6 herds (Mt. Langley, Mt. Baxter, Sawmill Canyon, Bubbs Creek, Mt. Gibbs and Mt. Warren; Table 3) were captured by wildlife capture specialists from Leading Edge Aviation using a net-gun fired from a helicopter. These captures occurred within Sequoia, Kings Canyon, and Yosemite National Parks and non-wilderness areas on the Inyo National Forest. All 34 Sierra bighorn were captured without injury, and no mortalities of these newly captured

animals were detected more than a month post-capture. To enable precise monitoring of demographic rates including cause-specific mortality and survival, 30-35% of ewes need to be collared. This year's capture efforts allowed us to reach this goal in the Mt. Langley, Mt. Williamson, Mt. Gibbs, and Mt. Warren herds (Table 3).

Collars deployed included 23 satellite-download GPS collars and 11 collars that store GPS locations. This capture was the first major attempt to collar rams in the Southern Recovery Unit. Of the 34 Sierra bighorn captured, 20 were rams. Deploying GPS collars on rams in the Southern Recovery Unit is necessary for a study of the effects of pack stock in Sequoia and Kings Canyon National Parks and will inform their new Wilderness Stewardship Plan.

Blood and hair samples as well as nasal swabs were collected for all animals. Blood samples were analyzed for Anaplasma marginale antibody, Bluetongue virus antibody, Bovine Herpesvirus-1 anitbody, Bovine Respiratory Syncytial virus antibody, Brucella ovis antibody, BVD type-2 virus – Border Disease virus antibody, BVD type-1 virus antibody, Chlamydia antibody, Contagious Ecthyma antibody, Epizootic hemorrhagic disease virus antibody, and Parainfluenza virus 3 (PI-3) antibody, as well as selenium, iron, magnesium, zinc, copper, calcium, phosphorus, sodium, and potassium levels. Nasal swabs were cultured and stored for Mycoplasma analysis. Overall, Sierra bighorn appeared healthy with no visible signs of disease. Lab results confirm that Sierra bighorn exhibit no, or very little, exposure to disease.

Table 3. Distribution of radio collars by herd unit. Additions indicate the number of previously-uncollared animals captured during the reporting period. Recaptures are collared animals that were recaptured to replace collars and potentially remove collars that contained GPS data. The percent of the population collared is based on population size from the most recent complete minimum counts, except as noted.

	Langley		**Williamson**		**Baxter**		**Sawmill**		**Bubbs**		**Wheeler**		**Gibbs**		**Warren**	
	Ewes	Rams	Ewes	Rams	Ewes	Rams	Ewes	Rams	Ewes	Rams	Ewes	Rams	Ewes	Rams	Ewes	Rams
5/1/2011	**13**	**2**	**6**	**2**	**9**	**1**	**5**	**1**	**2**	**0**	**9**	**9**	**5**	**5**	**8**	**5**
Additions	3	6	0	0	2	6	4	2	2	2	0	0	0	1	0	1
Recaptures	3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
Mortalities	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	-1	-1
Censors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/30/2012	**16**	**7**	**5**	**2**	**11**	**7**	**9**	**3**	**4**	**2**	**9**	**9**	**5**	**6**	**7**	**5**
% Pop. Collared	**34**	**16**	**36**	**20**	**29**	**23**	**20**	**10***	**24**	**20**	**26**	**25**	**71**	**100**	**50**	**56**

***** The number of rams in the population was estimated from the number of ewes using a ratio of 7 rams per 10 ewes.

Sierra Bighorn Population Dynamics

Population Size

Populations change over time due to the difference between gains from successful reproduction (recruitment) and immigration and losses due to mortality and emigration. Because immigration and emigration are rare events in bighorn sheep herds and likely involve few sheep, they can largely be ignored in considerations of population dynamics. Consequently, we first consider overall population dynamics, and then mortality and recruitment patterns that influence those dynamics.

Since listing in 1999, herds of Sierra bighorn have grown from fewer than 20 adult and yearling females to, in the largest herds, more than 40 females (Figure 3). Significant gains were documented in the Sawmill Canyon herd after the addition of radio collars in 2007 (Figure 3). These gains largely reflect an increase in detection probability. This year's decline in the number of females at Mt. Warren reflects deaths caused by the heavy winter of 2010-11 (Figure 3). A decline of similar cause was documented during 2010 counts in the Wheeler Ridge herd (Figure 3), which occurred immediately following the same heavy winter. Deaths resulting from heavy-snow winters are primarily associated with avalanches.

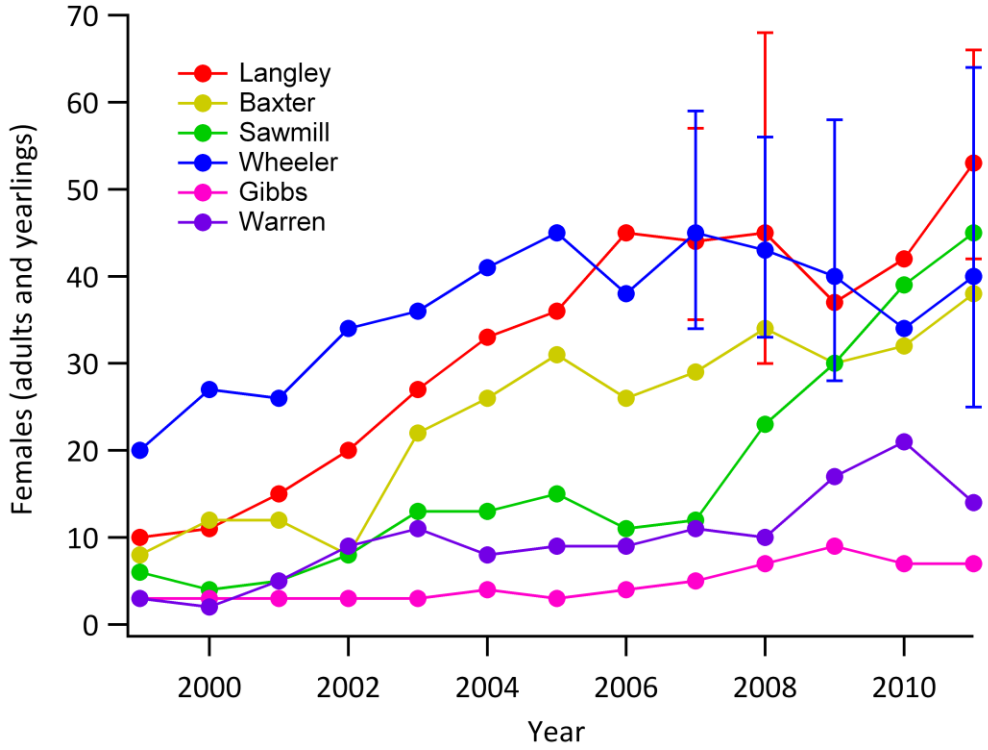


Figure 3. Population trajectories for adult and yearling females from 1999-2011 based on a combination of minimum counts, mark-resight estimates, and reconstructed data for 6 herds in the Sierra Nevada with annual population data. Data from mark-resight estimates are plotted with error bars representing 95% confidence intervals.

Despite large losses after the heavy winter of 2010-11, the number of adult and yearling females has made significant gains. There are now at least 220 female bighorn in the Sierra Nevada. This is a 4-fold increase in just over a decade. With continued population growth and reintroductions to vacant herd units, Sierra bighorn may reach down-listing goals within a decade.

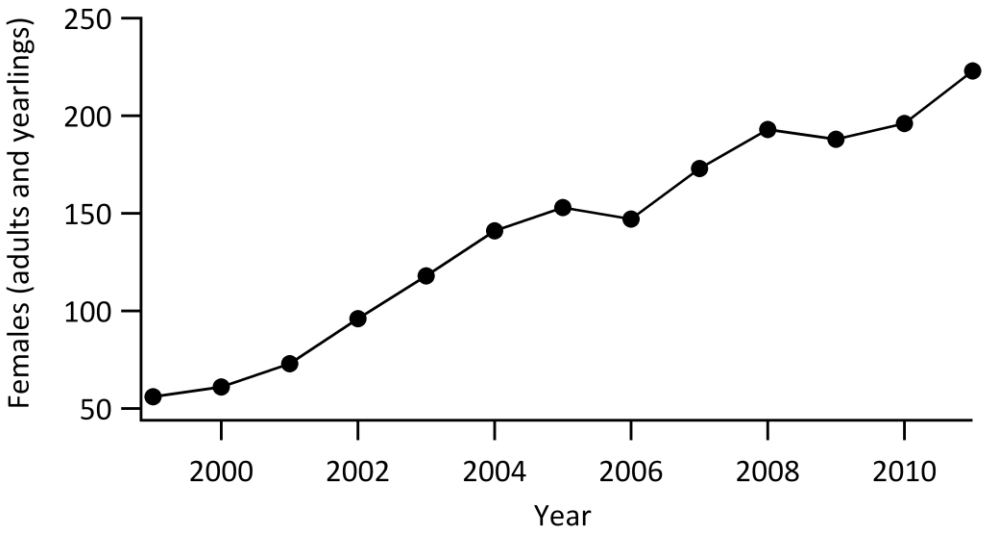


Figure 4. Combined population trajectories for adult and yearling ewes from all occupied herds (Mt. Langley, Mt. Williamson, Mt. Baxter, Sawmill Canyon, Bubbs Creek, Wheeler Ridge, Convict Creek, Mt. Gibbs, and Mt. Warren) from 1999-2011. Population estimates in earlier years lack data for some herds. Some of the significant increases have been due to better data and cannot be construed as population gains; for example the increase between 2007 and 2008 is largely due to increased detection at Sawmill Canyon.

Mark-Resight Estimates

For this report we recalculated all past mark-resight (MR) estimates to ensure consistency over time. All MR estimates were calculated for adult and yearling ewes using Bowden's Estimator in Program NoRemark (http://warnercnr.colostate.edu/~gwhite/software.html). We calculated MR estimates without resampling from each survey attempt, and then combined all observations for multiple survey attempts in a season to calculate an MR estimate with resampling (Table 4). These calculations assume equal and independent sighting probability of all animals. When this assumption is violated, MR estimators produce underestimates with little variation (Neal et al. 1993). Thus, we chose a methodological approach to select the best MR estimate from a season rather than taking the statistical approach of selecting the MR estimate with the lowest coefficient of variation. When a single survey attempt yielded a fairly complete minimum count, including observation of more than 67% of the collars, the MR estimate from the best single survey attempt that season was selected. In seasons where no single minimum count attempt was successful, all observations from the survey season were used in the MR estimate.

Table 4. Mark-resight estimates of adult and yearling ewes for populations in which approximately 30% of the ewes are marked, with 95% confidence interval in parentheses.

Year	Mt. Langley	Mt. Baxter	Wheeler Ridge
2005	-	-	39 (23-47)
2006	40 (32-50)	-	44 (34-57)
2007	44 (35-57)	16 (9-31)	45 (34-59)
2008	45 (30-68)	27 (18-40)	43 (33-56)
2009	33 (33-34)	27 (24-32)	40 (28-58)
2010	34 (24-51)	26 (26-27)	31 (25-39)
2011	53 (42-66)	20 (17-24)*	40 (25-64)

*Estimate is a significant underestimate of total ewes; 38 ewes were observed on winter ranges during the reporting period (Table 2).

Survival and Cause-Specific Mortality

Population growth is very sensitive to changes in adult female survival; however in ungulates, juvenile survival typically contributes more to changes in the population growth rate due to low variation in adult female survival (Gaillard et al. 1998, 2000, Gaillard and Yoccoz 2003, Raithel et al. 2007). Contrary to this generalization, a recent study of individual populations of Sierra bighorn showed that population growth rates at Wheeler Ridge, Mt. Gibbs, and Mt. Warren were driven by changes in adult female survival, which was highly variable (Johnson et al. 2010). Similarly, another study of small populations of endangered bighorn in the Peninsular Ranges showed that population viability was more sensitive to changes in adult female survival than to other demographic parameters (Rubin et al. 2002). Because population sizes of endangered species are small, the deaths of even a limited number of adults can have substantial effects on adult survival rates.

To determine whether populations experience large fluctuations in adult female survival, we calculated Kaplan-Meyer survival rates by aggregating monthly survival data of radio-collared ewes (Pollock et al. 1989) for each occupied recovery unit. Between 2007 and 2011, survival varied between 0.625 and 1 (Figure 5), with the lowest survival rates occurring in the Northern Recovery Unit (NRU) in 2007 and in the Southern Recovery Unit (SRU) in 2008. More recently, survival rates declined in the Central Recovery Unit (CRU) and NRU in 2010 after avalanches during a heavy winter killed 14 bighorn sheep including 7 ewes.

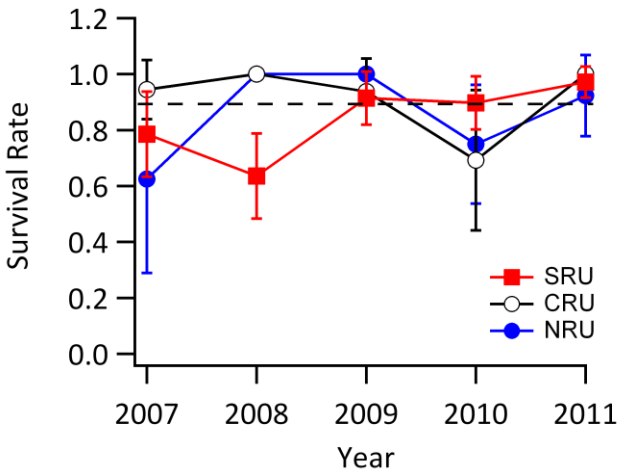


Figure 5. Annual Kaplan-Meyer survival rates of radio-collared ewes for 2007-2011 by recovery unit. The dashed line represents 90% survival. Survival rates above this line are likely to support population growth.

To determine which conservation actions will most effectively aid recovery, it is important to understand the factors affecting adult survival. Since listing, we have investigated new mortalities to determine causes of bighorn deaths. From 2000-2011, mortalities were detected by inspecting GPS clusters from radio-collared bighorn and from collared mountain lions. Since July 2011, no additional mountain lions were captured, so mortalities were primarily detected by monitoring radio-collared bighorn. The goal is to maintain collars on 30-35% of ewes for sufficient and reliable detection of mortalities. Here, we examine the natural factors affecting adult survival by analyzing cause-specific mortalities of collared bighorn. In each of the last 3 years the primary factor influencing adult survival has been different (Figure 6). In 2009 mountain lion predation in the Mt. Baxter and Wheeler Ridge herds was the largest identified cause of mortality. The following year avalanches resulting from the heavy winter of 2010-11 were the primary cause of mortality. Most deaths caused by avalanches were in the Wheeler Ridge and Mt. Warren herd units, but 1 mortality was recorded at Sawmill Canyon. In this reporting period, 2011, there were only 3 mortalities. In part, this may have been a result of the mild winter of 2011-12 and less lion predation in the Southern Recovery Unit following culling through 2010.

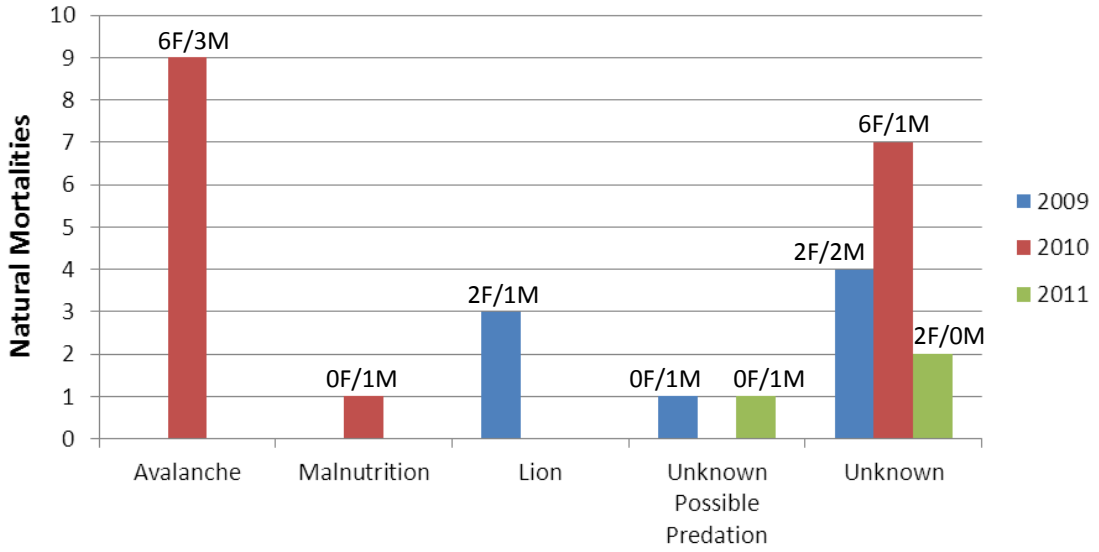


Figure 6. Cause-specific natural mortalities of radio-collared bighorn from May 1, 2009, 2010, or 2011 to April 30 of the following year.

Reproduction and Recruitment

In most herds the number of adult ewes counted in 2011 was equal to or slightly less than the number predicted by complete recruitment of yearling ewes from the year prior (the number of adult and yearling ewes in 2010 or total ewes). This suggests high survival of both yearling and adult ewes. The number of adult ewes observed in 2011 at Sawmill Canyon is larger than the total number of ewes counted in 2010 after accounting for recruitment of yearlings. This indicates the 2010 count was incomplete

and allows the minimum total of ewes for Sawmill Canyon in 2010 to be reconstructed to 41. At Mt. Warren, the number of adult ewes observed in 2011 is significantly smaller than what would be predicted from the number of adult and yearling ewes in 2010. This herd experienced the greatest proportion of severe-weather-related mortalities (i.e. avalanches and falls) during the heavy winter of 2010-11, and the 2011 count data reflect those mortalities.

Table 5. Comparison of the number of adult ewes in 2011 to the number of ewes in 2010 after accounting for recruitment of yearlings (Total Ewes).

Herd	**2010**			**2011**
	Adult Ewes	Yearling Ewes	Total Ewes	Adult Ewes
Langley	36	6	**42**	**41**
Baxter	27	5	**32**	**30**
Sawmill	33	6	**39***	**41**
Wheeler	29	5	**34**	**31**
Convict	3	0	**3**	**3**
Gibbs	7	0	**7**	**7**
Warren	16	5	**21**	**12**

*Indicates an incomplete minimum count. The count of total ewes (adults and yearlings) can be reconstructed to 41 based on the number of adult ewes observed in 2011 in the Sawmill herd.

At Mt. Langley and Mt. Baxter the total yearling to ewe ratio in 2011 is slightly less than the lamb to ewe ratio in 2010 (Table 6). This is typical because not all lambs survive to become yearlings, and yearling survival is highly variable. However, at Mt. Baxter the difference in these ratios is caused by a change in the number of adult ewes observed (Table 7). In the 2 smallest herds, Convict Creek and Mt. Gibbs, these ratios are the same because all lambs survived to become yearlings and all ewes survived. At Sawmill Canyon, Wheeler Ridge, and Mt. Warren, the total yearling to ewe ratio in 2011 is much smaller than what would be predicted from the lamb to ewe ratio in 2010 (Table 6). At Mt. Warren this is likely a result of the heavy winter of 2010-11. Weather may also be an explanation at Sawmill Canyon and Wheeler Ridge. Alternatively, density or predation may be factors reducing survival of young.

Table 6. Estimates of recruitment (ratios of juvenile age classes to ewes) for Sierra bighorn for 2010-11.

Herd	***Lamb:Ewe 2010***	***Total Yearling:Ewe 2011***	***Yearling Ewe:Ewe 2011***
Langley	0.32	0.225	0.15
Baxter	0.54	0.45	0.28
Sawmill	0.45	0.15	0.1
Wheeler	0.72	0.29	0.13
Convict	1.0	1.0	0.67
Gibbs	0.14	0.14	0.0
Warren	0.69	0.36	0.18

In populations with nearly complete minimum counts, lamb survival can be estimated by dividing the number of yearlings observed in 2011 by the number of lambs observed in 2010. It is important to note that these estimates are likely overestimates of lamb survival because many neonatal lambs die before they are observed. Also, these estimates are sensitive to undercounts in either year. Lamb survival varied greatly across herds from 0.36 to 1.0 (Table 7). At Mt. Baxter, Convict Creek, and Mt. Gibbs, all lambs survived and were observed as yearlings in 2011. At Sawmill Canyon and Mt. Warren lamb survival was low. This likely reflects losses over the heavy winter of 2010-11; however, at Sawmill Canyon, this may also be a density effect or be caused by predation.

Table 7. Lamb survival estimated by comparing the number of yearlings in 2011 to the number of lambs in 2010. All data are from minimum counts.

Herd	*2010 Lambs*	*2011 Yearlings*	*Lamb Survival*
Langley	11	9	0.82
Baxter	13	13	1.0
Sawmill	16	6	0.375
Wheeler	21	9	0.43
Convict	3	3	1.0
Gibbs	1	1	1.0
Warren	11	4	0.36

Wheeler Ridge offers a unique opportunity to determine neonatal lamb survival because lambing habitat is readily observable. Because ewes can be observed almost daily during lambing season, it is possible to determine how many lambs are born and then determine lamb survival over their first year by surveying the population in winter when those lambs are approaching 1 year of age. At Wheeler Ridge in 2011, 15 of 21 lambs born survived the first year. Of the 22 lambs born in 2010, 20 survived their first year.

Predator Monitoring

Predation on bighorn has been a significant source of mortality. Although golden eagles, coyotes, and bobcats are all known to kill bighorn, the primary documented predator of adult bighorn is the mountain lion (USFWS 2007). In an attempt to monitor mountain lion predation, we place VHF and GPS collars on mountain lions residing near bighorn habitat. Successful captures of mountain lions in the 2011-2012 period occurred in October, and all of those were efforts to recollar adults. This resulted in the deployment of 3 VHF collars (Table 8). Two of those recollared in October 2011 and 1 collared in March 2011 died during the following reporting period (Table 9). Two were road kills and 1 was shot for depredation of a goat. Three mountain lions remain collared: 1 north of Bridgeport with a GPS collar, 1 that has been located repeatedly behind the Glass Mountains with a VHF collar, and 1 with a VHF collar that was last heard in the Baxter area in March 2012 but was subsequently killed by an automobile south of the Sierra bighorn recovery area.

Table 8. Mountain lions captured between May 1, 2011 and April 30, 2012. Juveniles defined as > 6 months and < 2 years old.

		Northern		Central		Southern	
Age	**Year**	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Adult	2010-11	2	3	0	0	0	0
Juvenile	2010-11	0	0	1	0	0	0
Adult	2011-12	2	0	0	1	0	0

Table 9. Mountain lion mortalities between May 1, 2011 and April 30, 2012. Juveniles defined as > 6 months and < 2 years old.

		Northern		Central		Southern	
Age	**Year**	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Adult	2010-12	1	0	0	1	0	0
Juvenile	2010-12	1	0	0	0	0	0

Mean survival rate for mountain lions over the last 12 years in the Sierra bighorn program area was 71.08% (Figure 7). Survival rate fluctuated yearly with a high of 90% and a low of 35%. However, efforts to recollar mountain lions have been reduced significantly since 2011, decreasing the total population of collared animals, likely increasing the proportion of undetected animals, and increasing the apparent importance of any mortality.

The greatest source of mortality for adult mountain lions is removal to facilitate the recovery of Sierra bighorn (Figure 8a). Including all adult mountain lions known to have died and those suspected of emigrating, Recovery Program removal accounts for 20% of mortalities. Removal due to other depredation is the second most prevalent cause of mortality. For adult females depredation on domestic animals and natural causes are the predominant sources of mortality with no confirmed emigration (Figure 8b). For adult male mountain lions, removal for Sierra bighorn is the most common cause of mortality (Figure 8c).

From May 1st, 2011 to April 30th, 2012 adult females composed 76 % of the mountain lion population (defined in Figure 9 as a fractional count of animals that use a recovery unit). This classification has the greatest number of individuals in the total program area (Figure 9). Adult males and dispersal age females (> 1.5 and < 3.0 years of age) made up 11% of the known animals and a male kitten (< 1.5 years old) accounted for 2 percent. These values were determined by calculating the percentage of months within the year that a specific individual was known to inhabit an area. For example, an individual mountain lion that was known to inhabit a specific herd unit area for 6 months of the year would be given a value of 0.5 for that period. Mountain lion monitoring was not consistently available each month of this reporting period; therefore our confidence in the composition of mountain lions that were in the program area is limited. Fluctuations in total numbers and among classifications appear to be independent

among unit areas. Furthermore, there appears to be more use of herd unit areas by female mountain lions when adult male numbers are relatively low.

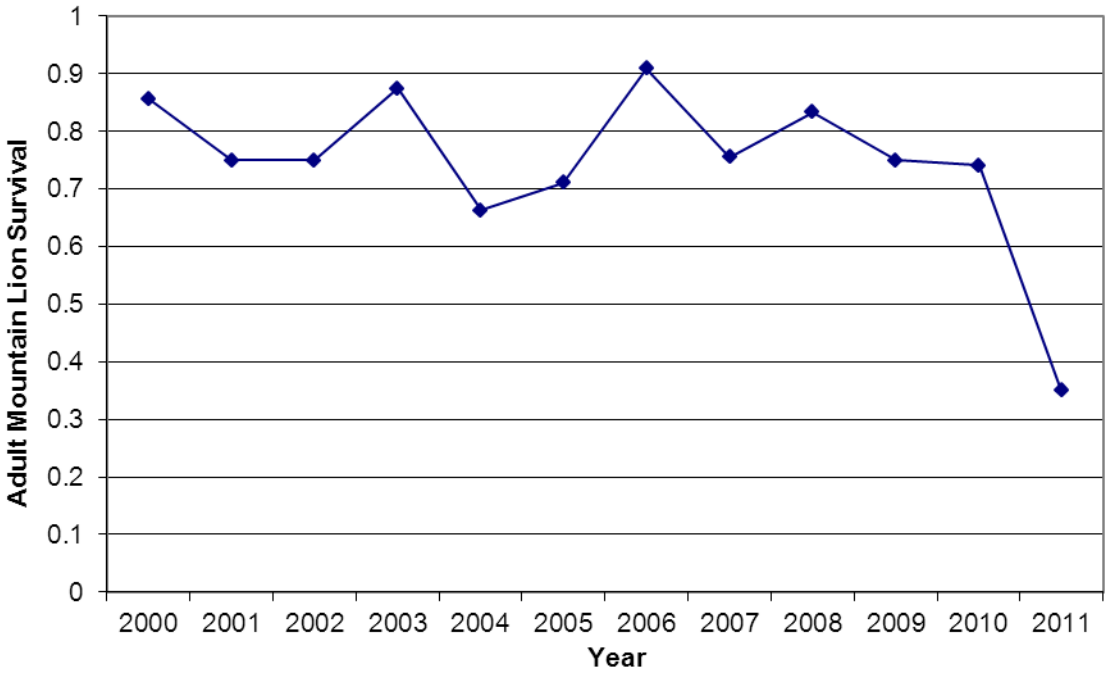


Figure 7. Survival rate of adult mountain lions in the eastern Sierra Nevada using Kaplan-Meier staggered entry (Kaplan and Meier, 1958).

Home range sizes for mountain lions in the eastern Sierra Nevada are typical of those found for mountain lions throughout the west. Using minimum convex polygons (MCP), mean total home range size for males is 1167 km2 (n=11), and for females is 777 km2 (n=16). For winter (November 1 – April 31), the mean size for males is 570 km2 (n=9) and for females is 225 km2 (n=13). Mountain lions have been collared throughout the program area except for the Bubbs Creek area and the Olancha Peak proposed unit area (Figure 10). The distribution of collared mountain lions is somewhat biased because individuals that travel near bighorn sheep are selectively captured. There may be a small proportion of mountain lions that use areas between Sierra bighorn herd units, although the discovery of new bighorn groups on Taboose Creek, Coyote Flat, and Esha Peak expands the area in which mountain lion monitoring will need to be concentrated. Areas east of Highway 395 are not a priority except for the Mono Basin, south of Mono Lake (Figure 10), because mountain lions from the Glass Mountains and Casa Diablo areas have frequently moved to the Wheeler Ridge area when the Round Valley deer herd arrives on the winter range. Additionally, mountain lions that move back and forth from Wheeler Ridge to the Mono Basin have been killed while south of Mono Lake because of the difficulty in removing mountain lions while they are on Wheeler Ridge.

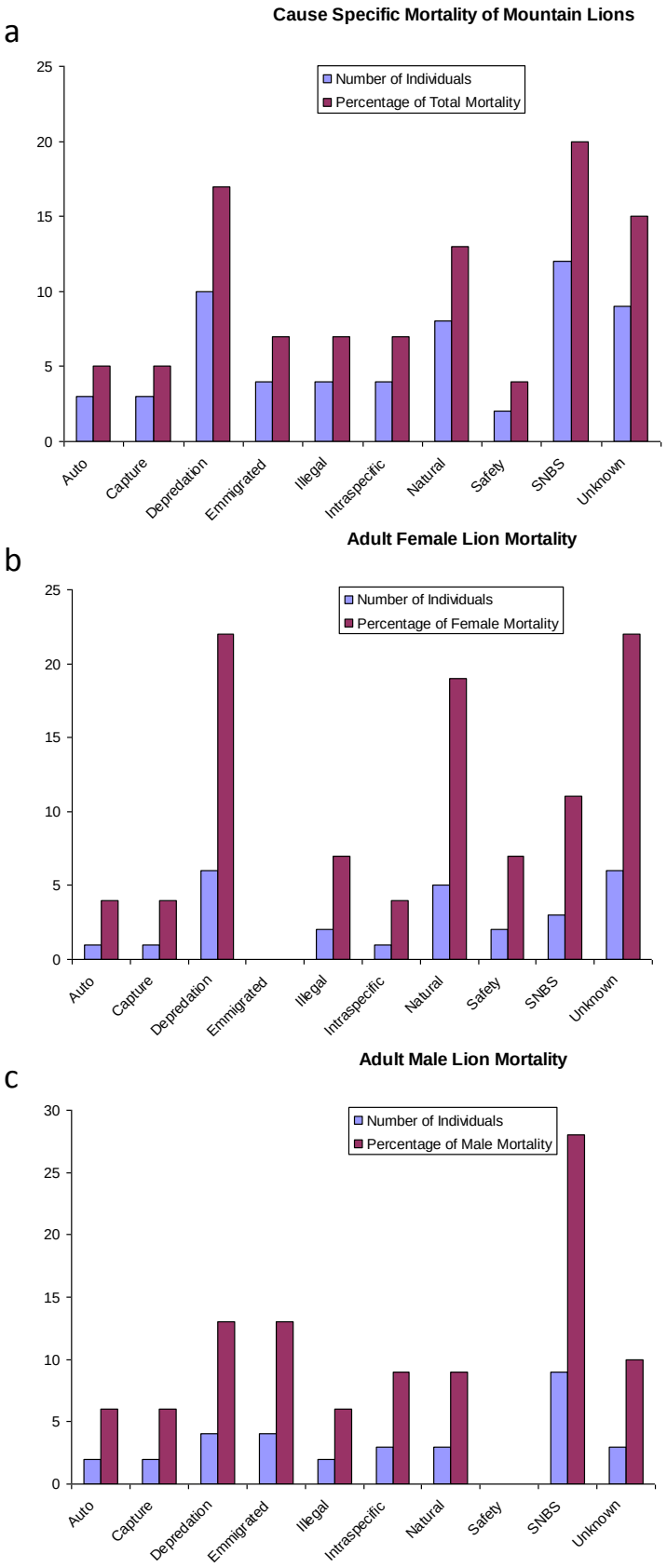


Figure 8. Cause-specific mortality and emigration of adult mountain lions identified by the Recovery Program since 2000. Proportions are biased as all adult mountain lions were included, including uncollared animals. For example, uncollared lion depredations or roadkills are more easily detected than those that die from natural causes.

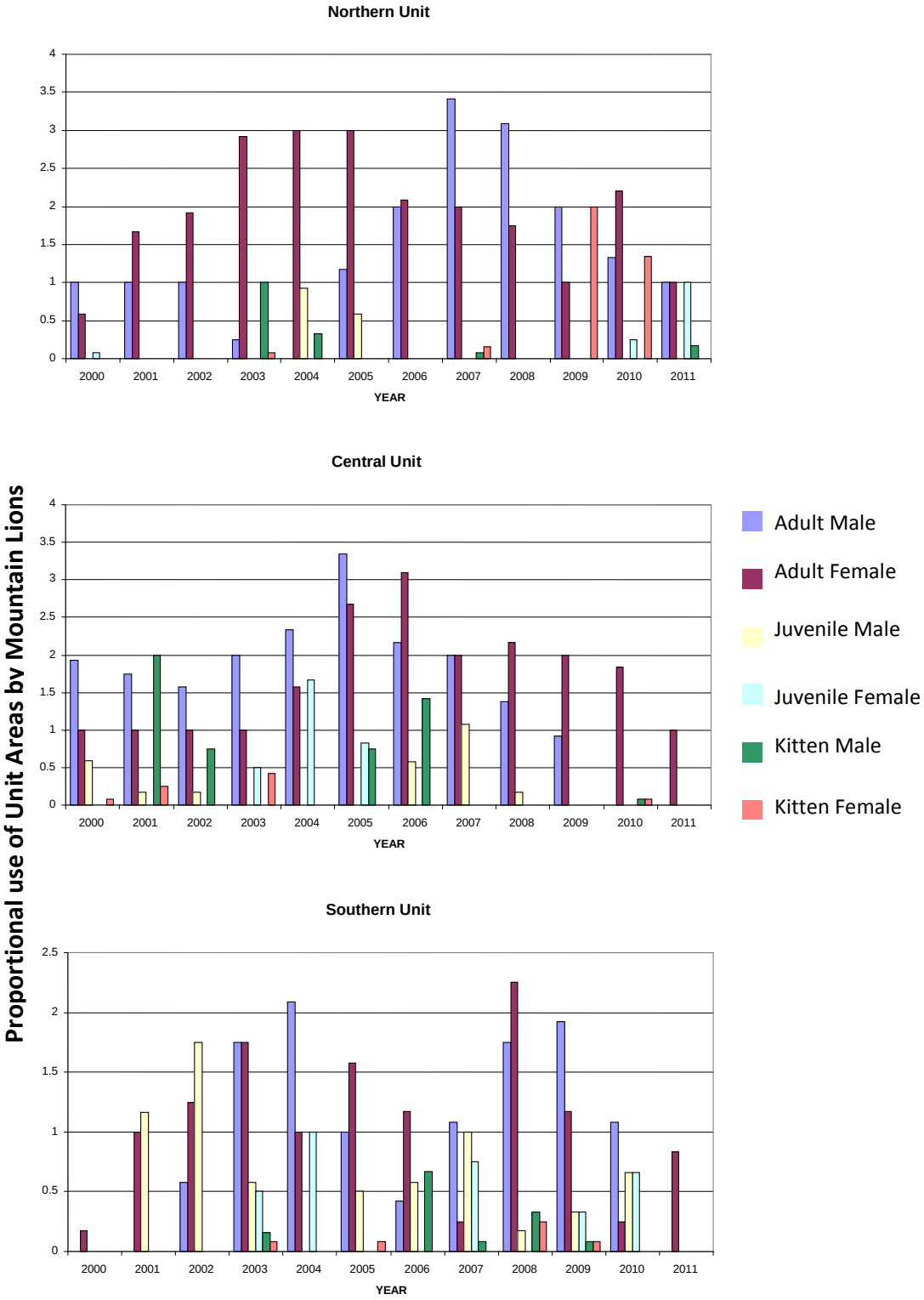


Figure 9. Sex and age class of mountain lions in Sierra bighorn recovery units. Number represents the sum of percentage of months each individual in each class was known to be alive for each year. Years are defined as May 1st through April 30th and labeled by the year with May.

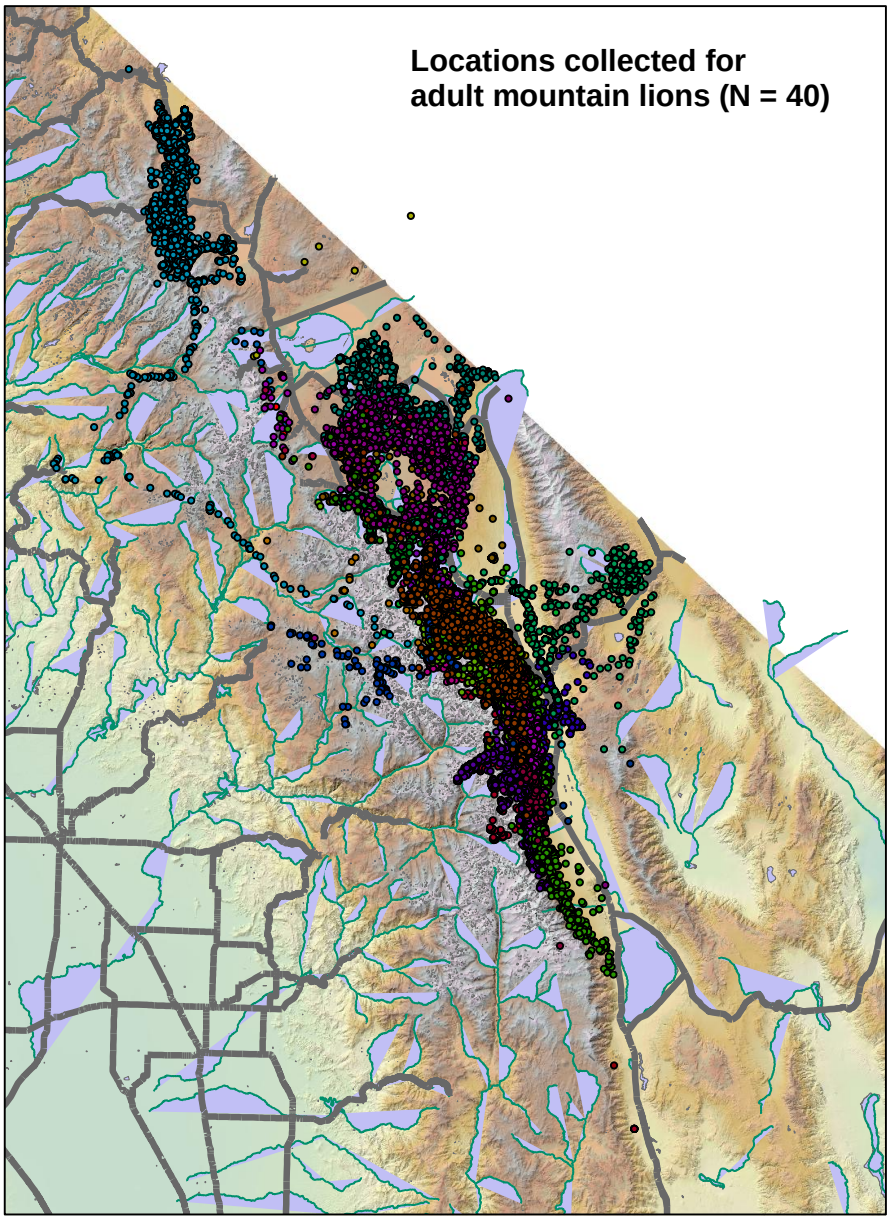


Figure 10. Plotted location data for 40 different adult mountain lions marked since 2001. Most regions of the Sierra bighorn program area have been used by radio-collared mountain lions. A majority of locations are at low elevations and very few locations are in lambing habitat.

Studies of mountain lion demography suggest that juvenile male mountain lions are limited by the number of adult males with established territories (Stoner et al. 2006, Robinson et al. 2008, Cooley 2009). Preliminary data suggest the same is true in the Sierra bighorn recovery area (Figure 11). However, at this time, sample sizes are too small to test this hypothesis. Additionally, a lack of personnel over the last year has limited our ability to detect and radio-collar immigrating individuals.

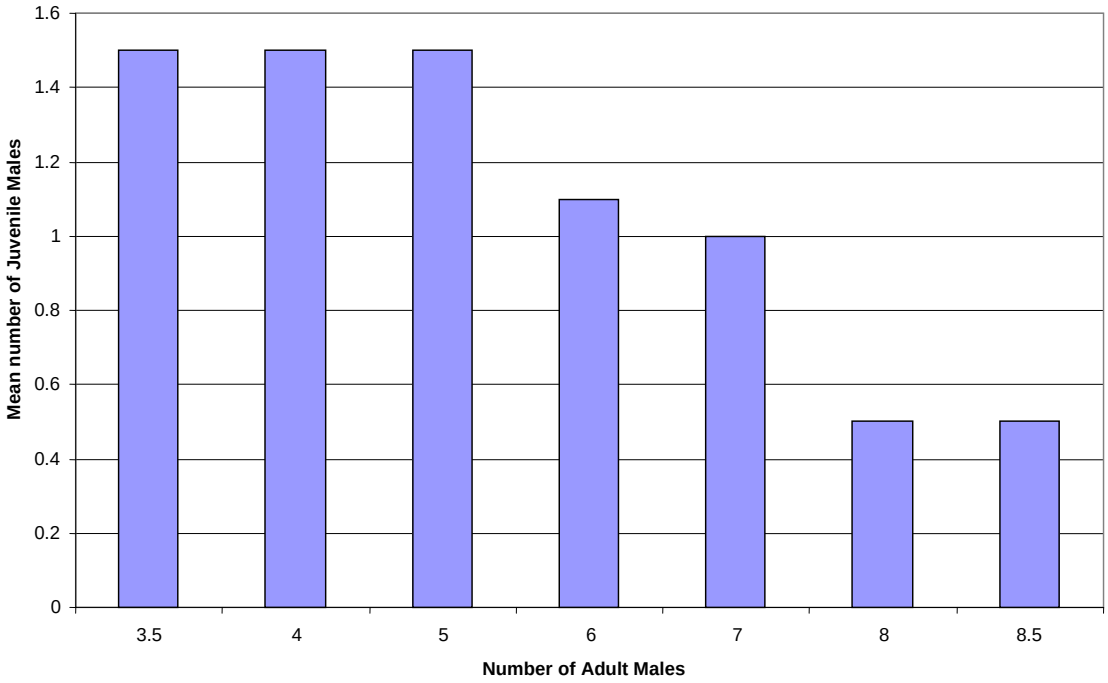
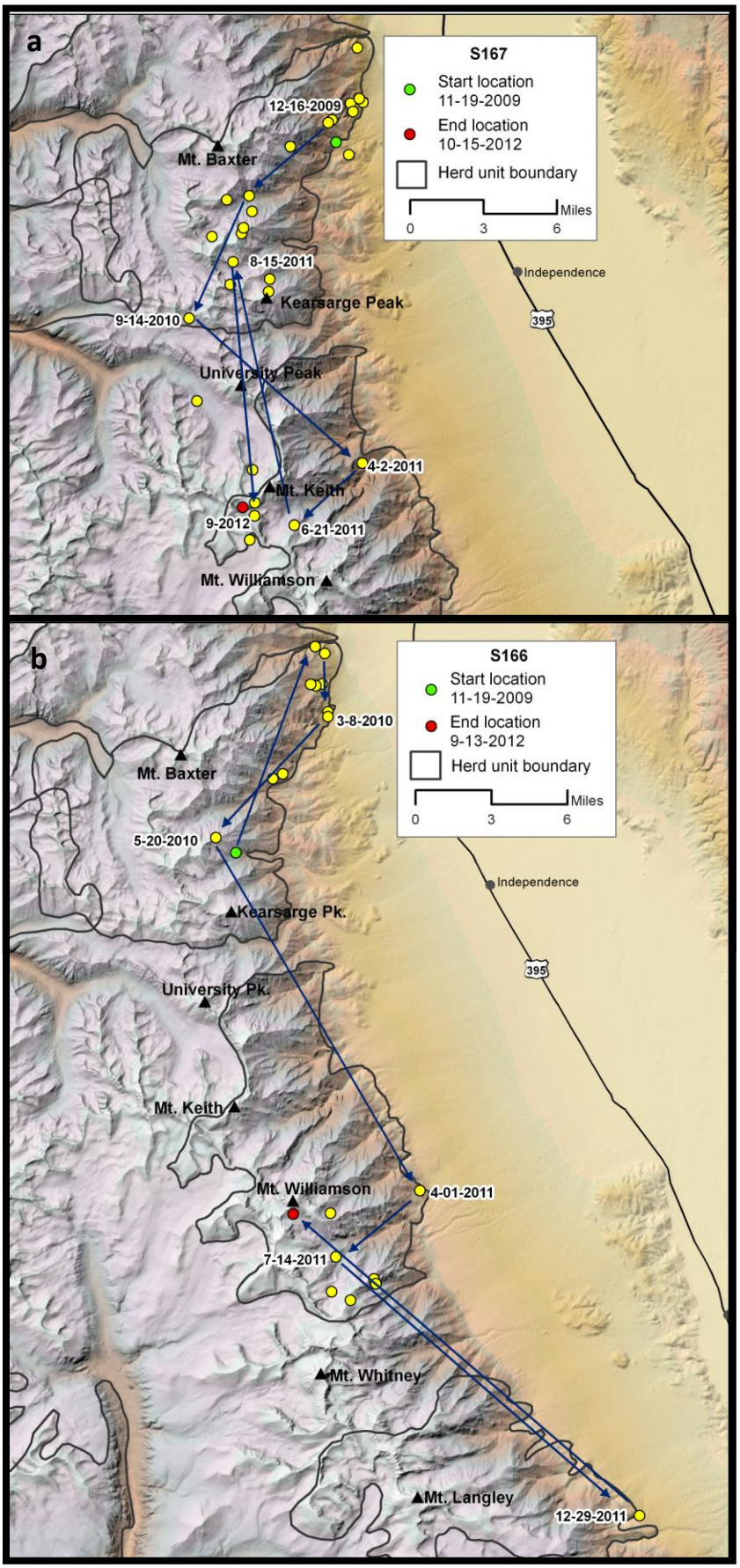


Figure 11. Mean number of juvenile males for years with different total numbers of adult males. Years span 2000 – 2011 and were defined as January through December. Includes animals in the entire Sierra bighorn program area.

New Findings

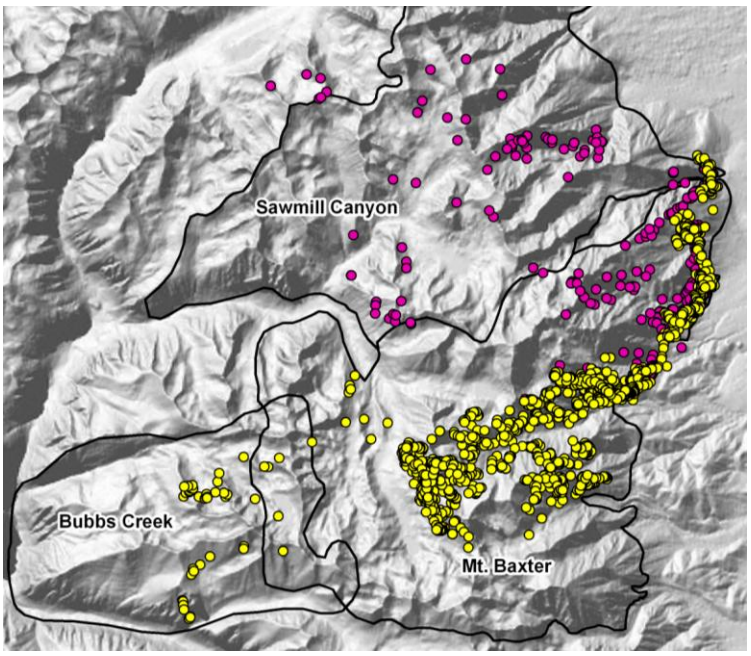
Long-Distance Movements by Ewes

Two radio-collared females from the Mount Baxter herd, S166 and S167, moved 18 miles south to Mount Williamson in 2010. These ewes were observed a considerable distance apart on winter ranges in early April of 2011. S167 was located in Shepherd Creek (Figure 12a) in a group of 12 sheep that included 4 collared females from Mount Williamson. Behavioral interactions (dominance and association) suggested that she was a lone immigrant. By August 2011, S167 returned to Mt. Baxter where she remained until September 2012.



S166 was located between George Creek and South Bairs Creek (Figure 12b) in a patch of habitat that was the most favored winter range of the Mount Williamson sheep prior to 1985 when they abandoned use of low-elevation winter ranges south of Shepherd Creek. Accompanying S166 was another adult female and a yearling of each sex. Genetic analyses confirmed these uncollared bighorn were also from the Mt. Baxter herd. One flight location indicates S166 made another exploratory trip south to the Mt. Langley herd; however all other ground observations and flight locations indicate S166 remains a resident of the Mt. Williamson herd unit. These observations indicate the total emigration of 4 Mount Baxter sheep: 2 adult females and a yearling of each sex.

Figure 12. Locations from telemetry flights and ground observations for 2 GPS-collared bighorn ewes, S166 and S167. **A**, S167, migrated repeatedly between Mt. Baxter and Mt. Williamson and briefly explored Mt. Langley. **B**, S166, migrated to Mt. Williamson and has remained resident there.



Long-Distance Movements by Rams

GPS data from rams captured in October 2011 indicates movement between Mt. Baxter, Sawmill Canyon, and Bubbs Creek during the rut (Figure 13). Rams mating with ewes from neighboring herds preserves genetic variability.

Figure 13. GPS locations from October 2011 to March 2012 of 2 rams captured in the Bubbs Creek (yellow) and Sawmill Canyon (pink) herd units.

Lion Predation Affects Survival Rates

Johnson et al. (2013) examined the demographic consequences of lion predation by testing whether predation had additive effects on adult bighorn sheep survival, the vital rate with the highest elasticity (i.e. effect on population growth) for Sierra Nevada bighorn sheep. When annual survival rates from each population were regressed against their respective annual rates of lion predation, the corrected regression slopes indicated that predation additively affected bighorn sheep survival. The relationship between annual survival and lion predation was highly correlated and statistically significant in Baxter and Wheeler, demonstrating a strong influence of lion predation on annual survival rates in these herds (Johnson et al. 2013).

Public Outreach

Implementing the DFW Vision

The Recovery Program is committed to providing a positive example of 1 way to implement the DFW vision. In October 2011, we published a new program website: http://www.dfg.ca.gov/snbs. The efforts to build the website embody a number of key aspects of the vision complemented by specific objectives from our recovery plan: partnerships and coalition-based approaches, internal and external communication, education, teamwork, and transparency of operation. The website was produced by a collaborative effort involving DFW program personnel, National Park Service staff, Yosemite Conservancy funding, and a California-based scientific illustrator, Jane Kim. Revisions to the website are built around the idea that a picture is worth a thousand words. This approach is critical to modern web-based communication. The website is designed to foster effective internal and external communication. It includes photos and videos of Sierra Nevada bighorn sheep and a detailed presentation of Sierra bighorn natural history. To foster internal communication, it also includes the environmental

review and listing documents as well as many scientific publications authored by program staff, past and present. Our intent with this website is to provide the public with details of how our program operates and what data are used as a basis for our decision-making.

Educating the Community

Public outreach is an important part of DFW's mission and a stated goal of the Recovery Plan (USFWS, 2007). Recovery Program staff regularly participate in outreach events. This April, we manned a table at the Earth Day event in Bishop. In addition to answering questions about Sierra bighorn sheep, we displayed skulls of male and female desert and Sierra sheep to educate the public on differences between the local subspecies. We displayed a spotting scope, sheep collars, and telemetry equipment to show visitors how we monitor local herds. To further educate the public, we displayed posters on Sierra bighorn natural history and conservation and handed out pamphlets on the Recovery Program and disease transmission between wild and domestic sheep. We also created and passed out bighorn sheep coloring books to children. On September 13, 2011, Recovery Program leader Dr. Tom Stephenson gave a presentation at the Yosemite Forum which was widely attended by park staff, park partners, and the general public. The presentation was titled "Sierra Nevada Bighorn Sheep: Recovering the "Bravest Mountaineer" in the Yosemite Region." In March 2012, Recovery Program biologist Dr. Alexandra Few gave a presentation at the White Mountain Research Station titled "Recovery of Sierra Nevada Bighorn Sheep: Understanding Habitat Use and Distribution." An article on the same topic was published in California's Wild Sheep Magazine.

Environmental Analyses

Collaborative partnerships with Sequoia and Kings Canyon National Parks (SEKI) and the Inyo National Forest have resulted in environmental impact analyses that were circulated for public review. After an initial public scoping period, both agencies determined that the Environmental Assessments (EA) would be required to meet National Environmental Policy Act (NEPA) standards. SEKI circulated a draft EA for public comment on June 14, 2011 and signed a decision in August of that year. This EA also met California Environmental Quality Act (CEQA) requirements. The Inyo circulated a draft EA for comment on October 11, 2011. A decision was finalized on June 11, 2012.

Migrating Mural

When conservation crosses political and cultural boundaries, bringing communities together can be challenging. Perhaps we as conservationists can navigate the societal crossroads by combining art and science. Sierra bighorn and DFW's Recovery Program are lucky to have captured the attention of Bay Area artist and scientific illustrator Jane Kim. Kim chose to make Sierra bighorn the subject and muse of the first chapter of her National Geographic Viewer's Choice Award-winning concept, "The Migrating Mural." The goal of the Migrating Mural (http://ink-dwell.com/portfolio/migrating-mural-chapter-one-sierra-nevada-bighorn-sheep/) is to showcase migratory endangered

species and the need to protect them. Each chapter will reveal the habits and behaviors of hard-to-see wildlife. Over the next year, 4 murals will be painted in visible locations along Highway 395 from Olancha to Lee Vining, in the shadow of the Sierra bighorn's range. By bringing elusive Sierra bighorn into the towns and hearts of our community, the Migrating Mural has the potential to create enthusiasm for endangered species recovery. Art has the ability to influence hearts and emotions often more than "hard science" can. With media coverage planned by National Geographic and Oprah Magazine, the Migrating Mural will elevate awareness of recovery efforts by DFW. Murals that bring visibility to this growing yet fragile population can inspire further cooperative efforts to save Sierra bighorn, the rarest mountain sheep in North America.

Future Recovery Actions

Reintroductions

Planning efforts are underway for a series of reintroductions that could begin as early as the spring of 2013. These will be the first reintroductions since 1988, prior to listing under the Endangered Species Act. To meet recovery goals, 10 ewes and 5 rams will be reintroduced to vacant herd units in the Kern Recovery Unit (KRU) or the Southern Recovery Unit (SRU). The first reintroduction will most likely occur at Olancha Peak (SRU) or Big Arroyo (KRU). Reintroductions will be followed by augmentations of additional animals within 2 years to reduce the risk of extirpation and to maximize genetic diversity. These reintroductions will allow Sierra bighorn to reach recovery goals as quickly as possible.

Predator Management

A protocol for the monitoring and management of predation on Sierra bighorn is currently under development. Following completion, it will receive public and scientific peer review. The protocol, when approved by DFW, will ensure that mountain lion removal will follow humane, professional, legal methods that have been proven to be effective. Following approval of the protocol, we will implement predator monitoring and selective removal of mountain lions as needed for Sierra bighorn recovery.

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