

Sierra Nevada Bighorn Sheep: 2007-08 Status  
July 2007-June 2008

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August 2008

This report synthesizes population information for bighorn sheep herds in the Sierra Nevada developed over the past year beginning in July 2007 as part of the Sierra Nevada Bighorn Sheep Recovery Program lead by the California Department of Fish and Game. As in previous such reports, this one first reviews pertinent prior information needed to interpret data developed during this time period for each herd unit. While pertinent data were collected for some herd units through this past winter, numbers of sheep are presented for the first half of the sampling year, the summer of 2007 for this report. While data on numbers of sheep present represent one year beginning in July 2007, we discuss mortality patterns over a longer time period beginning January 2007 to help provide a more meaningful perspective on those patterns.

Efforts are made every year to develop some data on every herd in the Sierra Nevada. Over the years these efforts have used knowledge of habitat use patterns of each herd to attempt to count as many sheep as possible when they were most concentrated. Such counts all represent minimum numbers present by population, which is a primary criterion in the recovery plan for these sheep. Those minima, however, can vary considerably in what percentage of the population was accounted for. It has been our experience that, for most bighorn sheep populations, it will be difficult to develop consistent good minimum counts once the number of females has increased beyond 30, unless aided by extra technology like telemetry.

Rapid increases in sizes of some populations this decade, while very desirable, have made population monitoring more difficult in some herd units because of higher numbers of sheep that need to be found in a short time period for a complete or nearly complete count. A

result is that some minimum counts can be well below actual population levels. We have attempted to counter this problem with the addition of telemetry collars to populations. These collars increase minimum population counts by helping us find otherwise missed groups of sheep. They also allow us to develop independent estimates of population sizes using mark-resight methods. Depending on their statistical resolution, these estimates can help in the evaluation of the completeness of minimum counts. Consequently, a sampling approach that is now often employed involves multiple observers first finding as many sheep as possible without the aid of telemetry for mark-resight estimates, followed by the use of telemetry to find sheep groups not yet sampled to maximize the minimum count. McClintock and White (2007) suggested that the Bowden estimator (Bowden and Kufeld 1995) was more appropriate for mark-resight estimates of bighorn sheep. Consequently we present only Bowden estimates.

Over the years, the judgment on the completeness of minimum counts also has been based on recorded numbers and reproduction in previous years tempered by potential mortalities, and sometimes coupled with interpretation of field evidence (including collared sheep) of additional groups of sheep not seen. Better counts in subsequent years also have been used to evaluate and correct past counts to higher minimum numbers present by sex and age categories. These are known as reconstructed counts.

Our population surveys focus primarily on females because they are the reproductive base of the population. However, in the Mono Basin it has been possible to track numbers of males for many years. The same has been true for the Wheeler Ridge herd in most years.

We were greatly assisted in the collection of data by Jonathan Fusaro, Lacey Greene, Kathleen Knox, and Cody Schroeder.

## **Highlights of the Past Year**

### *Bighorn Sheep Collaring*

During multiple collaring efforts, 44 bighorn (29 females, 15 males) were captured in 7 herd units in the Sierra Nevada between October 2007 and April 2008 (see Table 1 for details). Because 25 of the successful captures involved re-collaring, and 19 collared bighorn died during the monitoring year (discussed below), the total number of marked bighorn sheep actually declined from 75 to 71. Of particular note is that the Mount Williamson herd unit received its first telemetry collars this past year (Table 1). As has been the case in other herds, the addition of telemetry collars is expected to greatly increase our understanding of habitat use patterns while aiding in population monitoring.

### *Mount Baxter Herd Unit Winter Range Fire*

In early July, 2007, numerous lightning strikes ignited major fires propelled by strong winds along the eastern escarpment of the Sierra Nevada from Independence to Big Pine. Those fires burned nearly the entire winter range of the Mount Baxter herd unit -- a winter range considered the best in the Sierra Nevada, and not expected to benefit from fire. When bighorn sheep descended to that winter range in February, initially they had to find little unburned patches to obtain forage; but, as the weather warmed and more re-growth occurred in the burn,

the burned areas appeared to be an attraction. The effects of this fire are being studied in detail and will be reported in future years.

Table 1. Changes by herd unit in numbers of bighorn sheep (females/males) in the Sierra Nevada that carried telemetry collars, July 2007 through June 2008. Mortalities and additions do not include new sheep caught that died due to capture.

|               | Langley | Williamson | Baxter | Sawmill | Wheeler | Gibbs | Warren | Total |
|---------------|---------|------------|--------|---------|---------|-------|--------|-------|
| 1 July 2007   | 17/1    | 0/0        | 4/0    | 3/2     | 17/11   | 3/3   | 5/9    | 49/26 |
| additions     | 0/0     | 2/1        | 3/0    | 1/0     | 0/7     | 0/0   | 0/1    | 6/9   |
| re-collarings | 8/0     |            | 1/0    |         | 8/2     | 2/1   | 4/2    | 23/5  |
| mortalities   | 4/0     |            | 1/0    | 0/1     | 1/4     | 0/1   | 3/4    | 9/11  |
| migrations    |         | +1/0       | -1/0   |         |         |       |        | 1/0   |
| 30 June 2008  | 13/1    | 3/1        | 5/0    | 4/1     | 16/14   | 3/2   | 2/6    | 46/25 |

### *Population Dynamics*

This monitoring year produced good to excellent data on numbers of females in all herd units. Of particular note was the first good count of the Mount Williamson herd since 1985. The total of 185 adult and yearling females in the Sierra Nevada in the summer of 2007 is the highest in recent history, and is about 60% of the recovery goal. However, the gain since the last reliable figure obtained 2 years earlier was modest and mostly had already disappeared by the end of the past winter due to high levels of mortality. Indeed, the overall population appears to have stabilized over the past few years at around 400. Herd dynamics are not synchronous, varying from declining to increasing status (Figure 1). Three regions are of particular concern because of high mortality rates: Mount Baxter and Sawmill Canyon herd units; Wheeler Ridge herd unit; and the Mount Warren herd unit. Mountain lion predation has played a significant role in the first 2 of these areas, while the cause of high winter mortality in the Mount Warren herd unit is not entirely clear. This report examines the dynamics of those herd units in considerable detail.

### **Mount Langley Herd Unit**

While this herd utilizes low elevation winter range areas, a substantial proportion of the population has remained at high elevations every year. Consequently, population surveys are conducted in summer. This herd unit has exhibited strong population increases for numerous years (Fig. 1) with a minimum of 45 adult and yearling females and 91 total sheep accounted for in 2006, when the population undoubtedly exceeded 100. Three summer surveys were carried out in 2007 (early July, early August, and late August), of which only the latter two produced sample sizes worth using for population estimation. The first of those two produced the highest overall count at 32 adult females, 10 yearling females, 14 lambs, 6 yearling males, and 75 total sheep, which increases to 77 when 2 collared females not seen are added. In combination, the

two counts accounted for 83 different sheep (34 adult females, 10 yearling females, 17 lambs, 6 yearling males, 16 adult males). Both samples yielded Bowden estimates of 47 adult and yearling females with 95% confidence limits of 38-60 for the combined sample. For the combined sample, the lamb:adult female ratio was 0.50, the yearling:adult female ratio was 0.45, and the yearling female:adult female ratio was 0.27. Yearling females comprised 21.5% of the adult and yearling females.

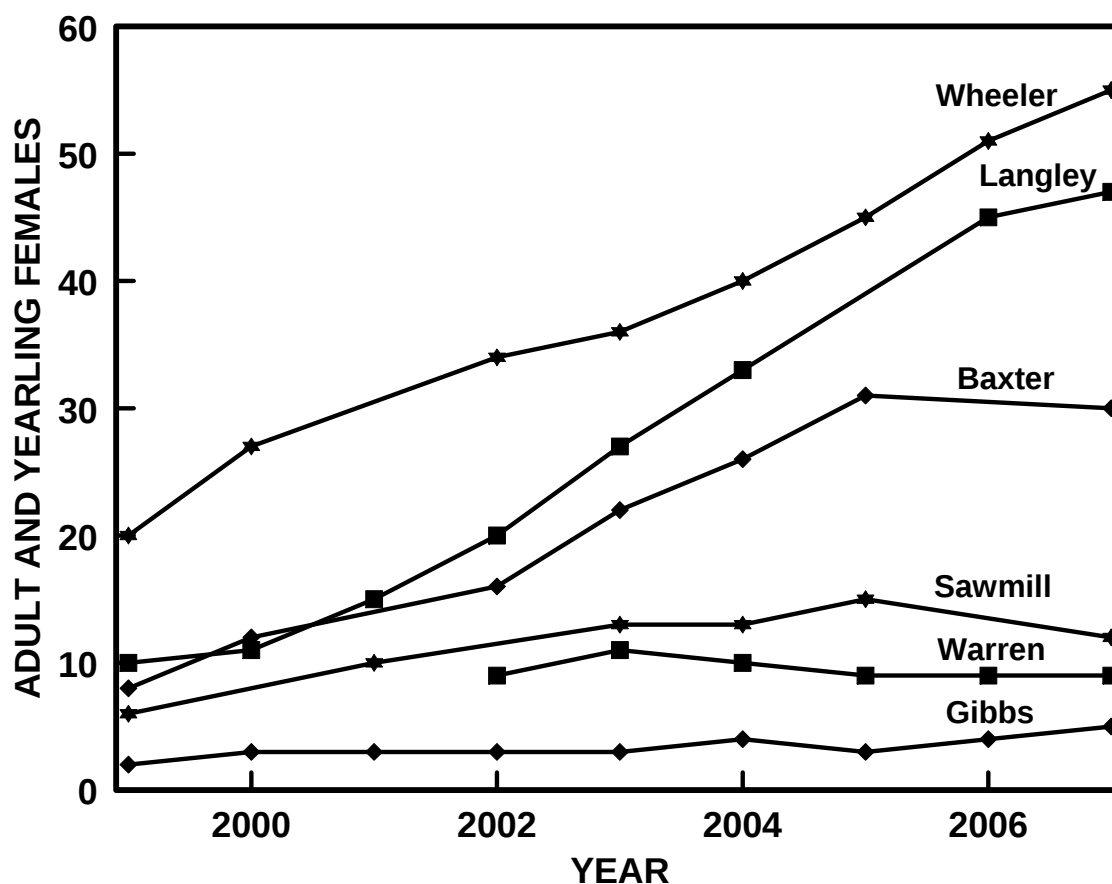


Figure 1. Recent reproductive base histories for 6 herd units of bighorn sheep in the Sierra Nevada for which adequate data exist. Data are all minimum counts except for mark-resight estimates for the Mt. Langley herd unit in 2007 and the Wheeler Ridge herd unit in 2006 and 2007.

During the 2007-08 winter, use of low elevation winter ranges increased from the very low level the previous winter, but was still low compared with earlier years. Of 15 collared females that might have used those winter ranges, one third remained high all winter and another third used low elevation winter ranges for less than a week. Only 3 (20%) utilized low elevation winter ranges for more than a month. Three of 16 collared females died during late winter and early spring at high elevations. Analysis of GPS collar locations determined numerous months later that one of these had not moved after it was released from a capture in later October, and likely died due to capture. Of the other 2, one was a females that remained all winter at high elevations and the other was one of the 3 that spent more than a month on low elevation winter

range.

### **Mount Williamson Herd Unit**

The Mount Williamson population has been notoriously difficult to monitor for numerous years since their abandonment of use of escarpment base winter ranges after 1985 and the resumption of attempts to count these sheep a decade later. Few sheep have been seen during annual summer monitoring efforts beginning in 1996, while a maximum of only 6 sheep has been documented on a small winter range in Shepherd Creek. However, fecal genotyping documented as many as 7 different lambs each year in 2001 and 2002, and at least 10 females at the end of the previous decade. In the summer of 2004, some verification of those numbers finally occurred when 7 females and 4 lambs were seen in one group on the north ridge of Mount Williamson above North Bairs Creek, and fresh tracks possibly from a couple more females were observed in neighboring South Bairs Canyon.

In 2005 a new analysis of fecal DNA was initiated for the Mount Williamson herd to assess sheep numbers in this population through different genotypes. Analyses of 46 fecal samples collected during 2004-06 only on the east side of Mt Williamson, primarily from North Bairs Creek, yielded genotypes of 18 different sheep (11 females and 7 males).

A unique opportunity for a good direct count of this population occurred in the summer of 2007. A reconnaissance trip up South Bairs Creek found evidence of considerable sheep use in that canyon and adjacent George Creek, both of which have had very limited use by sheep since 1996. A trip with three observers in the first half of September in this area yielded 12 adult sheep, 8 of which were males (7 adults and 1 yearling). Near the end of September a second trip with the same observers netted 20 different sheep: 10 adult females, 3 yearling females, and 7 lambs. Adding the males from the first trip yields 28 different sheep. This was the first significant (nearly complete?) count of this population since 1985, when this population was last counted on escarpment base winter range areas. The 2007 count was similar to good winter range counts between 1978 and 1985 that varied from 29 to 31 total sheep. The major shift in summer distribution in 2007 may have been a consequence of the extreme drought conditions the previous winter. The 18 individuals genotyped primarily from 2005 and 2006 were only 3 fewer than the number of adults recorded in the 2007 count.

During the summer of 2007 a colonization event occurred that may create a new female deme within the Mt Williamson herd unit. One of 2 of the 5 females translocated from Wheeler Ridge to the Mt. Baxter herd in 2005 that had remained in the Mt. Baxter herd unit migrated south to the Mt. Keith area. She spent the past winter in a small winter range in Symmes Creek, one canyon north of current winter distribution of Mt. Williamson sheep. With her in winter were a lamb and a 2-3yr old male.

In late winter this year three sheep (2 females, 1 male) were caught on the low elevation winter range in Shepherd Creek and received telemetry collars. These are the first sheep in this population ever to be collared. However, a couple of telemetered bighorn translocated to Mount Langley in the 1980s joined the Mount Williamson herd and briefly provided telemetry collars in this herd unit, but were never monitored.

## **Bubbs Creek Herd Unit**

A helicopter survey in mid January of 2008 produced the highest count of this herd to date, totaling 27 sheep in 5 groups (13 adult females, 1 yearling female, 6 2007 lambs, 1 yearling male, 1 2-yr old male, and 5 older males).

## **Mount Baxter Herd Unit**

This herd has shown increasing use of low elevation winter ranges beginning in 2003, including Sand Mountain, where most of the sheep translocated during 1979-88 were caught. Those winter ranges have provided the only good opportunities to assess the total size of this herd in recent years. Particularly good winter range counts were obtained in 2005 and 2006 when, respectively, 26 and 31 adult and yearling females were documented as the reproductive base (Fig. 1). Extreme drought conditions in the 2006-07 winter resulted in little winter range use and no further data on population size.

During the summer of 2007 five short trips by one observer were made into the summer range of this herd in the area of upper Oak Creek and Baxter Pass – an area that is the center of summer distribution of the females in this herd due to regular use of Baxter Pass as a mineral lick. Four sheep groups observed during those trips totaled 19 adult females, 5 yearling females, 13 lambs, 3 yearling males, and 5 adult males. Two of the groups seen included the same collared female (not found with telemetry), but the composition of that group was different in those two observations. The high lamb:adult female ratio (68:100) and high yearling:adult female ratio (42:100) suggested reproduction consistent with further population growth; 21% of the females seen were yearlings. However, winter range counts made this year suggested a different picture.

Most of the low elevation winter range of this herd unit burned in a fire fueled by high winds in early July of 2007, leaving only a few small patches of unburned forage. This winter range received a soaking storm in early December of 2007 that normally would have initiated vegetation growth of the more cold tolerant forage species. When sheep began appearing on that winter range in early February there was essentially no new and little old forage available to be eaten. The sheep quickly found the few small unburned forage patches. One group of 9 remained a month on the snowy north-facing side of Sawmill Canyon. Another smaller group that included a telemetered female crossed into the Sawmill Canyon herd unit winter range on the north side of Sawmill Canyon that was mostly unburned and spent a month there before returning to the Mt Baxter herd winter range. Because the fire burned the water birches near the mouth of Sawmill Canyon, there was no longer the usual barrier of thick vegetation separating those herd units.

By early March there was enough new forage growth available in the burn to allow sheep to use that habitat. It appears that this burned habitat became a strong attraction to sheep as temperatures warmed and more perennial species sprouted from root stock. The lack of vegetation cover that could hide predators may have been part of that attraction. Some sheep remained on this winter range into the second half of April.

The sheep using the Mt Baxter herd winter range were carefully monitored as their

numbers grew through March, and the highest count was obtained in late March and early April. Totals accounted for on the winter range were 25 adult females, 3 yearling females, 9 lambs, 4 yearling males, 2 2-yr old males, 3 3-yr old males, and 4 4-yr old males (50 total sheep), of which 2 died before leaving the winter range (one adult female from a fall and a lamb). Additionally, an adult female was killed by a lion on this winter range before counts were made, which would bring the initial minimum count to 26 adult females and 29 total females.

Compared with past data, the 29 total females accounted for this year are 2 fewer than the count two years ago, but are really only 1 different when the translocated female that emigrated to the Mt. Williamson herd unit is considered. The winter lamb:adult female ratio (36:100) is about half what was recorded the previous summer. The winter yearling:adult female ratio (28:100) is also lower than what was recorded in summer. Sampling error may account for some of these ratio differences, but the apparent loss of half the lambs between summer and winter may reflect more than sampling error.

We saw evidence from telemetered animals of many bighorn in the Sierra Nevada remaining high throughout the past winter. While the 6 telemetered females in the Mt. Baxter herd all utilized low elevation winter ranges, there remains the question of how much of the discrepancy between numbers counted this winter and two years ago might be due to females that remained at high elevations throughout the winter. A population increase was expected given the prior trend (Fig. 1).

### **Sawmill Canyon Herd Unit**

The size of the Sawmill Canyon herd also has been assessed on its low elevation winter ranges. This herd has shown increasing use of low elevation winter ranges in recent years, including Goodale Creek, where 13 sheep were seen in 2006. The total count of adult and yearling females in this herd unit had grown to 15 in the winter of 2005-06, including 3 that were translocated from Wheeler Ridge to the Mount Baxter herd unit but took up residence in the Sawmill Canyon herd unit (Fig. 1). Similar to the Mount Baxter herd unit, few sheep were observed on winter ranges in 2006-07; thus, no new information on population size was obtained. However, 2 of the 3 ewes translocated from the Wheeler Ridge herd in 2005 that ended up in this herd unit were killed over a short time period in May 2007 in Goodale Canyon in close proximity to each other, probably by one mountain lion.

This past winter no bighorn were observed in Goodale Canyon despite multiple efforts; yet, 4 sheep died there from lion predation during this time period: a telemetered male near the mouth of the canyon in February, an uncollared female nearby, and one of each sex further back in the winter range. The two remaining telemetered females in that area remained at higher elevations above Goodale Creek throughout the winter.

In the Sawmill Canyon winter range there was evidence of bighorn use beginning in late December, and sheep were seen there regularly beginning in February. However, it was not until mid April that the best count was obtained: 6 adult females, 1 yearling female, 3 female lambs, 1 male lamb, 2 yearling males, and 1 2-yr old male. Additionally, an adult female was killed by a mountain lion near the mouth of the canyon early in winter. Adding the 2 collared females known from the Goodale Creek area and the 3 killed by lions, the minimum number of adult and

yearling females in the Sawmill Canyon herd at the beginning of the past winter was 12 (Fig. 1). This is a 20% drop from 2 years ago, but there remains uncertainty regarding how many additional uncollared females remained at higher elevations. Nevertheless, the minimum of 5 adult females in this herd unit recently killed by mountain lions in less than a year represents a loss of probably at least a quarter of the reproductive base. While data are lacking for 2006-07, this undoubtedly substantially exceeds recruitment, which included only a single yearling female in our sample this winter. Current data suggest a declining trend in this herd unit, with mountain lion predation the apparent primary cause.

### **Wheeler Ridge Herd Unit**

The Wheeler Ridge herd has offered excellent opportunities to track population growth via direct counts on low elevation winter ranges in most years since it re-colonized those ranges in the late 1990s. This population has shown an increasing trend for many years (Fig. 1) and first exceeded 100 in 2004-05. Similar to other herd units, this population also made little use of low elevation winter ranges in 2006-07; consequently, the most recent figures were mark-resight estimates from April 2007 of 49 adult and yearling females (95% CL:37-61) and 59 adult and yearling males (95% CL:26-92), both of which were very close to mark-resight estimates from surveys the previous summer.

Three summer surveys were made in 2007, but varied greatly in numbers of total females sampled for mark-resight estimation (12, 14, and 36). The one large sample yielded a Bowden estimate of 54 adult and yearling females (95% CL:40-74). Combined, the three surveys yielded an estimate of 55 (43-70). Minimum totals that could be accounted for, including collared sheep not seen, were 36 adult females, 6 yearling females, 15 lambs, 4 yearling males, and 21 adult males. The estimate of 55 total females suggested an additional 13 uncollared adult and yearling females in addition to the 7 collared ones not seen.

The winter of 2007-08 again produced suboptimal opportunities for direct counts. Six of 16 collared females remained high through much of winter. One of those descended to the winter range at the end of February, and 2 in the second half of March, while the other 3 did not descend until April. In contrast, all collared males used low elevation winter ranges through winter.

Two surveys were made for mark-resight estimates: mid January and late March. The estimated number of adult and yearling females from those combined surveys was 50 (38-65) for the Bowden estimator. This estimate assumes that there were also uncollared females at high elevations unavailable to be sampled in these surveys, and that they occurred in that habitat in the same proportion to collared females as in the whole population. Twelve of 16 collared females were seen in the two surveys, including in the second survey 3 of the 6 that had been at higher elevations earlier in winter. Given one known mortality between the summer and winter surveys, the mark-resight estimates from those two seasons differ by only 4 females. Given the larger total sample size in summer and uncertainty about potential biases in the winter sampling, the summer estimate may be more reliable.

The highest minimum winter population count was 36 adult females, 4 yearling females, 10 lambs, 3 yearling males, and 35 adult males, the last of which puts the summer total

population estimate at 109. These winter minimum values are lower than minima the previous summer for yearlings (3) and lambs (5). The remains of 4 of those lambs were found in winter during other activities. At least 19 lambs were known to be born into this population in 2007, of which 3 died soon after birth. Eleven of 17 collared females (65%) were documented with newborn lambs. Of the 16 collared females that were alive in winter, only 4 (25%) had surviving lambs. Similarly, for the winter minimum count, the lamb:adult female ratio was 0.28. This indicates a survivorship of lambs through winter of only about 36%.

The Wheeler Ridge herd has seen a high level of mortality in the 18 months since the beginning of 2007, totaling 18 sheep that were recovered as carcasses. Of the 14 dead adults, 2 (1 of each sex) died as a result of captures, 5 (all adult males) were definitive lion kills, 3 (1 female, 2 males) were likely lion kills, while the remaining 4 were of unknown cause, all (2 females, 2 males) of which were of older ages (10-13). Of the 12 adult mortalities that were not capture related, two-thirds (8) were collared sheep, whose deaths were discovered via mortality sensors in transmitters. Given that less than a third of the adult sheep in this herd carried such collars, this suggests the existence of 16 or more mortalities of uncollared adults in this time period, of which only 4 were found.

Past investigations of clusters of GPS points obtained from GPS telemetry collars on lions have suggested that there are twice as many sheep killed by individual lions as are found without the aid of such technology. If the projected level of mortality is correct, the relatively low number of surviving lambs can only mean that this population has shifted from an increasing to a declining trend. In the summer of 2007 only 10 yearlings were documented (6 females, 4 males), which dropped to 7 in winter sampling, while in one year beginning in May 2007, 10 adult mortalities were documented (8 male, 2 female). It is likely that both samples missed some yearling sheep, but proportionally it is likely that recorded mortalities missed considerably more. However, the predominance of males in the mortality data suggests that change in the number of males in this population may account for much of the projected decline in population growth.

During capture activities in October of 2007, a high proportion of sheep caught at Wheeler Ridge exhibited lesions of a viral disease known as contagious echthyma, or soremouth. It is a self limiting disease that rarely results in mortalities, and apparently ran its course, as there was no evidence of it when sheep entered the winter range. Nevertheless, this was the first documented appearance of this disease in bighorn sheep in the Sierra Nevada, which raises questions about the source of infection. The scabs from soremouth lesions can remain infective in the soil for more than a decade.

### **Mount Gibbs Herd Unit**

The Mount Gibbs herd has very limited low elevation winter range; thus population data are collected primarily in summer. However, it is of note that herd was observed using lower elevations above Walker Lake this past April for the first time. This herd has grown steadily from a reproductive base of only a single female in the middle of the last decade (Fig. 1). In 2006 it consisted of 3 adult females, 1 yearling female, 2 lambs, and 3 adult males. In the summer of 2007 this herd grew significantly to 4 adult females, 1 yearling female, 4 lambs, 1 yearling male, and 3 adult males, for a total of 13 (Fig. 1). One of the adult males (12 years of age) died during the past winter, and only 3 of the lambs were evident when this group was seen

multiple times from a helicopter in spring.

### **Mount Warren Herd Unit**

In recent years this population has been documented to move regularly between Mount Warren, Tioga Crest, and the north side of Lundy Canyon. The summer of 2007 was no exception. While these sheep can use lower elevations back in Lundy Canyon later in spring, females in this population have not used low elevation winter ranges since they abandoned use of Lee Vining Canyon after a lion was hunting them there in 1998. Consequently, population data are collected primarily in summer.

The total number of bighorn sheep in the Mount Warren herd unit from 2003 to 2006 was a pattern of steady slow decline: 28, 27, 25, 23; however, the reproductive base of adult and yearling females changed only from 10 in 2004 to 9 in 2005 and 2006 (Fig. 1). That reproductive base remained the same in 2007, at 7 adult females and 2 yearling females, along with 4 lambs, and 13 adult males, for a total of 26.

The total Mono Basin population grew to 39 in the summer of 2007, which meant it essentially returned to the size it had been 4 years earlier. However, those gains were short lived, being followed by at least 9 mortalities in 8 months: a capture mortality of a yearling female in October, 6 adults (4 males, 2 females) in February, and 2 adults (1 of each sex) in March. Of these 9, only 1 (a 12-yr old male) was from the Mount Gibbs herd. Additionally, only 2 of 4 2007 lambs at Mount Warren were known to be alive this spring. Thus, the Mount Warren herd potentially declined 38% to 16 sheep by the end of this past winter. Eight of these mortalities were telemetered sheep. Considerable effort was made to retrieve the carcasses of the 7 Mount Warren sheep that died in winter, but only 3 males were located. All three had depleted all fat reserves and appeared malnourished at death; however, one also showed histological evidence of pneumonia.

Contagious echthyma also was documented in this herd unit during a brief capture episode this spring.

### **Discussion**

#### *Total Population and Trend*

Data compiled in this report total 185 adult and yearling females and 67 lambs in the summer of 2007, for a total of 252 (Table 2). Given that some of those females were from mark-resight estimates, there were undoubtedly more lambs that accompanied some of those additional females estimated to exist. Our 2007-08 data on numbers of males are probably good for the Mount Williamson, Bubbs Creek, Mount Gibbs, and Mount Warren herd units (Table 1), which are the smallest herds. This cannot be said for the remaining herd units, which constitute the bulk of the overall bighorn population. In recent years we have recorded more total males than females in the Wheeler Ridge and Mono Basin herd units, but there is no reason to believe that this is the case in general. Earlier figures suggested a male:female ratio of about 0.7 (Wehausen 1980). If the numbers of males and females at least one year of age are equal, the total population in the summer of 2007 probably exceeded 437. If the overall male to female ratio

was 0.8, that total would barely exceed 400. Two years ago we comfortably estimated the total population to have exceeded 400 by an unknown amount. For 2007 we can comfortably project the same; however, with the high rate of mortality over the past winter it is possible that the total population dropped below 400. In short, the overall bighorn population in the Sierra Nevada appears to have stabilized around 400 in recent years.

Table 2. Summary of population data for all herd units of Sierra Nevada bighorn sheep in summer 2007. All values are minimum numbers present except where marked with an asterisk, which include mark-resight estimates.

| <u>Herd Unit</u> | <u>adult ewes</u> | <u>yrlyg ewes</u> | <u>total ewes</u> | <u>lambs</u> | <u>yrlyg rams</u> | <u>adult rams</u> | <u>total rams</u> | <u>total</u> |
|------------------|-------------------|-------------------|-------------------|--------------|-------------------|-------------------|-------------------|--------------|
| Langley          | 34                | 10                | 47*               | 17           | 6                 | 16                | 22                | 86*          |
| Williamson       | 10                | 3                 | 13                | 7            | 1                 | 7                 | 8                 | 28           |
| Bubbs            | 13                | 1                 | 14                | 6            | 1                 | 6                 | 7                 | 27           |
| Baxter           | 27                | 3                 | 30                | 10           | 4                 | 9                 | 13                | 53           |
| Sawmill          | 11                | 1                 | 12                | 4            | 2                 | 3                 | 5                 | 21           |
| Wheeler          | 36                | 6                 | 55*               | 15           | 4                 | 35                | 39                | 109*         |
| Gibbs            | 4                 | 1                 | 5                 | 4            | 1                 | 3                 | 4                 | 13           |
| Warren           | 7                 | 2                 | 9                 | 4            | 0                 | 13                | 13                | 26           |
| Total            | 142               | 27                | 185*              | 67           | 19                | 92                | 111               | 363*         |

The recovery plan for Sierra Nevada bighorn sheep sets a downlisting goal of 305 female bighorn at least one year of age distributed across the four recovery units. The emergency listing of this animal in 1999 coincided with the beginning of a long period of sustained growth of the overall population that has been driven largely by the Wheeler Ridge, Mount Langley, and Mount Baxter herds. These gains occurred because recruitment in those populations has substantially exceeded adult mortality. The 185 adult and yearling females in the summer of 2007 (Table 2) is more than triple what was thought to exist at the time of emergency listing, and is 60% of the recovery goal. While this is cause for optimism, signs of population stabilization give reason for concern. The overall gain since 2005 was modest at 19 females (11.4% over 2 years), and much of that gain is already known to have disappeared as mortalities in approximately half a year since the summer of 2007 (Figure 2). While yearling recruitment in 2008 should counter some of those losses, there were few remaining 2007 lambs in some herds that might be recruited as yearlings.

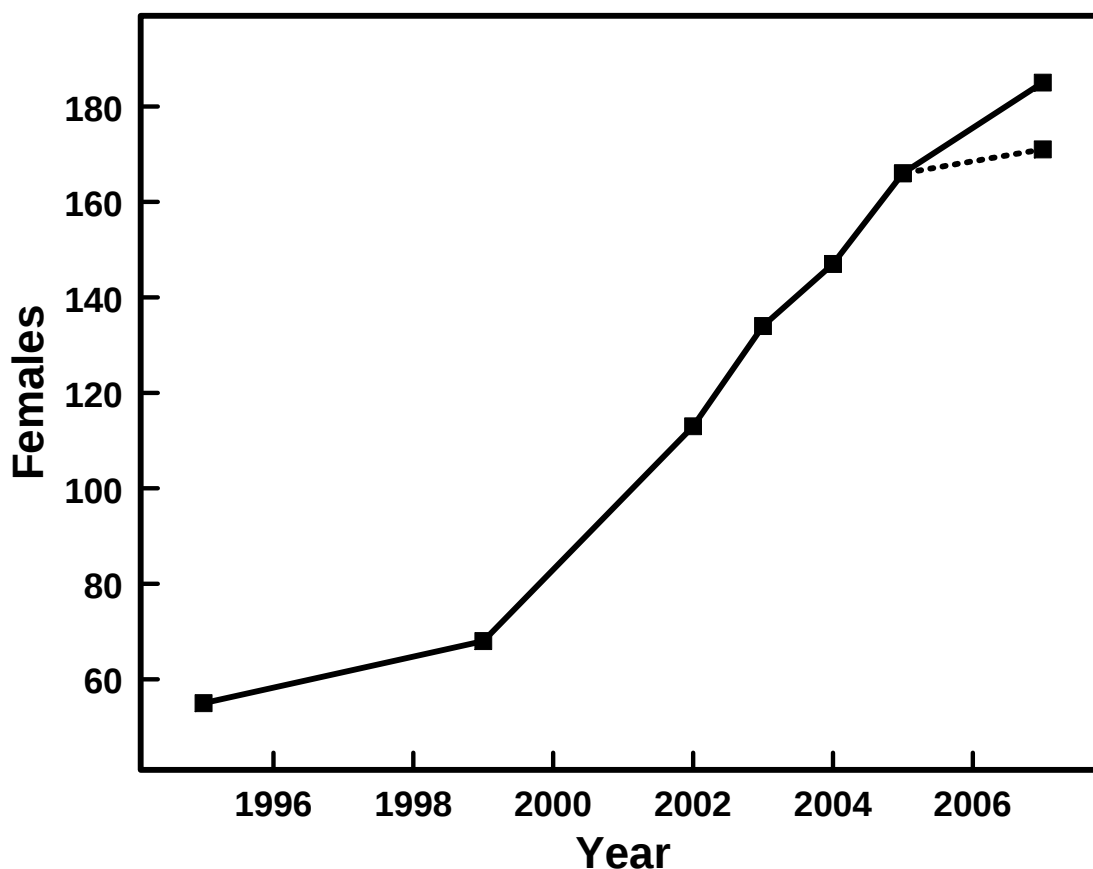


Figure 2. Numbers of adult and yearling female bighorn sheep in all herd units in the Sierra Nevada in summer, 1995-2007. The second point for 2007 with the dashed line is adjusted for known mortalities over the past winter season.

The Mount Baxter herd is considered key to the future of these sheep as a source of translocation stock; yet it appears to have made no gains since 2005. The Mount Warren herd clearly has shifted to a negative growth rate. The same is probably true for the Sawmill Canyon herd, while population growth of Wheeler Ridge herd also has undoubtedly declined significantly. It is conceivable that the next data point on Figure 2 will show a decline from the 2007 high.

These recent changing dynamics are driven by what appear to be increasing mortality rates of adults and young. In an 18 month period from the beginning of 2007, 44 mortalities have been documented throughout the Sierra Nevada, of which most (86%) occurred in a one year period beginning in May 2007. Of the 44 mortalities, 39 have been adults and 28 (72%) of those have been collared sheep. This represents about one-third of all collared bighorn in the Sierra Nevada. If representative of the whole population, this would indicate a major mortality event in implying the existence of a large number of mortalities among uncollared sheep, only a few of which have been found. While these mortalities of collared sheep do imply a

considerable number of additional unrecorded mortalities in some populations, the uneven distribution of collars among the herd units precludes such a projection across all herd units, as do some of the causes of mortality. For instance, a very high proportion of sheep in the Mono Basin carried telemetry collars in 2007; thus, there were few additional sheep available there to have died. In some herd units (Mount Gibbs, Mount Williamson, Bubbs Creek) we either know that there has been no major mortality event or have no reason to suspect one. It is the remaining herds that deserve some scrutiny relative to causes of mortality and future implications. Below we discuss three categories of these mortalities that account for about 80% of those deaths. The remaining 20% include miscellaneous sources, including accidents and unknown causes such as old age.

### *Capture Mortalities*

Bighorn sheep capture efforts typically experience mortality rates of 5-10% even with very experienced personnel. Prior to the past year, captures of bighorn sheep in the Sierra Nevada have had a particularly good record of <2% mortality going back to 1979 for more than 200 sheep caught. In the fall and winter of 2006, bighorn captures in the Sierra Nevada transitioned to a new approach in two ways: sheep were caught at high elevations rather than on low elevation winter ranges; and a new capture team outside of the California Department of Fish and Game was employed. The change to high elevation is a response to concern about the potential negative behavioral effects of regular capture activities on winter range use by the sheep. The new capture team has very extensive experience in the capture of a wide variety of species and uses a different helicopter that operates better at high elevations. In their first capture effort in the Sierra Nevada, this new capture team successfully caught 18 females in three herd units spanning the length of bighorn distribution in that range with no mortalities. What did not survive well were the GPS collars deployed in that operation, most of which had failed within a few months. This necessitated a subsequent capture effort in late October 2007 aimed at recapturing many of those same sheep to replace the faulty GPS collars. This made it a much more difficult operation because the capture team did not have the freedom to capture sheep that were the easiest to net. Two mortalities occurred during that operation (1 female each in Wheeler Ridge, and Mount Warren herd units). Additionally, the post-capture mortality of a female from the Mount Langley herd unit discovered months later was likely capture related; and, an adult male at Wheeler Ridge died during a different capture operation in April 2008. These capture mortalities represent 12% of the 33 adult sheep that were recorded to die in the year beginning in May 2007. These capture mortalities probably do not imply other mortalities. (Note: At the time this report was released, an additional capture of 22 Sierra bighorn had occurred during October 2008 and no mortalities occurred.)

### *High Elevation Winter Mortalities*

Another 30% of adult mortalities in the year beginning in May 2007 were 10 collared adult sheep that died at high elevations this past winter in 3 herd units: 2 females (ages 6, 9) at Mount Langley; 1 male (age 12) at Mount Gibbs; and 3 females (ages 4, 4, 4) plus 4 males (ages 4, 7, 9, 12) at Mount Warren. As discussed above, attempts to retrieve these carcasses met with limited success. Three of the dead males (ages 4, 9, 12) that could be examined at Mount Warren had no remaining body fat and one also had evidence of pneumonia.

One hypothesis about these mortalities has involved a combination of extreme weather phenomena resulting in suboptimal summer nutrition and extreme winter conditions at high elevations. The winter of 2006-07 was the driest in the southern Sierra Nevada in at least 4 decades. This negatively affected forage phenology in 2007, thus nutrient availability, on both low elevation winter ranges and summer alpine ranges, of which the latter depend substantially on snow melt for soil moisture. There was a north-south gradient in the severity of that winter drought, with forage phenology effects most evident in the Mount Langley herd unit at the southern end of bighorn distribution in the Sierra Nevada. In the summer of 2007, meadow systems at Mount Langley that are normally green through July and used extensively by bighorn were already brown at the beginning of that month. However, there were multiple significant rain events in July in the Sierra Nevada that likely mitigated the effects of the winter drought somewhat.

Sheep have commonly wintered at high elevations in the Mono Basin and Mount Langley without high levels of mortality, except in unusual years (notably 1995). Such unusual years have been thought to involve conditions where snow did not blow off high ridges and plateaus, leaving sheep largely snowbound. This past winter was not such a year, and exhibited an extreme amount of snow-free terrain at high elevations throughout winter. The extreme winter conditions that might have contributed to winter mortalities occurred over about a 2 week period at the end of January just prior to the beginning of those mortalities. During that period there was constant snowfall and extreme winds. The extreme wind chills and potentially limited feeding opportunities might have significantly depleted fat reserves in animals already in poor condition from limited summer nutrient availability.

A number of factors do not lend support to this hypothesis. First, the only mortalities at Mount Gibbs, where all sheep winter at high elevations, were an old male and 1 of 4 lambs. Second, 2 lambs in the Mount Warren herd unit are known to have survived, but would have been expected to be the first to succumb to extreme winter weather conditions. Third, bighorn sheep captured in various herd units in late October appeared to have adequate fat reserves as measured by ultrasound. The Mount Langley sheep should have suffered the most from the previous dry winter given the extreme conditions there; yet only 2 of 15 (13%) collared females died, compared with 60% at Mount Warren, and 1 of those Mount Langley mortalities had spent more than a month on a low elevation winter range where she would have had access to early greenup. Also noteworthy is that all the Mount Warren females that died were in their prime at 4 years of age – an age at which their survivorship would be expected to be very high. Why would they die when lambs survived?

A pneumonia epizootic in the Mount Warren herd unit that did not reach the whole population is an alternative explanation of the mortality patterns. Consistent with this explanation is the finding of evidence of pneumonia in the only lung tissue collected that was adequately preserved to detect this histologically. The loss of prime age sheep also is consistent with an acute pneumonia epizootic. However, it is not clear that the complete lack of body fat in all three males necropsied is necessarily consistent with such an epizootic. In short, there is considerable uncertainty regarding the causes of the 10 documented high elevation adult mortalities this past winter.

Relative to potential additional mortalities, the 2 deaths of collared females at Mount

Langley do suggest the potential for a few uncollared females to have died similarly. As mentioned previously, this appears not to be the case for the Mount Warren population. In fact, all of the uncollared females there were documented to be alive this past spring.

### *Mountain Lion Predation*

Another 36% of the adult mortalities beginning in May 2007 and 41% of the 18 month adult mortalities are mountain lion kills discussed above by herd unit. Recent data implicate mountain lions in mortality statistics of only the Mount Baxter, Sawmill Canyon, and Wheeler Ridge herd units. In those herd units these confirmed and likely lion kills represent 62% of the recorded mortalities of adults since the beginning of 2007. All three of those herd units showed strongly increasing trends 2 years ago, but all now appear to be in various phases of demographic shifts toward declining population growth. The smallest of these, the Sawmill Canyon herd, shows evidence suggesting a significant population decline driven by high predation rates. The other two populations may be on the cusp of that transition, delayed only because of some buffering from larger population sizes.

By the nature of their habitat selection and related habitat use patterns, bighorn sheep populations typically exist as a series of relatively small demes. Their population dynamics are very sensitive to small changes in adult survivorship, which can shift a population between increasing and decreasing population trajectories. The smaller the population, the larger is the effect of each predation event on adult survivorship rate (Festa-Bianchet et al 2006). Recruitment rates also figure importantly into these population dynamics, which lion predation also can influence significantly through predation on younger age classes. This can be more difficult to assess because lions typically leave so little behind after consuming a lamb in winter. Lions also consume those kills so quickly that they potentially leave less evidence of their own presence; thus, their influence on recruitment is easily underestimated.

As discussed above relative to the Wheeler Ridge herd unit, documented lion kills of bighorn sheep typically imply considerably more undocumented mortality. Five of the documented kills in the Mount Baxter and Sawmill Canyon herd units were by one lion, but three of those were found well after the event by investigating clusters of GPS points from the collar on that lion. This recovery program was set up to include detailed monitoring of such predation and to use that information to prevent mountain lion predation from again making significant inroads into these bighorn populations. This program appeared to be successful at this in its early years when the mountain lion and bighorn populations were smaller and predation events involving bighorn sheep relatively infrequent. That appears to have changed in recent years and the recovery program has recently adjusted its approach to better measure actual losses to mountain lions and to use that information to better protect bighorn sheep herds. The Mount Baxter and Wheeler Ridge herds have been identified as critical to future translocation efforts for these sheep. The apparent cessation in the recovery of the Mount Baxter herd over the past 2 years is very concerning and may translate to additional years before recovery goals can be reached. While this change in population growth rate likely reflects more than predation effects, predation is among the few factors amenable to management actions and was emphasized in the Recovery Plan for that reason.

## Conclusions

The past year is likely to stand out in the history of bighorn sheep in the Sierra Nevada because of a variety of events. On the positive side, the highest total count of females to date occurred, including the first good direct count in 22 years for the Mount Williamson herd. Virtually the entire winter range of the Mount Baxter herd burned in a wild fire. This was considered the best winter range in the Sierra Nevada, and would not have been projected to benefit from fire. Initial information from the past winter and spring suggests that this fire may nevertheless prove beneficial. Two diseases (pneumonia and contagious echthyma) were documented in bighorn sheep in the Sierra Nevada for the first time, both of which raise questions about causes. Adult mortality rates jumped significantly in 5 herd units, most of which appear to have a resulting decline in population growth rate. Some of these herds are somewhat buffered by their sizes due to numerous recent years of increase. Other smaller ones are far more vulnerable. In the long run, populations in neither size category can sustain continued high mortality levels, especially given the need to use larger herds for translocation stock. Addressing this mortality and taking appropriate actions where possible is consequently of utmost importance to the future of these sheep.

One such action would be translocation of some animals to the Mono Basin to re-establish use of low elevation winter ranges and bolster genetic diversity. The current low population size of the Mount Warren herd makes this an opportune time to effect the latter. That the overall number of bighorn in the Sierra Nevada appears to be stabilizing near 400 sheep may reflect the complexity of multiple factors potentially interacting to limit continued population growth. This highlights the importance of this recovery program moving as soon as possible to a new phase that involves reintroducing bighorn to vacant habitat to enhance the potential for the total population to grow further. Because the current larger herds are the potential sources of that reintroduction stock, this only further emphasizes the need to maximize survivorship in those herds to the extent possible to maximize the availability of translocation stock.

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