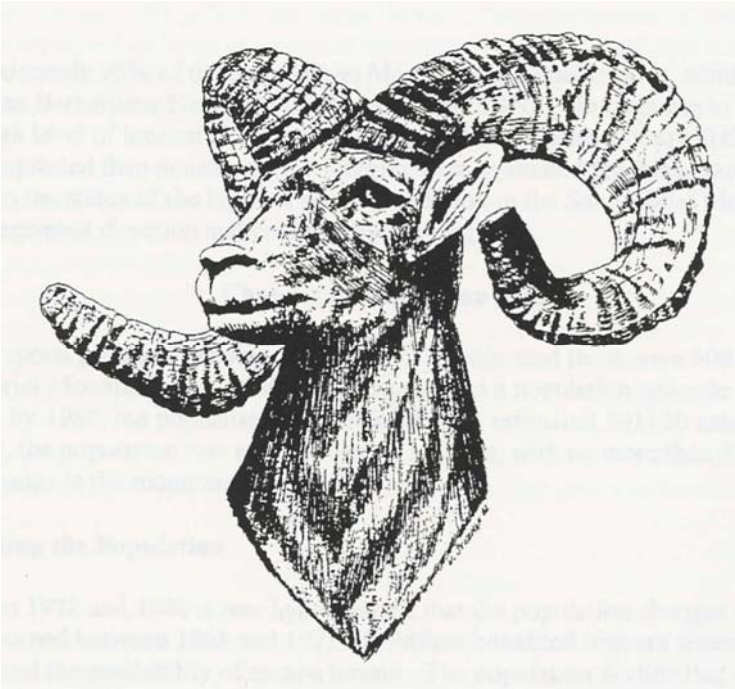
San Gabriel Mountains Bighorn Sheep Restoration Program

2006 Report



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EXECUTIVE SUMMARY

This report describes efforts initiated by the U. S. Forest Service and California Department of Fish and Game in 2003 to restore the San Gabriel Mountains bighorn sheep population (*Ovis canadensis nelsoni*). The most recent survey was conducted April 2, 6, and 13, 2006 using aerial surveys and a total of 167 bighorn sheep were observed. Concurrent ground surveys were conducted by 53 volunteers on April 2 and they counted 29 bighorn sheep in two canyons. Three population estimates were calculated from the surveys. A population estimate of 229 bighorn sheep was calculated using probabilities of animals seen by different observers in the helicopter. An estimate±standard error of 249±29.6 sheep was calculated from the concurrent aerial and ground surveys. Finally, radio-collared animals were used to provide a mark-recapture population estimate±standard error of 291±69.4 bighorn sheep. The highest population estimate was below the threshold of 322 animals and the Middle Fork of Lytle Creek, Deer/Cucamonga/Barrett-Cascade Canyons, and the East Fork of the San Gabriel River winter-spring ranges met the restoration goal for the required number of ewes on a winter-spring range. Nine radio-collared animals died between September 2003 and March 2006. Mean annual adult survival rates were 0.833 for males and 0.785 for females; these rates are inconsistent with a species characterized by an unbalanced sex ratio favoring females. The mean annual ram survival rate was higher than that previously reported for rams in the San Bernardino Mountains. Cause of mortality was not determined in five cases but mountain lion (*Felis concolor*) and black bear (*Ursus americanus*) predation were implicated in four cases. Lamb recruitment rates have been variable during the past 10 years; below normal rainfall in 2000-2002 was associated with low recruitment rates. Rates of increase, adult mortality rates, and recruitment rates were used to reconstruct population estimates from 1990-2006. The reconstructed population estimates indicated the bighorn sheep population has been increasing since 1996. The calculated rate of increase was 0.06, and assuming that does not change, the threshold restoration goal of 322 animals would be achieved in 2008. The required number of ewes on winter-spring ranges may not be met at that time, however. The relationship between fire and bighorn sheep was evaluated. Fire increases habitat availability and improves suitability; however, it does not appear to improve productivity, as determined by lamb recruitment rates.

INTRODUCTION

This report describes the results of efforts initiated by the Forest Service and California Department of Fish and Game and others in 2003 to restore the San Gabriel Mountains bighorn sheep (*Ovis canadensis nelsoni*) population. The restoration efforts are implemented by an interagency team of wildlife biologists:

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- Chanelle Davis, California Department Fish and Game
- Steve Holl, Steve Holl Consulting

- Steve Loe, San Bernardino National Forest
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This report summarizes the restoration efforts since September 2003. It includes the results of the 2006 annual survey, describes patterns of adult mortality of bighorn sheep, evaluates factors affecting lamb recruitment rates over the last 10 years, reconstructs annual population estimates from 1990-2006, and evaluates the role of fire and its affects on bighorn sheep. Information on mountain lion studies and movement and seasonal home ranges of bighorn sheep will included in separate reports.

Acknowledgements

The San Bernardino National Forest has been a source of major funding for the restoration effort, with additional funding provided by the Forest Service Full Curl program, Los Angeles County Fish and Game Commission, Quail Unlimited, Safari Club, Society for the Conservation of Bighorn Sheep, and the California Chapter of the Foundation for North American Wild Sheep. The San Bernardino and Angeles National Forests and California Department of Fish and Game provided staff and logistical support. Sincere thanks are also given to John Hybarger, Brad Nuremburg and Tim Jones from Los Angeles County Fish and Game Commission for their support and participation. To John Aziz, Susan Crew, Tim Glenner, and Clint Kearns from Wrightwood, CA who participated in captures, monitored radio-collared animals, website development, graphic arts, and/or the annual survey; and to John Nelson from the Society for the Conservation of Bighorn Sheep for the preparing the barbeque associated with the 2006 survey and for participating in the survey. The efforts of all these individuals and others have been major contributions to this project.

2006 ANNUAL SURVEY

The annual San Gabriel Mountains bighorn sheep survey occurred April 2, 9, and 13, 2006. The Middle Fork of Lytle Creek, South Fork of Lytle Creek, Deer Canyon, Cucamonga Canyon, Barrett-Cascade Canyons, and Cattle Canyon were surveyed by concurrent ground and aerial (helicopter) surveys on April 2. Fifty-three volunteers participated in the ground surveys on that day. Late season storms and helicopter availability delayed the surveys of other areas until the later dates.

A total of 167 animals were observed from the air (Table 1). Two rams could not be classified in Barrett-Cascade Canyon and one ram could not be classified in the East Fork of the San Gabriel. Lambs in Table 1 were those that were born last year and are now 10-12 months old. In all previous years the survey was conducted in March and these 10-12 year old lambs became yearlings in April, as the next cohort of lambs was being born. The 10-12 month old animals are still considered lambs in this survey; however, two newborn lambs were observed in the East Fork of the San Gabriel River.

There had been documented sightings of mixed groups of bighorn sheep in summer 2004 and 2005 on the north side of the mountain range, near Little Rock Reservoir, near Burkhart Saddle, at Reed Spring, up stream of the campground on the South Fork of Big Rock Creek, and at the Devil's Chair in Devil's Punchbowl County Park. No animals have been seen at Devil's Punchbowl since last July (Jack Farley, *pers. com*.). The team intended to survey the area this year; however, the survey was not conducted. In mid-April, 2006, the Department of Fish and Game received a photograph and report of a mixed group of bighorn sheep (rams, ewes, yearlings) near the Devil's Chair in Devil's Punchbowl County Park. Confirmed sightings in 2004-2006, indicate bighorn sheep use this area, at least seasonally.

Table 1. Total number of individual animals observed during the 2006 aerial survey.

Winter-Spring Range	*Ewes*	*Lambs*	*Ram I*	*Ram II*	*Ram III*	*Ram IV*	*Unkwn*	*Total*
M. Fk. Lytle Creek	11	3		1	4	1		20
S. Fk. Lytle Creek	2					2		4
Day Canyon						1	1	1
Deer Canyon	2			1				3
Cucamonga Canyon	3	2						5
Barrett-Cascade	12	5	1	2	4	4	2 (rams)	30
Cattle Canyon	11	3	4	3	6	4	3	34
E. Fk. San Gabriel	24	3	1	6	10	7	5 (1 ram)	56
San G. Wilderness	6	3		2	1	1		13
Total	**71**	**19**	**6**	**15**	**25**	**20**	**11**	**167**

Compared to recent surveys, similar numbers of sheep were observed in the Middle Fork Lytle Creek in 2004 and 2005 and in the San Gabriel Wilderness in 2004. More sheep were observed in Deer/Cucamonga/Barrett-Cascade Canyons compared to 2004, while fewer sheep were observed in South Fork Lytle Creek and Cattle Canyon. In South Fork, 12 animals were observed in 2005. Fewer sheep may have been observed in 2006 because the survey was prematurely terminated to allow the helicopter to assist an injured volunteer at the end of the day. Another complete survey of the South Fork of Lytle Creek was attempted April 13; however, no sheep were observed and the previous results were used in the analysis. There were approximately 32% fewer sheep observed in Cattle Canyon in 2006 compared to 2004 and 2005. It is not clear if this represents a population decline or a poor survey. The consistently low number of sheep in South Fork of Lytle Creek and the San Gabriel Wilderness is a concern because in 1983 these ranges supported an estimated 80 and 160 bighorn sheep, respectively (Holl and Bleich 1983). Trends are difficult to compare in the East Fork of the San Gabriel because a similar number of sheep was observed in 2004; however, 71 sheep were observed in 2005. Therefore, it is not clear if animals were missed in 2006 or if there has been a decline.

Population Estimates

A population estimate of 229 animals was calculated using simultaneous counts of bighorn sheep seen by the helicopter observers. This formula is based on the number of animals seen or missed by front and rear observers; however, it does not include animals known to be in the range but not counted. Therefore, it should be interpreted as a minimum population estimate. Concurrent ground and aerial surveys were previously used in the San Gabriel Mountains to calculate population estimates (Holl and Bleich 1983), using the Magnusson et al. (1978) formula. In 2006, the concurrent ground and aerial surveys yielded a population estimate±standard error of 249±29.6. This estimate is probably conservative because bighorn sheep were only counted by the ground survey in two canyons. Another population estimate was calculated using the radio-collared animals in a modified Peterson mark-recapture calculation (Caughley 1977). The aerial surveyors counted 14 of 26 radio-collared animals observed and this yielded a population estimate±standard error of 291±69.4. This population estimate included animals known to be in the sample survey but were not observed, and marked animals that were well distributed in the mountain range; therefore, it is probably more representative of the population than the previous two estimates.

Relationship to Restoration Goals

The restoration goal for the San Gabriel Mountains is to achieve a self-sustaining population. A self-sustaining population includes two criteria:

- at least 30 ewes are in five areas and 15 in one area (Table 2); and
- at least 322 bighorn sheep are well distributed for six consecutive years (Holl 2004).

The number of ewes in each winter-spring range was estimated using the modified Peterson formula (Table 2). The Middle Fork of Lytle Creek, Deer/Cucamonga/Barrett-Cascade Canyons, and the East Fork of the San Gabriel River winter-spring ranges meet the first criterion. The total population estimate is below the second criterion and has not been maintained yet for six years. Therefore, the restoration goal for this population has not been achieved, at this time.

Table 2. Number of ewes on winter-spring ranges.

Winter-Spring Range	*Goal*	*Current Estimate*
Middle Fork	15	19
South Fork	30	5
Deer/Cucamonga/Barrett-Cascade	30	31
Cattle Canyon	30	21
East Fork San Gabriel	30	43
San Gabriel Wilderness	30	12

ADULT SURVIVAL

Thirty-five adult bighorn sheep were captured between September 2003 and January 2006. Each of the animals was fitted with a radio telemetry collar designed with a mortality sensor. The location of bighorn sheep was determined from a fixed-wing aircraft 2-4 times per month and the type of signal emitted by the collars was monitored from the ground 3-6 times per week. When a mortality signal was received the dead animal was investigated within 2-36 days, with a mean of 5 days to determine the cause of death. Mortality investigations were often delayed because the helicopter was not available or weather conditions precluded the helicopter from flying. Annual mortality rates of radio-collared adults were calculated using the Kaplan-Meier procedure for a staggered entry design as described by Pollock et al. (1989). The year was assumed to start April 1, just before the initiation of lambing and end March 31, when all lambs surviving to this time are assumed to be recruited into the population.

Table 3. Annual calculated survival rates based on radio-collared animals.

Year	*Rams*				*Ewes*			
	Initial	Added	Mortality	Survival Rate	Initial	Added	Mortality	Survival Rate
2003-2004	2	2	0	1.00	1	2	0	1.00
2004-2005	4	8	1	0.917	3	7	2	0.778
2005-2006	11	7	4	0.749	7	7	2	0.791

During the project, five rams and four ewes died. The initial number of collared animals present in April each year, the number added during the year, number of mortalities, and annual survival rates are described in Table 3. Survival rates in 2003-2004 are probably representative of the population because of the small sample size and that is the only year where no mortality was detected. The mean survival rate for the other two years was 0.785 for adult females and 0.833 for adult males. These rates are inconsistent with a species that has an unbalanced sex ratio favoring females. There was a larger sample size of rams; and it was assumed the calculated survival rate for ewes was low because of the small sample size. Eighty-eight percent of the mortalities occurred between December and March (Figure 1).

The mean survival rate for males in the San Gabriel Mountains was higher than that reported for rams in the San Bernardino Mountains (0.763, Schaefer et al. 2000). The majority of sheep in the San Gabriel Mountains died during winter. This is similar to studies of bighorn sheep and mule deer (*Odocoileus hemionus*) in the San Bernardino Mountains (Schaefer et al. 2000, Nicholson et al. 1997) and bighorn sheep in the Peninsular Ranges (Hayes et al. 2000, Boyce 2005).

The cause of death was not determined in five cases; however, based on the field investigation, mountain lion (*Felis concolor*) predation was the probable cause in three cases and black bear (*Ursus americanus*) predation was the probable cause in one case.

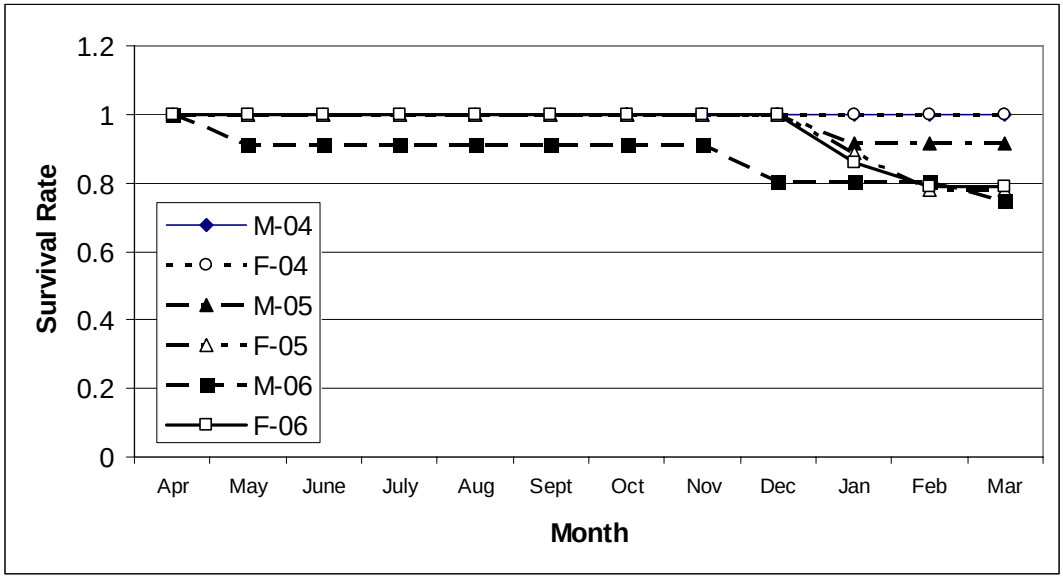

Figure 1. Timing of mortality in radio-collared bighorn sheep in the San Gabriel Mountains.

The cause of death could not be determined in five cases and mountain lions were associated with three mortalities in the San Gabriel Mountains. Seventy-five percent (n = 9) of all bighorn sheep mortalities (n = 12) in the San Bernardino Mountains were caused by mountain lions and cause was not determined in three cases (Schaefer et al. 2000). Sixty-nine percent of all bighorn sheep mortalities (n = 61) in the Peninsular Ranges were attributed to mountain lions and nine occurred from unknown causes (Hayes et al. 2000). More recently, 71% of all radio-collared bighorn sheep in Anza Borrego Desert State Park were killed or fed upon by mountain lions (Boyce 2005). Black bear predation was implicated in the mortality of a 9-year old ram in the San Gabriel Mountains.

One mortality investigation identified an interaction between mountain lions and black bears. When the team arrived by helicopter to retrieve the radio collar of a ram in the East Fork of the San Gabriel on April 13, 2006 they encountered a large bear that was reluctant to retreat from the area. After the bear left the team investigated the area and found the dead ram and its radio collar. The cause of death for the ram was unknown because of the amount of time that had expired from when the mortality signal was first received (March 7). They also investigated the area where the bear had been observed and found a half-consumed mountain lion that the bear had been feeding on. The lion was an adult and appeared to be healthy. The bighorn sheep had been dead for over a month, so it is unlikely the lion or bear were defending its prey. At this point, the relationship between the lion and bear would be speculative; however, the first-hand observation is interesting.

LAMB RECRUITMENT

Surveys since 1995 indicated the San Gabriel bighorn sheep population was stable at very low numbers, until recently, when the population estimate increased to 292 animals. Lamb recruitment rates are an important metric when evaluating population dynamics. Lamb recruitment has been highly variable from 1995-2006 (Figure 2). There was not a significant correlation (r = 0.435, *P >0.05*) between lamb recruitment rates and the number of adult ewes counted for this time period, indicating lamb recruitment rates were independent of sample size.

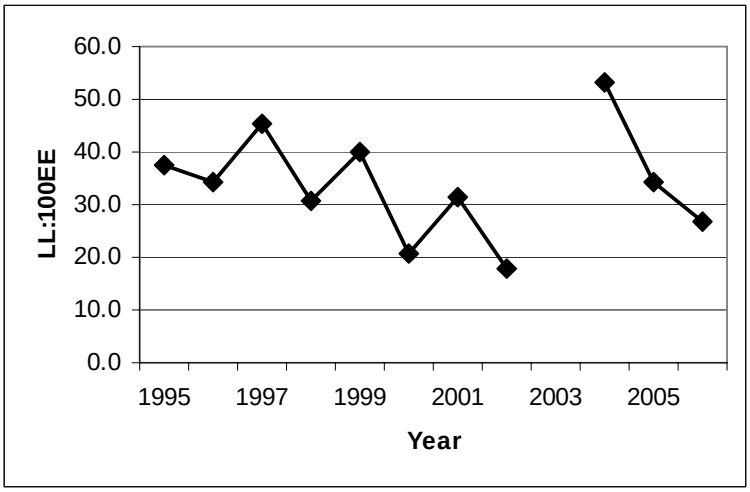

Figure 2. Lamb recruitment rates, 1995-2006, San Gabriel Mountains

Lamb recruitment rates were adversely affected by spring rain and minimum temperatures from 1976-1984 when the population was at carrying capacity (Holl et al. 2004). Monthly rainfall recorded at Mount Wilson from 1985-2005 was evaluated to determine if seasonal rainfall during pregnancy and lambing were correlated with lamb recruitment the following year (Table 4). There were no significant correlations (*P >0.05*) between monthly rainfall and lamb recruitment. When months with the strongest correlations were combined, there were no significant correlations, and, finally, there was no correlation between total fall and winter rainfall and lamb recruitment.

Table 4. Correlation coefficients between seasonal rain and lamb recruitment rates, 1995-2005.

Month	r	*Significance*	*Combined Months*	r	*Significance*
November	0.343	*n.s.*	Nov-Dec	0.255	*n.s.*
December	0.091	*n.s.*	Feb-Mar	0.418	*n.s*
January	-0.127	*n.s.*			
February	0.367	*n.s.*	Nov-Mar	0.366	*n.s.*
March	0.267	*n.s.*			
April	-0.224	*n.s.*			
May	0.173	*n.s.*			

n.s. = not significant

The lowest recruitment rates occurred in 2000-2002 (Figure 2). These rates are significantly lower (Mann-Whitney test $U_{5,3}= 14$, $P < 0.05$) than recruitment rates in 1995-1999. The difference appears to be associated with below normal rainfall 2000-2002 (Nov-March mean annual rainfall = 23.3 inches) compared to 1995-1999 (Nov-Mar mean annual rainfall = 29.5inches), which is closer to the 1985-2004 mean (31.7 inches). Substantially lower rainfall would affect forage production and quality and be manifested by low lamb recruitment.

Lamb recruitment rates in 2006 approached those observed in 2000-2002. Rainfall occurred in April and May 2005; however, minimum temperatures at Mt. Wilson were one degree (Fahrenheit) lower in April 2005 and one degree higher in May than the mean for that weather station. Thus, it does not appear cold, wet weather during lambing affected neonatal survival.

RECONSTRUCTING POPULATION ESTIMATES FOR BIGHORN SHEEP IN THE SAN GABRIEL MOUNTAINS

Bighorn sheep in the San Gabriel Mountains have been surveyed annually since 1976. From 1976-1989, population estimates were calculated using the concurrent double survey of ground and helicopter counts (Magnusson et al. 1978). No population estimates are available from 1989 to 2005.

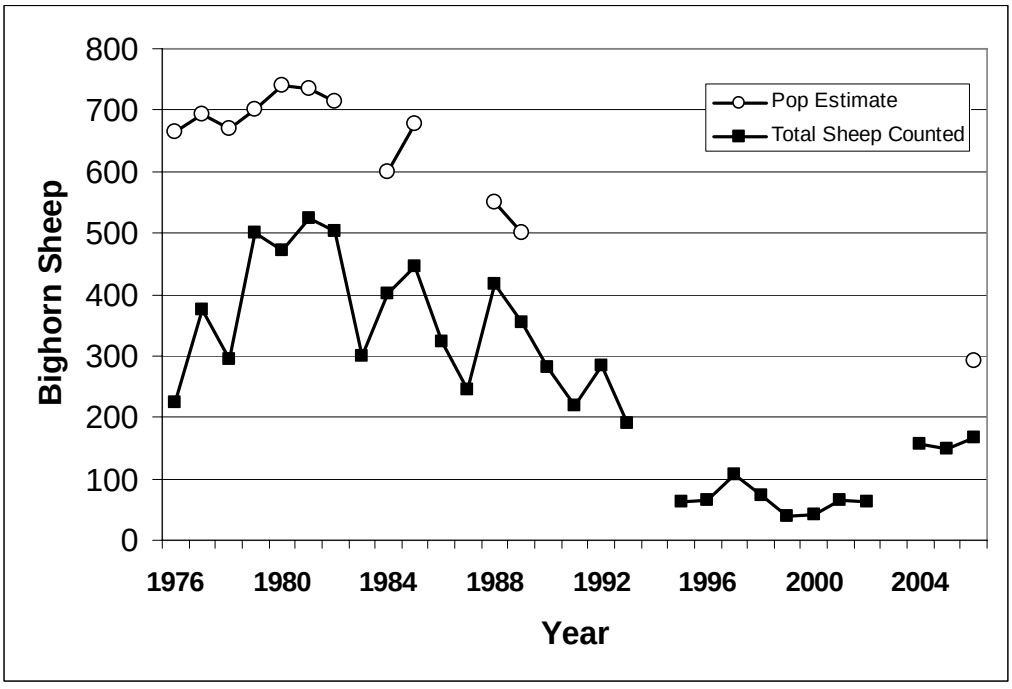

Figure 3. Total number of bighorn sheep counted and population estimates, 1976-2006.

Population estimates from 1967-1989 indicated the population increased from approximately 500 animals in 1967 to 740 in 1980, then declined to approximately 500

animals in 1989 (Figure 3). The total number of bighorn sheep counted increased from 224 animals in 1976 to 523 animals in 1981, then declined to a low of 39-42 animals in 1999-2000, during incomplete surveys (Figure 3). In 2004, the number of bighorn sheep counted increased to 157 animals. In 2006, 167 animals were observed and the population was estimated at 291±69.4 animals. The consistently low number of animals counted from 1995-2002 led Holl et al. (2004) to conclude the population was stable; however, the 2004 survey and subsequent surveys indicate the population had suddenly increased. Reconstructing the population estimates can determine when the change in the population trajectory occurred and be used to develop a projection of future changes.

Population Estimates 1976-1982

Population estimates from 1976 to 1982 were calculated using an initial population estimate of 665 bighorn sheep (developed from the double survey estimate), the rate of increase (r = 0.015, Holl et al. 2004), and the exponential growth equation ($N_t = N_0 * e^{rt}$. Where N_t = the year in question, N_0 = the initial year's population estimate, e = a constant [2.7183], r = the rate of increase, and t = the year in question. The population estimates developed from the rate of increase was very similar to those obtained from the double survey (Table 5).

Table 5. Population estimates based on the double survey and rate of increase, 1976-1982.

Year	*Population Estimate (Double Survey)*	*Population Estimate (r = 0.015)*
1976	665	665
1977	692	671.1
1978	669	685.3
1979	700	695.6
1980	740	706.1
1981	735	716.8
1982	714	727.6

Population Estimates 1982-1989

Population estimates for this period were developed assuming an initial population size of 714 animals and a mean rate of increase calculated from the number of bighorn sheep counted (r = –0.076) (Holl et al. 2004) and number of sheep observed per hour helicopter flight (r = –0.071) in the exponential growth equation. These population indices were not used to calculate the original population estimates; therefore, the rates of change are independent of those population estimates.

Using the average rate of increase, the population was underestimated after 1985 (Table 6). This occurred because more sheep were observed during the 1985 survey, resulting in a higher population estimate. The highest number of rams counted (n = 211) during the entire survey period occurred in 1985 and the lamb recruitment rate was higher that year compared to the previous two years. Therefore, the population estimate of 665

was used in 1985 and population estimates recalculated from 1986 to 1989, using the same average rate of increase. Where those estimates could be compared (1984, 1988, 1989) the reconstructed estimates were within the 95% confidence limits of those calculated from the double survey.

Table 6. Population estimates based on the double survey and rates of change, 1982-1989.

Year	*Population Estimate (Double Survey)*	*Population Estimate (r = –0.073)*	*Population Estimate (r =–0.073)^{reconstruct}*
1882	714	714	714
1983	n.a.	663.7	661.9
1984	600	617.0	613.6
1985	677	573.6	677
1986	n.a.	533.2	629.3
1987	n.a.	495.7	585.0
1988	550	460.8	543.8
1989	501	428.3	505.6

n.a. = not available

Population Estimates 1989-1995

Population estimates for this period were calculated similar to previous estimates using an initial population of 501 animals in 1989 (Table 6) and a mean rate of increase calculated from the number of bighorn sheep counted (r = –0.26) and number counted per hour of helicopter flight (r = –0.228) (Holl et al. 2004). The population estimate was incorrect in 1992 and 1993 because it was lower than or approximately equal to the actual number of animals counted (Table 7). Therefore, the number of animals counted was used as the starting point and remaining years recalculated with the average rate of increase for this period.

Table 7. Number of bighorn sheep counted and population estimates calculated with the rate of increase, 1989-1995.

Year	*Number Counted*	*Population Estimate (r = –0.244)*	*Population Estimate (r = –0.244)^{reconstruct}*
1989	355	501	501
1990	281	392.5	393.5
1991	220	307.5	207.5
1992	283	241.0	283
1993	190	188.8	221.7
1994	n.s.	147.9	173.7
1995	62	115.9	136.1

n.s. = no survey

Population Estimates 1995-2006

Population estimates for this period were calculated similar to previous years, using an initial population of 136 animals in 1995 (Table 7) and a mean rate of increase calculated from 1995 to 2002 for number of bighorn sheep counted (r = –0.008) and number counted per hour of helicopter flight (r = –0.018) (Holl et al. 2004). It was assumed the mean rate of increase remained constant through 2006. The population estimate in 2004 and subsequent years is incorrect because it is substantially below the actual number of bighorn sheep counted during the annual survey (Table 8).

Table 8. Number of bighorn sheep counted and population estimates calculated from the rate of increase 1995-2006.

Year	*Number Counted*	*Population Estimate (r = –0.013)*
1995	62	136
1996	65	134.2
1997	106	132.5
1998	74	130.8
1999	39	129.1
2000	42	127.4
2001	65	125.8
2002	63	124.2
2003	n.s.	122.6
2004	157	121.0
2005	148	119.4
2006	167	117.9

n.s. = no survey

Revised Estimates 1995-2006

Population estimates for 1995-2006 were recalculated using the following data and methods. It was assumed there were 136 animals in 1995 (Table 7). Annual mortality rates were based on radio-collared adult ewes and rams from 2003-2006, as described above. The sample size for collared rams was assumed to be adequate and the sample size for ewes was assumed to be inadequate. This was tested using two different sets of adult ($\geq$ 2 years) survival rates (S). In the first test, survival rates (S_1) were based on the mean of the observed rates (0.833 rams, 0.785 ewes). The mean survival rates did not include the first year's data because the sample sizes were small and there was no mortalities recorded. A second set of population estimates were calculated assuming a mean annual survival rate (S_2) of 0.833 for rams and 0.91 for ewes. The ewe survival rate was selected by an iterative process that maintained a ram:ewe ratio of approximately 66:100, the mean ratio observed from 1976-2006. Survival rates of yearlings are generally higher than older animals (Geist 1971, Hansen 1980, Festa-Bianchet 1989), except in declining populations (Festa-Bianchet 1989, Rubin et al. 2002).

Therefore, yearling survival rates were assumed to be 0.98, the mean of other bighorn sheep populations (Festa-Bianchet 1989) and an even sex ratio was assumed. Observed lamb:ewe ratios were used to estimate annual recruitment into the adult cohort, assuming an even sex ratio. No survey was conducted in 2003; therefore, the mean lamb:ewe ratio of the previous seven years (0.31) was used in the modeling. Annual population sizes for adults and lambs in March were estimated by the following formulas:

$R_y = (R_{y-1} * S_1 \text{ or } S_2) + ((L_{y-1}/2) * 0.98)$;

$E_y = (E_{y-1} * S_1 \text{ or } S_2) + ((L_{y-1}/2) * 0.98)$; and

$L_y = E_y *$ (observed recruitment rate);

where R = rams, E = ewes, L = lambs, y = year, S_1 = calculated mean survival rates, and S_2 = calculated mean survival rate for rams and estimated 0.91 for ewes. The total population size at the end of March was estimated by summing the number of adult rams and ewes and lambs.

The population estimates calculated from the observed survival and recruitment rates indicated the population had been declining since 2000 and there were substantially fewer animals than the actual number of animals counted after 2004 (Table 9). Therefore, the values used in the model were not consistent with the observations.

Table 9. Population estimates based on sex and age ratios and mortality rates.

Year	*Number Counted*	*Population Estimate (S_1)*	*Population Estimate (S_2)*
1995	62	136	136
1996	66	135.9	146.9
1997	106	141.1	167.1
1998	74	137.6	177.6
1999	39	137.6	196.3
2000	38	127.1	198.2
2001	65	120.7	209.4
2002	63	109.0	207.5
2003	n.s.	102.6	219.1
2004	157	105.8	259.2
2005	148	103.4	282.9
2006	167	96.7	294.0

n.s. = no survey

The population estimates calculated from the observed ram survival rates and recruitment rates and estimated ewe survival rates indicate the population had increased since 1996. Although actual adult survival rates are unknown for the entire period, the mean adult ram survival rates for 2004-2006 appear to be reasonable estimates for some portion of the period between 1995 and 2006. The adult ewe survival rates are substantially higher than those measured; however, reducing them to the observed rates

resulted in population estimates that were lower than the actual number of animals counted during the annual survey. The mean ram:ewe ratio from 1995-2006 was 67.8, nearly identical to the mean for the entire period of record. The recruitment rates were based on observed lamb:ewe ratios that should have been measured with little error. The 2006 population estimate (294.0) was nearly identical to the mark-recapture population estimate (291±69.4). The number of bighorn sheep counted each year, the population estimates based on the double survey, and the reconstructed population estimates derived in Tables 5, 6, and 7 are shown in Figure 3.

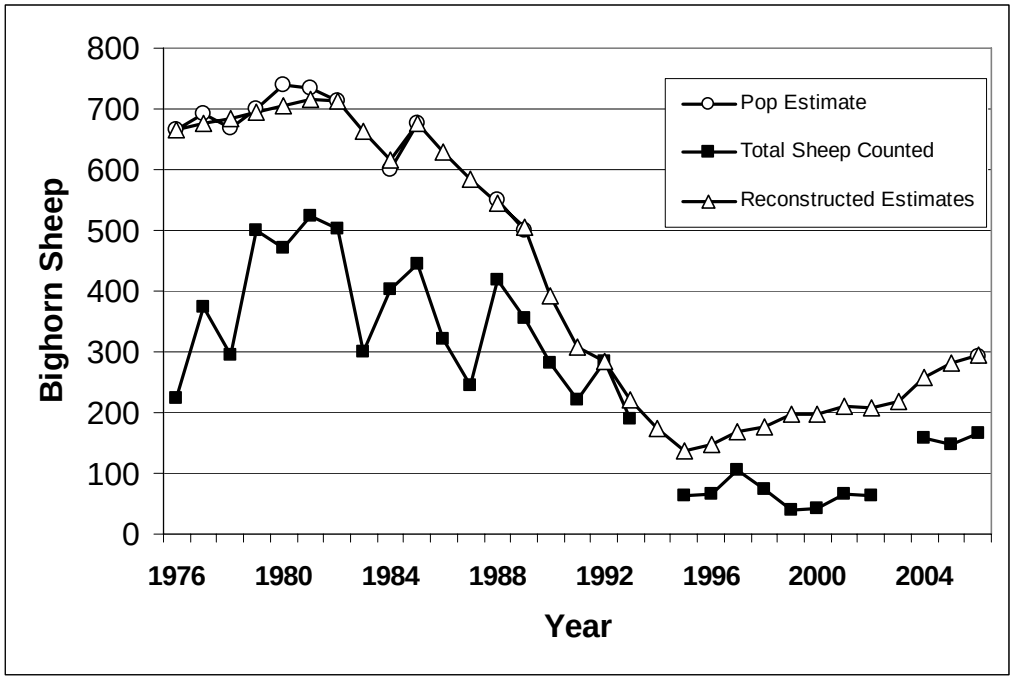

Figure 3. Population estimates and number of bighorn sheep counted from 1976-2006, San Gabriel Mountains.

The reconstructed population estimate agrees with the 2006 survey and verifies there were more bighorn sheep in the San Gabriel Mountains than previously thought. Second, the reconstructed population estimates also demonstrated the population had been increasing since 1996. Using the reconstructed population estimates the rate of increase from 1995-2006 is 0.06. Assuming this rate of increase does not change, the population threshold of 322 animals would be achieved in 2008 when the population would be estimated at 329 animals. This is however, only one of the two criteria that must be achieved to conclude the population has achieved the self-sustaining level.

The rate of increase is substantially lower than the initial maximum rate of increase, r = 0.028 calculated by Buechner (1960) or that calculated for rapidly expanding populations r = 0.265 (Woodgerd 1964) and r = 0.25 (Rominger et al. 2004). The doubling time was calculated to compare these rates. In the San Gabriel Mountains the population would double every 11.5 years, compared to 2.7 years when r = 0.25. In rapidly growing populations the population would double four times before the first

doubling in the San Gabriel population. Thus, the growth rate is positive in the San Gabriel Mountains population but it is constrained when compared to rapidly growing bighorn sheep populations.

These results are consistent with the hypothesis that described the decline in this population (Holl et al. 2004). The sharpest population decline occurred between 1989 and 1995 when there was a decrease in the number of adult animals counted while lamb recruitment rates were increasing and continued to increase until 1997 (Figure 4). This scenario would not be consistent with a disease outbreak or a decline in habitat quality/quantity, where lamb recruitment would have been adversely affected.

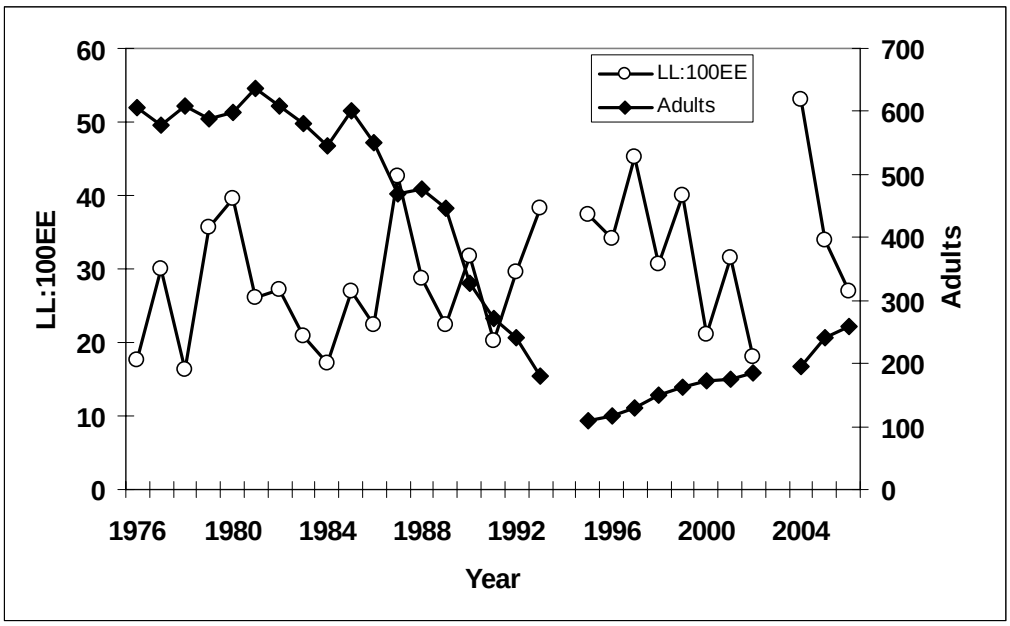

Figure 4. Relationship between the reconstructed number of adult bighorn sheep and lamb recruitment rates in the San Gabriel Mountains.

The loss of adult sheep coincided with an increase in the number of mountain lion depredation permits issued between 1993 and 2002, with the peak period being 1995-1997. There is a delay in time between the sheep population decline and issuance of mountain lion depredation permits. The depredation permits are not a direct measure of mountain lion numbers, but they are a measure of mountain lions searching for prey. All of the depredation permits were issued in communities adjacent to the San Gabriel Mountains. Therefore, the permits were issued for lions that likely were leaving the San Gabriel Mountains in search of prey because the prey base (mule deer and bighorn sheep) had declined so dramatically. The number of depredation permits declined after 2002, suggesting there is sufficient prey in the mountain range to support the current population of mountain lions.

ROLE OF FIRE

Fire is the primary disturbance element affecting vegetation in the San Gabriel Mountains. Most low intensity fires are quickly suppressed; however, large conflagrations occur during Santa Ana winds. Bighorn sheep move into recently burned areas and move out of those areas as the vegetation matures and limits their ability to move and detect predators (Holl et al. 2004). More recently, an analysis of spring habitat selection and availability for this population determined bighorn sheep were positively associated with areas that had burned up to 15 years previously and negatively associated with areas that had not burned in more than 15 years (Bleich et al. 2005). Thus, it appears that fire increases habitat availability and improves suitability in the San Gabriel Mountains.

Studies of black-tailed deer (*O. h. columbianus*) inhabiting coastal chaparral determined that browse in recently burned areas had a higher protein content than unburned areas. As a result, fawn survival was higher in burned areas than unburned areas for three years post-fire (Taber and Dasmann 1958). Browse comprises 60% of the diet on an annual basis of bighorn sheep in the San Gabriel Mountains (Perry et al. 1987). Thus, it was hypothesized a similar relationship between nutrition and productivity, as measured by lamb recruitment occurred in the San Gabriel bighorn sheep population.

The effect of fire on lamb recruitment in the San Gabriel Mountains was evaluated for three fires. The Village Fire occurred in 1975 and burned a substantial amount (1,560 acres) of the Cattle Canyon winter-spring range. The Narrows Fire occurred in 1997 and burned a substantial amount (2,025 acres) of the East Fork winter-spring range. The Grand Prix and Padua Fires in fall 2003 burned substantial portions of the entire Cucamonga subgroup of bighorn sheep winter-spring ranges (from Middle Fork of Lytle Creek in the east to Barrett-Cascade Canyons in the west). All fires occurred in fall.

Two hypotheses were tested. The first was that recently burned seasonal ranges would have higher nutrition and consequently higher lamb recruitment. This was tested by evaluating lamb recruitment rates within the first four years following a fire. The second hypothesis was that over a longer period of time, increased habitat availability and improved suitability would increase lamb recruitment. This was tested by comparing lamb recruitment rates within the first eight years following fires. Lamb recruitment rates in those winter-spring ranges were compared to recruitment rates in the remainder of the population where no fires had occurred for at least 5 years (Table 10). Lamb recruitment rates obtained the first March after the fires were not used in the analysis because those lambs were 6-8 months old when the fires occurred and the fires would not have had an impact on prenatal or neonatal nutrition.

There were no significant differences ($U_{3,3.} = 5.5$, $P > 0.05$) in recruitment rates Cattle Canyon and unburned ranges 2-4 years following the fire. Only one year of recruitment rates was available in the East Fork; however, that was substantially less than the mean observed in the unburned ranges. Only two years of data are available

following the Grand Prix and Padua fires and it appear recruitment may be higher in burned ranges. At this time the effect of nutrition on lamb recruitment is not clear in the San Gabriel Mountains.

There were no significant differences in lamb recruitment rates in Cattle Canyon ($U_{7,7.} = 35.5$, $P > 0.05$) and in the East Fork San Gabriel ($U_{4,6.} = 15$, $P > 0.05$) compared to unburned ranges 2-8 years following fires. Therefore, increased habitat availability and improved habitat suitability do not appear to improve lamb recruitment.

Table 10. Mean±standard deviation lamb recruitment rates (LL:100EE) in burned and unburned winter-spring ranges.

Years Post-Fire	*Cattle Canyon*	*Unburned Ranges*	*East Fork*	*Unburned Ranges*	*Cucamonga Subunit*	*Unburned Ranges*
2-4	29±13.6	24±13.5	14*	40±2.5	52**	25**
2-8	30±9.1	20.9±11.3	33±24.2	38±16.3		

* one year, only

** first two years, only

MANAGEMENT ISSUES

The 2006 survey indicated the San Gabriel Mountains population had not met or exceeded the criteria established for a self-sustaining population. The trajectory of the population is positive; however, it is constrained. There are no data to indicate disease is an issue in this mountain range. Consistently low numbers of bighorn sheep have been observed in the San Gabriel Wilderness and the South Fork of Lytle Creek. Large portions of the San Gabriel Wilderness have not burned in years, possibly reducing the amount and suitability of habitat. The recent observations of bighorn sheep on the north side of the mountain range occurred near the traditional range of the San Gabriel Wilderness subpopulation. This may indicate animals have moved out of that traditional area. The Grand Prix fire burned most of the South Fork of Lytle Creek winter-spring and portions of the summer ranges; therefore, habitat availability or suitability should not be a constraint on that group of sheep. Historically, the largest number of mountain lions removed by bounty hunters in the San Gabriel Mountains came from Lytle Creek and San Sevaine Ridge. Additionally, bears are known to inhabit San Sevaine, a recent phenomenon. Both species prey on bighorn sheep in this mountain range. Therefore, predation may be constraining the South Fork of Lytle Creek subpopulation.

There are currently 12 radio-collared male and 13 radio-collared female bighorn sheep. The current emphasis should be on having 12-15 radio-collared males and 15-20 radio-collared females that are well distributed in the mountain range. This emphasis should not change in the near future; however, more animals should be collared in the South Fork of Lytle Creek to evaluate causes of mortality in that area. Secondary predators and delays in reaching the animal are hampering investigations of the cause of mortality. Substantially more effort should be directed at determining the cause of death of radio-collared animals. This will provide data to verify the ewe survivorship rate and evaluate the effects of predation on this population.

The annual survey should continue because it provides the data required to determine if the restoration goal has been achieved. The population estimate derived from the simultaneous helicopter survey should not be relied on if the mark-recapture or concurrent ground and aerial survey calculations are available.

The Angeles National Forest should consider implementing a prescribed burn to improve habitat in the San Gabriel Wilderness. The last fire of any significance occurred in 1986, when the Tecolote Fire burned 17% of bighorn sheep winter-spring range. Prior to that, the last fire of any significance was the Gale Fire in 1957 that burned 83% of the winter-spring range.

REFERENCES

Boyce, W. M. 2005. Mountain lion project report. http://www.vetmed.ucdavis.edu/whc/scp/2005mountain_lion_report.pdf

Bleich, V. C., H. E. Johnson, S. A. Holl, L. Konde, C. Davis, and T. R. Stephenson. 2005. Habitat selection by mountain sheep: implications of fire history in the San Gabriel Mountains. Unpublished draft manuscript. Bishop, CA

Buechner, H. 1960. The bighorn sheep in the United States, its past, present, and future. Wildlife Monographs no. 4. The Wildlife Society.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, NY.

Farley, J. 2006. Devil's Punchbowl County Park staff, personal communication with Steve Holl, March 28, 2006. Los Angeles County, CA

Festa-Bianchet, M. 1989. Survival of male bighorn sheep in southwestern Alberta. Journal of Wildlife Management 53(1):25-263.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. University of Chicago Press, Chicago, IL.

Hansen, C. G. 1980. Population dynamics. *in* G. Monson and L. Sumner, The desert bighorn, its life history, ecology, and management. University of Arizona Press, Tucson, AZ.

Hayes, C. L., E. S. Rubin, M. C. Jorgensen, R. A. Botta, and W. M. Boyce. 2000. Mountain lion predation of bighorn sheep in the Peninsular Ranges, California. Journal of Wildlife Management 64(4):954-959.

Holl, S. A. 2004. Implementation strategy to restore the San Gabriel Mountains bighorn sheep population. Unpublished report prepared for the Los Angeles

Fish and Game Commission, California Department of Fish and Game, and U.S.D.A., Forest Service. 46 pp.

Holl, S. A. and V. C. Bleich. 1983. San Gabriel Mountain Sheep: biological and management considerations. Unpublished report, San Bernardino National Forest, San Bernardino, CA.

Holl, S. A., V. C. Bleich, and S. G. Torres. 2004. Population dynamics of bighorn sheep in the San Gabriel Mountains, California, 1967-2002. Wildlife Society Bulletin 32(2):412-426.

Magnusson, W. E., G. J. Caughley, and G. C. Grigg. 1978. A double survey estimate of population size from incomplete counts. Journal of Wildlife Management 42:174-176.

Nicholson, M. C., R. Terry Bowyer, and J. G. Kie. 1997. Habitat selection and survival of mule deer: tradeoffs associated with migration. Journal of Mammalogy 78(2):483-504.

Perry, W. M., J. W. Dole, and S. A. Holl. 1987. Analysis of the diets of mountain sheep from the San Gabriel Mountains, California. California Fish and Game 73(3):156-162.

Pollock, K. H., S. R., Winterstein, C. M. Buck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry system. Journal of Wildlife Management 53(1):7-15.

Rominger, E. M., H. A. Whitlaw, D. L. Weybright, W. C. Dunn, and W. B. Ballard. 2004. The influence of mountain lion predation on bighorn sheep translocations. Journal of Wildlife Management 68(4):993-999.

Rubin, E. S., W. M Boyce, and E. P. Caswell. 2002. Modeling demographic processes in an endangered population of bighorn sheep. Journal of Wildlife Management 66(3):796-810.

Schaefer, R. J., S. G. Torres, and V. C. Bleich. 2000. Survivorship and cause-specific mortality in sympatric populations of mountain sheep and mule deer. California Fish and Game 86(2):127-135.

Taber, R. D. and R. F. Dasmann. 1958. The black-tailed deer of the chaparral. California Fish and Game, Game Bulletin 8. Sacramento, CA.

Woodgerd, W. 1964. Population dynamics of bighorn sheep on Wildhorse Island. Journal of Wildlife Management 28(2):381-391.