

Observations on the distribution and abundance of bighorn sheep in Baja California, Mexico

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The Baja California peninsula is an area of considerable interest for ecological investigations and conservation efforts. It supports a wide variety of marine and terrestrial fauna, including bighorn sheep (*Ovis canadensis* ssp.). Using the Bering land bridge, wild sheep from Asia entered North America more than 70,000 years ago (Brown 1989). In Mexico, they eventually reached as far south as La Paz on the Baja California peninsula and the western mountains of Sonora, near Guaymas (Leopold 1959).

The history of land and wildlife management activities, including bighorn sheep hunting, in Mexico was described previously by Lee (2000, 2009). Of particular note is that the horns of a ram taken in Baja California in 1946 were scored at 205-1/8 Boone and Crockett points — still, and by a considerable margin, the world's record for desert bighorn sheep (Reneau and Spring 2011).

In an attempt to better determine bighorn sheep distribution and opportunities for management, standardized helicopter surveys were initiated in Mexico in 1992. As a result of those surveys, bighorn sheep hunting was reopened in the states of Sonora and Baja California Sur (and more recently in Coahuila and Chihuahua; Lee and Segundo 2011), and other management activities, such as translocations, have been initiated. Despite the positive results from surveys in the state of Baja California (Figure 1) in 1992, 1995, and 1999, however, hunting opportunities for bighorn sheep have remained unavailable due to politics and antihunting sentiment.

Estimates of the number of bighorn sheep on the Baja California peninsula have varied considerably through the years. Villa (1959) estimated the bighorn sheep population

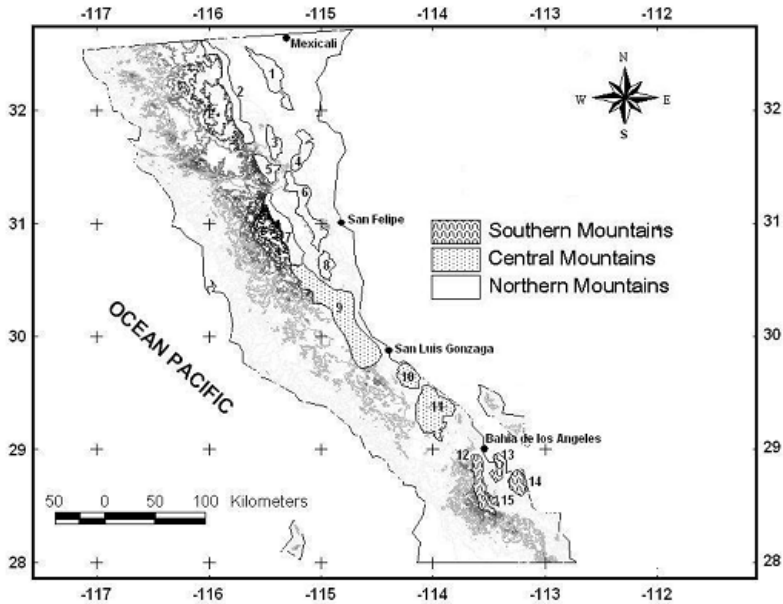


FIGURE 1.—The mountain ranges of Baja California, Mexico, by geographic areas referred to in the text. Northern mountains: 1 - Cucupa; 2 - Juarez; 3 - Las Tinajas; 4 - Las Pintas; 5, 6, 8 - San Felipe; 7 - San Pedro Martir. Central mountains: 9 - Santa Isabel; 10 - Calamajue; 11 - La Asamblea. Southern Mountains: 12 - La Libertad; 13 - Las Animas; 14 - Agua de Soda; 15 - Los Paredones. Degrees north latitude are shown on the Y-axis, and degrees west longitude are shown on the X-axis.

for the entire peninsula to be 2,000 animals. In 1974, a terrestrial survey was conducted in an effort to better determine the number of bighorn sheep on the peninsula. Alvarez (1976) reported on this survey, during which 327 animals were observed, and from which a population estimate of 4,560-7,800 animals was extrapolated. Both Villa (1959) and Alvarez (1976) stressed that these estimates were imprecise because bighorn sheep distribution and densities were not well known.

To better determine the status of bighorn sheep in the state of Baja California, a helicopter survey of northern Baja California was conducted in April 1992 during which biologists observed 603 individuals among 116 groups in 68 hours of flight time (DeForge et al. 1993; Table 1). As a result, a population of 780 to 1,170 adult bighorn sheep was estimated for the areas surveyed. DeForge et al. (1993) concluded that, "1) it was possible that previous population estimates for Baja California were too high, and/or that this survey underestimated the current population, 2) the major differences between spring and fall surveys was that 45% fewer lambs were seen during fall surveys, 3) it was necessary for a stable population to be shown to cause the withdrawal of the proposal to list the peninsular ranges' populations as endangered, 4) observation rates of 40-60% were appropriate for this survey, and 5) there was considerable competition and potential for disease exposure from cattle, goats, and burros, all of which were observed in bighorn sheep habitat during the survey."

TABLE 1.—Total numbers of animals classified and percentages of adult males, adult females, young, and yearling bighorn sheep recorded during aerial surveys, Baja California, Mexico, 1992–2010. The ratio of each age or sex category per 100 adult females is shown parenthetically following the percent composition within columns.

Classification	1992 (<i>N</i> = 603)	1995 (<i>N</i> =279)	1999 (<i>N</i> =282)	2010 (<i>N</i> =381)
Adult Males	16.1 (32)	27.2 (57)	28.7 (61)	22.6 (51)
Adult Females	50.2 (100)	48.0 (100)	46.8 (100)	44.6 (100)
Young	22.4 (45)	20.4 (43)	11.3 (24)	23.9 (54)
Yearlings	11.3 (23)	4.3 (9)	12.8 (27)	8.9 (20)

In 1993, the Mexican Foundation for the Conservation of Wild Sheep (MFCWS) worked to establish a conservation program for bighorn sheep throughout their range in the states of Baja California and Baja California Sur. MFCWS enlisted the aid of the Foundation for North American Wild Sheep, and a standardized helicopter survey (i.e., flying the same type of helicopter with the doors removed, at the same speed, with the same number of observers, pilot, and survey leader, at the same time of day, and during the same season) of bighorn sheep ranges in Baja California was conducted during September 1995 (Lee and Mellink 1996). During this survey most mountainous areas in the state of Baja California were sampled to some degree; obviously given the limited number of hours expended, some areas were flown only cursorily—primarily to document the presence of bighorn sheep rather than to provide an index to population size. Areas surveyed included Sierra San Pedro Martir, Sierra Santa Isabel, Sierra San Felipe, Sierra Juarez, and Sierra Las Tinajas (Figure 1). During this survey, 279 individuals were observed among 97 groups during 32.1 hr of flight time (Table 1).

In October 1999, various areas in the state of Baja California again were surveyed for the abundance of bighorn sheep and to help identify management units for local conservation programs. This survey, conducted under the auspices of the National Institute of Ecology, was also intended to meet some of the requirements of the National Program for the Management, Conservation, and Sustainable Use of Bighorn Sheep (Secretary of the Environment, Natural Resources, and Fisheries [SEMARNAP] 2000). The 1999 survey was implemented primarily to revisit areas surveyed during 1992 and 1995, and 282 individuals were observed among 62 groups of bighorn sheep during 21.2 hours of survey time (Table 1).

During 5–13 December 2010, we conducted another aerial survey to provide a comparison with the results from 1992, 1995, and 1999 in order to evaluate changes in distribution, demographics, and relative abundance of bighorn sheep in the northern portion of the state of Baja California. We also attempted to obtain better information regarding the distribution and relative abundance of bighorn sheep throughout the peninsula, because logistical difficulties previously had limited the efficacy of helicopter surveys of the southernmost mountain ranges in the state of Baja California.

Standardized surveys (Lee and Lopez-Saavedra 1993 and 1994, Lee and Mellink 1996) were flown at about 100 km/hr, contouring the more rugged, mountainous areas. We

recorded the classification of animals comprising each group (Geist 1968; Appendix I), survey hours flown, and weather conditions to ensure consistency and to facilitate comparisons with other helicopter survey efforts in Mexico (Lee and Lopez-Saavedra 1993 and 1994, Lee and Mellink 1996). We detected 381 individuals among 91 groups of bighorn sheep during 30.5 hours of survey time (Table 1).

Surveys that depend upon direct observations tend to underestimate the total number of animals in an area. Indeed, only 40-60% of the target population is seen during a typical desert bighorn sheep helicopter survey (Miller et al. 1989, DeForge et al. 1993, Hervert et al. 1998, Wehausen and Bleich 2007). We did not survey all of the potential bighorn sheep habitat within each mountain range. For example, in the Sierra Juarez and the Sierra San Pedro Martir, we surveyed only those canyons on the eastern side of the mountain ranges, a result of a change in vegetation type on the western slopes. Evaluating the number of animals per unit of survey effort provides a meaningful method of evaluating bighorn sheep densities. To enhance the value of repetitive surveys in the same areas, catch per unit effort (CPUE) was calculated from previous reports. CPUE provides the number of animals observed per hour of standardized survey effort. Since terrain inhabited by bighorn sheep typically is so rugged that it does not lend itself to transects or complete coverage, CPUE provides an index to relative abundance, and is a useful way to compare population trends.

A review of the results of the 1992, 1995, 1999, and 2010 surveys revealed no indication that the bighorn sheep population in the state of Baja California has decreased since 1992. On the contrary, there is evidence that in some areas the bighorn sheep population has increased since then: observation rates showed an increase from 1992 (8.9 bighorn sheep/hour) to 2010 (12.5 bighorn sheep/hour).

Further consideration of the demographics of bighorn sheep provides additional useful information. The proportion of males, females, young, and yearlings are largely similar among the four years for which data are available (Table 1). The difference in the ratio of males to females during the 1992 survey, when compared to those from other years, is because that survey occurred in the Spring (April) while the others occurred during Fall (late September through early December). As a result of sexual differences in animal behavior, males are less frequently associated with females during Spring (Remington and Welsh 1989) and survey data are apt to be affected (Rubin and Bleich 2005) because males and females utilize different habitats at that time of the year (Bleich et al. 1997).

In Arizona, which has a long history of annual helicopter surveys, the long-term survey average for bighorn sheep populations is 58 males: 100 females: 23 young: 17 yearlings. It is generally agreed that a ratio of ≥ 25 young: 100 females will result in increasing populations (Remington 1989). During previous surveys, bighorn sheep in the state of Baja California have exhibited recruitment rates much greater than those necessary for population maintenance (Table 1).

Bighorn sheep move relatively freely among mountain ranges (Witham and Smith 1979, Cochran and Smith 1983, Ough and deVos 1984, Scott et al. 1990), behavior which facilitates metapopulation function (Schwartz et al. 1986; Bleich et al. 1990, 1996; Epps et al. 2007). During 2010, the distance from the most northern observation to the southernmost observation was 460 km, and only two paved roads occurred within that span: there are no freeways, canals, or urban areas to disrupt movements. Thus, a bighorn sheep could travel between the northern and southern borders of the state of Baja California and almost never encounter an anthropogenic feature.

Despite the near absence of anthropogenic features that could disrupt opportunities for movement, the state of Baja California is a large area with substantial variation in local climates, which has resulted in considerable differences in the flora and fauna among the mountain ranges. As a result, we suggest it is reasonable to separate the bighorn sheep in the state of Baja California into three metapopulations (see Martinez-Gallardo and Eaton-Gonzalez 2008, Levins 1969) as follows: (1) a northern metapopulation extending from the northern border southward to and including Sierra San Felipe; (2) a central metapopulation extending southward from Sierra Santa Isabel to and including Sierra La Asamblea; and, (3) a southern metapopulation extending southward from Sierra La Libertad to the southern border of the state.

The probable northern metapopulation occupies the widest point (~170 km) of the Baja California peninsula. Sierra Juarez reaches an elevation of 1,980 m, with a line of peaks reaching >1,900 m in elevation. Sierra San Pedro Martir is even higher, reaching 3,096 m with lesser peaks exceeding 2,600 m. These mountains are very steep on their eastern side, rising from an elevation of 600 m to 2,500 m in 6 km, and from 600 m to 3,000 m in 8 km, respectively. These mountains create a considerable rain shadow, which determines the vegetation available to wildlife. While the tops of these ranges support areas of Sierran Montane Conifer Forest, to the east the primary biotic community is the Lower Colorado River Subdivision of Sonoran Desertscrub (Brown and Lowe 1980). Bighorn sheep, which prefer an open terrain (Cunnigham 1989), occupy primarily the eastern side of these ranges. The habitat occupied by the northern metapopulation is impacted to some degree by humans and their activities (such as recreation and mining), the towns of Mexicali and San Felipe, and Highways 2D, 3, and 5.

The probable central metapopulation occurs at the narrowest point (~97 km) of the peninsula, and the central mountain range in this area is much lower. While there are spots in Sierra La Asamblea that reach 1,660 m and there is an isolated peak at 1,349 m, most of the peaks reach elevations below 1,200 m. This area is essentially all Lower Colorado River Subdivision of Sonoran Desertscrub, with very small areas of Californian Chaparral. This area is less populated and used by humans than the area occupied by the northern metapopulation. Southward from Puertocitos the roads are mostly unpaved until reaching the road between Highway 1 and Bahia de los Angeles. There are only very small communities in the vicinity of Bahia San Luis Gonzaga, and anthropomorphic features in the area occupied by the central metapopulation are few.

The probable southern metapopulation occurs in an area where the peninsula widens to ~140 km, with mountains rising to 1,810 m and substantial changes in vegetation occur. The Lower Colorado River Subdivision gives way to the Central Gulf Coast Subdivision of Sonoran Desertscrub and Californian Chaparral. From the road to Bahia de los Angeles to the southern border of the state of Baja California there is little human development with the exception of several communities near Bahia de los Angeles.

Considering each of these metapopulations separately allowed us to make some comparisons between surveys and elucidate the trajectory of the bighorn sheep population in the state of Baja California. In the northern metapopulation there has been a decline in number of observations in Sierra San Felipe and Sierra San Pedro Martir, but there has also been an increase in the number of observations in Sierra Cucapa and in Sierra Juarez (Table 2). The fact that there was little actual change in the number of animals observed per hour (range = 8.2-10.3; Table 2) is consistent with the possibility that bighorn sheep move among these mountain ranges, and that the total population in this area has changed

little since 1992. Moreover, bighorn sheep inhabiting the Sierra Juarez may be part of the metapopulation inhabiting the southern end of the peninsular ranges north of the international border.

TABLE 2.—Mountain ranges, hours flown, number of bighorn sheep observed, and observation rates of bighorn sheep in the northern metapopulation of bighorn sheep, Baja California, Mexico, 1992-2010.

Mountain Range	1992 Hrs	1992 # obs	1995 Hrs	1995 # obs	1999 Hrs	1999 # obs	2010 Hrs	2010 # obs
Cucapa	2.0	2	0.5	0	---		1.5	19
Las Pintas	4.5	25	2.0	27	1.2	1	2.3	22
Las Tinajas	5.5	67	2.1	23	2.0	25	2.0	53
San Felipe	17.7	282	6.7	85	5.0	25	5.4	50
Juarez	10.0	4	2.8	2	---		1.7	16
San Pedro Martir	13.7	83	5.1	14	3.7	72	4.7	16
Totals	56.4	463	19.2	151	11.9	123	17.6	176
#Obs/Hour	8.2		7.9		10.3 ^a		10.0	

^a The higher number of animals observed per hour during the 1999 survey is directly related to having not surveyed Sierras Cucapa and Juarez - areas that at that time supported very few bighorn sheep.

The central metapopulation occupies an area between Sierra Santa Isabel and Sierra La Asamblea (Figure 1). Although the area consists of many square kilometers of apparently suitable bighorn sheep habitat, consistently low observation rates in the Sierra La Asamblea (2.2, 8.0, and 1.6 sheep/survey hour in 1995, 1999, and 2010, respectively) suggest that range supports few bighorn sheep. Moreover, habitat quality, seasonal movements, or a loss of bighorn sheep due to disease could have played a role in the substantial reduction in the number of animals observed in Sierra Santa Isabel, where observation rates declined from a high of 20.1 sheep/survey hour in 1995 to only 5.1 in 2010.

TABLE 3.—Mountain ranges, hours flown, number of bighorn sheep observed, and observation rates of bighorn sheep in the southern metapopulation of bighorn sheep, Baja California, Mexico, December 2010.

Mountain Range	Survey Hours	# Observed	Obs/Hour
Agua de Soda	1.5	43	28.7
Las Animas	1.2	58	48.3
Las Paredones	1.3	47	36.2
La Libertad	1.1	30	27.3

The southern metapopulation supported the highest relative densities and numbers of bighorn sheep in Baja California (Table 3). When compared to areas occupied by the other metapopulations, this area consists largely of Central Gulf Coast Subdivision of Sonoran Desertscrub — the same formation as the productive bighorn sheep areas of Sonora (including Tiburon Island) — and, when compared to areas occupied by the other metapopulations, contains the fewest people and anthropogenic features, as well the least amount of grazing by domestic livestock.

The 1992 survey, which yielded classifications of 400 adult bighorn sheep, produced a population “estimate” of 780-1,170 adult animals in the limited area surveyed (DeForge et al. 1993). To derive population estimates, it is necessary to know the sighting rates (% of animals observed during the survey), the percentage of suitable habitat that was surveyed, and the total suitable habitat available. Using these data from the 2010 survey, we concluded that the present population of bighorn sheep in the state of Baja California is approximately 2,500 adult animals, a number essentially the same as that reported by DeForge et al. (1993) when their results are extrapolated to include habitat that was not surveyed by those investigators. The similarity between these values suggests that the bighorn sheep population in Baja California has changed little over the past two decades.

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Appendix I: Data from the aerial survey conducted in Baja California, Mexico, December 2010

The survey results for each mountain range, listed in order of flight, are shown. The sum of the classifications for each category of animal are listed in the following order: number of males (class 1, class 2, class 3, class 4), females, young, yearling females, and yearling males.

Range	Survey Hours	# Observed	Classifications
Cucapa	1.5	19	1-1-4-2-7-2-1-1
Pintas	2.3	22	1-1-0-0-11-6-1-2
Las Tinajas	2.0	53	0-2-2-2-26-16-4-1
San Felipe	5.4	50	1-4-9-8-17-9-2-0
Santa Isabel	3.9	20	0-2-0-0-11-6-1-0
Calamajue	2.0	0	
La Asamblea	2.4	7	0-0-0-1-3-2-1-0
Agua de Soda	1.5	43	0-1-4-2-19-11-4-2
Las Animas	1.2	58	2-2-2-3-29-15-3-2
Las Paredones	1.3	47	2-2-4-1-21-13-2-2
La Libertad	1.1	30	1-2-2-6-12-4-2-1
San Pedro Martir	4.7	16	0-0-1-2-8-3-1-1
Juarez	1.9	16	1-1-2-2-6-4-0-0
Totals	30.5	381	9-18-30-29-170-91-22-12