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RESPONSES OF MOUNTAIN SHEEP TO HELICOPTER SURVEYS[1]

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Effects of helicopter surveys on distribution and movements of desert-dwelling mountain sheep, *Ovis canadensis*, were studied in San Bernardino County, California during April and June 1988. Adult males and females with radio collars moved about 2.5 times farther the day following a helicopter survey than on the previous day. Further, 35-52% of these animals changed polygons (8-83 km^2) following sampling from a helicopter, whereas only 11% did so on the day prior to the survey. Likewise, some animals left the study area following surveys. Sampling intensity (0.8 min/km^2 vs. 2.0 min/km^2) had little effect on movement of mountain sheep. Similarly, terrain type (steep vs. rolling) did not influence movement of female mountain sheep following helicopter surveys. Movement by mountain sheep during a helicopter survey may violate fundamental assumptions of several population estimators.

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INTRODUCTION

Helicopters are used for numerous wildlife management and research purposes (Thompson and Baker 1981, Bleich 1983*a*), and the potential for aircraft to alter wildlife behavior has been known for many years (Petrides 1953, Grzimek and Grzimek 1960, Siniff and Skoog 1964, and others). Geist (1971) and Klein (1972, 1973) cautioned that wildlife may respond negatively to aircraft, but only recently have studies of such responses been undertaken (Calef et al. 1976, MacArthur et al. 1979, Miller and Gunn 1979, 1980, Davis et al. 1983, Gunn et al. 1983, Krausman and Hervert 1983, Valkenburg and Davis 1983, Krausman et al. 1986, Miller et al. 1988). To date, only Calef et al. (1976), Miller and Gunn (1979, 1980), Gunn et al. (1983), and Miller et al. (1988) have detailed the effects of helicopters on wildlife.

Krausman and Hervert (1983) reported that 41% of 32 mountain sheep, *Ovis canadensis*, were disturbed by fixed-wing aircraft and >19% changed habitats as a result of that disturbance. Thus, we tested whether low-flying helicopters also would disturb mountain sheep. We hypothesized that individual mountain sheep: (i) would move further the 'day' immediately following the helicopter survey than the 'day' immediately preceding such sampling; (ii) would change sampling polygons following a helicopter survey; (iii) should respond differently to helicopter surveys, depending upon the type of terrain in which they were located (V. Geist, Unpubl. Rep. to the Berger Commission, Univ. Calgary 1975); and (iv) would exhibit a greater response to high than low intensity sampling.

METHODS

This research was conducted at Old Dad Peak and the Kelso Mountains, San Bernardino County, California (Lat. 115 degrees, 50 min W, Long. 35 degrees, 06 min N). The study area is located in the Mohave Desert; two vegetative types, the creosote bush, *Larrea tridentata*, and Joshua tree, *Yucca brevifolia*, series predominate (Paysen et al. 1980). Geologically, the western one-fourth of the 225 km^2 study area consists of a series of limestone massifs that are extremely steep with slopes normally >100% (hereafter referred to as steep). To the east the area is dominated by a series of rolling hills of primarily granitic origin with slopes generally <100% (hereafter referred to as rolling). The study area was divided into nine polygons inhabited by sheep, ranging in size from 8 - 83 km^2 ($\bar{x} = 25.8$ km^2, SD = 22.5 km^2). Polygons were delimited by roads and natural breaks in topography. At least 200 mountain sheep occurred in the study area (Bleich 1983*b*).

Thirty mountain sheep (15 male, 15 female) were captured using drive-nets (Beasom et al. 1980) or a net-gun fired from a helicopter (Krausman et al. 1985) and were fitted with radio-telemetry collars (Telonics, Mesa, AZ). These animals were located weekly from a fixed-winged aircraft (Cessna 185) in the manner described by Krausman et al. (1984). Responses of mountain sheep to the presence of a low-flying helicopter were evaluated on two occasions (April and June 1988). Mountain sheep with radio collars were located from the airplane the morning prior to the day of the helicopter survey (T1), the morning of (but before) the helicopter survey (T2), and the morning immediately following the morning helicopter survey (T4). In April, animals also were relocated in the afternoon (T3) immediately following the morning helicopter survey. These telemetry locations (error $\leq$ 4 ha; Krausman et al. 1984) were plotted on 15 min USGS topographic maps; error was small relative to the size of polygons.

Demographic surveys were conducted by three experienced observers and an experienced pilot using a Bell 206B-III turbine-powered helicopter. Such surveys began immediately after the fixed-wing aircraft exited the study area (0730 PST), and the crew had no knowledge of the locations of radio-collared animals. We varied survey intensity between April (0.81 min/km^2) and June (2.03 min/km^2). We flew low-level contours similar to normal surveys of mountain sheep in this area. Because of high topographic diversity, both vertical and lateral distances from the ground varied considerably (50-200 m) but were similar for April and June. Observers recorded mountain sheep locations on 15 min USGS topographic maps, as well as sex and age class of sheep, and topography of terrain.

Effects of helicopter surveys on mountain sheep were analyzed by comparing straight-line distances between locations of radio-collared animals before and after the survey (Wilcoxon Matched-Pairs Signed-Ranks Test, Siegel 1956). These relocations served as an index to distances moved by mountain sheep. Changes in distribution among polygons before and after the survey and under low and high survey intensity were compared with the *Z*-test for proportions (Zar 1984). Relationship between the size of polygon and proportion of sheep leaving a polygon was tested with a Spearman rank correlation (Siegel 1956). Differences in distances moved by females before and after helicopter sampling, as a function of terrain type, were tested using the Mann-Whitney *U*- test (Siegel 1956).

RESULTS

Distances between relocations of male mountain sheep during the 24-hour period prior to the helicopter survey (T1-T2) were less than distances moved

Table 1. Movements of adult male and female mountain sheep before and after helicopter surveys, San Bernardino Co., California, 1988.

	Distances moved (km)[a]							
	Before				After			
	n	$\bar{x}$	SD	Range	*n*	$\bar{x}$	SD	Range
Males								
April	12	1.7	0.8	0.9-3.8	12	6.4	2.9	2.2-12.0
June	13	1.1	0.8	0.2-2.4	13	3.3	2.0	1.0-8.1
Females								
April	14	1.4	1.4	0.3-5.5	14	2.3	1.8	0.3-7.1
June	14	1.6	1.0	0.3-3.6	14	2.9	2.2	0.5-9.9

[a] Sampling intensity varied between April and June; see text for explanation.

Table 2. Percent of mountain sheep that moved among sampling polygons before and after helicopter surveys, San Bernardino Co., California, 1988[a].

Sampling interval		April		June	
		n	% moved	*n*	% moved
Before	(T1-T2)	26	11.5	27	11.1
After					
Same Day	(T2-T3)	26	34.6	-	-
Next Day	(T2-T4)	26	38.5	27	51.9

[a]Sampling intensity varied between April and June; see text for explanation.

between the morning of the helicopter survey and the following morning (T2-T4) for both April ($T=1$, $P<0.01$) and June ($T=3$, $P<0.01$) (Table 1). Differences in distances moved also occurred for females during June ($T=5$, $P<0.01$), but not April ($T=32$, $P<0.10$), although that difference was marginally nonsignificant.

Proportion of animals that moved to a different sampling polygon after the helicopter survey (T2-T4) was greater than the number that changed polygons during the preceding 24-hour period (T1-T2) for both April ($Z=2.37$, $P<0.02$) and June ($Z=3.59$, $P<0.001$) (Table 2). During the afternoon in April (T2-T3) the proportion of animals moving among polygons also differed from the morning sample (T1-T2) ($Z=2.06$, $P<0.05$; Table 2). Proportions of males (5 of 12) and females (5 of 14) changing polygons did not differ in April ($Z=0.313$, $P>0.70$) or June (7 of 13 males, 7 of 14 females; $Z=0.305$, $P>0.70$).

No correlation existed between the size of a polygon and proportion of telemetered mountain sheep moving from it following helicopter surveys (T2-T4) (April and June combined; $r_s=0.16$, 11 df, $P>0.50$). During April, 9 of 26 telemetered animals changed sampling polygons within 6 hours of the beginning of the helicopter survey (T2-T3), and 10 of 26 changed polygons overnight (T2-T4). During June, 14 of 27 animals changed sampling polygons the day following the helicopter survey (T2-T4). Four (all males) of 26 sheep completely left the study area in April, whereas none of 27 animals did so during June.

Survey intensity was 2.5 times greater in June than in April, and a larger proportion of mountain sheep moved to a different sampling polygon in June (Table 2). This difference, however, was not significant ($Z=0.989$, $P>0.30$). Likewise, a Mann-Whitney *U*-test showed no significant differences between distances moved by female sheep inhabiting steep or rolling terrain (Table 3) in either April ($Z=0.495$, $P>0.60$) or June ($Z=0.452$, $P>0.65$).

DISCUSSION

Caughley (1974) and Caughley et al. (1976) reviewed potential biases of estimates obtained from aerial sampling of large mammals; accuracy declined with increasing width of transect, cruising speed, and altitude. Further, several researchers recognized the potential for aircraft to alter the behavior of animals

Table 3. Change in distance moved (distance moved after helicopter survey minus distance moved before survey) by type of terrain by female mountain sheep, San Bernardino County, California, 1988.

Change in distance moved (km)[a]

	April				June			
Terrain	*n*	$\bar{x}$	SD	Range	*n*	$\bar{x}$	SD	Range
Steep	10	1.1	2.1	-1.7 - 5.3	6	1.9	3.5	-0.9 - 9.4
Rolling	4	0.3	3.1	-4.2 - 4.3	8	0.9	0.5	0 - 1.8

[a]A negative value under range results from an animal having moved a lesser distance after than before the helicopter survey. Sampling intensity varied between April and June; see text for explanation.

and thereby influence survey results (Petrides 1953, Gilbert and Grieb 1957, Grzimek and Grzimek 1960, Bergerud 1963, Siniff and Skoog 1964, and others). Only recently, however, have investigators begun to evaluate this potential bias, and much of this effort has focused on the effects of fixed-wing aircraft on telemetered animals (Krausman and Hervert 1983, Krausman et al. 1986).

With the exceptions of Gunn et al. (1983) and Beasom et al. (1986), effects of helicopters on the distribution or sightability of wildlife has not been evaluated. Beasom et al. (1986) determined that intensive helicopter sampling resulted in multiple sightings of individual white-tailed deer, *Odocoileus virginianus*, but concluded only that duplication may serve to render total counts less conservative. Gunn et al. (1983) observed that helicopter overflights, followed by landings up to 2 km from post-calving aggregations of caribou, *Rangifer tarandus*, elicited behavioral responses leading to displacements of at least 1-3 km. We documented that helicopter censusing had a substantial effect on movements of mountain sheep.

Mountain sheep altered both distribution and movements in response to helicopter surveys (Tables 1 and 2). Although some data (T4) were obtained 12-14 hours after the completion of the helicopter surveys, we believe that long-distance movements, as well as changes in distribution by sheep with respect to sampling polygons, began at the onset of the helicopter surveys. Many mountain sheep took flight at the approach of the helicopter. Daily point relocations are not the best measure of total distance moved (Bowyer 1981, Laundré et al. 1987), but we suggest such measures provide a reliable index to distance moved. Indeed, Bowyer (1981) reported that point relocations were a conservative measure of daily movements.

Although mountain sheep were disturbed by helicopters, no differences occurred in distances moved by females in steep or rolling terrain (Table 3). These data do not support speculation by Geist (unpubl. rep. to the Berger Commission, Univ. Calgary, 1975) that mountain sheep in escape terrain should respond less strongly to disturbances by aircraft than those in less precipitous terrain, but our sample size is small. Ostensibly, sheep in precipitous terrain reacted as strongly to the helicopter as those in less rugged areas because of the extreme noise associated with the helicopter (Klein 1972, Kufeld et al. 1980).

No significant difference occurred in distribution of mountain sheep as a result of survey intensity. Even the low survey intensity during April was sufficient to cause major changes in mountain sheep distribution. Again, we postulate that noise associated with helicopter censusing caused considerable disturbance.

The double-sampling technique of Magnusson et al. (1978) has been used to census mountain sheep in California (Holl and Bleich 1983) and Arizona (J. de Vos, pers. comm., Arizona Game and Fish Dept.), even though this procedure requires that the location of sample animals be fixed (Pollock and Kendall 1987). This double-sampling procedure is an extension of the Lincoln-Peterson estimator (Magnusson et al. 1978) and must comply with a number of assumptions to yield reliable information (Rice and Harder 1977:203).

Helicopter surveys of mountain sheep in this study would have resulted in violations of several fundamental assumptions required by most mark-recapture estimators: i) mountain sheep movements resulted in the population not being closed (4 sheep left the study area following the April survey); ii) the probability of "recapturing" an animal was not constant (sheep moved considerable distances, and 35-53% of them changed sampling polygons following the helicopter survey; this only would be important where locations of unmarked animals during the first survey were used to identify them during the second survey — a practice used in both California and Arizona); and (iii) surveys were not independent. Violations of assumptions i and ii would affect the accuracy of the estimate, whereas violation of assumption iii would affect its precision (Rice and Harder 1977).

The potential for overestimating population size in other types of surveys exists (i.e., from double counting animals that changed sampling polygons; Grzimek and Grzimek 1960, Siniff and Skoog 1964, Beasom et al. 1986). This might be mitigated by animals leaving the study area, or by using an estimator that allowed for sampling with replacement (Rice and Harder 1977).

Helicopters have many advantages over fixed-wing aircraft for sampling large animals (Samuel et al. 1987). Further, in some instances helicopters may disturb wildlife less than airplanes (Calef et al. 1976). Additionally, animals moving because of the noise generated by helicopters (Kufeld et al. 1980) might be easier to see than standing or bedding ones (Gasaway et al. 1985, Samuel et al. 1987). Nevertheless, mountain sheep reacted severely to our helicopter surveys, and these reactions may introduce biases into results obtained from similar sampling procedures. We have termed these reactions the "Bo-Peep" effect, because investigators cannot know the precise locations of previously observed animals as the survey progresses. Thus, we caution that the use of helicopters to estimate population size of mountain sheep using the double sampling technique (Magnusson et al. 1978) may be problematical, especially when the first survey is conducted with a helicopter.

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