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Conflicts in National Parks: A Case Study of Helicopters and Bighorn Sheep Time Budgets at the Grand Canyon

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ABSTRACT

Wildlife in numerous national parks of the United States experience frequent overflights by aircraft. Such activities may disturb wildlife populations. We analysed time budgets for desert bighorn sheep Ovis canadensis nelsoni *in the presence and absence of helicopter overflights at Grand Canyon National Park (GCNP) to determine the extent to which food intake may be impaired. Bighorn were sensitive to disturbance during winter (43% reduction in foraging efficiency) but not during spring (no significant effect). This seasonal difference may have arisen because the sheep were farther from helicopters during the spring after they had migrated to lower elevations. Further analyses indicated a disturbance distance threshold of 250–450 m. The conservation implications of these results are discussed.*

INTRODUCTION

As habitats become fragmented, the importance of national parks as refugia for wildlife increases. In many US national parks the popularity of

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sightseeing via private and commercial aircraft has increased with the demand for outdoor recreation. Because aircraft have varying impacts on large ungulates (MacArthur *et al.*, 1979, 1982; Krausman & Hervert, 1983; Miller & Smith, 1985; Krausman *et al.*, 1986), the goals of sightseeing via aircraft and the maintenance of undisturbed wildlife populations may be incompatible.

Bighorn sheep at Grand Canyon National Park (GCNP) experience heavy helicopter traffic, with estimates ranging from 15 000 to 42 000 flights per year (R. Ernenwein, pers. comm., 1987; ADOT, 1991, respectively). Helicopter traffic is expected to double by 1995 and triple by 2010 (ADOT, 1991). Although few data exist regarding its influence on wildlife populations at GCNP, such data are needed to allow mitigation of potential negative impacts.

The behavior of wildlife has been used to assess the influence of human activities (Hicks & Elder, 1979; Berger *et al.*, 1983; King & Workman, 1986). Because large ungulates devote much time to feeding, foraging behavior and time budgets may be important parameters to evaluate disturbances. Bighorn sheep spend up to 7 h a day feeding (Stockwell, 1989), and may require 1 h of rumination for every hour of active feeding (Belovsky & Slade, 1986). The amount of time allocated to foraging is influenced by a variety of environmental and social variables including forage quality and density, and group size (Berger *et al.*, 1983). The coefficient of foraging efficiency measures the relationship between feeding and scanning, and has been applied to a wide variety of topics including the costs and benefits of sociality (Berger, 1978; Knight & Knight, 1986; Stacey, 1986), habitat utilization (Risenhoover & Bailey, 1985; Warrick & Krausman, 1987) and human disturbance (Berger *et al.*, 1983; King & Workman, 1986). Long-term disturbances may lead to acute or chronic reduction in foraging efficiency (Berger *et al.*, 1983; King & Workman, 1986). In this paper we examine the extent to which helicopter overflights affect the time budgets of bighorn sheep and determine the threshold of distance sufficient to cause disturbance.

STUDY AREA AND METHODS

We observed bighorn sheep between November 1985 and July 1986 in the central region of GCNP in Hermit, Horn, Monument and Salt Canyons. Observations were limited to sheep occurring in the upper strata of the Grand Canyon—Supai, Hermit Shale and Toroweap strata (Fig. 1). Thirty-five sheep were counted during a survey from the rim in the vicinity of the study site in September 1987 (Stockwell, 1989). This group represents a small portion of the total population at Grand Canyon. The distribution of

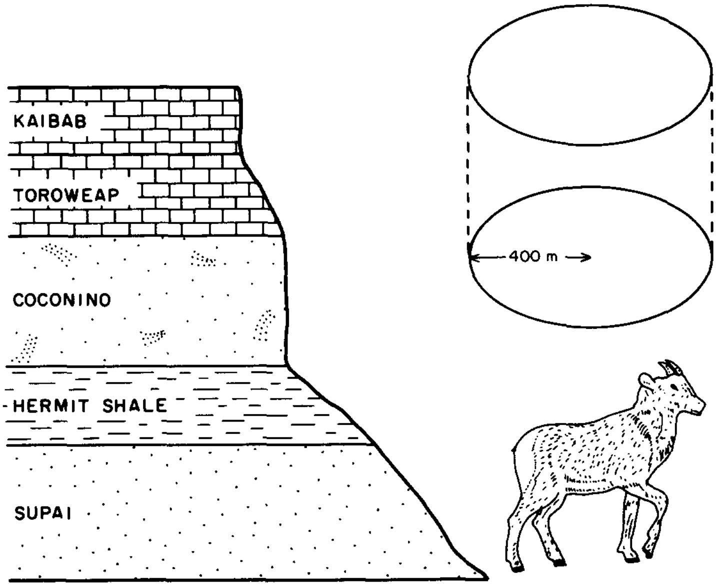


Fig. 1. A schematic cross-section of the strata of Grand Canyon in which animals were observed. Bighorn occupied the Supai, Hermit Shale and Toroweap strata, and occasionally were observed on the rim. During the spring bighorn migrated to lower elevations and did not use the Toroweap stratum. The cylinder represents the relationship between helicopter overflights and their relative proximity to bighorn occupying various strata of the canyon. Helicopters were considered to be overhead if they were flying at rim level or lower and were within 400 m horizontal distance.

bighorn throughout GCNP appears to be patchy and the population size is not known (Stockwell, 1989).

Data collection

Individual animals were located by scanning side canyons with spotting scopes (20–45 ×) from the rim of the Grand Canyon. Upon locating bighorn sheep, data were collected via scan sampling and focal animal sampling (Altmann, 1974). During each 15-min scan sample, data were collected on date, location, group size, group composition and activity patterns of all band members. Observations generally lasted 2 to 3 h.

Animals were classified according to Geist (1971), but class one males and male yearlings were grouped together. Lambs less than six months old were not included for analyses of group size, activity pattern or foraging efficiency data.

Sheep were categorized as either resting (lying down) or active. The total hours of daily activity were determined following the methodology outlined by Hansen (1984) and analysed by season.

Focal animal sampling (Altmann, 1974) was used to record data only on active animals for 300-s periods, using a micro-recorder and later transcribed onto data forms. Foraging bouts were analysed for animals that were in view and active for more than 180 s (≥60% of the bout). Animals were considered active if they engaged in any of the following three activities—foraging (*F*): animal's head down in a foraging or searching position, or animal foraging with neck extended into a tall bush; head up (*HU*): animal's head was up (vigilance and scanning were included here); walking (*W*): movement between two different activity patterns. If walking occurred between two foraging bouts, it was included with *F* unless the animal was vigilant while walking, or if more than five consecutive seconds were allocated to walking.

A foraging efficiency index (FE) was calculated by dividing *F* by the sum of *F* and *HU*, and multiplying by 100 (Berger *et al.*, 1983). Foraging efficiency is an index of time allocated to feeding or searching for food relative to time spent scanning; it is not intended to convey information about assimilation efficiency.

Sheep in a group were observed systematically to avoid potential observer bias. Foraging bouts were recorded for females first, rams second and juveniles last. Furthermore, selection procedure was standardized by beginning at the right side of the band and proceeding toward the left. To decrease pseudoreplication, only one foraging bout was recorded for each animal on a given day.

Data were collected when helicopters were flying overhead and when helicopters were absent. Observations during which helicopters were audible but not overhead were omitted.

Helicopters were visually determined to be overhead if they were flying at the canyon's rim level or lower and were within a horizontal distance of 400 m (Fig. 1). The flight generally originated (or terminated) at rim level and gradually descended below (or ascended to) the rim. Most helicopters flew at altitudes which corresponded with levels between the rim and the top of the Coconino stratum as they flew over the band (Fig. 1). Thus, for bighorn occupying the Toroweap, Hermit Shale and Supai strata, helicopters were generally 50–200 m, 100–450 m and 250–700 m distant, respectively. These values overlap because of the variable altitude flown. Although crude, this measure provides the best possible estimate of helicopter proximity, because monitoring the behavior of the bighorn and the simultaneous path of the helicopter was not possible.

Analyses

We partitioned data into two seasons, winter (October–February) and spring–summer (March–July), which corresponded to bighorn sheep migrations. Bighorn used upper portions of the canyon during winter, but they migrated to lower strata at the commencement of lambing in March, and the upper Toroweap stratum was virtually unused until August (Stockwell, 1989). The migration also appeared to be related to the lack of free water in the Toroweap stratum (Stockwell, 1989).

Foraging efficiency data were transformed by arcsin transformation and then analysed by two-way ANOVA to examine possible seasonal and other interactive effects. Except where noted, one-tailed *t*-test was used in all pairwise comparisons.

Helicopter presence may be correlated with weather (e.g. helicopters usually flew during calm conditions), yet precipitation had no interactive effect with helicopter overflights on foraging efficiency ($F < 0{\cdot}01$, $n = 307$, $p = 0{\cdot}970$). Therefore data obtained under various weather conditions were included in the analyses.

Although foraging bouts in the absence of helicopters were recorded during all diurnal hours, in the presence of helicopters they were recorded only between 0700 and 1100 h, and 1300 and 1700 h. Therefore we compared foraging bouts in the presence or absence of helicopters during these time periods only.

When the foraging efficiencies of treatment and control groups were significantly different, the reduction in foraging efficiency was determined by using the control group as a standard. For instance, if the mean foraging efficiencies of treatment and control animals were 60% and 80%, respectively, treatment animals were considered to be 25% less efficient than the control animals.

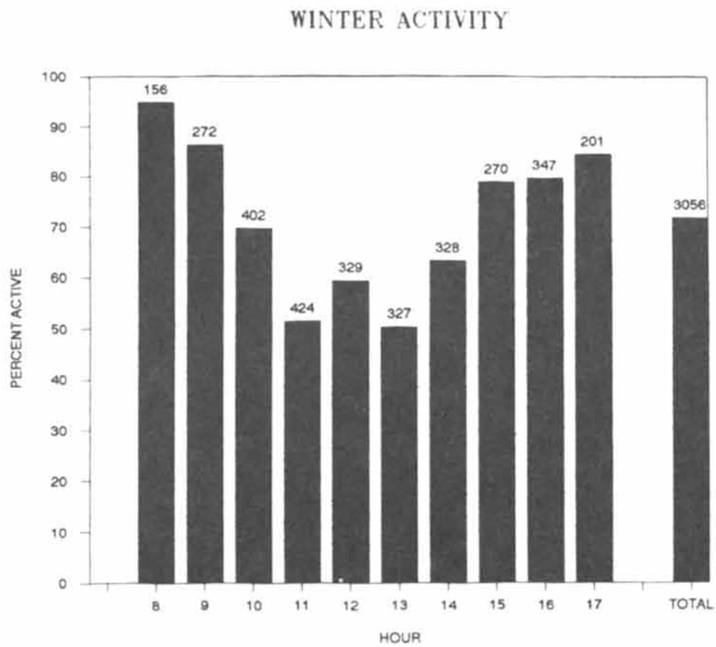
RESULTS AND DISCUSSION

Seasonal patterns in activity

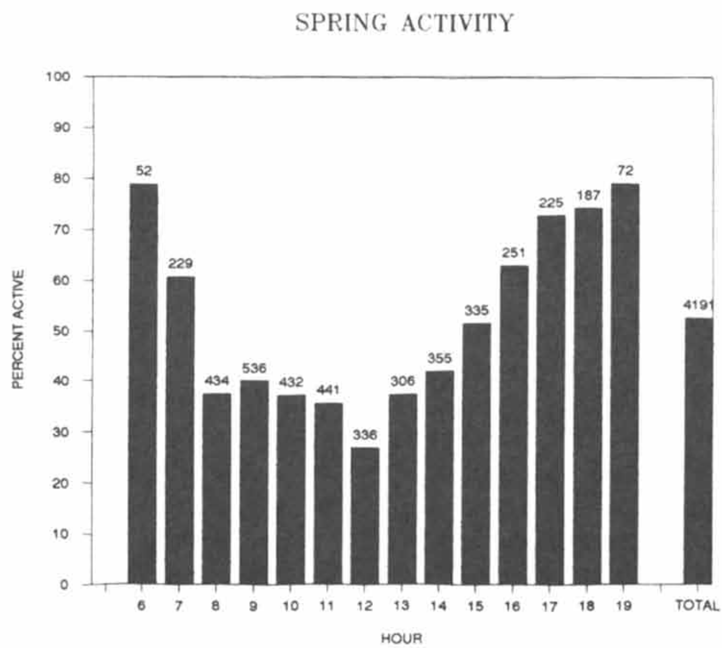
Bighorn were active 6·9 h/day during the winter and 6·4 h/day during the spring (Fig. 2(a) and (b)). During winter, they were active throughout the day, but activity was greatest in the morning, late afternoon and evening (Fig. 2(a)). Within each 1-h time period at least 50% of the animals observed were active. During spring, most activity occurred in early morning and late evening (Fig. 2(b)). Other studies have also shown that bighorn sheep reduce activity in the middle of the day (Chilelli & Krausman, 1981; Hansen, 1984).

Time budgets

Data for all animals were combined because helicopter overflights had no interactive effect with age and sex classes of bighorn (males, females and



(a)



(b)

Fig. 2. The diurnal activity patterns of bighorn sheep in winter (a) and spring (b). One point was assigned for each animal during each 15-min scan sample.

lambs older than six months) ($F=0{\cdot}52$, $n=297$, $p=0{\cdot}593$). The presence or absence of helicopters also had no interactive effect with group size (group sizes 1–4, 5–8, 9–13) on foraging efficiency ($F=1{\cdot}81$, $n=268$, $p=0{\cdot}166$).

Helicopters had a seasonal effect on foraging efficiency ($F=6{\cdot}64$, $n=320$, $p=0{\cdot}01$). During winter bighorn foraged 43% less efficiently in the presence of helicopters, $FE=42{\cdot}7\% \pm 7{\cdot}8$ ($n=16$) (mean $\pm$ SEM), than when they were absent, $FE=74{\cdot}6\% \pm 1{\cdot}7$ ($n=160$) ($t=4{\cdot}83$, $p<0{\cdot}001$). During spring helicopters had no effect on foraging efficiency, which averaged $79{\cdot}3\% \pm 4{\cdot}6$ ($n=24$) and $84{\cdot}2\% \pm 2{\cdot}0$ ($n=120$) in the presence and absence of helicopters, respectively ($t=1{\cdot}42$, $p=0{\cdot}079$).

Because group size influences bighorn foraging behavior (Berger, 1978) and varies seasonally in other areas (Leslie & Douglas, 1979; Chilelli & Krausman, 1981), the seasonal relationship reported here could be related to variation in group size. However, group sizes did not differ between seasons for either undisturbed desert bighorn ($t=0{\cdot}52$, $p=0{\cdot}607$ (2-tailed p), $n=254$) or for sheep foraging in the presence of helicopters ($t=0{\cdot}64$, $p=0{\cdot}529$ (2-tailed p), $n=34$).

Proximity of disturbance

Helicopters were closer to bighorn sheep during winter than spring because bighorn used the Toroweap stratum in winter. Thus the seasonal relationship may have been related to differences in the relative proximity of helicopters between seasons, indicating a possible threshold in disturbance distance. To address this possibility, the data were analysed by strata, holding season constant.

Helicopter overflights had no interactive effect with strata usage on foraging efficiency in winter ($F=0{\cdot}23$, $n=169$, $p=0{\cdot}63$) or in spring ($F=2{\cdot}52$, $n=140$, $p=0{\cdot}115$). Nevertheless, because effects may be subtle we also examined (1) treatment and control bighorn foraging efficiencies within each stratum; (2) inter-strata foraging efficiencies of control bighorn; and, if no difference existed between these groups, (3) inter-strata foraging efficiencies of treatment bighorn.

Winter

Winter strata comparisons were limited to Toroweap and Hermit Shale bighorn because few bands were observed in the Supai stratum. Within-stratum comparisons showed that helicopters had a significant effect on the foraging behavior of both Toroweap bighorn ($t=4{\cdot}04$, $p<0{\cdot}001$) and Hermit Shale bighorn ($t=2{\cdot}8$, $p=0{\cdot}003$) (Table 1).

Inter-strata comparisons revealed that in the absence of helicopters, sheep in the Hermit Shale foraged more efficiently than animals in the Toroweap

TABLE 1
The Influence of Proximity of Helicopters on Bighorn Foraging Efficiency, during Winter

	Control	*Treatment*[a]
Toroweap bighorn	71·8 ± 2·7 (51) a*	35·1 ± 11·1 (7) b
Hermit shale bighorn	76·6 ± 2·2 (103) c	50·2 ± 12·2 (8) b

[a] Helicopters were within 50–200 m and 100–450 m of bighorn in the Toroweap and Hermit Shale strata, respectively.
* Groups with the same letter are not significantly different from each other.

($t = -1{\cdot}93$, $p = 0{\cdot}056$) (2-tailed p) (Table 1), suggesting possible habitat differences between these two strata. Therefore inter-strata comparison of experimental bighorn is not justified. Because helicopters influenced the foraging behavior of bighorn sheep within each stratum, a disturbance distance could not be determined.

Spring

Spring comparisons were limited to bighorn occupying the Hermit Shale and Supai strata, because the Toroweap stratum was virtually unused by bighorn during this period. The within-stratum comparisons also illustrate that only bighorn closest to helicopters were sensitive to disturbance. Hermit Shale bighorn foraged 17% less efficiently in the presence of helicopters than when helicopters were absent ($t = 1{\cdot}91$, $p = 0{\cdot}03$) (Table 2). In contrast, foraging efficiencies were similar for Supai bighorn irrespective of the presence of helicopters ($t = -0{\cdot}35$, $p = 0{\cdot}366$) (Table 2).

Inter-strata comparisons of control bighorn revealed similar foraging rates for bighorn in the Hermit Shale and Supai ($t = 0{\cdot}90, p = 0{\cdot}370$) (2-tailed p) (Table 2). This justifies an inter-strata comparison of the foraging efficiencies of bighorn in the presence of helicopters. In the presence of helicopter overflights, foraging efficiencies for Hermit Shale and Supai bighorn were 71·3% ± 9·1 ($n = 11$) and 89·5% ± 2·0 ($n = 11$), respectively ($t = -1{\cdot}40$, $0{\cdot}05 < p < 0{\cdot}10$).

TABLE 2
The Influence of Proximity of Helicopters on Bighorn Foraging Efficiency, during Spring

	Control	*Treatment*[a]
Hermit shale bighorn	86·0 ± 2·4 (66) a*	71·3 ± 9·1 (11) b
Supai bighorn	82·2 ± 3·5 (52) ac	89·5 ± 2·0 (11) c

[a] Helicopters were within 100–450 m, and 250–700 m for bighorn in the Hermit Shale and Supai strata, respectively.
* Groups with same letter are significantly different from each other.

Because only those sheep using the Toroweap or Hermit Shale strata were disturbed by helicopters, these results indicate a disturbance distance threshold of 250–450 m. Other studies have also shown that the degree of disturbance is a function of proximity to the stimulus (Altmann, 1958; Berger *et al.*, 1983; Krausman & Hervert, 1983; Knight & Knight, 1984; Miller & Smith, 1985; Krausman *et al.*, 1986). Physiological data also report this relationship. Heart rates of Rocky Mountain bighorn *O. c. canadensis* did not respond to high-flying aircraft (>400 m), but those exposed to low-flying aircraft (90–250 m) ran and incurred up to a 3·5-fold increase in heart rate (MacArthur *et al.*, 1979, 1982).

Implications

If bighorn do not habituate to helicopters, the impacts will be cumulative; as the frequency of flights increases, so will impacts, which would be most severe in winter.

An animal may compensate for an energy loss by foraging longer if time is not limiting. However, ruminants require sufficient time to consume and ruminate large quantities of food. During winter, time constraints may be acute because bighorn were active approximately 69% of the daylight hours (Stockwell, 1989), and additional time may be required for rumination since bighorn often ruminate while lying down. Therefore additional compensatory activity may have an important influence on the total time budget of Grand Canyon bighorn.

Determining the average number of helicopters a bighorn may experience is problematic because helicopter traffic is spatially and temporally variable, and the distribution of bighorn at GCNP is not well documented. Following this study, the Federal Aviation Administration adopted Special Federal Aviation Regulation (SFAR) 50–2 on 1 November 1988, which created flight-free zones and flight corridors (Mazzu, 1990). This has effectively concentrated helicopter traffic over designated regions, which now may experience as many as 15 helicopter flights/hour during the fall (Mazzu, 1990). How these flight corridors overlap with areas occupied by bighorn throughout the park is not known; however, bighorn inhabit the strata below one flight corridor (Dragon Corridor) which experiences the heaviest helicopter traffic in the park (Stockwell, 1989; Mazzu, 1990).

Although helicopters caused a notable reduction in foraging efficiency, the long-term effects of such modified behavior are difficult to assess. Under ideal conditions one may design an experiment to compare the reproductive rates of populations exposed to varying levels of helicopter overflights while controlling for other variables. However, environmental factors that influence lamb survival are poorly understood (DeForge & Scott, 1982;

DeForge *et al.*, 1982), and the control of such variables in free-ranging populations will always remain difficult. Therefore, time budgets offer an alternative method for the determination of potential impacts of human activities on wildlife populations.

In summary, our data indicate that helicopter overflights alter the foraging behavior of desert bighorn—impacts which may be minimized by either restricting the number of flights or by regulating the flight altitudes of helicopters.

Restricting the number of flights during the winter appears to be a good strategy because impacts on bighorn foraging occurred only in winter. However, potential impacts may also occur during spring if helicopters haze bighorn during lambing. Although the frequency of such events is not known, at least one incident of hazing bighorn has been reported at Grand Canyon (Steve Carothers, pers. comm.).

Flights could also be restricted during specified periods of the day, especially in the spring when bighorn are most active during early morning and late afternoon. During winter, helicopters would be likely to encounter active sheep during all hours since at least 50% of the animals were active during every hour.

Alternatively, current regulations of helicopter flight altitudes could be modified to reduce impacts on bighorn. Current altitude regulations vary throughout GCNP, but generally helicopters must fly 152·4 m (500 ft) above the south rim; however, such altitudes are often below the north rim of the canyon. Because our data indicate a disturbance distance of approximately 250–450 m, impacts would be minimized if helicopters were to fly no nearer to bighorn habitat than 500 m.

The information reported here illustrates how time budget data may be used to mitigate impacts in national parks. Such an approach should prove useful in other areas where conflicts between human activities and wildlife populations may exist. As the demand for outdoor recreation continues to increase, data on potential human-induced impacts will become essential to mitigate possible long-term impacts.

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