

THE EFFECT OF HELICOPTER OVERFLIGHTS
ON THE FORAGING BEHAVIOR OF DESERT BIGHORN SHEEP
(Ovis canadensis nelsoni)
AT GRAND CANYON NATIONAL PARK

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Abstract.

The foraging efficiencies of desert bighorn sheep at Grand Canyon National Park were recorded in the presence and absence of helicopter overflights. Bighorn foraged 17% less efficiently and took 60% more steps (steps/minute during a five minute foraging bout) when helicopters were present than when they were absent. Bighorn were most sensitive to helicopter disturbance in winter, as indicated by a 42% reduction in foraging efficiency and a two fold increase in the number of steps taken during a five minute foraging bout. In spring, helicopters caused a slight, yet significant, reduction in foraging efficiency, but had no influence on the number of steps taken during a foraging bout. The seasonal difference in sensitivity may reflect the migration of bighorn to lower elevations, where they are further from helicopters, during the spring. The biological implications of these results are discussed.

INTRODUCTION

The impacts associated with the non-consumptive use of wildlife deserve attention (Boyle and Samson, 1983, 1985). The popularity of sight-seeing via private and commercial aircraft has increased with the demand for outdoor recreation. The maneuverability and power of small planes and helicopters now allow access to remote areas. Thus wildlife in these areas may be vulnerable to intrusions.

Aircraft have varying impacts on large ungulates (MacArthur et al., 1982; Krausman and Hervert, 1983; Krausman et al., 1986). Bighorn sheep, Ovis canadensis canadensis, exposed to low flying aircraft (75-250m) were extremely stressed as indicated by a 3.5 fold increase in heart rate (MacArthur et al., 1982). Sensitivity to disturbance may vary with a variety of social or environmental parameters such as group composition or habitat. For instance, Wehausen (1983) reported that ewes with lambs were particularly vulnerable to disturbance.

Human activities may have negative influences on the reproductive success, physiology or behavior of a population. Measuring the influence of human activities on the fitness of individuals is operationally difficult at best. This is especially true for large mammals, which may not react quickly to environmental changes. Physiological measurements of the reaction of wildlife to human activities have proven successful, but unfortunately this approach is quite expensive (MacArthur et al., 1982). Finally, many authors have used behavioral approaches to address this question (Schultz and Bailey, 1978; Hicks and Elder, 1979; Berger et al., 1983; Hamilton, 1983; King and Workman, 1986; Pedevillano and Wright, 1987).

Foraging behavior may serve as a sensitive indicator of potential disturbance (Berger et al., 1983). Optimal foraging theory maintains that animals are selected to maximize energy gain per unit time while minimizing expenditures (Pyke et al., 1977; Pyke, 1984). The rate of energy intake is influenced by a suite of factors such as the density of selected plants, cropping rates and the amount of time the animal devotes to scanning the environment, presumably for predators. Thus, scanning is a cost in terms of the rate of energy intake.

The coefficient of foraging efficiency measures the relationship between feeding and scanning. Foraging efficiency has been applied to a wide variety of topics including the costs and benefits of sociality, (Berger, 1978; Stacey, 1986), habitat utilization (Owen-Smith, 1979; Risenhoover and Bailey, 1985; Warrick and Krausman, 1987) and human disturbance (Berger et al., 1983; King and Workman, 1986). Long term disturbances may lead to acute or chronic reduction in foraging efficiency (Berger et al., 1983; King and Workman, 1986). A chronic reduction in foraging efficiency may lead to an energy deficit and ultimately reduce reproductive fitness (Berger et al., 1983; Berger, pers. comm.).

At Grand Canyon National Park (GCNP), Nelson's desert bighorn, O. c. nelsoni, may be especially susceptible because helicopter traffic is heavy, exceeding 15,000 flights per year (Rick Ernenwein, GCNP, Resources Management and Planning Division., pers. comm.). Here, we employ foraging efficiency to address the following questions: 1) Do helicopter overflights have a negative influence on the foraging efficiency of bighorn sheep, seasonally and overall. 2) If so, what mechanisms may explain the disturbance.

STUDY AREA

All behavioral observations were made in the central region of Grand Canyon National Park in Hermit, Horn, Monument and Salt Canyons (Fig. 1). Our observations were limited to those sheep occurring above the Redwall and utilizing the Supai, Hermit Shale, and Toroweap strata (Fig. 2). The Supai and Toroweap strata are characterized by a mosaic of precipitous cliffs and talus slopes whereas the Hermit Shale is primarily characterized by talus slope. The study area occurs in the pinyon juniper woodland plant community (Whitney, 1982). Dominant plant species and associates include: pinyon pine (Pinus edulis), Utah juniper (Juniperus osteosperma), big sagebrush (Artemisia tridentata), rabbitbrush (Chrysothamnus nauseosus), fernbush (Chamaebatiaria millefolium), broom snakeweed (Gutierrezia sarothrae), gambel oak (Quercus gambelii), banana yucca (Yucca baccata), cliff rose (Cowania mexicana), apache plume (Fallugia paradoxa), and Utah serviceberry (Amelanchier utahensis). Small pockets of douglas fir (Pseudotsuga menziesii) occur on the north and east facing slopes of the Toroweap and upper Hermit Shale strata (Mouat et al., 1981).

METHODS

Data collection:

Bighorn were visually located from the rim of the Grand Canyon with high power spotting scopes. To avoid disturbing the band, observers were typically 800m from bands under observation. Upon encountering sheep the following data were collected: date, location, time, group

size, group composition, and activity patterns of all band members. These data were recorded every 15 minutes during the observation period which generally lasted 2 to 3 hours.

The activities of individual bighorn were recorded for 300 seconds (Berger et al., 1983) using a micro-recorder and later transcribed into data books and log sheets. Six general activity patterns were recorded: 1) Foraging (F) which included any time the animal's head was down in a foraging or searching position or when the animal was foraging with neck extended into a tall bush. 2) Head up (HU) included all time when an animal's head was up (vigilance or looking around were included here). 3) Walking (W) included any 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 5 consecutive seconds were allocated to stepping. 4) Maintenance (MN) included scratching, resting, defecation, urination, and horning, however the latter two were classified as social interactions if exhibited in a social context. 5) Social interactions (SI) included any interaction with other bighorn or other animals such as deer. 6) Out of sight (OOS) included all time when the animal was not visible to the observer.

Total steps were recorded during all activities following Risenhoover and Bailey (1985). Total steps during foraging may reflect the dispersion of selected plants (Berger et al., 1983). Total steps during the bout may also indicate an animal's level of nervousness or agitation. An increase in stepping rate will also be energetically expensive since stepping rates are correlated with metabolic costs (Robbins, 1983; Fancy and White, 1985).

Foraging bouts were only analyzed if the animal was in view and active for more than 180 seconds (i.e., 60 % of the bout). Also, bouts in which the animal walked more than 120 seconds were not analyzed. The foraging efficiency (FE) (Berger et al., 1983) was calculated as follows:

$$FE (\%) = \frac{F}{F + HU} \times 100$$

To avoid potential observer bias, the procedure for selection of the individual to be monitored was standardized. Foraging bouts were recorded for females first, rams second, and juveniles last. Furthermore, we standardized the selection procedure by beginning at the right hand side of the band and proceeding left. To insure independence of data points, only one foraging bout was recorded for each animal on a given day .

Foraging data were collected when helicopters were flying overhead or when the helicopters were absent. Helicopters were visually determined to be overhead if they were flying at rim level or lower and were within a horizontal distance of 400m (Fig. 3). Helicopter flight paths followed a general pattern throughout the year. The flight originated (or terminated) at rim level and gradually descended below (or ascended to) the rim. Although exact measurements were not possible most helicopters flew at altitudes which corresponded with levels between the rim and the top of the Coconino as they flew over the band (Fig. 3). Thus for bighorn occupying the Toroweap, Hermit Shale and Supai, helicopters were generally 50-200m, 100-450m and 250-700m distant respectively.

Analyses:

We partitioned data into two seasons based on bighorn migration patterns, winter (November-February) and spring-summer (March-July). During winter bighorn utilized the upper strata of the canyon extensively, but in March they migrated to the lower strata while upper strata were virtually ignored (Table 1); however, occasional observations indicate that the sheep began utilizing the Toroweap stratum again in August. Thus, data are analyzed overall and seasonally.

Time of day or weather may be correlated with helicopter presence. Data were typically recorded only when visibility was adequate, thus data were not recorded on days with high winds or substantial precipitation. Precipitation was recorded on less than 20% of the field days (data from South Rim weather station). The influence of helicopter overflights on foraging efficiency did not vary with the presence or absence of precipitation ($F = 0.037$, $P = .848$). Therefore, data under various weather periods are included in the following analysis. Since the frequency of helicopter traffic may vary throughout the day our data analysis controlled for time. Only those time periods in which foraging bouts were recorded in both the absence and presence of helicopters were used in the analyses (Table 2). We treat our data in an experimental fashion, such that helicopter overflights are considered an experimental treatment. In other words we assume variables such as group size have similar effects for both treatment and control groups.

All analyses were performed utilizing the SPSS statistical package (Nei, 1975). Two-way analysis of variance was used to test for seasonal and other potential interactions. The Kolmogorov-Smirnov one sample

test (Nel, 1975) was used to test the distributions of treatment and control data for normality. The distribution of treatment data was found to be normal (K-S Z = 1.193, P = .116), but the distribution of control data was not normal (K-S Z = 2.77, P < .001). Therefore we have used the non-parametric Mann Whitney U test to test for differences between treatment and control groups. Null hypotheses were rejected if the one-tailed probability (P value) was lower than or equal to 0.05 (Zar, 1974).

When treatment and control groups were significantly different we employed the following coefficient to measure the difference:

$$1 - \frac{\text{FE treatment}}{\text{FE control}}$$

where FE is mean foraging efficiency in percent. In this way the foraging efficiencies of the control group served as a standard against which the treatment animals could be compared. 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

We analyzed 312 foraging bouts which met the criteria outlined above. An analysis of all data showed that the influence of helicopter overflights did not vary with age and sex classes (F = .773, P = .463) of sheep. Therefore, the following analyses combined data for all animals.

An analysis of all data revealed that helicopter overflights caused a reduction in foraging efficiency and an increase in stepping rate. Bighorn foraged 17% less efficiently in the presence of helicopters

(FE = 65.4% $\pm$ 5.1, n = 39 vs. FE = 78.7% $\pm$ 1.3, n = 273) than when helicopters were absent (U = 4001.5, Z = -2.510, P = 0.006). Helicopters also had a significant influence on movement frequency. Bighorn took 60% more steps (as measured by total steps/minute) in the presence of helicopters (8.1 steps/minute $\pm$ 1.4, n = 35) than when helicopters were absent (5.1 steps/minute $\pm$ 0.4, n = 265)(U = 3613.5, Z = -2.123, P = 0.017). Since, helicopter overflights should not influence the distribution of selected plants, it seems reasonable to suggest that an increased stepping rate may reflect increased nervousness. This reduction in foraging efficiency and increased stepping rate show bighorn were disturbed while helicopters were overhead.

The influence of helicopters on foraging efficiency varied seasonally (F = 11.398, P = 0.001). In contrast, the influence of helicopters on the number of steps taken during foraging did not vary seasonally (F = 2.967, P = 0.086). Nevertheless, since this P value approaches statistical significance we have analyzed the seasonal influence of helicopters on stepping rates and foraging efficiency.

During winter, helicopter overflights had a significant negative influence on the foraging efficiency of bighorn sheep. Bighorn foraged 42% less efficiently in the presence of helicopters (FE = 43.2% $\pm$ 8.3, n = 15) than when helicopters were absent (FE = 74.4% $\pm$ 1.7, n = 153) (U = 484.5, Z = -3.688, P = 0.0001). Also, bighorn took twice as many steps when helicopters were present (9.6 steps/minute $\pm$ 2.9, n = 13) as when they were absent (4.3 steps/minute $\pm$ 0.4, n = 153)(U = 711.5, Z = -1.701, P = .045).

During the spring helicopters caused a slight, but statistically significant, reduction in foraging efficiency. Foraging efficiencies were 84.2% (± 0.01 , $n = 120$) and 79.3% (± 0.04 , $n = 24$) in the absence and presence of helicopters, respectively ($U = 1120.5$, $Z = -1.716$, $P = 0.043$). The number of steps taken during a foraging bout was not influenced by the presence of helicopters ($U = 1068.0$, $Z = -0.985$, $P = 0.162$). Bighorn took 7.1 steps/minute (± 1.4 , $n = 22$) and 6.0 steps/minute (± 0.8 , $n = 112$) in the presence and absence of helicopters respectively.

This seasonal relationship may have been related to the relative proximity of helicopters between seasons. During the winter, bighorn were closer to helicopters than during spring, because bighorn used the higher strata in the winter. To further address this possibility we have divided our spring bighorn data into two categories, bighorn occupying the Supai layers, Supai bighorn, and bighorn occupying the Hermit Shale, Hermit Shale bighorn. Helicopters were within 100-450m and 250-700m of Hermit Shale bighorn and Supai bighorn, respectively. Here we have evaluated the foraging behavior of bighorn by strata.

The influence of helicopters on foraging efficiency varied between strata ($F = 4.72$, $P = 0.031$). The influence of helicopter overflights on total steps taken during foraging did not vary between strata ($F = 0.96$, $P = 0.328$). Therefore, within stratum and between strata comparisons are made only for foraging efficiency. The influence of helicopter proximity was tested by examining the foraging efficiencies of treatment bighorn between strata and comparing treatment and control bighorn within each stratum.

The foraging efficiencies of control bighorn in the Hermit Shale and Supai were similar, with values of 86.0% (± 2.3 , $n=66$) and 82.2% (± 3.5 , $n=52$) respectively ($U = 1592.5$, $Z = -0.6713$, $P = 0.251$). Because potential habitat differences were not reflected by foraging efficiencies, we assume the one factor that varied between strata was the proximity of helicopters.

In the presence of helicopter overflights the foraging efficiencies for Hermit Shale bighorn and Supai bighorn were 71.3% (± 9.1 , $n = 11$) and 89.5% (± 1.9 , $n = 11$), respectively. This difference approaches statistical significance and indicates that those animals in close proximity to helicopters were 21% less efficient than those more distant from helicopters, ($U = 43.0$, $Z = -1.150$, $P = .125$).

The within-stratum comparisons illustrate that only those bighorn in close proximity to helicopters were sensitive to disturbance. Hermit Shale bighorn had foraging efficiencies of 86.0% (± 2.3 , $n = 66$) and 71.3% (± 9.1 , $n = 11$) in the absence and presence of helicopters, respectively ($U = 254.5$, $Z = -1.585$, $P = 0.057$). These values closely approach statistical significance suggesting Hermit Shale bighorn incurred a 17% reduction in foraging efficiency in the presence of helicopters. In contrast, Supai bighorn had similar foraging efficiencies whether helicopters were present or absent. The foraging efficiencies of Supai bighorn in the presence of helicopters were 89.5% (± 1.9 , $n = 11$) compared to 82.2% (± 3.5 , $n = 52$) when helicopters were absent ($U = 266.0$, $Z = -0.363$, $P = .359$). These results suggest that bighorn are only disturbed by helicopters in close proximity (i.e., 450m).

Finally, the precipitous nature of the Supai stratum may allow bighorn a greater sense of security than those habitats at higher elevations which have more gentle slopes. The data at hand will not allow us to examine this alternative. The data suggest that proximity is one mechanism explaining the level of disturbance, however a greater sense of security in steeper terrain may also play a roll.

The proximate mechanism causing the reduction in foraging efficiency (for those animals in close proximity to helicopters) is unknown. Overt responses to helicopters were rare (except when helicopters were within 100m of bighorn, see appendix A), but the increased stepping rates may indicate induced nervousness, thus heart rate may have increased as well. Alternatively, the noise of helicopters probably blocks out typical background noises, and thus may reduce hearing acuity. Bighorn in such circumstances may rely more on their vision to detect predators and/or other environmental stimuli. Vigilance would increase at the expense of foraging.

Biologically, what does a reduction in foraging efficiency mean? Although helicopters caused a notable behavioral reaction, the long term effects of such modified behavior are difficult to assess. Nevertheless, we can speculate on potential long term impacts, based on our general knowledge of foraging and time budget constraints.

Ultimately, the long term impacts of helicopter overflights should be frequency dependent. For instance, one helicopter overflight per day should not have negative reproductive effects, but as the frequency of flights increase the potential for impacts increases. Simple calculations support this contention. During winter, for each disturbed 5 minute foraging bout a bighorn will need to forage an additional 2

minutes to gain the same amount of gross energy (foraging recovery period), had there been no disturbance, assuming cropping is relatively constant. But if a helicopter flies over during the foraging recovery period the bighorn will need to forage 3 minutes and 43 seconds (in addition to the original 5 minutes) to consume as much food (Fig. 4). These figures do not account for the added cost of standing while eating during the additional time period. Standing increases the metabolic rate 18-19% over lying for bighorn (Chappel and Hudson, 1979).

An animal may compensate for an energy loss by foraging longer if time is not a limiting factor. However, bighorn have demands in addition to feeding, such as rumination. The ratio of rumination time/foraging time for bighorn (O. c. canadensis) has been reported as 1.00 (Belovsky and Slade, 1986) and for red deer (Cervus elaphus) as .21 and .48 for succulent and lower quality forage, respectively (Clutton-Brock et al., 1982).

The potential impacts may be compounded by energetic demands. Domestic ewes in late stages of gestation generally require 33-50% more energy than required for maintenance (calculated from gross feed requirements reported in National Research Council, 1964; see Oftedal, 1985). Energy deficits in early and mid gestation may lead to restricted placental development, which may in turn influence fetal growth (for review see Rattray, 1977).

In spring, females are faced with the additional cost of lactation. The energetic demands of lactating domestic ewes are 77-100% above maintenance costs (calculated from gross feed requirements reported in National Research Council, 1964; Oftedal, 1985). The summer drought period (May through June) during which females are lactating is

also a stressful period in terms of forage quality. For instance, in June protein levels are low for many forage items selected by bighorn (summarized from Morgart et al., 1986). High nutritional requirements for lactation and low forage quality are thought to cause low lamb survival in many desert bighorn populations (Berger, 1979). Foraging rate may need to be above some minimal threshold to provide necessary amounts of potentially limiting nutrients (Owen-Smith, 1979). Thus a 5-13% reduction in foraging efficiency during summer could have detrimental effects on reproduction.

These factors taken together suggested the need to build a model to predict the number of flights an animal could withstand. Initially, this seemed appropriate, however, considering the assumptions necessary the predictive power of a model may be inadequate for management purposes. For instance, a model would require known cropping rates, dietary knowledge, and 24 hour activity pattern data. None of these data are available for Grand Canyon bighorn. It would be possible to extract such data for other populations from the literature, however the associated variances would lower the precision of the model. Also, the assumptions for such models are often unrealistic. Hanley has outlined the potential biases involved with time energy budget models (Hanley, 1980).

Currently, helicopter overflights are altering the foraging behavior of desert bighorn sheep. These influences could have long term detrimental effects on the bighorn population at Grand Canyon National Park. Fortunately, impacts to foraging behavior and potential long term impacts may be minimized by regulation of helicopter traffic over the park. Our study and others indicate a threshold to disturbance at

approximately 300-450m (MacArthur et al., 1979, 1982). Therefore, we recommend that helicopter traffic fly no nearer than 500m to bighorn sheep habitat. Bighorn occupy strata near the rim between the months of August and March, therefore helicopters should fly 500m above the rim during this period. Between April and July bighorn occupy lower strata (within 300m of the rim), therefore we recommend a minimum altitude of 200m above the rim between April 1 and July 31. Since current guidelines suggest all aircraft fly 2000 feet (612 m) above the rim, an enforcement of the current guidelines would also minimize the influence of helicopter overflights on the bighorn sheep population at Grand Canyon National Park.

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Table 1. The percentage of band sightings in each stratum by month. Note that usage in the upper elevation Toroweap begins to decline in March, and Torweap usage is virtually nonexistent for the rest of the year.

	<u>MONTH</u>								
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL
Number of bands observed	(11)	(12)	(45)	(11)	(22)	(22)	(43)	(56)	(32)
<u>PERCENTAGE OF SIGHTINGS IN EACH STRATUM</u>									
TOROWEAP	09	25	60	73	23	00	02	00	00
HERMIT SHALE	82	75	38	27	14	18	70	73	59
SUPAI	09	00	02	00	64	82	28	27	41

Table 2. The number of foraging bouts recorded in the presence and absence of helicopter overflights as a function of time is depicted. To control for the confounding variable of time only those time periods in which bouts were recorded in both the presence and the absence of helicopters were used in the analyses. (* indicates time periods used in the analyses)

NUMBER OF FORAGING BOUTS IN THE:

<u>TIME</u>	<u>ABSENCE OF HELICOPTERS</u>	<u>PRESENCE OF HELICOPTERS</u>
0600-0659	7	0
0700-0759*	8	4
0800-0859*	40	3
0900-0959*	39	6
1000-1059*	53	3
1100-1159	39	0
1200-1259	23	0
1300-1359*	32	2
1400-1459*	26	7
1500-1559*	29	11
1600-1659*	46	3
1700-1759	22	0
1800-1859	7	0
1900-1959	6	0

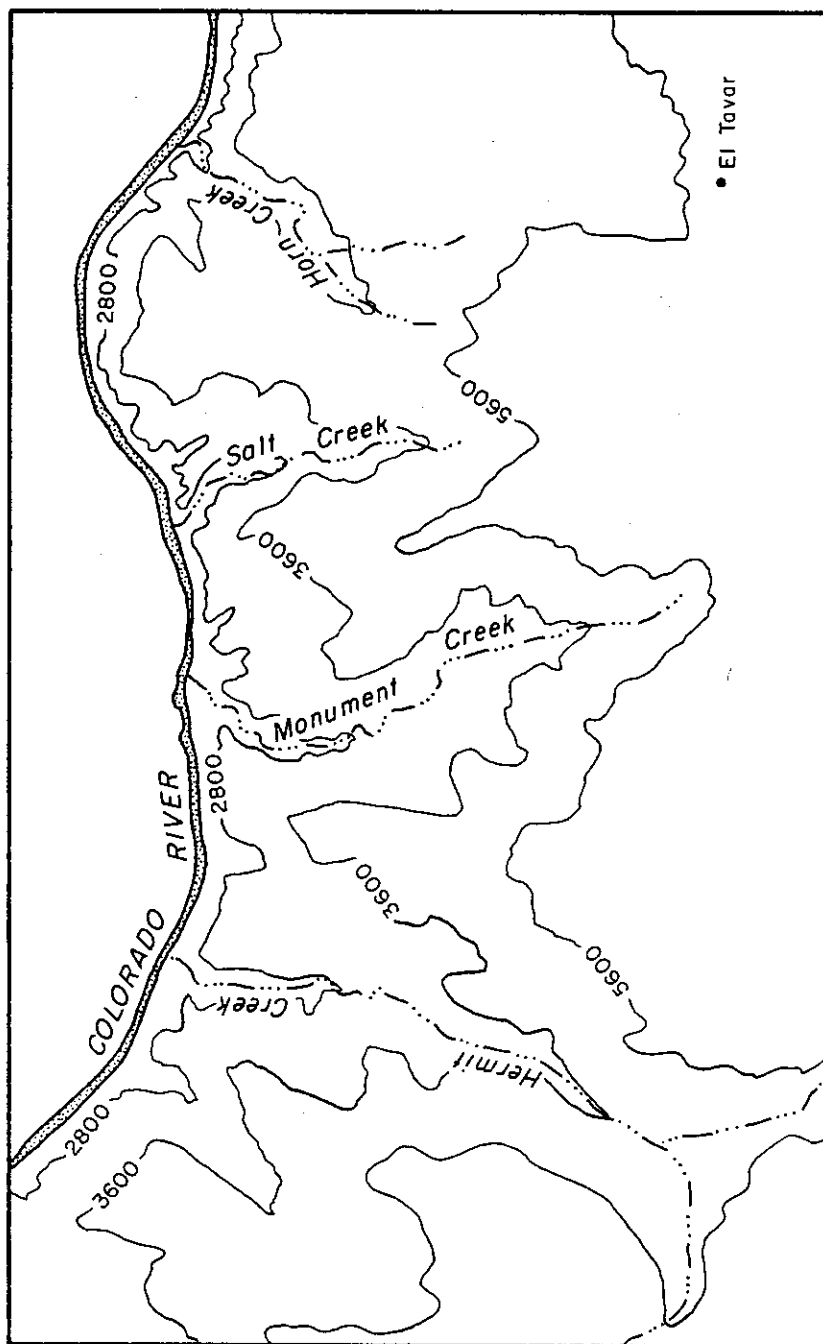


Figure 1. Map of the central region of Grand Canyon National Park. The study areas included Hermit, Horn, Monument and Salt Canyons.

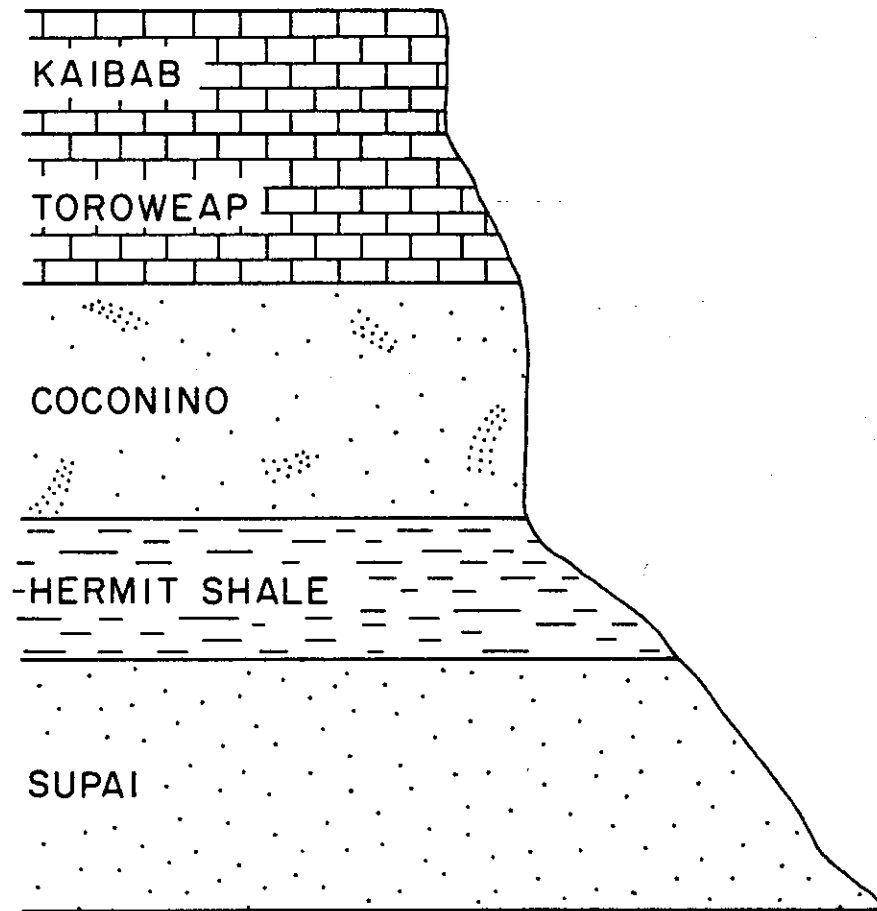


Fig. 2. A schematic cross section of the strata of Grand Canyon in which animals were observed.

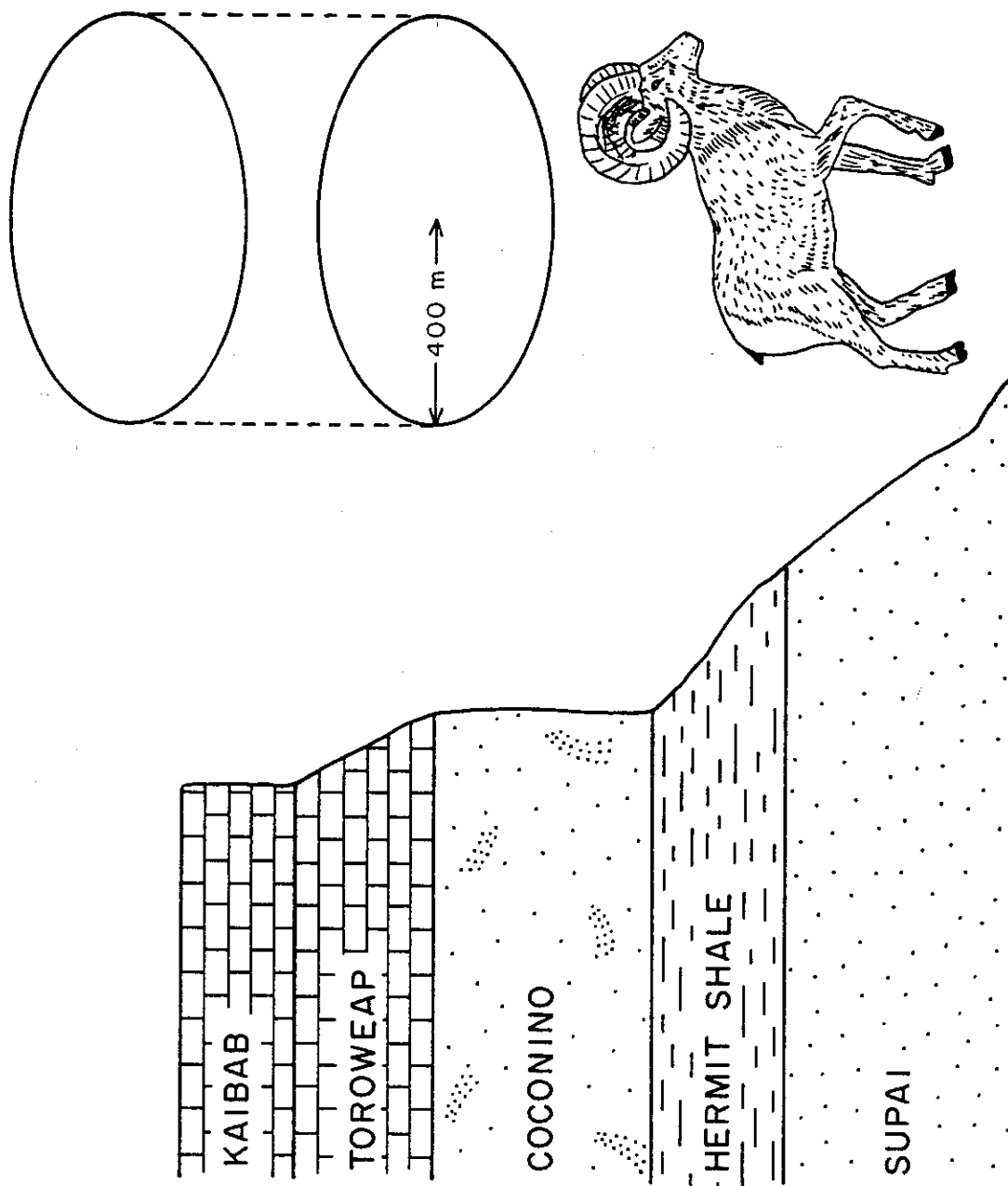


Figure 3. A schematic representation of the relationship between helicopter overflights and sheep. Flights were considered overhead if they were at rim level or below and within 400m horizontal distance.

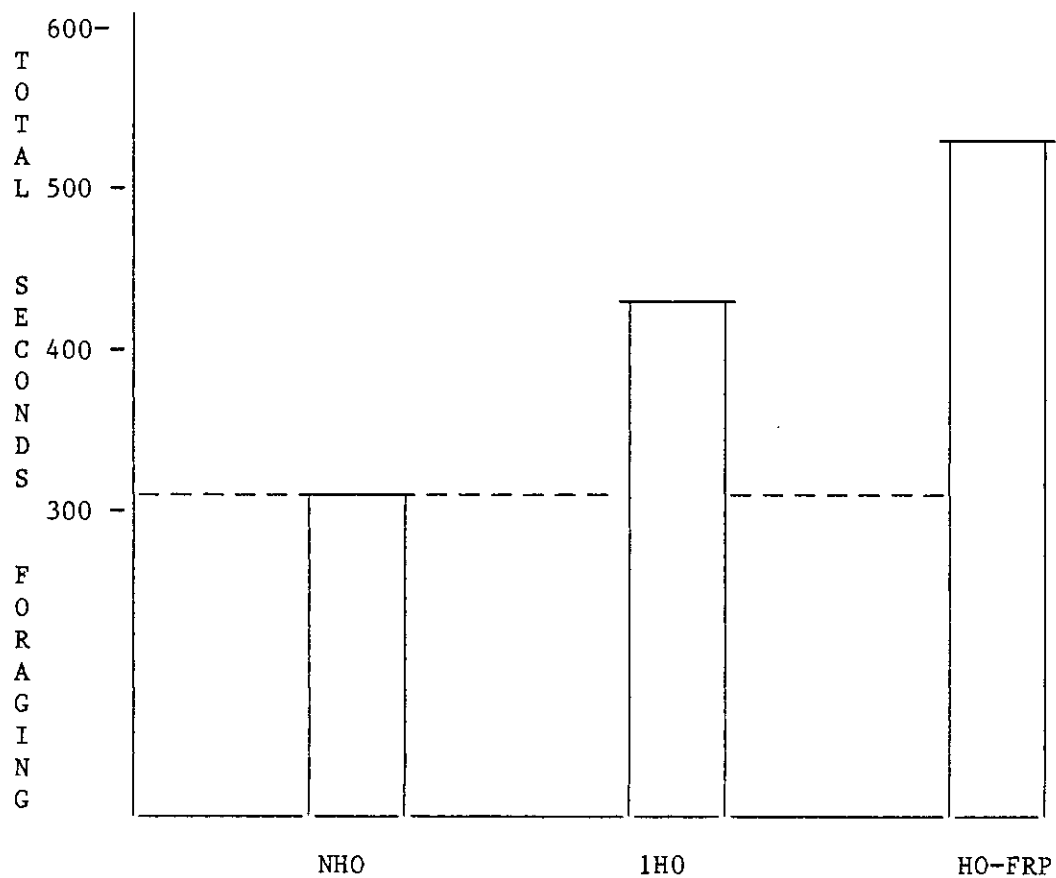


Fig. 4. Bighorn foraging in the absence of helicopters (NHO) devote 225 seconds to cropping food (CF) during a 300s bout. Those animals foraging in the presence of a helicopter overflight allocate 129s to CF, thus incur 96s of CF deficit. To recover this the animal will either forage an additional time period (foraging recovery period) in the absence of additional helicopters (75% efficiency) (lHO), or in the presence of an additional helicopter (43% efficiency) (HO-FRP). Thus, in order to allocate the same amount of time to CF, animal must forage for 300s if NHO, 429s if lHO or 523s if HO-FRP.

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APPENDIX

Low flying helicopters were observed within 50-100m of bighorn on six occasions. In all cases the sheep ran as the helicopter flew overhead and they remained vigilant for at least 10 seconds and as long as 5 minutes. In three instances the band ran over 100m as the helicopter came directly overhead.

We personally know of one case where a commercial aircraft intentionally carried tourists directly over a bachelor band of 18 sheep. In this case the pilot was aware that the animals had been seen in the area before and flew at a low altitude to allow passengers a better view. The aircraft was flown approximately 100m above the band which responded by running 100m before the aircraft regained altitude (Steven Carothers, pers. comm.). The long term effects of such incidents are difficult to determine, but could be detrimental for females in late stages of pregnancy or for young lambs. For instance, ewes and lambs may be separated as the band flees from low flying aircraft. Injury to escaping lambs is also quite possible. One of us (CS) observed a lamb that fell and rolled downhill while running from a turkey vulture (Cathartes aura) circling overhead.