W-0039

CARDIAC AND BEHAVIORAL RESPONSES OF MOUNTAIN SHEEP TO HUMAN DISTURBANCE

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Abstract: Telemetered heart rates (HR) and behavioral responses of mountain sheep (*Ovis canadensis canadensis*) reacting to human disturbance in the Sheep River Wildlife Sanctuary, southwestern Alberta, were recorded. Cardiac and behavioral responses of sheep (4 ewes, 1 ram) to an approaching human were greatest when the person was accompanied by a dog or approached sheep from over a ridge. Reactions to road traffic were minimal as only 8.8% of vehicle passes elicited HR responses. No reactions to helicopters or fixed-wing aircraft were observed at distances exceeding 400 m from sheep. Responses to disturbance were detected using HR telemetry that were not evident from behavioral cues alone. However, mean duration of the HR response (138.6 sec) was not greater ($P > 0.05$) than mean period of the behavioral reaction when sheep were alert or withdrawing from harassing stimuli (112.4 sec). Use of HR telemetry in harassment research is discussed.

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Survival and optimal use of habitat by individuals demand high levels of vigilance so that stimuli indicating presence of predators, conspecifics, food, or shelter do not go undetected (Dimond and Lazarus 1974). Yet if an animal is excessively aroused, as from human disturbance, the added cost of excitement may interfere with health, growth, and reproductive fitness (Geist 1979:5).

Recent studies of free-living birds (Kanwisher et al. 1978) and ungulates (Ward et al. 1976, MacArthur et al. 1979) have revealed that heart rate is a sensitive indicator of arousal, the first stage of an alarm reaction to stress (Jenkins and Kruger 1975). These and other investigations (Thompson et al. 1968, Cherkovich and Tatoyan 1973, Moen et al. 1978) have demonstrated consistent HR responses to disturbing visual or auditory stimuli, often in the absence of overt behavioral changes.

Expanding upon earlier work (MacArthur et al. 1979), the present paper integrates cardiac and behavioral observations to better understand how individuals in a population of mountain sheep perceive and respond to environmental perturbations. In view of escalating use of alpine areas by hikers, particular attention is focused on the sensitivity of sheep to approaches by humans (Dunaway 1971). The study also addresses relative merits of HR telemetry and overt behavioral observations as methods for detecting and defining harassment responses in ungulates. Preliminary findings (MacArthur et al. 1979) suggested cardiac responses may persist longer than behavioral reactions, and a quantitative comparison of these 2 indices of disturbance is reported here.

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METHODS

All observations were made in the Sheep River Wildlife Sanctuary, 27 km west of Turner Valley, Alberta. The sanctuary encompasses the winter range of a hunted population of 90–120 mountain sheep. Detailed descriptions of habitat and ecology of this population have been provided by Wishart (1958) and Horejsi (1976). Within the sanctuary, sheep are regularly exposed to human activities along a gravel road following the Sheep River Valley. During periods of peak recreational use, sheep may encounter 25–30 vehicles passing per hour.

The telemetry system and instrumentation procedures have been previously described (MacArthur et al. 1979, Johnston et al. 1980). Briefly, the electrocardiogram (ECG) was detected from subcutaneous electrodes by an externally mounted FM transmitter (range 2–6 km). Receiver output was fed into 1 channel of a stereo tape recorder, while a verbal commentary was provided on the 2nd channel. The ECG was recovered from the taped signal using an audio FM demodulator connected to a strip chart recorder. During locomotor activity the ECG was often obscured by background "noise" attributed to skeletal muscle potentials and electrode movement. At such times it was difficult to separate ECG from artifact on the strip chart tracing, although heart beat could often be discriminated by listening to the audio tone.

Heart rates and behavioral data were gathered from 5 adult ewes (E1 through E5) between 4 March and 10 May 1978, 1979, and from 2 adult ewes (E6, E7) and 1 3-year-old ram (R1) between 30 October and 18 December 1979. Sheep adjusted well to transmitters (Johnston et al. 1980), and observations were begun 24–48 hours following release of the animals.

Sheep were observed from a parked vehicle as described by MacArthur et al. (1979). During continuous surveillance (1–4 hours) of an instrumented sheep, HR and behavior were noted at 10-minute intervals. When opportunities arose, HR was also recorded during social interactions and normal exposure to predators, road traffic, aircraft, and people. Standardized harassment trials were also conducted in which sheep were approached to within 50 m by a person walking with or without a leashed dog (MacArthur et al. 1979). Beginning in March 1979, a stepwise approach was adopted in which the advancing person made 3-minute stops at distances from the sheep of 150, 100, 50 and 25 m, respectively. Distances were determined with a Rangematic, Mark V, optical range finder. Fifty-eight stepwise harassment trials were conducted in which 5 instrumented sheep were approached by a person walking either directly from a parked vehicle on the road (Type I, $N = 28$ trials), or from over a ridge away from the road (Type II, $N = 30$ trials). An additional 10 approaches were made from the road, in which the person was accompanied by a leashed dog (Type III).

For each HR recording, positions of sheep were plotted on aerial photographs and minimum distances from escape terrain (canyon or cliff habitat), tree cover, and roads were determined. Black bulb temperature (Pereira et al. 1967) and windspeed (hand-held anemometer) were recorded 1–1.5 m above ground level at the observation site. When possible, inclines of slopes on which the sheep occurred were measured (Suunto Clinom-

Table 1. Behavioral and heart rat approaches by a human.

Approach type[a]	No. trials
I. Off road	28
II. Over ridge	30
III. Off road with dog	10

[a] Described in text.
[b] Total distance that sheep withdrew fr
[c] Maximum change in HR between con
[d] Mean HR during approach sequence (

eter) following observ
Group size, band compos
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Heart rates were calcu
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Mean values were comp
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Table 1. Behavioral and heart rate responses ($\bar{x} \pm 1$ SE [range]) of mountain sheep (4 ewes, 1 ram) to standardized approaches by a human.

Approach type[a]	No. trials	Withdrawal distance (m)[b]	Heart rate response (bpm)		
			Maximum HR	Maximum Δ HR[c]	Overall Δ HR[d]
I. Off road	28	11.8 ± 3.01 (0–50)	90.7 ± 4.22 (54–174)	31.1 ± 3.73 (6–102)	0.72 ± 0.46 (−17.7–36.3)
II. Over ridge	30	45.9 ± 11.67 (0–265)	124.1 ± 8.94 (60–204)	56.8 ± 7.91 (0–144)	8.5 ± 1.34 (−12.9–75.0)
III. Off road with dog	10	65.2 ± 18.14 (0–180)	124.8 ± 13.70 (66–216)	51.6 ± 11.07 (18–120)	12.8 ± 2.52 (−11.0–125.3)

[a] Described in text.
[b] Total distance that sheep withdrew from approaching person.
[c] Maximum change in HR between consecutive 10-second counts.
[d] Mean HR during approach sequence (150–25-m stops, inclusive), minus mean HR during 3-minute period preceding harassment trial.

eter) following observation periods. Group size, band composition, and spatial relationships within the band were also noted.

Heart rates were calculated over 10-second intervals and expressed as beats per minute (bpm). Based on normal HR variation of undisturbed sheep (MacArthur et al. 1979), a HR response to disturbance was defined as that involving a change in HR between consecutive 10-second counts equal to or greater than 18 bpm. The probability of such a change in HR occurring in an undisturbed sheep engaged in lying, standing, or foraging activities was less than 5% (MacArthur et al. 1979). Duration of a HR response was defined as the time (sec) required for HR to recover to within ±12 bpm of the pre-disturbance level. A withdrawal response was defined as that in which the subject bolted or walked away from the source of disturbance in "alarm posture" (Geist 1971). An interruption in maintenance activity (IMA) was the period during which a sheep interrupted resting or foraging activities to assume an alert posture or withdraw from the disturbing stimulus.

Mean values were compared with analysis of variance, Student's t test, and the Neuman-Keul multiple range test. When appropriate, logarithmic transformation was used to produce homoscedasticity. When homogeneity of variances could not be assumed, Student's t test for unequal variance was applied. Frequencies of behavioral patterns were compared using the chi-square statistic with Yates correction for continuity. Unless otherwise stated, significance was set at the 5% level. Means are presented with ± 1 SE. All statistical procedures followed Steel and Torrie (1960) and Zar (1974).

RESULTS

Approach by Humans

Mean maximum rise in HR (ΔHR), overall mean elevation in HR throughout the entire approach sequence, and mean withdrawal distance were all greater ($P < 0.01$) in Types II and III than in Type I approaches (Table 1, Fig. 1). In Types II and III trials, HR generally increased from beginning of the advance until the approaching person (accompanied by a dog in Type III trials) was within 50–25 m of the sheep, after which HR declined as the person withdrew. In Type I approaches, no discernible rise in HR occurred until the person was within 50–25 m of the subject (Fig. 1). Moreover, sheep withdrew from the advancing person at distances exceeding 50 m in only

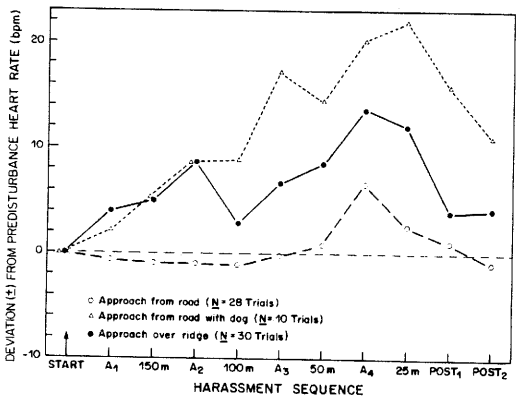

Fig. 1. Mean heart rate responses of mountain sheep (4 ewes, 1 ram) to standardized approaches by a human. Distances (m) at which person made 3-minute stops are indicated along the abscissa; $A_1 \ldots A_4$ = person approaching sheep; $Post_1$ = 2-minute postdisturbance; $Post_2$ = 4-minute postdisturbance.

3.6% of Type I, as opposed to 27.6% of Types II and III approaches ($P < 0.02$). In all trials (Types I through III), there was no difference ($P > 0.05$) in HR when the person was walking towards the sheep or standing stationary at the prescribed stops. Although most HR responses were positive, a drop in HR (−6 to −30 bpm) occurred in 28% of all trials when sheep were first observed to orient, or become alerted to the approaching person. This alarm bradycardia has been often reported in mammals (Adams et al. 1971, Moen et al. 1978, Jacobsen 1979).

There was usually little correspondence ($r = 0.03$–0.31, $P > 0.05$) between mean elevation of HR in any of the trials, and day of observation, time, weather, or social and physical environments of sheep. In no case did we observe a reduction in HR response with repeated harassment trials. In Type III approaches, HR response actually increased with successive trials ($r = 0.77$, $P < 0.01$). As expected, inclines of slopes on which sheep occurred (0–33.5°) and mean elevtion in HR varied inversely ($r = -0.37$, $P < 0.05$) in Types I and II approaches. A negative correlation ($r = -0.36$, $P < 0.05$) also existed between HR response and group size in Types II and III approaches.

Vehicular Traffic and Aircraft

Only 19 of 215 documented passes (8.8%) of sheep by vehicles evoked HR responses. These responses were usually of low amplitude, with a mean maximum rise in HR of 25.0 ± 3.6 bpm, and a mean recovery time of 26.7 ± 9.8 sec. Moreover, 73.7% of all HR responses occurred when vehicles passed within 25 m of the subject. We observed no consistent relationship between HR response and vehicle type (cars, trucks, motorbikes, snowmobiles, graders), frequency of successive vehicle passes, time, or location in the sanctuary. Behavioral reactions were minimal; only 2 of the 215 vehicle passes (0.9%) evoked withdrawal responses by sheep.

No HR responses were associated with helicopter or fixed-wing aircraft at distances exceeding 400 m from sheep. However, during 5 direct overflights by Bell-206 or Hughes-500 helicopters at 90–250 m above ground level, HR of 3 ewes increased 2–3.5× (ΔHR = 60–120 bpm), with recovery times of 20–65 seconds. In each instance, sheep ran for 2–15 seconds prior to attainment of maximum HR.

Sensitizing Effects

There was some evidence of increased sensitivity to further disturbance for a short period following initial arousal. The strongest HR reaction to a vehicle (ΔHR = 84 bpm) occurred when a motorbike passed within 50 m of a ewe (E4) 8 minutes after she had been alarmed by a coyote (*Canis latrans*). In 3 other instances, within 30 minutes following disturbance by a canid or conspecific, ewes

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Cardiac vs. Behavioral

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(E1, E3, E4) responded to such subtle stimuli as the sound of a car door closing, sight of people walking across a distant field, or appearance of a low-flying common raven (*Corvus corax*). Normally, these stimuli evoked no detectable HR response.

Cardiac vs. Behavioral Indices

A total of 142 instances (N = 8 sheep) was documented in which a HR response clearly coincided with disturbance by a human, vehicle, aircraft, conspecific, or predator. Confirming earlier work (MacArthur et al. 1979), 73.9% of all HR responses preceded or occurred in the absence of any motor activity by sheep. However, mean duration of HR responses occurring in absence of withdrawal from stimuli by sheep (37.9 ± 4.2 sec) was only 15.6% of mean duration of HR responses (243.6 ± 5.3 sec) also accompanied by motor reactions ($P < 0.001$). Significance of motor activity was also apparent from the positive correlation ($r = 0.50$, $P < 0.001$) between duration of withdrawal (walking, trotting, running) and HR recovery time. Moreover, when sheep assumed an alert posture but did not withdraw, mean HR recovery time (41.0 ± 7.1 sec) did not differ ($P > 0.05$) from that observed when there was no behavioral reaction (36.6 ± 5.7 sec).

Overall, mean duration of the HR response to disturbance (138.6 ± 26.8 sec) was not significantly greater than the mean period (112.4 ± 16.2 sec) during which maintenance activity was interrupted (IMA). However, discrepancy between these variables was related to duration of the cardiac response. For instances (N = 117) where HR recovery time was less than 200 seconds, mean duration of IMA (72.1 ± 9.9 sec) actually exceeded that of the HR response

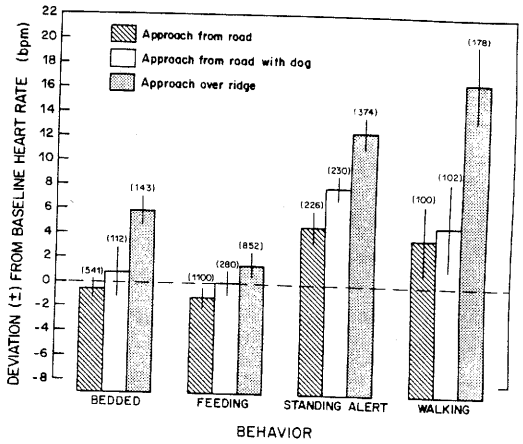

Fig. 2. Heart rates of mountain sheep (4 ewes, 1 ram) in relation to behavior during harassment trials. For each activity, HR is expressed as a deviation (±) from mean baseline value recorded for that same activity when sheep were undisturbed. Values are means with 95% confidence limits indicated by vertical lines and sample sizes given in parentheses.

(57.5 ± 4.5 sec), although not significantly. Conversely, in instances (N = 25) where HR recovery time exceeded 200 seconds, HR response averaged 1.9 × IMA (664.6 vs. 343.5 sec, $P < 0.10$).

These findings suggest that HR usually recovered to predisturbance levels before, or shortly after maintenance activity was resumed. They further imply that so long as the animal is engaged in maintenance behavior, its physiological response to a potential stressor is likely minimal. In fact, mean heart rates of sheep feeding or bedded during harassment trials were usually within 1.5 bpm of mean baseline values recorded for these same activities when sheep were undisturbed (Fig. 2). In contrast, when sheep were standing alert or walking away from the advancing person, HR averaged 4–16.6 bpm higher than when undisturbed. These latter deviations from baseline values were greater ($P < 0.01$) for all trials than deviations recorded during bedding and feeding behavior.

DISCUSSION

The low reactivity of Sheep River mountain sheep to human disturbance confirms expectations for a population existing in a known, and largely predictable environment (Geist 1979:24). As the road was the focal point of human activity in the sanctuary, it is not surprising that few responses were observed to traffic or approach by humans walking directly from parked vehicles. Predictably, strongest reactions to an approaching human occurred when the person was accompanied by a leashed dog (Fig. 1, Table 1). Canids are traditional predators of mountain sheep (Murie 1944), and an earlier study (MacArthur et al. 1979) identified free-ranging dogs and coyotes as stimuli evoking maximal HR responses. Behavioral studies (Walther 1969, Baskin 1974, Bergerud 1974) have also emphasized strong alarm reactions by ungulates to canid predators.

The greater sensitivity of mountain sheep to human approach from over a ridge (Type II), rather than directly from the road (Type I) was expected. Most encounters with humans (often amateur photographers) in the sanctuary occur proximal to the road, hence the Type II approach was a departure from the usual experience of these sheep. The increased sensitivity of sheep to approach from above may also relate to the tendency for mountain sheep to run uphill into cliff terrain when alarmed (Hicks and Elder 1979).

Though statistically weak, negative correlation between HR response and inclines of slopes on which sheep occurred may reflect security associated with precipitous terrain (Oldemeyer et al. 1971). We have also observed (MacArthur et al., unpubl. data) that when sheep were feeding on slopes (incline 10–34°), HR was significantly lower than when the same animals were feeding on open meadows (incline 0–6°). These observations suggest the importance of steep terrain in the habitat requirements of mountain sheep. In agreement with behavioral studies of mountain sheep (Berger 1978) and other social ungulates (Walther 1969, Bergerud 1974), our data also imply greater security (i.e., lower HR response to disturbance) with increasing group size.

The ability of mountain sheep to coexist with humans in areas protected from hunting is well known (Geist 1971, 1978; Hicks and Elder 1979), and the present study reveals the extent to which this species is capable of habituating to common human-related stimuli. Our data also suggest that on sheep range used heavily for recreation, disturbance to sheep may be minimized by restricting human activities to roads and established trail systems. The presence of dogs on sheep range should be discouraged.

EVALUATION

Cardiac responses harmonize with classical learning theory, and in many instances, confirm overt reactions of animals to disturbing stimuli. However, as physiological telemetry is costly, the relative merits of HR vs. behavioral observations in harassment research should be assessed.

First, as HR is a principal determinant of blood flow to tissues, much interest has been generated in using HR telemetry to predict metabolic rate (MR) in unrestrained animals (Flynn and Gessaman 1979). Though acceptable correlations often result, the regressions relating HR and MR may vary with individual animal, time, behavior, and social context. Also, there are neither convincing theoretical nor empirical reasons why HR should accurately predict MR during periods of

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WINTER HABITAT SE

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E. EARL WILLARD, School of Forestry

Abstract: During winter 1975–7 *densis*) provided data on habitat s against upper elevations, drainag east and southeast aspects, areas ($P < 0.1$) were shown for cliffs, a terrain or cliffs, and shrubland-gr at higher elevations ($P < 0.05$) t elevations throughout the winte from direct observations and fe

The importance of win welfare of mountain she pressed by several inves and Frost 1942, Smith 1960, Oldemeyer et al. 1972). However, the mi logical, topographic, and which provide adequate received limited study variables selected woul for selecting transplant dequate winter range. observed that evaluat transplant sites is com tuountain sheep are se bitat requirements ar vided. obtaur objectives were alonscribe the habitat clarifo in winter, identi sheeamong those avail mans. reference of m HR re and abiotic e ration, n winter range. behavio populatio frequency cardiac and the National HR telemeti nt Institute means of q periment S rassment th e Researc This is espec ess: Soil 170.