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HEART RATE RESPONSES OF BIGHORN SHEEP TO SOME ENVIRONMENTAL FACTORS[1]

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ABSTRACT ONLY

Responses of free-ranging bighorn sheep to their environment were examined via heart rate telemetry. Heart rate is a well-established correlate of arousal and anxiety. Thus, it is a good indicator, though not an exact physiological equivalent of the stress experienced by an individual. Equally important, heart rates could be determined in the field.

Cardiac electropotential changes were monitored by two sub-cutaneous electrodes inserted over the sternum to minimize noise from muscle artifact. The EKG's were transmitted by a 1 milliwatt FM transmitter designed by the University of Calgary and mounted externally in a leather "backpack" harness. EKG signals were recorded as audio tones on one channel of a stereo cassette recorder with simultaneous verbal accounts of visual observations on the other. Observations were usually made from 400 to 500 m away and rarely from within 20 m of the sheep.

The study population was located on Ram Mountain, Alberta. This is a healthy, isolated, non-migratory herd in almost daily contact with one or two researchers through each summer since 1971. Five sheep were studied from 3 1/2 to more than 9 weeks each during June, July and August, 1979. Three were ewes with lambs, one a ewe without a lamb and the fifth study sheep was a two year old ram. Effects of environmental factors on heart rate were examined by multivariate analysis using the ANOVA program of the SPSS computing package. This allowed the results to be adjusted for interactions among the factors and to be simultaneously adjusted for the effects of activity, metabolic weight and individual differences. Additionally the results were adjusted for time of day since the study sheep were found to display circadian heart rate rhythms. The results of this analysis were extremely significant. The summary equation generated was further tested by separate analysis for each sheep, each habitat type, each major activity and with detailed control for circadian rhythms. Though these results were not all identical, the few exceptions were essentially consistent with the relationships shown by the summary equation.

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Variables known to affect heart rate caused it to change as expected. Heart rate decreased with increasing metabolic weight [HR (bpm) $\propto$ -2.67 $(kgm)^{0.75}$] and increased with increasing activity level. For example, heart rates averaged 13.2 bpm higher when feeding than when bedded. Individual differences in baseline heart rate were present and appeared to reflect in part the rate of growth, lactation and age of the sheep.

Thermal conditions were evaluated by means of black-bulb temperature, a measure integrating the effects of ambient temperature, solar radiation and convective cooling. Heart rates decreased quadratically as temperature increased [HR $\propto$ - 0.00688T^2 (C°)] reflecting decreased heat production in the thermoneutral zone. Evidence of heat stress was also seen in some sub-samples with heart rate increasing with tempeature. Occurrence of heat stress was contingent upon the baseline heart rate of the sheep which, in turn, depended upon time of day and activity. Although the upper limit of the thermoneutral zone clearly depended upon a number of factors it is felt to have been in the range of 25 to 30°C, black bulb. This is equivalent to ambient temperatures of 18-20°C, sunny with up to 4/8 cloud cover and light breezes. The sheep responded to heat stress by postural changes, by using favourable microclimates, particularly higher elevations, and by decreasing time spent foraging.

Results also showed that the heart rates of sheep responded to security features. Expotential increase in heart rate with increase in distance from escape terrain [HR $\propto$ 0.594 $(DESC(m)/100)^{1.5}$] was one of the most significant effects observed, physical or environmental. Once adjusted for distance from escape terrain heart rates were also low when the sheep were on talus slopes, higher on meadows, and more so, in shrubbery (+4.5 and +6.2 bpm relative to cliffs, respectively). It is hypothesized that these increases were the result of loss of advantage with respect to potential predators due to changes in footing and visibility. Though footing on talus slopes is poor for bighorns, it is worse for predators, as seen during the study in the uncomfortable, noisy and ineffectual approaches of the sheep executed by two dogs. Meadows do not provide this advantage to the sheep. Areas of shrubbery further disdvanntage them by severely restricting their ability to detect predators. Responses to tree cover were mixed. When in secure habitat (cliffs and talus) the sheep perceived tree cover as a noxious feature, as seen in increased heart rate with proximity to trees. However, in unsecure habitat heart rates were lower near tree cover. Within cover there also appeared to have been both secure and unsecure situations depending upon undetermined factors. Minimal predation on the herd probably allowed cover to be conditionally secure - except for its distance from escape terrain.

Heart rate increases in response to security features could be considerable. A change in location from cliffs into shrubbery 300 m away was accompanied by a heart rate increase of 11.8%. This shows that the situation of the sheep with respect to key environmemtal features was important enough to produce sustained physiological changes indicative of chronic stress. In spite of this, the sheep were still found in the

unsecure habitats (meadows, shrubbery and cover) over half of the time recorded because of the forage found there. Here, they attempted to minimize anxiety by staying close to escape terrain. Seldom were they further than 300 m away and continuations of good feeding sites extending more than 500 m from cliffs were never utilized by the study sheep.

CONFERENCE DISCUSSION

Q. Did you say the predation rate in the area was low?

Ans. Yes, the predation rate was low. There are apparently some cougar up there and some black bears. I've heard coyotes around the mountain a number of miles to the east, when I was driving in. But there were no scats or tracks on the upper parts of the mountain. I think there may have been predation, but not a large amount.

Q. Is it possible that the unusually nervous ewe had seen a predator and others had not?

Ans. Yes, it's possible. Also the low growth rate of her lamb occurred prior to my using her in the study. It was not a response to the study; to wearing that backpack harness. On the 3rd of June, her lamb was 3-4 Kg. heavier than any other lamb measured around that time. But, by the 17th of August, her lamb had only gained 3 Kg. Other lambs were much heavier than that 2 weeks earlier. I think this was largely the result of her staying close to the cliffs and not using the best meadows. Although there will be some physiological stress effects, I think one of the most important costs of anxiety due to habitat changes that bother sheep, or due to harassment, may be functional loss of habitat.

Q. Two questions. First, did you ever have an opportunity to record heart rates in denser cover types, say with greater than 25% tree coverage?

Ans. Some of the data were from such types. But I had to group the data just to get reasonable sample sizes so one category was not swamped by others. In this type of analysis, if you divide a variable into categories and you have one category that has a very small sample, its effect may be exaggerated. I had to group the cover category to include everything greater than 10% tree cover for that reason. Part of the mixed response to cover may well have been due to differences in density of cover included in one category. Normally, when they bedded in cover, they were in the less-dense margin. But still, a lot of time spent standing in cover--when they were noticeably not secure, having high heart rates,--not like when bedded--was still in that less dense margin.

Q. And finally did you have any chance to measure any group-size effects on heart rate.

Ans. Group size was untestable. I really wanted to test it, but I found that group size responded similarly to heart rate, when tested against a number of the other variables. Partly this was coincidence and partly, I think, because of behavioral response. For example, when the sheep were distant from escape terrain, you tended to get large groups and high heart rates. What happened in the analysis was that group size stepped in as a proxy for all the other variables and so was the first in the equation versus heart rate. So it produced a high positive relationship with heart rate. I was able to test the effect of group size in my harassment trials. When I looked at my, something like 47 approaches or overpasses, I found a significant shortening of the relaxation time with increases in group size. It only explained about 11% of the variance but it was significant. That's the best I could come up with on group size.

Q. Shortening of the length of the response?

Ans. Of the period during which a significantly higher heart rate occurred. This was shorter, the larger the group was. It was significant at the 10% level, but it only explained 11% of the variance.

Q. Would you comment more on your harassment trials. What you did, what you found.

Ans. That would take a fair bit. There were only 21 completely separate trials, involving about 47 or 48 approaches or overpasses. I only considered them to be demonstrations of what can happen. What they do demonstrate is that physiological and behavioral responses are very different and they demonstrate that some of the relaxation times can be extremely long. Single approach by two individuals, unknown to the sheep required 960 seconds before heart rate returned to normal. That's something like 16 minutes. A single overpass by a helicopter, which caught them by surprise away from escape terrain--it came directly from behind them over cliffs, so it was 1400 feet above them, but only a few hundred feet above the cliff, and flew straight over them at 80 Km/hour and away--produced significantly higher heart rate for about 27 minutes. But the effect was not always that great. Another sheep, with a helicopter overpass, a number of overpasses, while she was at the base of the best cliff on the mountain, had relaxation times of less than 3 minutes.

Persistence, I'm convinced is an important factor. If an intruder continues to approach, or makes a second approach after the sheep has responded with increased heart rate or intent to break away, the heart rate is higher and the relaxation time is longer the second time. And that is not because the intruder is closer. Often the sheep has broken off, and if the individual comes towards it again it is at a much greater distance; yet you get a much longer relaxation time. So persistence is an important factor.

I can give perhaps a little bit of information on the difference between behavioral and heart rate responses. After excluding the

helicopter data, which tended to be intense, I was able to partition the responses into two characteristic patterns, based on period of interrupted maintenance activity. This is when the animal is no longer bedding or feeding, but either standing, walking or running. With interrupted maintenance acitivity of a minute or less, heart rate relaxation times were always as long or longer than activity interruption. The heart rate response was always as long or longer than the behavioral response. With periods of interrupted maintenance activity of longer than a minute, maintenance activity interruption tended to be longer than the heart rate responses. But the exceptions were profound. Exceptions were extremely long heart rate responses, 2715 seconds, when the behavioral estimate was no more than 1400 seconds. You are under-estimating by 1300 seconds. If you looked at interrupted maintenance activity periods of less than 60 seconds, the average was 8.6 seconds. For more than 60 seconds, the average interrupted maintenance time was on the order of 7 minutes. But for both of those categories, more or less than a minute in terms of interrupted maintenance activity, the heart rate relaxation was on average 6 minutes. So just by looking at the sheep you can't tell how much it is responding.

Bob MacArthur, using Sheep River sheep, (one of his articles is in Canadian Journal of Zoology in 1979) found much shorter responses of sheep to helicopters. Perhaps 65 seconds longest relaxation time. That's right, 20 to 65 seconds relaxation time. Those sheep were probably more used to helicopters than were mine. It would seem that habituation can occur but it does not always. On the other hand, I often found sensitization occurring, and Bob has found this with approaches of a person over a ridge or of a person with a dog. You cannot always assume habituation, but it seems that it does occur in some cases. The behavioral responses of my sheep to helicopters are more like Bob MacArthur's, although I had very long heart-rate relaxation times. Then there are to some that Brian Horesji has reported. He has noted some panic runs of up to a mile. How, behavioral ahd physiological responses may not be equivalent, but if you see an animal in a panic run for a mile due to an object a half mile away, then I think you can pretty safely predict there's a profound physiological response too. So the Ram Mountain sheep seem to be intermediate insensitivity.

Oh, and one other thing, a very short sharp stress response is very adaptive. Individuals that are particularly healthy, particularly well adapted, and coping well tend to have short sharp responses. If you should approach an animal and it finally gets to the point where it doesn't like you and bolts and then stops, if the heart pattern is doing the same thing, you may very well have a minimum response compared to an individual who did not move. One sheep remained bedded through the whole trial, yet heart-rate relaxation time was 1980 seconds. Yet I was positive that there was no response. I was positive I would have nothing out of that trial, just showing that this sheep could not be bothered. There was one time that I threw a rock at her, I was convinced that she was stuffed. But she was responding all of the time.

Q. Was your ram more comfortable away from the escape terrain than the ewes?

Ans. Did not appear to be. He was a 2-year old ram.

Q. Was he with the ewe-lamb groups then?

Ans. He was. His heart rate fluctuated a lot.