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Limitations of Receiver/Data Loggers for Monitoring Radiocollared Animals

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Abstract

We evaluated the effectiveness of receiver/data loggers for monitoring the presence/absence of radiocollared animals in discrete areas. Our primary objective was to determine how variation in transmitter signal strength affected the size of area being monitored. This information will help researchers better manage the uncertainty related to determining an animal's location relative to a discrete boundary. We used an adjustable attenuator to measure signal strength to determine the minimum number of decibels (dB) required to eliminate detection of a radio signal by receiver/data loggers. We quantified how dB varied depending upon orientation of the transmitter on the animal and distance from receiver/data logger (radius of detection). Based upon this signal strength variation, we then calculated a zone of uncertainty (i.e., the area in which detection of a radio signal was uncertain at a particular radius of detection). The zone of uncertainty increased exponentially with a linear increase in radius of detection. We do not recommend using receiver/data loggers to monitor radiocollared animals in discrete areas unless uncertainty is acceptable. (WILDLIFE SOCIETY BULLETIN 34(1):111–115; 2006)

Key words

data logger, presence/absence, radiotelemetry, signal strength variation, wildlife.

Determining the presence/absence of animals within a defined area or at a specific site can be an important goal for both research and management. Radiotelemetry data loggers have been used in studies to determine the presence/absence of radiocollared animals (Harrington and Mech 1982, Cooper and Charles-Dominique 1985, Petron et al. 1987, Licht et al. 1989). For most applications the area being monitored was not specified (see Callo et al. 2002). Knowing the presence/absence of an individual without knowing the area being monitored is of limited use, particularly for questions of site fidelity and activity patterns (e.g., feeding sites or den sites).

Conceptually the amount of area being monitored by a receiver/data logger is dependent solely on a transmitter's signal strength. However, all else being equal, a stronger transmitting signal will be detected at a greater distance by a receiver/data logger than a weaker transmitting signal. Consequently, the size of the area being monitored will be larger for stronger transmitting signals and smaller for weaker transmitting signals. This implies that variation in transmitting signals is related to the size of the area being monitored. This relationship may make it difficult to say definitively whether an animal is within a defined area.

Transmitter signal strength can vary both between transmitters and within transmitters. Between-transmitter signal strength variation results from inconsistent manufacturing and can be controlled by purchasing high-quality transmitters that are bench-tested for consistency prior to their deployment. Within-transmitter signal strength variation is caused by a number of factors, including radio frequency interference (ambient background radio traffic), vegetation type, environmental factors, topography and orientation of the transmitting antenna. The orientation of transmitting antenna on the animal accounts for most of the variation experienced in the field (Beaty 1992). Controlling this source of variability is operationally impossible because it is affected by animal movements and the position of the transmitting antenna (vertical or horizontal and facing toward or away from the receiver/data logger).

We were interested in determining if we could identify an area to be monitored and then set the range of a receiver/data logger so radioed animals were detected only when they entered the discrete area. There is little information on whether receiver/data loggers can be used in this manner and, if so, how to reliably adjust receiver/data loggers to monitor different sized areas.

We evaluated how within-transmitter signal strength variation affected the use of receiver/data loggers for monitoring presence/absence of radiocollared animals in a discrete area. We initially quantified how transmitter signal strength varied relative to the orientation of the transmitter antenna and then calculated how this variation would be influenced by the size of the area being monitored. To conduct this evaluation, we had to adjust the distance at which a receiver/data logger would detect a transmitting signal and, thus, the size of the area monitored. Setting the distance at which transmitter signals are received has been attempted by controlling sensitivity of the receiver/data logger through manipulation of the squelch or gain (Callo et al. 2002, S. W. Breck, USDA-WS-National Wildlife Research Center, personal experience). This procedure attempts to attenuate the strength of the transmitting signal. However, for our application we found this method to be unreliable. Concomitantly, we evaluated an alternative method using an adjustable radio frequency (RF) attenuator.

Study Area

This study was conducted at the Shortgrass Steppe (SGS) Long-term Ecological Research (LTER) site, located approximately 60 km northeast of Fort Collins, Colorado (http://sgs.cnr.colostate.edu/About/SiteDescription/SiteDescription.htm). The topography varied from flat to small rolling hills and the vegetation was dominated by shortgrasses, forbs, succulents, and half-shrubs. We

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selected treeless sites where we could maintain line of site between the receiving station and the transmitter without signal interference.

Methods

To quantify variation in signal strength, we established 4 transects where each transect had a 1-m wooden post hammered into the ground at 25, 50, 75, 100, 150, 200, 300, and 400 m. We refer to these distances as detection radiuses. We conducted 2 trials at each transect and used the same transmitter for all trials. For each trial we set up an omnidirectional receiving antenna at 0 m and connected it to a receiver (model R2100)/data logger (DCC Model D5041, Advanced Telemetry Systems, Incorporated, Isanti, Minnesota) with 20 m of RG-58 coaxial cable. Because signal attenuation can occur with RG-58 coaxial cable that is over 15 m, we recommend using RG-8 to compensate for long runs (>15 m) of coaxial cable. The receiving antenna was a custom-designed dipole with +1 decibels (dB) of gain mounted 0.5 m above the ground on a wooden box. The typical detection pattern of this type of antenna is close to a circle, which we verified prior to use of the antenna in the field.

We used a Manual Step RF Attenuator (Model 839, Kay Elemetrics Corporation, Lincoln Park, New Jersey) placed between the receiver/data logger and antenna to adjust the amount of area being monitored. The Manual Step Attenuator was able to attenuate a signal by 0–101 dB in increments of 1 dB. We placed all equipment inside a metal box and grounded the box by hammering 1 m of rebar into the ground and attaching grounding wire from the box to the rebar. We found that grounding the entire system was critical for attaining consistency in our receiving system because it prevented transmitting signals from carrying through the ground and being detected by the receiving system. Thus, our receiver/data logger was set up and grounded 20 m away from our antenna so our presence would not affect radio signals received by the antenna (Fig. 1).

A trial consisted of a person operating the receiver/data logger and another person walking to each marker with a radiotransmitter (Telonics Mod-500, Telonics, Incorporated, Mesa, Arizona). At each marker 3 scenarios were enacted: 1) the transmitter was hung on the wooden stake with the transmitting antenna in vertical position and facing the receiver/data logger (unattached); 2) the transmitter was attached to a dog and the dog sat so the transmitter antenna was in vertical position and faced the receiver/data logger (best-case); and 3) the transmitter remained on the dog with the antenna in vertical position but the dog sat with the transmitter antenna facing away from the receiver/data logger (worst-case). For each scenario the person walked 20 m away from the transmitting antenna and notified the person at the receiving station to begin. The person at the receiving station then used the attenuator to add or subtract decibels until the minimum number of decibels was added so that the data logger no longer recorded a signal. All work was performed following approval by the National Wildlife Research Center's Institutional Animal Care and Use Committee under QA-872.

Theoretically, the relationship between number of decibels required to prevent a signal from being detected and distance of transmitter from the receiver/data logger is logarithmic, with an addition of roughly 10 dB to the attenuator equating to a halving of the distance at which a transmitter can be detected (Naval Air Warfare Center 1999). To determine whether our data conformed to this theory, we conducted linear regression analysis using the number of dB required to eliminate a signal as the dependent variable and the log-transformed detection radius as the independent variable (SAS Institute, Incorporated 1999 [PROC REG]). It is possible that data from the 2 trials at each transect were not independent; therefore, we used the data from the 2 trials at each transect to calculate average minimum dB at each distance for each of the 4 transects and used these values in our analyses. We completed a separate analysis for all 3 scenarios. We calculated difference in minimum dB between each scenario by first computing the mean dB for each scenario using a mixed-models approach and treating distance data as repeated measures (SAS Institute, Incorporated 1999 [PROC MIXED]). We then subtracted mean values of scenario 2 (best-case) from scenario 1 (unattached), and scenario 3 (worst-case) from scenario 2.

Figure 1. Photo demonstrating the setup of equipment used in field trials to evaluate the effect of variation is transmitter signal strength on the size of area being monitored. The metal box next to the person is grounded and contains the receiver/datalogger and manual step attenuator. An omnidirectional antenna is mounted on a wooden stake approximately 20 m from the box and connected to the receiver with coaxial cable. Maintaining distance from the receiving antenna was important for reducing interference with radio signals. The dog (Reed) has a radiocollar around his neck and is sitting next to a stake that is 25 m from the antenna.

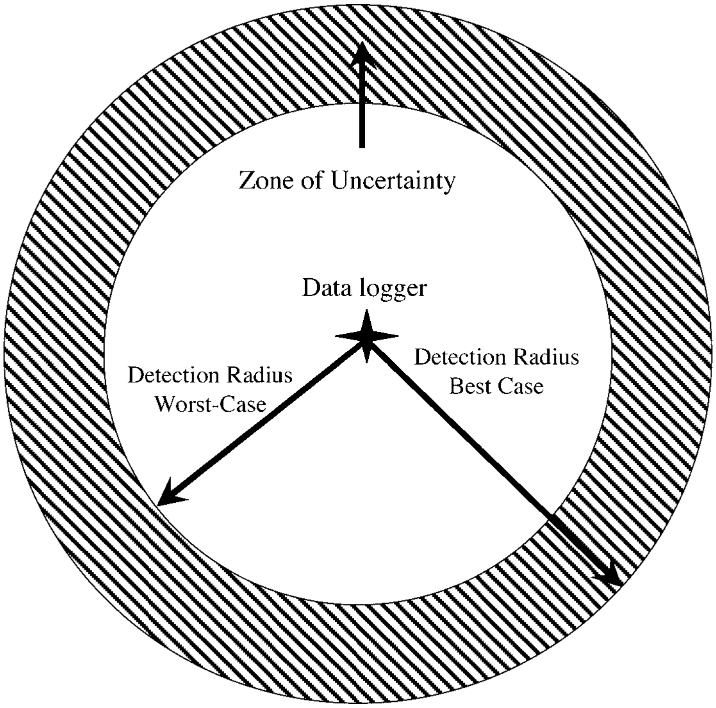

Figure 2. Schematic demonstrating how variation in transmitter signal strength between best-case and worst-case scenarios can create a zone of uncertainty where a radiocollared animal may or may not be detected by a receiver/data logger.

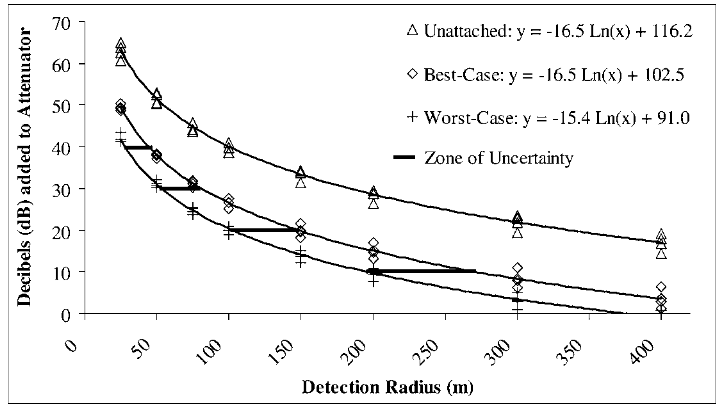

Figure 3. Minimum dB added to an attenuator to eliminate the transmitter signal from being detected by a receiver/data logger. Unattached scenario has a transmitter hanging on a wooden stake with the antenna in vertical position; best-case scenario has a transmitter attached to a dog and the dog placed so that the transmitter faces the receiver with the antenna vertical; worst-case scenario has a transmitter attached to a dog and the dog placed so the transmitter faces away from the receiver with the antenna in vertical position. Formulas were derived from regression analysis.

We also calculated a variable defined as the zone of uncertainty (Fig. 2). This variable represents the area where a radio signal may or may not be detected by a receiver/data logger because of variation in transmitter signal strength. For best- and worst-case scenarios, we used the regression equations from the above analyses to calculate a detection radius at each of 5 attenuator settings (50, 40, 30, 20 and 10 dB: Fig. 3). We used these detection radiuses to calculate the amount of area being monitored and then calculated the area of the zone of uncertainty for each of the 5 attenuator settings by subtracting the area for worst-case from best-case scenarios.

Results

Data from all 3 scenarios verified a logarithmic relationship between decibels added to the attenuator and distance of transmitter from receiver (unattached: $r^2 = 0.989$, $P < 0.0001$; best case: $r^2 = 0.989$, $P < 0.0001$; worst case: $r^2 = 0.986$, $P < 0.0001$), demonstrating that an addition of 10 dB to the attenuator equated to an approximate halving of the distance at which a signal was detected (Fig. 3). The mean difference in minimum dB between scenarios 1 and 2 (unattached and best-case) and 2 and 3 (best- and worst-case) were 13.6 and 3.5 dB, respectively. Both the difference in detection radius between strongest and weakest scenarios and area of the zone of uncertainty increased exponentially as minimum dB added to the attenuator decreased (Table 1, Fig. 3).

Discussion and Management Implications

We demonstrated that variation in transmitter signal strength has important consequences that limit the utility of receiver/data loggers for monitoring the presences/absence of radiocollared animals in discrete areas. Specifically, we showed that signal strength from a transmitting antenna facing away from the receiver (worst-case scenario) will be less than when the transmitting antenna is facing toward the receiving antenna (best-case scenario). The difference between the strongest and weakest transmitting signal creates a zone of uncertainty where an animal may or may not be detected by the data logger. Because the relationship between the number of decibels required to prevent a signal from being detected and distance of transmitter from the receiver/data logger is logarithmic; the zone of uncertainty increases exponentially as the detection radius increases (Table 1).

Our trials investigated how transmitter signal strength can vary because of a single factor (i.e., orientation of transmitter) and how

Table 1. Calculated detection radiuses and corresponding areas for best- and worst-case scenarios at 5 attenuator settings. Detection radiuses were calculated using regression equations generated from empirical data. Difference in area between best and worst cases represents the size of the zone of uncertainty.

dB	Detection radius (m)			Area (m^2)		
	Worst-case	Best-case	Difference	Worst-case	Best-case	Difference
50	15	24	9	658	1,820	1,162
40	28	44	16	2,421	6,110	3,689
30	53	81	28	8,905	20,513	11,608
20	102	148	46	32,756	68,864	36,108
10	196	271	75	120,492	231,186	110,694

this variation influences the uncertainty of knowing whether an animal was present in a discrete area. We focused on this variable because it is a primary source of uncontrollable signal-strength variation. However, it is likely that other orientations of the transmitting antenna (e.g., vertical versus horizontal) and heights of the transmitter (e.g., flying birds and arboreal/fossorial mammals) also influence signal strength variation. For biologists considering the use of data loggers for monitoring the presence/absence of radiocollared animals, it is critical to experiment with different orientations of the transmitting antenna to fully understand the range of possible variation in signal strength. Understanding how the zone of uncertainty is influenced by variation in signal strength and distance of transmitter from the receiving station should help biologists evaluate whether receiver/data loggers could be a useful tool.

A wide variety of other factors influence transmitter signal strength and the ability of data loggers to detect a radio signal, including radio frequency interference (ambient background radio traffic), vegetation type, topography, height and configuration of receiving antenna, receiver sensitivity, and tuning the optimal transmitter frequency on the receiver. These variables are important but should remain constant within a monitoring site and, therefore, not cause variation in signal strength that leads to uncertainty of the presence/absence of a monitored individual. Knowledge of equipment (e.g., how antenna type and configuration influence detection patterns) and field testing will help biologists adapt receiving systems to local conditions and, therefore, control for those variables that vary between but not within monitoring sites.

Our data suggests that receiver/data loggers have limited utility in reducing the uncertainty related to an animal's presence/absence in a discrete area. In situations where this is acceptable, receiver/data loggers as a detection mechanism may be useful as long as the users understand that uncertainty increases with distance. For those situations deemed appropriate for using receiver/data loggers to monitor the presence/absence of radiocollared animals, we offer the following advice for setting up a system. First, a radiotransmitter should be attached to a surrogate animal; doing so attenuates the signal (in our trials on average of 13 dB) and simulates what happens when a transmitter is attached to a study animal. If a surrogate animal is not used, the area being monitored would be smaller than expected because an unattached collar has a stronger signal strength than an attached collar. In this case the user may incorrectly increase the number of dB added to the attenuator and, thereby, decrease the area being monitored.

Second, with the transmitter attached to the surrogate animal, the strategy is then to determine the orientation of the animal so that the strongest and weakest signals from the attached transmitter can be determined. Understanding the strong and weak signals is essential for properly setting up a system.

We used receiver/data loggers in conjunction with message transmitters to alert personnel of the presence of habituated black bears (*Ursus americanus*) in campgrounds (S. W. Breck, USDA-WS-National Wildlife Research Center, unpublished data). In this case we set our boundary using the weakest signal to ensure that when an animal entered the discrete area the receiver/data logger would definitely detect its presence. However, setting a boundary with a weak signal will mean that animals outside the established boundary could be detected. In this example having bears detected outside the discrete areas was acceptable because it was likely those bears were going to enter an area off-limits.

The last step is to position the surrogate animal at the periphery of the area to be monitored and have another person add or subtract dB to the attenuator so that the transmitting signal is no longer detected by the receiver/data logger. The person with the surrogate animal should then walk the perimeter of the monitored area, periodically stopping so the person at the receiver/data logger can evaluate whether a signal is being logged. In this way the perimeter of the radiotelemetry detection area is determined and if the perimeter needs to be expanded or contracted, the radius of detection is adjusted by subtracting or adding dB, respectively.

We recommend using an adjustable attenuator to create different-sized areas to be monitored. We found using an attenuator to be more reliable than using the squelch or gain primarily because it was impossible to accurately quantify adjustments to the gain with our receiver/data logger. Furthermore, the receiver/data logger used in these trials was designed to operate most effectively with the gain maximized. It is possible other brands of receivers have different gain controls and that they can be used effectively to attenuate a signal, though we did not investigate this in our study.

Utilizing receiver/data loggers to monitor discrete areas for the presence/absence of radiomarked individuals is possible, though the error associated with the method probably limits their utility in many instances. However, for those situations that are deemed appropriate for receiver/data loggers, we highly recommend the use of an adjustable attenuator to help control the signal strength received by the unit and recommend that time is spent understanding how signal strength can vary with your particular transmitters and system.

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