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A Cost-Effective System for Measuring Microscale Habitat Use of Small Mammals with High Precision

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Abstract

*Radiotelemetry provides an opportunity to measure animal behavior when other methods are not feasible, but triangulation errors limit the grain at which habitat relationships can be inferred. Additionally, inferred behavioral patterns often are biased toward times when organisms are accessible; often, for nocturnal organisms, when the organisms are resting. We developed an automated radiotelemetry system that is precise, temporally unbiased, and cost-effective. The system consisted of a sensor grid composed of radio receivers that detect the presence of a radiocollared animal within a measurable, adjustable area. The aerial extent of detection is testable, precise (mean error <0.5 m), and consistent. After the sensors are installed, data collection effort is minimal. We tested this system by collecting microscale habitat-use data on snowshoe hares (*Lepus americanus*) in eastern Idaho, USA. This system will be useful in applications where extremely precise location data and representative sampling across time are important for assessing use patterns. It is most useful for smaller animals where the spatial constraints are not limiting and Global Positioning System collars are not currently an option.* (WILDLIFE SOCIETY BULLETIN 34(5):1345–1349; 2006)

Key words

Lepus americanus*, microhabitat, radiotelemetry, sensors, snowshoe hare.*

Microhabitat use is difficult to obtain for many wildlife species because telemetry triangulation often lacks precision, and direct observation of wildlife may cause animals to move. Both methods tend to be temporally and spatially biased. Activity indices, such as fecal counts and browsing intensity, are frequently used as alternatives; these methods are cost-efficient and can evaluate habitat use within a predefined plot area (Putman 1984). However, the relationship between the index and actual animal behavior generally is unknown. As an example, for mule deer (*Odocoileus hemionus*), Collins and Urness (1981) observed that defecation rates were highest when deer were most active and immediately following resting. General, coarse-grained patterns of habitat use could be evaluated through relative abundance of pellet groups (see Leopold et al. 1984, Loft and Kie 1988), but interpretation of habitat use at finer scales was not possible.

For snowshoe hares (*Lepus americanus*), virtually all habitat associations have been derived through pellet counts (Conroy et al. 1979, Wolfe et al. 1982, Fuller and Heisey 1986). While there is some evidence that pellet counts reflect hare abundance at broad scales (Krebs et al. 1987, 2003, Mills et al. 2005), their relationship to habitat use at finer scales is untested. Recently, there has been interest in developing complex thinning patterns in lodgepole pine (*Pinus contorta*) to increase biodiversity and tree growth while maintaining snowshoe hare habitat. Designing these thinning patterns requires knowledge of hare behavior at an extremely fine scale, because the thinning involves creating a fine-grained mosaic of gaps within dense forest. One approach would be to design a plot-based system that would detect hares when they were present on the plots, but not otherwise. The plots could then be placed representatively within a stand and frequency-of-use directly related to plot-level vegetation.

Although not related to habitat use, several telemetry devices have been used to monitor either nesting activity (Gilmer et al. 1971, Licht et al. 1989, Callo et al. 2002) or trap encounter rates (Ivan 2000). These devices are based on very short-range detection of radiocollared individuals and were designed to be triggered when the organism approached or crossed the sensor antenna, limiting sensor response to specific behaviors such as nest visitation. This approach, in theory, could be incorporated into a plot-based system to evaluate microhabitat use within a particular area of interest. Our objectives were to develop and evaluate this method to measure microhabitat use of snowshoe hares in young lodgepole pine stands.

Methods

We developed an electronic system of "sensor-arrays" and established this system in 2 young lodgepole pine stands on the Targhee National Forest near Island Park, Idaho, USA. We positioned sensor-arrays 100 m apart in a systematic grid across each stand; sensor-arrays consisted of 9 sensors attached to a data-logger (Fig. 1). We attached sensors to data-loggers through computer network cables at a distance of 25 m (cardinal directions) to 35 m (diagonal distance) from the logger, with one sensor adjacent to the logger.

Data-Logger Design

The data-logger consisted of 3 main components: the micro-control unit (MCU), clock, and data storage, as well as several support components on a copper-etched circuit

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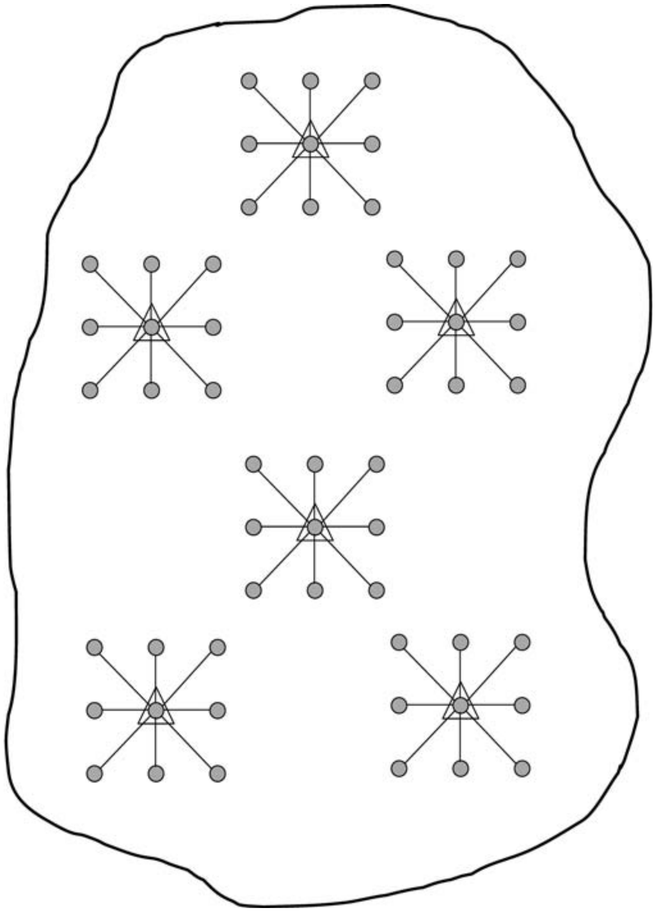

Figure 1. Example layout of sensor-arrays. Each data-logger (triangle) is placed in the center of an array of 9 sensors (circles). Sensor distance from the logger is 25 m along the cardinal directions and 35 m along the diagonals, with one sensor adjacent to the logger.

board. We used the BasicStamp II (Parallax, Inc., Rocklin, California) as the MCU and programmed the MCU using PBASIC (Parallax, Inc.). We attached a "TimeKeeper" (High Techgarage, Racine, Wisconsin) module to the MCU to provide both the clock and data storage in the form of 256-kb electrically erasable programmable read-only memory. Support components for the data-logger board included a 9-V regulator, serial port connection for attaching a palmtop computer, buzzer for testing sensors, a separate MCU (Microchip Technology, Inc., Chandler, Arizona), and an analog-to-digital chip to monitor battery voltage (a detailed schematic of the data-loggers is available from the authors).

Sensor Design

Most radio receivers are tuned to specific frequencies. This tuning both filters out signals at other frequencies and allows reception of weak signals at the desired frequency. We needed to detect hare transmitters associated with multiple frequencies, and only when the hare was immediately above the sensor antenna. Therefore, we designed a de-tuned radio that responded to a broad range of frequencies and only when the signal was strong. The sensor consisted of a modified germanium-diode radio receiver and wire antenna. Instead of using the combination of a tunable capacitor and radio coil common in germanium-diode radio receivers, we used only a radio coil so that the circuitry acquired a broad band of frequencies near 152 MHz. We attached a 2-m wire antenna to the signal-acquisition stage of the sensor (Fig. 2) and placed it in a spiral on the ground or snow surface. Following signal acquisition, the signal was amplified in 3 stages that included a combination of negative–positive–negative transistors (4401 transistors for maximum but stable signal gain), resistors (5% tolerance), and bipolar tantalum capacitors. We designed each amplification stage to provide maximum stability and consistency between sensors and across a broad range of temperatures.

We painted sensors with a nonporous paint to decrease potential corrosion and enclosed them in sealed plastic containers. After extensive experimentation, we found that hot glue provided the best adhesion to plastic containers and ensured a permanent seal. Desiccant was enclosed in containers to remove remaining moisture. We buried each sensor just below the surface (approx. 1 cm) of the ground during snow-free periods of the year, or beneath the snow surface during winter, to reduce any visual changes to the immediate area and moderate diurnal temperature fluctuations. We buried the network cable, attached between the data-logger and sensor, 1 cm in the ground to eliminate signal acquisition along the cable. A sensor could be triggered if the transmitter antenna touched exposed cable within 5 m of the sensor. We placed the antenna in a spiral (3 loops) on top of the ground or snow, extending 0.75 m in radius from the plot center.

Data-Logger Programming

The data-logger was programmed to 1) continuously monitor hare activity at sensors, 2) download data and clear memory, and 3) test sensors (see section below). Data-loggers accepted commands, via serial cable, from a palmtop computer (HP95LX; Hewlett Packard, Inc., Palo Alto, California). A serial communications program provided with the palmtop was used to give commands and download data into ASCII-format files.

The data-logger monitored for hare activity at sensors by waiting for a signal impulse (increase from 0.0 to >1.3 V with duration of approx. 30 milliseconds at >1.3 V) from each sensor. The data-logger polled each of the 9 attached sensors at least once per millisecond until a signal impulse was received from a sensor. Because sensors responded to a wide range of frequencies, the data-logger screened hare signals from other potential radio-frequency sources, such as lightning or vehicles that might pass close to a sensor, by utilizing the pulse-patterns of the hare collars. If a signal impulse was received, the data-logger waited for 1,192 milliseconds (the pulse width of the radiotransmitter signal) and then queried the same sensor again for a second signal impulse. If a second impulse occurred at the specified interval, the signal was assumed to be from a radiocollared snowshoe hare, and the date, time (to the nearest minute), and sensor identification were recorded. We tested the efficacy of this filtering by running the sensors during a

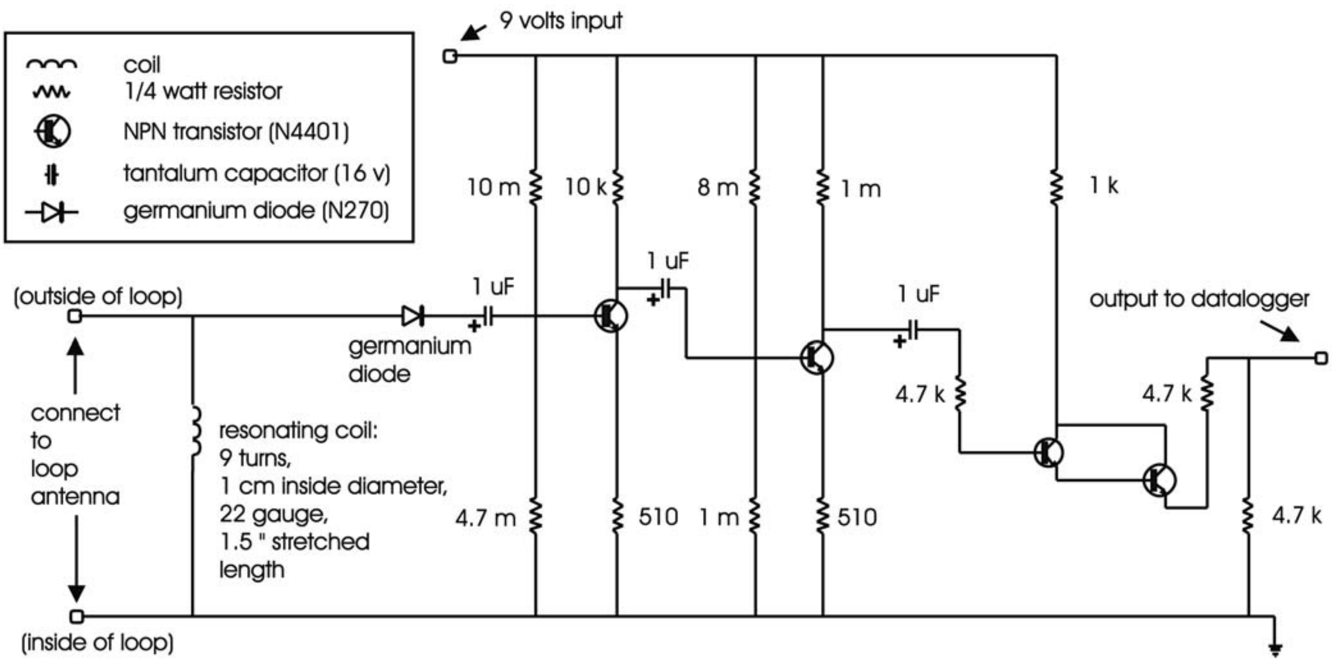

Figure 2. Schematic of the detection sensor.

period of 6 weeks when we knew that no radiocollared hares were present within the stand; no detections were recorded.

While monitoring sensors for hare activity, the data-logger automatically recorded battery charge every 12 hours to ensure that batteries provided the necessary operational voltage between 11.7 V and 13.5 V. We programmed data-loggers to store a maximum of 1,000 records and downloaded data every 1–2 weeks, which we then transferred to a desktop computer for analysis.

Sensor Testing

We tested each sensor using a “dummy” snowshoe hare to ensure that sensors only detected a snowshoe hare within a short distance of the antenna wire (approx. 10 cm). The dummy hare was tissue paper packed in a plastic bag the same size as a snowshoe hare and filled with water to simulate the normal signature of signal reflectance from a live animal (Telonics, Inc., Mesa, Arizona, personal communication). We shaped the dummy hare in the form of a snowshoe hare and fitted it with a radiocollar. We checked sensors every 2 months using the dummy hare. We determined the detection distance by moving from a distance of 1.5 m toward the center of the plot with the dummy hare from 4 cardinal directions. We moved the dummy hare at a slow pace (approx. 2 cm/sec) until the sensor detected the dummy hare (the data-logger was switched to “test mode” where an external buzzer was used to report detection). We computed detection area as an ellipse defined by the total distance between detections using the N–S tests as one axis and the E–W tests as the other.

Application

We monitored 2 sapling lodgepole pine stands: one young (approx. 15 yr) and the other older (approx. 35 yr). We captured 16 snowshoe hares in the older stand and 36 snowshoe hares in the young stand. We fitted all captured hares with radiocollars (Biotrack, Inc., Wareham, United Kingdom). Collars weighed approximately 3% body weight of snowshoe hares (27 g). Consistent with the data-logger programming, these transmitters produced a steady 1,192-millisecond pulse rate regardless of temperature. We followed procedures to capture and release snowshoe hares unharmed as specified in the State of Idaho Wildlife Capture Permit 020503.

Results

We collected a total of 828 detections (20.7 detections/hare/month) during winter, and 2,708 detections (21.5 detections/hare/month) during summer–autumn. Average detection distance between dummy-hare and center of sensor antenna was 0.70 m, and the average area where hares were detected was 1.26 m^2 (CV = 19.6%; Fig. 3).

Some sensors and data-loggers failed (winter = 0.0010 and summer = 0.0005 failure-rate/sensor/day), but overall maintenance was low. The primary cause of failure was moisture accumulation in sensor and data-logger enclosures; some sensors and data-loggers were, from time to time, completely submerged in standing water. During spring snowmelt, sensors were exposed on the snow surface and their enclosures expanded due to high internal temperatures (>26°C), causing most (70%) to lose their seal. Both submersion and expansion were addressable: we produced sensors that could withstand complete immersion by testing the enclosures to ensure that they were airtight, and we compressed the enclosures prior to sealing to make them less sensitive to expansion.

More effort in maintaining sensors was required during the winter than any other time of the year because it was

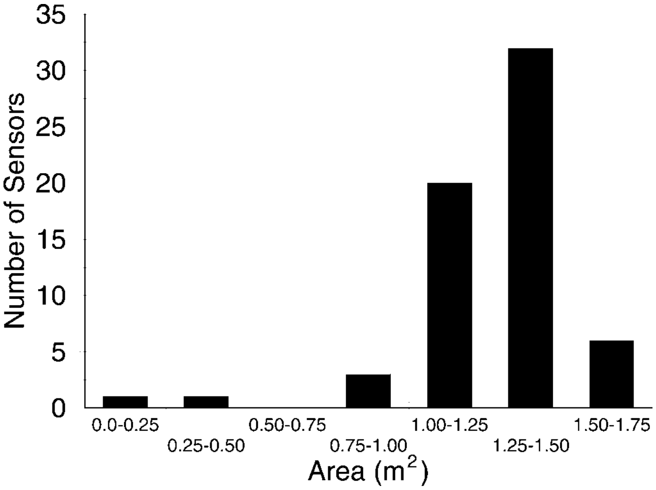

Figure 3. Histogram of detection area per sensor (elliptical area measured from 4 radial-distances of first detection of a radiocollared "dummy" snowshoe hare to plot center; *n* = 63 sensors).

necessary to move sensors to the snow surface following >30-cm snow accumulation. As snow accumulated above the antenna, distance between the antenna and snowshoe hares increased, potentially reducing sensitivity of detecting a radiocollared hare within the plot borders. We therefore moved sensors to the snow surface 3 times during winter. We added 2 m of cable to each sensor so they could easily be pulled up through the snow column and reestablished on the surface. In addition, some damage to the system occurred when animals chewed on either the cable or antenna wires (*n* = 5 incidents), but this damage did not lead to data loss.

Discussion

The system was successful in providing spatially accurate and temporally unbiased hare presence–absence data. Overall, maintenance was low and most of the problems we encountered, primarily associated with moisture accumulation, were easily remedied and should not be problematic in future studies.

The primary disadvantage to using this technique is that animals are not individually identified. In our study we exhaustively trapped hares within each stand and only inferred results to hare use at the stand level. In this implementation, sensors therefore provide an activity index, although one that is precisely related to hare use over time. If individual identification was desired, one possible approach is to identify individuals by having a unique pulse rate for each collar (Callo et al. 2002). It was relatively easy to program the data-logger to query for individual pulse rates, but this approach sets an upper limit to the number of individuals that can be identified. The need to retain sufficient separation between signal impulses for accurate identification limits this approach to a maximum of 10–20 individuals. Varying signal pulse rate, however, could be useful for separating use patterns by age or sex since only a few pulse rate patterns would be needed.

Another disadvantage is that habitat-use monitoring is strictly limited to the spatial extent of the sensor array. This limits its use to animals with generally small home ranges; that is, the radiocollared individuals must remain in an area so that they encounter sensors. However, this does not limit its utility for evaluating treatment effects or determining habitat use for a specific set of habitats. Snowshoe hares in our study occasionally moved outside of the sensor-arrays, but our primary interest was microscale hare use within sapling stands. For organisms with large home ranges, the massive arrays required for generalized habitat use clearly are impractical. However, questions about use patterns of specific treatments or resources could be assessed with much smaller arrays. For example, sensors could be placed in control versus burned areas to compare relative use and provide data on use of specific resources within the treatment areas.

A major advantage to this system was that, compared with most alternative methods, data were frequent, precise, and unbiased, both in space and time. Bias exists in either "loudest-signal" or "null-average" telemetry methods (Springer 1979), and we suspect that at least some animals are disturbed by the observer, or observed patterns of habitat use contain a diurnal–nocturnal bias. Determining whether an animal has moved prior to obtaining its location is problematic, especially if the animal moves a short distance and into a different habitat; we commonly observed hares moving from open to dense cover as we approached their locations. With sensor-arrays, observer visitation to the study area was minimal (every 1–2 weeks), the system was nonintrusive (almost visually undetectable), and operated autonomously and continuously.

Spatial configuration of sensors should represent a random or systematic selection of habitat characteristics. Although not tested, sensors probably can be placed at distances >35 m from the data-logger. The loggers we used supported 9 sensors, but data-loggers are available that can monitor a much larger number of sensors and, within distance constraints, any spatial pattern of sensors around a data-logger can be employed.

As tested, sensors provided a use-index for the group of radiocollared individuals. Index precision varies with both the number of collared individuals and sensors. In our study most variation (CV < 25%) in detection rate was captured at ≥37 sensors (Fig. 4). Variance can, of course, be reduced by increasing detection area at each sensor, but sensor area should be defined by the desired scale of habitat use rather than for variance reduction.

A greater knowledge of animal ecology is provided when habitat use is measured at several scales (Krebs 1994). A broad spectrum of ecological questions can be answered at the microscale and arguably most questions should be addressed representatively across time. We often are limited to identifying important habitats at a large scale, then inferring characteristics within these habitats important to the animal's biology. The use of sensor arrays allows within-habitat use patterns to be accurately measured. In this case we knew that regenerating clearcuts contained relatively

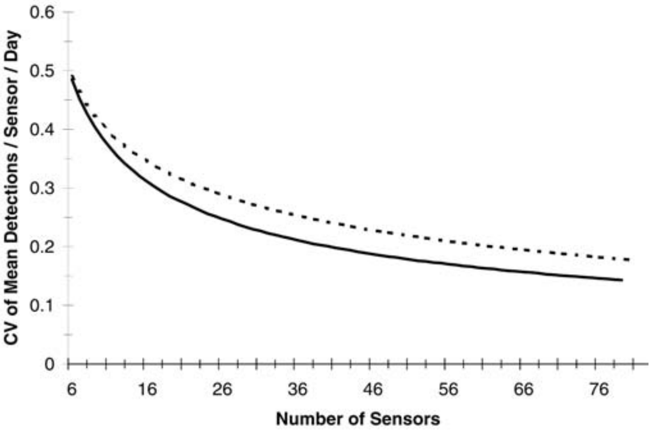

Figure 4. Expected coefficient of variation of mean number of detections per day related to number of sensors (100,000 simulations of random selections across 81 sensors) during summer (solid line) and winter (dotted line) at Island Park, Idaho, USA, 2001.

high numbers of snowshoe hares but, using conventional methods, we were unable to determine within-clearcut use patterns. Sapling density changed abruptly within a few meters and, with average error = 10.0 m in a preliminary evaluation of our null-peak tower system, we were unable to determine whether hares were using areas of dense saplings or were in adjacent openings. This is, however, the scale at which partial thinning will affect stands and, therefore, the scale at which habitat-use data should be collected.

Acknowledgments

We thank E. Gabriel for providing electronic advice and 2 prototypes that we used as a basis to construct sensors. We greatly appreciated the effort N. Doyle and J. Kidd provided in the field and laboratory, and we also thank D. Welsh for assisting in field tests. We are grateful to the hospitality and assistance provided by personnel at the Island Park Ranger Station, and we are especially thankful for funding and assistance with logistics provided by M. Orme, J. Reese, and B. Aber. V. Nams provided comments on earlier drafts. Source code for programming data-loggers can be obtained from authors.

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Associate Editor: White.