Temperature sensor evaluation of opossum winter activity

L. Leann Kanda, Todd K. Fuller, and Kevin D. Friedland

Abstract To effectively monitor winter foraging activity by the cryptic, non-site-faithful Virginia opossum (*Didelphis virginiana*), we tested the use of small data-logging temperature sensors (iButton Thermachrons®, Maxim/Dallas SemiConductors, Dallas, Tex.) attached to a standard radiocollar on 3 opossums over the winter of 2000–2001. Two replicate sensors were required to clearly show time periods with cooler temperatures, an indication that the animal was outside the den. These foraging bouts were consistent with the available radiotelemetry data. Daily duration of foraging showed a strong negative relationship with ambient temperature, quantitatively documenting for the first time a phenomenon previously known only anecdotally. The iButton Thermachron seems to be an effective, low-cost, and low-effort technology for monitoring foraging activities of any animal that rests and forages in different temperature environments.

Key words data-logging, *Didelphis virginiana,* foraging, temperature, Virginia opossum, winter

Foraging activity patterns are a crucial aspect of animal ecology (Stephens and Krebs 1986), and numerous methods have been developed to monitor animals without disturbing those patterns. Few species are undisturbed by direct human observation, so means of remote detection, radiotelemetry in particular, have become favored for monitoring movement of sensitive or cryptic animals (for review of radiotelemetry, see White and Garrott 1990; recent uses in time-budget analysis include Lode 1999, Gelatt et al. 2002, and Murray and Kurta 2004). Adaptations such as motion and temperature sensors, which report by altering the transmitter signal, enhance the information on an animal when the signal is monitored (e.g., Exo et al. 1996, Park et al. 2000, Murray 2002). Depending upon the available equipment and personnel, animals may be monitored for chosen durations, during which location, motion-trigger, or temperature readings may indicate the activity of the animal. As an alternative to monitoring the animals themselves, some researchers have found that monitoring denning or nesting sites can provide information on timing of activity. Cameras (both still and video) used inside the den can record when animals are (and are not) present (e.g., Cutler and Swann 1999, Codd et al. 2003).

Most of these established methods, however, are not suitable for monitoring animals when they are cryptic, forage rarely in relatively small areas, and are not site-faithful. Such is the case with Virginia opossums (*Didelphis virginiana*) during New England winters. The Virginia opossum is supposed to be limited in its northern distribution by winter energy restrictions (Gardner and Sunquist 2003), but observation of wild northern Virginia opossum winter foraging patterns have been limited to a few anecdotal reports on snow tracks (Wiseman and Hendrickson 1950, Brocke 1970). In an ongoing study of Virginia opossums over-wintering in Amherst, Massachusetts, we have sought methods to identify the short, rare winter foraging bouts crucial to these animals' survival. Our first attempts to

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monitor opossums with motion-sensitive radiotelemetry established that the motion-sensor was triggered more often when the animal was inside its den than it was during foraging bouts. Further, remote triangulation of opossum locations was not always precise enough to positively identify whether the animal had left its den, but approaching close enough to determine the status of the animal often disrupted foraging (L. L. Kanda unpublished observations). Finally, continuous monitoring of the animals (which, over winter, may not forage for a week, and though normally nocturnal may forage in the daytime) was not cost-effective in either equipment or personnel.

Faced with the logistical difficulty of monitoring Virginia opossum winter foraging activity, we tested small data-logging temperature sensors attached to standard radiocollars. Such sensors have previously been successfully deployed on marine fishes to identify migratory behavior (Friedland et al. 2001). If the sensors can identify the time periods during which terrestrial animals such as opossums are outside their dens, they could provide a low-cost, low-effort alternative for monitoring the activity period of any animal for which there is a temperature differential between the resting and foraging areas. Further, such sensors, correlated with information from the external environment, may document the conditions influencing foraging activity. In the winter of 2000–2001, we placed data-logging sensors on 3 Virginia opossums in order to determine 1) whether foraging bouts in cold external temperatures could be identified, and 2) whether these bouts could document a relationship between ambient temperature and foraging decisions.

Study area

We conducted this study on the campus of the University of Massachusetts at Amherst and in the surrounding residential and conservation areas of Amherst and Belchertown, Massachusetts. This central Massachusetts region received an average of 108 cm of precipitation annually (National Oceanic and Atmospheric Administration 2004). The mean January temperature over the last 30 years was 3.2°C; the mean June temperature was 18.5°C (National Oceanic and Atmospheric Administration 2004). The 3 study locations for winter 2000–2001 were in primarily mixed hardwood–coniferous forest dominated by red oak (*Quercus rubra*) and white pine (*Pinus strobus*). Each of the 2 Amherst areas was approximately 25 ha of natural area surrounded by urban development. One site was a solid block of forest, though opossum activity was confined to approximately 3 ha where the forest abutted pasture and urban development. The second site historically was an orchard but has been allowed to revert to a patchwork of forest and untended meadow (heavily invaded by *Rosa multiflora*). The third location was a residential area in Belchertown. Here the road density was approximately 24 km/ha, with 25 houses in the immediately surrounding 100 ha of otherwise mixed hardwood–coniferous forest.

Methods

For each monitored animal, we prepared four iButton Thermochrons® ($9 each [US]; Maxim/Dallas SemiConductors, Dallas, Texas) that are read and programmed by a personal computer. Each Thermochron holds 2,048 data points, with temperature readings taken at programmable time intervals (models with larger memories are now available for under $25). We programmed the Thermochrons to record every 15 minutes, thus covering roughly 22 days, with a delay to begin on a set date and time. We chose the 15-minute time interval as a compromise between the number of days sampled and the precision with which foraging times could be measured. We anticipated being able to recapture animals approximately once a month and felt that understanding activity to the nearest 15 minutes was adequate for identifying any activity bout that could be important to opossums (either in obtaining food or in exposing them to higher energetic demands).

We captured 3 opossums either in a wire cage trap or by hand when an animal was out foraging (2 animals were previously radiocollared). All 3 animals were approximately 9 months old in December (as the majority of opossums do not survive to their second winter, this is the most common age entering winter). The single animal that used a residential area was a male, while the 2 opossums which did not rely upon human resources were both female. We attached 2 Thermochrons (<5 g each) to the radiocollar (<50 g; Advanced Telemetry Systems, Isanti, Minn.), 1 on each side of the external, 15-cm whip antenna. Our Thermochrons were encased in plastic with small side flanges. We drilled small holes in these flanges, burned small holes into the nylon strapping of the collar, and bolted each sensor onto the collar. This was further secured by a single layer of vinyl electrical tape wrapped around the collar and sensor. Later recovery of the collar (8–12 weeks) showed that this wrapped tape was intact, and therefore we suggest that the tape would be sufficient to secure the sensors without the plastic casing (which is not standard).

Two additional sensors for each animal were similarly wrapped in a single layer of vinyl electrical tape and then suspended together by a loop of the same tape from a branch in the usual range of the animal, at approximately 60 cm off the ground (placed to be as low as possible without later becoming embedded in snow). These sensors recorded the ambient temperature in the areas where the opossums were active.

We located each marked animal by radiotelemetry at least once every 24–48 hours. After the first 22 days, we recaptured them and removed the sensors from the radiocollar, retrieved the environmental sensors from the study sites, and downloaded the data. Subsequently, we reprogrammed the sensors for a second period, in which 4 sensors (2 environmental and 2 on the animal) were deployed, but 1 environmental and 1 animal sensor were programmed to start only when the first 2 sensors completed 22 days, thus covering a total of 44 days (without replication). During the second deployment of the sensors, 2 animals died and were retrieved before the end of the 44-day period, and the third dispersed in the spring before the collar could be recovered.

To make sure that data interpretation was unbiased, data from the animal temperature sensors initially were graphed without reference to time of day or environmental temperature. We first identified putative foraging bouts by examining these graphs for periods in which the temperature recorded by the sensor dropped to a lower level and later increased (suggesting emergence from and then return to a den). Only subsequently were the corresponding time and environmental temperature identified for these bouts.

In addition, the putative foraging bouts were compared with radiotelemetry location data for consistency. We then compared foraging activity with environmental temperature. We summed multiple bouts for one 24-hour period to give the total foraging time per night. We calculated the environmental temperature for a bout as the average environmental temperature recorded during the bout. For nights without foraging, we used the evening temperature (@1700).

Results

Identification of foraging bouts

Temperatures recorded from the animal collars fluctuated between approximately 20°C and 35°C. These temperatures were well above ambient temperatures and reflected warming from the animals themselves. When we examined single-sensor data, we could not confidently identify periods during which the temperature was lower than at other times. However, when the paired sensors from an animal ("replicates") were compared, such periods became readily discernible. Most of the time, the temperatures recorded by the 2 sensors appeared to fluctuate either independently or in opposition; however, they would periodically synchronize at a lower temperature, a period that we took to be the animal foraging in the cooler temperatures outside the den (Figure 1). We defined the activity bout as

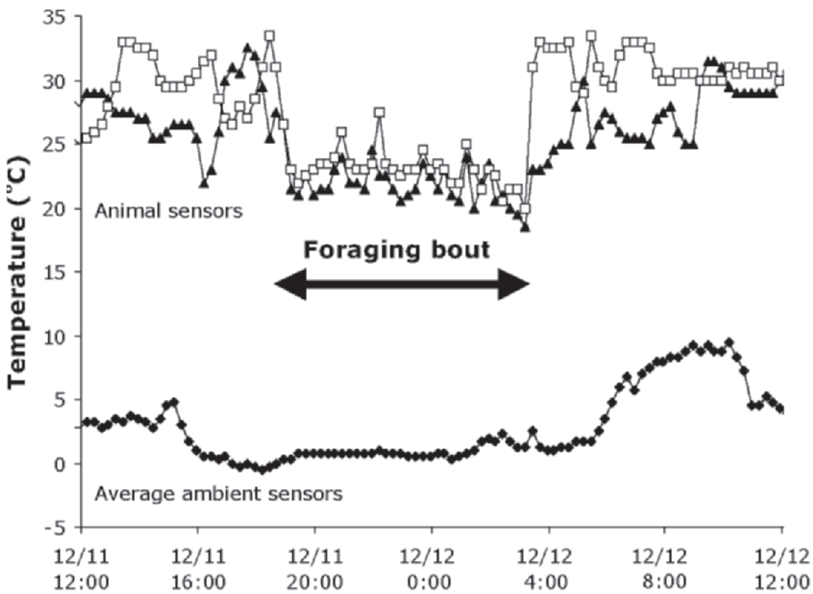

Figure 1. Temperature sensor data from Opossum B on the evening of 11 December 2000 in Amherst, Massachusetts. Two synchronized sensors from the animal indicate an activity bout. The average from the environmental sensors indicate that it was a relatively mild winter evening with ambient evening temperatures slightly above freezing.

beginning at the last time record before the temperature drop and ending at the last time recorded at the lower temperature.

Radiotelemetry locations on 2 of the 3 opossums were sufficiently precise to positively determine whether the animals were in known dens or out in the open. For each of these 2 animals, comparison of synchronized collar sensor data with radiotelemetry data from December showed that the putative foraging bouts were consistent with the telemetry locations (Figures 2 and 3). December evening (1700) temperatures ranged from −10°C on 9 December to 10°C on 17 December, for average temperatures during activity bouts between −11°C and 2°C. There was light snow cover of 2.5–7.5 cm during this period (National Oceanic and Atmospheric Administration 2004); however, we did not measure cover at the study sites. A relationship of activity to snow depth as well as ambient temperature has been suggested (Brocke 1970) but cannot be addressed in this study. Snow tracks were not useful in identifying activity because dens and foraging activity were both largely confined to sites with heavy undergrowth, which impeded researcher observation.

We obtained 18 radiotelemetry locations of Opossum A during 4–21 December 2000, and only 4 of those locations placed the opossum outside a known den (Figure 2). All 4 of these occasions coincided with lower temperature records. Of particular significance, on one evening (Dec. 19) the observer disturbed the animal while it was foraging; the animal took refuge in an underground hole. The temperature sensors indicated an activity bout

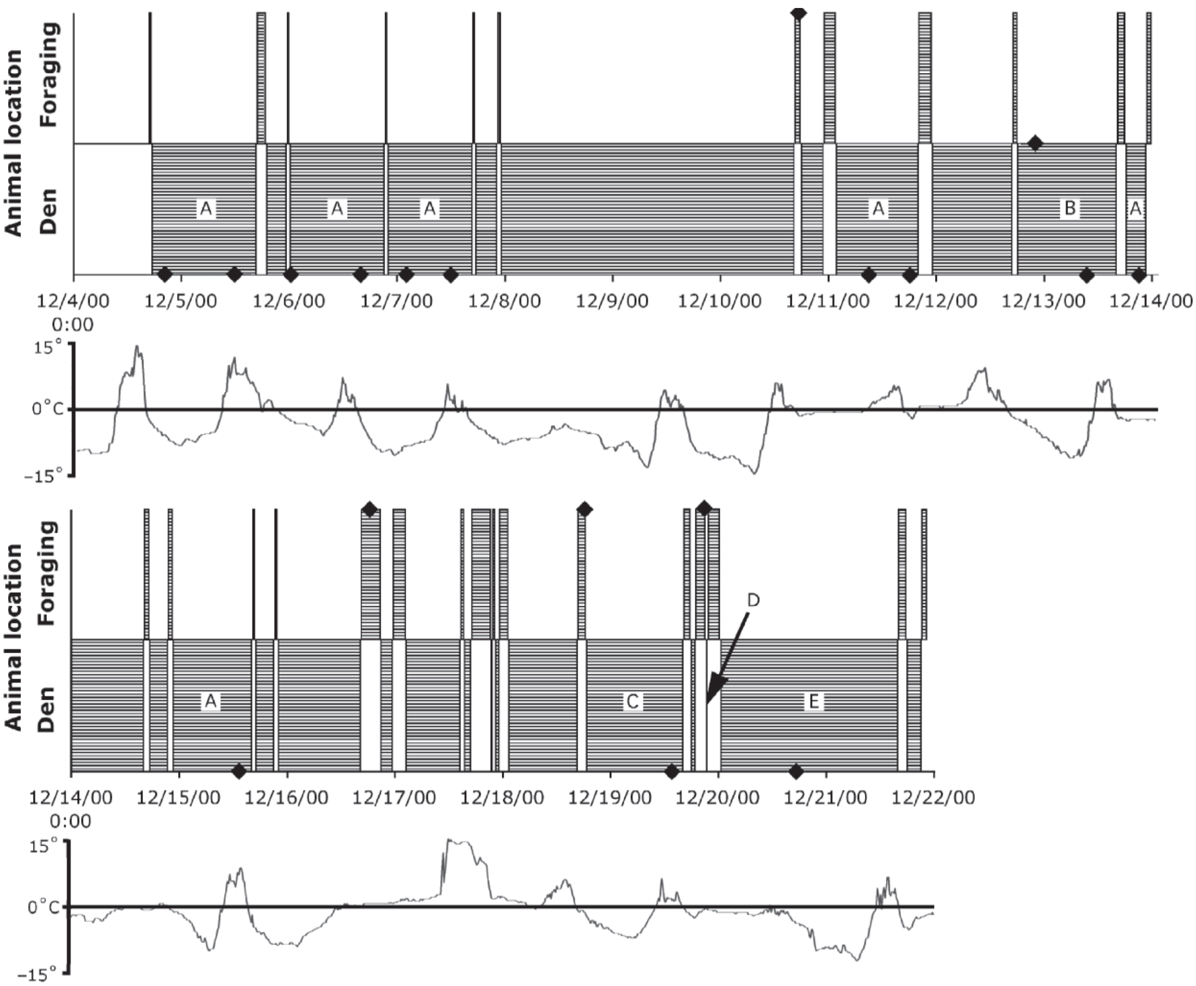

Figure 2. Comparison of activity bouts identified by temperature sensors and radiotelemetry locations of Opossum A in December 2000 in Amherst, Massachusetts. Striped blocks indicate time spent denning or foraging as identified by temperature sensors; diamonds indicate location by radiotelemetry. Letters indicate specific dens as identified by radiotelemetry. Ambient temperature as recorded by environmental sensors shows the animal spent more time outside the den on warmer nights.

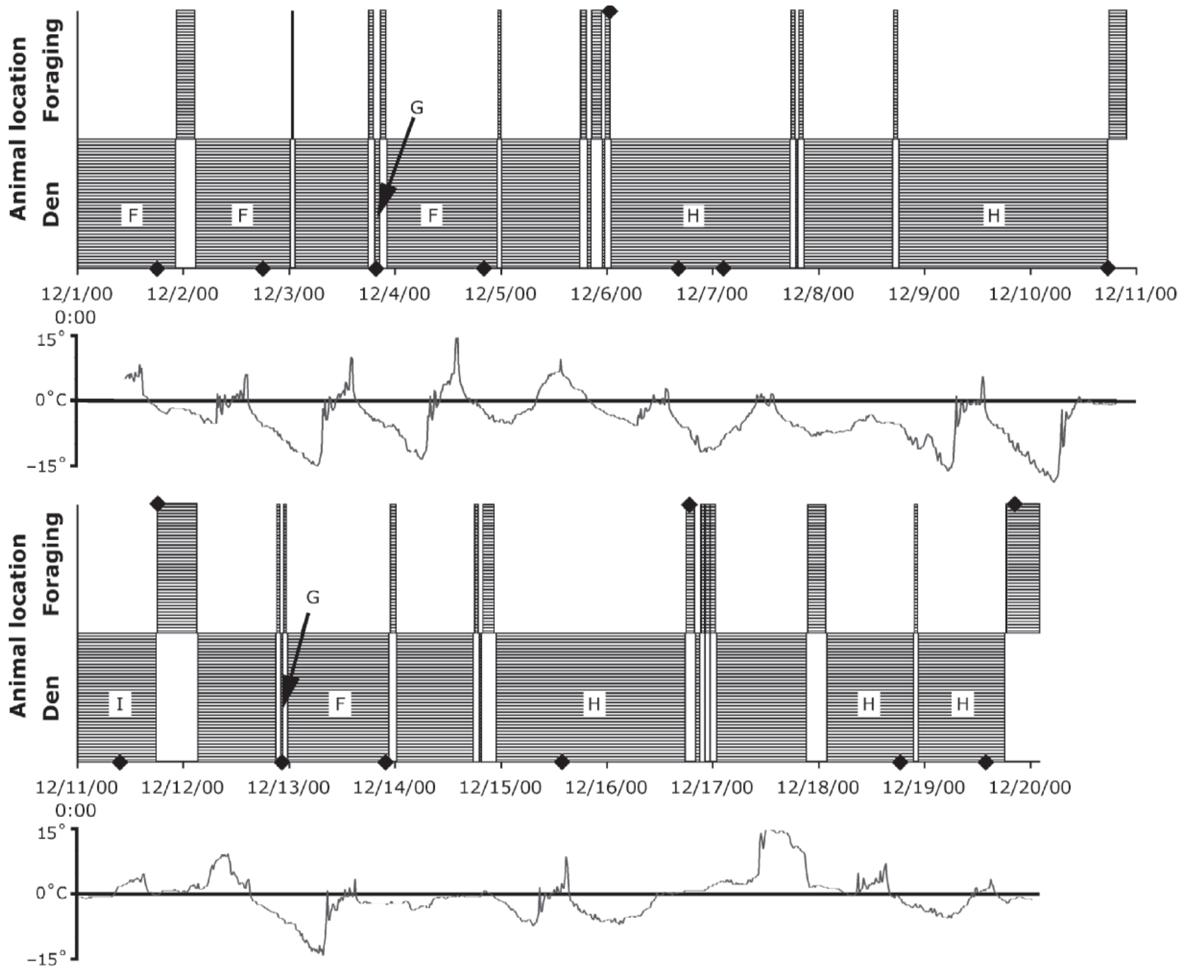

Figure 3. Comparison of activity bouts identified by temperature sensors and radiotelemetry locations of Opossum B in December 2000 in Amherst, Massachusetts. Striped blocks indicate time spent denning or foraging as identified by temperature sensors; diamonds indicate location by radiotelemetry. Letters indicate specific dens as identified by radiotelemetry. Ambient temperature as recorded by environmental sensors shows the animal spent more time outside the den on warmer nights.

ending at the time the observer saw the animal retreat. The temperature record suggested that a half-hour later the opossum resumed activity; the following day, the opossum was in a different den. The remaining 14 times Opossum A was located, both telemetry and the temperature data indicated the opossum was inside a den. Over this December period, Opossum A shifted den sites 3 times. In each case, the temperature sensors indicated an activity bout. There was one ambiguous case, on the evening of 12 December, when a foraging bout might have been missed by the temperature sensors. The telemetry location was unclear whether the animal was in or simply near (within 10 m of) a den at 2218 hours, while the temperature sensors did not record the animal as active at that time. If the animal was in fact in the den, the activity bouts identified by temperature and the telemetry data were in accord for the entire monitoring period.

We obtained 17 radiotelemetry locations of Opossum B during 1–20 December 2000 (Figure 3). Again, 4 locations indicated opossum activity outside of dens, and all 4 fell within activity bouts identified by temperature. The foraging pattern in the temperature data also was consistent with the 13 locations of the opossum at den sites. Opossum B shifted 7 times between 4 dens. For each move, the temperature sensors recorded an activity bout.

Foraging and ambient temperature

We did not discern any difference in activity patterns among the 3 opossums despite the differ-

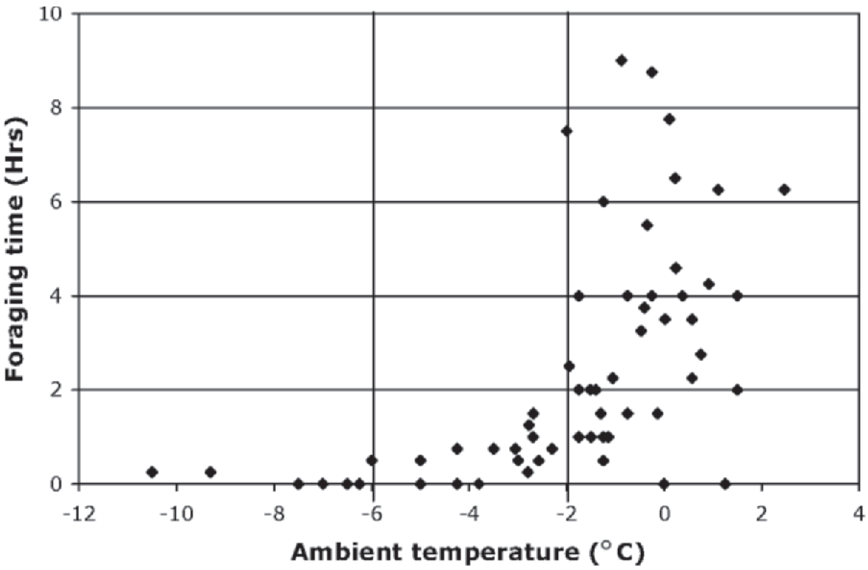

Figure 4. Total foraging time per night (hours) as a function of ambient temperature for 3 opossums in the winter of 2000 in central Massachusetts. Maximum foraging time is greatly restricted at temperatures below –2°C.

ences in sex and habitat use, so we pooled activity bouts identified for all 3 animals for comparison with ambient temperatures. When the ambient temperature averaged –2°C or higher, the opossums would forage for up to 6–9 hours a night, although the foraging time each night was highly variable (Figure 4). The average foraging time for bouts beginning at –2°C or warmer was 3.5 hours (±SE 0.06 hr). In contrast, at temperatures between –6°C and –2°C, maximum foraging for the night was no more than 1.5 hours, with average foraging time of 34 minutes (±SE 2 min). Below –6°C, opossums foraged for no more than 15 minutes, and on average spent only 5 minutes out of the den (±SE 1 min).

Radiocollared opossum foraging during winter in Belchertown, Massachusetts.

Discussion

For clear identification of opossum activity outside their winter dens, 2 synchronized data-logging temperature sensors on the animal's collar were necessary. The large "noise" in the temperature signal from each collar sensor probably represented a shifting of opossum posture in the den and the orientation of the collar on the neck. The warming of the temperature sensors through proximity to the animal did not completely obscure the signal, however, and when 2 sensors were placed on the collar, the concerted temperature change appeared to signal the animal's move outside the den.

The continuous record provided by the temperature sensors improved detection of foraging activity over that detected by radiotelemetry monitoring. Even with once-every-15-minute monitoring rates, sensors can reasonably substitute for person-hours that are best used otherwise. Because the technique relies on a temperature differential between the den and the ambient temperatures, the activity bouts are most easily distinguished at cold temperatures. For opossums, however, because of the animal's behavior, bouts at the coldest temperatures were shortest and most rare. Winter activity data are key to describing and interpreting the behavior of a species, such as the Virginia opossum, at the northernmost part of its range, and the continuous monitoring available through temperature sensors seems not only practical but also essential.

Acknowledgments. P. R. Sievert, E. M. Jakob, J. Podos, and 2 anonymous reviewers gave valuable comments on the manuscript. We thank B. Graves, M. Brenner, and K. Druzisky for assistance in the field. This fieldwork was approved under

University of Massachusetts Amherst Institutional Animal Care and Use Committee protocol 21-02-01. It was supported by the United States Geological Survey's Massachusetts Cooperative Fish and Wildlife Research Unit, by a Grant-in-Aid of Research from Sigma Xi, the Scientific Research Society, by Max McGraw Wildlife Foundation, and by the Cooperative State Research, Education, and Extension Service, United States Department of Agriculture, Massachusetts Agricultural Experiment Station, under Project No. MAS0071. This is Massachusetts Agricultural Experiment Station Publication No. 3355.

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Associate editor: *Murray*