Research Article

Evaluation of a Global Positioning System Backpack Transmitter for Wild Turkey Research

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ABSTRACT Radiotelemetry is the standard method for monitoring wild turkey (Meleagris gallapavo) movements and habitat use. Spatial data collected using telemetry-based monitoring are frequently inaccurate due to triangulation error. However, new technology, such as Global Positioning Systems (GPS) has increased ecologists’ ability to accurately evaluate animal movements and habitat selection. We evaluated the efficacy of micro-GPS backpack units for use on wild turkeys. We tested a micro-GPS developed specifically for avian species that incorporated a GPS antenna with a lightweight rechargeable battery and a very high frequency (VHF) transmitter. We conducted a series of static tests to evaluate performance in varying types of vegetative canopy cover and terrain. After static testing, we deployed micro-GPS on 8 adult male Rio Grande wild turkeys (M. g. intermedia) trapped in south Texas and 2 adult females trapped in the Texas panhandle. Micro-GPS units collected 26,439 locations out of 26,506 scheduled attempts (99.7% fix rate) during static testing. Mean distance error across all static tests was 15.5 m (SE = 0.1). In summer 2009, we recovered micro-GPS from 4 tagged males and both females to evaluate data collection. Units on males acquired approximately 2,500 locations over a 65-day test period (94.5% fix rate). We recovered units from the 2 females after 19 days and 53 days; those units acquired 301 and 837 locations, respectively, for a 96% fix rate. Cost analysis indicated that VHF will be cost effective when 1 location per day is required up to 181 days, but micro-GPS becomes less expensive as frequency of daily locations increases. Our results indicate that micro-GPS have the potential to provide increased reliable data on turkey movement ecology and habitat selection at a higher resolution than conventional VHF telemetric methods. © 2011 The Wildlife Society.

KEY WORDS Global Positioning System, habitat selection, Meleagris gallapavo intermedia, movement ecology, Rio Grande wild turkey, telemetry, Texas.

Telemetry-based monitoring has been the standard for research on movements and habitat selection for wildlife since the late 1950s (Rogers et al. 1996). Radiotelemetric techniques provide a wide array of information on animal survival, movements, habitat use, and demographic parameters (White and Garrott 1990, Millspaugh and Marzluff 2001). Information acquired using telemetry, however, often exhibits high variance due to errors in triangulation angle definition, animal movements between bearings, signal strength, and tracking frequency (White and Garrott 1986, Saltz 1994, Millspaugh and Marzluff 2001, Thogmartin 2001). Although telemetry biases are well known, researchers using radiotelemetry frequently do not employ techniques available to correct telemetry errors or fail to report these estimates with their results (Saltz 1994, Chamberlain and Leopold 2000, Moser and Garton 2007). Additionally, logistical and fiscal constraints can influence telemetry accuracy due to labor associated with manual data collection and the resulting number of locations collected (Bowman et al. 2000). Advancements in technology, such as Global Positioning System (GPS)-based telemetry, have provided researchers with a cost effective means for monitoring wild animals

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remotely. Global Positioning System-based telemetry has been widely used to obtain accurate location data for large mammals using less labor than required for radio triangulation (Moen et al. 1997, Rempel and Rodgers, 1997, Dussault et al. 2000, Lindzey et al. 2001, D’Eon et al. 2002). Satellite telemetry has been the primary non-labor intensive method used to monitor movements of medium to large birds (Fuller et al. 1995, Cadahia et al. 2005). In addition, GPS units have been used for capercaille (Tetrao urogallus; Wegge et al. 2007). Satellite telemetry, although useful for monitoring long distance animal movements, lacks the accuracy required for monitoring small-scale movements and habitat use (Keating 1994).

Historically, research on wild turkeys (Meleagris gallopavo) utilized point locations acquired via radiotelemetry and triangulation methods to evaluate topics such as individual movements, range sizes, habitat selection (e.g., use vs. availability), and identifying critical habitats for nesting and brooding (e.g., Miller et al. 1999, Chamberlain and Leopold 2000, Miller and Conner 2005, Hall et al. 2007). New techniques are required to identify habitat selection at the local scale, especially for evaluating phenological changes in habitat use between breeding and non-breeding seasons (Bingham and Brennan 2004). In 2008, we initiated a study to determine the efficacy of using micro-GPS backpack units to identify movements and habitat use of wild turkeys. Our objectives were to 1) evaluate and test a micro-GPS unit for spatial accuracy, 2) implement a field test of micro-GPS units on Rio Grande wild turkeys in Texas, and 3) compare cost effectiveness for micro-GPS versus traditional very high frequency (VHF) units.

STUDY AREA

We conducted our research on 3 study sites with various degrees of canopy cover and different terrain to evaluate GPS unit accuracy: one site located in the Central Rio Grande Plains of Texas (hereafter Rio Grande Plains), the second in the Texas Rolling Plains (hereafter Rolling Plains), and the third in the Atchafalaya River Basin (hereafter Atchafalaya Basin) in south-central Louisiana. The Rio Grande Plains study site was a privately owned ranch northwest of San Diego, Texas, USA in Duval County and consisted of thornscrub parklands with well-defined mosaic patterns of shrub clusters scattered throughout low-succession grasslands (Northup et al. 2005). Closed-canopy woodlands were intermittently present in clay loam drainages and consisted primarily of honey mesquite (Prosopis glandulosa), hackberry (Celtis occidentalis), and Texas persimmon (Diospyros texana; Archer 1990). Rolling Plains sites were on a privately owned ranch east of Matador, Texas in Motley County and on the Texas Tech University Native Rangeland in Lubbock County. Vegetative cover at the privately owned ranch consisted of mesquite-dominated rangeland with intermittent streams dominated by western soapberry (Sapindus drummondii) and hackberry (Celtis spp.) with a few cottonwood (Populus deltoides) and elm (Ulmus spp.) trees. Vegetative cover at the Native Rangeland site was dominated by mesquite with low grass cover (Sosa 2009). The Atchafalaya Basin site consisted of bottomland hardwood forests and was located within the Sherburne Wildlife Management Area in Iberia and Point Coupee parishes owned by the Louisiana Department of Wildlife and Fisheries; it was bordered by Highway 190 on the north, Interstate 10 to the south, and the Atchafalaya River on the west. The Atchafalaya River Basin site was about 87% forested with stands dominated by cottonwood, American sycamore (Platanus occidentalis), oaks (Quercus spp.), sweetgum (Liquidambar styraciflua), sugarberry (Celtis laevigata), black willow (Salix nigra), and bald-cypress (Taxodium distichum; Wilson 2005).

METHODS

Unit Design

Sirtrack Wildlife Tracking Solutions (Sirtrack, Havelock North, New Zealand) developed the micro-GPS we tested (Fig. 1). The micro-GPS incorporated a Fastrax GPS module and proprietary Sirtrack firmware to control GPS sample intervals, duty cycles, and power management. The unit was housed in a polyethylene terephthalate (PETG) vacuum-molded housing and contained 2 × 1/2AA lithium thionyl chloride cells in conjunction with a supercapacitor.

The micro-GPS was user-programmed by setting duty schedules and duty cycles using a Universal Serial Bus (USB) cable through a computer. Users can set up to 10 duty schedules and 10 duty cycles. For instance, one could set duty schedule 1 to run for 2 weeks using duty cycle 1, which tells the unit to collect 1 location every 6 hr for a total of 4 locations/day during those 2 weeks. Then, at the end of those 2 weeks, duty schedule 1 would time out and duty schedule 2 would initiate using the next duty cycle (2), perhaps programmed to collect 1 point every hour between 0600 hours and 1800 hours. Duty cycle 3 (also programmed under duty schedule 2) could be set to collect 1 location every 3 hr between 1800 hours and 0600 hours to minimize battery consumption at night while turkeys are roosted. The micro-GPS automatically rotates between cycles set under the same duty schedule. Available duty schedules and cycles allow the researcher to switch sampling intervals independently between minutes, hours, days, months, or year.

Attachment of the micro-GPS was similar to attachment of VHF backpacks where 3-mm shock cord was laced through each unit and looped underneath each wing. Before deployment, we attached neoprene (3 mm thick) to the base of each unit using waterproof silicone adhesive to provide a cushion on the base to prevent the edges of the micro-GPS (Fig. 1) from injuring turkeys. We used black vinyl tape and neutral cure waterproof silicone containing no cyanide to seal the computer connection port (cyanide is known to break down PETG; K. Lay, Sirtrack Tracking Solutions, personal communication).

Static Test

We designed a static test for the micro-GPS to establish expectations for the maximum locations that could be acquired and to evaluate accuracy and precision of locations. During September–November 2009, we conducted a series of static tests (units mounted onto stakes and driven into the
ground at a 45° angle with the units approximately 47 cm off the ground to simulate attachment to a turkey) in 3 regions (Rio Grande Plains, Rolling Plains, and the Atchafalaya Basin) to determine unit performance in various types of canopy cover and terrain (Townsend et al. 2007).

We used 6 static test sites in each region including 2 sites with >75% canopy closure, 2 sites with 25–50% canopy closure, and 2 sites with <25% canopy closure. We mounted 2 micro-GPS on stakes side by side (approx. 2 cm apart) at each site. We programmed micro-GPS with 6 different 12-hr sampling schedules with various intervals to determine whether fix interval times affected accuracy. Each static test ran for 6 days (12 hr/day from 0800 hours to 2000 hours) with units programmed to record locations at different intervals each day (day 1 = 3-min interval, day 2 = 10 min, day 3 = 20 min, day 4 = 60 min, day 5 = 120 min, and day 6 = 240 min). We used Garmin eTrex Legend handheld GPS or Garmin GPSMAP 60CSx GPS units to determine the actual location of our test sites. At each test site, we used the average of ≥100 positions from the Garmin GPS unit to provide locations accurate within 3 m (Oderwald and Boucher 2003).

**Field Test**

We captured 5 males on 11 March 2009 and 3 males on 14 March 2009 at the Rio Grande Plains site and we captured 2 females on 1 April 2009 in Hemphill County, Texas near the Rolling Plains site. We followed standard capture and marking procedures used on Rio Grande wild turkeys in Texas (Collier et al. 2007, 2009) as we weighed and fitted all turkeys with a Texas Parks and Wildlife Department (TPWD) aluminum leg band and the micro-GPS. We programmed 6 of the micro-GPS (2 F and 4 M units) to alternate every other day between 60-min and 120-min sampling intervals, whereas we programmed the remaining 4 micro-GPS to acquire locations every 10 min, 20 min, 30 min, and 60 min, respectively. The purpose of the various sampling rates was to evaluate potential protocols for determining turkey movements across the landscape. All micro-GPS recorded 3 locations at night to conserve battery life while turkeys were roosted. We recaptured 4 radio-tagged males during May 2009 using walk-in traps (Peterson et al. 2003) and released them after we removed the micro-GPS. We did not recapture the remaining 4 males so we could evaluate the longevity of the units in the field (expected recovery fall 2010). Both females were predated after 19 days and 53 days, respectively, at which time we recovered the micro-GPS units.

**Data Analysis**

For all static tests, we compared the location given by the micro-GPS to the averaged location using the handheld GPS to determine micro-GPS accuracy. We calculated distance differences in ArcGIS 9.3 and summary statistics using in JMP 8.0.1 (SAS Institute, Cary, NC). We used Hawths Analysis Tools (Beyer 2004) in ArcGIS 9.3 to estimate 50%, 75%, and 95% kernel densities (error polygons) for each static test and range estimates for male and female turkeys fitted with micro-GPS.

We conducted a per-point cost analysis evaluating the cost of equipment purchase and monitoring using VHF and micro-GPS for 1 individual. We used fixed transmitter costs of $200.00 for VHF and $1700.00 for micro-GPS and fixed labor costs of $9.00/hr for a technician tracking a tagged

**Figure 1.** Micro-Global Positioning System (micro-GPS) unit developed in 2009 for use on wild turkeys is shown comparing both length and height to a standard turkey very high frequency (VHF) radio transmitter.
individual carrying either a VHF or micro-GPS unit. We assumed fuel costs of US$ 2.50/gallon and travel distance of 64 km/tracking day in a vehicle getting 20 miles/gallon. We assumed that VHF tracking required 15 min to locate and 15 min to triangulate a location on one individual, based on the notion that telemetry studies using triangulation typically limit time among all azimuths used to triangulate the animal to 15 min (Chamberlain and Leopold 2000). For micro-GPS tracking, we assumed that 15 min was required to locate and conduct a live–dead check on an individual and that we conducted the live–dead check 1 time per week. We assumed costs associated with trapping, deployment, and telemetry equipment were fixed regardless of transmitter type. Using the costs described above, we estimated the per location cost over time for 1, 5, 10, or 20 locations per day using VHF or GPS.

RESULTS

Static Test

Our static test units collected 26,439 locations out of 26,506 possible for a successful fix rate of 99.7%. Mean distance error across all tests was 15.5 m (SE = 0.1; 95% CI = 15.3–15.7). The Rolling Plains had the lowest mean distance error across all canopy covers (μ = 10.9 m; SE = 0.12) when compared to mean distance errors for the Rio Grande Plains (μ = 13.9 m; SE = 0.16) and the Atchafalaya Basin (μ = 21.8 m; SE = 0.22). The micro-GPS accuracy decreased as percent canopy cover increased (Fig. 2), but individual micro-GPS performance at each test site did not differ (Table 1). Duty cycle sampling intervals had no significant impact on distance error (Table 2). We found all static test kernel density areas were ≤1.34 ha and our largest 95% kernel was in the Atchafalaya Basin closed canopy site 1 (Table 3, Fig. 2).

Field Test

Field micro-GPS units retrieved from the 4 males recaptured in 2009 collected 10,146 locations out of 10,738 possible locations for a successful fix rate of 94.5%. The micro-GPS were still functioning upon capture, so they were capable of collecting additional locations. Micro-GPS units recovered from the two females on the Rolling Plains site collected 301 locations (19 days) and 837 locations (53 days) out of 1,138 programmed locations for a successful fix rate of 96.0%.

Males traveled approximately 4.1 km/day moving longer distances during morning (approx. 2.9 km) than afternoon (approx. 1.2 km). Each male traveled at a mean velocity of 4.1 m/min. Data collected from the micro-GPS units allowed us to clearly identify habitat types each male used during the study period. All males used primarily wooded riparian areas and 95% kernel range estimates varied from approximately 220–400 ha for each individual (Fig. 3). Males used 1 primary roost (68% of the study period) and 9 alternate roosts. Females traveled approximately 2 km/day using one primary roost site. Estimated 95% kernel ranges for females were 82 ha (over 19 days) and 150 ha (over 53 days) and each female typically stayed within 1.5 km of the roost during the study period.

Cost Analysis

New micro-GPS costs (US$ 1,700/unit) were greater than those of the VHF radio units (US$ 200/unit) commonly used in wild turkey research. Based on our assumed costs and work schedules we evaluated 4 levels of data collection on one individual over time. First, when we located the individual 1 time per day, the per-location cost for VHF was lower than the per-location cost for micro-GPS when the number of locations (days tracked) was <181 (e.g., if <181 locations were necessary for study objectives then VHF would be the

Figure 2. Kernel estimates of 50% (inner polygon), 75% (middle polygon), and 95% (outer polygon) for static tests of the primary micro-Global Positioning System (micro-GPS) units conducted on wild turkeys in the Rio Grande Plains (TX), Rolling Plains (TX), and Atchafalaya Basin (LA), September–November 2009. Kernel estimates based on 6-day study period for each test site.
When the number of locations exceeded 181, per-point cost for VHF data collection was higher than for micro-GPS (VHF \( \approx \) US$ 10.55/location; micro-GPS \( \approx \) US$ 10.37/location; Fig. 4a). However, accurate evaluation of habitat use and movements often requires >1 location per day. Thus, we evaluated increasing the number of locations to 5, 10, and 20 per day. Our results indicate that per-location costs for VHF increased above per-location costs for micro-GPS for 5 points per day at 63 days (VHF \( \approx \) US$ 6.12/location; micro-GPS \( \approx \) US$ 5.60/location); for 10 points per day at 35 days (VHF = US$ 5.56/location; micro-GPS = US$ 4.96/location); and at 20 points per day at 21 days (VHF = US$ 5.22/location; micro-GPS = US$ 4.09/location; Fig. 4b–d).

**DISCUSSION**

Advancement and miniaturization of GPS-based tracking equipment has allowed researchers to collect data for a wide variety of species with increased spatial accuracy at lower cost.
than traditional methods. Our results indicate that spatial accuracy using micro-GPS provides a substantial improvement over VHF radiotelemetry for evaluating wild turkey movements and habitat use. Distance errors based on the micro-GPS static test and live-bird tests were substantially less than radiotelemetry errors reported in wild turkey literature (Thogmartin 2001, Hall et al. 2007). For example, Thogmartin (2001) reported 90% of turkey locations were only accurate to within 485 m from actual locations. Even doubling the estimated mean error (15.5 m) from our static tests, spatial error of the micro-GPS locations would still be an order of magnitude lower than estimates given by Thogmartin (2001). Positional error increased slightly as percent canopy cover increased, illustrating that canopy cover can negatively affect accuracy (Rempel and Rodgers 1995, Moen et al. 1997). Spatial error in the Atchafalaya Basin was

Figure 3. Kernel range estimates and area (ha) of male Rio Grande wild turkeys we used to test the primary micro-Global Positioning System (micro-GPS) units on the Rio Grande Plains (TX) study site. Roost locations (identified by a star) show males' spatial affinity, with kernel estimates of 50% (solid line), 75% (dash-dot-dot line), and 95% (dashed line). Kernel range estimates collected based on 75 days of data during spring of 2009. We indicate the study site boundary (gray line) for reference.
≤30 m, which is far less than predictions from other forested environments (Chamberlain and Leopold 2000, Thogmartin 2001). Furthermore, our largest error polygon (1.34 ha) was smaller than has been shown by turkey studies using radio telemetry. Chamberlain and Leopold (2000) reported error polygons of 3.3 ha, which is more than twice our estimate. It was our expectation that at some point micro-GPS would become less expensive on a per-location basis than VHF (Mourao and Medri 2002). Once deployed, the cost of data collection for a micro-GPS is zero with the only additional cost being that of live–dead checks for the radio-tagged individual. Locations acquired using radiotelemetry, however, will always require some minimum amount of labor and associated travel costs for data acquisition, thus VHF cost for each point taken should minimize to the fixed costs for tracking as shown by our cost analysis. We suggest that frequent VHF locations become logistically unreasonable as triangulation of 1 bird 20 times/day as we outlined would require 1 person 10 hr of focused effort. However, once deployed, micro-GPS units can be simply scheduled to collect data at predetermined times, which as we showed will reduce labor costs substantially.

Figure 4. Predicted cost (US$) per location taken for very high frequency (VHF; solid line) and micro-Global Positioning System (micro-GPS; dotted line) for 1, 5, 10, and 20 locations per day (a–d, respectively).
As the basis of our example cost analysis, we used an approximate time frame of 1 year. Battery life in these units is affected not only by the number of points collected but also by the frequency of collection, as 6 points collected in a 1-hr period expends less battery than 6 points collected over a 24-hr period because the unit does not need to update its location almanac when points are taking within a 2-hr segment. Based on micro-GPS tests, we predict that when collecting 1 point/day the micro-GPS will last for >7 years and when collecting 5 points/day, 10 points/day, or 20 points/day the unit should last 2 years, 1 year, and 1 year, respectively (K. Lay, personal communication). Taking 1 point/day, service life of the micro-GPS will exceed useful life of the VHF transmitter, as we expect the VHF to last approximately 3–4 years based on our experiences with similar units on turkeys. If a study were to necessitate multiple points (20 locations/day) then it is likely that battery limits would necessitate recovery and redeployment somewhere around 1 year. There would be some additional costs associated with deployment of a new micro-GPS, albeit lower than initial costs, as refurbish costs for a micro-GPS are $400; those costs associated with deployment of a new transmitter, however, would be rapidly mitigated if a similarly frequent sampling schedule continued to be used.

Potential negative aspects of the micro-GPS include reduced battery life and unit recovery difficulties. Although the micro-GPS units we tested likely would have lasted another 10–15 days in the field based on the sampling schedule we used, our high rate of data collection undoubtedly limited battery life. We thus suggest that future work evaluating different fix schedules and the effects on battery life should be conducted. Currently, the micro-GPS must be recovered to download the data unlike GPS units used on larger species that employ remote download technology (Schwartz and Arthur 1999). At this time, there are no capabilities for remote uplinks with the micro-GPS, but this issue is currently under evaluation (K. Lay, personal communication). Thus, recovery of micro-GPS at this time necessitates either recapture of the individual carrying the unit or recovery after natural or harvest mortality. One additional risk when using the micro-GPS is that if the VHF transmitter fails during a predation event, then data collected by the unit would be lost.

Assessing wildlife habitat use and movement requires precise, unbiased animal locations. Habitat use studies using radiotelemetry often over- or under-estimate importance of different habitat types due to telemetry errors (White and Garrott 1986, Saltz 1994). Programming the micro-GPS with short sampling intervals (10 min, 20 min, and 30 min) allowed us to clearly identify daily movement patterns typically centered in or directly adjacent to wooded riparian areas. Wide sampling intervals (60–120 min) provided adequate range estimates but were typically too coarse to accurately identify movement paths. Based on the average velocity of turkeys in our study, we suggest using sampling intervals ≤30 min when the intention is to quantify small-scale movements.

MANAGEMENT IMPLICATIONS

Our results indicate that use of micro-GPS offers fine scale resolution and almost unlimited sampling interval options, which allows wide flexibility in scheduling location acquisitions at lower cost and higher accuracy as compared to standard VHF telemetry studies. Using the technology we outlined here, biologically relevant questions for turkeys can be evaluated in a cost effective manner. For instance, use of the micro-GPS could benefit fine-scale measurement of pre-incubation habitat selection, temporal, and spatial variation in habitat selection of brooding females, remote monitoring of nesting female nesting locations, movements, and incubation recesses, as well as implementation of experiments to evaluate responses to manipulative disturbance of individuals or habitat. Using micro-GPS to understand the scale at which wild turkeys move through and select local and regional scale habitat will enhance managers’ ability to target areas to enhance or restore wild turkey populations throughout their range. Finally, availability of micro-GPS would allow researchers for the first time to coordinate sampling schedules for monitoring turkeys at multiple locations to evaluate whether generalities in species habitat selection and movement dynamics exist.

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LITERATURE CITED


