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EVALUATION OF A SOLAR-RECHARGED MICRO-GPS DATALOGGER FOR NORTHERN BOBWHITE IN THE ROLLING PLAINS OF TEXAS

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ABSTRACT

The use of Global Positioning Systems (GPS) transmitters on northern bobwhite (*Colinus virginianus*; hereafter, bobwhite) could increase our understanding of fine-scale movements and habitat use for a declining game bird species. We evaluated solar-recharged micro-GPS dataloggers to determine the effectiveness of the units on free-ranging bobwhite and we conducted a controlled experiment to determine the accuracy of the dataloggers under a variety of canopy cover. We deployed the micro-GPS dataloggers on 25 bobwhites between August 2016 and April 2017 across 4 different ranches in the Rolling Plains of West Texas, USA. Accuracy (± standard error) for the 8 dataloggers across 3 trials for the stationary tests was 25.4 ± 3.8 m. Daily movement of bobwhite averaged 0.96 ± 0.09 km and morning movements averaged 0.49 ± 0.07 km. Average 95% and 50% minimum convex polygons for bobwhite area utilization were 15.2 ha and 3.6 ha, respectively. Our data indicate that solar-recharged micro-GPS dataloggers can be used to monitor bobwhites' short-term fine-scale movements in West Texas.

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Key words: *Colinus virginianus*, daily movement, dataloggers, MCP, micro-GPS, northern bobwhite

Researchers traditionally have used very high frequency (VHF) telemetry to monitor wildlife to collect various forms of data (e.g., survival and movement; Burger et al. 1991, 1995; Parry et al. 1997). However, concerns have been raised about potential bias, ranging from personnel experience to equipment failures (Springer 1979, Fuller et al. 2005). For example, a researcher's presence may affect the animal's natural movements and introduce biases in estimates of habitat utilization. Additionally, adverse terrain and researcher errors may negatively affect VHF telemetry precision and accuracy (White and Garrott 1990, Fuller et al. 2005). Researchers have deployed Global Positioning Systems (GPS) equipment to monitor animal movements (Steiner et al. 2000, Hulbert and French 2001, Phillips et al. 2003). Advances in GPS technology have decreased the size of these GPS devices (from 150 g to 0.05 g) so dramatically that GPS dataloggers can now be placed on moderately small birds (i.e., <150 g).

Use of GPS transmitters has made possible research on large- and fine-scale movements (Bouten et al. 2013, Fremgen et al. 2017), and foraging (Phillips et al. 2003, Fedy et al. 2012) for large (~10 kg) and small (~109 g) avian species (Guthrie et al. 2011, Schwemmer et al. 2017, Watts et al. 2017, Moskat et al. 2019). Micro-GPS dataloggers for avian species have aided in estimating habitat utilization (Moskat et al. 2019, Wann et al. 2019). However, the reliability of such dataloggers should be carefully examined for target species to determine accuracy and precision (Forin-Wiart et al. 2015).

Northern bobwhite (*Colinus virginianus*, hereafter, bobwhite) is a popular game species in decline across much of its range (Hernández et al. 2013). Previous research has utilized the homing technique via VHF technology and equipment to monitor survival, nesting, and movement (Burger et al. 1991,

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1995; Buckley et al. 2015, 2018). To date, a study conducted in 2015–2017 has yielded 2 peer-reviewed manuscripts on using GPS on bobwhite. Marquardt et al. (2017) reported using 3.6 g PinPoint (Lotek Wireless, Inc., Newmarket, Ontario, Canada) GPS units and documented problems with battery life and number of location fixes. However, these units could be practical for short-duration studies. Additionally, Cohen et al. (2020) reported on use of these devices in research on movement and habitat utilization for bobwhite in Texas, USA. They found that home ranges estimated using GPS location fixes were comparable to those created from VHF telemetry data and recommended additional work across the different habitat types which bobwhites use. Due to the short battery life of the previous GPS dataloggers, it is important to test new GPS technology for use on bobwhite.

Our objectives were to 1) assess the accuracy of solar-recharged micro-GPS dataloggers, 2) compare the accuracy of micro-GPS dataloggers and human telemetry data collection, and 3) assess the effectiveness and feasibility of using such GPS units on wild bobwhite for future research.

STUDY AREA

Our stationary trials occurred on the Texas Tech University Native Rangeland in Lubbock, Texas, USA (33°36.260’N, 101°53.986’W). The dominant vegetation for the property consisted of honey mesquite (*Prosopis glandulosa*), blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), purple threeawn (*Aristida purpurea*), silver bluestem (*Bothriochloa saccharoides*), Arizona cottontop (*Digitaria californica*), and sand dropseed (*Sporobolus cryptandrus*; Sorensen 2010). Our research was conducted across 5 different locations in the Rolling Plains of West Texas. Vegetation and soils on the 4 study sites for the field trials consisted of the following: mostly honey mesquite and tobosa grass (*Hilira mutica*) on clay loam soils in Dickens County (Esperanza Ranch; 33°24.936’N, 100°53.445’W); shinnery oak (*Quercus havardii*) complex in Kent County (Morrison Ranch; 33°20.167’N, 100°59.269’W); midgrass prairie with mesquite encroachment over loam soils in King County (Pitchfork Ranch; 33°37.132’N, 100°28.593’W); and midgrass-shortgrass community with sideoats grama (*Bouteloua curtipendula*) and plains bristlegrass (*Setaria vulpiseta*) with fine sandy loam soils in Lamesa County (Indian Canyon Ranch; 32°46.610’N, 101°48.696’W; USDA NRCS 2017).

METHODS

Micro-GPS Datalogger

We evaluated 8 PICA solar-recharged micro-GPS dataloggers manufactured by Ecotone Telemetry (Ecotone Ltd., Gdynia, Poland). The internal memory of the datalogger held ~65,000 location fixes and the 25.4-mm × 12.7-mm solar panel recharged a 4.15 volt battery. Each datalogger had a mass of 5.6 g without any augmentations. The overall dimensions of each GPS datalogger unit were 35 mm × 16 mm × 10 mm (length × width × height). We coated each datalogger with a single thin layer of brown low-gloss paint to match feather coloration of bobwhites. We attached a 2.0 g VHF radio transmitter (American Wildlife Enterprises, Monticello, FL, USA) to the upper left side of each datalogger with epoxy resin (Loctite, Rocky Hill, CT, USA; Figures 1, 2) to help locate deployed units. After all components were compiled, including the harness material, the units weighed ~8.4 g.

Each PICA datalogger had ultra high frequency (UHF) digital upload and download capabilities through a portable base station for remote data collection. The manufacturer-documented maximum download distance was ~200 m, depending on topography. The PICA datalogger could be programmed to acquire location fixes at intervals from continuous to 240 minutes between fixes for a duration up to

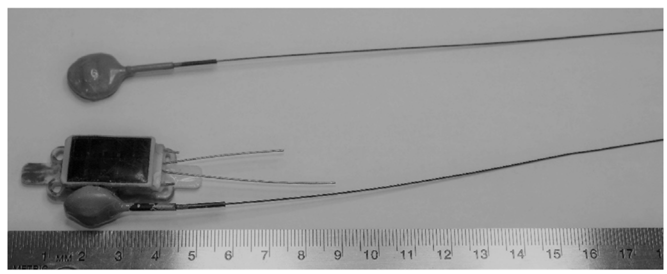

Fig. 1. Ecotone solar-recharged micro-GPS datalogger with a 2.0 g VHF transmitter (top unit) and how they were combined (bottom unit) for stationary and field trials in the Rolling Plains of West Texas, USA, 2016–2017.

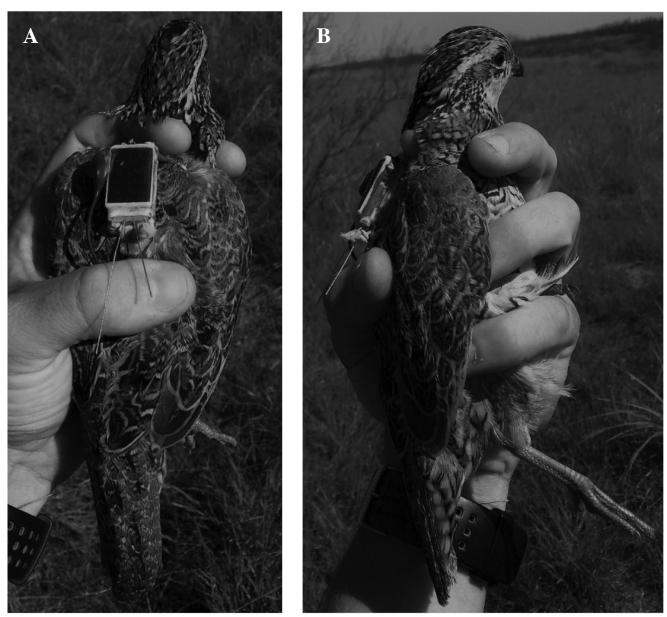

Fig. 2. Female northern bobwhite (*Colinus virginianus*) with a solar-recharged micro-GPS datalogger backpack attached, showing A) dorsal and B) profile views, in the Rolling Plains of West Texas, USA, fall 2016.

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24 hours. The PICA dataloggers could record data as soon as they were deployed or could be delayed for 24 or 48 hours. Each unit was set on a 1 minute broadcast interval which would transmit the data to the base station when in range. We employed a 90 second search time for the GPS satellite acquisition. The manufacturer stated that each unit had a full charge at ~4.15 volts and when the charge was < ~3.5 volts the battery level would be too low to transmit data to the base station, but the unit could still acquire GPS location fixes.

Stationary Trial

We evaluated the datalogger accuracy, download distance, and battery life in native rangeland conditions at 0, 25, 50, 75, and 100% canopy cover. We estimated the percent vegetation cover with a densitometer placed at a height of ~10 cm. We attached 8 dataloggers to wooden stakes at ~45° angle at 10 cm above the ground to simulate backpack-style attachment to bobwhites. GPS accuracy and battery life were measured for 7 days under each cover type at 5, 10, and 60 minute GPS fix intervals. Each unit was active 13 hours/day during daylight hours. We measured the true location of the dataloggers with a Trimble GeoXT GeoExplorer GPSr unit (Trimble Inc., Sunnyvale, CA, USA) by averaging 100 fixes/trial. We measured the Euclidean distance between the estimated location of each GPS dataloggers and the true location to determine the accuracy of each datalogger by point-centroid in QGIS (version 2.18.6; Quantum GIS Development Team 2017; https://www.qgis.org, accessed on 15 Apr 2017). We calculated the download distance by using the known location of each datalogger, and beginning at 200 m from the units we closed the distance at a rate of 1 meter/minute until the base station wirelessly connected remotely to the unit. We used 200 m as the starting distance based on the manufacturer's suggested maximum download distance of the dataloggers. We used a hand-held Garmin eTrex 20x GPSr (Garmin Ltd., Olathe, KS, USA) unit to close in on the known location of the dataloggers. We began moving toward the dataloggers only when the Garmin units were at their most accurate (±2 m) based on the unit's internal error measurements. Each unit was scheduled to broadcast a signal for the base station to record data every 60 seconds.

Field Trial

We captured bobwhite using walk-in funnel type traps (Stoddard 1931) baited with milo during winter 2016–2017. We determined age and sex of the bobwhite by plumage and wing characteristics (Leopold 1939, Petrides and Nestler 1943, Rosene 1969). Each bobwhite was weighed to the nearest gram and received a No. 8 butt-end aluminum leg band. We placed dataloggers on bobwhites weighing ~170g to be within the recommended "5% rule" for wildlife research (Fair et al. 2010, Millspaugh et al. 2012). We attached each micro-GPS datalogger backpack-style with a 2.5 mm elastic shock cord around each wing and a 10 mm distance between the GPS unit and the back of the bird. We tested each wing individually and simultaneously to ensure ease of movement for flight. We downloaded location data and established survival (i.e., VHF signal change location or visual confirmation) of each bird weekly. We recovered each micro-GPS datalogger when the battery of the VHF or GPS unit was depleted or if predation occurred. We uploaded programming for each GPS datalogger before releasing the birds with either a 10 minute (morning movement) or 60 minute (daily movements) duty cycle per location. We chose to delay each duty cycle a full 24 hours after capture to minimize the effects of capture and to allow the bobwhite to acclimate to the backpack before data collection began. We measured daily and morning movement for bobwhite by calculated straight-line distance between each consecutive location fix using QGIS (Figure 3). We combined all daily and morning movements, respectively, to estimate the average movement for bobwhite. We split location times into daily (30 minutes before sunrise to 30 minutes after sunset) and morning (30 minutes before sunrise to 10:00 a.m.) categories. Daily movements data were collected as 1 location fix/hour (~10 locations) and morning movements were assigned as 1

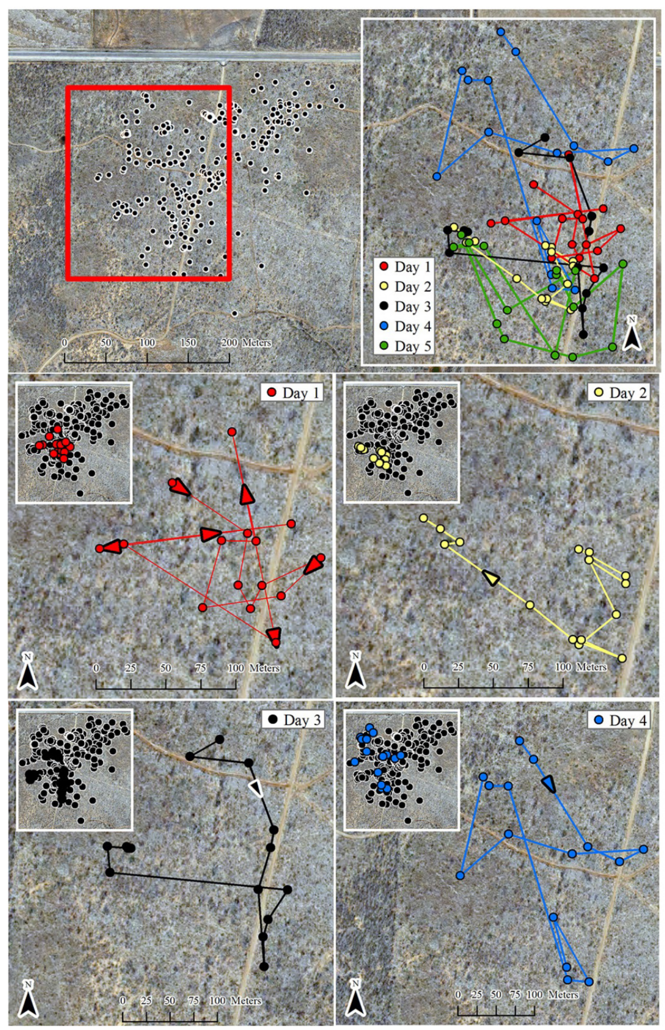

Fig. 3. Movement of northern bobwhite (*Colinus virginianus*) fitted with a solar-recharged micro-GPS datalogger monitored for 4 days on the Esperanza Ranch in the Rolling Plains of West Texas, USA, spring 2017.

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fix/10 minutes until 10:00 (~25 locations). We calculated 50% and 95% minimum convex polygons (MCPs) for each bird in QGIS. We also examined the power consumption for each datalogger for the duration of its deployment. We attempted to remove all backpack GPS dataloggers by recapturing the bobwhite before the VHF transmitter expired at 82 days. We recaptured bobwhite by flushing the bird 3 times, then grabbing the bird by hand or using a hand-held fishing dip-net. All aspects of this research were in accordance with Texas Tech University Animal Care and Use Committee # 16008-02.

RESULTS

Stationary Trial

We used the same 4 dataloggers for the 5, 10, and 60 minute duty cycle error trials on the Texas Tech University native rangeland. We also ran a third control test on the Esperanza Ranch (5 minute interval). The overall accuracy for the 4 dataloggers across the 3 trials was 25.42 m ± 3.80 (mean ± standard error) from 9,921 locations. The 10 minute location acquisition period was the most accurate with 21.19 m (±1.79) while the 5 minute and 1 hour location fix had an average accuracy of 27.79 m (±2.43) and 27.28 m (±7.34), respectively. We noted that location accuracy and location fix rate decreased as vegetation cover increased (Table 1). The battery power dropped below 3.50 volts on day 4 for the units placed in the 50–100% vegetation cover types whereas units in the 0–25% vegetation cover type lasted a full 5 days. None of the units in the 5 minute location fix group lasted throughout the full 7 day trial. The recharge rate for the 10 minute and 60 minute location fix trial group was sufficient throughout the 7 day trial period (Figure 4). During the stationary trials, the average download distance was 67.95 m (±14.48) from the dataloggers with a range of 33–145 m.

Field Trial

We deployed solar-recharged micro-GPS dataloggers on 25 bobwhites between August 2016 and April 2017. We measured daily movement for 13 bobwhites on 4 ranches and morning movements for 4 bobwhites on 1 ranch. Eight bobwhites with dataloggers were censored due to either predation early in the deployment (<3 days) or improper duty cycle uploaded. We removed these bobwhites from any data analysis. Average time deployed was 18.5 days (range = 6–52 days). Daily movement of bobwhite averaged 960 m (±9) with 2,795 locations and morning movements averaged 490 m (±7) from 1,672 locations. Measured area of use for the daily movements was 15.17 ha (±1.60) and 3.58 ha (±0.36) for the 95% and 50% MCPs, respectively. The morning areas used by bobwhite were slightly larger for the 95% MCPs (17.76 ha ± 5.78) and consistent for the 50% MCPs (3.04 ha ± 0.90). On average, GPS dataloggers were ~4.67% (± 0.14) of a bobwhite's body weight. The average distance from birds that were flushed was 46.6 m (36.7 m for 3 birds with dataloggers on the Esperanza Ranch and 51.0 m for 4 birds on the Morrison Ranch). We were unable to recover 3 GPS dataloggers due to a malfunction with the VHF transmitters. Power consumption and recharge varied between each datalogger attached to bobwhites (Figure 5).

Table 1. Accuracy results (± standard error [SE]) for 4 solar-recharged micro-GPS dataloggers with a 5-minute, 10-minute, and 1-hour location fix schedule during a stationary trial in West Texas, USA, spring 2017.

Datalogger unit	Vegetation cover	Location schedule	Error rate (m) ± SE	Locations (n)
PIC01	0%	5-mins	31.19 ± 3.56	1,130
PIC04	25%	5-mins	28.53 ± 1.84	1,333
PIC10	50%	5-mins	28.30 ± 2.87	905
PIC07	75%	5-mins	28.60 ± 2.08	983
PIC08	100%	5-mins	22.37 ± 1.83	808
PIC01	0%	10-mins	09.22 ± 0.52	907
PIC04	25%	10-mins	13.12 ± 0.90	917
PIC10	50%	10-mins	17.49 ± 1.22	921
PIC07	75%	10-mins	32.01 ± 2.67	513
PIC08	100%	10-mins	34.14 ± 3.64	516
PIC01	0%	1-hour	29.84 ± 15.49	273
PIC04	25%	1-hour	11.99 ± 1.58	196
PIC10	50%	1-hour	13.67 ± 1.82	196
PIC07	75%	1-hour	46.57 ± 9.10	100
PIC08	100%	1-hour	34.36 ± 8.75	100

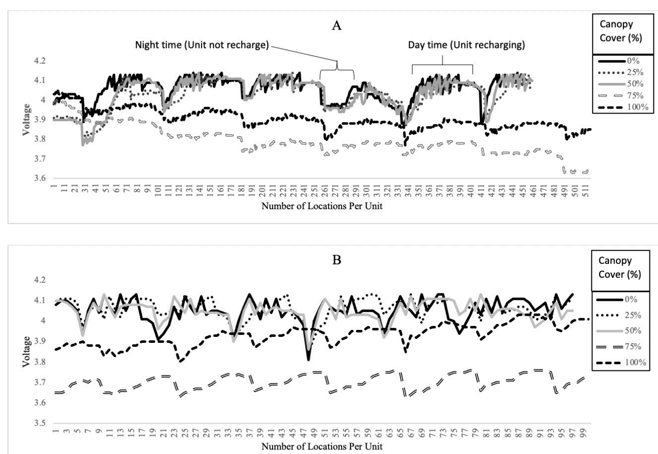

Fig. 4. Power consumption of 4 solar-recharged micro-GPS dataloggers with location fixes set for A) every 10 minutes and B) every 60 minutes over a 7-day trial period in 0–100% vegetation cover in the Rolling Plains of West Texas, USA, fall 2016.

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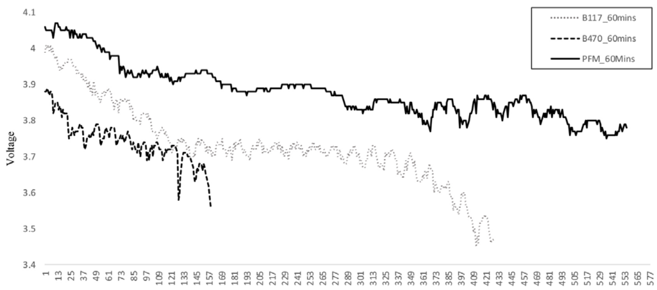

Fig. 5. Example of power consumption for solar-recharged micro-GPS dataloggers with location fixes set for every 60 minutes for northern bobwhite (*Colinus virginianus*) in the Rolling Plains of West Texas, USA, fall 2016.

DISCUSSION

Based on our results for accuracy and field tests, we believe these units have advantages and undoubted potential for monitoring bobwhite behavior, resource selection, and movements at the fine scale (i.e., roost and daily movement). Our stationary trials showed that PICA micro-GPS units exhibited a similar unit accuracy (27–31 m) to a previous research project (Marquardt et al. 2017) which used a different micro-GPS with shorter battery life. The units we selected were equipped with solar panels which we had hoped to increase the battery life of previous units. We found that as canopy cover increased during the stationary data collection the accuracy of the micro-GPS unit decreased and power consumption outpaced solar recharge, resulting in only ~1–2 days of data collection. We found that if bobwhite used areas with <50% canopy cover the solar panels on the units could maintain an adequate charge to continue data collection for 50+ days with a duty cycle of a location fix per 60 minutes for 13 hours/day. Previous research has shown that bobwhite in the Rolling Plains ecoregion of Texas tend to select areas with <50% canopy cover (Dabbert and Verble-Pearson 2017). Battery power consumption and deployment durations will depend on research needs such as an increased duty cycle (i.e., more locations per day), weather conditions (i.e., cloud cover), and bobwhite behavior (e.g., nesting). So if the research question revolves around nesting or is centered in a dense canopy, a reduced data collection cycle may be needed to increase battery power and ultimately longevity of the unit before it needs to be recovered.

Our data indicate that solar-recharged micro-GPS dataloggers can be used to monitor short-term movements for bobwhite in the Rolling Plains of West Texas. Previous research with VHF telemetry conducted on bobwhite found that mean daily movement of 149.31 m (±6.24) and an average distance reported for bobwhite of 960 m (± 9; Terhune et al. 2006). When we compared our data with Marquardt et al. (2017), their daily movement was higher (1,206–2,998 m) than our recorded movements. Yet our daily movement is slightly larger than movements reported by Cohen et al. (2020), which ranged from 704–785 m when they used micro-GPS units. These differences in daily movement could be due to the micro-GPS units used, location fix schedule, environmental conditions, or vegetation composition. Additionally, our home-range data showed a slightly smaller area (14.54 ha) than bobwhite home range (95% MCP) recorded in Southwest Georgia, USA (16.78 ha; Terhune et al. 2006). Yet bobwhite home range can vary based on resource availability, which could explain the difference we observed in our comparison with Terhune et al. (2006) regardless of differences in monitoring technology. Nevertheless, with micro-GPS units, we were able to utilize a large number of locations for multiple birds to estimate home ranges across multiple ranches at the same time, which could be costly or near impossible when using conventional VHF monitoring techniques.

A concern when using any monitoring technology on wildlife is that the units do not impede or harm the subject animals. When retrieving dataloggers from live bobwhite, we examined every bird for bruising under the wings or feather growth problems under each unit and did not observe any adverse effects caused by the solar-recharged GPS dataloggers. Yet a major concern we had with these units was the potential of the semi-reflective solar panel on each unit to draw the attention of raptors. Examining the effects of the micro-GPS units on bobwhite survival was outside the scope of the current project. Other researchers have found that upland game birds (i.e., greater sage-grouse [*Centrocercus urophasianus*]) fitted with dorsal solar GPS transmitters exhibited lower survival compared to VHF-tagged individuals (Caudill et al. 2014). It should be noted that Caudill et al. (2014) used suture dorsal-mounted backpack transmitters, which can have negative impacts on reproduction and survival (Paquette et al. 1997) and was different from our dorsal attachment method. We recommend that future research examine behavioral and survival impacts of solar-charged micro-GPS dataloggers on bobwhite across its range.

Even though the micro-GPS dataloggers can collect multiple locations without an observer present, currently there are limitations with the technology. The recharge capability of the solar units is limited by environmental conditions (i.e., sunny day vs. cloudy day). When solar-recharged GPS dataloggers are placed on wild free-roaming bobwhite, the duty cycle and environmental conditions must be considered to maintain sufficient voltage for the unit to function. When the duty cycle is set for intensive location fixes (e.g., 5 minutes), the recharging capabilities for the solar-recharged unit could be about 5 or 10 days with a 60 minute duty cycle with intermittent cloudy days (50% cloud coverage or more). If researchers can change the work duty schedule remotely before a cloudy day, it could reduce this potential negative impact on battery life. Another drawback for the GPS datalogger is the necessity for combining a VHF transmitter to relocate the datalogger or bird. With the current technological trade-off between small VHF unit and VHF battery power and detection distance, the best unit we could find was 2 g. These 2 extra grams could add too much weight to the units during certain times of the year when bobwhite

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weigh less (i.e., winter months) and could cause units to exceed the <5% body weight threshold that is recommended for telemetry units attached to wildlife (Caccamise and Hedin 1985, Aldridge and Bringham 1988, Bridge et al. 2011). White (2021) observed that bobwhite equipped with a ~8.5 g solar GPS and VHF backpack had a significantly lower daily survival probability than bobwhite wearing traditional 6 g necklace-style VHF transmitters. However, the author was unable to establish a positive linear relationship between increasing bobwhite mass and daily survival probabilities and suggested that the maximum tolerable mass may be lower for backpack configurations (White 2021). Since we began our research, however, technological advances have decreased the weight of VHF (<1.0 g) and micro-GPS (4.5 g) transmitters considerably, which could make this consideration a moot point. It is also our intent to acknowledge that the rapid improvements and reduction in the size of GPS devices are ever-changing, which could provide researchers with more-suitable equipment for monitoring for their species of interest. We suggest that researchers and managers should pay close attention to the available literature and wildlife monitoring equipment manufacturers for the newest forms of technology for monitoring wildlife to provide the best available information for behavior, habitat use, and environmental impact on their species of interest.

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