EVALUATION OF GPS-SIZED EXPANDABLE RADIOCOLLARS DESIGNED FOR WHITE-TAILED DEER FAWNS

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SUMMARY OF FINDINGS

During 2018-2020, we tested fit and function of 5 Global Positioning System (GPS)-sized expandable radiocollar mock-up designs on white-tailed deer (*Odocoileus virginianus*) fawns. We fitted 46 captive newborn fawns with ear tags and collars (20 Vectronic Vertex v1.0, 3 Telonics TGW v1.0, 3 Telonics Recon v1.0, 10 Vectronic Vertex v2.0, 10 Telonics TGW v2.0) and ear-tagged 15 captive control fawns without collars. We collected neck measurements from fawns at birth and at approximately 6, 9, and 12 months of age. Additionally, we conducted observations of fawns to evaluate the potential effects of collars on behavior. Vectronic collars overall accommodated the neck growth of fawns during the first 12 months of life. Telonics collars expanded prematurely resulting in loose collars, which failed (shed or removed) by 85.5 ± 41.1 (mean ± SD) days. During the first year of testing, notable effects of collars on fawn behavior included high-stepping with forelimbs during locomotion, erratic jumping behavior, and several instances of forelimbs getting caught in ill-fitting collars. Each of these atypical behaviors were most prevalent in younger collared fawns, from newborn to approximately 4 weeks of age. High-stepping was observed in fawns wearing both brands of collars, however, this behavior occurred most frequently in young fawns fitted with Vectronic collars. Collared fawns spent about 45% less time vigilant than uncollared fawns during the first 4 weeks of life. Additionally, fawns wearing Vectronic collars spent about 25% less time vigilant than fawns wearing Telonics collars. We did not observe any other significant differences in behavior (e.g., sleeping, suckling, grooming, etc.) between collared and uncollared fawns during the first 4 weeks of life. Our results suggest that the GPS-sized expandable collars tested in this study would benefit from modification before deployment in the field. We recommend modifications to each design to address collar retention issues and behavioral concerns, such as an improved stitching pattern, alternative thread and elastic materials that facilitate a more gradual elastic expansion, decreased battery housing size and weight, and improved weight distribution of the electronic components.

INTRODUCTION

Knowledge of population parameters (e.g., sex ratio, age structure, survival, recruitment) informs decision-making for management of white-tailed deer (*Odocoileus virginianus*) populations (Jacobson et al. 1997, Keyser et al. 2005). Survival of neonatal white-tailed deer is one of the most important factors influencing population growth (Gallard et al. 2003, Chitwood et al. 2015). However, estimating survival of fawns to recruitment is logistically challenging using

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current very high frequency (VHF) collar technology (Moen et al. 1996, Rodgers et al. 1996, Bowman et al. 2000, Pusateri-Burroughs et al. 2006, Severud et al. 2015). Accurate estimation of survival requires capturing and collaring fawns soon after birth and intensively monitoring them for the first few months of life when most mortalities occur (e.g., predation, starvation, disease; Pusateri-Burroughs et al. 2006). The ideal design of radiocollars should ensure the welfare of the animal, minimize impacts on behavior and maximize collar retention (Grovenburg et al. 2014). Expandable radiocollars are designed to accommodate rapid neck growth throughout the first 12 months of life by stretching, opening at folds, deteriorating, and finally dropping from the animal (Smith et al. 1998, Grovenburg et al. 2014).

Multiple field studies have reported premature loss or failure of expandable radiocollars for neonatal deer (Vreeland et al. 2004, Pusateri-Burroughs et al. 2006, Rohm et al. 2007, Hiller et al. 2008, Grovenburg et al. 2014, Obermoller et al. 2018). Ultimately, premature loss of collars reduces the sample size and power of inference. Additional modifications to expandable collar designs have been proposed to improve retention and facilitate a more gradual collar expansion (Diefenbach et al. 2003, Cherry et al. 2014, Grovenburg et al. 2014, Obermoller et al. 2018). Some of these modifications have been deployed in the field (Diefenbach et al. 2003, Bowman et al. 2014, Cherry et al. 2014, Grovenburg et al. 2014).

Integration of GPS technology with expandable collar designs allows researchers to more efficiently and effectively investigate survival and movements of neonatal white-tailed deer (Bowman et al. 2000, McCance and Baydack 2017). The primary factor limiting use of GPS technology is the battery size and weight required to support GPS transmitters (McCance and Baydack 2017). Testing of GPS-sized expandable collars in controlled settings is warranted before extensive deployment in field studies.

Aside from small experimental deployments, GPS-sized expandable radiocollar designs have not been fitted to white-tailed deer fawns and there is currently no literature on the use of GPS technology deployed on white-tailed deer fawns. Expandable GPS collars have been deployed only within the last decade on other neonatal ungulates in the wild (moose [*Alces alces*], Severud et al. 2015, Obermoller et al. 2018; fallow deer [*Dama dama*], Kjellander et al. 2012) or in captivity (domestic horse [*Equus caballus*], Hampson et al. 2010). Utilizing animals in a captive facility allows researchers to evaluate the efficacy of GPS-sized collars over time and observe collar fit and function, the overall health and well-being of animals, and the impact GPS-sized units may have on the behavior of fawns. Also, collars that become overly restrictive on captive fawns may be safely removed. Because most prior studies have deployed GPS-sized collars on species which give birth to considerably larger young than white-tailed deer (Hampson et al. 2010, Kjellander et al. 2012, Severud et al. 2015), it is logical to assume that the relatively larger offspring would better support the weight of a GPS collar. Therefore, testing of GPS-sized collars on white-tailed deer fawns in a controlled setting is warranted to ensure animal welfare for the duration of collar deployments.

OBJECTIVES

1. Evaluate the efficacy of GPS-sized expandable radiocollars designed for white-tailed deer fawns.
2. Determine the effects of GPS-sized radiocollars on the behavior of white-tailed deer fawns.
3. Provide collar companies recommendations to improve GPS-sized expandable radiocollar designs.

METHODS

Study Site

We conducted our study at the Whitehall Deer Research Facility on the University of Georgia campus in Athens, GA. Captive deer were held in 1-2-acre outdoor paddocks, each containing 12-14 adult does and their fawns. We provided all deer with pelleted feed (AntlerMax Breeder Textured 17-6, Purina Animal Nutrition LLC, Arden Hills, MN, USA), hay, and water *ad libitum*. All methods were approved by the University of Georgia Institutional Animal Care and Use Committee under Animal Use Proposal A2018 03-019-Y2-A0.

Animal Capture and Handling

We captured 61 total fawns from May to July in 2018 and 2019. We searched paddocks for newborn fawns twice daily. We captured, handled, and released each fawn within the first 24 hours after birth. We collected morphometric measurements of fawns (i.e., total body length, chest girth, hindfoot length; and neck circumference at upper, middle, and lower neck), affixed individually identifying ear tags in both ears (Allflex USA Inc., College Station, TX, USA), and fitted 46 fawns with GPS-sized expandable radio-collars. During 2018, we fitted 20 fawns with Vectronic Vertex v1.0 collars (Vectronic Aerospace GmbH, Berlin, Germany), 3 fawns with Telonics TGW v1.0 collars (Telonics, Inc., Mesa, AZ, USA), and 3 fawns with Telonics Recon v1.0 collars (Telonics, Inc., Mesa, AZ, USA). We left 5 fawns uncollared to serve as experimental controls for our behavioral assessments. During 2019, we fitted 10 fawns with Vectronic Vertex v2.0 collars and 10 fawns with Telonics TGW v2.0 collars, and we left 10 fawns uncollared. After handling, we immediately returned fawns to the outdoor paddocks to be reunited with their mothers until weaned.

Collar Fit and Function

We conducted assessments of collar fit and function 3-5 times per week on each collared fawn throughout the first 12 months of life. We remotely observed fawns in outdoor paddocks, recorded scores of collar fit and body condition, and examined each fawn's neck for signs of hair loss or lesions (Table 1). Additionally, we examined the expandable folds of each collar, recording the date at which each fold opened. We calculated collar retention by recording the date at which collars failed, dropped, or required removal to ensure animal welfare. We manually restrained fawns at approximately 6, 9, and 12 months of age to inspect the integrity of collars, evaluate the condition of fawns, and collect neck circumference measurements.

Vectronic Vertex

Vectronic Vertex v1.0 (Figure 1) collars weighed approximately 138 g, with the battery, VHF transmitter and GPS transmitter located within a single large housing at the front of the collar (dimensions = 6.2 cm x 3.9 cm x 4.4 cm). The housing was attached to the collar using high-performance glue and 2 plastic cable ties. The antenna was coated with a thin protective layer of plastic and measured 26.5 cm with 20.5 cm of its full length exposed. The neck band was 4-cm wide, composed of nylon and rubber materials with an initial circumference of 22.3 cm. The neck band included 6 expansion folds (3 sections of 2 folds each), which were 2-cm long. The section of folds furthest from the housing had a single straight stitch running through the middle of its folds, the middle section had 2 parallel straight stitches (2.4 cm apart) running through its folds, and the section closest to the housing had 2 parallel straight stitches (3.1 cm apart) through its folds. Fully expanded, the circumference of the neck band was approximately 34 cm, not including stretch of the elastic band material. The measurements of Vectronic Vertex v2.0 (Figure 2) were identical to the Vertex v2.0, except the battery housing of the updated design was slightly larger in size (dimensions = 6.5 cm x 4.2 cm x 4.4 cm). Additionally, the Vertex v2.0 (153 g) was 15 g heavier than the Vertex v1.0.

Telonics TGW and Recon

Telonics TGW v1.0 (Figure 3) and Telonics Recon v1.0 (Figure 4) collars weighed about 140 g and 150 g, respectively. The primary differences between the TGW v1.0 and the Recon v1.0 designs were the battery housing material and the distribution of electronics. The Telonics TGW v1.0 battery, VHF transmitter and GPS transmitter were located in 3 housings: a polymeric housing contained the battery (dimensions = 5.5 cm x 2.9 cm x 3.3 cm) and 2 plastic housings contained the VHF (dimensions = 1.8 cm x 0.5 cm x 1.8 cm) and GPS (dimensions = 2.8 cm x 0.9 cm x 2.8 cm) transmitters. The Telonics Recon v1.0 battery, VHF and GPS transmitters were distributed between only 2 housings: an aluminum housing contained both the battery and the VHF transmitter (dimensions = 4.3 cm x 2.6 cm x 3.5 cm) and a plastic housing contained the GPS transmitter (dimensions = 2.8 cm x 0.9 cm x 2.8 cm). The battery housings of both the TGW v1.0 and the Recon v1.0 designs were attached to the collar using 4 screws and glue. The antenna of each Telonics model measured 26.8 cm with 20.9 cm of its full length exposed. The collar bands of each Telonics models were 3.8-cm wide and composed of cotton and rubber (i.e., elastic portion) sewn to a 3.7-cm wide strip of static polymer. The length of the static polymer material for each model was 15 cm and initial length of the elastic portion of each was 7.9 cm. Therefore, the initial band circumference (i.e., pre-expansion) of each Telonics model was 22.9 cm. The bands of both designs included 6 expansion folds (3 sections of 2 folds each), which were 2 cm long. The section of folds closest to the housing had a single straight stitch running through the middle of its folds, the middle section had 2 parallel straight stitches (1 cm apart) through its folds, and the section furthest from the housing had 4 parallel straight stitches (0.5 cm apart) through its folds. Fully expanded, the circumference of the band was 34.9 cm not including stretch of the elastic band material. The measurements for the Telonics TGW 2.0 (Figure 5) were identical to the TGW v1.0, except the updated model utilized 3 protruding expansion folds designed to allow more initial stretching. Additionally, the TGW v2.0 used nylon thread stitched perpendicular to the long axis, whereas the v1.0 collars used cotton thread stitched parallel to the long axis. The TGW v2.0 (136 g) was 4 g lighter than the TGW v1.0.

Fawn Behavior

We conducted focal observation sessions of each fawn to evaluate effects of collars on their behavior during the first 12 months of life. During 2018-2019 the frequency of our observations decreased with fawn age: $\leq$30 days of age we obtained $\geq$1 morning and $\geq$1 evening session every week for each fawn; during 30-60 days of age we conducted 1 morning session per week; during 60-200 days of age we conducted 1 morning session every other week; and during 200-365 days of age we observed each fawn during 1 morning focal session every 4 weeks. We conducted focal sessions from 4.5-m stationary observation platforms within paddocks during crepuscular sampling periods: in the morning from 06:00 to 10:00 or in the evening from 17:00 to 21:00. Before conducting the first focal session of a sampling period, the observer sat quietly for 15 minutes to minimize impacts of human activity on the behavior of deer in the paddocks. During a focal session we recorded body orientation and behavior of the focal fawn each minute for 30 minutes. We recorded the overall body position, neck position, head position, and head tilt of the fawn based on a pre-determined scoring system (Figure 6). We coded all behaviors (e.g., vigilant, sleeping, foraging, suckling) in a preconstructed ethogram (Table 2). If the focal fawn moved out of sight for a period >5 minutes, we terminated the focal session and censored the data. We recorded a running tally of fawn and mother vocalizations, and tallied instances where fawns exhibited attention to collars (e.g. scratching at collar). We also monitored fawn-mother proximity using a laser rangefinder and a compass. Every 5 minutes, the observer recorded a distance (m) and compass azimuth for the fawn and mother to calculate proximity (Euclidean distance). We averaged all fawn-mother distances to obtain a mean fawn-doe proximity for each session. If the mother of the focal fawn was not visible, the observer did not record this information during the session. During 2019-2020, we conducted focal sessions 3 times per week on each fawn. During a focal session, we located each fawn and recorded a single score for body orientation and a single score for behavior. To date, we have conducted a series of two-sample t-tests in program R (R Core Team, 2019) to compare the proportion of time collared vs. uncollared fawns spent exhibiting various behaviors. In future analyses, we will use a bootstrapping technique to further analyze behavioral data and meet assumptions of normality, and then conduct an Analysis of Variance (ANOVA) with repeated measures to compare the proportion of time collared vs. uncollared fawns spent exhibiting specific behaviors with age. We will also use an ANOVA with repeated measures to compare behaviors between collar models (e.g., Telonics vs. Vectronic, TGW v1.0 vs. Recon v1.0, etc.)

RESULTS

During the first year of testing (2018-2019), Vectronic Vertex v1.0 collars accommodated neck growth well. As the necks of fawns grew larger (Table 3), collars initially became tight (but not restrictive) around the lower neck. This added pressure applied to the expandable materials of collars would cause 1-2 expansion folds to open, increasing the band circumference of the collar. The initial expansion resulted in some hair loss from the neck as loosened collars moved more freely along necks of fawns. This likely caused some minor discomfort; however fawns quickly grew into the expansion. We observed no effects of Vectronic collars on the body condition of fawns. Of the 20 collars deployed, 9 (45%) were retained for >365 days. No Vectronic collars exhibited premature expansion at a level that resulted in collar failure. Three (15%) Vectronic collars dropped from fawns in the outdoor paddocks at <365 days, but none were due to compromised stitching or elastic material. In 1 case, a fawn shed its collar at 256 days of age while being moved through the barn for researchers to collect neck measurements. In 2 other cases, fawns shed their collars at 261 and 270 days of age due to a large tear in the expandable material of the collars, likely caused by collars catching on fencing in outdoor paddocks. Of the 20 Vectronic collars deployed, 8 (40%) collars were retained on fawns until mortality before 365 days. Two of 8 mortalities occurred while moving deer in our captive facility, an inherent risk when handling wild animals. The other 6 fawns died from unknown causes, with 4 dying ≤14 days of life and 2 dying >100 days of life. Based on necropsy results and our own mortality assessments, these mortalities were not directly related to the collars. However, we could not discount the possibility that collars had some indirect influence on these mortalities.

During the second year of testing, we found the modified Vectronic Vertex v2.0 collars performed similarly to the Vectronic models tested the previous year. Of the 10 collars deployed, 1 collar shed prematurely in the outdoor paddocks at 109 days. This collar was loose on the fawn’s neck and easily slipped over the head of the animal. The collar prematurely expanded, but the elastic material of the collar was not yet fully compromised. While moving fawns at the facility, we witnessed 1 collar drop from a fawn after snagging and tearing (at the expandable material near the housing) on a perimeter fence. The other 8 collars are still deployed on fawns at the captive facility and are sufficiently accommodating neck growth to date (≤312 days).

During the first year of testing (2018-2019), the collar folds of all 6 Telonics v1.0 mock-ups expanded prematurely by 75.8 ± 27.9 days. The ill-fitting collars caused significant hair loss on the necks of all 6 fawns but did not appear to impact their overall body condition. Fully-expanded Telonics mock-ups were a source of apparent discomfort as collars moved freely along the necks of fawns. Once the stitching on the folds was compromised and the elastic material began to degrade, all 6 fawns were able to step through collars with their forelimbs.

This displacement resulted in collars positioned around the chest or waist of fawns. One of the collars dropped 20 days after the last fold expanded at approximately 80 days of age. For another individual, the fully expanded collar was removed from a fawn's waist when it fell ill at 105 days. In the case of the other 4 fawns with Telonics mock-ups, fully-expanded collars were removed from the chest or waist of fawns at approximately 6 months of age when fawns were manually restrained to collect neck measurements. Overall, Telonics v1.0 collars (N = 6) failed (dropped or removed) by 101.3 $\pm$ 45.5 (mean $\pm$ SD) days.

During the second year of testing (2019-2020), we found that the modified Telonics TGW v2.0 collars failed even sooner than Telonics v1.0 collars from the first year. Of the 10 collars deployed, 1 shed after only 5 days because the initial band circumference of the collar was too large and the collar slipped over the animal's head. Similarly, collars expanded prematurely, resulting in ill-fitting collars and hair loss. Four collars ended up around the chest or waist of fawns after the animals stepped through prematurely expanded collars. We found 7 collars were shed prematurely by 47 $\pm$ 25.4 (mean $\pm$ SD) days. We removed 2 collars from the waist at 122 and 126 days. Lastly, we found 1 fawn suffered a leg injury and was subsequently euthanized at 17 days of age. This collar was loose on the animal and no folds were open when the collar was removed. Overall, the Telonics v2.0 collars (N = 10) failed (dropped or removed) by 69.7 $\pm$ 36.7 (mean $\pm$ SD) days.

We collected >200 hours of behavioral observations during the first year of testing. Notable effects of collars on fawn behavior included high-stepping with forelimbs during locomotion, erratic jumping behavior and several instances of forelimbs getting caught in ill-fitting collars. Each of these atypical behaviors were most prevalent in younger collared fawns, from newborn to approximately 4 weeks of age. High-stepping during locomotion can occur to some degree in newborn fawns without collars, however, this behavior was more exaggerated in GPS-collared fawns and persisted for several weeks versus several days for uncollared newborn fawns. We did not observe any uncollared fawns exhibiting high-stepping behavior during behavioral focal sessions. We observed high-stepping in fawns wearing both types of collars, but this behavior occurred most frequently in young fawns fitted with Vectronic Vertex collars. During the first year, 2 (33.3%) Telonics v1.0 collared fawns exhibited high-stepping behavior for a total of 10 occurrences. For these fawns, high-stepping behavior was not observed after an average of 7 days. We observed 12 (60%) individuals with Vectronic v1.0 collars exhibiting high-stepping behavior for a total of 71 occurrences. High-stepping behavior was not observed after an average of 18 days. The oldest collared fawn (Vectronic) to exhibit high-stepping behavior was 39 days old; however, all other fawns exhibited this behavior at ≤4 weeks of life. We observed several instances of fawns, fitted with both Telonics and Vectronic collars, getting their forelimbs caught in loose-fitting collars during the first year of observations. In these cases, a fawn's leg would remain restrained in the collar for 1-6 minutes. We observed 3 instances of young fawns (<2 weeks old), fitted with both Telonics v1.0 (2 occurrences) and Vectronic v1.0 collars (1 occurrence), getting their forelimbs caught in loose-fitting collars (pre-expansion). We found collared fawns spent ~45% less time vigilant than uncollared fawns during the first 4 weeks of life ($p < 0.01$) (Figure 7). Additionally, fawns wearing Vectronic collars spent ~25% less time vigilant than fawns wearing Telonics collars ($p < 0.01$) (Figure 8). We did not observe any other differences in behavior (e.g., sleeping, vigilance, suckling, grooming, etc.) between collared and uncollared fawns during the first 4 weeks of life ($p > 0.05$). We have conducted approximately 150 behavioral observations per fawn during the second year of testing, and we are currently the in preliminary stages of analyzing these data.

DISCUSSION

Based on our preliminary results, we developed several recommendations for Telonics, Inc. and Vectronic Aerospace GmbH to improve their GPS-sized expandable radiocollars for neonatal white-tailed deer. Currently, we cannot recommend collar designs tested in our study for use in field studies. However, with modifications and further testing in controlled settings, researchers may have access to viable GPS fawn collar options in the foreseeable future.
We recommended Vectronic decrease the initial band circumference of their Vertex v1.0 collar, improve weight distribution, and reduce size and weight of the battery housing in order to minimize effects on behavior. Poor weight distribution, paired with an initial collar band circumference larger than the newborn fawn's necks caused the battery housing to swing freely as fawns moved. The high-stepping behavior was caused by the fawns' attempt to step around the freely moving collar to minimize contact with their forelimbs. The concern with this behavior is that a young collared fawn exhibiting high-stepping during locomotion may be more susceptible to predation than a normal fawn at that same age. If GPS-collared fawns die at a higher rate than uncollared fawns, then the results of fawn survival studies using these collars could be severely biased. We believed the erratic jumping behavior was from discomfort with the bulky and loose-fitting collars. Decreasing the initial band circumference may alleviate some behavioral issues and reduce the chance of fawns getting a forelimb caught in a loose-fitting collar. Weight of the Vectronic Vertex collar was focused at the front where a single large housing comprised all of the electronics. We believe that distributing electronics more evenly around the collar, perhaps similar to the Telonics models, would reduce the ill-effects of collars on fawn behavior. After testing the subsequent Vectronic version (Vertex v2.0), we maintain our original recommendations to improve the fit and potentially minimize impacts of collars on fawn behavior.

We recommended a slightly smaller initial band circumference for the Telonics TGW v1.0 and Recon v1.0 collars to accommodate the smaller necks of newborn fawns (Table 3). A more appropriately fitting collar may minimize issues with high-stepping and decrease the probability of fawns getting a forelimb caught in a loose-fitting collar. The primary issue with the Telonics collar was the expandable material intended to accommodate rapid growth of fawns during the first year of life. Material and stitching pattern caused collars to expand and deteriorate at an accelerated rate. Exposure to environmental elements (e.g., sunlight, temperature, humidity, precipitation) likely played a role in the rapid expansion and degradation of collar materials. We recommended incorporating an improved stitching pattern and more durable thread and elastic material to increase collar retention and promote a more gradual elastic expansion. Ideally, Telonics would use materials similar to those on the expandable band of the Vectronic Vertex collars. We recommended use of the polymeric-style housing (TGW) rather than the aluminum housing (Recon) because of lighter weight. When designing collars intended for newborn fawns, it is important to minimize weight wherever possible. Therefore, we recommended Telonics decrease collar weight to improve fit, reduce pressure on expandable materials and prevent premature expansion. After testing of the next Telonics version (TGW v2.0) during the second year of our study, we maintained our original recommendations to improve collar fit and retention. We recommended use of a fold design more similar to that of the Telonics TGW v1.0, but stitched using a more durable thread material like the nylon of the TGW v2.0. A durable elastic material more similar to that of the Vectronic collars would greatly benefit the Telonics design.

The VHF technology of fawn collars currently used in field studies limits the abilities of researchers to efficiently estimate fawn survival, recruitment, movements and habitat use. Enhancing our understanding of these factors would improve management of white-tailed deer populations (Gingery et al. 2018, Gulsby et al. 2015). Integrating GPS technology with expandable collar designs would provide researchers with more accurate information regarding the behavior of white-tailed deer (Bowman et al. 2000, McCance and Baydack 2017). With the primary limiting factor being the size and weight of batteries required to support GPS transmitters, we believe that further testing of GPS-sized collars in controlled settings is warranted to resolve these issues before extensive deployment in field studies. The results of this study will provide important information to telemetry technology companies seeking to improve collar performance and produce less invasive collar designs.

ACKNOWLEDGMENTS

We thank Bill Burger and Telonics, Inc. and Chris Kochanny and Vectronic Aerospace GmbH for their collaboration to alter collar designs. We thank volunteers Andrew Bray, Courtney Bunch, Randall Clark, Sarah Clark, Allison Colter, Tripp Colter, Seth Cook, Ryan Darsey, Jordan Dyal, Adam Edge, Matthew Hill, Miranda Hopper, Kayla Reeves, Jacalyn Rosenberger, Mischa Schultz, Nikki Shellong, Eryn Watson, A.J. Wesner, Gina Wesner, Chloe Westhafer, Cheyenne Yates, and Jordan Youngmann for their assistance with fawn handling. Nicole Davros and Tonya Klinkner of Minnesota Department of Natural Resources (MNDNR) provided administrative support. This project was funded by MNDRN, Daniel B. Warnell School of Forestry and Natural Resources at the University of Georgia, and the Wildlife Restoration (Pittman-Robertson) Program.

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Table 1. System used for scoring collar fit and body condition of white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, GA, USA, during 2018-2020 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

Collar fit score	Body condition score	Neck hair loss score	Neck lesions score
1 = Very loose	1 = Emaciated	0 = No hair loss	0 = No lesions
2 = Little loose	2 = Thin	1 = Coat thinning	1 = Single lesion ≤1cm
3 = Good fit	3 = Prime	2 = Single bald patch ≤1cm	2 = Multiple lesions ≤1cm
4 = Little tight	4 = Heavy	3 = Multiple bald patch(es) ≤1cm	3 = Single lesion >1cm
5 = Very tight	5 = Obese	4 = Bald patch(es) >1cm	4 = Multiple lesions >1cm

Table 2. Ethogram used for recording behavior of white-tailed deer (*Odocoileus virginianus*) fawns during focal sessions at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2020 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

Behavior	Code	Definition
Locomotion	L	Focal animal is moving forward (e.g., walking, running, jumping)
Foraging	F	Focal animal is eating or drinking (not suckling)
Suckling	S	Focal animal is actively suckling at adult doe
Grooming	GG	Focal animal is grooming another individual
Groomed	GD	Focal animal is being groomed by another individual
Grooming Self	GS	Focal animal is grooming itself
Urogenital Grooming	UG	Focal animal is being groomed by another at the urogenital region
Vigilant	V	Focal animal has eyes open and appears to be alert
Sleeping	SL	Focal animal has eyes closed and appears to be asleep
Undefined	U	Focal animal is exhibiting an undefined behavior
Out of Site	OS	Focal animal has moved out of sight

Table 3. Mean neck measurements with standard deviation collected from white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2020 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

Fawns measured	Age (months)	Mean upper neck (cm)	Mean middle neck (cm)	Mean lower neck (cm)
96	0	16.5 ± 1.5	16.7 ± 1.6	18.7 ± 1.8
50	6	25.5 ± 2.4	26.1 ± 2.7	30.9 ± 3.6
39	9	29.4 ± 3.1	30.6 ± 3.1	36.8 ± 4.3
18	12	31.4 ± 2.7	31.0 ± 2.6	38.6 ± 4.2

Figure 1. Vectronic Vertex v1.0 collar deployed on white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2019 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

Figure 2. Vectronic Vertex v2.0 collar deployed on white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2019-2020 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

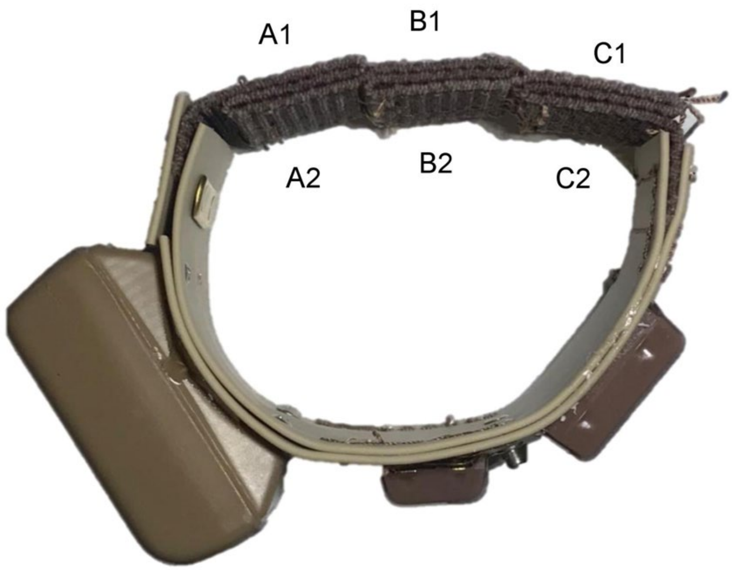

Figure 3. Telonics TGW v1.0 collar deployed on white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2019 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

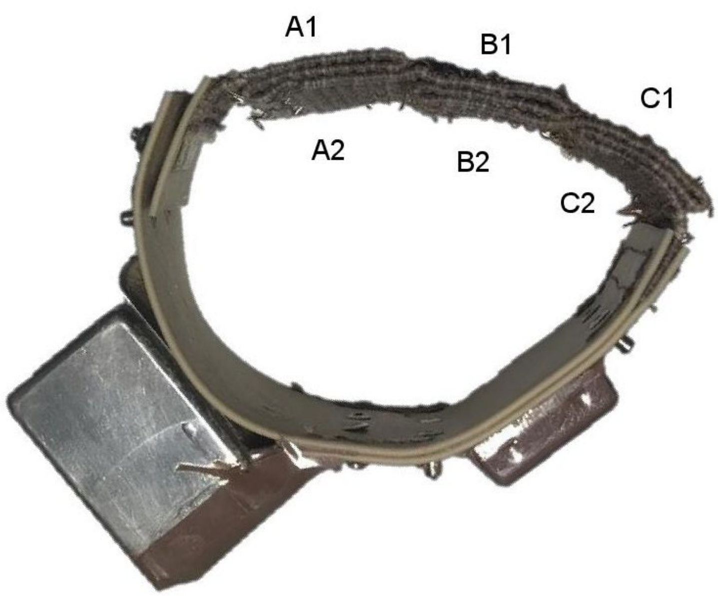

Figure 4. Telonics Recon v1.0 collar deployed on white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2019 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

Figure 5. Telonics TGW v2.0 collar deployed on white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2019-2020 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

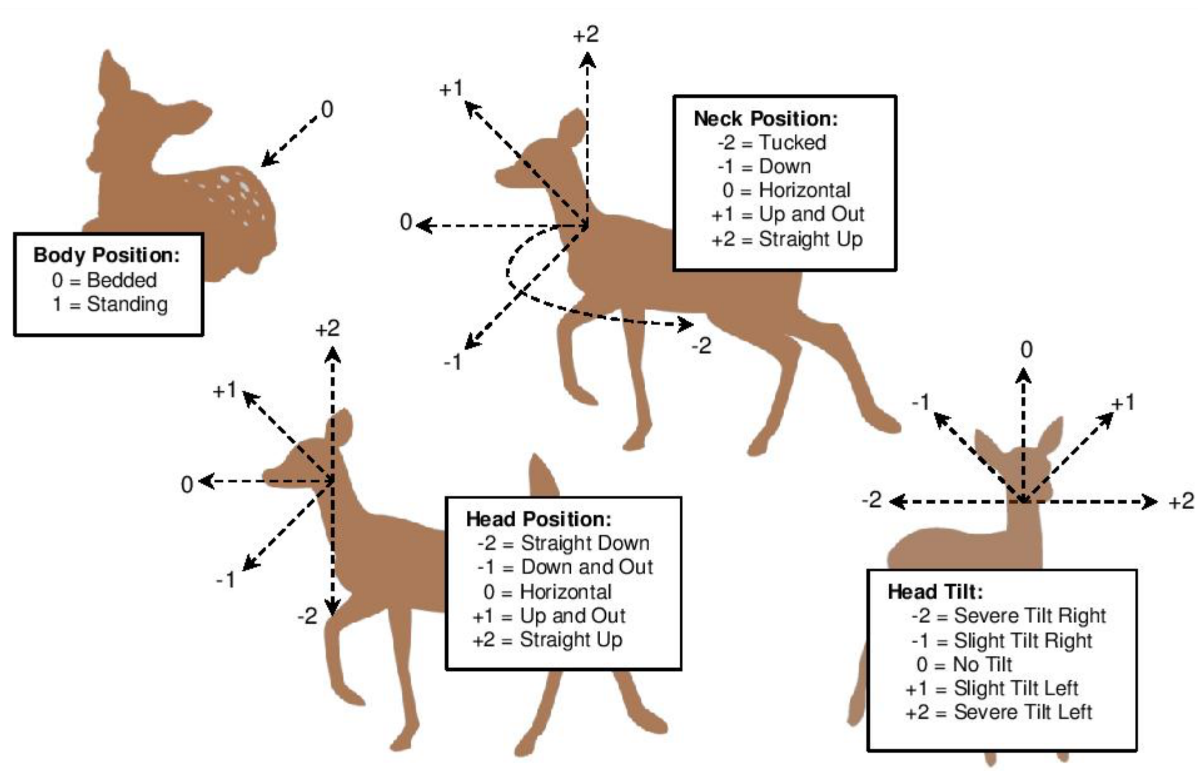

Figure 6. System for scoring body orientation during focal observation sessions of white-tailed deer (*Odocoileus virginianus*) fawns at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2020 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars.

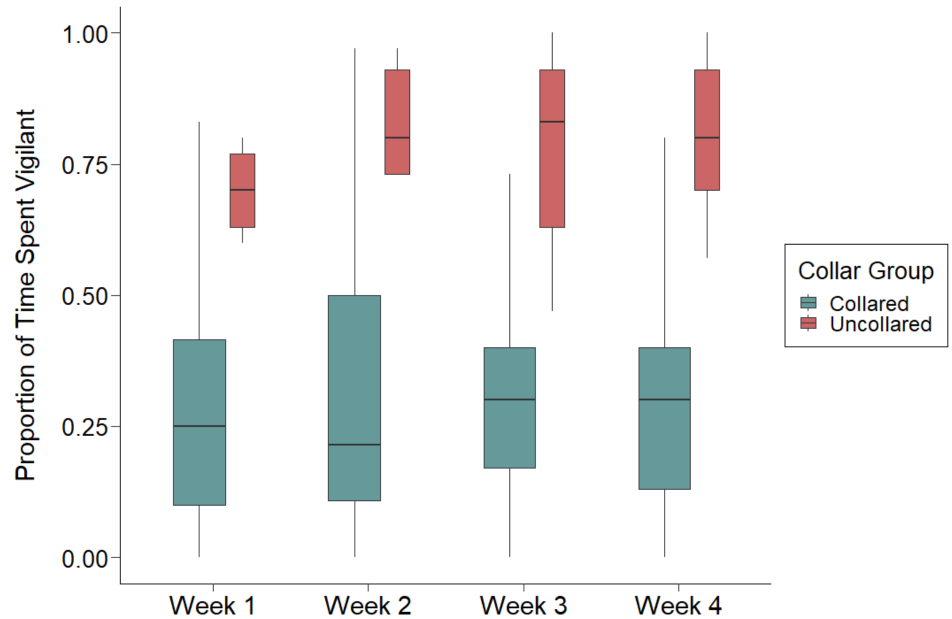

Figure 7. Proportion of time white-tailed deer (*Odocoileus virginianus*) fawns spent exhibiting vigilance during the first four weeks of life at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2019 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars. The width of boxes represent differences in sample size (i.e., the wider the box, the larger the sample size).

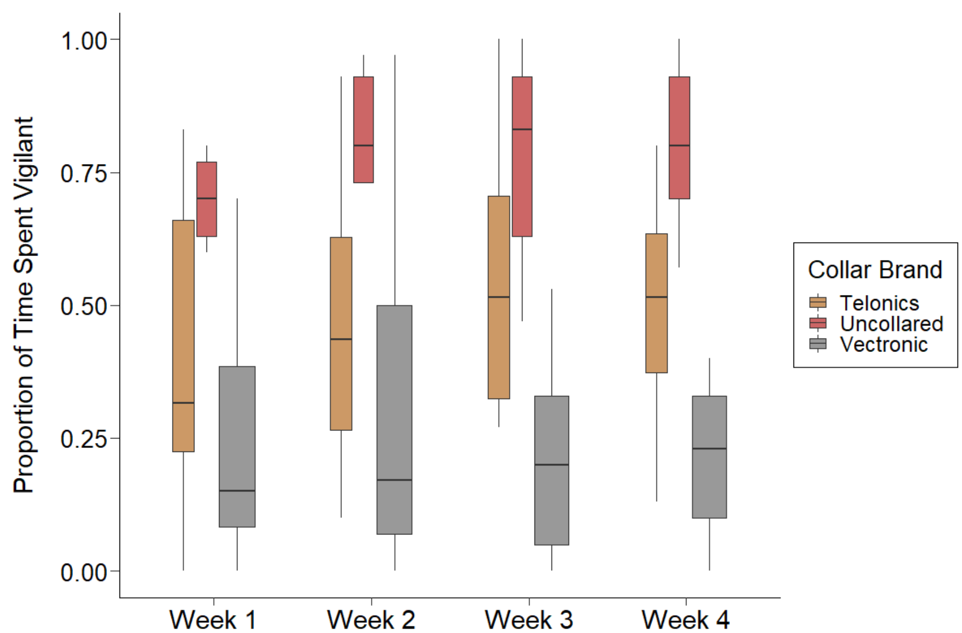

Figure 8. Proportion of time white-tailed deer (*Odocoileus virginianus*) fawns spent exhibiting vigilance during the first four weeks of life at Whitehall Deer Research Facility in Athens, Georgia, USA, during 2018-2019 for testing of experimental designs of Global Positioning System (GPS)-sized expandable radiocollars. The width of boxes represent differences in sample size (i.e., the wider the box, the larger the sample size).