Wildlife Society Bulletin 42(1):67–71; 2018; DOI: 10.1002/wsb.846

Original Article

Retention of Radiotransmitters Tail-Mounted on 6 Bird Species

RICHARD A. STANTON, JR.,[1] *Interdisciplinary Ecology Program, University of Florida, Gainesville, FL 32611, USA*
ALICIA D. BURKE, *Division of Biological Sciences, University of Missouri, Columbia, MO 65211, USA*
KAYLAN M. CARRLSON, *1405 2nd Street NW, Mandan, ND 58554, USA*
DYLAN C. KESLER, *Institute for Bird Populations, Point Reyes Station, CA 94956, USA*
JOHN FAABORG, *Division of Biological Sciences, University of Missouri, Columbia, MO 65211, USA*
FRANK R. THOMPSON, III, *U.S. Department of Agriculture Forest Service Northern Research Station, University of Missouri, Columbia, MO 65211, USA*

ABSTRACT Radiotransmitters can be tail-mounted using cyanoacrylate glue and an accelerant rather than using a harness. Tail-mounted transmitters are dropped or shed when the rectrices molt, which may reduce transmitter effects while providing retention times sufficient for most research objectives. However, retention times of tail-mounted transmitters for birds are insufficiently described, and bias from not following all birds until transmitters are shed has been ignored. We studied transmitter retention of 106 birds of 6 species in the United States of America, 2010–2013, using direct observations and survival modeling based on radiotelemetry tracking. Cox proportional hazard survival models predicted median transmitter retention times from 4 to 53 days, depending on species. Our results suggest that researchers should anticipate premature (i.e., <30 days) tag loss rates from 15% to 38% for adult birds, and adjust permit and funding applications accordingly. However, predicted premature tag loss approached 100% for independent juvenile birds, which frequently appeared to disperse long distances, leading to few or no failure events to inform models. Overall, our results provide guidance for the design of future telemetry studies while demonstrating that tail-mounting transmitters can yield adequate data for a variety of research objectives. © 2018 The Wildlife Society.

KEY WORDS *Helmitheros vermivorum*, *Picoides borealis*, radiotelemetry, *Seirus aurocapilla*, *Sitta pusilla*, tail-mounted radiotransmitters, *Tympanuchus cupido*, *Vireo olivaceus*.

There is value in tracking birds (Millspaugh and Marzluff 2001). Transmitters have become smaller over time, allowing researchers to track increasingly smaller species (Naef-Daenzer et al. 2005). Transmitters as light as 0.27 g with battery lives ≥45 days have been commercially available since 2012 (e.g., Advanced Telemetry Systems model A2414, Asanti, MN, USA). Transmitters have substantial research promise for birds, especially as new analytical approaches are developed and the utility of movement data is extended (Mennill et al. 2012, Steiger et al. 2013). Wildlife researchers have a scientific and ethical responsibility to use the best available evidence when choosing which transmitters and attachment methods to use. Researchers should choose a transmitter attachment method that can be deployed quickly, minimizes animal stress, and assures that transmitters will be retained long enough to meet study objectives.

Modern adhesives such as cyanoacrylates can be used to glue transmitters directly to bird rectrices, permitting transmitter attachment in approximately 90 s (e.g., Stanton et al. 2014). However, we have limited information about how long tail-mounted glue-on transmitters remain on birds, and transmitter retention studies have not accounted for biases from right-censored data (i.e., not following all individuals until transmitters are shed; Diemer et al. 2014, Streby et al. 2015). We present data on transmitter retention for 6 bird species that were part of studies where transmitters were attached to bird rectrices using cyanoacrylate glue and an accelerant (brown-headed nuthatch [*Sitta pusilla*], greater prairie-chicken [*Tympanuchus cupido*], ovenbird [*Seiurus aurocapilla*], red-cockaded woodpecker [*Picoides borealis*], red-eyed vireo [*Vireo olivaceus*], and worm-eating warbler [*Helmitheros vermivorum*]). Our primary objective was to estimate transmitter retention times for these species.

STUDY AREA

We used radiotelemetry data from studies on red-cockaded woodpeckers in the Sandhills region of North Carolina, USA (Kesler et al. 2010); brown-headed nuthatches in Arkansas, USA (Stanton et al. 2014); independent juvenile ovenbirds, red-eyed vireos, and worm-eating warblers in the Missouri Ozarks, USA (Burke 2013); and greater prairie-chickens in

Received: 5 January 2017; Accepted: 13 October 2017
Published: 12 January 2018

---

[1] *E-mail: richardastanton@ufl.edu*

southeastern Missouri (Carrlson et al. 2014). Details of bird species traits and study area ecological conditions can be found in each respective study (Kesler et al. 2010, Burke 2013, Carrlson et al. 2014, Stanton et al. 2014).

METHODS

Transmitter Attachment

We initially developed a glue-on tail-mounting method to improve transmitter retention, handling time, and safety for a study of dispersal in red-cockaded woodpeckers (Kesler et al. 2010); subsequent studies described here used the same method with several transmitter models (Holohil models PD-2, 1.40 g, and LB-2X, 0.27 g [Holohil Ltd, ON, Canada]; ATS model A2414, 0.27 g [Advanced Telemetry Systems, Asanti, MN, USA]). We captured birds using mist nets, hoop nets, and walk-in traps and marked each bird using unique combinations of colored plastic and aluminum bands. We mounted transmitters to birds by moving rump feathers away from the base of the rachides, which we then gently scraped with a sharp knife to remove wax and dirt from the rachides of the innermost rectrices. We applied an accelerant (Instaset^{TM}; BSI Inc., Atascadero, CA, USA) to the cleaned rachides using a cotton swab, applied a gel-type cyanoacrylate adhesive (Instacure^{TM}; BSI Inc.) to the surface of the transmitter, and placed the transmitter on the prepped rachides, glue-side down (Fig. 1). We held the transmitter in position for 15–30 s. We verified that the transmitter was firmly in place and the bird could move freely before moving feathers back into their correct position (Fig. 1a,b). We captured red-cockaded woodpeckers at dusk, and occasionally held them overnight before release at sunrise. Likewise, some greater prairie-chickens were translocated from Kansas, USA, to Missouri in 2010, requiring extended holding times (Carrlson et al. 2014). All other birds were released immediately after marking. We observed brown-headed nuthatches and red-cockaded woodpeckers for 1–5 min postrelease, and opportunistically during subsequent radiotracking to verify normal behavior and flight capability. The first 2 tagged brown-headed nuthatches preened antennae into pronounced curls, so we trimmed all subsequent antennae attached to nuthatches from 15 cm down to 8 cm in 2011 or 2 cm in 2012. We did not modify antennae in the other studies.

Radiotelemetry

In all studies, we located birds regularly until transmitter failure, transmitter shedding, the end of projected transmitter battery life, predation, or the end of the field season. Some transmitters that were shed by brown-headed nuthatches and red-cockaded woodpeckers when feathers with mounted radios were dropped were reattached to the same bird, which we subsequently located regularly until the end of projected transmitter battery life or transmitter reshedding. We directly observed within-season fates of most birds, but fate was unknown in several cases where independent juvenile birds may have dispersed (Burke 2013, Carrlson et al. 2014). We right-censored encounter histories for all birds with unknown fates at the last time we knew they were carrying a radio. We located and watched free-flying nuthatches and woodpeckers with transmitters suspected of mechanical failure to determine if the transmitter had been shed or had failed.

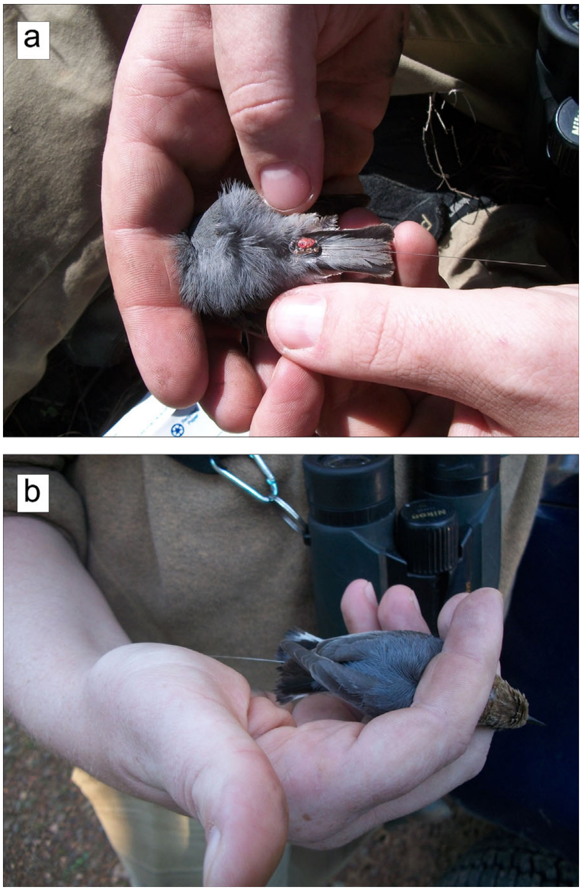

Figure 1. (a) A radiotransmitter mounted on the tail of a brown-headed nuthatch using cyanoacrylate glue and an accelerant, and (b) a brown-headed nuthatch after radiotransmitter attachment and ready to be released in Arkansas, USA, 2011.

Analysis

We calculated mean, standard error, and range of observed retention times for each species to facilitate comparison with previous studies. These summary statistics are biased because they reflect only the minimum time each transmitter was carried before observations ceased. We therefore fitted Cox's proportional hazard regression models in Program R version 3.1.3 survival package to get corrected estimates of expected time to transmitter loss for all birds combined and for each species by using species identity as a covariate (Fox and Weisberg 2011, R Core Team 2015). Cox proportional hazards models require fewer assumptions than Weibull models and are commonly used to model relationships between time-to-failure and covariates of interest by assuming a constant hazard rate rather than specific curves generally associated with survivorship (Fox and Weisberg 2011). This assumption is appropriate when there is little *a priori* reason to expect failures to be heterogeneous over time, such as when modeling mechanical failures (e.g., transmitter shedding when feathers detach; Fox and

Table 1. Observed minimum, maximum, and mean (±SE) transmitter retention times in days and number of observed transmitters shed (Detachments) for 106 birds of 6 species, 2010–2013, USA.

Species	n	Min.	Max.	$\bar{x}$	SE	Detachments
Brown-headed nuthatch	30	3	55	28.2	2.9	12
Greater prairie-chicken	14	1	52	18	3.7	3
Red-cockaded woodpecker	34	2	71	41.8	3.1	15
Ovenbird	7	1	20	6.4	2.8	0
Red-eyed vireo	15	1	20	7.5	1.7	0
Worm-eating warbler	6	1	27	13.2	4.8	0

Weisberg 2011). We assumed that species identity was a relevant predictor of transmitter retention when the 95% confidence interval for a species effect excluded zero and irrelevant otherwise. We used model results to predict the proportion of tags remaining after 30 days, which we treated as the minimally adequate time needed to follow an individual for studies of space-use or resource-selection using marked individuals.

RESULTS

We applied transmitters to 106 birds. We captured and applied transmitters to 30 brown-headed nuthatches, 14 greater prairie-chickens, 34 red-cockaded woodpeckers, 15 red-eyed vireos, 6 worm-eating warblers, and 7 ovenbirds. Observed mean retention times varied among species (range = 6–42 days) and there were 0–15 observed transmitters shed per species (Table 1). The Cox proportional hazard models predicted that 50% of transmitters would be retained for ≥30 days for all species pooled while revealing differences in transmitter retention times among species (All $P < 0.001$, $R^2 = 0.50$; Table 2). Predicted 30-day transmitter retention for red-eyed vireos, worm-eating warblers, and ovenbirds was approximately 0%; however, 27%, 62%, and 85% of transmitters were predicted to remain on ≥30 days for greater prairie-chickens, brown-headed nuthatches, and red-cockaded woodpeckers, respectively (Fig. 2).

DISCUSSION

This is the first published assessment of tail-mounted radiotransmitter retention for several bird species that accounts for censoring of observations. We confirmed that gluing radiotransmitters to the rectrices was an effective method of transmitter attachment and were able to attach transmitters in <2 min by using an accelerant. Studies using other methods had longer handling times (often >5 min; e.g., Anich et al. 2009). Our results indicate that these methods were appropriate for ≥3 species (brown-headed nuthatch, greater prairie-chicken, and red-cockaded woodpecker).

Predicted times to failure can be biased when failure events are few and many cases are censored early, such as when we tracked independent juvenile birds of 3 species, all of which frequently appeared to disperse during the field season (i.e., ovenbirds, red-eyed vireos, and worm-eating warblers; Demissie et al. 2003, Burke 2013). Unbalanced patterns of censoring times in these data may have created confounding that resulted in minimal information about transmitter retention for these species. If this was the case, our estimates for those species may be biased, predicting retention times that are too short (Demissie et al. 2003). However, independent juvenile birds of these species might behave in ways that reduce transmitter retention. For example, independent juvenile ovenbirds, red-eyed vireos, and worm-eating warblers used regenerating clear cuts with dense vegetation that can get entangled with transmitters that then break free (Burke 2013). Currently, we have no effective synthesis of how factors such as age and habitat associations affect the retention of radiotransmitters applied to birds, so we do not speculate further. Rather systematic review and meta-analysis may eventually provide valuable insights regarding how various morphological, behavioral, and other traits affect radiotransmitter retention.

The literature indicates several subjects researchers should consider when deciding whether to use tail-mounted radiotransmitters in their work. Glue-on transmitters are not suitable for studies that last through the prebasic molt. Likewise, caution and careful pilot studies will be necessary for studies of nestlings or fledglings where feather growth,

Table 2. Exponentiated model[a] coefficients, upper and lower confidence limits (CL), and predicted median transmitter retention time in days by species from Cox proportional hazard models fitted to data collected from 106 birds of 6 species, 2010–2013, USA.

Species	Status	Exp(coef)	Lower CL	Upper CL	Median retention	Lower CL	Upper CL
Brown-headed nuthatch	Resident	3.40	1.66	6.96	43	30	47
Greater prairie-chicken	Resident	7.79	3.43	17.69	21	17	46
Ovenbird	Migrant	40.46	13.37	122.39	9	2	17
Red-cockaded woodpecker	Resident	NA	NA	NA	53	47	66
Red-eyed vireo	Migrant	32.21	12.57	82.57	13	4	NA
Worm-eating warbler	Migrant	19.06	6.53	55.66	4	1	NA

[a] Model $R^2 = 0.50$. The baseline species was red-cockaded woodpecker for the model. We were unable to compute an upper confidence limit on median retention time for red-eyed vireos or worm-eating warblers.

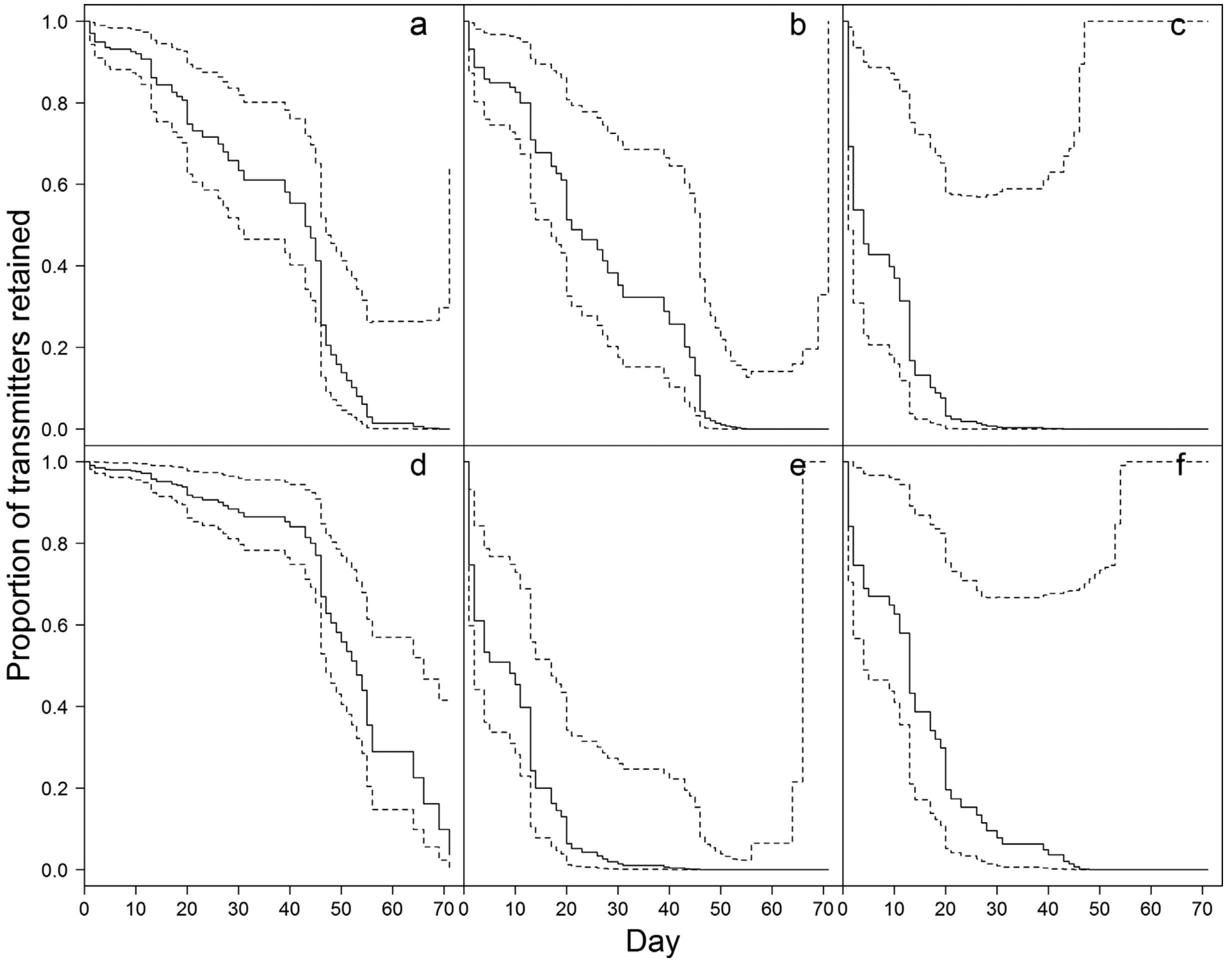

Figure 2. Predicted proportion of transmitters retained by number of days deployed for 6 species of birds: (a) brown-headed nuthatch; (b) greater prairie-chicken; (c) ovenbird; (d) red-cockaded woodpecker; (e) red-eyed vireo; and (f) worm-eating warbler. Predictions based on Cox proportional hazards models and data collected from 106 individuals of 6 species in the USA, 2010–2013. Dashed lines above and below each prediction curve indicate upper and lower 95% confidence intervals.

rapid molting, or parental behavior could render tail-mounting ineffective (e.g., Whittier and Leslie 2005). Some species also may be particularly prone to damage or remove transmitters for reasons that may not be obvious, so pilot studies should be undertaken to identify such cases early (e.g., bobolink [*Dolichonyx oryzivorus*], Diemer et al. 2014, and Puerto Rican parrots [*Amazona vittata*], Meyers et al. 1996). Lastly, tail-mounted transmitters might alter flight behavior in short-tailed birds and could affect mate selection in species where the tail is a sexual ornament.

With careful planning that accounts for attrition resulting from dispersal, predation, and transmitter loss, we are confident that tail-mounted transmitters will be effective for many more species than have been studied to date. Overall, our results and experience indicate that tail-mounting radiotransmitters with a cyanoacrylate adhesive and an accelerant can be a fast and effective method of attaching transmitters to birds. As such, we suggest researchers consider using tail-mounting for studies lasting <30 days in place of harnesses and back-mounting, both of which are more time-consuming and difficult. Likewise, by using tail-mounted transmitters researchers may be able to avoid abrasion and other self-injuries that can occur when transmitters are attached using harnesses (Hofle et al. 2004). Finally, estimates from our data can be used to inform the design of future studies by providing a quantitative basis for determining equipment needs and deciding how many animal contacts researchers should request in Institutional Animal Care and Use Committee applications and other permitting situations.

ACKNOWLEDGMENTS

W. Montague provided advice, direction, and logistical support. We thank J. H. Carter III and P. D. Doerr for initiating, directing, and managing the red-cockaded woodpecker project in the Sandhills. Valuable data and insight into data structure and field techniques were provided by K. Brust of the Sandhills Ecological Institute, K. Convery of the Virginia Tech Conservation Management Institute, and J. Britcher of the Ft. Bragg Endangered Species Branch. The Arkansas Game and Fish Commission provided field housing in 2011. The Missouri Department of Conservation provided logistical support, field resources, and housing during the summers of 2010–2012. S. Anderson, K. Bird, A.

Carrlson, H. Finch, J. Foggia, A. Henehan, H. Prelewitz, M. Roach, and E. Underwood collected field data. Research was conducted under permits from the US Fish and Wildlife Service (permit #MB36442A-0[DK] and ADB 09518-AK subpermits, endangered species permit TE070846-1]), the Arkansas Game and Fish Commission (permits #030720114 and 010920121), the Missouri Department of Conservation (permit #14674), and the U.S. Geological Survey (permit #23574 [DK] and 21544 [J. Walters]); we also received written authorization for our research from the Ouachita National Forest (File code 2620/2700) and Fort Bragg Endangered Species Branch. Research protocols were approved by the Institutional Animal Care and Use Committee of the University of Missouri (references #s 7006 and 6653) or Virginia Polytechnic Institute and State University (A-3208-01), as appropriate. This study was primarily supported by grants from the U.S. Forest Service, the U.S. Fish and Wildlife Service Southeast Region, the Midwest Migratory Bird Program, the Ouachita National Forest, the Audubon Society of Missouri, the Webster Groves Nature Study Society, and the Conservation Foundation of Missouri. Use of trade, product, or firm names does not imply endorsement by the U.S. Government. We also gratefully acknowledge the Associate Editor and several anonymous reviewers for valuable feedback.

LITERATURE CITED

Anich, A. M., T. J. Benson, and J. C. Bednarz. 2009. Effect of radio transmitters on return rates of Swainson's warblers. Journal of Field Ornithology 80:206–211.

Burke, A. D. 2013. Mature forest-breeding bird use of early-successional habitat. Thesis. University of Missouri, Columbia, USA.

Carrlson, K. M., D. C. Kesler, and T. R. Thompson. 2014. Survival and habitat use in translocated and resident greater prairie-chickens. Journal for Nature Conservation 22:405–412.

Demissie, S., M. P. LaValley, N. J. Horton, R. J. Glynn, and L. A. Cupples. 2003. Bias due to missing exposure data using complete-case analysis in the proportional hazards regression model. Statistics in Medicine 22:545–557.

Diemer, K. M., H. E. Wheeler, and J. J. Nocera. 2014. Retention rates of glue-attached radio-transmitters on two small bird species with contrasting life histories. Wilson Journal of Ornithology 126:39–46.

Fox, J., and S. Weisberg. 2011. Cox proportional-hazards regression for survival data: An appendix to An R Companion to Applied Regression, Second Edition. <https://socialsciences.mcmaster.ca/jfox/Books/Comp anion/appendix/Appendix-Cox-Regression.pdf> Accessed 24 Dec 2016.

Hofle, U., J. Millan, C. Gortazar, F. J. Buenestado, I. Marco, and R. Villafuerte. 2004. Self-injury and capture myopathy in net-captured juvenile red-legged partridge with necklace radiotags. Wildlife Society Bulletin 32:344–350.

Kesler, D. C., J. R. Walters, and J. J. Kappes. 2010. Social influences on dispersal and the fat-tailed dispersal distribution in red-cockaded woodpeckers. Behavioral Ecology 21:1337–1343.

Mennill, D. J., S. M. Doucet, K. A. Ward, D. F. Maynard, B. Otis, and J. M. Burt. 2012. A novel digital telemetry system for tracking wild animals: a field test for studying mate choice in a lekking tropical bird. Methods in Ecology and Evolution 3:663–672.

Meyers, J. M., W. J. Arendt, and G. D. Lindsey. 1996. Survival of radio-collared nestling Puerto Rican parrots. Wilson Bulletin 108:159–163.

Millspaugh, J., and J. M. Marzluff (editors). 2001. Radio tracking and animal populations. Academic Press, New York, New York, USA.

Naef-Daenzer, B., D. Früh, M. Stalder, P. Wetli, and E. Weise. 2005. Miniaturization (0.2 g) and evaluation of attachment techniques of telemetry transmitters. Journal of Experimental Biology 208: 4063–4068.

R Core Team. 2015. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Stanton, R. A., Jr., D. C. Kesler, and F. R. Thompson III. 2014. Resource configuration and abundance affect space use of a cooperatively breeding resident bird. Auk 131:407–420.

Steiger, S. S., M. Valcu, K. Spoelstra, B. Helm, M. Wikelski, and B. Kempenaers. 2013. When the sun never sets: diverse activity rhythms under continuous daylight in free-living arctic-breeding shorebirds. Proceedings of the Royal Society of London, Series B 280:20131016.

Streby, H. M., T. L. McAllister, S. M. Peterson, G. R. Kramer, J. A. Lehman, and D. E. Andersen. 2015. Minimizing marker mass and handling time when attaching radio-transmitters and geolocators to small songbirds. Condor 117:249–255.

Whittier, J. B., and D. M. Leslie. 2005. Effects of using radio transmitters to monitor least tern chicks. Wilson Bulletin 117:85–91.

Associate Editor: Streby.