Avian Radio-transmitter Harness Wear and Failure

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Abstract - Although investigators have compared radio-transmitter attachment devices and their likelihood of failure before the end of a study, few have directly evaluated the harness materials and fastening methods that are to be shed by a bird after the research period is over. We compared the likelihood of effective detachment after transmitter life of four harness materials (7-mm- and 9-mm-wide polyester ribbon tape and polyester-coated rubber elastic) and three fastening methods (polyester thread, cotton thread, and Gorilla Super Glue™) using dummy transmitters exposed to the elements for >1.5 years. Both polyester ribbon and polyester-coated rubber elastic materials resulted in similar physical wear and remained intact for longer than a typical field seasonal, but fastening harnesses using Gorilla Super Glue™ resulted in the earliest and most consistent harness failure. Polyester ribbon material and glue fastening resulted in the earliest failure; mean failure time for 7-mm- and 9-mm-wide polyester ribbon tape with glue fastening was 408 days ± 30 SE, and 249 days ± 29 SE, respectively. Failure times for both 7-mm- and 9-mm-wide polyester-coated rubber elastic and Gorilla Super Glue™ fastening treatments were in excess of one year (438 days ± 14 SE and 438 days ± 13 SE, respectively). All harnesses with sewn thread fastening treatments lasted a minimum mean of 456 days, and in the case of both 7-mm-wide polyester ribbon and polyester-coated rubber elastic, neither treatment ever failed over the period of study. Results suggest that using Gorilla Super Glue™ as a fastener maximized the likelihood of eventual harness failure, whereas transmitters fastened via sewing showed minimal signs of wear and were unlikely to be shed by a bird during a period of time less than two years. Additional experimental studies are warranted to examine alternative harness material types, fastening methods, and harness styles to maximize the potential of successful radio transmitter shedding.

Introduction

Radio and satellite telemetry studies are commonly used to better understand behavior, space use, migration routes, and survival of birds. Important assumptions for studies using radio or satellite transmitters (hereafter transmitters) are that the transmitters do not adversely affect the behavior (Mong and Sandercock 2007), reproductive success (Whidden et al. 2007), or survival (Palmer and Wellendorf 2007) of the study species. To test these assumptions, investigators have examined the use of different attachment methods (see Hill et al. 1999, Johnson et al. 1991, Woolnough et al. 2004). However, the intent of these studies was to simply ensure that transmitters

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were not prematurely lost and that transmitters and harnesses meet assumptions of behavior, reproductive success, and survival.

The Ornithological Council, a collective of eleven Western Hemisphere ornithological societies, developed guidelines for use of wild birds in research, including the ethical use of radio transmitters (Ornithological Council 1999). The intent of these guidelines is to minimize distress and pain to birds, consistent with sound research designs. The guidelines recommend that investigators consider alternatives to allow self-removal or failure at the end of the useful life of transmitters (Ornithological Council 1999). As a result, many investigators have included a weak point in their harnesses, usually cotton thread, assuming that transmitters can be shed after studies are completed (see Bedrosian and Craighead 2007, Chaves-Campos et al. 2003, Karl and Clout 1987, McIntyre et al. 2006). Dissolvable surgical thread has also been used as a harness material that will eventually fail, allowing transmitters to be shed. Doerr and Doerr (2002) examined transmitter retention time using dissolvable (surgical thread) harnesses and found that 19% of radio-tagged treecreepers harness loops prematurely broke and shed transmitters before harnesses failed. Of the remaining harnesses that were not shed prematurely, 85% remained intact for 149 ± 89 (SD) days (n = 13) before shedding (Doerr and Doerr 2002). Thus, the attachment devices were effective in that most transmitters remained attached for the duration of their study but not much longer.

However, dissolvable surgical thread is not used regularly in attachment of radio transmitters, perhaps because it is too small in diameter for use in harnesses for larger birds or because of concern of premature wear of the thread and loss of radio transmitters. Further, use of dissolvable harness material (e.g., surgical thread) may be inappropriate for transmitters that function longer than five months (Doerr and Doerr 2002) and for use with waterbirds that occupy aquatic habitats, where harnesses might dissolve rapidly. As a result, the assumption that radio transmitters are not permanently attached, but instead are either lost or weaken sufficiently to allow birds to remove transmitters remains untested for the most common attachment materials.

In this study, we tested durability and likelihood of eventual failure of four types of harness materials and three fastening treatments using the common figure-eight harness design (Rappole and Tipton 1991). Over a period of 547 days, we recorded physical wear and tested the likelihood of harness failure using a tensile resistance test. We tested the hypothesis that narrower harness materials and those fastened with natural cotton thread would fail sooner than other harness material and fastening treatments. This study provides recommendations for harness materials and fastening methods to maximize the likelihood that transmitters will be shed after studies are completed.

Methods

Testing transmitters on wild birds provides the most realistic assessment of wear (Powell et al. 1998). However, such studies require that birds be repeatedly recaptured to assess harness fatigue, which is unattainable for many species. While studies of captive birds (Small et al. 2004, Woolnough et al. 2004) are more feasible, it is usually difficult to obtain adequate sample sizes. Thus, in this study we used dummy transmitters attached to dummy bird bodies exposed to the elements for 547 days.

We made radio-transmitter harnesses using a two-part epoxy resin and hardener kit to create a replica of a radio transmitter of standard size and shape (Model A1260; Advanced Telemetry Systems, Isanti, MN). We drilled holes in either end of the dummy transmitter through which the harness material fastened (Fig. 1). Dummy transmitters weighed 10.1 ± 0.2 (SE) grams.

We tested four harness materials: 1) 7-mm-wide (hereafter narrow) polyester-coated rubber elastic (73% polyester, 27% rubber), 2) 9-mm-wide (hereafter wide) polyester-coated rubber elastic (73% polyester, 27% rubber), 3) narrow 100% polyester ribbon tape, and 4) wide 100% polyester ribbon tape. These materials have either been used in previous studies (Bedrosian and Craighead 2007, Buehler et al. 1995, Chaves-Campos et al. 2003, Hylton et al. 2006, Small et al. 2004, Weick et al. 2005) or in other concurrent research associated with this project (Beerens 2008, Herring et al. 2010) and are readily available at most fabric or craft stores.

We cut material to a standard length of 40 cm, sufficient for a harness to fit on a *Eudocimus albus* (L.) (White Ibis; Herring 2008). We attached harness materials to the dummy radio transmitter by threading them through the drilled holes (Fig. 1) and then tying a knot on either side of the dummy transmitter to prevent movement on the harness (Fig. 1). We mounted harnesses on a closed-cell foam mold in the approximate shape of a bird's body, with the fastening point of the harness on the dorsal side of the dummy. After tightening the harness, the loose end of the harness material was then fastened using one of three treatments: 1) Gorilla Super Glue™ (hereafter super glue) (Gorilla Glue, Cincinnati, OH), 2) 100% cotton mercerized thread, or 3) 100% polyester thread. For all harnesses, we left 1 cm of loose material at each end of the harness for the fastening treatment (Fig. 1). When applying the super glue treatment, we spread the glue liberally over one end of the harness material and then clamped the adjacent end of the harness to the glued section, allowing it to dry for approximately one minute before removing the clamp (Fig. 1). For sewn-fastening treatments, we began sewing beside the transmitter and moved away from it with each loop until eight tight loops were completed, and then fastened in a knot at the end. During the experiment, harness tension remained constant, with no apparent change in the foam mold shape or size. We used a total of 120 dummy radio-transmitters in the experiment, with 30 dummies per harness material and 10 dummies per fastening treatment.

We placed all dummy radio transmitters with their respective harness treatments on a frame in an outdoor area at Florida Atlantic University, Boca Raton, FL; all dummy transmitters were equally exposed to rain and sun during the experiment. Mean annual weather conditions at Boca Raton were: annual precipitation = 145 cm, temperature = 24 °C (range = 14–33 °C), and humidity = 72%. In this experiment, the degree of exposure was likely greater than would be the case with wild or captive birds because birds often preen feathers over harnesses (G. Herring, pers. observ.). Regardless of how these conditions mimicked natural conditions, any biases were equal across all treatments.

We surveyed avian telemetry literature published during 2007–2008 in the Journal of Field Ornithology, Journal of Wildlife Management, and Waterbirds; the mean length was 136 ± 36 days (n = 36) for radio-transmitter studies, and 286 ± 100 days (n = 7) for satellite-transmitter studies. In this study, we monitored harness treatments for 547 days, a period of time longer than most field studies where transmitters are used. We sampled dummy transmitters approximately every three months, assessing visual appearance of the transmitter and using a tensile test to mimic a

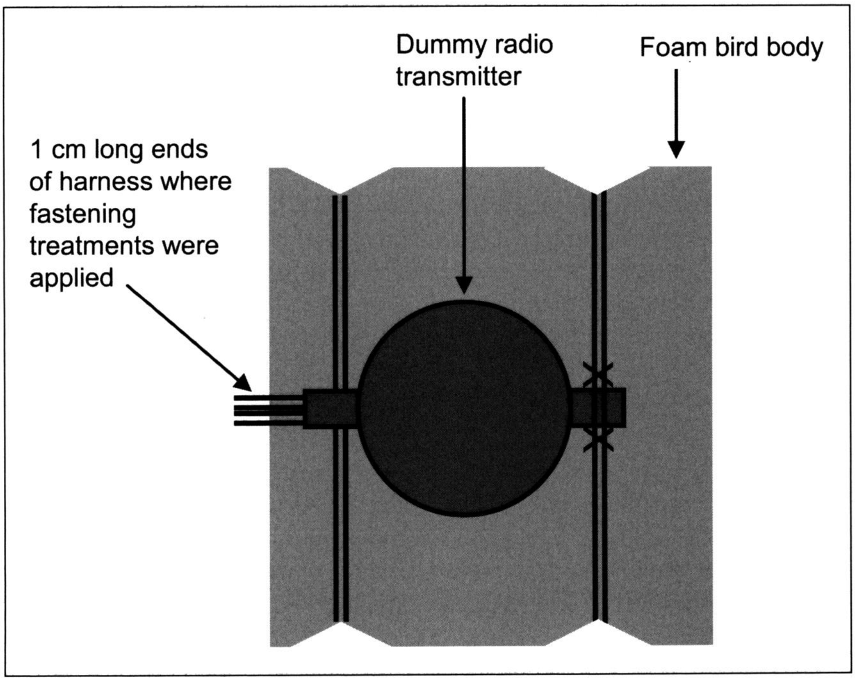

Figure 1. Dorsal view of dummy transmitters with figure-eight harness. Note the fastening point on the left side of the dummy transmitter, and the knots tied on the right side to prevent transmitter movement.

bird grabbing and pulling the harness with either its bill or foot. To assess visual wear, we used four scores: 0 = no wear (no apparent visual signs of wear), 1 = little wear (sewn harnesses: only a few threads were loose and or minimum thread fraying; glued harnesses: <33% of the glued portion of the harness was disconnected; sewn and glued harnesses: only a few threads were loose and/or there was minimum thread fraying and < 3% of the glued portion of the harness was disconnected), 2 = moderate wear (sewn harnesses: multiple threads were loose and/or there was intermediate thread fraying; glued harnesses: >33% and <66% of the glued portion of the harness was disconnected; sewn and glued harnesses: multiple threads were loose and/or there was intermediate thread fraying and >33% and <66% of the glued portion of the harness was disconnected), and 3 = heavy wear (sewn harnesses: many threads were loose and/or there was extensive thread fraying; glued harnesses: ≥66% of the glued portion of the harness was disconnected; sewn and glued harnesses: many threads were loose and/or there was extensive thread fraying and ≥ 66% of the glued portion of the harness was disconnected).

To assess physical wear, we attached a 1-kg Pesola spring scale to one side of the posterior point where the two loose ends of the harness material were fastened, applied 400 g of tension, and noted if the harness fastening point failed. During this test, we pulled the harnesses in both lateral directions once. We considered this tension to be a reasonable estimate of the potential pulling strength of a typical 800-g bird that the harness material and size was developed for use on. Although no estimates of the pulling strength of birds could be located to verify the tension used, the same weight was used across all treatments and thus provided the same opportunity for all harnesses to fail across the entire 547-day period.

We used a Kaplan-Meier survival model to estimate harness failure $(1 - \varphi)$ for all combinations of harness material and fastening treatments (Pollock et al. 1989). To determine if failure curves differed among harness materials and fastening treatments across the 547 days of the study, we used a log-rank test (Pollock et al. 1989). We used a repeated-measures two-way analysis of variance (ANOVA) to test for differences in physical wear on harnesses by material and fastening treatments. All data in the ANOVA model met assumptions of homoscedascity (Levene's test), and residuals were normally distributed. We conducted all data analysis using program JMP (Sall et al. 2001). Values are presented as means ± standard error.

Results

Harness failure only occurred at the fastening point during the experiment. We found that harness failure rates differed among treatments (χ^2_{11} = 149.2, $P < 0.001$), with wide ribbon material fastened with super glue failing the soonest (mean failure time = 248 days ± 29 SE), followed by narrow ribbon fastened with super glue (mean failure time = 407 days ± 30 SE), and both narrow and wide polyester-coated rubber elastic material fastened with super glue (mean failure time = 437 days ± 14 SE and 437 ± 13 SE, respectively; Fig. 2, Table 1). All other failure rates were similar among treatments (Table 1, Fig. 2). Physical wear on radio-transmitter harnesses was similar among material types ($F_{3, 8} = 2.1$, $P = 0.17$), but differed among fastening treatments ($F_{2, 8} = 7.5$, $P < 0.0001$). Physical wear of harnesses was highest for wide ribbon and super glue treatment, with moderate to low wear on all other treatment combinations (Fig. 3).

Discussion

Harnesses fastened with either polyester or cotton thread did not fail during the period of this study (>1.5 years), meaning that short-lived

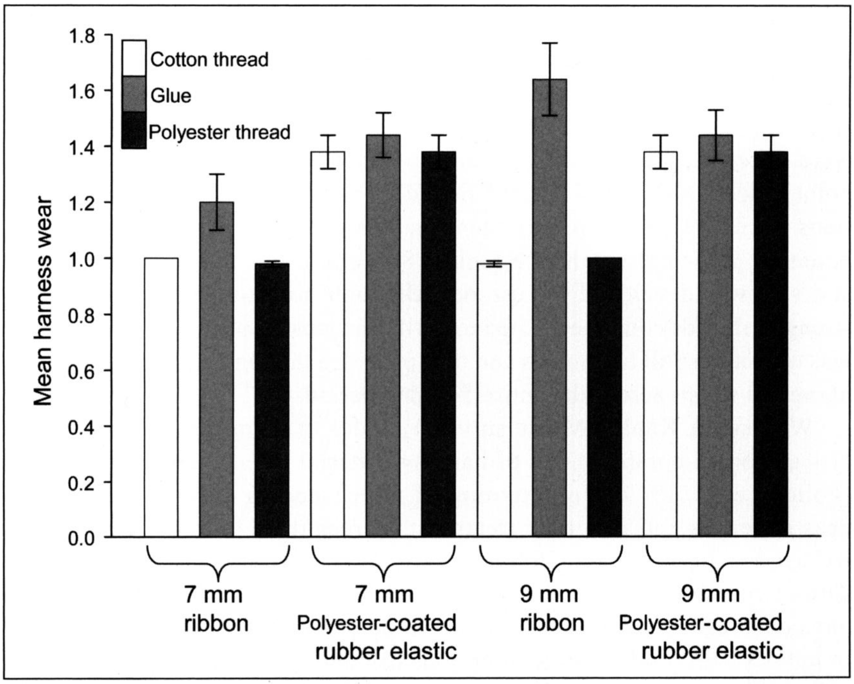

Figure 2. Mean physical-wear response of radio-transmitter harness material and fastening treatments to exposure to sun and rain during 547 days of experiment. Wear response scores: 0 = no wear, 1 = little wear, 2 = moderate wear, and 3 = heavy wear. Treatments: 1 = narrow ribbon and cotton thread, 2 = narrow ribbon and super glue, 3 = narrow ribbon and polyester thread, 4 = narrow polyester-coated rubber elastic and cotton thread, 5 = narrow polyester-coated rubber elastic and super glue, 6 = narrow polyester-coated rubber elastic and polyester thread, 7 = wide ribbon and cotton thread, 8 = wide ribbon and super glue, 9 = wide ribbon and polyester thread, 10 = wide polyester-coated rubber elastic and cotton thread, 11 = wide polyester-coated rubber elastic and super glue, and 12 = wide polyester-coated rubber elastic and polyester thread.

birds with radios attached using thread could carry the transmitters for the remainder of their lives. Thus, for smaller birds, using harnesses fastened with dissolvable surgical thread may be more appropriate (Doerr and

Table 1. Mean time (± SE) to failure of radio-transmitter harness treatments as determined during 547 days of exposure to natural weather conditions. Treatments with no reported data did not fail during this study. Treatments are listed as material width, material type, and fastening type, respectively. All treatments started with 10 experimental harnesses.

Treatment	# of harnesses failed	Mean days to failure	SE
7-mm - ribbon- cotton thread	0		
7-mm - ribbon - super glue	10	408	30
7-mm - ribbon - polyester thread	0		
7-mm - polyester-coated rubber elastic - cotton thread	3	456	14
7-mm - polyester-coated rubber elastic - super glue	3	438	14
7-mm - polyester-coated rubber elastic - polyester thread	4	520	15
9-mm - ribbon - cotton thread	3	538	11
9-mm - ribbon - super glue	10	249	29
9-mm - ribbon - polyester thread	5	547	0
9-mm - polyester-coated rubber elastic - cotton thread	3	456	0
9-mm - polyester-coated rubber elastic - super glue	6	438	13
9-mm - polyester-coated rubber elastic - polyester thread	4	520	15

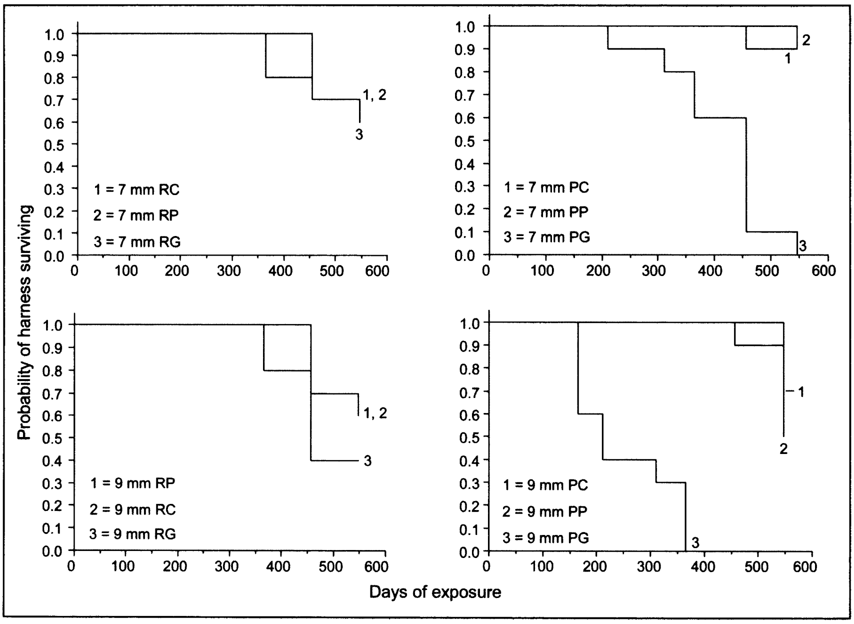

Figure 3. Probability of harness material and fastening treatments failing during 547 days of exposure. Treatments are listed as harness material first: P = polyester ribbon, R = polyester-coated rubber elastic, then fastening treatment, C = cotton thread, G = super glue, and P = polyester thread. All are labeled at the survival end point after 547 days of exposure.

Doerr 2002). However, high premature shedding rates (Doerr and Doerr 2002) and limited life span for long-term studies make surgical thread an inferior option for large birds.

During concurrent radio-telemetry field research using narrow polyester-coated rubber elastic harnesses and cotton sewn fastening (Beerens 2008, Herring 2008), we recaptured or recovered carcasses from several harnessed birds, observing no obvious signs of harness deterioration after one full year of natural exposure and wear. Also, contrary to our hypothesis, cotton thread did not fail sooner than polyester thread. If investigators want transmitters to be shed soon after a typical telemetry study, they should consider polyester ribbon fastened with super glue. We suggest caution in interpreting our estimates of error associated with wear and failure because we only measured transmitters approximately every three months. More frequent measurements (e.g., every month) in future experimental radio-transmitter harness studies may provide improved estimates of when harnesses fail and of the precision associated with those failure times.

Collectively, these results suggest that harnesses sewn with cotton or polyester thread do not provide a reliable option for telemetry studies if the intent is to guarantee that transmitters are shed at the end of a study. Only several of the most common transmitter attachment mechanisms were evaluated here, so more attachment options should be tested to better match attachment period of radio-transmitters with the duration of a particular study and the specific environmental conditions under which particular bird species live. Future studies should compare harness life when harnesses are covered in feathers, how preening oil from the uropygial gland affects harnesses and fastening treatments, and how weather conditions (e.g., sun exposure, rainfall) impact wear and failure of harnesses. We also suggest testing alternative fastening methods (e.g., water soluble sewing thread) and harness types that increase the likelihood of radio-transmitter shedding.

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