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Note

Non-Permanent Radiotelemetry Leg Harness for Small Birds

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ABSTRACT I developed a modified leg harness for mounting radiotelemetry transmitters to small birds, which includes a weak link that allows telemetry equipment to be shed. Over 4 years, I mounted 62 transmitters on 49 Tuamotu kingfishers (*Todiramphus gambieri*) using weak-link harnesses. Kingfishers retained 86% of transmitters for the duration of monitoring periods (23–66 days) whereas 22 of 23 transmitters were shed from birds resighted after 6–15 months. Apparent mortality was no higher for radio-marked birds than for birds without transmitters. The weak-link harness is an improvement to existing transmitter attachment techniques and provides a useful, effective, and ethical means of studying bird movements. © 2011 The Wildlife Society.

KEY WORDS endangered, harness, kingfisher, radiotelemetry, survival, *Todiramphus gambieri*.

Information about wildlife behavior, movement, and demography has been greatly enhanced by the use of radiotelemetry (White and Garrott 1990; Kenward 2001*a*, 2001*b*; Millspaugh and Marzluff 2001). Early studies focused mainly on large terrestrial animals capable of carrying the first crude and bulky transmitter devices, but in recent years miniaturized instrumentation has facilitated investigations of smaller and more mobile organisms. Consequently, radio transmitters have become indispensable tools for studying birds.

Technological developments for securing transmitters to birds have paralleled advances in electronics (Marion and Shamis 1977, Kenward 2001*a*). Surgical procedures have been used to insert transmitters entirely inside body cavities (Schulz et al. 1998, 2001; Small et al. 2004), subcutaneously with an external antenna (Hupp et al. 2006), or with subcutaneously anchored external transmitters (Newman et al. 1999). Others have glued transmitters directly to skin and feathers with cyanoacrylate or epoxy adhesives (Raim 1978, Kenward 2001*a*, Mong and Sandercock 2007, Kesler et al. 2010). Transmitters have also been mechanically attached using leg bands (Melvin et al. 1983), neck collars (Kenward 2001*a*), ponchos (Chipman et al. 2007), backpacks (Karl and Clout 1987, Hill et al. 1999, Sunde 2006), and lower-back leg-loop harnesses (Rappole and Tipton 1991).

Despite the importance of telemetry-based research, debate remains about the fates of radio-marked birds (Small et al. 2004, Robert et al. 2006, Sharpe et al. 2009) and researchers have reported problems with many attachment methods. Field investigations and studies of captive populations indicated poor transmitter retention with adhesives, mechanical abrasion and behavioral effects from backpack harnesses, and pathological effects from transmitter implants (Small et al. 2004, Woolnough et al. 2004, Whittier and Leslie 2005, Mulcahy 2006, Robert et al. 2006, Mong and Sandercock 2007). In addition, transmitter harnesses may become entangled with vegetation (Karl and Clout 1987) and they can reduce migrant return rates (Mong and Sandercock 2007). For many birds, the bulk, weight, and added aerodynamic drag of radiotelemetry equipment might also reduce mobility and increase energy expenditure so that radio-marked birds suffer lower growth and survival rates (Gervais et al. 2006, Whidden et al. 2007).

Problems are compounded for small and active birds because even the most miniature transmitters can comprise a great proportion of body mass. In recent years, studies of small birds employed an attachment technique described by Rappole and Tipton (1991). The leg harness secures transmitters to birds' backs with loops that wrap around the body and legs, and it seems to impair mobility less than other methods (Robert et al. 2006, Mong and Sandercock 2007). However, the attachment is long lasting and transmitters often remain on birds after completion of field investigations. Indeed, Mong and Sandercock (2007) reported that leg harnesses remained on upland sandpipers (*Bartramia longicauda*) for multiple years. Others observed similar longevity with transmitters attached to Micronesian kingfishers (*Todiramphus cinnamominus*) and black-backed woodpeckers (*Picoides arcticus*; Kesler and Haig 2007*a, b, c*, *personal observation*).

The need to investigate movement and demography of a threatened kingfisher, the Tuamotu kingfisher (*Todiramphus gambieri*; Critically Endangered classification, International Union for the Conservation of Nature 2008) necessitated development of a new transmitter attachment. Ethical considerations and permit stipulations required that telemetry equipment be designed to eventually drop from study subjects (Minister of the Environment 2005). The bird's natural history is typical of many Pacific kingfisher species that use coconut plantations and strand forests (Gouni et al. 2006). Tuamotu kingfishers nest in cavities excavated from soft wood of decaying trees and the birds are thought to be threatened by predation from introduced rats (*Rattus* spp.) and domestic cats (Gouni et al. 2006, Coulombe et al. 2009). I developed a modified version of the leg harness design (Rappole and Tipton 1991) with a

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built-in weak link designed to fail, and allow the equipment to drop off after transmitter batteries were depleted. I examined retention rates and assessed the impact of transmitter attachment on the kingfishers by comparing survival of color-banded birds with and without weak link mounted transmitters.

STUDY AREA

I conducted research on the island of Niau, French Polynesia (16°08′S, 146°20′W), which hosted the last remaining population of Tuamotu kingfishers. Niau is a raised atoll with a land area of approximately 26 km^2 and an enclosed lagoon (Andréfouët et al. 2005). Niau has a tropical oceanic climate without pronounced seasons, and with a mean annual temperature of 26°C and annual rainfall of 150–200 cm (Mueller-Dombois and Fosberg 1998).

METHODS

I developed a weak-link harness to mark Tuamotu kingfishers with radio transmitters (1.2–1.5 g, BD-2, Holohil Systems Ltd., Carp, Canada [2006–2008]; and A1020 Advanced Telemetry Systems [ATS], Isanti, MN [2010]). Holohil transmitters were coated with a dark resin and ATS transmitters were clear. Transmitters included 1-mm tubes on the front and back for securing the harness.

I fabricated harnesses using the basic design of Rappole and Tipton (1991), but I added a 10-mm section of rubber band (no. 19, 90 × 1.5 mm; Staples Brand Group, Framingham, MA; Fig. 1). The section of rubber band formed a weak link, which eventually broke and allowed the transmitter to shed. To construct the attachment, I used a square knot to tie a >150-mm length of nylon cord (1-mm diameter; commonly sold as drapery cord at fabric stores) to one end of a rubber band that I had cut open. I then marked a 110-mm length of the material so that it included 100 mm of nylon cord and 10 mm of rubber band. I determined harness size for Tuamotu kingfishers by trial and error, but the apparent optimal length was similar to predictions based on allometric

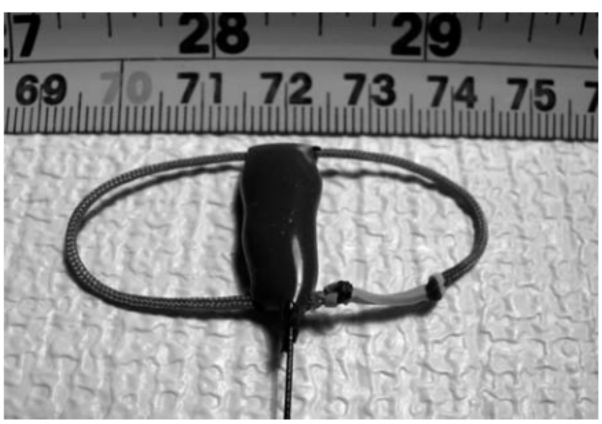

Figure 1. Weak-link radiotelemetry harness constructed for the Tuamotu kingfisher on Niau Atoll, French Polynesia. I tied a 10-mm section of rubber band into the harness that was primarily composed of 1.0-mm nylon cord. I strengthened knots with cyanoacrylate gel or gap-filling glue. I took care to reduce the size of knots, slide the weak link to the posterior section of the transmitter (end with antenna) before anchoring, and prevent glue from soaking into harness material.

equations (Kenward et al. 2001, Naef-Daenzer 2007). To facilitate threading the harness into transmitter tubes, I melted the end of the nylon cord in the flame of a candle until it was hardened and straightened. After threading the material through the transmitter tubes, I bound the open end of the rubber band and nylon cord with a square knot that met at the aforementioned 110-mm marks. I placed a small amount (<1 drop) of original, gel, non-drip gel, or gap-filling gel cyanoacrylate adhesive (Super Glue, Pacer Technologies, Ranco Cucamonga, CA) on each knot. I prevented excess glue from spreading away from the knot, as harness materials stiffened by glue might abrade birds. I clipped excess portions of rubber band and nylon cord away from the knots, and then rotated the harness loop until the rubber section abutted the distal end of the transmitter (end with antenna). I adjusted left and right portions of the harness so that the same amount of loop was present on each side of the transmitter, and I affixed the harness material to transmitter tubes with cyanoacrylate glue. Total harness weight was 0.10 g (SD = 0.02 g).

I used mist nets to capture Tuamotu kingfishers during February–March 2006 and 2010, and in October–November 2006, October–November 2007, and September–November 2008. I marked each captured bird with a unique combination of colored-plastic (high-density polyethylene) leg bands and a numbered aluminum band. I attached transmitters to 49 individuals during 62 bird-observation periods: I radio marked 39 birds during 1 observation period (i.e., a field season), 8 birds during 2 different periods, 1 bird during 3 periods, and 1 bird in 4 different periods.

I mounted transmitters to birds by placing one leg through a harness loop while pulling the harness material up the leg until it rested against the body. I pulled the transmitter around the back of the bird, and then passed the second leg through the remaining loop. I extended both legs away from the body so that the harness slid up the tibiotarsi and around the patellae, until the material rested snuggly in the notch between the upper leg and the belly. I visually verified the harness position by blowing contour feathers away from the joint. When fitted correctly, the transmitter rested immediately above the uropygial gland, and there was enough slack to fit a pencil between the radio and the bird. After marking, I released and visually observed Tuamotu kingfishers for 15–90 min for indications of stress. I then resighted birds each day until mortality, transmitter failure, transmitter shedding, or the end of the field season. Respectively for February–March 2006 and October–November 2006, October–November 2007, September–November 2008, and February–March 2010, I recorded daily observations for 9 birds, 9 birds, 14 birds, 19 birds, and 11 birds, and maximum observation periods were 30 days, 37 days, 38 days, 66 days, and 23 days. I directly observed within-season fates of each individual and radio transmitter, because no birds or radios went missing. I declared mortality when I located a bird's remains. When transmitters stopped working, I visually inspected live birds to determine if transmitters had failed or were shed. I recovered dropped transmitters to determine the cause of release.

I resighted radio-marked Tuamotu kingfishers within field seasons and used the known fate module of Program MARK (White and Burnham 1999) to estimate the daily retention rate for radios fitted to birds with the modified leg harness design. The known fate module is based on Kaplan–Meier methods (Kaplan and Meier 1958), and it is most often used to estimate animal survival. However, I parameterized the input file to estimate daily radio retention by entering the daily number of monitored birds and number of dropped transmitters. I fitted observation data to 2 models, which included daily estimates of radio retention (r_t) and a fixed daily probability of radio retention ($r.$). I ranked models using Akaike's information criterion (AIC_c) and selected the top-ranked model by an AIC_c weight (w_i) >95% (Burnham and Anderson 2002). I then used resulting top-ranked model parameter estimates to predict the probability of modified leg harness-mounted radiotelemetry retention for 3 example study periods. I predicted retention rates for 30 days, 60 days, and 120 days by raising daily retention estimates to the power of the observation period length.

I used inter-season mark and resight data to compare apparent survival between adult (after hatch year) birds marked with color bands and those marked with color bands and radio transmitters. I included adults only in the analysis to eliminate biases from juveniles that dispersed outside study areas. At the conclusion of the February–March 2006 and October–November 2006, October–November 2007, and September–November 2008 field seasons, I marked 3 birds, 6 birds, 14 birds, and 10 birds, respectively, with weak-link leg harness-mounted transmitters and color bands (Table 1). I marked 1 bird, 6 birds, 5 birds, and 29 birds, respectively, only with color bands. During each subsequent visit to Niau, I searched for birds that I had marked during the previous field season. Maintenance of long-term territories by Tuamotu kingfishers facilitated resightings. For all resighted birds, I visually assessed whether transmitters had been shed between observation periods. To account for differences in between-season length, I used a Mantel–Haenszel test of odds (Ramsey and Schafer 1997) to evaluate whether apparent survival differed between birds marked only with color bands and those that also had weak-link leg harness-mounted radio transmitters.

RESULTS

The weak-link leg harness facilitated radio marking Tuamotu kingfishers by flexing and easing tension, which in turn created more space for wrapping the second harness loop around the second leg. Birds preened equipment into contour feathers after release, so that transmitter bodies and antennas were only slightly visible. Kingfishers also occasionally adjusted transmitters with their bills, but there were few other indications of transmitter-generated irritation during 1,665 bird-days of observation. The exception came with a juvenile that showed irritation with the harness immediately after release. I later found the same bird dead with its bill stuck between the harness and its back.

Transmitters attached to Tuamotu kingfishers with weak-link leg harnesses remained on 53 birds for an entire field season (mean no. of observation days = 27), whereas 9 birds shed transmitters before the end of field work. Knots that came untied caused 8 transmitter releases, and frayed material suggested that one bird cut its harness with its bill. There were no indications that transmitters interfered with copulation or that they restricted passage through small nest cavity entrances. Known fate analysis indicated that a constant radio retention rate model ($r.$; $AIC_c = 114$, $w_i > 0.99$) was superior to a time-specific model (r_t; $AIC_c = 212$, $w_i < 0.01$). The parameter estimate for radio transmitter daily retention was 0.995 (95% CI = 0.990–0.997) under the constant rate model. Parameter estimates suggested that for a 30-day period, 85% (95% CI = 73–92%) of birds marked with weak-link leg harnesses would retain transmitters, 72% (95% CI = 54–84%) would retain transmitters during a 60-day study, and 52% (95% CI = 29–71%) would retain transmitters for 120 days.

Long-term transmitter retention was minimal, with only 1 of 23 individuals retaining radio equipment from one field season to the next (Table 1). I found no difference in apparent survival between birds marked only with color bands and those marked with color bands and radio transmitters (Mantel–Haenszel test, $P = 0.65$).

DISCUSSION

I used a weak-link harness to attach radiotelemetry transmitters to Tuamotu kingfishers without permanent marking or impairment. Most transmitters were retained through the duration of field work and there was no evidence of differences in apparent annual survival rates for birds marked with radiotelemetry and those without. Weak-link harness-mounted radios have substantial benefits over other radio attachment techniques. There are drawbacks to traditional methods of attachment because transmitters can remain on the birds long after research ceases (Doerr and Doerr 2002, Woolnough et al. 2004). Other weak-link and shedding transmitter mounts have relied on glue or sutures, but these

Table 1. Inter-season mark and resight data for Tuamotu kingfishers on Niau Atoll, French Polynesia. I marked birds with only color bands, or with color bands and weak-link radio harnesses, in February–March 2006 and October–November 2006, October–November 2007, and September–November 2008. I included adult (after hatch year) birds observed at the end of each field season in marked sets. I resighted kingfishers in the subsequent season and identified individuals by color bands. Results from a Mantel–Haenszel test indicated that birds fitted with weak-link radiotelemetry harnesses and color bands were no less likely to be resighted during the subsequent field season than birds marked only with color bands.

Season Interval	Mar 2006 Mark	Oct 2006 Resight	Oct 2006 Mark	Oct 2007 Resight	Oct 2007 Mark	Sep 2008 Resight	Sep 2008 Mark	Feb 2010 Resight
Color band	1	0	6	1	5	5	29	16
Band and radio	3	3	6	5	14	10	10	5

methods had variable retention times (Perry et al. 1981, Karl and Clout 1987, Hill et al. 1999, Doerr and Doerr 2002). In fact, adhesives were so unpredictable that Whittier and Leslie (2005) captured least tern (*Sternula antillarum*) chicks twice each day to remount transmitters. Leg harnesses are also extremely light (0.1 g), whereas other mounting techniques (e.g., epoxy or aluminum leg bands) can add substantial weight. Harnesses also require less bird manipulation than do glue or epoxy mounts and they do not necessitate feather removal or surgery (Warnock and Takekawa 2003). Furthermore, unlike radios glued to retrices or skin, leg harnesses are retained through molt and can place transmitter weight close to birds' center of gravity.

Although authors rarely report failures, many attachment systems result in premature equipment release, irritation, or mechanical abrasion. The weak-link harness also had drawbacks. One juvenile caught its bill in the weak link section of the harness, which was fixed to the anterior end of that particular transmitter. Additionally, I used a non-gel adhesive, which hardened the harness material enough that the juvenile bird might have been irritated. Thus, I urge caution when studying juveniles and recommend rotating the harness so that the weak link portion is at the posterior of the transmitter before affixing harness material to the transmitter tubing. Nine transmitters were dropped prematurely, 8 of which were shed because knots came untied. Several of the units that dropped prematurely were early designs made with original non-gel glue, which might not have secured the knots as well as the gel adhesives used later. Despite drawbacks, the weak-link harness was a substantial improvement over alternative attachment techniques because nearly all the equipment fell off of birds and inter-season survival was unaffected.

My weak-link harness design combines study-associated benefits of harness-mounted telemetry with the ethical benefits of non-permanent marking. The information gained from tracking radio-marked Tuamotu kingfishers has allowed a quick unveiling of the behavior, movement, and resource needs of this species. These data were essential for development of conservation plans that will hopefully rescue this endangered species (Gouni et al. 2006, Gouni and Zysman 2007, Kesler and Gouni 2008, Coulombe et al. 2009). Although this technique might not be suitable for larger birds, or aggressive species that can cut the weak link section with their bills, perhaps other weak link materials might be substituted for the rubber band so that the method can be used on other species.

MANAGEMENT IMPLICATIONS

Studies of small birds have benefited greatly from miniaturized radiotelemetry transmitter devices and from advances in attachment techniques. However, equipment that remains on birds beyond the life of the transmitter can pose risks to them long after field work ceases. These risks are especially disconcerting when research is focused on endangered species with small and vulnerable populations. Use of this modified version of the Rappole and Tipton (1991) harness attachment was effective during studies of the Tuamotu kingfisher. I recommend that investigations aimed at small and mobile birds consider the use of the weak-link leg harness design, especially if the research extends through molting periods, which precludes the use of adhesive-based attachments.

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