EVALUATION OF TECHNIQUES FOR ATTACHING TRANSMITTERS TO COMMON RAVEN NESTLINGS

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ABSTRACT—We assessed 4 methods of attaching transmitters to nestling Common Ravens (*Corvus corax*) in Grand Teton National Park, Wyoming, in preparation for a larger telemetry study. The attachment types included backpack style with a cross-chest harness, rump mount (''figure-8''), necklace, and tarsal mounts. We tested 2 to 5 transmitters of each attachment type and recorded the ease of attachment, agitation of the ravens (from the nestling stage through the post-fledging dependence period) caused by the transmitters, and any noticeable abrasions caused by the attachment. We preferred the tarsal mount attachment because the transmitters can be placed on the bird early in the nestling stage and 1 person can attach it quickly. We did not prefer the other methods. The necklace mount became ''bridled'' between the bird's upper and lower mandible and/or fell off. Backpack and rump mounts required extensive fitting time, and we felt they should not be used until the nestlings had attained maximum growth, reducing the window of time for attachment.

Key words: Common Raven, *Corvus corax,* transmitter, attachment, backpack, figure-8, rump mount, tarsal, necklace, Jackson Hole, Wyoming

Radio telemetry is a vital tool used in many avian ecological studies. Although a variety of radio transmitter attachment techniques are used, many assessments still need to be made regarding adequate attachment methods and package sizes for different species and age groups. Standard attachment methods have included backpack harnesses with at least 3 different arrangements (Gullion and others 1962; Gullion and Marshall 1968; Dwyer 1972; Johnson and Berner 1980; Smith and Gilbert 1981; Paton and others 1991; Buehler and others 1995), tail-mount, rump mount (or ''figure-8''; Radley 2003), necklace (Gilson 1998), and tarsal mount (Kenward and others 1993; McFadzen and Marzluff 1996; Overskaug and others 1999).

Most ornithologists have accepted the standard telemetry guideline that a transmitter for any particular bird species should not exceed 3% of the bird's mean adult body mass (Hegdal and Colvin 1986; Gaunt and Oring 1999). However, whether the 3% limitation on transmitters is an adequate safety measure for radio-tagging nestlings and fledglings is unknown. Because of low fledgling survivorship in most species (for example, Spear and Nur 1994; Ratcliffe 1997; Bennetts and others 1999; Webb and others 2004), any extra weight, color, and/or shape added by the transmitter might further affect survival rates, so greater care must be taken in choosing the transmitter size, shape, and attachment method to avoid potential adverse effects.

As a feasibility study prior to a long-term study on the post-fledging mortality and dispersal movements of juvenile Common Ravens (*Corvus corax*; Bedrosian 2005), we evaluated which transmitter attachment method (necklace, rump mount, backpack, and tarsal mount) was most suitable for this age class and species (Fig. 1). We determined ease of attachment using the 4 techniques and compared the advantages and disadvantages of each attachment method.

METHODS

Study Area.—The study area encompasses roughly 181 km^2 in Grand Teton National Park (GTNP), which is situated in northwestern Wyoming (UTM, Zone 12; 522834, 4833776). Elevations in the mountain valley range from 1932 to 2343 m, with the Teton Range to the west and Gros Ventre Range to the east. The valley contains the Snake River corridor and an isolated butte. Major habitat types include open Bitter-

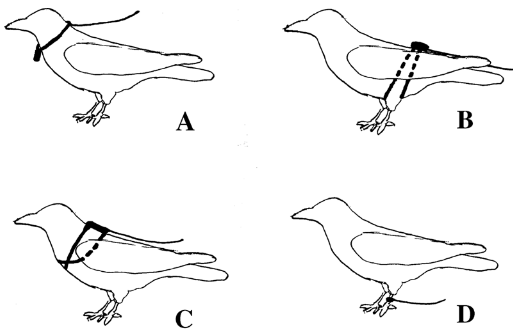

FIGURE 1. Transmitter placements using four attachment techniques on Common Raven nestlings. A = necklace. B = rump mount. C = backpack with a cross-chest harness. D = tarsal mount.

TABLE 1. Specifications of transmitters used on juvenile Common Ravens (*Corvus corax*) in Grand Teton National Park, Wyoming, 2002.

Attachment type	Total mass	Size	*n*	Maximum range[a]
Tarsal	6.1 g	16 × 9 × 7 mm	5	1–3 km
Neck	6.6 g	21 × 21 × 9 mm	3	1–3 km
Rump	9.7 g[b]	25 × 22 × 12 mm	4	0.5–3 km
Back	13.8 g	35 × 9 × 14 mm	2	2–5 km

[a] Maximum range found after transmitters were attached, but before nestlings fledged.
[b] A lighter harness material was used for 2 of the transmitters for a total package weight of 7.8 g.

brush-sagebrush (*Purshia tridentate-Artemisia* spp.) habitat, intermittent Quaking Aspen (*Populus tremuloides*) stands, and old cultivated hayfields. Riparian areas were dominated by willow (*Salix* spp.) and cottonwood (*Populus* spp.), and elevated slopes were dominated by coniferous forests (mainly *Pinus contorta* and *Psuedotsuga menziesii*) (see Craighead and Craighead 1956).

Field Procedures.—Thirteen nestlings from 8 nests were fitted with a transmitter 3 to 8 d before fledging. Attachment type was assigned randomly to the 13 nestlings (Table 1). United States Geological Survey numeric bands and green anodized aluminum alpha-numeric bands (Acraft; Edmonton, Alberta, Canada) were placed on their legs. Two of the 13 fledglings were fitted with backpack transmitters (Telonics; Mesa, AZ) attached with a cross-chest harness (Buhler and others 1995; also known as X-attachment) made of Teflon ribbon, a thin leather breast patch, and a 2-mm cotton breakaway thread placed where the ribbon attached to the transmitter (total weight = 13.8 g, Fig. 2). These transmitters were placed on the birds within 3 d of fledging, so nestling size was as close as possible to adult size to minimize possible restriction of the harness caused by future growth of the bird. Four 6.2-g transmitters (H.A.B.I.T. Research; Victoria, BC) were attached using the figure-8 rump method within 6 d of fledging. We attached 2 with the methods described by Rappole and Tipton (1991) using 2-mm cotton thread (total weight = 7.8 g). The other 2 were attached using 6-mm teflon ribbon (total weight = 9.7 g) to reduce the potential for abrasions on the legs of the birds. Three 6.6-g necklace mount transmitters (Holohil Systems Ltd.; Carp, ON) were used, all attached with the nylon string provided by the manufacturer and a 2-mm cotton breakaway thread. These transmitters were placed on the birds as early as 8 d prior to fledging. Finally,

FIGURE 2. Example of a breakaway configuration used for a backpack mount transmitter on nestling Common Ravens. Both sides of the Teflon ribbon used as harness material were placed through the manufacturer's attachment points and connected to a single cotton thread. When the cotton thread breaks, both sides of the harness fall away simultaneously and the transmitter can slip off of the bird.

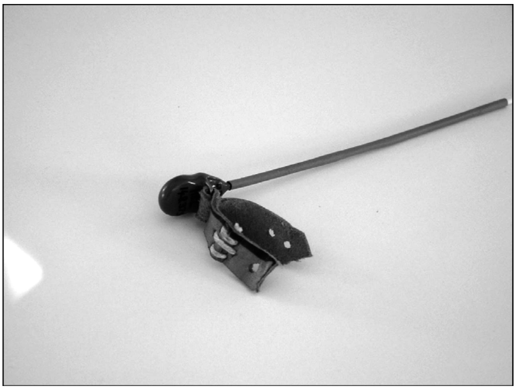

FIGURE 3. Tarsal mount transmitter used on fledgling Common Ravens. Transmitters were equipped with 2-mm cotton stitching as a break-away feature and colored shrink tubing on the antenna for ease of identification.

five 2.3-g tarsal mounts (Holohil Systems Ltd.) were tested. The tarsal mounts were attached around the fledgling's right leg with a leather strap that had a breakaway stitch (total weight = 6.1 g; Fig. 3) and were placed above the color band to maximize the distance of the antenna from the foot and ground while walking. All transmitters weighed from 0.3% to 1.1% of mean body mass at time of banding (mean nestling body mass = 841 g, n = 13), substantially lower than the recommended upper limit of 3% for birds (Hegdal and Colvin 1986; Gaunt and Oring 1999). Transmitter weights were chosen based on typical weights for each attachment type from the manufacturer's recommendation.

Common Ravens usually spend 1 to 4 d on the ground after fledging (Webb and others 2004; Bedrosian 2005). During this period, we made daily visual observations of each fledgling, and thereafter they were located every 1 to 2 d throughout the fledging dependence period. The birds were observed for 5 to 30 min each time they were located. When we were unable to locate the birds using ground telemetry, we performed an aerial search the following day in a small aircraft with dual wing-mounted antennas. Flights were directly followed by visual confirmation of the raven's location on the ground. This monitoring was continued until the transmitter failed or the raven died. If a deceased fledgling was found, we performed a gross necropsy to determine the cause of death, and special attention was paid to determine possible negative effects caused by the transmitter attachment techniques.

RESULTS

Backpack Attachment.—The 2 fledglings with backpack attachments survived only 6 to 12 d post-fledging. One was killed by a Great Horned Owl (*Bubo virginianus*) and the other was hit by a vehicle. Two researchers were needed to fit the transmitter adequately to the bird, and attachment took 20 to 35 min. One bird showed initial irritation with the transmitter (for example, picking at the transmitter for durations of 0.5 to 8 min) during the first 2 d after fledging. No other adverse behavior or abrasions were observed.

Rump Mount (Figure-8) Attachment.—The 4 fledglings outfitted with transmitters attached by the rump mount method were observed for 11, 16, 24, and 39 d. The final transmitter failed at 39 d. Three of the fledglings outfitted with the rump mount were found, or assumed to be, dead. In 2 cases, we continued to observe siblings and parents of the missing birds around habitually used perches. Dorn (1972) and Bedrosian (2005) observed that at nests with >1 fledgling, family units usually perch in close proximity to one another during the 1st month post-fledging. Because these radio-marked birds disappeared and the rest of the family group was present, we assumed these fledglings died. The 3rd bird died as a result of a vehicle collision and showed bruising on the synsacrum where the transmitter rested. However, we could not determine if the transmitter or the collision caused the bruising. This transmitter was affixed with cotton thread and it showed no visible abrasion around the legs where the thread contacted the skin. The rump mount technique took 15 to 18 min to attach and required 2 researchers to secure the bird and to attach the transmitter.

Necklace Attachment.—The 3 ravens with necklace transmitters survived only 1, 3, and 9 d post-fledging. One fledgling died due to injuries sustained by its 1st flight, and no abrasions caused by the transmitter were noted on the carcass. The transmitter had become ''bridled'' in the 2nd bird's mouth (the transmitter was caught between the upper and lower mandible) sometime before it died from Coyote predation between days 2 and 3 post-fledging.

Many fledgling ravens succumb to Coyote predation (Webb and others 2004; Bedrosian 2005), so we could not determine if the bridled transmitter factored into the bird's death. Regardless, it certainly would have impaired the bird's ability to function normally. The 3rd fledgling shed the transmitter 1 or 2 d prior to fledging. We refit the transmitter 1 d post-fledging so it could not slip over the bird's head. On day 5 post-fledging, the fledgling was sighted with the transmitter bridled in its bill. We caught the bird and replaced the bridled transmitter with a tarsal mount. On day 9 post-fledging, this bird had died of a kidney infection (diagnosed by the Wyoming State Veterinary Lab). We assume that the transmitters played no role in causing the infection. We did not observe any birds with necklace mounts preening or picking at the transmitters. The mean attachment time for the necklace mounts was 5 min for 2 researchers, but 1 researcher could adequately fit the transmitter, requiring slightly more processing time.

Tarsal Mount.—We tested a total of 5 tarsal mounts; 4 were attached initially, and 1 was attached to a juvenile, 5 d post fledging, to replace a necklace as described above. These birds survived 8, 9, 30, and 35 d post-fledging. Two of the 4 fledglings that died with tarsal mounts succumbed to Coyote predation. The 3rd fledgling died because of a bacterial infection, and the 4th died due to injuries sustained in a vehicular collision. The 5th bird made 2 flights over 8 km in length and 0.6 km in elevation, both times eventually returning to the nesting territory. We do not know the fate of this bird because the transmitter released 35 d post-fledging. One of the 5 birds appeared to be sensitive to the transmitter. This bird pecked at the leather attaching the transmitter and/or tripped over the antenna. Upon recovery, we noted that the leather affixing the transmitter to the leg was improperly placed below the colored leg band and had stretched, allowing the transmitter to drag below the fledgling's foot when it walked. We noticed no other adverse effects of the antenna hanging below the feet (for example, hindering perching or walking). The average tarsal mount took 1 researcher 1 to 2 min to attach.

Discussion

Many studies that involve placing radio transmitters on fledglings of corvids and raptors use a backpack-style harness that has proven highly successful (for example, Webb and others 2004). While both Webb and others (2004) and this study indicated no negative effects caused by backpack transmitters, we found that the backpack attachments were the most difficult and time-consuming to fit correctly, which increased stress to both nestlings and adults. Also, it was necessary to postpone transmitter attachment until the ravens were within a week of fledging, markedly increasing the chances of injury from premature fledging. Further, there is a risk of fitting the transmitter too snugly if it is attached too early because of continued muscle and bone growth just prior to and after fledging. However, while this method is an acceptable way to mount transmitters on young birds, we believe there are other methods that lower the stress levels and risks to the birds. Backpack attachments may be more suitable for different populations and subspecies of ravens because those populations may have different growth rates before fledging. Each researcher should evaluate potential risks of their study when using backpack attachments.

Very few studies have used rump mount attachments on large birds (>200 g; Radley 2003). This method required 2 researchers and took the 2nd longest time to attach (15 to 18 min). If researchers decide to use this method, we suggest using the modifications described by Radley (2003), who used a small-diameter (approximately 2 mm) elastic shock cord to attach the transmitter, instead of cotton thread or Teflon ribbon; the elastic shock cord allows for fledgling growth and expedites attachment time.

Many researchers prefer to use the backpack attachment because this attachment allows the transmitter to be centrally positioned and, therefore, it can have greater mass and size than an asymmetrical tarsal or neck mount. The rump mount similarly rests centrally on the bird. If large packages are needed for nestlings, we suggest using the rump mount method over the backpack mount due to decreased handling time. Also, the rump mount will not potentially interfere with wing movement or be as affected by pectoralis and supra-coracoideus muscle growth after fledging.

Necklace mounted transmitters have been successfully used by falconers to track trained hawks (DC, pers obs.). Necklace mounts prepared in advance can be quickly slipped over the bird's head or tied around its neck. During our work and during a study on juvenile Osprey (*Pandion halietus*; Gilson 1998), however, birds wearing necklace mount transmitters were prone to getting bridled. In our study, 1 bird shed its transmitter before fledging and another fledgling became bridled. Although the sample is small ($n = 3$), this is a very large failure rate (66%) and we were unwilling to test this technique on additional birds.

The use of tarsal mount transmitters has become more common in recent years (Kenward and others 1993; McFadzen and Marzluff 1996; Overskaug and others 1999). If the leather attachment straps are set up properly in advance, this attachment technique is the quickest and may be the least intrusive to the bird. This technique can be used much earlier in the nesting period than any of the other methods tested, thereby lowering the risk of forcing unprepared nestlings to fledge prematurely. The tarsal mount worked well on nestlings because they appeared to be unaware of the transmitter and its placement. Conversely, adult ravens in a rehabilitation aviary were agitated and continually picked at a tarsal mount (DC, BB, unpub. data).

While we advocate the use of a breakaway system, it may not be preferable for use in every study. For example, if researchers needed to place transmitters on adult ravens, the birds would likely break the weak link quickly and the transmitter would prematurely fall off. However, when placing the transmitter on nestlings prior to fledging, we have found that the birds become accustomed to the package and the chances of premature detachment diminish drastically. Each transmitter attachment method we used included a breakaway system that allowed detachment of the transmitter in a single stage (Figs. 2 and 3). Different diameter strings and threads can be used in the breakaway system to promote different detachment times depending on transmitter life. While some transmitters have the potential of prematurely falling off, we believe that this cost to the researcher outweighs the cost to a long-lived animal of carrying a transmitter that has ceased functioning. We submit that researchers have an ethical obligation to reduce the effects of their research on wild-caught animals and, therefore, should maximize efforts to remove any non-working, non-natural hardware from their study species and/or habitat. Because the designs and effects of breakaways are not yet universally agreed upon, further studies are needed to evaluate the effectiveness of any breakaway system.

The results of our study indicate that the least obtrusive and most effective transmitter attachment type for nestling ravens is a tarsal mount with a breakaway feature to ensure eventual release of the transmitter (Fig. 3). Unfortunately, when using a tarsal mount, we surmise that the total package mass should be well below the recommended 3% of body mass because the weight of a tarsal package is not centrally positioned on the bird. We suggest that a tarsal mount transmitter not exceed 1% of mean body weight, but further experimental studies are needed to adequately assess a proper weight that will not hinder flight abilities of fledglings. In studies where ideal transmitter size limits the use of tarsal mounts, we suggest the use of a rump mount. However, the rump mount also needs to be investigated further to determine any possible long-term effects and additional modifications that may improve this technique.

While our sample sizes are small, we believe that the data provide valuable insight into transmitter attachments for large-bodied nestlings. Following this pilot study, Bedrosian (2005) deployed 31 tarsal mount transmitters in 2003 and 35 more in 2004, using 1.0-mm cotton thread as the breakaway material. Mean detachment time was >60 d with the earliest transmitter falling off 41 d after attachment (BB). During both years, all but 4 transmitters stayed attached until after birds dispersed (approximately 60 d post-fledging). No detrimental effects were documented by the package or harness placement on any of the 66 fledglings throughout the fledging dependence period (Bedrosian 2005). To ensure the welfare of study animals, more studies are needed to thoroughly elucidate effects when attaching any foreign objects.

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