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CAPTIVE AND FIELD-TESTED RADIO TRANSMITTER ATTACHMENTS FOR BALD EAGLES

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Abstract.—The effects of two radio transmitter attachment techniques on captive and one attachment technique on wild Bald Eagles (*Haliaeetus leucocephalus*) were studied. A Y-attachment method with a 160-g dummy transmitter was less apt to cause tissue damage on captive birds than an X-attachment method, and loosely fit transmitters caused less damage than tightly fit transmitters. Annual survival of wild birds fitted with 65-g transmitters via an X attachment was estimated at 90–95%. As a result of high survival, only five wild birds marked as nestlings were recovered. Two of these birds had superficial pressure sores from tight-fitting harnesses. It is recommended that a 1.3-cm space be left between the transmitter and the bird's back when radio-tagging post-fledging Bald Eagles. Additional space, perhaps up to 2.5 cm, is required for nestlings to allow for added growth and development.

ADAPTADORES DE RADIO TRANSMISORES PARA *HALIAETUS LEUCOCEPHALUS* PROBADOS EN CAUTIVERIO Y EN EL CAMPO

Sinopsis.—Se estudiaron los efectos de dos técnicas para colocar radiotransmisores a individuos cautivos de *Haliaetus leucocephalus* y de una técnica en individuos silvestres de la misma especie. Un método Y para colocar un transmisor falso de 160 g de peso causó menos daño a los tejidos que un método X de fijación, mientras que transmisores colocados holgadamente causaron menos daños que los muy ceñidos. La supervivencia anual de aves silvestres

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con transmisores pesando 65 g usando el método X se estimó entre 90 y 95%. Como resultado de esta alta supervivencia, sólo se recuperaron cinco aves marcadas como pichones. Dos de estas aves tenían llagas de presión superficial causadas por arneses muy ceñidos. Se recomienda que se deje un espacio de 1.3 cm entre el transmisor y la espalda del ave cuando se coloquen radios en volantones de *Haliaetus leucocephalus*. En pichones se requiere un espacio adicional, tal vez hasta 2.5 cm, para permitir el crecimiento y desarrollo de éstos.

Many methods exist for attaching radio transmitters to animals, including neck collars (mammals and waterfowl), implants (waterfowl, fish and furbearers), tail mounts (raptors), and backpack harnesses (birds) (see review in Kenward 1987). The possible effects of transmitter packages on animal survival, energy budgets, and behavior have not been adequately evaluated, however, for most species and transmitter attachment designs. Recent studies have shown that carrying a transmitter and the means of attachment can affect these parameters (Gessaman et al. 1991, Gessaman and Nagy 1988, Obrecht et al. 1988, Pennycuick et al. 1989, review in White and Garrott 1990).

Attachment methods for Bald Eagles have focused on tail mounts or backpack harnesses. Although tail mounts have been used successfully, radios are lost during the subsequent molt (Kenward 1987). Backpack harnesses, in contrast, allow for prolonged attachment of transmitters. This approach may be particularly useful with long-lasting solar-powered transmitters.

Our objectives in this study were to: (1) determine the effects of two different backpack attachment designs and relatively large (160 g) satellite-compatible transmitters on captive Bald Eagles, (2) evaluate the effects of conventional 65-g radio transmitters on wild Bald Eagles and (3) determine the durability of several antenna designs on captive and wild birds.

METHODS

Captive birds.—We used 12 permanently captive Bald Eagles housed at the Patuxent Wildlife Research Center, Laurel, Maryland for the study. Seven birds had injured or amputated wings and were incapable of normal flight, and five birds were full-winged, but flight was limited within 4 × 10 × 2.5-m cages. We used 160-g 8.0 × 5.5 × 3.0-cm gray wood blocks to simulate satellite-compatible transmitters. Each block was equipped with four 25-cm long strands of 0.6-cm wide tubular teflon ribbon (Bally Ribbon Mills, Bally, PA) to form the harness. We attached a 7.5 × 3.5 × 0.15-cm piece of Goretex foam to the ventral side of the block to provide padding and reduce abrasion. An antenna was welded to a 1.2-cm bolt attached 1.5 cm from the trailing end of the block. The transmitter was placed in the midline of the bird's back between the junction of the wings and the body. The two neck straps were placed over the scapula, along the furcula, and joined at a point about one-third of the way posterior from the top of the sternum to form the neck loop. The body straps were passed behind the wings, in front of the legs, and joined about one-third of the way anterior from the bottom of the sternum to form the body

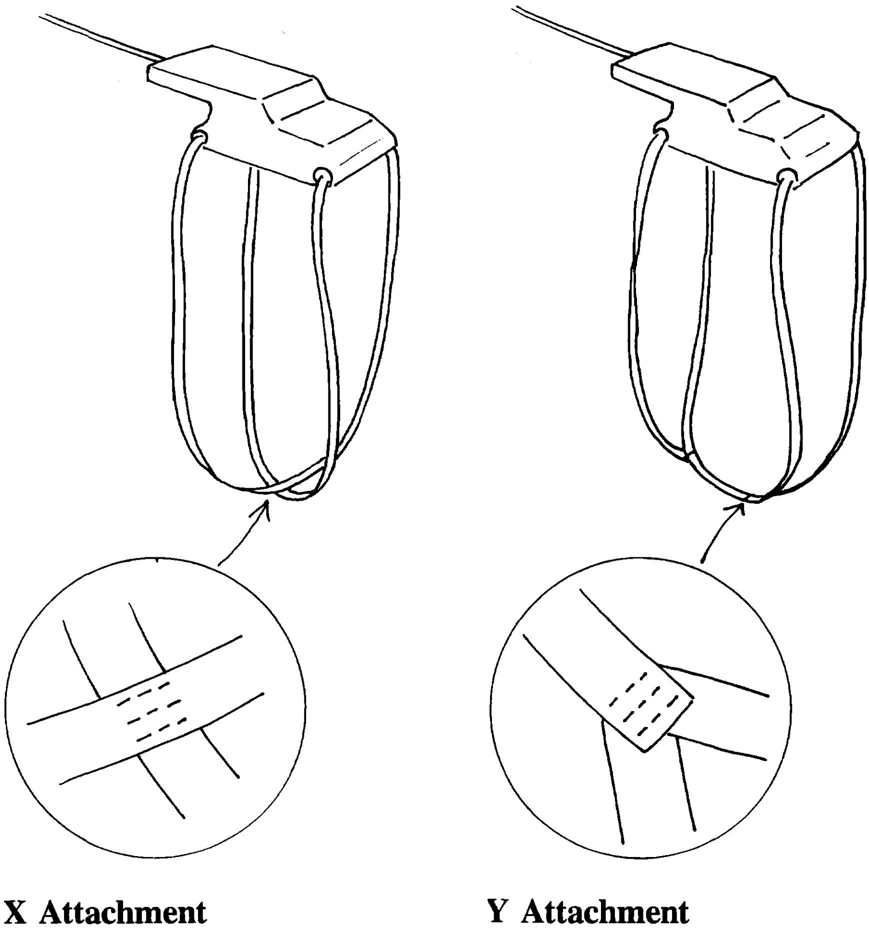

FIGURE 1. Configuration of X and Y transmitter harness attachments used on captive and wild Bald Eagles.

loop (Snyder et al. 1989). Neck loops and body loops were sewn together separately over the sternum with nylon thread and curved needles.

The neck and body loops were secured either by sewing all four straps together at one point (X attachment) or by connecting neck and body loops with a 2.25–3.5-cm connecting ribbon (Y attachment) (Fig. 1). Excess material was trimmed after sewing.

We varied the tightness of the harness to evaluate how differences in fit affected the bird. A tight fit would not allow the wood block to move fore and aft, and there was no slack in any of the straps. A snug fit allowed the block to move 0.5–1.2 cm fore and aft, and it was possible to slide a 0.5-cm rod between the harness and the back of the bird. A loose fit allowed the block to move up to 2.5 cm fore-aft with a 1.3-cm space between the block and the bird's back.

We fitted seven randomly-selected birds with blocks using the X attachment and five randomly-selected birds with blocks using the Y attachment in early December 1985. After 76 d, all birds were captured and examined. Blocks were removed at this time from three birds because harness and transmitter block wear may have led to possible injury. One bird was removed from the experiment at day 76 for captive breeding. The remaining eight birds were evaluated after an additional 111 d.

Four types of multi-strand antenna were tested on captive birds: type I = 1.2-mm diameter composed of 19 strands of wire; type II = 1.6-mm diameter with seven strands of wire; type III = 1.6-mm diameter with 19 strands of wire; and type IV = 1.6-mm diameter composed of seven bundles of wires of seven wires each. Upon inspection, antenna condition was defined as undamaged, frayed, bent or broken off.

Wild birds.—We trapped nine Chesapeake-hatched, eight northern, and nine southern adult and immature Bald Eagles using floating noose-fish (Cain and Hodges 1989) and padded leghold traps (Young 1983). In addition, we radio-tagged 39 Chesapeake eaglets at 8–10 wk of age in 1984–1989 (Buehler et al. 1991a). Eagles were equipped with 65-g solar-powered radio transmitters (2.4 × 3.2 × 7.8 cm) that charged nickel-cadmium batteries (Telemetry Systems, Inc., Mequon, WI) and had an expected life of 3–5 yr. We did not attach the Goretex pad to these transmitters. We used type IV antenna ($\bar{x}$ = 35.6-cm long) coated with plastic (0.8-mm diameter). We mounted transmitters via the X attachment. We covered the thread at the sewn junction of the four straps with 5-min epoxy to prevent unraveling. All transmitters were fitted loosely on the birds.

We tracked eagles 2–3 times weekly from fixed-wing aircraft on the northern Chesapeake Bay and recorded locations on 7.5-min U.S. Geological Survey (USGS) topographic maps. Once monthly, we flew the entire Chesapeake and relocated eagles that were found south of the study area. We flew the Maine coast once monthly during summer, 1987–1990 to relocate missing radio-tagged eagles that may have permanently moved north of the Chesapeake Bay. University of Florida personnel scanned for Chesapeake Bay radio-tagged eagle frequencies monthly in northern Florida during 1986–1990 to relocate birds that may have permanently moved south of the Chesapeake Bay (M. Collopy and P. Bohall Wood, pers. comm.). We ground-searched for birds to confirm possible deaths when radio signals came from the same point on 2–3 consecutive flights without visual contact.

We evaluated the condition of recovered birds and the effects of the transmitter package. We also evaluated the condition of harnesses and transmitters recovered without the birds.

We used the Kaplan-Meier product estimator (Pollock et al. 1989) and an interval length of 1 mo to estimate annual eagle survival for Chesapeake-origin birds (see Buehler et al. 1991b). Coverage of areas outside

TABLE 1. Effects of X and Y attachments of 160-g dummy transmitters for 187-d exposure on captive Bald Eagles.

Attachment method	Fit[a]	Exposure (wk)	Capable of flight	Harness movement	Tissue damage
X	tight	11	no	yes	yes
X	tight	11	no	yes	yes
X	snug	11	no	yes	yes
X	loose	27	no	yes	yes
X	loose	27	no	no	no
X	loose	27	yes	yes	no
X	loose	27	yes	yes	no
Y	tight	27	yes	yes	yes
Y	snug	27	yes	yes	no
Y	snug	27	yes	no	no
Y	snug	27	yes	no	no
Y	snug	11	no	no	no

[a] Tight fit = transmitter cannot move fore and aft on bird, no slack in harness straps. Snug fit = transmitter can move 0.5–1.2 cm fore and aft on bird with enough slack in harness to slide a 0.5-cm rod under harness straps. Loose fit = transmitter can move 2.5 cm fore and aft with a 1.3-cm space between the transmitter and the bird's back.

the Chesapeake was too infrequent to produce meaningful survival results for migrant eagles.

We lost radio contact with nine eagles. We generated minimum survival estimates by assuming these eagles died and we generated maximum survival estimates by assuming the transmitters on these birds failed.

Nestlings were aged from known hatch dates and previously unbanded trapped birds were aged by plumage characteristics (McCollough 1989). Most of the radio-tagged wild birds were marked as nestlings and transmitters operated consistently for 3–4 yr. When monitoring adults (≥4 yr old), we watched for signs of reproductive activity.

RESULTS

Captive birds.—The junction where the harness straps were sewn together had moved to one side of the keel on eight of 12 eagles (Table 1). Bone or tissue damage occurred in five of these eight cases because the body strap from the opposite side crossed and made a depression in the sternum. Four of five eagles with tissue damage had blocks attached with the X method.

Damage by the teflon harness occurred most often when the harness fit was tight (all three cases), whereas only one of four loosely-fit blocks damaged tissue on the bird (Table 1). Tissue damage occurred in two of five snug or loosely-fit cases with the X attachment, whereas no tissue damage occurred on eagles fit snugly with a Y attachment.

Wild birds.—We recovered four dead radio-tagged eagles and one bird with a broken wing that probably would have died without human intervention (Table 2). One eagle died from electrocution, one was shot and

TABLE 2. Effects of X-harnessed radio transmitters on Bald Eagles recovered on the Chesapeake Bay, 1984–1990.

Eagle ID	Age at radio-tagging	How recovered[a]	Years tagged	Tissue damage
049	immature	dead	3.3	no
452	nestling	broken wing	3.5	yes
578	nestling	lost radio	0.6	yes
699	immature	dead	0.8	no
785	nestling	dead	0.8	yes
879	nestling	lost radio	1.0	no
915	immature	dead	1.8	no
998	immature	lost radio	1.1	no

[a] The effects of radio transmitter attachment on eagles that lost their transmitters were evaluated on the basis of the presence of tissue on the harness or transmitter.

two died from unknown causes. Two eagles lost their transmitters because the harness stitching unraveled. One transmitter was lost because the harness was cut by the glass tube through which it passed on the transmitter. Minimum annual survival was 90% (95% CI = 85–95%). Maximum annual survival was 95% (95% CI = 93–100%).

No radio-tagged eagles less than 5 yr old nested during the study. We regularly observed only two older birds often enough to locate their nest sites. Both nested successfully.

Two of five eagles recovered and one of three transmitters recovered showed signs of eagle tissue damage from the transmitter package (Table 2). Eagles with tissue damage were radio-tagged as nestlings and the fit was excessively tight across the body straps upon recovery. Superficial pressure sores developed beneath the transmitter over a 1×1.5-cm area, and matted feathers and tissue were found on the transmitters. In one recovered eagle, superficial tissue damage occurred across the pectoral region of the sternum beneath the harness, although no damage occurred across the keel. In the other case, tissue damage occurred where the harness crossed the keel. Wounds caused by the transmitter and the harness were superficial and not life threatening (N. J. Thomas, D.V.M., U.S. Fish and Wildlife Service National Wildlife Health Lab, Madison, WI, pers. comm.).

Antennas.—Of the 12 antennas monitored on captive birds, seven broke off, three were bent or frayed and one had a broken wire, thus only one was undamaged. In contrast, all of the antennas on wild birds were functional at recovery, and only one of eight was damaged (bent). The increased damage of antenna on captive birds may have been caused by increased preening activity in captivity. Alternatively, plastic-coating of the antenna on wild birds may have prevented damage.

DISCUSSION

The Y attachment caused fewer problems than the X design on captive birds, with most problems occurring from tight-fitting harnesses. Even our loose harnesses (1.3-cm space) became too tight for some wild birds radio-tagged as 8–10-wk-old nestlings. Although nestlings were almost full grown in mass and other physical features (Bortolotti 1984) when radio-tagged, additional development of pectoral muscles apparently occurred post-fledging.

Although some of the recovered eagles had tissue damage associated with the radio-marking methods and tightly-fit transmitters, none of the deaths appeared to have been directly related to the transmitter. The consequences of harnesses being too loose might be greater than the problems we observed with transmitters that were too tight, because mortality from entanglement of harnesses can occur (Hines and Zwickel 1985, Hirons and Owens 1982, Schladweiler and Tester 1972). We believe that a harness with a 2.5-cm space between the transmitter and the bird's back would be adequate to allow for growth but avoid entanglement for 8–10-wk-old eaglets. Proper harness fit for younger birds can be difficult to attain because the need for even more slack in the harness to allow for growth might increase the risk of entanglement. In post-fledged eagles, our loose attachment (1.2-cm space) appeared to be adequate.

Our survival estimates for eagles hatched and radio-tagged on the Chesapeake (90–95%) exceeded all published estimates for Bald Eagles based on other marking methods (Brown and Amadon 1968:135, Gerrard et al. 1978, McCollough 1986, Sherrod et al. 1976). The very high survival of the Chesapeake eagles suggests that if radio-tagging decreased survival, it must have had a very slight effect. Such high survival, combined with high reproductive productivity, has resulted in exponential growth in the Chesapeake eagle population (Buehler et al. 1991b).

We do not know if or how the transmitters affected eagle movements. Studies on other species suggest that migration behavior and energetics could change with radio-tagging (Gessaman and Nagy 1988, Pennycuick et al. 1989). We also know that radio-tagged eagles can successfully reproduce, but we lack data on whether radio-tagging affects overall productivity. These areas need further study to evaluate fully the effects of radio marking at the population level.

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