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Pamela Pietz
Northern Prairie Science Center

David Brandt
Northern Prairie Science Center

Gary Krapu
Northern Prairie Science Center

Deborah Buhl
Northern Prairie Science Center

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MODIFIED TRANSMITTER ATTACHMENT METHOD FOR ADULT DUCKS

PAMELA J. PIETZ, DAVID A. BRANDT,
GARY L. KRAPU AND DEBORAH A. BUHL

Northern Prairie Science Center[1]
National Biological Service
8711 37th Street S.E.
Jamestown, North Dakota 58401 USA

Abstract.—The value of radio telemetry for waterfowl research depends on the availability of suitable methods of attaching transmitters. In previous studies, external transmitters attached to adult Mallards (*Anas platyrhynchos*) with sutures and glue did not stay on birds reliably. In an attempt to improve transmitter retention, a method of attachment was tested in which 4-g transmitters were attached mid-dorsally with sutures and with a stainless steel anchor-shaped wire inserted subcutaneously (anchor transmitters). Field tests indicated that all of 26 female Mallards and 63 of 65 female Gadwalls (*Anas strepera*) retained their anchor transmitters during 4369 bird-days of monitoring during nesting and brood rearing. Survival rates of females with anchor transmitters compared favorably with those reported from other studies. In this study, females with and without anchor transmitters did not differ with respect to survival rates of their ducklings. The anchor transmitter may be suitable for a variety of field studies on numerous species.

UN MÉTODO MODIFICADO PARA ADHERIR TRANSMISORES A PATOS ADULTOS

Sinopsis.—El valor de la radio telemetría para la investigación de aves acuáticas depende de la disponibilidad de métodos apropiados para adherir los transmisores. En estudios previos, transmisores externos adheridos a *Anas platyrhynchos* adultos con suturas y pegamento no quedaban fijados confiablemente a los adultos. En un intento de mejorar la retención de transmisores, probamos transmisores de 4-g, adheridos a medio dorso con suturas o con un alambre de acero inoxidable en forma de ancla que se insertaron subcutáneamente (transmisores anclas). Pruebas de campo indican que todas las 26 hembras de *Anas platyrhynchos* y 63 de 65 hembras de *Anas strepera* retuvieron sus transmisores ancla durante 4369 días-ave de monitoreo durante el anidaje y la educación de la camada. Las tasas de supervivencia de hembras con transmisores ancla compararon favorablemente con las reportadas en otros estudios. En este estudio, hembras con o sin transmisores no difirieron con respecto a las tasas de supervivencia de sus crías. El transmisor ancla puede ser apropiado para una variedad de estudios de campo en numerosas especies.

Biologists who use radio telemetry must consider two main objectives when choosing a method of attaching transmitters to research subjects: (1) the transmitter must be attached securely so that it remains on the animal for the desired data-collection period, and (2) the transmitter must be attached so that it does not harm the animal nor affect the animal in ways that would bias the data being collected. Over the past 20 yr, waterfowl biologists have tried a variety of attachment methods with varying results (e.g., Gilmer et al. 1974, Greenwood and Sargeant 1973, Perry 1981, Siegfried et al. 1977, Sorenson 1989, Wheeler 1991).

Transmitters attached with harnesses consisting of two body-loops

[1] *Formerly Northern Prairie Wildlife Research Center of the U.S. Fish and Wildlife Service.*

(Dwyer 1972) have been used extensively on adult dabbling ducks (e.g., Cowardin et al. 1985, Derrickson 1978, Frazer et al. 1990, Miller et al. 1992, Ringelman and Longcore 1983, Talent et al. 1982) and have provided satisfactory retention times. Some studies have reported, however, that transmitters attached with harnesses affected behavior and reproductive effort in female Mallards (*Anas platyrhynchos*; Chabaylo 1990, Greenwood and Sargeant 1973, Pietz et al. 1993, Rotella et al. 1993).

Transmitters attached only with sutures or with sutures and glue did not appear to affect Mallard reproduction (Pietz et al. 1993, Rotella et al. 1993). These transmitters, however, failed to remain on ducks long enough to be useful for many studies (Houston and Greenwood 1993; G. L. Krapu, unpubl. data). In one field test of transmitters attached with sutures and glue, Rotella et al. (1993) reported that 31 of 49 transmitters fell off adult Mallards within about 2 mo.

Transmitters that are surgically implanted in the abdominal cavity have proven successful for some telemetry studies (e.g., Rotella et al. 1993). Although they eliminate many potential problems associated with external attachments, implanted transmitters have several drawbacks of their own. The reduced transmission capabilities of internal antennas make it more difficult to locate transmitters (Rotella et al. 1993), especially with ground-based receivers. The antiseptic conditions and general anesthesia needed for surgical implantation require equipment and facilities that are difficult to provide in many field studies. Transporting birds to such facilities and administering general anesthesia may increase handling time of the birds. Implanted transmitters tend to be much larger than external transmitters (for a given battery life; e.g., see Rotella 1993), thus limiting the size range of species for which they are suitable.

These drawbacks led us to continue our search for an acceptable method of attaching external transmitters. In 1992–1993, we tried a transmitter attachment method on adult female Mallards and Gadwalls (*Anas strepera*) that combined the use of sutures, as in one of our previous transmitters (Pietz et al. 1993:701), and a subcutaneous wire anchor, modified from one designed by Mauser and Jarvis (1991) for a duckling transmitter. Our objectives were to determine (1) if this modified attachment method would provide adequate transmitter retention for studies of breeding dabbling ducks, and (2) if birds wearing these modified transmitters (hereafter "anchor transmitters") would have survival rates and brood-rearing success similar to birds without transmitters.

STUDY AREAS AND METHODS

We collected data at three study areas, each about 50 km^2, in the prairie pothole region (van der Valk 1989:3) of North Dakota. Study areas were located about 15 km south of Turtle Lake (47°23′N, 100°49′W) in McLean County (1992–1993), 27 km north of Jamestown (47°11′N, 98°40′W) in Stutsman County (1992), and 14 km south of Kulm (46°12′N, 98°53′W) in Dickey County (1993).

Nest searches were conducted on several grass-dominated fields (Waterfowl Production Areas and Conservation Reserve Program land) in each study area. Fields were searched using two vehicles dragging a chain to flush females from nests (Higgins et al. 1969). Searches included nesting habitat protected by two 25-ha predator exclosures (Pietz and Krapu 1994), one each on the Jamestown and Kulm study areas. We attempted to protect some nests found outside predator exclosures with 8-m^2 individual nest protectors made of wire mesh.

Female Mallards and Gadwalls were captured on their nests about midway through incubation using either a walk-in trap (Dietz et al. 1994) or a modified (Shaiffer and Krapu 1978) bow-net trap (Salyer 1962). Captured females were radio-marked with anchor transmitters, nasal markers (Lokemoen and Sharp 1985), and U.S. Fish and Wildlife Service leg bands (Federal Bird Marking and Salvage Permit No. 09352). Each bird was then anesthetized to a medium stage with methoxyflurane (Rotella and Ratti 1990) and placed beside her nest.

Birds with transmitters were located daily through incubation and brood-rearing, and less frequently if they lost their nest or brood. Radio-tracking ended earlier for birds that were killed or that left the study area after reproductive failure.

Transmitter design.—The anchor transmitter (Fig. 1) had two attachment features: (1) cylindrical tubes for threading sutures and (2) a subcutaneous wire anchor. Sutures served to hold the transmitter in place while the incision healed around the stem of the anchor (2–3 d). Subsequently, the anchor and sutures were expected to provide a greater retentive force than either an anchor or sutures alone.

Anchor transmitters had crystal-controlled frequencies and two-stage thermistor-controlled pulse rates (Advanced Telemetry Systems, Isanti, Minnesota). They were designed for 100 d of battery life and a range of 2.5 km when using truck-mounted four-element yagi antennas. A $\geq$30% decrease in pulse rate indicated mortality of the bird.

The body of the transmitter measured 21 $\times$ 12 $\times$ 6 mm. A 0.79-mm diameter stainless steel wire was bent to form a two-pronged anchor (Fig. 1) that protruded 12 mm forward from the anterior end of the transmitter and was deflected 15° down from the horizontal plane of the transmitter. The antenna consisted of a 21-cm length of seven-strand twisted stainless steel wire with a black nylon coating. A pliable sleeve and spring encompassed the base of the antenna, which joined the transmitter at a 40° angle. The complete transmitter package weighed about 4 g, $<$0.5% of the average adult body mass of female Mallards and Gadwalls.

Transmitter attachment.—Anchor transmitters were attached mid-dorsally, just anterior to the shoulder joints, with three polypropylene sutures and with the anchor-shaped wire that was inserted subcutaneously. We prepared the transmitter attachment site by trimming feathers from a patch of skin slightly larger than the base of the transmitter. The transmitter was placed beside the trimmed area to serve as a guide while reference lines were drawn on the skin, perpendicular to the body axis, to mark the suture and anchor insertion sites. The line for the anchor in-

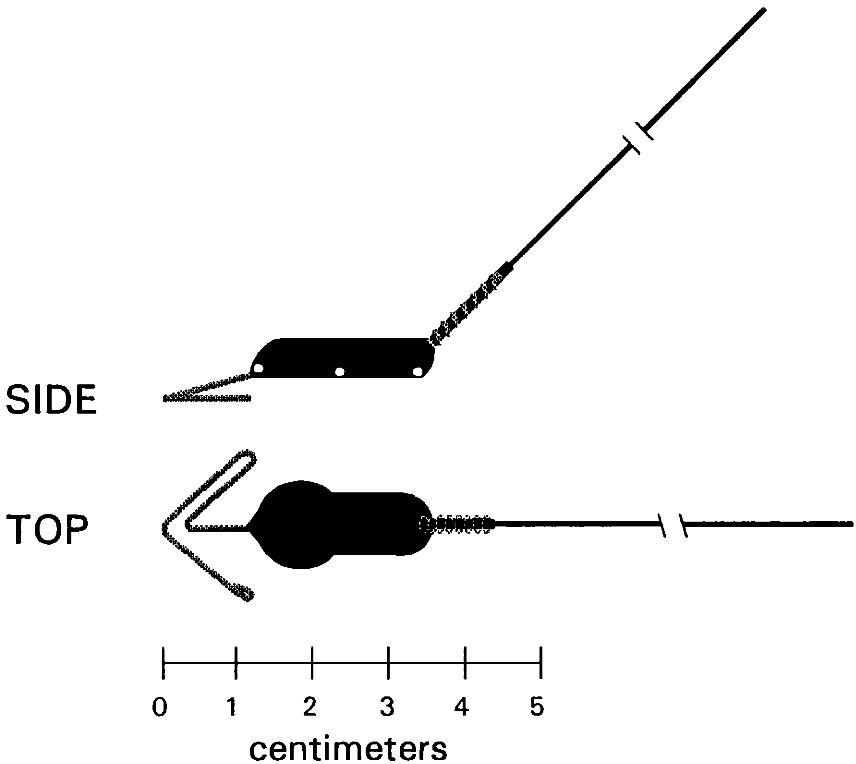

FIGURE 1. Four-gram transmitter designed for adult Mallards and Gadwalls includes a subcutaneously attached anchor (modified from Mauser and Jarvis 1991) and three cylindrical tubes for threading permanent sutures.

cision was made at the midpoint of the stem of the anchor, so that when in place the tip of the anchor would lie anterior to the incision. We sterilized the surgical instruments and transmitter with isopropyl alcohol. We made a 2–3 mm incision along the most anterior line by holding a fold of skin between two fingers, piercing the skin with a No. 11 surgical blade and cutting away from the bird's body. In a few cases, we had to separate the skin from the underlying muscle tissue with a blunt probe to create a space for the anchor of the transmitter. In most cases, there was no bleeding at the incision site.

To attach the transmitter, we first threaded three sterile monofilament polypropylene (0 metric) sutures through the cylindrical tubes along the front, middle and back of the transmitter. The sutures were then sewn through the skin along the three reference lines but left slack. Next, the stainless steel anchor was placed under the skin by threading the anchor wire through the incision as follows: (1) left prong, (2) outer loop of right prong, (3) inner loop of right prong and (4) stem. The sutures were then tightened and tied off with two square knots secured with a drop of clear nail polish. Properly tied sutures held the transmitter firmly in place without puckering the skin.

Experienced personnel required an average of 15 min to attach an anchor transmitter. Total handling time (including transport, banding, nasal marking, weighing and anesthetizing) averaged 30 min. We worked in two-person teams; one person restrained the bird, while the other one attached the leg band, nasal markers and transmitter.

All procedures used in this study were approved by the Northern Prairie Science Center (formerly Northern Prairie Wildlife Research Center) Animal Care and Use Committee. Techniques were developed in consultation with an experienced wildlife veterinarian and followed guidelines of the American Ornithologists' Union (1988) for use of wild birds in research. We chose not to inject a local anesthetic because (1) the dorsal skin is poorly enervated (Altman 1981), (2) the injection itself could be a source of trauma and (3) waiting for the anesthetic to work would prolong handling time.

Statistical analyses.—To estimate retention rates of transmitters, we totaled the numbers of days that each bird wore a transmitter (bird-days), excluding the capture day. Daily retention rates for each species were calculated using the method described by Mayfield (1961, 1975) (1 − [number of females that lost transmitters/number of days females wore transmitters]). Interval retention rates were calculated for a 75-d period, representing half of the incubation period (when most adults were radio-marked) plus the brood-rearing period. This was the interval through which transmitter retention was critical to our study. The 95% confidence limits for daily and interval retention rates were calculated as in Johnson (1979).

To estimate female survival rates, we totaled the numbers of days the birds were alive while wearing their transmitters (exposure days). We excluded from this total the day each bird was radio-marked and the incubation days for birds nesting inside predator exclosures or individual nest protectors. Daily survival rates (Mayfield 1961, 1975) were calculated (1 − [number of females that died/number of days females were alive while wearing transmitters]) separately for three reproductive stages: incubation, brood-rearing and post-brood/failed breeder. Interval survival rates were estimated for a 183-d period (April–September) for comparison with other estimates reported in the literature. To calculate our 183-d survival rate, we multiplied interval survival rates for (1) incubation, (2) brood-rearing, (3) post-brood/failed breeder and (4) other (pre-egg-laying, egg-laying, pre-migration). We used the period lengths given by Kirby and Cowardin (1986) for the first three intervals (using their "molt" category plus the first 12 d of their "premigration" category as equivalent to our "post-brood/failed breeder" category). The daily survival rate used for the fourth interval was assumed to be 1.0, based on rates given by Kirby and Cowardin (1986) for "nest initiation" and "premigration" and on our limited data for egg-laying birds. The 95% confidence limits for daily and interval survival rates were calculated as in Johnson (1979).

We also assessed whether ducklings of radio-marked females survived as well as those of unmarked females in our sample. Data for unmarked females were available from broods containing 1–4 radio-marked ducklings. These ducklings were radio-marked before leaving their nests, as part of a concurrent study in which ducklings were monitored to fledging. We assessed the effects that study area, year, site by year, duckling radio-marker and mother radio-marker had on duckling survival rates using the procedure LIFEREG of SAS (SAS Institute Inc. 1989) assuming a Weibull model. Further information on the duckling study will be provided elsewhere.

For this analysis, ducklings were treated independently rather than as parts of broods. Potential non-independence of ducklings (pseudo-replication) does not bias survival estimates (Pollock et al. 1989), but may make our estimates appear to have smaller variances than they actually do. Smaller variances, however, make it more likely to show a significant effect of the mothers' transmitters on duckling survival (i.e., less likely to make a type II error).

RESULTS AND DISCUSSION

We attached anchor transmitters to 26 Mallards and 65 Gadwalls at their nests from 21 May to 23 Jul. 1992 and from 18 May to 9 Aug. 1993 (Table 1). Radio-tracking ended by mid-September each year.

Transmitter retention.—Ninety-eight percent of the 91 birds with anchor transmitters retained their transmitters throughout the time they were monitored (Table 1). No Mallards and only two Gadwalls were believed to have shed their transmitters (i.e., detached transmitter recovered in good condition, no evidence of predation) during 4369 bird-days of monitoring. One Gadwall transmitter probably was shed on 22 August, 44 d after attachment; it was found undamaged, sutures intact, under 1.5 m of water in the middle of a large, open wetland. The other Gadwall transmitter probably was shed on 14 September, 80 d after attachment; it was found undamaged on emergent vegetation in a large wetland frequented by molting birds. Daily retention rates were 1.0 for Mallards and 0.9993 (95% CI = 0.9984–1.0) for Gadwalls. Retention rates for the 75-d interval of interest for this study were 1.0 for Mallards and 0.951 (95% CI = 0.885–1.0) for Gadwalls.

Incidental information was obtained for 12 females after their systematic monitoring period had ended. One Mallard still wore an anchor transmitter when recovered in December by a hunter in Arkansas, 165 d after transmitter attachment. The other 11 females were all recaptured on nests about a year after they were originally marked; one Mallard and three Gadwalls still wore transmitters, and one Mallard and six Gadwalls had shed transmitters.

The Mallard and two of three Gadwalls recaptured a year later with their transmitters still attached showed no evidence of infection, feather

TABLE 1. Data used to calculate transmitter retention rates and survival rates of female Mallards and Gadwalls equipped with anchor transmitters during the breeding season at three study areas in the prairie pothole region of North Dakota.

Species, location and year	# radio-marked birds	# birds that shed transmitter	# days transmitters retained	# birds that died	# days birds survived[1]
Mallard					
Turtle Lake					
1992	11	0	562	2	562
1993	4	0	109	1	73
Jamestown					
1992	4	0	263	0	237
Kulm					
1993	7	0	479	0	452
Gadwall					
Turtle Lake					
1992	8	0	167	1	167
1993	19	0	501	1	484
Jamestown					
1992	12	1	595	0	486
Kulm					
1993	26	1	1693	2	1581
Total	91	2	4369	7	4042

[1] Number of days birds survived is lower than number of days transmitters were retained because incubation days were subtracted from the total days survived for birds with nests inside predator exclosures or nest protectors.

wear or other problems. At the time of recapture, the sutures generally were still tied to the transmitter but were no longer attached to the bird; transmitter attachment sites were fully feathered. In two cases, both prongs of the anchor were still embedded in the skin, but the tip of the anchor was exposed. In the other case, the anchor was only attached to the bird by a small pedicle of skin around the anchor stem. Evidence from these birds suggests that the sutures and, eventually, the anchor are gradually expelled by migration through the skin as new layers of tissue grow. The condition of the seven birds recaptured without transmitters also suggests that transmitter loss is relatively benign rather than traumatic: transmitter attachment sites were visually indistinguishable from those of unmarked birds.

The third Gadwall recaptured a year later with her transmitter still attached had the anchor of her transmitter still fully embedded in the skin. Hardened tissue around one prong had thickened to form a slight lump. A small abrasion (about 2-mm diameter) was present near the distal end of the prong, suggesting that one prong of this anchor was causing irritation. Nevertheless, this bird appeared to be in good condition and exhibited normal nesting behavior.

Transmitter effects.—As it is not possible to measure survival rates for a control group of unmarked birds in the same way as measured for radio-marked birds, it is difficult to assess potential effects of transmitters on survival. Comparisons of survival rates between studies must be viewed cautiously because of differences between studies in trapping and marking procedures, wetland conditions and predator communities. With these caveats in mind, we attempted to assess survival rates of females with anchor transmitters monitored in this study.

Wearing anchor transmitters did not appear to affect survival of female Mallards or Gadwalls. Of 91 radio-marked females, 84 (92%) survived the monitoring period; seven were killed by predators (Table 1). Our April–September (183-d) survival rates (Mallards = 0.770; Gadwalls = 0.835) compare favorably with that estimated by Blohm et al. (1987) from band recoveries for female Mallards in southcentral Canada and northwestern Minnesota (0.603) and with that estimated by Johnson and Sargeant (1977) using a computer simulation model for female Mallards in the prairie pothole region of North Dakota (0.692). Our April–September survival rate is similar to that reported by Cowardin et al. (1985) in central North Dakota for female Mallards wearing harness transmitters (0.806). Although our survival rates look high compared with estimates for non-radioed females in the first two studies cited, these values do not differ statistically. As 95% confidence intervals for our survival rates are wide (Mallards = 0.409–1.0; Gadwalls = 0.583–1.0), we lack the statistical power to detect small differences in survival estimates.

Potential effects of anchor transmitters on female reproductive success were partially evaluated in this study. We could not evaluate effects on nest initiation date or clutch size because females were already incubating eggs when fitted with transmitters. We did, however, evaluate relative success of radio-marked females at the brood stage. Survival rates of the ducklings of females with anchor transmitters did not differ from survival rates of the ducklings of unmarked females in our sample (for 109 ducklings of radio-marked and 117 ducklings of unmarked Mallard females, $P = 0.989$; for 347 ducklings of radio-marked and 327 ducklings of unmarked Gadwall females, $P = 0.952$).

In terms of retention time, bird condition, survival rate and reproductive success, these findings suggest that the anchor transmitter offers a useful alternative to external and internal transmitters currently available for dabbling ducks. With appropriate adaptations (e.g., in size, battery life), the anchor transmitter may be suitable for a wide range of species and research topics. For new applications, however, investigators first should assess potential transmitter effects on the variables being measured for the species under study.

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