

Patagial Transmitters for Large Vultures and Condors

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During a study to develop release techniques for cathartid vultures (Wallace & Temple 1983), 20-gram transmitters were attached to the backs of 15 fledgling Black Vultures *Coragyps atratus* and Turkey Vultures *Cathartes aura*. Seven of these battery- and solar-powered transmitters were attached to scapular feathers by two leather strips glued to their bases. Another transmitter was incorporated into a harness similar to those used on eagles (Kenward 1987).

Large dark scapular feathers covering the solar packages were apparently sufficient to reduce the recharging capacity, causing radios to function intermittently or fail. Also, loss of some transmitters due to pulled feathers and one case of entanglement with the harness in brush encouraged the consideration of alternative methods of attachment.

During the same study, patagial identification tags were being evaluated for use on cathartid vultures (Wallace *et al.* 1980). If a light, aerodynamic radio-transmitter could safely be affixed to the patagium portion of the wing where the identification tags had proved successful, the short contour feathers of the wing might not inhibit solar transmitter function.

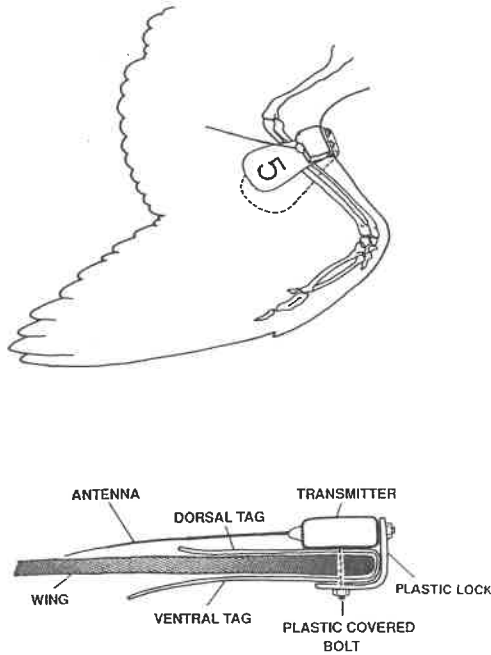
This paper outlines the development of patagial transmitters that are now being attached to Andean Condors *Vultur gryphus* and California Condors *Gymnogyps californianus* released to the wild in repopulation programmes in North and South America (Lieberman *et al.* 1991; Wallace & Toone 1992).

METHODS

On July 15, 1979, four Turkey Vultures were released to the wild, each carrying a radio-transmitter on one wing and a patagial tag on the other. The transmitters were solar-powered and the entire package weighed approximately 20g. Each measured 4.5cm x 2cm x 1.5cm tall, with a light 40cm antenna emerging from the centre of one of the narrow ends. It was mounted on the dorsal side of the wing, on the radial-ulna side of the patagium when the wing is folded. Its centre of gravity was over a plastic attachment rivet (See Fig. 1 for position). Using a similar position and attachment technique as vinyl patagial tags successfully in use, the rivet pierced the patagium 1cm from the leading edge (Wallace *et al.* 1980).

One of the birds was imprinted on humans and tame enough to be easily captured and released several times over a two-month period, allowing close inspection of its transmitter while in flight as well as in the hand. The other three vultures had been raised together and held captive for one year prior to release into a rural area near Madison, Wisconsin. These three wilder birds remained in the release vicinity for several weeks, allowing daily observations of the transmitters through

Figure 1.



binoculars. They were radio-tracked for several months after release as they explored new foraging areas before migrating south (Wallace & Temple 1983).

In the fall of 1979 a modified version of the Turkey Vulture patagial transmitter was attached initially to both wings of six Andean Condors at the Patuxent Wildlife Research Center in Maryland as a pilot study. These transmitters were different from those of the vultures in that they weighed approximately 40g (less than 5% of the condor's body weight). Instead of the plastic rivet of a modified cattle ear-tag, a plastic-covered 3 mm steel bolt was used to attach the transmitter to the wing. The acrylic rectangular block measured 40 x 45 x 13 mm. With manual restraint the incision in the patagium was made using a leather punch of the largest hole size prior to the insertion of the transmitter bolt. These birds were opportunistically observed through several breeding seasons.

In July 1982, 12 dummy transmitters, similar in design to those used in the pilot study, were attached to six more Andean Condors at Patuxent. They were observed for one month prior to their marking, using an ethogram consisting of 63 behaviour patterns. Four transmitters were replaced on the wings of three of the original six pilot study condors as well. The birds were observed immediately after marking in July and again in November. Observations lasted 15 minutes, during which time one of 63 behaviour categories was assigned to the bird every 15 seconds. Each bird was observed during 6 to 8 bouts of observation at various times of the day over a one-week period in June, July and November. Behaviour categories were compared among months and among birds (previously marked *versus* previously unmarked). Types of behaviour observed too infrequently were pooled into a broader category for statistical analysis. An analysis of variance (general linear model, SAS) was used to determine statistical significance ($P < .01$).

We were particularly interested in how working transmitters might function on free-flying condors in the wild. During a study to develop condor reintroduction techniques conducted in northern Peru, South America, between 1980 and 1984, 12 captive-reared Andean Condors were released to the wild, each carrying a patagial transmitter on one wing and a patagial tag on the other (Wallace & Temple 1987). The transmitters were similar in design to those tested at Patuxent but slightly heavier at 60-70g. Using binoculars and telescopes at distances and sometimes from close blinds, these birds were observed on a daily basis for three months and less frequently (weekly or monthly) for two years thereafter. During 21 recaptures their transmitters and wings were closely

inspected. Fifteen of 47 wild condors caught during the same study were similarly fitted. They were observed only from a distance after release. Two of these birds were subsequently killed by goat herders. Their carcasses were recovered in adequate condition for a wing and transmitter assessment. One adult male condor was obtained from the Lima Zoo, tamed and trained to fly loose and return. This bird proved invaluable, since he allowed us close observation while he flew with real and dummy patagial transmitters of different weights. His functional left transmitter was 75g, while the right wing dummy package was 100g.

Between 1982 and 1987 11 California Condors were radio-tagged, using patagial transmitters with frequencies of 410 and 411 Mhz (Meretsky & Snyder 1992). These higher frequencies allowed for a shorter, better-reinforced antenna 20cm long. Where the attachment bolt of previous transmitters required assembly of the bolt through a hole in the transmitter during placement on a wing, the California Condor version had the attachment bolt already soldered to a plate within the acrylic base of the transmitter, making it a more complete unit prior to placement. These transmitters weighed between 60g and 80g.

In order to test the efficacy of releasing California Condors within their former range, 13 Andean Condors were released in southern California between 1988 and 1991, carrying a patagial transmitter and tag combination on each wing (Wallace 1990). A one-piece, coloured vinyl tag, displaying identification numbers on both dorsal and ventral portions of the wing, was incorporated into the transmitter package (Fig. 1). The dorsal tag measured 8cm wide and 13.5cm long from the leading edge of the wing. The ventral tag was slightly larger at 9cm wide and 15cm long. A battery-powered transmitter was placed on the right wing and a solar-powered package on the left as backup. Having one battery unit insured a constant signal through the night, while the solar transmitter theoretically would have longer than the 15-month life expectancy of the battery units.

Weighing between 55 and 65 grams with tags attached, these transmitters were lighter than those previously used. To reduce technical complications of working at the higher frequency of 410 and 411 Mhz, we worked within the 164 Mhz band. The antennae were increased from 20cm to 29cm to maintain transmission efficiency for the new lower frequency and their bases were reinforced with graduating sizes of heat-shrink plastic tubing.

During 1991 a three-month study of transmitter balance conducted at the Los Angeles Zoo, eight dummy patagial transmitters were placed on six Andean Condors. All were housed together in a 30 x 14 x 14 m high pen. The dummy transmitters varied in weight, bolt location, antenna length and flexibility (Table 1). The bolt location was either in the centre of the transmitter, 1.7 cm from the front, or offset toward the back, 2.8 cm from the front. All the fake transmitter antennae were 0.20 cm in diameter except for number 7 (0.16 cm) and number 8 (0.13 cm), which were considerably more flexible. These condors were observed opportunistically throughout each day during the study period to detect malposition of any transmitter, a condition correlated with transmitter loss in the field. All six birds could be seen during each observation sample.

Table 1. Dummy transmitters on Andean Condors at the Los Angeles Zoo.

Unit Number	Weight (gm)	Bird (Wing)	Bolt Position	Antenna Length (cm)	Antenna Diameter (cm)
1	54.5	Y-1 (L)	Centre	Short (21.5)	Stiff (.23)
2	54.8	Y-2 (L)	Centre	Short(21.3)	Stiff (.23)
3	56.0	Y-1 (R)	Offset	Long (29)	Flexible (.23)
4	55.0	R-4 (L)	Offset	Long (29)	Flexible(.23)
5	45.6	R-4 (R)	Centre	Long (29)	Flexible (.23)
6	45.0	R-5 (L)	Centre	Long (29)	Flexible (.23)
7	51.6	R-2 (R)	Centre	Long (29)	Flexible (.16)*
8	51.0	R-5 (R)	Centre	Long (29)	Flexible (.13)*

*Denotes increased flexibility

RESULTS AND DISCUSSION

It became clear during the vulture release experiments in Wisconsin that patagial transmitters were not only feasible, but could also become a viable alternative to other methods of attaching transmitters to large soaring birds. The vultures' reaction to the transmitters, in all four cases, was to treat them in a similar fashion as they did patagial tags (Wallace *et al.* 1980); to be irritated by or merely attentive to the object for the first five to twenty-four hours before appearing to accept it.

The small package adhered well to the wing, with little or no movement on the surface during wing beats, and did not appear to interfere with flight. Attaching the transmitter, however, was cumbersome since it was a two-stage process. The plastic rivet was first pierced through the wing using a tag applicator designed for cattle. Then the transmitter was attached to the top of the plastic tag with pop rivets. Five inspections of the attachment site on the tame, free-flying Turkey Vulture over a three-month period did not reveal any noticeable irritation to the patagium. During the initial two weeks the incision site appeared reddened but soon after the area was smooth, healed and paler in colour, matching the surrounding skin.

Because the project was not designed to track the wilder birds on migration, only relatively short-term data were collected but seemed encouraging, with no loss of transmitters or any obvious negative effects on the birds.

At the Patuxent Wildlife Research Center in Maryland the pilot study on six Andean Condors yielded similar encouraging information. The presence of the transmitters did not appear to inhibit breeding activity or disrupt any other behaviour in general. The intensive study that followed focused more on quantifying individual relations to the transmitters.

On average, during all three observation periods from June through November, the condors could be seen only 17% of the observation time because they were otherwise behind or in their shelter. During the period they could be observed they were inactive (in a fixed *Posture*) an average of 75% of the time. The remaining 25%, during which they were active, could be broken down into components as follows: 14% *Preening*, 5% *Locomotion*, 5% *General Comfort*, 1% *Eating*.

The only observed activity that condors focused directly on the transmitters was *Preening*. *Preening* accounted for 7% of the time the birds were actually seen during the June observations, 10% during July, and 22% in November. Only 7% of the observed preening time was spent on the transmitter, 1% to 2% of the total time observed. Considered as a percentage of time spent preening, the difference becomes more apparent, changing from 1% of the time preening in June to 17% in July when they were marked, and falling to 5% during November.

The data were examined by categorizing the birds into groups, based on whether they had been newly fitted during the June observation period or whether the transmitters were replacements. To adjust for a general increase in overall activity observed from June to November, specific activities were expressed as proportions of the whole or by using a measure of overall activity as a co-variate in the analyses. The birds showed an increase in preening of the transmitters and the surrounding area immediately after these were attached ($P < 0.01$), but this activity returned to the same pre-tagging level within three months ($P < 0.01$). Individual condors varied significantly ($P < 0.01$) in the amount of preening attention given to newly-attached transmitters, which is not surprising given the high variability in their backgrounds and personalities.

Other than an increase in preening activity after attachment, the Andean Condors appeared to tolerate the patagial mounted transmitters well; however, after several years the patagia at attachment sites of three of the transmitters became distorted when the holes in the wing greatly enlarged, with no infection or trauma evident. Similar occurrences encountered in other studies suggest a possible balance problem with those particular packages.

With the release of Andean Condors in Peru, we could test patagial transmitters on flying birds. While most transmitters remained well positioned on the wing of all birds we released, there were two that tended to roll forward when the birds raised their wings, twisting the patagium at the attachment point. By repositioning where the attachment bolt emerged from the acrylic block (accomplished by drilling a new hole in the transmitter) and placing the centre of gravity at the bolt site, movement of the transmitter on the wing was largely eliminated.

Close inspection of the attachment site on the 15 wild condors was limited to two birds that were captured (13 weeks and 17 weeks after release) and two others that were shot (20 weeks and 43

weeks after release). The attachment sites of these birds appeared in good condition, with no sign of irritation to the area.

All 13 Andean Condors released in Peru were each examined carefully during recapture (Table 2) and one of them, the tame bird, was monitored continuously. Except for some initial redness and scabbing noticeable during the first weeks, the incision site normally healed to a smooth-edged 0.5 cm hole in the patagium of normal skin colour. No transmitters were known to fall off or be pulled out of the wing of any of the released wild birds over the two-year period during which they were intensively monitored.

Table 2. Transmitter attachment site inspection on 11 Andean Condors at various times after release (- day indicates inspection prior to release).

Andean Condor	Inspection Date	Days After Release	Weight (lbs)	Condition of Attachment Site
13-Y	22/7/80	-5	23 lbs	Reddened, no scabbing
	30/11/80	126	15 lbs	Normal colour, no scabbing
17-Y	22/7/80	-5	21 lbs	Reddened, scabbing
	23/8/80	27	15 lbs	Normal colour, no scabbing
	04/9/80	39	16.5 lbs	Normal colour, no scabbing
	06/12/80	132	15lbs	Normal colour, no scabbing
11-Y	22/7/80	-5	21.5 lbs	Reddened, no scabbing
	18/4/81	342	22 lbs	Normal colour, no scabbing
	13/8/81	459	22 lbs	Normal colour, no scabbing
16-Y	10/8/80	-6	19 lbs	Reddened, scabbing
	18/4/81	322	18 lbs	Normal colour, no scabbing
	23/3/82	661	23 lbs	Normal colour, no scabbing
15-Y	10/8/80	-6	24 lbs	Reddened, no scabbing
	18/4/81	322	25 lbs	Normal colour, no scabbing
	13/8/81	439	25.5 lbs	Normal colour, no scabbing
14-Y	10/8/80	-6	24.5 lbs	Reddened, no scabbing
	22/4/81	326	25 lbs	Normal colour, no scabbing
	13/8/81	439	28 lbs	Normal colour, no scabbing
21-0	15/1/81	2	23 lbs	Normal colour, no scabbing
	13/8/81	208	23 lbs	Normal colour, no scabbing
22-0	14/1/81	1	23.5 lbs	Normal colour, no scabbing
	14/6/81	150	15 lbs	Normal colour, no scabbing
23-0	28/1/81	-6	23 lbs	Normal colour, no scabbing
	13/8/81	191	23 lbs	Normal colour, no scabbing
	10/12/81	309	15 lbs	Normal color, no scabbing
	31/3/82	420	23 lbs	Normal colour, no scabbing
24-0	28/1/81	-6	24 lbs	Normal colour, no scabbing
	30/8/81	208	bias reading	No colour, no scabbing
25-0	28/1/81	-6	22.5 lbs	Normal colour, no scabbing
	13/8/81	191	22.5 lbs	Normal colour, no scabbing
	10/12/81	309	16.5 lbs	Normal colour, no scabbing
	02/3/82	391	22.5 lbs	Normal colour, no scabbing

Both the 12 zoo-raised released birds and the 15 wild-caught condors became habituated to the patagial transmitters, substantially within 48 hours and almost completely within the week. After the initial pulling at and intense investigation behaviour shown by some individuals to the tags or transmitters, the condors could be seen mandibulating the antenna or tag during preening bouts as if they were their own feathers. Others seemed to ignore the new appendage from the onset. Certain individuals defensively protected their transmitters from other curious condors.

Weights of 70g and 100g were tested on the trained condor (#10-W) to try to determine the consequences of heavier transmitters. After 46 hours of observing the 100g dummy transmitter (an acrylic block 2.5cm x 7cm x 4.5cm) on condor 10-W over a three-week period, we discontinued the test. Although the bird did not appear to have difficulty flying, the block moved considerably on the wing during flapping flight, no doubt stressing and irritating the patagium at the attachment point. The bolt hole in the patagium remained reddened and had increased to 1cm in diameter. The other wing of this bird carried a 70g functional transmitter for over one year without any signs of hole enlargement.

The long and flexible antenna proved to be too weak at the base for even the infrequent flapping of condors. Even after reinforcing the area with extra layers of heat-shrink tubing, virtually all the antennae were broken at the base within 2.5 years of being on the birds, reducing the functional 200 km transmission range to no more than 3km.

Based on these results, transmitters placed on California Condors between 1982 and 1987 had shorter, stiffer antennae. Only one antenna loss was recorded on any of the 11 wild birds that received transmitters and this was one of the first prototypes (D. Clendennen, pers. comm.). There were, however, three cases of transmitter loss off the wings. It was felt at the time that the nut securing the transmitter to the wing had loosened and the package fell off (F. Grantham, pers. comm.). A drop of fast-drying "super glue" was thereafter used to secure the nut on the bolt. Occasionally, however, the adhesion would be lost over time. By using teflon locking "aircraft" nuts this problem has been eliminated.

It was thought that the technical problems causing some unreliability with these transmitters were related to the high frequency band of 411 Mhz and 412 Mhz. By using the lower frequency of 164 Mhz many of the complications could be avoided. The transmitters used during the test releases of Andean Condors in Southern California mountains in 1988 used this lower frequency. The most efficient antenna for 164 Mhz is longer than that used on the California Condors and more flexible. Several months into the project we began to lose transmitters off the wings of some of the birds and eventually six fell off. These losses seemed correlated with transmitters that tended to be unstable on the wing. Examination of such transmitters that had been on wings varying lengths of time indicated that the units were not tearing out of the wing, but that the attachment bolt was slowly migrating toward the wing's leading edge until the transmitter eventually fell out. The patagia of these birds healed remarkably quickly and within a month of an incident it was often difficult to determine by examining the wing that it had occurred. We appeared, again, to be dealing with a balance problem, causing transmitter movement on the wing with the end result of transmitter loss and trauma to the patagium.

To look more closely at transmitter balance, we attached eight dummy transmitters to the wings of four Andean Condors at the Los Angeles zoo (Table 1). Only two of the eight were seen flipped over out of position. Out of 23 observer days, No. 7 malpositioned 8% of the time and No. 8 30% of the observed time. The centre of gravity on these two dummy transmitters was more toward the antennae than the others, except for Nos. 5 and 6. Having smaller gauge cable made the antennae of Nos. 7 and 8 more flexible than any of the others. No. 8 was the most flexible and most often seen out of position. Due to the particular characteristics of condor wing-beat frequency and amplitude, a flexible antenna tends to increase torque to the transmitter attachment site, which would lead to greater irritation of the patagium.

Based on these and other observations, the modifications we included on 12 transmitters placed on six California Condors released on December 1, 1992, appear to have made a positive difference. The antennae were stiffened and shortened to 20cm. This reduced flexibility and maintained the centre of gravity close to the attachment bolt. Including the patagial tag these transmitters weigh between 50g and 55g. By properly balancing the transmitter and slightly increasing the size of the plastic securing piece along the leading edge of the wing (Fig. 1), there appears to be little movement or malpositioning of the transmitter on the wing.

The use of radio telemetry has allowed researchers new and valuable insight into many areas of study of wild vertebrates. In some cases data on behaviour, movements and life span of wild species would be nearly impossible to obtain otherwise. In release programmes, such as with condors, where successful management necessitates knowledge of the daily positions and movements of each bird, it is a critically important tool. There are, however, moral and practical obligations to ensure that there are no adverse effects of transmitters on the animals being studied. Obviously an impaired individual in a release programme may have a reduced chance of survival and could compromise the ultimate goal of reestablishing a population. An overriding consideration throughout the development of this transmitter design has been the safety and wellbeing of the birds.

At this time it appears that there is a viable patagial transmitter for use on large vultures and condors, but no doubt we will continue to make refinements as the need arises.

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