What's Inside Counts: An Exploration of Methods and Limitations with Internal Telemetry in Free-Flighted Macaws

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Abstract

Radio telemetry has been used since the 1960s to study and track wildlife, and the modern use of telemetry equipment as a safety device has become common in falconry and when free-flying a variety of birds for educational and entertainment purposes. While various methods exist for successfully attaching telemetry to many species, Natural Encounters, Inc, ("NEI") began to search for a safe method of using telemetry tracking with free-flying macaws during the development of their "Winged Encounters" experience. The use of telemetry on parrots—particularly on free-flying macaws—is challenging for a number of reasons, not the least of which involves the tenacity of the individual in regard to removing any externally-fixated object. NEI investigated and tested available tail mounts, backpacks, neck mounts, and leg mounts, but all were found to be inadequate to the needs of both animal and trainer. After considering available alternatives, and with a new and far more 'urban' macaw experience in the works, it was decided to research and implement the use of the same sort of internal transmitters that have been safely and successfully used in wildlife research for decades. During this process, the valuable information collected covered the methods developed, potential complications, and overall efficacy of tracking. Using internal telemetry, a number of improvements were made in NEI's existing methodology for tracking and recovering free-flighted birds that have wandered out of sight. Sharing this information may assist others in finding new methods to keep their animals safe and secure in the future.

Introduction and Current Protocol

During large-scale (40+ individual) free-flight macaw training, birds are trained to fly free on a large property in central Florida. The general methodology used has been previously described (Blair et al. 2014), but in brief, birds are trained first individually and then in progressively larger groups, moving through novel areas (indoor flights, net-covered areas) until they demonstrate the necessary skills and confidence to work outdoors. Once outside, birds learn further skills which are difficult to train indoors: navigating wind, flying into and out of trees at various angles and to various trainers, and working with increasing heights, distances, and additional birds. As this training process progresses and becomes more complex, situations intermittently arise wherein one or more novice birds fly higher than desired and/or beyond the usual training area, and visual contact (or "line of sight") with the bird may be lost. For the purposes of this paper, the previously described situation will be referred to as a "fly-off".

When a fly-off occurs in which line of sight with the bird has been lost, NEI protocol involves sending staff to pre-established perimeter locations within and beyond the property line in order to reestablish visual or auditory contact with the bird, while one staff member goes up in a 50ft lift to observe the area at tree-top level. The staff member in the lift is in charge of relaying communications, coordinating locations, and additionally has the best view when the bird is in the air, aided further by the use of binoculars. In most fly-off situations the bird roosts for a period of time, then returns home either on their own, or when prompted by the calls of other macaws or by their trainers. More rarely, a bird is called down to the hand or to a perch, and is secured by a trainer off-site and transported back. This protocol, when quickly enabled and reinforced by knowledge of the area, wind, macaw behavior, and other factors, has proven highly successful in tracking and recovering macaws. However, it is also time intensive. Enacting fly-off protocol results in a reduction of staff time spent on typical duties, including husbandry and daily care of the 400+ animal residents of the Ranch. Employees tend to accrue significant amounts of overtime, and fly-off protocol additionally requires that staff be in position before dawn and/or after dusk to ensure the location of the bird's roosting spot is under good observation. While training 54 macaws over a period of more than 5 months, 12 significant fly-offs occurred. While all birds were recovered, the overall reduction of functionality at the Ranch during these fly-offs, as well as the operational strain on the staff involved, was significant.

There is also notable risk to the animal during a fly-off situation. Predation, vehicle strikes, environmental toxins, and a myriad of other potential dangers—including the possibility that contact may be lost and not re-established due to distance or theft— are ever-present concerns during these times. Although the established protocol has proven effective at recovering lost birds, it does not mitigate or reduce the environmental risks to the animal. Therefore, to increase the safety of novice macaws while also increasing the efficiency of established fly-off protocol, the following goal was set: the ability to track individual macaws via semi-permanent internal radio frequency (RF) telemetry from a minimum distance of one-eighth to one-quarter of a mile. For the sake of practicality, this RF telemetry would additionally need to be technically compatible with receivers and other equipment already used on-property for raptors, corvids, and other species.

Technical Requirements

Internal telemetry was established as a primary goal only after less invasive methods were considered and dismissed—and in some cases, tested and discarded—as unfeasible. These tests were conducted during the original Winged Encounters training, and the methods explored included but were not limited to:

- **Tail-mounted transmitters**
  Units were designed to be as small and light as possible, and the antenna was mounted along the rachis of the deck feather in the hopes of it being as unobtrusive as possible. The birds destroyed the units and in some cases removed the feathers entirely.

- **Backpacks**
  The use of backpacks was discussed, but the potential dangers to birds that live in a flock situation and engage in social allopreening were considered too great, and this method was not attempted.
- **Neck-mounted transmitters**
  When made tough and durable enough to be 'macaw proof', the units were too bulky and cumbersome… and weren't necessarily macaw proof. These units were ordered, but once received and examined in hand, were discarded as unfeasible.

Considering the strength and destructive capability of macaw beaks, the natural tendency of the birds to explore and manipulate novel objects in their environment, and the flock-style management of the individuals in question, internal telemetry was established as the best option for successfully tracking macaws. Additionally, the macaws being trained were required to fly in a highly urbanized area for their final behavior, which included an environment full of new hazards and complications.

Once internal telemetry was settled upon as a leading option, we established a set of criteria required from the technology in order to make use in macaws feasible. This included:

- Size of unit (as small as possible)
- Weight of unit (10g or less in weight)
- Battery life (at least 6 months to 1 year)
- Pulse rate (between 20ppm and 60ppm)
- Usable Range (minimum of one-eighth to one-quarter of a mile)
- Compatibility with current systems (hand-held Marshall receivers)
- Non-overlapping frequencies (40-50 distinct frequencies required)

Multiple companies were researched and contacted, and Advanced Telemetry Systems (ATS) was ultimately chosen as a provider. After consultation and research, the F1100-series body implant was eventually picked as the leading candidate for testing. The unit fit most of our established criteria: it has an internal coil antenna, weighs only 4g, has a battery life of between 189 and 441 days, and measures 14x24x7mm. The expected range was difficult to estimate without field-testing, as the unit was designed for use in fish and had not been tested in birds.

Process

Once we selected the model that best fit the established criteria, three preliminary test units were ordered. The first unit was implanted in a resident, non-working chicken in order to establish proof-of-concept, as we were not certain the range of the coil antenna would be sufficient outside of water. With the bird under general anesthesia, a veterinarian implanted the unit subcutaneously so that it sat low and off-center over the

pectoral muscle. The small incision was closed with surgical glue and the hen was allowed to rest. By the following day, the hen had recovered and was exhibiting normal behavior. She was then carried into a bucket lift by a trainer, which was raised to a full height of 50ft— roughly treetop height—so that the range of the transmitter could be established. The unit performed well, and when the bird was facing the receiver, the signal was detectable at a distance 0.6 miles, which was comfortably above our minimum acceptable range. However, we discovered that the direction the animal was facing significantly impacted the distance at which the signal was detectable, which we confirmed with hand-held telemetry receivers and additionally with an omni-directional antenna mounted to the roof of a vehicle. When the chicken was 'facing' the receiver, the signal was strong. When the chicken was held facing the opposite direction, the receiver had difficulty picking up the frequency and the effective range was reduced to just under 0.25 miles, with the density of the hen's body being a likely culprit.

While the reduction in range was unfortunate, the unexpected ability to discern what direction the animal was facing by interpreting the increase or decrease in the signal's strength was useful. The unit performed to our expectations overall, and the chicken healed well and showed no irritation at the site of implantation. With proof-of-concept achieved, we moved on to the next stage of testing.

Before we committed to the investment and potential risks of implanting internal telemetry in all 54 of the macaws, we had additional considerations that needed to be addressed. While the chicken had healed quickly, we were uncertain as to the recovery time for the macaws, and how significantly the implantation would impact their ongoing training. The location for implantation was also discussed; when compared to the chicken, the macaws have thinner skin, are more active and more muscular, and have a narrower torso. We were also uncertain how the macaws would react to the implant. Would they notice it? Would they attempt to remove it, or would the presence of the implant encourage feather destructive behavior?

In order to gain more information, we chose to further test the concept by selecting two of our stronger flying macaws: a Green-winged Macaw, and a Blue-and-Yellow Macaw. Following the same procedures as with the chicken, the two macaws had units implanted under general anesthesia by a veterinarian. Surgical glue was used to close the small incision, and a single suture was used to provide additional strength with the expectation of increased levels of activity when compared to the chicken. Additionally, the veterinarian was careful to disturb as few feather follicles as possible during the procedure, and only one or two small body feathers were removed in order to minimize the likelihood of the macaws interacting directly with the incision site.

Both macaws recovered from anesthesia without incident, and both were returned to their flocks later the same day. By the next morning, they were demonstrating normal behavior and were participating in weighing sessions along with the rest of the flock. Both birds interacted as expected with trainers, and were navigating their enclosure—including horizontal and vertical flying—with no visible latency or difficulty. As they appeared physically sound, they were given the opportunity to fly with their flocks during training.

Both birds were successful, though somewhat slower than usual, during that inaugural flight. They returned with the flock and showed no signs of discomfort. The next day, and daily thereafter, they flew with their previous strength. Both macaws were monitored carefully throughout the day for multiple days, and throughout that time, neither bird showed any sign of interest in the incision location or had complications that required additional attention. When tested during flights, the new transmitters performed similarly to the original test unit implanted in the chicken, in terms of both range and directional variability.

The testing was successful by our established criteria, and the macaws were performing behavior at the same level they had before they received their internal telemetry. The units functioned as expected and no complications occurred. When ordering further units, we were notified by ATS that they had a supply issue with component parts and were unable to complete the spread of frequencies we'd requested in the period of time required, so we would not be able to get all 54 of the originally desired units. Consequently, less than two weeks later, 41 macaws (in addition to the two who had paved the way) also received internal telemetry.

Telemetry Day

Two veterinarians, multiple veterinary technicians, support staff, and an additional host of NEI managers and trainers were present for 'telemetry day', which was conducted on site in a pre-constructed temporary hospital ward. Each bird was identified visually by trainers and had that identification confirmed by microchip, then was masked down and given a WNV vaccination and a full body examination, before a small incision was made in the skin over the pectoral muscle in an area of apteria so as to disturb as few follicles as possible. The telemetry unit was inserted beneath the skin, above the incision site. As with the first two macaws, the incision was closed with surgical glue and a small number (most commonly 1-2) of sutures, as needed. The opportunity was also taken to trim nails, remove any broken feathers to allow regrowth, remove existing leg bands to avoid future risk of entrapment, and to treat with an insecticidal spray for any topical ectoparasites that the macaws may have acquired. The birds were then passed off to trainers for recovery, where their transmitters were tested and a tuned frequency was recorded. Once the bird was awake and stable, they were returned to individual cages until they were perching and alert before ultimately rejoining the rest of their flock. The entire process functioned like a conveyer belt, with separate staff responsible for different aspects of the operation and one additional staff member taking detailed notes. In this manner, 41 birds were implanted with internal telemetry in less than 4 hours. By the end of the process, thanks to the increased efficiency and efficacy of everyone involved, it took approximately 5 minutes from the moment an individual bird was masked down to the moment when that bird was passed off to a trainer to recover.

All birds had been returned to their flocks by mid-afternoon, and by the end of the day (except for some ruffled feathers) the majority of the macaws appeared behaviorally normal. However, although all birds were alert and responsive, a Blue-throated Macaw

and a Scarlet Macaw seemed more affected than the others and were less active than their individual behavioral norms. During subsequent observation, this lowered activity was unaccompanied by further symptoms. Those birds were identified as potentially 'sore', and were left separated from their flocks overnight to rest, and then were returned the following morning. The next morning most birds came down to weigh as though nothing had happened. A few chose not to participate, which included the birds previously identified as potentially 'sore', and a few parent-raised birds with less working history than the majority of the flock. The birds who seemed less active improved throughout the morning, and the parent-raised birds who seemed reluctant to come down showed signs that they were choosing not to participate due to a lowered trust account rather than because of physical discomfort. Over the next two days, the birds who were reluctant to participate due to trust returned to their usual behavior once a reinforcement strategy was established and enacted.

All birds were given the opportunity to fly the day after surgery. The birds we had identified as 'sore' chose not to leave the flight on the first day, or else left the flight and landed early before returning home without completing their behavior. Additionally, 2-3 birds in each flock seemed reluctant to fly or performed at less than their usual capacity. The considerable majority of macaws were successful in performing their full behavior. By four days post-implantation, all birds had returned to their pre-surgery behavior, and continued to progress in their training. Additionally, the transmitters were tested when the birds were flying, and all were found to be functioning as expected.

Challenges

The initial testing and subsequent implantation of internal telemetry units in the majority of our working macaws went very well overall, and exceeded most of our expectations. The initial concerns regarding self-removal of the unit, self-mutilation, or the prompting of feather-destructive behavior proved unfounded, as none of the 43 macaws who received the units engaged in those behaviors. That said, some concerns did arise.

The withdrawal of trust caused by getting the birds in the hand was easily overcome in all but the parent-raised birds who had a shorter working history with trainers. In these birds, additional work was required to recover behavioral fluency. This was compounded three weeks later when the birds were caught up a second time to deliver the WNV booster and manually check the implantation sites. All of the parent-raised birds ended up being successful, but the damage to the relationship set their training behind birds with a stronger working history by approximately one week, which was a significant amount of time in the overall schedule of the project. Additionally, birds were—as noted above—observed to demonstrate behavior that indicated some level of physical discomfort. This resolved without treatment within 24 hours, and was primarily observed in the smaller macaws. While not unexpected, it was monitored closely and could potentially have impacted behavior to a greater degree than it did had it continued or required medical intervention.

The biggest concern came during the WNV booster delivery, when birds who had received telemetry had their incision sites physically checked by a veterinarian. We discovered that not all of the incision sites had fully healed. In some cases, birds still had significant scabs present. In other cases, the telemetry unit was partially visible or in the process of being rejected by the body. In 6 of the 43 birds, these units either fell out during examination or were manually removed, and—except in the case of two individuals—were not re-implanted. One bird had the transmitter repositioned away from the healing incision, and one bird who had partially rejected the transmitter was masked down later that day, had the transmitter repositioned, and was re-sutured. It was during this examination that it was also discovered that the Blue and Yellow Macaw who had originally received one of the test units was no longer producing a detectable RF signal. On examination, no transmitter was found in the bird, and no scab or wound was found either. This suggests that she had rejected the transmitter early after implantation and had fully healed by the time of the physical examination.

Rejections continued over the next few months at a lower rate, and during that time only two birds had telemetry surgically reinserted. In these birds, some changes were made to increase the likelihood of the implantation site healing fully. These changes included making the incision above the unit rather than below it in order to remove pressure placed on the healing incision site, increasing the thickness and number of sutures used and reducing the size of the incision to the absolute bare minimum required, resting the bird and restricting exercise for a longer period after implantation, and placing the transmitter further from the bird's midline so that movement of the pectoral muscles would be less likely to cause migration of the transmitter over time. Birds implanted using the new methodology successfully retained their transmitters, but since these changes only applied to two individuals, there is not yet enough evidence to definitively state that using these new methods would significantly reduce the issue of transmitter rejection.

A small percentage of the birds had their transmitters migrate from the initial implantation area—dorsal on the pectoral muscle—to very near the keel. In smaller birds (primarily in Blue-throated Macaws) the result was a visible lump under the feathers. While this issue was strictly cosmetic, it was not at all desirable, and is another reason we are working with our veterinarian to reduce the frequency and intensity of transmitter migration in the future.

Use of Transmitters in The Field

Four days after the transmitters were implanted, we had our first significant fly-off wherein the bird was found and monitored using telemetry rather than more traditional methods. The telemetry worked as expected, and we were able to track the Hyacinth Macaw through dense swamp and identify his roost location using two primary trainers, without significantly affecting the daily routine of the Ranch. Though he remained outside overnight, he was found immediately with telemetry before dawn the next morning, and was thereafter tracked consistently until he returned to property and came down to a trainer. Two days later, a nearly identical fly-off occurred with that

individual's sibling. Again, only two staff members were required to reliably track the bird, and when the bird was inactive only one was required, with the second trainer attending to nearby tasks while on standby. As before, the day-to-day functionality of the Ranch was largely unaffected.

Three days after the second telemetry-based fly-off was resolved, the biggest test of the new system occurred when two of the higher performing Scarlet Macaws left property and quickly moved out of line of site. The fly-off log reads as follows:

> ***Shepherd/Tam*** *- Flew big during flock flight on first day, gained huge amount of altitude, lost LOS in the clouds flying north from Carlton Arms. Got faint signal on both from lift and then confirmed with receiver on the ground at State Farm. Found them at back of retaining pond with telemetry. Called intermittently until dark, but no interest. Found them on foot with telemetry and got LOS in AM. Before we could call them down to 126, both birds got up and flew back into swamp. Tracked them around swamp all day, at one point both birds returned to property and did a fly-by of Northern and the lift before going back into the swamp. By 4:30pm, both ended up in cul-de-sac at Carlton Arms, then got bumped by a vulture and moved close enough to Ranch to have partial LOS of lift. Got all the birds in Northern excited, Shepherd and Tam responded to flock calls, flew home, landed in James' tree, went to top of Northern, came down to back perch, and were secured just before 5pm.*

This situation is particularly significant; it was the first time we tracked two birds simultaneously on two different frequencies, and the faint signal, which was identified by the trainer on the lift, was picked up when the birds were 1.5 miles away—considerably above the maximum expected range of the units. While the signal was very faint, it was enough to get the second trainer on the right track and triangulate from the ground. The individual macaws had moved so far away so quickly from the area in which we would normally establish a perimeter that, had we needed to rely only on our traditional methods of tracking, there's a real possibility we would not have located them at all. Also of note, this situation was the first significant fly-off during which we were able to continue training the rest of the birds, as we had the staff available to do so safely while also tracking the off-property birds. Later in the season, this evolved and became a preferred and efficient method of encouraging fly-off birds to return to the property; the sound of 18 other macaws vocalizing in flight is a far more efficient recall than any human voice.

The rest of the season's fly-offs progressed in much the same way. The telemetry functioned reliably and resulted in a significant reduction in hours of staff time spent seeking and monitoring macaws, as well as a reduction in the overall number of staff necessary to track those birds. The required compliment of trainers dropped from between nine and twelve full-time staff to a maximum of two or three. Additionally, we saw a significant reduction in the length of time spent locating macaws after losing line of sight: from hours down to minutes. There was no observed reduction in the overall length of the fly-offs or in the time it took to recover birds. This was not particularly

surprising because at the stage of training when the macaws are confident and skillful enough to explore outside, they are almost always also confident and skillful enough to make it home on their own when they choose to do so. Finally, it should be noted that the presence of the telemetry provided additional comfort and peace of mind to the trainers, especially once the macaws were moved to an urban environment filled with new and sometimes unexpected hazards.

Conclusion

The ability to safely track free-flighted macaws with RF telemetry was a serious goal, set for the purpose of protecting the animals in our care at the highest level possible while simultaneously ensuring a high level of operational efficiency on every level. To this end, using internal telemetry in the manner described within this paper was successful, and we were able to meet the stated goal. However, along with the possibility of transmitter rejection and the other potential complications discussed earlier, there are additional considerations that should be taken into account before internal telemetry is used. These considerations include the availability of less invasive methods of tracking the animal in question, and whether a veterinarian with experience in implanting transmitters in wildlife is available to do the procedure. While the cost per unit is not dissimilar to traditional commercially available RF units (each unit was purchased for approximately 250.00 USD), their use still requires a surgical procedure, and consequently all of the risks associated with that surgery—as well as those involving avians undergoing general anesthetic—still apply. The battery life of the transmitters we selected is approximately 1 year. For our birds, this covers the most crucial learning period and the time during which the birds are most likely to experience a serious fly-off. Once the battery fails, the unit must be removed and replaced with another transmitter to continue use, which requires a further procedure. In our flocks, we have chosen not to replace transmitters in birds who have completed a full season of training. These birds demonstrate a high level of competency, reduced length and frequency of fly-offs, and show a reliable ability to navigate back to their home location even when they've moved beyond their usual training area. Due to these factors, the experienced macaws have their transmitters removed once the battery fails, and we have chosen to reserve the use of new internal telemetry for novice macaws during their first season of training. To have ongoing coverage, a yearly procedure to remove the old unit and replace it would theoretically be possible, but has not proven necessary in this particular training scenario. Before deciding on the use of internal telemetry, all of the above possibilities must be considered and a commitment must be made to manage the consequences of the choices made.

The use of internal telemetry also does not, in any way, lessen the need for our trainers to have a deep understanding of macaw behavior. Furthermore, it does not remove the inherent risk to the animal during a fly-off situation or supersede the absolute requirement of expert training at all times. The most effective protection for free-flying birds has not changed: it is comprised of knowledge of the animal as an individual, a high level of skill possessed by the trainer, and an animal with a strong reinforcement history who has demonstrated behavioral fluency with a myriad of required behaviors before being exposed to the hazards of outdoor flight. Internal telemetry is simply another tool

in the trainer's toolbox to assist in tracking and recovery, and it provides another safety option for species of birds that were not previously viable candidates for externally mounted RF telemetry. In partnership with our veterinarian, we will continue to improve and modify the procedure involved in implanting telemetry units in the next flock being trained, and we will share this information as it becomes available.

The journey to meet our goal was challenging. It required a significant monetary investment, the availability and expertise of our veterinary partners, and ongoing support from NEI staff and trainers on all levels. Beyond that, it would not have been possible without the absolute dedication and commitment of Steve Martin and the management team at Natural Encounters, Inc. While the results were not perfect, they were extremely promising overall, and the additional safety provided by the presence of internal telemetry has encouraged us to explore and improve on the methodology with our next flock of young macaws. These birds will be the second generation of free-flying NEI macaws to 'gain their wings' with an additional piece of technology on board, which will help to ensure their ongoing safety while they engage thousands of zoo guests and inspire caring and conservation action in every life they touch. For the staff of NEI, that fact alone makes the entire project a worthwhile—and deeply rewarding—endeavor.

Citations

Blair, D., Bailey, A., Jenkins, C., 2014. Winged Encounters: A Kingdom Takes Flight – A Macaw Story, IAATE Annual Conference Proceedings.

Telemetry Provider: Advanced Telemetry Systems – https://www.atstrack.com/index.html