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THE IMPACT OF MARKING ON CRANES: AN ISSUE PAPER

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Abstract: As crane researchers and conservationists, our overarching objective is to learn and gather information about our study subjects while doing as little harm as possible. New technologies may be emerging too rapidly for researchers to assess the effectiveness or potential adverse effects of the devices, despite the ease and increasing accuracy of the information they provide. Researchers need to be able to gather information to answer various questions in a way that balances ethics and expense. With marking of cranes as a focal point, we discuss issues surrounding crane research based on various techniques, some health issues that are a direct result of marking cranes, and consultation with telemetry companies to improve design of devices to be deployed on cranes. We submit a Call to Action: create a global crane research working group under the oversight of the International Union for Conservation of Nature (IUCN) Crane Specialist Group (CSG), a group dedicated to promoting the study and conservation of the world's 15 crane species.

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Cranes are large-bodied, long-lived wading birds, and there are many potential techniques available to mark these birds (e.g., Boise 1979, Drewien and Bizeau 1981, Ellis et al. 1992, Nowald 2010, Veltheim et al. 2015, Pearse et al. 2018). We use the term "marking" to mean any identifier that researchers place on cranes for identification or research purposes, including national or custom alphanumeric ring or band, colored bands, VHF radio, or satellite based (Platform Transmitting Terminal [PTT] or Global System for Mobile communications [GSM]) devices. There is currently a lack of published or shared information regarding the possible direct harm or bias in data gathered specifically from marked cranes, and we believe it is increasingly important to share learned experiences and best practices with researchers worldwide to minimize negative effects of marking on the health and behavior of cranes.

The rapid pace of microelectronics technology and marketing for animal telemetry devices may exceed the ability of field researchers to assess their welfare impacts on study subjects and potential for information bias due to uncertainties with long-term effects from new attachment methods, geometries, weight distribution, and aerodynamics. Decades of research on birds have led to several meta-studies that evaluated the long-term effects of marking with various devices on morbidity and mortality, productivity, parental care, and behavior across the annual cycle, including migration (Barron et al. 2010, Bodey et al. 2018, Geen et al. 2019). Often, researchers will never actually observe the bird after marking, thus never discovering any potential impact of attached transmitters. Visual observations through time are 1 avenue to assess impacts of transmitter on behavior and well-being. Movements of long-distance migrators after marking make observation and discovery of any potential impact of attached transmitters especially difficult. Though the number of studies using various technology increased at a rate of 4.4% per year since 1962, up to 55% of those published studies involving marked birds contain no information on effects of those markers (Geen et al. 2019). Failure to adopt more proactive thinking about the unintended consequences of markers and electronic tagging could lead to exploitation and disturbance of the very organisms that researchers hope to understand and conserve (Cooke et al. 2017).

In addition to aerodynamics and physical effects, additional considerations are placement and attachment method of the markers (e.g., leg band vs. back-pack harness attachment), and the reliability of the device (e.g., does it work, receive/transmit quality data, longevity). The necessary considerations of attachment method and position suggest that efforts to alleviate negative effects of marking may not be solved by simply fitting smaller, lighter markers. Auxiliary marking authorization in North America is set by the Bird Banding Lab of the U.S. Geological Survey, which states that "All bands, auxiliary markers and attachment materials should not

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exceed 2% body weight for leg attachments and should not exceed 3% body weight for all other attachment types" (U.S. Geological Survey Bird Banding Lab 2021). However, it has been shown that not only has the invention of smaller devices now made it possible to study smaller and smaller animals, but this body weight ratio is often exceeded (Portugal and White 2018). Although very useful as a benchmark, transmitter-to-body weight ratio is largely considered an arbitrary target with obscure origins, and the consensus is that more than just body mass should be taken into consideration when determining the type and placement of markers (E. Paul, Ornithological Council, personal communication; Casper 2009, Barron et al. 2010). There are other issues to consider that may serve to exacerbate the potential physical harm to a bird. When researchers mark a bird, it is often for life; markers rarely detach of their own accord, and if effort is made to capture a bird again, it is typically for replacement of the marker. Though the effects of any individual marker may be small, multiple markers may have a cumulative effect and be difficult to detect. In the case of geolocators, a miniature device typically placed on smaller birds, it has been shown that survival decreased the longer a bird carried the device in comparison to birds that either did not receive a geolocator or had it removed, suggesting that potential effects of even 1 small device are cumulative over time (Pakanen et al. 2020). Markers of minimal mass can still have deleterious effects if they are of a poorly designed shape or attached in inappropriate locations (Brlik et al. 2020, Cleasby 2021). A better approach is to consider design, placement, and mass as a combined effect.

Certainly, the morphology and life history of cranes plays a role in their possibly being more tolerant of various marking techniques long term, though it is incumbent on crane researchers to document what any effects may be. As recommended by Bodey et al. (2018), all studies involving markers should, at a minimum, provide clear information on 6 measures to increase this knowledge: review of the species being studied, number of devices deployed and individuals tagged (including failed devices and non-returning individuals), mean study subject mass, attachment method, mass of markers deployed, and longevity of marker deployment (particularly if different than the length required to address the specific questions analyzed).

While some crane studies were involved in the meta-analyses described above, none have looked in depth at this family of birds. The North American Crane Working Group is in a position to add to this body of knowledge because of members' work with captive cranes and numerous research projects that monitor marked birds over many years. For example, research by coauthor Hartup and colleagues from the USGS National Wildlife Health Center and University of Wisconsin-Madison documented visible and microscopic skin lesions in 20 deceased reintroduced whooping cranes (*Grus americana*) marked with leg band-attached VHF, PTT, or GSM tags (Hartup et al. 2022). The lesions were not deemed to be associated with cause of death or loss of tarsal joint range of motion, but localized bacterial infection was a notable risk identified in the pathology reports. In addition, some of the lesions developed within weeks of application in hatch-year cranes. By comparison, Urbanek (2018) examined more than 122 live cranes captured for band and transmitter replacement from the same population during 2001-2017. With a few exceptions, apparent physical impacts to integument were limited to calluses and thickened areas of skin on which the transmitter bands rested with no significant effects on long-term health or behavior of these cranes (R. Urbanek, personal communication). We recognize the potential bias inherent in using recovered carcasses (dead birds may have overrepresented numbers of tarsal lesions) versus comparisons from live birds, but since many cranes in this population also have never been recovered, a true measure of the prevalence and significance of lesions cannot be known. Nonetheless, skin lesions were described in a number of cranes and were striking to the veterinary staff and biologists working on this project. We interpret these findings as evidence that a subtle, but concerning, problem existed, and that it was difficult to detect without very specific inspection protocols.

As crane conservationists, we can use our knowledge and experience to collectively decrease negative impacts but maximize information return. As the references to the various techniques available to mark cranes (above) illustrate, crane researchers have often taken advantage of newer technologies but also adapted them to best serve the crane and the question to be answered. The extensive experience of many crane researchers around the world, placing markers of varying types on numerous cranes, has all increased the depth and breadth of our knowledge base of cranes; however, it has also exposed potential problems. External antennas have collected ice in wet and freezing conditions, causing behavioral issues, and are known to break prematurely,

thereby ending data acquisition. Most GSM transmitters on the market today utilize an internal patch rather than an external whip style antenna, potentially mitigating this drawback. Anecdotal evidence, observations, and limited recaptures, however, have shown that GSM units fused to leg-bands and mounted above the hock can cause skin lesions both above and below the hock, and–worst-case scenario–life-threatening injury to the leg. Experimenting with design, collaboration between manufacturers and researchers, and testing on captive birds, yielded a completely new design which distributed the electronics on 3 sides of a solid leg-band thereby reducing the dimensional bulk of the package and repositioning it away from the tibio-tarsus by several centimeters, substantially reducing the potential for any contact with the lower leg. Tests on captive cranes produced satisfactory results and field deployments of new designs indicated issues identified in earlier designs likely were eliminated. Working with manufacturers of these new technologies to develop suitable designs is critical for successful implementation of new or existing studies. A working knowledge of the rapid changes in both technology and design allows researchers to be involved in product development for deployment in the field on wild birds. We encourage working with our colleagues at captive centers to assist in this process. Though tests on captive birds have significant limitations–no long migratory flights for example–the ability to observe the fit and long-term wear of new designs on captive cranes cannot be overstated.

One method of deployment of transmitters in different crane populations is via backpack attachment technique. This method requires both the experience and correct materials to attain the proper fit–one that is not too tight or too loose, especially on a migratory crane–to ensure that injury does not occur. Use of backpack attachment for transmitters is not common in North American cranes. Teflon ribbon was used to attach VHF transmitters to juvenile sandhill cranes in a study by Hayes (2015). All marked cranes that lived past first southward migration (n = 24 of 26 total from this study) were observed after marking for an average of 7.7 years (International Crane Foundation, unpublished data). In contrast, a number of juvenile Eurasian cranes (*Grus grus*) were fitted with backpack transmitters and released as part of the reintroduction of this species into Great Britain. These birds had transmitters attached via elastic bands that stretched significantly and led to entanglement issues; this put the birds at increased risk of injury and 1 assumed mortality and will not be used in future research (D. Bridge, Royal Society for the Protection of Birds, personal communication). Similarly, 121 individuals of the endangered subspecies of Mississippi sandhill crane (*G. canadensis pulla*) raised in captivity were released wearing backpacks over the course of 7 years; 7 of those individuals had known deleterious effects attributed to the back-pack harness, including mortality (S. Hereford, Mississippi Sandhill Crane National Wildlife Refuge, personal communication). As a result of little direct information on backpack effects, experience and communication with other researchers who are experienced in this technique are encouraged before using this particular method.

In December 2018, an information gathering session was held at the Ninth European Crane Conference in Arjuzanx, France; the issue at hand was the physical harm that can result from the marking of cranes. The ethics of crane marking was passionately discussed. One perspective held that the value of the information obtained from marking cranes far outweighed the few cranes that were injured or died as a result. Another perspective held that the death of even 1 crane due to device attachment was unacceptable. A common sentiment was a caution about becoming too paralyzed by these issues to ask questions that are critical for conservation action. This discussion was continued as a symposium at the Fifteenth North American Crane Workshop in January 2020. This symposium began to explore in more detail the effects of telemetry and marking of cranes for research and monitoring, and how we can better design devices to lessen potential physical impacts and energetic effects.

The intended outcome from these meetings and future information sharing will be a system that crane researchers can use to critically evaluate telemetry/marking devices, based on analysis of various risks to cranes. This in turn will feed information to a Crane Research Working Group within the International Union for Conservation of Nature (IUCN) Crane Specialist Group (CSG) to develop a dynamic method to document and describe questions, methods, and expected outcomes from various methods of marking cranes for research worldwide. To facilitate this process, some questions researchers must ask themselves include (but are certainly not limited to):

- What are our sensitivities when asking questions critical to crane conservation, especially with a

rare species, given any harm they may sustain in answering them?
- We need to ensure valid data are collected to make good decisions, but can we identify bias from markers and potential morbidity/mortality on migratory species?
- What is an acceptable limit of loss or alteration of behavior or data, or loss of birds?
- How do researchers share important information regarding marking device effects with each other?

In light of these important questions that researchers should consider, we submit a *Call to Action:* we propose a system where there is a shared responsibility regarding outcomes from research on cranes. This is a call to improve documentation and reporting to the crane community of the best practices, foibles, and consequences of our research. It is the responsibility of *all* stakeholders–manufacturers, funders, researchers, and animal-care committees–to take responsibility to improve our methodology and to seek alternatives or mitigate for injuries and challenges.

Action 1: Create a network among captive centers to test all types of markers on captive cranes for improved understanding of the real challenges so that mitigation measures can be taken either at fitting or in the design.

Action 2: Standardize measurement of impacts from the marking of cranes. This can be done in 2 ways: by documenting measurable physical impacts to cranes directly (Table 1) and by implementing robust statistical analyses to assess marker effects on behavior, reproduction, survival, and body condition (Cleasby et al. 2021). Data from marked cranes from across the world would build a broad base for further understanding various deleterious effects and monitoring of issues as they occur.

Action 3: Work with manufacturers of bands and telemetry devices to continually assess and modify the design and size of bands, trackers, and attachment methods as new information becomes available.

Action 4: Develop a shared platform to explore issues resulting from marking cranes more thoroughly and from this, to work together to improve marking practices across the globe via the IUCN CSG to find solutions and to improve practices.

Action 5: Explore the ethics of fitting cranes with markers with experts in the ethics field.

We encourage the membership of the North American Crane Working Group to be an active participant in the IUCN CSG and the recently established Research Working Group. This is part of global effort to formulate best practices for the study of cranes, as has been done with vultures (https://www.iucnvsg.org/). This would be a voluntary practice, and these documents could be stored and available to researchers on the internet by using the IUCN CSG web portal. The database would establish a central, accessible location to gather data from crane researchers, a space to share information regarding questions, methods of data collection, and any issues of which others should be aware. Our research must be based on an ethical standard, and we need to make sure that the questions we ask when designing a study using marked birds are clearly defined and relevant. We need a standard of acknowledgment that we share information and learn from each other to improve practices and the devices we use on cranes to minimize further injuries and mortalities.

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Table 1. Recommended scoring system for evaluation of recaptured or recovered cranes with leg-mounted transmitters.

Device effect	Description	Score
None	No lesion discernable, normal appearing skin and leg contour	0
Mild	<1 cm diameter abnormal skin/discoloration, no open wound or scab	1
Moderate	1-2 cm diameter lesion, thick scab or open wound present	2
Severe	>2 cm diameter lesion, thick scab or open wound present	3

topic. We thank the editors and 2 reviewers for helpful comments and suggestions on the manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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