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Troubling issues at the frontier of animal tracking for conservation and management

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Developments in electronic tagging and tracking, including biotelemetry and biologging, have provided unprecedented insight into the ecology of wild animals (Cooke et al. 2004) and revealed hidden movement patterns, habitat associations, animal–environment interactions, and mortality rates for even the most cryptic of species (Hussey et al. 2015; Kays et al. 2015). Natural history, ecology (including movement ecology), conservation, and resource management have all benefitted from the application of this technology. Yet, as use of electronic tagging in research and public awareness of this technology has increased, a number of troubling and unanticipated issues have emerged. We submit that these issues need to be addressed proactively by the diverse range of people involved in animal-tracking studies—manufacturers, funders, researchers, and animal-care committees. Ignoring these issues may have serious negative consequences for individual animals, animal populations, conservation, and the future use, regulation, and public perception of electronic tracking. We recount examples of such issues in freshwater, marine, and terrestrial realms. We did not consider issues related to the effects of capturing and fitting animals with tracking devices; these are discussed at length elsewhere (e.g., Wilson & McMahon 2006; Cooke et al. 2013).

Animal tracking can reveal animal locations (sometimes in nearly real-time), and these data can help people locate, disturb, capture, harm, or kill tagged animals. In Minnesota (U.S.A.), some anglers petitioned for access to movement data derived from electronic tagging of northern pike (*Esox lucius*) to aid in fish capture (Grover 2001). The petitioners argued that the data should be publicly available because it was publicly funded, even though the study goal was not to improve recreational catch rates. Although their attempts failed, the case highlights perceptions among some stakeholders regarding their right to data. Similarly, tracking data were misused in a shark-culling program in western Australia (Meeuwig et al. 2015). Researchers tagged imperiled white sharks to study their spatial ecology and inform conservation planning. The tagged sharks were also used as warning systems at beaches. The agency that granted the research permits had access to the tagging data as part of the permitting requirements. However, these data were then used to locate and kill tagged animals to allegedly reduce human–wildlife conflict (Meeuwig et al. 2015). Similar scenarios may occur in other areas where human–wildlife conflict is related to livelihoods (e.g., predator attacks on livestock). In an era where open and transparent data are trending (Roche et al. 2015) and often a requisite of funding agencies, it is important for researchers and funding bodies to accept and acknowledge responsibility for the consequences of public access to electronic-tagging data.

Also troubling is that members of the public have acquired tracking equipment for nonresearch purposes, such as photography or wildlife viewing. The frequent exposure of animals to people can habituate them to human interaction, which at minimum alters the animal's natural behavior, thus negatively influencing research findings. Such interactions also contribute

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to human–wildlife conflict and the potential euthanasia of an animal. After photographers used telemetry to track animals tagged by researchers and managers, Parks Canada implemented a public ban on VHF radio receivers in Banff National Park, Alberta (http://www.pc.gc.ca/apps/scond/Cond_E.asp?oID=24602&oPark=100092). Given that many researchers use social media and other forms of outreach to share information with the public and that research results are often freely available online, it is necessary to increase the curation, stewardship, and security of electronic-tagging information, including tag codes, coding schemes, and receiver–station locations and share data in forms that do not facilitate abuse. In India, attempts were made to hack GPS collar information from endangered Bengal tigers in a case of "cyber poaching" (http://www.computerworld.com/article/2475200/cybercrime-hacking/cyber-poaching-hacking-gps-collar-data-to-track-and-kill-endangered-tigers.html). The attempts were unsuccessful but revealed an unanticipated potential negative outcome of a conservation tracking program.

Nonresearchers could also purchase and deploy their own tags. Such actions are not well regulated, and most management agencies are ill-prepared to respond (Pope 2001). In some jurisdictions, scientific-collection permits and animal-care protocols may be needed (especially in developed countries), so this activity could be regulated. Many researchers may consider the costs of capturing and fitting electronic tagging equipment to animals as so prohibitive that the public could be dissuaded from exploiting the technology. However, researchers strive for statistically valid sample sizes (dozens or hundreds of tags). For the public, a single tagged animal (e.g., consider the Judas goat used for predator control [e.g., Lennox et al. 2016]) could be used to track and harm untagged animals.

We anticipate malicious attempts to derail telemetry studies or distort study findings. For example, intentional deployment of duplicate tag codes could preclude the ability of researchers to discern real detections or know what they are tracking. For some technologies (e.g., r-code acoustic telemetry), it is possible to deploy so many tags such that the receiving systems cannot decode tags, rendering a receiver disfunctional. Although telemetry terrorism may seem far-fetched, some fringe groups and industry players may have incentives for doing so. Such interference may affect data quality and put animals in jeopardy. Dynamic marine-protected areas (DMPAs) are used to protect vulnerable marine biodiversity and require diligent tracking for their implementation (Game et al. 2009). If tracking data used to outline the spatial and temporal boundaries of a DMPA are corrupted, animals could be exposed to harm (e.g., ship strikes) or exploitation at a critical period in their life history. Speculation in the media suggests that hunters may target tagged wolves from Yellowstone National Park to interfere with research (https://www.outsideonline.com/1913831/out-bounds-death-832f-yellowstones-most-famous-wolf). Moreover, although tag codes are classified, websites operated by some wolf-persecution groups provide strategies for figuring out tag codes.

A negative public perception of tagging and tracking could result in protest or cessation of research. For example, a minority of aboriginal fishers in the Fraser River watershed (Canada) regard the tagging of wild Pacific salmon (Nguyen et al. 2015) as "playing with food," which is offensive to their culture. In general, however, there is a surprisingly high level of support (or indifference to) for telemetry among these aboriginal fishers (Nguyen et al. 2012). In Pangnirtung (Canada), members of an Inuit community were sufficiently concerned that telemetry tags and receivers would scare away culturally important wildlife that research was temporarily suspended. Although the study was resumed with a positive impact for the management of the community fishery (Hussey et al. 2017), community concerns over telemetry tracking of animals are still prevalent across the Arctic and in many other indigenous communities. Some members of the community believe that acoustic transmitters would allow marine mammals to find and consume tagged animals (Cunningham et al. 2014) or contribute to noise pollution and disrupt natural behavior of marine wildlife (Erbe et al. 2016). In Australia wildlife managers have speculated that acoustic tags on sharks could provide an early warning of predation risk to marine mammals. Sharks might then feed on alternative prey, including people (http://www.perthnow.com.au/news/western-australia/wa-shark-study-questions-affect-of-tagging-on-animals-feeding-ability/news-story/535c6d51fa06b293d0addb17cd7d9c27). In the Bahamas, divers are attempting to remove satellite tags from sharks, especially when biofouling organisms are attached (Hammerschlag et al. 2014). In the United States, visitors to national parks have raised concerns about tagged wildlife detracting from the "wilderness" experience (Mech & Barber 2002). Wildlife photographers often object to any form of external tagging (Hammerschlag et al. 2014). It is possible, however, as publics become more accustomed to tagging studies and their value that norms and thus acceptance of tagging may change.

At present, researchers have little guidance about how to evaluate and respond to these perceptions and criticisms from stakeholders. In the worst-case scenario, fear of criticism means important science remains undone or proceeds with less-than-ideal tools or research design (Frickel et al. 2010). To counter these issues, we argue that greater research on the human dimensions of animal tracking is needed, including research on public perceptions and attitudes toward research needs, animal welfare, and data stewardship. A social science approach could be used to identify areas of accommodation and

compromise among researchers and interested parties (Hess 2015). Given the regional, ecological, and cultural variability across research settings, case studies with qualitative methods (e.g., interviews, participant observation) are essential for uncovering and addressing multiple stakeholder perspectives and concerns.

We identified issues that must be considered if animal-tracking science is to continue to contribute meaningfully to animal conservation and management (Cooke 2008) and devised suggestions that may help facilitate this: cocreation of the research agenda to obtain partner buy-in; include stakeholders in the research (e.g., animal capture, tagging, and tracking); share information on the technology through workshops; provide project updates to partners and stakeholders via avenues that reach different segments of the population; create a data-sharing policy that clearly articulates who has access to what type of data and how it can be used; ensure data are secure; encourage the telemetry industry to help prevent instances of sabotage or exploitation; encourage regulators to develop clear and enforceable policies and regulations that limit the ability of the public to use telemetry tools for activities that are inconsistent with the mission of management agencies; listen to and consider stakeholder concerns; create opportunities for stakeholders (e.g., telemetry industry, regulators, and researchers) to come together to discuss issues of mutual concern; encourage telemetry practitioners to work closely with human dimensions researchers to identify stakeholder concerns and barriers to use or application of telemetry; and learn from and share successes and mistakes.

Failure to adopt more proactive thinking about the unintended consequences of electronic tagging could lead to malicious exploitation and disturbance of the very organisms researchers hope to understand and conserve. We suggest that electronic tracking manufacturers, researchers, managers, and stakeholders have joint discussions about their responsibilities so that use of tagging equipment and data is consistent with the foundations of animal conservation and management. The onus is on researchers to take a leadership role in this effort to illuminate the tenebrous frontier of animal tracking and to engage with other partners in a proactive manner.

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