Conservation Biology

Essay

Effect of Monitoring Technique on Quality of Conservation Science

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Abstract: *Monitoring free-ranging animals in their natural habitat is a keystone of ecosystem conservation and increasingly important in the context of current rates of loss of biological diversity. Data collected from individuals of endangered species inform conservation policies. Conservation professionals assume that these data are reliable—that the animals from whom data are collected are representative of the species in their physiology, ecology, and behavior and of the populations from which they are drawn. In the last few decades, there has been an enthusiastic adoption of invasive techniques for gathering ecological and conservation data. Although these can provide impressive quantities of data, and apparent insights into animal ranges and distributions, there is increasing evidence that these techniques can result in animal welfare problems, through the wide-ranging physiological effects of acute and chronic stress and through direct or indirect injuries or compromised movement. Much less commonly, however, do conservation scientists consider the issue of how these effects may alter the behavior of individuals to the extent that the data they collect could be unreliable. The emerging literature on the immediate and longer-term effects of capture and handling indicate it can no longer be assumed that a wild animal's survival of the process implies the safety of the procedure, that the procedure is ethical, or the scientific validity of the resulting data. I argue that conservation professionals should routinely assess study populations for negative effects of their monitoring techniques and adopt noninvasive approaches for best outcomes not only for the animals, but also for conservation science.*

Keywords: animal welfare, cost-effective monitoring, ethics and science, ethics in monitoring, invalid assumptions in data collection, noninvasive monitoring

Efecto de la Técnica de Monitoreo en la Calidad de la Ciencia de la Conservación

Resumen: *Monitorear animales de libre distribución en su ambiente natural es clave en la conservación de ecosistemas y de creciente importancia en el contexto de las tasas actuales de pérdida de la diversidad biológica. Los datos colectados de individuos de especies en peligro informan a las políticas de conservación. Los conservacionistas suponen que estos datos son confiables, es decir que los animales de los cuales los datos son colectados son representativos de la fisiología, ecología y el comportamiento de la especie y de todas las poblaciones de donde son tomados. En las últimas décadas ha habido una adopción entusiasta de técnicas invasivas para la colecta de datos ecológicos y de conservación. Aunque éstas pueden proporcionar cantidades impresionantes de datos y supuesta penetración hacia los rangos y distribución de los animales hay creciente evidencia de que estas técnicas pueden resultar en problemas de bienestar animal a través de los amplios efectos fisiológicos de estrés crónico y agudo y por medio de movimiento dificultado o heridas directas o indirectas. Sin embargo, los conservacionistas pocas veces consideran el problema de cómo estos efectos pueden alterar el comportamiento de los individuos hasta el punto en el que los datos que recopilen sean desconfiables. La literatura reciente sobre los efectos inmediatos y a largo plazo de la captura y el manejo indican que ya no se puede suponer que la supervivencia de un animal silvestre al proceso implica la seguridad del procedimiento, que el procedimiento sea ético o la validez científica de los datos resultantes. Yo explico que los conservacionistas deberían evaluar rutinariamente estudios poblaciones para saber si hay efectos negativos de las técnicas de monitoreo y adoptar aproximaciones no-invasivas para el mejor resultado no solamente para los animales sino también para la ciencia de la conservación.*

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Palabras Clave: bienestar animal, ciencia y ética, ética en el monitoreo, monitoreo económico, monitoreo no-invasivo, suposiciones inválidas en la colección de datos

Introduction

Advances in technology in the last few decades have made it increasingly feasible to monitor the number and distribution of free-ranging animals, and this in turn has provided conservation professionals with vital new insights into how to protect and manage threatened populations. As a result, species monitoring in conservation biology is less reliant on experiential or ad hoc strategies and increasingly informed by scientific data (Pullin & Knight 2003). Although recommendations continue to be made for improved methods to improve conservation science (Pullin et al. 2004), they have centered on the development of improved evidence-based conservation methods. For example, Legg and Nagy (2006) believe that many conservation-monitoring programs suffer from "lack of details of goal and hypothesis formulation, survey design, data quality and statistical power" and thus "most programs are likely to" be unable to reject "a false null hypothesis with reasonable power." They posit that "results from inadequate monitoring are misleading . . . and dangerous because they create the illusion that something useful has been done."

However, there is a striking paucity of comment on the link between the ethics applied in collection of abundance and distribution data and the resulting reliability of the data collected. Ethical monitoring of wildlife is not only a laudable aim, uniting ethicists and conservationists and the public and scientists, but also is fundamental in acquiring reliable data required for good science. Although good ethics alone do not necessarily result in good science, poor ethics can be clearly linked with poor science in conservation monitoring.

Ethics in Conservation Monitoring

Studying free-ranging animals in their natural environment presents a substantial ethical dilemma (Wilson & McMahon 2006). To what extent does one behave ethically when one interferes with the lives of the animals under study? How can one reconcile the welfare of individual animals with the welfare of the species? It is rarely possible to monitor free-ranging animals without affecting their environment, so these ethical issues have generally been ignored or left to personal interpretation, in striking contrast with other academic fields. Between 1995 and 2005, top conservation and ecology journals published just 14 papers that contained the words *ethics* or *ethical* in their titles or keywords. By comparison, a single medical journal, *The Journal of the American Medical Association* published 173 papers with those words in their titles (Vuchetich & Nelson 2007). Although there have been recommendations that peer-reviewed natural science journals formally incorporate research ethics in their instructions to authors and reviewers (Marsh & Eros 1999), few do. For example, the Conservation Measures Partnership, whose partners included the World Wildlife Fund and the International Union for the Conservation of Nature published Open Standards for the Practice of Conservation (2007) and therein made no explicit mention of ethics in guiding species monitoring.

Recently, however, bioethicists have begun to consider some of the more important ethical questions in conservation biology, including the reconciliation of individual needs versus species requirements (Minteer & Collins 2005; Vuchetich & Nelson 2007; McCarthy & Parris 2008; Pacquet & Darimont 2010; Linklater & Gedir 2011; Harrington et al. 2013; Vuchetich & Nelson 2013). Others have simply outlined the need for empathy with nonhuman animals (Nelson 1996; Bekoff 2006, 2007).

There is another concern regarding the relation between ethics and science in conservation biology that is rarely addressed. If the techniques used in monitoring interfere with the natural behavior of the individual or population, either in terms of physical harm or significant disturbance, how does this affect the quality of the data collected, and how in turn does it affect the conclusions drawn and decisions made? These questions are not without precedent in the use of animal subjects in laboratory testing of pharmaceuticals. Despite the scientific protocols of standardized conditions and parallel studies in laboratories, the confounding factor of stress is rarely considered, and stressful laboratory conditions likely affect a subject's physiology to the extent that their stress can cause misinterpretation of the effects of the test drug (Baldwin & Bekoff 2007; Bekoff 2008; Knight 2008).

Monitoring Techniques and Animal Welfare

There is still no effective method for monitoring endangered species that does not cause some degree of disturbance to the individuals of that population. Human presence alone in the environment of free-ranging populations can cause physiological or behavioral modification, unwanted transmission of disease, and mortality (Lott & McCoy 1995; Green & Giese 2004).

This aside, let us consider some of the monitoring techniques used in conservation biology. I have divided them into two broad categories on the basis of degree of disturbance they cause: invasive and noninvasive. Invasive techniques include lengthy direct observation within sensing distance of the animal, and physical marking for identification, which can include ear notching or tagging, toe or fin clipping, hot-iron branding, bar-code implantation, and attachment of VHF (Very High Frequency) radio or satellite transmitters. Transmitters can be attached to the animal in a variety of ways, including external collars or imbedded transmitters (e.g., subcutaneous and intraperitoneal implants); the latter requires surgery.

In the last few decades, there has been a considerable increase in the availability of tagging devices and hence use of invasive techniques. Tagging devices are particularly attractive to scientists because they can provide a wealth of data on movement, allow inferences about behavior, and allow hands-on physical contact with the study species which permits simultaneous collection of physiological data. Satellite GPS systems are also increasingly popular and can provide huge quantities of data on animal movement (Hebblewhite & Haydon 2010).

Noninvasive techniques include an increasing number of remote sensing approaches made possible by advances in technology and include camera trapping (Karanth et al. 2006), in which an image of an animal is taken along a trail or grid, and biometric approaches, including footprint identification (Jewell et al. 2001; Alibhai et al. 2008), coat-pattern recognition (Hiby et al. 2009), and vocalization identification (Terry et al. 2005). Satellite imagery provides ever-better resolution, and remote robotic cameras even further potential for acquiring the data needed to undertake effective monitoring of individuals and populations (Kamphof 2011). Noninvasive genetic sampling of feces and hair follicles is increasingly used (Taberlet & Luikart 1999) as is noninvasive fecal glucocorticoid metabolite measurement (Millspaugh & Washburn 2004).

Invasive monitoring techniques may require either physical or chemical immobilization. Physical traps create stresses similar to those of being caught by a predator, and the trapped individual may engage in a prolonged struggle to escape that causes pain, fear, and anxiety. Repeated stressors may induce chronic stress. Physical capture alone, without chemical immobilization, can result in capture myopathy, a syndrome in which extreme muscular activity and hyperthermia lead to death minutes to weeks after the inciting event. Herraez et al. (2007) reported this syndrome in ungulates, carnivores, rodents, primates, marsupials, pinnipeds, and birds.

Chemical immobilization requires the delivery of potent sedative or anesthetic drug, delivered after capture in a physical trap, or directly in the field, and can present considerable risk for both operator and animal. Drug dosages must be estimated, and delivery of the required dose depends on many challenging variables. Operators are usually not required to have a veterinary qualification. Immobilizing drugs have the potential to disturb normal regulatory systems, particularly respiration and thermoregulation, which can lead to neurological or myocardial problems and multiple organ failure. Individuals and species can react very differently to the same drug, and drug combinations can have unpredictable effects depending on physiological and reproductive status, body condition, etc. If anesthetic induction is slow there is a risk of limb and head trauma, laceration, and bruising. These scenarios would present a formidable challenge to a medical anesthetist or veterinarian working under controlled conditions, let alone a field technician, and resulting morbidity and mortality rates are often many times higher than would be acceptable under controlled conditions.

Negative Welfare Outcomes and Unreliable Data

A monitoring program may induce several of the welfare effects noted above that may interact synergistically to amplify stress. For example, a standard capture-mark-recapture protocol may include trapping, restraining, marking, sampling, and release and then a repetition of the process at each capture point and time sequence.

Stress is a common theme in any process involving capture and handling of free-ranging animals. It has profound effects on vertebrate immunity, but when, how, and why stressors affect immunity in wild animals remains practically unstudied (Martin 2009). The adrenocortical response to stress is common across mammals, and, given its pivotal role in the evolution of the predator-prey relation there is no reason to expect it to be significantly different in other vertebrates. Reeder and Kramer (2005) detail behavioral responses to a stressor that include escape or avoidance behaviors, altered cognition and attention span, increased awareness, altered sensory threshold, sharpened memory, stress-induced analgesia, suppression of feeding behavior, and suppression of reproductive behavior. Capture and handling induces these acute stress responses. The permanent attachment of a marker that causes physical impediment or increased visibility to a predator or prey may produce chronic stress. In either circumstance, it is unlikely that the recorded behavior and ecology of the subject animal will approximate that of an unmarked animal in the study population. The effects of stress on individuals of a population can also be passed to the next generation. Symptoms analogous to post-traumatic stress disorder were reported (Bradshaw et al. 2005) in juvenile elephants born into herds that had experienced social disruption and breakdown, including an inability to regulate stress-reactive aggressive states. Stress caused by the collection of samples may also produce results with an unreliable baseline. The immobilization required for hands-on sample collection may involve veterinary field practices that would never be considered ethical (or safe) by veterinarians working in domestic practice, but which circumstances impose on those who are working on free-ranging animals (Jewell et al. 2001).

Negative effects are most likely to be reported when they occur during the initial stages of the research (Murray & Fuller 2000). However there is rarely any obligation to report the negative effects of monitoring, and there is a disincentive to do so because reporting such outcomes could jeopardize the funding that supports the research. Effects may become manifest at different stages of a life-cycle, or season, or only in conjunction with certain behaviors, etc., and the magnitude of the effect may be more evident in some individuals than others depending on their individual responses to stress (Murray & Fuller 2000).

Various authors have reviewed the literature on the effects of marking for conservation monitoring, including the negative effects of marks and devices on birds (Calvo & Furness 1992) and marine (Gales et al. 2003) and terrestrial mammals (Murray & Fuller 2000). The ethics of immobilization for fitting markers have also been considered (Jewell & Alibhai 2010).

In addition to general stress, invasive monitoring studies have recorded physical damage, disruption to social hierarchy, disruption of natural movement, disruption to breeding behavior, sex changes, and increased vulnerability to predation. Tracking devices can cause physical damage, often the byproduct of a chase, capture, restraint, or fitting. In a study of black rhinoceros (*Diceros bicornis*) ranges, 89 VHF radio-collared animals were monitored over 7 years (Alibhai & Jewell 2001). As animal body condition improved during the wet season or animals matured, collars became tighter. Fifteen percent of collars had to be removed due to injuries, including deep ulcerated lacerations, chronic inflammation, and active myiasis. Attempts by the rhinoceroses to remove the collars were evidenced by scarring around the ears and head.

The effect of collars on plains zebra (*Equus burchelli antiquorum*) females in the Makgadikgadi, Botswana, was studied by Brooks et al. (2008). They compared two types of GPS collars, both within the accepted weight norms. The group with slightly heavier collars (0.6% of total body mass) exhibited a >50% reduction in the rate of travel when foraging than the group wearing a slightly smaller collar (0.4% of body mass). Heavier collars particularly affected grazing behavior, demonstrating that small differences in collar weight or fit can affect specific behaviors and perhaps limiting the utility of fine-scaled GPS data. This revelation was possible because the study used two different collar types and challenges the assumption that collars within the recommended weight limits (0.7–9% of body mass [Kumpala et al. 2001]) have little or no effect on animal movement.

Toe clipping is a routine physical marking process in small mammal and amphibian monitoring (Alibhai & Key 1985; McCarthy & Parris 2004). It decreases the overall lifespan of the meadow vole (*Microtus pennsylvanicus*) (Pavone & Boonstra 1985). McCarthy and Parris (2004) found that for each toe removed, frogs and toads are 4–11% less likely to be recaptured. These authors concluded that their results had important ethical and scientific implications, although others have noted that despite evidence of significant morbidity, it remains a widely used tool (Murray & Fuller 2000).

Directly marking the body surface is likely to cause pain, distress, and occasional mortality. Hot- and cold-iron branding in marine mammals, usually without analgesia during or after the procedure, is a commonly used tool for marking individuals (Walker et al. 2012). Post-branding mortality of 0.5–0.7% was reported in Steller sea lion (*Eumetopias jubatus*) young and was considered attributable to the branding event (Hastings et al. 2009). Hot-iron branding has provoked public disapproval (Jabour-Green & Bradshaw 2004) and hence jeopardized support for projects in which this technique is used. This is an example of poor welfare negatively affecting science.

Markers are sometimes placed in positions that cause direct interference with mobility. The attachment of flipper transmitters in sea otters (Garshelis & Siniff 1983) resulted in injuries, including broken digits and webbing and altered behavior. One hundred and forty-four sea otters were fitted with transmitters secured with steel bolts on the rear flipper that were typically torn off within 3 months. In another study 22 of 75 tagged otters were never seen again and 18 of the remaining 53 sustained flipper damage.

Heavy or buoyant markers interrupt diving patterns in marine mammals. King Penguins (*Aptenodytes patagonicus*) fitted with external loggers performed almost twice as many shallow dives, which resulted in interruption of deep-diving sequences and extended time to reach the surface (Ropert-Coudert et al. 2000). These results suggest an extra energy cost induced by external loggers. Banded King Penguins arrived late at the colony, resulting in lower breeding probability and lower chick production. The survival rate of unbanded, electronically tagged King Penguin chicks after 2–3 years was approximately twice as high as that reported in the literature for banded chicks (Gauthier-Clerc et al. 2004).

A review of marking techniques on marine mammals (Walker et al. 2012) noted that most studies reviewed did not examine the behavioral effects of external devices on cetaceans with reference to pretagging behavior. One exception was a study on a single harbor porpoise (*Phocoena phocoena*) that recorded changes in log-rolling behavior, roll duration, dive duration, daily food intake, and surfacing areas after a radio transmitter was attached through the dorsal fin (Geersten et al. 2004).

The effects of invasive monitoring procedures on maternal behavior can result in negative outcomes for offspring. Average postpartum foraging-trip nursing-visit cycles were significantly longer in 105 Antarctic fur seals (*Arctocephalus gazella*) carrying time-depth recorders and radio transmitters, than those carrying only radio transmitters (Walker & Boveng 1995). There was apparently no investigation of the effect of carrying transmitters or recorders on pup growth and subsequent maturation.

The success of a monitoring procedure cannot be guaranteed by the apparent survival of all the individuals throughout the procedural process. A method of inserting a transmitter into the oviduct of Atlantic salmon (*Salmo salar)* and rainbow trout (*Oncorhynchus mykiss*) was examined (Peake et al. 1997). Following insertion no behavioral or survival differences were observed, but 33% of the tagged trout died during the observation period. It seems likely that a procedure that results in 33% mortality will have an effect on the natural behavior of survivors. Kock et al. (1990) reported no mortality during the translocation of 64 black rhinoceroses in Zimbabwe in 1988, but there was an indirect mortality rate of 14% up to 2 months after capture.

Invasive interventions can have other, less expected effects on the validity of the resulting data. Monitoring radio-collared black rhinoceroses in Zimbabwe, showed that the regular immobilization of females increased their intercalving interval from a normal 3 years to almost 10 years (Alibhai et al. 2001), possibly due to the stress of repeated immobilization and collaring. Moorhouse and McDonald (2005) noted changed sex ratios in radio-collared voles. Other authors report reduced body condition and survival of Lesser Snow Geese (*Chen chen caerulescens*) goslings (Williams et al. 1993) and negative effects of immobilization on ranging behavior and body condition in grizzly (*Ursus arctos horribilis*) and black bears (*Ursus americanus*) (Cattet et al. 2008) and polar bears (*Ursus maritimus*) (Dyck et al. 2007). Chemical immobilization of male bighorn sheep (*Ovis Canadensis*) negatively affects their fighting ability, despite apparent full recovery (Pelletier et al. 2003). Even apparently minor interference in the life of a free-ranging animal can have serious negative effects. Lane and McDonald (2010) pointed out that temporary removal of individuals from a population can cause social disruption and lead to permanent hierarchical changes, particularly in social animals such as wolves. Dehorning black rhinoceroses as an antipoaching deterrent unexpectedly increased juvenile mortality. Females without horns were less able to successfully defend their calves against hyenas (*Crocuta crocuta*) than females with horns (Berger 1994).

Monitoring the welfare of an animal after it has been fitted with a device is crucial for the scientific validity of the study but depends very much on the success or otherwise of the marking or tracking system. Transmitters are notoriously unreliable. In one study, there was a 60% failure within 6 months of fitting collars to black rhinoceroses in Zimbabwe (Alibhai & Jewell 2001). Twelve percent of collars were lost because the transmitter failed, and the fate of the animals carrying the collars could not be recorded.

Monitoring data may also be compromised by a desire for more data. Some researchers question the slavish addiction to GPS telemetry and argue that scientific field observation skills are being lost in favor of the huge amount of data that can be collected over a short period from GPS-collared animals (Hebblewhite & Haydon 2010). Challenges have been made to the fundamental assumption in wildlife studies reliant on radiotelemetry that radio-tagged animals are “moving through the environment, responding to stimuli and behaving in a manner similar to non-instrumented animals” (Withey et al. 2001).

The emerging literature on the immediate and longer-term effects of capture and handling therefore indicate it can no longer be assumed that the survival of a wild animal through the process of immobilization implies the safety of that procedure, good ethics, or the scientific validity of the resulting data.

Improved Ethics in Data Collection and Improved Science

Although invasive techniques have undoubtedly contributed enormously to conservation biology, one can no longer assume that the effects of monitoring are not negatively affecting the quality of observations. However, it is often impractical, given the relative paucity of funding, and urgency of many conservation initiatives, to run control observations on unmarked and undisturbed populations alongside our test subjects.

More than half a century ago Murie (1954) proposed that professional standards should be established for members of the Wildlife Society, yet the challenges in uniting animal-welfare ethics with science and conservation (Travers 2010; Harrington et al. 2013) make such standards very hard to define. Perhaps because of this, a review of 547 papers in three prominent conservation journals reported that only 12.5% of studies tested or reviewed the possible effects of the study method on the animal subjects (Fazey et al. 2005).

One approach to addressing this challenge is to encourage increased testing and adoption of noninvasive techniques that do not rely on marking and cause no disturbance or minimal disturbance to the study animal or population. These techniques can also confer advantages in terms of cost-effectiveness (Alibhai & Jewell 2001; Alibhai et al. 2008) and free vital funding for further enquiry. When noninvasive techniques are used alongside their invasive techniques, new insights may be gleaned. Jewell et al. (2001) and Alibhai et al. (1996) estimated the home ranges of four radio-collared black rhinoceroses with VHF data and repeated the exercise after the collars had failed by identifying footprints. Without collars animals greatly expanded their home ranges, which appeared to be due to the fact that VHF radio data were only collected during the daytime, whereas rhinoceroses were most active at night. Without collars the animals appeared to exhibit greatly expanded home ranges. Although this may have been due to the collars inhibiting movement, it was likely also to be due to the fact that the VHF radio data were only collected during the daytime, whereas rhinoceroses are most active at night. Footprints were left day and night and collected each day.

Noninvasive approaches can also bring new opportunities to engage local communities and thus result in better sustainability, long-term conservation success, cross-disciplinary engagement, and more robust science (Berkes 2004). The traditional ecological knowledge of indigenous peoples, honed over millenia, can inform more sustainable means of monitoring (Kasisi 2012). Tracking, arguably the foundation of modern science (Liebenberg 1990), evolved through the development of acute observation of animal signs in the environment, and includes observations of footprints and behavior and listening to vocalizations, techniques that have been adopted by modern science for animal identification. Research scientists can offer employment to local communities who report sightings or signs of target species. In China researchers help support local communities by paying for sightings of Amur tiger footprints and have succeeded in documenting many more tiger trails in this manner than would otherwise have been possible with limited resources (G. Jiang, personal communication). With the advent of remote cameras, communities anywhere can now play a part in local conservation efforts (Sullivan et al. 2009).

McCoy and Berry (2008) reasoned that the desire to balance the needs of the individual animal against those of the species or aims of the conservation initiative, ultimately depends on the personal values of the researcher. I propose that conservation science can move forward by recognizing that ethical treatment of animals improves the quality of the data collected and the strength of monitoring and management decisions.

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