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Taking the time to assess the effects of remote sensing and tracking devices on animals

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Abstract

The remote monitoring of animal behaviour using telemetry and bio-logging has become popular due to technological advances, falling costs of devices and the need to understand behaviour without causing disturbance to subjects. Over the past three decades thousands of animals have had their movements tracked by these devices; however, attaching devices to streamlined bodies raises concerns about energetic costs and effects on vital rates and the reliability of the data collected (eg survival probability). We encourage researchers to discuss concerns, quantify the possible effects that devices and attachment methods have on subjects and present this work for peer review.

Keywords: *animal welfare, bio-logging, conservation, ethics, remote sensing, satellite tracking*

Introduction

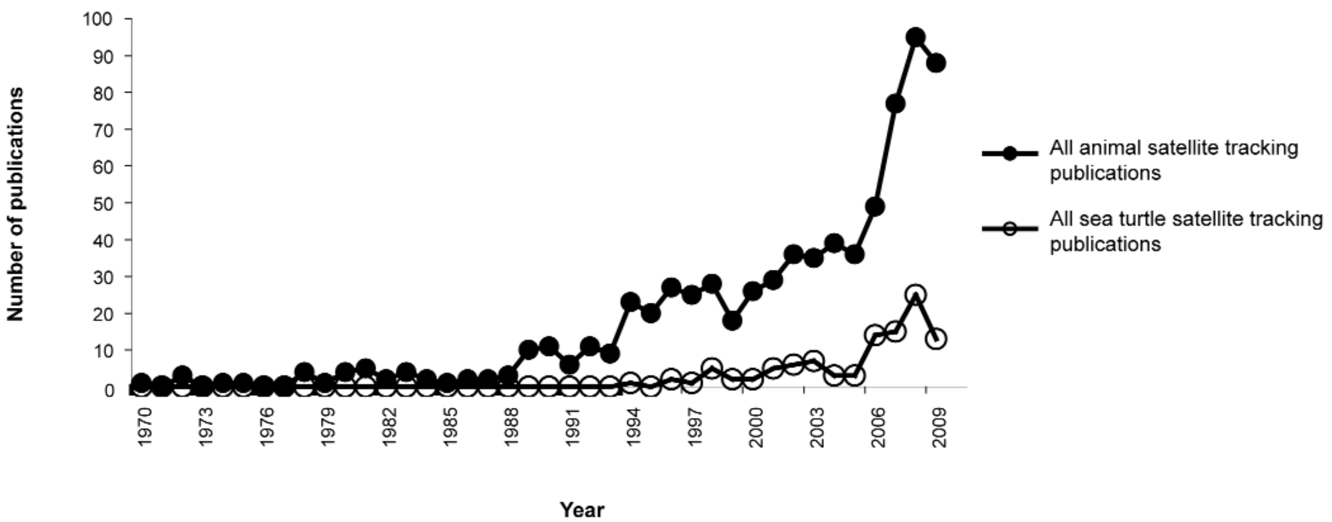
With advances in technology, especially in the field of animal telemetry and bio-logging, it is now possible to investigate the cryptic behaviours of animals (Ropert-Coudert *et al* 2009), such as recording the exceptional diving capabilities of elephant seals (*Mirounga leonina*) (Hindell 1991; Slip *et al* 1994), the behaviours, movements and migratory patterns of sea turtles (Ferraroli *et al* 2004; Hays *et al* 2004), and the at-sea behaviour of enigmatic species such as whale sharks (*Rhincodon typus*) (Graham *et al* 2006). Not only do these advances allow unparalleled and unique insights into behaviour and provide valuable conservation information for biodiversity managers, but they are relatively simple to use with typically straightforward software applications and user-friendly downloads of data. Consequently, remote monitoring of animal behaviour is a popular research area of intense investigation (Ropert-Coudert *et al* 2009) (Figure 1).

An example of a cause for concern — sea turtles

While the quantity of data collected using these devices is increasing exponentially (Godley *et al* 2008), there is a clear lack of complementary research on the effects of these devices on the research subjects — which is a cause for concern — and sometimes limited analysis of work undertaken in their area by researchers working in the field (Wilson & McMahon 2006). A pertinent example is in the field of sea turtle research. Sea turtles are high profile, charismatic animals that attract much attention from the public and media alike, while also acting as important environmental health indicators (Aguirre & Lutz 2004). This interest has resulted in a proliferation of studies investigating at-sea turtle movements and behaviour (Figure 1). These data may provide a vital tool for future projects monitoring populations of marine megavertebrates, however it is interesting to note that bio-logging and data-tracking is generally not used for conservation purposes (Ropert-Coudert *et al* 2009). Although these numbers account for < 15% of all satellite-tracking publications; when considered in terms of actual numbers of sea turtles being monitored then one must look at www.seaturtle.org. This website allows interested parties conducting satellite tracking to place a record of their data on the website. Notwithstanding the fact that not all parties are willing to do this, since 2003, www.seaturtle.org has detailed and archived the at-sea movements of 558 sea turtles (Figure 2), not to mention the movements of 270 sea turtles currently being tracked.

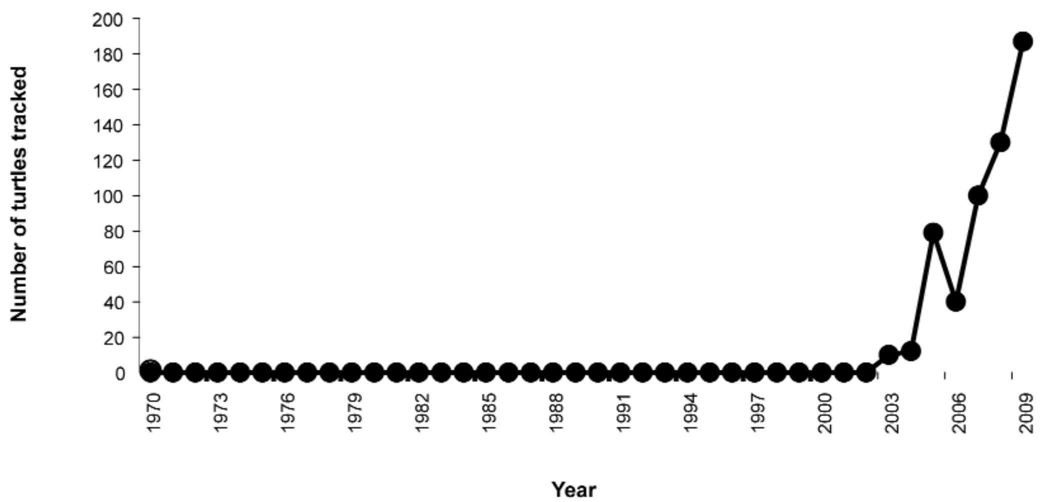
While there has been a rise in the number of publications concerned with satellite tracking of sea turtles since the 1990s (Figure 1), only a small number of these have considered the effect of the device on the animal (Ferraroli *et al* 2004; Hawkins 2004; Troëng *et al* 2006; Fossette *et al* 2008; Godley *et al* 2008). Ethical and welfare considerations need to be at the forefront of this type of research, ensuring scientists have accessible data for refining techniques and undertaking ethical practices. Of the few

Figure 1



Graph detailing (i) the number of animal satellite tracking publications and (ii) sea turtle satellite tracking publications. Data come from a general search on Web of Knowledge. For (i), the keyword 'satellite tracking' was used within publication years 1970 to present. Results were refined by subject categories pertaining to biology, ecology and the environment. For (ii), the keyword was again 'satellite tracking', within the same time period as (i). A further search within these results was carried out using the keyword 'turtles'. For both searches, results were sorted by publication year using the Web of Knowledge results analysis tool.

Figure 2



Graph detailing the number of turtles tracked on www.seaturtle.org, on a year-by-year basis. Monitoring data were retrieved from the archive section of www.seaturtle.org.

published examples, considerable problems have been highlighted (Troëng *et al* 2006). With improved longevity of both the device and attachment, turtles can now be monitored remotely for periods of over a year, sometimes returning to their natal beach years later with the device still attached (Troëng *et al* 2006). While it is unclear what effects such long-term deployments have, there are well-documented cases in marine vertebrates showing that such deployments may have detrimental effects in terms of life history (Massey *et al* 1988; Wanless *et al* 1988; Taylor & Gangopadhyay 2001; Simeone *et al* 2002a; Whidden *et al* 2007). For example, it has been noted that animals have suffered negative consequences from devices when foraging and breeding (Massey *et al* 1988; Wilson & Wilson 1989; Croll *et al* 1996; Ballard *et al* 2001; Beaulieu *et al* 2010) as well as decreases in survival rates (Jackson & Wilson 2002; Dugger *et al* 2006). However, there is also good evidence on the short- and long-term effects of devices which shows no impact on the key life-history traits of growth and survival, even of the most vulnerable animals

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Table 1 Potential effects of device attachment.

Stage of device deployment	Concern	Mitigation
Capture	The capture process includes: • Selection; • Capture; • Restraint; and • Release (Casper 2009) • NB Animals see the capture process as predation and is therefore probably the most stressful event an animal can experience	• Researchers must possess the skills to undertake each component of the capture process, or seek specialised support (Murray & Fuller 2000; Gannon & Sikes 2007; Casper 2009) Actions may include: • Limiting handling times; • Sensory deprivation; and • Invoking the use of safe, fast-acting anaesthesia agents (Casper 2009) • NB Not all drugs and methods are equal, an area in need of research
Device type	• Size and shape, potential drag effect	• Smaller equipment is recommended for use on animals, but attention needs to be paid to a series of other aspects (Withey *et al* 2001) • Streamline equipment for aquatic and flying animals (Obrecht III *et al* 1998)
	• Positioning, not allowing for natural mobility	• Ensure that placement does not impair insulation, preening, feeding or sleep posture (Smith *et al* 1998)
	• Colour, predator attraction	• Camouflage/conform to animals pelage, may influence behaviour and vulnerability to predation (Casper 2009)
	• Instrumentation, may cause drag	• Reduce size or internalise within the device, some devices can cause drag and effect foraging (Wilson *et al* 1990; Elliott 2008)
Attachment method	• Attachment can occur through various methods, with some components having the potential for harm (Casper 2009) • Physical problems include skin abrasion, impairment of movement, feather loss and necrosis under the unit (Sykes Jr *et al* 1990; Godfrey *et al* 2003; Ackerman *et al* 2004)	• A review of device attachment methods is needed. This has become a fertile field which needs to be addressed and can be done under controlled conditions, eg zoos • Do not attach over injuries, may cause necrosis • Small amounts of quick-setting inert glue that does not generate excessive heat during curing; may cause burning of the underlying integument (Sykes Jr *et al* 1990; Foster 1992) • Avoid harness attachments for field deployments where possible. However, there is evidence that harness attachments can be effective in some taxa (Hays *et al* 2004)
Timing and attachment duration	• Timing, eg effects are most pronounced when device is attached during the breeding season rather than at the beginning or end of the breeding season (Sohle *et al* 2000)	• An area in need of investigation regardless of the subject species
	• Duration, increasing duration may exacerbate effects	• As short as is necessary to answer the key question (Wilson & McMahon 2006) • Drop-off collars might be considered, although these have limitations and need monitoring (Strathearn *et al* 1984; Soderquist 1993)

most likely to be impacted by carrying devices (McMahon *et al* 2008). Although there are obvious caveats in comparing device effects and welfare across species, it would seem prudent to investigate the potential life history impacts that these devices may be having on turtles especially given the longevity of the deployments. Duration of sensor attachment is not the only consideration; other concerns include the consequence of capture and restraint during attachment, and the potential increase in the energy budget required to find and to store food. Also, concerns exist for breeding and maintenance due to drag from the attached sensor, as observed in fur seals (*Arctocephalus* spp) (Boyd *et al* 1997) and penguins (Wilson *et al* 1986; Culik & Wilson 1991, 1992).

General effects of device attachment

While data are limited on the effects devices may have, it is prudent to consider the potential effects. These can be split into four main categories: (i) those arising from the capture of the animal (Croll *et al* 1991); (ii) the type, which includes shape, size and colouration, of device; (Wilson & Wilson 1989; Bannasch *et al* 1994; Ropert-Coudert *et al* 2007); (iii) the attachment method (Bannasch *et al* 1994; Fossette *et al* 2008); and (iv) the timing and duration of the device attachment (Watanuki *et al* 1992; Ropert-Coudert *et al* 2000) (Table 1). In Table 1 we summarise the concerns regarding device attachments and some of the solutions that might be considered to mitigate these effects. Of the concerns highlighted, all may increase energy consumption and therefore possibly compromise fundamental life history traits, such as survival and breeding probability (Wilson & Wilson 1989; Wilson & McMahon 2006; Godley *et al* 2008). In the interest of sound and unbiased research that provides accurate and representative data, or indeed information that can be assessed in the context of the effect it has on animal life history, it seems prudent to take all of the aforementioned into account when studying the behaviours of wild animals. In our assessment, capture is one of the most likely issues requiring to be addressed when fitting devices to animals (Murray & Fuller 2000; Gannon & Sikes 2007; Casper 2009).

In the first instance, we would urge researchers to quantify the effects of capture on animals and then to go on to investigate the mitigating effects of sedatives and anaesthetic agents used for immobilisation. There have been cases in which internal implantation has been investigated, however this seems only to be of merit over the longer term (Green & Bradshaw 2004). There is limited research examining the steps of the surgical procedure (capture, sedation, laparotomy, and implantation) and results are not well known (Beaulieu *et al* 2010a,b). However, for immobilisation to occur, bodies and agencies that regulate research need to be aware of the importance of experimentation with chemical agents in wildlife research and need to acknowledge and indeed accept a degree of responsibility for studying wild animals. A hands-off approach (preservation) to conservation is simply not pragmatic in the present biodiversity crisis.

Addressing all parties

In the light of the previous argument, we advocate an active animal welfare research role for researchers, scientific ethics and governing bodies, NGOs and animal welfare advocates, in the pursuit of sound study of the effects of device attachment and research (in general). These are necessary components of gathering vital conservation information (McMahon *et al* 2007). Yet many researchers often see the ethics' process as a hurdle to conducting research; once overcome, less attention is paid to the effects of devices on animals. So, while not questioning the necessity for research and the need to attach devices to wild animals, eg using our case study of sea turtles, we are, however, concerned by the number of animals being subjected to study and the paucity of information on the capture and effects of the devices made publicly accessible from these studies in terms of published peer-reviewed papers. Moreover, as the financial investment and costs involved in the application of these sensors diminish, it is likely that in the future we will see continued increases in the numbers of sea turtles (and for that matter, other animals) being tracked (Figures 1 and 2).

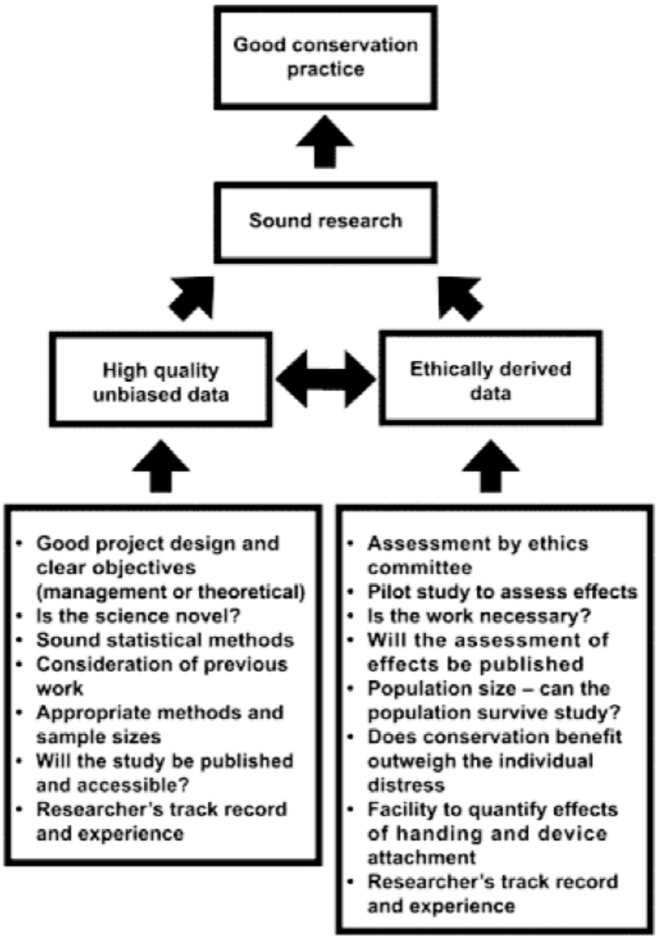
Of paramount importance in this debate is the answer to the question: why is there such a lack in quantification of the effects of these applications on animal behaviour and welfare? One potential answer could be the multifaceted nature of conservation. Conservation has many parties involved (eg scientists, veterinarians, NGOs, welfare and conservation groups) and emotions can therefore run high especially when the animals being studied are charismatic (Jabour-Green & Bradshaw 2004; McMahon *et al* 2006). All these groups have different agendas, all of which are commendable, but sometimes the true objective can be missed (McMahon *et al* 2006; Wilson & McMahon 2006). How do all parties reach this common goal in a unified way? The answer is with good conservation practice (see Figure 3) that includes the presentation of data on the effect handling and devices have on animals in a clear, uniformly quantifiable way. Indeed, in many cases it seems that this information may already exist but has not yet been analysed and presented in terms of assessing research impacts. For example, there are studies where animals have been tracked for long periods of time and the information from these studies has provided vital information about the ranges of turtles and the potential hazards they encounter, eg by-catch (Hays *et al* 2004). Consideration could also be given to the evaluation of device impacts as part of the ethics process, encouraging researchers to explore device effects further as part of ongoing ethical considerations and not as an afterthought, or worse, not a thought at all. It would seem prudent that information from such studies on return rates and measurements of the effects of the attachments can be useful to other researchers. Perhaps such retrospective analysis of data — with welfare in mind — prior to carrying out further studies will not only introduce a more cautionary approach to prospective experimental work, but also produce some much-needed information regarding the welfare of these animals.

Animal welfare implications

We do not intend to criticise or question the research or the proponents performing the work, however we do suggest ways in which researchers can improve their practices. Hopefully, when considered on an individual basis, a reasonable case can be made for each animal carrying remote sensors. However, if the goal is to conserve animal populations then the research community must become more strategic in their research and be willing to evaluate their methods more frequently. For example, in those instances where specific areas or species suffer a scarcity of information, there is a case for researchers being more specific in their application of remote sensing equipment. Our approach advocates as much as possible to be learnt from as few animals as possible and is closely aligned to the

Figure 3

Flow chart detailing good conservation practice.



3Rs approach — a framework used widely in the animal research and husbandry fields, however limited in wildlife research. For example, an ISI Web of Science search with the keywords '3Rs' and 'animal' and 'wild' returns no results. As outlined by Russell and Burch (1959), the 3Rs framework recommends reducing the number of animals used in experiments, while remaining statistically relevant, refining procedures to minimise pain and distress in experimental subjects and providing for their well-being based on their behavioural needs, and replacing experiments involving whole animals with *in vitro* models such as tissue and cell culture wherever possible. It is with the 3Rs in mind that researchers should undertake some basic measures prior to beginning their research (Figure 3): (i) are the methods being employed the least invasive and how can the effects of the capture process be minimised (Murray & Fuller 2000; Gannon & Sikes 2007; Casper 2009); (ii) how can animal welfare impacts be minimised and what methods of attachment are best suited to the animal (Withey *et al* 2001); (iii) what are the best attachment methods and how can the effects of the methods be minimised (Sykes Jr *et al* 1990; Godfrey *et al* 2003; Ackerman *et al* 2004); and (iv) what is the minimum duration that the device should be fixed to the animal and are there alternatives that could be investigated (Wilson & McMahon 2006).

We encourage those researchers attaching devices to animals to consider our broader framework so that animal welfare concerns are explicitly incorporated into future research. This broader framework includes the 3Rs principles when considering, undertaking and assessing the effects of devices on animals, in the interests of sound unbiased research.

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