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PERSPECTIVE

A case for restoring unity between biotelemetry and bio-logging to enhance animal tracking research

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Abstract

Monitoring animals with electronic tags is an increasingly important tool for fundamental and applied ecological research. Based on the size of the system under study, the ability to recapture the animal, and research medium (e.g., aerial, freshwater, saltwater, terrestrial), tags selected may either log data in memory (bio-logging), transmit it to a receiver or satellite (biotelemetry), or have a hybrid design. Over time, we perceive that user groups are diverging based on increasing use of technology specific terms, favouring either bio-logging or biotelemetry. It is crucial to ensure that a divide does not become entrenched in the community because it will likely hinder efforts to advance field and analytical methods and reduce accessibility of animal tracking with electronic tags to early-career and new researchers. We discuss the context for this emerging problem and the evidence that this is manifesting within the scientific community. Finally, we suggest how the animal tracking community may work to address this issue to maximize the benefits of information transfer and integration between users of the two technologies.

Key words: ecology, environmental monitoring, electronic tagging, user communities, animal tracking

Background

Electronic tagging of free-ranging animals has transformed our understanding of their movements, behaviours, physiological capabilities, and ecological interactions, providing a powerful means for identifying and improving conservation practices (Hussey et al. 2015; Kays et al. 2015;

Lennox et al. 2017). Two different types of electronic tags have been developed for animal tracking: those that log data onboard and those that transmit data to an external receiving station. Loggers have the advantage of recording at constant or frequent time intervals, features of the environment (depth/altitude, temperature, sound, salinity, ambient light), or internal state of the animal (heart rate, acceleration, internal temperature), but require physical recovery by researchers to access data onboard (Rutz and Hays 2009). Transmitters overcome the limitation of physical recovery by communicating data remotely to receivers. The data transmitted by these devices (including optional temperature, acceleration, depth, conductivity, or predation sensors, among other parameters), are often at a lower temporal and spatial resolution and only collected when tagged animals are within range of receivers (Cooke et al. 2004; Hussey et al. 2015) or greatly compressed to enable data transmission (Harcourt et al. 2019).

Devices that either log or transmit data have been coarsely organized into the subfields of bio-logging and biotelemetry, both of which have been applied to a range of fundamental and applied research questions across animal taxa and environments. Cooke et al. (2004) defined biotelemetry as "remote measurement of physiological, behavioural, or energetic data," essentially identical to how Rutz and Hays (2009) defined biologging "use of miniaturized animal-attached tags for logging and/or relaying of data about an animal's movements, behaviour, physiology and/or environment." The technical differences between the electronic platforms seems to be driving a division between users of the two technologies within animal tracking science. Our team (comprised of a diverse, globally dispersed group of researchers whose research interests span the aquatic and terrestrial domains) has perceived a persistent and potentially growing divide between users of devices that log data and users of those that transmit data, and we hypothesize that this is connected to social/professional networks around each technology type associated with studies of certain animal taxa and ecosystems. This separation is leading to a divergence of specialized language reflecting the use of the two technologies. Should this divide continue to widen, we predict that researchers might limit their choice of tagging technologies to those favoured by their subfield, when really the choice of tools should be driven by the specific needs and challenges of the research agenda. Ensuring that there is but a single community of users of electronic tags is important to advance the discipline of animal tracking, improve and integrate the science conducted, and enable a deeper understanding of fundamental and applied ecological phenomena.

In this perspective, we address this divergence within the animal tracking community and make a case for proactively working towards increased unity between biotelemetry and bio-logging. In so doing, we hope that we can foster the goals of integration, inclusivity of users, and scientific advancement championed by the conferences, journals, and societies developed to connect animal tracking scientists. We acknowledge that the ideas presented here reflect our lived experiences and thus others in our community may have different experiences, perceptions, and opinions. We suggest that semantics are crucial to addressing this divergence, because within what we perceive as two separate communities, we suggest each is of the opinion that the technology that they use more frequently, biotelemetry or biologging, is the "umbrella" term representing the whole community of electronic tag users. We hope that this opinion piece will stimulate discourse on what we regard as a troubling issue.

Context for the divide

Bio-logging and biotelemetry have a common ancestry in the fundamental technology used to make remote measurements. The need for tags that log information compared to those that transmit it to a remote station depends on the scale of the study system, recoverability of the animal or tag package, and the research medium. Primarily, the scale of the project, including both the size of the study system and the size of the animal being tagged, influences selection of the type of tag. Bio-loggers that

cannot be recovered from animals that are challenging to recapture (e.g., those that move long distances or live entirely underwater) or from environments where pop-off tag packages (i.e., underwater bio-loggers that are brought to the surface by floats and transmit data to satellites) cannot be used. Bio-logging technology advanced most rapidly in research on animals from which tags could be reliably recovered, in particular on terrestrial animals, homing marine animals, and more recently on birds. In these circumstances, an investigator's best option for collecting a large and informative data set involved attaching bio-loggers and recovering the tag via recapture of the animal or timed release of the logging package and recovery (Wienecke and Robertson 2002). Using bio-loggers avoided the potential bottleneck of having to transmit very large quantities of data. The characteristics of the medium in which a tracked animal is moving regulates how far or often (if at all) information can be transmitted to receivers and satellites. In terrestrial environments, small tags broadcasting on radio frequencies can transmit in air across long distances, thereby increasing the probability of successfully transferring a large amount of data to a receiver. Radio signals can also transmit through water, but signals attenuate rapidly in saltwater or at depth in freshwater. High-frequency (67–417 kHz) acoustic signals are used, often to receivers (with hydrophones) within 100–500 m depending on the noise, depth, salinity, temperature, and relief of the area (Reubens et al. 2019).

Ultimately, the biological question has substantial influence on the type of tag needed. Bio-loggers offer the potential to archive continuous high-resolution time series data (e.g., accelerometers recording at >100 Hz), whereas transmitters may provide fewer data points when within range of a receiver or satellite, limiting the spatial and temporal scales at which data are available (i.e., acoustic detection data; Whoriskey et al. 2019). Analytical approaches can therefore differ when continuous time series data are available from bio-loggers compared with discrete data that are more frequently available from transmitters. Importantly, the division is bridged to some extent by specialized devices that both log and transmit data, again the choice driven by the expected behaviour of the animal and the study system. Acoustic transmitters can be programmed to log additional data in the event that they are recovered in recaptured animals and satellite transmitters often log additional data on board beyond what can be transmitted through air. These hybrid devices offer clear evidence of the compatibility of usership and also the need for more clear terminology to understand how these devices can be organized together.

We now perceive that the division between bio-logging and biotelemetry has begun to cause a rift between users of tags that log and users of tags that transmit data. The specifics of the technology have become entrenched in the naming of conferences (e.g., the International Conference on Fish Telemetry series versus the International Bio-logging Symposium series), specialized journals focused on a particular technology (i.e., *Journal of Animal Biotelemetry*), or specialized societies (e.g., the International Bio-logging Society). However, the division does not seem to stem from a conscious decision in the science community, and the lines are far from fixed. Investigators in the field will undoubtedly have their own idea of where bio-logging and bio-telemetry fall in the hierarchy. It is likely that no researchers favour a division and regardless of their opinion, inclusivity should probably be emphasized. For example, the *Journal of Animal Biotelemetry* accepts research that use bio-loggers, and the International Bio-logging Society states that their goal is to

> *"[. . .] bring together researchers from around the world who are interested in bio-logging methods and the scientific insights they generate. Its remit is broad, covering the use of bio-logging and bio-telemetry approaches to study aquatic, terrestrial and aerial species, across the world's ecosystems".*

The constitution of the society provides clarification that bio-logging is an umbrella term that includes biotelemetry (bio-logging.net/files/media/cdn.php?params=% 7B%22id%22%3A%22MDB-28847bbe-c7f4-4e87-a925-0a0a4d161620-MDB%22%2C%22type%22%3A%22stream%22%2C%22date% 22%3A%221522849956%22%7D&Constitution_Internation-Biologging-Society.pdf).

> *"Bio-logging" science is concerned with the use of miniature animal-borne electronic devices for logging and/or relaying of data about an animal's movements, behaviour, physiology and/or environment. In the context of this constitution, it is understood to encompass "bio-telemetry", including passive technologies"*

Despite a clear desire to be inclusive, we are concerned that this goal is not being achieved simply by stating that the terminology is intended to be inclusive. The reason for standardized terminology in science (and society) is to provide common language so there is shared understanding and clarity. Having inconsistent use of terminology creates confusion, particularly in early-career researchers or those less familiar with tracking science.

Evidence of the divide

We predicted that the naming of scientific outlets influences the research presented. For example, bio-logging research would be highly represented at the Bio-Logging Symposium, while biotelemetry research would be highly represented in the *Journal of Animal Biotelemetry*. We collected evidence for this from conference abstracts for the most recent International Bio-Logging Symposium in Konstanz, Germany (2017) and from articles published in the *Journal of Animal Biotelemetry* from 1 January 2013 to 15 May 2020. Content was screened manually and categorized based on the technology used by the investigator.

Two hundred and seventy-one abstracts from the 2017 Bio-logging Symposium were reviewed, 48 of which lacked sufficient detail to ascertain the technology used. Nonspecific abstracts described quantification of some form of sensor data (mostly acceleration), but failed to mention whether it was logged or transmitted—although based on species and our knowledge of the technology, we believe that the majority of these studies used archival logger technology even though not explicitly mentioned. An additional 20 abstracts were generic and not specific to any technology (e.g., sensor development, policy, software). Of the remaining 203 studies, 49 used telemetry technology while 107 used archival logger technology. As such, there were nearly twice as many bio-logging studies than telemetry studies. An additional 47 studies either combined technologies in a single study (e.g., different logging and transmitting devices on the same animal or used in the same study) or used technology that was inherently combined on the same animal (e.g., a pop-off satellite archival tag that initially logs data and then later transmits or global positioning system/global system for mobile communications tags). This is consistent with our argument that there are many ways in which these technologies can be combined in interesting and effective ways. This is also promising as it demonstrates exactly what we are advocating for here—using the best technology for the job at hand and combining tools and approaches where necessary.

The technology used in 201 articles published in the *Journal of Animal Biotelemetry* between 1 January 2013 (Vol. 1) and 15 May 2020 (Vol. 8, partial) was assessed. Thirty-eight papers were deemed to be "not applicable" in that they were editorials, corrections, or otherwise irrelevant (e.g., database structures). Telemetry studies ($n = 93$) dominated content with comparatively fewer archival logger studies ($n = 30$). There were sixteen studies that were hybrid (e.g., PSAT–logging and then transmitting data). Twenty-four studies combined technology (again, a promising finding); however, more than half of those were reviews where the content spanned technology types rather than using both telemetry and archival logging technology within a single study. The papers spanned

a variety of taxa including birds ($n = 13$), fish ($n = 73$), herpetofauna ($n = 17$), invertebrates ($n = 2$), marine mammals ($n = 20$), and terrestrial mammals ($n = 23$). It remains unclear if the divide between bio-logging and biotelemetry also represents a taxonomic divide (the sample size was too small to explore this quantitatively), but for all taxa except invertebrates (which only covered two studies) there was evidence of methods being used that spanned bio-logging and biotelemetry platforms.

Evading the divide

The data presented here are not a definitive diagnosis of a divide but support our prognosis that increasing division will have consequences for the efficient advancement of animal tracking science. If we as a community avoid this discussion and turn a blind eye to potential adverse effects, the rift will limit information transfer between the bio-logging and biotelemetry usership. The intent of this perspective is to identify, define, and call for a common culture for animal trackers that use biotelemetry, bio-logging, or both to monitor animals around the world. The first step towards creating this shared culture is to identify the potential pitfalls of using device-specific language to define or name conferences, workshops, or journals that are intended to invite all animal tracking scientists. Both the Bio-Logging Symposium and Animal Biotelemetry aim to be inclusive, but is this enough to ensure users of both technologies feel equally welcome and represented? Having a unified community has the potential to generate transformational science that uses the best tool (or tools) for the question at hand.

Readers may not necessarily agree that there is a divide and may dismiss the need for better representation and information transfer; we do not ignore this perspective but wish to encourage dialogue to explain different perspectives. Indeed, the authors of this paper acknowledge that the present commentary derives from subjective experiences but with limited supporting data. We note that the outlets highlighted in this perspective (Bio-logging Symposium, *Journal of Animal Biotelemetry*) would likely argue that they are already being as inclusive as possible, but the terminology used in their mission statements is ambiguous at best, probably because of inconsistencies in definitions. It is our experience that users of biotelemetry consider "biotelemetry" to encompass both bio-logging and biotelemetry, and users of bio-loggers equally feel that "bio-logging" term encompasses both technologies (see Cooke et al. 2004 and Rutz and Hays 2009 for evidence). We believe that this perception is not reality, which challenges new users to navigate, and inclusivity of existing networks and networking opportunities such as professional societies and conferences will be critical to foster an inclusive culture—especially for early-career researchers or those new to using these tools. We emphasize that a desire or mandate to be inclusive is not necessarily enough to ensure representation of both bio-logging and biotelemetry given how we found divisions manifesting at conferences and in journals that use device-specific terminology. It may be worthwhile to consider terminology such as "electronic tagging and tracking tools" (E3Ts) to better describe the varied technologies that are available and encompass tags that log, transmit, or do both. Silos that form when specialized groups convene to discuss biotelemetry or bio-logging in isolation will lead to further division but using inclusive terminology will invite different user groups and promote parallel advance. This can be overcome immediately by recognizing the division that is forming and actively trying to address this problem by reflecting on how to include different user groups. Active efforts to represent different technologies for tracking animals is critical to ensure that divisions do not persist in animal tracking science. Doing so will benefit animal trackers of all experience levels and ensure that cross-pollination is embraced with all of the benefits that are derived from interdisciplinary and integrated approaches to ecology and conservation (Dick et al. 2016).

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Author contributions

SJC, RJL, JWB, SJI, FGW, JJM, NEH, GTC, BJG, and RH conceived and designed the study. SJC, RJL, JWB, SJI, FGW, JJM, NEH, GTC, BJG, and RH performed the experiments/collected the data. SJC, RJL, JWB, SJI, FGW, JJM, NEH, GTC, BJG, and RH contributed resources. SJC, RJL, JWB, SJI, FGW, JJM, NEH, GTC, BJG, and RH drafted or revised the manuscript.

Competing interests

Steven Cooke is a member of the Editorial Board.

Data availability statement

All relevant data are within the paper.

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