The burden of a failed error culture in biologging

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Abstract

Driven by technological advancements and reduced costs, biologging has seen a rapid growth transforming the study of animal behaviour and ecology providing unprecedented insights into wildlife, aiding conservation efforts and ecological research. However, in the wake of the rapid growth loom pressing ethical and methodological challenges, including a lack of error reporting, inconsistent standards, and insufficient consideration of animal welfare. Here we highlight the urgent need for a robust error culture in biologging to address these issues. We propose four key directions for action: (1) establishing a biologging expert registry to enhance collaboration and knowledge sharing; (2) implementing pre-registration as well as post-reporting of studies and devices to reduce publication bias and improve transparency; (3) demanding industry standards for biologging devices to ensure reliability and minimize harm; and (4) developing educational programs and ethical guidelines tailored to the unique challenges of biologging research. By continuing a more rigorous implementation of a 5R principle —Replace, Reduce, Refine, Responsibility, and Reuse (data)— alongside these initiatives, the biologging community can balance technological progress with ethical responsibility. These measures aim to improve research quality, safeguard animal welfare, and foster a sustainable future for this critical field.

Introduction

The field of animal bio-telemetry, more generally biologging, is growing at an unprecedented rate (Bridge et al., 2011; Wilmers et al., 2015; Ropert-Coudert and R. P. Wilson, 2005). Increasing numbers of animals are equipped with electronic devices, resulting in soaring data volumes and publications (Joo et al., 2022). This success is clearly technology-driven, amplified by plummeting prices for devices and a thriving diversity of commercial and academic suppliers (Cooke et al., 2004). The miniaturization of electronic sensors, increased battery capacities, and lower energy consumption permit smaller, cheaper, and longer-lived devices (Ropert-Coudert and R. P. Wilson, 2005). Technological innovation extends to data transmission networks, from GSM/GPRS and IoT to global satellite-based communication networks, potentially allowing data reception from anywhere, anytime (Elias et al., 2017; Wild et al., 2023).

Engineers' creativity is further fuelled by a continuous supply of novel sensors that can be added to devices deployed on animals, opening up new avenues of research (Wilmers et al., 2015). This serendipitous alignment of circumstances has created a field full of opportunities, accelerating scientific discoveries and giving rise to what has been termed the "golden era" of biologging (Wilmers et al., 2015). The transformative power provided by the ubiquity and affordability of biologging devices seems boundless, offering increasing options for using better technology at lower costs (Kays and Wikelski, 2023). The field of tech-driven animal research in the wild has reached a stage where we believe the time being ripe to question and reflect on how this rapid growth and development can –and should– be achieved sustainably and ethically (Soulsbury et al., 2020; R. P. Wilson and McMahon, 2006; Palmer and Greenhough, 2021).

The Rise of Biologging

Studying animals in their natural environments is essential for understanding the proximate and ultimate mechanisms that defined life on our planet in the most relevant of contexts, and the reason for why biologging, formerly niche, has now arrived in the mainstream (Cooke et al., 2004; Kays and Wikelski, 2023; Wikelski, Kays, et al., 2007). Biologging devices attached to animals provide invaluable and irreplaceable knowledge on animal behaviour, physiology, neurobiology, ecology, and eolution in the wild, among others (A. Wilson et al., 2015; Costa-Pereira et al., 2022; Wikelski, Kays, et al., 2007; Beltran et al., 2025; Hawkes, Fahlman, and Sato, 2021a; Hawkes, Fahlman, and Sato, 2021b; Rattenborg et al., 2016; Vyssotski et al., 2009). Many aspects of biologging research directly relate to global change and the challenges that growing human impact poses to nature and people (Tucker et al., 2018). Without biologging, our ability to protect species in their natural habitat would be severely impaired (A. Wilson et al., 2015). Biologging is not only used for purely scientific purposes, as such data serve to inform decision-makers, decide on the placement of conservation areas, and are a corner stone in monitoring and documenting change and mitigating human-wildlife conflicts, thus considered most effective tool in avoiding animal death, as they provide information on mechanisms leading to population decline (A. Wilson et al., 2015; Morelle et al., 2023; Altizer, Bartel, and Han, 2011; Bengtsson et al., 2016; Yanco et al., 2024; Jetz et al., 2022; Tucker et al., 2018). Addressing these wide range of topics is facilitated through understanding of physiological limits and reaction norms, animals' processing of information at sensory and neurological level, and -in an ecological context- by knowing how, when, and why animals move in relation to the changing environmental conditions (Nathan et al., 2008; Hawkes, Fahlman, and Sato, 2021b; Hawkes, Fahlman, and Sato, 2021a; Rattenborg et al., 2016; Vyssotski et al., 2009). Biologging devices both document and provide unprecedented insights into the behavioural heritage of the natural world linking usto the living planet, where irrespective of affordability, everyone can appreciate the importance of ecological and natural phenomena, the physiological performance animals are capable of, and the impact that they have on us humans and vice-versa (Yanco et al., 2024; Jetz et al., 2022).

The Flip Side of Progress

Often, when choosing which biologging device to deploy, how to capture and handle an animal (particularly when working with new species), or how to attach a device, the decision-making process is largely based on varying amount of acquired previous experience (personal or learned via word-of-mouth) (Houstin et al., 2022; Fijn et al., 2024; Cullen et al., 2023; but see Andrews et al., 2019). Largely, decision and advancements are based on trial and error. This is a consequence of scientists pioneering new research avenues using novel technology on species that have never before been tagged (Beltran et al., 2025; Ropert-Coudert et al., 2009; Andrews et al., 2019).

Increasingly, critical voices are highlighting the ethical and environmental impacts of biologging (Portugal and White, 2022; Longarini et al., 2023; Casper, 2009; R. P. Wilson and McMahon, 2006; Soulsbury et al., 2020; Payne et al., 2024, Palmer and Greenhough, 2021). Since biologging inherently relies on the use of animals to obtain data, ethical considerations must be a core element of the field (Parker and McElligott, 2023; Petkov et al., 2022; Richter et al., 2025). However, the drive for data collection overshadows equally important considerations related to animal welfare.

A recent review of biologging devices' widespread use (Arrondo and Pérez-García, 2025) notes that a majority of animals equipped with biologging devices never contributed to scientific publications, leading to trivializing of the use of biologging devices and the associated burden on animals. The focus on publication output overlooks the potential benefits of biologging in important aspects such as monitoring and management. Arrondo and Pérez-García (2025) emphasize, however, an important and undervalued consideration: what are the expected achievements for the planned use of animals in biologging studies— regardless of the context and purpose of the use of biologging? Ultimately trying to turn back time on the fact that the biologging has long, and irreversibly, become mainstream, is futile; too large are the benefits of the technology.

The main body of the current discourse on ethics on animal use in biologging is focused on refining aspects directly pertaining to the animals' welfare particularly considering ethical approval processes and/or discussing the valuing system where a putative (scientific) outcome is weighed against an imposed burden (Arrondo and Pérez-García, 2025). This momentum in the field happens against the background that the uptake and implementation of a 3Rs principle, the ARRIVE and PREPARE guidelines, which are aimed to improve animal welfare and research quality, has been slower in wildlife research compared to its laboratory counterpart (Lindsjö, Fahlman, and Törnqvist, 2016; Smith et al., 2018; Percie du Sert et al., 2020). This is likely due to a mismatch between the controlled lab conditions that these initiatives have originally been tailored to and proposed for, and the inherent complexity of working in the wild. Extending existing principles to a 5R principle specific to the area of wildlife research using biologging can clearly help reduce animal burden .

The 5R principle would represent an extension to the well-known 3Rs:

- *Replace*: Assess if biologging using animals is essential for answering research questions. Prioritize using existing data through collaboration and permissions before deploying devices on animals. Ensure questions can be reliably answered with the planned number of animals and devices.
- *Reduce*: Minimize animal use by advancing technology, setting device standards, and improving data collection efficiency. Clearly articulate hypotheses and verify methods to use only the necessary number of animals.
- *Refine*: Lower burden on animals by improving device technology and wearability/comfort and enhancing deployment expertise among researchers.
- *Responsibility*: Establish, and uphold ethical accountability throughout research, prioritizing animal welfare and adhering to institutionalised ethical standards.
- *Reuse*: Emphasize data reuse to improve reproducibility, reduce animal burden, and accelerate scientific discovery.

Beyond these important considerations on ethics, and despite the traction biologging has gained in so many aspects of studying animals in the wild, the near-absence of a reporting and error culture is striking. While journals and societies are increasingly more rigorous about the declaration of ethical approvals and publishing detailed description of methodology, failures --in the most generic meaning of where animals had been used but no or inadequate data obtained-- are neither publicly documented, nor requested to be reported (Animal Behaviour, 2020; Ecology, 2021). This focus on success publishing leads to a “file drawer effect" (Csada, James, and Espie, 1996). Failures, when shared and learned from, can increase the return on investment of research –both financially and intellectually, which should be considered an indispensable cornerstone in (wild) animal welfare.

We would like to address and discuss the lack of error and reporting culture from three interconnected perspectives:

- Animal welfare, , with a focus on the elements relevant to the individual animal being used for research.
- Technology, mainly the aspects that rarely have been part of a discourse beyond the effects of weight and shape.
- The human factor, in relation to largely neglected foundational aspects of the cultural and professional standards in pursuing biologging research.

Based on a non-representative and personal assessment of the status-quo in these three areas, we would like to propose four action items that could tackle the challenges of a sustainable and ethical growth of the biologging field.

Animal welfare

All biologging researchers are more or less intimately familiar with the more difficult realities of our work, as we have injured or lost animals and/or know of colleagues who have. Yet reports or publications of failure very rarely surface in the field (but see Crofoot et al., 2009; Houstin et al., 2022; Fijn et al., 2024). Mostly it is through hearsay or because we have witnessed the loss or harm to animals ourselves. Clearly, everyone’s top priority in the field is and should be the welfare of their study animals. But owing to the trial and error based nature of acquiring experience and improving procedures, combined with the lack of transparent reporting of (negative) experiences in publications and communication between different researchers, mistakes are made due to ‘ ‘reinventions of the wheel’ ’. As mistakes happen and lessons are being individually learned, the community is not invoking the full potential due to a largely absent culture of openly sharing experiences, or even seriously demand for, and engage in, systematic reporting (Christensen and Fantuzzi, 2024; Lameris and Kleyheeg, 2017; Payne et al., 2024; MacCallum, 2010).

Biologging studies begin with capture and immobilisation of animals, marking the beginning of animal burdening. Occasionally, animals succumb to handling stress,– referred to as capture myopathy– a diagnosis essentially for a malignant outcome of stress through handling (animals) with a lethal outcome (Breed et al., 2019). Hence, any biologging research begins with burdening animals through capture and continue by the deployment of biologging devices which themselves inflict a multitude of documented consequences on their survival (Lameris, Müskens, et al., 2018), social behaviour (Lameris and Kleyheeg, 2017), reproduction (Barron, Brawn, and Weatherhead, 2010), and energy expenditure (Kyte et al., 2019; Barron, Brawn, and Weatherhead, 2010) to name a few. As proposed by the various existing publications and initiatives, biologging should attempt to reduce its impact, for the sake of the individual animals' welfare, foremost as a moral obligation towards every living being (Soulsbury et al., 2020; Petkov et al., 2022) but also to minimize bias on the data and the insight gained from them. Reporting on the entirety of the process from capture through immobilisation, and device attachment, all of which are specific to the species, is currently neither common nor required, particularly when it comes to reporting on negative outcomes. It is crucial to consider the lifestyle of the animal in the context of the technology used even beyond the time of data collection. A lack of consideration of the impact of biologging devices on all aspects of an animal’ s behaviour can lead to harm and discomfort for the animal, but also limit the generalizability and reproducibility of findings because the device itself altered or hindered the animal's normal lifestyle and social interactions. In cheetahs, for example, it was found that while a 3% device to body mass ratio had little impact on a stationary animal, quick acceleration during hunting amounted to forces up to 54% of the body mass exerted on the animal (R.P. Wilson, Rose, et al., 2021). Furthermore, these impacts could have cascading, multifarious, impacts on other species down the food-chain if for instance hunting success is affected. finally, a further consideration would be the impacts of biologging on non-research-target individuals and species– whether through trap by-catch (Hotopp et al., 2022) or through indirect negative welfare effects after capture and release (Soulsbury et al., 2020).

Technology

Another almost accepted aspect of working with biologging devices in the wild is that a certain, sometimes substantial proportion of the devices deployed on animals will never deliver actual data. While researchers embark on expensive expeditions, work under potentially dangerous conditions to catch and equip animals with impactful devices, not seldom these devices yield little or much less required data than needed to answer the scientific questions. There are endless intangible stories of epic tech failure that are shared orally among researchers, about devices stopping to work after being deployed on animals, release mechanisms not working at all or at the wrong times, firmware errors leading to useless data, attachments failing, sensors drifting with time and deteriorating, and animals getting trapped in their own biologging attachments (just to name a few). These device failures mark a unnecessary harm to the animals and a complete loss and waste of research efforts. For years, and still to this day, we think, biologging devices had and have to be considered experimental electronic devices with no liability or guarantee to work as advertised regardless of the promises of the vendors. In fact, under the pressure for high impact publications, often it seems that research is driven rather by pushing technological boundaries, than by answering fundamental biological questions. Due to the lack of reporting, there is no objective, independent or quantitative prediction of how well devices perform despite existing methodologies aimed to do precisely that (Bidder et al., 2014). The diverse companies and workshops catering to biologging, the rapid development cycles, varied deployment conditions and taxa, as well as the individual field biologists' input create a noisy backdrop making it nearly impossible to objectively assess device reliability and acceptable failure rates.

Although some companies refund the price of failing tags, there is no recompensation of the expenses that a failed expedition, due to tech failure, entails, with no way of compensation for the animals burdened with dead weight or the environment for the pollution with electronic waste. The worst outcome of failing technology can include sacrificing animals to prevent further suffering (see e.g. https://www.swissinfo.ch/eng/sci-tech/deer-study-goes-awry/36812992).

The human aspect

Surely, with the development of ever more sophisticated devices, there has been a steep learning curve. In the time preceding the wide availability of commercial collars, we had to often rely on Do-It-Yourself and experimental engineering to push the boundaries. We were, are, and will continue to be, in uncharted territories– trying, failing, and learning from our mistakes. However, as the field of tech-driven animal research matures and grows, it is time to reflect on how the biologging community can initiate a more systemic and systematic approach to error culture when it comes to the dissemination of knowledge and state-of-the-art in attaching tech to animals. Most researchers, rather than through standardised curricula, learnt tagging through informal apprenticeships under experienced mentors, complemented by individual study of publications, refined with individually acquired experience from the field. As a consequence, there is diversity in the ways field work is pursued, a variation that could represent a fertile ground for evolving better procedures and improve, if there was a reproducible and quantitative approach to speaking about the art of catching and handling animals, best practices in using devices, and making wildlife wearables better.

Towards a (better) Error Culture

As biologging technology is indispensable its use will continue to grow and thus the necessity to consider the path of progression. No one is in a better position to propose improvements than the biologging community itself. If we do not attempt to improve, one day rules and regulatory measures might be imposed both formally, through legal means, and informally through public admonishment– and not necessarily driven by optimizing the balance between welfare and research necessity. Our freedom in what we do comes with a responsibility which we must begin to shoulder more seriously.

Four action items

As a community we still must acknowledge untapped potential for improvement: the endorsement of an error culture that holistically improves our research by establishing better communication and exchange tools to maximize our ability to improve (Figure 1).

« Insert Figure 1 about here »

We acknowledge that publishing our failures, or even an external auditing procedure in case of failures, are unlikely or infeasible to implement in the short run, albeit in the interest of our field's progress. However, we suggest clear improvements to the current DADT (don't ask, don't tell), "elephant in the room" status-quo.

For one, a biologging experts registry could be a major step (Figure 2), which combined with, second, a request for pre-registration, results (post-) reporting, and publication bias reporting (Figure 3) would clearly enhance our knowledge pool and allow us to overcome the current complete absence of an error culture (Nosek et al., 2018). These two most important measures would provide the basis for a quantitative assessment based on which we could define success and navigate a path towards avoiding to commit to more failures (see also the fourth proposal). A third pivotal action item is a demand for industry standards from device manufacturers (Figure 4). Fourth, and finally, we need to conceive an educational and training programme tailored to the demands and required skills that biologging specifically poses towards the researchers, including how we collaborate and interact (Figure 5). That will require targeted research into animal welfare tailored to the research of wild animals — providing the academic backdrop that an educational training programme would need.

A Biologging Expert Registry

One immediately feasible option that could improve communication in our growing community would be a registry of biologging experts (Figure 2) cross-linked to various existing or emerging repositories and databases through individual identifiers like ORCID. A registry could serve as a point of contact for other researchers and as a reference for ethics committees and help propagate relevant information efficiently and provide ethical and legal entities a reference to the experience and contemporary continued education on relevant matters of animal experimentation and ethics. This registry could be managed by the international biologging society (BLS), the Animal Behavior Society (ABS), or the Association for the Study of Animal Behaviour (ASAB). The registry could archive relevant information about biologists and veterinarians conducting and involved in biologging research and their field of expertise (species, tagging methods, devices experience etc.). Taking in consideration privacy rights, individuals could be identified and contacted by peers to foster the exchange of expertise concerning methods (capture, handling, marking, biologging implantations, anaesthesia, etc.) and materials (devices, harnesses).

Pertaining to international field work, such a linked registry could help to identify relevant experts across national boundaries and different regulation schemes. Such a registry would inform about the type of field actions and methods such as capture, handling, marking, invasive and non-invasive technology and attachment methods, anaesthesia, and experience with working in specific field sites that they have worked at. This registry could be linked to the tag/device registry (Rutz, 2022) allowing to know who has used which kinds of hardware, and to share experience and expertise. Likewise, the unique animal identifiers of handled animals could be crossreferenced (Wikelski, Quetting, et al., 2024), allowing researchers to follow up on events associated with specific individual animals, including the roles that bio-loggers played in their lives. Ideally, the registry would also cross-reference to the studies that have emerged from the activities a person was involved in, regardless of whether they were named authors or not (in addition to listing publications or referencing ORCID-iDs), including re-use of data they contributed to by consortial and comparative initiatives increasing visibility and ownership beyond the role of co-authorship. This would require the registry to accommodate adding publications to the profiles other than author roles, for example data contributor, technical assistance, paid assistance, veterniary oversight, and other forms of contribution to animal based studies.

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Pre-registration of biologging devices and animal use

The problem of biased positive reports and unreported failures is that it takes far too long for the field to react to singular, yet important discoveries which request a change in procedures to penetrate the field quickly. This is similar to the “file drawer effect", (Csada, James, and Espie, 1996) where a bias towards desired outcomes leads to a publication of false positives and faulty science (Smaldino and McElreath, 2016). However in this case, the negative externality is the welfare of animal research subjects as well as the well-being and time of researchers. Since new biologging studies tend to follow published methodologies, it is almost inevitable that positive reporting bias will manifest in suboptimal, or even outright detrimental, procedures for a long time despite better knowledge existing. It will also be very hard to impossible to purge knowledge deemed or proven as detrimental from the knowledge base. The publication bias against negative results also means that experiments and procedures get repeated many times with no prospect of success.

As with the file drawer effect, the only solution is collective action and institutional change (Smaldino and McElreath, 2016; Kohrt et al., 2023). We should continue to systematically question what we do and how we do things, instead of just following the trodden paths of days past (Figure 3) and aim to move from copying historic and possibly highly problematic yet published methodologies to a system that follows the most recent quantitative and peer reviewed assessment of procedures. Adopting a reporting system that allows standardised and systematic reporting particularly of negative results is of central importance. With the advent of large language models, there are new possibilities for quantitative analysis of narrative reports and data aggregation, which could provide a tremendous opportunity. Storing narratives about field events from capture over handling to deployment, even including images and videos of tech and all the circumstantial experiences when attaching devices to animals, however irrelevant and small they might have seemed at the time, could be summarized and quantified efficiently, across languages and media.

One of the fundamental steps taken to improve drug discovery clearly is the FDA imposed registration, results reporting, and publication bias of clinical trials (FDAAA: The Food and Drug Administration Amendments Act, Zou et al., 2018). Introducing this measure led to a marked improvement in virtually all aspects of drug discovery improving the ratio between trials and successful discoveries saving money and leading to better treatments. Likewise a pre-registration of biologging devices (for example for GPS position logging devices in combination with the suggested tag-registry) requiring researchers to published the intended use of biologging devices on animals would provide the opportunity for the relevant researchers to invoke synergies. A mandate on following up on the preregistered devices after deployment would allow to improve performance by quantitatively assessing success to failure ratio. We would also learn about the bias that is introduced by failing to publish negative results. Such a registry could also actively suggest links between technology, targeted taxa, attachment methods, researchers and possibly more metadata without disclosing raw data.

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Demanding industry standards

As a community we should define what our acceptable ratio between the burden on animals and the volume as well as the quality of the data obtained is, and refrain from buying cheap and likely to fail, or quickly to deteriorate, technology. It is not acceptable (and in the European Union unlawful) to do a simple economic calculation weighing low unit price for accepting high failure rates or inadequate data; the wellbeing of the animals we handle is a currency that is too-often ignored. The biologging community should demand that industry defines standards and imposes external auditing and certification for devices brought to the market, a measure that could enhance accountability (Figure 4). providers of devices catering to the wide community representing off-shelf and market established units that can be bought and deployed currently with little to no oversight should self-impose industry standards, certification and registration.

Technological advancements can reduce the burden dramatically and have done so in remarkable ways (Bograd et al., 2010; Williams et al., 2020). The reduction in size, weight and increased reliability of devices are responsible for the surge in biologging research activity. By further improving device to animal mass ratio and by adjusting their shape and size, new devices have yielded new opportunities that were unimaginable a decade ago. Interestingly, however, the miniaturization of biologging devices has not resulted in a decreased device to body mass ratio borne by animals, a measure that quite arbitrarily is set at a maximum of 5% (for terrestrial) or 3% (for birds) respectively representing the maximum device to animal mass ratio (Meierhofer et al., 2024; R. P. Wilson, Rose, et al., 2021). Instead, as a community we have invested the technological advances in equipping ever smaller species (Portugal and White, 2018) keeping the burden steady. . We could certainly do better and rein in our greed for data which is paid for by heavier than necessary devices due to additional sensors and/or larger batteries for longer deployments while keeping religiously to weight thresholds. The relative weight ratio is not even considering the potential improvements that could be achieved by harnessing the effects of shape, form, placement and refinement of attachment method in interaction with the species' specific mode of movement and the media it moves through (Kay et al., 2019; Mizrahy-Rewald et al., 2023; Longarini et al., 2023).

However, as we will continue to rely on experimental technology to achieve groundbreaking research, we should expect even experimental and pilot-devices to meet certain baseline published and agreed upon standards and procedures before being considered fit for deployment. Strictly speaking, testing devices on any animal has to be considered an animal experiment requiring the same level of ethical approval as biological research projects do. Ratings, or labels, indicating different levels of "quality" would help distinguish between experimental and established devices with clear requirements that have to be met and come with liability in cases of failure or malfunction.

Although requesting standards will increase unit costs, the benefits and positive externalities to animals, researchers, funding sources, and research quality will justify the investment and possibly even lead to lower per datum expenses when the full-cost of the research life cycle is accounted for– both environmentally and economically. Standardization would also level the industry playing field by preventing price-based competition between the tech providers that compromises diligence in craftsmanship and testing at the cost of animal welfare and research quality. Demanding standards from the industry will additionally give justification and credibility to the permitting authorities and ethical commissions assessing the research proposals to enforce the use of devices considered and certified as fit for purpose. By engaging in pre- and post- reporting, a more realistic and quantitative assessment of the percentage of devices that can be expected to provide data given the proposed procedures and species involved could be empirically estimated weighing the risks against the realistically expectable reward based on methods such as BET (the Biotelemetry Event Tree; Bidder et al., 2014).

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Educational programmes and defining ethical standards for our field

As the field and subsequently the number of researchers deploying devices grows, we have to define and formalize the qualifications, training and skills required to be considered a biologging expert (Figure 5). To our knowledge, there is no curriculum or institutionally defined education programme that addresses the art of animal wearables and how best to deploy devices to animals and what the consequences of using alternative methods are. Just as laboratory animal science systematizes the standards involving care, housing, feeding, and medical treatment of laboratory animals, we should aspire to establish systematic research to quantify the impact of studying wild animals and subsequently define and refine education programmes from a holistic perspective (Forni, 2007; Erichsen and Hopla, 2021). If biologging, as Beaulieu and Masilkova (2024) suggested, was to place the study of welfare of wild animals more at its centre, it would not only advance understanding the external factors, such as human disturbance affecting wild animal welfare, but potentially lay the groundwork for a more institutionalized, systematic, and evidence-based approach, extending to a self-reflection of how biologgings affects wild animal welfare. Refinements in relation to deploying biologging devices on animals – more specifically the wildlife biologists' or veterinarians' experience and expertise and continued improvements in attaching devices to animals– are a crucial aspect that affect data quality and quantity. An educational programme would also establish the culture of pre-registration and post-reporting as an integral part of the responsibility that that are expected biologging experts and which provide the quantitative basis for progress. Ultimately we should aim to challenge old habits and increase the pace of improvements in handling and studying wild animals, which could be much improved, if it was evidence-based, academically organised, quantitatively assessed and formally developed. Some current legislation, and the way authorities interpret them, makes training scholars formally in handling and deploying biologging devices as part of ongoing research in the wild very difficult. But at the same time, mandated courses aimed at acquiring skills and knowledge are currently mostly on laboratory animals (mice and rats) or other taxa that have little relevance for a specific research project, but accepted qualifications for being permitted of catching, handling and deploying devices on wild animals.

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Regulatory suggestions

With the growth of the field, the existing reporting procedures and trainings mainly geared towards working with laboratory animals as well as the mandated qualifications that allow researchers to conduct animal experiments in laboratories and animal housing facilities, are creating an increasing mismatch between the true requirements of the biologging field. The legal and formal procedures, while well meant, are becoming an obstacle that need to be addressed. The ethical applications, the pre-registration, and post-reporting procedures, and administrative forms and legal documents should be bespoke to the requirements of this meanwhile matured field to serve the purpose of improving the welfare and quality of research specifically for the tech-driven study of wild animals. Defining these procedures will also prevent competition nurtured by different levels of national requirements that may incentivise the field to move into studying in certain places based on the administrative load (or the lack thereof) on the researchers and their budgets rather than more reasonable objectives. In laboratory animal welfare, the same considerations have given rise to elevating the original 3R principle to the principle of 4Rs with an emphasis on cultivating the moral responsibility that working with animals entails globally (Kang et al., 2022) (see also Box 1).

That the Federation of European Laboratory Animal Science Associations (FELASA) explicitly considers sample sizes an important aspect of animal experiments should require, in some way, quantification on the ratio between animals burdened and realistic estimations of data obtained (Bidder et al., 2014). By the time tech failures and the above mentioned other sources of failure accumulated, the percentage of success in terms of data obtained per individual burdened can drop dramatically. Besides reporting successes and failures, the description of attachment method and procedures, materials used, and the duration of handling should all be catalogued and reported as part of the crucial metadata along with the raw data. This should be part of a reproducible science approach, as it fundamentally affects the quality and volume of the data with implications on cross-comparability of study results.

Ultimately, the proposed four action items could be embedded in the existing landscape of data bases, where data, people, devices, and industry can be better connected with the help of intelligent and intuitive software solutions and use of AI. Eventually, data collected on individual animals could be linked to their histories based on their unique animal ID (Wikelski, Quetting, et al., 2024) and linked to researchers, studies, and devices (Rutz, 2022) all of which have associated meta information.

Conclusions

As the field of animal biologging continues to grow and evolve, it will be crucial to establish a robust error culture; one which fosters open communication about failures, and prioritizes animal welfare. Thus, technological advancements can translate into ethical and effective scientific progress. The proposed action items, including the biologging expert registry, standardization efforts, and adoption of the bespoke 5R principle, represent suggestions for crucial steps towards a more responsible, inclusive, and transparent research community. The aim of burdening animals with biologging devices should be to deliver data that are reliable and possibly definitive. The replication crisis (Kelly, 2019; Yang et al., 2024), makes ethical considerations directly related to the scientific ambitions of the biologging field. Due to the logistical challenges and costs associated with tagging and tracking animals, we often face challenges with statistical power and/or robust experimental design (Yang et al., 2024); challenges that are shared among the field of ecology and evolution (Kelly, 2019; Yang et al., 2024). But, as outlined in Yang et al. (2024) and Nakagawa et al. (2024) small studies can still be valuable if we prioritize transparent reporting of all results, including effect sizes and confidence intervals, regardless of whether they are positive or negative. Actions that would counter-argue the trivialisation accusation (Arrondo and Pérez-García, 2025). We need to emphasize theoretically informed, well-designed studies over mere statistical significance and encourage the publication of all findings to combat the file-drawer effect (Smaldino and McElreath, 2016; Smaldino, Turner, and Contreras Kallens, 2019; Stewart and Plotkin, 2021).

By investing in an error culture, we can facilitate more comprehensive meta-analyses that aggregate data from multiple (also small-scale and possibly unpublished) studies, thereby increasing statistical power and enhancing the replicability of our findings without further use of animals (Yang et al., 2024). The biologging field would greatly benefit from embracing open science practices increasing its credibility. Transparent reporting protocols, pre-registering studies, utilizing registered reports, archiving data and code, and importantly establishing a solid educational, ethical research based foundation for the use of animals in our field are steps we consider important. How we do our research remains something that we as a community should decide on together; the four action items representing points and topics that we could start considering and talking about.

Establishing an error-culture has to be a community driven and democratic process balancing the costs and benefits considering the wide range of the field that biologging is serving. The community should strive to reduce questionable research practices, detrimental competition and misguided incentives. Naturally, achieving these goals comes with allocating worthwhile resources, mainly time but also money, into activities yielding long term benefits to the field elevating quality over quantity at the cost of not being able to publish as many papers in as little time as possible. There simply is no option for reaping benefits without committing to carrying the costs.

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Ethical Note

This commentary does not report new empirical research involving animals. Instead, it discusses ethical and methodological issues in the field of biologging and animal behaviour research, with a particular focus on animal welfare and responsible research practices.

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Conflict of interest

All authors are actively engaged in research involving the deployment of biologging devices on wild animals and have a professional interest in this field. While they are committed to ethical standards and objective reporting, their involvement in this area may be perceived as a potential conflict of interest, which should be fully disclosed here for transparency

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Captions

Figure 1: A suggested comprehensive approach to ethical and effective animal biologging practices, emphasizing animal welfare as the central priority. Harmonious integration of human expertise and technological advancements can enhance animal welfare while collecting valuable telemetry data. Specifically, a biologging expert should be equipped with certified continuous training and committed to transparent and systematic reporting. Tag devices should meet industrial standards and be continuously improved. The combination of the human and technology aspects alleviates the burden on animals and provides reliable insights crucial for science and its applications, while supporting further technological innovations through precise sensor measurements. Existing and proposed infrastructures support the application of the suggested framework. Platforms and databases, are assisted by the hereby proposed registries of biologging experts and devices, along with pre-registration of studies and complete reports. Colour coding used throughout this and subsequent figures is the following: green is animal use and welfare, red represents human aspects, blue represents technology and telemetry devices, purple represents industrial standards, orange represents biologging training, and yellow represents infrastructures.

Figure 2: Suggestion for a potential biologging expert registry. Each expert's profile includes their personal information, such as education path, résumé/CV, and ORCID profile. Each expert's experience with study species and tags is documented, with links to the proposed tag/device registry, along with cross-references to unique IDs for tagged animals, relevant databases, and resulting publications and data repositories. The registry: 1. details the expert's experience in specific handling/attachment methods, including continuous training records, 2. contains pre-registrations of animal studies, transparent reports, and the associated ethical approvals and 3. aims to facilitate communication and feedback within the global biologging community.

Figure 3: A pre-registration and post-reporting registry, both at the device and animal use level. Only devices meeting quality certification standards required by industry regulations are included.

Each device is connected to documentation of pre-deployment tests, detailed attachment procedures and post-deployment reports. For each device, the registry includes the biologging expert identity and the animal species it has been applied to, along with detailed handling methods. Each pre-registered study is also cross-linked to unique IDs for tagged animals, relevant databases, and resulting publications and data repositories. Complete field notes are incorporated, including records of negative outcomes, such as device failures or animal losses in the field. The proposed registry is naturally integrated with the biologging expert and device registry, as it aims to facilitate communication and feedback within the global biologging community.

Figure 4: Suggested industry standards for biologging device production. To be included in the biologging device registry, tags must have certifications of standardized quality and testing, validated by external neutral companies, and ethical approvals for animal use. Manufacturers must collaborate with other industries and the community of biologging experts, reporting how feedback and shared experiences have been applied to improve technology and reduce animal burden.

Figure 5: Our suggested educational programme for biologging experts. Comprehensive training integrates technological expertise with hands-on experience, it is therefore closely linked to both the biologging expert and device registries. The programme includes collaborative lessons and workshops among specialists in similar study systems, facilitating the exchange of species-specific knowledge, handling methods, and different device applications. A robust theoretical foundation is given through educational materials and documented field notes, equipping researchers with the tools for efficient and ethical biologging practices.

Figure 1:

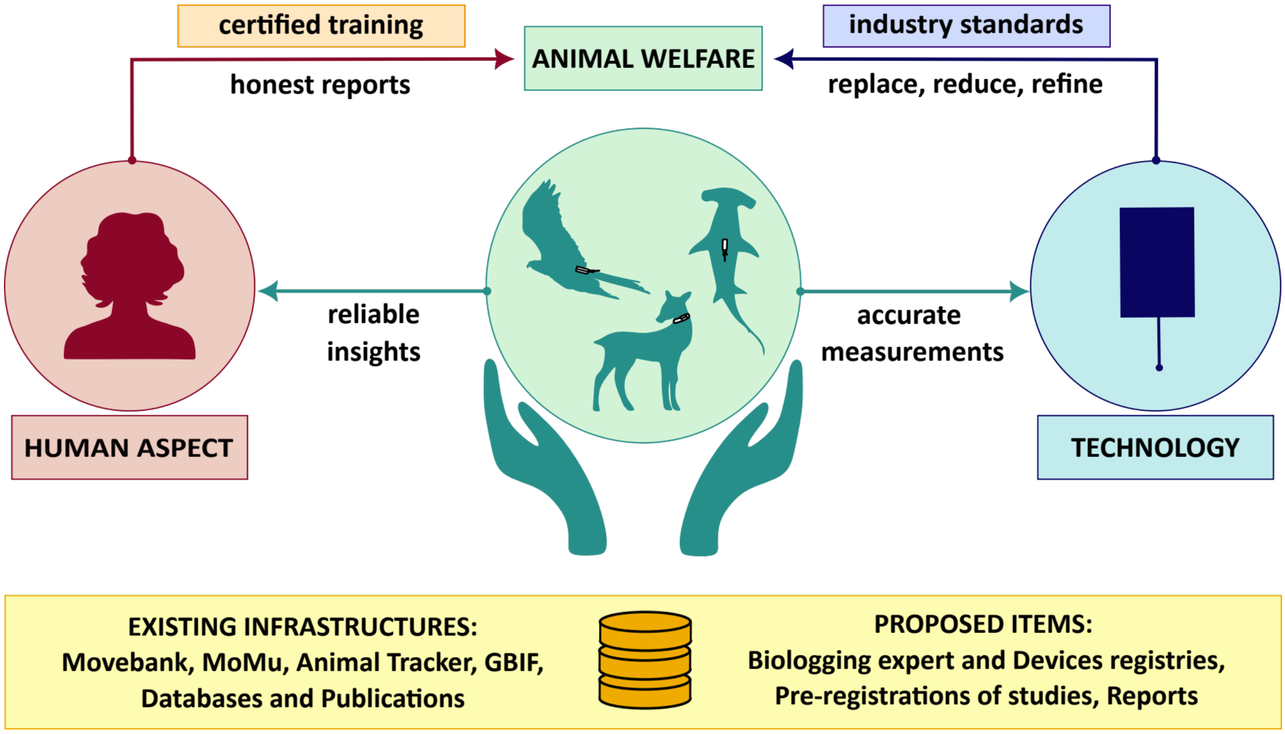

certified training
honest reports
ANIMAL WELFARE
industry standards
replace, reduce, refine
reliable insights
accurate measurements
HUMAN ASPECT
TECHNOLOGY
EXISTING INFRASTRUCTURES:
Movebank, MoMu, Animal Tracker, GBIF,
Databases and Publications
PROPOSED ITEMS:
Biologging expert and Devices registries,
Pre-registrations of studies, Reports

Figure 2:

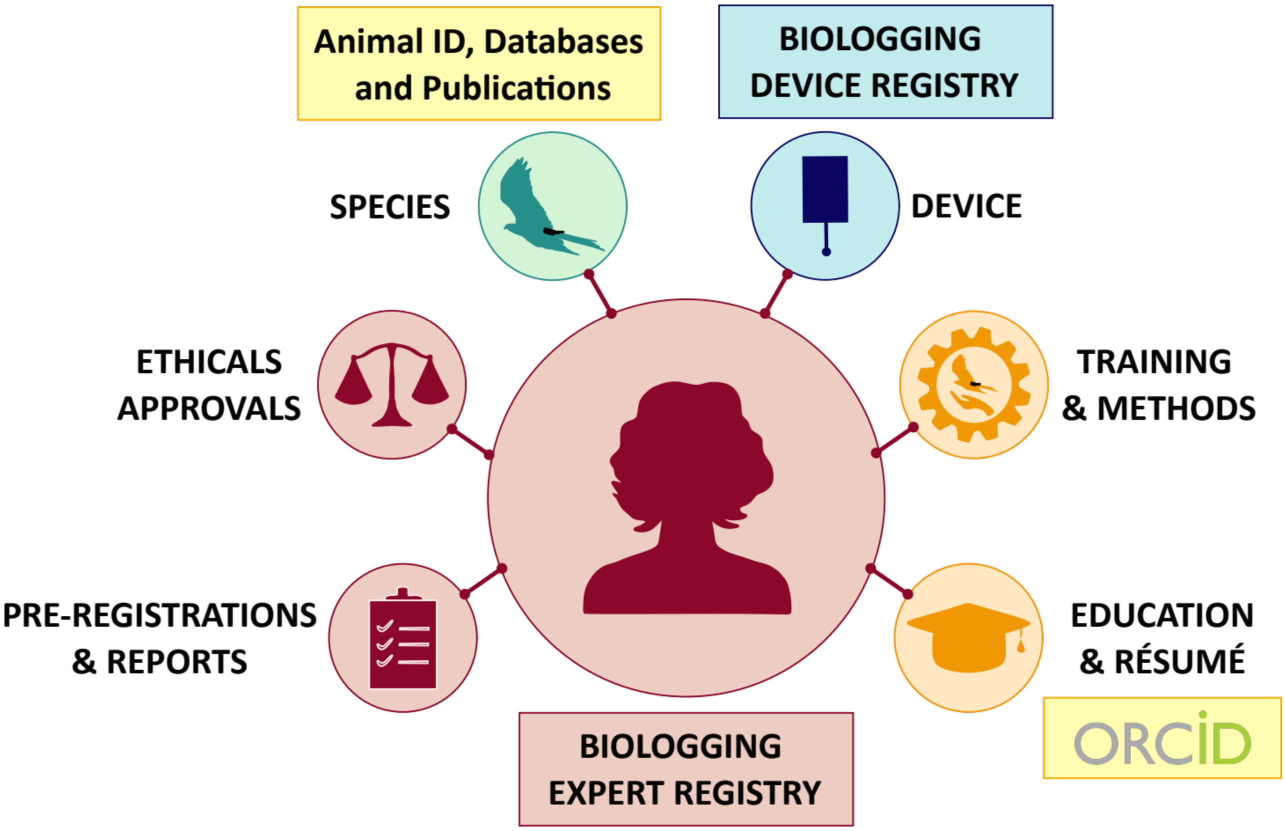

Animal ID, Databases and Publications
BIOLOGGING DEVICE REGISTRY
SPECIES
DEVICE
ETHICALS APPROVALS
TRAINING & METHODS
PRE-REGISTRATIONS & REPORTS
EDUCATION & RÉSUMÉ
ORCID
BIOLOGGING EXPERT REGISTRY

Figure 3:

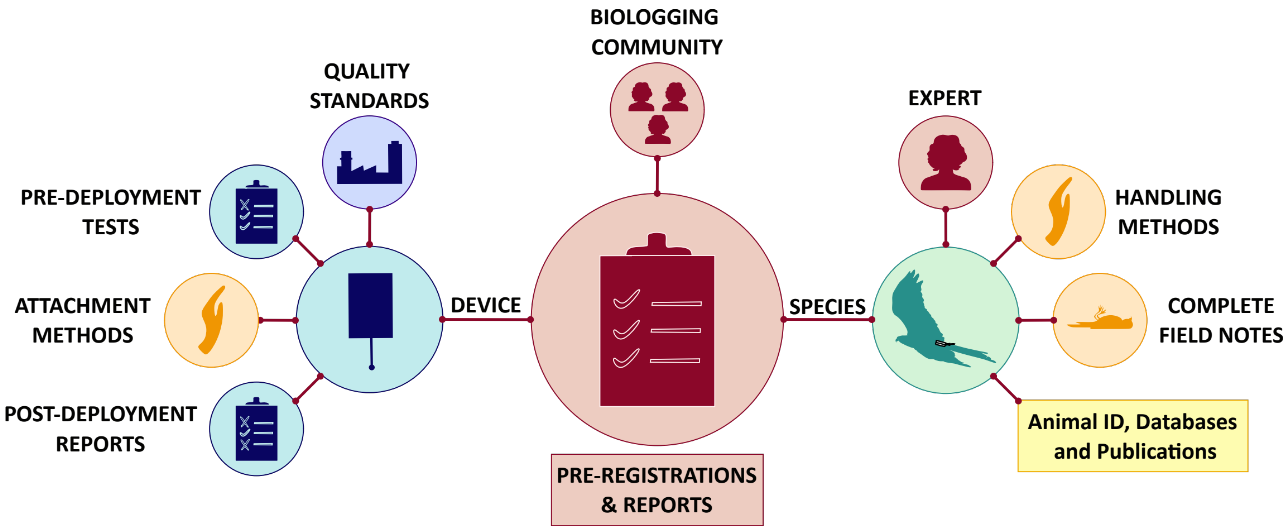

BIOLOGGING COMMUNITY
QUALITY STANDARDS
EXPERT
PRE-DEPLOYMENT TESTS
HANDLING METHODS
ATTACHMENT METHODS
DEVICE
SPECIES
COMPLETE FIELD NOTES
POST-DEPLOYMENT REPORTS
Animal ID, Databases and Publications
PRE-REGISTRATIONS & REPORTS

Figure 4:

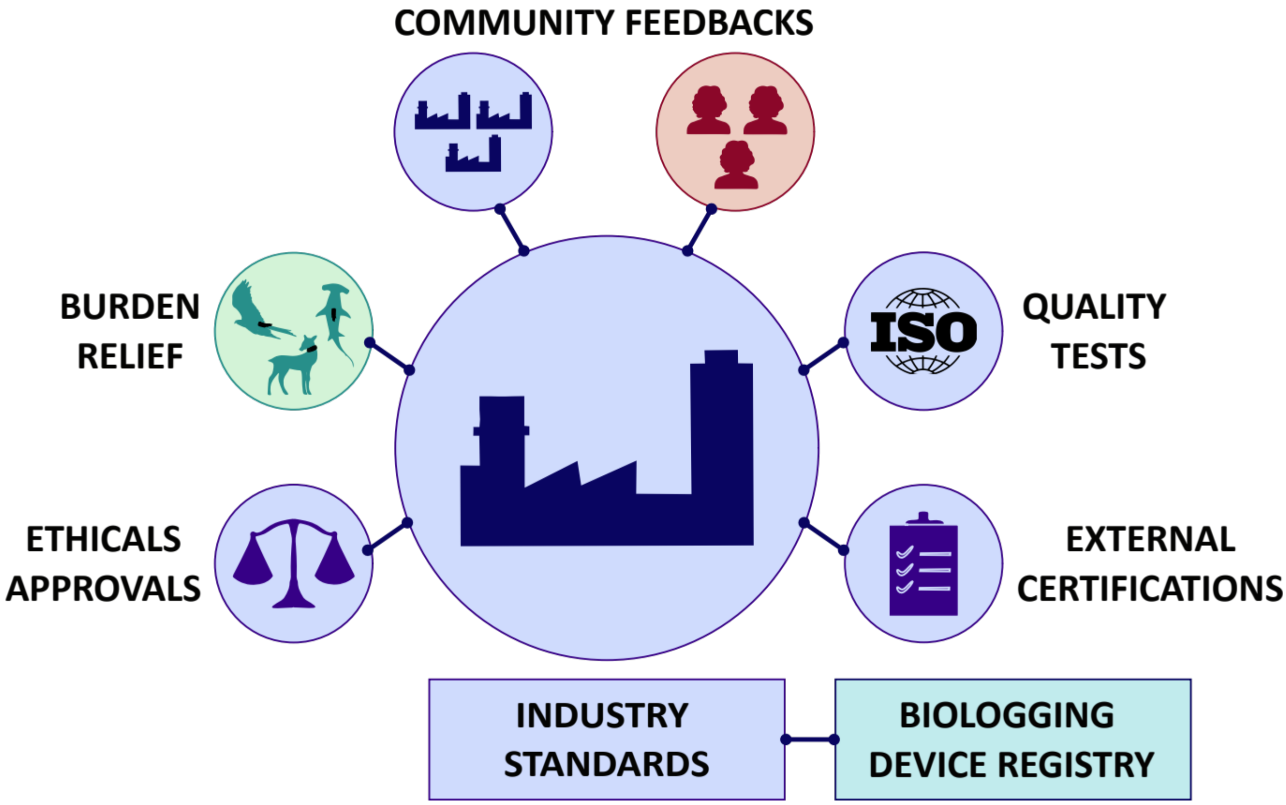
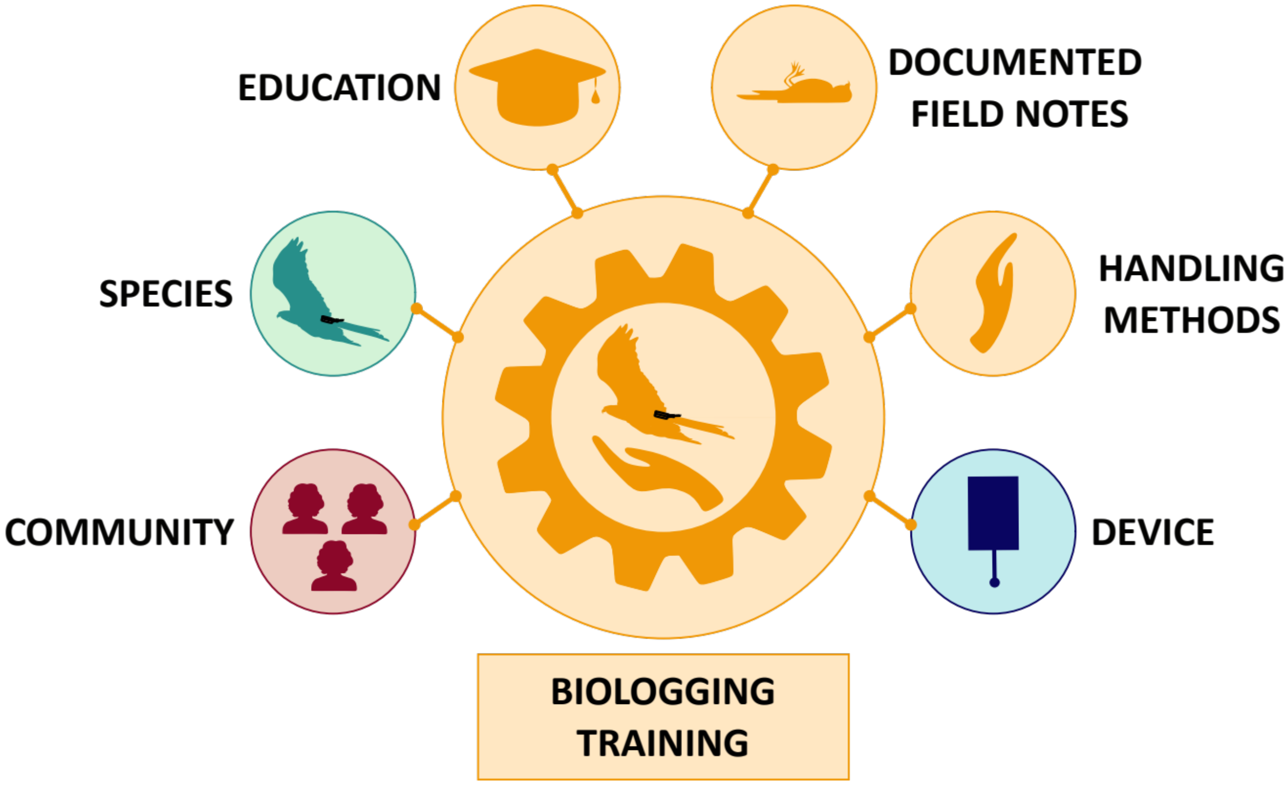

COMMUNITY FEEDBACKS
BURDEN RELIEF
QUALITY TESTS
ISO
ETHICALS APPROVALS
EXTERNAL CERTIFICATIONS
INDUSTRY STANDARDS
BIOLOGGING DEVICE REGISTRY

Figure 5:


EDUCATION
DOCUMENTED FIELD NOTES
SPECIES
HANDLING METHODS
COMMUNITY
DEVICE
BIOLOGGING TRAINING