Paper:

Fehlmann, G. & King, A. (2016). Bio-logging. *Current Biology, 26*(18), R830-R831.
http://dx.doi.org/10.1016/j.cub.2016.05.033

Quick guide

Bio-logging

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Bio-what?

Bio-logging! Bio-logging refers to a device — a bio-logger — attached to an animal, either directly or mounted on a collar or harness, or even implanted in the animal, that provides data about the animal's movement, behaviour, or physiology (Figure 1). Bio-loggers are also increasingly used to collect data that focus on the animal's environment rather than on the animal itself; the animal acts as a bio-monitor, with attached loggers gathering data as the animal moves within (and reacts to) its environment. The data generated by bio-loggers can be saved onto on-board memory for later retrieval, relayed to remote receivers carried by people or positioned at key locations, or uploaded to satellites, sometimes even using the Global System for Mobile communications to receive the latest location of your tagged individual by SMS to mobile devices.

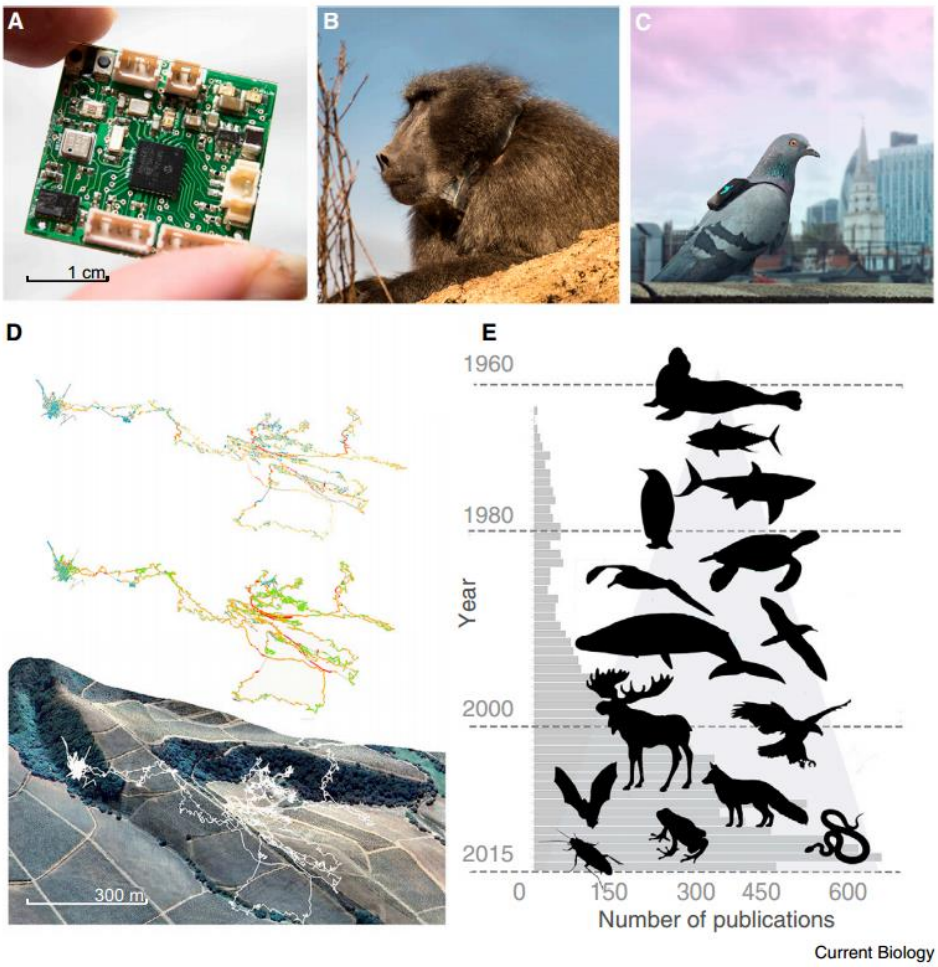

Figure 1. The diversifi cation of research opportunities through bio-logging. (A) 'Daily Diary' device (http://www.wildbyte-technologies.com/), a multi-channel bio-logger that comprises tri-axial accelerometer, tri-axial magnetometer, barometric pressure sensor, light dependent resistor, and depth sensor (image: G. Fehlmann). (B) Collar fitted to a male chacma baboon (*Papio ursinus*) in

South Africa (image: G. Fehlmann). The collar is designed by the authors and houses a Daily Diary and GiPSy 4 micro GPS data-logger (http://www.technosmart.eu). (C) Animals as bio-monitors: birds can make good bio-monitors for pollution, and initiatives like Pigeon Air Patrol (http://pigeonairpatrol.com) use homing pigeons to monitor air pollution in the cities where they live (image courtesy of DigitasLBi). For a similar concept, see http://www.gallinazoavisa.pe/ using vultures to identify illegal waste-dumping hotspots. (D) Daily movement of the baboon shown in (B) at the edge of the City of Cape Town. His movement is shown in white (recorded at 1 Hz GPS), and this has been combined with accelerometer data recorded at 40 Hz to provide an indication of position and behaviour on the middle track (blue = resting; green = foraging; orange = walking; red = running) and activity level (from blue for low energy activity to red for high energy activity). (E) The 'bio-logging boom'. With the miniaturisation of devices and the diversification of sensors, bio-logging is represented in a growing number of publications (search term "bio-logging and biotelemetry" in Web of Science for biology-related subjects on 06/04/2015).

How did bio-logging start?

Since the early 1900s, marking techniques, such as bird ringing, have provided information on survival rates of animals and information about their movements. However, for devices to record data, the scientifi c community had to wait until the second half of the century. In 1964, Gerald Kooyman fi tted Weddel seals (Leptonychotes wedelii) with devices that recorded depth against time on a smoked glass disc. Since then, the development of new technologies, such as Global Positioning Systems (GPS), which started in 1995, and subsequent miniaturisation of these technologies have allowed researchers unprecedented insight into the behaviour and ecology of a variety of species. The greatest scientific impact has been in studies of marine mammals and birds where direct observation is diffi cult or impossible.

What have we learned from bio-logging?

A lot! In the 5th Bio-logging symposium held in Strasbourg in 2014, around 90% of the work presented involved birds or marine animals, mainly focusing on space use applications, but the range of species and contexts in which bio-logging is being used continues to grow. Nowadays, bio-loggers are being deployed on insects as small as cockroaches and mammals as big as blue whales and provide all sorts of data. For example, combining GPS (animal position) and acceleration (animal motion) have allowed us to quantify the incredible maneuverability of wild cheetahs pursuing prey, or the aerodynamic interactions of flocking birds.

What are the main challenges when attaching bio-loggers?

A prime concern is animal welfare, which is paramount in bio-logging studies and should be considered at every stage of research, from animal capture and handling to device attachment and retrieval. It is also crucial to quantify the short- and long-term consequences of bio-logging for study animals. Depending on species and context, considerations will differ, but considering the size and shape of the bio-logger is critical. Regarding weight for instance, the rule of thumb is that any bio-logger and the paraphernalia used to attach it to an animal should weigh no more than 2–5% of the animal's total body weight. But loggers must also not significantly impact on the animal's interaction with conspecifics (e.g. colourful loggers may alter interaction dynamics) or heterospecifics (e.g. individuals with loggers could become more conspicuous to a potential predator). A famous example of such negative effects comes from work with king penguins (*Aptenodytes patagonicus*), where a research team showed that attached flipper bands led to lower survival and reproduction over a 10-year period. Harnesses or collars are the most commonly used methods to attach bio-logging devices to animals. But when researchers are using loggers to track movement, they must consider how the motion of a logger housed in a collar or harness relates to the motion of the animal under investigation. Imagine we wanted to record a person's commute to work on a bicycle with an accelerometer. Depending on where we fitted the device (e.g. the knee or head of the rider, or the wheel or seat of the bicycle) it would return a very different signal. The differences that arise from logger location become paramount when studying animals' posture or activity levels, for instance.

‘Glued on’ loggers provide an advantage in this respect, providing more accurate data. Furthermore, directly attaching loggers to an animal’s exoskeleton, skin, hair, feathers, fur, wool, or antlers which shed or moult is also a simple and elegant way to retrieve the data as researchers just have to wait for the loggers to drop off naturally and don’t need to re-capture their subjects. Implanted loggers can offer insight into the animals’ physiology too and are often used to record internal temperatures. For example, in 1992 Rory Wilson pioneered the use of stomach temperature loggers in seabirds and was able to show that drops of temperature in the stomach cavity represented foraging events.

How to deal with a shedload of data?

Historically the sample sizes for bio-logging studies were often determined by how many loggers the project could afford. With the explosion of commercial companies offering bio-logging devices at increasingly affordable prices (e.g. a few hundred pounds), it means that it is relatively easy for an eager researcher to get their hands on bio-logging devices, attach them to their study animal, and generate millions of data points. In addition, free online databases for animal tracking data, like Movebank (https:// www.movebank.org) hosted by the Max-Planck-Institute for Ornithology in Germany, are allowing researchers to manage and share their existing datasets, providing a wealth of data for everyone to play with. The analysis of bio-logging data, however, is quite different to traditional approaches and often requires a pre-processing stage. By nature, the data are time auto-correlated or spatially auto-correlated, and the signal measured is rarely the output used for analyses. For example, acceleration data are rarely gathered for quantifying acceleration itself, but more typically to infer behaviour, posture or activity. Much effort has been devoted to this task, and increasingly, user-friendly open-source software is available to automate much of this inference (e.g. AcceleRater online application: http://accapp.move-ecolminerva.huji.ac.il/). Most importantly, with all the data generated, scientists must remember that bio-logging is first and foremost a tool, allowing us to address specific questions and to test hypotheses grounded in theory and observation.

Where can I find out more?

Boyd, I.L., Kato, A., and Ropert-Coudert, Y. (2004). Bio-logging science: sensing beyond the boundaries. Mem. Nat. Ins. Pol. Res. 58, 1–14.

Kooyman G.L. (2004). Genesis and evolution of biologging devices: 1963–2002. Mem. Nat. Ins. Pol. Res. 58, 15–22.

Resheff, Y.S., Rotics, S., Harel, R., Spiegel, O., and Nathan, R. (2014). AcceleRater: a web application for supervised learning of behavioral modes from acceleration measurements. Mov. Ecol. http:// dx.doi.org/10.1186/s40462-014-0027-0.

Wikelski, M., and Cooke, S.J. (2006). Conservation physiology. Trends Ecol Evol. 21, 38–46.

Wilson, A.M., Lowe, J.C., Roskilly, K., Hudson, P.E., Golabek, K. A. and McNutt, J. W. (2013). Locomotion dynamics of hunting in wild cheetahs. Nature 498, 185–189.

Wilson, R.P., Cooper, J., and Plötz, J. (1992). Can we determine when marine endotherms feed? A case study with seabirds. J. Exp. Biol. 167, 267–275.

Portugal, S. J., Hubel, T. Y., Hailes, S., Heese, S., Trobe, D., Voekl, B., Fritz, J., Wilson, A. and Usherwood, J. (2014). Position and flap phasing between ibises in formation flight: evidence for upwash exploitation and downwash avoidance? Nature 505, 399-402