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Ways to measure body temperature in the field

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ABSTRACT

Body temperature (T_b) represents one of the key parameters in ecophysiological studies with focus on energy saving strategies. In this study we therefore comparatively evaluated the usefulness of two types of temperature-sensitive passive transponders (LifeChips and IPTT-300) and one data logger (iButton, DS1922L) mounted onto a collar to measure T_b in the field. First we tested the accuracy of all three devices in a water bath with water temperature ranging from 0 to 40 °C. Second, we evaluated the usefulness of the LifeChips and the modified iButtons for measuring T_b of small heterothermic mammals under field conditions. For this work we subcutaneously implanted 14 male edible dormice (*Glis glis*) with transponders, and equipped another 14 males with data loggers to simultaneously record T_b and oxygen consumption with a portable oxygen analyzer (Oxbox). In one individual we recorded T_b with both devices and analyzed recorded T_b patterns.

LifeChips are able to measure temperature within the smallest range from 25 to 40 °C with an accuracy of 0.07 ± 0.12 °C. IPTT-300 transponders measured temperature between 10 and 40 °C, but accuracy decreased considerably at values below 30 °C, with maximal deviations of nearly 7 °C. An individual calibration of each transponder is therefore needed, before using it at low T_bs. The accuracy of the data logger was comparatively good (0.12 ± 0.25 °C) and stable over the whole temperature range tested (0–40 °C). In all three devices, the repeatability of measurements was high.

LifeChip transponders as well as modified iButtons measured T_b reliably under field conditions. Simultaneous T_b-recordings in one edible dormouse with an implanted LifeChip and a collar-mounted iButton revealed that values of both measurements were closely correlated. Taken together, we conclude that implanted temperature-sensitive transponders represent an appropriate and largely non-invasive method to measure T_b also under field conditions.

1. Introduction

Body temperature (T_b) represents one of the key parameters in ecophysiological studies with focus on energy saving strategies, as especially in endotherm organisms already slight decreases in T_b may considerably reduce energy expenditure (e.g. Wang and Wolowyk, 1988). Because of the close association of T_b and energy expenditure, both parameters should be measured continuously and at the same time, with a high accuracy and minimally invasive to avoid disturbance of the study animal.

There are an increasing number of studies using different methods to measure T_b, each of them having their advantages and disadvantages especially when used in the field. Thermo-sensitive radio transmitters and data loggers are battery dependent and can be implanted intraperitoneally, where they measure core body temperature (T_{core}). The implantation and the removal of those devices require a major surgery under anesthesia. In field studies, animals have therefore to be kept in the laboratory for some days before they can be released. Alternatively these transmitters or loggers can be mounted onto collars where they measure skin body temperature (T_{skin}) which was shown to be a good predictor of T_{core} in small endotherms (Dausmann, 2005; Körtner and Geiser, 2000; Willis and Brigham, 2003, but see Audet and Thomas, 1996; Barclay et al., 1996). Even though no surgery is needed for this method, collar-mounted devices represent a risk for study animals, especially if they inhabit dense vegetation and seek shelter in tree holes with narrow entrances or in other crevices. Data loggers have a built in memory and are usually programmed to take and save readings in predefined intervals automatically. When used in the field, the study animal has to be recaptured to retrieve the data. In thermo-sensitive radio transmitters the signal has to be continuously received via an antenna, which means that the animal has to be within the range of the reading device.

Thermo-sensitive passive transponders are generally implanted subcutaneously with a syringe-like injector and measure subcutaneous body temperature (T_{sub}). In comparison to the methods described above, this method is less invasive, as transponders can be easily injected without anesthesia and the whole procedure takes only a few minutes. Although some researcher use anesthesia for

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injecting transponders (Kort et al., 1998; Wacker et al., 2012), the individual marking of animals with passive transponders without anesthesia is a widely used technique in capture-mark-recapture studies in the field (Castro-Santos et al., 1996; Fietz and Weis-Dootz, 2012; Gibbons and Andrews, 2004; Harper and Batzli, 1996). However, thermo-sensitive transponders are up to now mainly used for veterinary purposes in laboratory animals (Kort et al., 1998), companion animals and animal husbandry (Goodwin, 1998; Quimby et al., 2009).

To the best of our knowledge there are no studies using thermo-sensitive passive transponders for measuring T_b in the field. The aim of our study was to evaluate the range and accuracy of temperature measurements taken with temperature-sensitive passive transponders and an iButton data logger. In addition we tested their usefulness for measuring T_b of small heterothermic mammals under field conditions.

2. Material and methods

2.1. Study animal

Edible dormice (*Glis glis*) are nocturnal tree-dwelling rodents that use artificial nest boxes for resting during the day and are therefore easily accessible for scientific studies. In Germany they occur preferentially in deciduous mixed forests dominated by European beech (*Fagus sylvatica*; Schlund, 2005), whose energy rich seeds represent their main food resource during lactation and pre-hibernation fattening (Fietz et al., 2005). A dramatically reduced or even no reproduction in years with low food availability was observed independently in several free-living dormouse populations (Bieber, 1998; Schlund et al., 2002). Edible dormice are heterothermic and their T_b can vary between values close to 0 °C during hibernation (September until May) and up to 38 °C in active animals (Bieber and Ruf, 2009; Von Vietinghoff-Riesch, 1960). Heterothermia is a physiological adaptation to survive unfavorable environmental conditions like low ambient temperature (T_a) and limited food availability (Geiser and Ruf, 1995; Geiser, 2004). By decreasing T_b and metabolic rate (MR), energy expenditure can be reduced by up to 98% (Wang, 1989). Typical for hibernators, dormice show extreme seasonal body mass changes. Accordingly, adults emerge from hibernation with a body mass between 80 and 120 g and may increase their body mass during summer/autumn up to 200 g shortly before they enter hibernation (Fietz et al., 2004).

2.2. Study site and capture-mark-recapture

This study was conducted at two different sites located in mixed deciduous forests in south western Germany (Baden–Württemberg). The first study site covers an area of about 12 ha and contains 120 nest boxes (Schwegler 3SV, entrance diameter: 34 mm, Schorndorf, Germany) and is situated within the “Schönbuch” Nature Reserve (48.550606N, 8.999172E; 450–500 m above sea level). The second study site is located in the Botanical Garden of the University of Ulm (48.422124 N, 9.962407E; 560–620 m above sea level) and contains 70 nest boxes on 7 ha. Nest boxes were set up in a grid pattern (30 × 30 m) and mounted to tree trunks at a height of 2–3 m. From May until September 2012 and 2013 we checked all nest boxes in both study sites at bi-weekly intervals. Upon first capture edible dormice were individually marked with a subcutaneously implanted passive transponder (Trovan, EURO I.D. Usling GmbH, Weilerswist, Germany; Table 1). All individuals were sexed, aged and weighed with a 300 g spring balance (Pesola, Baar, Switzerland; division: 2 g, accuracy: 99.7%). At the end of the measurements, animals were returned to their nest boxes. Adults were defined as fully grown individuals that have hibernated at least twice. For this study we exclusively used adult males for T_b and MR measurements. Our studies were conducted under license from the Nature Conservancy (Permit number: 55-6/8852.15-1) and the Committee on the Ethics of Animal Experiments of the Regional Commission of Tübingen (Permit number: HOH 25/13).

2.3. Temperature measuring devices

In this study we tested three different T_b measuring devices: two miniature glass-encapsulated thermo-sensitive passive transponders and one data logger.

LifeChips with Bio-Thermo technology (Destron Fearing, South St Paul, USA; Table 1) are thermo-sensitive passive transponders. They measure temperature between 25 and 40 °C and the manufacturer's specifications state that they are calibrated within this temperature range. We used the Global Pocket Reader (Destron Fearing, South St Paul, USA) to record temperature measurements and the software DF Direct version 1.0 (Destron Fearing, South St Paul, USA) to transfer readings to a computer file. For the application of this reader in the field set up, the Global Pocket Reader had to be modified to take readings within distinct intervals. Therefore, it was connected to a purpose-built circuitry and an external data logger ELV SDSD1 (ELV Elektronik AG, Leer, Germany) to trigger and save readings with the respective time of the day in a predefined interval. Power supply for an extended period of continuous measurements was provided by two VRLA batteries (a 12 V for the reader and the circuitry and a 6 V for the data logger). Additionally, speakers of the reader were disabled to avoid acoustic disturbance of our study animals.

IPTT-300 thermo-sensitive passive transponders (Bio Medic Data Systems, Inc., Seaford, USA; Table 1) measure temperature within a range of 0–43 °C and are factory calibrated between 32 and 43 °C. Measurements in the water bath were recorded with a Smart Probe 6005 reading device (Bio Medic Data Systems, Inc., Seaford, USA) and transferred to a computer file with the software DAS-Host Version 2.15 (Bio Medic Data Systems, Inc., Seaford, USA). IPTT transponders were only used for the calibration experiment.

iButtons DS1922L-F5 (Maxim Integrated Products, Inc., San Jose, USA; Table 1) are thermo-sensitive computer chips encased in a durable stainless steel can that can be programmed to log temperatures (−40 to 85 °C) with the respective time of the day in predefined intervals. As the length of the measuring period is generally an important aspect in field studies, we set the resolution of temperature measurements to 0.5 °C, which allows us to record twice as many data points compared to the higher resolution (0.0625 °C). We used the Blue Dot Receptor DS1402D-DR8, the

Table 1
Characteristics of the thermo-sensitive devices tested; manufacturer, mass and size.

Device	Manufacturer	Mass (mg)	Size (mm)
ID-100 BC	Trovan, EURO I.D. Usling GmbH, Weilerswist, Germany	95	Ø=2.12, length=11.5
LifeChip with Bio-Thermo technology	Destron Fearing, South St Paul, USA	120	Ø=2, length=14
IPTT-300	Bio Medic Data Systems, Inc., Seaford, USA	120	Ø=2, length=14
iButton DS1922L-F5	Maxim Integrated Products, Inc., San Jose, USA	3300	Ø=16, height=6
Modified iButton		1500	≈ 16 × 13 × 5