Published by Associazione Teriologica Italiana
Hystrix, the Italian Journal of Mammalogy
Volume 26 (2): 169–172, 2015
Available online at:
http://www.italian-journal-of-mammalogy.it/article/view/11475/pdf
doi:10.4404/hystrix-26.2-11475

Short Note

Mechatronics meets biology: experiences and first results with a multipurpose small mammal monitoring unit used in red squirrel habitats

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Keywords:
red squirrel
monitoring
monitoring device
mechatronics

Article history:
Received: 8 July 2015
Accepted: 22 December 2015

Acknowledgements
We would like to thank DHBW location Karlsruhe and Dürr Systems GmbH Bietigheim-Bissingen, Germany, National Trust Scotland Rangers on Arran, Scotland, Wildhut Davos and Kantonales Jagdamt Chur, Switzerland and two reviewers for their helpful comments to improve this paper.

Abstract

Monitoring is a fundamental aspect of species conservation and research. Technological advances, especially with respect to camera trap technologies, have allowed glimpses into unknown aspects of species behaviour and have the potential to greatly assist species distribution monitoring. Here we present the findings of a pilot study combining existing biological monitoring techniques with mechatronics to advance monitoring technologies and develop a multi-purpose, species specific, automated monitoring system. We developed a Small Mammal Monitoring Unit (SMMU) that integrates automated video, and sound recording, carries out body weight measurements and takes hairs samples with a bait station in a portable perspex box. The unit has the potential for use with a range of small mammal species, but has been field-tested here on red squirrels, *Sciurus vulgaris*, in Germany, Scotland and Switzerland. We successfully collected hair-samples, body mass data as well as video and sound recordings. Preliminary data analyses also revealed behavioural information. Heavier individuals first gained access to the feeder in the morning and have longer feeding bouts. Our prototype demonstrated that the collaboration between mechatronics and biology offers novel, integrated monitoring techniques for a range of research application. The development of units for other mammal species is planned. Future developments will explore the possibilities for wireless data transmission, built-in collection of weather data and collection of images from inside the unit for the recognition of individuals.

The monitoring of mammal populations is critically important for a wide range of management objectives: to determine species distributions, abundance or occupancy probabilities, and demographics, allowing the ability for managers to assess the effects of landuse change on species and assist in conservation efforts (e.g. Bertolino et al., 2009; Bartolommei et al., 2012; Lurz et al., 2015), to name but a few examples. As a result of extensive differences in body size, behaviour, habitat and space use, mammal monitoring is undertaken using a gamut of different approaches. These include live-trapping and tagging and/or radio-collaring, visual counts, bioacoustic sampling, track/ sign counts, hair tubes, nest counts, scat counts, and DNA analysis of scat/hair samples. Many citizen science project approaches involving the public also use automated devices such as camera traps (Don, 1985; Lurz et al., 1995; Drennan et al., 1998; Petty, 1999; Bertolino et al., 2009; Di Cerbo and Biancardi, 2013; Goldstein et al., 2014; O'Meara et al., 2014).

New technologies may offer a wider range of monitoring options (e.g. movement and/ or heat activated cameras in remote locations) and increase rare observations of small mammal behaviour (e.g. Bosch and Lurz, 2012b; Rovero et al., 2013). In addition, the combination of different approaches to monitoring also can improve accuracy, and increase the quality and quantity of data collected. Our objectives in the study presented, were to bring together different monitoring technology in a portable, automated unit suitable for data collection in ecological research on small mammals.

We developed the design for a battery operated, Small Mammal Monitoring Unit (SMMU), which integrates a bait station with automated video, and sound recording to assess behavioural interactions and to potentially identify individuals; carry out body weight measurements to assess age and condition; and to test the feasibility of collecting hair samples (e.g. for DNA testing). A key additional objective in using this approach was that data collection minimises stress to the animals as they enter and leave the station on their own accord. Herein, we present this novel monitoring approach for red squirrels (*Sciurus vulgaris*). We show initial results from field-tests of the SMMU prototype from study sites in Germany, Scotland and Switzerland, and discuss lessons learned and potential future applications for squirrels and other species.

Monitoring unit description

The key components of the small mammal monitoring unit (SMMU; Fig. 1) consisted of:

- infrared movement sensor (IR sensor by Sharp Type GP2D150A, RS Components GmbH, Mörfelden, Germany);
- electronic scales to determine body mass (strain-gauge beam arrangement of a commercial scale by Söhnle Type 65840, seller Conrad Electronics, Hirschau, Germany);
- a miniature video camera to obtain images (plus video sequences) and vocalisations of animals (type NavGear MDV 2250), specifically to get information on behaviour, age, coat colour and other external characteristics of individuals (e.g. moult, health status etc.). The camera was situated so that it captured individuals entering the tunnel and could take close-up images at the bait station (see Fig. 1).

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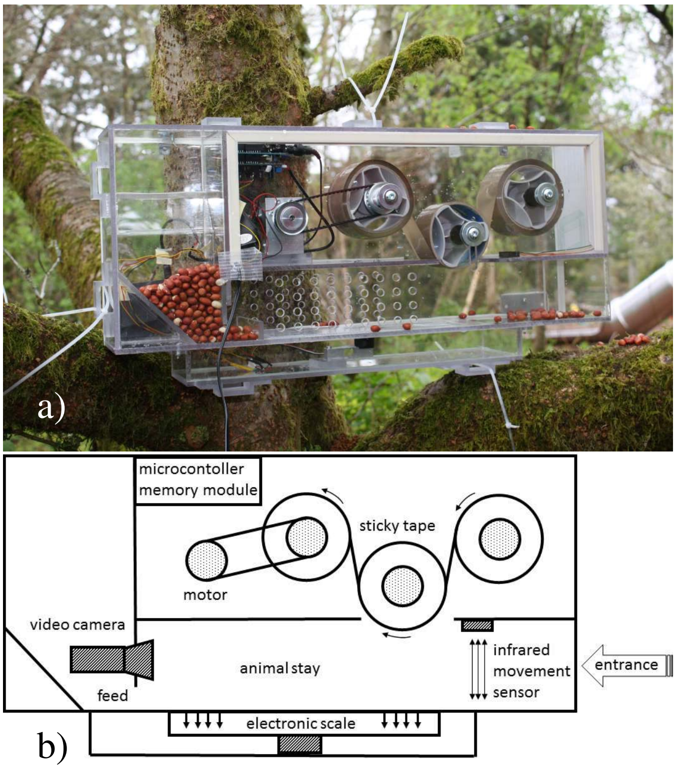

Figure 1 – Small Mammal Monitoring Unit (SMMU) with labelled components employed on the Isle of Arran Scotland (a) together with a schematic design (b).

- Electronically controlled wheels that hold and roll up sticky tape (3M adhesive tape) to obtain individual hair-samples and ectoparasites;
- memory module to save obtained data (Snootlab, Toulouse, France);
- microcontroller (type Arduino Uno, seller Conrad Electronics SE, Hirschau, Germany) to steer and control the whole device;
- a 12 V car battery power source; a solar-powered model is being developed but was not yet available for use.
- The unit also contained a storage area for bait, which is accessible at the end of the entrance tunnel. To attract red squirrels we used shell-less peanuts.

These components are housed in a perspex (Plexiglas®) box (Fig. 1) to provide sufficient lighting for the entrance tunnel to take dolour images and to add to camouflage in the environment. The transparent housing greatly reduced visibility of the device and thus disturbance or interference by the public in the field. Following the clear success of the perspex housing, no other types were tested. Material costs for building the prototypes were approximately 600 €, although we estimate that these could be reduced to ca. 350 € in larger production runs. Production time of a unit was 4–7 days (2–3 days for cutting and assembly, 1–2 days for soldering, calibration and installation of software, 1–2 days of test runs).

Control of the wheels for collecting hair samples and the scales as well as data storage (including date and time for each data point stored) are carried out by a micro-control board (Arduino UNO), which also houses the microcontroller made by ATmega. The "open-source electronic board" used can be extended at need and coding of necessary software can be done with little effort. A light-beam activates the rollers holding the tape and the tape, after a set delay, is rolled up and a clean area exposed. This way samples can be collected over an extended period of time for each visit.

Deployment for squirrels in this pilot study was in woodlands and thus in the shade, overheating or interference of sunlight in image quality was therefore not an issue. There is however, the potential of housing the unit under a cover or roof if needed. We visited deployed units twice a day (morning and late afternoon) to check the equipment, collect initial data, and to check the level of bait remaining. In the case of Arran, we also monitored the deployment site with two prototypes in close proximity using a camera trap.

Study areas

SMMU prototypes were tested in three different locations during spring and summer: one prototype placed at the ground for 3 weeks in a garden bordering a tree-lined stream in Sternenfels-Diefenbach, Enzkreis, Southwest Germany (49.025 N, 08.858 E). The stream is a known dispersal corridor for red squirrels (Bosch and Lurz, 2013). Two prototypes where tested for 4 weeks (placed on a wall and on a tree branch) in a deciduous woodland, near the National Trust for Scotland Ranger Centre at Brodick Castle on the island of Arran, Scotland (55.595 N, -5.153 E) where red squirrels are supplementary fed and habituated to artificial, man-made boxes with food (e.g. peanuts). One prototype was placed at the ground for 10 days in a spruce-larch conifer strip within a wooded area on the eastern shore of the lake at Davos, Switzerland, Alps 1560 m (46.816 N, 9.856 E). The area around Davos has a long history with respect to supplementary feeding of red squirrels (Bosch and Lurz, 2012a,b).

An important aspect in testing the SMMU prototype aside from digital data collection in different habitats was the response of red squirrels to the device. Different setup locations were tried (i.e. on the ground, mounted in trees and on artificial raised platforms (e.g. on top of a stone wall). Ideal placements were at the base of trees, secured and sitting in branches of trees as well as near or on stonewalls with nearby cover for squirrels (Figs. 1 and 2). Interactions between the SMMU with other animals, such as other rodents species or birds were also recorded.

Figure 2 – Inquisitive, wet red squirrel exploring the SMMU on the rainy Island of Arran, Scotland.

Figure 3 – Great tits exploring the baits in the SMMU, image taken by a camera trap, Sternenfels, Germany.

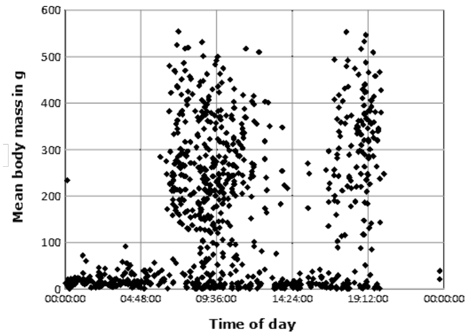

Figure 4 – Mean body mass measured in relation to time of day (period May 10th to May 22nd 2013, Island of Arran, Scotland).

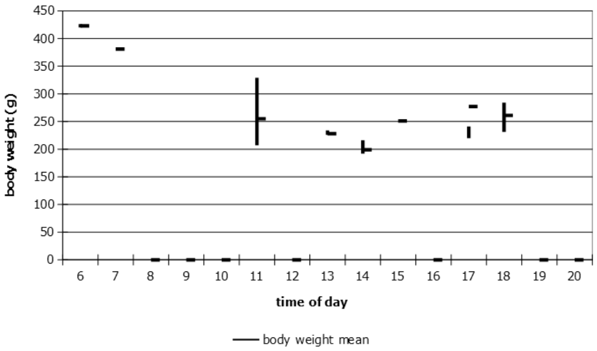

Figure 5 – Body weight data from Davos, Switzerland indicate that heavier animals visit the monitoring unit first in the morning, suggesting a dominance hierarchy (August 2013, Davos, Switzerland).

Data analysis

In order to account for animal movement when an individual stepped onto the weighing plate inside the SMMU, we recorded and analysed body mass data using two methods. Firstly, to avoid problems with false electronic readings, the final measurement stored consisted of the mean of 5000 individual values taken within a few milliseconds. Test runs in the lab also indicated that the error around a mean value could be greatly reduced with this set up. Secondly, a mean body mass value was stored every second. The latter value varied depending on animal movements and/ or if the animal rested completely on the weighing plate. It is important to note that the collected body mass data represent relative values as a result of animal movements on the weighing plate, but small, heavy, or pregnant animals can easily be recognised. In the case of smaller species such as mice accurate body mass can be determined by selecting data points when the individual remained still. The data were stored on an SD-card and read into an Excel sheet for analysis.

Results

Aside from red squirrels (Fig. 2), a number of non-target species visited the monitoring unit. These included mice (*Apodemus* sp.) who entered during the night with one individual attempting and abandoning building a nest in the tunnel; as well as a number of bird species attracted by the bait such as Great Tit (*Parus major*), Coal Tit (*Periparus ater*), Jays (*Garrulus glandarius*), Spotted Nutcracker (*Nucifraga caryocatactes*) and Common chaffinch (*Fringilla coelebs*). Of these only great tits entered the tunnel (Fig. 3), the others remained outside (e.g. curious Jay at the entrance).

Figure 4 illustrates the range of body mass measurements in relation to time of day and neatly shows a constant stream of visits by small species such as tits and two peaks in squirrel visits, one in the morning and one in early evening. More interestingly, data on individual squirrels in Fig. 5 clearly show that heavier individuals visited first in the day. There are also more visits of squirrels in the afternoon but feeding bouts last longer in the morning (Figs. 6 and 7). The availability of a relatively large amount of food does attract the same individuals time and again.

The frequent visits of squirrels later in the day as well as repeat footage of visiting mice suggest that it is the same individuals that return to feed or collect food. The recorded body mass sequences showing an increase in body weight and the video data showing individuals with the same coat colour patterns also support this.

Hair-collection using the light-beam activated tape worked perfectly and samples even included a tick (*Ixodes* spp.). First attempts to collect body measurements (Fig. 8) suggested that estimating foot length (and potentially other data such as length of vibrissae or tail hairs), using a camera positioned below the SMMU and taking the image through a semi-transparent measuring surface are possible in principle, but require refinement.

Problems encountered focused mainly on power supply and data storage. To test the functioning of the prototype, we were able to connect the power to the mains supply in Sternenfels-Diefenbach and on Arran. However, Arran suffered a power failure during one night of operating the two prototypes there. When run on battery power it was necessary to change the battery daily. There were no problems with disturbance by the public and only on one occasion was a cable gnawed through (presumably by a mouse or squirrel) leading to a power failure. The large volume of activity by mammals and birds in some sites e.g. Sternenfels-Diefenbach and Arran led to a huge amount of video data (and power use) and available data storage was insufficient.

Discussion

The Small Mammal Monitoring Unit (SMMU) integrates several monitoring approaches (species recognition using a camera, hair samples, body weight measurements, activity patterns) and opens up opportunities to monitor species continuously. More importantly, the close cooperation between mechatronics and biology enables a new dimension

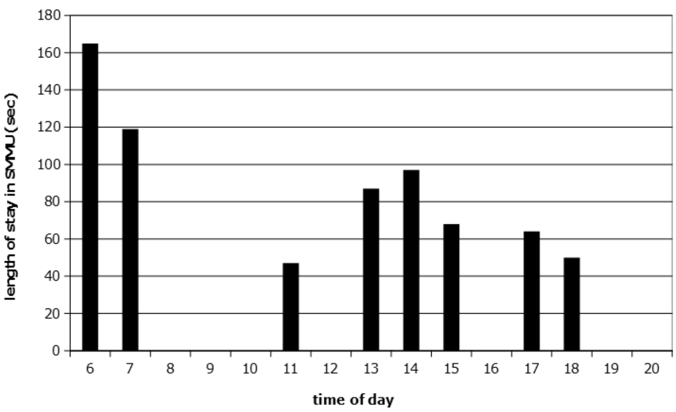

Figure 6 – Length of squirrel visits at SMMU in relation to time of day illustrating that visits in the morning lasted longer (August 2013, Davos, Switzerland).

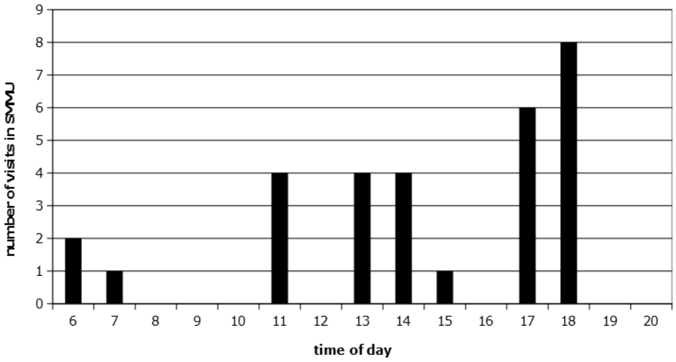

Figure 7 – Number of visits by red squirrels for each hour of the day for a day in August 2013 at Davos, Switzerland. Activity varied and most visits were recorded in late afternoon. Video surveillance shows that high numbers of visits are due to several visits of the same individual in sequence.

Figure 8 – Image of hindfoot from below to indicate approximate foot length using a transparent scaled paper (Davos, Switzerland).

of data collection. However, the successful pilot project with field trials in Scotland, Germany and Switzerland indicated a number of areas for improvement and the potential need for automated screening of data. For example, the data collection on Arran alone created 68000 data points and images during a 14 day period and a C++ program written specifically to sort and analyse the body weight data would be useful for future applications.

The recorded video sequences allowed a determination of species and provided information on activity patterns and potential dominance hierarchies (Wauters and Dhondt, 1992). Heavier individuals clearly gained access first to the bait in the feeder in the morning and their feeding bouts were longer. The use of bait is a common practice in squirrel monitoring (e.g., Gurnell et al., 2009, 2011) but attracting animals via bait does also have disadvantages as it may create points of contact for disease transmission within the SMMU. This may be a concern in areas where grey squirrels (*S. carolinensis*) carry squirrelpox virus and are sympatric with red squirrels (Bruemmer et al., 2010; Shuttleworth et al., 2014; McInness et al., 2015). Good hygiene and the cleaning of the monitoring unit would therefore be essential to reduce the risk of disease transmission, although the frequency of cleaning to reduce transmission needs to be defined. With respect to other species, the SMMU was attractive to some smaller species of songbird, as well as small mammals such as mice (e.g. *Apodemus sylvaticus*).

The SMMU may be of particular use in areas where squirrel monitoring is critical to determine range expansion of native and introduced species and squirrelpox virus disease is absent, such as in Switzerland where the introduced grey squirrel is expanding its range from nearby Italy and an introduced Asian squirrel (*Callosciurus erythraeus*; Mazzamuto et al., 2015) has recently been found. Automated monitoring units like the SMMU allow data collection on wild animals, which is normally obtained through a large effort with large demands on personnel and time. A particular benefit is the fact that target species do not have to be captured and exposed to stressful situations. Our prototype demonstrated that the collaboration between mechatronics and biology offers monitoring solutions for a range of applications and the development of units for other species is possible. The inclusion of temperature or humidity probes is possible without problems where such data might be meaningfully combined with the species monitored. Future developments will address issues of power usage and data storage encountered in the field trials, explore the possibilities for wireless data transmission, the in-built-in collection of transponder data, collection of weather data and the potential of collected images from inside the unit for the recognition of individuals (biometrics).

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Associate Editor: L.A. Wauters