A novel radar triggered camera trap system for reptile monitoring: evaluation for detection of the non-native lizard *Podarcis muralis*

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(image: D Forman 2012)

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Executive Summary

Reptiles are currently facing some of the most significant and widespread declines of any vertebrate group on the planet. Conservation monitoring is essential for managing their populations, but there are few effective automated tools to assist with, and help standardise, data collection. Many conventional monitoring technologies are redundant for reptiles; for instance infra-red based sensors (such as stealth cameras) are ineffective for the detection of small ectothermic animals.

Doppler sensing radar systems employing low power microwaves can be used as highly sensitive motion sensors, capable of detecting animals independent of their heat emissions. They offer excellent target discrimination abilities for the rapid detection of small, fast moving animals over short detection ranges. Here we describe initial studies using a coherent continuous wave Doppler sensing radar system termed 'CATCHER', which processes this information in real time and uses it to trigger a camera to record the animal's image. This allows a comprehensive detection of all animals using the survey area during the study period, which can later be identified and recorded by interpreting the time-stamped images produced. Difference images, produced from consecutive pictures, can reduce image processing time considerably, and made otherwise cryptic animals easy to spot.

To evaluate the effectiveness and utility of this new tool, the CATCHER system was trialled at a site in South Wales frequented by wall lizards (*Podarcis muralis*). During a short monitoring period, we were able to detect the presence of several lizards and demonstrate interactions between them. These encouraging results suggest this comprises a capable system which could provide a useful addition to the methods available to provide the monitoring data required for effective conservation management of reptiles.

CONTENTS

1.0 Introduction

Three lizards (common lizard, sand lizard and slow worm: *Lacerta vivipara*, *L. agilis* and *Anguis fragilis*) and three snakes (grass snake, adder and smooth snake: *Natrix natrix, Vipera berus* and *Coronella austriaca*) are post-glacial natives of Britain. Their conservation status varies from widespread and locally abundant to severely restricted [1, 2]; however, even common species have declined locally in many areas, and all six are now listed as priority species in the UK Biodiversity Action Plan [3]. In addition, there is an increasing need to monitor introduced species, since the effect of their presence on native reptiles is, at present unclear. Several species of European reptiles have become naturalised in some areas of the UK, including the Aesculapian snake, *Zamenis longissimus*, green lizards *L. viridis* and *L. bilineata*, and the wall lizard *Podarcis muralis. P. muralis* is a small diurnal old world lizard which has established colonies in the UK, and is currently listed as a species of high strategic research priority [4]. Threats to other reptiles could include competition, predation and spread of disease [1], and improved monitoring could assist in the accurate assessment of these risks. Although, in Europe, *P. muralis* has been found not to pose a competitive threat to other sympatric lizard species [5], they can carry reptile paramyxovirus and act as hosts to tick- and mite-borne pathogens [6].

The need for conservation management planning has resulted in the development and refinement of standard survey and monitoring methodologies, but reptiles can be cryptic and are often difficult to detect. Reptile monitoring is, as a result, challenging and often frustrating. There are few tools available, and monitoring relies heavily on skilled and highly labour-intensive procedures, such as visual search or visual encounter survey methods [2]. Although effective for large scale presence/absence surveys of species, these methods are difficult to standardise between workers, and suffer from the limits of human perception and endurance. An automated tool which could effectively monitor reptiles would provide a welcome addition to the suite of survey methods available.

Camera trapping has proved to be an efficient technology to provide information about large mammals, and its use for monitoring and surveying has been widely explored [e.g. 7, 8-11]. It is a robust, non-invasive method with relatively low labour costs, resulting in minimal environmental disturbance. It can also provide information on highly cryptic species and in terrain unsuited to other field methods. A camera with an effective short range detection system for small fast-moving ectothermic animals would be ideal for surveying activity at specific sites used preferentially by reptiles.

For this, the properties of radar systems appear to be ideally suited. Coherent continuous wave Doppler sensing radars [12] employ low power microwave emissions that cannot be discerned by animals, and detect movement of even small animals, independent of thermal signature and light conditions. The radar returns an almost instantaneous measurement of the target velocity, allowing very rapid camera triggering, and imaging of fast moving animals.

Here we trial a new system, Conservation Active Temporal Coherent Homodyne Ecological Radar (*CATCHER*) [13], based on this radar methodology, to assess its utility for monitoring a population of the small, non-native lizard, *Podarcis muralis*.

CATCHER is an automated tool which, in addition to the species which conventional IR triggered camera systems are useful for, can effectively monitor a range of species they are currently unable to detect, including insects, amphibians and reptiles. The conservation ecology and functional ecology of these groups are broad subject areas of significant research effort. There is also increasing focus on the study of the impact of non-native species on indigenous biodiversity and ecosystem services [14-17]. The aim of this study was to demonstrate the capability of this radar triggered system to record field-based information on a non-native reptile species, the wall lizard (*Podarcis muralis*).

2.0 Methods

The trial was undertaken at an undisclosed location in South Wales in July 2011. The focus of the trial was within a large, old, walled garden known to contain an active and breeding population of *P muralis*. The trials were conducted in sunny conditions, between 10.15 and 11.15 am. CATCHER was deployed 2.5 m away from a south-facing wall, and the system left to run independently. The field of view covered approximately 3 m^2.

2.1 Radar technology

A small, commercially-available[18] coherent continuous wave (CW) Doppler sensing radar using low power (< 1 mW) microwaves was used to detect movement in the sample area. The radar operates at a frequency of 24GHz and has a beamwidth of 250 in azimuth by 70 in elevation, determining its field of view. The reflected signal frequency is changed by an amount relative to the target speed - (the Doppler Effect) [12], and Doppler frequencies were calculated and processed in real time. Filtering was set to reject unwanted ground echo, termed '*clutter*' which results from surface motion such as wind blown vegetation or flowing of river water. To achieve this, the radar data was digitised by a sound card then transferred by USB to a lap-top computer where it was processed using bespoke software and target velocity and amplitude limits imposed.

The limits set were for targets with a velocity between 0.5 and 5 m/s and with a power in excess of 300 times the background level. The camera (Canon EOS 1000D) was set up to include the radar field of view, and to be triggered by the computer when the preset limits were exceeded. The response speed between the threshold being crossed and the image being recorded was approximately 200ms.

2.2 Image processing

Photographs may record the presence of an animal, or result from background movement, from, for example, a gust of wind, so need to be further processed. Records of animals may be quite cryptic and occur in small regions of the images, making them time consuming and tiring to process, possibly resulting in missed events. Automated image comparison can highlight the difference between successive photographs, making this process much easier and quicker to achieve. Bespoke image processing software was written to undertake a standard image processing technique known as image Moving Target Indication (MTI) to produce a differential image. The software subtracts one image from the next, pixel by pixel. To account for changes in general illumination, it then subtracts the mean of all pixels in the differential image from each pixel, and displays the extent of difference between pixels in false colour gradation. Static objects common to both images cancel each other out, whereas regions of difference stand out in high contrast. Changes from either image are displayed in the same way, so both prior and subsequent positions are recorded when an animal moves. The stark contrast between the stationary and mobile parts of the image makes them easy and quick to interpret, with reference to the original images.

3.0 Results

The equipment, which in its prototype form comprises a small tripod mounted unit (Figure 1), was easy and straightforward to set up with the camera and laptop, and we were able to start recording data within a few minutes. There were no apparent changes in lizard behaviour resulting from the presence of the equipment. Many photographs were triggered over a short period, successfully recording the lizards' presence and capturing their movements .

Typical detection event information is illustrated in Figure 2. Over a 35 minute survey period, 166 photographs were triggered, some within 1 second of the previous photograph (the smallest interval recordable by the camera software). 33 (19.9%) of these photographs were not obviously triggered by lizards. A total of 133 (68%) images contained at least one wall lizard, and 63 contained two individuals. The system recorded interactions between animals over time, as well as behaviours including basking, foraging, and feeding (see Figures 3 and 4).

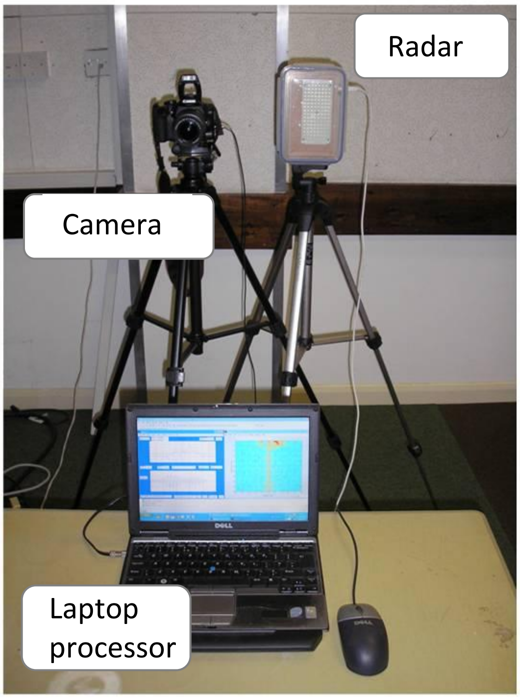


Figure 1. The CATCHER system

A total of 165 MTI images were created from the original 166 photographs (n – the first image) and visually analysed. Examination of the photographs suggested the presence of a maximum of two animals in any one photograph. Five MTI images, however, clearly showed the presence of three animals in equivocal shots.

Figure 6 shows examples of otherwise cryptic animals highlighted by MTI .

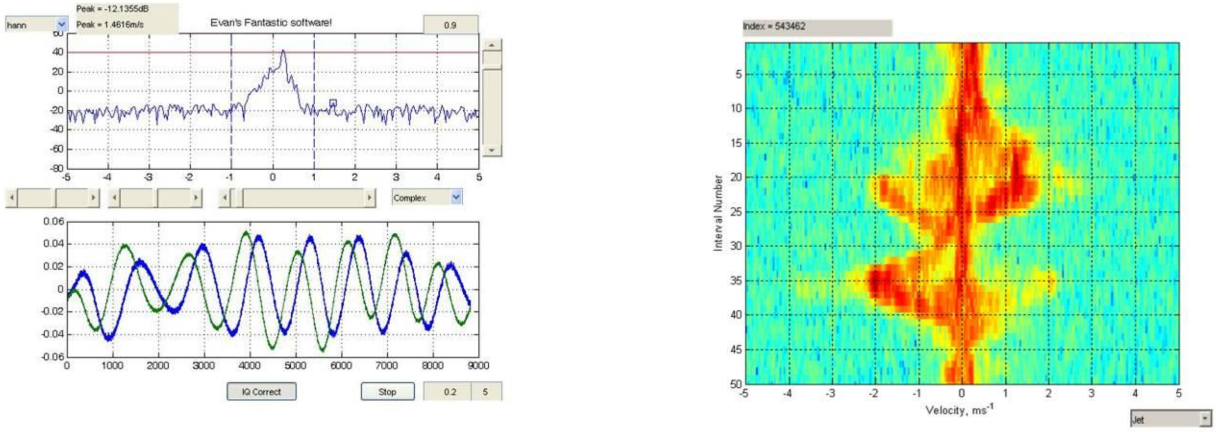


Figure 2. Screenshot illustrating typical detection event information derived from Doppler data (Upper left: Doppler spectrum of returns; lower left: Voltage waveforms of returns; right: Waterfall diagram of Doppler history as a function of time).

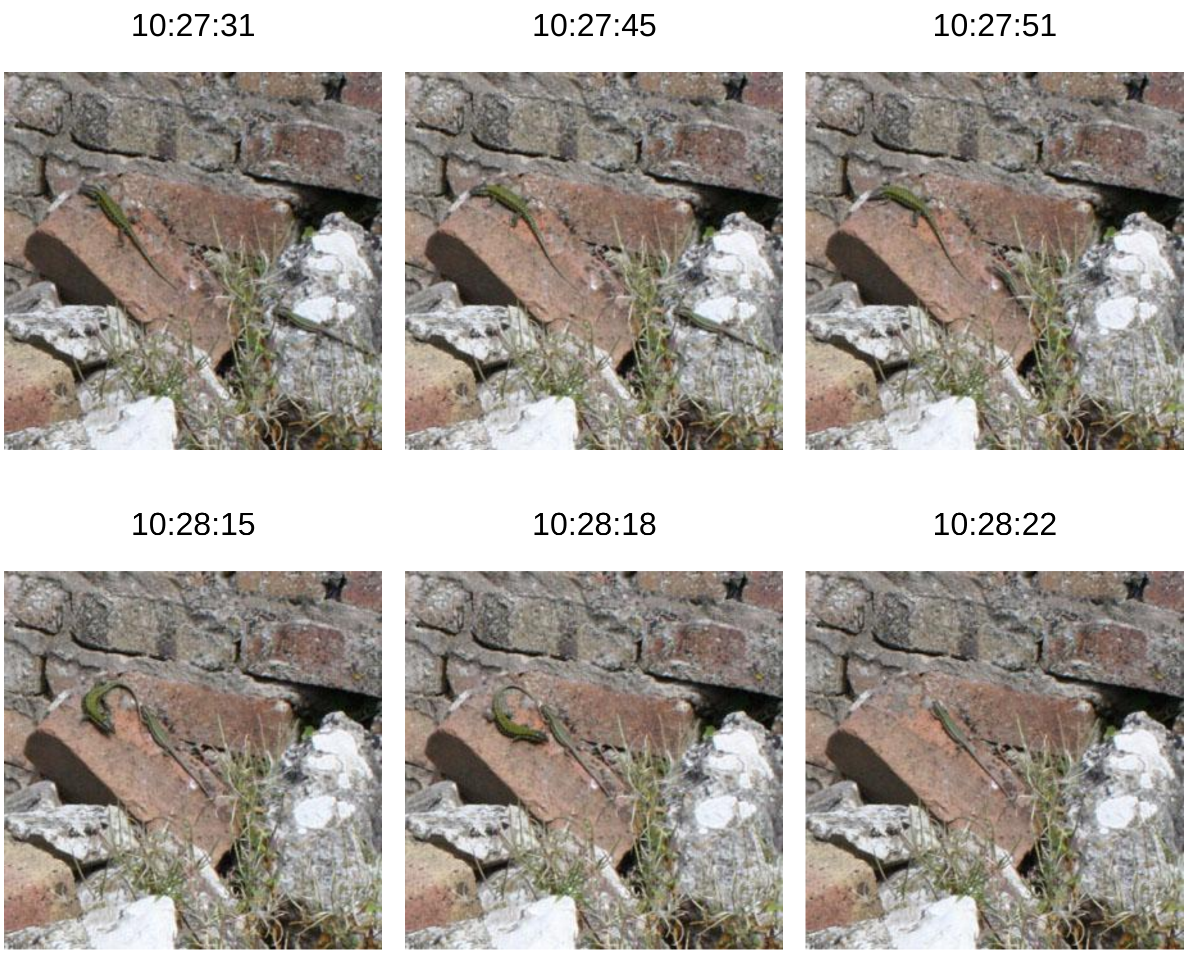


Figure 3. Interactions recorded between two wall lizards over the course of 91 seconds

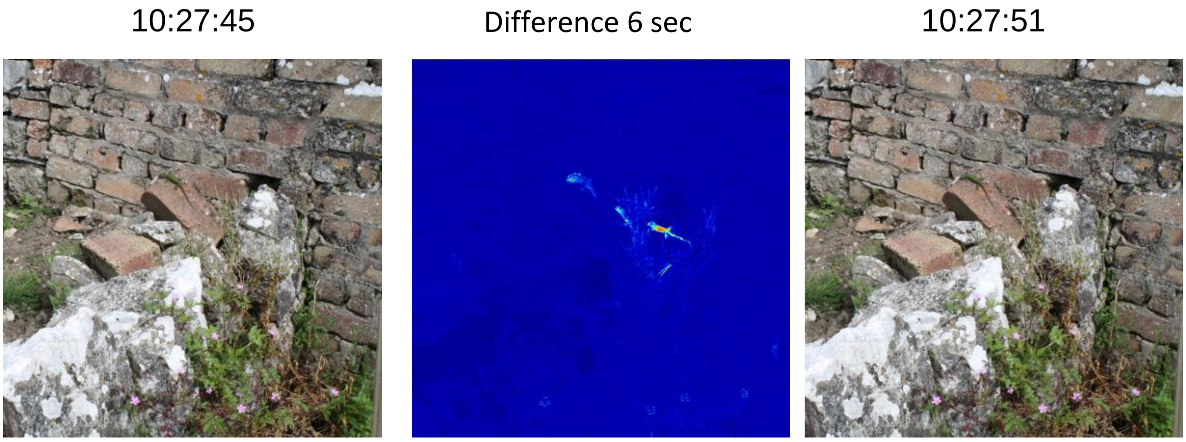
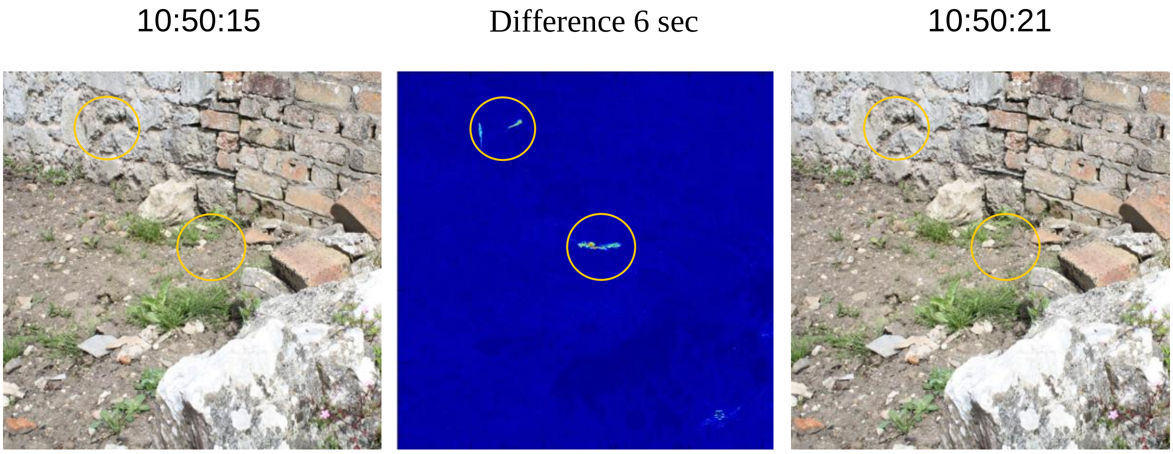
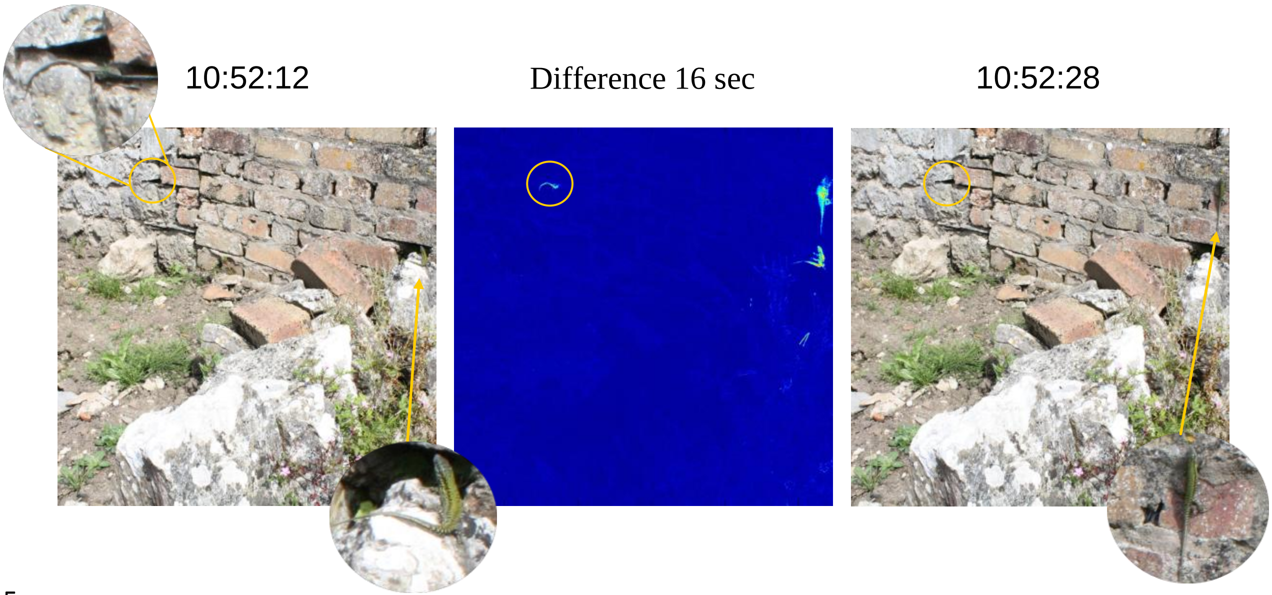


Figure 4. MTI images assist with interpreting interactions: here, the larger lizard turns on the approach of a smaller lizard.

5a



5b



5c

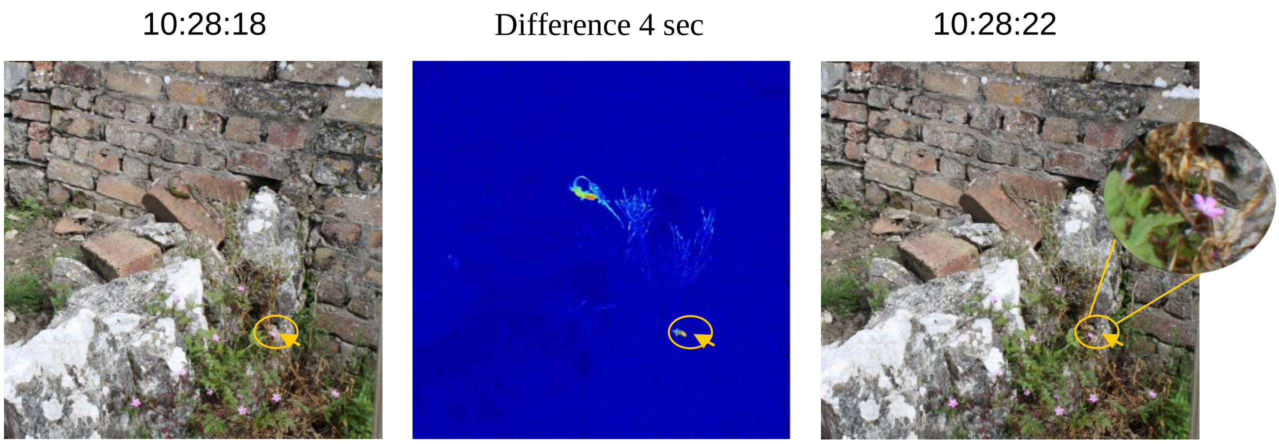


Figure 5 a, b, and c.

MTI images constructed from two photographs (shown either side). Movement is highlighted in bright colours, and clearly reveals animals that otherwise would be difficult to spot.

Discussion

Monitoring programs are key components of strategies for the management and conservation of species and biodiversity. [7, 19-21]. Evidence-based conservation [22] has become a methodological gold standard, and monitoring has revealed striking insights into the conservation status of species and habitats [23]. It provides essential long-term baseline data, but also allows identification of population declines prior to local extinction, and can highlight where conservation management is critical for the protection of species and habitats.

Worldwide, reptile declines are growing and serious, and of particular concern as reptiles are an integral part of many ecosystems, often occupying high trophic positions in food webs [24, 25]. They are vulnerable to habitat loss and degradation, from human disturbance, climate change [26] and invasive species, and to health challenges such as disease, parasitism and environmental pollution [24, 25]. Many populations are poorly understood [27, 28], and there is pressing need for effective strategies for their conservation. Recently, a program was initiated to record U.K. baseline data according to standardised protocols using trained volunteers [29]. This will provide important data on the status of UK reptiles, and has already highlighted a concern for *V. berus*. Some European reptiles have become naturalised in specific areas of the UK, and there is a particular need also to monitor such introduced species, to develop an understanding of their impact on native reptiles.

The application of automated methodologies has contributed significantly in recent years to the quality and quantity of data collected to support conservation of species and biodiversity. The advantages are easily identified: monitoring can be undertaken for extended periods without fatigue related performance reduction or intruder effects on animal behaviour. Simultaneous events do not create distraction, and skill dependant variation in detection is largely eliminated, creating datasets comparable between sites and across the years

Camera traps are valuable tools that provide a range of useful data for conservation managers and ecologists. Radar is highly suited to this application as it is capable of detecting targets that do not easily trigger conventional PIR and IR systems, which lack sensitivity to small animals and those that do not register a relatively large thermal target, such as reptiles. This study clearly demonstrates that radar can successfully trigger a camera system to record such organisms. As such, radar based camera traps may have some considerable advantage over existing camera trap systems, and may provide opportunities for many new monitoring applications.

Camera traps cannot replace many reptile monitoring methods currently in use which often involve the investigation of large areas. These include defined transect surveys, using cover objects to detect inactive thermoregulating animals, and road surveys to detect animals actively moving through habitat, as well as noting the presence of animal signs, such as grass snake egg-laying heaps or hibernacula [2]. They can, however, replace visual encounter survey (VES) point sampling at specific locations. These locations should be carefully chosen by experienced researchers to include frequently visited sites, such as basking areas and refuges, or frequently used routes between sites, such as culverts or the edge of drift fencing. They can provide the advantages of lengthy continuous monitoring times, and can be used to monitor the use of ponds, the activity at hibernacula, and at egg laying sites. *P. muralis* congregates at specific breeding sites, making it particularly suited for study using a camera based system.

An additional benefit of radar for monitoring reptiles is that rapid triggering generates successive images which enable the creation of MTI images. Human error is a significant limitation in many visual sampling approaches and MTI imaging reduces this error substantially by providing an objective measure of the difference between pairs of photographs, thereby increasing the accuracy of data. The movements of individual wall lizards were clearly evident in the MTI images, and led to the visual identification of individuals that were not recorded in the original photographs used to create the MTIs. It is strongly recommended, therefore, that MTI imaging is used when using radar based camera systems to monitor cryptic animals in future studies.

For species where individuals can be identified, camera traps have the potential to be used as a non-invasive mark-recapture tool [30], one of the most powerful methods for monitoring species. Although recapture rates may be a concern, robust design models can be used which allow analysis of data from elusive species [31]. In the initial trial, it was not possible to reliably identify *P.muralis* individuals, but this may improve with increased image resolution. Other reptile species where individuals are more distinct may be good candidates for this application.

Camera trap data could also be used to help refine other reptile survey protocols. Successful reptile surveying and monitoring relies on actively increasing capture probabilities by incorporating knowledge of species patterns of behaviour and habitat use into protocols. Careful standardisation of these protocols is important to ensure comparability of data over long time periods and across study sites, and reduce heterogeneity in detectability - a particular problem when surveying for elusive or cryptic species [28, 32]. In particular, abiotic factors such as weather conditions can have dramatic effects on detection [33].

Sensitive camera traps used in conjunction with other automated methods [34] have the potential to be used to refine our understanding of the effect of measurable environmental variables such as temperature, rainfall and wind speed, on behaviour of specific species. Camera data could also be used to provide baseline data to measure the effects of improvements in manual surveying methods. Development of robust monitoring of reptiles will contribute to large-scale, integrated biodiversity monitoring systems - an essential prerequisite for policy development in reaction to the current biodiversity crisis [35].

Photographic evidence has several additional advantages for the surveyor. It can provide clear and demonstrable proof that species exist in the study area [7], and it allows for detailed investigation and sharing of information after the survey. Experts can be engaged for accurate species identification, and in some cases, the sex, reproductive status, and even individual identity of the animal can be determined. Additional data can be derived, such as activity patterns calculated from digital time records, species distribution and habitat use. Photographs can also reveal threats to habitats and wildlife including human activity. Images can also be used to communicate the importance and effectiveness of the monitoring program to a wider audience. Photographic evidence of local rare and cryptic species can be used to inspire community interest and involvement in their conservation. This can result in more effective conservation management interventions, often undertaken by community members [36].

It is clear that sensitive camera traps for reptiles will be a significant addition to the currently available methodology. The CATCHER system also overcomes several disadvantages of traditional infra red based camera traps which preferentially detect larger animals [7, 10], have reduced performance on hot days, and have a relatively slow trigger rate which can result in missed detections [10]. Radar capture can be calibrated to detect very small animals including insects, is less susceptible to environmental variation, and our system features very rapid camera triggering, photographing even fast moving animals.

Conclusion

This study constitutes a successful trial of a new and sensitive camera trapping technology, CATCHER, for use with reptiles. The device is relatively low cost, has low energy requirements, and can be used for long periods limited only by the availability of power and the storage requirements of data acquisition. It is useful in all weathers, although it is susceptible to 'clutter' in high winds and near running water. It can be easily adapted to work with video and infrared if required. The initial results with *P. muralis* have been successful and encouraging, resulting in rapid and sensitive triggering and ease of detection in images by using the MTI- based difference image program to process the results. There is great potential for this to be to developed into a useful and reliable device which will make an important contribution to the effective monitoring of Britain's reptiles.

Acknowledgements

TO ADD

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Recommended citation for this report:

Greig, C., Neyland, P., Roberts, L., Harris, W., Alabaster C., Hughes, E., and Forman, D. 2012. A novel radar triggered camera trap system for reptile monitoring: evaluation for detection of the non-native lizard *Podarcis muralis.* Swansea Ecology Research Team, Swansea University.