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Article *in* Journal of Ornithology · March 2020

DOI: 10.1007/s10336-020-01758-9

Journal of Ornithology
https://doi.org/10.1007/s10336-020-01758-9

TECHNICAL NOTE

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Adjusting trail cameras to improve monitoring of small open cup nesting birds

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Received: 25 November 2019 / Revised: 7 February 2020 / Accepted: 10 February 2020

Abstract
Camera traps are a valuable tool in wildlife monitoring. Despite their wide use to capture large or medium-sized species, modern techniques also allow them to capture small animals. However, customized cameras, which meet the challenging demands for this purpose during fieldwork, are still quite expensive and require a certain technical know-how. Here we present a way to modify commercial trail cameras to monitor open-nesting songbirds. In particular, we describe how to adjust focus and exposure in order to capture close-up situations of small animals which are very distinct from the default settings when capturing large wildlife. We illustrate the applicability of the modifications from data of a nest predation survey in the Blackcap (*Sylvia atricapilla*). Compared to pictures from a preliminary study using unmodified trail cameras of the same kind, the pictures were much improved in picture focus and in nocturnal exposure. In addition to improved species identification, the modifications also allowed the cameras to capture more details of life-history events (e.g. of hatching processes and feeding). The manipulation protocol offers a promising and cost-effective approach for nest monitoring as well as for different areas of "close-up" applications to study small endothermic animals.

Keywords Camera focus · Camera traps · Flashlight · Manipulation · Nest monitoring · Trail cameras

Zusammenfassung
Anpassungen von Wildkameras für optimiertes Monitoring von freibrütenden Singvögeln

Kamerafallen sind ein wertvolles Hilfsmittel für das Monitoring von Wildtieren. Trotz ihres breiten Einsatzes zur Erfassung großer oder mittelgroßer Arten ermöglichen moderne Techniken auch die Erfassung von kleineren Tieren. Speziell angefertigte Kameras, die den anspruchsvollen Anforderungen für diesen Zweck bei der Feldarbeit gerecht werden, sind jedoch immer noch recht hochpreisig und erfordern ein gewisses technisches Fachwissen. Hier stellen wir eine Möglichkeit vor, handelsübliche Wildkameras so zu modifizieren, dass sie freibrütende Singvögel überwachen können. Insbesondere beschreiben wir, wie Fokus und Belichtung angepasst werden können, um Nahaufnahmen von kleinen Tieren zu machen, die sich von den Standardeinstellungen bei der Aufnahme großer Wildtiere stark unterscheiden. Wir veranschaulichen

Communicated by F. Bairlein.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10336-020-01758-9) contains supplementary material, which is available to authorized users.

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Published online: 13 March 2020

die Anwendbarkeit der Modifikationen anhand von Daten einer Nestprädationsstudie bei der Mönchsgrasmücke (*Sylvia atricapilla*). Im Vergleich zu Bildern aus einer Vorstudie mit den gleichen aber nicht modifizierten Kameras waren die Bilder hinsichtlich Bildschärfe und nächtlicher Belichtung deutlich verbessert. Neben der optimierten Artbestimmung erlaubten die Modifikationen den Kameras auch, mehr Details von lebensgeschichtlichen Ereignissen (z. B. von Schlupfprozessen und Fütterungen) zu erfassen. Das Manipulationsprotokoll bietet einen vielversprechenden und kostengünstigen Ansatz für das Monitoring von Nestern sowie für verschiedene Bereiche der „Nahaufnahme "-Anwendungen zur Untersuchung kleiner endothermer Tiere.

Introduction

Areas of application for camera traps are very diverse as are trail cameras themselves. Technical innovations (Kucera and Barrett 2011) as well as an increasing interest in animal welfare (Long et al. 2008) have resulted in a plethora of commercially available products (see Rovero et al. 2013 for an overview) and custom-made fit-for-purpose units. In recent years, literally hundreds of studies and surveys have been conducted that involved camera traps from which our knowledge and understanding of ecological relationships and population dynamics has tremendously improved (O'Connell et al. 2011; Rovero and Zimmermann 2016). This is especially true for remote study areas as well as for elusive species (Gray et al. 2017; Murphy et al. 2018), where novel insights were highly driven by the use of trail cameras.

Nevertheless, many studies rely on commercially available products that meet a specific market demand driven by private and professional hunters and which often conflicts with the specific needs of wildlife research (Apps and McNutt 2018; Meek and Pittet 2012; Newey et al. 2015). Capturing small animals, for instance, becomes very challenging with such game or trail cameras as the effective detection distance of small animals is under two meters (Rowcliffe et al. 2011). However, many commercially available models are built to detect large mammals (e.g. deer) at distances > 2 m (Meek and Pittet 2012). To be able to capture small animals, the design and sensitivity of important camera components such as the passive infrared (PIR) sensor, the focal range of the lens, or the type and intensity of the flashlight need to be adjusted (Hobbs and Brehme 2017; Meek and Pittet 2012). To meet these necessary requirements, camera traps are often purpose-built or available models are manually adjusted as only a few brands offer services to customize their models (Meek and Pittet 2012). While a special custom-made device is great, invention, building and testing requires a technical knowledge not every wildlife research group has access to and is costly and labor intensive. These costs become further magnified by the large number of cameras that are needed to gain a powerful sample size to make proper inferences of the research question (e.g. Rovero et al. 2013). To overcome some of the limitations of available game or trail cameras, we present an easy to follow, cost-efficient, and reversible protocol to adjust a camera model with a low unit price of ~ 115€ (~ 130 US$), to monitor small endothermic animals in dense vegetation.

We want to illustrate the effect of these modifications in a study of the nest predator community in the Blackcap (*Sylvia atricapilla*)—a small open-cup shrub nesting passerine. The study conditions were very challenging for the use of commercially available trail cameras because the "close-up" conditions of nest monitoring in dense vegetation lead to: (1) a lack of focus at low distances of 40–120 cm from the monitored object, and (2) an overexposure of night shots because of a high amount of reflectance of the surrounding vegetation. In the following, we illustrate the adjustments and compare the outcomes to initial pictures of a preliminary test run, where the same kind of cameras without manipulation had been used. We also provide a tutorial to adjust the cameras to overcome these problems that might also provide guidance for similar modifications of other camera types.

Material and methods

Manipulation of the camera focus

Usually trail cameras use a lens with a fixed focus and aperture (often at f/3.x; see also Meek et al. 2014) resulting in a depth of field (i.e. the distance within which an object appears focused) ranging from a few meters to infinity (Fig. 1). Objects closer than that will appear blurred. In order to shift the depth of field to closer distances in a fixed-focus lens, one needs to increase the distance between lens and sensor and thereby the focal length.

For this study we used Wild-Vision Full HD 5.0 cameras (VenTrade GmbH, Köln, Germany; serial number SYC2.6_SB05_V2.1). The following procedure is illustrated in a series of pictures in Online Resource 1. To adjust the focal length of one camera, we first removed the eight crosshead screws to open the camera. The camera case was set aside and all batteries were removed. Then we disengaged the three crosshead screws of the smaller circuit board that connect it to the mainboard. This had to be done very carefully, because the board was additionally connected to the camera by a flat ribbon cable. By unlocking the two ZIF (Zero Insertion Force)-connectors on both sides, we also removed the ribbon cable. Thereby, two crosshead screws on the reverse

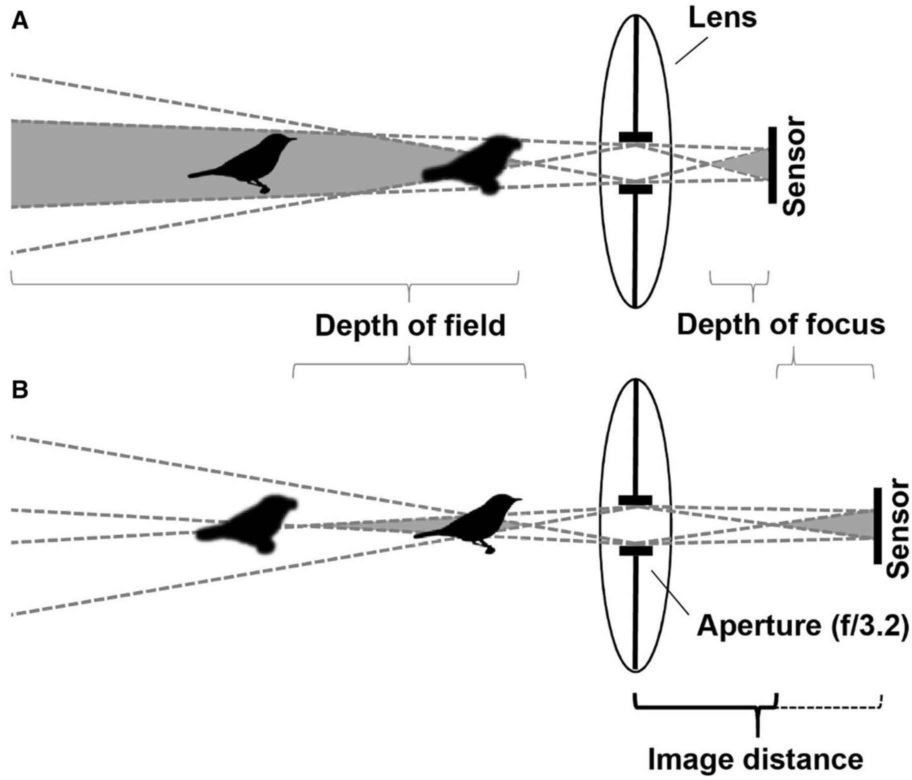

Fig. 1 Differences in image distance result in different depths of field**.** With a small distance between sensor and lens, near objects appear blurry while the background stays clear (**a**). By lengthening the distance between sensor and lens (image distance), the increased depth of focus (and focal length) results in a decreased depth of field. Therefore, near objects appear focused in front of a blurry background (**b**)

side of the circuit board became visible. These fixed the camera lens to the board. In the beginning, we completely removed these screws and pulled the plug to see the dimensions of the CMOS sensor. Later it was sufficient to loosen the screws a bit and insert the spacers. We used small plastic stripes (2×20 mm) placed above and below the sensor to increase the space between lens and sensor and hence the focal length. A spacer thickness of 0.15 mm increased the focal length and led to a depth of field ranging between around 300 and 1400 mm (Online Resource 2). Afterwards, we put everything back together, inserted batteries and took a test photo to see if everything was working correctly.

Cover of flashlights

Modern trail cameras usually consist of an LED flashlight in the visible (white flashlight) and/or the infrared ("black" flashlight) spectrum. While some models consist of two arrays of LEDs to increase illumination a single array cannot be further adjusted. The cameras we used have two black LED arrays (emitting at a wavelength of 940 nm) and originally come with two options for flashlights: Using one array with 19 LEDs and one using both arrays with 40 LEDs in total, which illuminates an area up to 20 m in front of the camera. According to the operating instructions, no branches or leaves should be in this area as they reflect the flashlight leading to overexposed pictures. To reduce the amount of light emitted from the single (upper) LED array, we used pond liner (Ubbink AquaLiner, 1 mm, Outside Living Industries GmbH), cut it in the shape of the LED array and punched holes 4 mm in diameter in it. For our purpose of recording nocturnal predation events at nests placed in dense vegetation, using a single hole for the LED, placed in the middle of the film, and another hole for the light sensor worked best. It is essential to not cover the light sensor, so that the flashlight can be automatically triggered when it is to dark outside. By using adhesive tape, we kept the liner cutout in place (Fig. 2).

Camera testing under field conditions

For our nest monitoring, we manipulated 31 cameras and observed 41 Blackcap nests during the 2018 breeding season in southern Germany. At nests with at least three eggs we

Fig. 2 Modified trail camera for nest monitoring purposes. The upper LED panel was covered by a lightproof film to reduce the flashlight intensity. Two holes (4 mm diameter) are left out: one for a single LED and one for the light sensor. The lower LED panel was turned off

installed one manipulated trail camera at an average distance of 70 cm depending on the vegetation to keep disturbance to a minimum. We set them up with medium sensitivity, a resolution of 5 MP, two images per trigger and a break of five seconds between each trigger for 24 h each day. Battery changes were done at least every third to fourth day until nest success (fledging) or failure (predation) was documented. We compared image quality of these adjusted cameras to a preliminary study from 2017 with unmodified trail cameras of the same model.

Results and discussion

For monitoring Blackcap nests, cameras are usually placed at a distance of 0.5 to 1 m to the nest (Schaefer 2002). Therefore, we assumed our change of the depth of field appropriate for the field study.

Modified cameras showed much improved pictures. The sharpness increased remarkably and revealed details of the nest (Fig. 3). Depending on the camera placement, it was now possible to document feeding and even hatching processes in satisfactory quality. Also nest predation events of many species ranging from medium sized birds and mammals to small rodents could be documented, and clearly identified at a species-level (Figs. 3, 4).

To date, our method represents the most applicable adjustment of commercial trail cameras. In contrast to the only other method published so far (Stille 2017) the modification can be applied in general in a wide range of camera models. Stille (2017) used the camera brands Reconyx HC600 Hyperfire and CUDDEBACK C3 for studying small mammals. To change the depth of field to closer distances, they opened the cameras, broke the sealing and turned the lens a quarter turn to the left. This had the same effect of increasing the focal length as in our preparation. However, this method depends on the type and sealing of the lens and is hence not applicable to all camera models. Therefore, we tried a different method that has the advantage that it is completely reversible, because no sealings have to be broken. This means, that the same units can be used for different research purposes from monitoring large vertebrates to small songbirds. The focal length is easily adjustable to various requirements depending on the thickness of the spacers used.

Another advantage are the costs: The model used here are with around 115€/130 US$ at the lower price-range of trail cameras (Meek and Pittet 2012; Rovero et al. 2013). Hence, the applicability of adjusting the depth of field in such a comparably cheap model allows for reduced costs or maximized replication in similar studies. Nevertheless, we also found limitations in our approach. In particular, we manipulated trail cameras of our model with the serial number SYC2.6_SB05_V2.1, whereas cameras with the previous serial number SYC2.6_SB05_V2.0 were harder or even impossible to adjust due to glued screws. We recommend checking the applicability with test units and noting serial

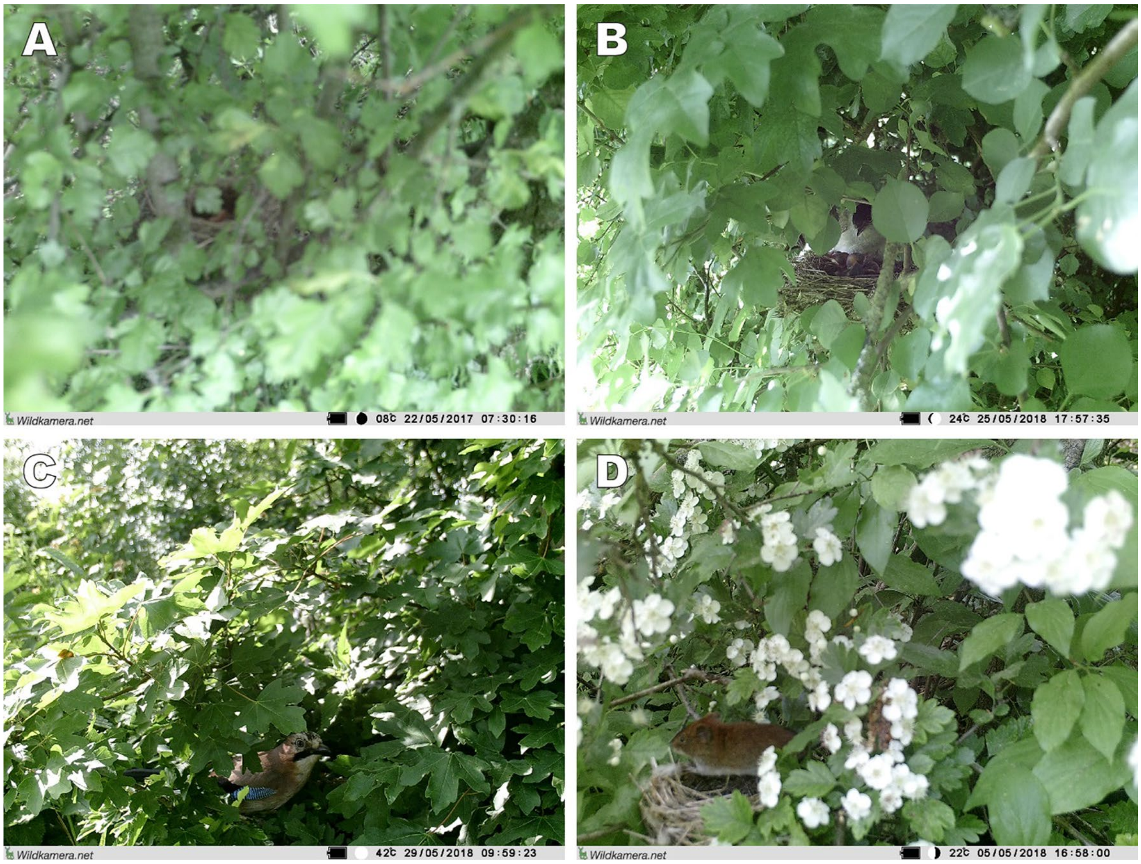

Fig. 3 Comparison of the effect of a manipulated camera focus. The first picture (**a**) was taken without focus manipulation: The background is focused, but the nest itself is blurry. The other pictures (**b–d**) were taken with a manipulated camera: A nest with begging nestlings in a similar distance is now focused (**b**). Nest predators such as a jay (*Garrulus glandarius*) (**c**) or a bank vole (*Myodes glareolus*) (**d**) are now clearly identifiable

numbers before buying a larger number of cameras. Also, understand that the manufacturer warranty lapses after this kind of internal manipulation.

Covering the flashlight turned out to be essential for nocturnal nest monitoring. Due to the reflecting foliage of the shrubs, pictures taken at night without manipulation were totally overexposed and only showed a white space (Fig. 4a). With a single punched hole into a lightproof cover, the exposure of pictures taken at night was much improved and allowed, for instance, the clear identification of nocturnal nest predation (Fig. 4b, d). However, there is still potential for improvement here, as pictures taken during twilight were still overexposed in some cases due to a deficiency of the light sensor, which we have not been able to change. Depending on the concealment of the camera location, sometimes the light intensity during dusk or dawn was too low to trigger the light sensor turning off the flashlights. This combination of daylight and flashlight was again too bright and resulted in overexposed camera pictures.

Nevertheless, the modification of trail cameras presented here describes a valuable approach in terms of time and money for monitoring small endothermic animals. With little effort, common trail cameras can be adjusted to specific needs. This makes them perfect for studies that need to minimize anthropogenic disturbance (e.g. nest monitoring) or for use in hard-to-reach terrain (e.g. shrub nesting birds). Since the general design of trail cameras is largely comparable among models, we are confident that the adjustments we described will be applicable beyond the model used in this study.

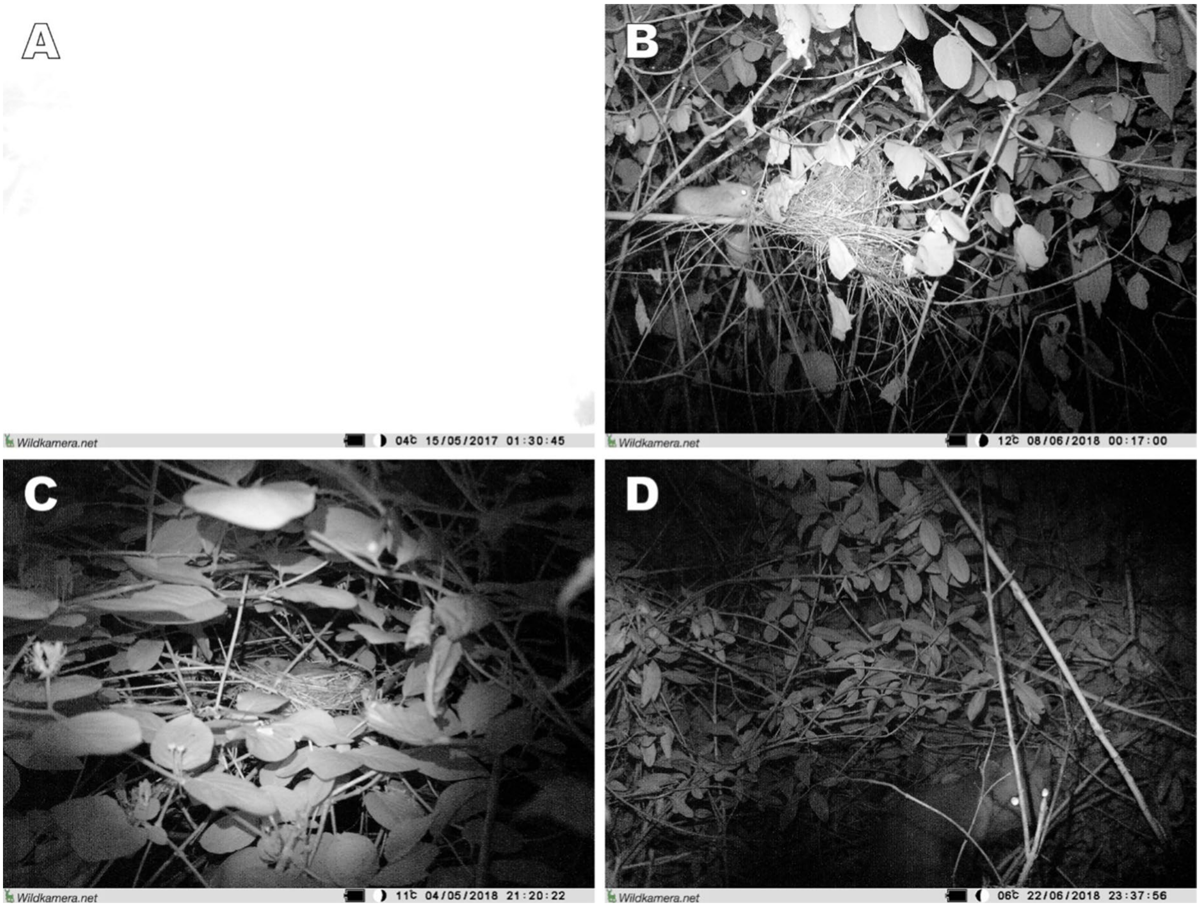

Fig. 4 Comparison of the effect of a covered flashlight. The first picture (**a**) was taken with unmanipulated flashlight: Foliage of the shrubs reflected the light, so that all pictures during the night were overexposed and appeared white. The other pictures (**b**–**d**) were taken after adjustment: Details such as a hazel dormouse (*Muscardinus avellanarius*) approaching a nest (**b**), a female blackcap sitting on the nest (**c**) or a marten (*Martes* spec.) during nest predation (**d**) were now visible

Acknowledgements We would like to thank Stefan Hannabach for his technical advice and D. Stille for an instruction on his method of camera manipulation. We further thank Simone Bosert, Leona Frieboese, Kathrin Grube und Chloé Vescera for field assistance and in helping to adjust the cameras and to the reviewer for improving the manuscript. J.O.E. received additional funds by a Postdoctoral Fellowship from the Research Foundation—Flanders (FWO; 12G4317N). All experiments mentioned here comply with German law.

Author contribution statement LU and JOE conceived the ideas and designed the methodology, with input from KA and AS. LU led the fieldwork and improved the camera adjustments with support from JOE. LU drafted the manuscript with critical revisions by JOE. All authors contributed to the drafts and gave final approval for publication.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest. Also, no commercial relationship or interest exist with the camera manufacturer of which cameras where used in this study.

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