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— Short Note on Methodology —

PORTABLE DIGITAL VIDEO SURVEILLANCE SYSTEM FOR MONITORING FLOWER-VISITING BUMBLEBEES

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Abstract—In this study we used a portable event-triggered video surveillance system for monitoring flower-visiting bumblebees. The system consist of mini digital recorder (mini-DVR) with a video motion detection (VMD) sensor which detects changes in the image captured by the camera, the intruder triggers the recording immediately. The sensitivity and the detection area are adjustable, which may prevent unwanted recordings. To our best knowledge this is the first study using VMD sensor to monitor flower-visiting insects. Observation of flower-visiting insects has traditionally been monitored by direct observations, which is time demanding, or by continuous video monitoring, which demands a great effort in reviewing the material. A total of 98.5 monitoring hours were conducted. For the mini-DVR with VMD, a total of 35 min were spent reviewing the recordings to locate 75 pollinators, which means ca. 0.35 sec reviewing per monitoring hr. Most pollinators in the order Hymenoptera were identified to species or group level, some were only classified to family (Apidae) or genus (*Bombus*). The use of the video monitoring system described in the present paper could result in a more efficient data sampling and reveal new knowledge to pollination ecology (e.g. species identification and pollinating behaviour).

Key words: *bumblebee, flower-visitors, mini digital video recorder, pollination, rhododendron, video motion detection*

INTRODUCTION

Recent development in video monitoring technique has allowed sampling of data on insect behaviour (e.g. Manetas & Petropoulou 2000; Bumrungsri et al. 2008; Marten-Rodriguez & Fenster 2008; Micheneau et al. 2008; Brechbuhl et al. 2010; Micheneau et al. 2010). In those studies, continuous video recording has been used, which demands a great effort in reviewing the material. To avoid this time demanding reviewing, some wildlife surveys have used infrared detectors (Cutler & Swann 1999 and references therein), where the animal has to physically enter the area covered by the infrared beam to trigger the recording. The infrared system could either be passive infrared sensors (PIR) that detect energy from warm blooded animals in motion, or by active infrared sensors detecting changes by moving animals between a transmitter and receiver (Don et al. 2004). Since the PIR sensor is mainly developed for detecting warm blooded animals in motion it's most likely improper for monitoring small cold blooded animals like insects. However, a small active sensor may be suitable for monitoring insects, although it will be very spatially limited, and to our knowledge this has only been used in combination with probe traps (Epsky & Shuman 2002; Shuman et al. 2004; Shuman et al. 2005). On the other hand, a different sensor system has been developed (Rodgers et al. 1994), a video motion detection (VMD) sensor which detects changes in the image captured by the camera, where the intruder triggers the recording immediately, and the sensitivity and the detection area are adjustable, which may prevent unwanted recordings. Such a VMD sensor system has successfully been used for monitoring prey deliveries in raptor nests (Steen 2009) and predation of bird nest (Bolton et al. 2007). This system may as well be applicable for monitoring insects. To our best knowledge this is the first study using VMD sensor to monitoring flower-visiting insects. Observation of flower-visiting insects has traditionally been monitored by direct observations or recently by continuous video monitoring (e.g. Manetas & Petropoulou 2000; Nielsen & Ims 2000; Bumrungsri et al. 2008; Marten-Rodriguez & Fenster 2008; Micheneau et al. 2008; Ono et al. 2008; Brechbuhl et al. 2010; Micheneau et al. 2010). This is time demanding compared to event triggered video recordings. In addition to more efficient sampling of insects pollinating wild plants and agricultural crops, the portable digital video system may also obtain data on plants that rarely are visited by pollinators. The purpose of this paper was to examine if the portable monitoring system with VMD sensor system was suitable for monitoring flower-visiting bumblebees, by using a garden plant as a model species.

METHODS

Study area

The study was conducted in Vestby (59° 36′ 8″ N, 10° 44′ 52″ E), Southern part of Norway.

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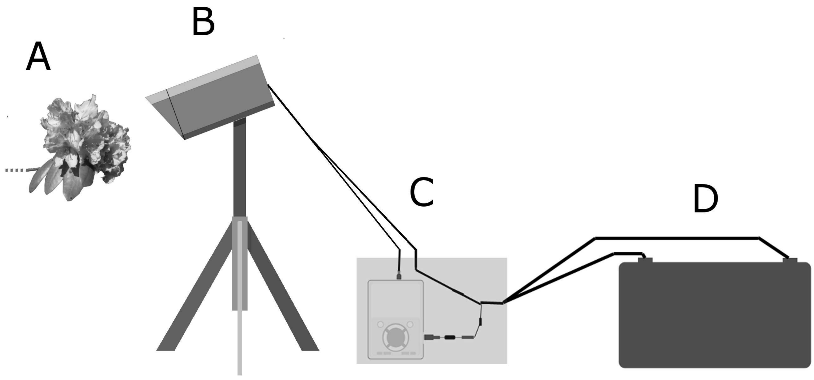

FIG. 1. Schematically drawing of the monitoring system: (A) rhododendron flower stand, (B) colour CCD camera with IR illumination, (C) rainproof plastic box, containing the mini DVR, voltage converter and two fuses, and (D) power supply, 12-volt battery.

We monitored a garden plant, common rhododendron (*Rhododendron ponticum*), hereafter called rhododendron. The rhododendron was located on a farm close to a building. The test period lasted for 5 days, at the end of June 2010.

A waterproof CCD (charge-coupled device) camera (with IR illumination) was placed on a tripod, facing towards one of the flowers (ca. 15 cm between the center of the capitulum to the camera). The camera had a standard 4.3 mm lens, although when studying small flowers and small flower-visiting insects we recommend a camera with a longer focal length (i.e. larger magnification). The camera was connected with a video cable to a mini digital video recorder (mini DVR), see (Fig. 1). Both the camera and mini DVR system were powered by a sealed marine 12-volt DC (80 Ah) lead battery, for technical specification of the setup see (Steen 2009). The monitoring setup weight ca. 1.5 kg (2x10 m cables included), and the battery used in this study (80 Ah 12 VDC) weight ca. 20 kg and will last for approx. 8-12 days (power consumption ca. 0.4 Ah). Smaller batteries could be used, either by shortened the monitoring time or change the batteries more frequently. Another solution is to use a small battery in combination with a solar panel (i.e. battery change will not be needed). To operate the mini DVR, a portable LCD TV was used, Denver model DFT-709, powered by the same battery used for the mini DVR and camera. Approximately the whole system costs 400 £.

The video monitoring system

The mini DVR has a built-in VMD sensor, which detects changes in the image captured by the camera and automatically records the events on the secure digital (SD) card. A SD card with a storage capacity on 2 gigabyte (GB) was used. The sensitivity, as well as the detection area which trigger the recordings, are adjustable. When performing the sensitivity adjustments, the mini-DVR automatically measure the percent change in the image captured by the camera and displays the values both as a number and as a horizontal bar. By watching on a monitor the sensitivity level was set by displaying the percent change in the monitoring area when a bumblebee visited the flower. The system is more sensitive towards large moving object and objects that are in strong contrast with the environment. Selection of detection area is performed by using a masking tool, the detection area was only set to cover the flower (Fig. 2). The recording duration for each event was set to 5 sec. Time used for installing and doing the adjustments was about 15 min.

The SD cards with stored material were transferred to a laptop with a SD card reader, and arranged in folders. The mini DVR records the events in ASF file format (see http://www.microsoft.com/ for details), and the files with flower-visiting insects were detected by viewing the files, using thumbnail function, where the start of the recording is displayed as a screenshot. In this manner, files were shown as small screenshots, and files with pollinating insects were easily separated from files with unwanted recordings (i.e. recording caused by other environmental factors). Each file was automatically assigned with a unique identification number with the date and time expressed. The recordings could be viewed in detail (frame by frame) with a DivX-player (see http://www.divx.com/ for detail) or with the mini DVR.

The reliability of the system was examined by monitoring the rhododendron both continuously and with VMD for the last day of the monitoring period (7 am to 9 pm). Hence, two mini DVRs were used simultaneously, one with the VMD activated, and one with continuous recording at the lowest quality setting. A video split cable was used to provide both mini DVRs with the same video signal from the camera.

Classification of the flower-visiting bumblebees

The flower-visiting bumblebees were identified by visual inspection of the video material on a monitor. Typical individuals of common species/groups in the genus *Bombus* are usually recognized by the colour pattern, although a thorough inspection under a magnifying glass is required to get a 100% certain identification (Carvell et al. 2007). Moreover, in some cases, only a DNA analyses can reveal the true identity of a bumblebee (Ellis et al. 2006; Carvell et al. 2007; Stewart et al. 2010; Wolf et al. 2010).

FIG. 2. Screenshots from recordings made of the rhododendron illustrating the video motion detection sensor. The upper left picture shows the camera view of the capitulum. The upper right picture shows the area that was masked (i.e. the dark grey square boxes). Only the unmasked area is sensitive to movements and triggers the recordings. In the lower left picture the approaching bumblebee that triggers the recording. In this case (picture lower right) it was a classified to *B. terrestris / B. lucorum* group.

RESULTS AND DISCUSSION

A total of 98.5 monitoring hours were conducted. For the mini-DVR with VMD, a total of 35 min were spent reviewing the files (i.e. recorded events) to locate 75 flower visiting insects, which means ca. 0.35 sec used for reviewing per monitoring hr. Hence, VMD system is much more effective compared to the continuously monitoring, which has been used in earlier studies (Manetas & Petropoulou 2000; Bumrungsri et al. 2008; Marten-Rodriguez & Fenster 2008; Micheneau et al. 2008; Brechbuhl et al. 2010; Micheneau et al. 2010). Only 22 of the registered insects were in contact with the flower (i.e. touching anthers/stigma) and 53 were classified as insect passing without being properly in touch with the flower. Of the flower visiting insects being in touch with the flower, 72.7 % were bumblebees and 27.3 % were flies (Tab. 1).

The VMD revealed unwanted recording either caused by an insect triggering the recordings continuously (e.g. flies staying and moving on the flower for a while) or environmental factors such as wind creating too much motion in the flower. In fact, ca. 85 % of the stored files was triggered by the wind. However, the cons of unwanted recordings were considered as minor since after 5 days of monitoring 67 % of the storage capacity still remained, and most important it was efficient to distinguish the files with pollinating insects from files without insects by viewing the small screenshots (ca. 0.35 sec used for reviewing per monitoring hr). For future studies, the amount of unwanted recordings due to wind could be reduced by supporting the flower with sticks and small threads. The VMD system recorded all flower-visiting insects (i.e. classified as being in touch with the flower) that were recorded by the continuously monitoring during the last day of monitoring (n = 8). However, the reliability of the system is dependent on the environmental conditions. Each plant monitored needs a unique and proper adjustment of both detection area and sensitivity level, this to make sure that is sensitive enough to record flower-visiting insects of interest.

The quality of the recordings was satisfactory and enabled identification or classification (see supplementary video material). The flower-visiting bumblebees were identified to species level (*Bombus pratorum* and *Bombus hortorum*) or to subgenus or group level (subgenus *Bombus* sensu strictu, hereafter referred to as *B .terrestris / B. lucorum* group (Prys-Jones and Corbet 1991; Dramstad & Fry 1995; Croxton et al. 2002)). In the *B. terrestris / lucorum* group, *Bombus terrestris* and *Bombus lucorum* are by far the most common species in South-Eastern parts of Norway (Løken 1973; Dramstad & Fry 1995; Öberg et al. 2009), but the *B. terrestris / lucorum* group contains two additional, less known species: *Bombus magnus* and *Bombus cryptarum* (Ødegaard et al. 2009; Wolf et al. 2010). Only one hymenopteran pollinator left some uncertainty concerning its identity. Although it was identified to be a *Bombus hortorum,* the angle of the bumblebee hid some important parts in shadow and thereby made it impossible to make a 100% positive identification. The flies (Diptera) were only possible to identify into taxon Cyclorrhapha within the infraorder Muscomorpha. In total, 43.8 % of the true pollinating bumblebees were identified at species level, 56.2 % were classified as group (i.e *B. terrestris / B. lucorum*) (Tab. 1). For the bumblebees passing without being properly in touch with the flower (i.e. non pollinating behavior), none was identified at species level, 80.0 % were classified to group (i.e *B. terrestris / B. lucorum*), and 20.0 % were classified to genus (*Bombus*) (Tab. 2).

The main limitations of this monitoring system are that only one flower or small number of flowers can be observed at each time. Further, only insect species which are identifiable by colour pattern or other apparent morphological traits can be determined. A lead battery is needed for power supply and this ad up almost all of the weight, one the other hand a smaller battery could be used in combination with a solar panel.

Overall, the video monitoring system described in the present paper could result in a more efficient data sampling of pollinating insects. The setup is portable and reveals identification to species level for bumblebees that is recognized on their color pattern and size. This system may be applicable for future studies on wild plants and agricultural crops, with the emphasis on species identification and pollinating behaviour. Further, the system may also obtain unique data on plants that rarely are visited by pollinator.

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Order	Family	Genus	Species	No. of obs.
Hymenoptera	Apidae	*Bombus*	*B. pratorum*	6
Hymenoptera	Apidae	*Bombus*	*B. terrestris / lucorum*	9
Hymenoptera	Apidae	*Bombus*	*B. hortorum*	1*
Diptera**				6

*not 100% positive identification
**only identified into taxon Cyclorrhapha within the infraorder Muscomorpha

TAB. 1. Registered flower-visiting species (i.e. classified as being in touch with the flower, n = 22).

Order	Family	Genus	Species	No. of obs.
Hymenoptera	Apidae	*Bombus*	*B. terrestris / lucorum*	24+8*
Hymenoptera	Apidae	*Bombus*		8
Diptera**				3
Not identified				10

*not 100% positive identification
**only identified into taxon Cyclorrhapha within the infraorder Muscomorpha

TAB. 2. Registered flower-visiting species that were only passing by (i.e. just passing by the flower, n = 53)

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