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First results on the performance of LOGCAVE, a new device to monitor human disturbance on cave-dwelling bats

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Introduction

Anthropogenic disturbance can be of conservation concert for certain animal species, especially when it happens in their most sensitive areas (e.g. nesting sites) or periods of their life cycle (e.g. hibernating). Amongst bats, cave-dwelling species are especially vulnerable to this problem, as some of their underground roosts can be easily visited by humans and are of special interest for tourism o speleology. Summer and winter roosts, when bats form maternity and hibernating colonies respectively, are sensitive periods where human visits to these roosts can have a significant impact on the local population. Summer is when females give birth to young bats, increasing their energy demands until juveniles can feed by themselves, hence unnecessary flights and movements caused by human disturbance to the colony can cause the loss of their juveniles. In winter, temperate bats reduce their metabolic rate to a point where energy demands decrease as insect availability (the main food of many bat species) greatly decreases. Disturbance during this period force bats to wake up and increase their metabolic rate unexpectedly, causing an imbalance between their high energy consumption and low food intake, increasing their risk of death by starvation.

The aim of the LOGCAVE project is to design and build a device to monitor human disturbance on underground roosts efficiently. The LOGCAVE allows to infer human presence by measuring changes in light conditions inside the roost. As these roosts are usually too dark to human sight, people visiting these sites use headlamps, phone flashes or torches. The device records every light event and the time only when the light conditions exceed a threshold value set by the researcher. This threshold configuration is needed as some roosts are not fully dark as some natural light can enter the roost, and therefore it allows to adjust the device performance to each roost's light conditions. The device also records temperature and humidity.

Camera traps can be useful for monitoring of human presence, but the processing of hundreds of pictures may not be cost-effective in some situations and energy consumption of some brands can be too high for long-term monitoring. In contrast, the LOGCAVE has a low energy consumption and generates a text file which can be easily analysed.

This report presents the preliminary results of a field test of the LOGCAVE device, carried out in 2023.

Figure 1. LOGCAVE being installed in an underground roost.

Material and methods

The study area corresponds to three important underground bat roosts located in Catalonia (NE Spain): Cave 1 in La Noguera county, Cave 2 in La Noguera county and Cave 3 in Berguedà county (Figure 2). All three roosts are known to hold bat species of conservation concern such as Schreiber's Bat (*Miniopterus schreibersii,* Vulnerable[12] on national and global levels) or Long-fingered Bat (*Myotis capaccinii,* Endangered[1] and Vulnerable[2] on a national and global level respectively), amongst others. All three sites are natural caves easily accessible and usually frequented by people. Cave 1 is connected to a hydro-electric power plant and the local council organizes regular group visits to the cave.

One LOGCAVE was installed at each site from late March to beginning of August 2023. The three devices were fully functional 24 hours a day every day, except for Cave 2 where the LOGCAVE did not log the data correctly between the 30th of May and the 19th of June (10 days), possibly due to human error when programming but cannot be confirmed. The LOGCAVEs were placed inside the cave, in an area as dark as possible but exposed to any artificial light used by the visitors. For each LOGCAVE, a threshold value was set after measuring the minimum light intensity while a researcher with a headtorch walked around the cave during the deployment on the first day. The

[1] Spanish Catalogue of Endangered Species (2008)

[2] IUCN Red list of Threatened species, Global status (2016)

thresholds values varied between sites due to different natural light conditions as not all sites were equally dark, and in two sites these values where better adjusted after a few days working with a different value (Table 1).

Figure 2. Location of the three study sites: Cave 1 (green dot), Cave 2 (blue dot) and Cave 3 (red dot).

Simultaneously, a camera trap was installed at each site and close to the LOGCAVE, to test the effectivity of the device. The camera trap allowed to know when a person entered the site. All three camera traps but Cave 3 were fully functional 24 hours a day every day. Due to technical issues, the camera trap at Cave 3 did not work between the 26th of April and the 18th of May.

All LOGCAVES and camera traps were checked monthly for data downloading and battery replacing when needed.

Table 1. Working days for each device and threshold value set for each site.

Site	N days LOGCAVE and camera trap simultaneously working	Light threshold value	Notes
Cave 1	135	0,00005	
Cave 2	97	0,00021	Threshold value on the first days was below 0,00012.
Cave 3	46	0,00355	Threshold value on the first days was 0,0001033.

Results

LOGCAVE performance

All visits registered by the camera trap were easily identified as peaks on the light data registered by the LOGCAVE in all sites (60 visits positively detected by the camera traps; Table 2), showing the maximum sensitivity possible (1) for all three devices during the study period. However, the LOGCAVE registered more days with light events falling above the threshold value, indicating that the threshold could be further adjusted to avoid false positives (Table 2). However, these values are much lower than the values registered when true visits happen.

Table 2. Results on the LOGCAVE performance for each site, showing the number of visits per device, and the sensitivity (rate of days with visits identified as such).

Site	N days with events registered by LOGCAVE	N visits registered by LOGCAVE*	N visits registered by camera trap	Sensitivity
Cave 1	33	23	23	1,00
Cave 2	79	20	20	1,00
Cave 3	81	17	17	1,00

* N visits registered by LOGCAVE correspond to events where lux values fall well above the rest of the data registered.

Examples of LOGCAVE recorded data

Figure 3 shows maximum light intensity values per minute collected by the LOGCAVE deployed at Cave 1 during April 2023. The data shows values above the set threshold on five days of April and mostly around 13:00-14:00h, showing 6 clear peaks (two peaks on the 2nd of April). The camera trap registered pictures from people on all these days at similar times (slight differences in times probably corresponding to difference in clock settings between devices). The rest of the values recorded by the LOGCAVE correspond to light conditions overpassing the set threshold, possibly due to an artificial light nearby used by technicians from the power plant, suggesting further adjustments can be made to obtain neater results.

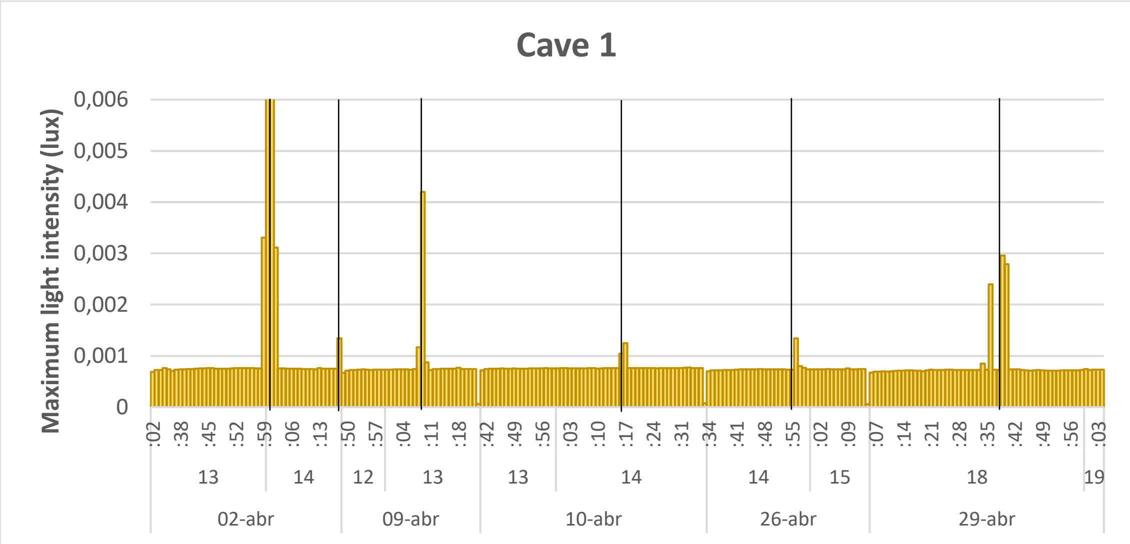

Figure 3. Maximum light intensity recorded per minute by the LOGCAVE at Cave 1 during April 2023. Highest values on the 2nd of April are cut by the axis scale max. value set at 0,006 lux to show lower peaks in the rest of the days. Black vertical lines show visits also recorded by the camera trap in April.

Figure 4 shows maximum light intensity values per day collected by the LOGCAVE deployed at Cave 2 during April 2023. The data shows lux values above set threshold and every day but the 4th of April, with values highly above the rest on ten days. The camera trap registered pictures from people on all these peak days but on the 30th of April due to malfunctioning issues mentioned above. The rest of the values recorded by the LOGCAVE correspond to light conditions overpassing the set threshold due to natural sunlight entering to the cave, again suggesting further adjustments can be made to obtain neater results.

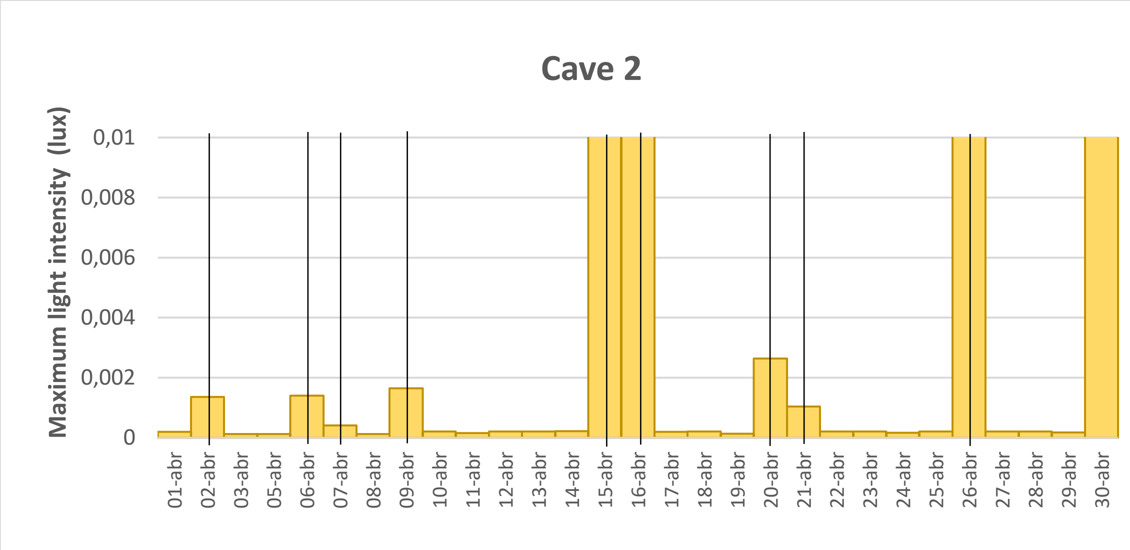

Figure 4. Maximum light intensity recorded per day by the LOGCAVE at Cave 2 during April 2023. Highest values on the 15th, 16th, 26th and 30th of April are cut by the axis scale max. value set at 0,01 lux to show lower peaks on the rest of the days. Black vertical lines show visits recorded by the camera trap in April.

Figure 5 shows maximum light intensity values per day collected by the LOGCAVE deployed at Cave 3 during July 2023. The data shows lux values above threshold on the seven days. The camera trap registered pictures from people on all these days but the 27th of July, when the LOGCAVE unusually registered very high light values.

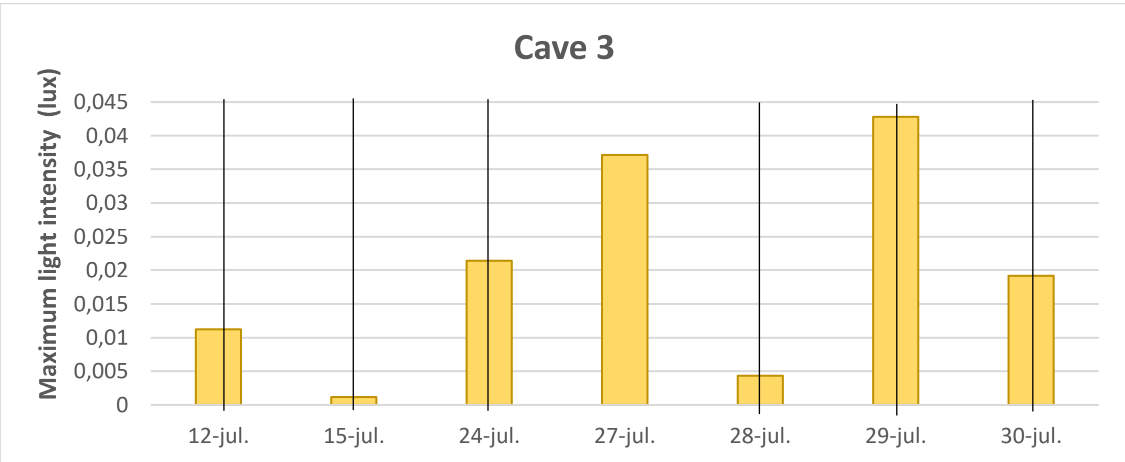

Figure 5. Maximum light intensity recorded per day by the LOGCAVE at Cave 3 during July 2023. Black vertical lines show visits recorded by the camera trap in July.

Conclusions

1. The field test concluded with a maximum sensitivity of the tested LOGCAVE devices, allowing to detect all 60 visits done by humans to all three caves during the sampling period after a quick data processing and visualization.
2. Setting the light threshold value adequately is critical for improving efficiency in terms of battery and data analysis, as this avoids collecting thousands of light events which are false positives caused by natural light conditions. In this sense, although we aimed to find the correct value by measuring the minimum light intensity while a researcher with a headtorch walked around the cave during the deployment on the first day, the devices registered light events caused by natural light conditions during daytime, as the devices were deployed near the roost entrance. Therefore, it is recommended to check registered data regularly to detect values coming from natural light events (false positives) and re-adjust the threshold value accordingly.
3. Battery length of the device allow long-term monitoring feasible. The field test lasted for 6 months during which no battery change was needed. Considering that all three tested devices' threshold values could be further adjusted for neater results, reducing the number of registered events, battery could show even longer lifespan.
4. Its small size facilitates deployment and reduces the risk of being detected by humans.
5. Given the fact the device also records temperature and humidity, the use of LOGCAVE, in combination with ultrasound autonomous recording units like Audiomoth, would highly increase the knowledge and understanding of population dynamics of endangered cave-dwelling bats in underground roosts, by collecting data of many key variables simultaneously, both natural and anthropogenic.

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