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Relative Performance and Practicality of Night Vision Aids and Naked Eye Counts for Emerging Bats

Greater horseshoe bats (*Rhinolophus ferrumequinum*).

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The Bat Conservation Trust's *Good Practice Guidelines* now require the use of night vision aids for bat emergence surveys. In light of this, we compared the efficacy and efficiency of three bat emergence roost count methods: naked eye counts, infrared recording playback counts and thermal recording playback counts. Emergence surveys were performed at four soprano pipistrelle (*Pipistrellus pygmaeus*) maternity colonies across Scotland during the breeding season. The use of either night vision aid (thermal or infrared) significantly improved the rate of bat detection relative to the naked eye. However, when it was darkest (60–90 minutes after sunset), thermal outperformed infrared.

Introduction

What are night vision aids?

Night vision aids (NVAs) come in many different forms, but infrared night vision goggles are a popular device that use reflected infrared light to enable the surveyor to see moving bats in low-visible-light environments without the added disturbance of white light. Thermal recording devices are another form of NVA. They differ from infrared devices in that thermal imaging captures how heat is radiated from an object, versus how light is reflected off an object. Although both devices utilise infrared energy, for brevity we call them 'infrared' and 'thermal' devices. In terms of bat surveys, these NVA devices are usually used as an aid to the surveyor once the natural light becomes too poor for the naked eye to see.

Both thermal and infrared NVAs can be used during bat surveys by a surveyor or from a fixed point on a tripod without the presence of a surveyor. Infrared NVAs are currently more widely used for bat monitoring, partially due to the affordable cost. While these devices allow visual monitoring to continue past dusk, contrast on the display is generally minimal and background clutter in the environment can exacerbate this. Thermography is rapidly gaining popularity in the wildlife conservation community, but Cilulko *et al*. (2013) emphasises some key limitations such as weather conditions and presence of sunlight altering thermal detection rates. Surveys performed in very warm and humid climates have decreased contrast between the warm animal and the background when compared to surveys performed in cooler ecosystems.

Why maternity roosts?

The goal of any biological monitoring endeavour is to obtain the most accurate information while causing the least amount of disturbance to the animals. Bats emerge from their roosting structure to feed or travel at dusk when the predation risk is reduced (Speakman *et al*. 1995). A non-invasive way to determine the size of any colony is to count emerging bats as they are exiting. This behaviour becomes more predictable as the size of the colony increases (Speakman *et al*. 1995).

Female bats of some species, such as soprano pipistrelles (*Pipistrellus pygmaeus*), gather in large groups when breeding to provide the pups with warmth and security throughout the summer breeding season. Pregnant and nursing females need to feed regularly to support their young. Surveys of maternity colonies were therefore used in this study to ensure predictable emergences of high numbers of bats that could be recorded for several nights in a row. This ensured a good sample size would be obtained to compare the methods.

Objective

Our objective was to determine any differences in detection rates of three frequently used emergence count methods – naked eye, and recordings by infrared and thermal NVAs – by conducting them simultaneously at maternity roosts in varying levels of ambient light and examining the reliability and user accessibility of these methods.

Methods

Site selection

Each of the study sites hosted a maternity colony of pipistrelles with a main roost entrance that most of the colony emerged from. The last consideration ensured that emerging bats would be in the field of view of the recording devices being used. Four sites were selected that covered a range from the Scottish Borders to near Inverness (Figure 1).

Figure 1. The geographic distribution of the four field sites in Scotland used in this study.

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Equipment

We used the Nightfox Swift 2 Pro infrared night vision goggles and the Pulsar Helion 2 XQ thermal monocular as our NVAs, models commonly used by ecological consultants (based on the authors' personal observations). Nightfox is a popular make of infrared goggles among bat surveyors due to their affordability and usability. The infrared goggles are sensitive to infrared light and can also emit infrared light if necessary to be able to see objects and scenes without natural visible light. The settings on the infrared goggles were kept consistent (infrared 1, exposure 1, brightness 5) throughout the study. The Pulsar thermal monocular uses heat signatures emitted by both animate and inanimate objects to create an image that represents those heat signatures. This form of technology does not require any visible light (natural or artificial). In addition to the different way that the two NVAs work, there are other fundamental differences that could affect data quality (Table 1).

We watched back all recorded footage using VLC media player since it has the capability of displaying footage in the recorded frame rate. We used an HP EliteBook 850 G4 with a refresh rate of 60 Hz which was equivalent to the fastest frame rate of the Nightfox at 60 frames per second.

Protocol and data management

The Bat Conservation Trust's (BCT's) *Good Practice Guidelines* (Collins 2023) lay out the standard protocol for UK bat surveys. They state that "…dusk emergence surveys should start…15 minutes before sunset and finish 1.5–2 hours after sunset, with survey times adjusted depending on the observations made during previous surveys". The guidelines highlight the likelihood of early emergences on overcast evenings or when the roost

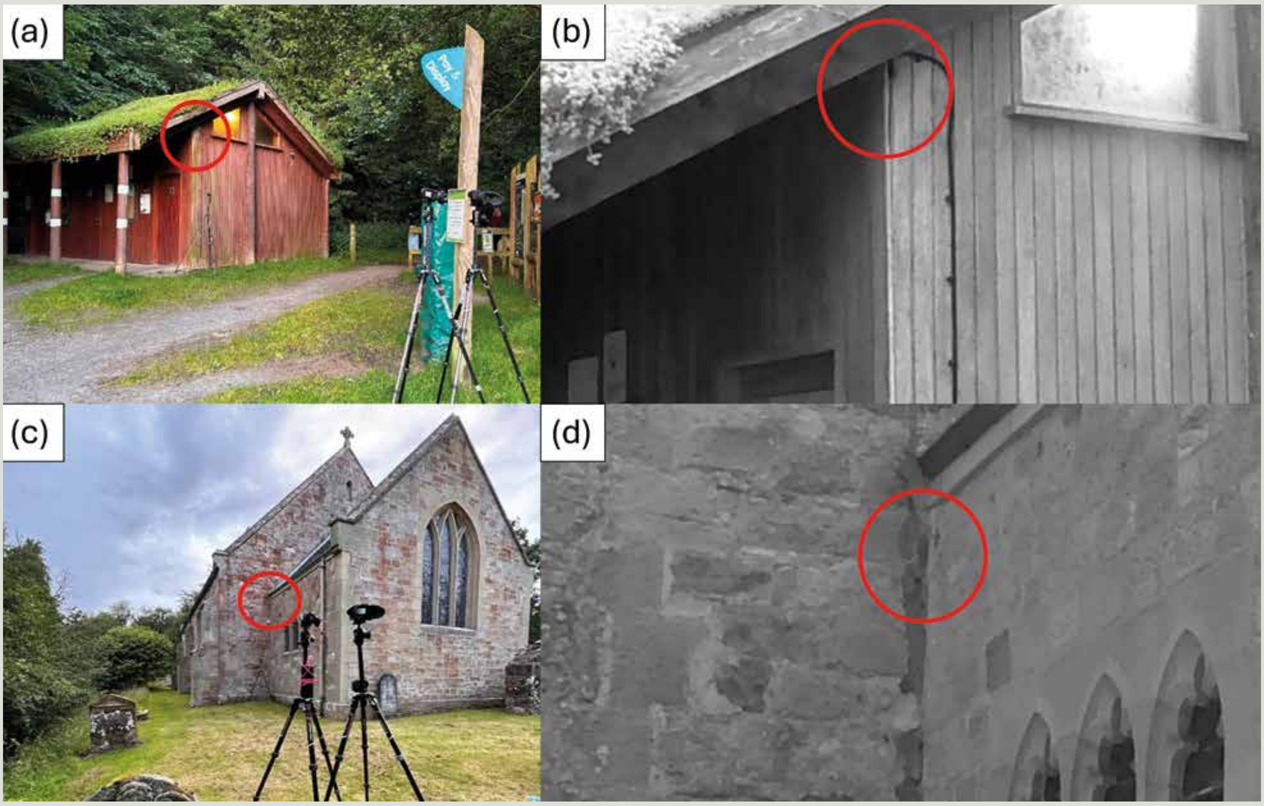

Figure 2. Panel (a) and (c) show the devices set up on two of the sites. In each photo the thermal device is on the left and the infrared on the right. Panel (b) and (d) demonstrate the fields of view of the infrared device. Red circles highlight the roost entrances.

Table 1. Manufacturer details of frame rate and screen resolution of two NVAs used in this study when used live or with recordings.

Detail	Infrared Nightfox Swift 2 Pro		Thermal Pulsar Helion 2 XQ	
Mode	Used live	Recordings	Used live	Recordings
Frames per second	30	Up to 60	30	50
Screen resolution	480×360	1280×720	1024×768	1024×768

entrance is hidden from the setting sun. Thus, we started the survey 30 min before sunset and ended 1.5 h after sunset on almost every survey night, capturing the monitoring period recommended by the guidelines.

We placed both NVAs on tripods 10 m from the base of the focal roost entrance (Figure 2). The Pulsar thermal monocular used in this study had a minimum zoom setting of 3× built in, so the Nightfox infrared goggles were adjusted to 3× zoom to maintain consistency. The recording devices were positioned such that the focal roost entrance was located at the top of the field of view. Bats tend to drop out of the roost, swooping down to gain momentum before taking flight, so this field of view allowed for each bat to be detectable on the screen during playback for the maximum amount of time. The surveyor stood adjacent to the two devices such that all three methods (naked eye, infrared, thermal) had the same viewpoint and distance and were counting simultaneously. The surveyor had one season of bat survey experience prior to this study, but as the bats were emerging from a known point, minimal experience would have been necessary to see and identify the emerging bats. The sampling strategy is shown in Table 2. It consisted of tally counting bats in four 30 min time periods between 30 min pre and 90 min post sunset and summing these for a total count.

To obtain the infrared and thermal counts, video footage was watched after the survey. Each survey night

Table 2. Sampling strategy per night per site.

30–0 min pre sunset	0–30 min post sunset	30–60 min post sunset	60–90 min post sunset
# of emerging bats	# of emerging bats	# of emerging bats	# of emerging bats
Total # of emerging bats across all four time periods			

Counts were organised into four 30 min periods in relation to the time of sunset. These were summed to provide a count across the complete survey period.

produced 4 h of video footage (2 h per device) that was watched on 2× speed. The playback process was initially trialled at 3× and 4× speed early in the data collection process, but we found that many bats were being missed due to the lack of time they were present on the screen.

To compare methods, we plotted counts per period per night for each pair of methods onto scatterplots and added the line of equality ($x = y$) along which would lie any counts that were equal between the two methods. Points above the line show where the method on the y-axis is better and those below the line where the method on the x-axis was better. We also coloured points by time relative to sunset (as per colours in Table 2) so we could visualise whether differences in methods depended on light conditions. Because there was a positive skew in the count data, for visualisation we carried out a $\log_{10}$ transformation, adding a small constant (0.5) to allow inclusion of zero counts. This is a standard approach for variables including zeros that cannot otherwise be log-transformed.

Post study, we critically reflected that the 2× speed might bias the results relative to real time speed, which many ecologists use (authors' personal observations). To test this, we rewatched a subsample of videos in real time. This was conducted as a blind comparison. This was performed on the recorded footage from each site on both NVA devices from the two darkest time periods that encompass 30–90 min post sunset. These were the periods that demonstrated the largest difference in counts (see Results) between the methods and therefore seemed appropriate to focus on. To test for any bias between 2× and real-time playback, we performed the same analysis as between methods.

Results

Comparison of emergence counts

The species at all four maternity roosts were identified with a bat detector as likely soprano pipistrelles. Peak counts (the highest count for any single method) per site ranged between 29 and 884, although counts varied within each site throughout the course of the summer survey period. A summary of counts per site and per method is shown in Table 3. Peak emergence times across all four survey sites were highest in the 1 h period after sunset. This is consistent with BCT's guidelines which state that the mean emergence time for soprano pipistrelles is 27–35 min post sunset.

Scatterplots of counts per time period per night for each pair of methods are shown in Figure 3. For earlier time periods (lighter blue points), most points lay on, or very close to, the line of equality, indicating very similar counts regardless of method. However, for later time periods

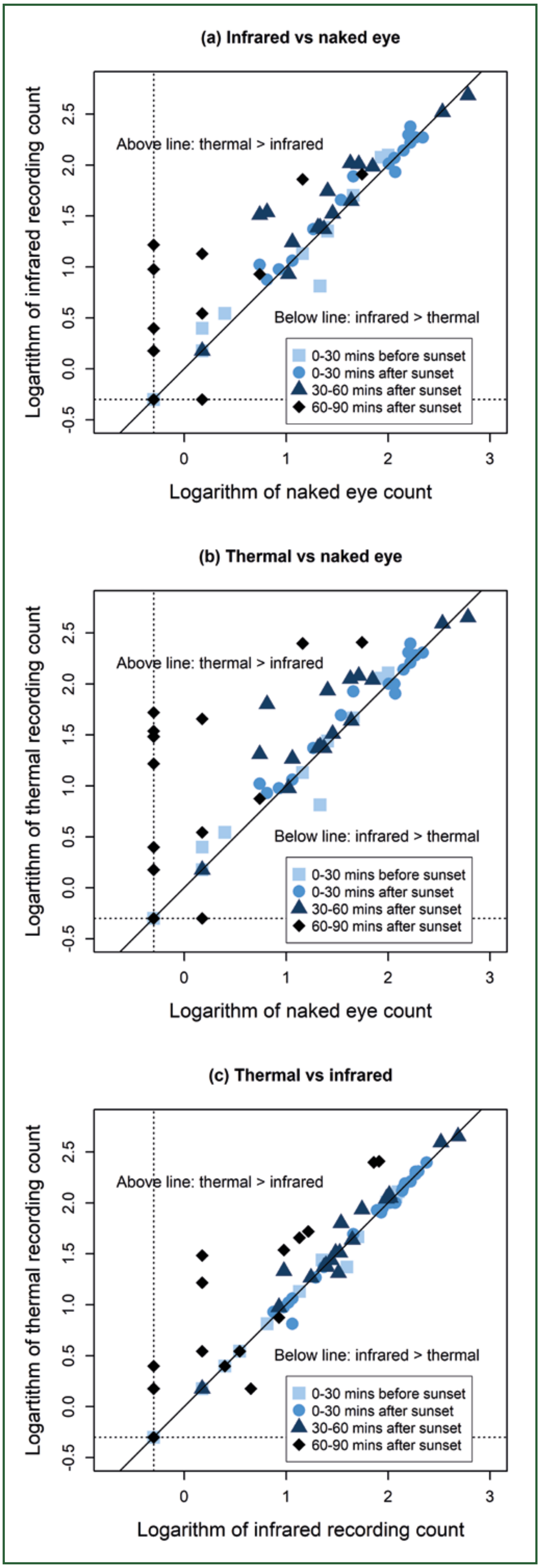

Figure 3. Direct comparisons of counts using three possible pairs methods: (a) infrared vs naked eye, (b) thermal vs naked eye and (c) thermal vs infrared, separated by time relative to sunset in 30 min periods. The solid lines are not best-fit lines, but rather represent the line of equality along which would lie any counts that were equal between the two methods. Points above the line show where the method on the y-axis is better and those below the line where the method on the x-axis was better. The dotted lines represent counts of zero on the $\log_{10}$+0.5 scale.

Table 3. Summary of counts per method per site.

Site	Eye count	Infrared count	Thermal count
1	671 (564–777)	631 (568–693)	828 (785–870)
2	216 (204–233)	238 (196–292)	269 (196–339)
3	36 (34–41)	44 (42–46)	44 (42–46)
4	185 (143–226)	212 (170–246)	204 (161–278)

Sites are anonymised by listing from north to south (see Figure 1). Values shown are median and interquartile range in parentheses, rounded to whole numbers.

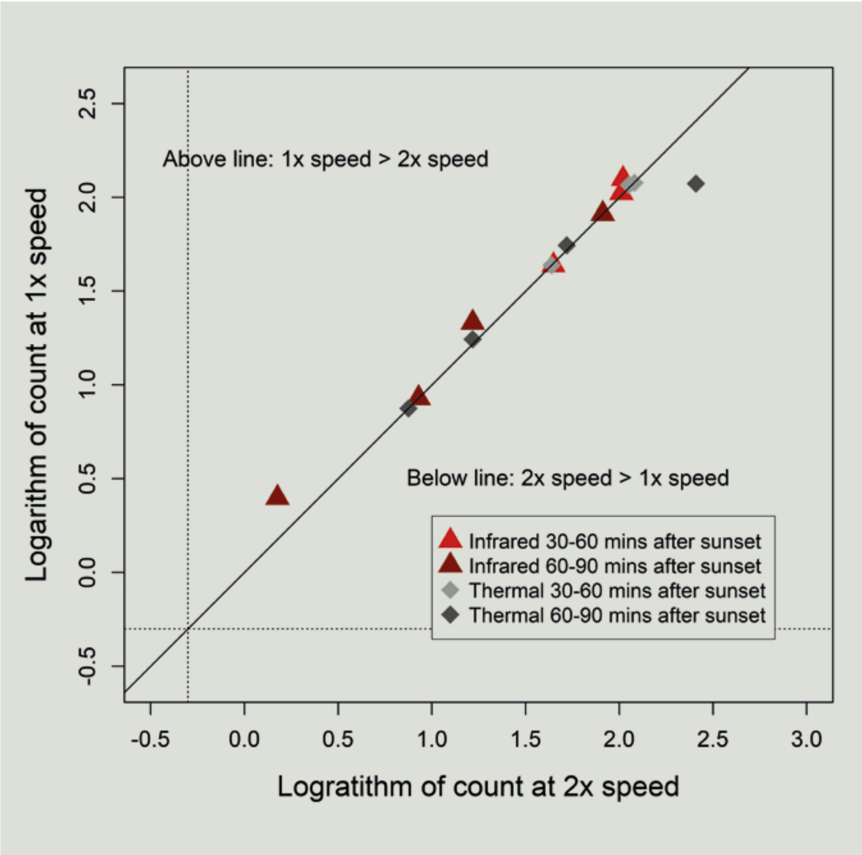

Figure 4. Direct comparison of counts from recordings (on infrared and thermal devices) watched in real time and at 2× speed. See Figure 3 caption for interpretation of data and lines.

Table 4. Overview of user evaluation highlighting differences between methods.

Parameter	Naked eye	Infrared Nightfox	Thermal Pulsar
Data extraction (post survey)	0 h	1 h	1 h
Cost	£5*	£180	£3500
Bat detection after dark	Low	Medium	High
Dependence on ambient or artificial light	Yes	Yes	No
Reproducibility	No	Yes	Yes

*Cost for naked eye counts is indicative cost of a hand-held tally counter if required.

(30–90 min after sunset; darker blue points) when light levels are low, there tended to be a positive bias in favour of infrared and thermal over naked eye counts, and also thermal over infrared counts. Paired Wilcoxon signed rank tests showed that these differences were significant for infrared versus naked eye total count (V=34, p=0.008) and thermal vs naked eye total count (V=25, p=0.003). The difference between thermal and infrared was only significant for the final, darkest time period (V=8.00, p=0.01).

In our comparison of 2× speed and real-time playback, there was a relatively very small amount of difference between counts across infrared or thermal counts (Figure 4), and any differences were low compared to differences between methods (Figure 3). Paired Wilcoxon signed rank tests showed no evidence of an effect for infrared (V=6.5, p=0.462).

User evaluation

The three different counting methods are compared across a range of parameters in Table 4. We used devices and software packages that are readily available. Naked eye counts were used as this was standard before the 2023 guidelines, enabling comment on whether the introduction of NVAs facilitates more accurate detection. The obvious issue with naked eye counts is that reduction in light shortens the effective survey window. NVAs are a way around this limitation. The main consideration for the use of a thermal recording device compared to an infrared device is cost (Table 4).

Logistical differences and battery or storage considerations may also influence the choice of equipment. The Pulsar battery pack takes nearly 10 h to fully charge, while the Nightfox takes only 3–4 h when charged via USB-C cable. Both devices can also be charged in the field while recording. The Nightfox uses micro-SD cards to store recorded footage, which can be easily removed and inserted into a computer for fast data transfer, meaning multiple cards can be used in rotation. The Pulsar has internal memory and can only store 2.5 nights (5 h) of footage before reaching capacity.

The Pulsar monocular would be uncomfortable to hold to one's eye for

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extended periods of time, whereas the Nightfox goggles better suit in-person surveys due to the binocular-type design. Nevertheless, the display resolution and the frame rate (Table 1) are both inferior to those of the recordings from both devices. The Nightfox records videos as audio video interleave (AVI) files while the Pulsar outputs MP4 files. AVI files are not able to be played back on the standard Windows Media Player on most computers, so VLC Media Player was utilised.

Conclusion

The use of NVAs proved to be significantly more effective at detecting emerging bats than naked eye counts after sunset. The thermal device produced the highest detection rate of the three methods and was the most effective in low light conditions. These findings are well aligned with previous studies suggesting that thermal videography is the best method of population estimation in the absence of ambient light (Cilulko *et al*. 2013). Most interestingly, in a direct comparison, the thermal device detected significantly more bats (or missed fewer) than infrared 60–90 min after sunset. This may have implications for bat ecologists in terms of choice of equipment for various bat surveys. Other sources of natural or artificial light such as the moon, streetlamps or security lights near a target roost could alter the discrepancy between detection rates of the thermal and infrared devices after dusk (60–90 min after sunset). Although we recognise many ecologists will watch footage at real-time speed, it was of note that we found no significant difference in counts between this and 2× speed in a direct comparison.

When using a thermal device, emerging bats appear completely white from wing tip to wing tip. As they fly around, the wings cool, and then appear dark grey to black on the device. A practical use for thermal devices is in roost entrance discovery. During an exploratory survey, it is useful to walk around the target structure to find glowing white areas through a thermal device. These cracks or crevices are usually where the bats will start to emerge. The bats can also be seen crawling out of a roost entrance more easily on a thermal device before they take flight. This elongates the time the bat is in the surveyor's field of view, which is likely to improve detection rates.

Different brands of equipment should be compared against each other to determine reliability and aid ecologists in making decisions regarding investment in equipment. Although costly, thermal devices allow for more accurate detection into the night and have the added benefit of roost discovery. If only a general colony estimate is needed, a much more cost-effective infrared device would suffice.

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