

ORIGINAL ARTICLE

Different bat detectors and processing software... Same results?

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ABSTRACT

There has been an increase in commercial bat detectors and noise filtering software for monitoring bat activity. In this study, we compare the recording efficiency of three bat detectors from the popular brand Wildlife Acoustics (Echo Meter 3, Echo Meter Touch Pro 1 and Song Meter 2 BAT) and the effectiveness of two noise filtering software (Kaleidoscope and SonoBat Batch Scrubber). To do so, we recorded 7513 files from 13 urban parks in Madrid in 2017, that were manually identified to species level. The results show that the Echo Meter 3 records significantly less activity than the Echo Meter Touch Pro 1 and Song Meter 2 BAT. Our results also identify SonoBat Batch Scrubber as more reliable than Kaleidoscope for preventing false negatives. Therefore, our study demonstrates that different bat detectors, and different noise filtering software, can provide different results.

INTRODUCTION

Monitoring bats echolocation using bat detectors is a common, non-intrusive technique for studying the behaviour and ecology of bats (Collins & Jones 2009). This can be used to complement other techniques such as roost surveys or direct capture (Flaquer et al. 2007, Fenton 2013). It facilitates the collection of large quantities of data which is used by researchers to determine the presence of bats, species identification, to investigate their behaviour and differences in habitat use, as well as estimating relative abundance or quantifying activity (Adams et al. 2012, Russo & Voigt 2016).

Nevertheless, sampling bats using bat detectors has a series of limitations that must be considered. Variability amongst sampling methodologies, detector models, microphones and detection algorithms can significantly affect the detection efficiency among bat detectors, as demonstrated by Adams et al. (2012) between bat detector brands. In addition, the echolocation calls produced by bats is highly variable between species which can result in interspecific differences in detection efficiency (Adams et al. 2012, Russo & Voigt 2016). Other sources of variability include intraspecific variation in call structure, which is influenced by factors such as habitat, the presence of conspecifics, environmental noise, age, sex, geographic variation or existence of sympatric acoustic variants (Walters et al. 2012, Barataud 2015, Russo et al. 2018).

Since the late 1990s, the acoustic identification of bat species has undergone a radical change thanks to assisted identification systems and noise filtering software (Russo & Voigt 2016). These systems are based on algorithms that help classify recordings (e.g. as noise or to species) to reduce

the demand for manual processing. These changes have promoted an increased use of bat detectors and encouraged subsequent improvements to their recording capacity. Nowadays, there are two types of bat detectors commonly used: hand-held bat detectors, for active use such as walking transects and roost surveys; and static bat detectors, that are now capable of recording continuously for many hours generating large acoustic datasets, which in turn feed the increased need for these kinds of assisted identification and noise filtering software (Lemen et al. 2015, Rydell et al. 2017).

In this study we have two aims: (i) to compare the number of bat recordings captured between three models of Wildlife Acoustic bat detectors (Wildlife Acoustics Inc., U.S.A.; Echo Meter 3, Echo Meter Touch Pro 1, Song Meter Bat 2); and (ii) to compare the efficiency and accuracy of two noise filtering software (Kaleidoscope 4.5.4 (Wildlife Acoustics Inc., U.S.A.) and SonoBat Batch Scrubber 5.1 (SonoBat. Bat Call Analysis Software). Both the bat detectors and noise filtering software vary in price and release date.

MATERIAL AND METHODS**Study site**

Sampling was conducted across 13 urban parks in Madrid, Spain (Fig.1) during July 2017. One sampling period was carried out once per park and consisted of multiple ten-minute sampling stations in order to determine the presence and activity of bats per park. The number of sampling stations per park was determined by the park size (Tena et al. 2019) (see Supplementary Table 1 for sampling stations per park and park size). All bat detectors used were positioned

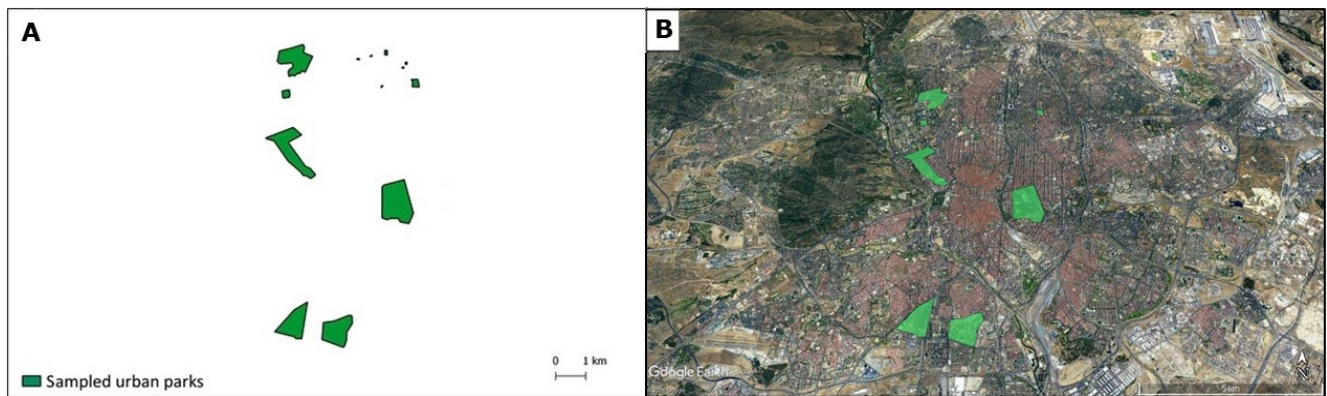


Fig. 1 - A) Polygons of the 13 urban parks sampled in the study. **B)** Parks within the urban matrix green represented by the polygons shaded with the contour in black.

Table 1 -Trigger settings for each bat detector. All recordings were recorded as full-spectrum. *Prices are according to the release date of each bat detector.

Settings	Release date	Sampling Rate (kHz)	File compression	Trigger (s)	Trigger sensitivity	Division ratio	Price*
EM3	2012	384	WAV	1	Medium	1/10	High
EMT	2015	384	WAV	4	Medium	1/10	Medium
SM2BAT	2009	384	WAV	1	Medium	1/10	High

to record simultaneously at each sampling station, with the same orientation and inclination to avoid biases.

Equipment and recorder conditions

Three Wildlife Acoustics bat detectors were used in this study; two hand-held bat detectors (Echo Meter 3 and Echo Meter Touch 1 Pro) and one static bat detector (Song Meter 2 BAT) with a SMX-US ultrasonic microphone (see Table 1 for bat detector settings).

Manual call processing

For the manual identification, each recording was split into five second sequences, using Kaleidoscope 4.5.4 (Wildlife Acoustics Inc., U.S.A.), in order to standardize the bat call study (Bertran et al. 2019). A bat pass consisted of at least two echolocation pulses above -60 dB (Russ 2012). Audacity 2.2.1 was then used to analyse the recordings. The following parameters were measured manually (Rydell et al. 2017) from each pulse to identify species (Russo & Jones 2002, Barataud 2015): start frequency, end frequency, frequency of maximum energy, duration and inter-pulse interval. Recordings were discarded where it was not possible to determine the species identification. In this study, noise was considered as recordings with no echolocation pulses or less than 2 pulses above -60dB. The total number of bat passes and noise were summarized for each bat detector.

Noise filtering software

Two types of commercial software were selected to compare the effectiveness of noise filtering: a free license software, Kaleidoscope 4.5.4, and a paid license software, SonoBat Batch Scrubber 5.1 (SonoBat. Bat Call Analysis

Software). For Kaleidoscope, the signal parameters were configured as follows: 8-120 kHz, 2-500 ms, 500 maximum inter-syllable gaps and 2 minimum number of pulses. For SonoBat Batch Scrubber the default settings were selected: medium, accepts all calls except low quality calls; accepts some noise with tonal content and includes from 5-20 kHz signals.

Statistical procedures

A heterogeneity test was performed to compare the total number of pulses recorded by each bat detector. Non-parametric Chi-square test were performed to compare the total number of bat passes between bat detectors and the total number of bat passes by species for each bat detector. Non-parametric Chi-square test were also performed to compare the correct and incorrect ID bat and ID noise between both software and manual identification; and between noise filtering software. Statistical analysis was conducted in R 3.3.2 (R CoreTeam 2012).

RESULTS

In total 18 hours of recordings were collected which comprised 7513 five-second files. Of these, 2828 were manually identified as bats and 4685 as noise. The total number of echolocation pulses observed were 198688. Across the study, four different species were identified manually: Common pipistrelle (*Pipistrellus pipistrellus*), Soprano pipistrelle (*Pipistrellus pygmaeus*), Kuhl's pipistrelle (*Pipistrellus kuhlii*) and Savi's pipistrelle (*Hypsugo savii*).

Comparison among bat detectors

The heterogeneity test showed a significant difference in the total number of echolocation pulses recorded between bat detectors (Fig. 2; $\chi^2= 45203.34$, $p < 0.001$), as a greater number of echolocation pulses were recorded by the EMT and SM2BAT than the EM3.

There were significant differences in the number of bat passes between bat detectors ($\chi^2= 470.25$, $p < 0.001$) and also for *P. pipistrellus* (Fig. 3; $\chi^2= 280.27$, $df = 2$, $p < 0.001$), *P. pygmaeus* (Fig. 3; $\chi^2= 79.10$, $df = 2$, $p < 0.001$) and *P. kuhlii* (Fig. 3; $\chi^2= 139.45$, $df = 2$, $p < 0.001$). In contrast, there was no significant difference for *H. savii* (Fig. 3; $\chi^2= 5.44$, $df = 2$, $p = 0.657$), which was the least recorded across the study.

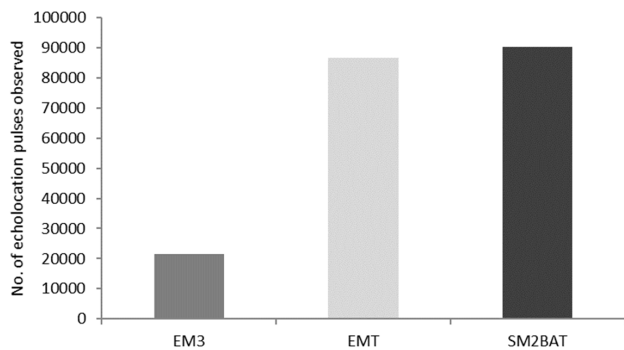


Fig. 2 - Total number of echolocation pulses observed for each detector.

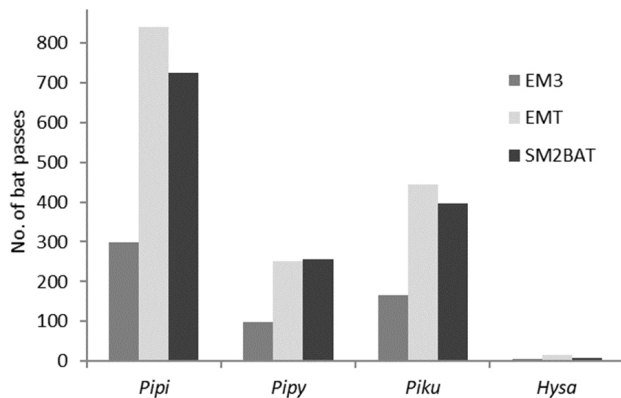


Fig. 3 - Total number of bat passes observed by species for each detector. *Pipi*: *Pipistrellus pipistrellus*; *Pipy*: *Pipistrellus pygmaeus*; *Piku*: *Pipistrellus kuhlii*; *Hysa*: *Hypsugo savii*.

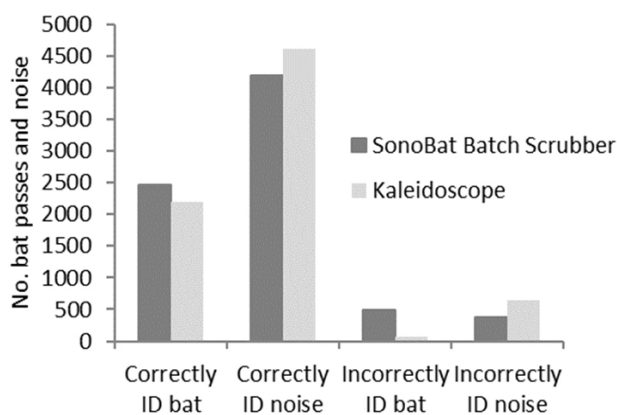


Fig. 4 - Comparison of correctly and incorrectly ID bat and ID noise between SonoBat Batch Scrubber and Kaleidoscope noise filtering software.

Comparison between noise filtering software

There were significant differences between the number of files manually identified as a bat pass or as noise compared to those identified by both noise filtering software (Manual ID - Kaleidoscope, $\chi^2= 184.88$, $p < 0.001$; Manual ID - SonoBat Batch Scrubber, $\chi^2= 8.44$, $p = 0.004$). There was a significant difference in the number of files classified as bat passes and noise between the two noise filtering software ($\chi^2= 2867.44$, $p < 0.001$). The results show Kaleidoscope has higher true negatives (correctly ID noise) but higher false negatives (incorrectly ID noise), whereas SonoBat Batch Scrubber has higher false positives (incorrectly ID bat) but lower false negatives (incorrectly ID noise) (Fig 4).

DISCUSSION

Supporting previous studies (Fenton 2000, Adams et al. 2012), our results showed that recordings made by different bat detector models can vary significantly. Overall, the EM3 recorded significantly less echolocation pulses than EMT and SM2BAT, as well as bat passes for *P. pipistrellus*, *P. pygmaeus* and *P. kuhlii*. It is possible no significant differences were observed for *H. savii* due to the small sample size for this species. We also identified significant differences between manual ID and both noise filtering software and between the noise filtering software. We demonstrated that the SonoBat Batch Scrubber has a lower risk of misclassifying bat passes as noise than Kaleidoscope.

Apart from these results, there is a series of advantages and disadvantages that differ between bat detectors: SM2BAT is a static bat detector that, despite being more expensive, allows the bat detector to be programmed with a recording schedule and placed during the day, therefore eliminating the need to work at night. Hand detectors, on the other hand, are cheaper than static detectors and allow the user to observe bat activity while recording but require the user to operate them in the field.

The EMT recorded more bat passes overall, as well as for three of the four species in our study, and was not significantly different from the most expensive bat detector in our study, the SM2BAT (Fig. 3). Therefore, it provides a cost-effective alternative to the SM2BAT where it is not necessary to programme the recording schedule. Researchers using an EM3 should be aware of the risk that recorded activity is likely to be lower than true bat activity. Even though the EM3 recorded fewer bat passes than the other two bat detectors, it also recorded less noise than the EMT (see supplementary table) and there were no significant differences in the number of species recorded for this study.

Although Kaleidoscope is a free license software, we recommend researchers use SonoBat Batch Scrubber rather than Kaleidoscope as files containing bat calls is more likely to be mistakenly discarded in the latter which may result in a false representation of bat activity. However, previous studies recommend the use of more than one filtering program in order to minimize possible loss of information (Méndez et al. 2016). Different commercial, automated identification classifiers have similar variability in their effectiveness to classify bat calls to a species (Russo & Voigt 2016).

This variability inherently produces differences in results between studies. Therefore, this study supports previous work highlighting the importance of combining automated identification classifiers with manual identification to avoid possible misidentification (Russo & Voigt 2016). There are some species that due to their echolocation calls have higher probabilities of being classified as noise such as the short sweeps of *Plecotus auritus* flying in clutter (Rydell et al. 2017).

As our study was geographically and temporally limited, we advise future studies to conduct further studies in additional areas, over larger time periods, and between different brands and species. In doing so, these studies would highlight potential differences between other species and other recording factors.

CONCLUSIONS

In conclusion, we demonstrate that using different bat detectors, and processing software may produce different results for the same study. We recommend the SM2BAT or EMT for recording bat activity, over the EM3, as they detect greater activity. Both bat detectors offer different user requirements such as cost and programming options. For subsequent noise filtering of recording, we recommend the SonoBat Batch Scrubber rather than the license free software of Kaleidoscope to reduce the risk of false negatives.

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REFERENCES

- ADAMS, A. M., JANTZEN, M. K., HAMILTON, R. M. & FENTON, M. B. (2012). Do you hear what I hear? Implications of detector selection for acoustic monitoring of bats. *Methods Ecol Evol*, 3(6): 992-998. <https://doi.org/10.1111/j.2041-210X.2012.00244.x>
- BARATAUD, M. (2015). Acoustic ecology of European bats. Species identification and studies of their habitats and foraging behaviour. ed.: Biotope - Muséum national d'Histoire naturelle. Paris, France, 340 pp.
- BERTRAN, M., ALSINA-PAGÈS, R. M. & TENA, E. (2019). *Pipistrellus pipistrellus* and *Pipistrellus pygmaeus* in the Iberian Peninsula: an annotated segmented dataset and a proof of concept of a classifier in a real environment. *Appl Sci*, 9(17): 3467. <https://doi.org/10.3390/app9173467>
- COLLINS, J. & JONES, G. (2009). Differences in bat activity in relation to bat detector height: implications for bat surveys at proposed windfarm sites. *Acta Chiropterologica*, 11(2): 343-350. <https://doi.org/10.3161/150811009X485576>
- FENTON, M. B. (2000). Choosing the "correct" bat detector. *Acta Chiropterologica*, 2(2): 215-224.
- FENTON, M. B. (2013). Questions, ideas and tools: lessons from bat echolocation. *Animal Behaviour*, 85(5): 869-879. <https://doi.org/10.1016/j.anbehav.2013.02.024>
- FLAQUER, C., TORRE, I. & ARRIZABALAGA, A. (2007). Comparison of sampling methods for inventory of bat communities. *Journal of Mammalogy*, 88(2): 526-533. <https://doi.org/10.1644/06-MAMM-A-135R1.1>
- LEMEN, C., FREEMAN, P. W., WHITE, J. A. & ANDERSEN, B. R. (2015). The problem of low agreement among automated identification programs for acoustical surveys of bats. *Western North American Naturalist*, 75(2): 218-225. <https://doi.org/10.3398/064.075.0210>
- MÉNDEZ, D., MARTÍNEZ, S., PÉREZ G. & DE PAZ, O. (2016, December 3-4). Análisis comparativo de diferentes índices y softwares para el estudio de la quiropterofauna a través sus ultrasonidos. VI Jornadas de la Asociación Española para la Conservación y Estudio de los Murciélagos (SECEMU), Vairao, Portugal
- R CORE TEAM. (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. <http://www.R-project.org/>
- RUSSO, J. (2012). British bat calls. A guide to species identification. ed.: Pelagic Publishing. Exeter, United Kingdom, 192 pp.
- RUSSO, D. & JONES, G. (2002). Identification of twenty-two bat species (Mammalia: Chiroptera) from Italy by analysis of time-expanded recordings of echolocation calls. *Journal of Zoology*, 258(1) 91-103. <https://doi.org/10.1017/S0952836902001231>
- RUSSO, D. & VOIGT, C. C. (2016). The use of automated identification of bat echolocation calls in acoustic monitoring: a cautionary note for a sound analysis. *Ecological Indicators*, 66: 598-602. <https://doi.org/10.1016/j.ecolind.2016.02.036>
- RUSSO, D., ANCILLOTTO, L. & JONES, G. (2018). Bats are still not birds in the digital era: echolocation call variation and why it matters for bat species identification. *Canadian Journal of Zoology*, 96(2): 63-78. <https://doi.org/10.1139/cjz-2017-0089>
- RYDELL, J., NYMAN, S., EKLÖF, J., JONES, G. & RUSSO, D. (2017). Testing the performances of automated identification of bat echolocation calls: a request for prudence. *Ecological Indicators*, 78: 416-420. <https://doi.org/10.1016/j.ecolind.2017.03.023>

- TENA, E., FANDOS, G., DE PAZ, O., DE LA PEÑA, R. & TELLERÍA, J. L. (2019). Size does matter: passive sampling in urban parks of a regional bat assemblage. *Urban Ecosyst.* <https://doi.org/10.1007/s11252-019-00913-2>
- WALTERS, C. L., FREEMAN, R., COLLEN, A., DIETZ, C., FENTON, M. B., JONES, G., OBRIST, M. K., PUECHMAILLE, S. J., SATTLER, T., SIEMERS, B. M., et al. (2012). A continental-scale tool for acoustic identification of European bats. *J Appl Ecol*, 49(5): 1064-1074. <https://doi.org/10.1111/j.1365-2664.2012.02182.x>