2001

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Recommended Citation

White, E.P., and S.D. Gehrt. 2001. Effects of recording media on echolocation data from broad band bat detectors. Wildlife Society Bulletin 29:974978.

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Effects of recording media on echolocation data from broad band bat detectors

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Abstract: Bat detectors are an important tool for ecological studies of bats. However, the quality and quantity of data may be affected by the recording devices used to record the output from the detector. We compared recordings of bat activity from audiocassette recorders and computers. Numbers of calls/hour, passes/hour, identifiable passes/hour, and feeding buzzes/hour were similar (all P's > 0.1) between recording devices. All call characteristics, except for the minimum frequency and characteristic frequency, differed ($P < 0.05$) between tapes and computers. Species identification with discriminate function analysis was less reliable with tape data than with computer data, particularly when the model built with computer-recorded reference calls was tested with tape-recorded calls. Therefore, we suggest when tape recorders are used for field recording that they also are used to record reference calls.

Key words: acoustic monitoring, Anabat, bat detectors, echolocation calls, recording, sound, technique

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Wildlife Society Bulletin 00(0): 000-000

Introduction

Using ultrasonic bat detectors for ecological research has increased in recent years (e.g., Rydell et al. 1994, Hayes 1997, Vaughan et al. 1997*b*). Some studies have not discriminated calls by species (Walsh and Harris 1996*a*,*b*; Hayes 1997), whereas others have attempted to differentiate recordings between species based on frequency and structure of echolocations (Krusic et al. 1996, Vaughan et al. 1997*a*, O'Farrell et al. 1999*a*). Some species may be identified by recording reference calls from known individuals and developing definitive characteristics from the sonograms to compare with unknown calls (Vaughan et al. 1997*a*, Betts 1998). These definitive characteristics have been defined qualitatively (Fenton and Griffin 1997, O'Farrell and Miller 1997, O'Farrell et al. 1999*a*) and quantitatively (Zingg 1990, Vaughan et al. 1997*a*, Betts 1998).

Echolocation calls may be recorded either directly to a computer or to a tape recorder. Data recorded directly to a computer tend to contain less interference. However, in large-scale studies, it may be cost prohibitive to place a computer in the field with each detector. Therefore, tape recorders have been used in many studies (Hart et al. 1993, Krusic 1995, Hayes 1997). However, some of these studies have recorded reference calls directly to computer (Krusic 1995) and other studies have used reference calls without indicating which recording media was used (Conole and Baverstock 1995, Fenton and Griffin 1997, McCracken et al. 1997).

O'Farrell et al. (1999*b*) indicated that recording directly to computer increased the quality and quantity of call recordings. However, no studies have investigated directly effects of recording method on number and quality of call recordings. Misidentification of species may result if media type affects pass quality and subsequent analyses. Therefore, we compared number of passes, buzzes, and calls recorded by each recording device and compared the call characteristics recorded by each medium. We also assessed how recording media affect quantitative classification.

Methods

We recorded echolocations of free-flying bats on 12 nights between 7 July and 19 August 1998 at 12 sites in northeastern Illinois using the Anabat 5 detector system (Titley Electronics, Australia). The sites were a sub-sample of those established for another study and included a variety of habitats. The recording system included an Anabat 2 broad band, frequency-modulated bat detector, a Zero-Crossings Analysis Interface Module (ZCAIM), and a laptop computer (Fujitsu Note Book, Pentium 200MHz). Although broadband detectors simultaneously scan all frequencies commonly used by bats, the output lacks amplitude modulations and harmonic information and therefore is designed for identification of bat species, not detailed echolocation study (Corben 1992). We used the ZCAIM to interface the audio-frequency signal from the bat detector—tape recorder with the computer.

We split the output cable from the bat detector using a standard audio cable Y splitter, with one lead connected to the ZCAIM and then to the computer, and the other lead connected to an Optimus (Radio Shack Inc., USA) microcassette recorder. The bat detector was hung 1.5 m from the ground with a tripod and the microphone pointed vertically. This system allowed us to simultaneously record the output to both recording media. We conducted all monitoring sessions during the first 3 hours following sunset. The tape recorder recorded the same output to MC-60 microcassettes (Radio Shack Inc., USA).

We used Anabat software (Version 5.7) to calculate number of calls, passes, and feeding buzzes/hour for each type of recording device. We defined a pass as a sequence of >2 calls that were separated by >one second from the next sequence. We objectively removed interference and clutter from each pass used in species identification by using the filter command in Analook. For the remaining passes we used Analook to measure 10 parameters describing the shape and frequency of the call (individual pulse) and pass (Table 1, Figure 1). We calculated these parameters for each call and then averaged over all calls in the pass.

We paired passes simultaneously on 2 computers: one computer displaying the data recorded directly to the computer and the other displaying the data recorded to tapes. This allowed us to match the same passes recorded in each sample by comparing the order and the general shape and frequency of the calls. We paired passes to remove variation from any source other than recording media. In cases where one member of the pair did not contain ≥4 calls we did not include the pair in the analysis, because they were considered to be unidentifiable.

Statistical analysis

We compared number of calls/hour, passes/hour, identifiable passes/hour, and buzzes/hour using paired *t*-tests. Samples were paired by night to prevent problems of variability in activity between nights. Paired *t*-tests also were used to test for differences in call parameters between media types. We examined effect of pass frequency on differences between media using Pearson's correlations between the mean frequency for each of the passes recorded with the computer and the difference between the tape and the computer data for each of the associated call characteristics. We arbitrarily chose mean frequency from computer data as a baseline for comparison. This should not cause independence problems because we were correlating with the difference between characteristics, not the characteristics themselves. Because of the large number of variables used in the paired *t*-tests, *P*-values were adjusted using a sequential Bonferroni correction (Rice 1989).

To determine if recording media may contribute to misclassification of bat species, we used Discriminant Function Analysis (DFA) to construct models using 2 species with similar call structures: little brown bats (*Myotis lucifugus*) and eastern pipestrelles (*Pipistrellus subflavus*). We recorded reference calls on 2 July 1998 at Indian Creek, Missouri, from a group of bats that we captured at a cave entrance with a harp trap. We light-tagged (Hovorka et. al 1996) each bat with colors coded for species, and we recorded calls after release using separate tape and computer systems.

We constructed the DFA_{comp} model using SPSS (version 7.5), with Wilk's Lambda variable selection, within group covariance matrices, and prior probabilities calculated from group size. Because using models with different discriminant function variables could underestimate classification rates for test data, we forced all the models to use the variables selected for the DFA_{comp} model. Although logistic regression may be a more suitable test with only 2 species, we were attempting to address effects of media on studies containing multiple species and therefore used previously established techniques (Krusic 1995, Vaughan et al. 1997*a*). We constructed 3 DFA models: one each from computer (DFA_{comp}) and tape (DFA_{tape}) data, and one from a combination of computer and tape (DFA_{mix}) data. We removed 12 passes from each recording type prior to model construction for accuracy tests. We used test data to determine if models for a given media type classified the passes for that media type more accurately than those of the other media (Snyder and Linhart 1998).

Results

We recorded 1,715 passes (12,636 calls) during 17 hours on 12 nights. On one night when 330 usable passes by similar frequency bats were recorded, we used a random sub-sample (n = 150) to prevent this sample from dominating the analysis. After discarding surplus and unidentifiable passes, 306 passes remained for pairwise comparison of call characteristics.

Number of calls, passes, identifiable passes, or feeding buzzes/hour did not differ between recording devices (Table 2). All call characteristics, except for the minimum frequency and characteristic frequency, differed between recording media (Table 3). The average difference between means for the 8 significant variables was 9.5%. Correlation coefficients for mean frequency and differences in parameter measures between media (Table 4) indicated that as frequency of the pass increased, so did the difference between computer and tape data.

The DFA_{comp} model (0.9 Sc – 3.0 Fc + 2.5 Fk) classified correctly *M. lucifugus* and *P. subflavus* 100% (n = 19) of the time and also classified correctly 100% (n = 12) of computer test passes, but classified correctly only 67% (n = 12) of tape test passes. The DFA_{tape} model (1.0 Sc – 0.5 Fc + 0.3 Fk) classified correctly 81% (n = 26) of the passes, 67% (n=12) of the tape test passes, and 100% (n = 12) of the computer test passes. The DFA_{mix} model (1.2 Sc – 2.1 Fc – 0.2 Fk) classified correctly 84% (n = 45) of the passes and 83% (n = 24) of the test passes were classified correctly. Computer test data inserted into this model were classified correctly 100% of the time (n = 12), while only 67% (n = 12) of the tape test passes were identified correctly. DFA classification results were not significantly different when variables were selected independently for each model.

Discussion

Measures of bat activity (passes/hour, calls/hour, identifiable calls/hour) and feeding (buzzes/hour) did not differ by media type. Our results suggest that measures of general bat activity are relatively robust to types of recording devices. However, differences in most pass characteristics increased with frequency of the pass, as demonstrated by the positive correlation between mean frequency and the differences between media. These differences may be due to greater attenuation of echolocations at greater frequencies (Fenton and Bell 1981), as indicated by the reduction of maximum frequency and relative consistency of minimum frequency as mean frequency increased.

The difference between the recording types may be great enough to cause misclassification of some species based on quantitative comparisons. Given the magnitude of some of the differences, it also may affect qualitative classification, especially when it is based partially on the frequency of the call and the length of its initial section. Bats with high-frequency calls are probably of greatest concern for misclassification, because of large differences between the media in this frequency range and because multiple species of *Myotis* and *Pipistrellus* are difficult to differentiate due to their similar call structures (Rydell et al. 1994, Krusic 1995, Vaughan et al. 1997*b*). Even in these simple 2-species models, there was a significant amount of misclassification caused by recording media. In more complicated models involving greater numbers of species, this misclassification could become even greater.

When tape data were used in either DFA_{comp} or DFA_{mix} models there was an increase in misclassified observations. Some studies have used DFA models to determine which passes can be classified to species and which can only be assigned to a group or remain unclassified (Vaughan et al. 1997*a*,*b*). The DFA_{comp} model indicated that we could identify correctly all collected passes, and the DFA_{tape} model could only identify 75% of the test passes. Had we been using these models to evaluate tape-recorded field data, the DFA_{tape} model would have classified correctly the acceptable passes and discarded the rest; however, the DFA_{comp} model would have classified all passes, thereby assigning one third of passes to the wrong species. Interestingly, there was a 100% correct classification for computer test data in all DFA models.

Our tests indicate that echolocation data recorded directly to computer are greater quality than those recorded with tape. However, tapes remain the most effective method for large-scale recording in the field and are adequate for general measures of activity. If species identification is an objective, we suggest when tape recorders are used for field recording that they also are used to record reference calls. This will probably result in reducing the number of classifiable passes, but should reduce misclassification of bat species from recordings obtained using bat detectors.

Acknowledgments. We thank J. Ebersole, M. Snyder, and R. Keen for advice on statistical analysis and J. Thompson, B. Montgomery, D. Miller, K. Miller, J. Gore, and M. Conner for helpful reviews of earlier versions of the manuscript. Funding was provided by the Max McGraw Wildlife Foundation, Chicago Wilderness, the Restoration Research Fund as administered by the Forest Preserve District of Cook County, and the Nature Conservancy. In memory of Scott Bruce Anderson.

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Table 1. Parameters describing shape and frequency of bat echolocation calls and passes. The knee is the point at which the slope of the sonogram changes most abruptly. When calls do not have an abrupt change in slope this measure becomes the initial frequency (Corben 1992).

Variable	Measurement Unit	Definition
Characteristic slope	Octaves/sec	Most common slope/unit time
Maximum frequency	KHz	Greatest recorded frequency
Minimum frequency	KHz	Least recorded frequency
Mean frequency	KHz	A weighted mean of frequency calculated by dividing area under the call curve by the duration
Frequency at knee	KHz	Frequency at the knee
Characteristic frequency	KHz	Frequency at the flattest part of the call
Duration of call	Msec	Duration of a call
Time between calls	Msec	Time expired from the start of one call to the start of the next
Time at knee	Msec	Elapsed time between the start of the call and the knee
Time at characteristic frequency	Msec	Elapsed time between start of the call and when the characteristic

frequency was reached

Table 2. Means and standard deviations for activity measures of bats recorded simultaneously to computer and to tape in Illinois, 1998.

		Tape		Computer		
Variable	n[a]	$\bar{X}$	SD	$\bar{X}$	SD	P[b]
Calls/hour	12	162.6	286.6	423.5	744.6	0.20
Passes/hour	12	40.8	54.4	41.6	54.8	0.23
Identifiable passes/hour	12	13.6	22.3	23.6	39.4	0.28
Feeding buzzes/hour	12	2	3.7	1.6	3.7	0.29

[a] n = number of nights

[b] *P* values were obtained using paired *t*-tests

Table 3. Mean (SD) echolocation call characteristics of bats recorded simultaneously to computer and to tape in Illinois, 1998. Error was distributed over the entire table using a sequential Bonferroni conversion. Variables retaining significance at $P \leq 0.05$ are indicated by *.

Parameter[b]	Computer	Tape	P[a]
Characteristic slope	38.96 (21.68)	34.72 (15.69)	< 0.001*
Maximum frequency	34.20 (6.06)	32.57 (4.25)	< 0.001*
Minimum frequency	26.87 (3.72)	26.67 (3.98)	0.059
Mean frequency	29.21 (4.16)	28.55 (3.74)	0.001*
Frequency at knee	28.84 (4.54)	28.48 (3.92)	< 0.001*
Characteristic frequency	27.62 (4.10)	27.81 (4.63)	0.252
Duration of call	6.73 (2.05)	6.18 (2.00)	< 0.001*
Time between calls	238 (118)	272 (188)	< 0.001*
Time at knee	3.77 (1.91)	3.21 (1.72)	< 0.001*
Time at characteristic frequency	5.75 (1.88)	4.66 (1.64)	< 0.001*

[a] *P* values were obtained using paired *t*-tests

[b] For all variables n = 306

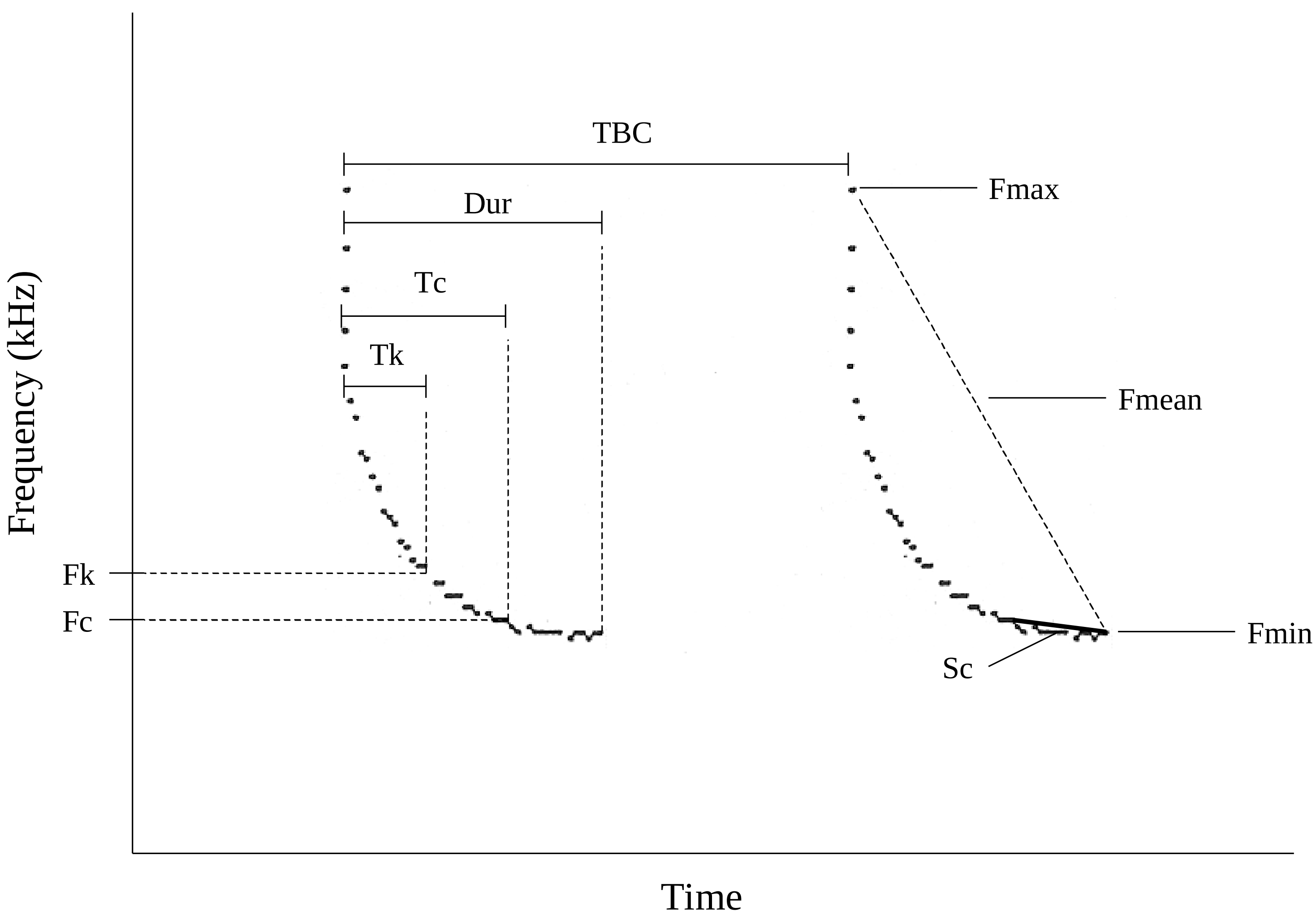
Table 4. Pearson correlation coefficients (*r*) for echolocation call characteristics of bats recorded simultaneously to computer and to tape in Illinois, 1998. Correlations are between the mean frequency of the pass recorded to the computer and the difference between the computer and the tape measurements for the characteristic.

Call Characteristic[a]	r
Characteristic slope	0.459**
Maximum frequency	0.480**
Minimum frequency	0.113*
Mean frequency	0.448**
Frequency at knee	0.222**
Characteristic frequency	0.124*
Duration of call	-0.201**
Time between calls	0.382**
Time at knee	0.072
Time at characteristic frequency	0.252**

* $P < 0.05$ ** $P \leq 0.01$.

[a] For all variables n = 306

Figure 1. Call and pass characteristics measured for bat echolocation calls and passes. The 2 curves represent echolocation calls recorded by a broad band bat detector. Abbreviations: Characteristic Slope (Sc), Maximum Frequency (Fmax), Minimum Frequency (Fmin), Mean Frequency (Fmean), Frequency at Knee (Fk), Characteristic Frequency (Fc), Duration of Call (DUR), Time Between Calls (TBC), Time at Knee (Tk), Time at Characteristic Frequency (Tc).


TBC
Dur
Tc
Tk
Fmax
Fmean
Fmin
Sc
Fk
Fc
Frequency (kHz)
Time