Response and comments to:
Draft Revised Indiana Bat Summer Survey Guidelines
(January 2013)
and associated documents

Joseph M. Szewczak

Humboldt State University

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Acoustic detection and classification of bats

All North American bats emit regular pulses of vocalizations during flight that create echoes used for navigation and for detecting and pursuing prey. Ultrasonic-sensitive bat detectors can record these vocalizations to register bat activity and in many instances these signals enable some level of species recognition. The January 2013 Draft Revised Indiana Bat Summer Survey Guidelines (hereafter referred to as DRG) provide guidelines for acoustic surveys (Phase 2) that presume acoustic species recognition has reached a sufficient state of maturity for confident automated deployment. The comments and discussion that follows address this issue and inherent concerns of the state of the art for acoustic recognition of Indiana bats.

Acoustic detection. As bats exhibit dynamic movements across the landscape where they typically forage in several different locations each night (Lacki et al. 2007), activity as measured by recorded bat passes can vary significantly at any one location so that a single night of data will not statistically represent the overall trend of bat activity at that location. Hayes (1997) showed that any one night of bat detection likely misrepresents the mean activity at a site, and that as many as seven days of monitoring may be needed to approach a 90% confidence level of mean representation of activity or presence (also see Gannon et al. 2003, Szewczak and Arnett 2007). Although mean bat activity can be assessed on the order of one week of monitoring, confident assessment of species presence in a given season requires even longer survey efforts, typically on the order of weeks (Moreno and Halffter 2000). Longer-term temporal variations occur from seasonal movements of bats, such as migration, (Johnson et al. 2004, Arnett et al. 2008).

Because of this limitation recorded levels of activity at any one site do not necessarily directly correlate with presence because: 1) of differential detectability of bats due to recording conditions and orientation of the bat relative to the microphone (Weller and Zabel 2002), 2) all individuals may not call at the same rates from their type of flight activity, e.g., whether foraging or commuting, 3) some species may remain out of detection range of a detector despite their presence, e.g., if foraging on insects farther aloft and out of range of ground-based microphones, 4) variable foraging behavior (e.g., a detector deployed in the open is likely to miss bats that forage along the edge of vegetation), and 5) temporal variations in activity. The latter factor can vary on a scale of days as bats follow local insect activity.

In light of these concerns, and the ability to acoustically discriminate Indiana bats notwithstanding, the DRG guidelines of

> …sampling to be conducted for at least six suitable nights. To reduce the survey duration, additional detectors may be added at individual survey sites accordingly: 5 nights for 2 detectors per site, 4 nights for 3 detectors per site, and 3 nights for 4 detectors per site…

may still provide an insufficient level of sampling effort to rule out presence if no detections. Although better than a single night, this guidance should be considered a bare minimum, and when resources permit more detector nights will always improve detection confidence.

Acoustic classification of Indiana bats. Acoustic identification of bat species poses a greater challenge than follows from our audible experience with birds. Whereas bird songs and calls have undergone selection to be different from those of other species, echolocating bats use their calls for acquiring information from the environment and their prey, and in general natural selection has operated to optimize this function without regard for species differentiation (Parsons and Szewczak 2009). For syntopic species such as those in the genus Myotis to which the Indiana bat belongs there appears to be little selective pressure to emit calls differently from their congeners or other species. Many species lack obvious discriminating differences in their vocal characteristics across at least a part of their call repertoires (Betts 1998, Barclay 1999, Szewczak 2004, Parsons and Szewczak 2009). This results from the additional complication that bats exhibit considerable plasticity in their vocalizations and produce call variants that overlap in many parameters with those emitted by other species (Thomas et al. 1987, Obrist 1995, Barclay 1999). In the case of the Indiana bat, although some early data sets seem to indicate some different acoustic trends between calls from the Indiana bat (Myso) and the congener, and range overlapping, little brown bat, *M. lucifugus* (Mylu), more robust data sets seem to indicate that either of these species can make calls like the other across the entirety of their repertoires. Sample bivariate plots of acoustic parameters from calls recorded across the range of Indiana bats from species-known tracked individuals display the considerable overlap and range of call characteristics from this species pair, and reveal no discernible region of discriminating feature space (Figure 1).

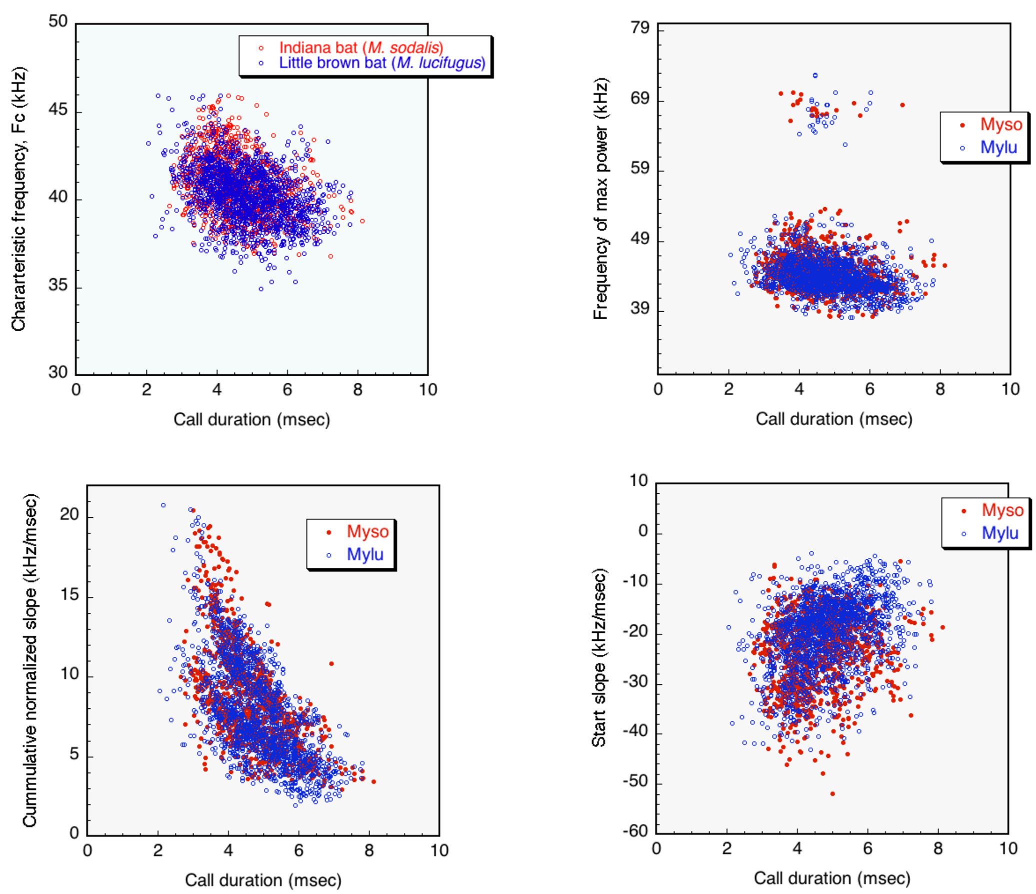

Figure 1. Sample bivariate plots of overlapping call parameters of Indiana bats and little brown bats showing the similarity in acoustic characteristics between these species.

Upon consideration of a fully robust set of Indiana and little brown bat call data, no species-discriminating call types emerge. That is, there does not appear to be any single or set of exclusive call characteristics between these species, and no single call or sequence of calls in a bat pass can be classified as one of the other of these species with certainty. This leaves only statistical likelihood as a means of assessing presence.

Although the overlapping call characteristics of these two species present a challenge to discriminate, as with most species, longer duration calls provide more information content and consistent data that enhances discrimination performance. Classification results parsed by call duration for 366 Indiana bat (Myso) and little brown bat (Mylu) sequences recorded in IN, IL, MO, KY, TN, PA, NJ, and VT reveal classification confidence improved with longer duration calls (Table 1).

Table 1. Individual echolocation call classification results for Indiana bats (Myso) and little brown bats (Mylu) using SonoBat v3.1.4[1].

call duration (msec)		%correct	%accepted[2]
	Myso	0.0	0.0
↓	Mylu	100.0[3]	2.5
3.5	Myso/Mylu[4]	100.0	24.8
3.5	Myso	37.5	0.7
↓	Mylu	60.6	3.6
4.5	**Myso/Mylu**	**100.0**	**52.9**
4.5	Myso	93.5	11.7
↓	Mylu	78.0	5.8
5.5	**Myso/Mylu**	**100.0**	**92.2**
5.5	**Myso**	**96.0**	**36.9**
↓	**Mylu**	**89.7**	**32.1**
6.5	**Myso/Mylu**	**100.0**	**92.3**
6.5	**Myso**	**96.2**	**71.4**
↓	**Mylu**	**97.2**	**73.4**
	Myso/Mylu	**100.0**	**75.2**

[1] The results reported here represent idealized classification performance based on high quality recordings made with Pettersson and Binary Acoustic Technology detectors. Actual performance will decline along with recording.

[2] Values listed as %correct considered just those results that emerged from the classifier at or above an acceptance threshold of 0.90. The %accepted reports the proportion of the sample that met or exceeded the discriminant probability threshold, whether correct or incorrect.

[3] Although correct, just 3 calls of the 118 in the sample accepted and may result from a statistical artifact of a small sample size.

[4] Myso/Mylu indicates a result of MysoMylu, Myso, or Mylu, whether correct or incorrect for Myso (if Mylu) or Mylu (if Myso), i.e., the overall rate for correctly discriminating this species pair from other species.

Calls less than 5.5 msec achieved high rates of correct classification. However, note the very low %accepted. Although correct, very few calls of the data set contributed to this result, and performance may reflect an artifact from applying this automated classifier on a finite and unrepresentative data. Accepting less than ~33% of the sample indicates a weak, non-robust discrimination that will likely produce unreliable results with actual field data, i.e., the inherent nature of the call characteristics do not separate well for confident discrimination.

For the acoustically difficult discrimination between Indiana and little brown bats, the results indicate diminishing confidence for calls less than 5.5 or 6 msec and increasing confidence for calls of longer duration. These results were from individual calls. The combined result of sequence classification based on longer calls would provide the most confident classification results. This has relevance to the DRG provided guidelines for acoustic surveys (Phase 2). Classification confidence increases with longer calls. Bats generally produce longer calls when flying in open, uncluttered microhabitat (Parsons and Szewczak 2009). However Indiana bats tend to forage more in cluttered habitats where they produce shorter, less species-discriminating calls types. Thus for Indiana bats the microhabitats that optimize acoustic detection run contrary to the microhabitats that optimize acoustic classification. To address this conflict, the recommendation for acoustic detector deployments should perhaps include dual sampling in suitable conditions to record free-flight open air search phase calls to increase confident assesment of presence, and suitable habitat to record activity of foraging Indiana bats.

Comment on detector placement

Successful results from acoustic monitoring depend upon acquiring high quality, distortion free, sound data. The Detector Placement recommendations in the DRG provide some provisions in this regard, but omit a vital recommendation for avoiding the distorting affects of echoes produced from multiple signal paths: *recording near the ground*.

Simply elevating a detector one or two meters above ground level can dramatically improve recording quality by reducing surface echoes, avoiding thermal layering, or near-ground air convection currents, all of which can distort ultrasound signals and render unusable or poor signals that result in misclassifications. *Detectors with microphones on cables separate from the detector electronics provide the best options for placement and best results.* Microphones can be attached horizontally to a pole or other means from 3-6 m to listen out into flight space covering both down toward the ground *and* up from there, rather than just listening up from the ground. This increases the volume of airspace sampled and avoids the distortion effect of recording near the ground.

Comment on DRG FAQ #20

The acoustic detection probabilities listed in this FAQ response presume accurate acoustic classification of Indiana bats using EchoClass. Presentations at the 2013 Northeast Bat Working Group and Southeastern Bat Diversity Network meetings this year demonstrated inordinately high Type I errors of false classifications of Indiana bats when not present (as high as 10 times as many little brown bats classified incorrectly as Indiana bats. This indicates that these acoustic detection probabilities for Indiana bats should be reconsidered, and may actually more closely match the mist net results.

Comments regarding the Acoustic Bat Identification Software Testing Criteria – Draft January 2013

Point #6: Any call library or set of training data will always represent a finite set of data. As such, classifiers can always be constructed that precisely know the training data (and its iterated cross-validated subsets) to produce an indication of a high correct rate of classification. Such a condition of overfitting will perform well on the training data but lack the generalization essential to perform well on the larger set of actual data in the field. Accuracy rates on training data should only provide a first assessment of classification performance, and full assessment should come from performance on data novel to the classifier.

1) *Test data should only come from free-flying species-known tracked bats, flying in conditions as close as possible to free-flying bats in their natural environment, i.e., the type of calls that passive recording detectors will acquire for the software to classify.* Recordings from hand-released or zip-lined bats do not typically provide call samples of search phase calls that bats make under free, unencumbered flight. Light tagged bats perhaps provide the closest approximation of free-flight bats, but even these may encumber bats to some extent and provide some differences from bats in natural, free-flight bats.

2) *Test data should not include any presumed species identifications.* No one has ever been demonstrated to infallibly identify Indiana bats from other species by inspection of the recordings. Multiple times during the building of the SonoBat classifiers we have encountered cases in which we found instances from data recorded from species-known tracked bats that revealed that one species could produce calls with characteristics previously considered to be exclusive of another species. These instances grew as the data sets grew. The data presented above indicates this to be the likely case for Indiana bats and little brown bats as well. Although some call types may have become "known" to indicate one species over the other, there is no proof of exclusivity of such characteristics. Including data for these species based on inspection rather than recording of species-known individuals will likely introduce bias, errors, and invalidate the testing process.

3) *Passive recordings of free-flying bats using software-developer recommended procedures in areas outside of the Indiana bat range can provide a test for Type I errors of detecting Indiana bats when they are not present.* Several presentations at the 2013 Northeast Bat Working Group and Southeastern Bat Diversity Network meetings demonstrated this approach.

4) *Test data should correspond to the procedures to suitably record and present data from the software developers.*

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