Indiana Bat, FW3 <indiana_bat@fws.gov>

IBat Protocol comments

Chris Corben <cjcorben@hoarybat.com> Mon, Mar 11, 2013 at 12:00 PM
Cc: "Kim (Yahoo)" <km_livengood@yahoo.com>, indiana_bat@fws.gov, mike_armstrong@fws.gov, Andrew_King@fws.gov, robyn_niver@fws.gov

Hi all

I attach three documents of comments on three of your documents.

I hope this is clear enough.

I respect the courage shown by the FWS in advocating an acoustic approach to a difficult problem. I do think that Indiana Bat acoustic identification is complex. It is typically oversimplified to just an issue with Little Browns, but identification from Eastern Small-footed is likely an even more difficult problem. I also expect problems with Northern Long-eared, as well.

I find it disappointing that so much of what I have heard so far has been about assessing the effectiveness of a small number of software suites, and very little (almost none) about addressing what features of the acoustic repertoires of these species might be helpful or important for identification.

My personal view of it is this. MYSO and MYLU have fundamentally different acoustic strategies, and would be easy enough to distinguish if you compared animals which you knew to be flying in very open situations. Unfortunately, passive recording cannot give you that contextual information. The same calls could be produced by a MYSO in the open or a MYLU in some clutter. We don't yet know of a surrogate for clutter which works across species boundaries - in fact it seems that Myotis species are often differentiated acoustically by producing different types of calls in the same situation. A subset of MYLU calls produced in low clutter is very distinctive from MYSO or any other eastern species. However, I am not convinced that MYSO produce any calls which cannot also be produced by MYLU.

I do think, however, that MYSO and MYLU typically hunt in different situations, with MYSO preferring to be closer to vegetation. If this is so, then it should be reflected in the types of calls they usually produce in the wild. That would suggest that MYSO will typically produce steeper calls of shorter duration than MYLU, and they may be actually more different in the field than reference call collections would suggest. But there is nothing stopping a MYSO from coming out into the open to hunt if there is a major hatching of Mayflies, for example. Or MYLU hunting close to a forest edge if lots of insects are congregating there to avoid the wind. So an important question is, just how often are these trends violated and does that make identification extremely difficult. This is where I think the MLE probabilities should be derived!

In any case, it may be possible to reliably identify the presence of MYSO over time, even if no individual MYSO could be identified as such. Establishing criteria for this purpose will be much more complex than just recording captured bats on release, but it could ultimately make the whole process a lot more meaningful.

I am glad to say that the FWS proposals have at least focused attention on one of the more tricky aspects of acoustic ID, and I fervently hope that as a result, people will start paying attention to issues which should have taken center stage a long time ago.

Cheers, Chris.

3 attachments

CJC_CommentSoftwareTestingCriteria.doc
28K

CJC_CommentsOnFAQ.doc
37K

CJC_CommentsOnGlossary.doc
86K

Comments on:

Acoustic Bat Identification Software Testing Criteria – Draft January 2013

Your original text is in BLACK. My comments are in RED.

QUOTE:
2. Any call identification analysis program must be based upon an extensive call library of free-flying bats (see question #27 in the FAQs). Program developers must provide the Service with a copy of their call library, which must indicate the number of calls per species, call recording location and the method of collection (e.g., free-flying bats, hand release, light tag).

What does "free-flying" mean? A bat which has been captured, handled and released is not in the same state as an un-encumbered bat which is out hunting for food. An essential point to understand is that ANY method by which we identify the species of a bat will automatically ensure that we only record a subset of its repertoire. Thus, reference call libraries are inherently biased. This bias is different from the bias which operates when bats are being passively recorded for survey purposes. The impact of this bias needs to be properly assessed before we can have any idea how it affects the identification of bats from their echolocation calls.

To make this point clearer, just consider that the distribution of call types which will be recorded in a reference call library is never likely to be the same as will be encountered in the field during a survey. The biased subset of calls recorded from bats of known species might be either more or less difficult to identify than calls from a survey.

Consider that possibly the least biased sample you could obtain would come from shooting bats in flight. But they still have to be close enough to the observer and not behind anything or in amongst vegetation. And they probably also have to be flying more or less in a straight line! All these requirements will affect the types of calls which will be recorded from them.

QUOTE:
6. Accuracy rates of the program must be derived through cross-validation (e.g., qualitative assessment). Correct classification rates of files identified to individual bats species for the underlying analytical program within identification software, i.e., discriminant function analysis, neural networks, classification and regression tree (CART) or other statistical tests (see #6) must be provided to show the initial basis used for maximum-likelihood estimator calculations. Minimum correct classification rate on the software's training data must be 90% or better for all Myotis species that may occur within the range of the Indiana bat.

It is essential to understand that accuracy rates do NOT represent the accuracy of identification of a bat recorded in a survey. They could only do this if the reference call library represents a completely unbiased sample of the calls which will be recorded during a survey. It cannot, because the reference set must be based on recordings of bats of known species.

You could devise an automated ID method which always correctly identified every call in a reference set. Your accuracy rate would then be 100%. But it doesn't follow that such a method would be of any use for identifying new bats recorded during a survey.

My personal view of this is that we are still in a state where reference sets are not diverse enough to avoid the situation where a new reference set will make an automatic ID system perform worse than expected. Note I said "diverse enough", not "large enough"! So if I am right about this, we are not yet in a situation where we could even, in principle, assess the impact of the bias inherent in reference sets from identified animals.

Comments on:

FREQUENTLY ASKED QUESTIONS (FAQs)

Range-wide Indiana Bat Summer Survey Guidance
January 2013
Appendix B- Acoustics:

Your original text is in BLACK. My comments are in RED.

13. Why does the acoustic protocol specify the use of directional microphones?

Microphones available for different bat detectors vary in the size and shape of their detection cones (i.e., the area/volume of air space in which a sound will be detected). Microphones can be classified into two broad categories: directional and omnidirectional. Omnidirectional microphones can detect sound from any direction; while directional microphones have a narrower detection cone. The focused detection cone of a directional microphone allows for better detection of sound in the direction that the microphone is oriented from farther away. While both types of microphones have their uses, directional microphones allow greater flexibility in sampling a wider variety of habitats. Furthermore, specific instructions on the most appropriate/effective orientation and placement of omnidirectional microphones for the detection of Indiana bats is not as readily available as it is for directional microphones making it imprudent at the current time to develop guidance necessary to allow their use for these protocols. We currently have developed protocols for deployment of directional microphones and are interested in developing similar methods that would allow for omnidirectional microphones to be used in the future.

There are some things I would like to add to this.

1) Directionality is not an on or off thing. It is primarily affected by the ratio of the microphone diameter to the wavelength of a sound. So in one microphone, it can vary profoundly depending on the frequency of the signal. If you attempt to specify directionality, it should be done in consideration of the frequency of interest. 40 kHz is about the most relevant frequency for Indiana Bats.

2) Everything else being equal (which it never is!), a more directional microphone should be able to detect bats over a greater distance, while a less directional microphone should be able to detect bats over a greater volume. In practice, which is more important will be difficult to assess. Here are some things to consider:

- The most distinctive calls (those most likely to be identifiable to species) are usually those given by a bat flying in the open. Being near a microphone compromises that. So detecting a bat over a large volume may not be very useful if it is too close to the microphone.
- A directional microphone will allow detection of bats over a greater range of distances - that diversity could be important.

- An omnidirectional microphone can always be made directional by use of suitable cones or reflectors. Making a directional microphone less directional is not so easy.

14. Why does the Service recommend use of PVC elbows when weather proofing is desired?

The Service recommends use of PVC elbows because they have been shown to have minimal interference with call quality. Surveyors are interested in protecting their acoustic detectors from unforeseen weather events that could damage the equipment, especially given the fact that detectors will be deployed in the field for extended, unattended monitoring (i.e., overnight). Unfortunately, these methods have the potential to affect the ability to detect bats. Currently, there are two popular types of weatherproofing options: (1) PVC elbow and (2) flat reflector systems. Both rely on reflective surfaces to guide sounds to the microphone.

Britzke et al. (2010) found that the use of a 45-degree PVC elbow resulted in performance similar to unprotected units. The PVC-elbow weatherproofing system allows for recording of suitable call quality and, therefore, is an approved method for weatherproofing detectors (see O'Farrell 1998; Britzke et al. 2010 for examples of this setup). Although the results of Britzke et al. (2010) suggested that reflector plates and PVC had the same ability to document the presence of Indiana bats at a given site, the differences in call quality, number of calls recorded, and species detected suggested there was a significant difference in detectability of Indiana bats between methods. Thus, other available weatherproofing, including the use of a flat reflector, is currently not accepted. As other after-market weatherproofing options become available, they may be compared to unprotected units to determine if they perform at an acceptable level.

I have to say I find this completely unconvincing. Britzke et al compared an elbow with a reflector when the orientations of their axes of greatest sensitivity were in completely different directions. Their results should most definitely not be considered general enough to be drawing such conclusions.

My own investigations show that a variety of both reflectors and elbows work well with Anabat detectors, but that different elbows (or reflector setups) can have very different characteristics. For example, two elbows of the same angle but different designs can have axes of greatest sensitivity in very different directions relative to the obvious features of the pipe. To put this in perspective, you cannot know where a pipe is "pointing" without testing it.

In any given direction, an elbow will result in a frequency response which is "lumpy" (showing fluctuations in the frequency domain) compared to the response of a microphone in open space. A reflector has far less effect of this kind. This lumpiness does not prevent a system from working well.

A full-spectrum recording system will be more affected by such effects in this sense - the "lumpiness" of the frequency response will cause changes in the relative amplitude of the signal at different parts of a call. If the amplitude envelope is considered important for identification, it will be affected by this process. Personally, I doubt this is a significant problem for species identification, but some of the call parameters measured from such systems could be significantly altered.

15. Why is it important to closely evaluate the orientation and placement of detectors?

Ultrasonic detectors can be deployed in a variety of orientations depending on the recording situation; however the orientation of the detector and relative position of the microphone may have a significant impact on the quality of recordings obtained (O'Farrell 1998). When deciding the orientation of the detector, the user should always keep in mind that the detection cone extends out from the unit. Horizontal orientations are not appropriate as they waste roughly half of the detection cone that is pointed to the ground. This serves to reduce call quality and detection (Britzke et al. 2010).

Greater horizontal and/or vertical spatial variability within a sampling area increases the probability of missing bat species (Hayes 2000, Weller and Zabel 2002, Broders et al. 2004). The positioning of detectors can also create biases. The relative position of the microphone to the bats is also an important factor in call quality. If a microphone is above the bats (e.g., on a stream bank) call quality will be reduced.

A horizontal orientation will not cause significant loss of sensitivity if the microphone is raised well above the ground.

Your own arguments above seem to suggest that if there is marked vertical spatial variability (assuming that means in the sampled habitat) then samples should be taken from a variety of heights. Do we know enough about where Indiana Bats hunt to be making assumptions about where they will most likely be detected?

I agree that it is often true that recordings from above a bat tend to be poorer, but be aware this could be because of an inherent bias - you tend to be above a bat which is flying low to the ground. It may mean nothing more than that. I don't see any inherent reason why being above a bat should result in poorer calls. It may make the bat harder to detect in some cases, but you can easily detect a bat from behind, so it is clear that focusing of its beam by a bat is not going to make all that much difference.

27. Is the Service requiring a minimum size for call libraries used by acoustic identification program developers?

No. Acoustic identification programs rely on a library of known bat calls for the correct classification of species. While there is no magic number of calls needed to adequately represent the call repertoire of a given species, in practice, a call library must be extensive enough to include the normally accepted sources of variation (i.e., intra-individual, inter-individual, and geographic). Sufficiency and utility of a program's associated call library will be assessed by the accuracy rates achieved by the developers and ultimately by the Service during our validation testing.

Please note that the "accuracy rates achieved by the developers" will be no indication at all of the "sufficiency and utility of a program’s associated call library". It couldn't possibly be so. A very inadequate call library of just one pulse per species would make it very easy to achieve a 100% success!

Comments on **Glossary of Acoustic Bat Survey Terms**

Your original text is in BLACK, except that I have marked in BLUE text that I think should be changed. I have added text in GREEN as suggestions for replacements for the BLUE text. I have included extra comments in RED.

Glossary of Acoustic Bat Survey Terms

Acoustic bat survey – bat sampling conducted through recording and analyzing echolocation calls.

Acoustic sampling site – the location where a single bat detector will be deployed to sample bat echolocation calls.

Active recording – a method of recording echolocation calls whereby the researcher actively orients the bat detector to follow bats as long as possible in real time; this method generally results in higher quality pulses and longer call sequences than passive recording.

Atmospheric attenuation – a property of sound that results in the loss of energy in the call with increasing distance, higher frequency in the calls, humidity, and temperature.

Atmospheric attenuation – a property of air that results in absorption of energy from a sound wave through heating of the air. Atmospheric attenuation always increases with frequency, so its effect is profound in ultrasonic bat calls. It is also affected by temperature, humidity and pressure of the air.

[[[[Atmospheric attenuation is a property of the medium, not the sound. It is not the only reason why amplitude decreases with distance.]

Automated bat call ID software – a form of echolocation identification in which recorded files are filtered and identified within a software program; the program compares the statistical properties of a recorded call to a library of known calls to classify to species.

Bat detector – equipment capable of detecting ultrasonic echolocation calls of bats that are above the range of human hearing.

Broadband detector – a bat detector that can simultaneously detect a wide range of ultrasonic frequencies.

Call amplitude (or call intensity) – the energy contained in a bat echolocation call, often measured as the decibels a set distance from the bat.; a characteristic that affects the distance at which a call can be detected.

Call amplitude – the amplitude of a sound is the magnitude of the pressure changes in the sound wave. The amplitude perceived by a bat detector (measured in dB SPL) is dependent on the amplitude of the sound produced by the bat (in dB SPL at a set distance from the bat), but attenuated across the distance between bat and detector. The amplitude of a bat call is a key parameter determining how far away it can be detected.

[[[[Amplitude and Intensity are two quite different features. Amplitude is actually the magnitude of the air pressure change associated with the sound. Intensity is actually the energy density (ie power per unit area) of the sound wave. The Intensity is proportional to the square of the Amplitude. But Intensity is also proportional to the square of the frequency. I haven't yet seen a single page on the web which gets this right! There is no point in talking about Intensity in the context of bat acoustics - no-one will ever be evaporated by a bat call!]

Call frequency – the characteristic frequency of a bat call in kHz; the ending frequency of the flattest part of a call (the body); one of the most useful call characteristics for identification.

Call library – a collection of bat calls, known to species, that allows comparison to bat calls without known identity.

Call parameter characterization – properties of a call (statistical or qualitative) that aid in describing the shape and frequency range of the echolocation calls.

Call quality – how closely the sequence matches typical search-phase behavior for the species.

Call quality – how closely a recording of a bat call matches the features of the call as emitted by the bat. Degraded by distance, noise, atmospheric attenuation, echoes and detector characteristics. Low quality recordings will often be hard to identify or even recognize as bat calls.

[[[**[**"Quality" would be better treated as a function of how well the recording represents the pulse emitted by the bat, rather than what part of the bat's repertoire was detected. Perhaps more importantly, how measurements made from a recording would match the parameters of the call as emitted by the bat.

Your concept of "Quality" is really about what sort of calls can be most readily identified. But that doesn't always correlate with "typical search-phase behavior".]

Call sequence – a series of bat echolocation call pulses.

Clutter –obstacles present in an area that can affect recording of bat echolocation calls; may be caused by either scattering echolocation calls from sound bouncing off obstacles (thereby reducing call quality) or by bats adjusting their normal search phase calls in response to additional obstacles resulting in changed bat echolocation call parameters.

Clutter –the presence of objects close enough to a bat to produce echoes the bat can detect. Typically, a bat will respond to such echoes by changing the types of calls it produces. Most often, calls produced in clutter will be harder to identify than calls produced in more open contexts.

[[[**[**The term "Clutter" is used in your second sense - objects close to a bat which cause it to change its echolocation calls. A bat in zero clutter (so it hears no echoes from the pulses emitted) will give its flattest, longest pulses ("commuting calls"). The maximum distance at which clutter can be detected by a bat will vary greatly between species. The term "Clutter" originates from radar, and means echoes from things of no interest. That's a bit different to a bat's situation, where avoiding being impaled on a stick may be just as important as catching food. In any case, a bat may, but won't necessarily, change its calls in response to clutter in a similar way to echoes of importance.

Bats don't change their " normal search phase calls in response to" clutter. Calls given in clutter are a normal part of a bats echolocation repertoire! They just give different parts of their repertoire in different levels of clutter.]

Cone of detection – the volume of space that is effectively sampled by a bat detector.

Zone of detection – the volume of space in which a bat can be detected by a bat detector. Widely affected by the species of bat, the nature of the microphone and type of detector, and also by the weather.

[[[[Most people naively think of the sampled volume as a cone with the pointy end at the detector. It is actually closer to the opposite! What is always true of a microphone in the open is that the maximum distance of detection is achieved for a signal which is on the microphone's axis. IE if you point the detector straight at the bat you will detect it from the greatest possible distance. You can usually detect a bat from any other angle, provided it is close enough.]

Constant frequency (CF) – a type of bat call that remains at one frequency over the entire call duration, in contrast to frequency modulated (FM) calls.

Constant frequency (CF) – a type of bat call where the frequency remains essentially constant for a large part of the call. Normally associated with Horseshoe Bats, which are not found in America.

[[[[No such thing in North America! Closest to this are the Horseshoe Bats of the Old World, but even they start the call with an upsweep and end it with a downsweep. The term itself comes from an age when our understanding of bat calls was very primitive compared to today, and when it was actually believed there was such a simple dichotomy, though later the term QCF was introduced in recognition of the greater complexity of reality. Nowadays it is obvious that calls can cover a huge range of slopes even in one species.]

Decibel (dB) – in acoustics, a measure of the amount of pressure exhibited by a sound wave, often utilized to measure the ‘loudness’ of a call.

Decibel (dB) – a way to express the ratio between two values. In acoustics, typically used as dB SPL to express the amplitude of a sound compared to the reference pressure amplitude of 20 microPascals. A logarithmic scale where a fixed difference always means the same ratio. So 20 dB is a factor of 10, 6 dB is a factor of 2 etc.

[[[[It is just a way of expressing a ratio. Even dB SPL only specifies how the amplitude of a sound wave compares to a reference value - 0 dB being an estimate of the faintest audible sound. The problem with your statement is that the term is also used to compare sensitivities of microphones, or bat detectors or atmospheric attenuation, etc. Also, loudness is a very different concept related to perception of a sound by a brain.]

Detection probability – the likelihood of detecting the presence of a species when that species is present.

Detection range – the maximum distance, under specific circumstances, that a bat call can be detected; this factor is affected by clutter, atmospheric attenuation, and the frequency and amplitude of bat calls.

Detection range – the maximum distance at which a bat can be detected by a specific detector or detection system. This is affected by the amplitude and frequency of the bat call, the orientation of the bat to the detector and of the detector to the bat, the distance between bat and detector, the weather and the sensitivity of the detector. The maximum Detection Range would only be realized when all these factors were at their most favorable.

[[[**[**Of course, it is also affected by sensitivity of the detector and distance to the bat, the latter being by far the most important variable!]

Detector sensitivity – measures the ability of a bat detector to detect an echolocation call.

Detector sensitivity – measures the sensitivity to sound at the microphone of a detector. Expressed in dB SPL (but will vary with frequency). Is also profoundly affected by the sound analysis system in use (eg FFT, ZCA etc).

[[[**[**It could be argued that the "ability" will also be a function of the skill with which the detector was deployed!]

Detector - see "bat detector".

Directional microphone – a microphone that is more sensitive to sound arriving from certain directions.

Doppler shift – a physical property of sound that results in an apparent change in frequency of sound because of an object's movement; a sound source moving towards a microphone is perceived as a higher frequency and vice versa.

Doppler shift – an apparent change in frequency of sound caused by the velocity of the source relative to the detector. If the source is moving towards the detector, frequencies will be increased, but durations will be decreased. A bat's flight speed could cause Doppler shifts of about + and - 3%. If detected from a moving vehicle, the effect could be much greater.

[[[**[**Not only frequency is affected! A positive Doppler Shift increases frequency and decreases duration. Also it's not really a property of sound, but of the way a wave propagates through space.]

Echolocation – use of ultrasound and the returning echoes to orient and navigate in the environment.

False negative – the failure to detect a bat species when it is actually present in the area; statistically a type II error in hypothesis testing.

False negative – the failure to detect a bat species when it is actually present.

[[[**[**I think the comparison to Type II errors is a bit dubious. If the null hypothesis was that bats were present, then a false negative could result in a Type I error.]

False positive – the detection of a bat species when it is not present; statistically a type I error in hypothesis testing.

False positive – the detection of a bat species when it is not actually present.

[[[**[**I think the comparison to Type I errors is a bit dubious. If the null hypothesis was that bats were present, then a false positive could result in a Type II error.]

Feeding buzz – a phase of a bat echolocation call that results in rapid-fire sound pulses as a bat approaches a potential prey object; these calls typically lack the species-specific characteristics needed for species identification.

Frequency band – the range of frequency that bat calls or detector covers.

Frequency division detector – a type of bat detector that reduces the frequency of echolocation calls of bats so they may be heard by humans or stored more easily by dividing the frequency of sound by a set number called the division ratio (n).

Frequency division detector – a type of bat detector which produces an audible signal from bat calls by dividing the frequency by a constant, the division ratio. Can only detect one signal at a time, so the signal which gets detected is always the one with most amplitude. Does not retain information about signal amplitude. Normally a broadband detector. It will not require tuning. Has the advantage of requiring a very low data rate. Less sensitive than full-spectrum and heterodyne detectors.

[[[**[**It certainly has no effect on what the bat emits! It only produces a representation of the sound of the bat with its frequency divided by a constant. It is simply not true that it "divides" or "converts" the sound - a common misconception.]

Frequency modulated (FM) – a type of bat call that varies or “modulates” in frequency throughout the call, in contrast to constant frequency (CF) calls.

Frequency modulated (FM) – a type of bat call with a frequency which varies throughout the call, in contrast to constant frequency (CF) calls. Usually thought of as a call which sweeps rapidly through a wide range of frequencies.

[[[[Just to reiterate, there is no such dichotomy between FM and CF. The Europeans commonly talk of QCF, as well.]

Full-spectrum detector – bat detectors in which all desirable information about the recorded sound is preserved, including time, frequency, and amplitude.

Full-spectrum detector – a bat detector which samples bat calls at a high enough rate to maintain the spectral quality of the original signal. Full-spectrum recordings store information about amplitude and can simultaneously record multiple signals. Normally a broadband detector which will not require tuning. Requires a very high data rate. More sensitive than Frequency division detectors, but only if the data is processed in such a way as to maximize detection of faint signals buried in noise.

[[[**[**Information isn't necessarily desirable!]

Harmonics – whole-integer multiples of fundamental sound frequencies used by bats, which assist in pinpointing an insect's location; overtones.

Harmonics – whole-integer multiples of the fundamental frequency. The first harmonic is the fundamental and the second harmonic has twice that frequency. The harmonic with most amplitude is called the dominant harmonic. In most bat calls, the fundamental is dominant, but it many species, the second harmonic is dominant. The harmonic structure (how the signal energy is distributed among the harmonics) can vary between genera of bats and also within a single pulse. However, the perception of harmonic structure by a bat detector can vary depending on many factors.

[[[**[**Overtones and harmonics are quite different. I am honestly not sure what is going on in bat calls. Human voice consists of many overtones, which aren't integer multiples of the fundamental. But in bats it looks simpler, and seems to be a genuine, simple harmonic structure.]

Heterodyne detector – a type of bat detector that lowers the frequency of echolocation calls of bats so they may be heard by humans or stored more easily by mixing with a known signal frequency, thereby resulting in a narrow-band detector.

Heterodyne detector – a type of bat detector which produces audible frequencies from bat calls by mixing them with an adjustable frequency. Its output is the difference in frequency, which can be in the audio range if the detector is tuned correctly. Narrow band at any one setting, so must be tuned. Most sensitive detection system when tuned to desired bat calls. Not usually used for recording, because output frequency has no simple relationship to bat call frequency.

[[[**[**Again, no detector changes the frequency of a bat call! An important thing about a heterodyne is that it is the most sensitive approach, all other things being equal, which is never true! Narrow band means it must be tuned to a given bat. Output signals don't relate in a simple way to bat frequencies.]

High-frequency calls – a general classification of calls that refers to those with minimum frequencies >35 - 40 kilohertz.

High-intensity calls – calls with greater than 110 decibels sound pressure from 10 centimeters; 'loud' calls.

Kilohertz (kHz) – a unit of measure of the frequency of sound; one thousand hertz.

Low-intensity calls – calls with 10-80 decibel sound pressure from 10 centimeters.

Maximum-Likelihood Estimate (MLE) – a statistical method of estimating the parameters of a statistical model. For our purposes, the MLE is a statistical method that can be used to determine species presence or probable absence at a particular site on a particular night by means of a classification matrix.

Microphone sensitivity – the minimal amplitude required at a given frequency for a microphone to detect a sound.

Microphone directionality – the degree to which a microphone is sensitive preferentially to sound arriving from certain directions; see directional microphone.

Microphone orientation – the direction in which a microphone's axis of greatest sensitivity is pointed.

Microphone orientation – the direction in which the microphone is pointing' thereby affecting the cone of detection**.** May not correspond to any obvious physical feature of the microphone, especially if the signal is redirected for weather protection.

[[[**[**It's more complex than that. The direction of greatest sensitivity may not correspond to any obvious physical direction in which it is "pointing". It will if the microphone can be represented as a simple, flat plate.]

Narrow-band detector – a detector that can only record bat calls from a small frequency range at a specific time.

Narrow-band detector – a detector which can only record bat calls from a small frequency range at any one time. This has the advantage of increasing sensitivity by improving the signal to noise ratio.

[[[**[**At "any one time" would be more accurate than at "a specific time".]

Noise – unwanted or extraneous environmental sound or electronic interference detected by a bat detector.

Noise filters – statistical processes that remove noise from bat echolocation pulses.

Noise filter – any process which helps separate bat calls from noise (which is any signal detected which is not of interest). This is most often applied by software examining a recorded signal.

[[[**[**Doesn't have to be a "statistical" process! Whatever that is! Important point is that a noise filter distinguishes noise from signal. Very simple algorithms can work very well.]

Omni-directional microphone – a microphone that can detect equally in all directions (i.e. has a spherical cone of detection).

Omni-directional microphone – a microphone that can detect equally in all directions. However, a microphone can be more directional for some frequencies (and therefore bat calls) than others.

[[[[How can a cone be spherical?!]

Pass – a single crossing of a bat through a bat detector's cone of detection; see 'call sequence'.

Pass – a single crossing of a bat through a bat detector's zone of detection; see 'call sequence'.

[[[["cone of detection" is incorrect and misleading.]

Passive recording – bat echolocation sampling from a spatially fixed recorder, opposite of active sampling, in contrast to active recording.

Passive recording – bat echolocation sampling where there is no observer present to orient the detector towards bats or to observe other features which might help identify them.

[[[[The critical thing is that there is nobody present to either orient the detector or to gain insight into where the bat is flying (which is important for understanding some ID issues). A passive detector could be mounted on a boat or train, for example.]

Phonic groups – groups of bat calls categorized by their echolocation frequencies; typically grouped as high, medium or low.

Phonic groups – groups of bat species which are difficult to acoustically identify to species.

[[[[The real point is that if you cannot identify calls to species, you can assign them to a phonic group, which would include two or more species which are hard to ID. The whole idea of using terms like "high" or "low" is to identify a sequence as belonging to a group without being able (or willing) to identify which species is involved.]

Pulse – a brief, continuous emission of sound; see 'call sequence'.

Preamp gain – the amount that a signal is amplified (increased) before processing.

[[[[Not sure why this is here or what the significance of it really is! Even the term "preamp" will have different meanings in different contexts.]

Qualitative call identification – identification of call sequences through visual comparison with a known call library; accuracy can be highly variable based on researcher experience.

Qualitative call identification – identification of bat calls without measuring them. - eg by visual inspection of sonograms or by hearing the sound from a bat detector. Identification by ear would be completely qualitative, while a sonogram inherently provides measurements, so the distinctions are blurred.

[[[[Could be true, but much more often the comparison would be with the user's experience (or memory).]

Quantitative call identification – identification of call sequences via mathematical algorithms/statistical models that compare multiple call parameters from unknown calls to those of known calls and assign them to a particular species or other category.

Quantitative call identification – identification of bat calls using actual measurements of call parameters.

[[[**[**I think there is a tendency to confuse Qualitative versus Quantitative with Manual versus Automated. While Automated ID is inherently quantitative, Manual ID could be either.]

Signal-to-noise ratio – a measure of call quality comparing the relative amplitude of desirable and undesirable components.

Search-phase call – the type of echolocation call emitted as a bat is commuting or looking for food; characterized by regular consistent call characteristics.

Search-phase call – the type of echolocation call emitted by a bat in flight when it is not actively chasing something or rapidly changing its context. Search-phase is characterized by regularity - a series of calls showing similar characteristics. This is an old term, which has traditionally been associated with calls given in low clutter. We now know that echolocation calls can change rapidly along a broad continuum ranging from commuting calls (zero clutter) to feeding buzzes (extreme clutter).

[[[**[**I think the regular nature of the sequence is the key here. Doesn't matter what the bat is doing, and you never know that. Typically it was thought that search-phase was a well-defined entity, but now we talk of a search-phase continuum, where call types can vary over a wide range, mainly determined by how a bat reacts to echoes.]

10/40 Rule – a method to assess whether a site was sampled effectively; the 10 represents a minimum of 10 individual call sequences being recorded and 40% refers to the percentage of bat sequences that are identifiable to species.

Time-expansion – a type of full-spectrum bat detector that reduces the frequency of recorded calls so they may be heard by humans and stored more easily by electronically stretching the calls over a longer time period.

Time-expansion – a type of full-spectrum bat detector technology which produces audible signals from bat calls by storing them and playing them back slowly. Has all the capabilities of full-spectrum recording, except that it cannot record while playing back, so it cannot continuously record.

[[[**[]**

Ultrasonic/ultrasound – sounds made of frequencies that are beyond the range of human hearing (often arbitrarily set at 20 kilohertz, although most adults have trouble hearing sounds above 15 kHz.)

Ultrasound-conversion techniques – also see "frequency division", "heterodyne", and "time-expansion"; the method in which the frequency of recorded calls is reduced so they may be heard by humans or recorded more easily.

Ultrasound-conversion technique – also see "frequency division", "heterodyne", and "time-expansion"; the method by which an audible signal is produced from an electronic representation of a bat call.

[[[**[**Recording need not be part of the process.]

Weather proofing – various methods/materials used to protect a bat detector/microphone from the elements (primarily rain).

Zero-crossing detector – a detector type that calculates frequencies by measuring the time between moments of zero sound pressure, which corresponds to the period of the wave.

Zero-crossings detector – an electronic circuit or piece of software which detects the zero-crossings in an electronic signal or digital representation of such.

[[[[Really, a ZCD is a small electronic circuit which detects the Zero-crossings from the electronic output of a microphone. Or software which detects the Zero-crossings from some other sort of signal (eg a wave file). Zero-crossings Analysis is how you derive frequencies from Zero-crossings data, which might be provided by any type of detector. A Frequency Division detector makes use of a Zero-crossings detector, then counts the time between a number of consecutive zero-crossings. Zero-crossings data consists of a series of time intervals. Zero-crossings Analysis can be used to draw sonograms from Zero-crossings data. I don't think this term really has much relevance here! It would be like talking about an FFT detector.]

Some other suggested topics:

Zero-crossings Analysis – one of many methods used to analyze signals. In bat acoustics, can be used to produce sonograms of bat calls, showing the frequency-time course of a signal, the feature most important for species identification. Can use either full-spectrum recordings or Zero-crossings Data.

Fast Fourier Transform (FFT) – one of many methods used to analyze signals. In bat acoustics, typically used to produce sonograms and power spectra of bat calls from full-spectrum data, showing amplitude information as well as the frequency-time course of the signal.

Zero-crossings Data – the output of a Zero-crossings detector, typically from a Frequency Division bat detector, where each value stored is the time taken for several cycles of the original signal. Because there is only one sample per several input cycles, very little data is required to store a bat call.

Full-spectrum Data – the output of a full-spectrum bat detector. Full spectrum data requires more than 2 samples per cycle of the highest frequency intended to be stored unambiguously, but that data rate must be retained for lower frequencies as well, so a high data rate is required.