Overview
Acoustic Detection and Identification of Bats

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We can’t hear them

Humans hear <20kHz generally and most speech is <5 kHz in frequency.

Most bats echolocate >20kHz (ultrasound).

We need to transform ultrasound into a lower frequency.

This can be done in different ways:

How to hear bats

- Heterodyning. Mix the ultrasound with another signal and amplify the difference.

  Eg. 32 kHz (bat ultrasound) - 30 kHz (tuned detector) = 2 kHz (what we hear)

Main Disadvantage: narrow frequency range – must tune to range of interest

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- Frequency division. Divide the frequency of the signal from the bat, usually by 16, so that it lies in the range humans can hear.

  Eg. 32 kHz (bat ultrasound) ÷ 16 kHz = 2 kHz(what we hear)

  Main Disadvantage: will not pick up very quiet sounds - the call must exceed a certain threshold.
  Main Advantage: broadband, sensing all frequencies - does not need tuning

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- Time expansion. The signal is literally stretched out in time, so that the frequency is reduced. Often 10x. Preserves properties of sound (time, frequency, amplitude).

  Eg. 32 kHz (bat ultrasound) slowed down 10x = 3.2 kHz (what we hear)

Problem: 'Deaf' while it time expands the signal.

But Seeing is Believing…

- To record bats for *visualizing* calls.

Heterodyne **NO**

Frequency division **YES**

Time expansion **YES, but….**

Problem: "Deaf" during time expanding (10x 'down-time')

Solution: Advance the technology. Real-time direct digital recording instead….

Some new guys on the block…

Real-time Digital Recording

(and you don't need a laptop)

Pettersson D500x

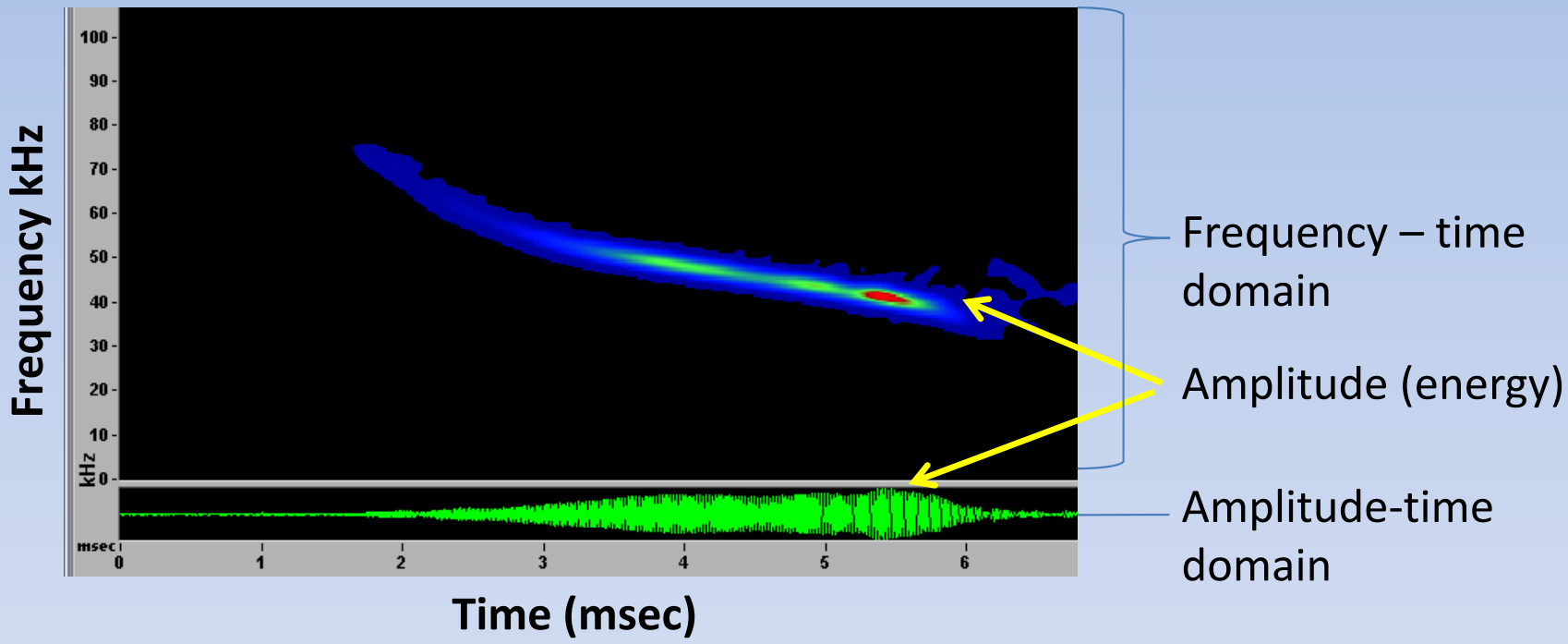
Binary Acoustic Technology,
AR125
(+FR125 or *New*: iFR4)

Wildlife Acoustics
SM2BAT

What they have in common: **Full Spectrum** Sound Recording

What full spectrum means….

– time, frequency, amplitude properties of original sound



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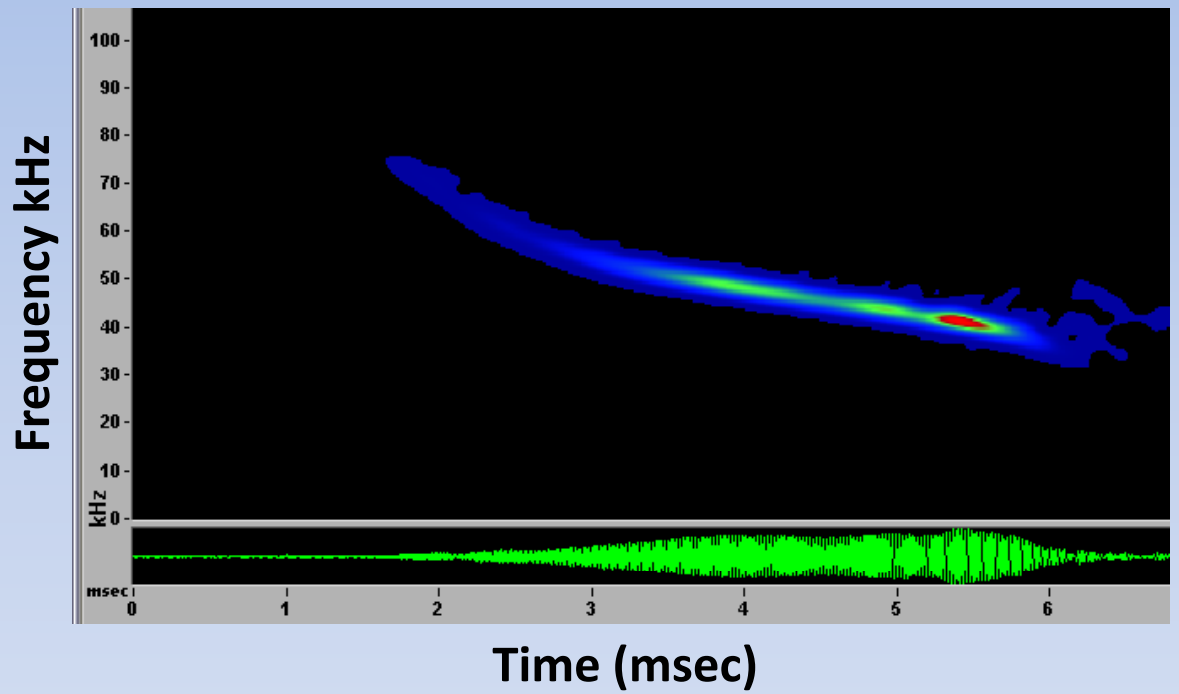

– heavy memory needs (digital sound files can be very large!)

– substantial energy requirements for these detectors

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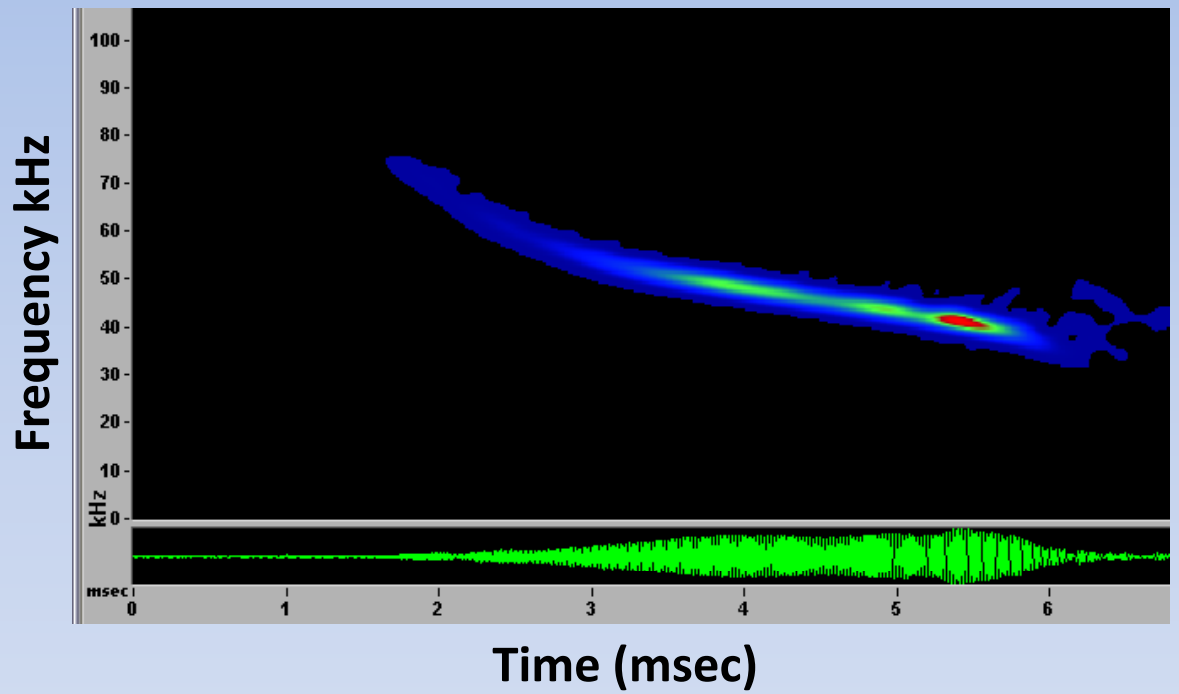

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– substantial energy requirements for these detectors

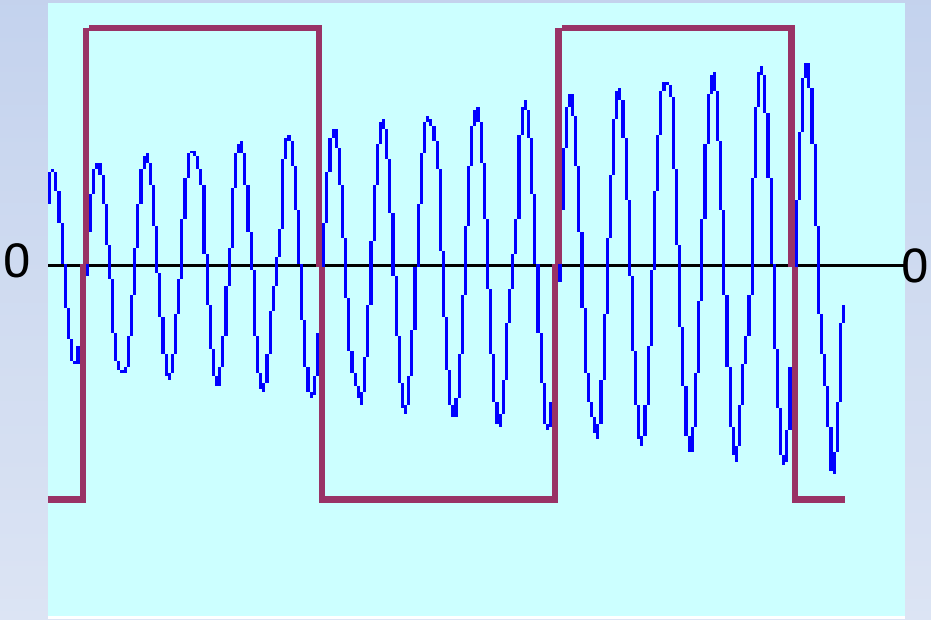
These used to be bigger problems than they are today….

A way of getting around these issues….

Zero-crossings Analysis (ZCA)

-count each time a sound wave passes the *zero point*

-at a preset number of crossings (called Division Ratio, often 8 or 16), a time measurement is made (allowing frequency to be recorded)



Time and frequency properties to describe original sound wave, but not amplitude.

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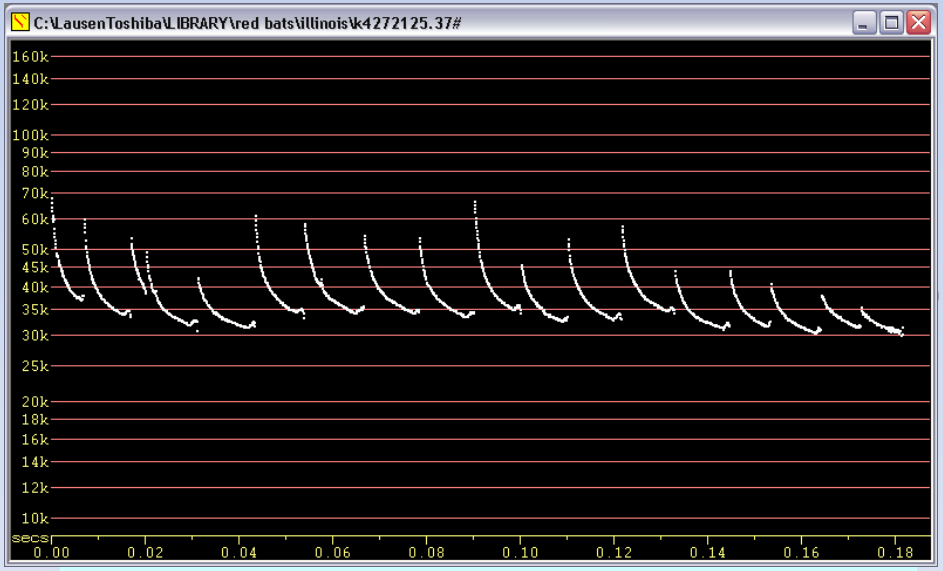


Frequency kHz

Time (msec)

Time and frequency properties to describe original sound wave, but not amplitude.

Small memory needs and low energy requirements.

The question is:

How much information about the original sound wave do we need to meet our goal(s)? (ie. full spectrum or ZCA?)

Depends on your goal/question.

So now the question becomes:

Is full spectrum better for species ID?

Maybe, in some situations. Not yet clear. No published scientific studies!

-*Some call parameters available in full spectrum are:*

i. not available in ZCA data

ii. represented differently in ZCA recording

*But does this facilitate full spectrum detectors to provide **better** species ID??..... And if so, how often is this advantageous? Does it make a large difference? In what locations? For what species? Worth the huge memory storage burden?

Published comparison is needed!

Other considerations for differences among detectors:

SAMPLING RATES

- Full spectrum detectors
  - how often does a detector ‘sample’ the sound to record it digitally
  - affects quality and maximum recordable frequency
    - ½ the sampling frequency = max recordable frequency

Sampling Rates

Pettersson D500x

up to 500 kHz

B.A.T.
AR125 (+FR125)

250 kHz

Wildlife Acoustics
SM2BAT

192 or 384 kHz,
Depending on model

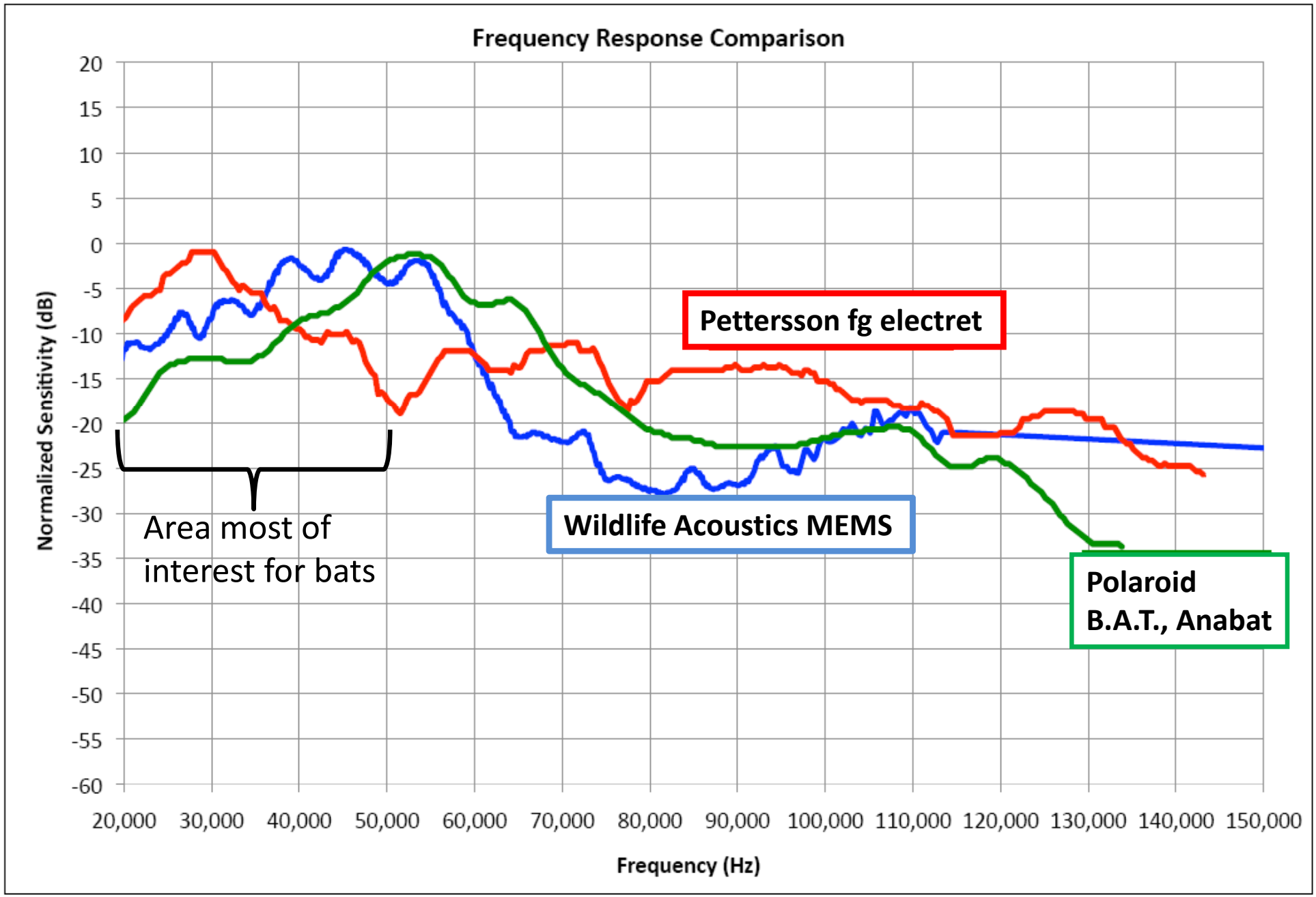
All 16 bit recording (file compression options available which reduce bits and can reduce quality).

Other considerations for differences among detectors:

MICROPHONES

- They are not all created equally.
  - levels of noise
  - directionality (e.g. unidirectional mics are inherently noiser but records bats from basically all directions)
  - volumes of detection space
  - different sensitivities to different frequencies (frequency response curves)

Frequency Response Curves



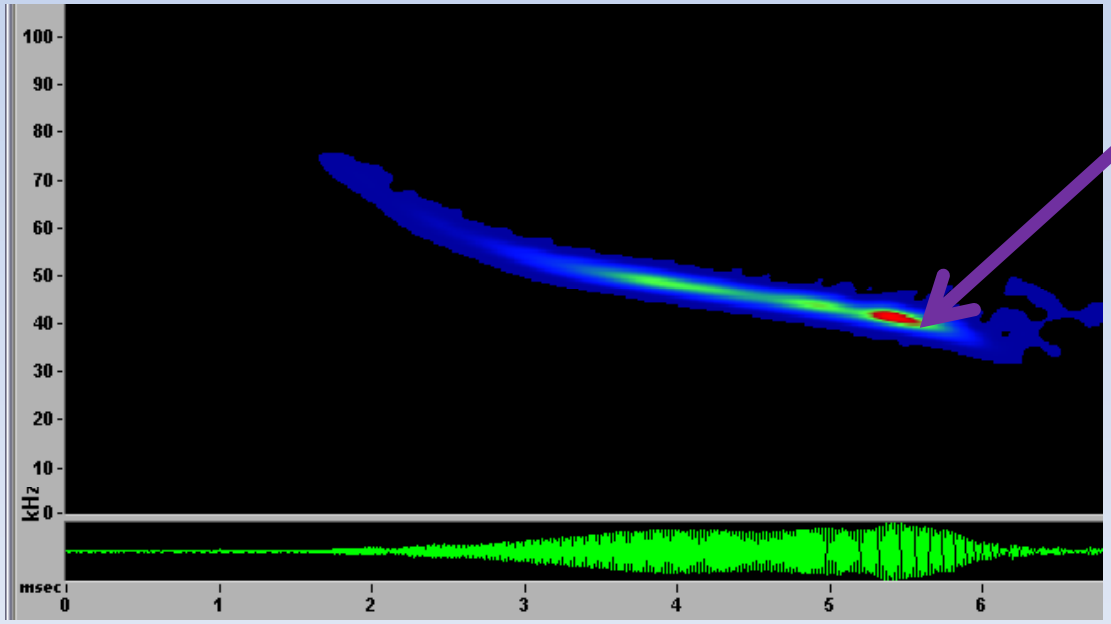
GRAPH COURTESY OF WILDLIFE ACOUSTICS

Effect of Different Mics

Reference Call Libraries

What type of **detector/microphone** was used to record the reference calls that you are using for your statistical identifications.

- different types of microphones = different sensitivities
  - so if amplitude plays into how one differentiates between species, then this is an important consideration.



Frequency of maximum amplitude (energy)….
But would this be the same on all bat detectors?

Digital Compensation being employed in some software to facilitate use of different detectors.

Software

Detector	Software Associated with Downloading/Recording	*Manufacturer's Software* and other software that recordings directly feed into for analysis
B.A.T.	SPECT'R	*SCAN'R*, Sonobat
Pettersson		*BatSoundPro*, Sonobat
Anabat	CFCRead	*AnalookW*
SM2BAT	Wac2Wav	*SongScope*, Sonobat, AnalookW

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Ability to 'scrub' or remove files that contain noise and no bat pulses.

Testing this is always important – how well does it work in different recording situations? False positives and false negatives will happen. Minimizing these is the goal (consider subsampling). *Calculation of error rate may be desired.*

SM2BAT – currently the only system that allows analysis of recorded files in either full spectrum or zero-crossing software; recordings are full spectrum files though.

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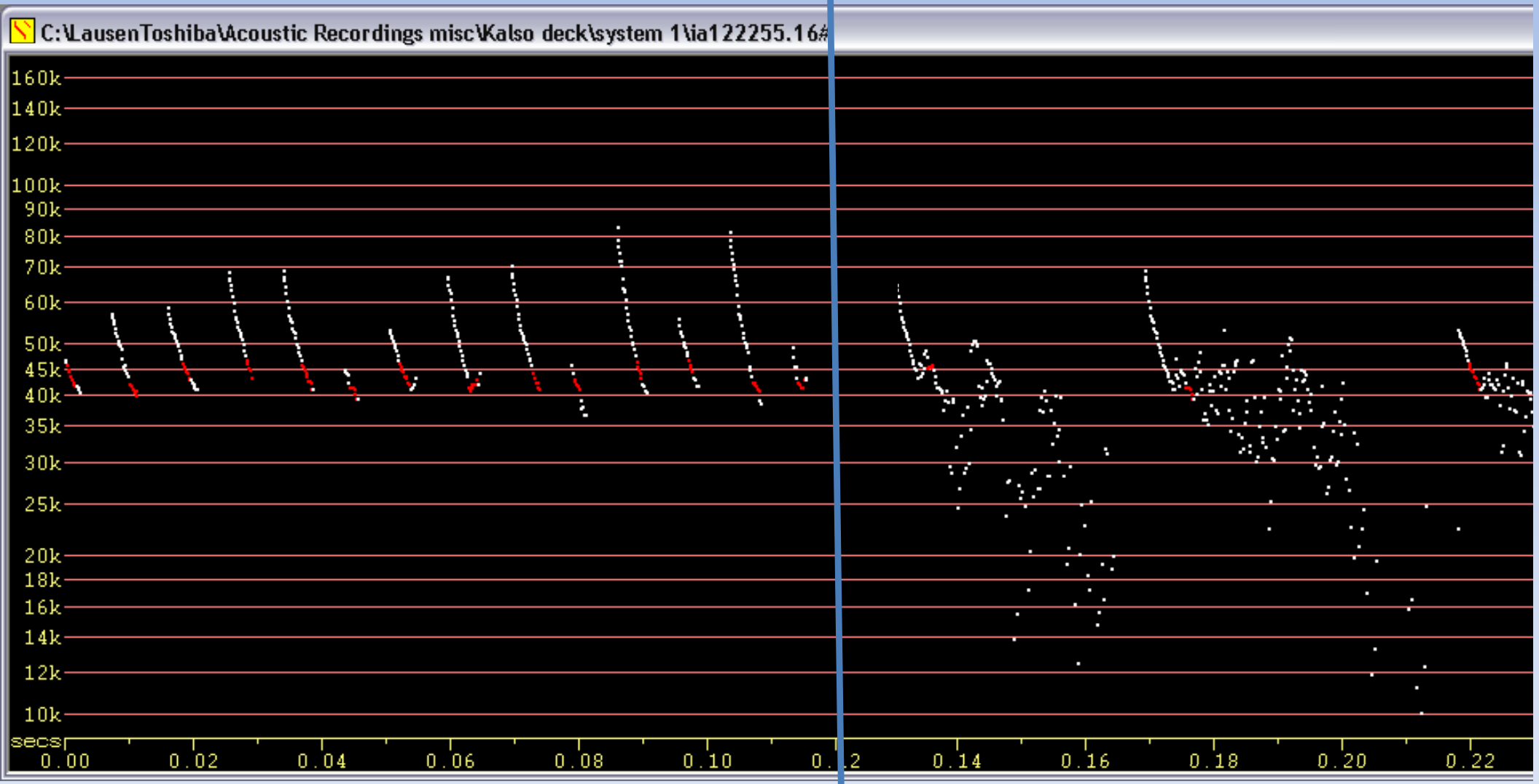
SM2BAT	Wac2Wav	*SongScope*, Sonobat ✓, AnalookW ✓

✓ Auto-ID options for bulk identification of files to species or species-groups.

Testing this is always important – how well does it differentiate species? Best to review all unexpected identifications and subsample all other files - calculation of error rate may be desired.

AnalookW Noise (*AllBats*) Filter

- Works on datasets to scrub out noise files, but also works within each file
- Can apply *Filter* to make visualizing files “cleaner” – good for measuring and displaying



Noise Filter applied (cleaned)

Without Filter applied

Visualizing, Processing, Identifying

Analysis Software

Zero crossing analysis

AnalookW (Chris Corben)

FFT spectral analysis

Sonobat (Joe Szewczak)

SCAN'R (Binary Acoustic Technology, Mark Jensen)

SongScope (Wildlife Acoustics, Ian Agranat)

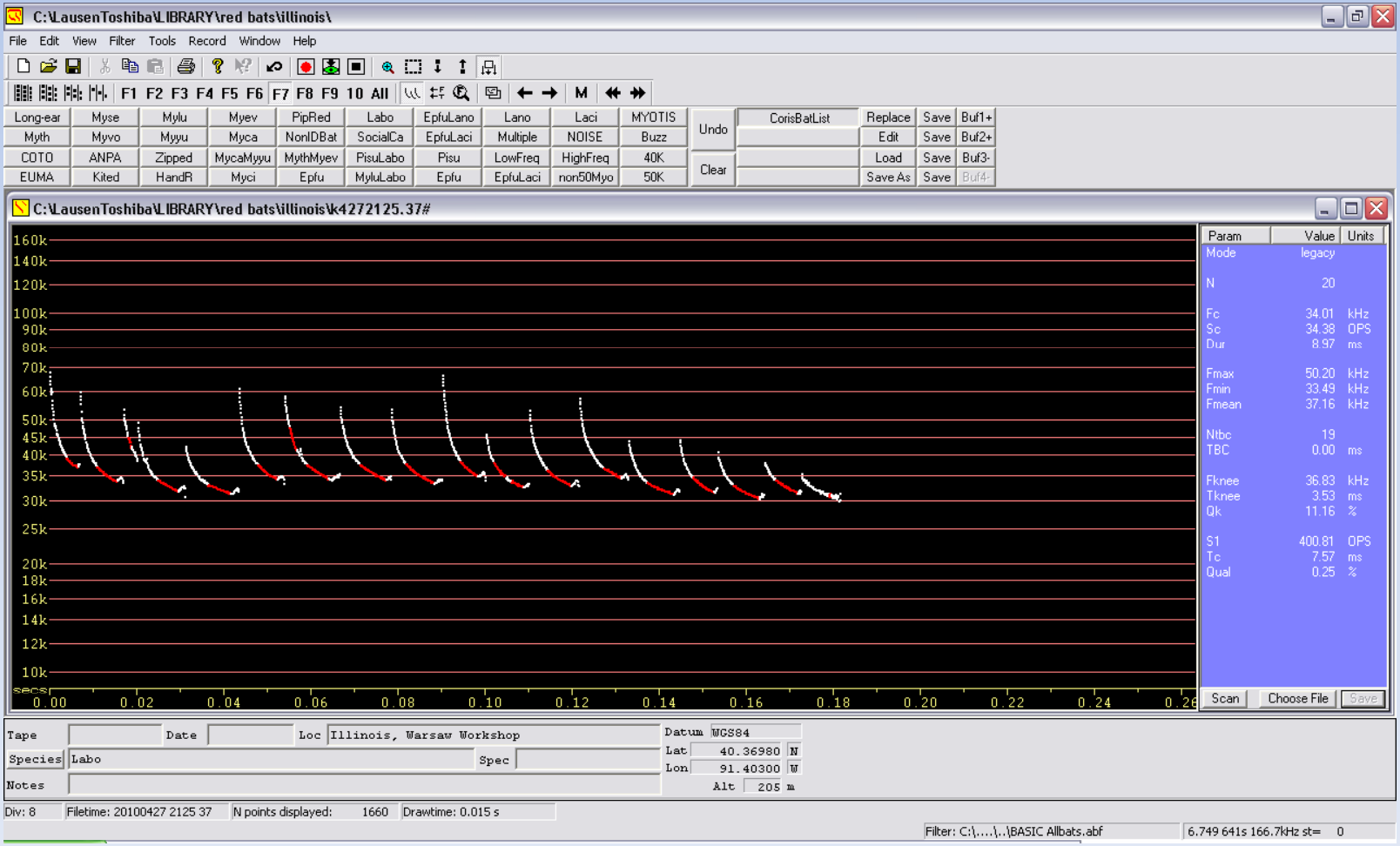
Others: BatSoundPro, Raven, Avisoft, SoundRuler, etc. (many programs allow you to visualize/record but not necessarily *analyze* for automated ID or bulk file labeling, etc.)

Visualizing, Processing, Identifying

Analysis Software

Zero crossing analysis

AnalookW – **Anabat Files; can employ filters for auto-ID and noise removal**



Visualizing, Processing, Identifying

Analysis Software

Zero crossing analysis (cont'd)

AnalookW – Map, ZCA files (full night at a glance)

Visualizing, Processing, Identifying

Analysis Software

Zero crossing analysis

AnalookW (Chris Corben)

FFT spectral analysis

Sonobat (Joe Szewczak)

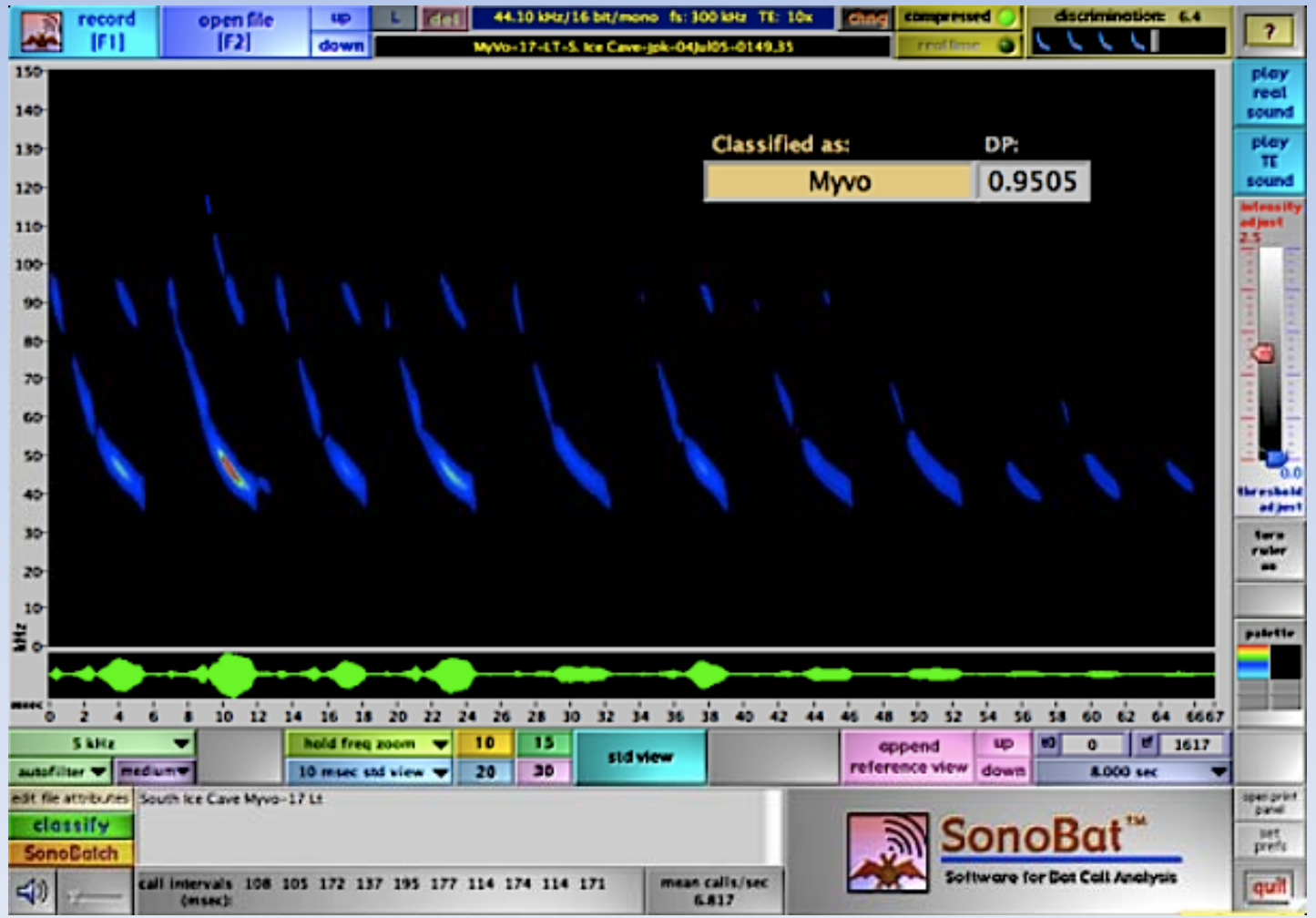
Sonobat

Version 2 = to visualize and measure bat pulses

- short sequence files – a few seconds of a bat pass

Version 3 = all functionality of Version 2 + autoID based on DFA

- provides probability of identification for each file



Based on Pettersson and some B.A.T. detector recordings.

In the process of accommodating SM2BAT recordings *(Wac2Wav currently does a digital compensation)*

Best for viewing short sequences of data.

Visualizing, Processing, Identifying

Analysis Software

Zero crossing analysis

AnalookW (Chris Corben)

FFT spectral analysis

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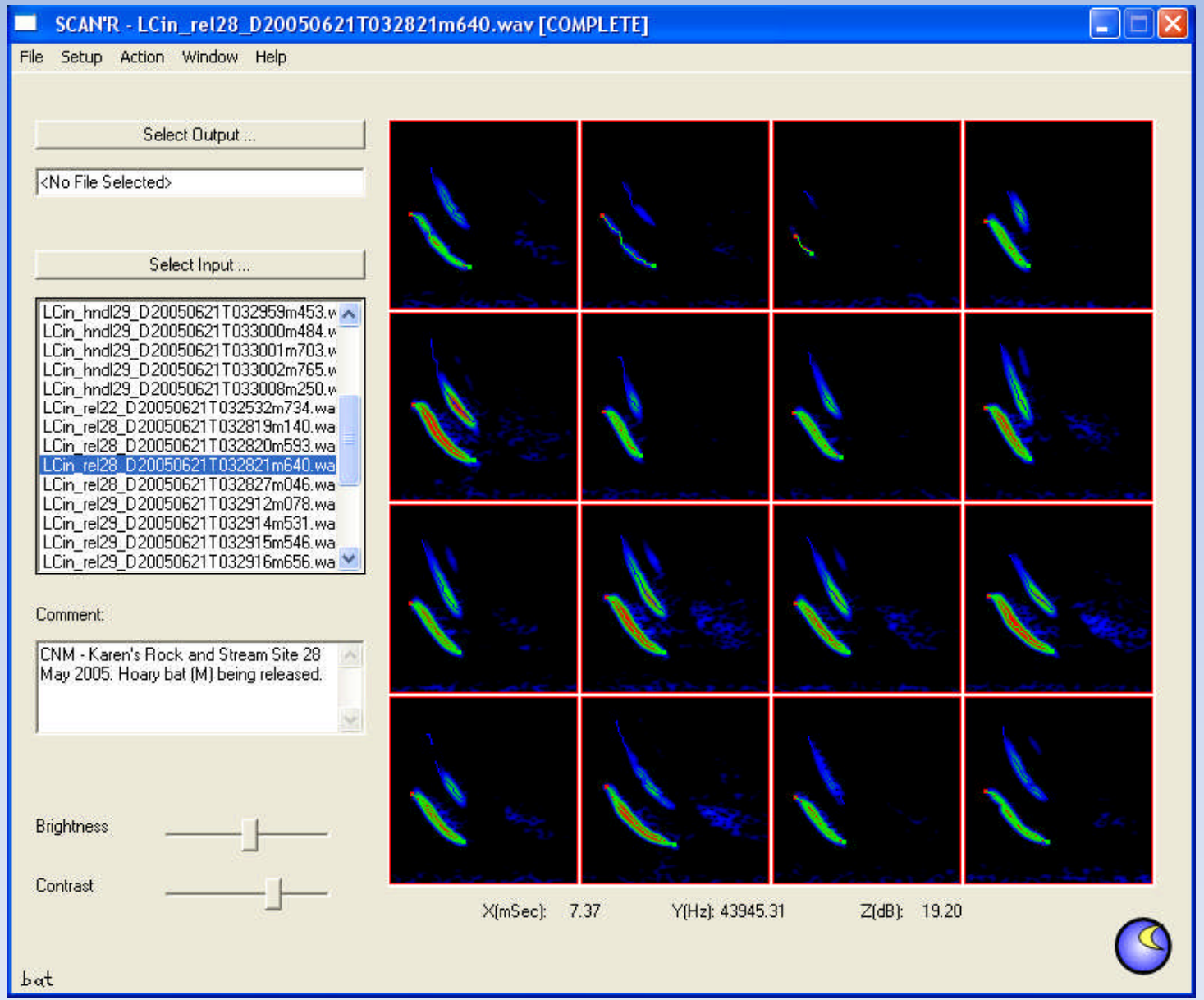
SCAN'R

Visualize and measure

(can also export AnalookW zero-cross parameters or Sonobat parameters for further statistical analyses)



Visualizing, Processing, Identifying

Analysis Software

Zero crossing analysis

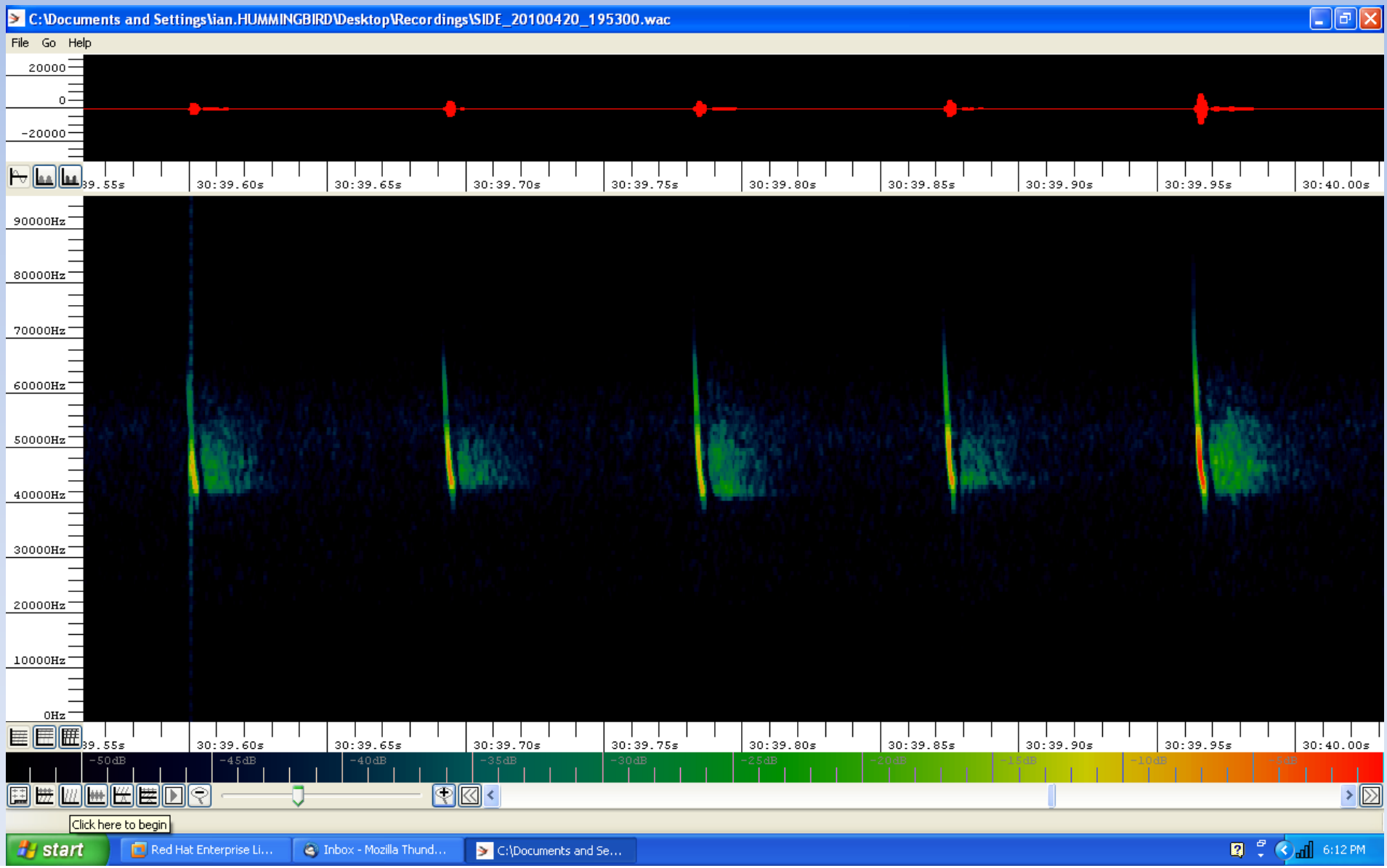
- AnalookW (Chris Corben)

FFT spectral analysis

- Sonobat (Joe Szewczak)
- SCAN'R (Binary Acoustic Technology, Mark Jensen)
- **SongScope** (Wildlife Acoustics, Ian Agranat)

SongScope

Potential for autoID – build with reference calls (‘recognizers’ using algorithms similar to voice recognition). Can view very long sequences of data.



Output of Analysis Software

Sonobat 3

– Discriminant Function Analysis [DFA] with hierarchical analysis – can take some sequence parameters into consideration.

– ID for each file (species or species-group) with a percentage value assigned to each file (distance from centroid of each species or species-group).

– measurements of calls provided (for further stats if desired)

– 'known' species are fixed (software specific to regions) – must order regional-specific

– automated classification – no parameters are entered

AnalookW

– ID assigned to files that meet criteria of the filter(s) through which they are scanned (species or species-group). Files with no identifiable elements are not labeled.

– measurements of calls provided (for further stats if desired)

– user decides what species and call parameters are considered – must construct filters based on knowledge of bats.

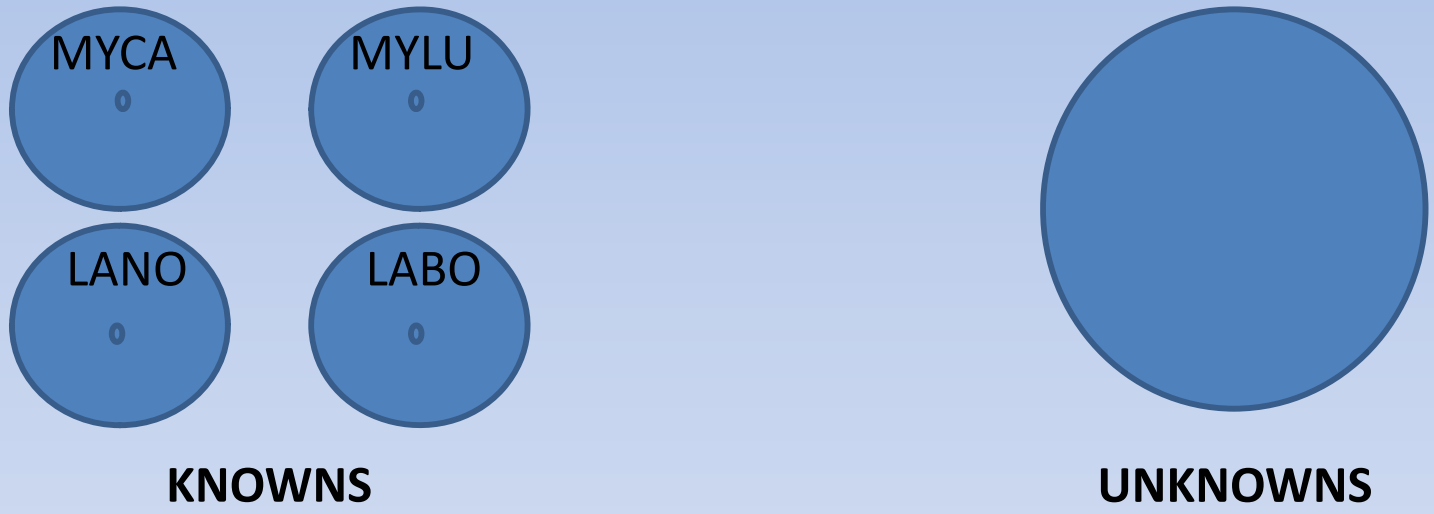
‘Auto-ID’

Currently popular:

- Statistical (probability) approach – DFA
  - Sonobat (for full spectrum data)
  - others on horizon (e.g. BCID for zero-cross data)
- Matching criteria – filters
  - AnalookW

‘Auto-ID’

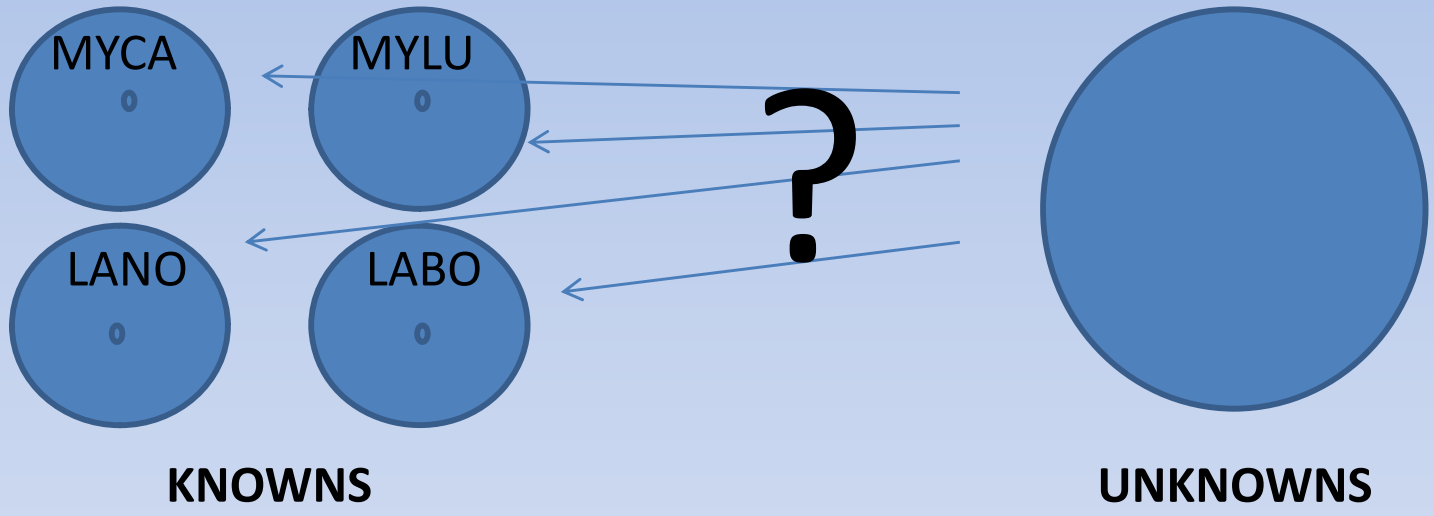
- Discriminant Function Analysis (DFA)



Use a reference library of bat pulses from bats for which species identification is known, to assign a ‘probability of identification’ to unknown bat calls.

‘Auto-ID’

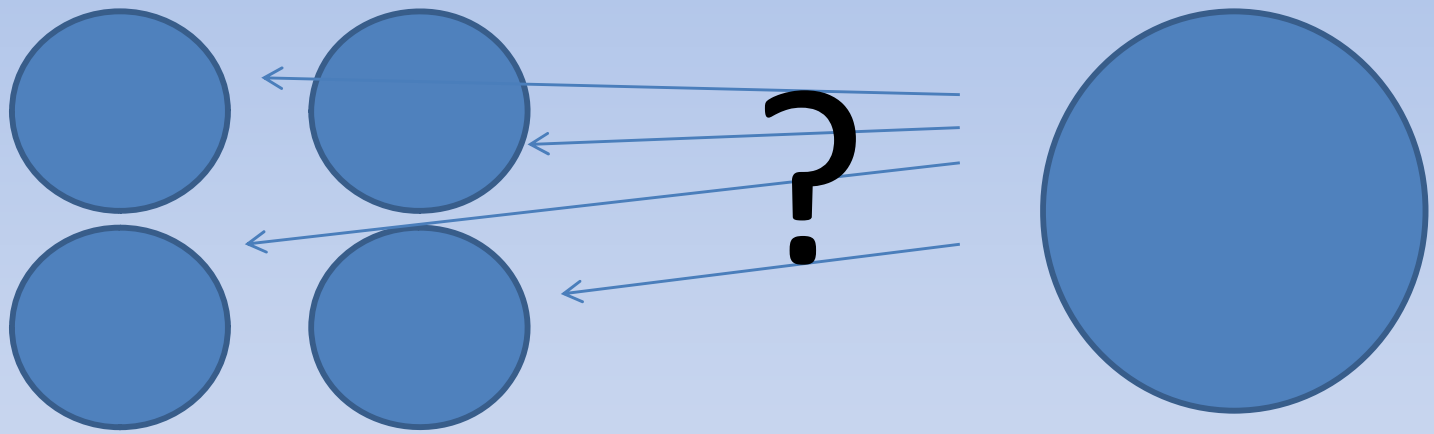
- Discriminant Function Analysis (DFA)



‘Probability of identification’ (distance from centroid) based on features of echolocation calls

(e.g. call shape, characteristic frequency, slope, duration, etc.)

Difficulties inherent in ‘Auto-ID’



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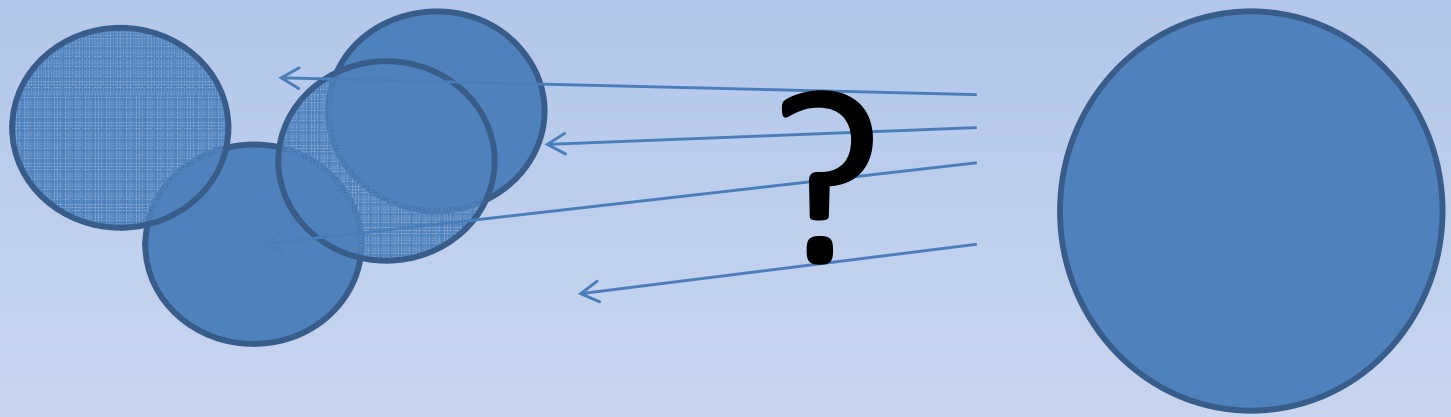


In reality, many species have overlapping call features – because echolocation is *functional*.

Difficulties inherent in ‘Auto-ID’

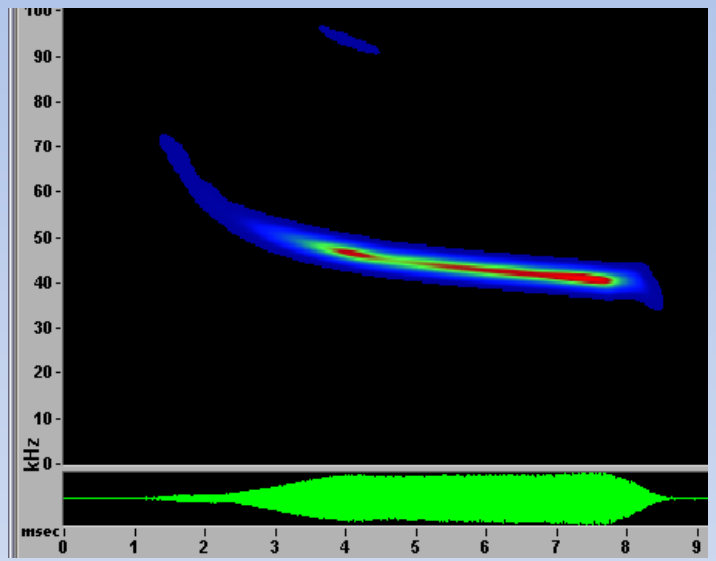
- Auto-ID is only as good as the input

  How well can it differentiate the ‘Knowns’

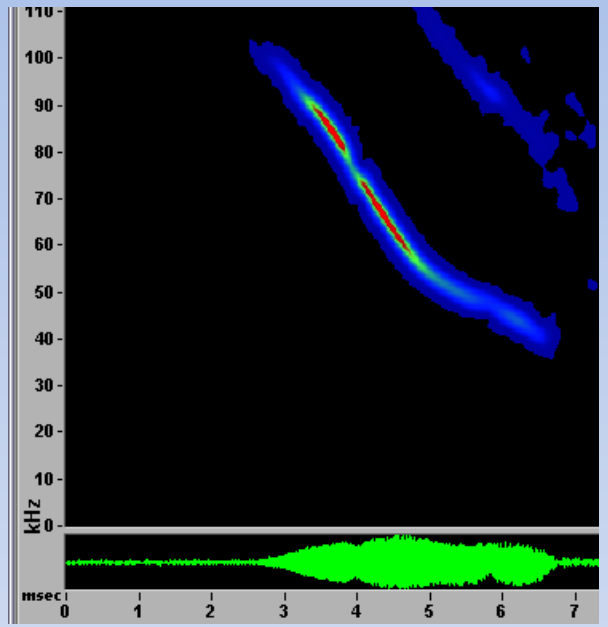
  – ‘Knowns’ can produce similar echolocation calls under conditions where they are receiving a lot of echoes

    (ie. effect of ‘clutter’ such as vegetation, other bats, water surface, etc.)

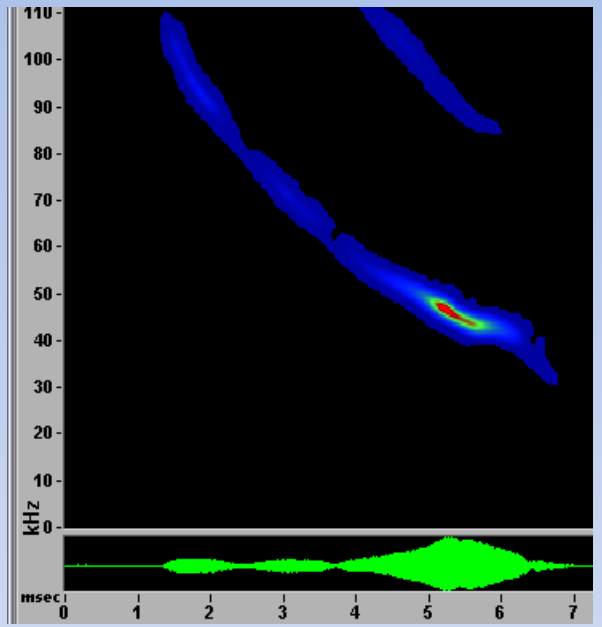
Clutter …
clutters the identification



Little Brown
in **low** clutter



Little Brown
in **high** clutter

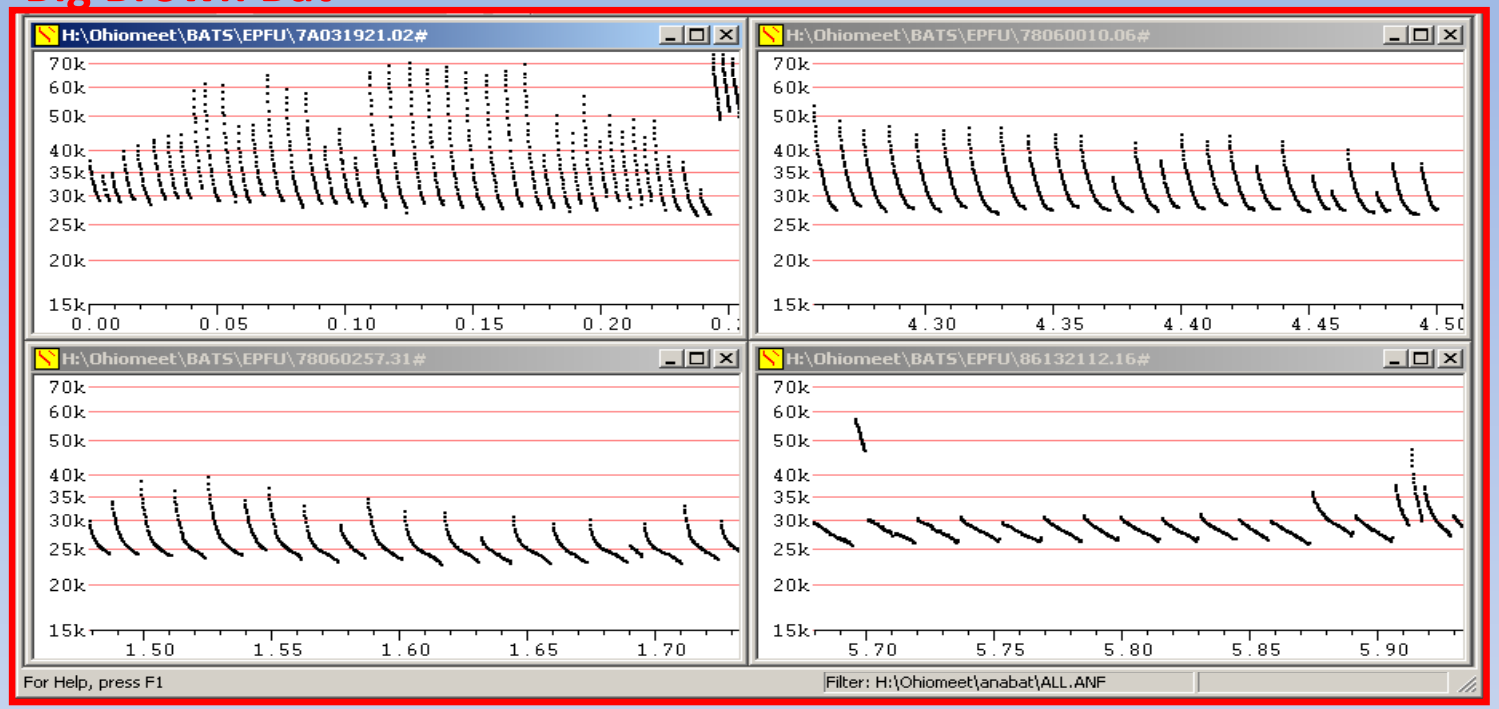


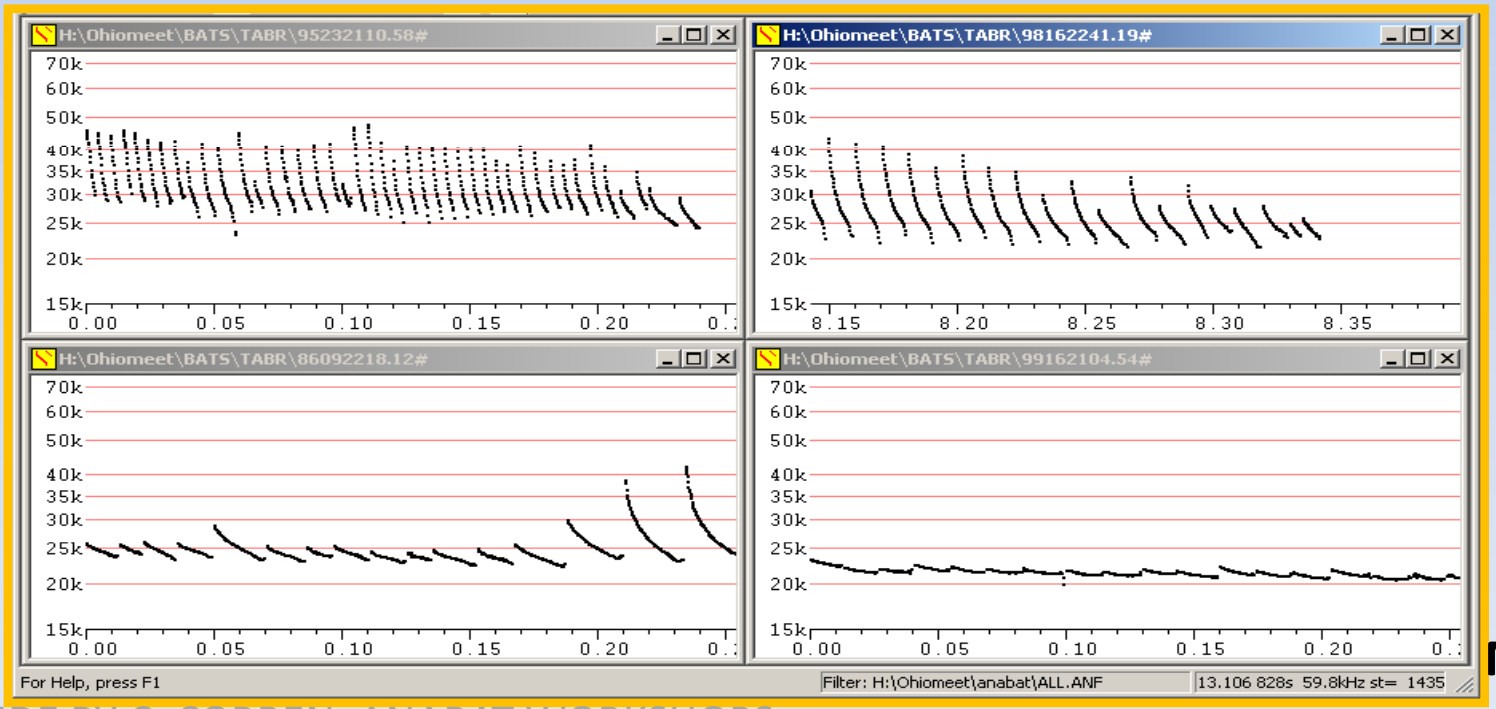
Northern Myotis
(a bat that tends to stay in high clutter)

Calls of little browns can resemble northern Myotis when they are in high clutter situations such as near trees, or flying close to the ground.
In fact, calls of many Myotis species look increasingly similar in high clutter situations.

Search-phase Continuum

Big Brown Bat





- Two species of different families
- These are all search-phase calls!
- Produced at different levels of clutter
- Variation within an individual is much greater than between families!

Mexican Freetail Bat

SLIDE BY C. CORBEN, ANABAT WORKSHOPS

Difficulties inherent in ‘Auto-ID’

- Auto-ID is only as good as the input

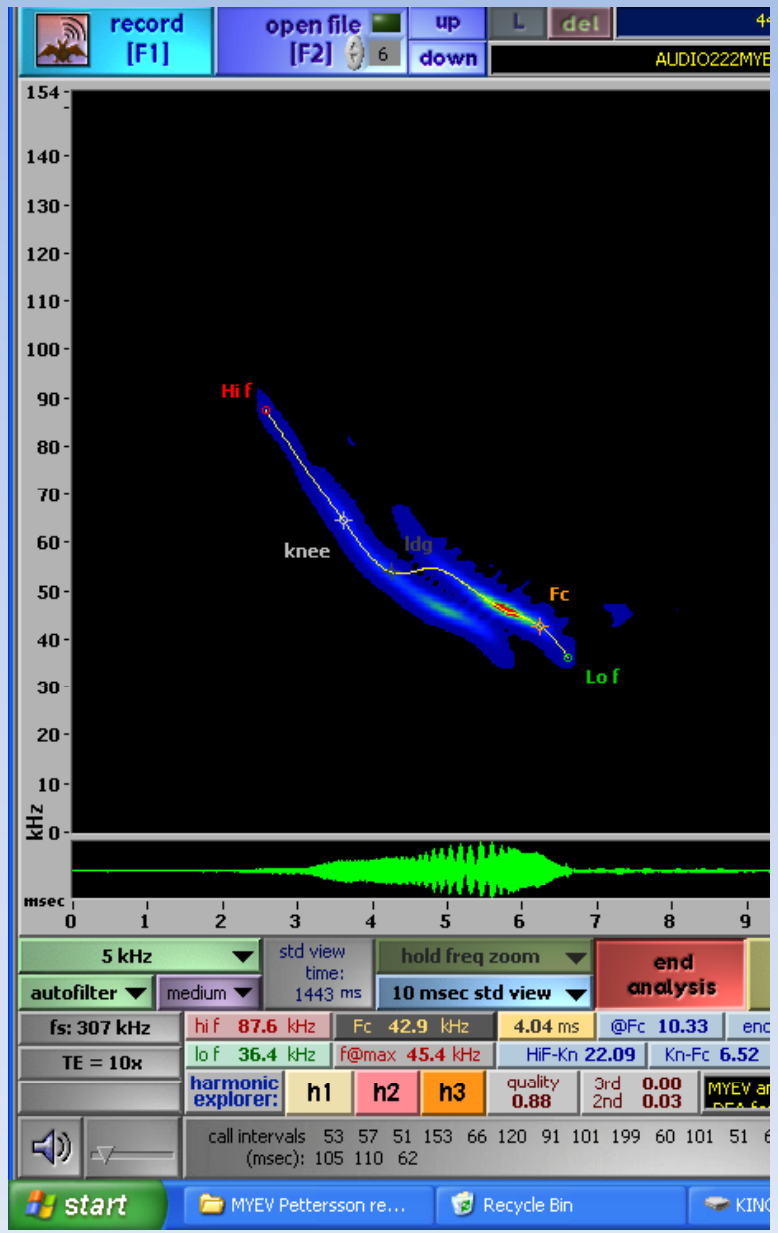
  How well can it differentiate the ‘Knowns’

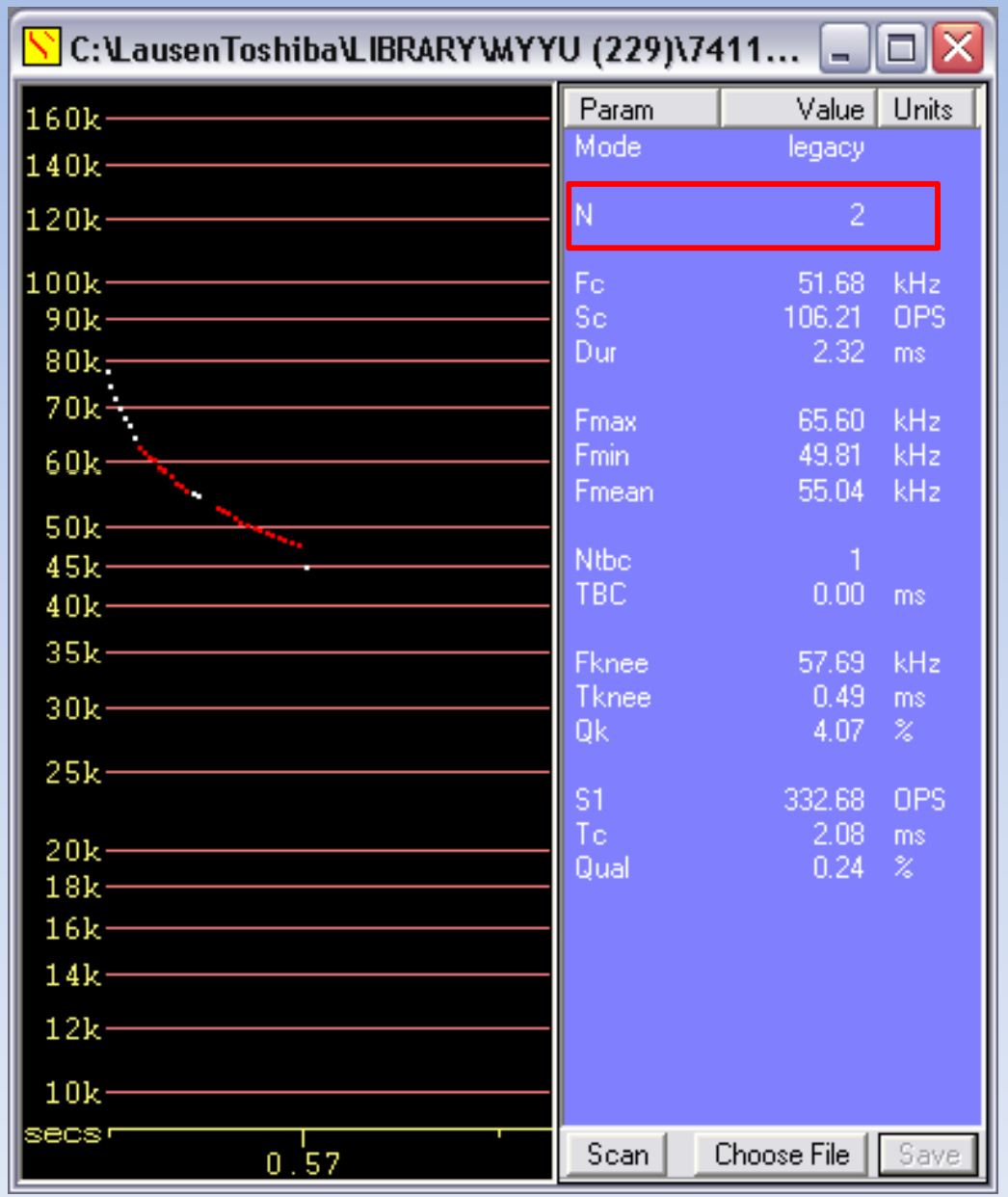
  – ‘Knowns’ can produce similar echolocation calls (e.g effect of clutter).

  – Algorithms for measuring calls and describing sequences of calls are not perfect (but progress continues)

Auto-detection of Bat Pulses

is not perfect (e.g. a pulse can be incorrectly measured)





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  Take-home messages:

  1. Auto-ID has ***limits***. We must acknowledge these. Even high quality recordings are not always identifiable to species.
  2. Know what you are doing. Don't just accept auto-ID output blindly.

Future in AutoID

Challenges

- More sophisticated algorithms for differentiating species

- Functioning similarly with all of the different detectors/microphones.

Acoustics Break-Out Groups
Friday

- Sonobat and Pettersson (Joe Szewczak)
- Binary Acoustic Technology (Mark Jensen)
- Wildlife Acoustics – SM2BAT (Ian Agranat)
- Anabat (Chris Corben)

Pettersson Elektronik, D500x

Wildlife Acoustics SM2BAT

Full Spectrum
Direct Digital Recording

Binary Acoustic Technology, AR125 + FR125

iFR4 – *new* –show-casing at this conference; internal battery rechargeable with direct attach solar panel; SDcard; lowered power consumption

Zero-crossing
Recording

Titley Scientific
SD2 Anabat