Montana Bat Call Identification

Montana Natural Heritage Program

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*Special thanks to Joe Szewczak and the Humboldt State University Bat Lab for their ongoing efforts in acoustic identification of bats. Much of the information in this powerpoint was derived from Joe's trainings and their 2011 Western and Eastern U.S. Echolocation Call Characteristics tables

http://www.sonobat.com/

http://users.humboldt.edu/joe/

http://www.sonobat.com/download/EasternUS_Acoustic_Table_Mar2011.pdf

http://www.sonobat.com/download/WesternUS_Acoustic_Table_Mar2011.pdf

**Unless otherwise noted spectrograms in this powerpoint are from the Montana Bat Call Library

Bats of Montana

Pallid Bat
(*Antrozous pallidus*)

Townsend's Big-eared Bat
(*Corynorhinus townsendii*)

Big Brown Bat
(*Eptesicus fuscus*)

Spotted Bat
(*Euderma maculatum*)

Silver-haired Bat
(*Lasionycteris noctivagans*)

Eastern Red Bat
(*Lasiurus borealis*)

Hoary Bat
(*Lasiurus cinereus*)

California Myotis
(*Myotis californicus*)

Western Small-footed Myotis
(*Myotis ciliolabrum*)

Long-eared Myotis
(*Myotis evotis*)

Little Brown Myotis
(*Myotis lucifugus*)

Northern Myotis
(*Myotis septentrionalis*)

Fringed Myotis
(*Myotis thysanodes*)

Long-legged Myotis
(*Myotis volans*)

Yuma Myotis
(*Myotis yumanensis*)

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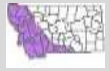
discover, preserve, protect

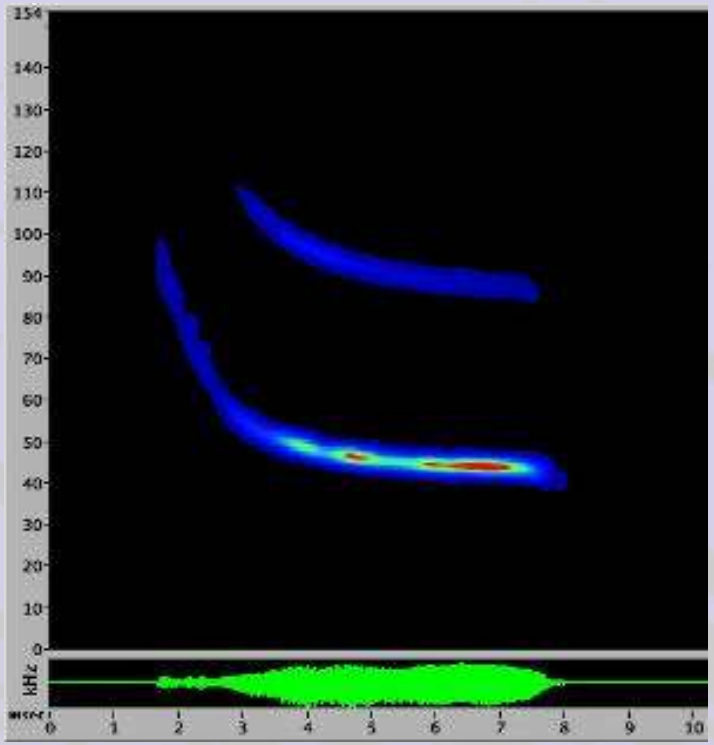
For more information on all of Montana's native species visit the Montana Field Guide
http://fieldguide.mt.gov

Thanks to the contributing photographers, editors, and sponsors that made this poster possible!

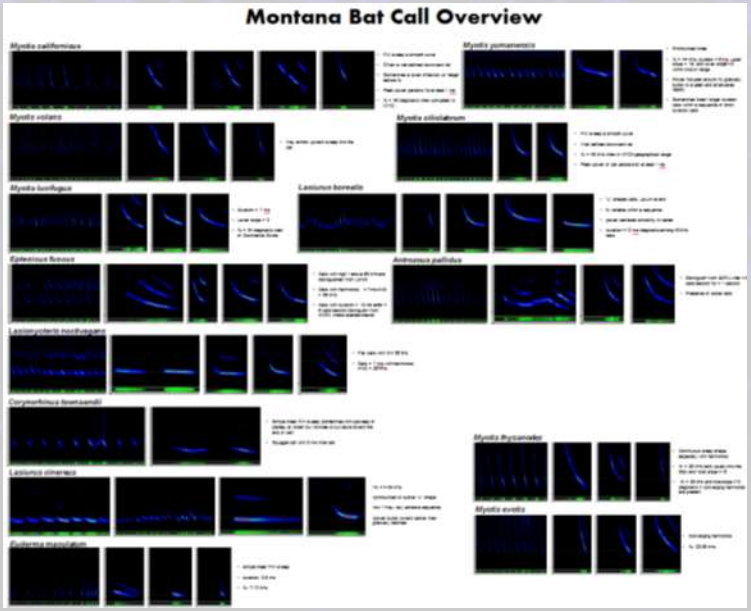
Bats of Montana

- 6 Species of Concern
- 4 Potential Species of Concern

Common Name	Scientific Name	4-Code	MT Range/No. Recs
Pallid Bat	*Antrozous pallidus*	ANPA	 17
Townsend's Big-eared Bat	*Corynorhinus townsendii*	COTO	 281
Big Brown Bat	*Eptesicus fuscus*	EPFU	 1,090
Spotted Bat	*Euderma maculatum*	EUMA	 108
Silver-haired Bat	*Lasionycteris noctivagans*	LANO	 1,381
Eastern Red Bat	*Lasiurus borealis*	LABO	 65
Hoary Bat	*Lasiurus cinereus*	LACI	 1,041
California Myotis	*Myotis californicus*	MYCA	 189
Western Small-footed Myotis	*Myotis ciliolabrum*	MYCI	 917
Long-eared Myotis	*Myotis evotis*	MYEV	 1,085
Little Brown Myotis	*Myotis lucifugus*	MYLU	 1,468
Northern Myotis	*Myotis septentrionalis*	MYSE	 1
Fringed Myotis	*Myotis thysanodes*	MYTH	 130
Long-legged Myotis	*Myotis volans*	MYVO	 252
Yuma Myotis	*Myotis yumanensis*	MYYU	 34



Library of Bat Calls of Known Species Identity Used for Hand Identification of Acoustic Recordings and in Automated Classifiers such as SONOBAT 3.0 and Kaleidoscope Pro 2.0



Math and Potential Discriminating Resolution of Bat Echolocation

- $V = \lambda f$
- Velocity (344,000 mm/s) = Wavelength x Frequency
- Wavelengths less than 2 times the length of an object can generally be used to detect the object

Frequency	Wavelength	Object Discrimination Examples
120 kHz	2.9 mm	1.4 mm – Biting Midge on pine needles
50 kHz	6.9 mm	3.4 mm – fruit fly
40 kHz	8.6 mm	4.3 mm – smallest of mosquitos
20 kHz	17.2 mm	8.6 mm–house fly, small moths/beetles
10 kHz	34.4 mm	17.2 mm – larger moths and beetles

General Factors to Keep in Mind When Recording Bats

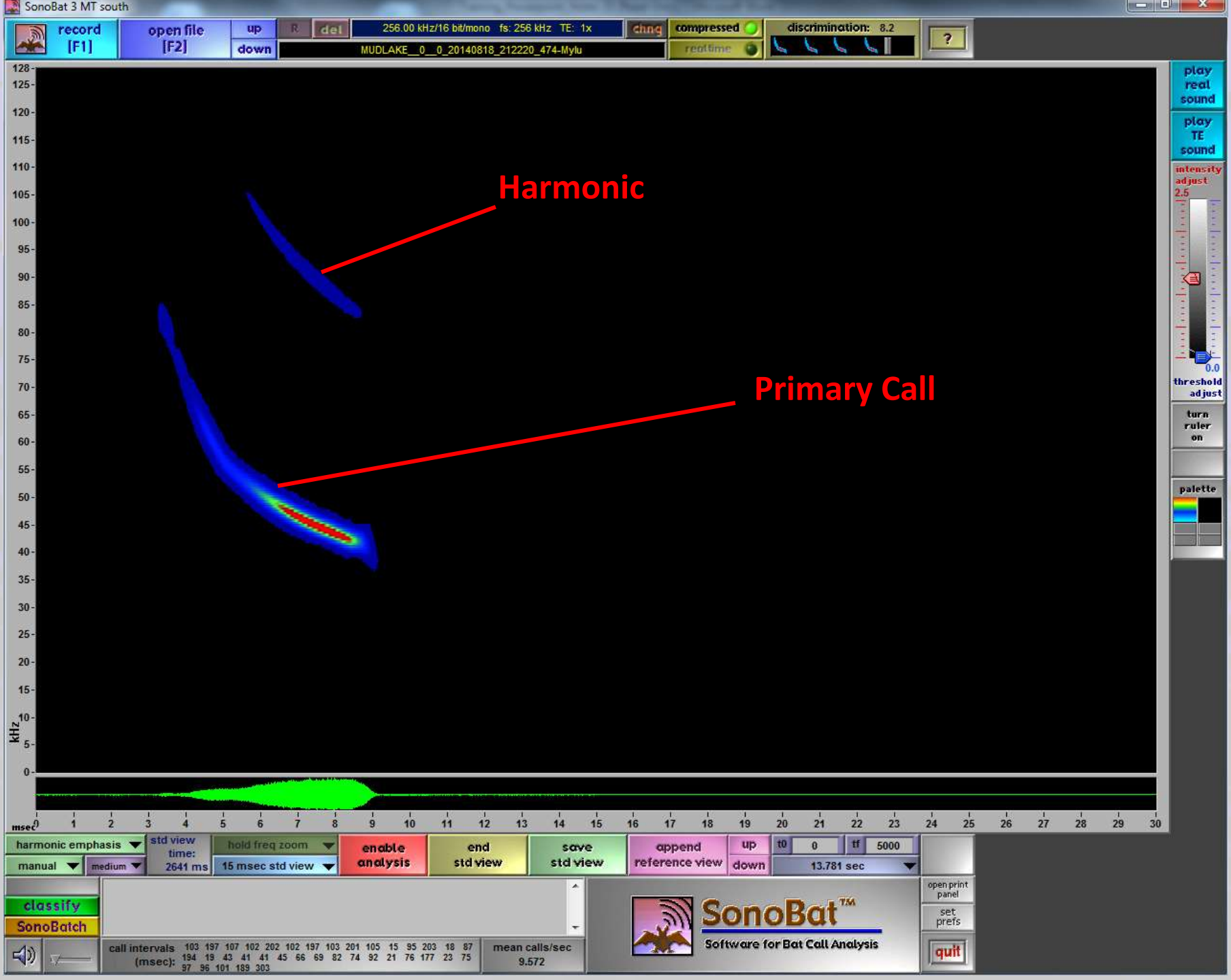
- Recording high quality search phase calls is of paramount importance for identifying bat call sequences to species.
- Avoid environmental clutter that will cause bats to use approach phase calls instead of search phase calls.
- Avoid areas with reflective surfaces that might result in multiple echoes of a call.
- Higher frequency sounds attenuate more rapidly than low frequency sounds in general and are more affected by humidity, wind, and convection currents; mount microphones accordingly.
- Bats need to be within at least 30 meters of a microphone to be detected and when in the same air space they adjust frequencies so they don't overlap with one another; avoid foraging areas and target flight corridors that are potential commuter routes where search phase calls with dominate.

Spectrogram Terminology

Spectrogram Terminology - I

Primary call: the component of the sound emitted by a bat with the lowest frequency; typically the most powerful and sometimes the only part of the call visible on a spectrogram.

Harmonic: multiple, typically subtle components of the call, existing at higher frequencies but roughly parallel to the primary call component; presence may indicate higher call quality unless a call is oversaturated.


SonoBat 3 MT south
record [F1]
open file [F2]
up
down
256.00 kHz/16 bit/mono fs: 256 kHz TE: 1x
MUDLAKE__0__0_20140818_212220_474-Mylu
compressed
discrimination: 8.2
Harmonic
Primary Call
play real sound
play TE sound
intensity adjust
threshold adjust
turn ruler on
palette
kHz
msec
harmonic emphasis
manual
std view time: 2641 ms
hold freq zoom
15 msec std view
enable analysis
end std view
save std view
append reference view
up
down
13.781 sec
classify
SonoBatch
call intervals (msec):
mean calls/sec 9.572
SonoBat™
Software for Bat Call Analysis
open print panel
set prefs
quit

Spectrogram Terminology - II

Characteristics below refer to attributes of the primary call

low *f*: lowest frequency (kHz)

high *f*: highest frequency (kHz)

***f*c**: characteristic frequency, the frequency of the call at its lowest slope (kHz)

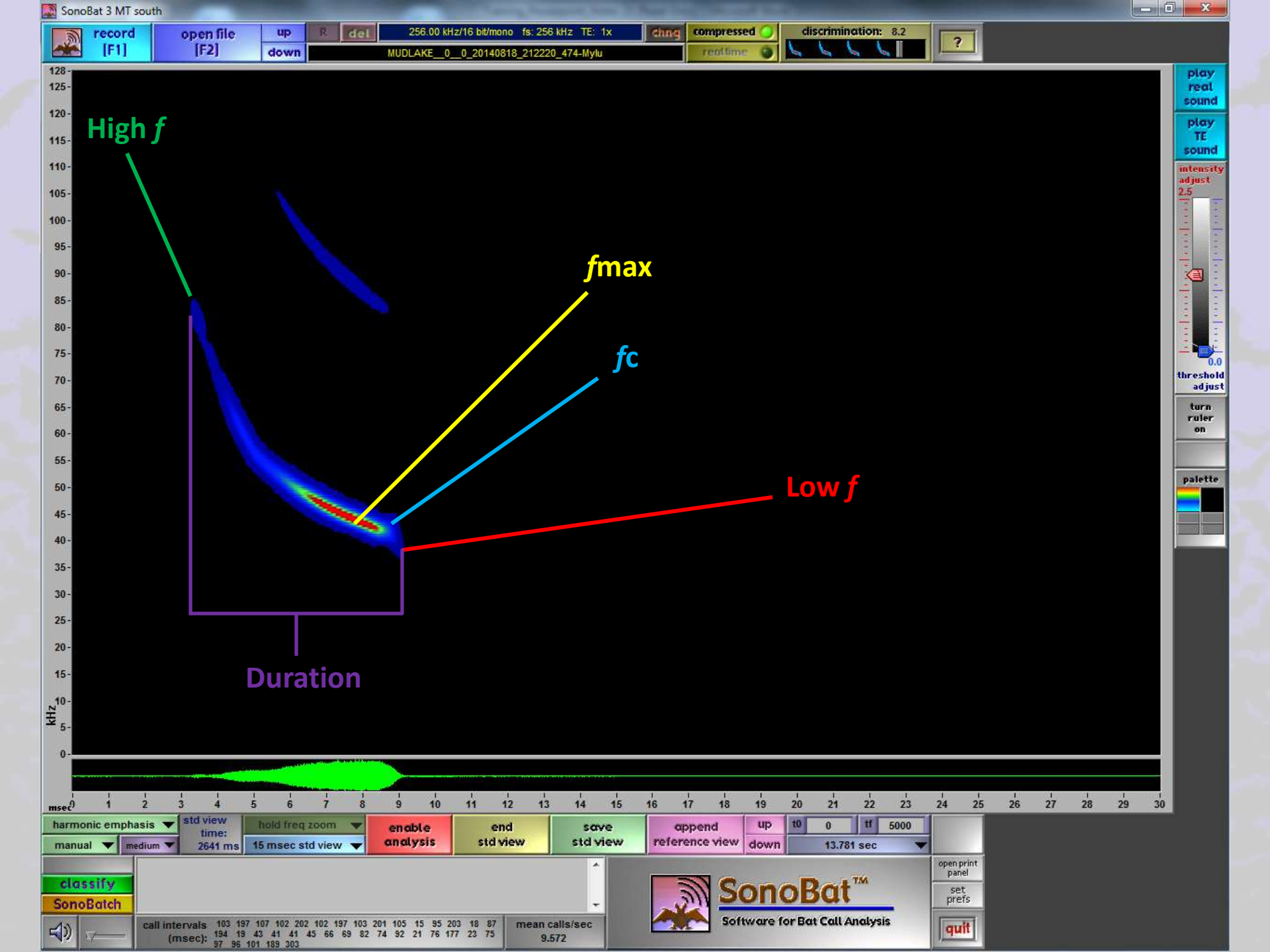
***f*max**: the frequency where the power is greatest (kHz)

duration: duration in (ms) from the start to the end of a call, abbreviated: dur

upper slope: the slope of the call (kHz/ms) between the high *f* and the knee, abbreviated: upprSlp

lower slope: the slope of the call (kHz/ms) between the knee and the *f*c, abbreviated: lwrSlp

total slope: the slope of the call (kHz/ms) between the high *f* and the low *f*, abbreviated: totalSlp


SonoBat 3 MT south
record [F1]
open file [F2]
up
down
256.00 kHz/16 bit/mono fs: 256 kHz TE: 1x
MUDLAKE__0__0_20140818_212220_474-Mylu
compressed
discrimination: 8.2
play real sound
play TE sound
intensity adjust
threshold adjust
turn ruler on
palette
High f
fmax
fc
Low f
Duration
kHz
msec
harmonic emphasis
manual
medium
std view time: 2641 ms
hold freq zoom
15 msec std view
enable analysis
end std view
save std view
append reference view
up
down
t0 0
tf 5000
13.781 sec
classify
SonoBatch
call intervals (msec): 103 197 107 102 202 102 197 103 201 105 15 95 203 18 87 194 19 43 41 41 45 66 69 82 74 92 21 76 177 23 75 97 96 101 189 303
mean calls/sec 9.572
SonoBat™
Software for Bat Call Analysis
open print panel
set prefs
quit

Spectrogram Terminology - III

Characteristics below refer to attributes of the primary call

FM: frequency modulation, change in frequency over time; most calls start at a high frequency and sweep down to a lower frequency

bandwith: total range of frequencies a call sweeps through

power: amplitude or sound energy (i.e. volume)

oversaturation: powerful, loud calls may exceed the microphone/recorder capability and produce anomalies in the spectrogram such as full spectrum “noise” (clipping) or alias harmonics (upside-down harmonics); peak power duration cannot be calculated from these calls

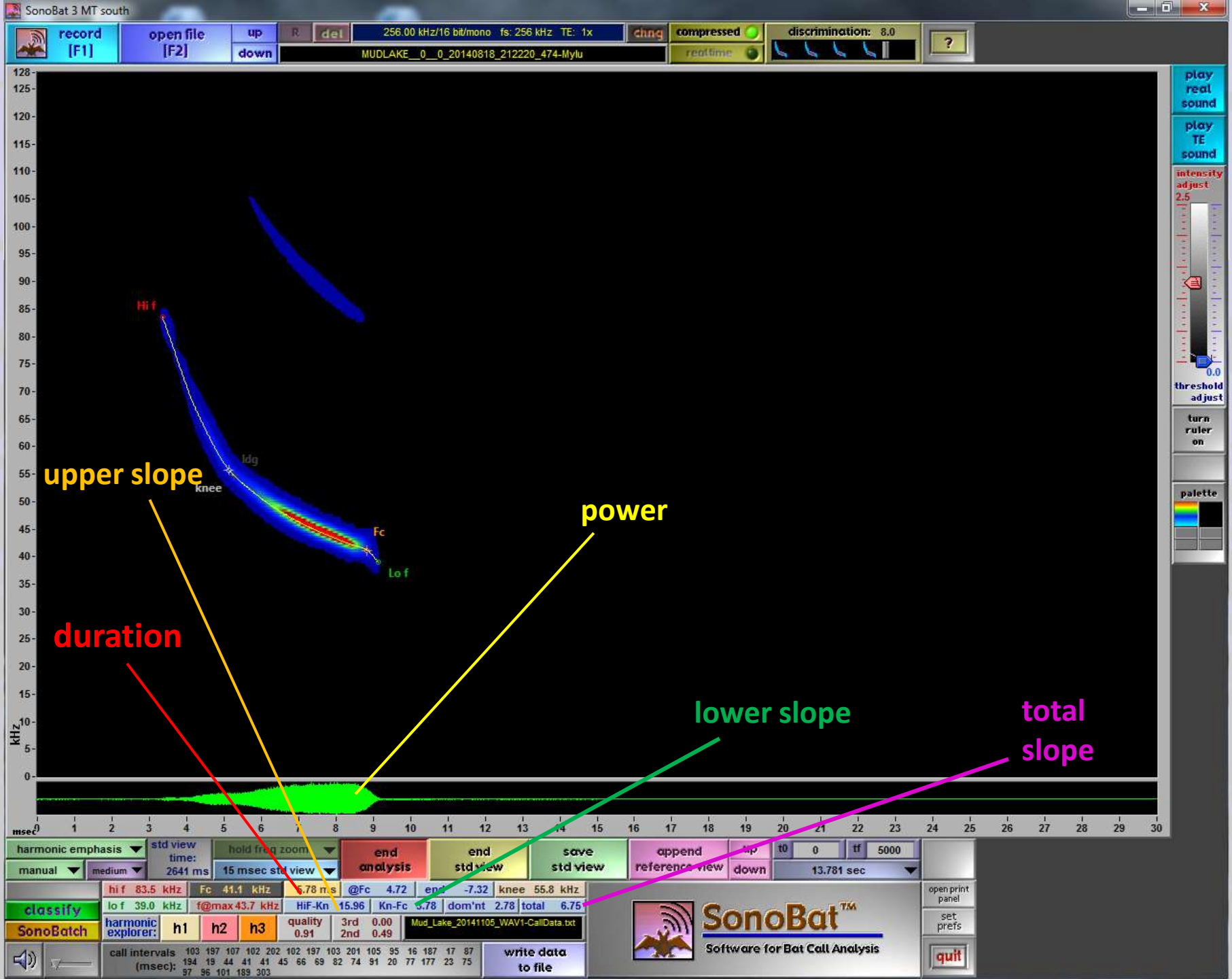
inflection or knee: pronounced change in slope; some calls may not have an obvious knee if very steep or smoothly curved

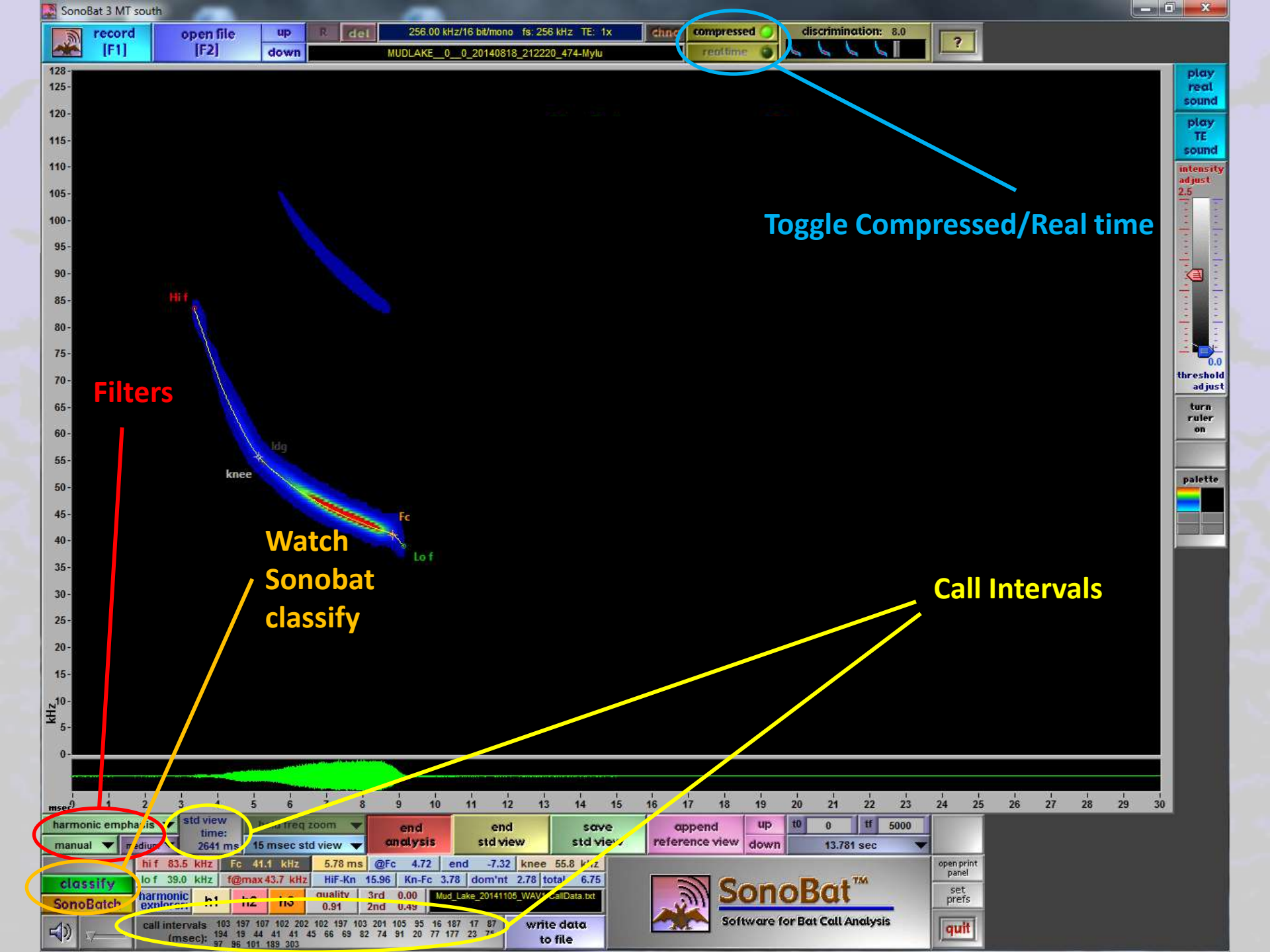
ledge: a secondary change in slope before *f*c

flat: a call or portion of a call with very low or no slope (horizontal); i.e. constant frequency (CF)

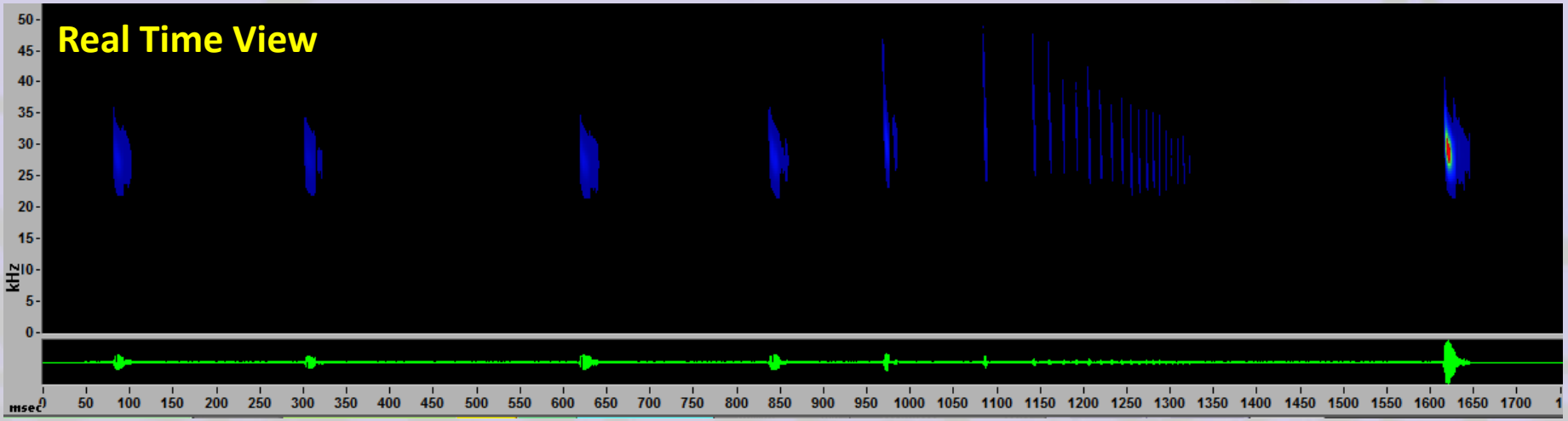
sequence: a series of bat calls, produced as a bat flies past the detector

calls/sec: the number of calls per second for a given period; note that values listed by Sonobat may be incorrect due to multiple bats in a recording, low intensity calls, and dead air space in a sequence. **ms between calls should be examined and calls should be looked at in real time to accurately estimate this characteristic if needed for species identification

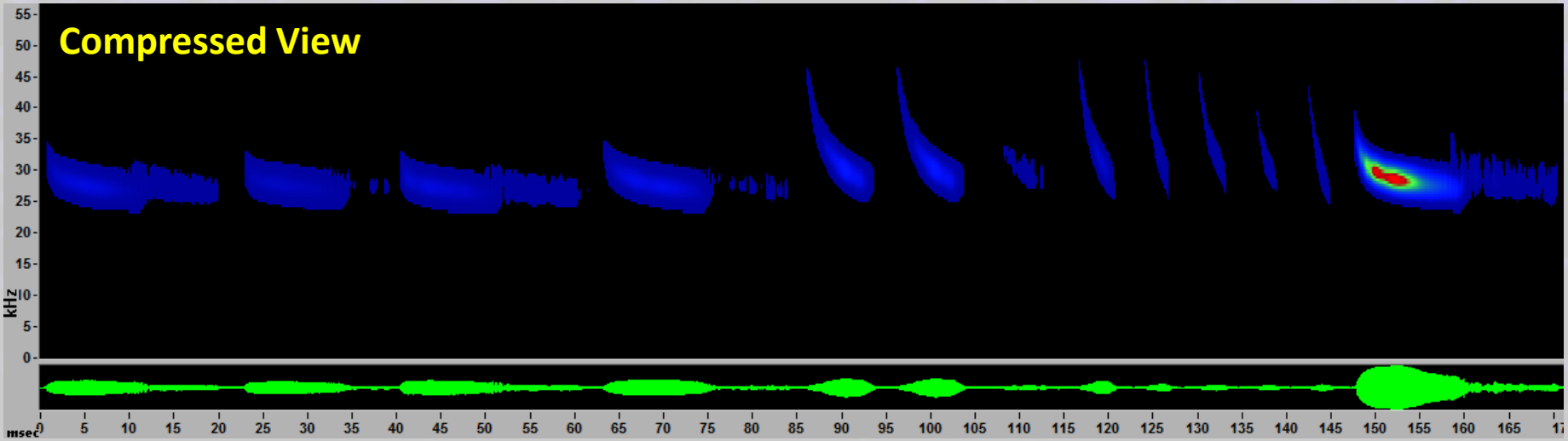

SonoBat 3 MT south
record [F1]
open file [F2]
up
down
256.00 kHz/16 bit/mono fs: 256 kHz TE: 1x
MUDLAKE__0__0_20140818_212220_474-Mylu
compressed
discrimination: 8.0
play real sound
play TE sound
intensity adjust
threshold adjust
turn ruler on
palette
Hi f
Fc
Lo f
knee
ldg
upper slope
power
duration
lower slope
total slope
kHz
msec
harmonic emphasis
manual
medium
std view time: 2641 ms
15 msec std view
end analysis
end std view
save std view
append reference view
up
down
13.781 sec
hi f 83.5 kHz
Fc 41.1 kHz
@Fc 4.72
knee 55.8 kHz
lo f 39.0 kHz
f@max 43.7 kHz
HiF-Kn 15.96
Kn-Fc 6.78
dom'nt 2.78
total 6.75
classify
SonoBatch
harmonic explorer:
h1
h2
h3
quality 0.91
3rd 0.00
2nd 0.49
Mud_Lake_20141105_WAV1-CallData.txt
call intervals (msec):
write data to file
SonoBat™
Software for Bat Call Analysis
open print panel
set prefs
quit


SonoBat 3 MT south
record [F1]
open file [F2]
up
down
del
256.00 kHz/16 bit/mono fs: 256 kHz TE: 1x
MUDLAKE__0__0_20140818_212220_474-Mylu
compressed
realtime
discrimination: 8.0
?
play real sound
play TE sound
intensity adjust
2.5
0.0
threshold adjust
turn ruler on
palette
Toggle Compressed/Real time
Hi f
ldg
knee
Fc
Lo f
Filters
Watch Sonobat classify
Call Intervals
kHz
msec
harmonic emphasis
manual
std view time: 2641 ms
15 msec std view
end analysis
end std view
save std view
append reference view
up
down
t0 0
tf 5000
13.781 sec
classify
SonoBatch
hi f 83.5 kHz
lo f 39.0 kHz
Fc 41.1 kHz
f@max 43.7 kHz
5.78 ms
@Fc 4.72
end -7.32
knee 55.8 kHz
HiF-Kn 15.96
Kn-Fc 3.78
dom'nt 2.78
total 6.75
quality 0.91
3rd 0.00
2nd 0.49
call intervals (msec):
write data to file
SonoBat™
Software for Bat Call Analysis
open print panel
set prefs
quit

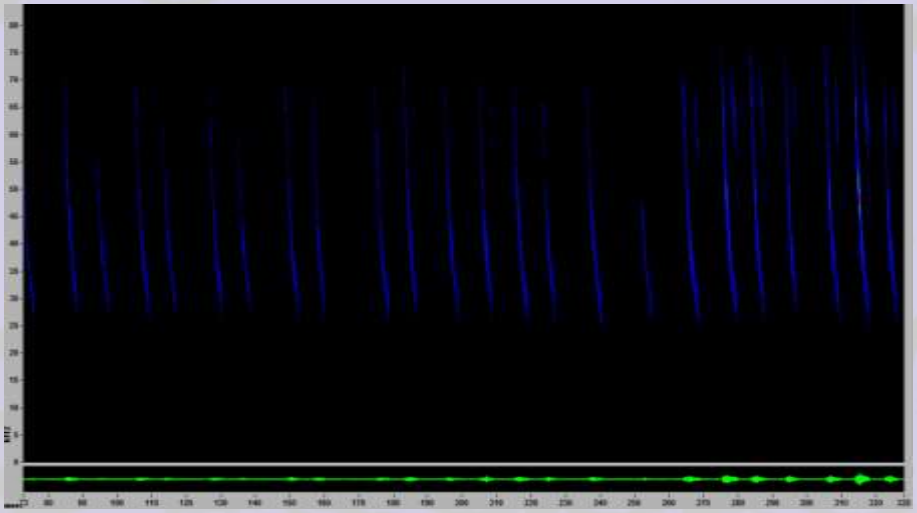
Call Types



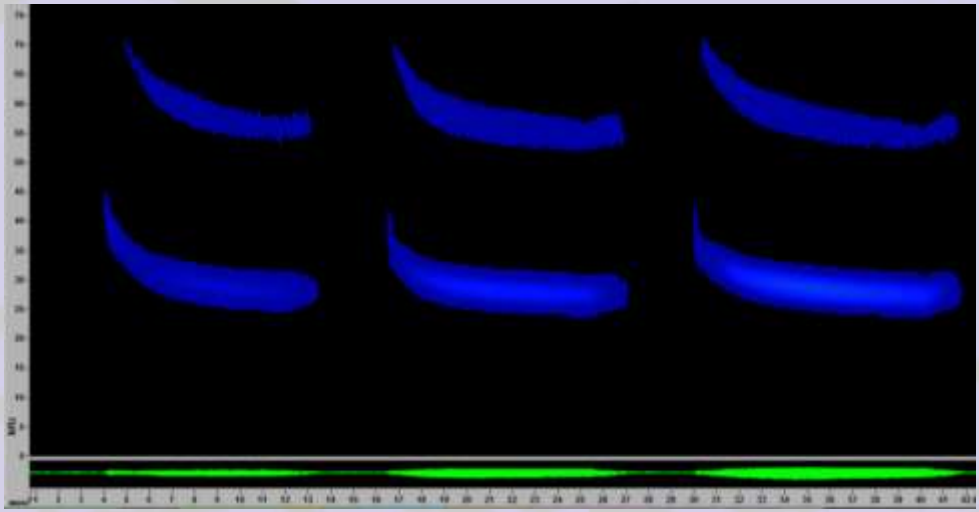
Search | Approach | Feeding Buzz | Search



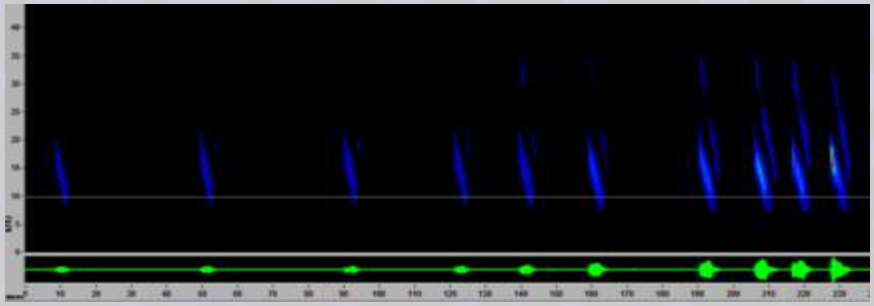
Search Phase Calls



MYTH



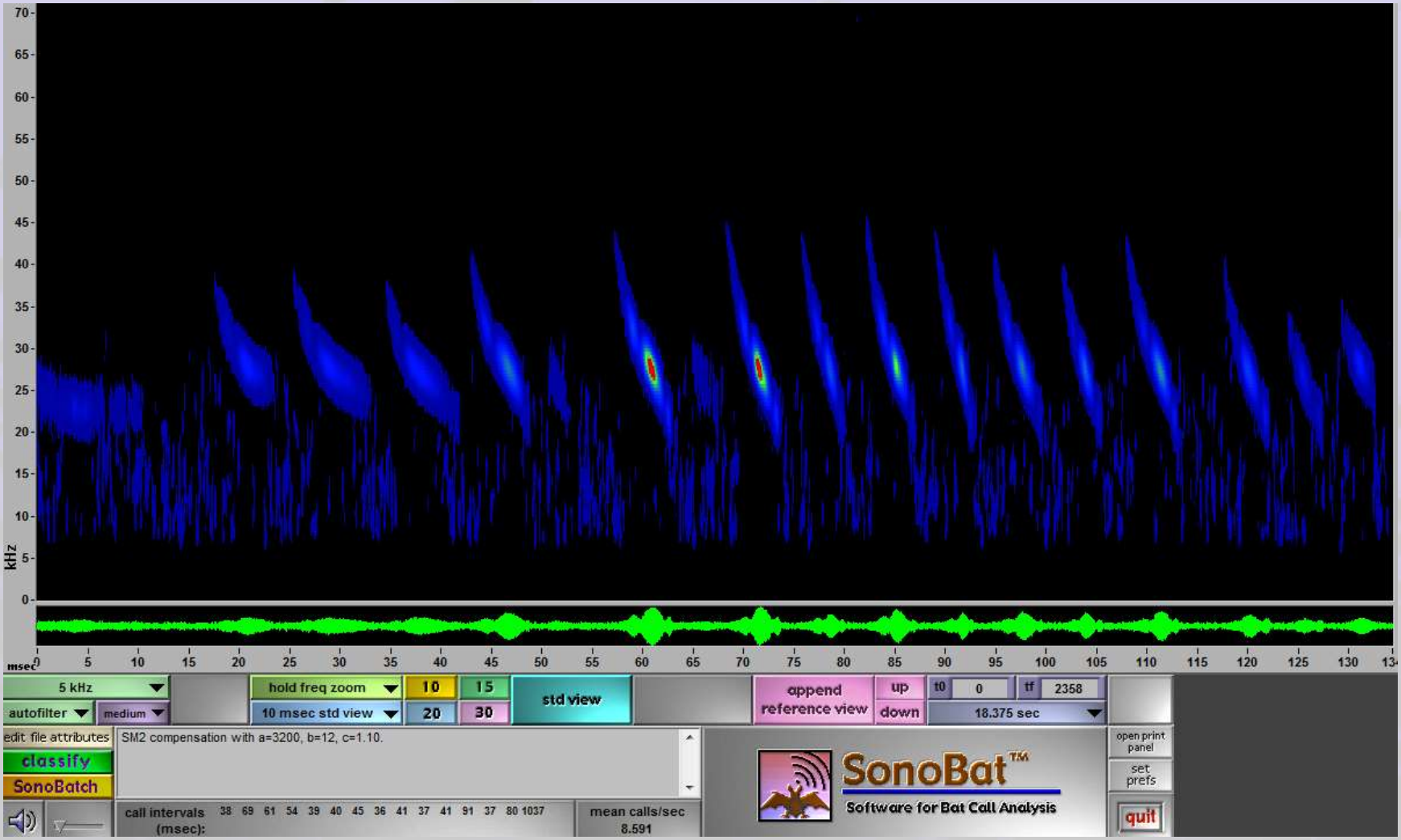
LANO



EUMA

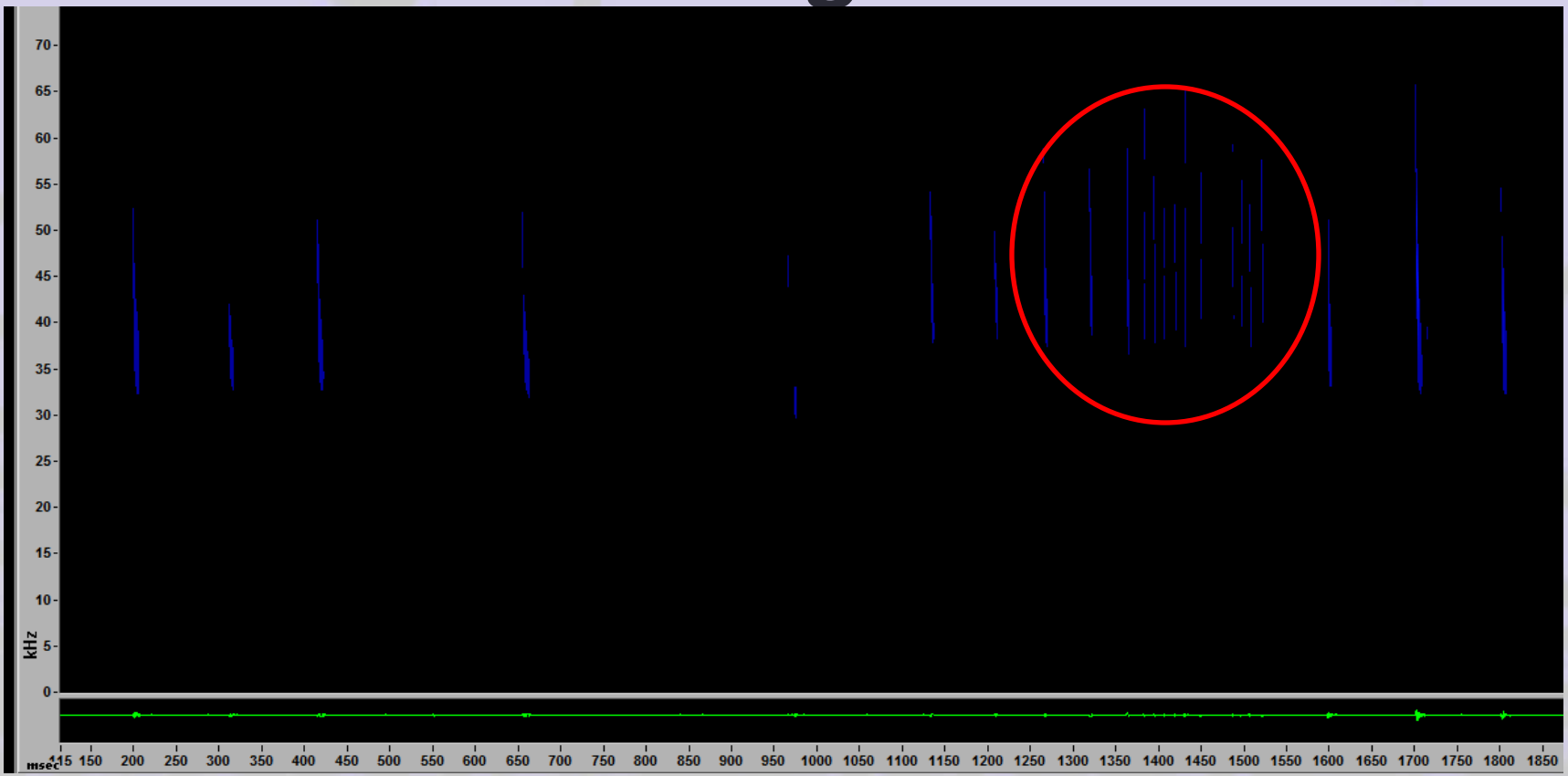
Used for general navigation and searching in uncluttered areas. Search phase calls generally have consistent call characteristics so are the most useful call type for species identification. Often have 3-12 calls per second. Bats may be able to detect objects >10 meters away with these calls.

Approach Phase Calls



Used when approaching either prey or a landing site or in cluttered airspace, such as when flying around vegetation. These calls are typically steeper and shorter than search phase calls and frequencies may shift up significantly, often with 10-20 calls per second. Approach phase calls have greater overlap between species and are less useful for species identification.

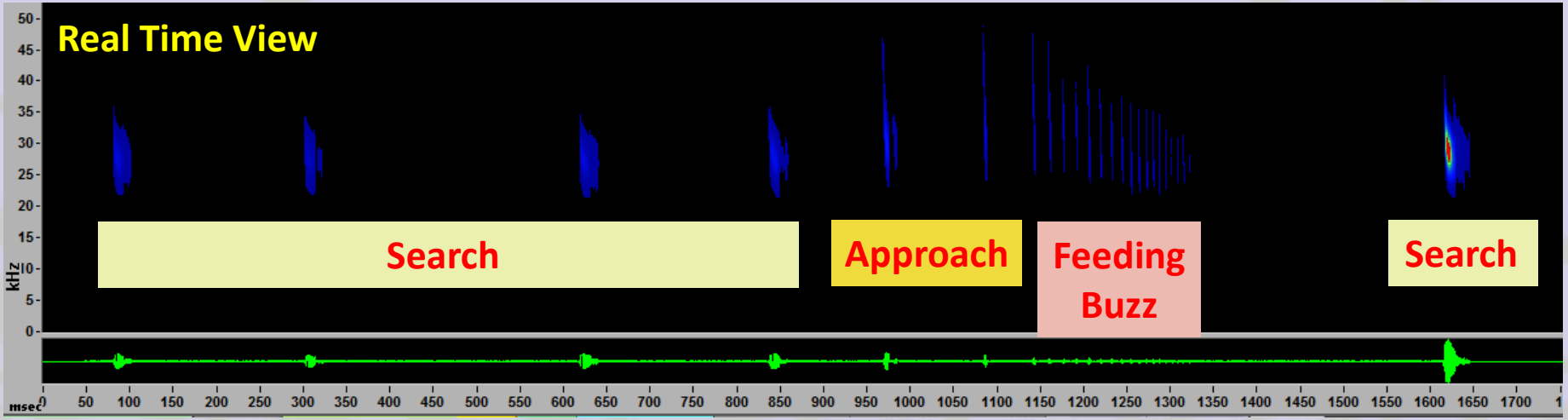
Feeding Buzz

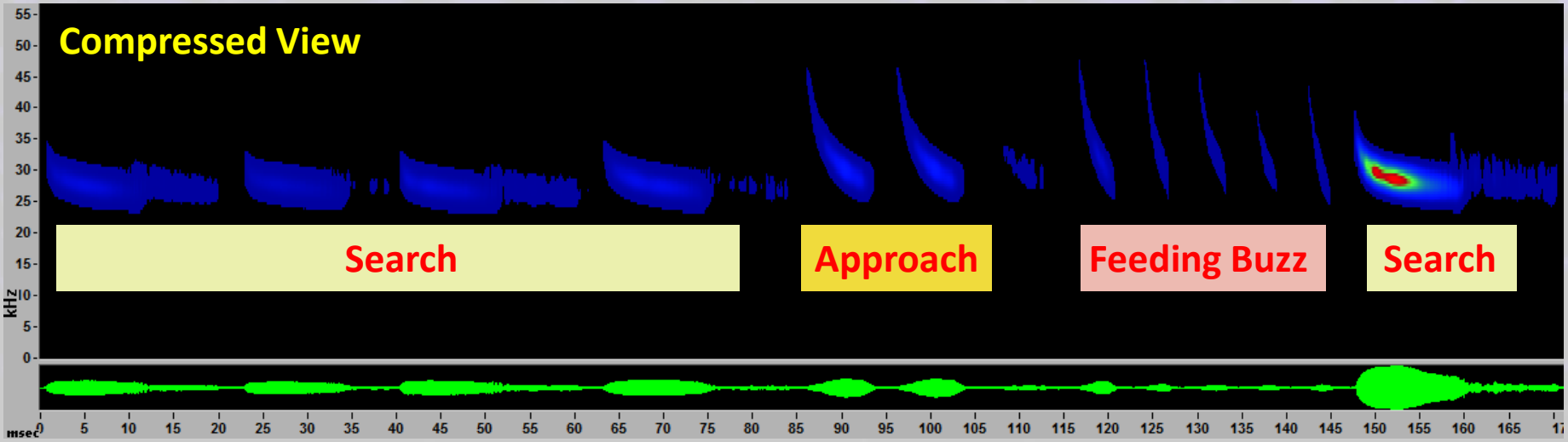


Also called terminal phase calls. These are used for discriminating close objects during prey pursuit/capture with call rates possibly exceeding 100 calls per second. These are often very steep and short calls (often with lower power) and there can be a great deal of overlap between species so are not useful for species identification.

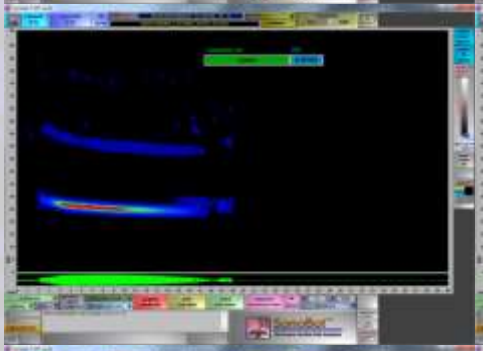
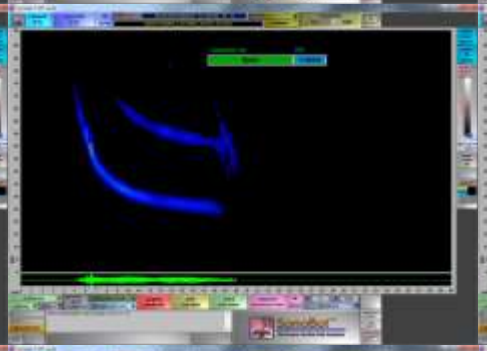
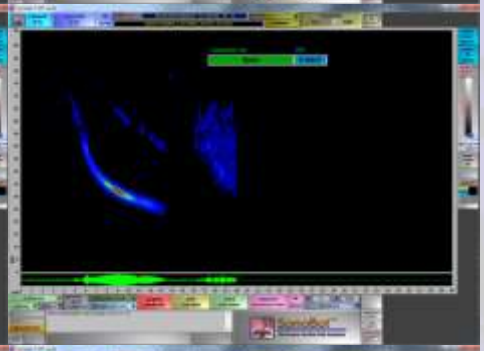
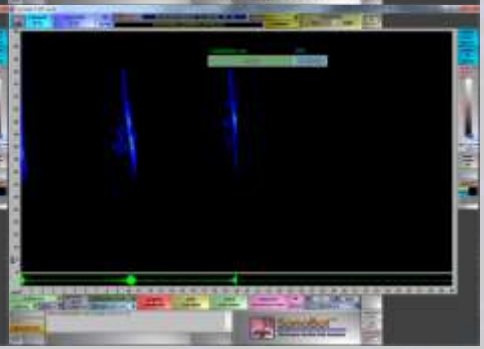
Note: feeding buzzes are generally not visible in the “compressed view” of a sequence, but are usually visible in “real time” view (pictured above). They can be identified easily by listening to the whole sequence.

Call Types in Real Time and Compressed Views



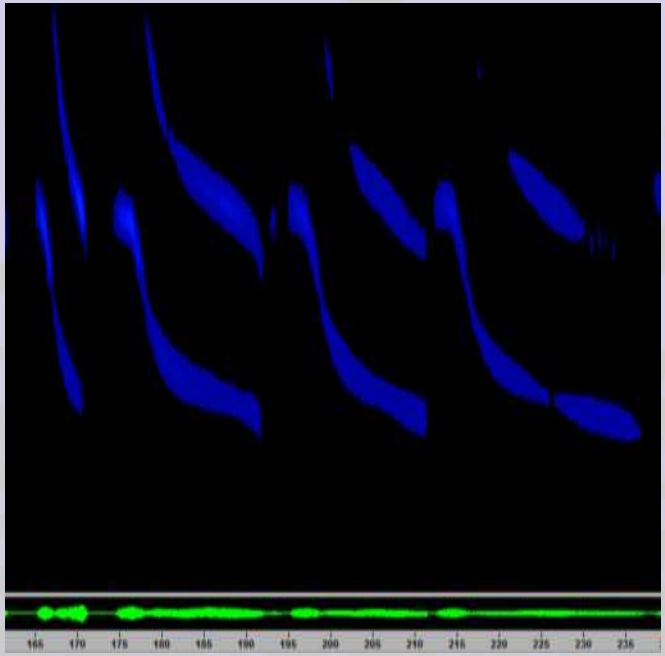


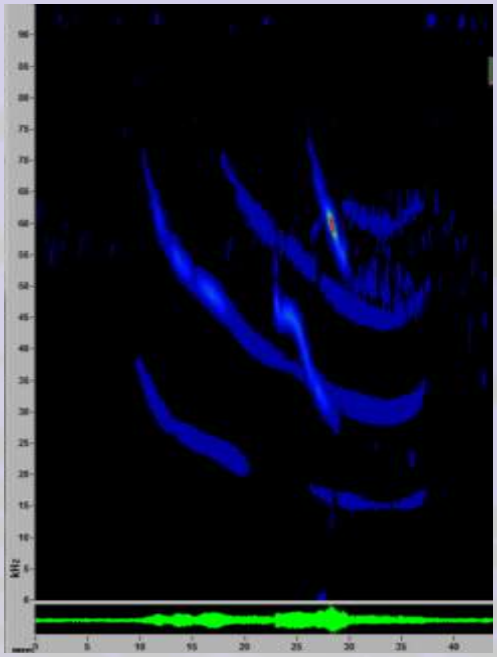
Potential Call Variations in Different Environments

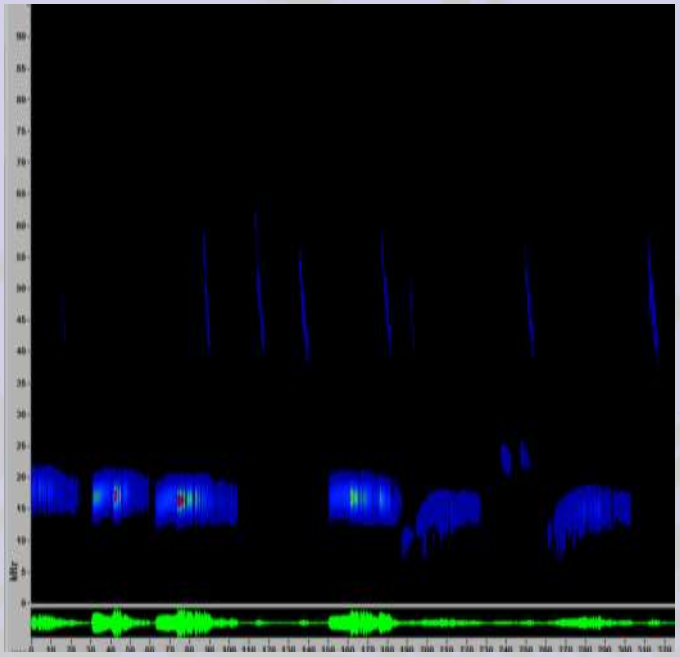
	Uncluttered	Background Cluttered	Highly Cluttered
LACI			
LANO			
MYLU			

NOTE: Calls shown above are actually from search phase, approach and feeding buzz sequences. Since all of our detectors are in open, uncluttered environments, these are the most analogous calls we have to those seen in different environments.

Social Calls







Used to communicate with other bats. Social calls are often lower in frequency than search phase calls and may contain complex frequency modulation patterns. Social calls may be very helpful for identifying some species (e.g. ANPA) but may not be recorded with regularity.

General Guidelines For Recording, Processing, and Hand Classifying Call Sequences

General Guidelines - I

1. Deploy bat detector in an open, uncluttered environment so that it is more likely to detect bats using more diagnostic search phase calls.



2. Accept the fact that not all call sequences can be definitively identified to a species.

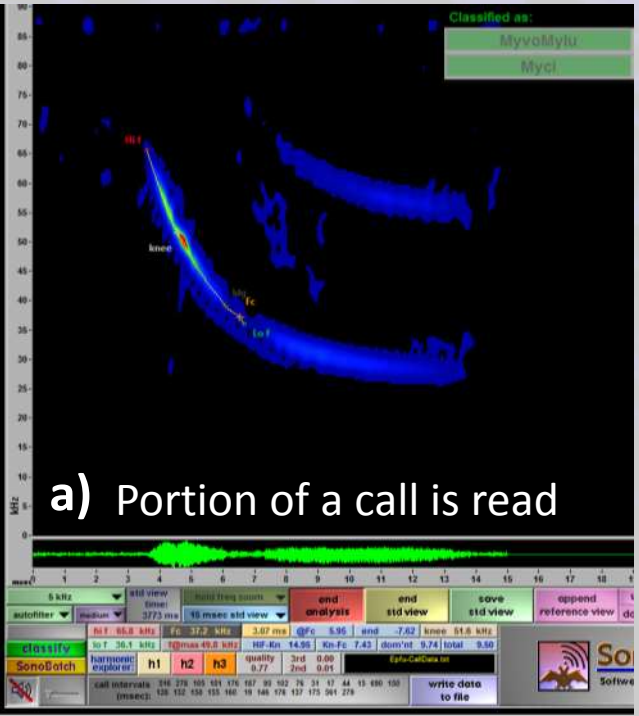
3. To expedite hand review, focus on reviewing call sequences that were assigned an automated species identification using Sonobat or Kaleidoscope because they are more likely to be higher quality call sequences. Even if the auto-id is a misidentification, an auto-identified call is likely to be one of a handful of species whose calls tend to overlap.

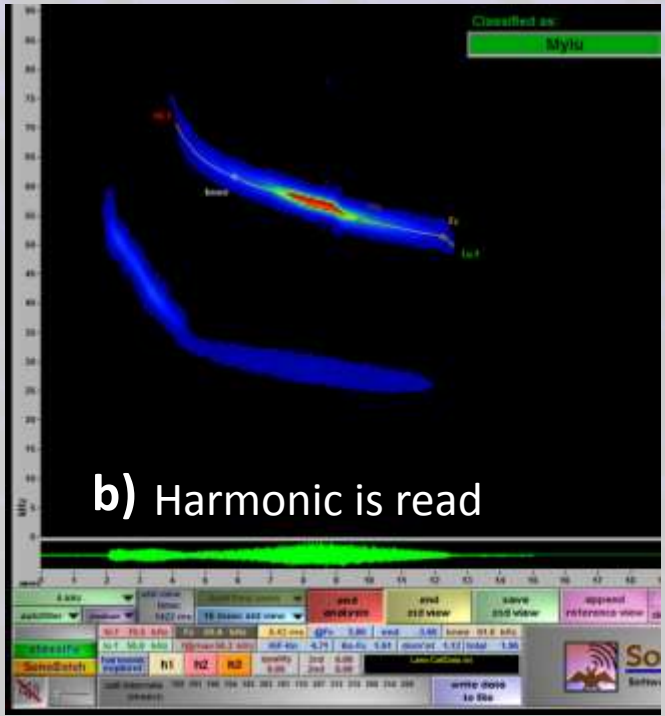
General Guidelines - II

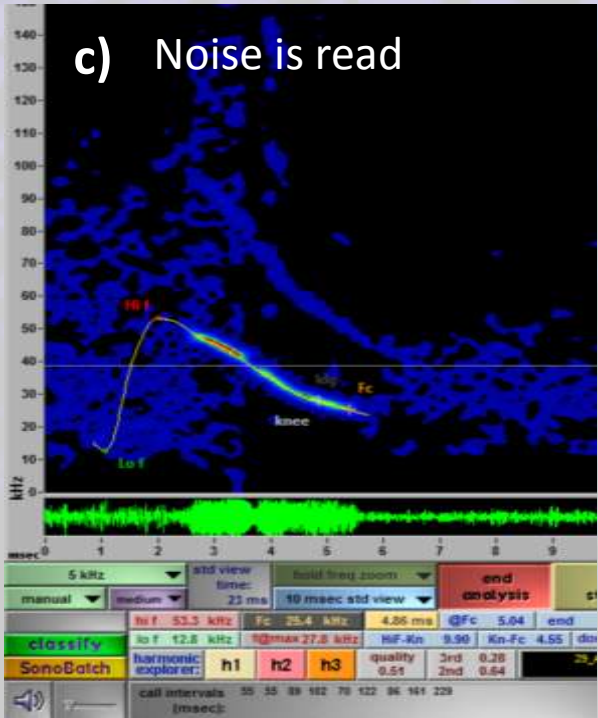
4. Review a single species at a time in order to be consistent and efficient in your hand review; importing the Sonobat or Kaleidoscope batch analysis files into a relational database will allow all files that were automatically identified as a particular species to be sorted together.
5. Limit the potential species list for a particular acoustic survey site by the known geographic ranges of species; depending on the degree of call overlap it may be worth reviewing some that would be extralimital if species identity can be confirmed.
6. For species identification, focus your review on clear search phase calls and take precautions (i.e. view in real time view) to avoid using approach phase calls, feeding buzzes, and social calls for most species.
7. Where possible, select noise free calls that have harmonics for review so that you are more likely to have full calls instead of call fragments. Note that some calls may be oversaturated if the bat closely approached the microphone; these should be avoided if possible.
8. Use the general call shape and characteristic frequency to identify the phonic group so that you have fewer species to consider.

General Guidelines - III

9. Look at the entire sequence in both compressed and real time views. This will help you see the whole picture (are there multiple bats, feeding buzzes or other non-search phase calls?). This is particularly important when differentiating EPFU vs. ANPA, MYLU vs. LABO, and for COTO in general.
10. Review multiple calls in a sequence with the standard view. The more calls with definitive features, the more confidence in the identification.
    BE AWARE that Sonobat's automated analysis sometimes uses inappropriate information in the spectrogram.





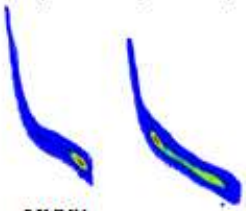


Diagnostic Montana Bat Call Shapes

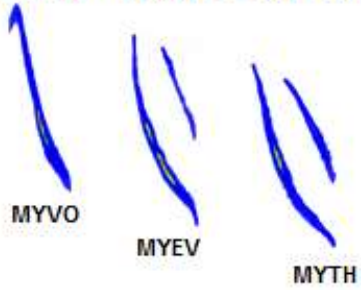
(Within groups calls are organized by relative frequency)

Pronounced Inflections

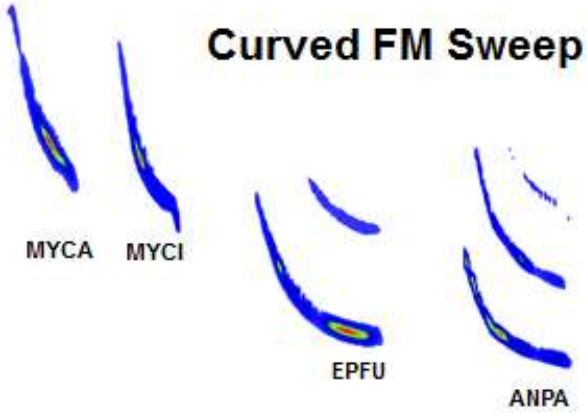
(hockey stick)



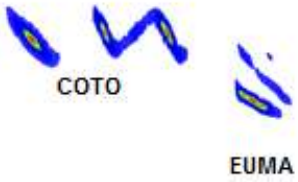
Steep with High Bandwidth



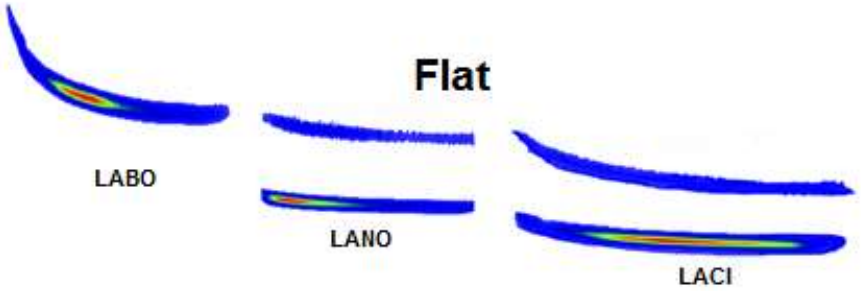
Curved FM Sweep



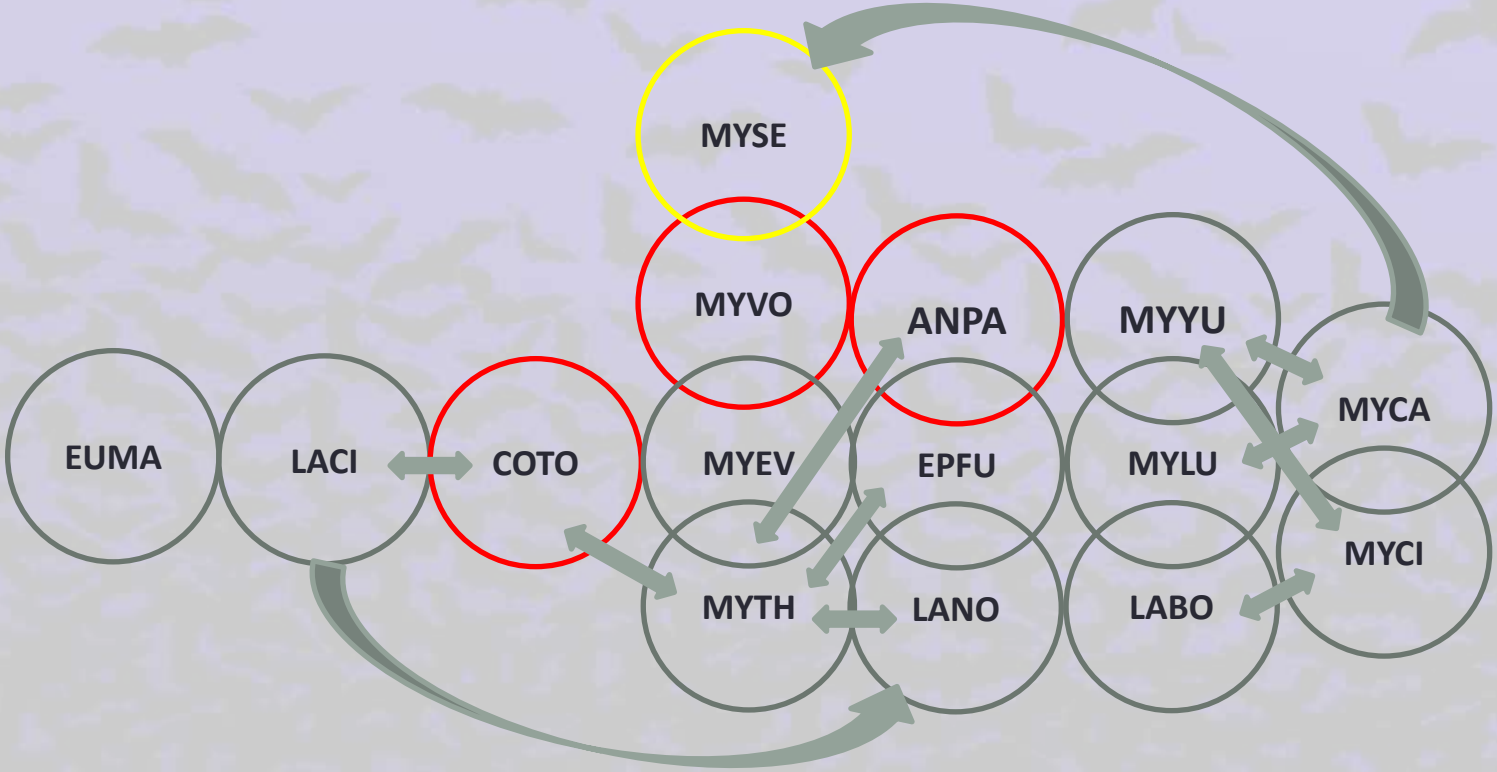
Simple Linear FM Sweep



Flat

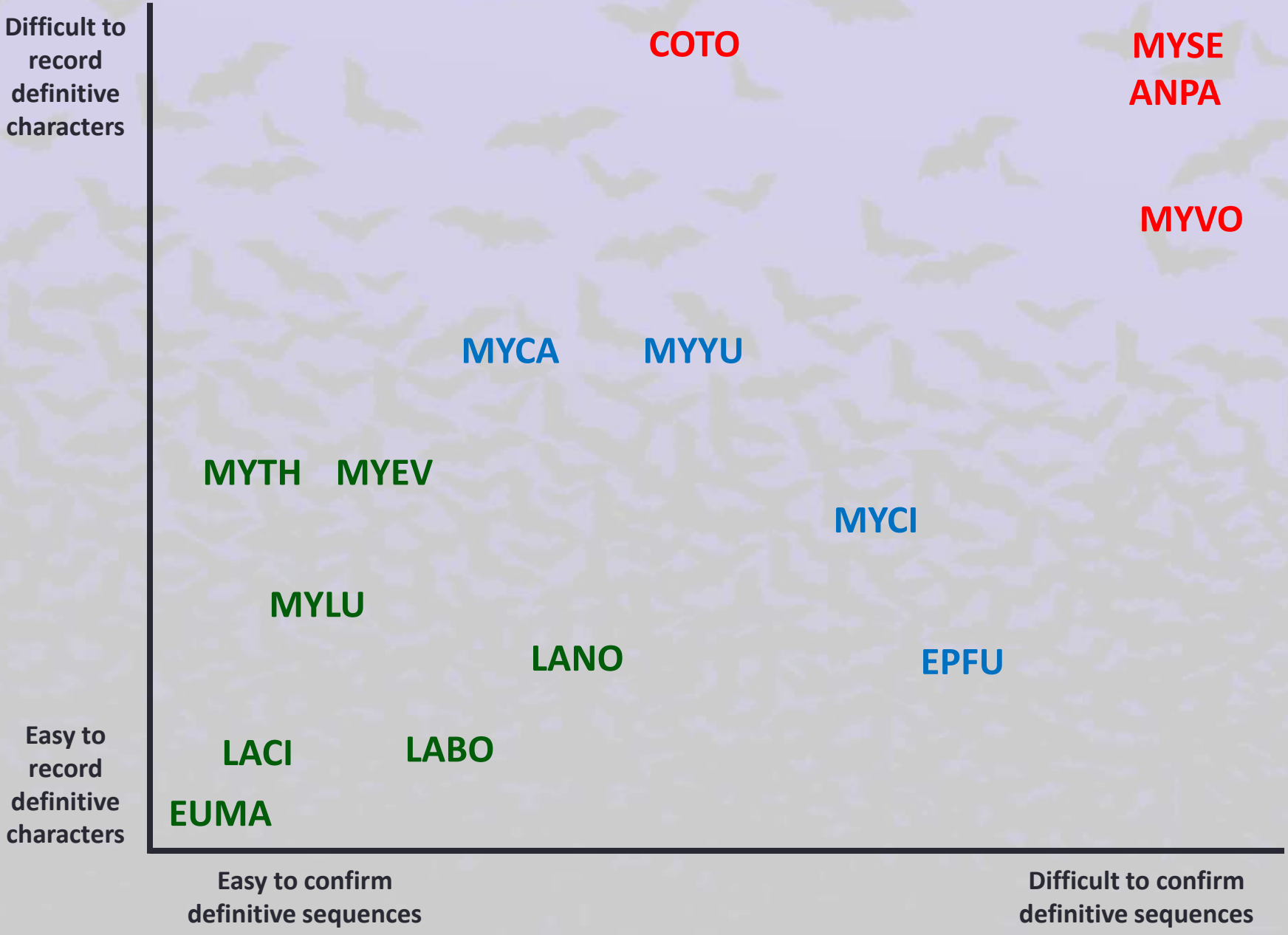


Individual Species Calls and Call Overlap Between Species that will be Reviewed



Bats are grouped based on search phase call shape and overlap. As noted earlier, there may be even greater overlap between species for approach phase calls. Within groups, bats are organized by characteristic frequencies. It is particularly difficult to find definitive ANPA, MYVO, and COTO call sequences.

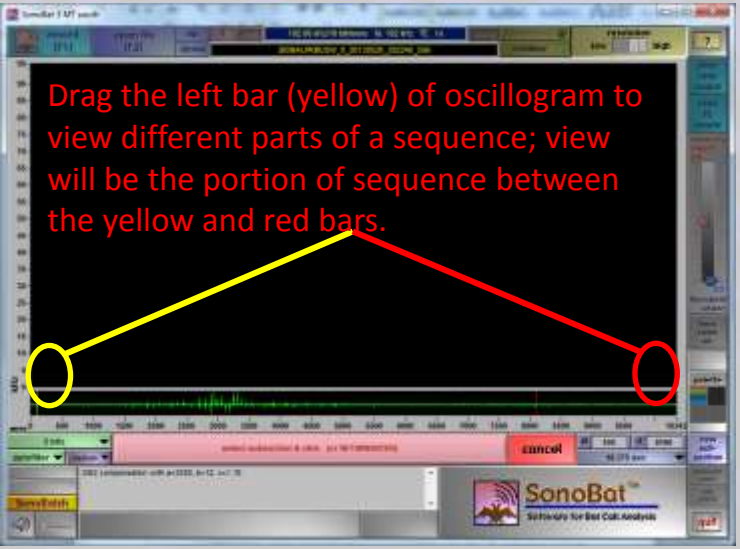
Relative Ease of Recording and Confirming Definitive Call Sequences for Montana Bats



Specific Hand Review Steps I

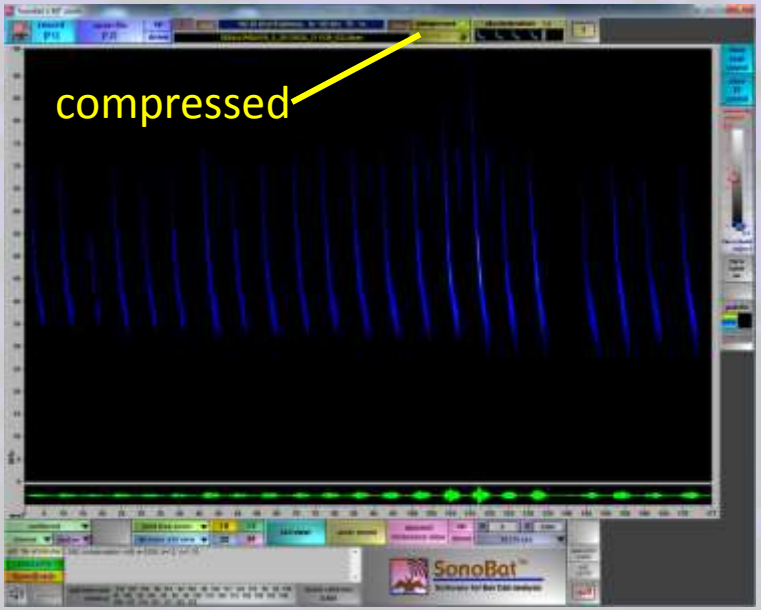
1. Use automated species classifications from Sonobat and Kaleidoscope and output on certain call characteristics from these software packages (e.g., FcMean, FcDuration, FcStdDev) as noted in the Echolocation Call Characteristics Key for Montana Bats to locate sequences most likely to be the species of interest. Best to use a relational database to do this, but this can also be done in a spreadsheet.

2. Open file. If the sequence is more than 8 s long, you can determine which portion you will look at. If calls appear to be horizontally truncated, you can lengthen the discrimination setting to spread them out in compressed view.



Specific Hand Review Steps II

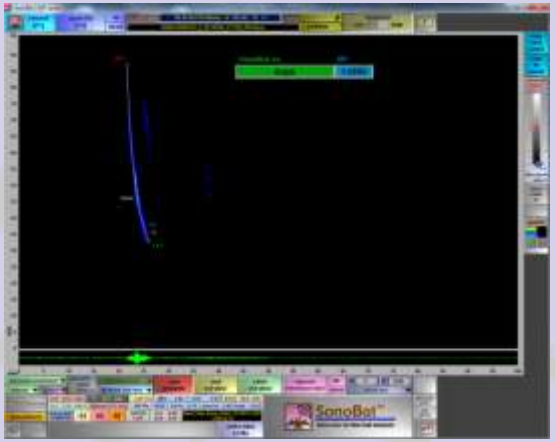
3. In compressed view, get an overview of the call shapes, frequencies, harmonics, highest powered calls, etc.. Then toggle to “real time” view to get a good sense of time intervals, whether or not there is variation in frequency across the sequence, call types, and number of bats recorded in the sequence.



4. Think about all species in the phonic group of your species of interest and consider geography and differentiating call characteristics. If there are characteristics that are not indicative of the species of interest or if the sequence is of poor quality or lacks search phase calls, potentially skip the call sequence at this stage and jump to one of better quality where you are more likely to definitively confirm the species.

Specific Hand Review Steps III

selected call at “10 msec std view”



selected call at “50 msec std view”

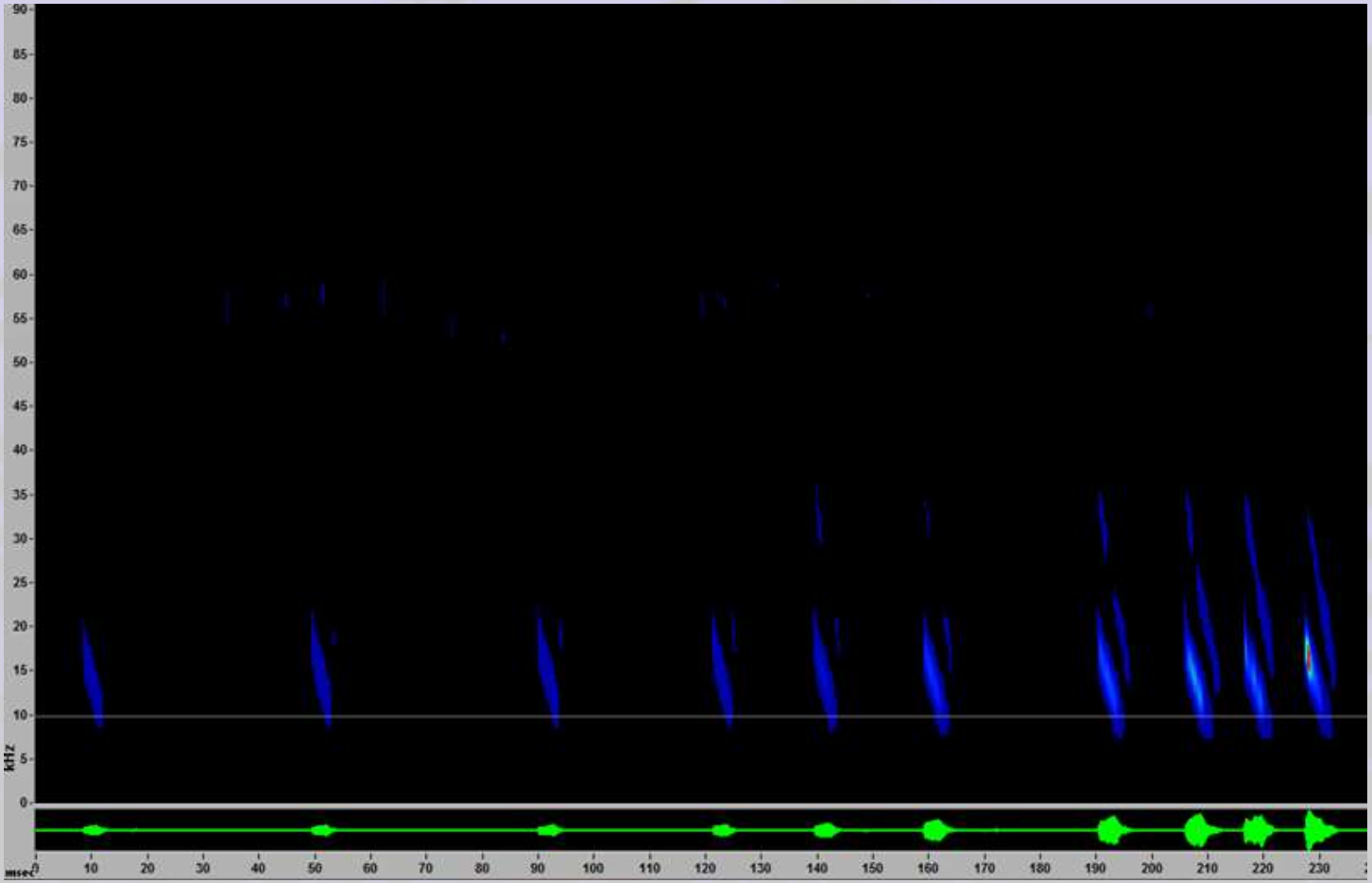
5. Pick a call with a strong power center (but avoid over-saturated calls), harmonics, and clear search phase intervals. Use “std view” to zoom in and measure the call. Note that the automated measurements from Sonobat are sometimes incorrect and some parameters will need to be measured by hand.

5. Toggle between different “std view lengths” and look closely at call shapes and various call measurements relative to definitive characteristics.

6. In most cases, you will want to have multiple definitive calls across a sequence to definitively assign a species to a call sequence.

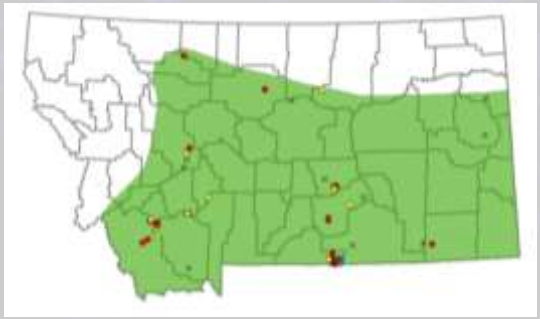
Overview of Call Characteristics for Montana's Bats

Spotted Bat (*Euderma maculatum*) = EUMA

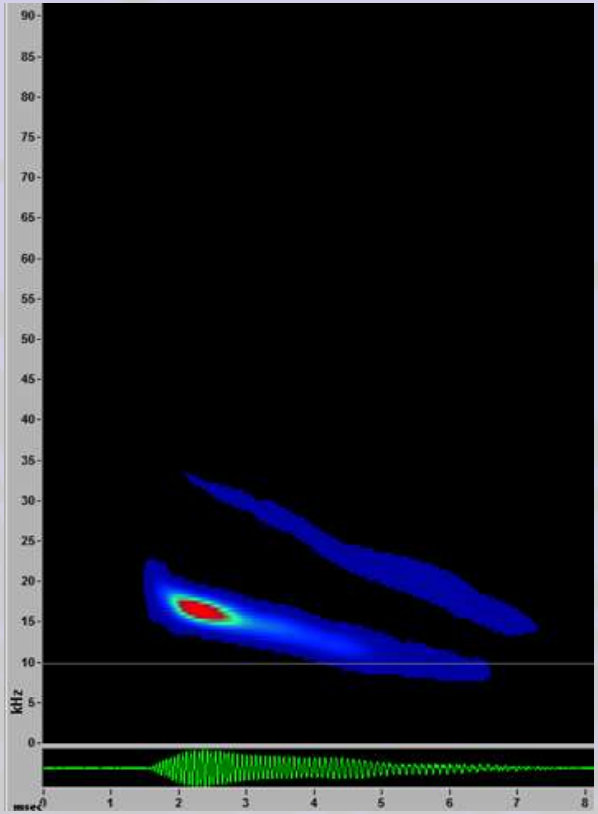


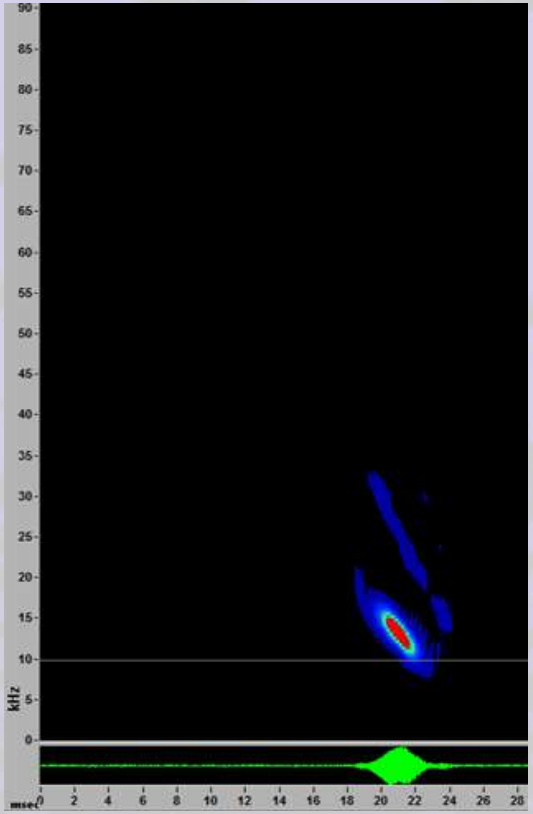
EUMA_real_time

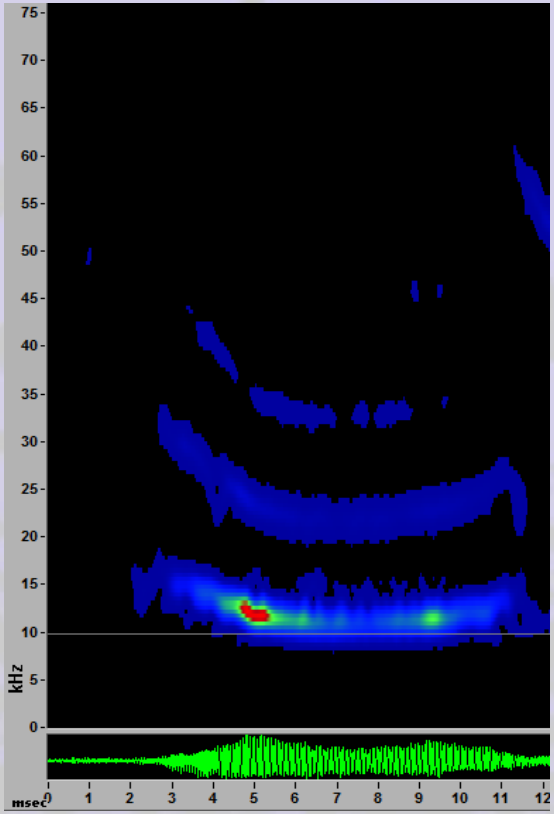
EUMA_time_expanded



EUMA Call Shapes



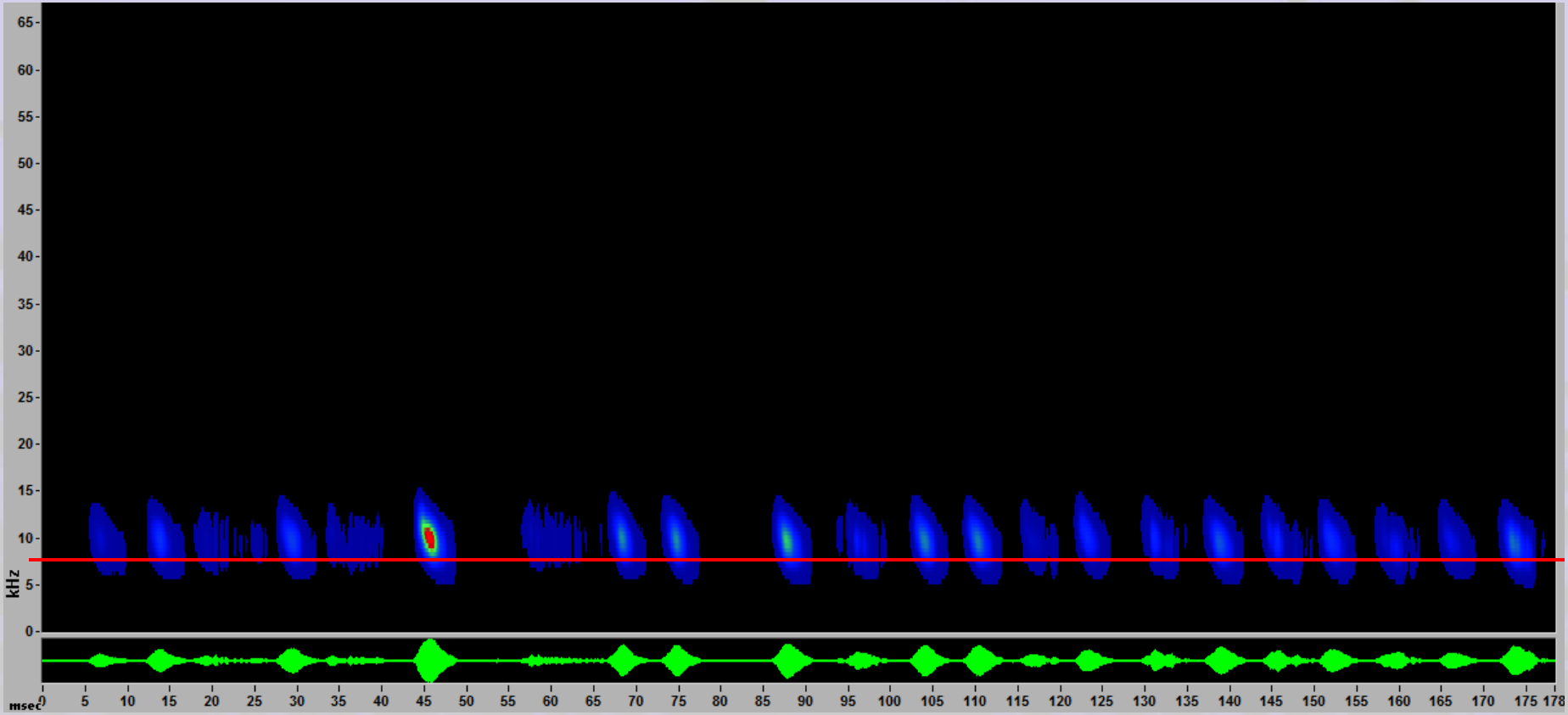




- Short, simple linear FM sweep at low frequency
- Harmonics are usually present, sometimes with second harmonic persisting beyond the primary call component
- Sometimes a mild inflection or curvature

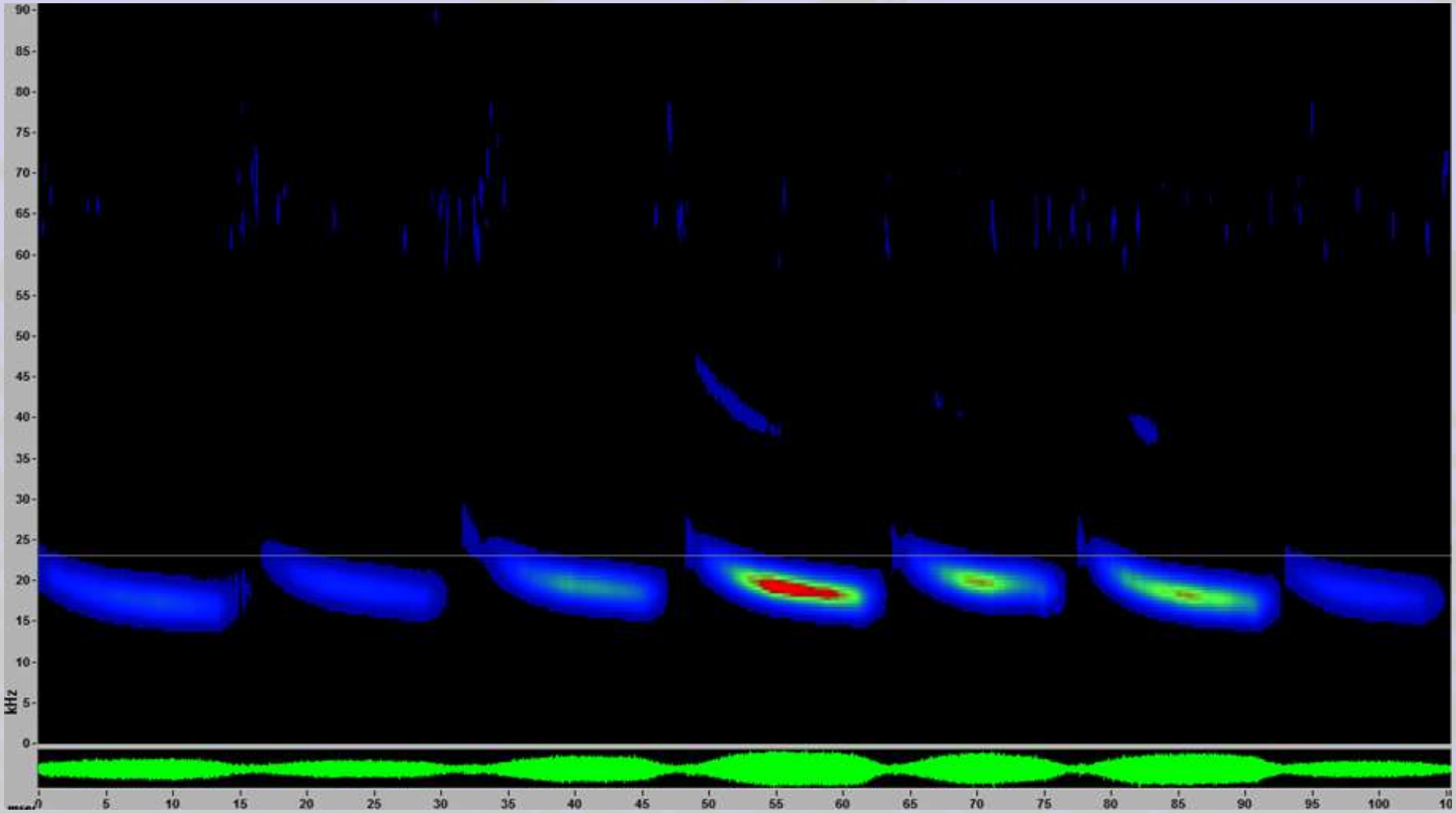
** No bat in Montana is easily confused with EUMA because search phase calls are the lowest frequency of any bat in the state

EUMA Definitive Characteristics



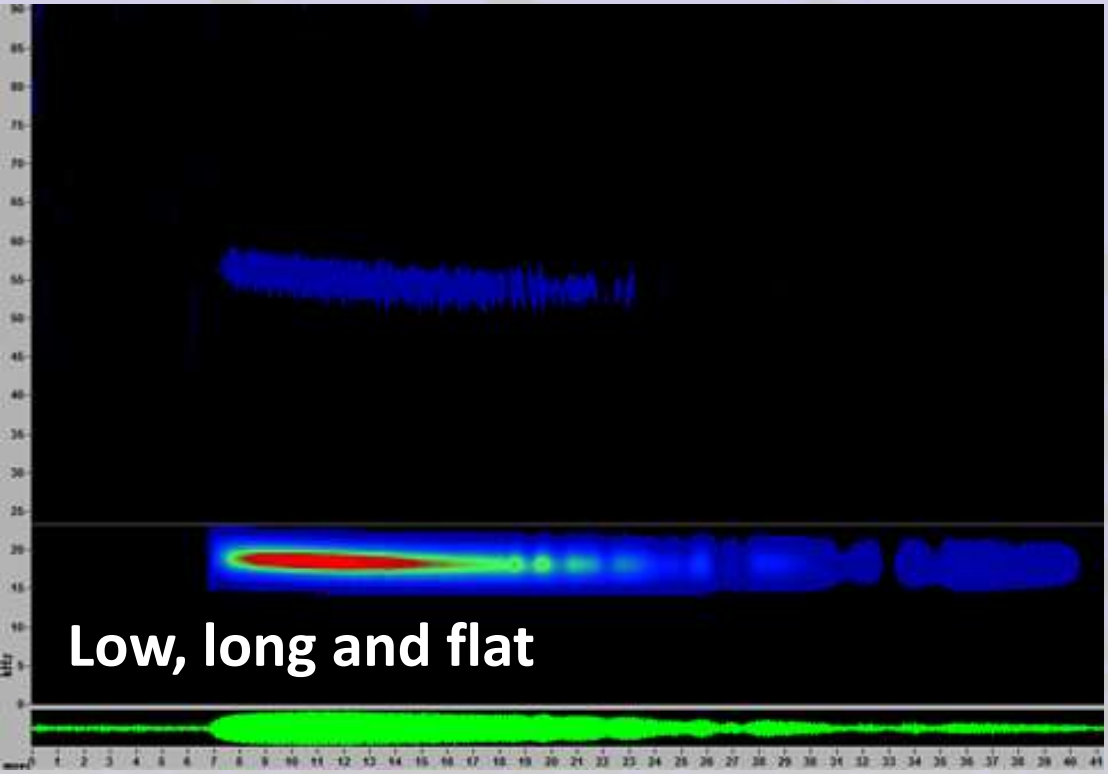
- Simple linear FM sweep
- *f*c: 7-10 kHz
- Duration: 3-8 ms

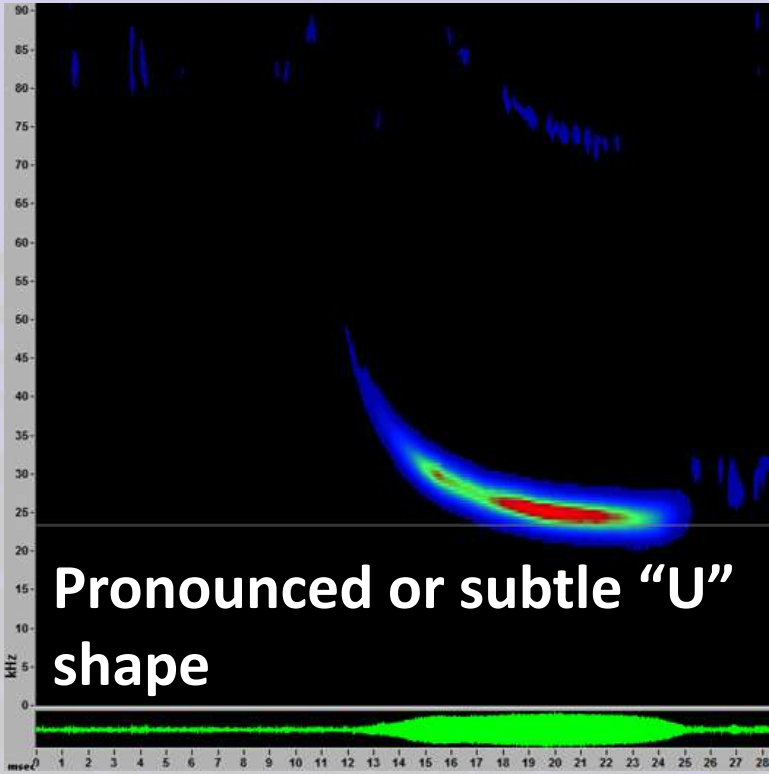
Hoary Bat (*Lasiurus cinereus*) = LACI



LACI_time_expanded

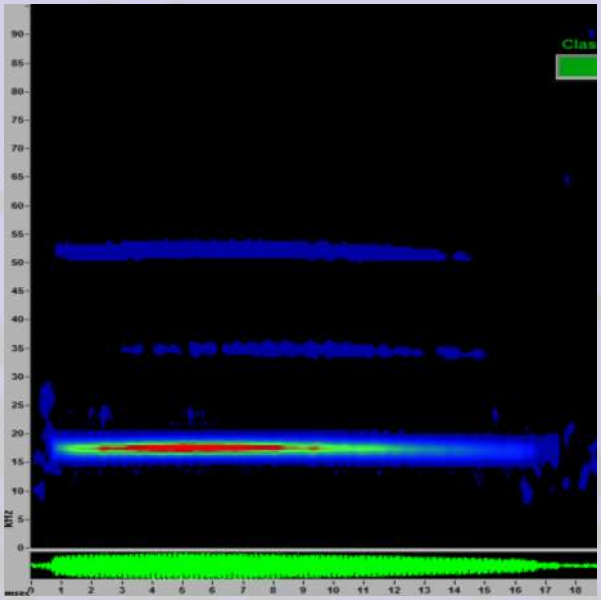
LACI Call Shapes

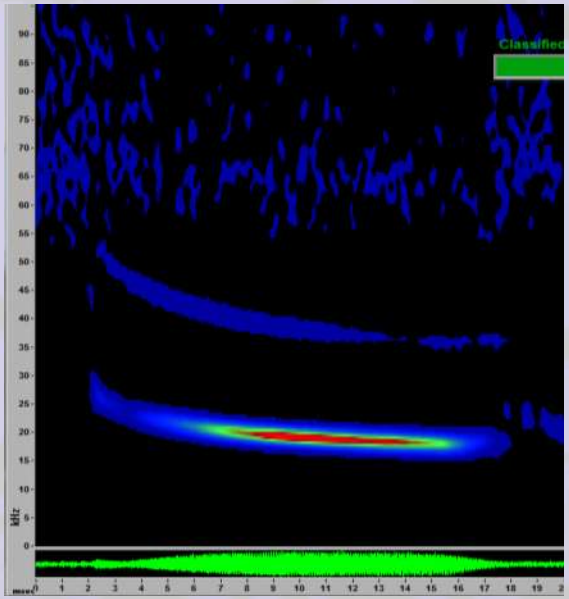


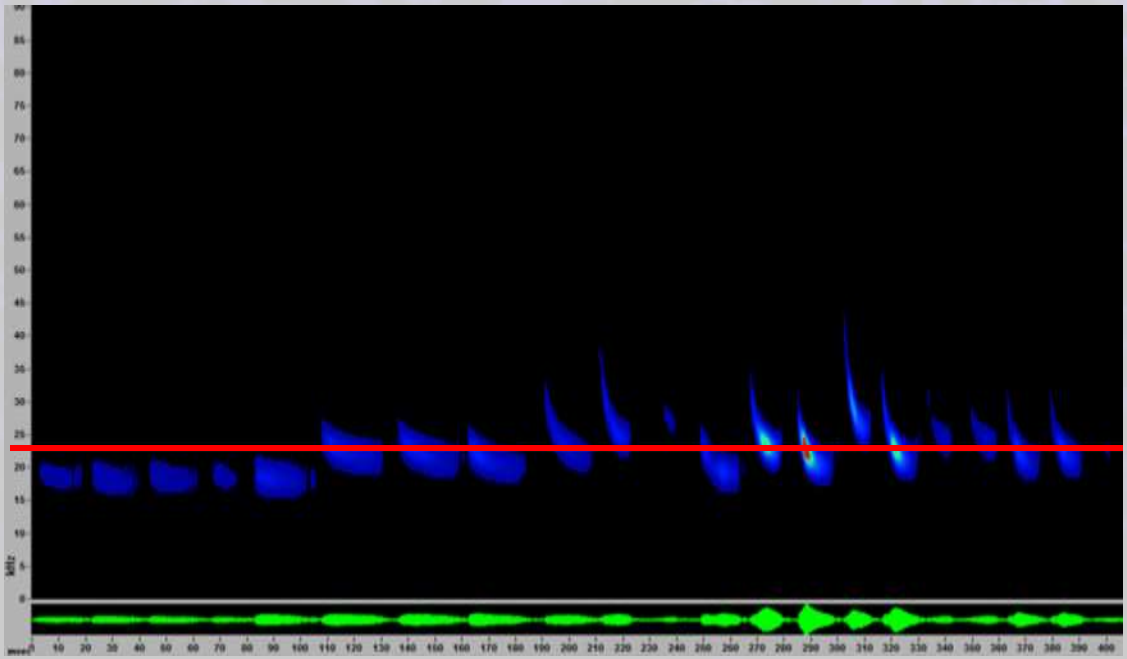


- Very flat calls may have slight downturn into call and/or upturn at the end

LACI Definitive Characteristics

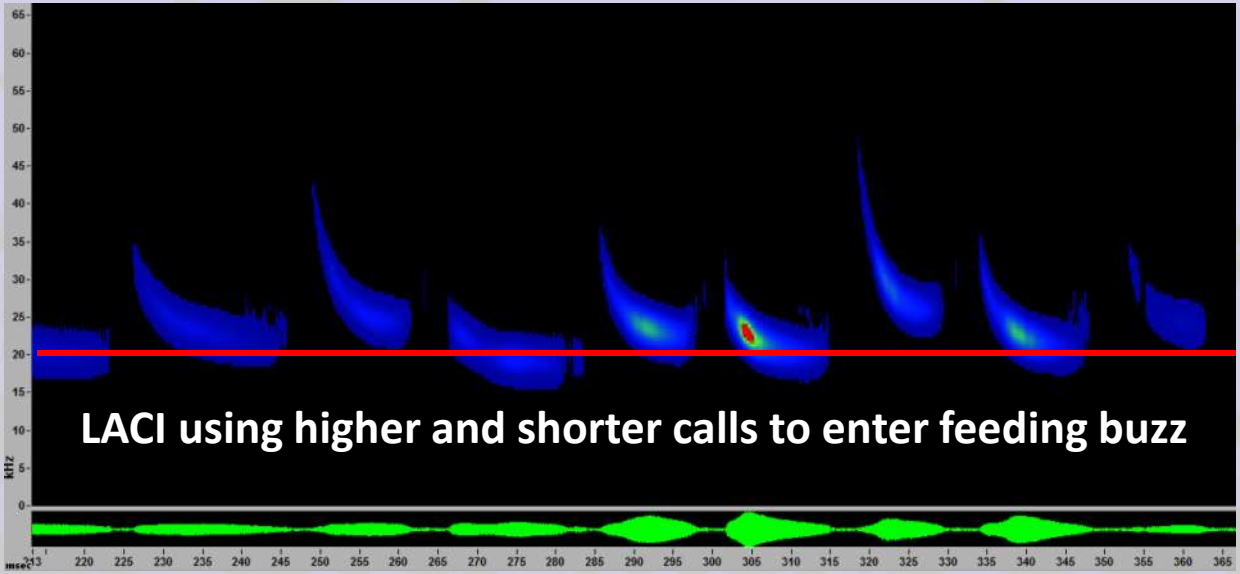


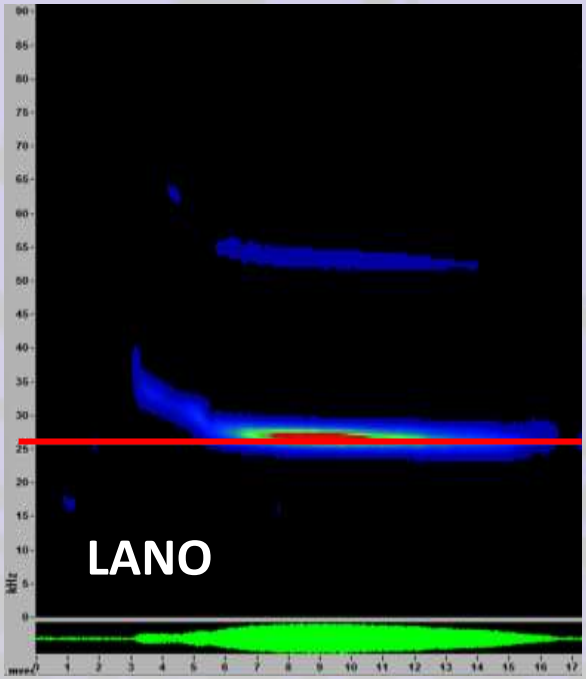




- Pronounced or subtle “U” shape OR flat; often frequencies down into the teens
- Power builds toward center then gradually declines
- Low *f* and *f*c may vary across a sequence

LACI Similar Species

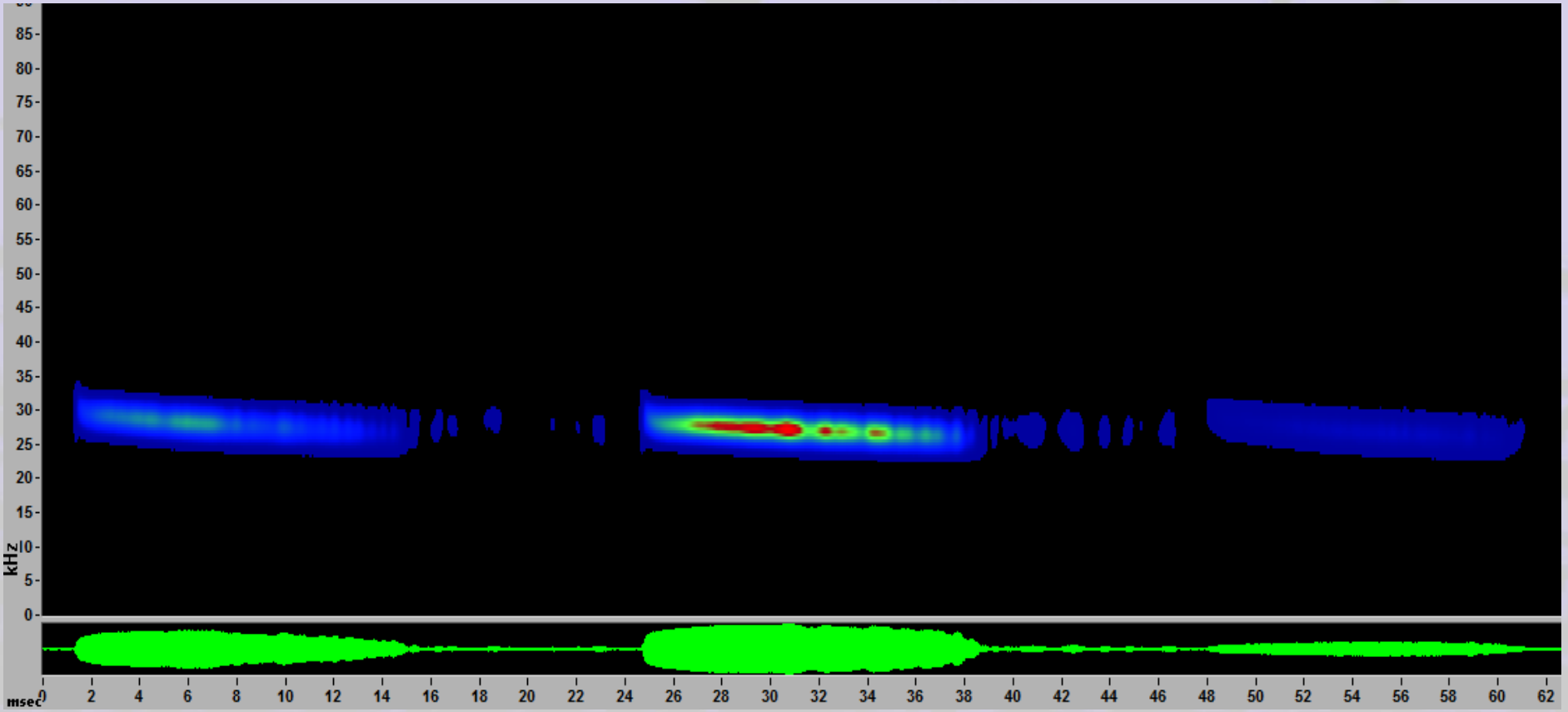




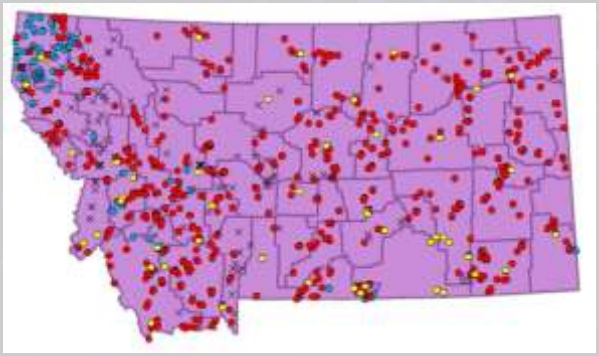
LACI vs. **LANO**: Flat calls in the *fc* = 23-26 kHz range are indistinguishable. Low sloped calls in the *fc* = 25-26 kHz range with inflection are distinguished from LACI. Short LACI approach calls may overlap undiagnostic, short LANO calls.

LACI vs. **EPFU**: Approach calls can be confused with undiagnostic , short EPFU and LANO calls.

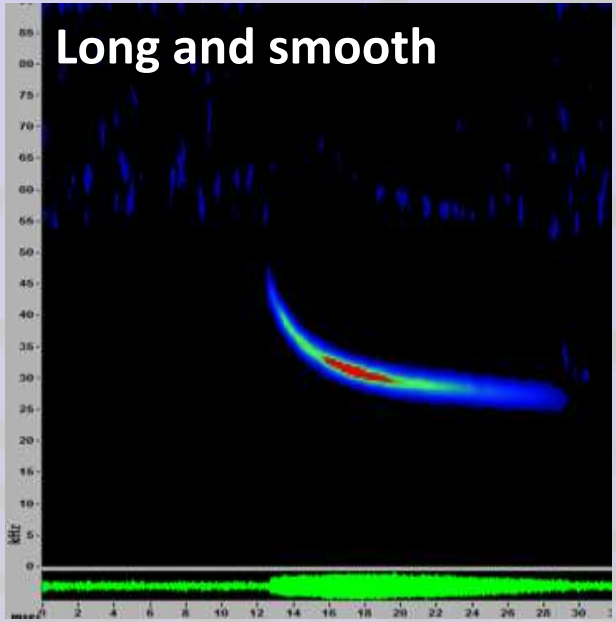
Silver-haired Bat (*Lasionycteris noctivagans*) = LANO

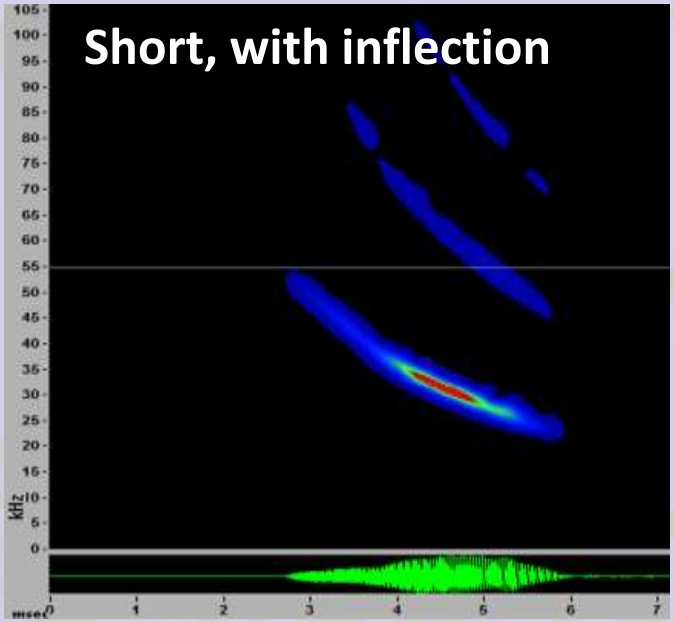


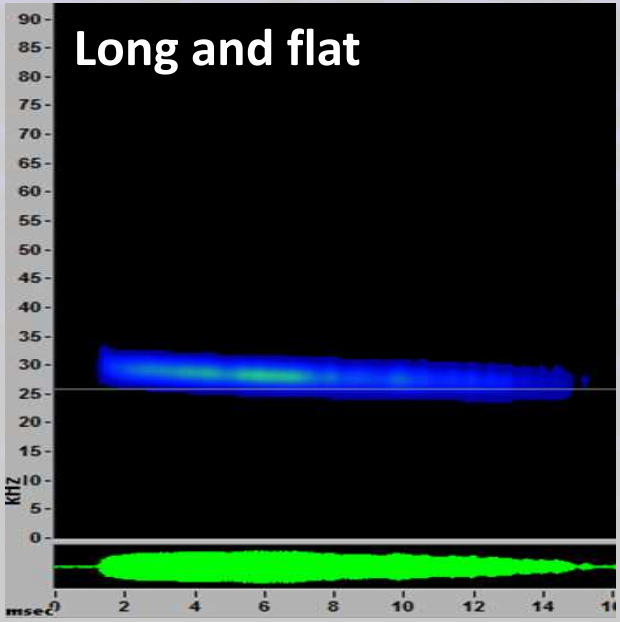
LANO_time_expanded

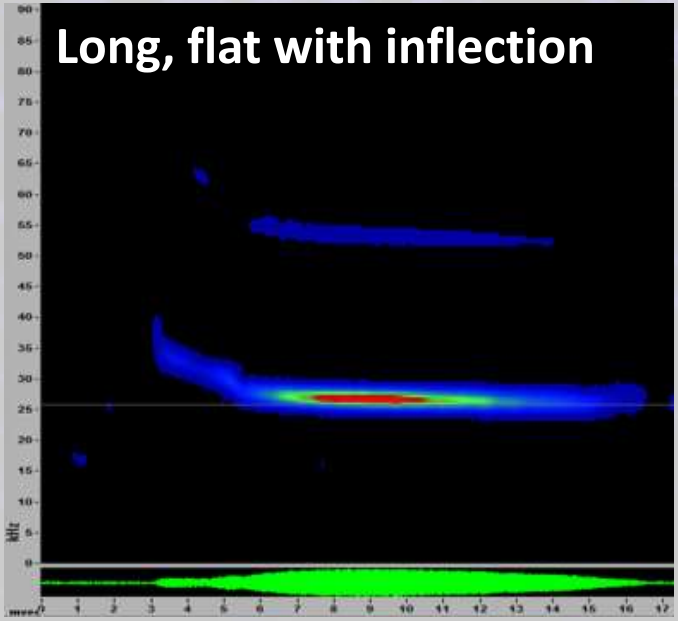


LANO Call Shapes

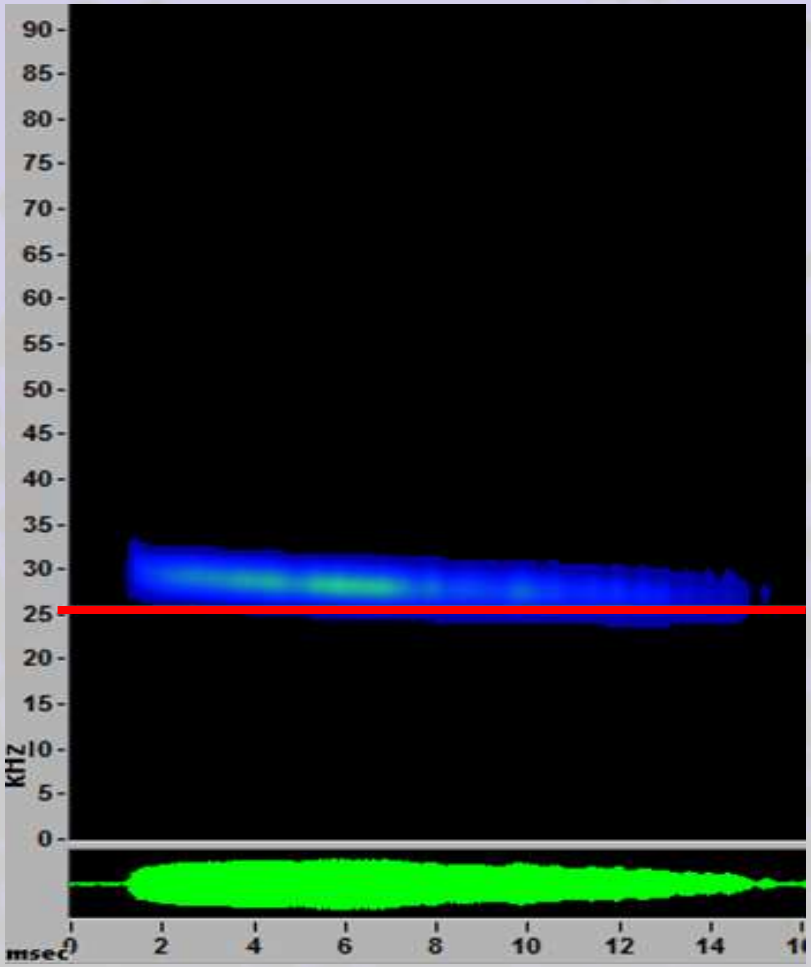


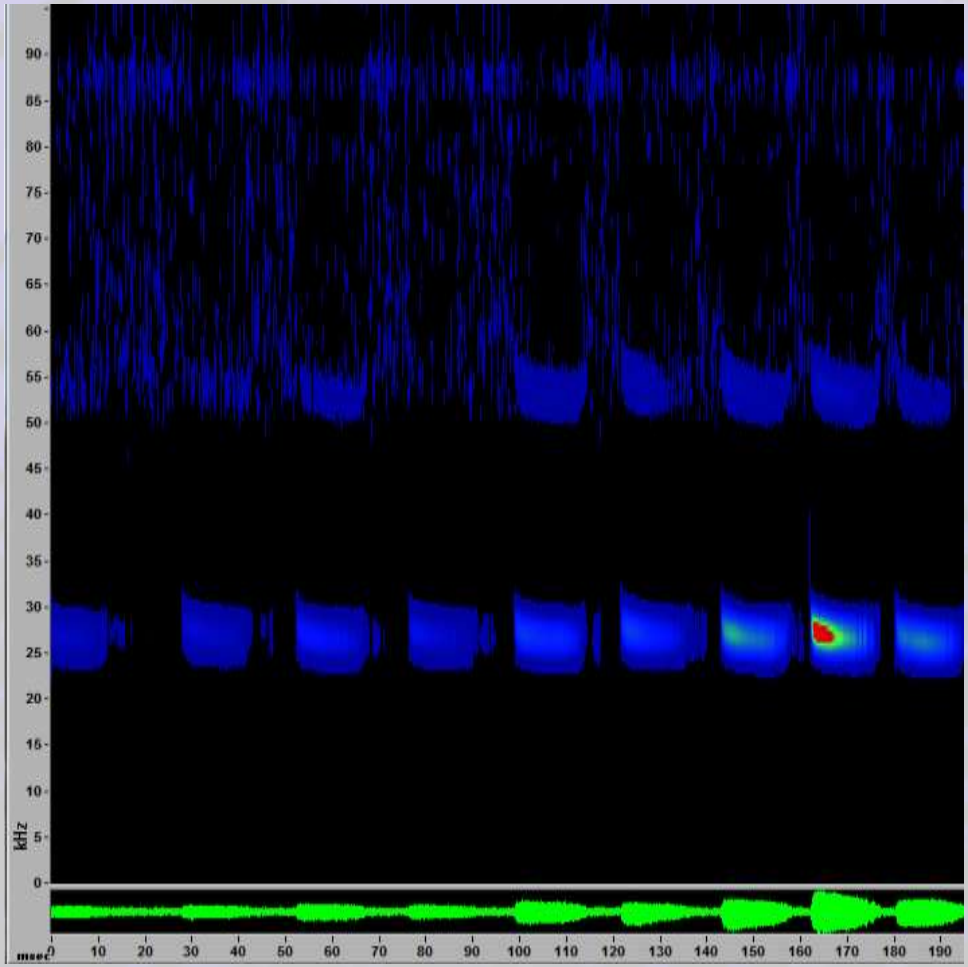






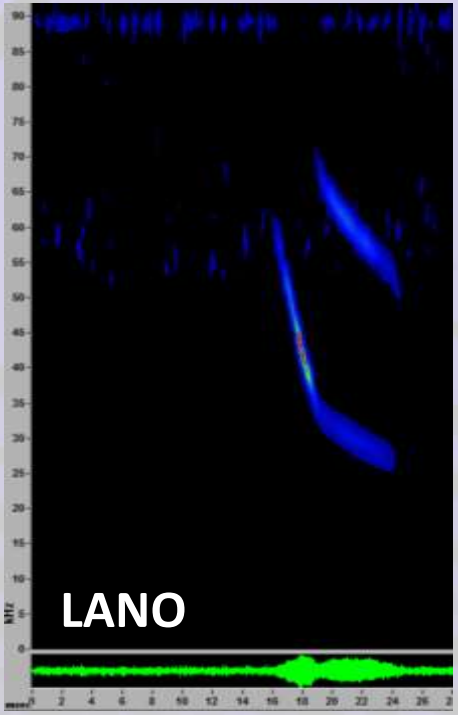
LANO Definitive Characteristics

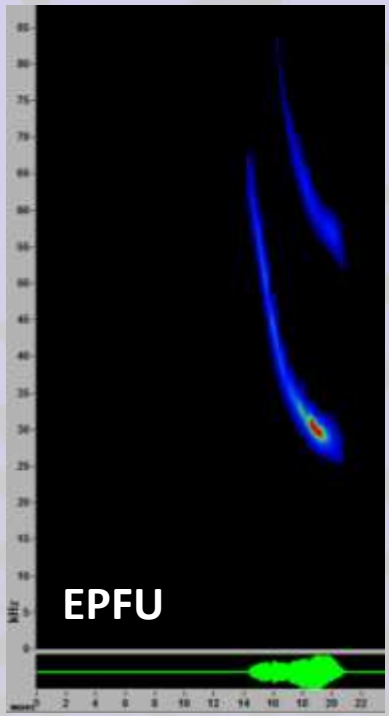


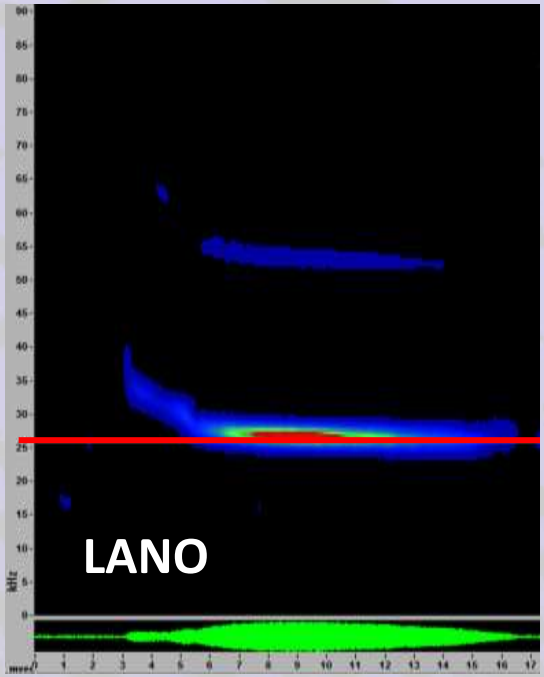


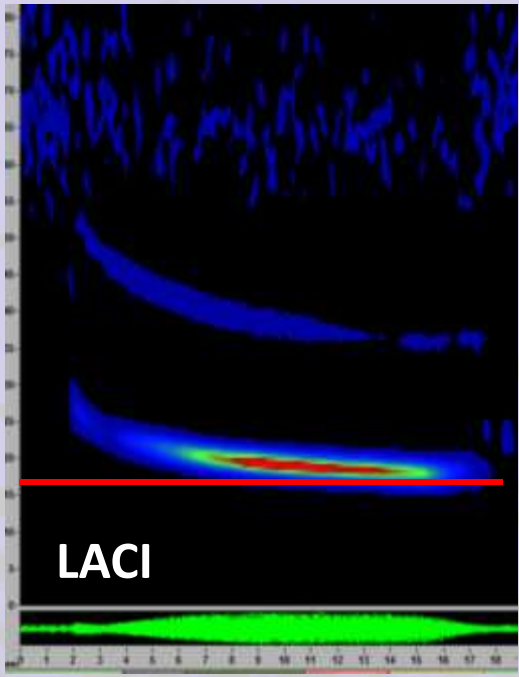
- **Flat calls with *f*c >26 kHz**
- **Long, flat calls with some frequency modulation have a distinct inflection between upper and lower portions of call**

LANO Similar Species





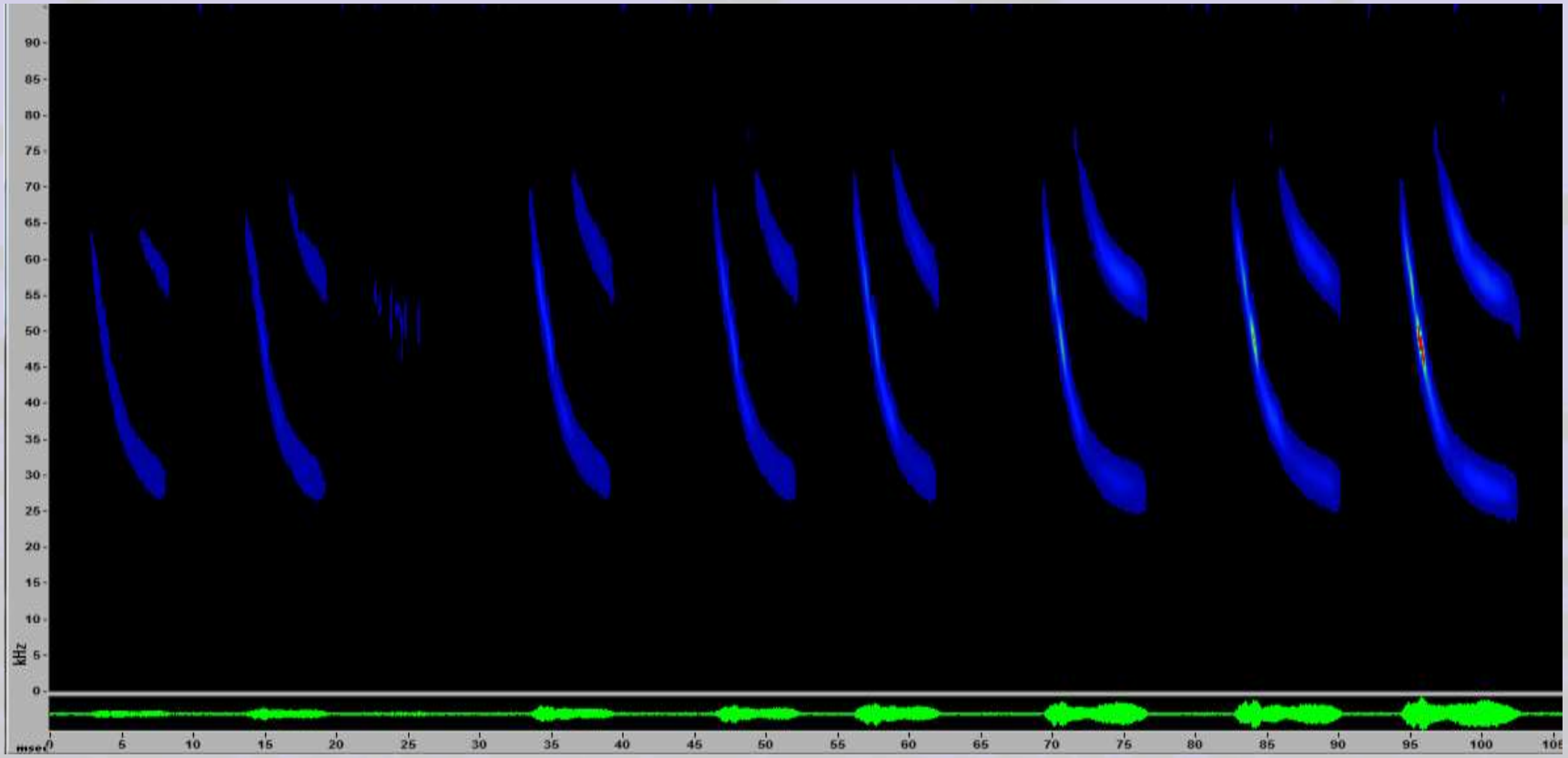




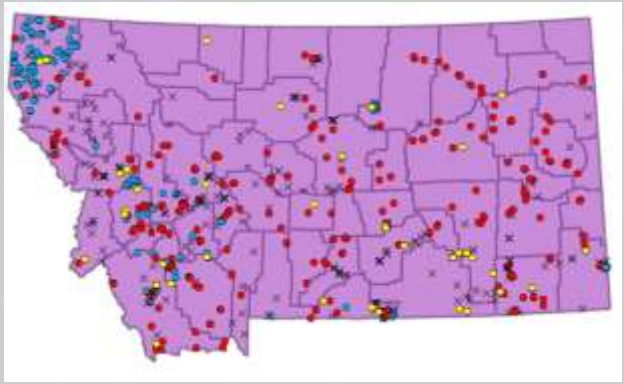
LANO vs. **EPFU** and **ANPA**: EPFU has more frequency modulation; lower, longer calls with a pronounced inflection help distinguish LANO from EPFU. LANO does get <6 calls/sec but tends to drop below ANPA *fc* range and higher LANO calls tend to have inflection, while ANPA does not.

LANO vs. **LACI**: Flat calls in the *fc* = 23-26 kHz range are indistinguishable. Low slope calls in the *fc*= 25-26 kHz range with inflection are distinguished from LACI. Short LACI approach calls may overlap short LANO. Examine entire sequence!

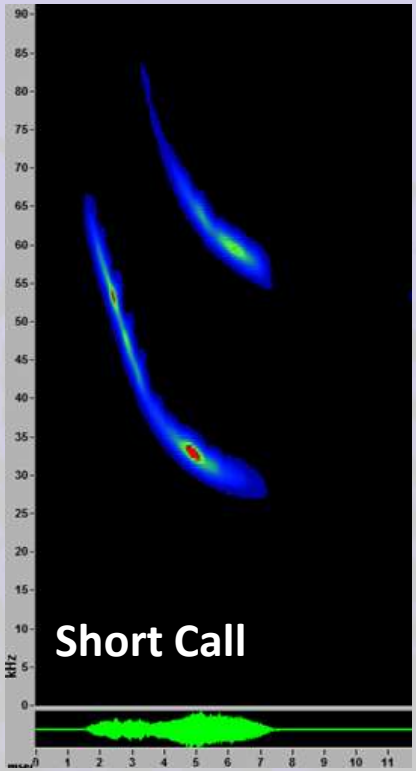
Big Brown Bat (*Eptesicus fuscus*) = EPFU

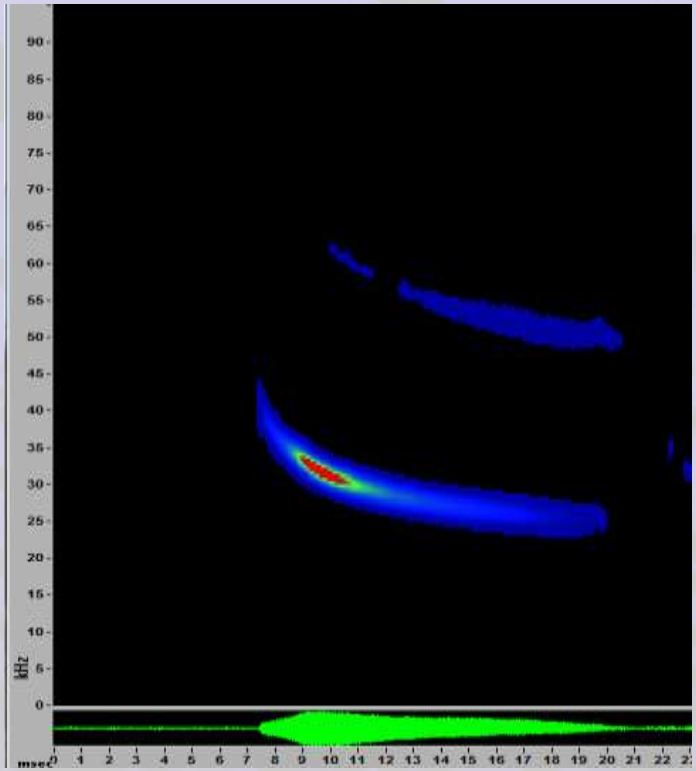


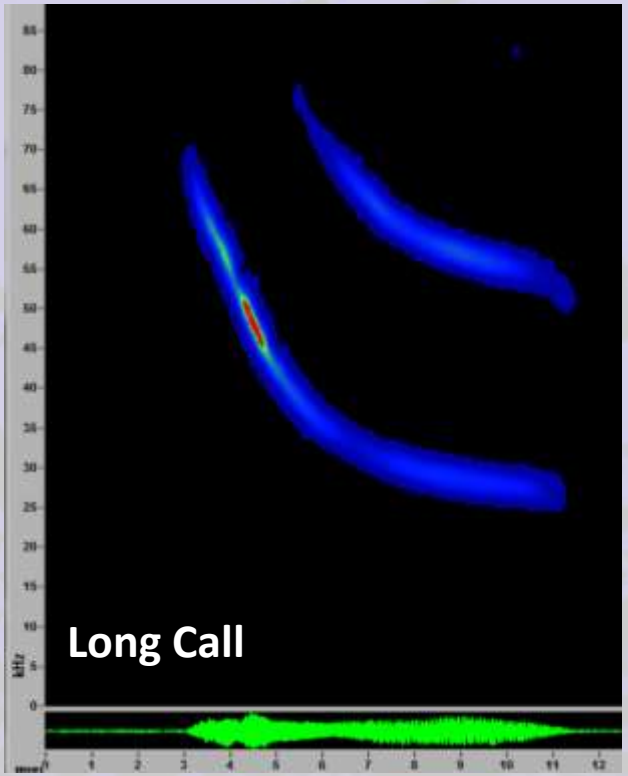
EPFU_time_expanded



EPFU Call Shapes

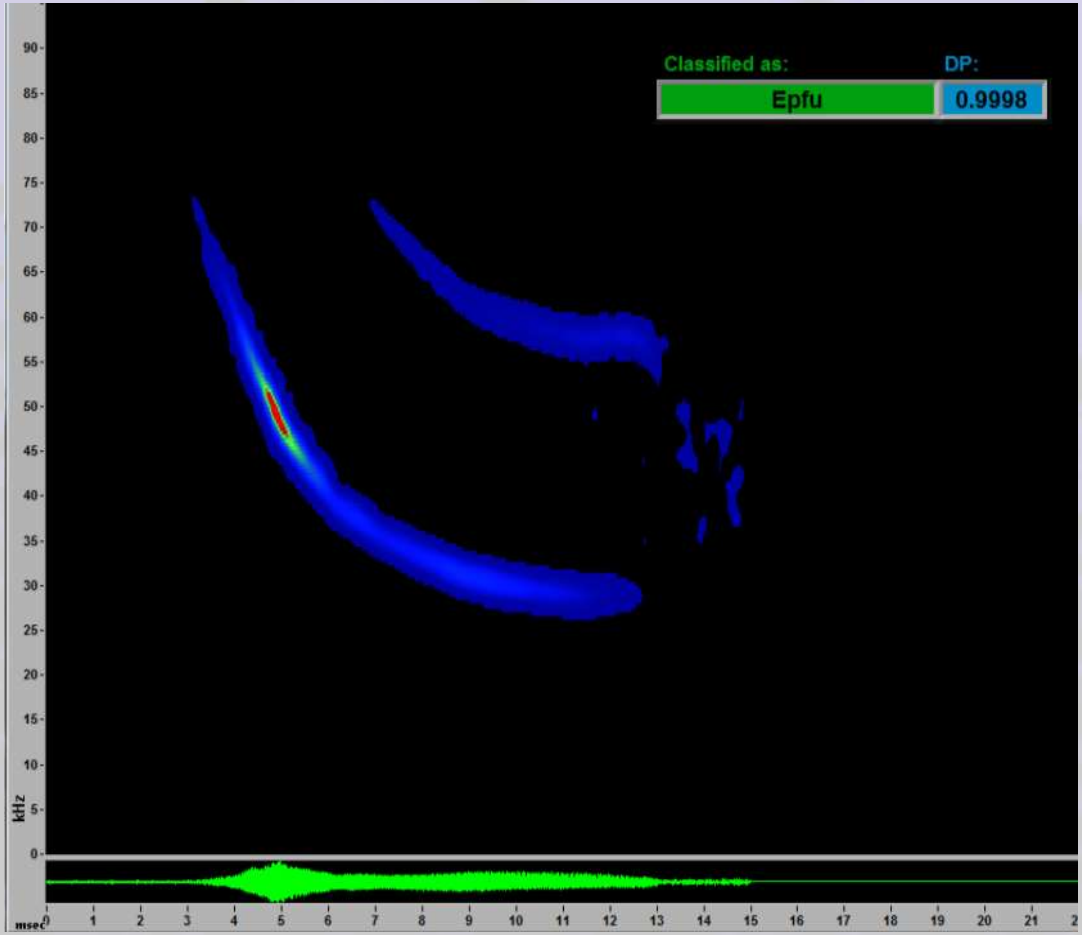






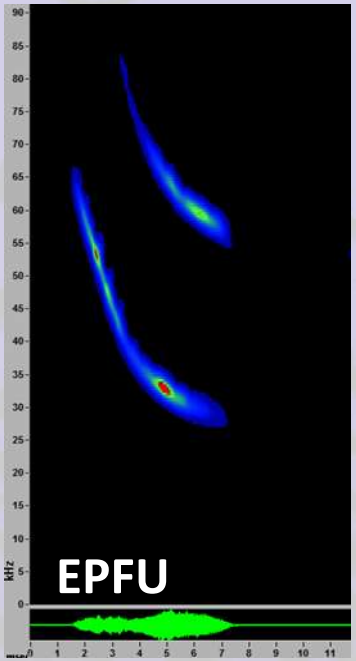
- Variable; smoothly curved FM sweeps. Even long calls have some FM component.
- Harmonics usually parallel, but may slightly converge or “drip down” at ends.

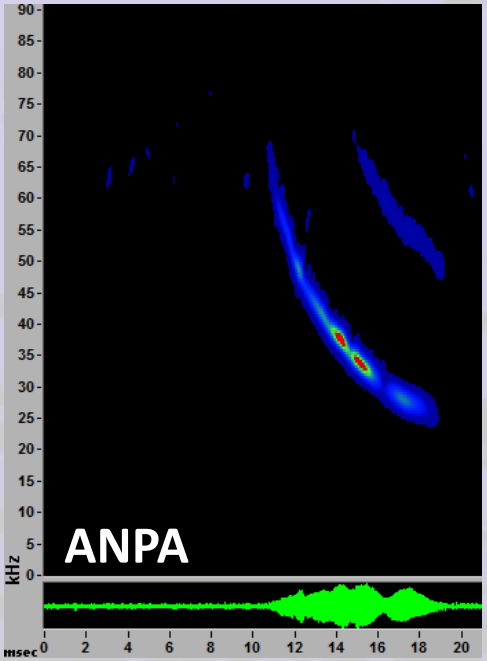
EPFU Definitive Characteristics

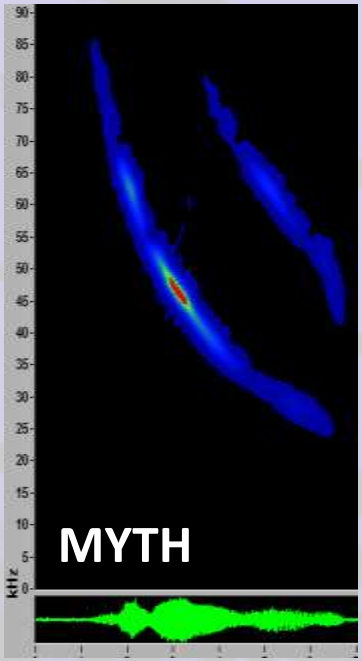


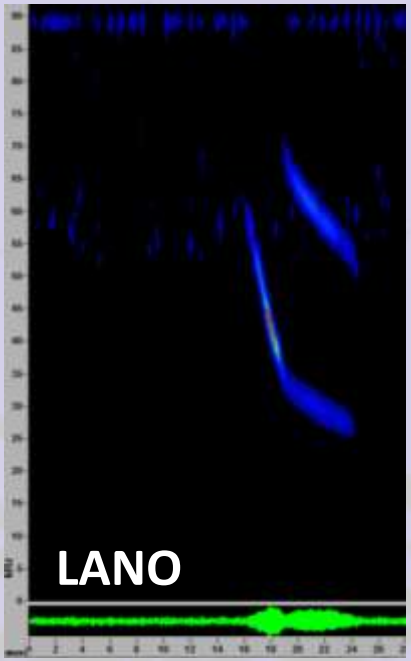
- high $f \geq 65$ kHz
- calls with duration > 12 ms distinguish EPFU from ANPA where species coexist

EPFU Similar Species





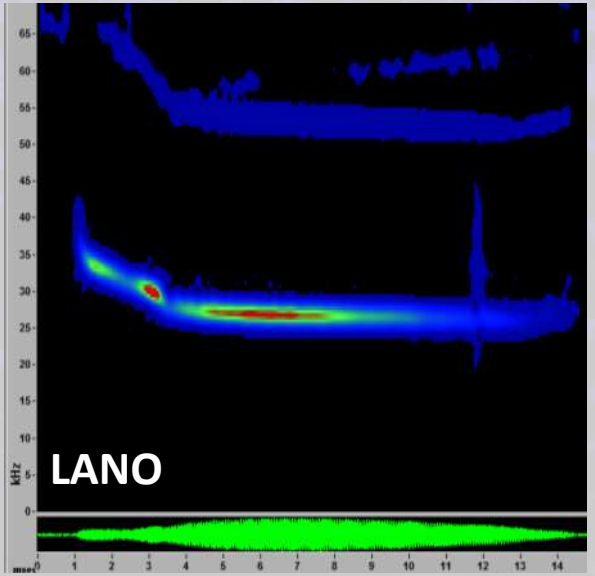




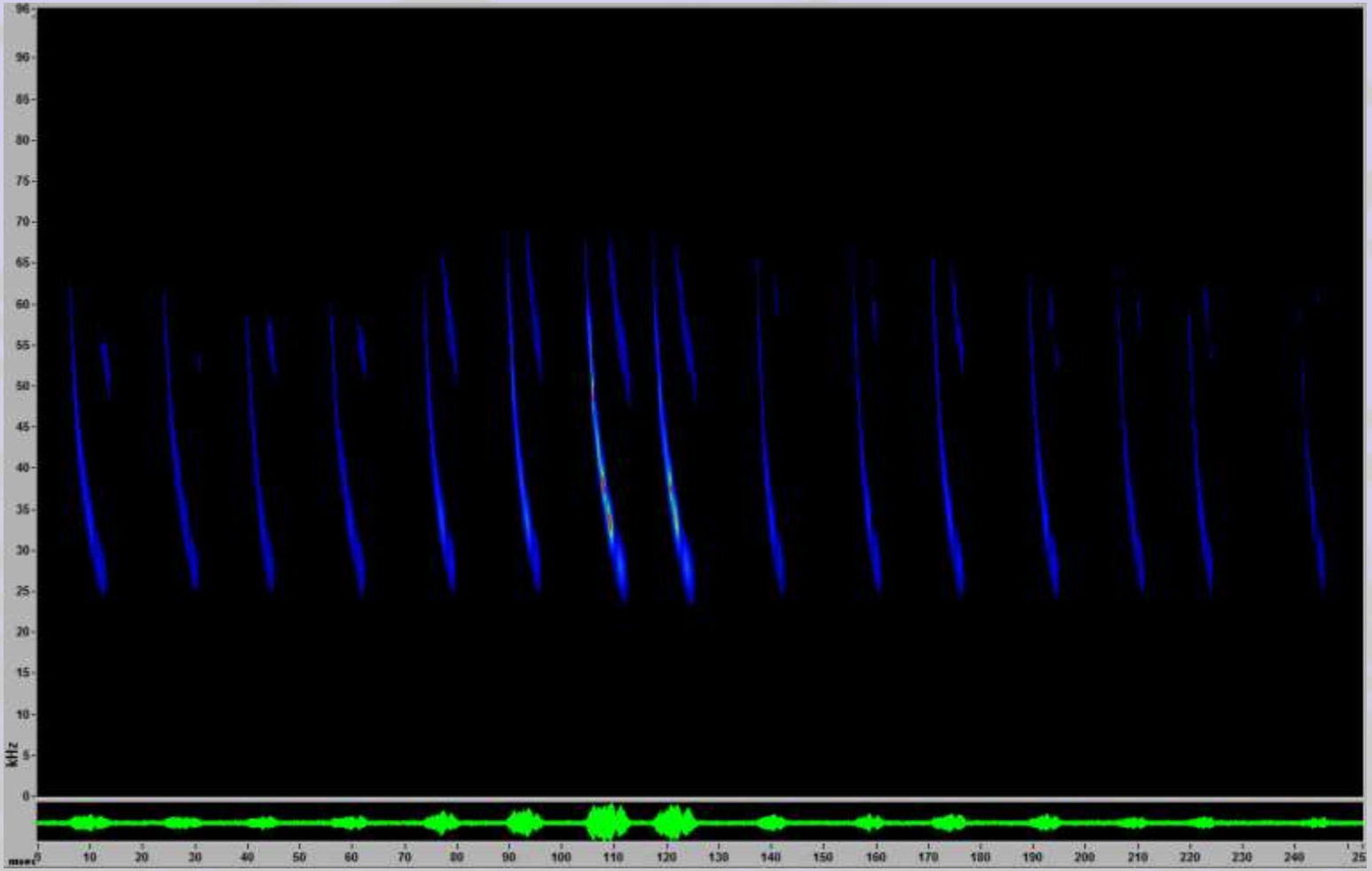
EPFU vs. ANPA: Calls with duration > 12 ms and/or > 6 calls/second distinguish EPFU from ANPA where species coexist. Geographic range also distinguishes EPFU from ANPA.

EPFU vs. MYTH/MYEV: Converging harmonics, shorter calls, higher total slopes, and tails distinguish MYTH/MYEV from EPFU.

EPFU vs. LANO: Search phase calls with high $f \geq 65$ kHz distinguish EPFU from LANO.

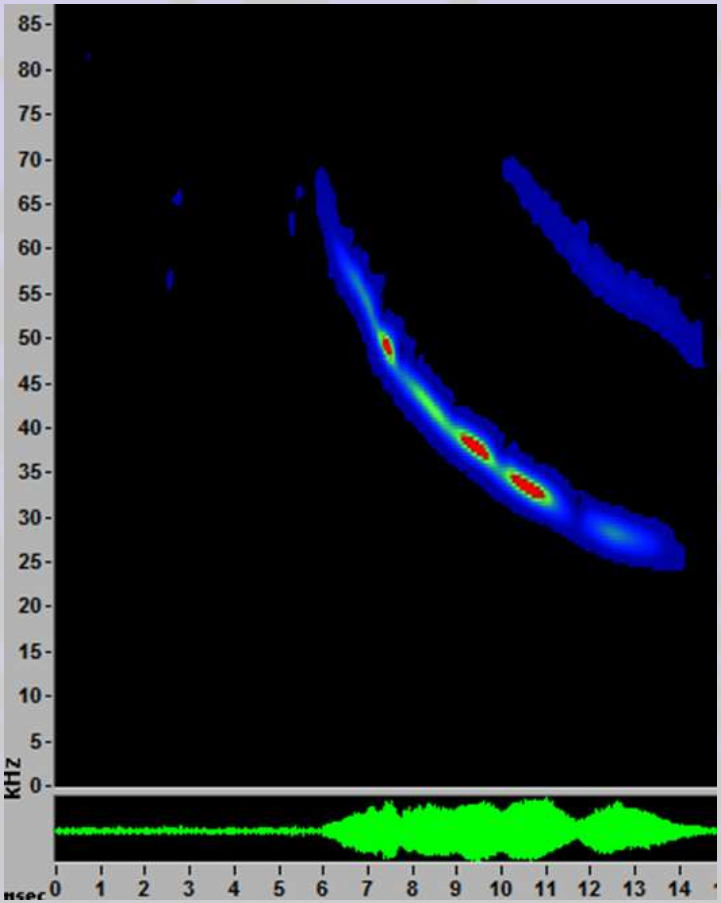


Pallid Bat (*Antrozous pallidus*) = ANPA

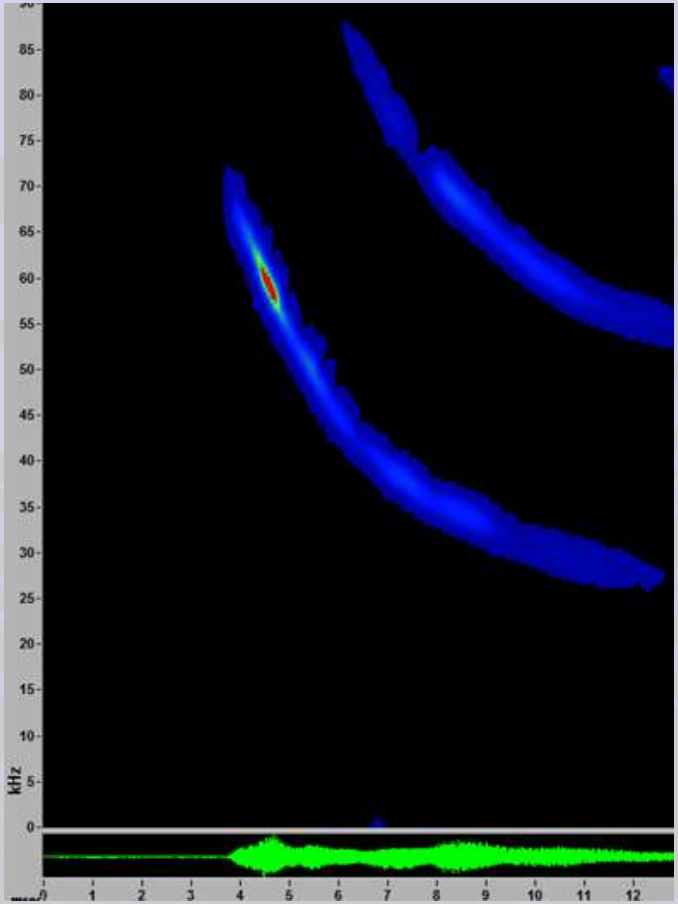


ANPA_time_expanded

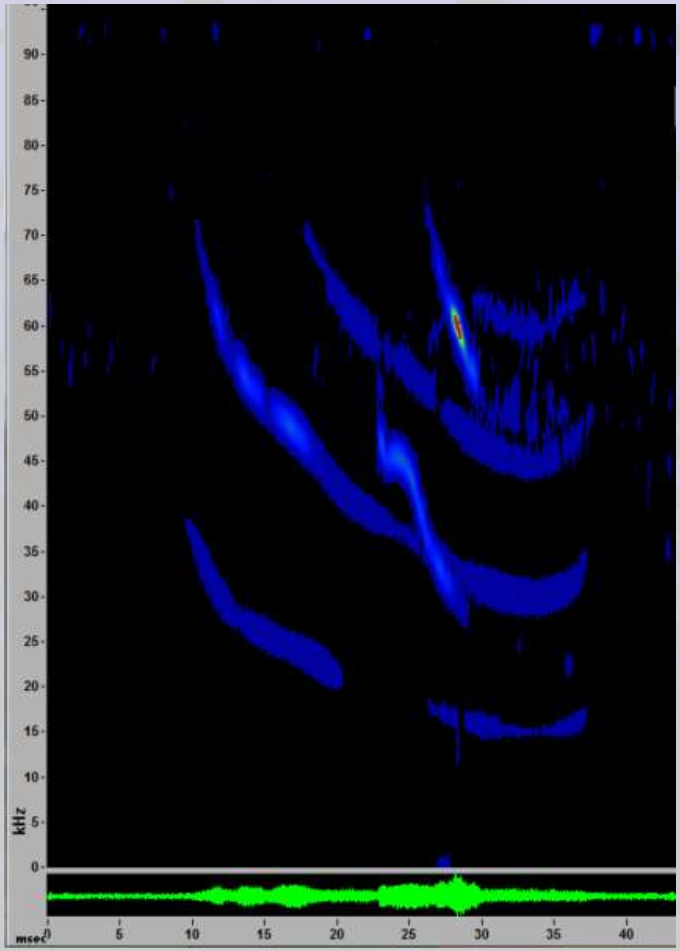
ANPA Call Shapes

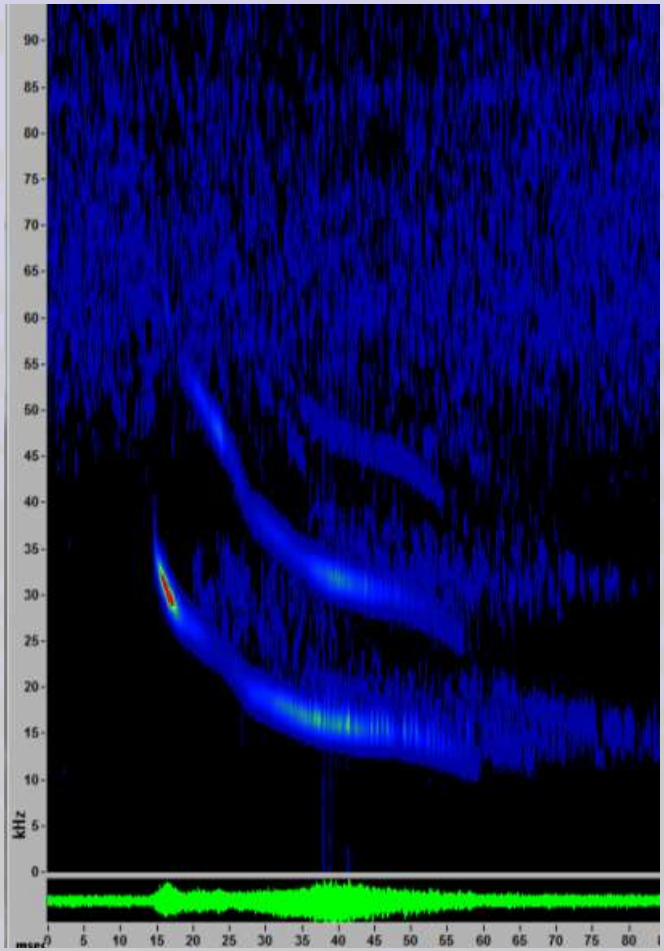


- Simple curved FM sweep
- No tail!
- Parallel harmonics



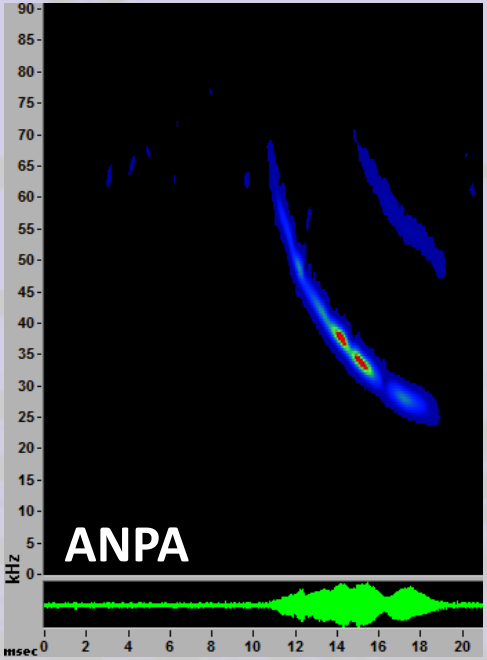
ANPA Definitive Characteristics

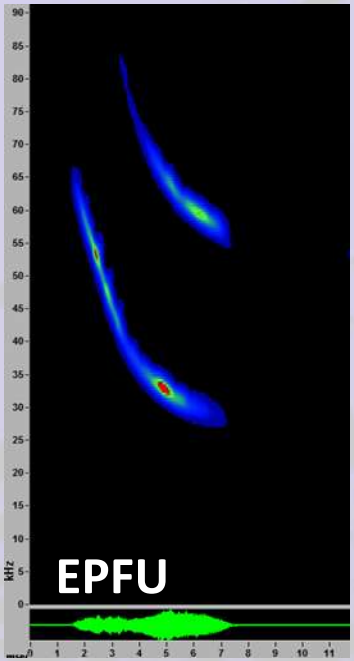


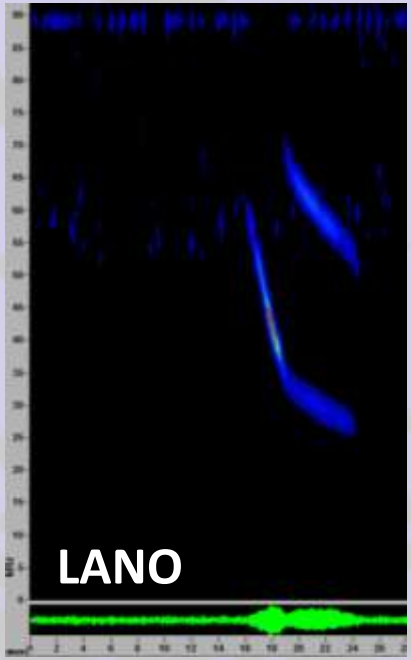


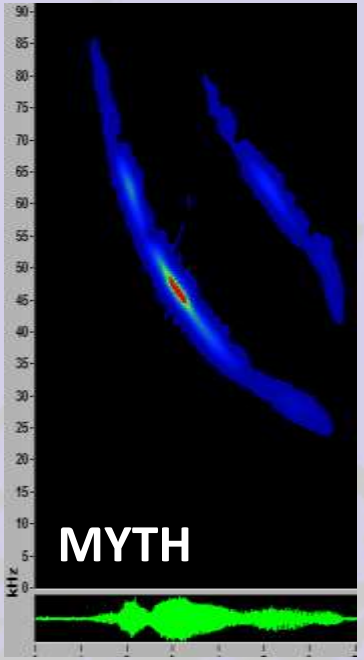
- **Presence of social calls**

ANPA Similar Species





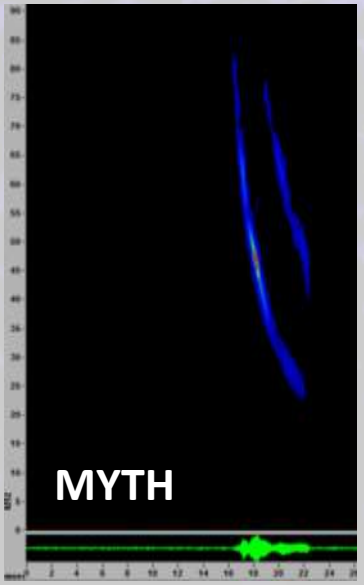




ANPA vs. EPFU: Presence of social calls distinguishes ANPA from EPFU. Sequences with < 6 calls/second may distinguish ANPA from EPFU?

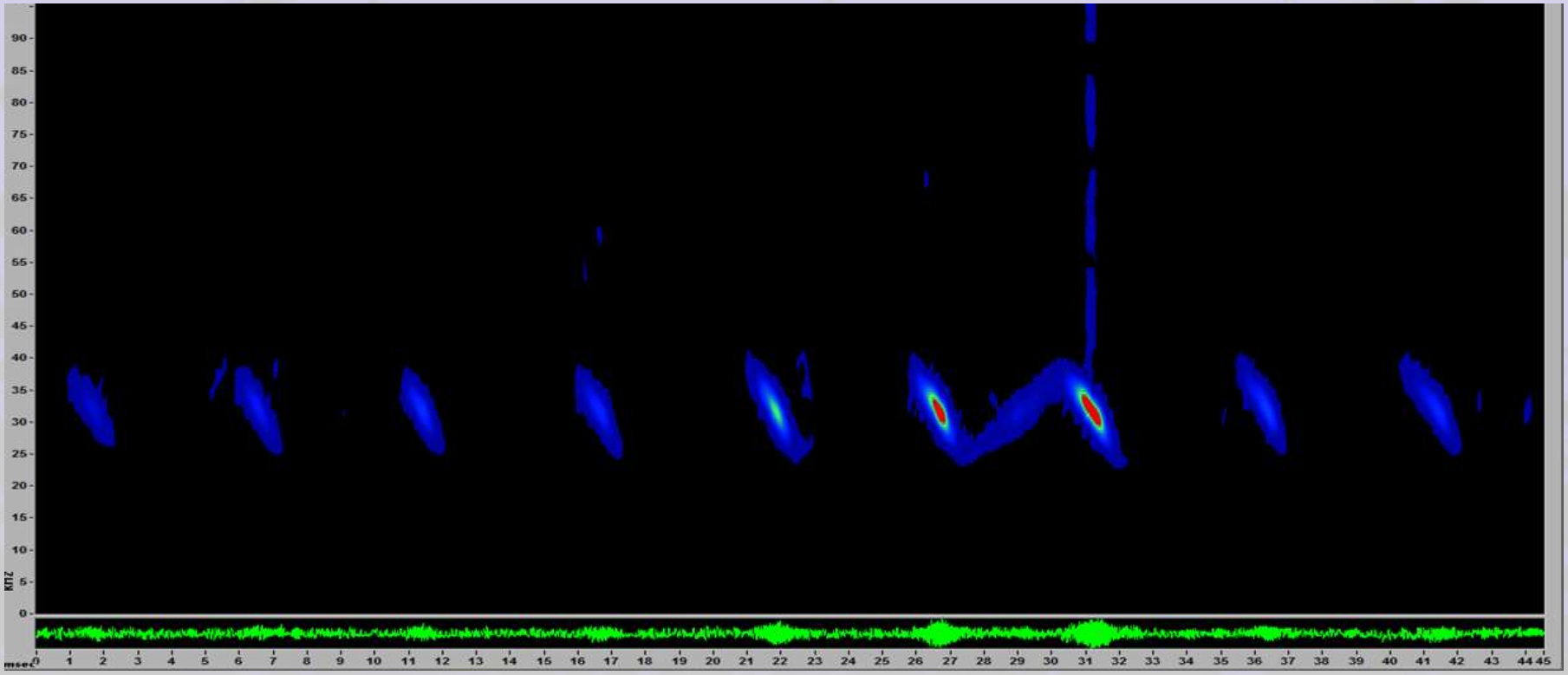
ANPA vs. MYTH/MYEV: MYTH/MYEV can have < 6 calls/second and look like ANPA in certain standard views, but converging harmonics, shorter calls, higher total slopes, and tails distinguish MYTH/MYEV from ANPA.

ANPA vs. short/higher LANO: LANO does get <6 calls/sec but tends to drop below ANPA *fc* range; higher LANO calls tend to have inflection.



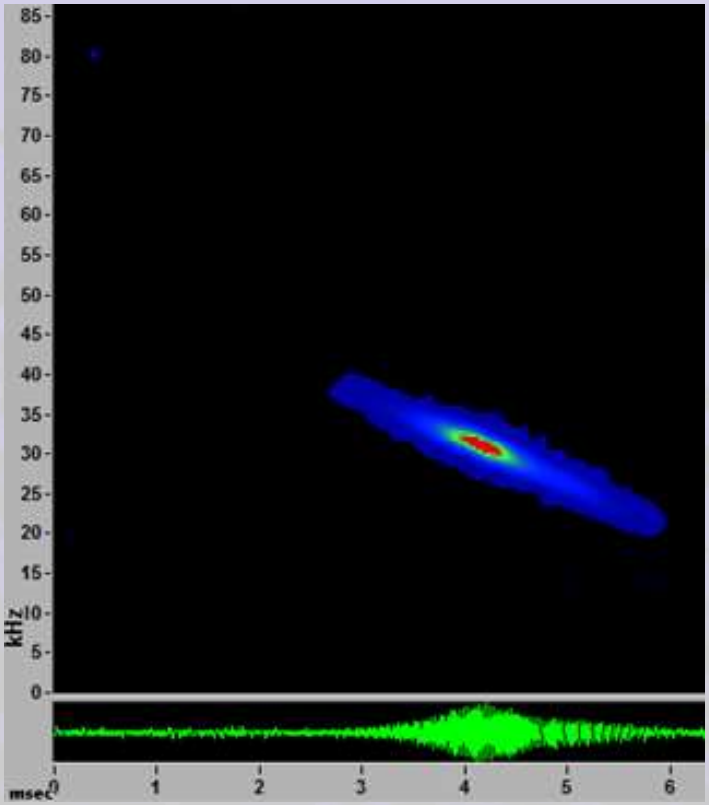
Townsend's Big-eared Bat (*Corynorhinus townsendii*)

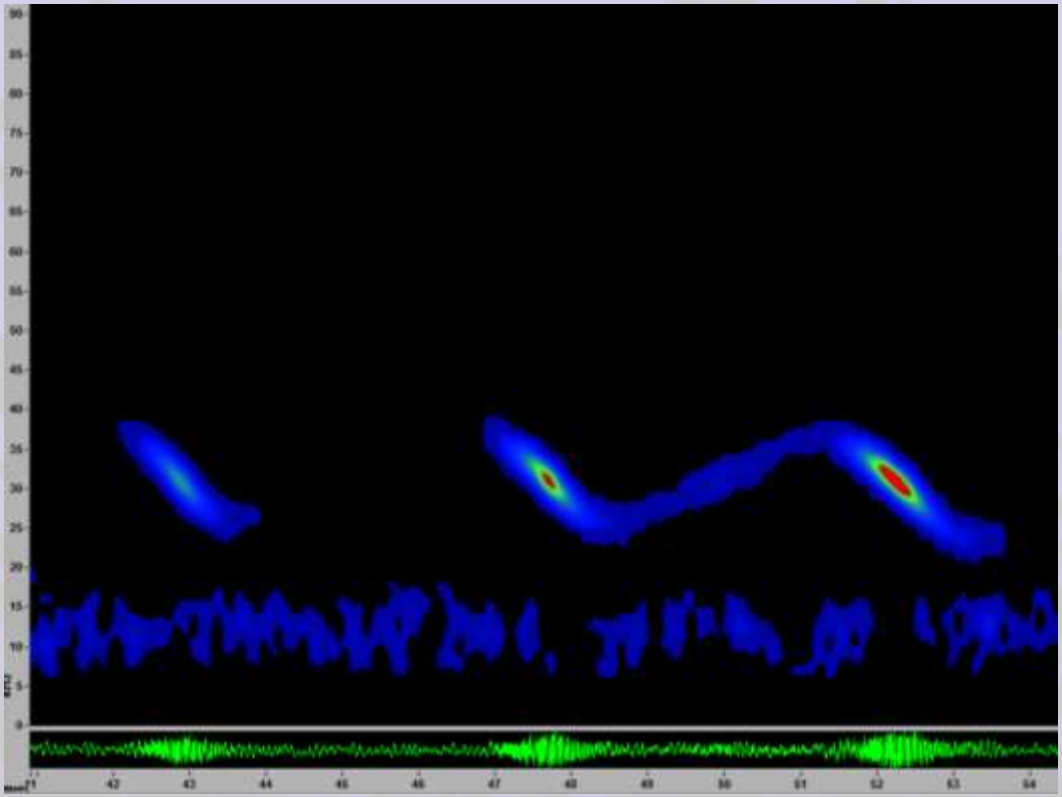
= COTO



COTO_time_expanded

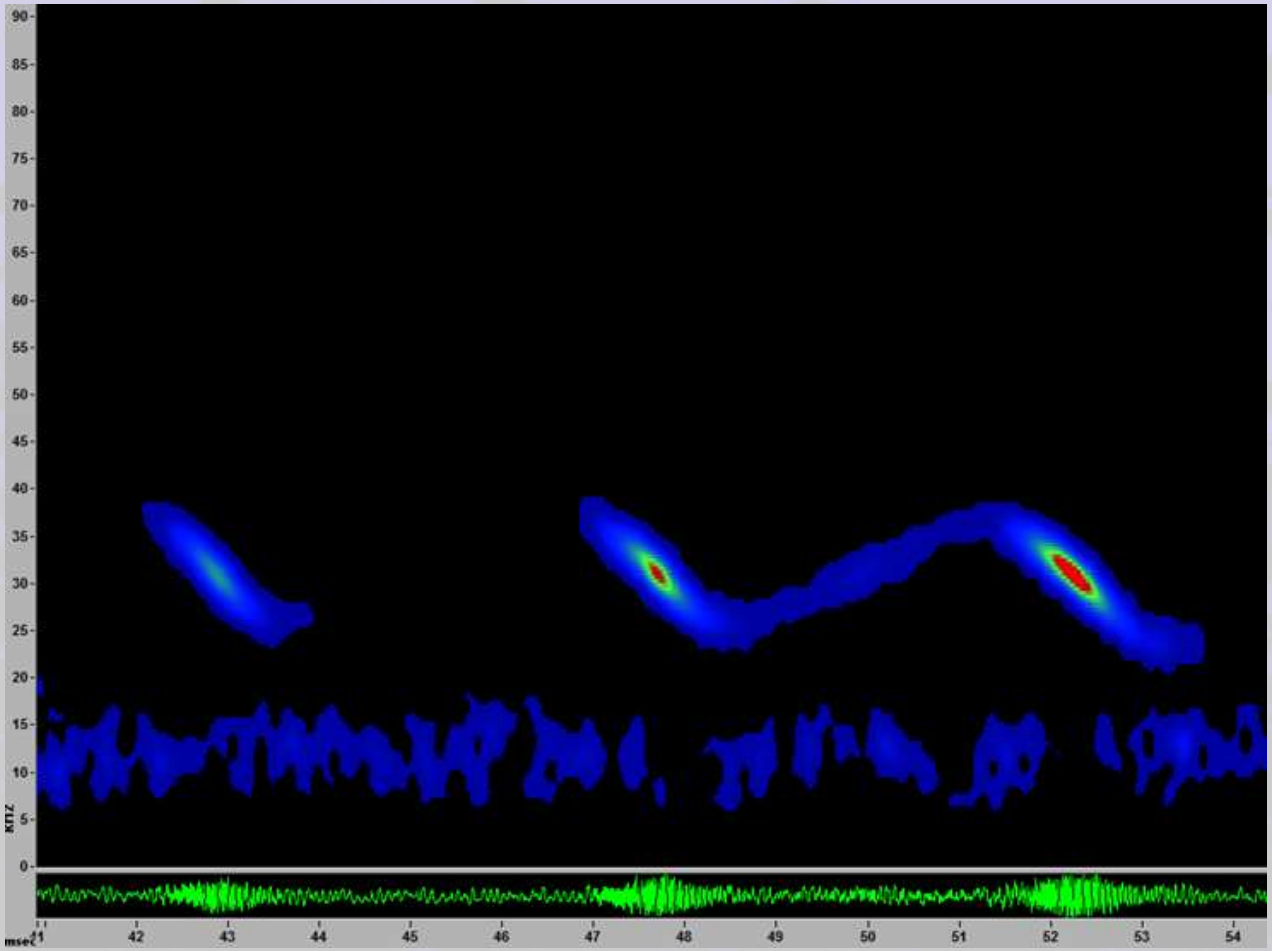
COTO Call Shapes





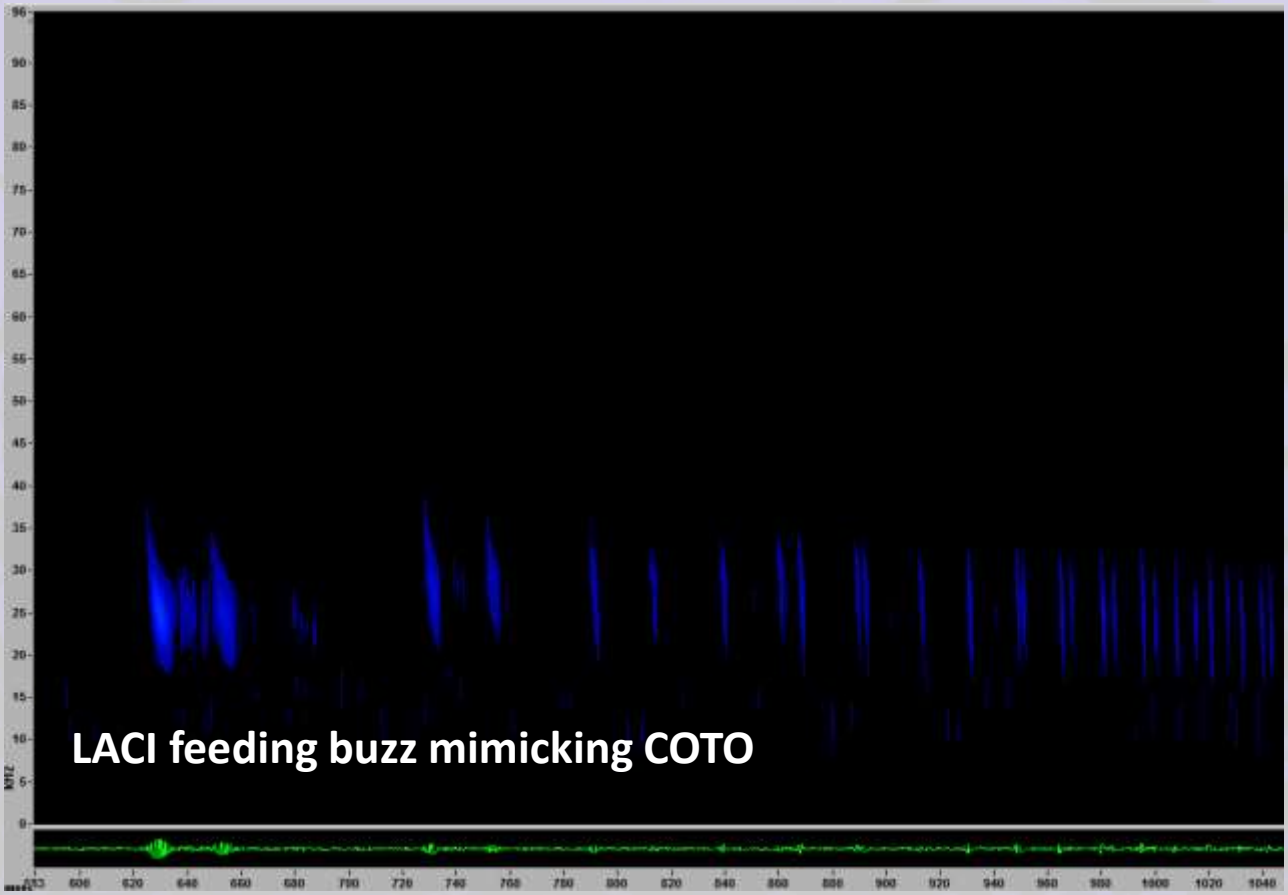
- low intensity calls that are difficult to detect; harmonics may be present
- *f*max may alternate between primary call component and harmonic
- For search phase calls, COTO typically have high *f* <50 kHz, *f*c <32 kHz, and *f*max <41 kHz

COTO Definitive Characteristics

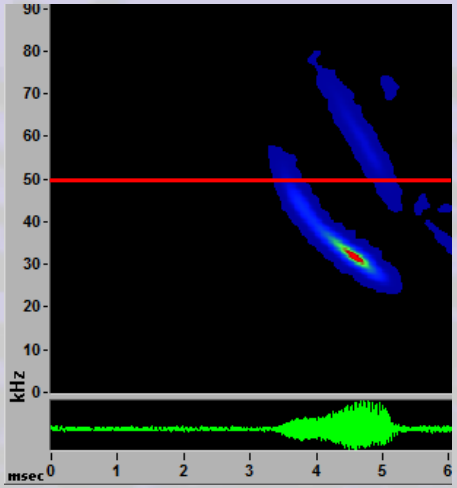


- **Simple linear FM sweep** (sometimes with upsweep or plateau at onset- **NO** knee or upward facing curvature toward the end of call)
- **Squiggle call with 5-7 ms intervals**

COTO Similar Species



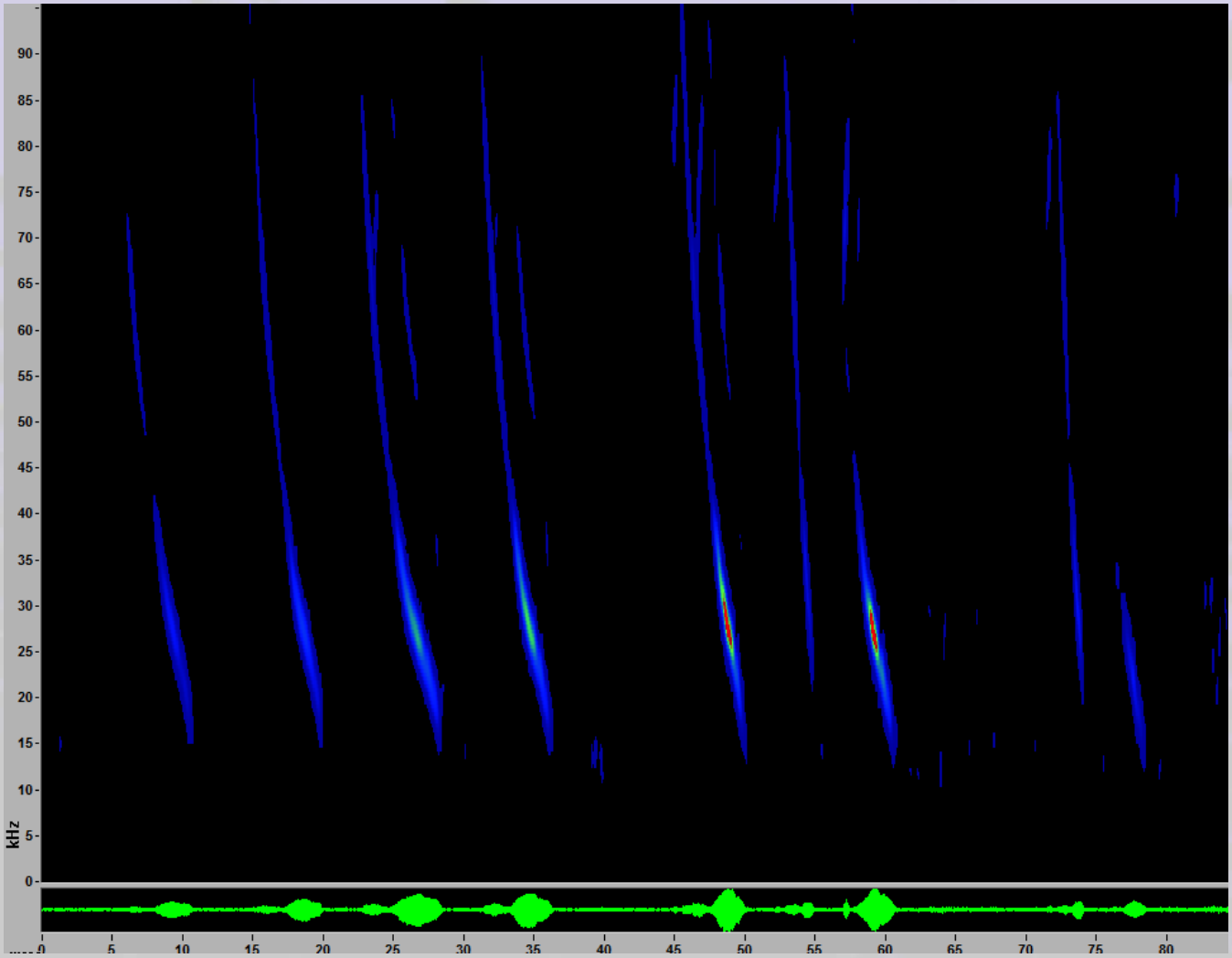
MYTH fragment; note converging harmonics and the fact that high *f* is out of COTO range



COTO vs. **MYTH**: Linear MYTH fragments and other partial calls without harmonics mimic COTO; look at entire call sequence for any curvature.

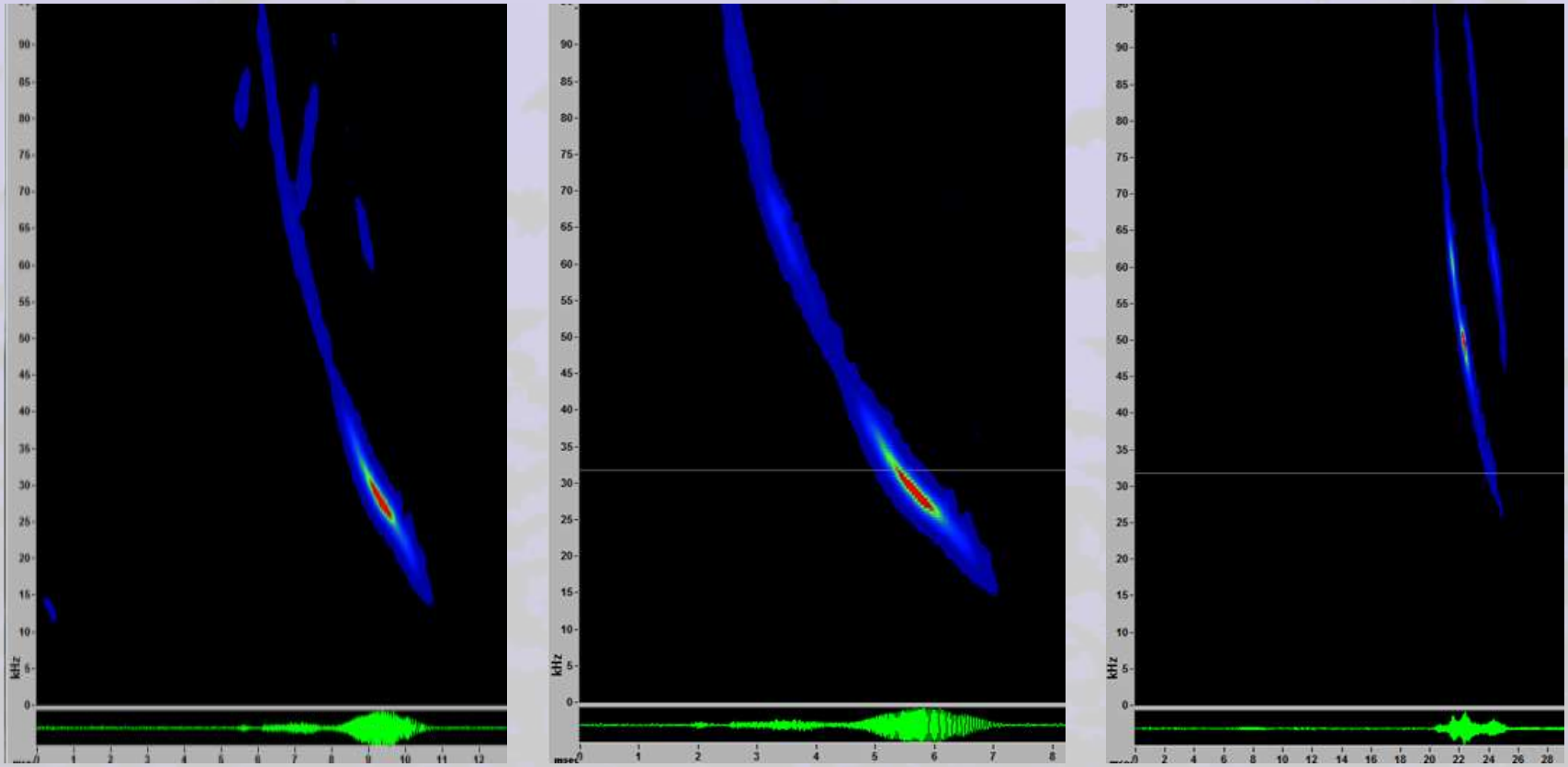
COTO vs. **LACI** vs. **LANO**: Approach calls and feeding buzzes of LACI/LANO may be similar in appearance and frequency to COTO, but those species may be ruled out by examining entire call sequence.

Fringed Myotis (*Myotis thysanodes*) = MYTH



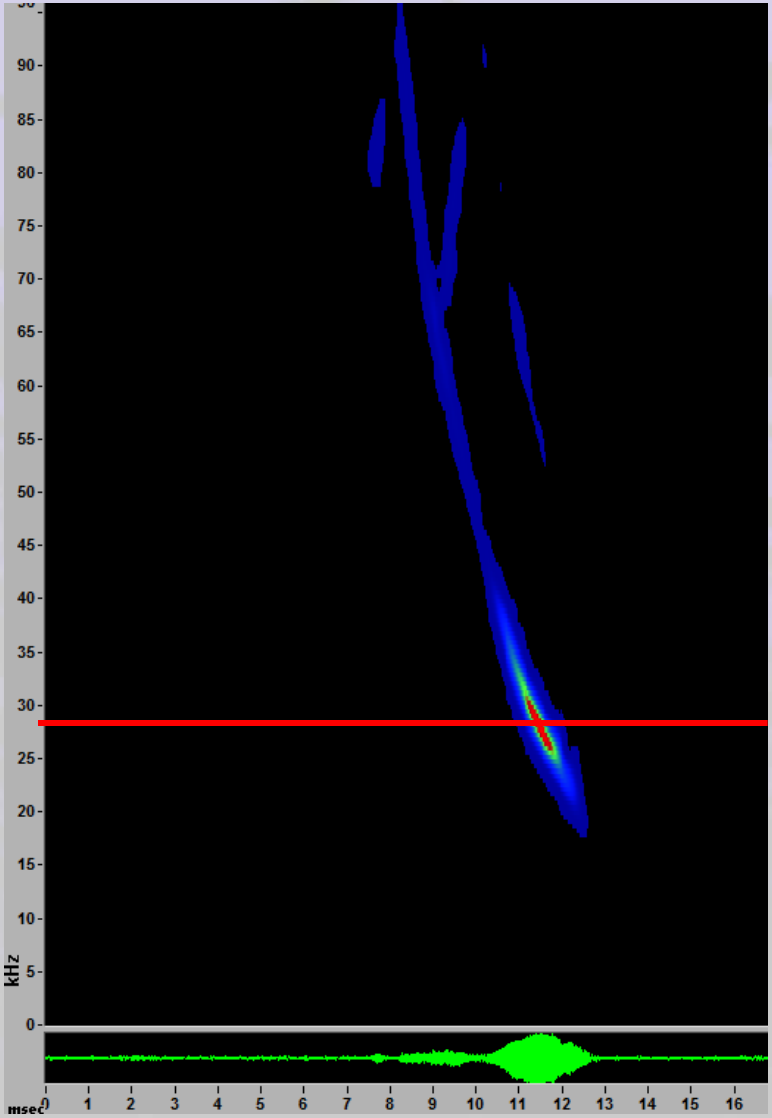
MYTH_time_expanded

MYTH Call Shapes



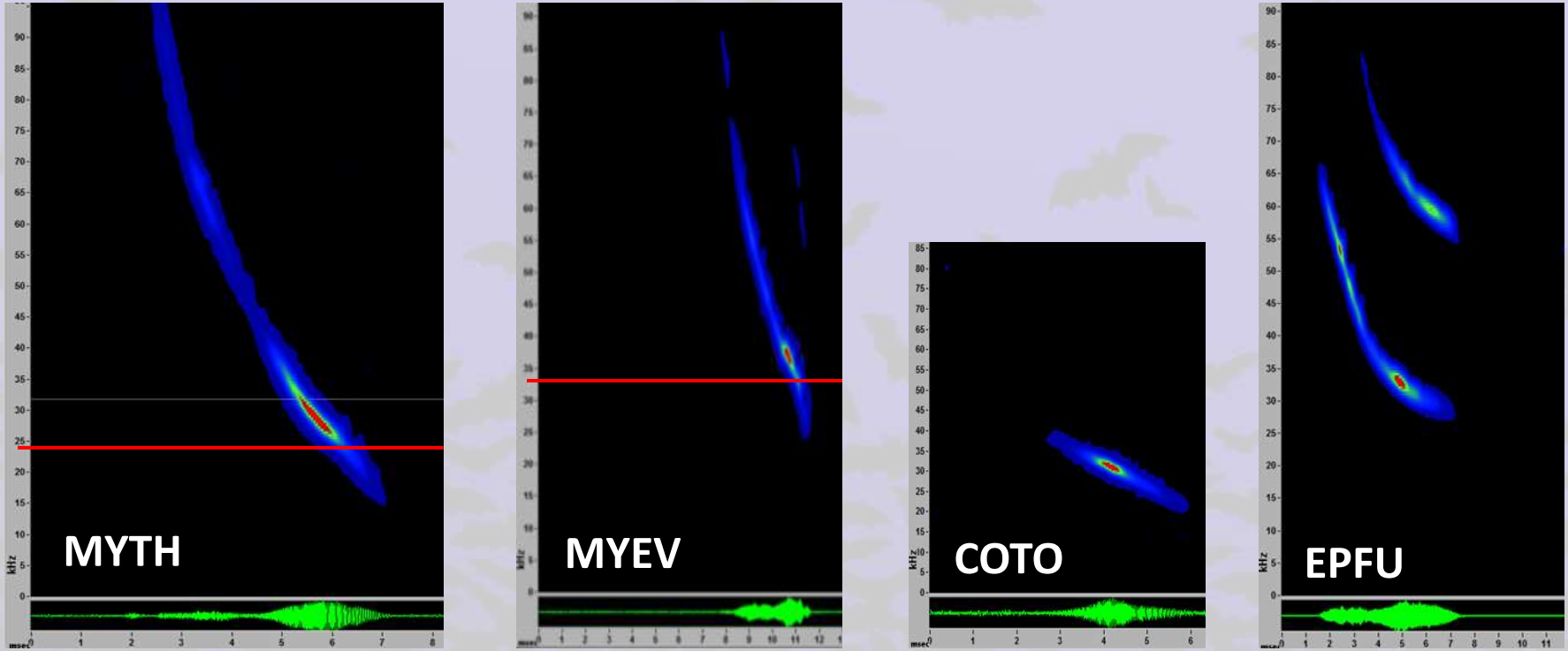
- Calls may have up to 100 kHz of bandwidth
- FM sweep may be nearly linear, making *f*c difficult to recognize
- Shaped like MYEV but distinguished by *f*c
- Converging harmonics

MYTH Definitive Characteristics



- Continuous steep shape, especially with harmonics
- *f*c < 28 kHz (and usually into the 20s), total slope >15, and low *f* < 24kHz
- *f*c < 28 kHz, total slope >10, and low *f* < 24kHz diagnostic IF harmonics converge toward primary call component

MYTH Similar Species

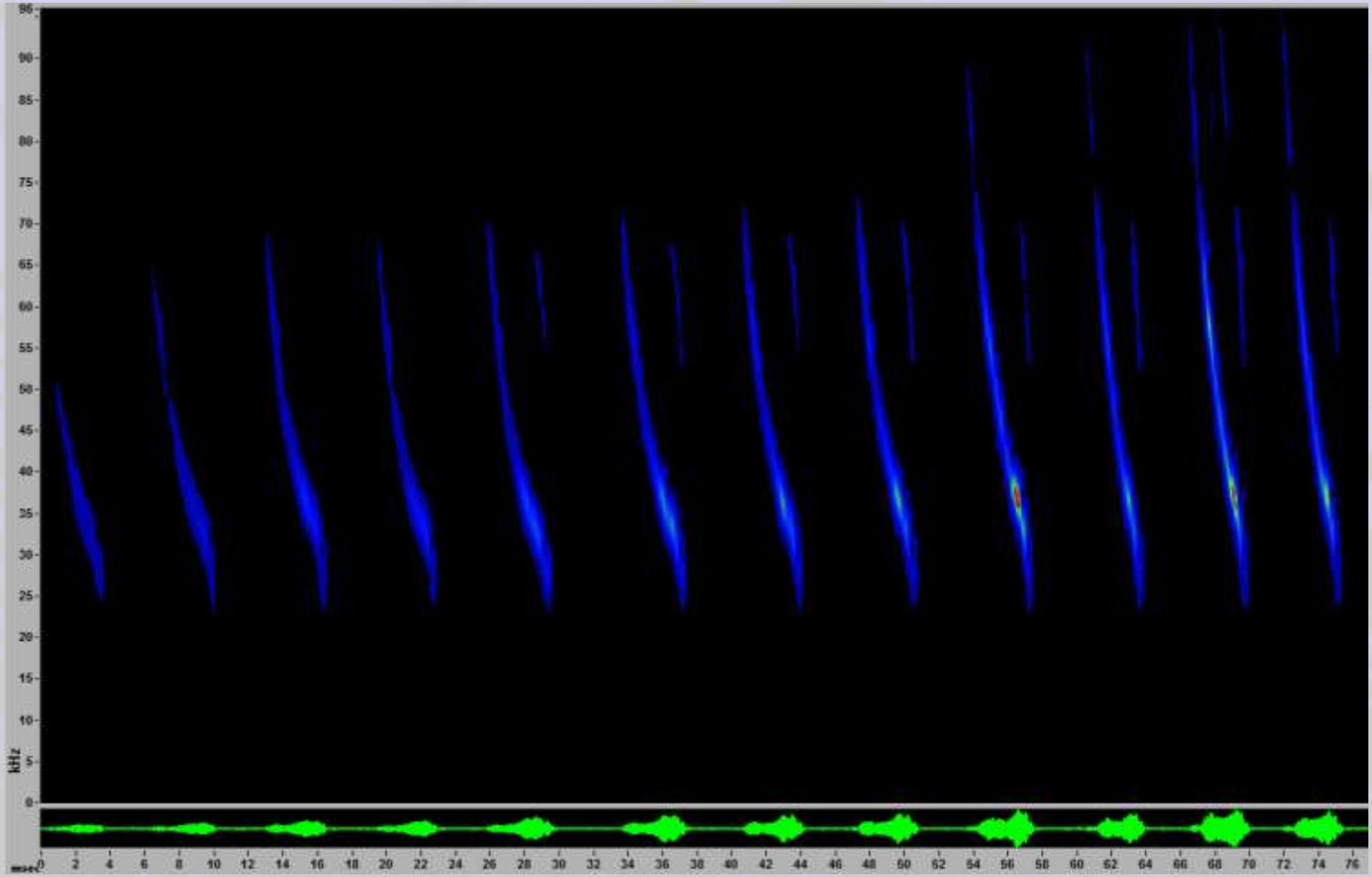


MYTH vs. **MYEV**: Calls are almost identical in appearance. Use *f*c and low *f* to distinguish.

MYTH vs. **COTO**: MYTH fragments with high *f* <50 kHz can look like COTO; use high *f* and converging harmonics to rule out COTO.

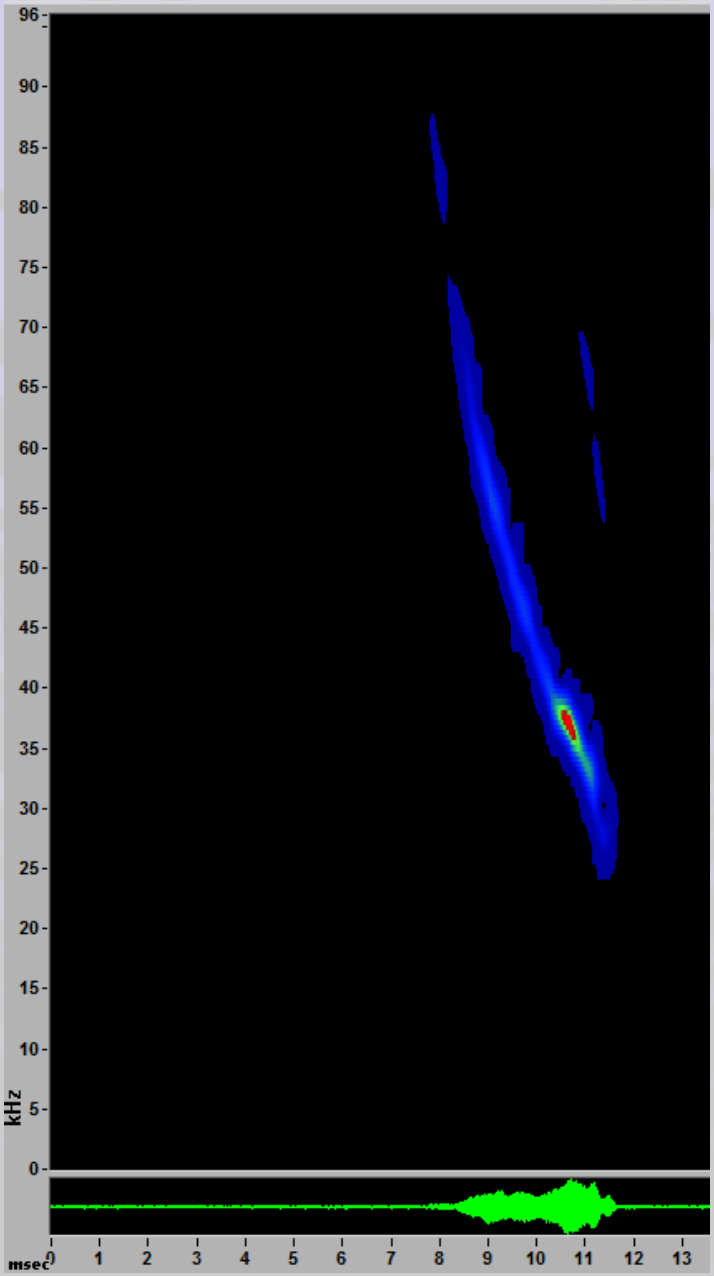
MYTH vs. **EPFU/ANPA**: Lower slope and frequency MYTH overlap EPFU/ANPA. Look at geographical range for COTO vs. ANPA, converging harmonics, and total slope to distinguish COTO from both EPFU and ANPA.

Long-eared Myotis (*Myotis evotis*) = MYEV



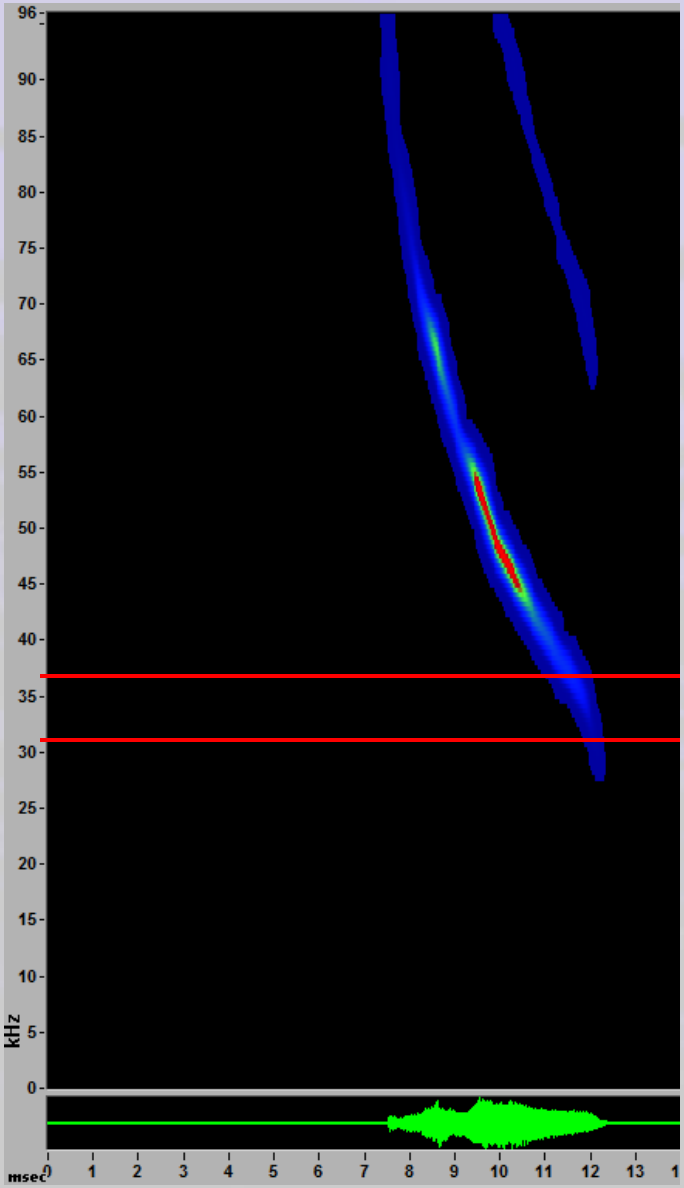
MYEV_time_expanded

MYEV Call Shapes



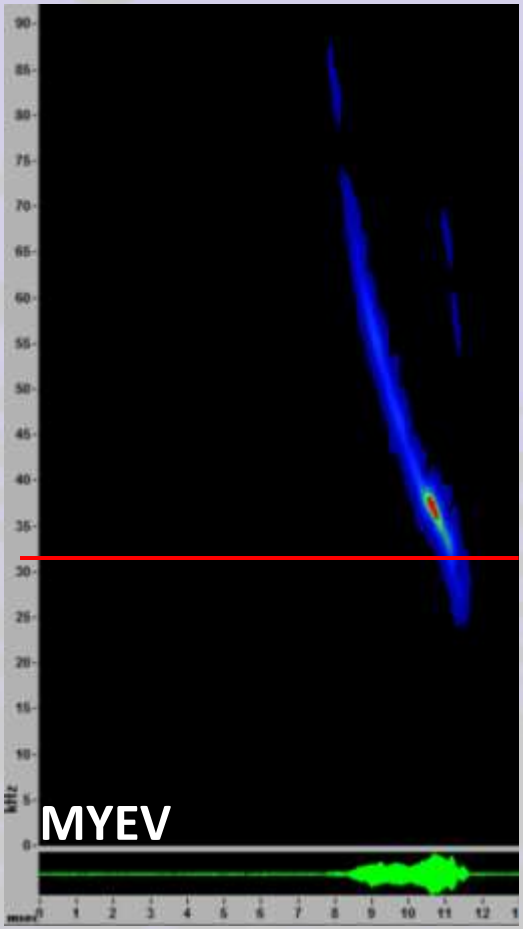
- Calls may have up to 100 kHz of bandwidth
- FM sweep is sometimes nearly linear, making *f*c difficult to recognize
- Shaped like MYTH but distinguished by *f*c
- Converging harmonics

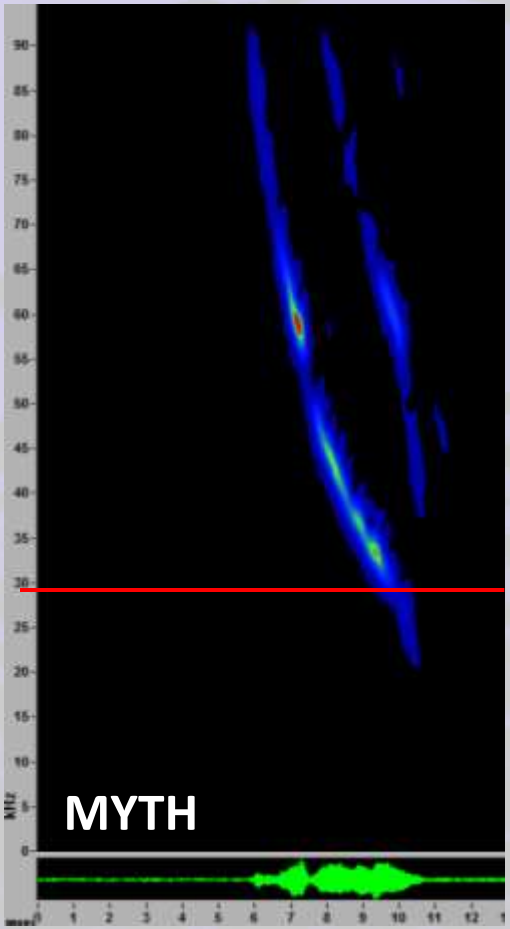
MYEV Definitive Characteristics

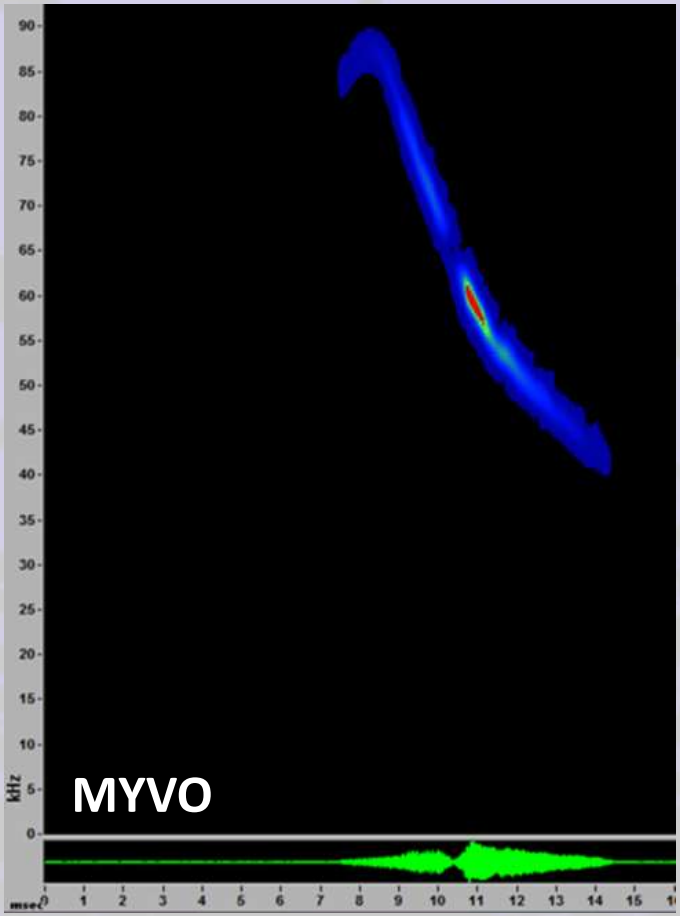


- Converging harmonics
- *fc*: 32-36 kHz

MYEV Similar Species





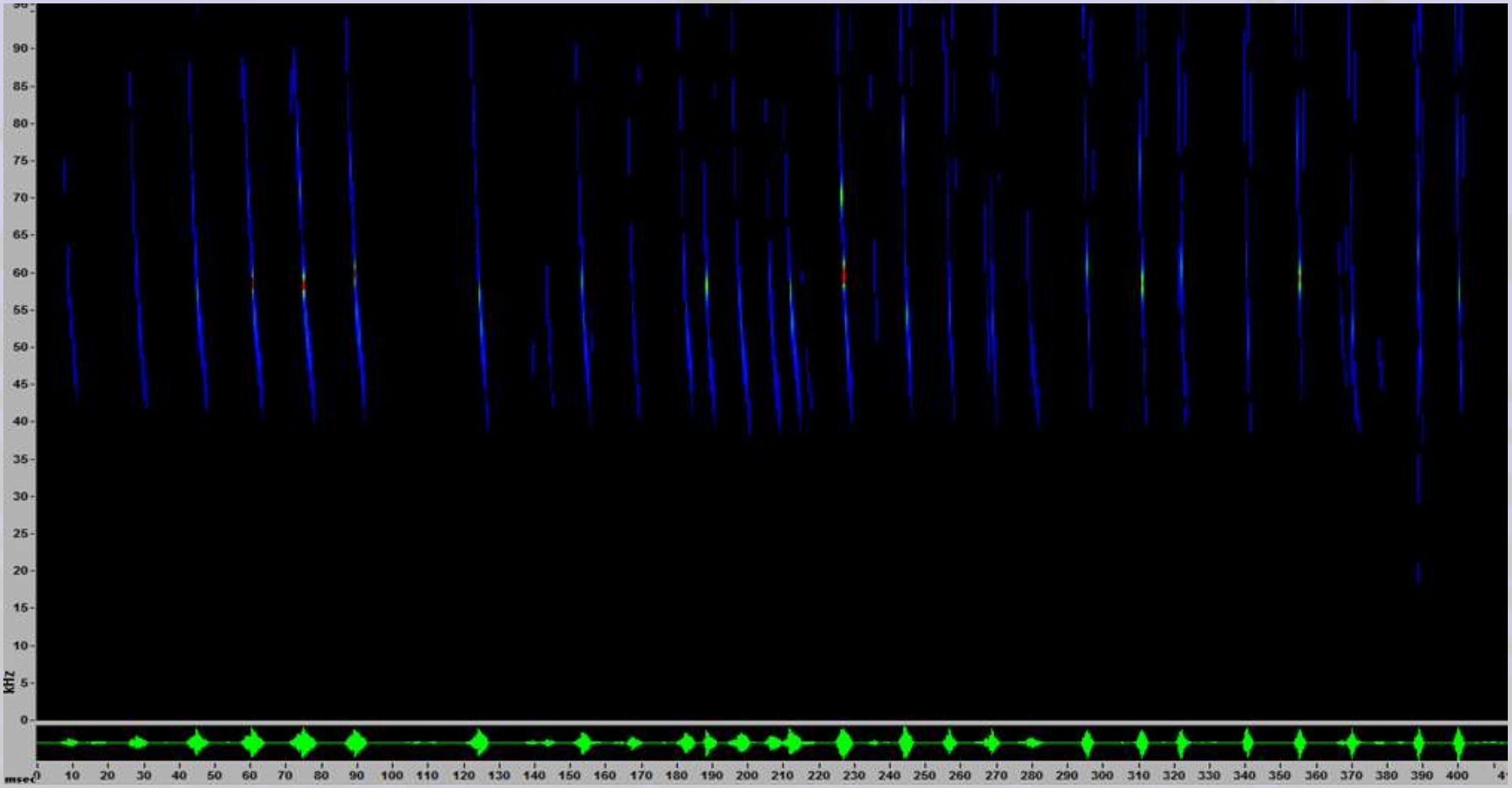


MYEV vs. **MYTH**: Calls are almost identical in appearance and characteristics; use *f*c to distinguish.

MYEV vs. **MYVO**: Lower, non-diagnostic MYVO calls can have overlap; unable to distinguish unless upsweep is present for MYVO.

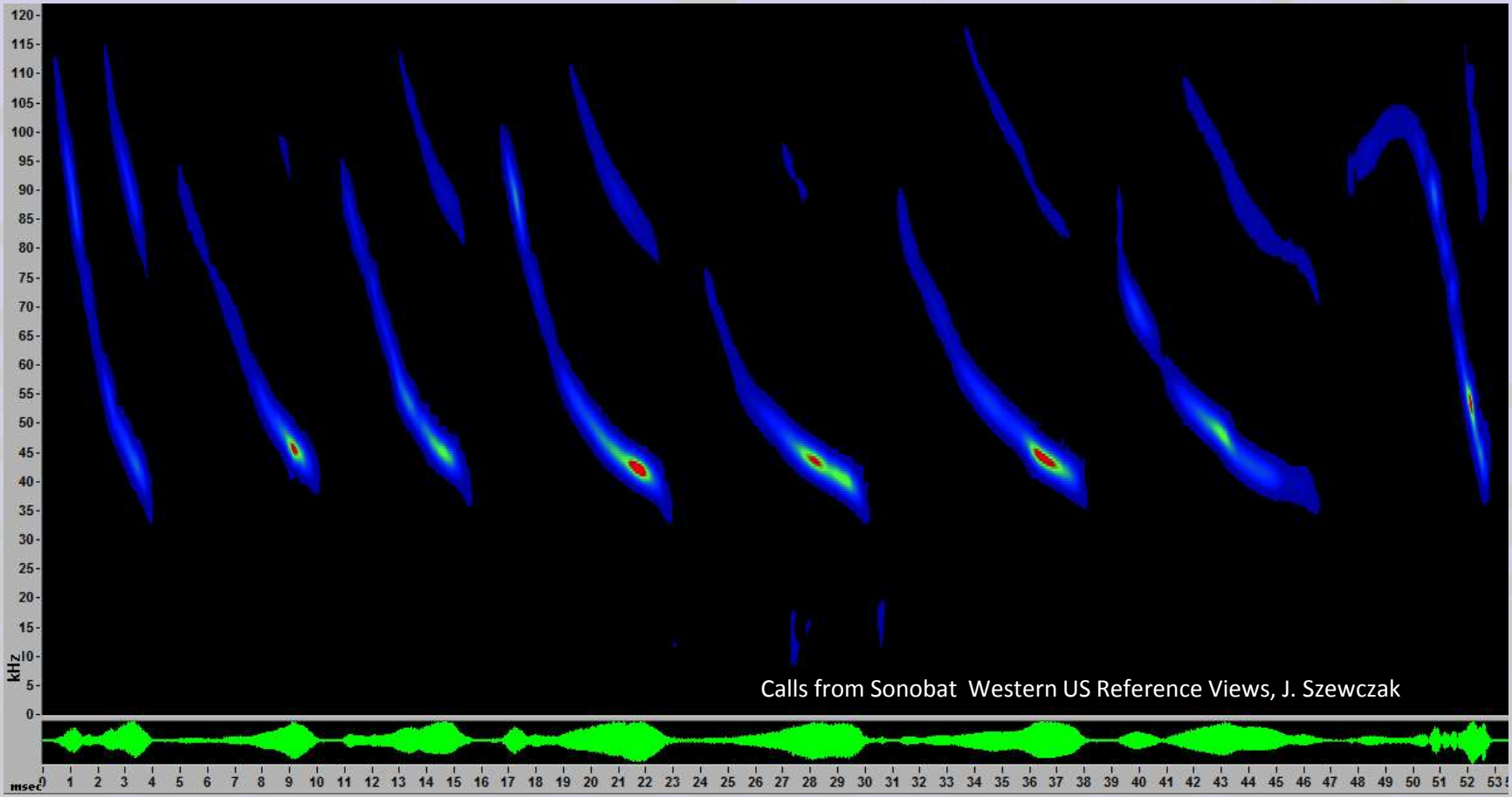
MYEV vs. **MYSE**: Calls are similar in appearance and characteristics;use *f*c to distinguish.

Long-legged Myotis (*Myotis volans*) = MYVO



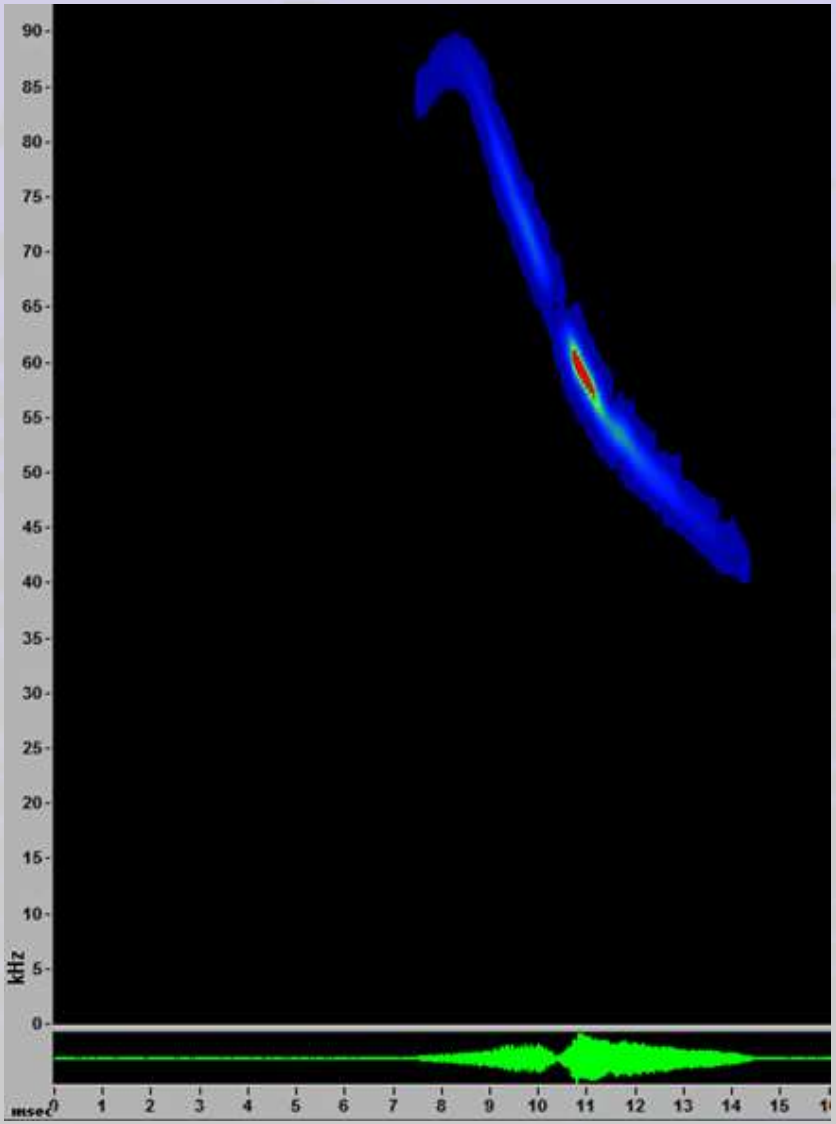
MYVO_time_expanded

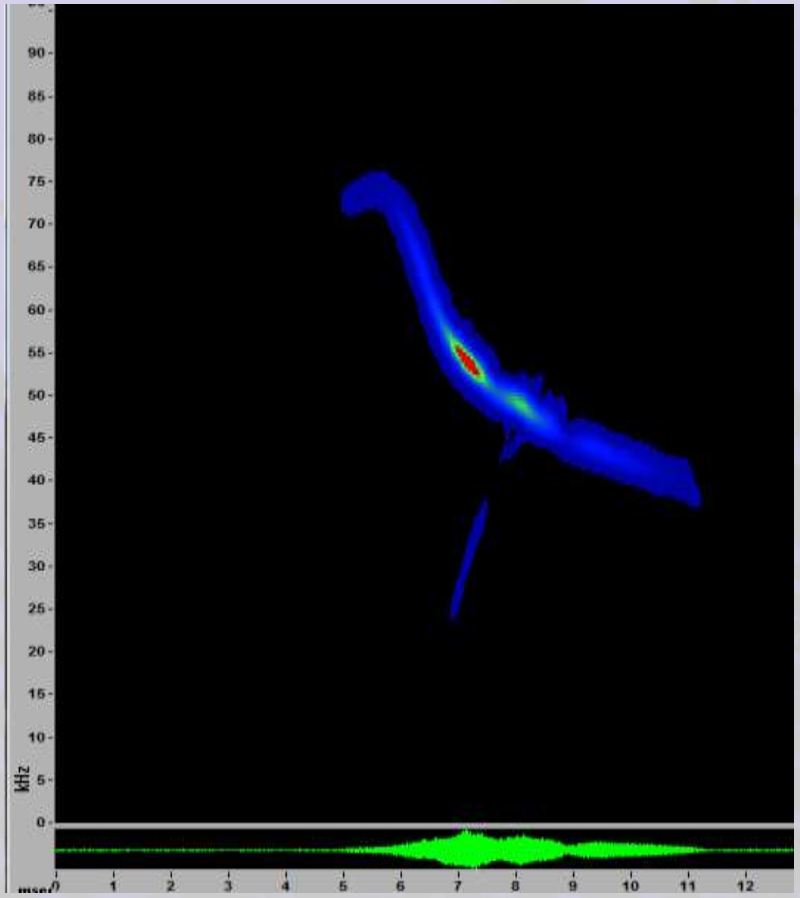
MYVO Call Shapes



- Upsweep into call is uncommon, but diagnostic
- Generally has steeper, shorter calls in open, uncluttered areas
- Note alias harmonics may resemble upsweep in truncated spectrograms produced by SM2 recordings with a sampling frequency of 192 kHz

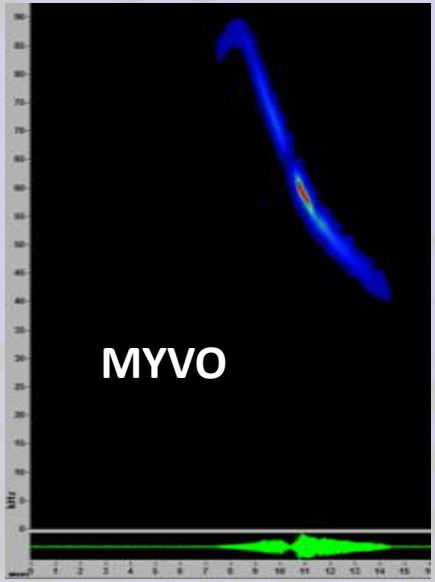
MYVO Definitive Characteristics

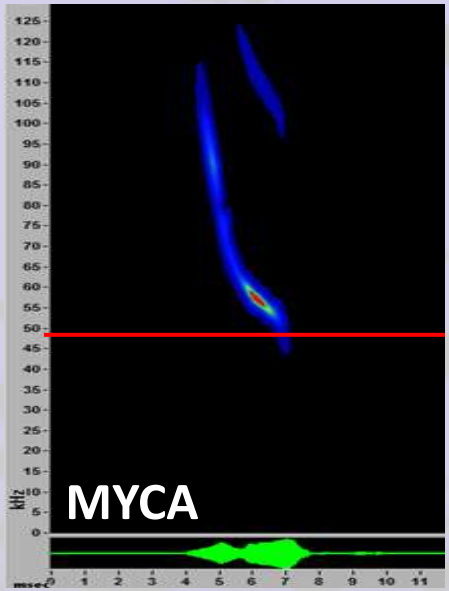


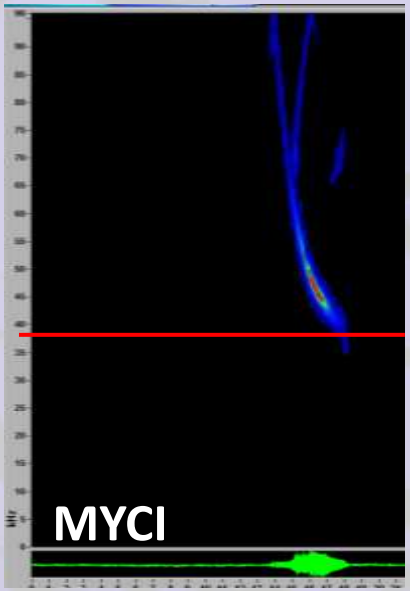


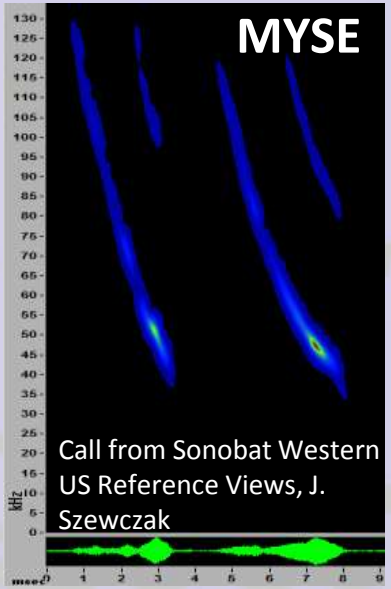
- **Upward sweep into the call is diagnostic, but rare**

MYVO Similar Species







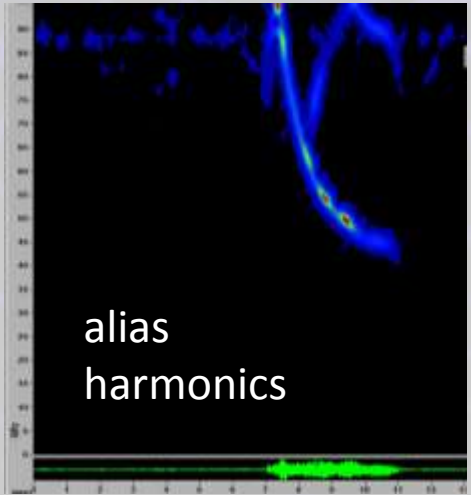


MYVO vs. **MYCA** **MYVO** vs. **MYCI** **MYVO** vs. **MYEV** **MYVO** vs. **MYSE**

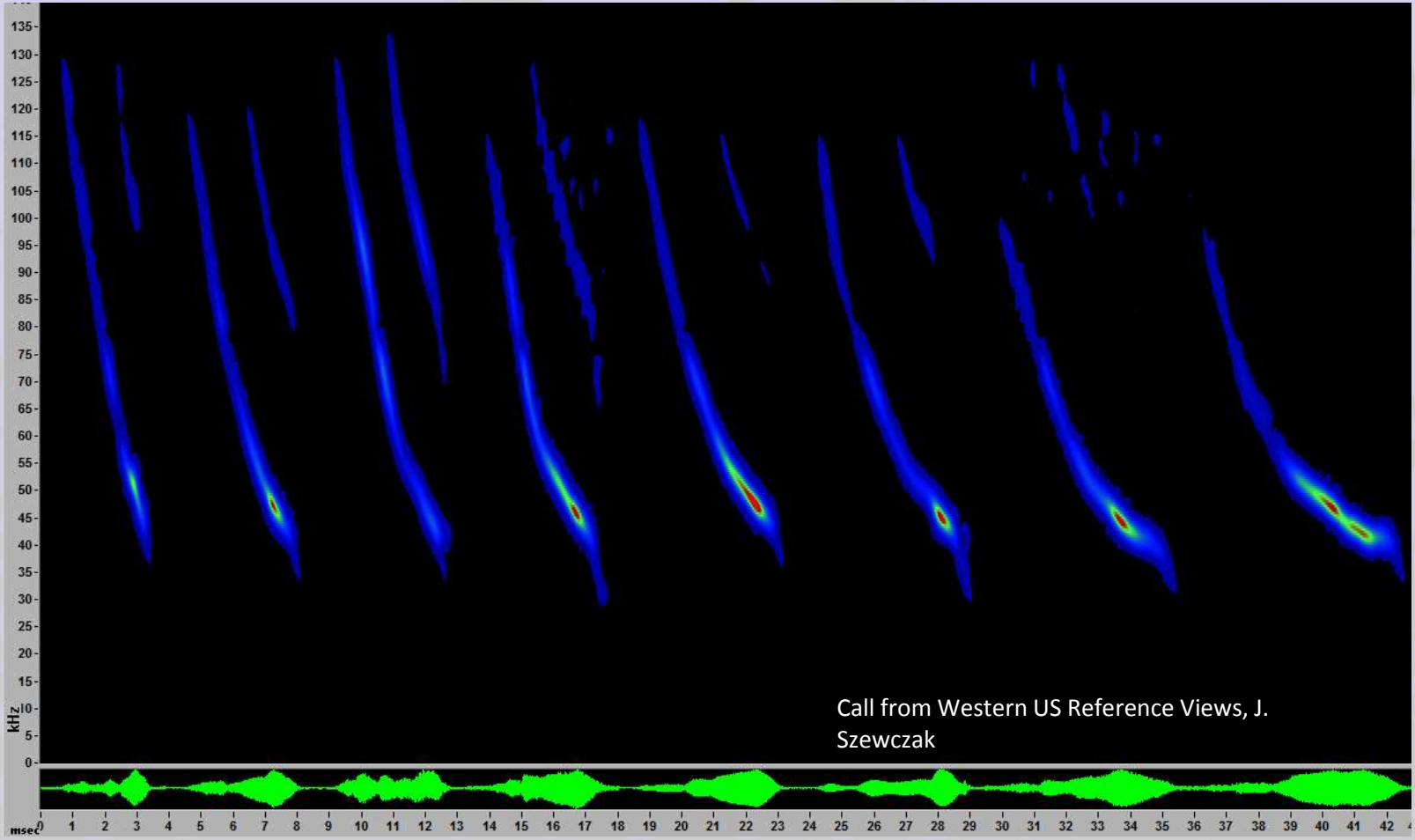
For all of these comparisons, non-diagnostic calls can be similar in appearance; unable to distinguish unless there is an upsweep into the call, which is diagnostic for MYVO.

BEWARE of ALIAS HARMONICS THAT CAN RESEMBLE UPSWEEP INTO MYVO CALLS

Alias harmonics are upside-down harmonics resulting from truncation of the upper limits of calls due to sampling frequency limitations (e.g., 96 kHz maximum for SM2 Bat+ detectors with sampling frequency set at 192 kHz). These are typically sharply inflected at the upper end of the upsweep relative to the actual MYVO upsweep.

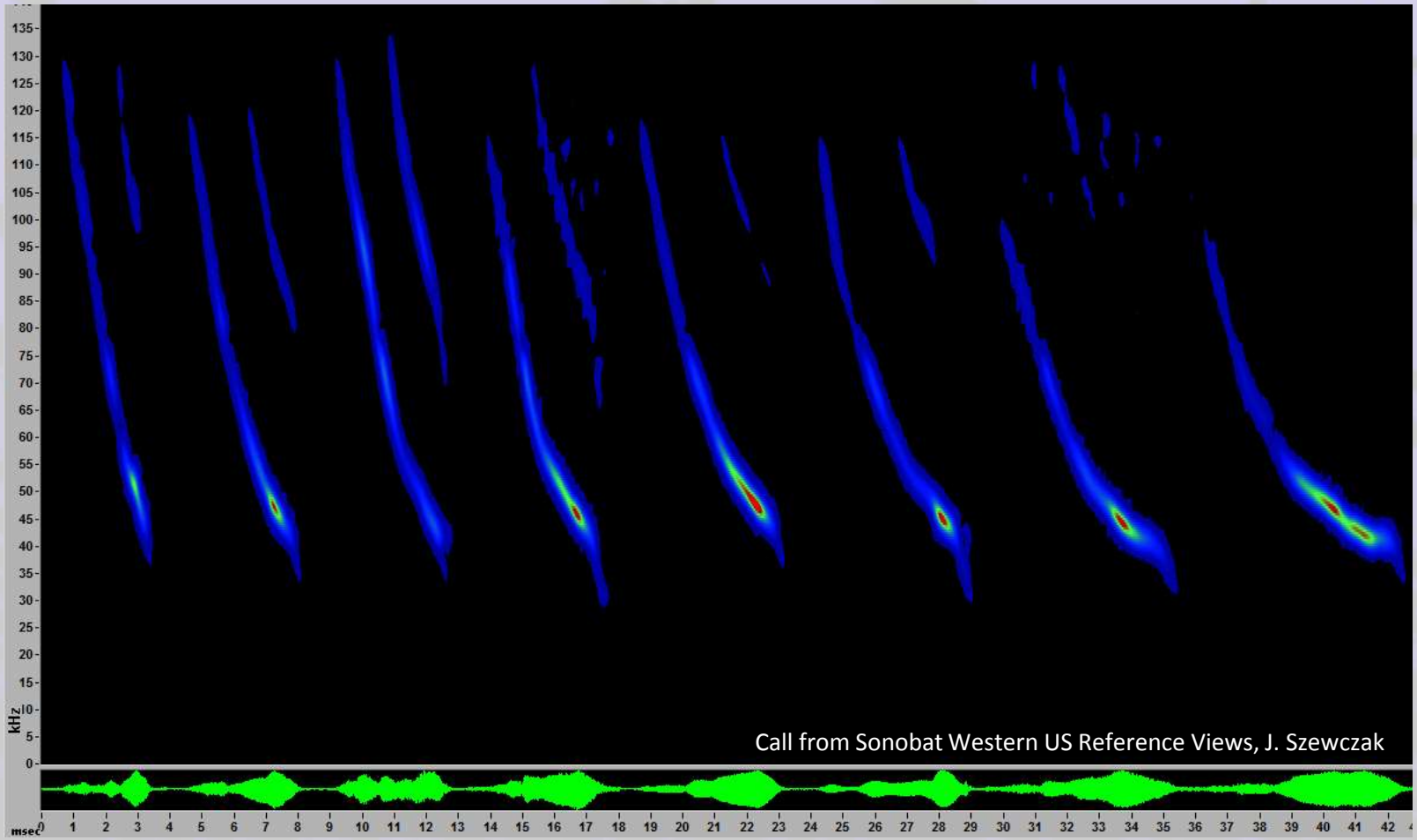


Northern Myotis (*Myotis septentrionalis*) =MYSE



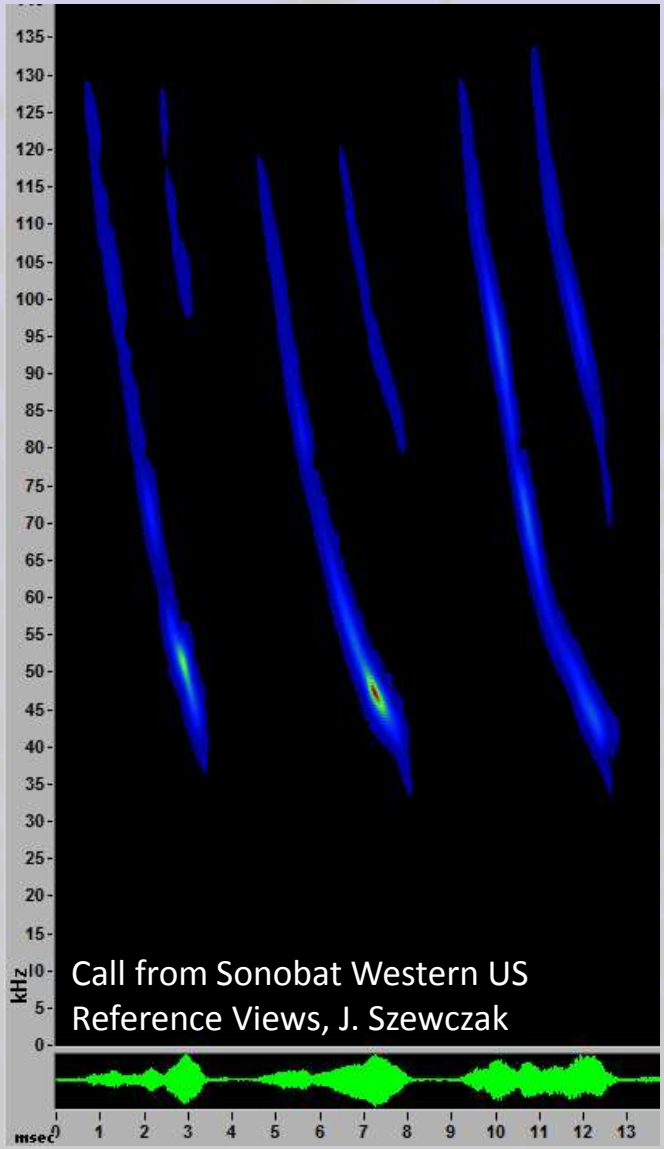
Call from Western US Reference Views, J. Szewczak

MYSE Call Shapes



- FM sweep may be nearly linear making *f*c difficult to determine
- Shaped like MYEV and MYTH but distinguished by fc
- Quiet but consistent calls

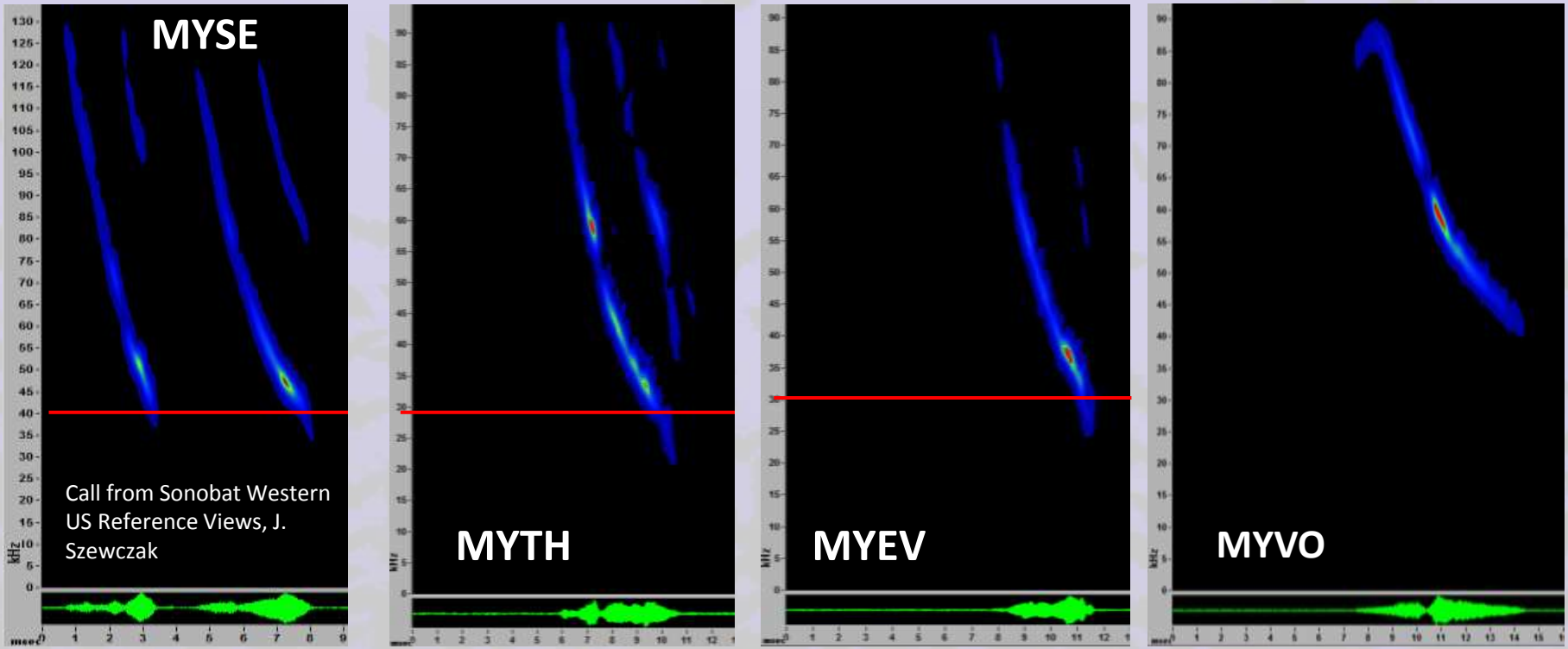
MYSE Definitive Characteristics



Call from Sonobat Western US Reference Views, J. Szewczak

- Presence in Montana is uncertain. Genetic testing of museum specimens is underway. Follow-up capture and genetic testing along eastern border may be needed
- Calls shaped like MYTH and MYEV with up to 100 kHz of bandwidth
- Fc > 40 kHz is our initial cutoff for hand review, but we are just starting to look for calls of this species

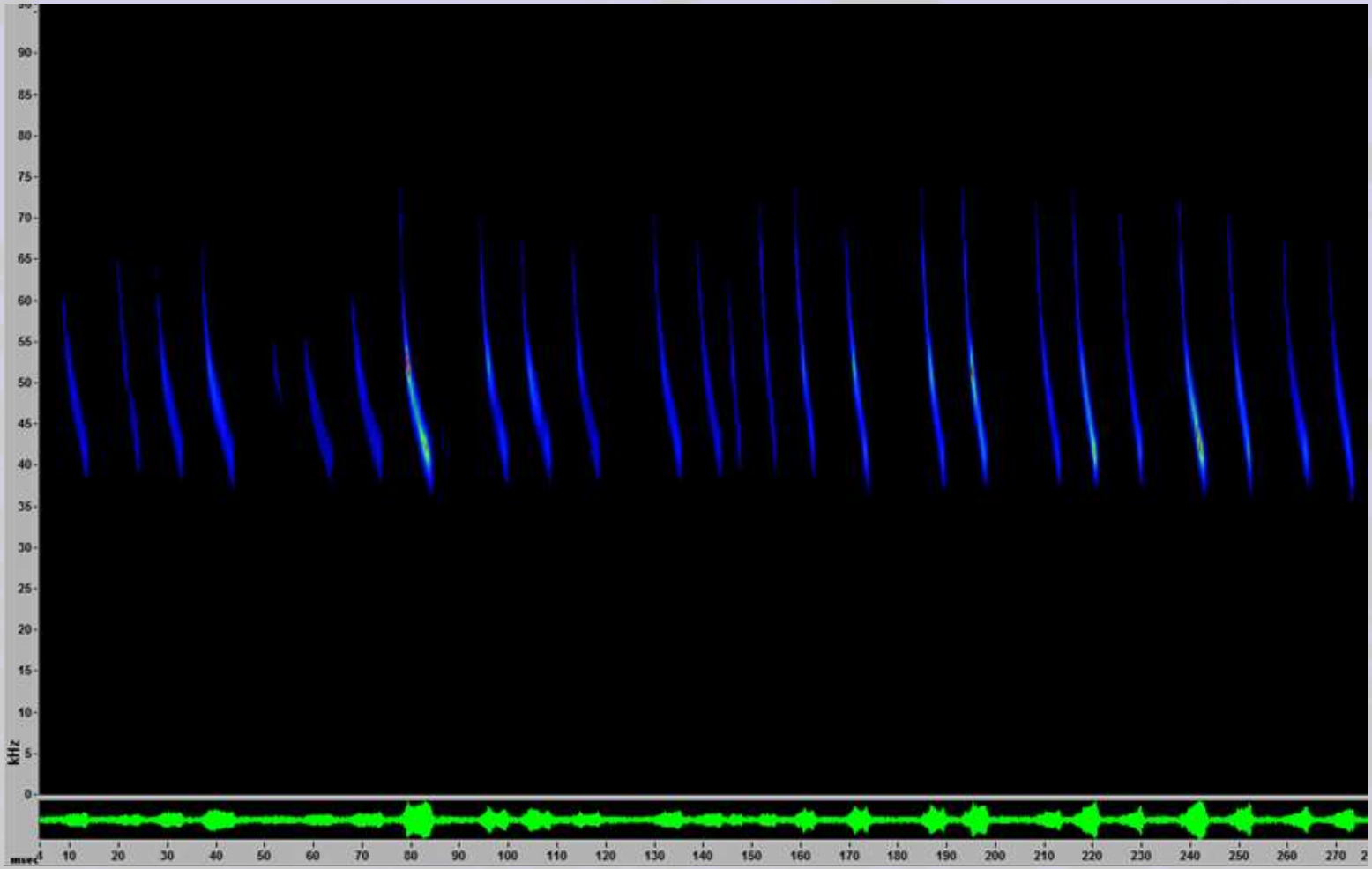
MYSE Similar Species



MYSE vs. **MYTH/MYEV**: Similarly shaped steep calls with overlap in non-diagnostic calls. *f*c < 28 kHz is diagnostic for MYTH, *f*c between 32-36 kHz is diagnostic for MYEV, and *f*c into the 40 kHz range is diagnostic for MYSE.

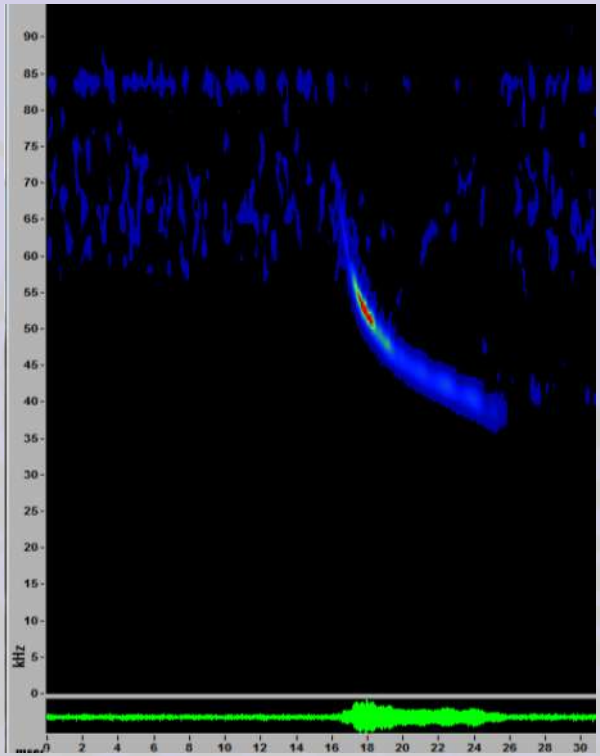
MYSE vs. **MYVO:** Non-diagnostic calls overlap; unable to distinguish unless there is an upsweep into the call (which is diagnostic for MYVO).

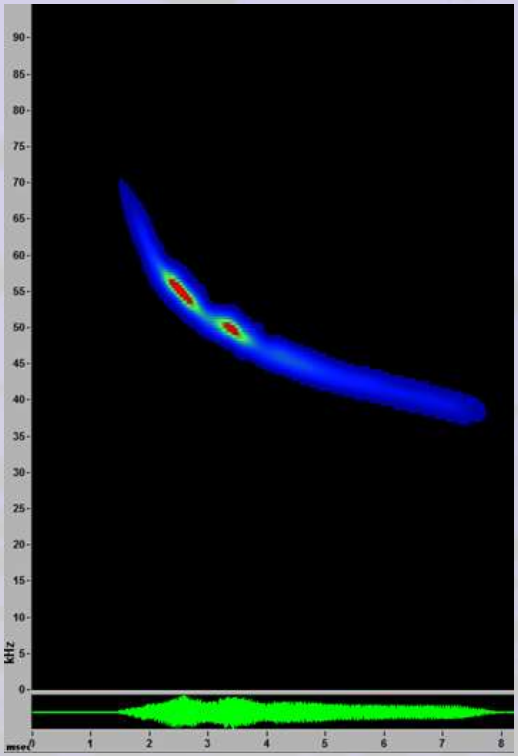
Little Brown Myotis (*Myotis lucifugus*) = MYLU

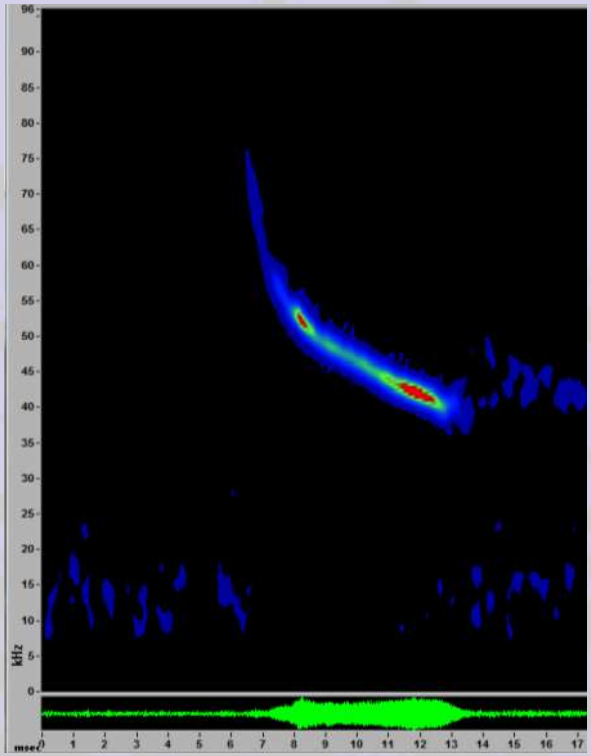


MYLU_time_expanded

MYLU Call Shapes

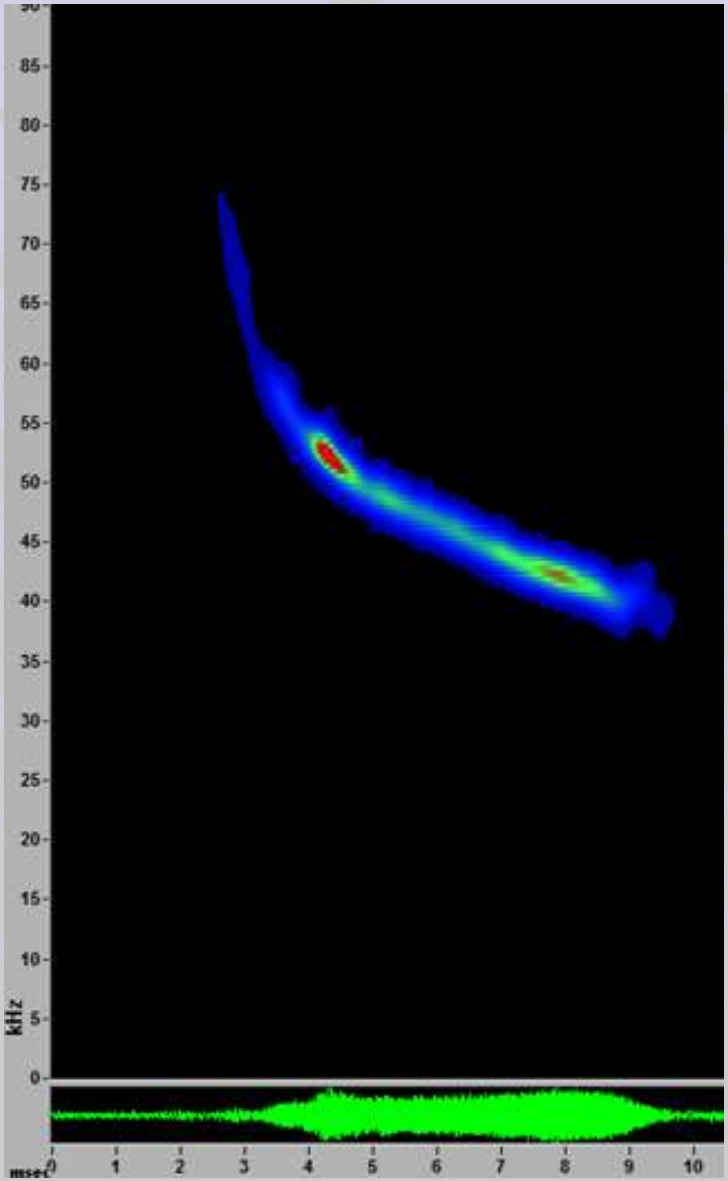






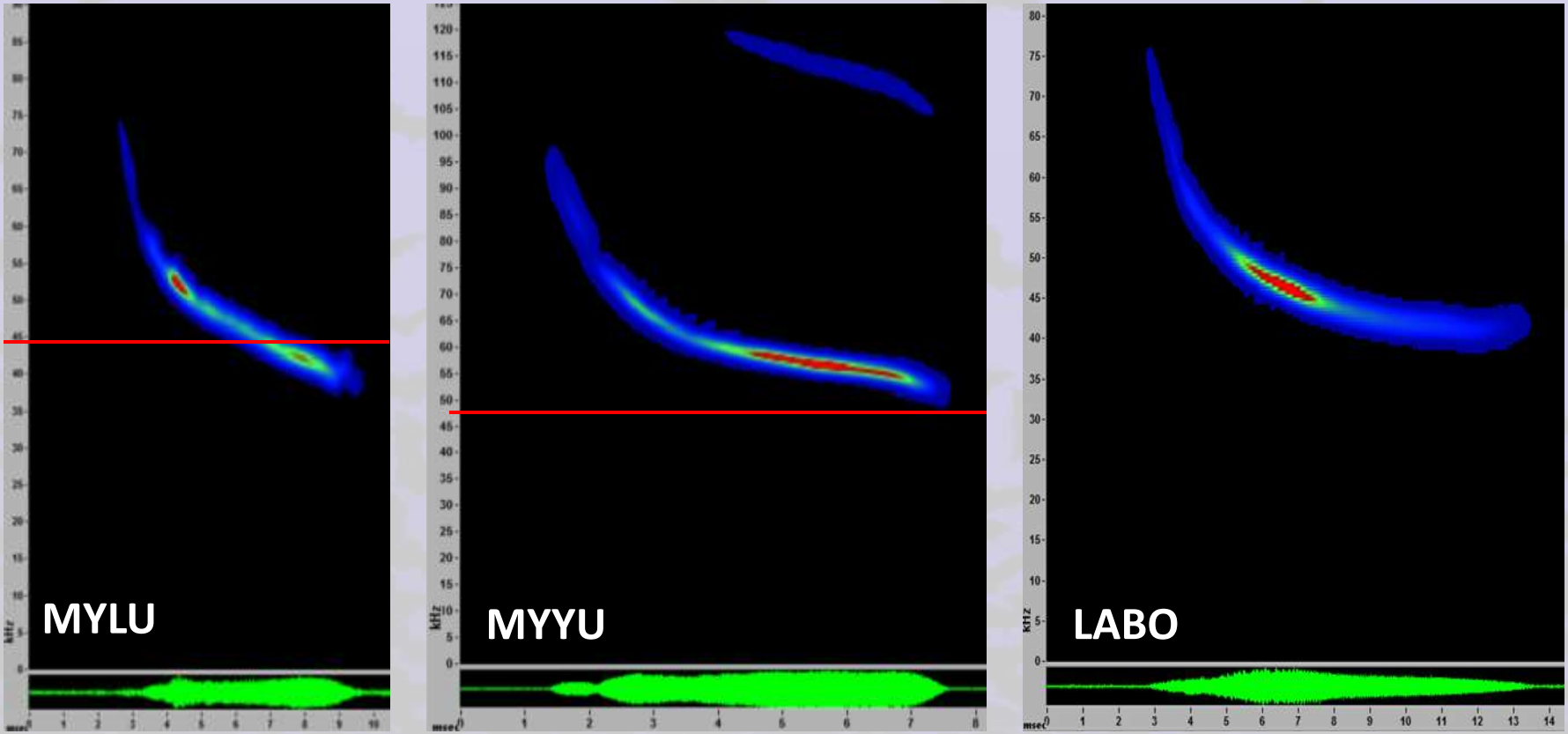
- Sometimes have multiple power centers making calls appear clumpy
- Usually have inflection
- Can make the longest duration and lowest slope calls of all *Myotis*

MYLU Definitive Characteristics



- Duration > 7 ms
- Lower slope < 3
- *f*c < 44 diagnostic west of Continental Divide when comparing with MYYU

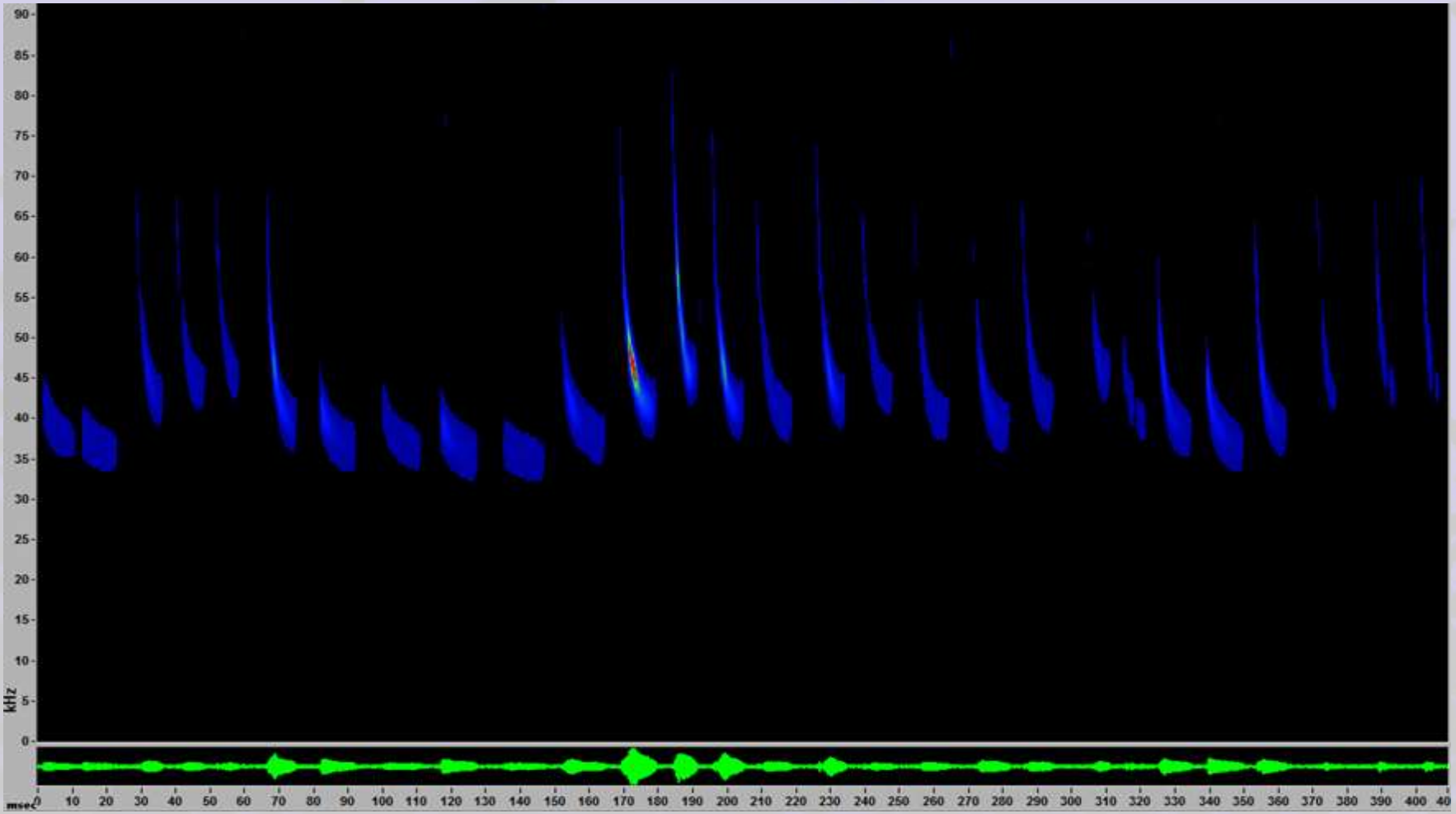
MYLU Similar Species



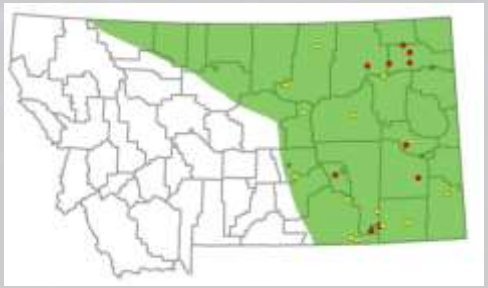
MYLU vs. **LABO**: LABO calls have up-turns at ends, smooth power centers and longer duration. LABO call sequences often have variable *f*c across the sequence (see next slide).

MYLU vs. **MYYU**: *f*c < 44 kHz distinguishes MYLU from MYYU where there is overlap in geographical range west of the Continental Divide.

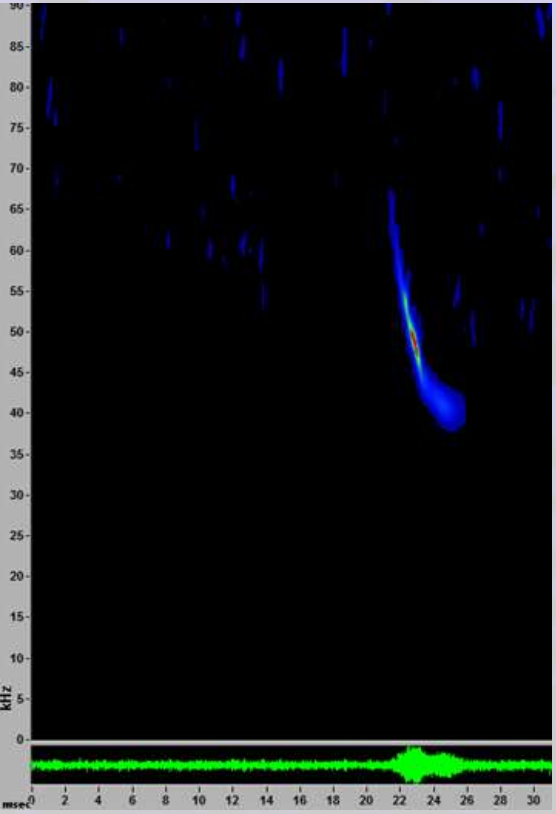
Eastern Red Bat (*Lasiurus borealis*) = LABO



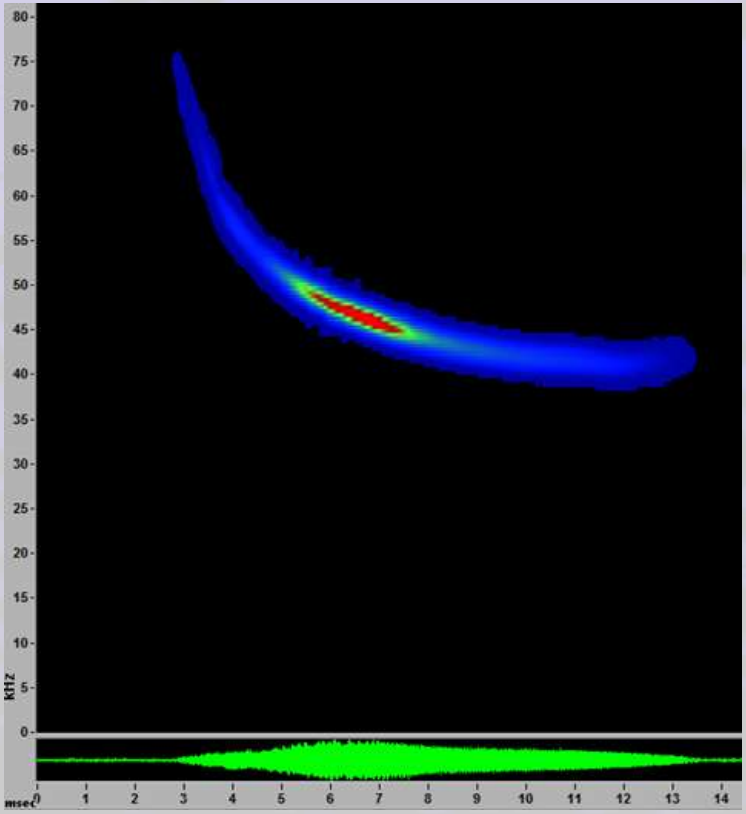
LABO_time_expanded



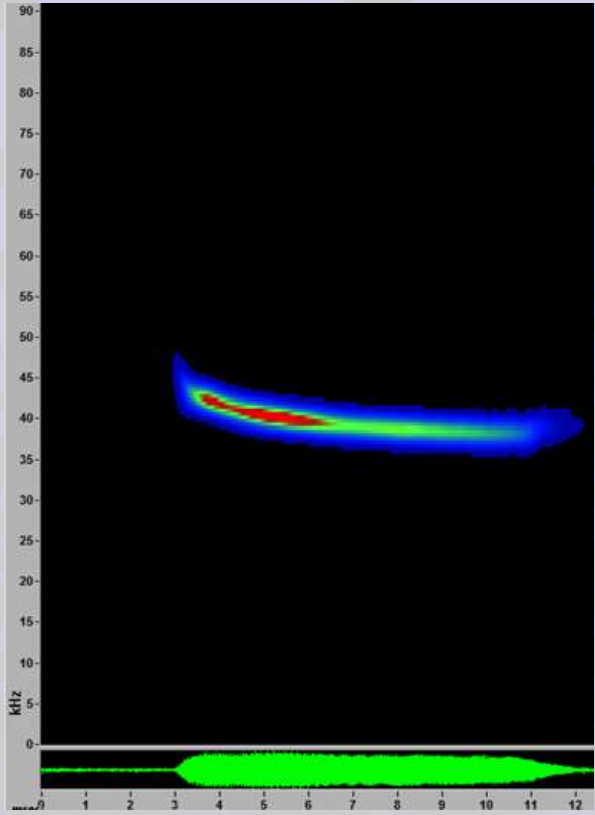
LABO Call Shapes



Short and steep

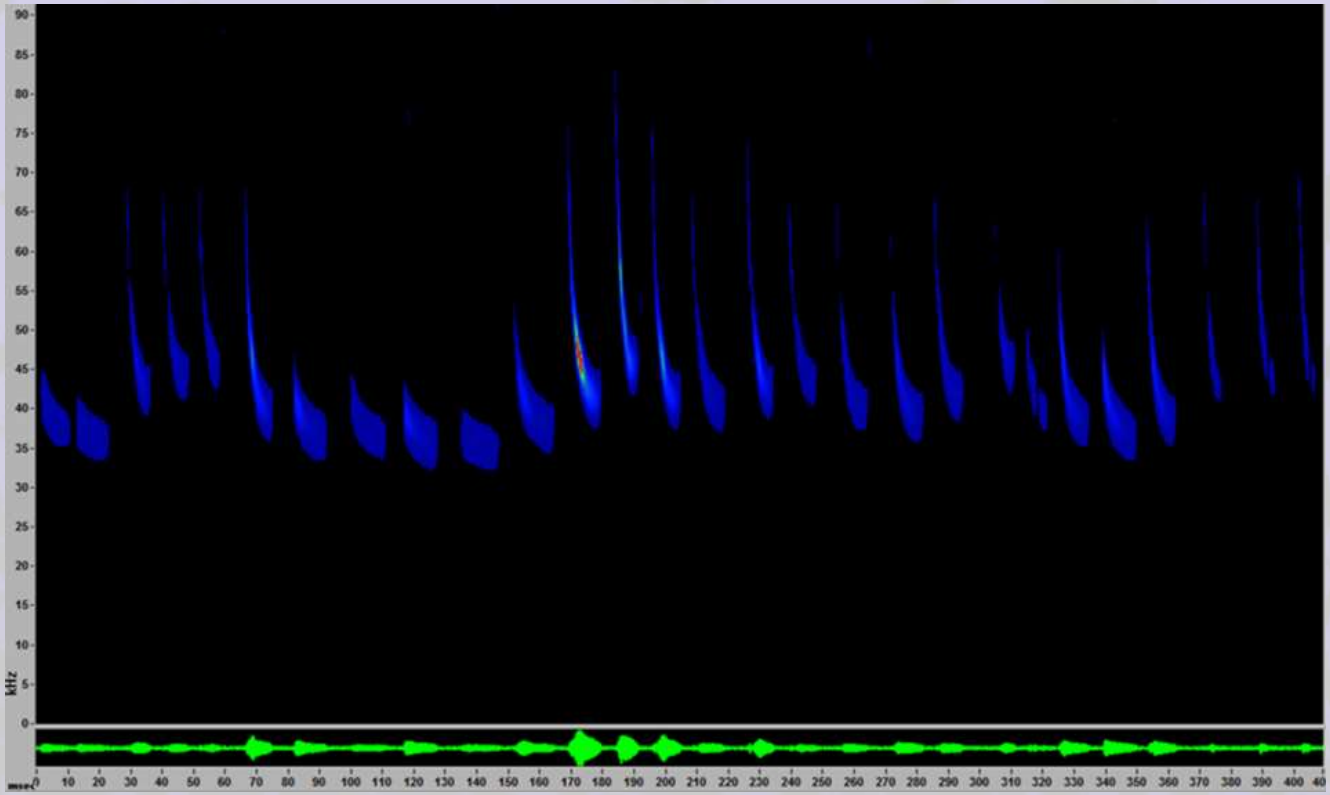


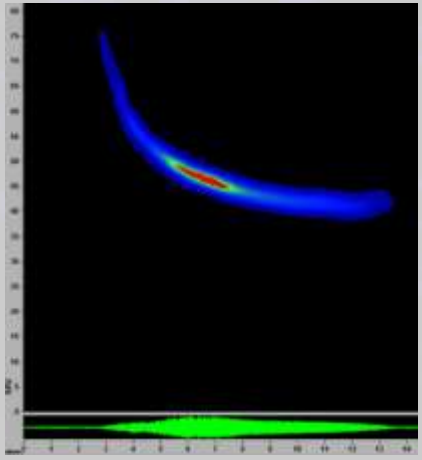
Long and “U” shaped; power centered smoothly in center



Long and flat with upturn

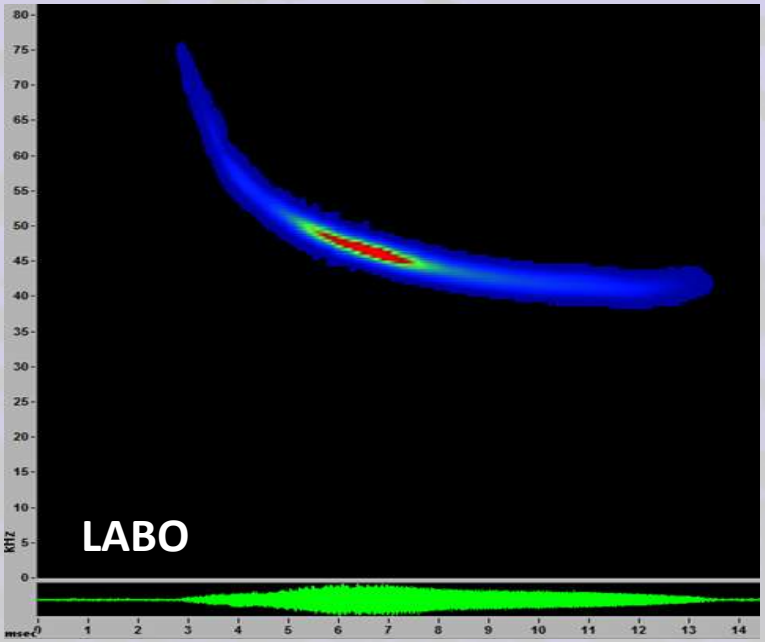
LABO Definitive Characteristics

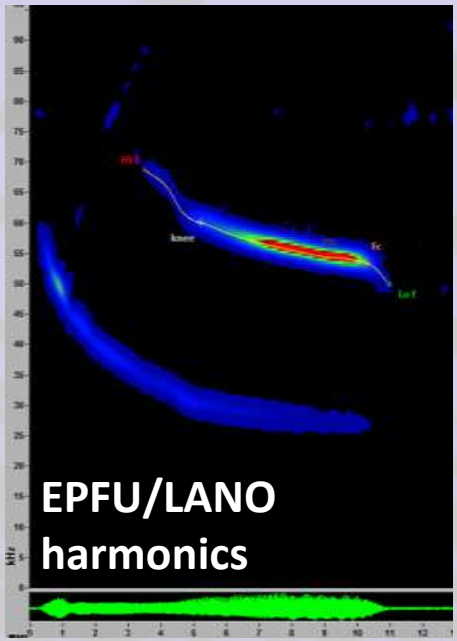


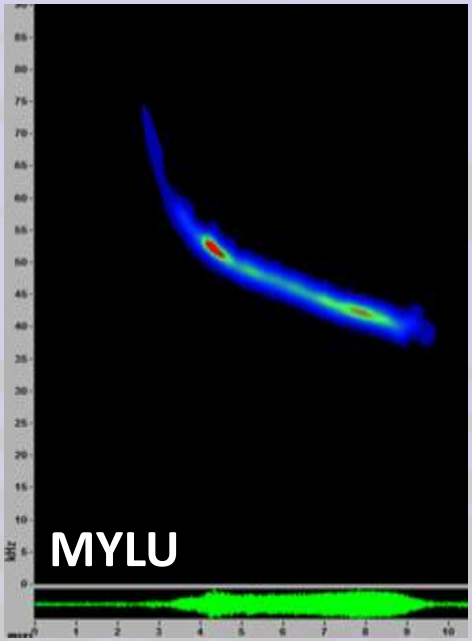


- “U” shaped calls; upturn at end
- *fc* variable within a sequence

LABO Similar Species



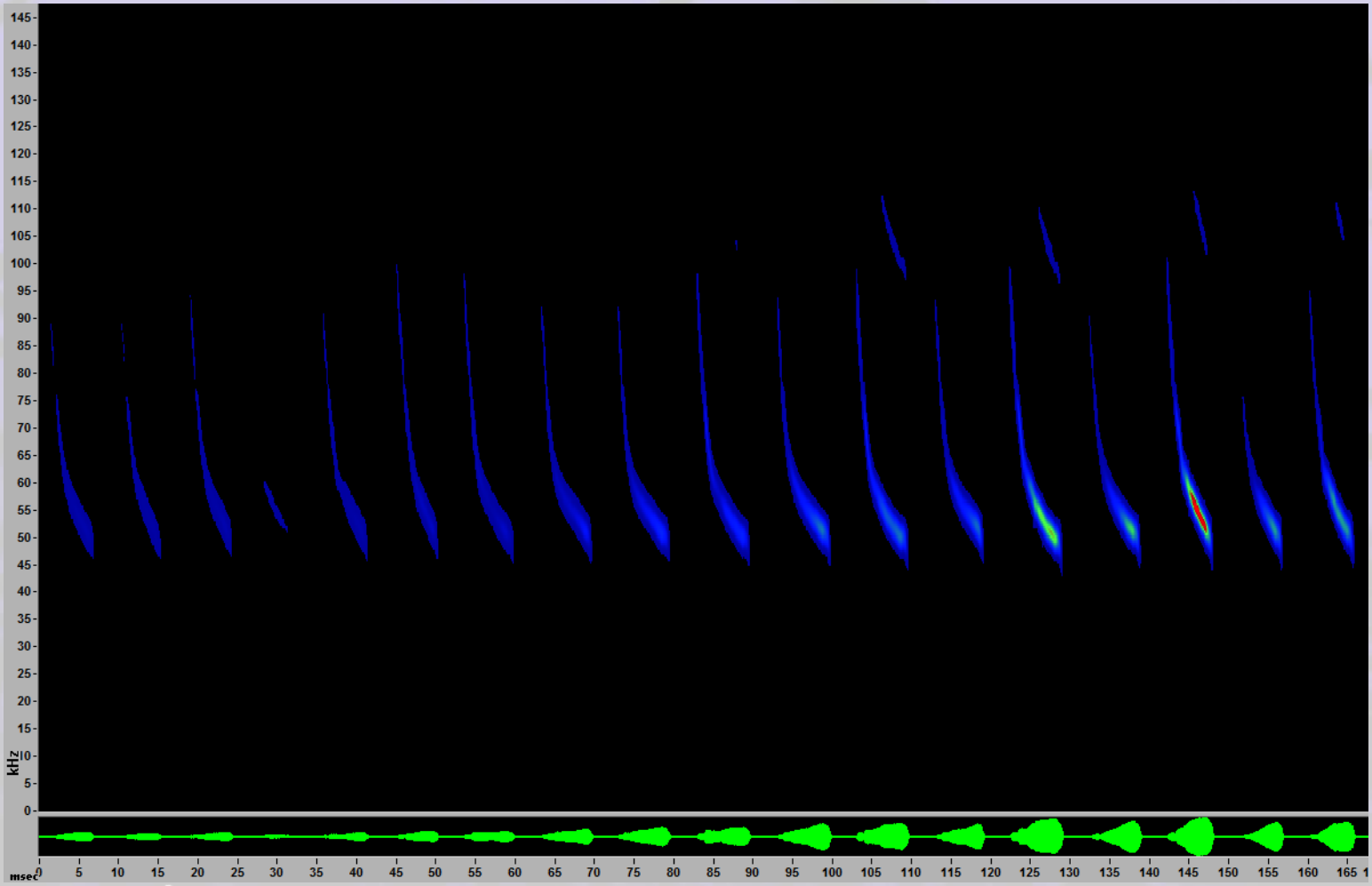




LABO vs. **MYLU**: MYLU calls infrequently exceed 10 ms, are not upturned at the end; instead, have a steadily decreasing frequency or a steady *f*c across a sequence. **NOTE:** Sonobat sometimes classifies EPFU/LANO harmonics as MYLU or LABO.

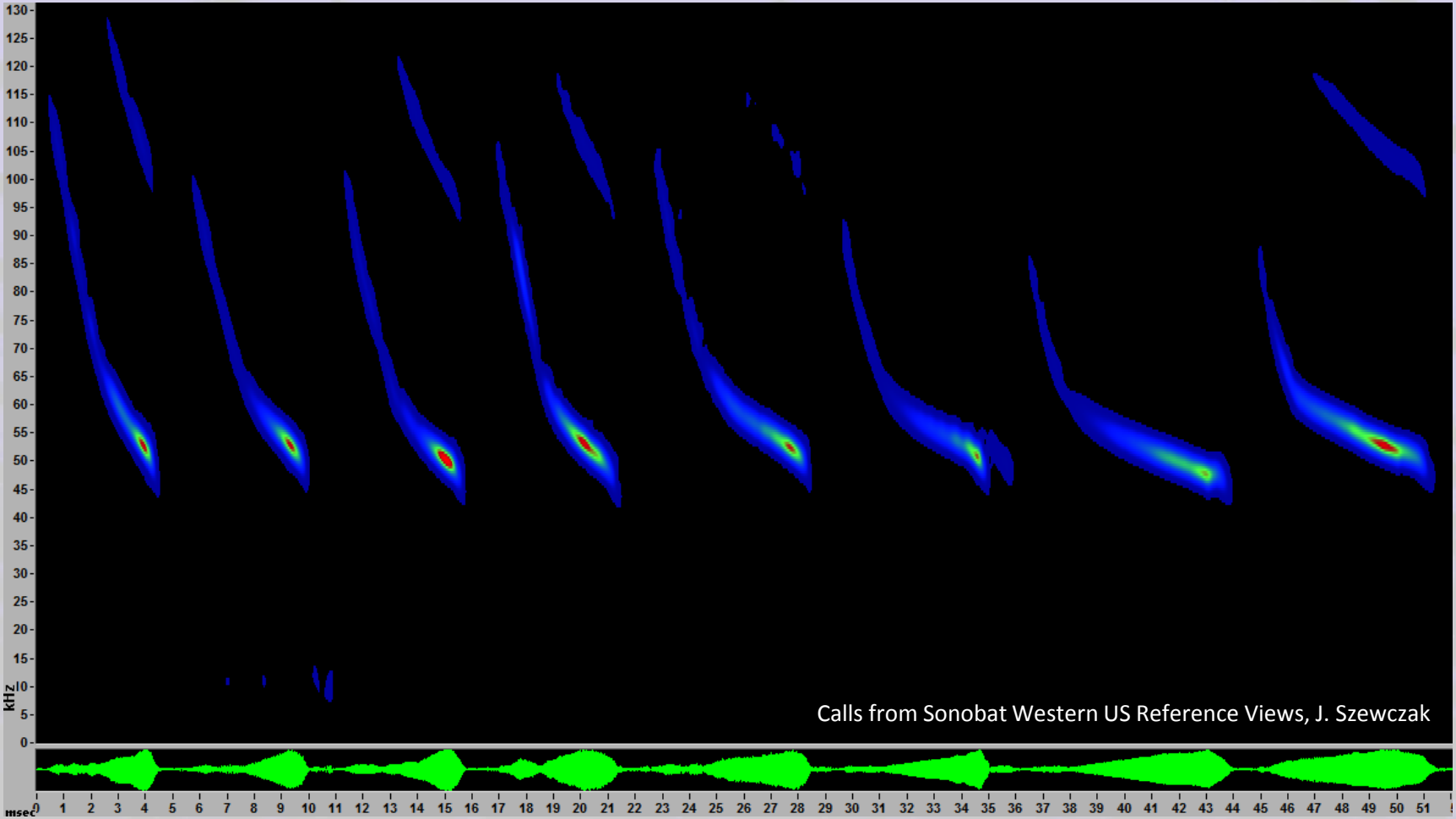
LABO vs. **LANO**: LANO can have a similar shape to LABO, but are much lower in *f*c.

Yuma Myotis (*Myotis yumanensis*) = MYYU



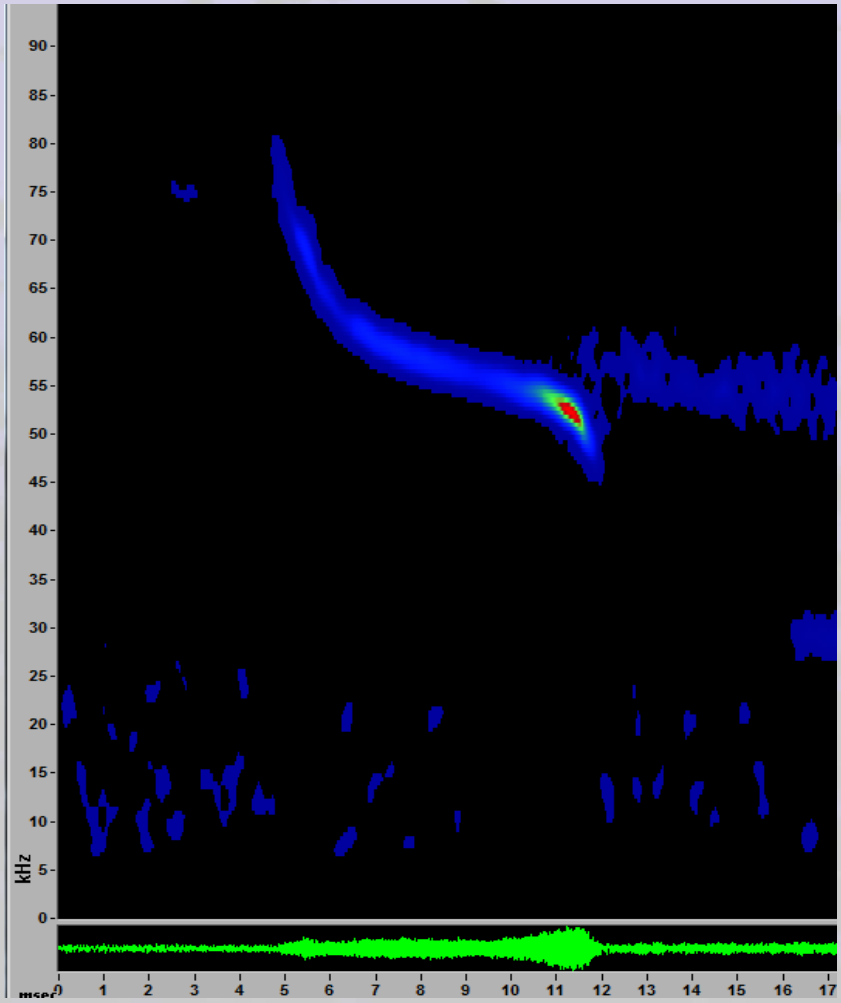
MYYU_time_expanded

MYYU Call Shapes



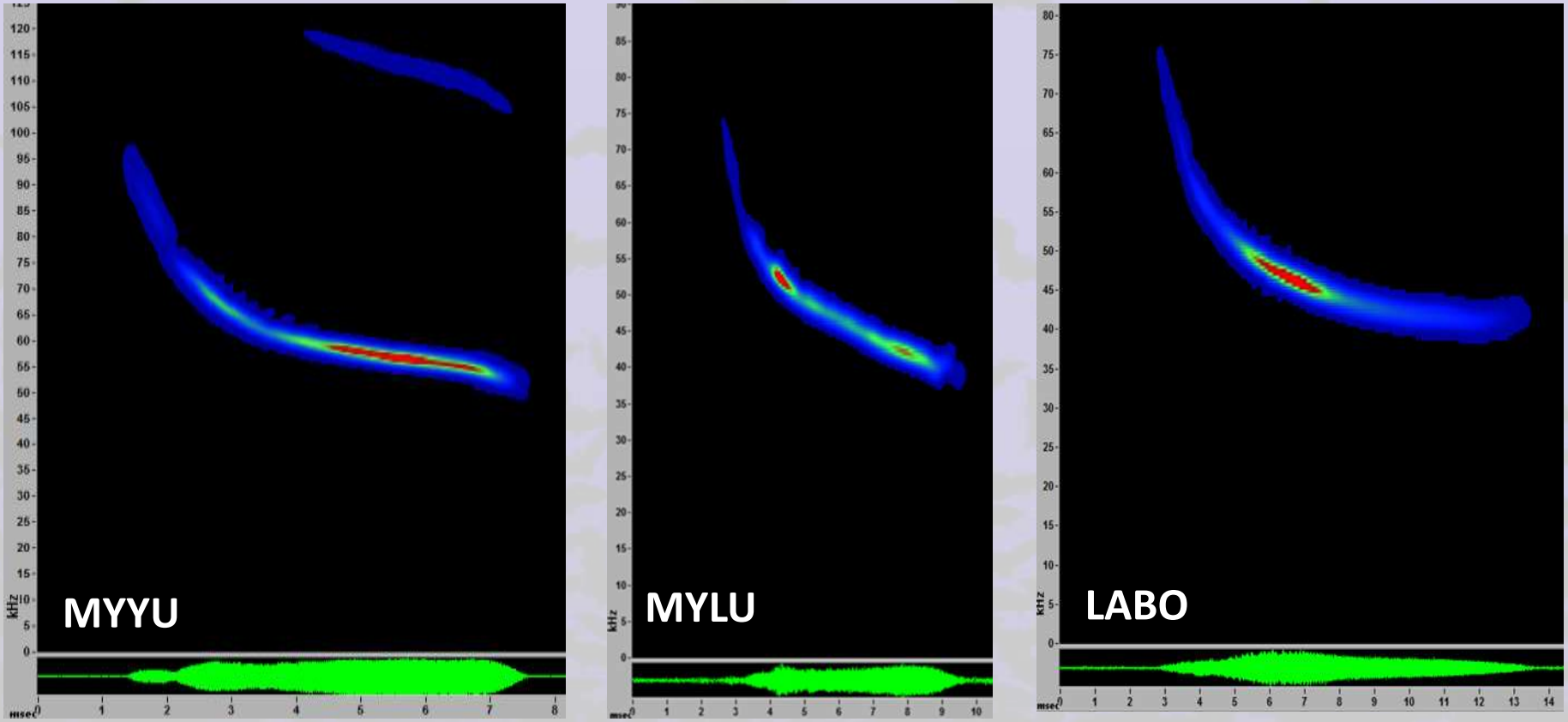
- **Power focused around *fc*; gradually builds to a peak and attenuates rapidly**
- **Typically exhibit a hint of a tail**

MYYU Definitive Characteristics



- Pronounced knee
- *f*c > 47 kHz, duration > 6 ms, upper slope < 16, and lower slope < 3 within known range west of Continental Divide
- Sometimes insert longer duration calls within a sequence of short duration calls

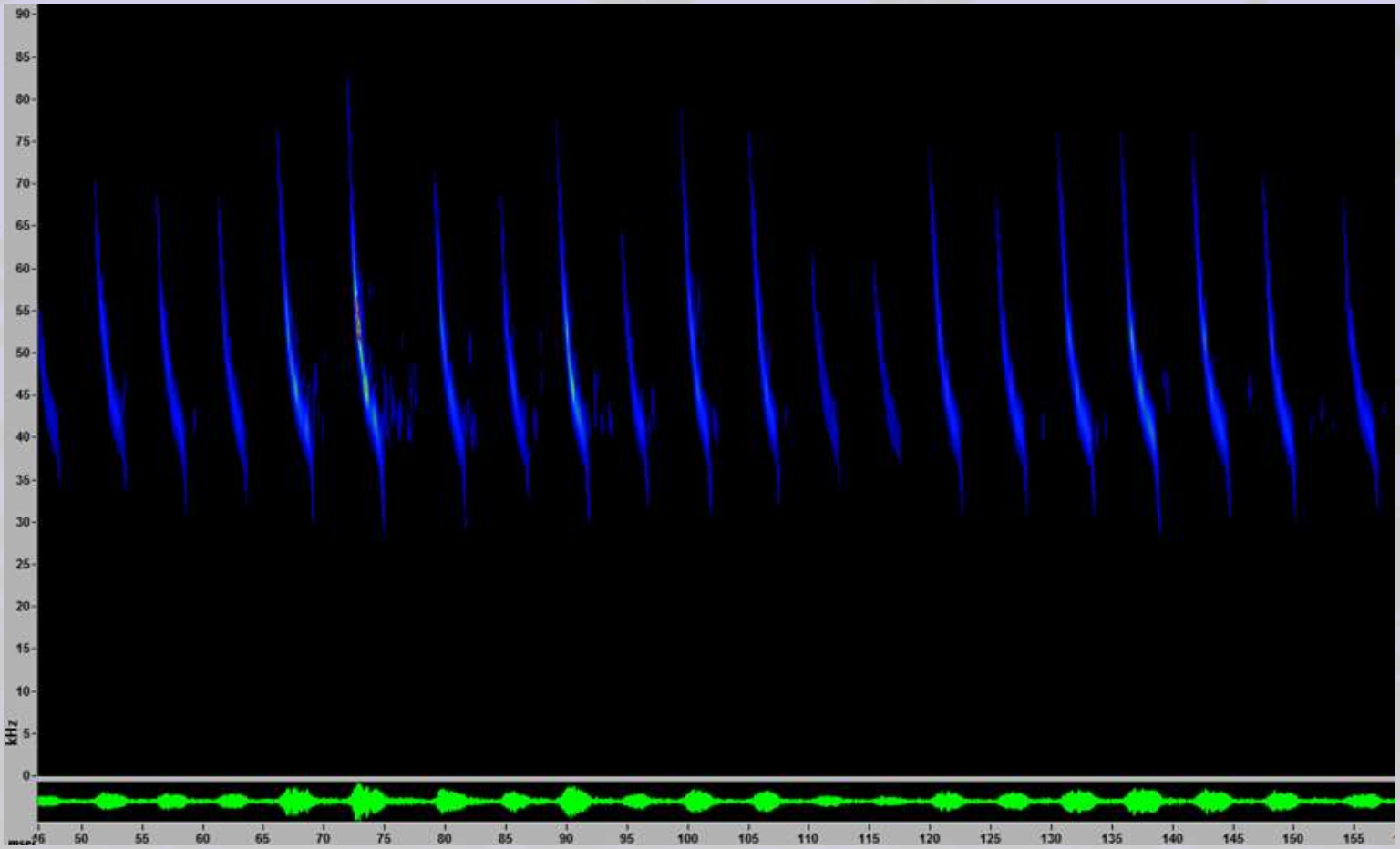
MYYU Similar Species



MYYU vs. **LABO**: LABO calls tend to have a variable *f*c across a sequence, up-turns at ends, and longer durations. MYYU duration does not exceed 8 ms. MYYU *f*c is generally higher.

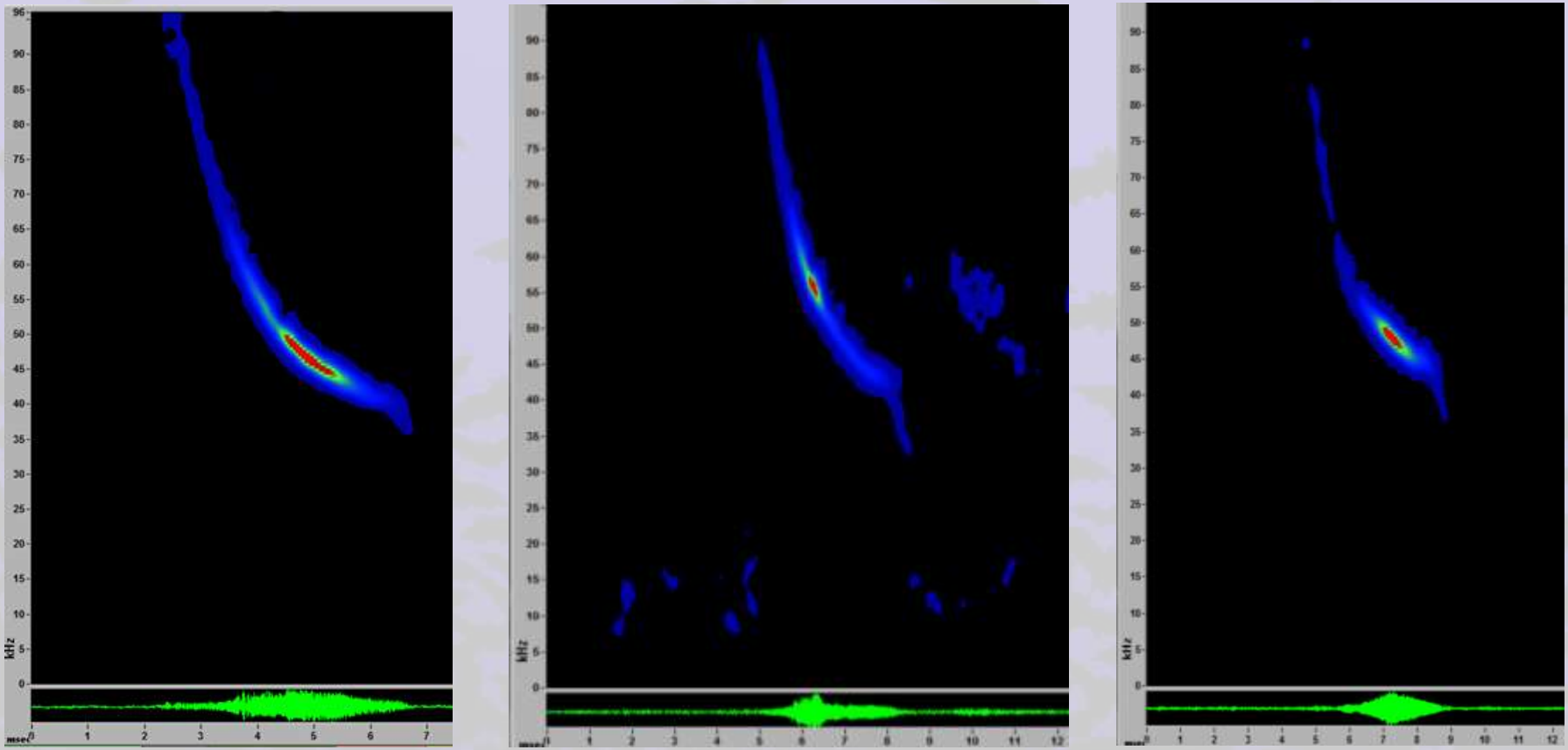
MYYU vs. **MYLU** vs. **MYVO**: *f*c > 47 kHz distinguishes MYYU from MYLU and MYVO when the two overlap geographically.

Western Small-footed Myotis (*Myotis ciliolabrum*) = MYCI



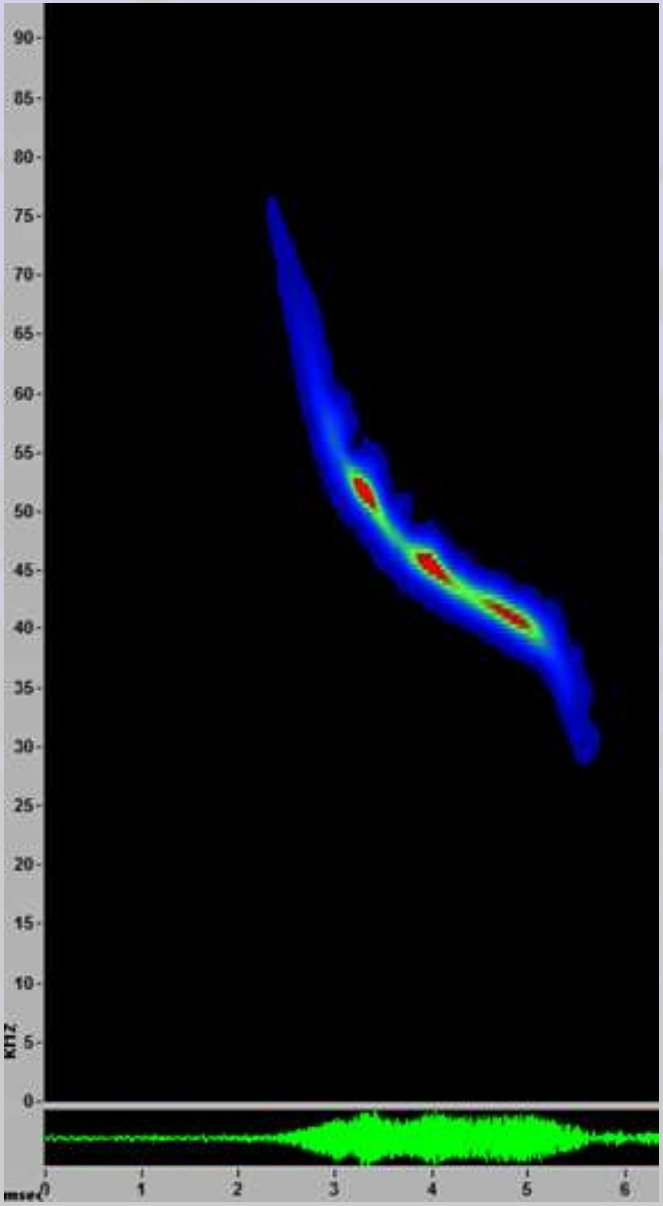
MYCI_time_expanded

MYCI Call Shapes



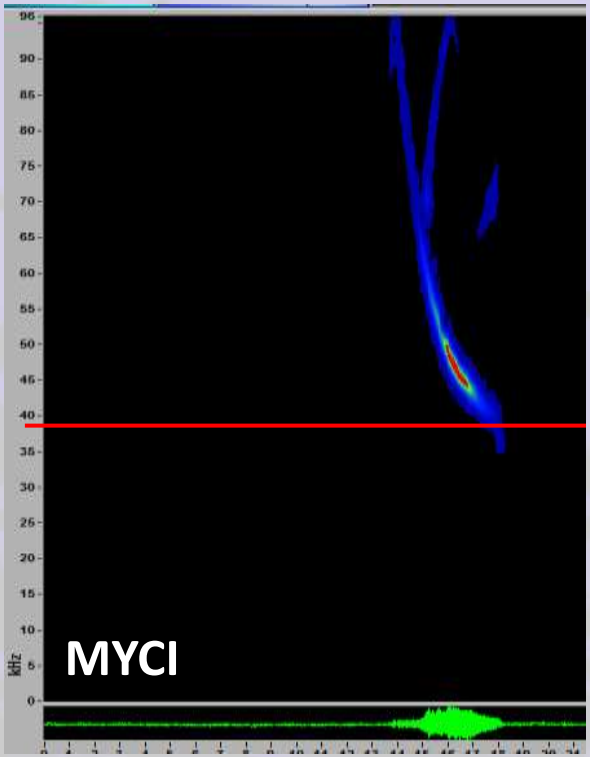
- FM sweep a smooth curve, beginning steeply and then increasing in curvature
- Often with a prominent downward tail
- Some calls have inflection, but smooth variant is diagnostic

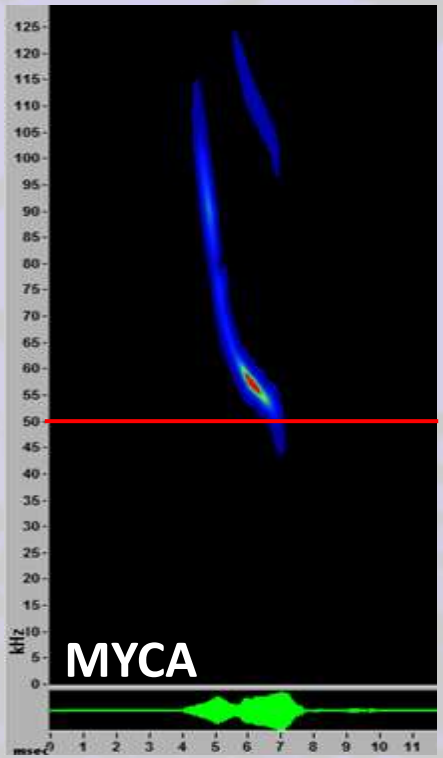
MYCI Definitive Characteristics

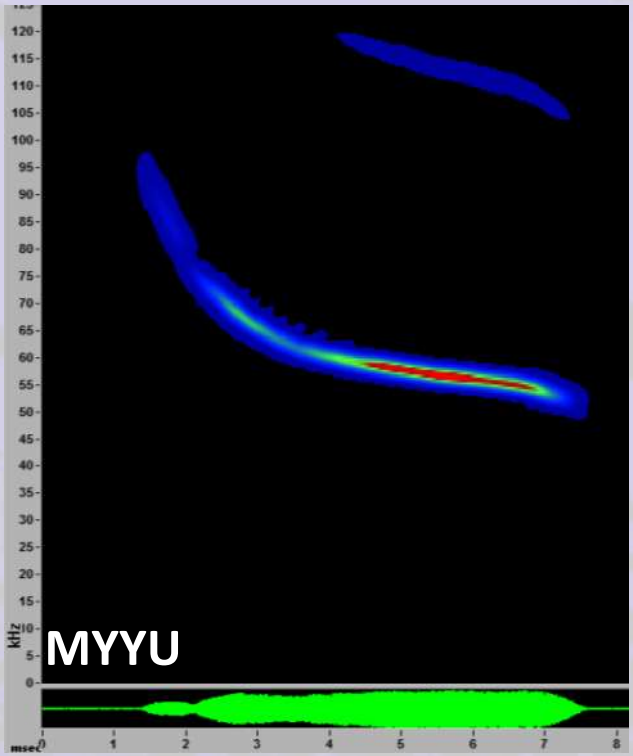


- FM sweep a smooth curve
- Well defined downward tail
- *f*c < 45 kHz when within MYCA geographical range
- Peak power of call persists for at least 1 ms

MYCI Similar Species





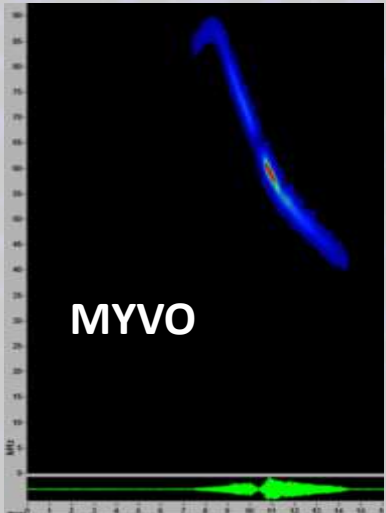


MYCI vs. **MYCA**: Calls are similar in appearance and characteristics. When the two species overlap geographically, *f*c > 45 kHz is diagnostic for MYCA.

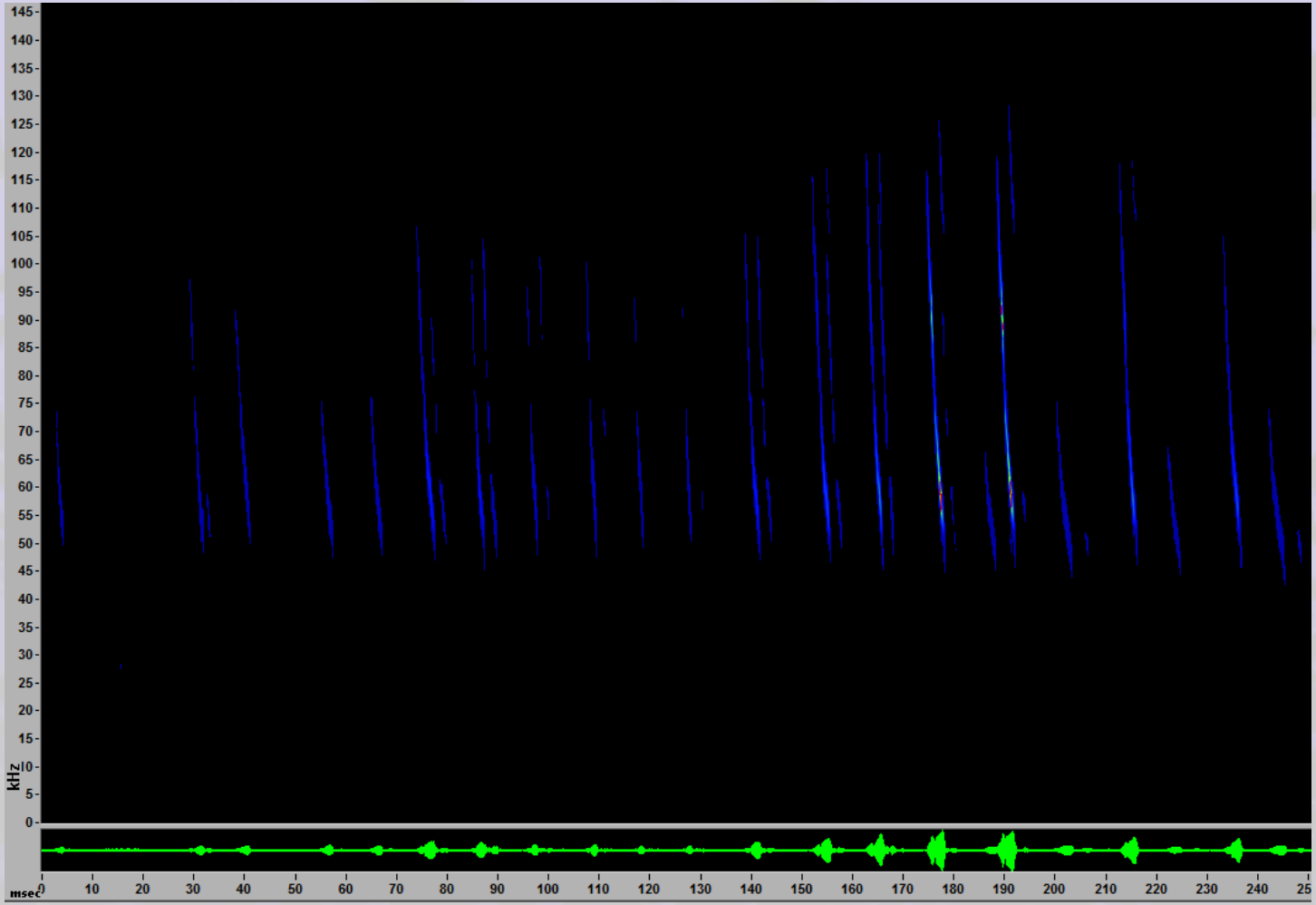
MYCI vs. **MYYU**: Non-diagnostic calls can overlap in shape; diagnostic calls do not.

MYCI vs. **MYLU**: Diagnostic MYLU are longer duration (> 7 ms) and have a strong inflection.

MYCI vs. **MYVO**: Non-diagnostic calls overlap; unable to distinguish unless there is an upsweep into the call which is diagnostic for MYVO.

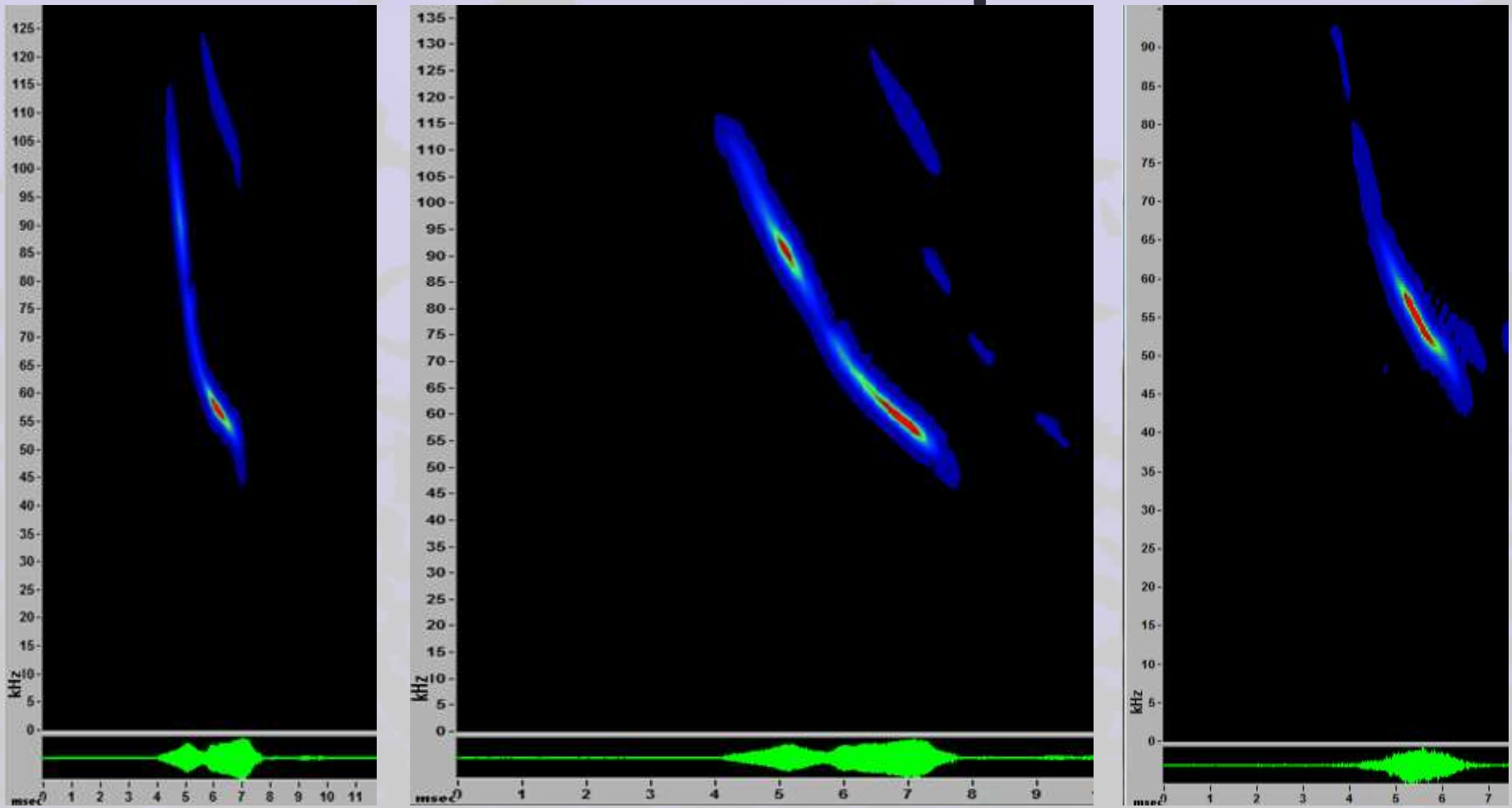


California Myotis (*Myotis californicus*) = MYCA



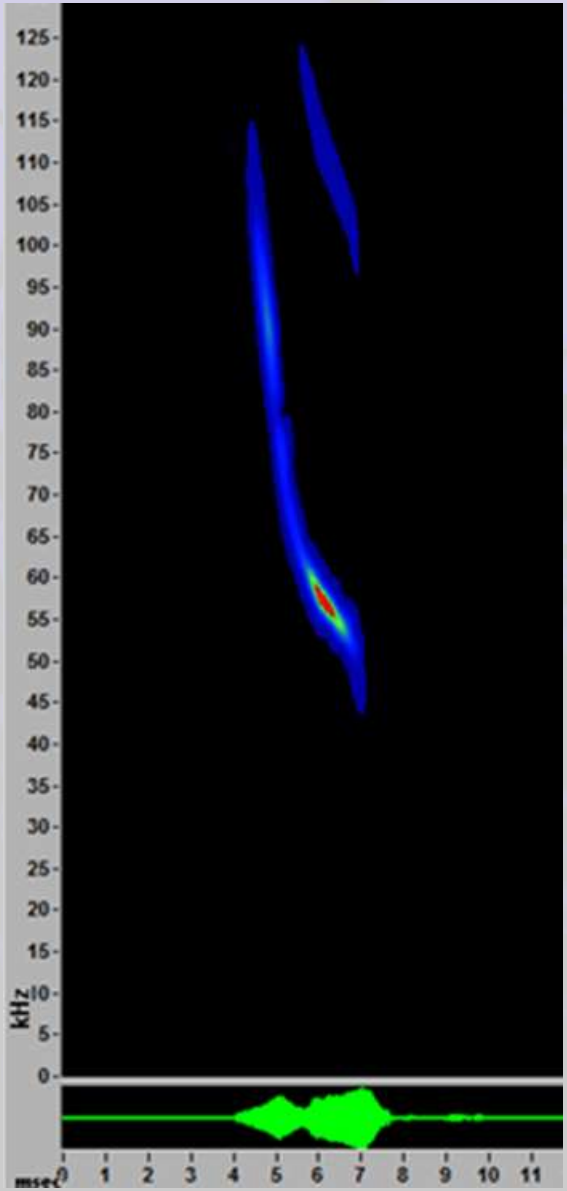
MYCA_time_expanded

MYCA Call Shapes

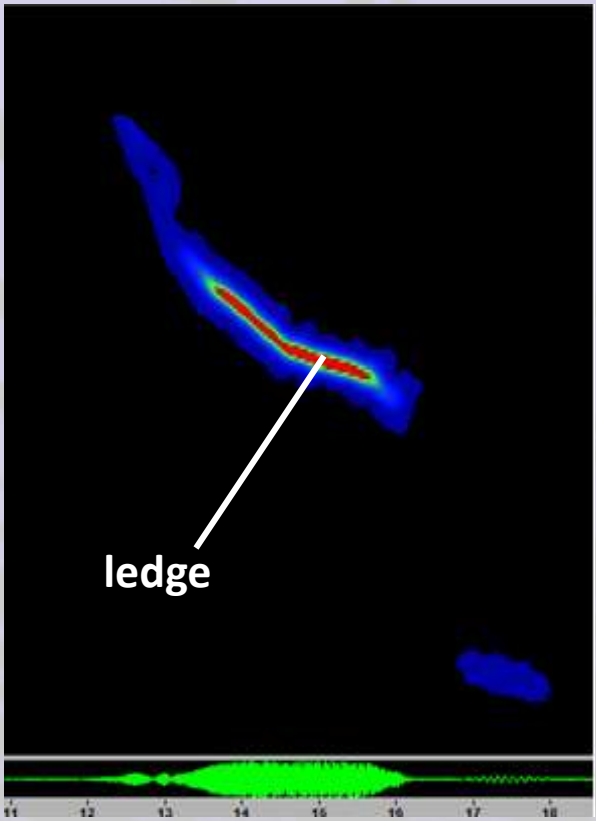


- FM sweep a smooth curve, beginning steeply and then increasing in curvature
- Often with a prominent downward tail
- Some calls have inflection, but smooth variant is diagnostic

MYCA Definitive Characteristics

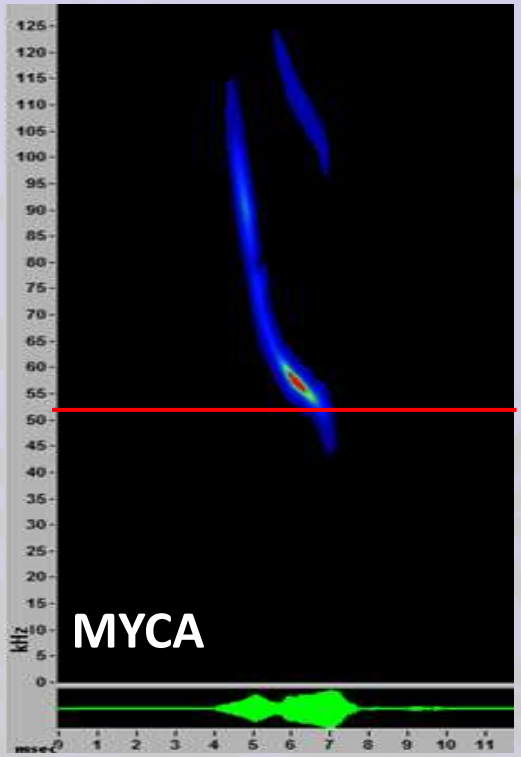


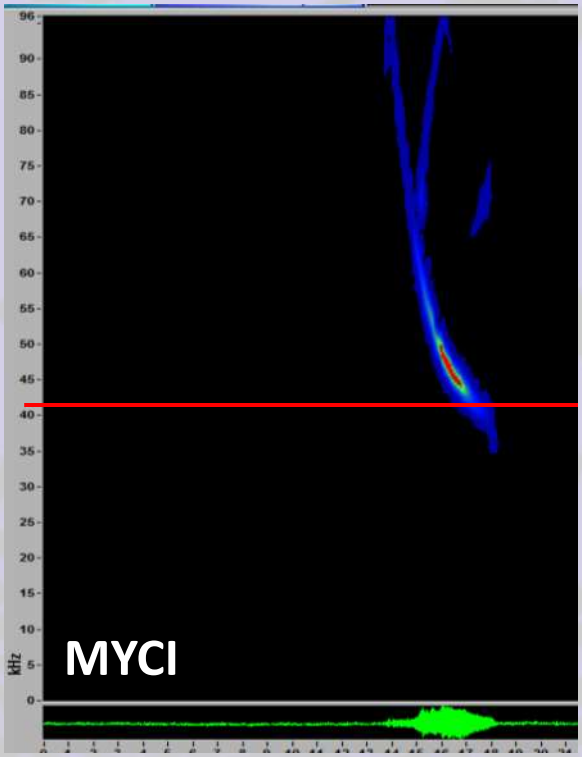
- FM sweep a smooth curve
- Sometimes a lower inflection, or "ledge," before *fc*
- Often a well-defined downward tail
- Peak power persists for at least 1 ms

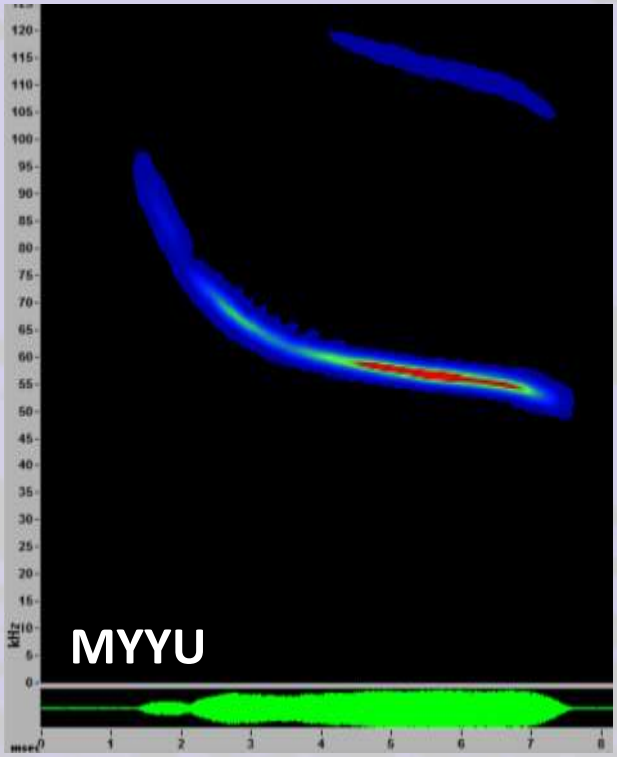


- *fc* > 48 diagnostic when within MYCI geographical range

MYCA Similar Species







MYCA vs. **MYCI**: Calls are similar in appearance and characteristics. When the two overlap geographically, *f*c > 48 kHz is diagnostic for MYCA.

MYCA vs. **MYYU**: Non-diagnostic calls can overlap in shape but diagnostic calls do not.

MYCA vs. **MYLU**: Diagnostic MYLU are longer (> 7 ms) in duration and have inflection.

MYCA vs. **MYVO**: Non-diagnostic calls can be similar in appearance; unable to distinguish unless there is an upsweep into the call which is diagnostic for MYVO.