

Echolocation Call Characteristics of Montana Bats

Table 6. Frequency characteristics and diagnostic criteria for bat species found in Montana. Mean frequencies are shown in bold for each feature and the range of measurements is displayed below in each box. Call sequences analyzed to produce this table are from Humboldt State University Bat Lab and the Montana Bat Call Reference library.

	species	f_c	low f	high f	f_{max}	dur	Upper slope	Lower slope	Total slope	Diagnostic ² and Special characteristics	Hand-Class Priorities ³	MTNHP Notes ³	Search Phase call intervals ³	
50	<i>Myotis yumanensis</i>	49.2	45.6	90.0	55.2	5.5	16.6	4.4	8.1	<p>Pronounced knee, dur >6 ms, upprSlp <16, lwrSlp <3, f_c >47 kHz diagnostic within known range (95% CI for MYVO). Sometimes insert longer duration calls within sequence of short duration calls. Power focused around f_c; gradually builds up to peak and attenuates rapidly. Typically exhibit only a hint of a tail. Limited geographic range in MT (west of Continental Divide).</p>	$f_c > 50$ kHz dur > 6 ms	Date range: Year round	90-175 ms	
	Yuma Myotis	44.8-54.8	42.4-48.4	64.0-116.0	46.0-78.8	3.3-7.9	5.4-27.4	1.6-9.4	2.2-17.9					
50	<i>Myotis californicus</i>	49.1	45.3	99.6	52.8	3.8	28.0	7.4	15.1	<p>FM sweep a smooth curve (i.e., no inflection), beginning steeply and then increasing in curvature*. Often a well-defined downward tail. Sometimes a lower inflection; with the appearance of a “ledge” or “shelf” or “secondary change in slope” before f_c. Peak power of call typically persists for at least 1 ms on non-saturated calls. $f_c >48$ kHz diagnostic (95% CI for MYCI). Limited geographic range (western MT). *some calls may have an inflection, but the smoothly curved variant is diagnostic.</p>	$f_c > 50$ kHz dur < 5 ms	<p><i>D calls should have:</i> $f_c > 48$ kHz uppr slp >20 total slp > 10 dur < 4 ms tail > 3 kHz</p>	Date range: Year round	75-125 ms (occ. >175 ms)
	California Myotis	44.9-52.9	40.7-48.7	78.4-122.4	45.0-65.2	2.0-5.6	14.0-42	2.4-12.6	3.9-26.9					
40	<i>Myotis ciliolabrum</i>	44.3	40.6	95.1	49.1	3.2	33.5	9.6	16.9	<p>FM sweep a smooth curve (i.e., no inflection), beginning steeply and then increasing in curvature*. Often a well-defined downward tail. Peak power of call typically persists for at least 1 ms on</p>	$f_c > 42$ kHz dur < 5 ms Kaleido Accurate	<p><i>D calls should have:</i> $f_c > 42$ kHz uppr slp >25 total slp > 12 tail > 3 kHz</p>	Date range: Year	75-125 ms

	species	f_c	low f	high f	f_{max}	dur	Upper slope	Lower slope	Total slope	Diagnostic ² and Special characteristics	Hand-Class Priorities ³	MTNHP Notes ³	Search Phase call intervals ³
	Western Small-footed Myotis	39.7-47.7	37.4-43.4	76.9-112.9	42.9-54.9	1.8-4.6	20.5-46.5	4.4-14.4	7.1-27.1	non-saturated calls, $f_c < 45$ kHz diagnostic if within MYCA geographic range (95% CI for MYCA). *some calls may have an inflection, but the smoothly curved variant is diagnostic.		round	
	<i>Myotis septentrionalis</i>	43.2	37.0	104.0	51.3	3.9	24.2	11.7	18.6	Calls may have up to 100 kHz of bandwidth. Shaped like MYEV or MYTH but distinguished by f_c . FM sweep may be nearly linear making f_c difficult to recognize. Quiet but consistent calls. Examine sequence in real time and confirm consistent search phase call intervals across the sequence to rule out approach phase calls from other Myotis spp. Distribution in Montana very limited - capture and genetic analysis needed to confirm ID.	$f_c > 40$ kHz	Look for $F_c > 40$ kHz and ensure they aren't approach-phase calls from other Myotis by confirming consistent search phase call intervals across the sequence.	unknown
	Northern Long-eared Myotis	36.8-50.8	27.0-47.0	86.0-124.0	30.7-72.7	2.3-5.3	11.8-35.8	3.1-20.3	9.4-29.4				
	<i>Myotis volans</i>	41.6	36.9	89.6	48.0	4.8	15.1	7.7	12.0	May exhibit an upward sweep into the call; uncommon, but diagnostic when present on steep calls. May have subtle lower slope or backward bend at higher frequencies. End of call may exhibit a rounded, lazy drop. Generally has shorter, steeper calls than MYLU in uncluttered areas. Note that alias harmonics may resemble upsweeps if sonogram is truncated (e.g. 96 kHz maximum for SM2s with FS = 192 kHz).	$f_c > 35$ kHz	Date range: Year round	80-160 ms?
	Long-legged Myotis	36.4-46.4	31.1-43.1	66.4-112.4	39.0-60.0	2.4-7.0	6.9-22.9	1.1-14.3	4.0-22.0				
	<i>Myotis lucifugus</i>	40.8	38.1	74.5	44.5	6.0	13.1	3.9	6.2	Can make the longest duration and lowest slope calls of all Myotis. Dur > 7 ms (95% CI for MYVO) and $lwrSlp < 3$ diagnostic among 40 kHz Myotis; $f_c < 44$ kHz diagnostic	dur > 6 ms	Date range: Year round	100-200 ms

	species	f_c	low f	high f	f_{max}	dur	Upper slope	Lower slope	Total slope	Diagnostic ² and Special characteristics	Hand-Class Priorities ³	MTNHP Notes ³	Search Phase call intervals ³
	Little Brown Bat	37.2-43.2	33.9-41.9	51.5-97.5	36.0-53.5	3.2-8.6	2.7-26.9	0.8-9.1	1.6-13.8	west of Continental Divide (95% CI for MYYU). Calls may have abrupt upturn at end (unlike smooth LABO upturn). Sometimes with multiple power centers making calls look clumpy.			
	<i>Lasiurus borealis</i>	40.4	40.2	67.6	43.8	6.8	10.0	2.0	4.4	U-shaped calls; up-turn at end of call; may exhibit variable f_c across sequence. Power smoothly centered in call. Typically 32-40 kHz calls with dur >10 ms are LABO, but look at shape. $f_c > 30$ kHz in sequences with characteristic variation in frequencies (as opposed to LACI <30 kHz). Limited geographic range in MT (eastern plains).	Kaleido Accurate, dur > 9-11 ms	Date range: June 14 - Oct 26	100-250 ms (occ. >300 ms)
	Eastern Red Bat	31.6-47.6	33.8-45.8	40.4-94.4	34.2-54.2	3.2-11.4	0.1-22	0.0-4.4	0.1-9.8				
30	<i>Myotis evotis</i>	34.3	28.1	78.5	39.1	3.7	20.5	8.7	13.5	Calls may have up to 100 kHz of bandwidth. Shaped like MYTH and MYSE but distinguished by $f_c = 32-36$ (upper range boundary for MYTH, 95% CIs for MYVO and MYSE). FM sweep may be nearly linear making f_c difficult to recognize. Harmonics converge toward primary call component.	$f_c = 33-36$ kHz dur < 3-4 ms; Sonobat=EPFU and dur <5 ms	Date range: Year round	90-200 ms
	Long-eared Myotis	31.7-37.7	23.9-33.9	49.5-107.5	31.0-46.9	2.1-5.3	6.1-35.5	2.3-15.3	4.9-24.5				
	<i>Eptesicus fuscus</i>	28.2	27.2	56.6	31.9	7.8	8.5	2.1	4.0	Variable; calls with high f below 60 kHz can be confused with LANO. Calls with high $f > 65$ kHz distinguish from LANO (range boundary for LANO), duration >12 ms to distinguish from ANPA where species coexist (range boundary for ANPA). May produce nearly flat calls (with f_c as low as 23 kHz) but never 100% flat at any point in call. Parallel harmonics. Some calls may have inflection.	$f_c = 28-32$ kHz dur > 6 ms	Look at longer calls if in ANPA geographic range, but note that long calls (>10ms) may have call/sec < 6	100-150 ms (150-250 ms for long, low calls)
	Big Brown Bat	25.8-31.8	24.8-30.8	43.4-69.4	25.0-40.1	2.8-12.2	2.5-15.5	0.3-4.3	0.6-7.6			Date range: Year round	

	species	f_c	low f	high f	f_{max}	dur	Upper slope	Lower slope	Total slope	Diagnostic ² and Special characteristics	Hand-Class Priorities ³	MTNHP Notes ³	Search Phase call intervals ³
	<i>Antrozous pallidus</i> Pallid Bat	28.0 26.0-30.0	26.2 23.8-29.8	54.5 41.5-67.5	31.0 25.0-37.0	6.8 3.8-10.0	8.1 3.0-15.9	2.7 0.6-5.1	4.3 2.1-7.9	Often simple curved FM sweep, sometimes with knee in center. Distinguish from short, steep EPFU calls by looking for call intervals >180 ms for ≥1 second (<6 calls/sec) . Note that MYTH & MYEV can also be <6 calls/sec. No Myotis-like tail, but calls may end in a foot-like arch or "dog paw". Parallel harmonics. Presence of social calls diagnostic (see ref. calls). Limited geographic range (southeastern MT).	dur < 10 ms calls/sec < 6 f_c < 35 kHz	<i>Probables:</i> Sequences of short, steep calls with >200 ms intervals <i>Definitives:</i> Social calls, must view "unfiltered" to see these Date range: Apr 1 - Sept 23	150-300 ms?
20	<i>Lasionyct eris noctivagans</i> Silver-haired Bat	26.5 25.5-27.5	25.4 22.6-28.6	41.5 26.0-58.5	28.8 24.0-33.2	9.2 2.3-16.8	5.2 0.0-12.6	1.3 0.0-3.7	2.5 0.0-6.7	Some call variants can be confused with EPFU. Flat calls with $f_c \geq 26$ kHz diagnostic . Shorter calls reverse J-shaped; often with a distinct inflection . Short search phase calls (<7 ms) with harmonics do not exceed 55kHz . Parallel harmonics. Flat LACI calls are lower in f_c , but shorter LACI approach calls may overlap short LANO calls (examine entire sequence and call interval). Low slope calls with $f_c = 25-26$ kHz may be distinguished from LACI by the presence of an inflection. EPFU typically has more FM, with smooth curvature (no inflection), but may produce nearly flat calls (with f_c as low as 23 kHz).	f_c < 28 kHz	Date range: Year round	200-500 ms (100-200 ms for short, steep calls)
	<i>Myotis thysanodes</i>	24.5	19.8	72.4	30.7	3.9	19.0	9.2	13.9	Calls may have up to 100 kHz of bandwidth. Shaped like MYEV but distinguished by f_c . FM sweep may be nearly linear making f_c difficult to recognize. Want to have presence of harmonics to distinguish from COTO if high f < 50 kHz. Continuous steep shape and	f_c < 24 kHz, dur 3-5 ms, and/or Kaleido Accurate	Date range: Mar 28 - Oct 31	100-160 ms

	species	f_c	low f	high f	f_{max}	dur	Upper slope	Lower slope	Total slope	Diagnostic ² and Special characteristics	Hand-Class Priorities ³	MTNHP Notes ³	Search Phase call intervals ³
	Fringed Myotis	21.5-27.5	14.2-24.2	41.6-103.6	24.0-39.3	1.9-5.9	7.1-33.0	3.1-16.8	4.9-24.1	f_c down into the 20s is diagnostic: totalSlp >15, f_c <28 kHz, and low f <24 kHz diagnostic or totalSlp >10, f_c <28 kHz, and low f <24 kHz diagnostic if harmonics converge toward primary call component.			
	<i>Corynorhinus townsendii</i>	23.4	21.4	42.5	31.1	4.6	7.1	4.9	5.0	Low intensity, difficult to record; harmonics may be present. Call-shape simple linear FM sweep (sometimes with upsweep or flat at onset - no knee or upward facing curvature toward end of call unless a connected squiggle). Squiggle calls diagnostic (5-7 ms period); rare, likely social and used near roosts. f_{max} may alternate between primary call component and second harmonic. For search phase calls, COTO will have high f <50 kHz, f_c <32 kHz, and f_{max} <41kHz (upper range boundaries). *Examine entire call sequence and look for upward facing curvature on any call; if found, likely not COTO. LACI and LANO approach calls and some linear MYTH fragments can mimic COTO.	f_c < 35 kHz	Date range: Year round	70-120 ms (occ. >150 ms)
	Townsend's Big-eared Bat	18.6-28.6	17.0-24.6	37.5-47.5	24.9-36.9	1.7-8.0	0.2-18.9	1.5-8.3	2.0-8.0				
	<i>Lasiurus cinereus</i>	20.1	19.7	26.0	20.8	11.0	2.2	0.4	0.7	Pronounced or subtle U-shape or very flat calls (<20 kHz). Low f & f_c may vary across sequence; power builds toward center then gradually declines. Short calls can be confused with LANO or EPFU. f_c < 30 kHz in sequences with characteristic variation in frequencies (as opposed to LABO >30 kHz).	f_c < 20 kHz and/or Kaleido Accurate	Date range: Mar 22 - Nov 15	250-400 ms (occ. >500 ms)
	Hoary Bat	16.0-23.9	16.3-24.3	17.0-36.0	17.0-25.2	4.0-19.0	0.1-6.0	0.0-1.2	0.0-2.1				

	species	f_c	low f	high f	f_{max}	dur	Upper slope	Lower slope	Total slope	Diagnostic ² and Special characteristics	Hand-Class Priorities ³	MTNHP Notes ³	Search Phase call intervals ³
10	<i>Euderma maculatum</i> Spotted Bat	10 8.6-12.0	9.6 8.2-10.4	14.5 12.0-17.5	12.5 10.0-15.5	3.2 1.6-6.0	2.2 0.1-5.2	1.5 0.1-3.1	1.7 0.9-2.7	Simple linear FM sweep , sometimes with a mild inflection. Short calls at low frequency. Harmonics often present, with second harmonic persisting beyond primary call component. $f_c = 7-10$ kHz and dur = 3-8 ms diagnostic.		Process separately in Kaleidoscope, view "unfiltered" Date range: Mar 10 - Nov 12	200-500 ms

¹ data from Humboldt State University Bat Lab (Eastern and Western US Bats 2011); numbers represent means and approximate 95% confidence intervals - if the 95% CI exceeded the observed range of a characteristic, the range boundary was used.

² diagnostic characteristics for determination of species identification are bolded in text.

³ filters and notes represent work in progress or draft guidelines to speed hand review of call sequences; seasonal range dates are from either definitively identified calls or captures in the Montana Point Observation Database as of February 2017.

Important Characteristic/Sonogram Terminology¹

Primary call: the component of an echolocation sound emitted by a bat with the lowest frequency, also called the fundamental; typically the most powerful and sometimes the only part of the call visible on a sonogram

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

The characteristics below refer to attributes of the primary call. In rare cases, a harmonic may be the most powerful component of a call; these characteristics and their corresponding values in this key are not applicable to those measured from a harmonic component.

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)

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

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

Other terms used to describe calls:

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

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

oversaturation: powerful calls may exceed the microphone/recorder capability and produce anomalies in the sonogram such as full spectrum “noise” (clipping) or alias harmonics (upside-down harmonics resulting from truncation of the upper portions of calls due to sampling frequency limitations); peak power duration cannot be accurately estimated

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

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 Sonobat's calculation of this characteristic 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

Note that all frequencies should be interpreted as apparent or observed frequencies. These values may vary from the frequency emitted by the bat due to distance to detector (decreasing call power or volume). Call volume may have a noticeable effect on all frequencies recorded depending on the location of the power in the call (>5 KHz).

Call Types²

The values for the characteristics listed in this key are based on search phase calls. Therefore, it is important to make sure that search phase calls are examined and analyzed during hand classification.

Search phase calls: used for general navigation and searching in uncluttered areas, generally consistent call characteristics, approximately 3-12 calls per second; bats may be able to detect objects >10 meters away with these calls³

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 calls and frequencies may shift up significantly, often 10-25 calls per second

Feeding buzz: also called terminal phase calls, used for close proximity object location during prey pursuit/capture, may exceed 100 calls per second⁴; very steep and short calls that can mimic other species if interpreted as search calls, but can be much lower in volume/power; not useful for species ID

Social calls: used to communicate with other bats, often lower in frequency than search phase calls for a species and may contain complex frequency modulation patterns; may be very helpful for identifying some species (e.g. ANPA) but are irregularly recorded

How to Use the Key for Montana Bats¹

Tip: Put bat detector in an open, uncluttered environment so that it is more likely to detect bats using search phase calls.

1. Load auto-identification analysis results into a database in order to expedite hand review of calls by sorting calls to species or species groups and/or sorting on call characteristics.
2. Look at search phase calls (not approach calls, feeding buzzes, or social calls) within a sequence.
3. Choose noise free calls with harmonics so that you are more likely to see the whole call instead of just a portion. Note that some calls may be oversaturated if the bat closely approached the microphone and these should be avoided if possible.
4. Look at the entire sequence in both compressed and real time views. This will help you see the whole picture (Are there multiple bats? Are there feeding buzzes or other non-search phase calls?). This is particularly important for differentiating EPFU vs. ANPA, MYLU vs. LABO, and for COTO in general since many other species may have calls that mimic COTO.

5. Look at the standard view for multiple calls within a sequence. BE AWARE that Sonobat sometimes identifies incorrect characteristics, analyzes strong harmonics instead of the primary call, and occasionally includes noise along with the primary call of interest.

¹ Adapted from Humboldt State University Bat Lab. 2011. Eastern and Western US Bat Keys.

² Reviewed in Fenton, M. B. 2013. Questions, ideas and tools: lessons from bat echolocation. *Animal Behaviour* 85, 869-879. Originally described in Griffin, D. R., et al. 1960. The echolocation of flying insects by bats. *Animal Behaviour* 8, 141-154.

³ Fenton, M. B. 2004. Bat Natural History and Echolocation. *In* Brigham, R. M., et al., eds. *Bat Echolocation Research: tools, techniques, and analysis*. Bat Conservation International, Austin, TX.

⁴ Elemans, C., et al. 2011. Superfast Muscles Set Maximum Call Rate in Echolocating Bats. *Science* 333, 1885-1888.

Call Characteristics for Montana's Bats

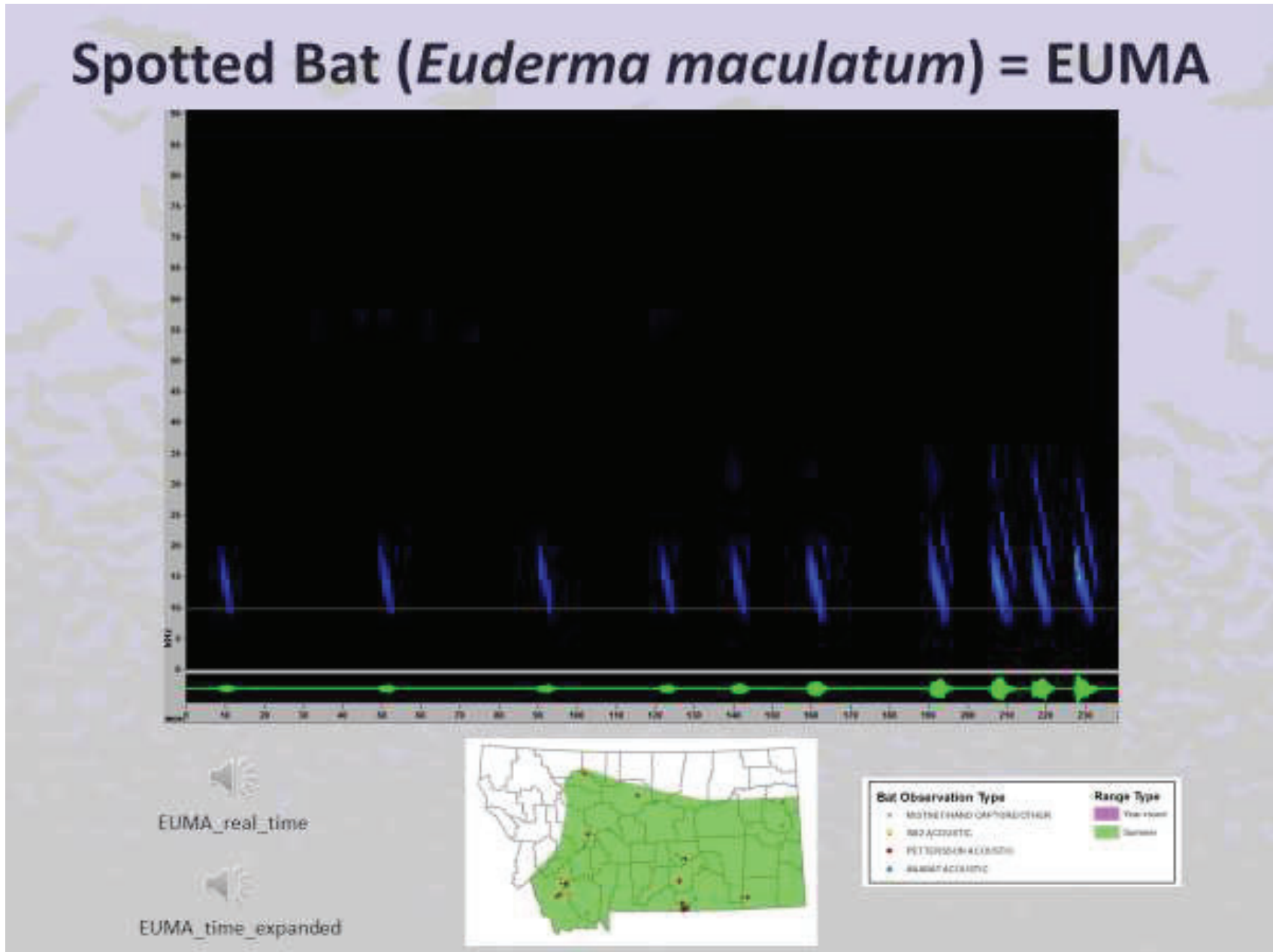
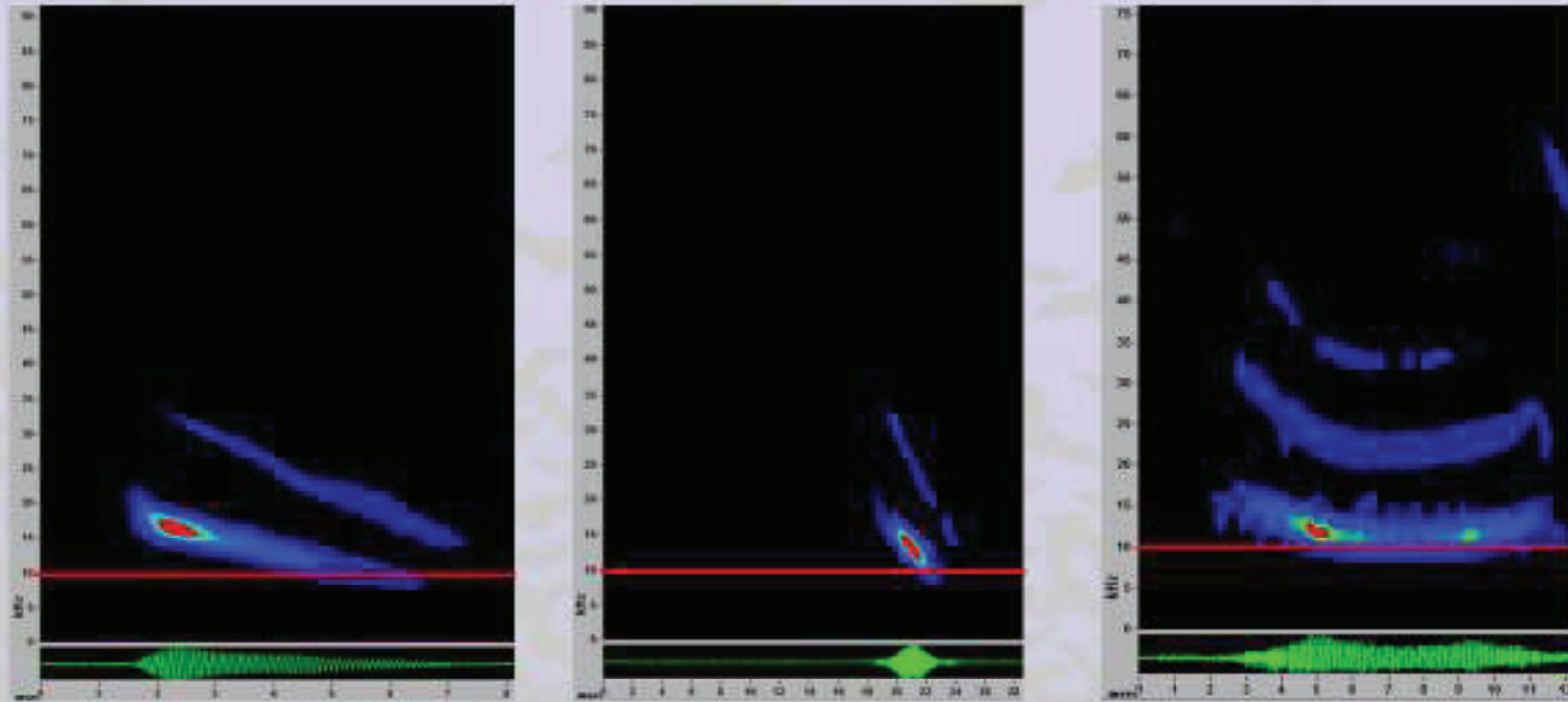


Figure 30. Example calls for the Spotted Bat (*Euderma maculatum*, EUMA)

EUMA Call Shapes

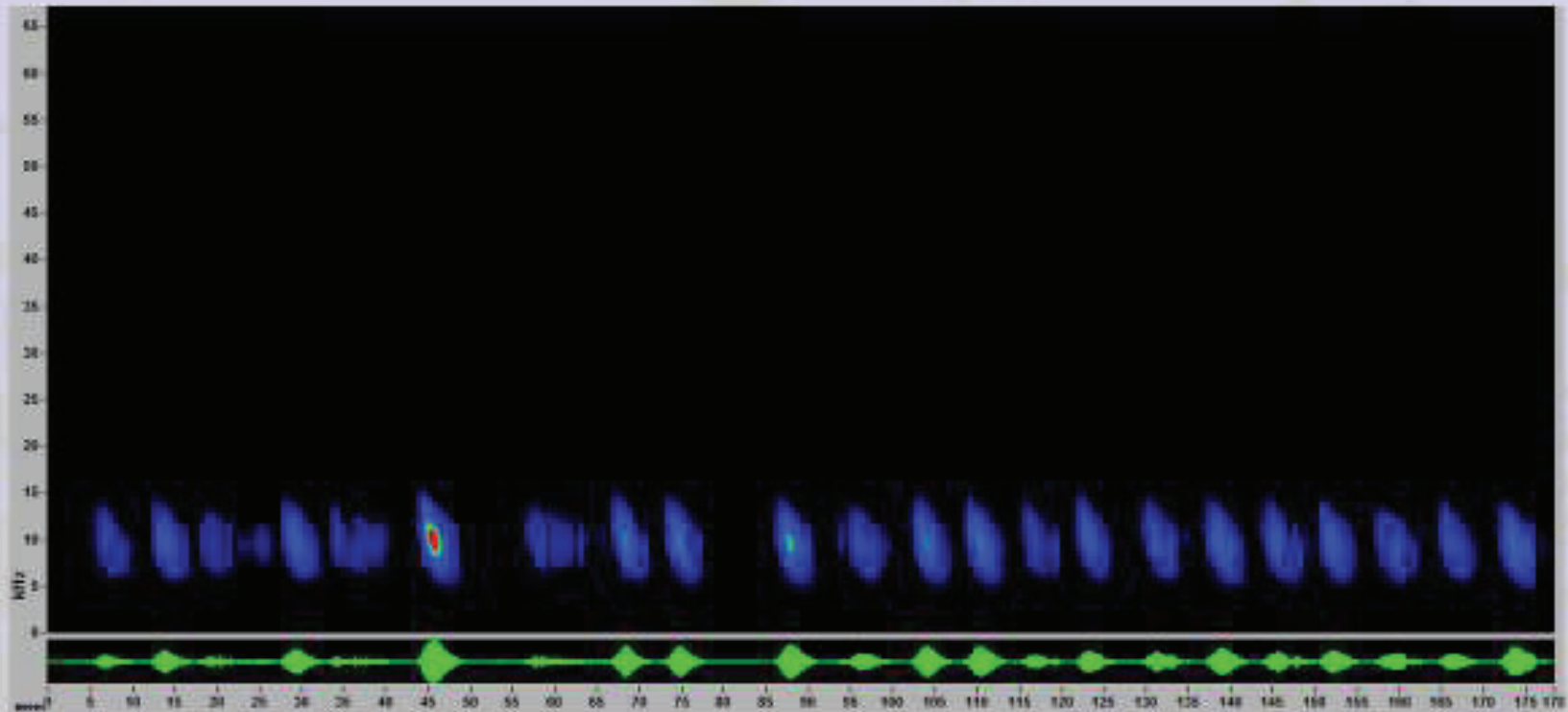


*Red scale bars are set at 10 kHz.

- Short, simple linear FM sweep at low frequency
- Sometimes a mild inflection or curvature
- Harmonics are usually present, sometimes with second harmonic persisting beyond the primary call component
- ** No bat in Montana is easily confused with EUMA because search phase calls are the lowest frequency of any bat in the state

Figure 31. Call shapes of the Spotted Bat (*Euderma maculatum*, EUMA)

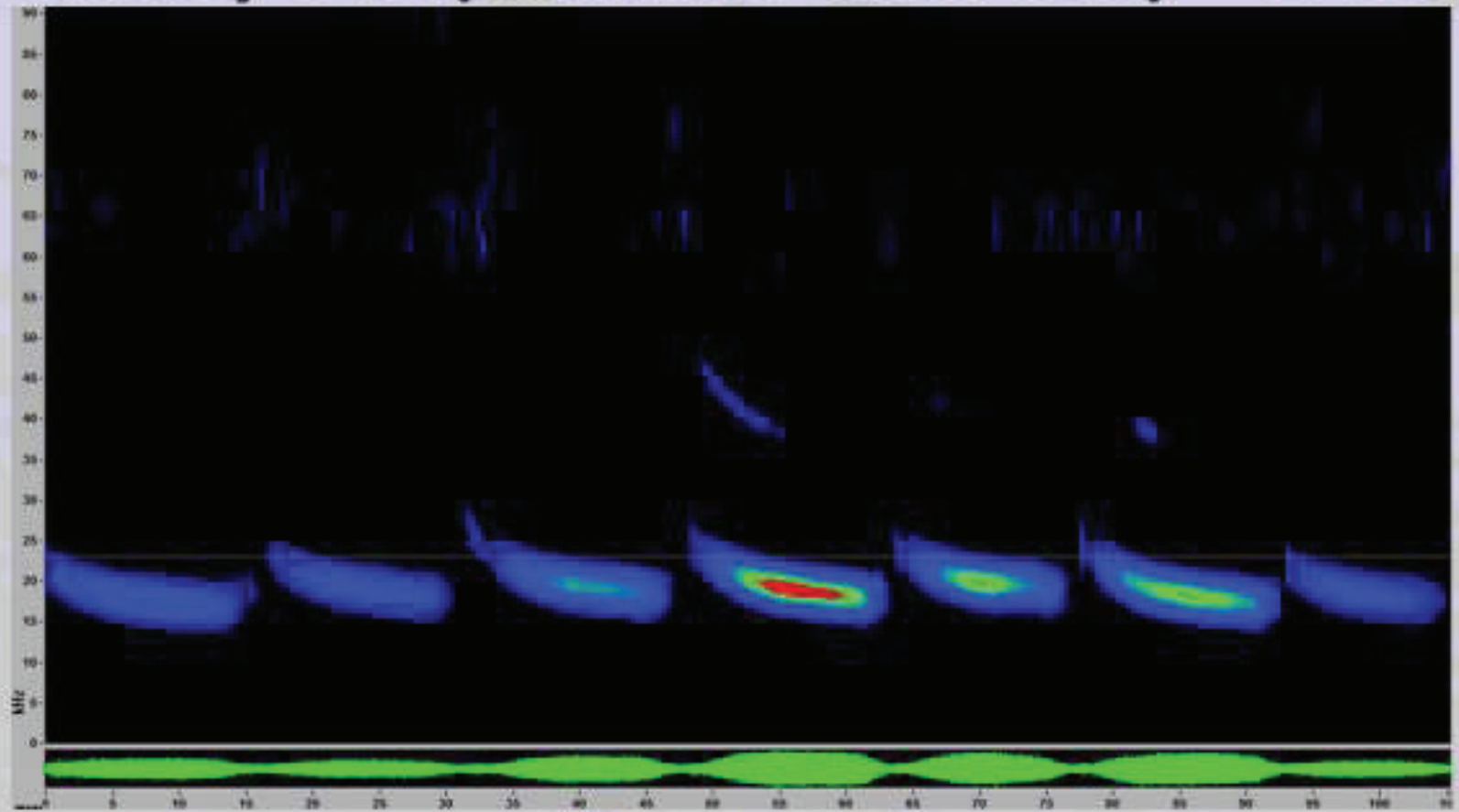
EUMA Definitive Characteristics



- Simple linear FM sweep
- Duration: 3-8 ms
- f_c : 7-10 kHz

Figure 32. Definitive characteristics for the Spotted Bat (*Euderma maculatum*, EUMA)

Hoary Bat (*Lasiurus cinereus*) = LACI



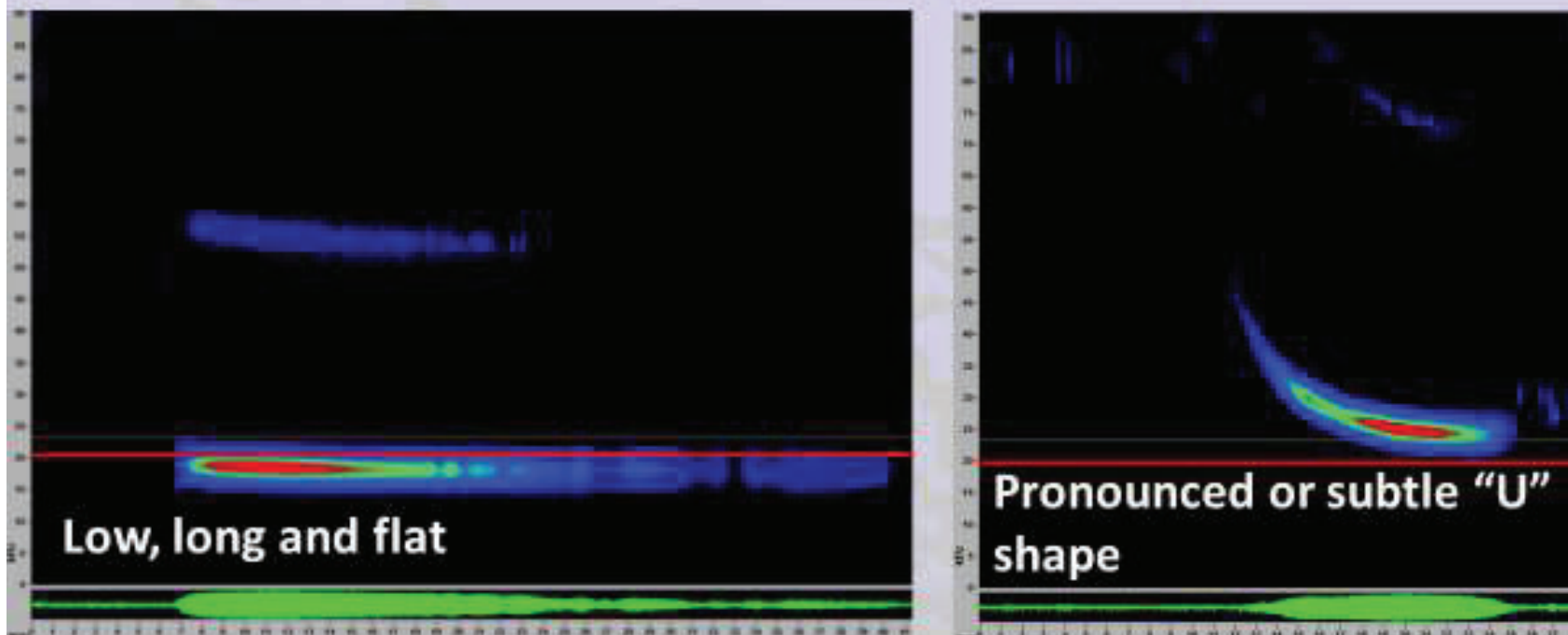
LACI_time_expanded



Bat Observation Type		Range Type	
○	MISTNET/SAMU CAPTURE/OTHER	■	Fall/Winter
○	DIY ACOUSTIC	■	Summer
●	PETTERSON ACOUSTIC		
●	WRIGHT ACOUSTIC		

Figure 33. Example calls for the Hoary Bat (*Lasiurus cinereus*, LACI)

LACI Call Shapes

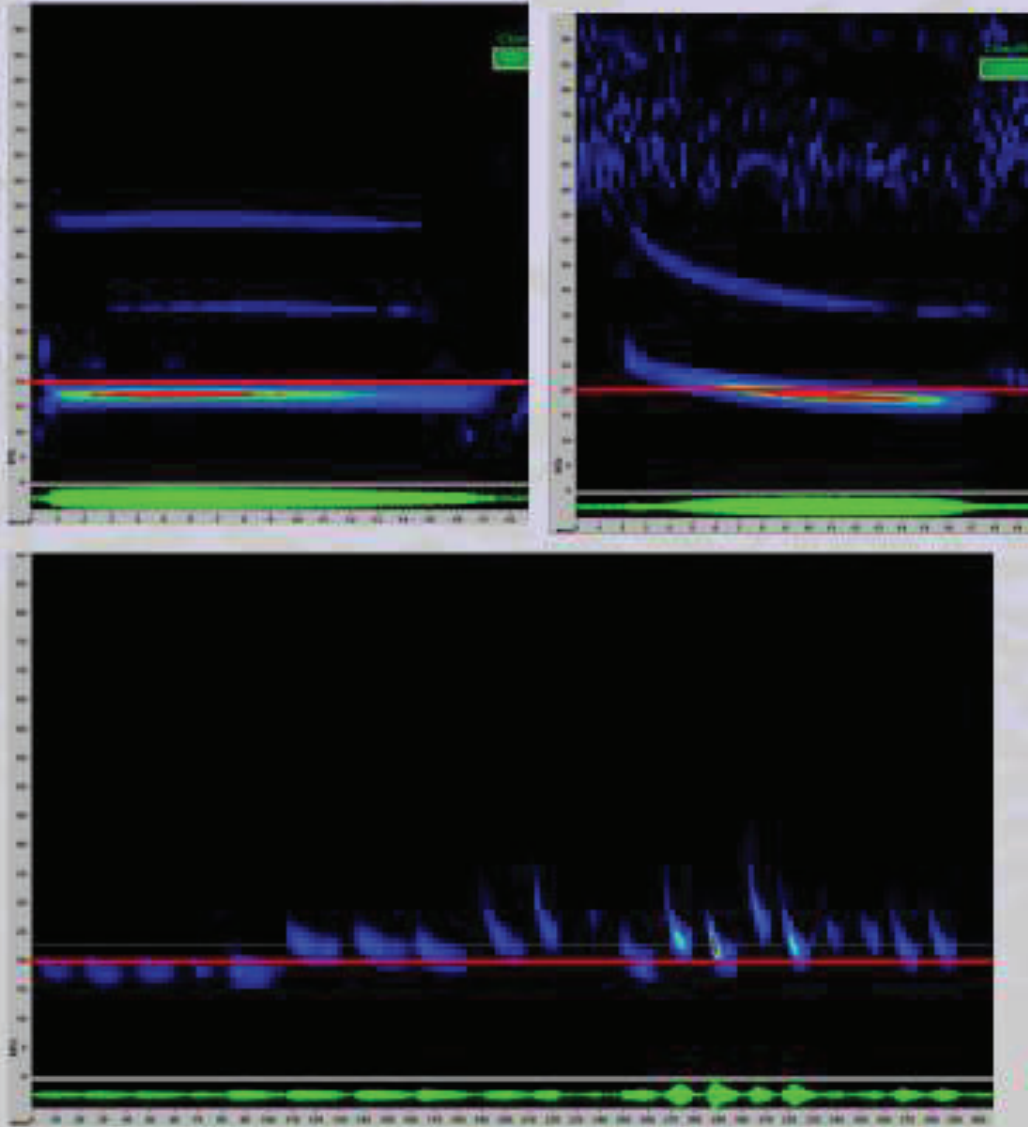


- Very flat calls may have slight downturn into call and/or upturn at the end

***Red scale bars are set at 20 kHz.**

Figure 34. Call shapes of the Hoary Bat (*Lasiurus cinereus*, LACI)

LACI Definitive Characteristics



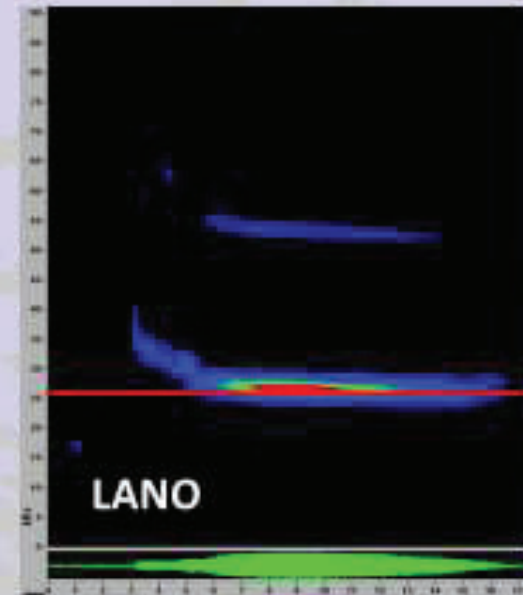
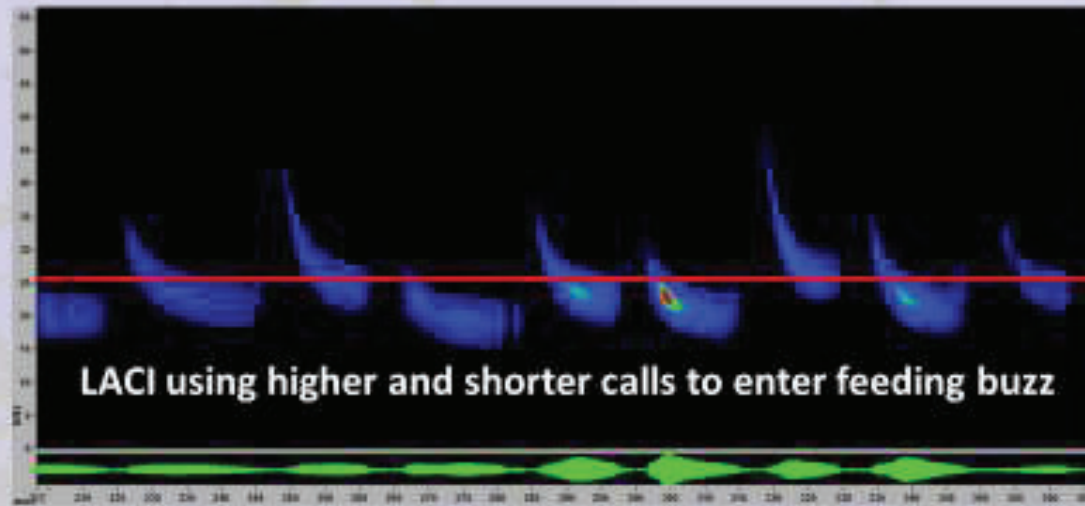
- Pronounced or subtle “U” shape
OR very flat calls
<20 kHz

- Low f and f_c may vary across a sequence;
 $f_c < 30$ kHz in these sequences

*Red scale bars are set at 20 kHz.

Figure 35. Definitive call characteristics for the Hoary Bat (*Lasiurus cinereus*, LACI)

LACI Similar Species



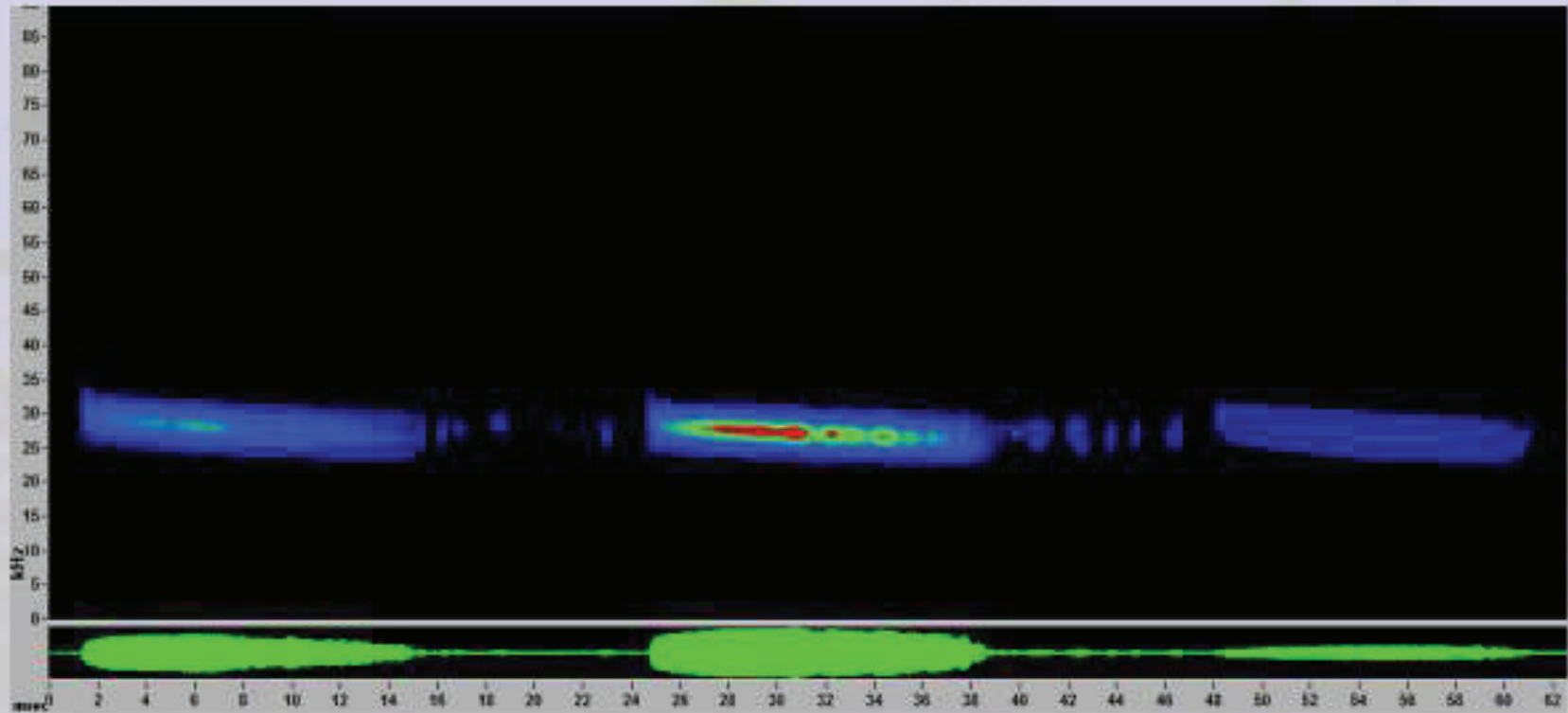
LACI vs. LANO: Flat calls in the $f_c = 23-26$ kHz range are indistinguishable. Low sloped calls in the $f_c = 25-26$ kHz range with inflection are distinguished from LACI. Short LACI approach calls may overlap undiagnostic, short LANO calls.

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

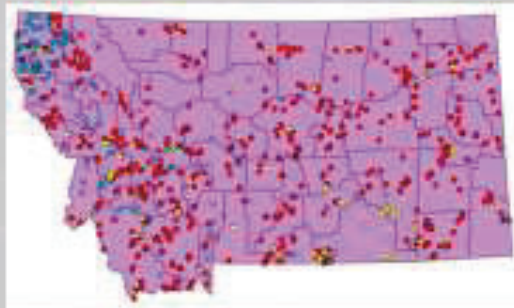
***Red scale bars are set at 26 kHz.**

Figure 36. Call sequences produced by other species that may be confused with the Hoary Bat (*Lasiurus cinereus*, LACI)

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



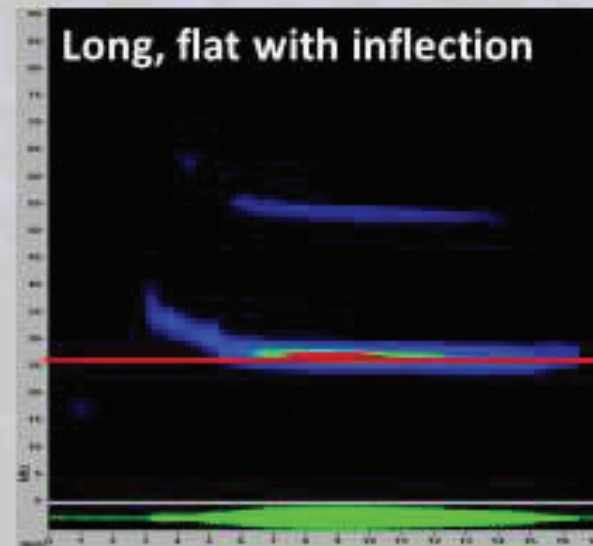
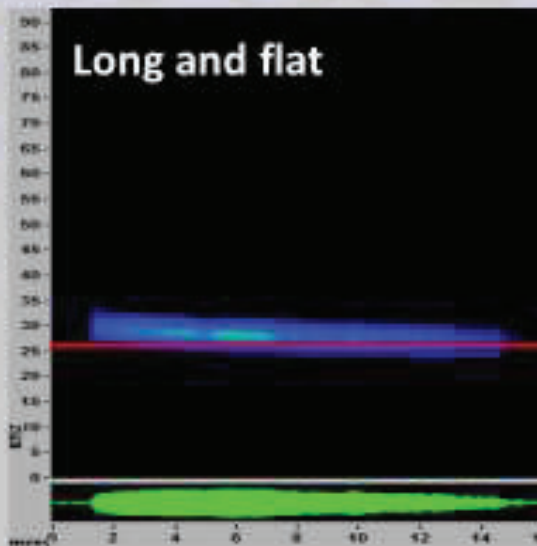
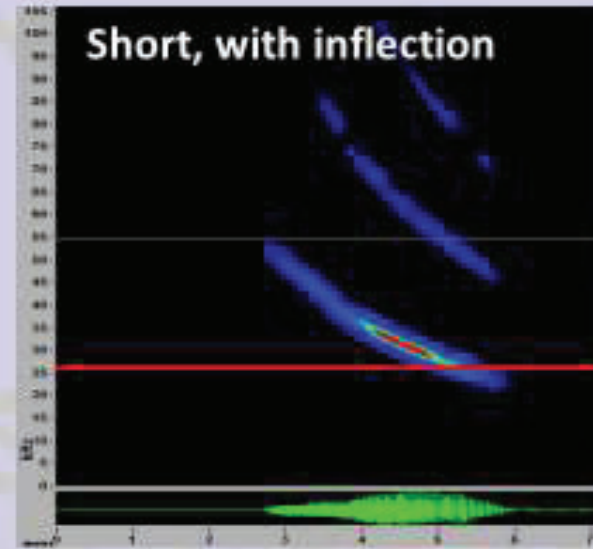
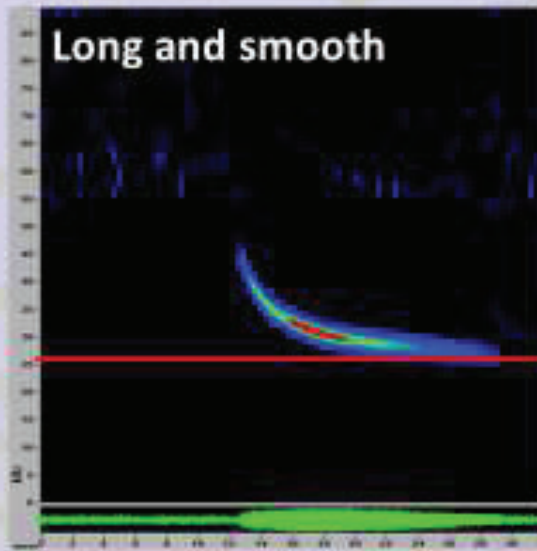
LANO_time_expanded



Bat Observation Type	Range Type
○ MISTNET/HAIR CAPTURE/OTHER	■ Year-round
● SPRING ACUSTIC	■ Summer
● WINTER/SPRING ACUSTIC	
● SUMMER ACUSTIC	

Figure 37. Example call sequence for the Silver-haired Bat (*Lasionycteris noctivagans*, LANO)

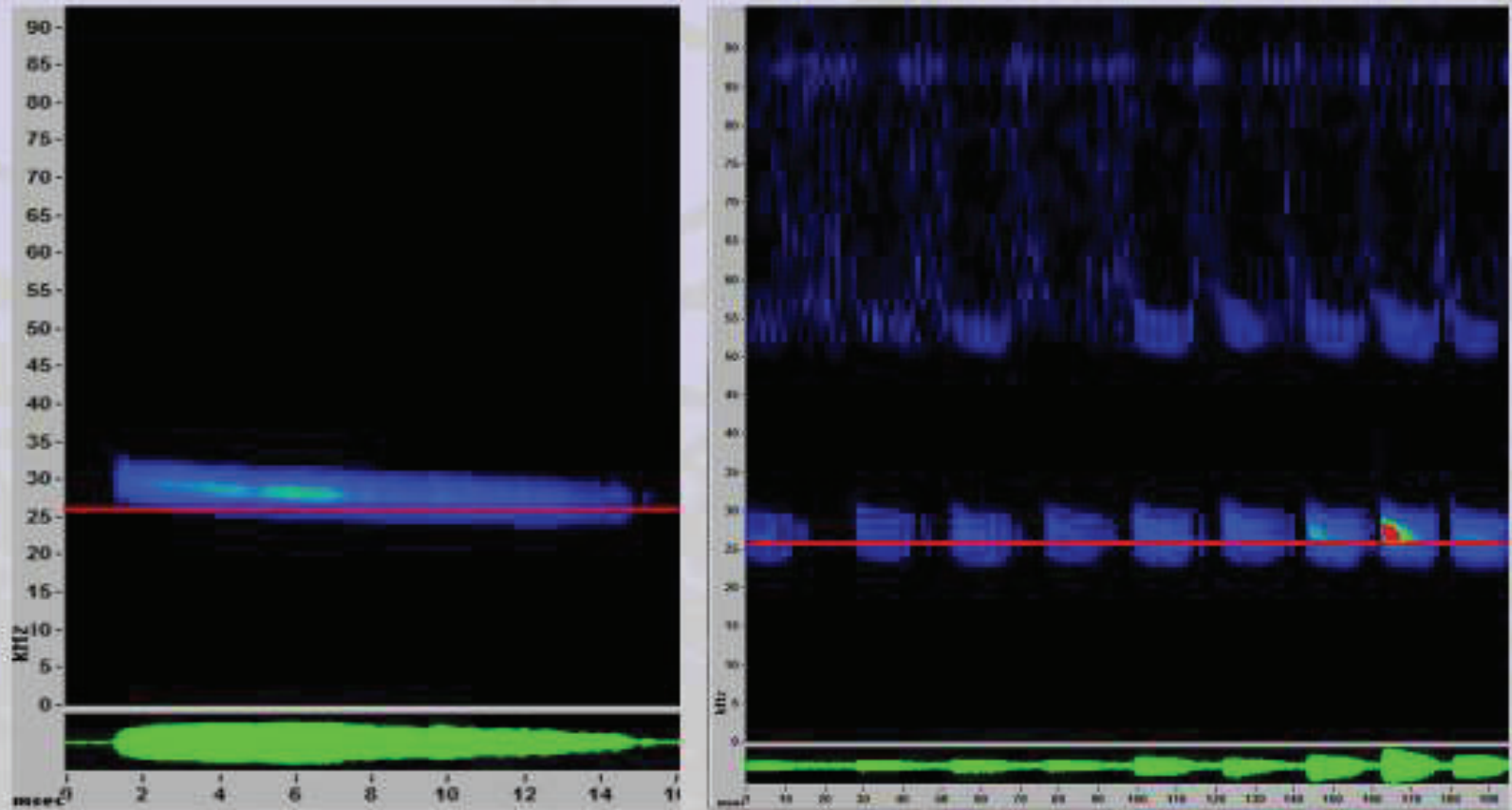
LANO Call Shapes



*Red scale bars are set at 26 kHz.

Figure 38. Call shapes of the Silver-haired Bat (*Lasionycteris noctivagans*, LANO)

LANO Definitive Characteristics

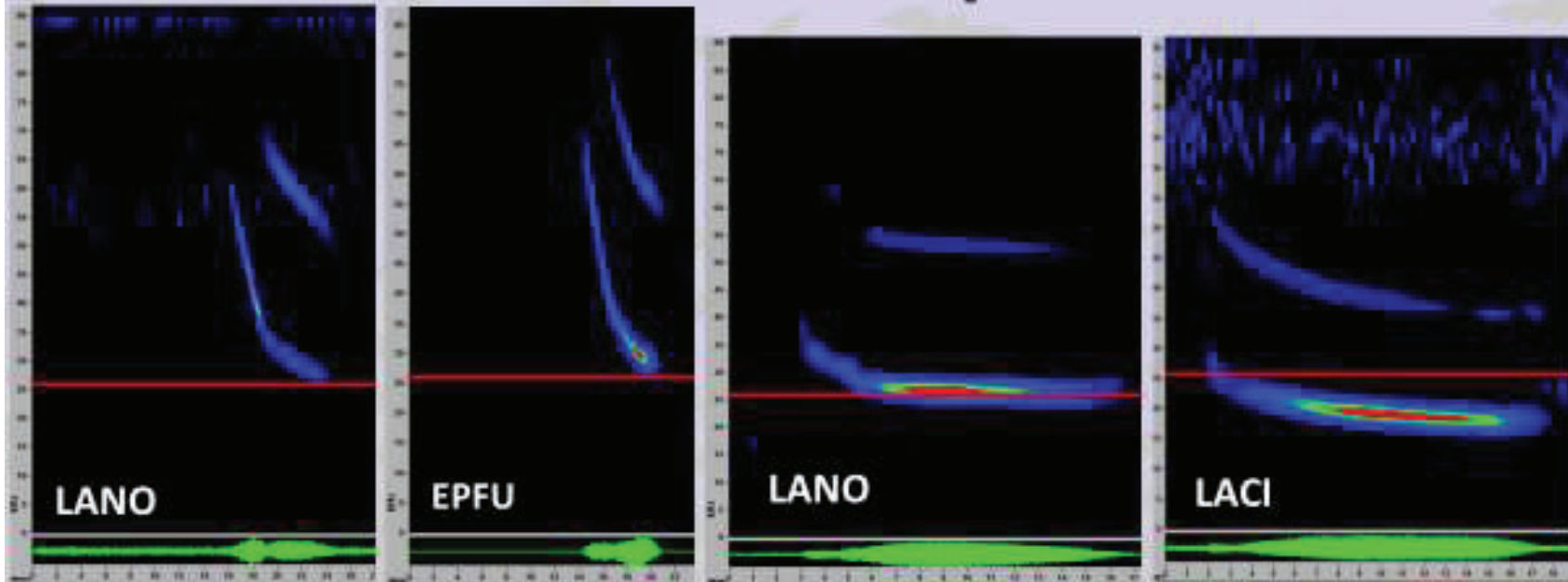


*Red scale bars are set at 26 kHz.

- 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

Figure 39. Definitive characteristics of call sequence for the Silver-haired Bat (*Lasionycteris noctivagans*, LANO)

LANO Similar Species



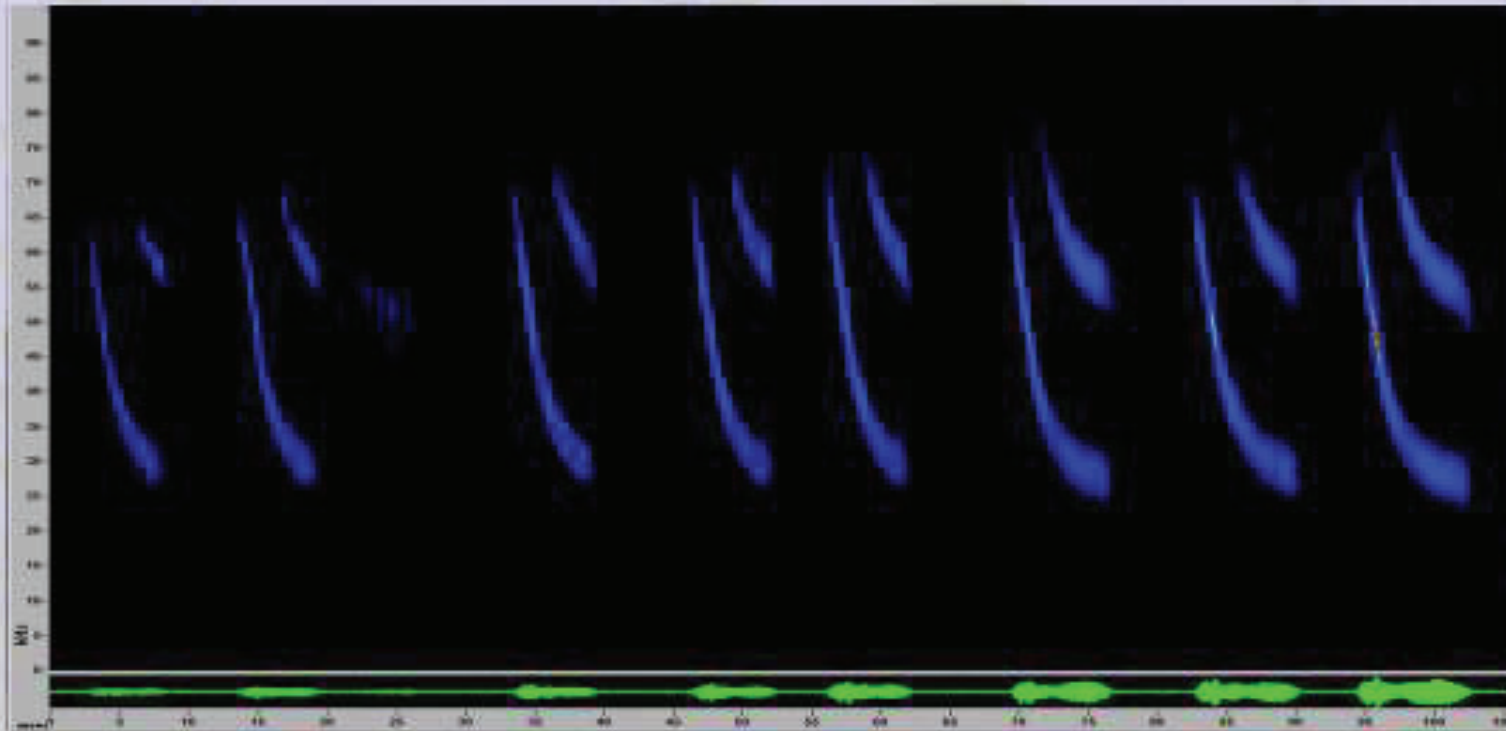
LANO vs. EPFU and ANPA: EPFU has more frequency modulation; lower, longer calls with a pronounced inflection help distinguish LANO from EPFU. LANO does get <6 calls/sec but tends to drop below ANPA f_c range and higher LANO calls tend to have inflection, while ANPA does not.

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

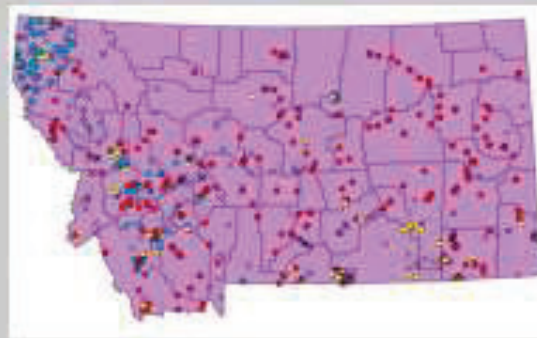
***Red scale bars are set at 26 kHz.**

Figure 40. Calls sequences produced by other species that may be confused with the Silver-haired Bat (*Lasionycteris noctivagans*, LANO)

Big Brown Bat (*Eptesicus fuscus*) = EPFU



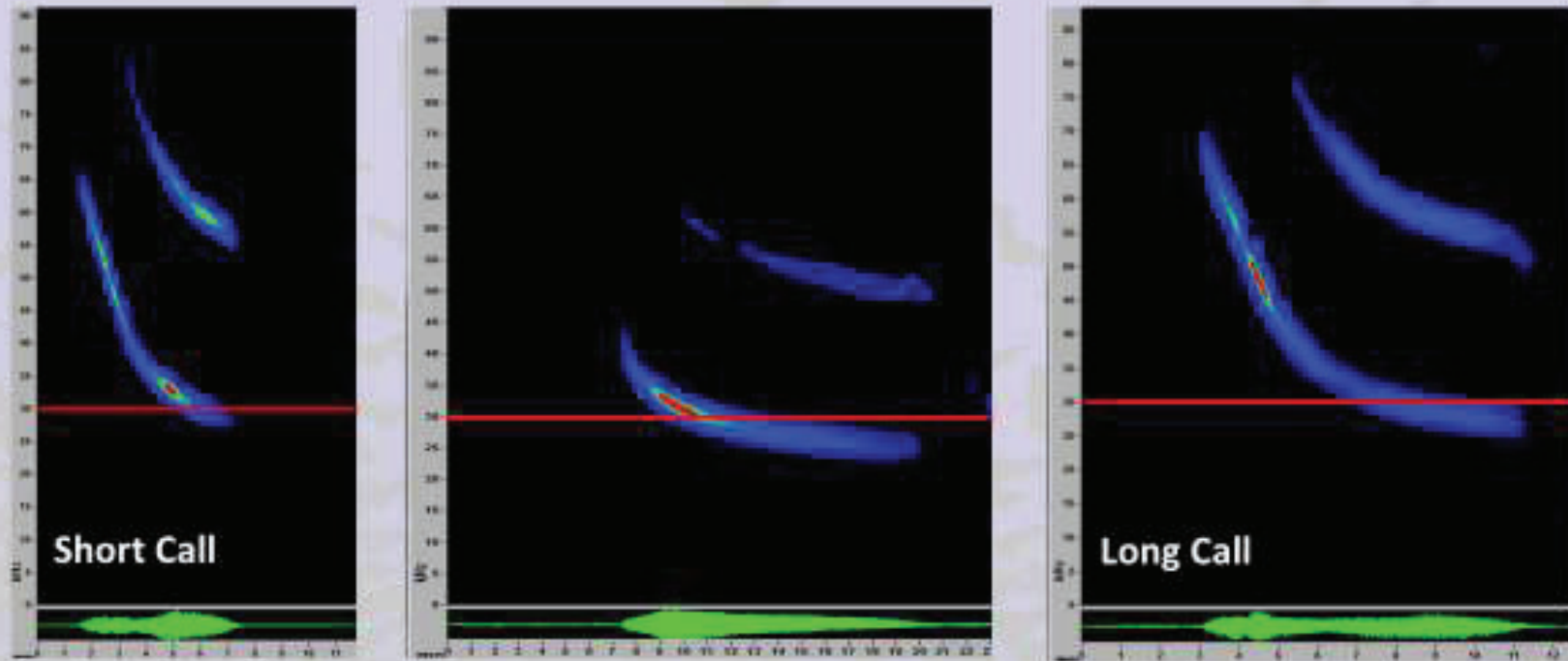
EPFU_time_expanded



Bat Observation Type		Range Type	
●	BEST FISHING CAPTURED	■	Year-round
●	INVASIVE	■	Summer
●	PETSONSONA CONDE		
●	INVASIVE		

Figure 41. Example call sequence for the Big Brown Bat (*Eptesicus fuscus*, EPFU)

EPFU Call Shapes

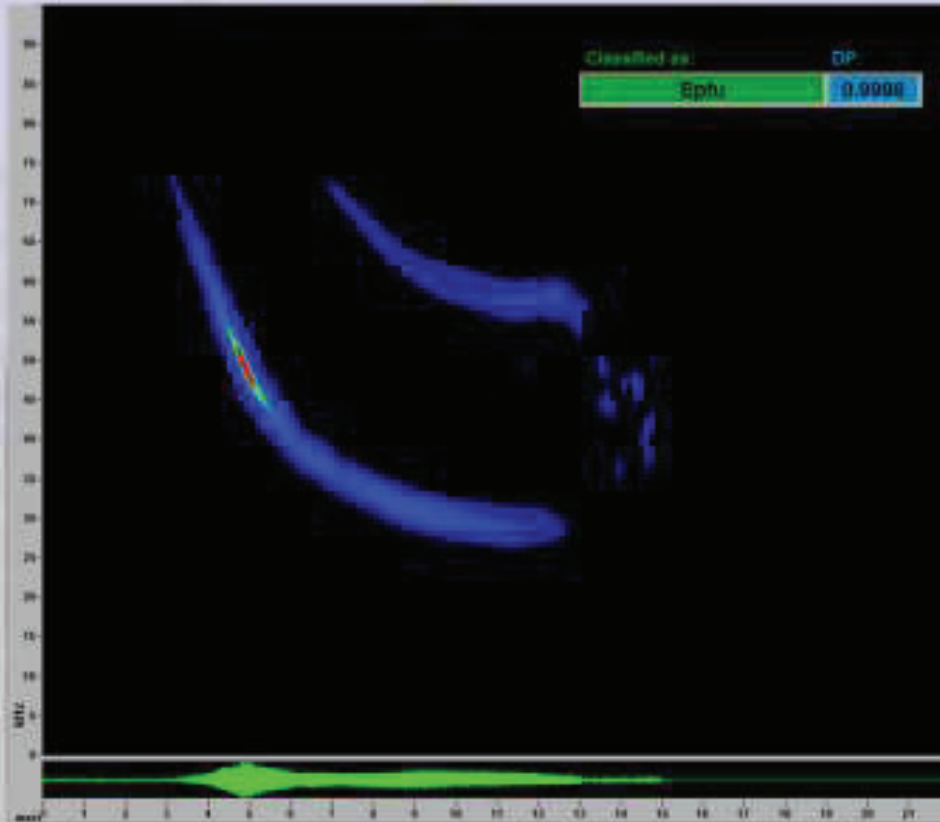


- Variable; smoothly curved FM sweeps. Even long calls have some FM component.
- Harmonics usually parallel, but may slightly converge or “drip down” at ends.

***Red scale bars are set at 30 kHz.**

Figure 42. Call shapes of the Big Brown Bat (*Eptesicus fuscus*, EPFU)

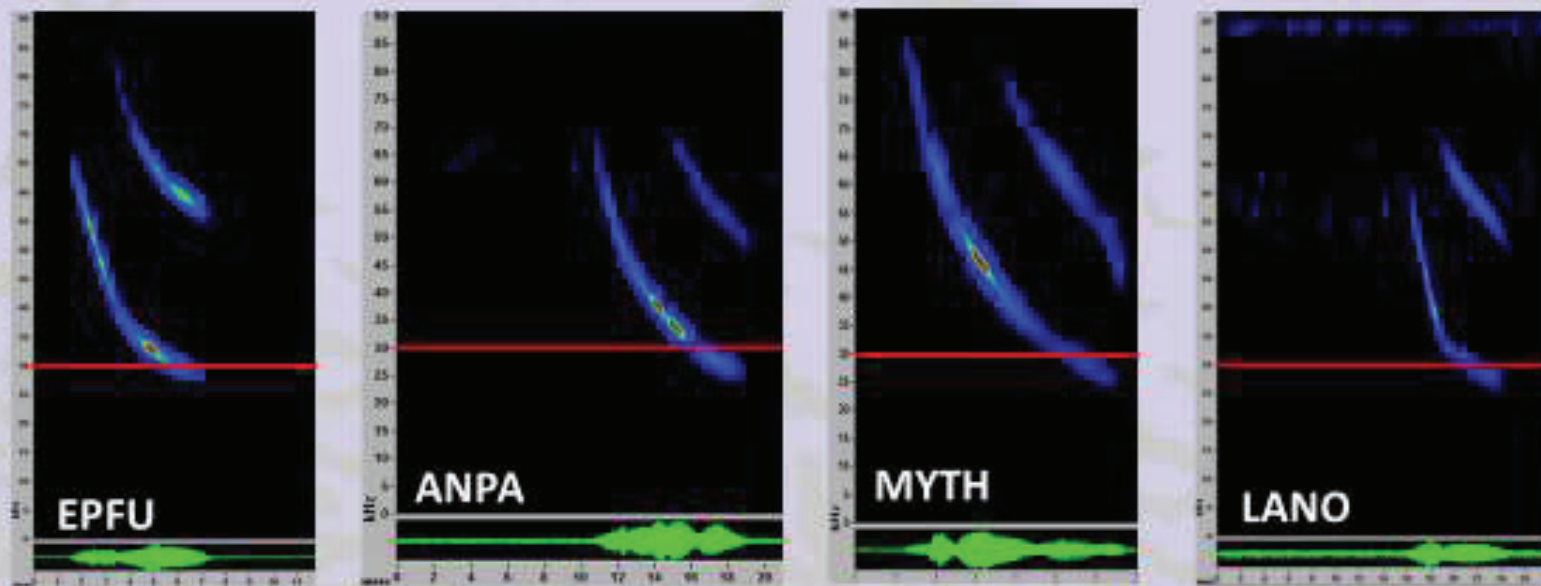
EPFU Definitive Characteristics



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

Figure 43. Definitive characteristics of call sequence for the Big Brown Bat (*Eptesicus fuscus*, EPFU)

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.

***Red scale bars are set at 30 kHz.**

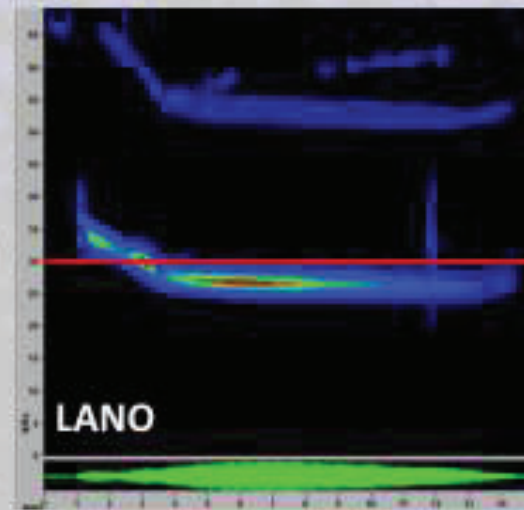
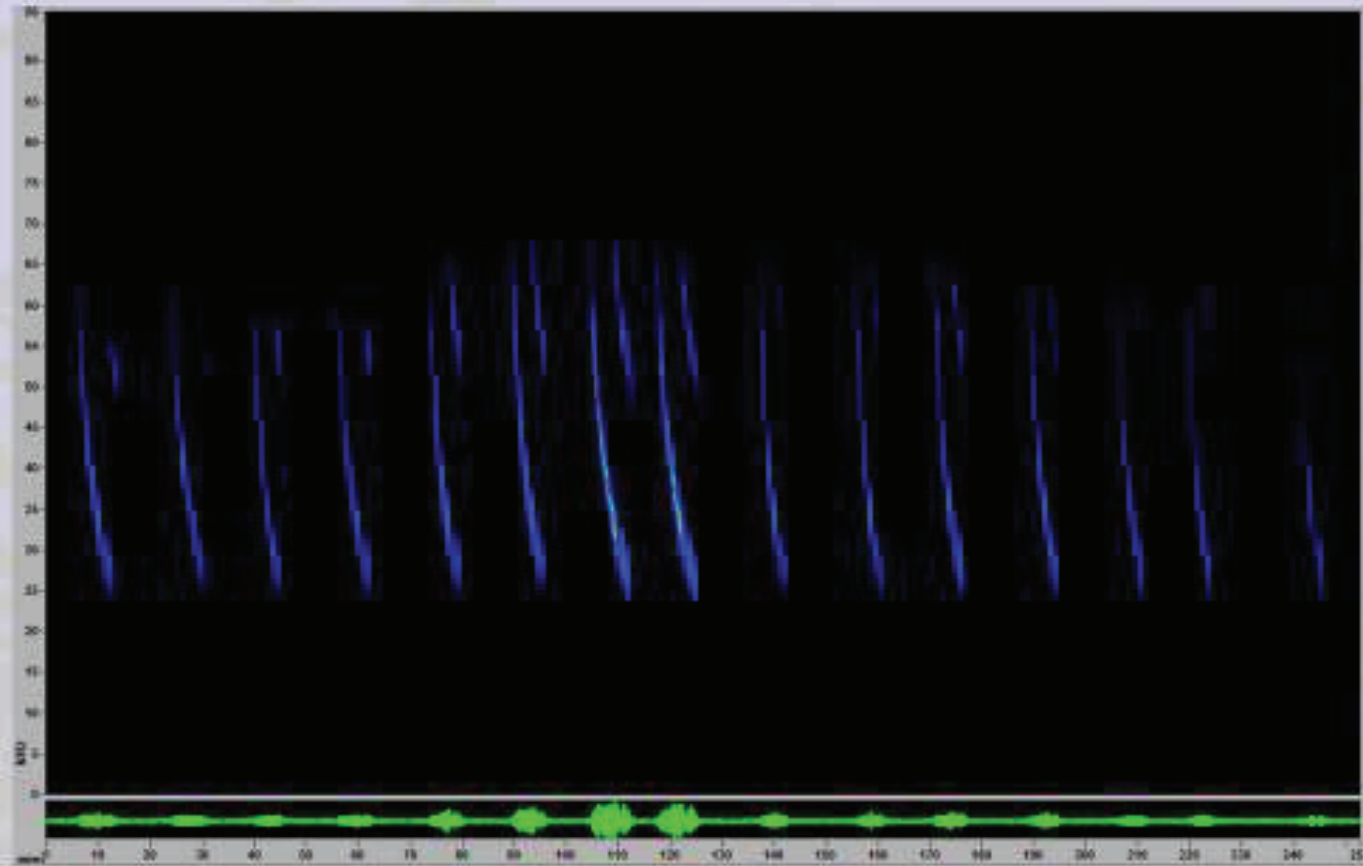
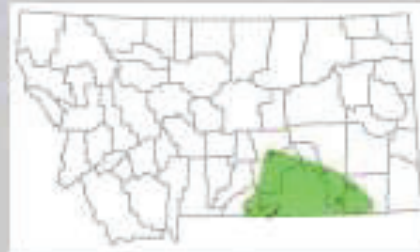


Figure 44. Calls sequences produced by other species that may be confused with the Big Brown Bat (*Eptesicus fuscus*, EPFU)

Pallid Bat (*Antrozous pallidus*) = ANPA



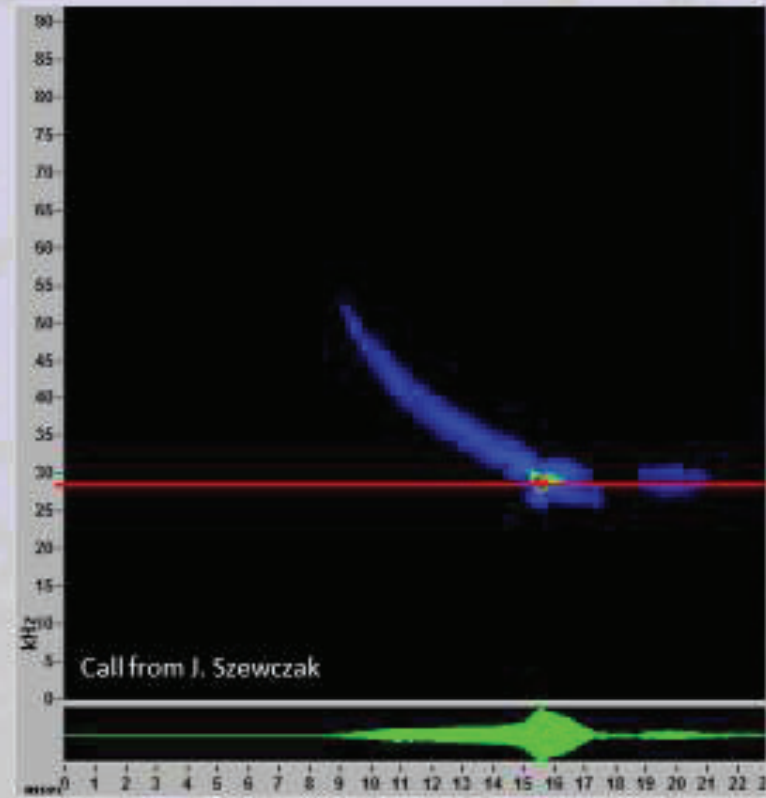
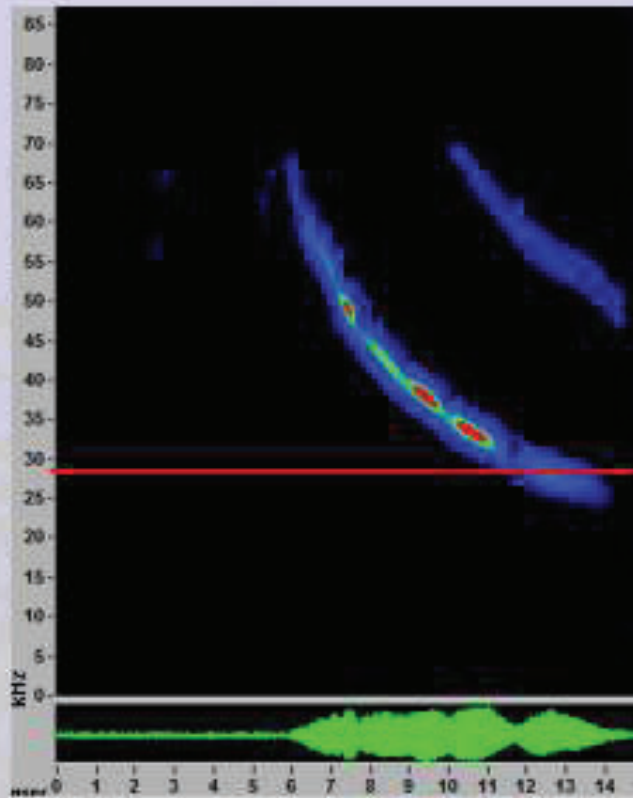
ANPA_time_expanded



Bat Observation Type	Range Type
• BEST FINGER CAPTURED	• Year-round
• INVASIVE	• Seasonal
• PETERSON + COVDE	
• SONAR ACUSTIC	

Figure 45. Example call sequence for the Pallid Bat (*Antrozous pallidus*, ANPA)

ANPA Call Shapes

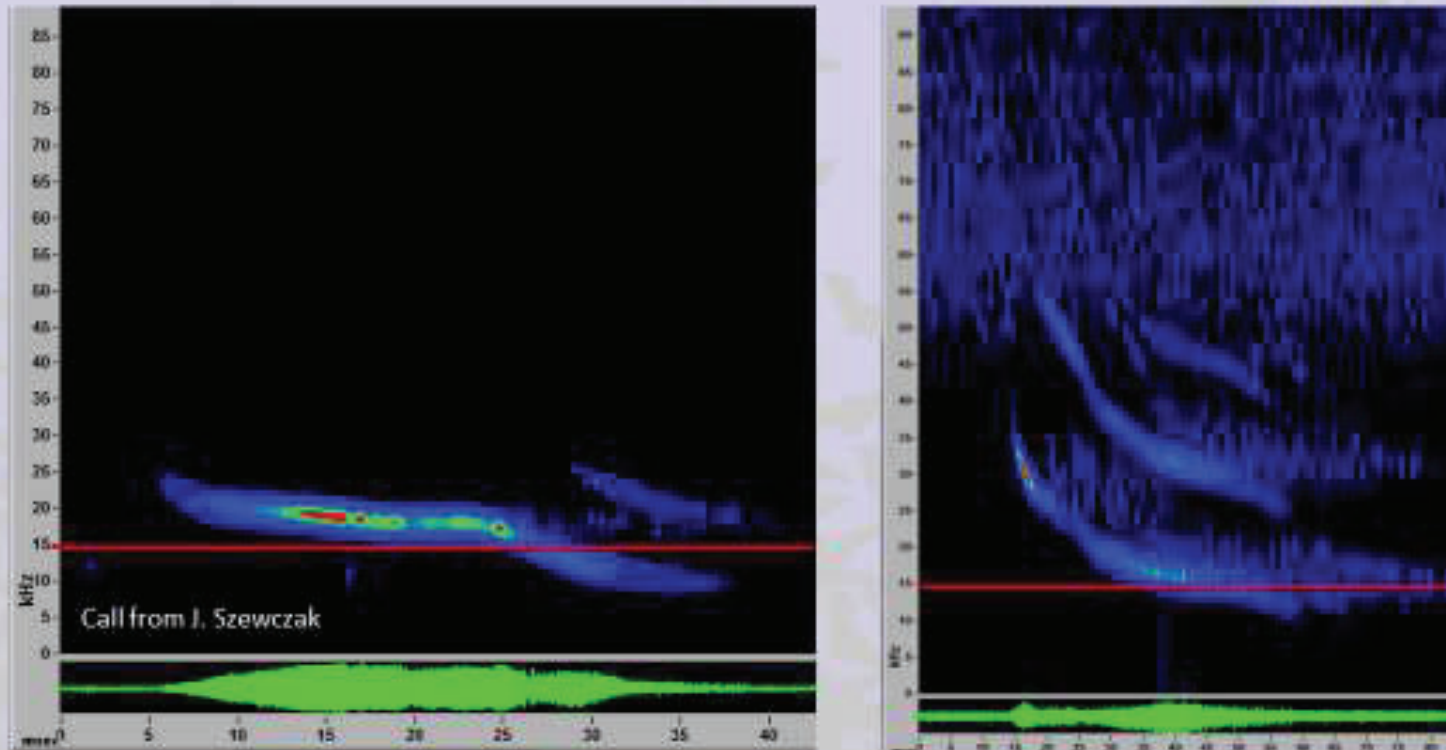


- Simple curved FM sweep
- No tail, but calls may end in a foot-like arch
- Parallel harmonics

***Red scale bars are set at 28 kHz.**

Figure 46. Call shapes of the Pallid Bat (*Antrozous pallidus*, ANPA)

ANPA Definitive Characteristics

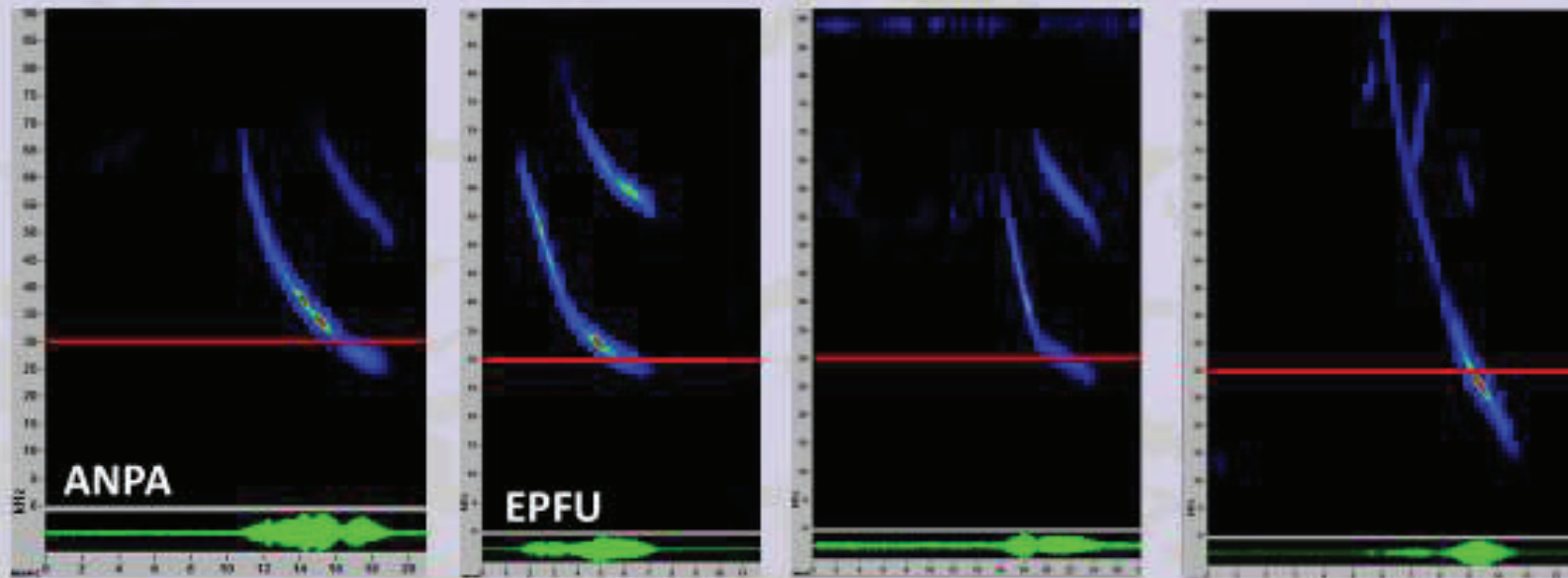


- Presence of social calls; usually long in duration and low in frequency
- < 6 calls per second

*Red scale bars are set at 15 kHz.

Figure 47. Definitive characteristics of call sequence for the Pallid Bat (*Antrozous pallidus*, ANPA)

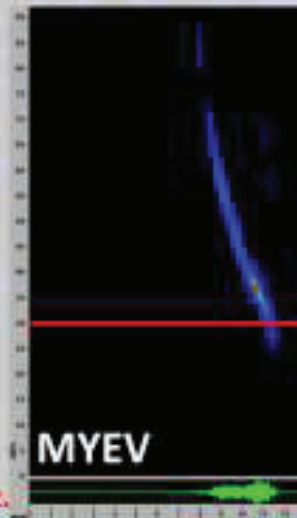
ANPA Similar Species



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

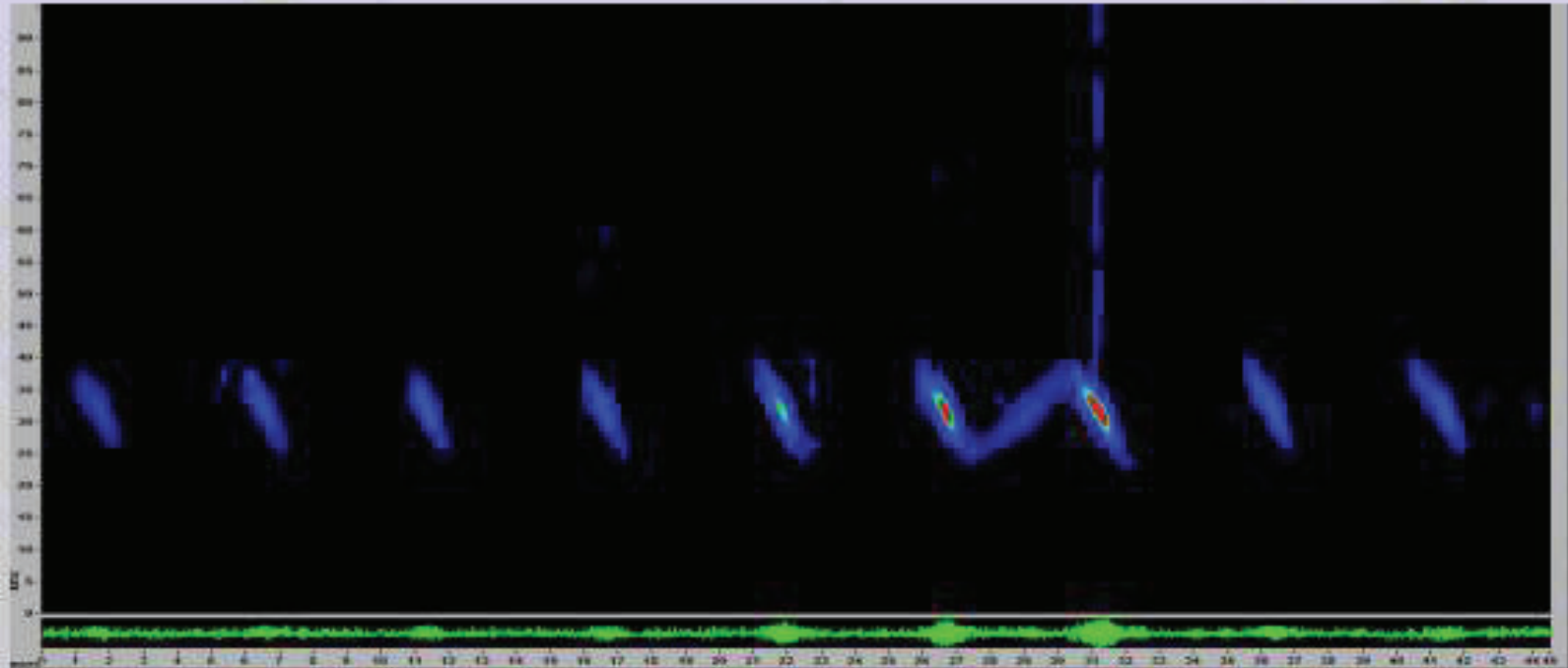
ANPA vs. short/higher LANO: LANO does get < 6 calls/sec but tends to drop below ANPA fc range; higher LANO calls tend to have inflection.



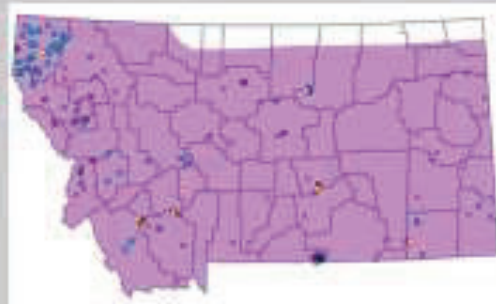
*Red scale bars are set at 30 kHz.

Figure 48. Calls sequences produced by other species that may be confused with the Pallid Bat (*Antrozous pallidus*, ANPA)

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



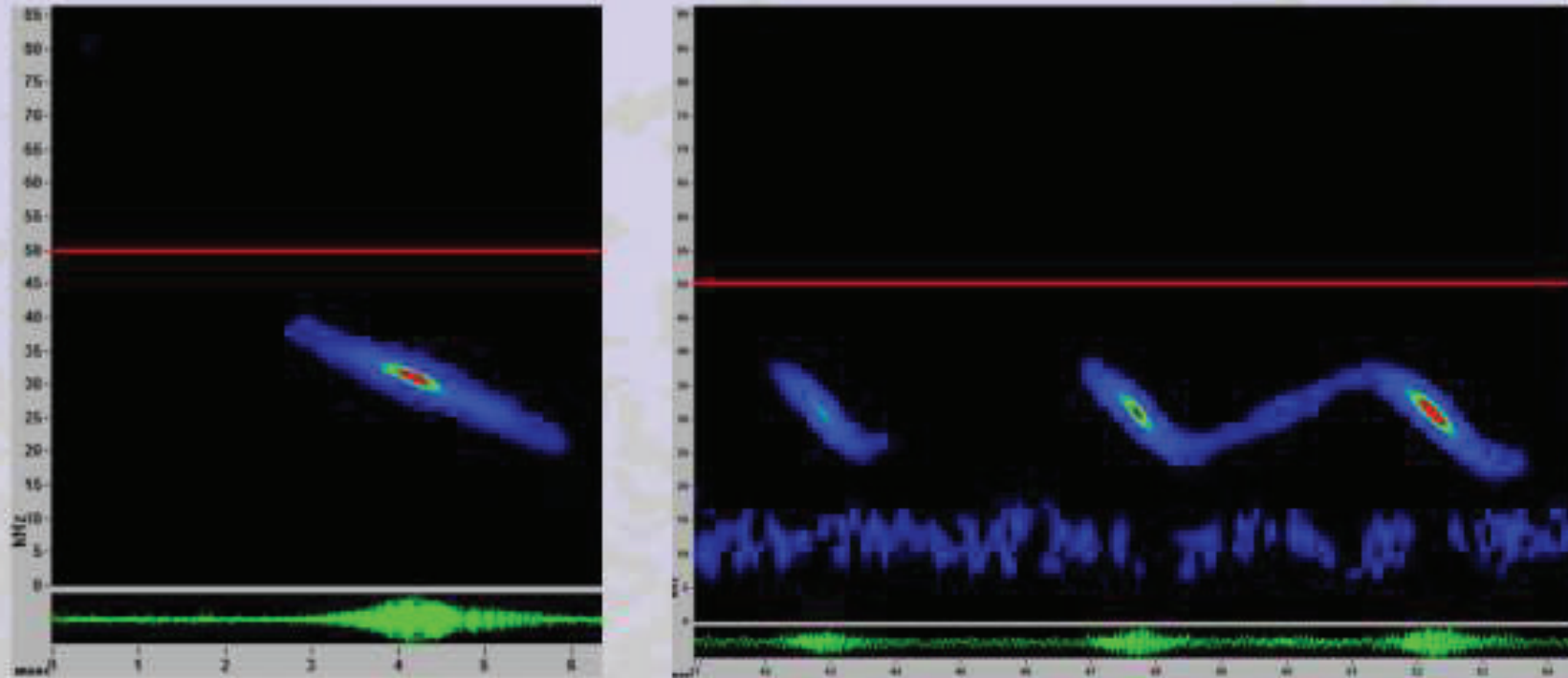
COTO_time_expanded



Bat Observation Type	Range Type
• MISTNET HAND CAPTURE/OTHER	• Year-round
• BWP ACQUISITE	• Seasonal
• PETERSON ACQUISITE	
• BWP ACQUISITE	

Figure 49. Example call sequence for the Townsend's Big-eared Bat (*Corynorhinus townsendii*, COTO)

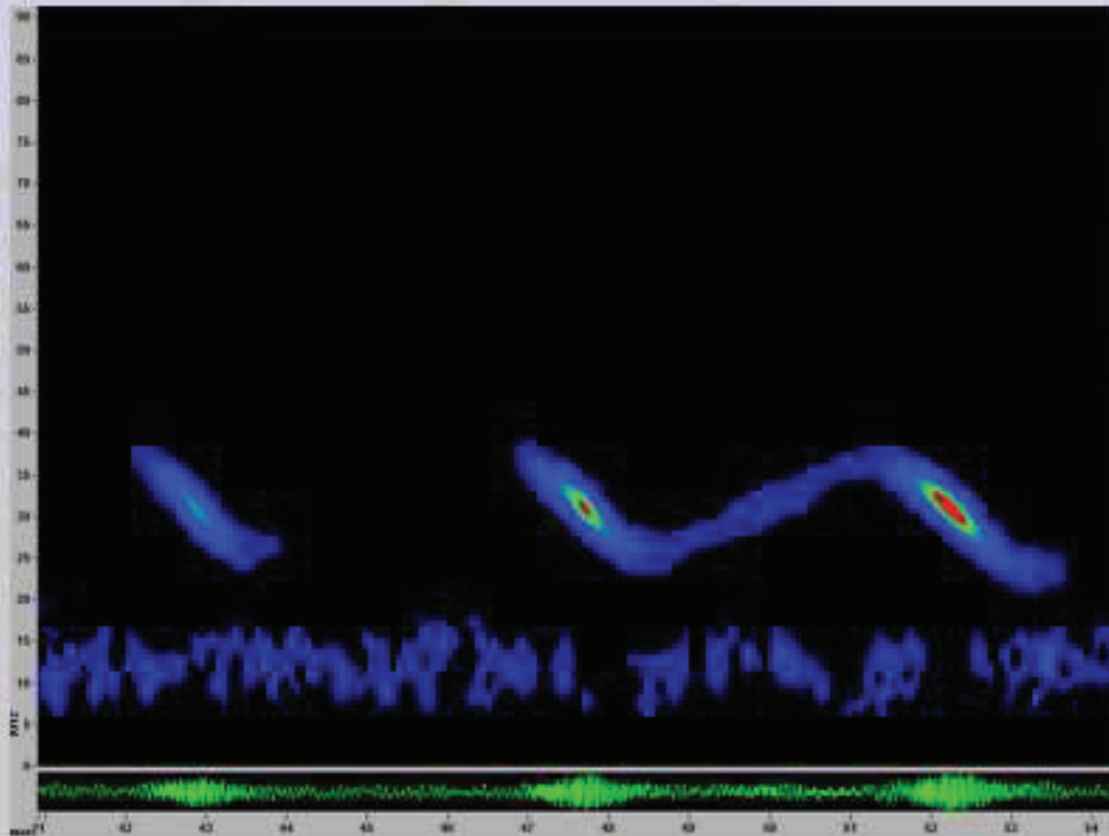
COTO Call Shapes



- 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
- *Red scale bars are set at 50 kHz.**

Figure 50. Call shapes of the Townsend's Big-eared Bat (*Corynorhinus townsendii*, COTO)

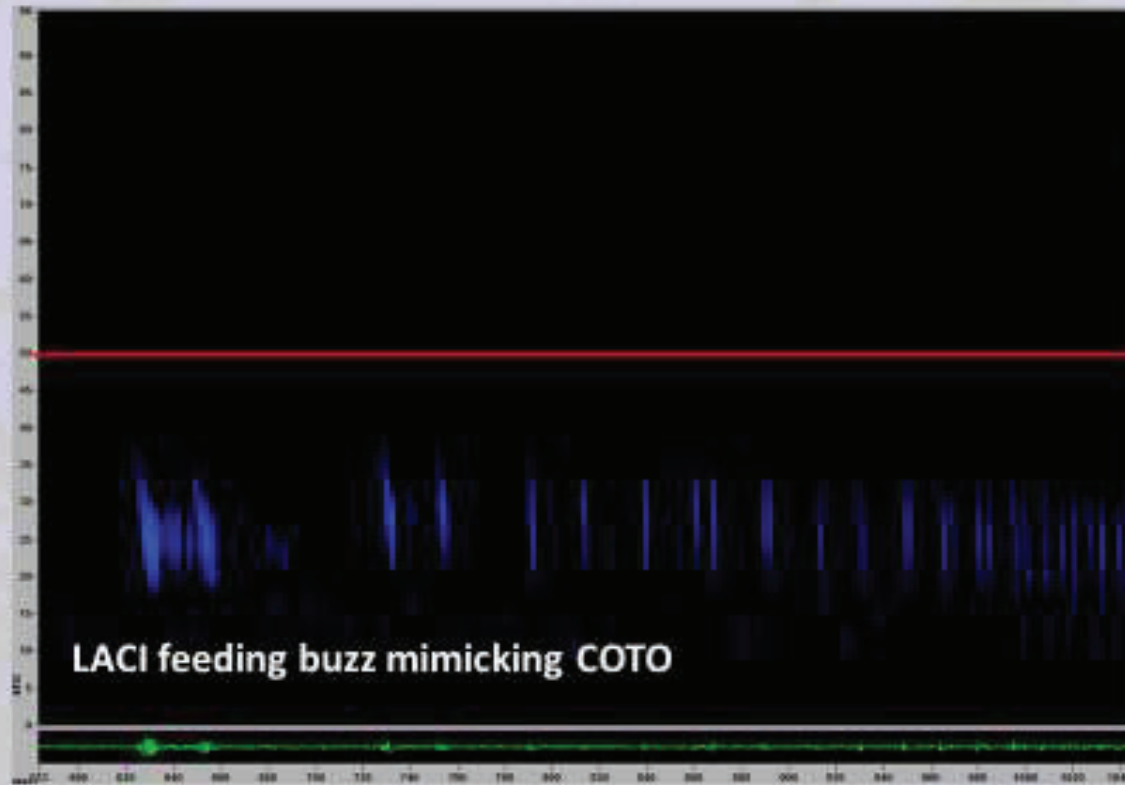
COTO Definitive Characteristics



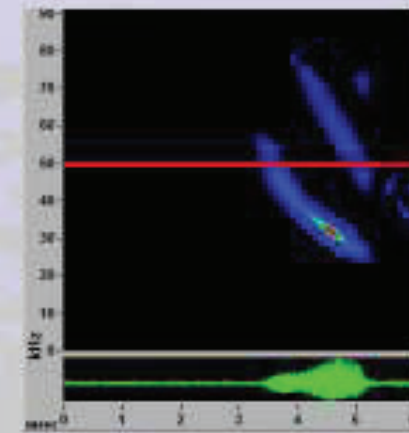
- **Simple linear FM sweep** (sometimes with upsweep or plateau at onset- **NO** knee or upward facing curvature toward the end of call)
- **Squiggle call with 5-7 ms intervals**

Figure 51. Definitive characteristics of call sequence for the Townsend's Big-eared Bat (*Corynorhinus townsendii*, COTO)

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.

*Red scale bars are set at 50 kHz.

Figure 52. Calls sequences produced by other species that may be confused with the Townsend's Big-eared Bat (*Corynorhinus townsendii*, COTO)

Fringed Myotis (*Myotis thysanodes*) = MYTH

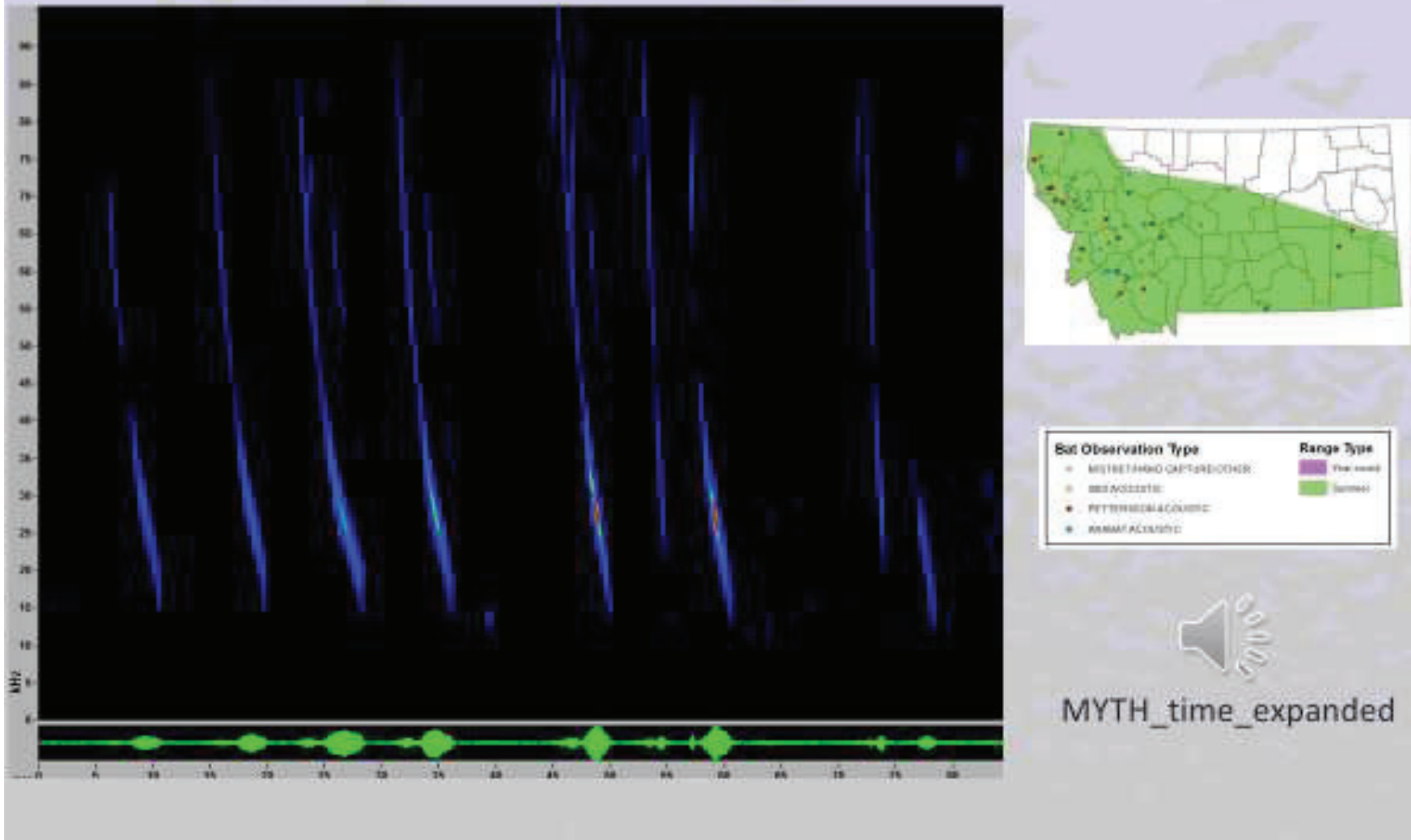
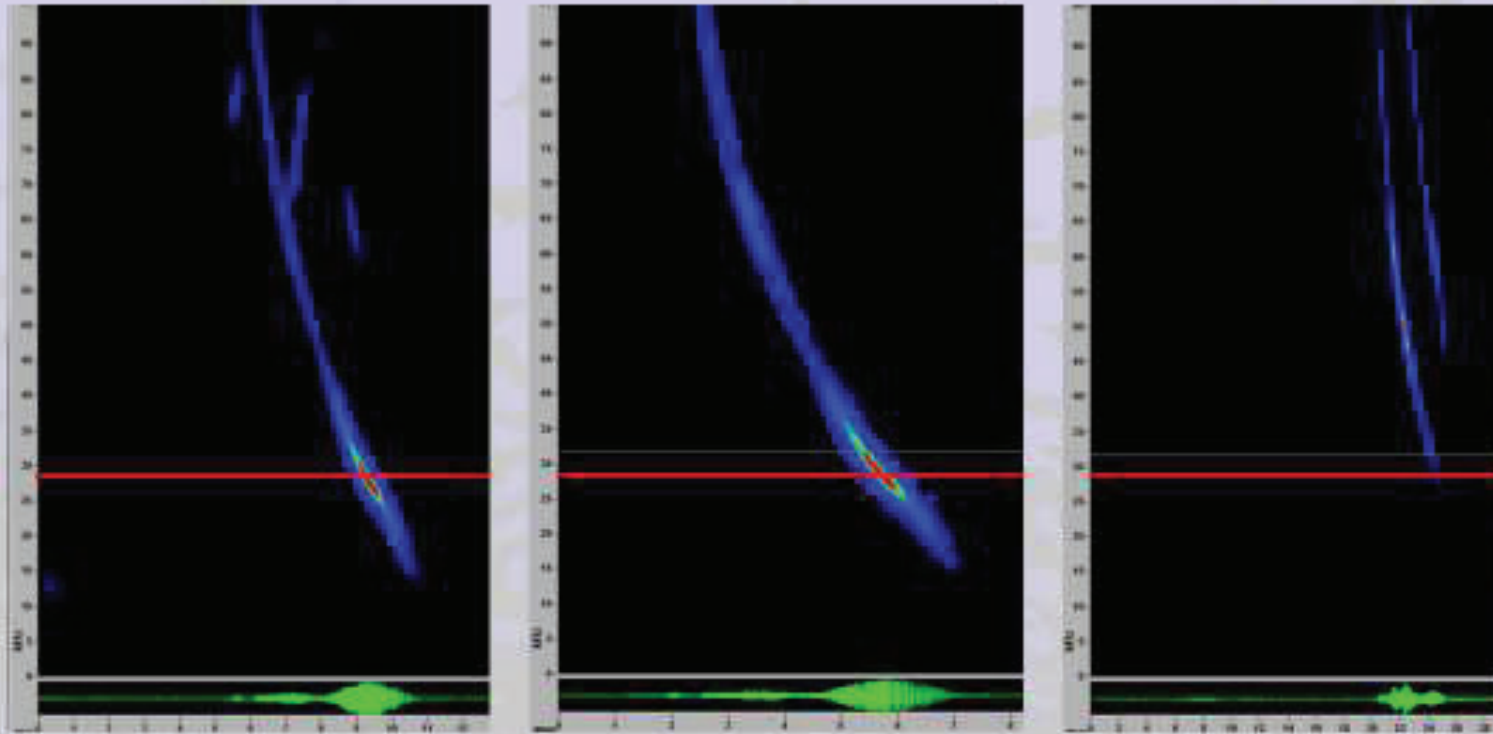


Figure 53. Example call sequence for the Fringed Myotis (*Myotis thysanodes*, MYTH)

MYTH Call Shapes

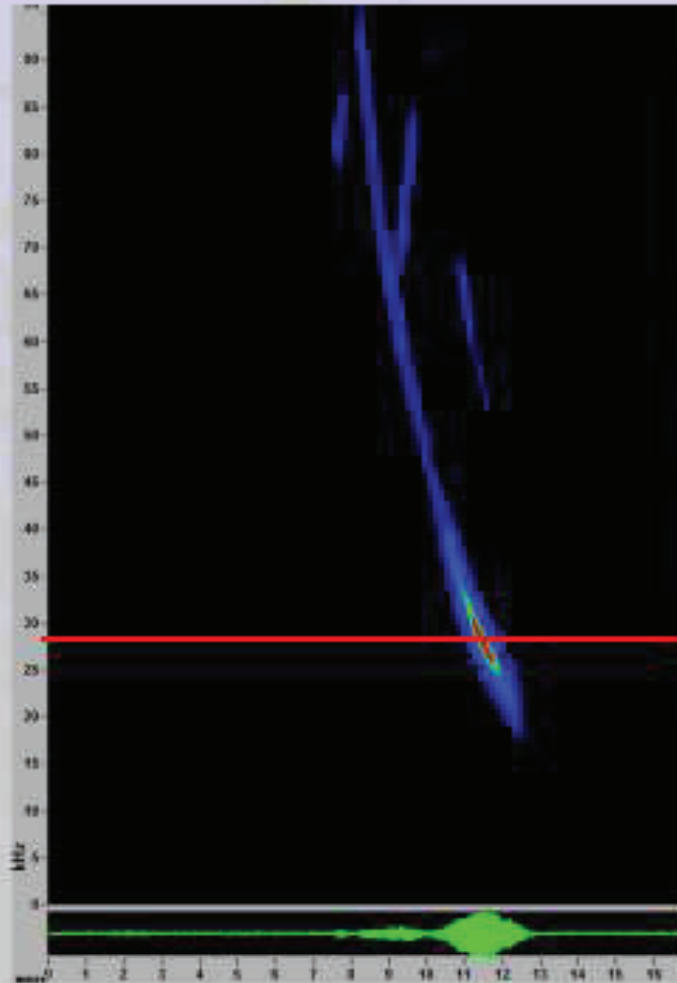


- Calls may have up to 100 kHz of bandwidth
- FM sweep may be nearly linear, making f_c difficult to recognize
- Shaped like MYEV but distinguished by f_c
- Converging harmonics

*Red scale bars are set at 28 kHz.

Figure 54. Call shapes of the Fringed Myotis (*Myotis thysanodes*, MYTH)

MYTH Definitive Characteristics

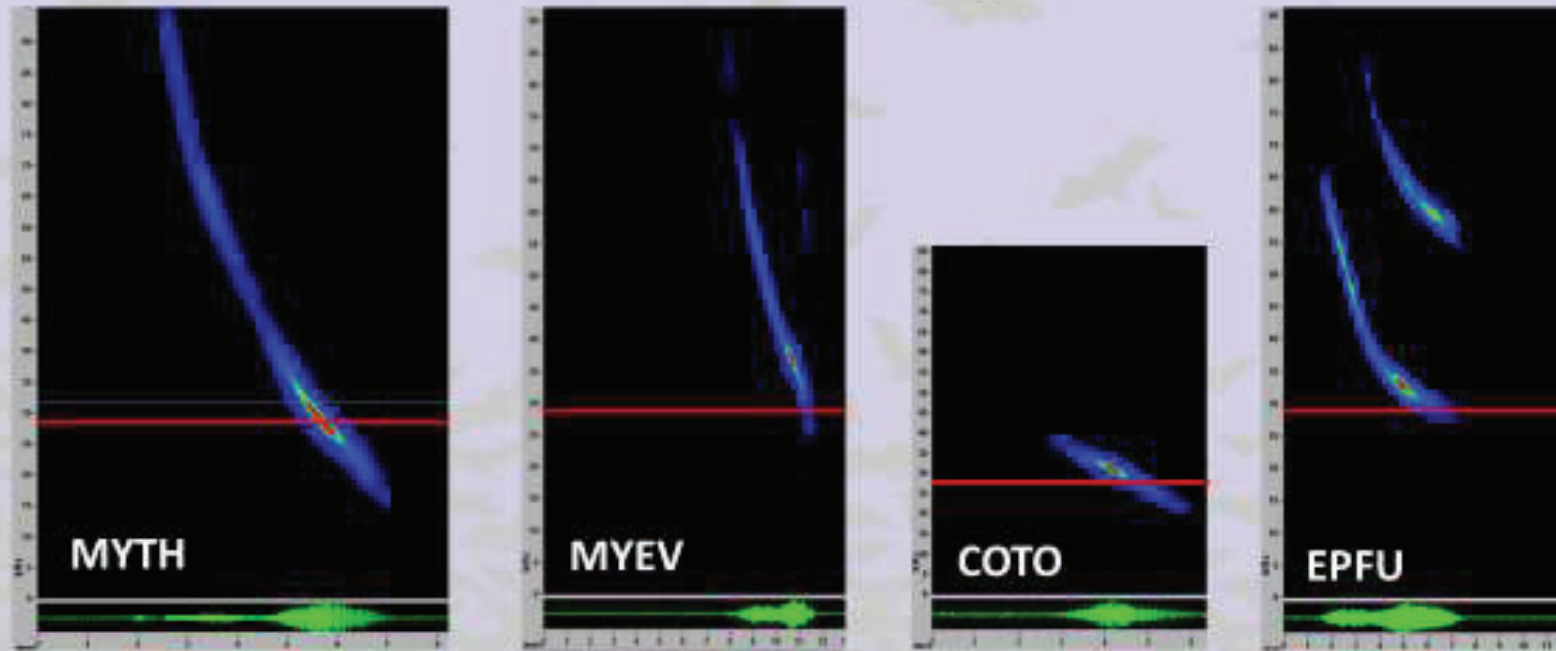


- Continuous steep shape, especially with harmonics
- $f_c < 28$ kHz (and usually into the 20s), total slope >15 , and low $f < 24$ kHz
- $f_c < 28$ kHz, total slope >10 , and low $f < 24$ kHz diagnostic IF harmonics converge toward primary call component

*Red scale bar is set at 28 kHz.

Figure 55. Definitive characteristics of call sequence for the Fringed Myotis (*Myotis thysanodes*, MYTH)

MYTH Similar Species



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

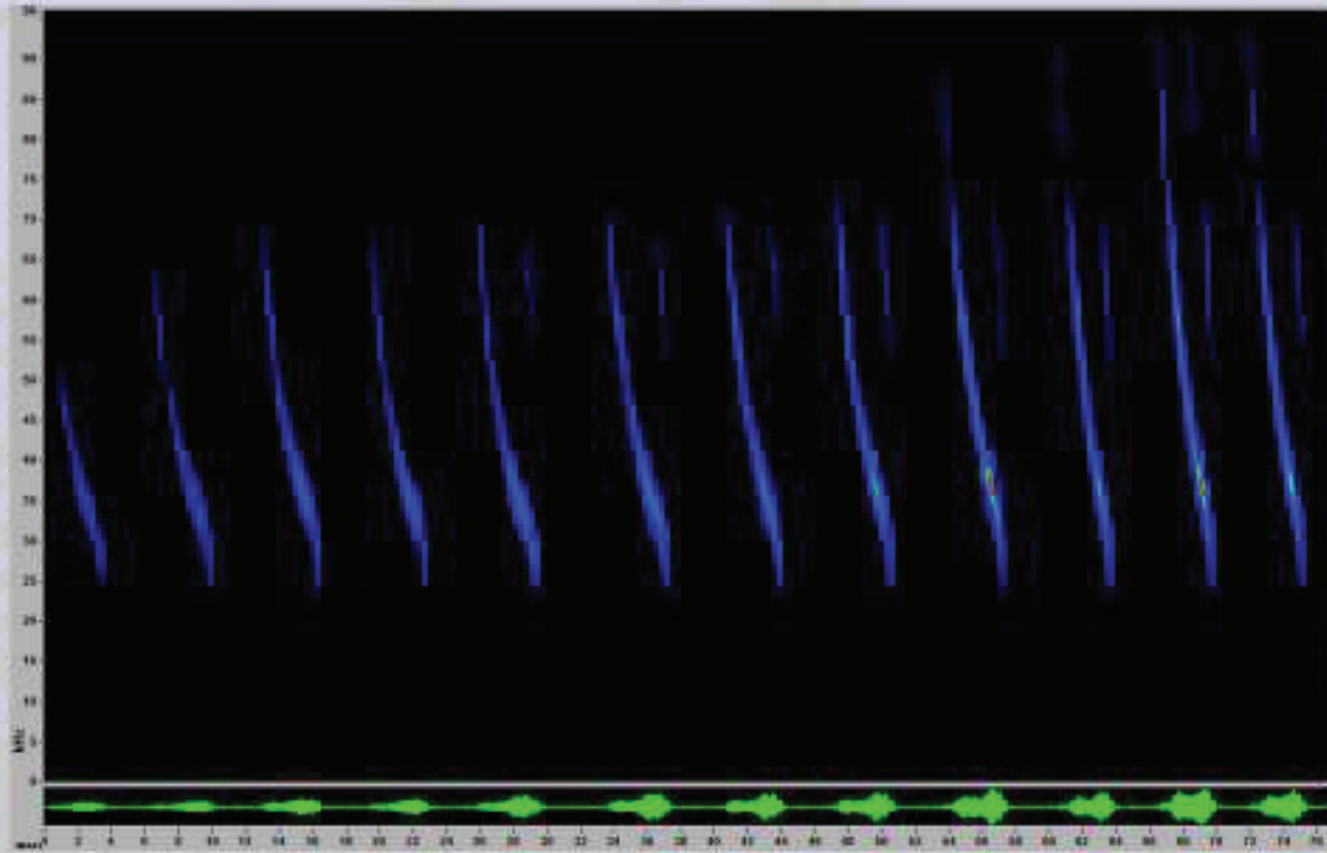
MYTH vs. COTO: MYTH fragments with high $f < 50$ kHz can look like COTO; use high f and converging harmonics to rule out COTO.

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.

***Red scale bars are set at 28 kHz.**

Figure 56. Calls sequences produced by other species that may be confused with the Fringed Myotis (*Myotis thysanodes*, MYTH)

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



MYEV_time_expanded

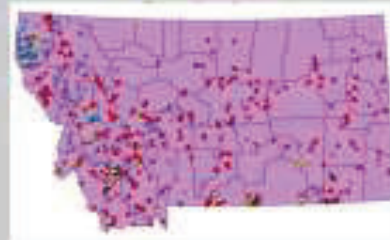
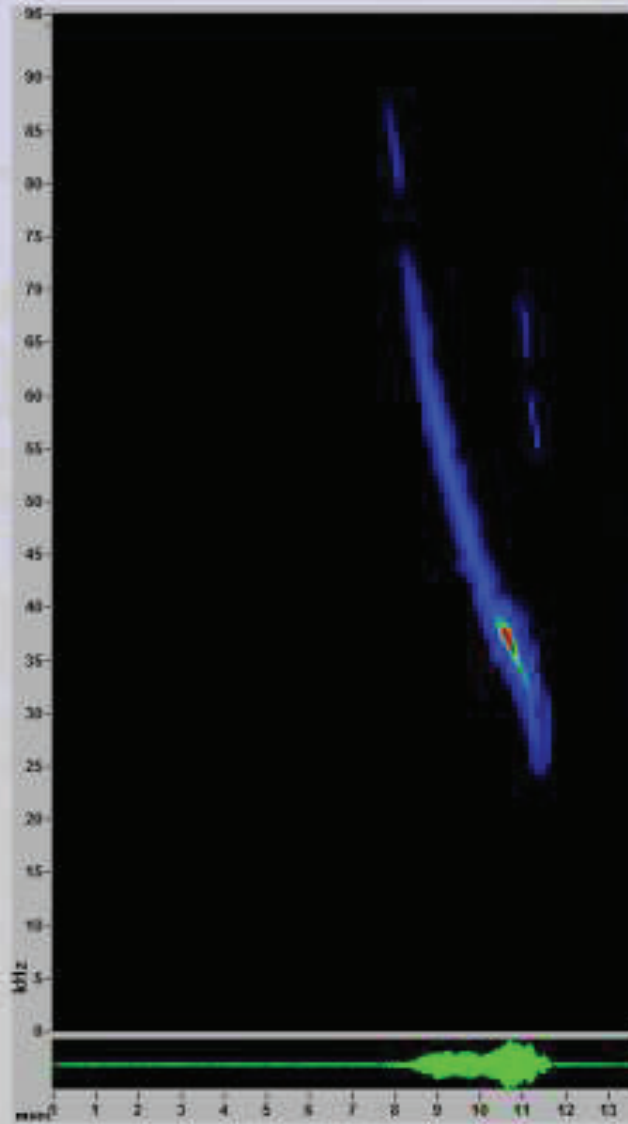


Figure 57. Example call sequence for the Long-eared Myotis (*Myotis evotis*, MYEV).

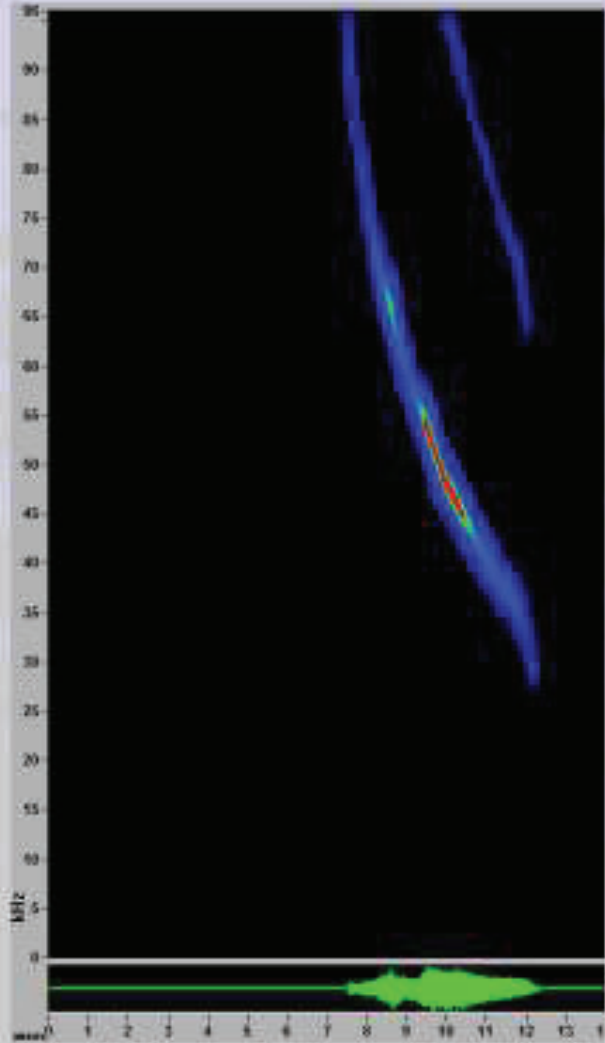
MYEV Call Shapes



- 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

Figure 58. Call shapes of the Long-eared Myotis (*Myotis evotis*, MYEV)

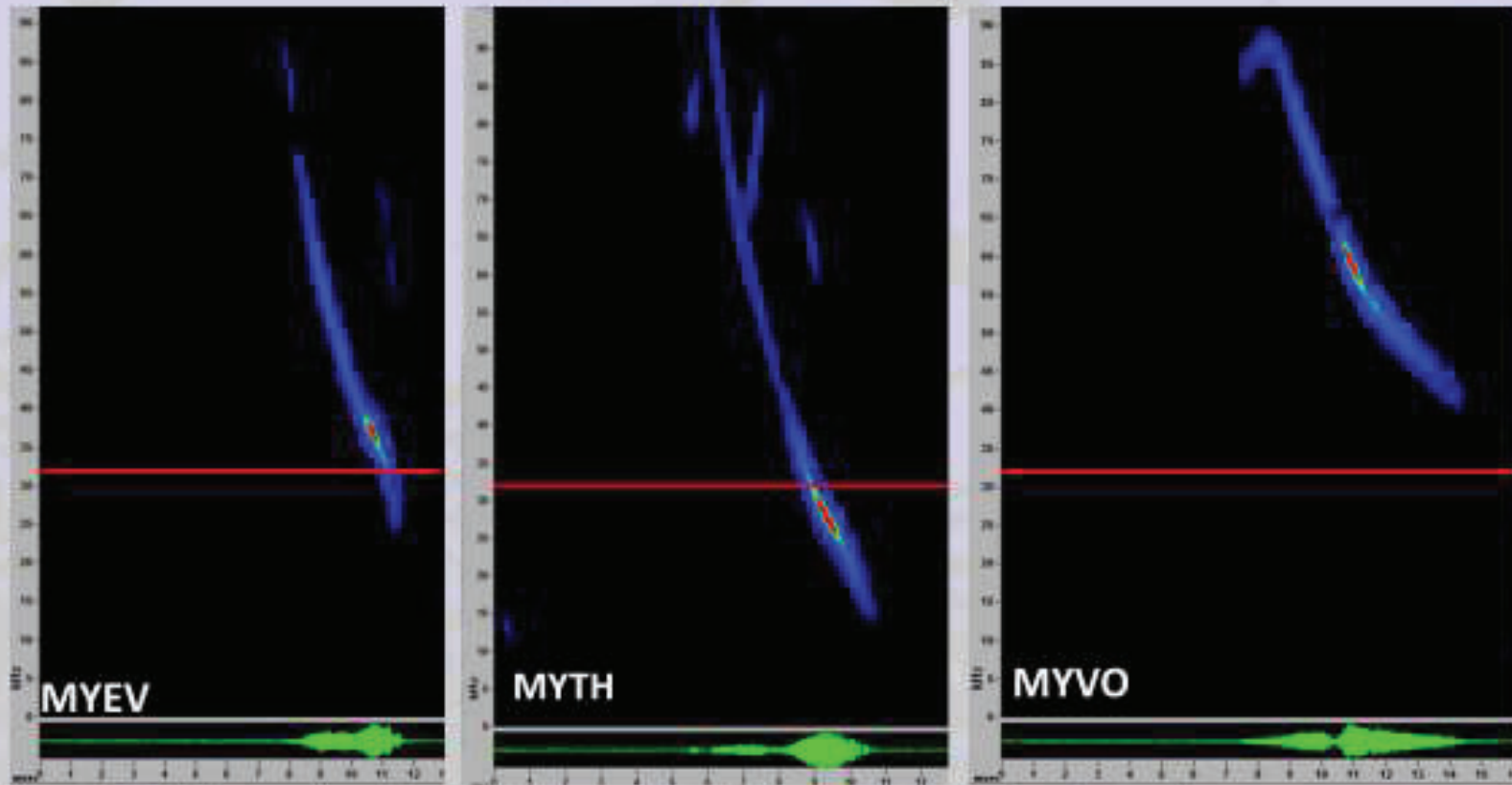
MYEV Definitive Characteristics



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

Figure 59. Definitive characteristics of call sequence for the Long-eared Myotis (*Myotis evotis*, MYEV)

MYEV Similar Species



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

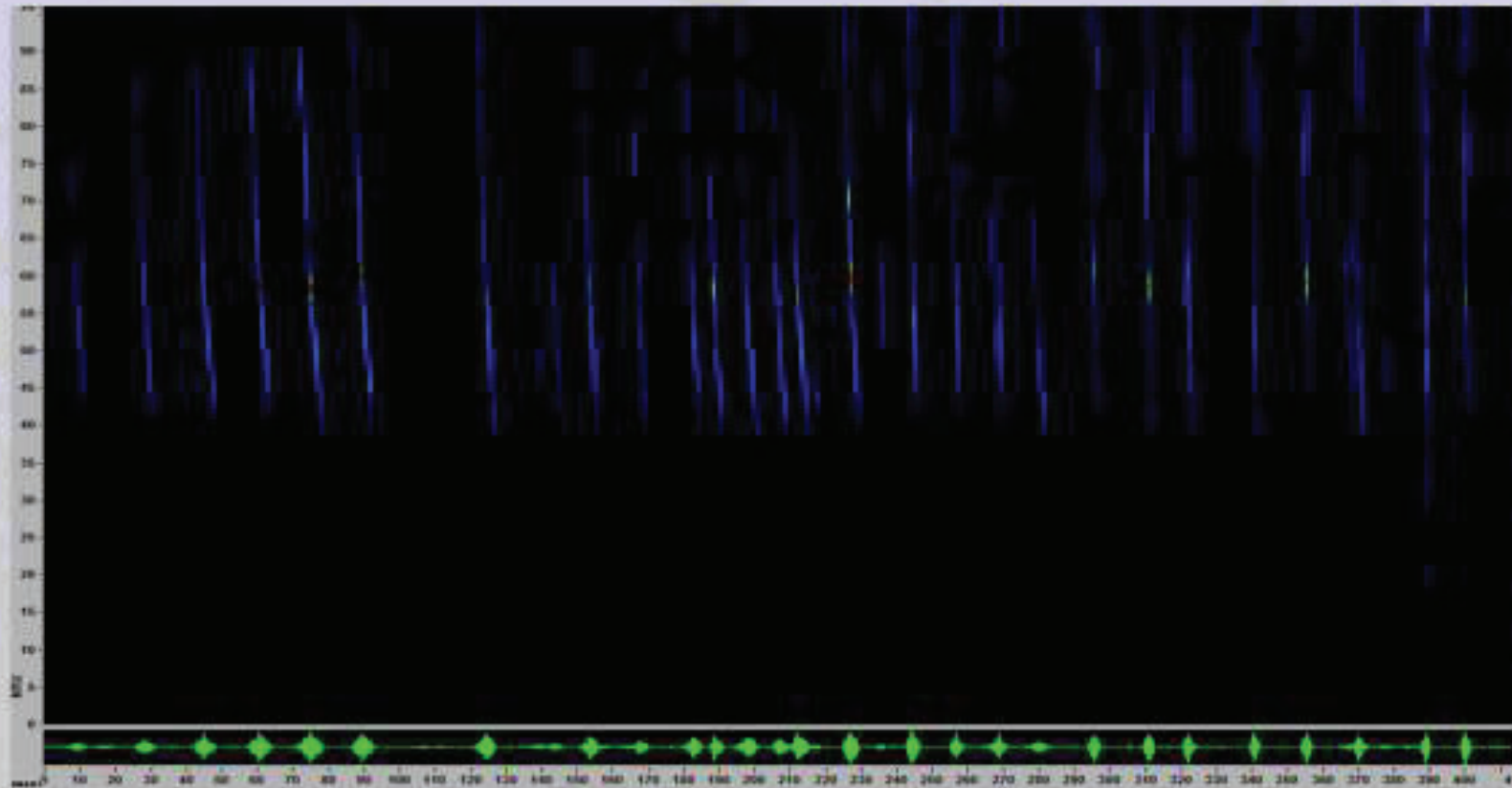
MYEV vs. MYVO: Lower, non-diagnostic MYVO calls can have overlap; unable to distinguish unless upsweep is present for MYVO.

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

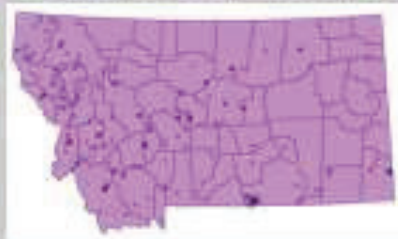
***Red scale bars are set at 32 kHz.**

Figure 60. Calls sequences produced by other species that may be confused with the Long-eared Myotis (*Myotis evotis*, MYEV)

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



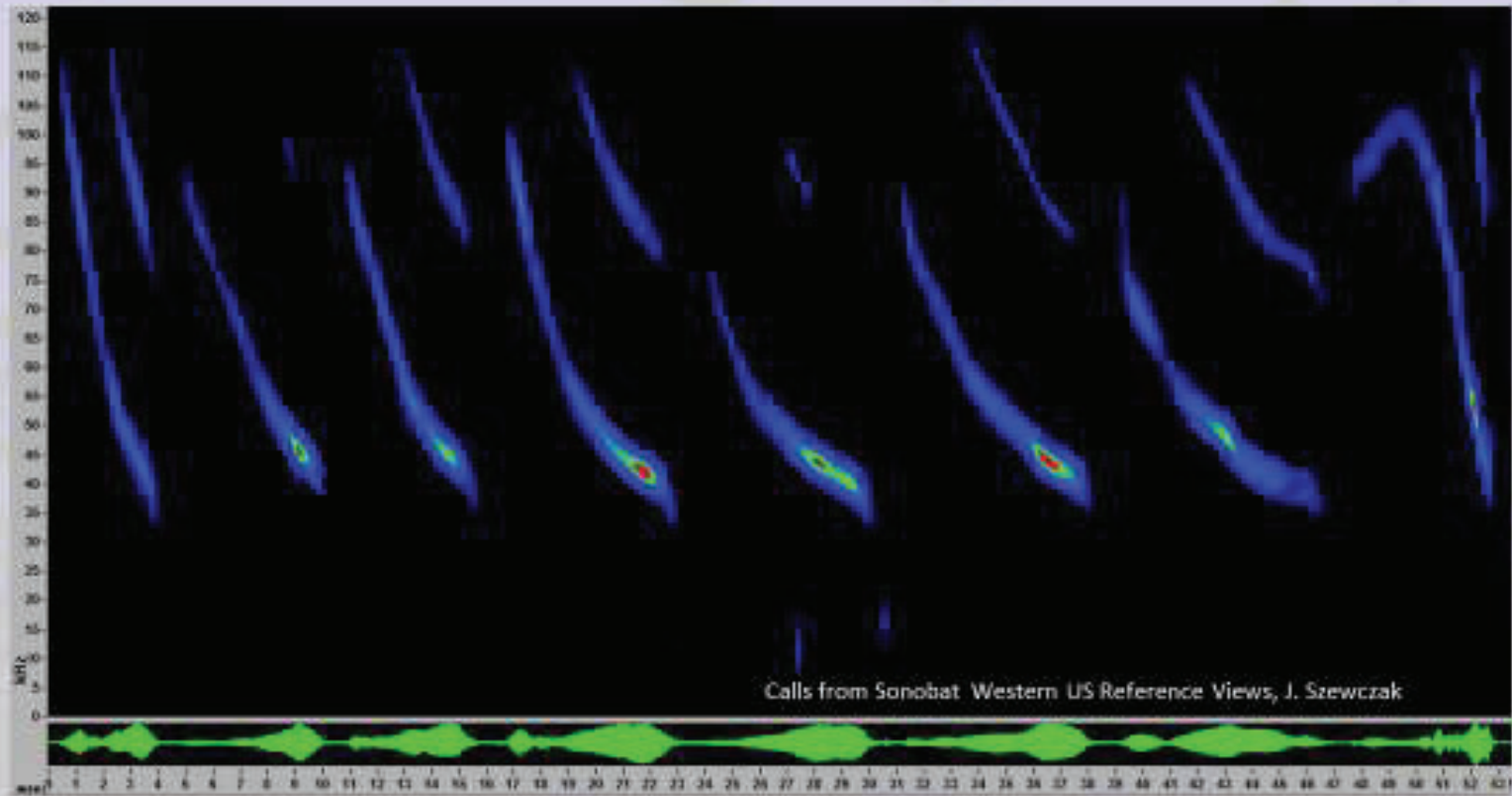
MYVO_time_expanded



But Observation Type	Range Type
• BEST FIRM CAPTURED	■ Year-round
• MYACISSEIC	■ Seasonal
• PETTYSON-HA CONDE	
• BLANFACISSEIC	

Figure 61. Example call sequence for the Long-legged Myotis (*Myotis volans*, MYVO)

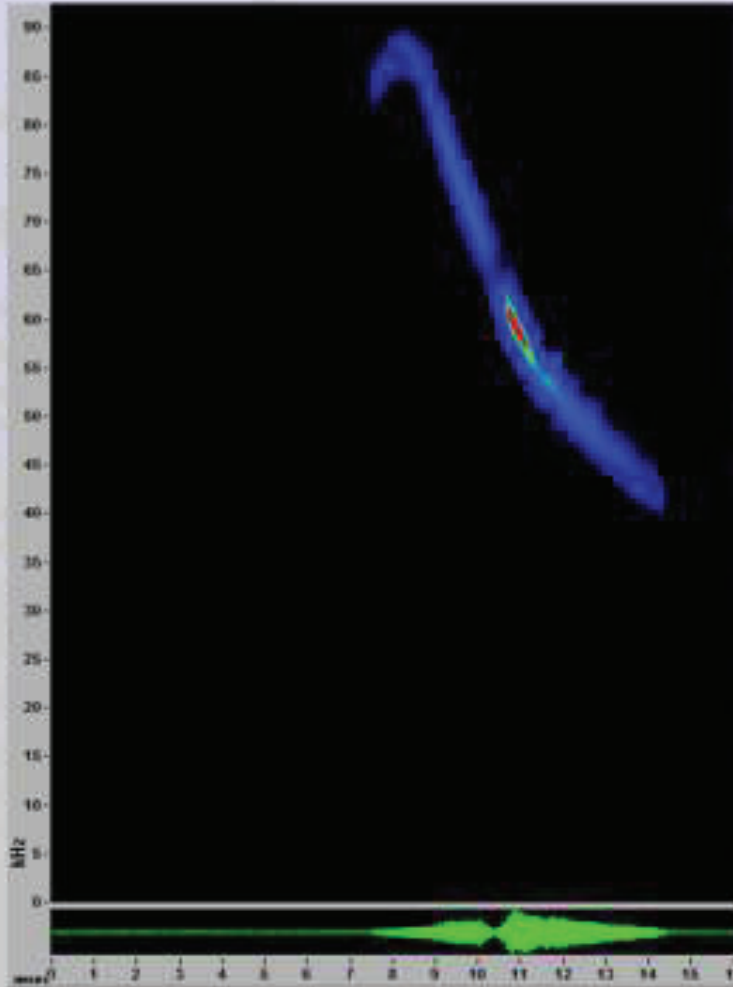
MYVO Call Shapes



- 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

Figure 62. Call shapes of the Long-legged Myotis (*Myotis volans*, MYVO)

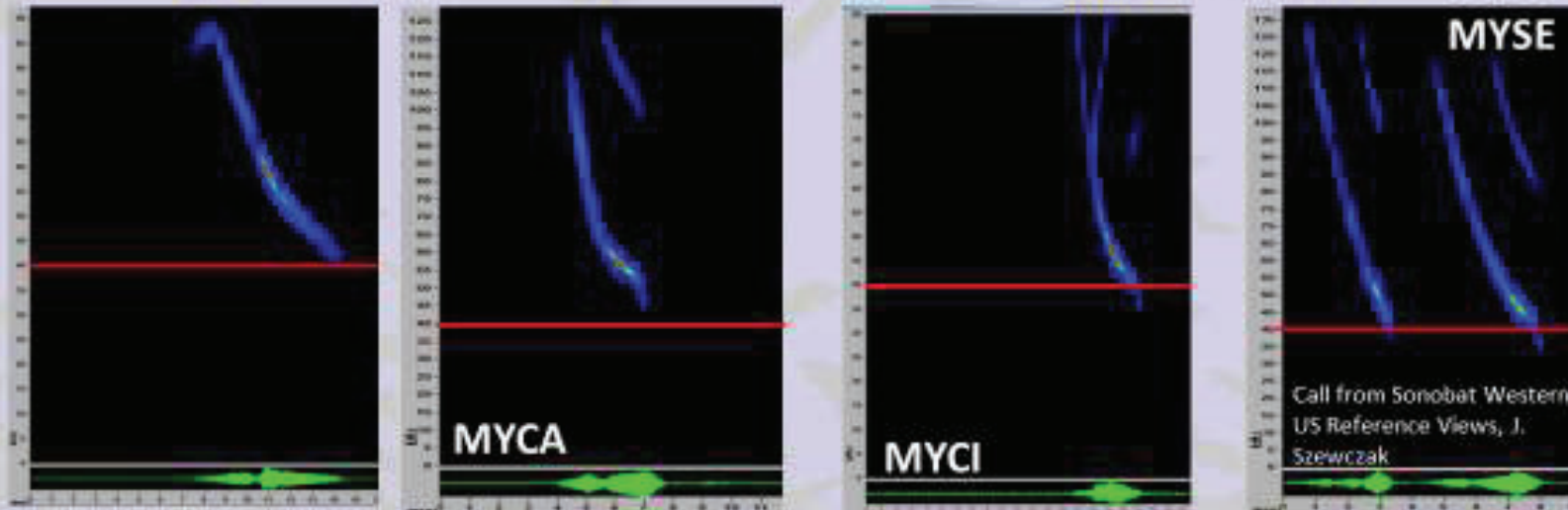
MYVO Definitive Characteristics



- Upward sweep into the call is diagnostic, but rare

Figure 63. Definitive characteristics of call sequence for the Long-legged Myotis (*Myotis volans*, MYVO)

MYVO Similar Species



*Red scale bars are set at 40 kHz.

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. MYVO may have subtle lower slope or backward bend at higher frequencies.

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. To avoid this, set sampling frequency at 256 kHz or higher.

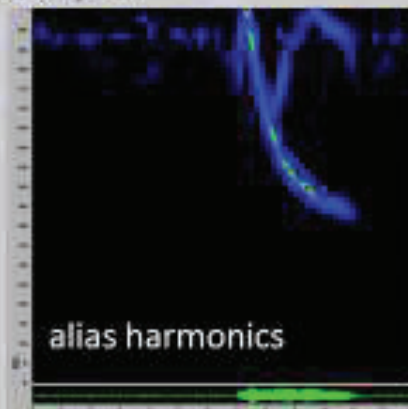
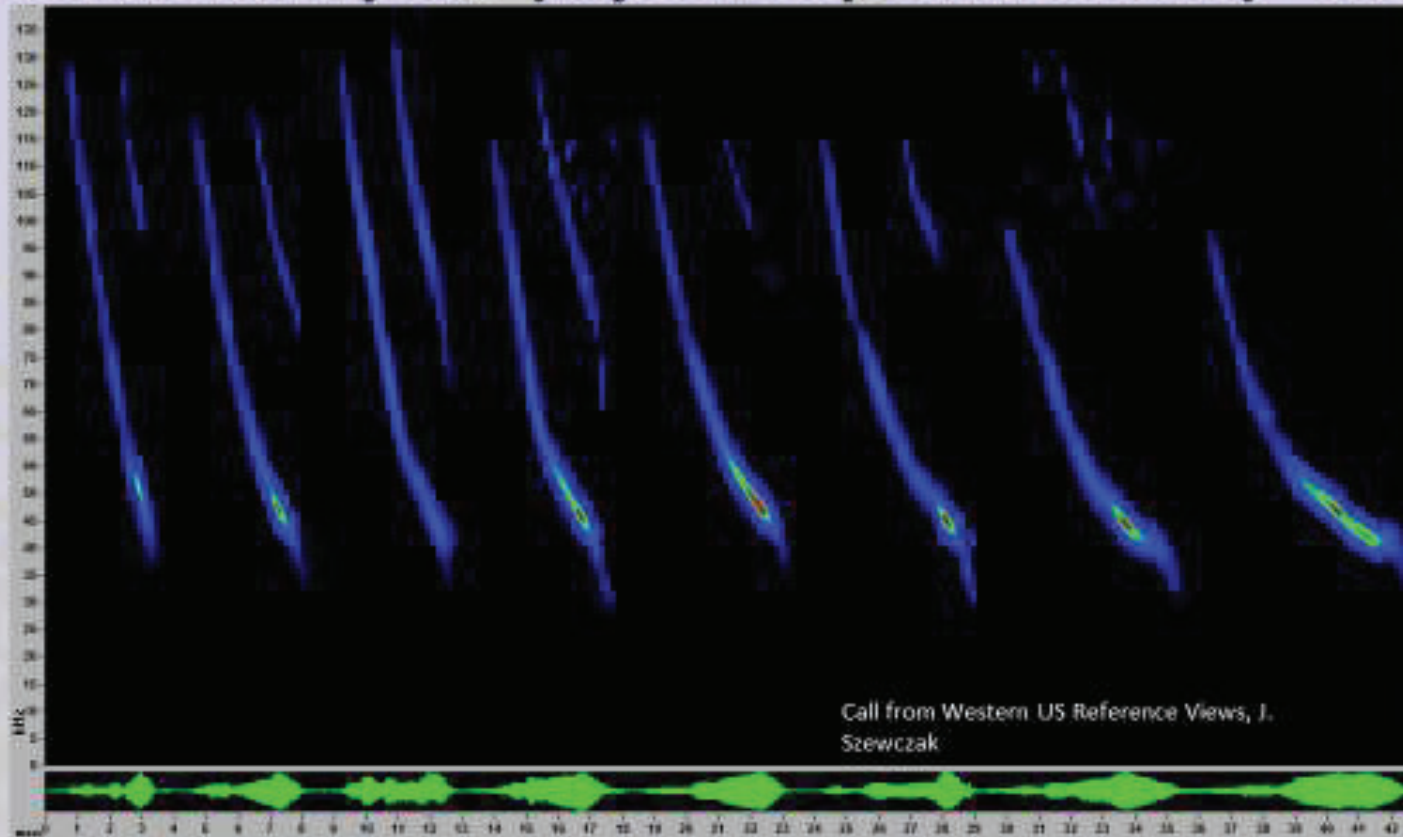


Figure 64. Calls sequences produced by other species that may be confused with the Long-legged Myotis (*Myotis volans*, MYVO)

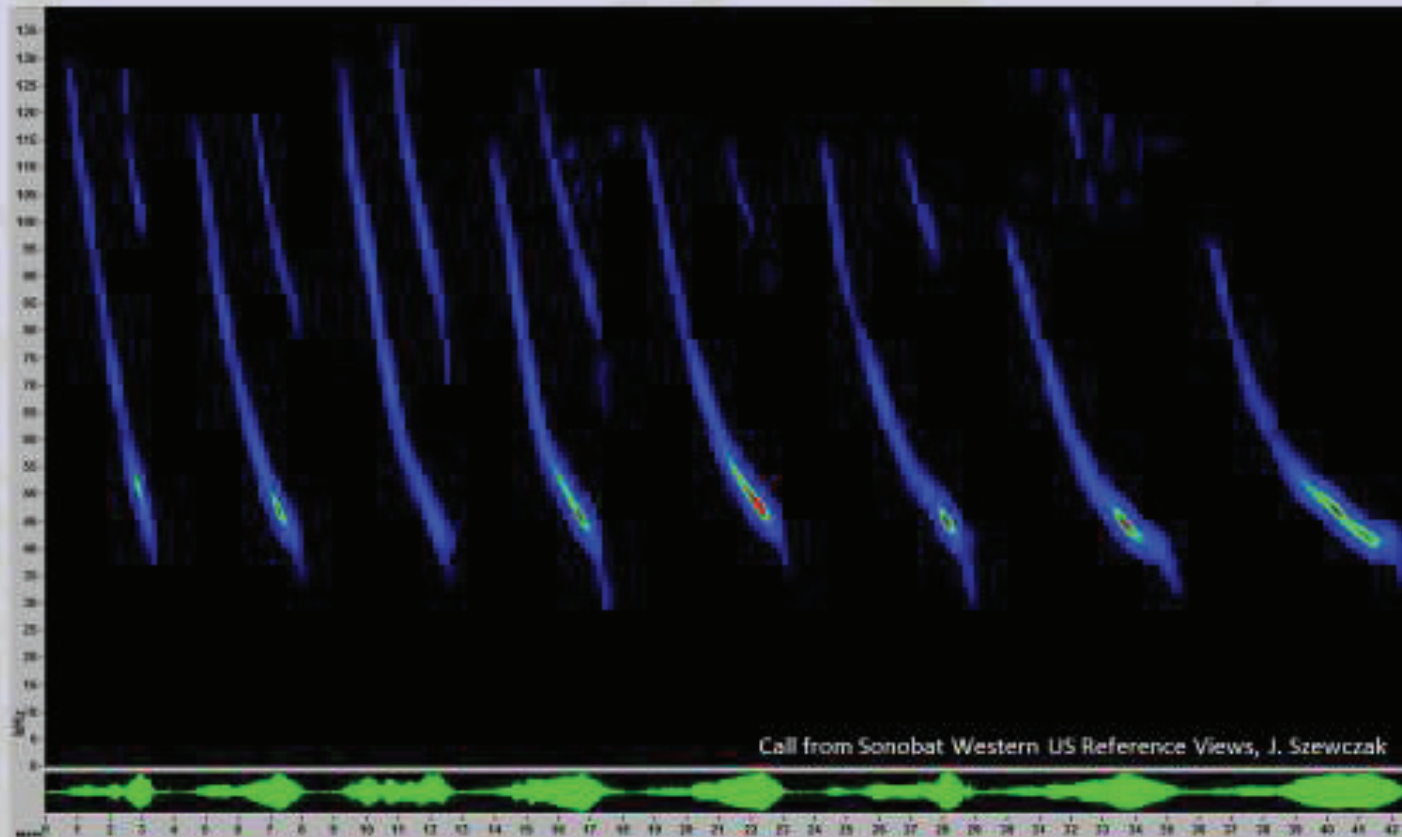
Northern Myotis (*Myotis septentrionalis*) =MYSE



Bat Observation Type	Range Type
● BEST FIRM CAPTURED	■ Year-round
● MYACUSTIC	■ Seasonal
● PETTYSON-HAUGHE	
● BARNACUSTIC	

Figure 65. Example call sequence for the Northern Myotis (*Myotis septentrionalis*, MYSE)

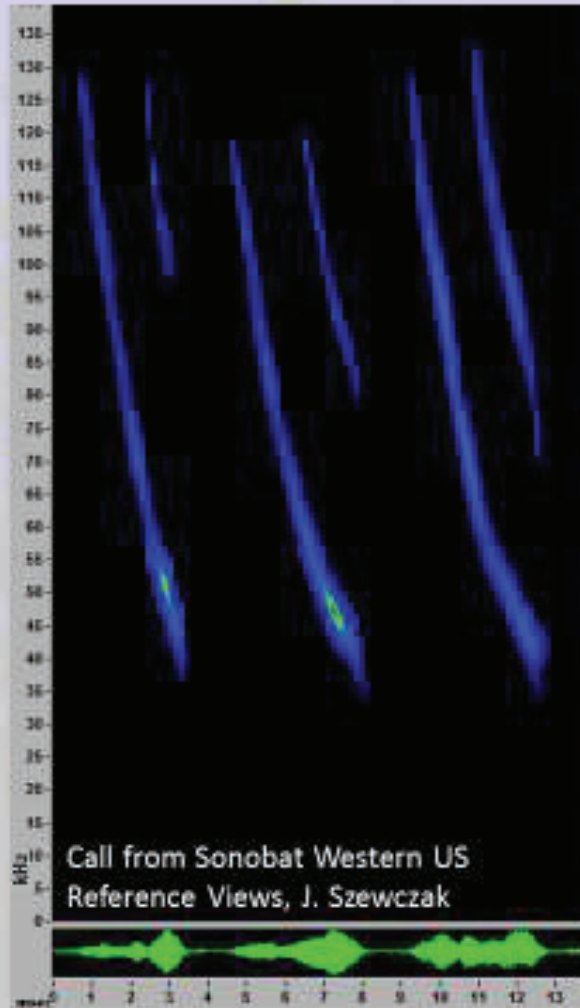
MYSE Call Shapes



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

Figure 66. Call shapes of the Northern Myotis (*Myotis septentrionalis*, MYSE)

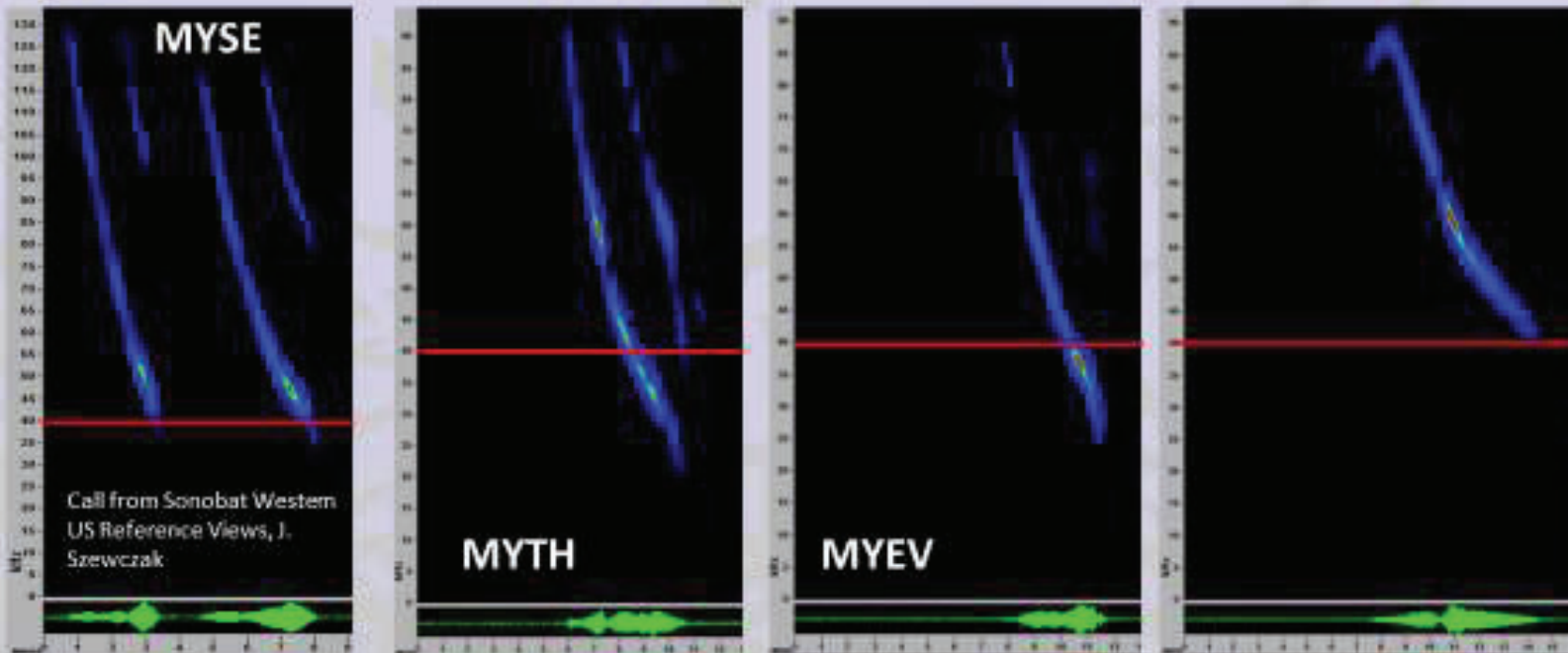
MYSE Definitive Characteristics



- Presence in Montana is uncertain. Genetic testing of museum specimens is underway. Follow-up capture and genetic testing along eastern border is needed
- Calls shaped like MYTH and MYEV with up to 100 kHz of bandwidth
- $F_c > 40$ kHz
- Examine sequence in “real time” and confirm consistent search phase call intervals across the sequence to rule out approach phase calls from other *Myotis* spp.

Figure 67. Definitive characteristics of call sequence for the Northern Myotis (*Myotis septentrionalis*, MYSE)

MYSE Similar Species



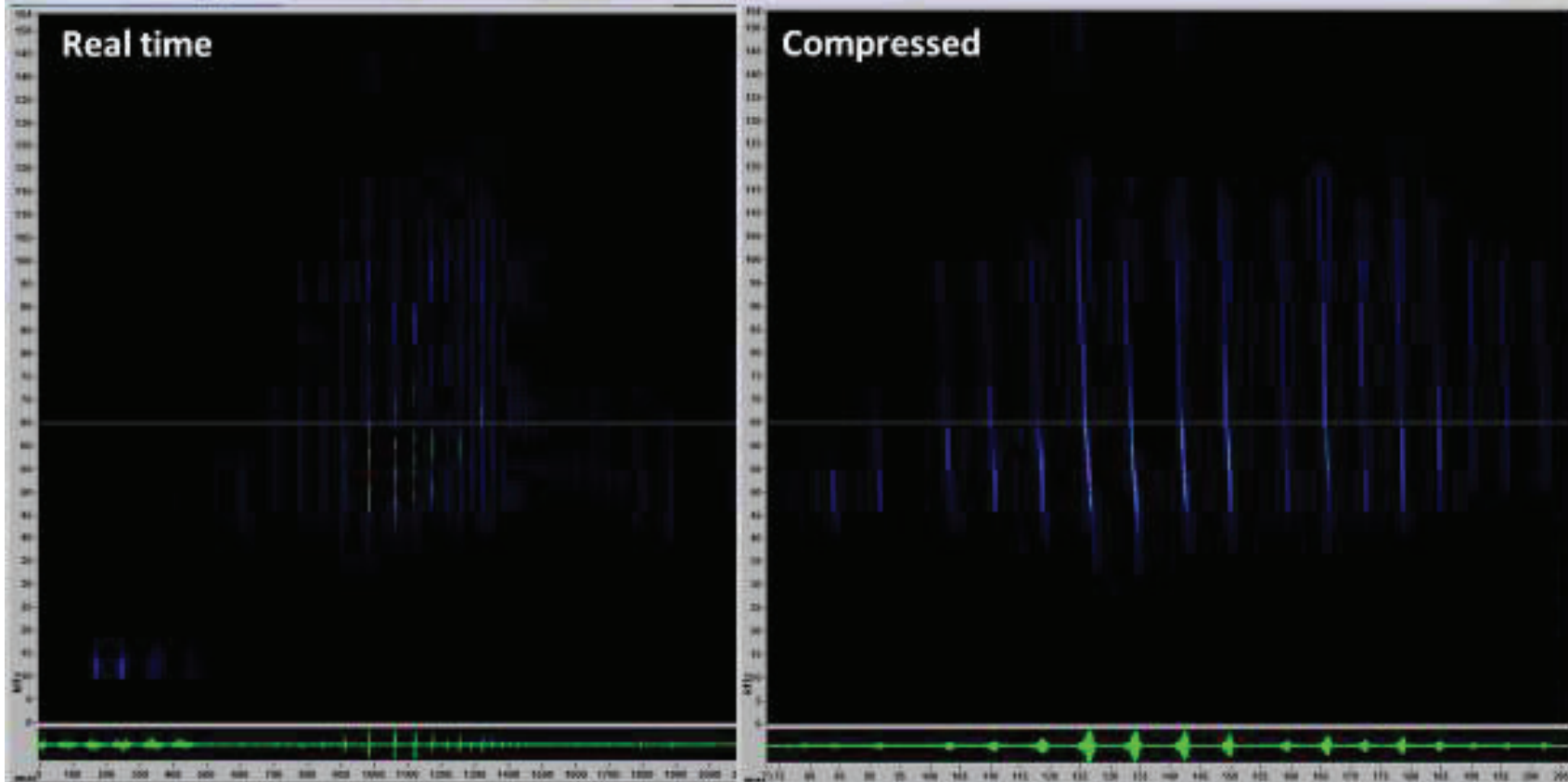
MYSE vs. MYTH/MYEV: Similarly shaped steep calls with overlap in non-diagnostic calls. $f_c < 28$ kHz is diagnostic for MYTH, f_c between 32-36 kHz is diagnostic for MYEV, and $f_c > 40$ kHz is diagnostic for MYSE.

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

***Red scale bars are set at 40 kHz.**

Figure 68. Calls sequences produced by other species that may be confused with the Northern Myotis (*Myotis septentrionalis*, MYSE)

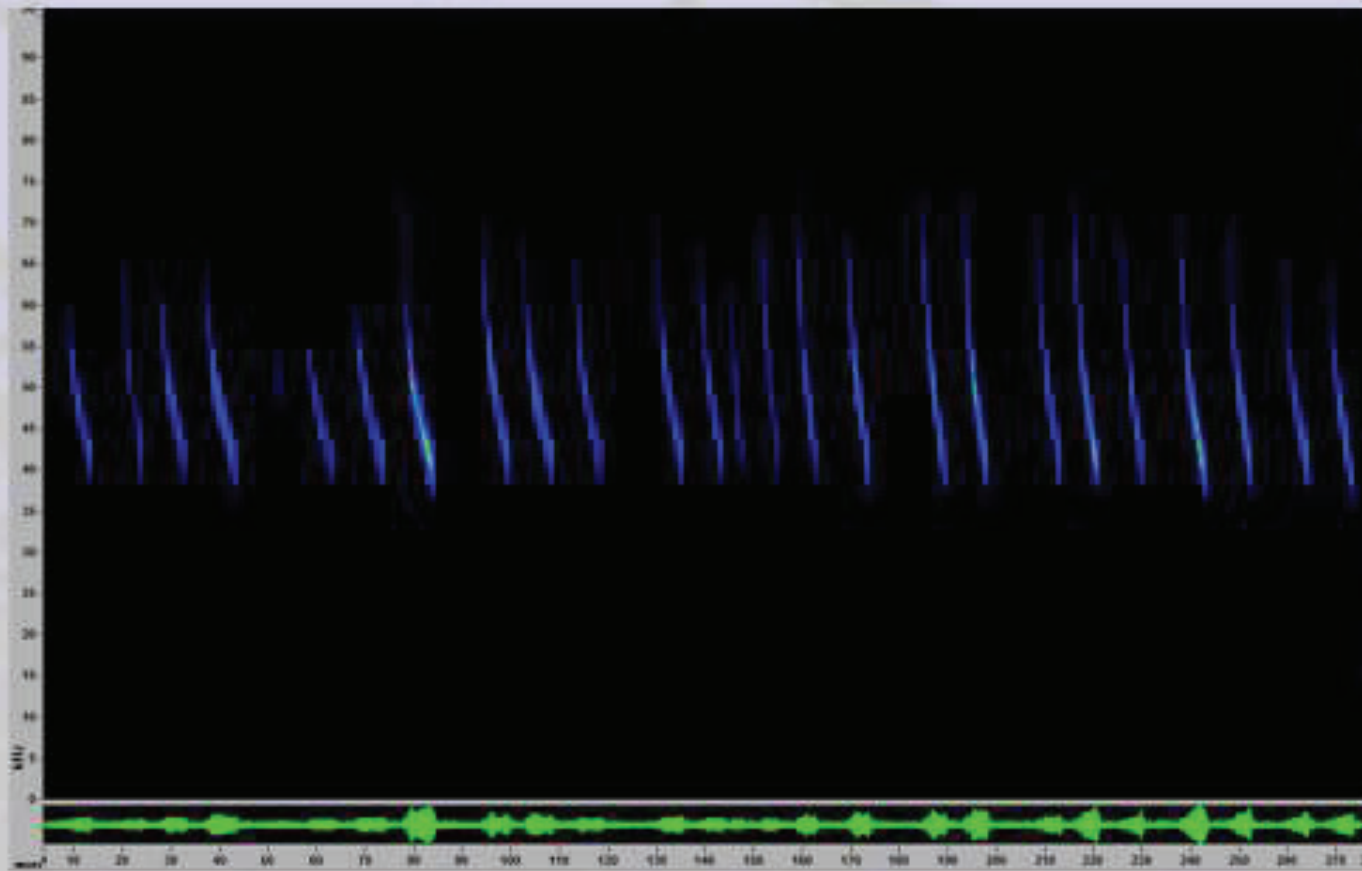
Sequences Incorrectly Auto-identified as MYSE



Call shapes look similar to MYSE. However, when you view calls in “real time” and listen to the sequence, it becomes apparent that these are actually approach calls going into a feeding buzz because the call interval is shortening across the sequence of calls.

Figure 69. Example of the similarity between a feeding buzz produced by a *Myotis* bat and the call sequence of a Northern *Myotis*

Little Brown Myotis (*Myotis lucifugus*) = MYLU



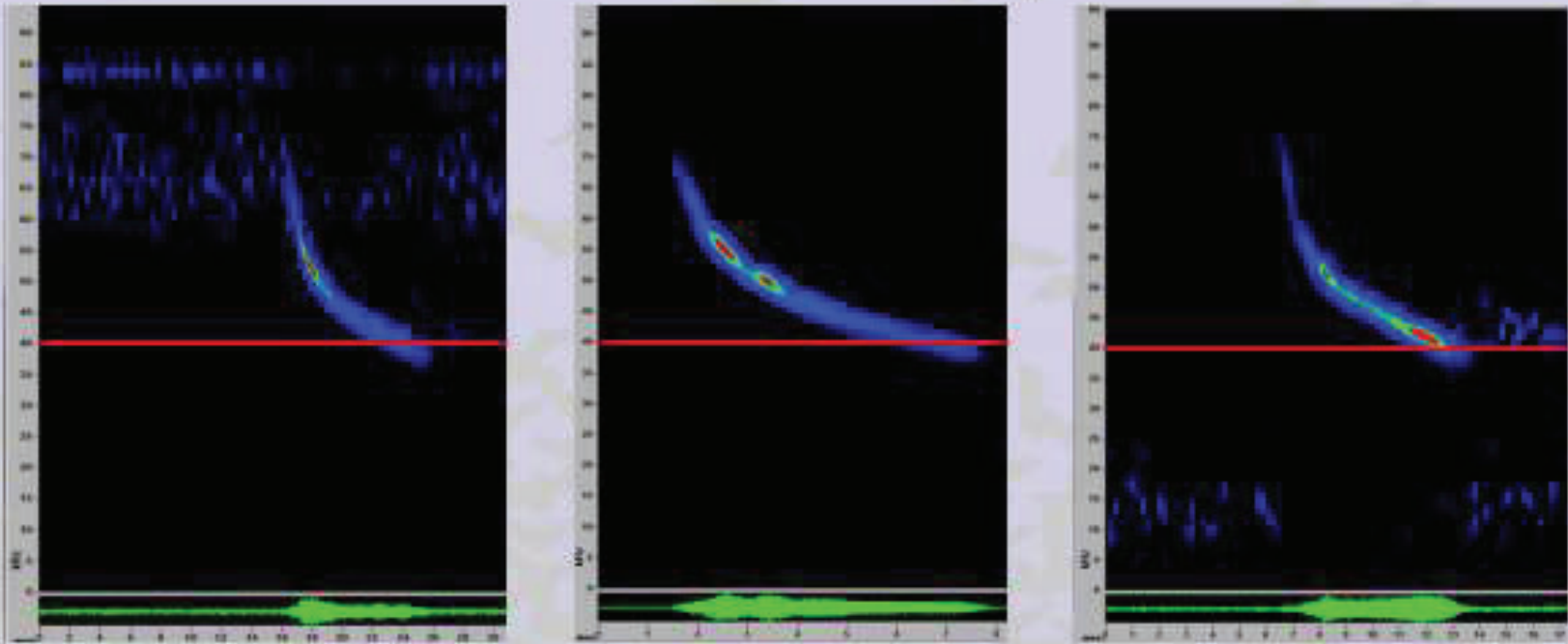
MYLU_time_expanded



Bat Observation Type	Range Type
• BEST FISHING CAPTURE CHAIR	■ Year-round
• BRYAN ACUSTIC	■ Seasonal
• PETERSONSON+COVODE	
• SHERMAN ACUSTIC	

Figure 70. Example call sequence for the Little Brown Myotis (*Myotis lucifugus*, MYLU)

MYLU Call Shapes

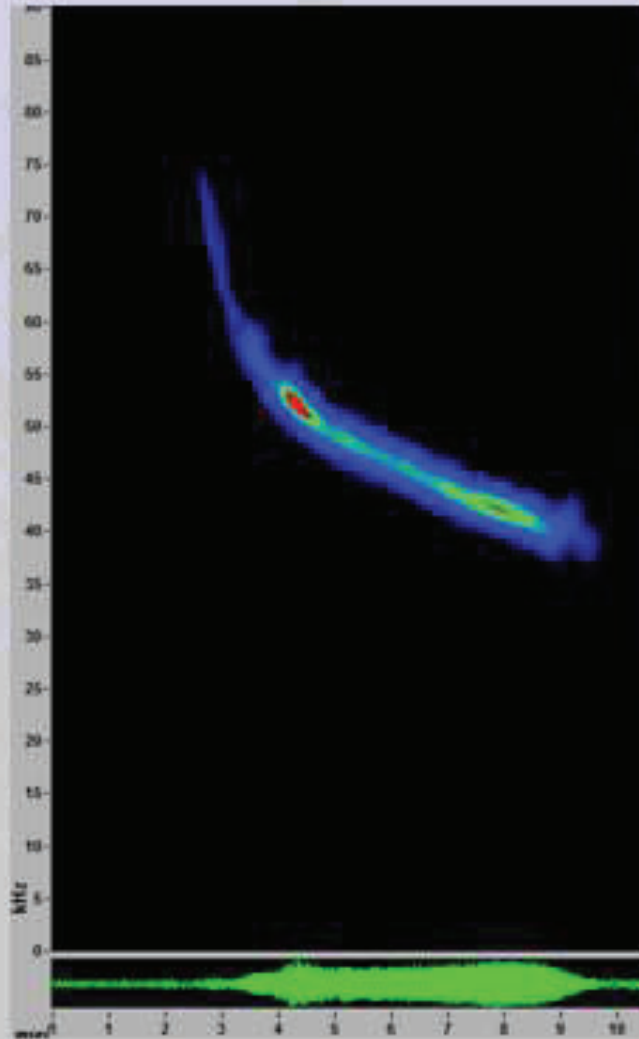


*Red scale bars are set at 40 kHz.

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

Figure 71. Call shapes of the Little Brown Myotis (*Myotis lucifugus*, MYLU)

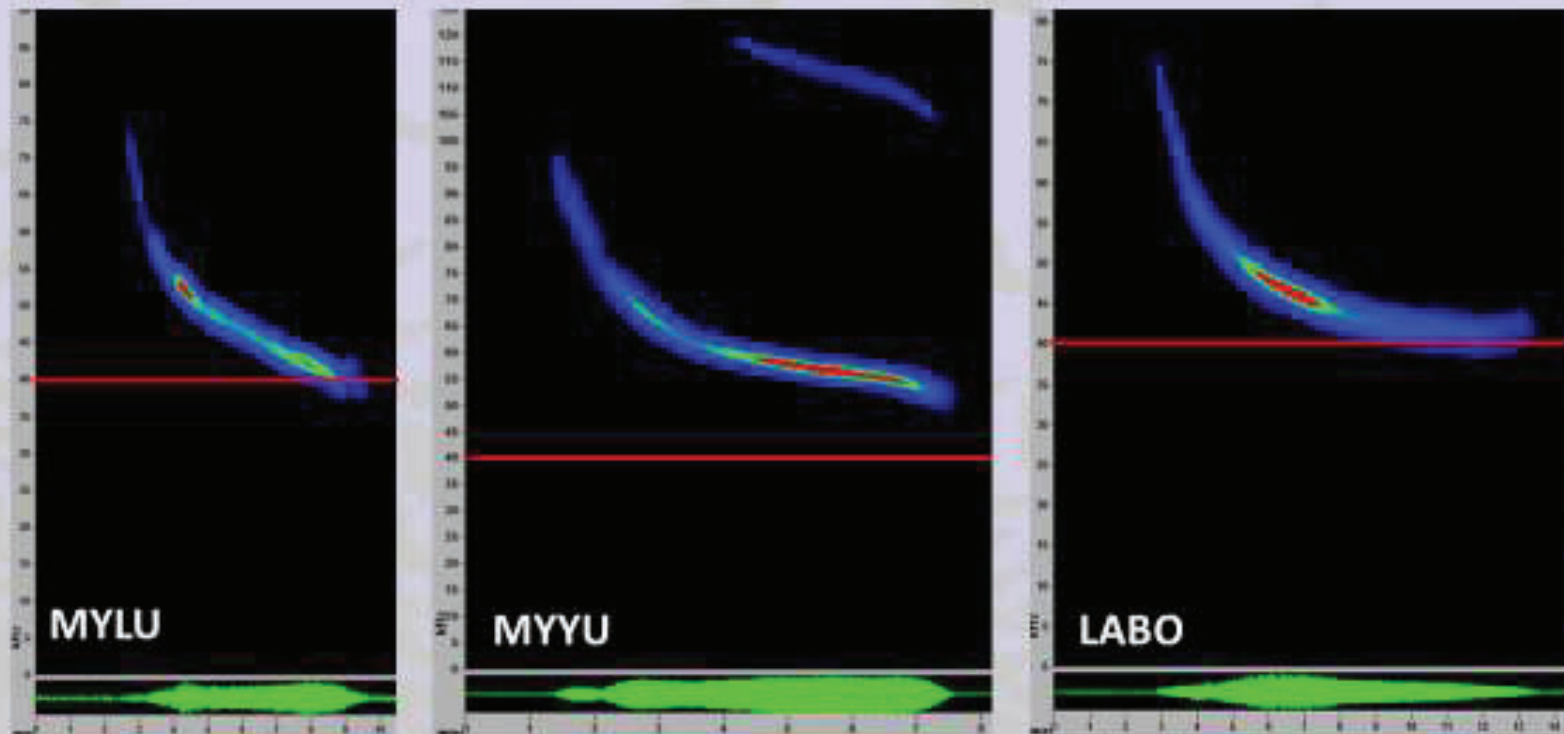
MYLU Definitive Characteristics



- Duration > 7 ms
- Lower slope < 3
- $f_c < 44$ diagnostic west of Continental Divide when comparing with MYYU

Figure 72. Definitive characteristics of call sequence for the Little Brown Myotis (*Myotis lucifugus*, MYLU)

MYLU Similar Species



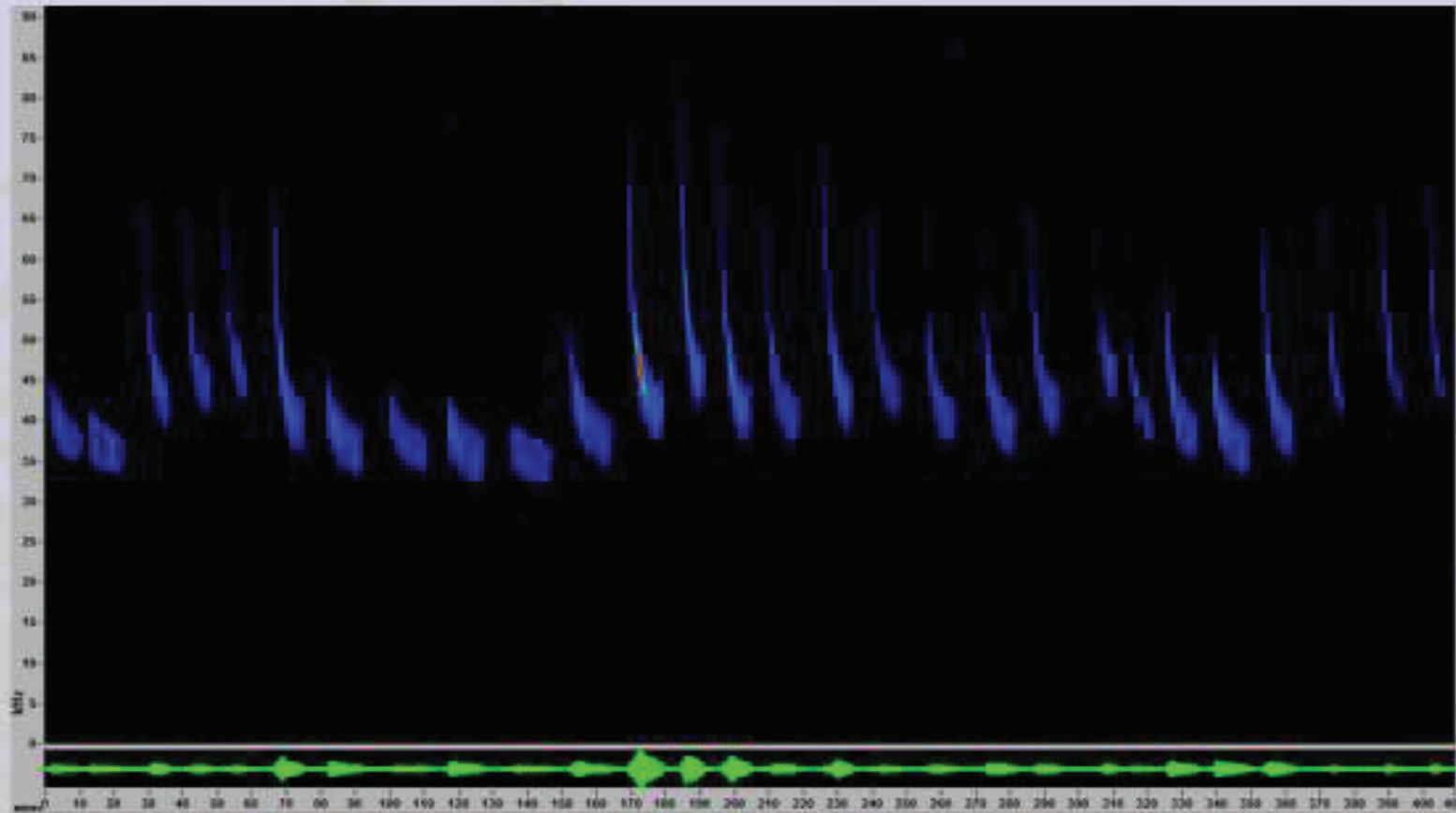
MYLU vs. LABO: LABO calls have up-turns at ends, smooth power centers and longer duration. LABO call sequences often have variable f_c across the sequence (see next slide).

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

***Red scale bars are set at 40 kHz.**

Figure 73. Calls sequences produced by other species that may be confused with the Little Brown Myotis (*Myotis lucifigus*, MYLU)

Eastern Red Bat (*Lasiurus borealis*) = LABO



LABO_time_expanded



Bat Observation Type	Range Type
• BEST FLYING CAPTURED	■ Year-round
• INYACUSTIC	■ Seasonal
• PETTYSON-HA-COVIDE	
• SAMAACUSTIC	

Figure 74. Example call sequence for the Eastern Red Bat (*Lasiurus borealis*, LABO)

LABO Call Shapes

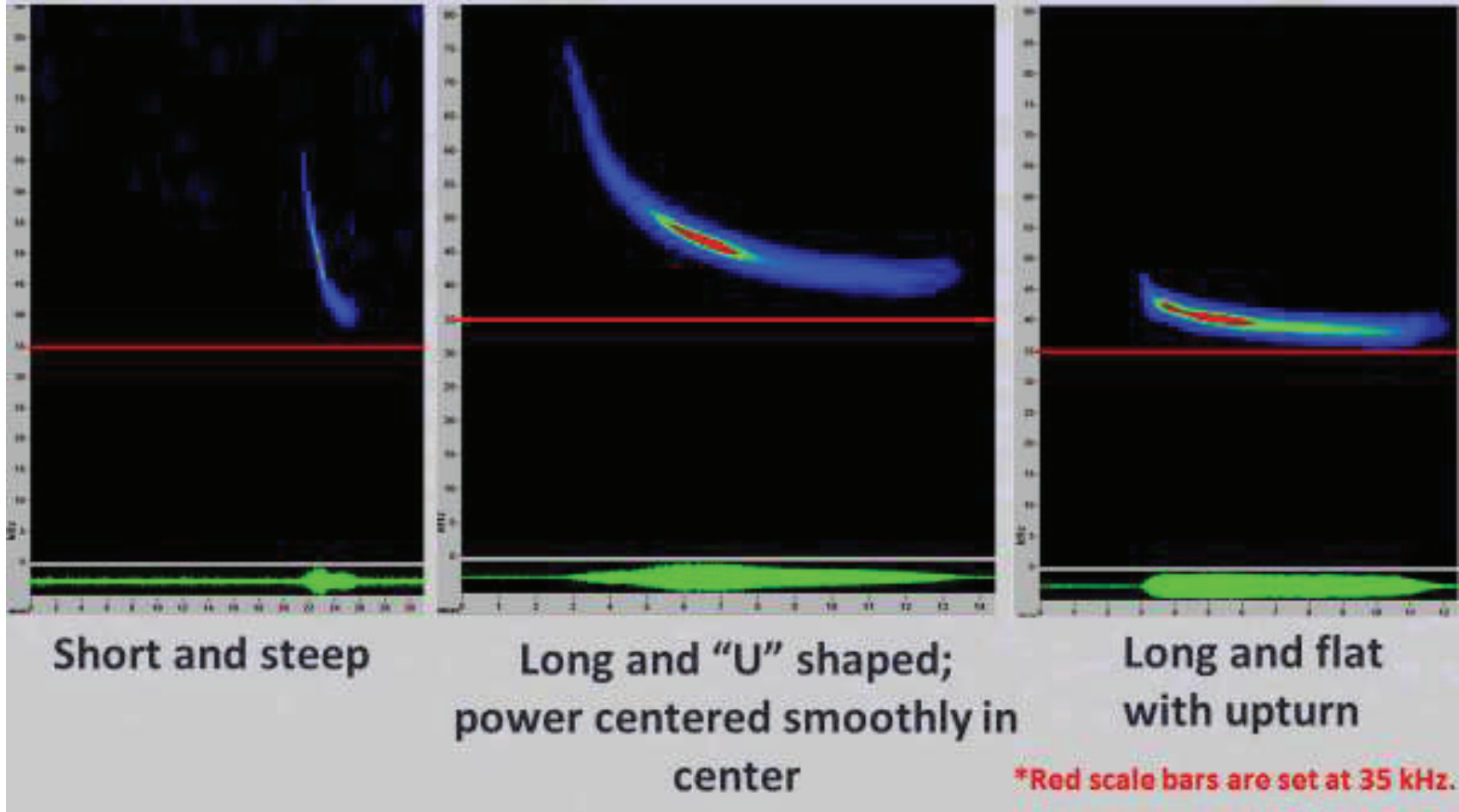
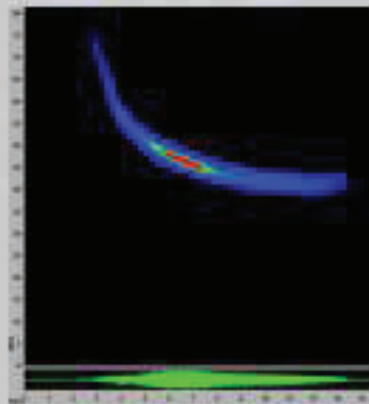
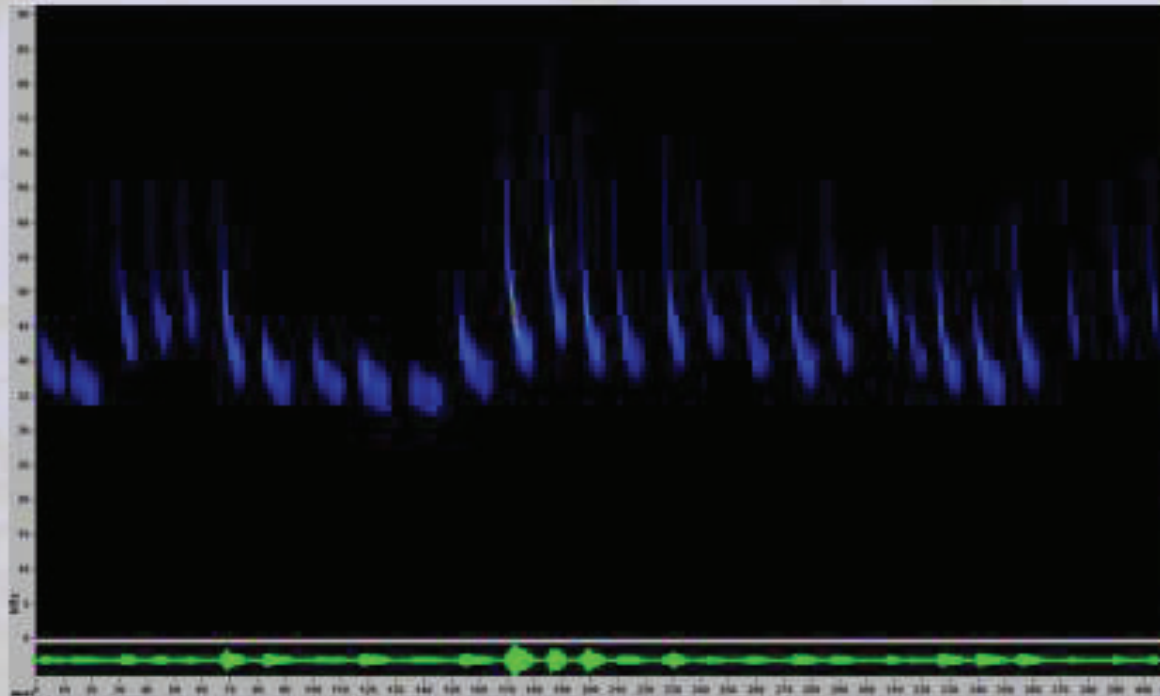


Figure 75. Call shapes of the Eastern Red Bat (*Lasiurus borealis*, LABO)

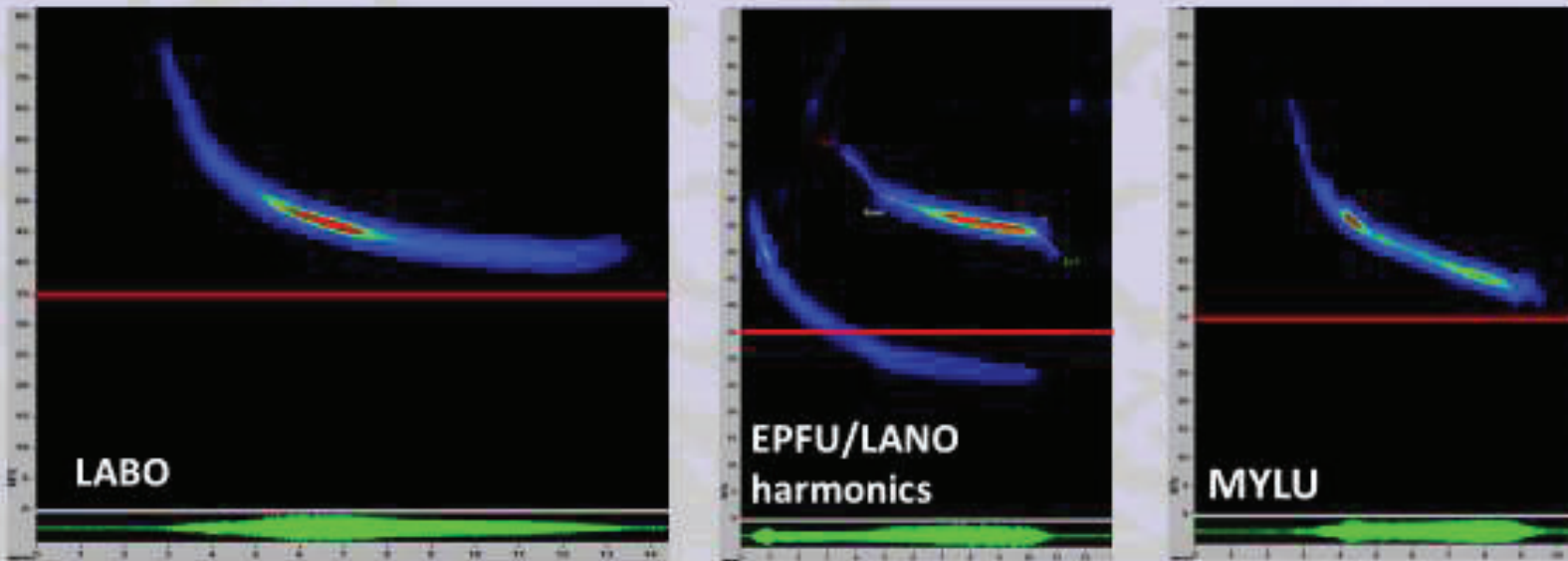
LABO Definitive Characteristics



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

Figure 76. Definitive characteristics of call sequence for the Eastern Red Bat (*Lasiurus borealis*, LABO)

LABO Similar Species



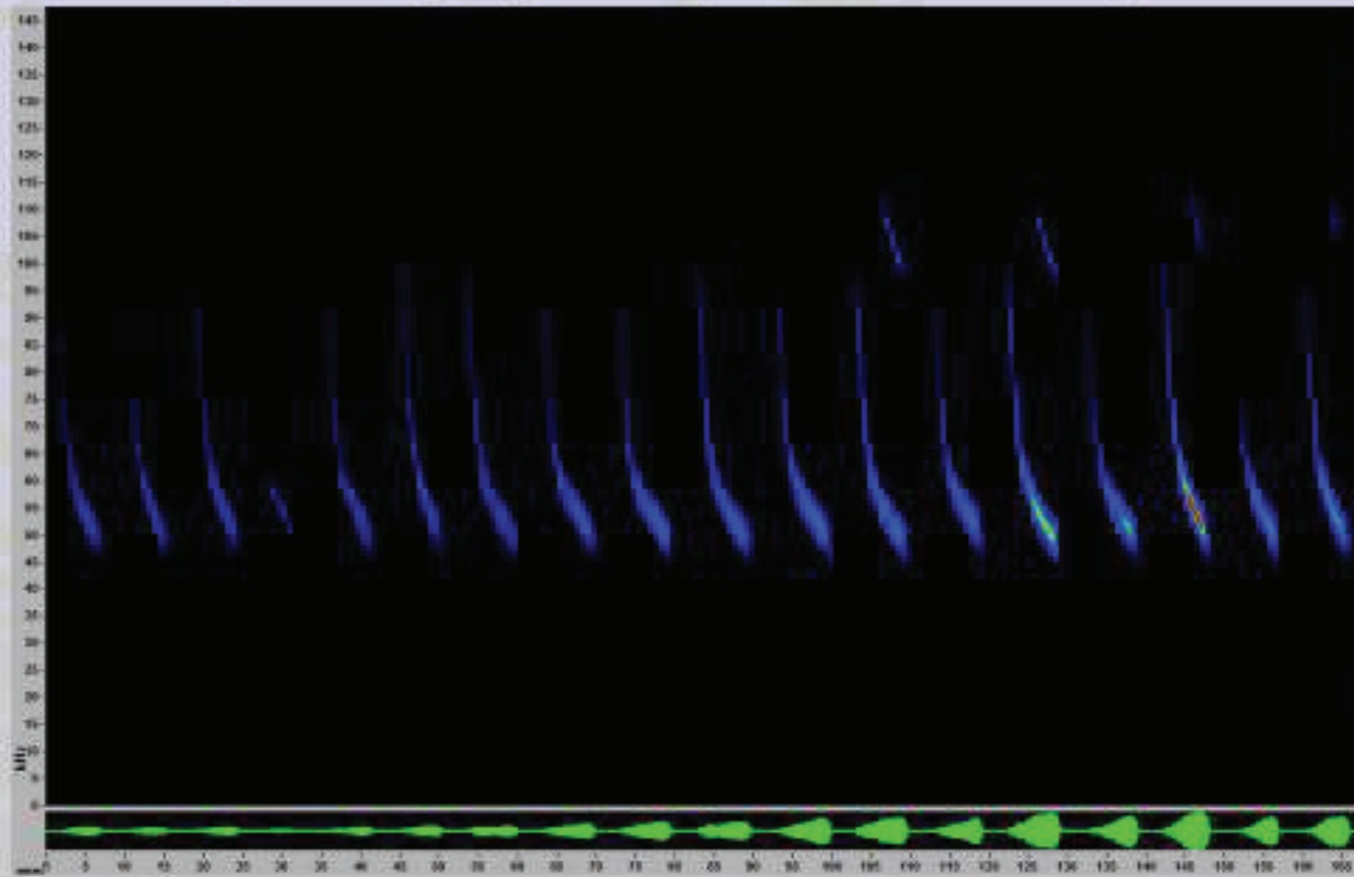
LABO vs. MYLU: MYLU calls infrequently exceed 10 ms, are not upturned at the end; instead, have a steadily decreasing frequency or a steady f_c across a sequence. **NOTE:** Sonobat sometimes classifies EPFU/LANO harmonics as MYLU or LABO.

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

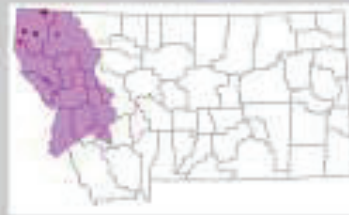
*Red scale bars are set at 35 kHz.

Figure 77. Calls sequences produced by other species that may be confused with the Eastern Red Bat (*Lasiurus borealis*, LABO)

Yuma Myotis (*Myotis yumanensis*) = MYYU



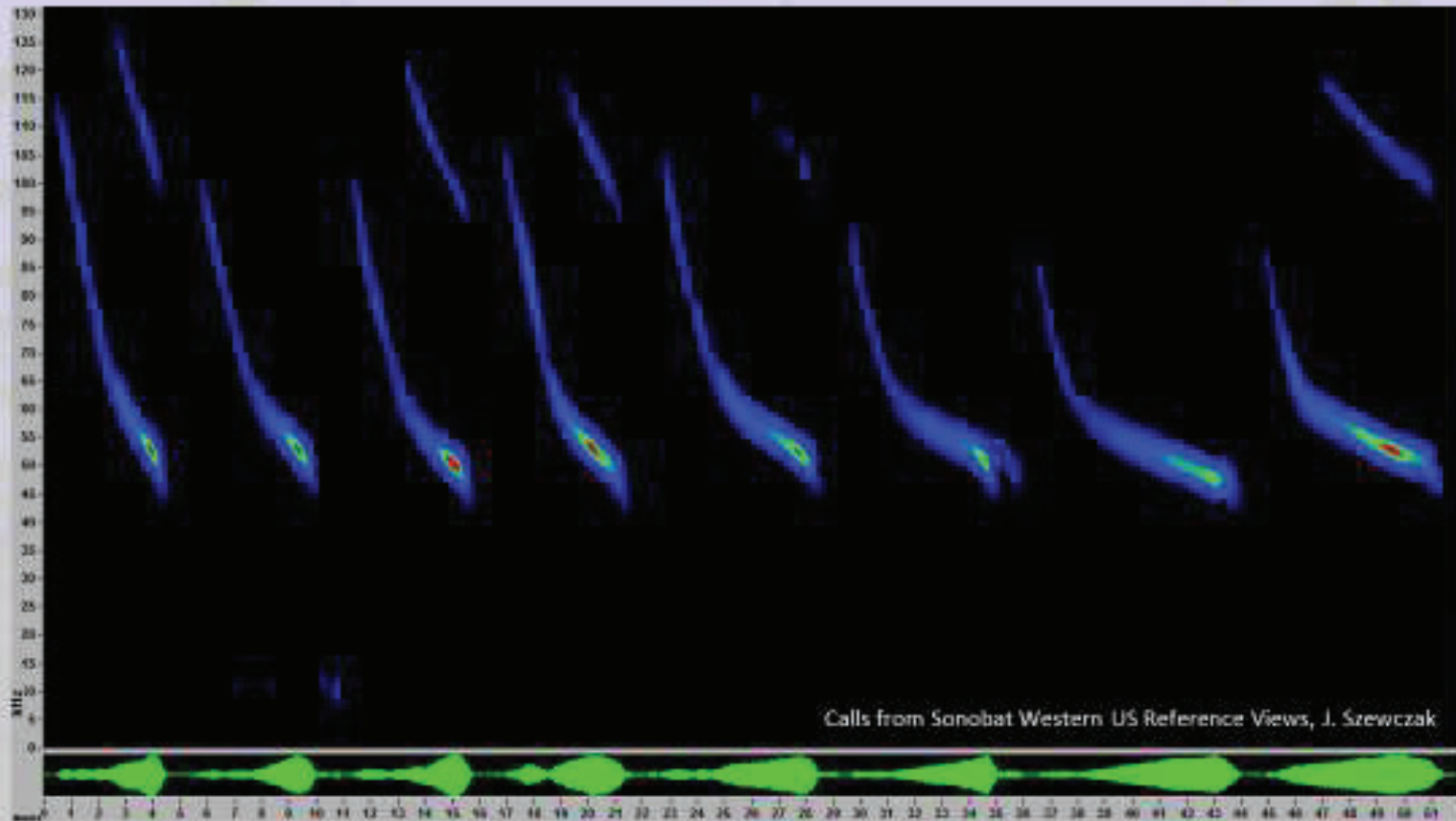
MYYU_time_expanded



Bat Observation Type	Range Type
● BEST FIRM CAPTURED	■ Year-round
● OBSERVED	■ Seasonal
● PETTIBONHACONDE	
● SERRAVALLENTIC	

Figure 78. Example call sequence for the Yuma Myotis (*Myotis yumanensis*, MYYU)

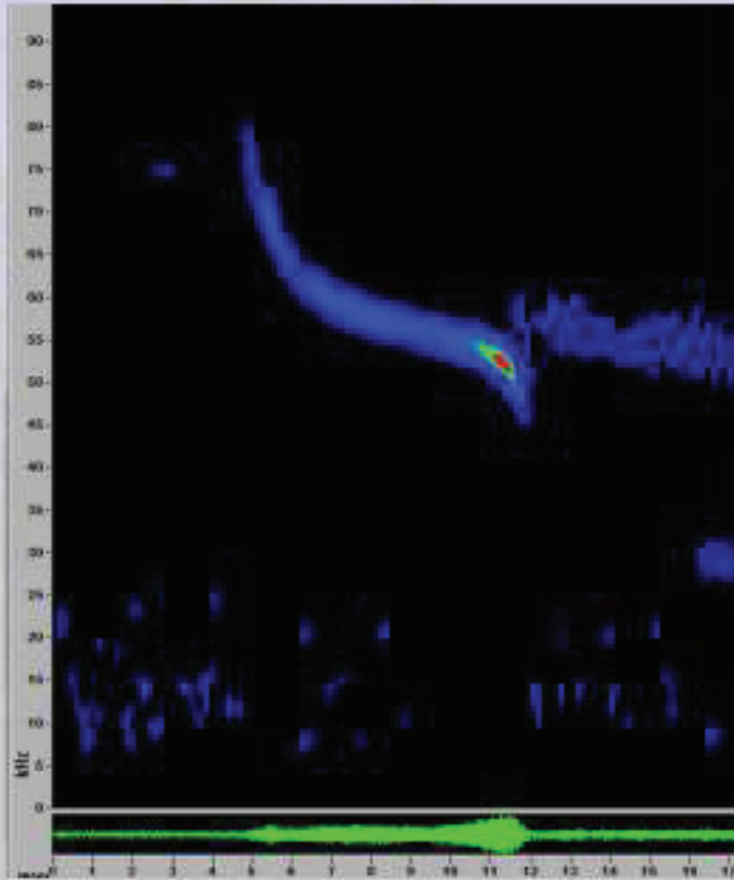
MYYU Call Shapes



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

Figure 79. Call shapes of the Yuma Myotis (*Myotis yumanensis*, MYYU)

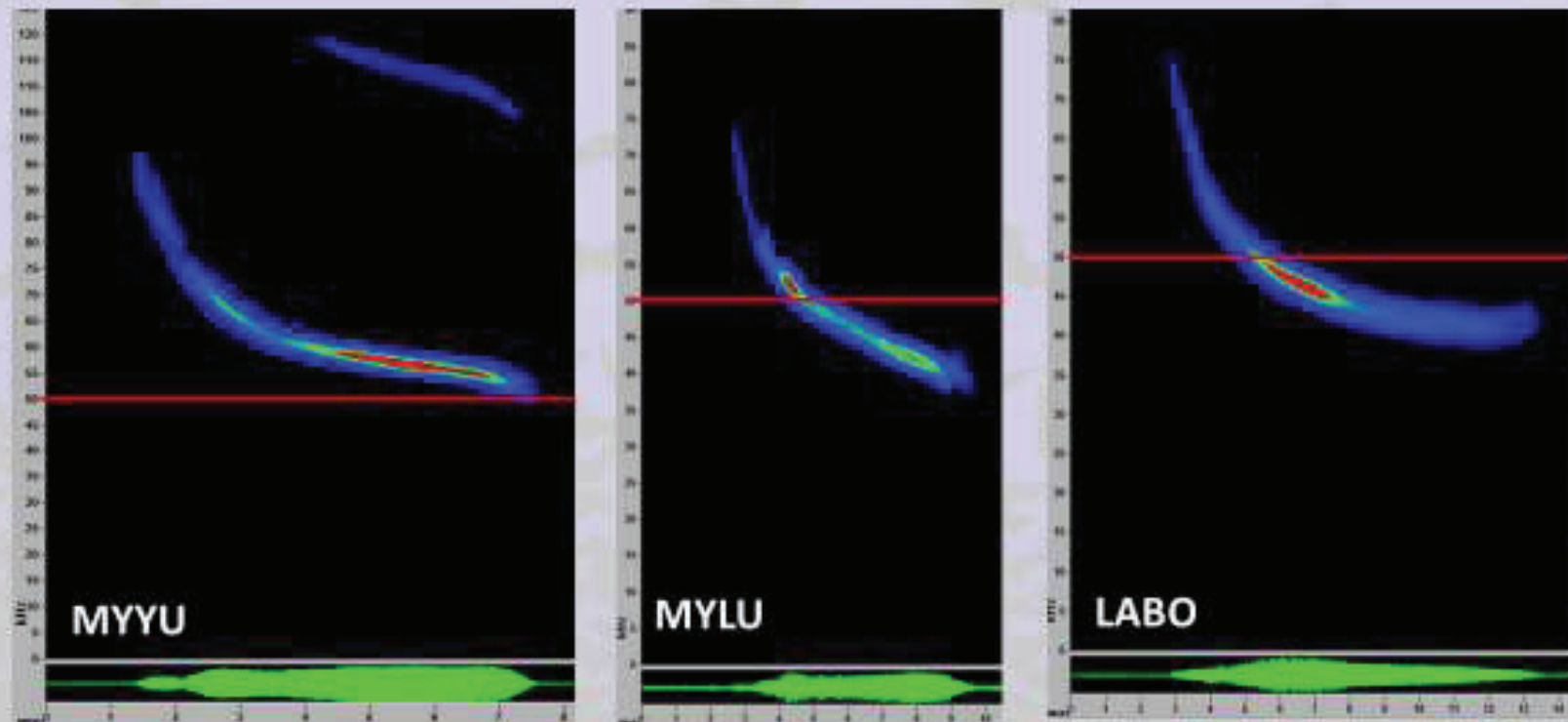
MYYU Definitive Characteristics



- 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

Figure 80. Definitive characteristics of call sequence for the Yuma Myotis (*Myotis yumanensis*, MYYU)

MYYU Similar Species



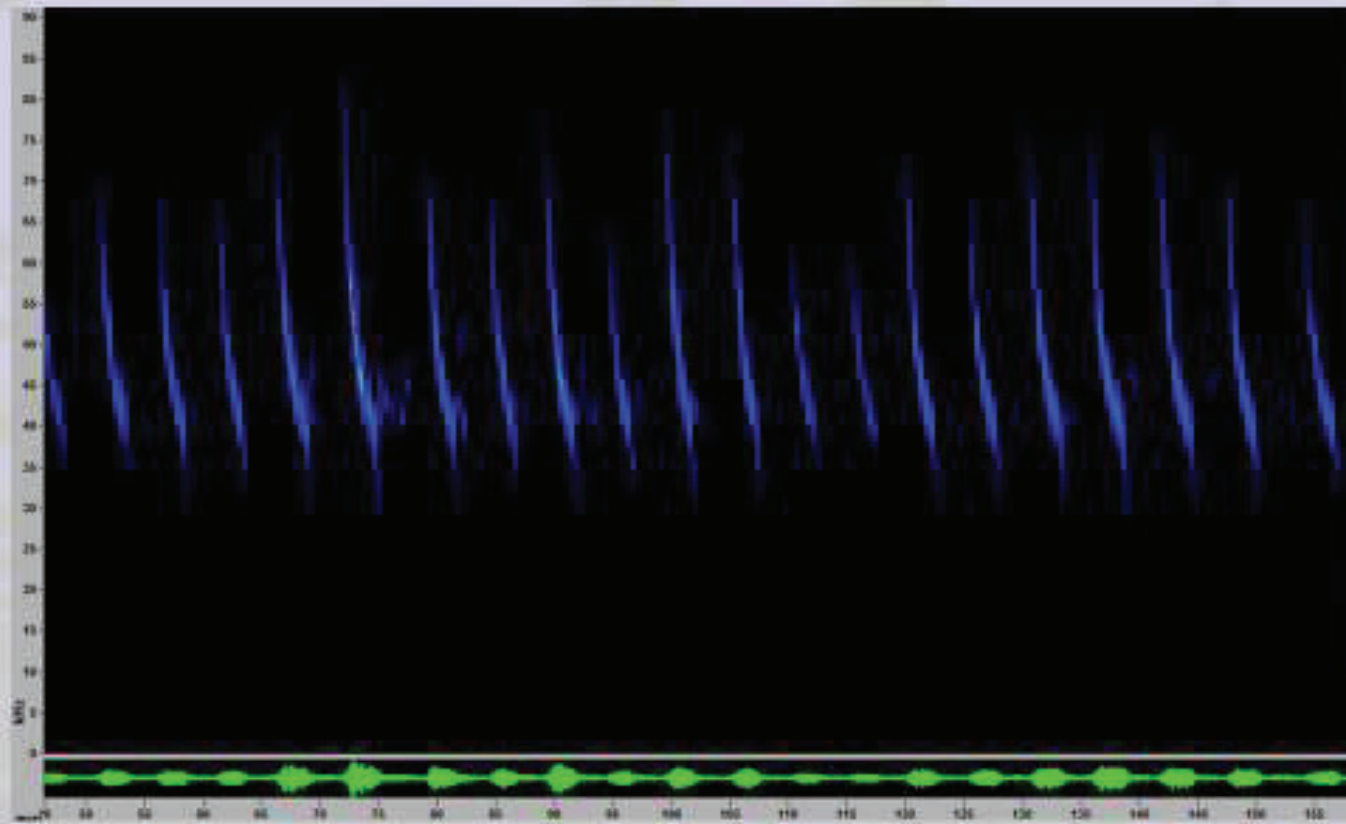
MYYU vs. LABO: LABO calls tend to have a variable f_c across a sequence, up-turns at ends, and longer durations. MYYU duration does not exceed 8 ms. MYYU f_c is generally higher.

MYYU vs. MYLU vs. MYVO: $f_c > 47$ kHz distinguishes MYYU from MYLU and MYVO when the two overlap geographically.

***Red scale bars are set at 50 kHz.**

Figure 81. Calls sequences produced by other species that may be confused with the Yuma Myotis (*Myotis yumanensis*, MYYU)

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

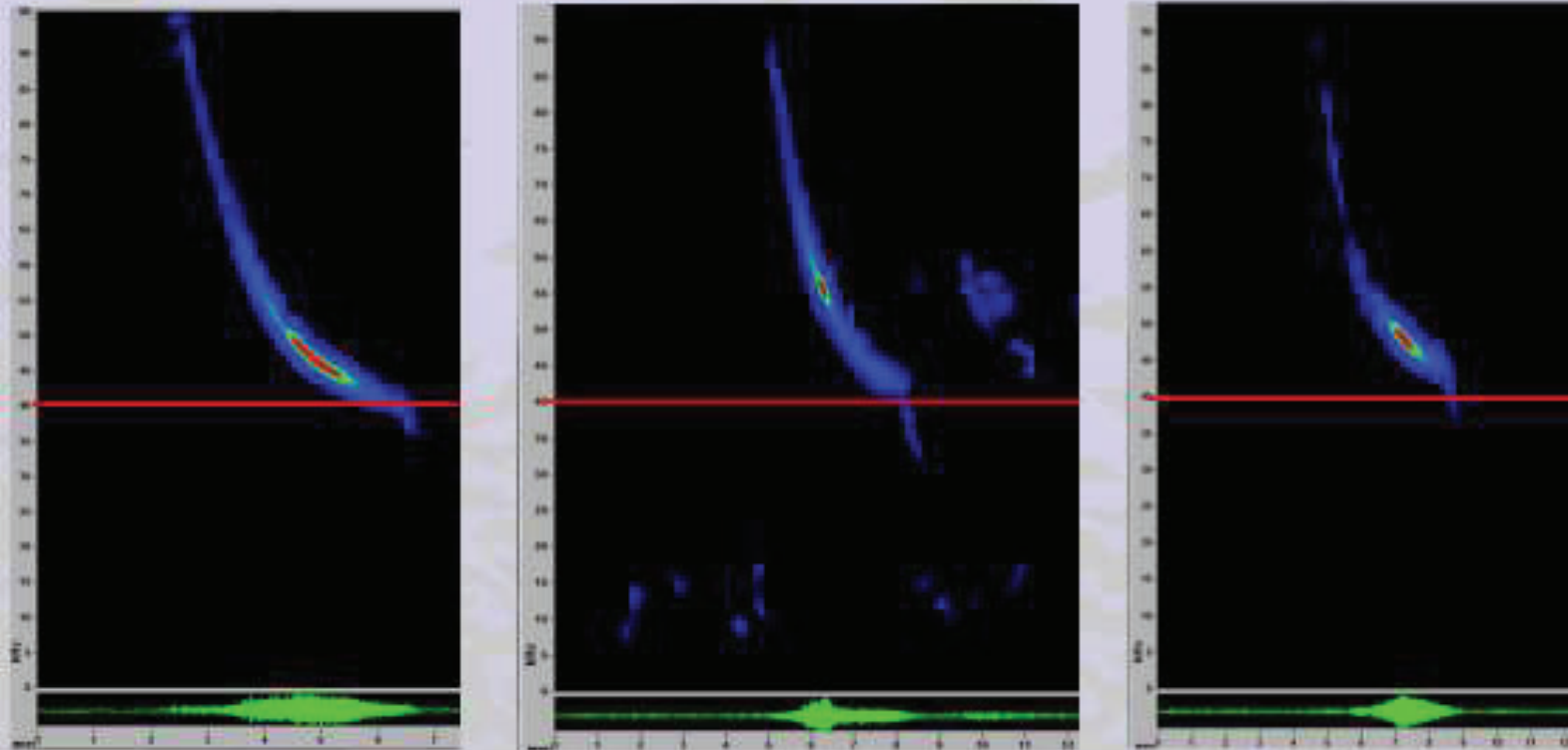


MYCI_time_expanded



Figure 82. Example call sequence for the Western Small-footed Myotis (*Myotis ciliolabrum*, MYCI)

MYCI Call Shapes

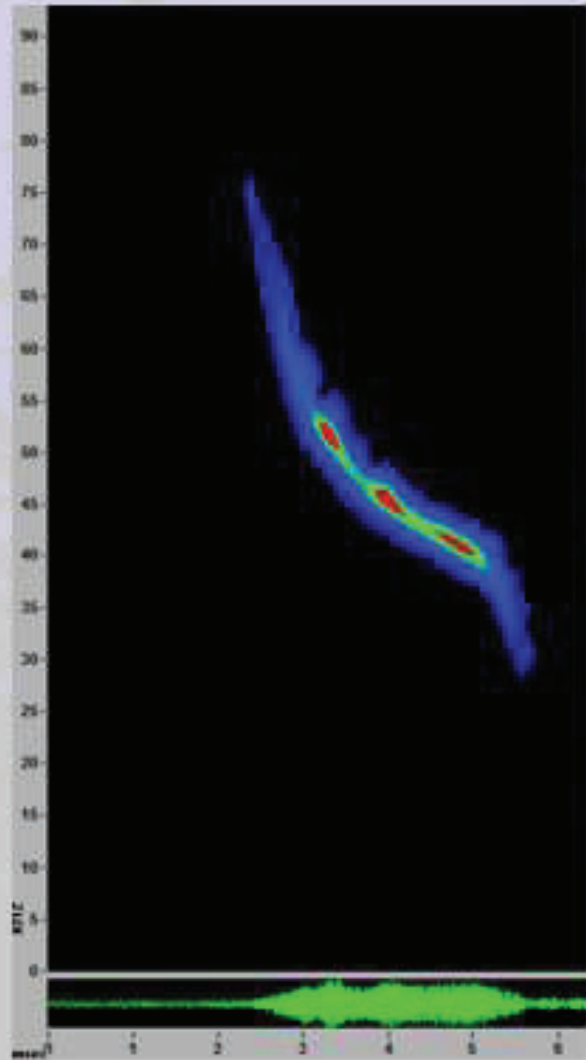


- FM sweep a smooth curve, beginning steeply and then increasing in curvature
- Often with a prominent downward tail
- Some calls have inflection, but smooth variant is diagnostic

*Red scale bars are set at 40 kHz.

Figure 83. Call shapes of the Western Small-footed Myotis (*Myotis ciliolabrum*, MYCI)

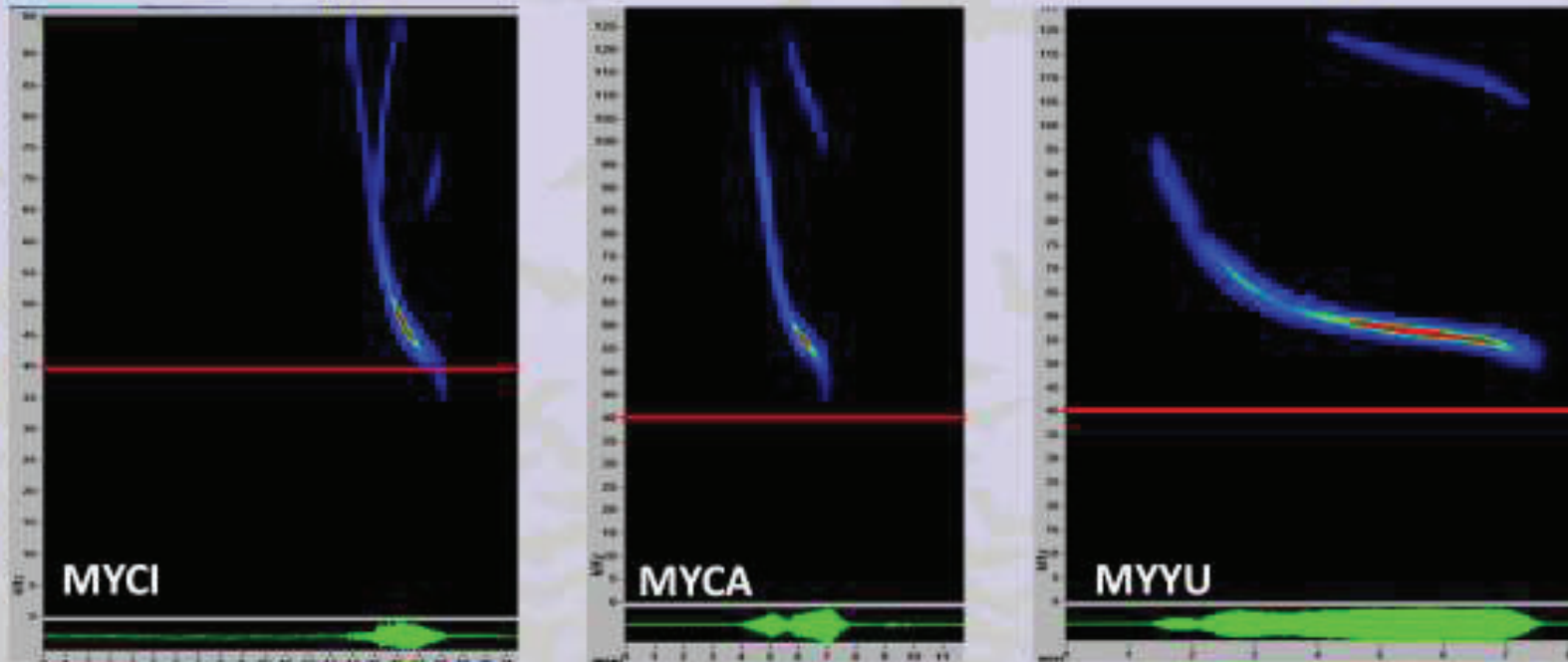
MYCI Definitive Characteristics



- 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

Figure 84. Definitive characteristics of call sequence for the Western Small-footed Myotis (*Myotis ciliolabrum*, MYCI)

MYCI Similar Species

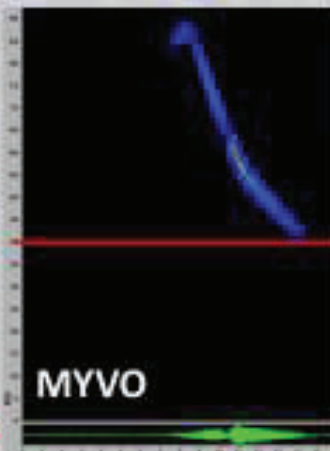


MYCI vs. MYCA: Calls are similar in appearance and characteristics. When the two species overlap geographically, $f_c > 45$ kHz is diagnostic for MYCA.

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.

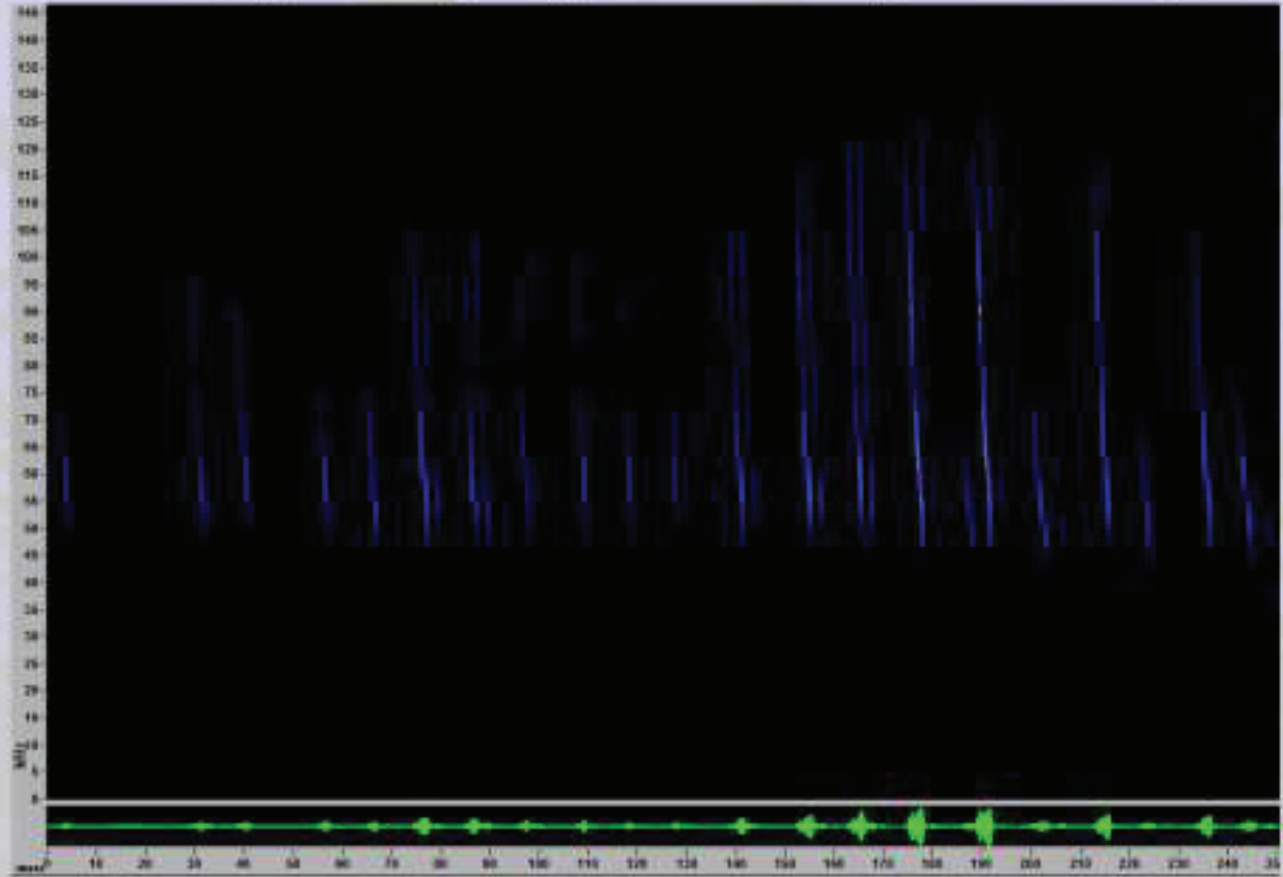
MYCI vs. MYVO: Non-diagnostic calls overlap; unable to distinguish unless there is an upsweep into the call which is diagnostic for MYVO.



***Red scale bars are set at 40 kHz.**

Figure 85. Calls sequences produced by other species that may be confused with the Western Small-footed Myotis (*Myotis ciliolabrum*, MYCI)

California Myotis (*Myotis californicus*) = MYCA



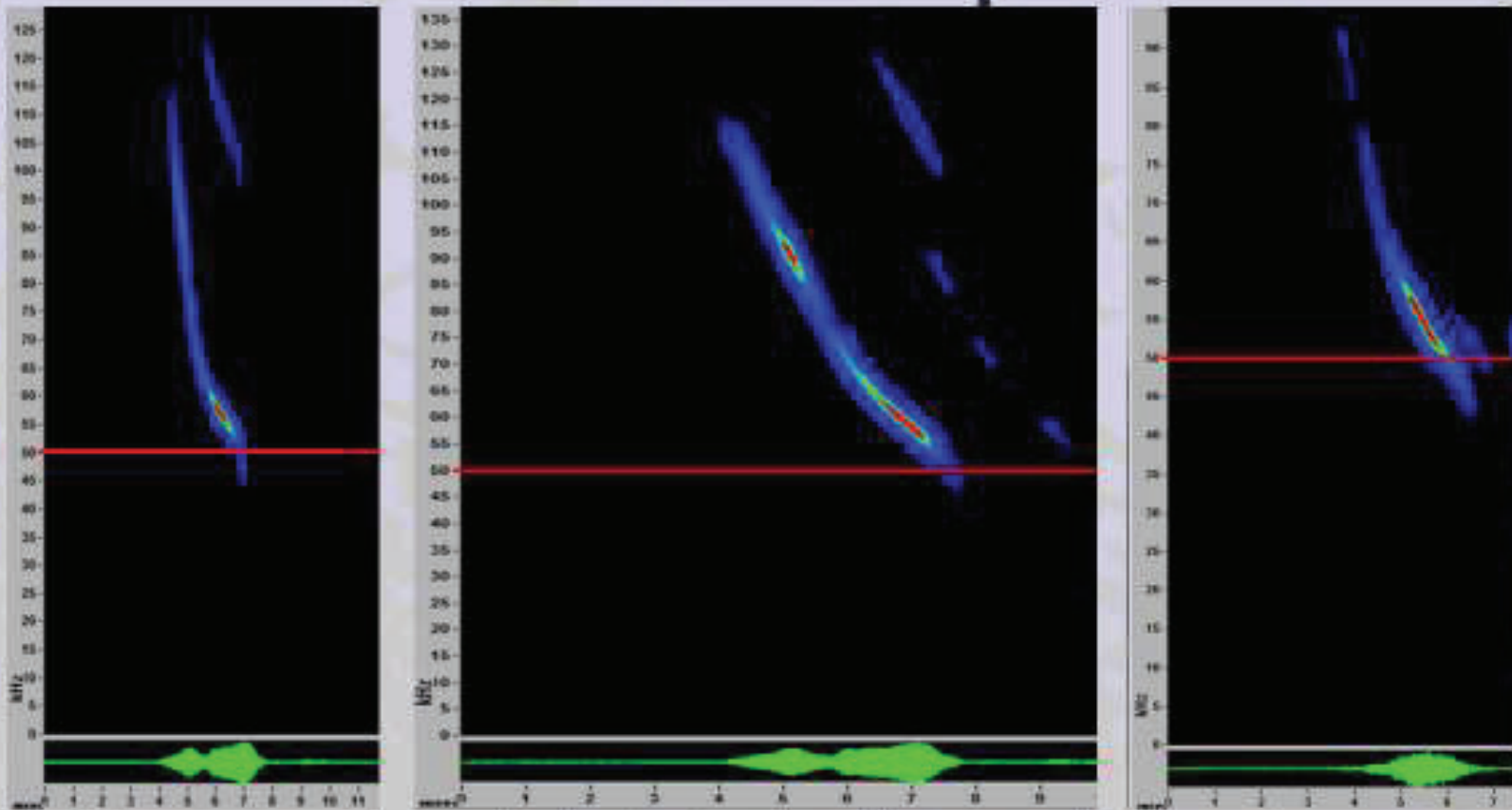
MYCA_time_expanded



But Observation Type	Range Type
• BEST FINGER CAPTURED	• Year-round
• BAY AREA	• Seasonal
• PETTISVILLE	
• SAN FRANCISCO	

Figure 86. Example call sequence for the California Myotis (*Myotis californicus*, MYCA)

MYCA Call Shapes

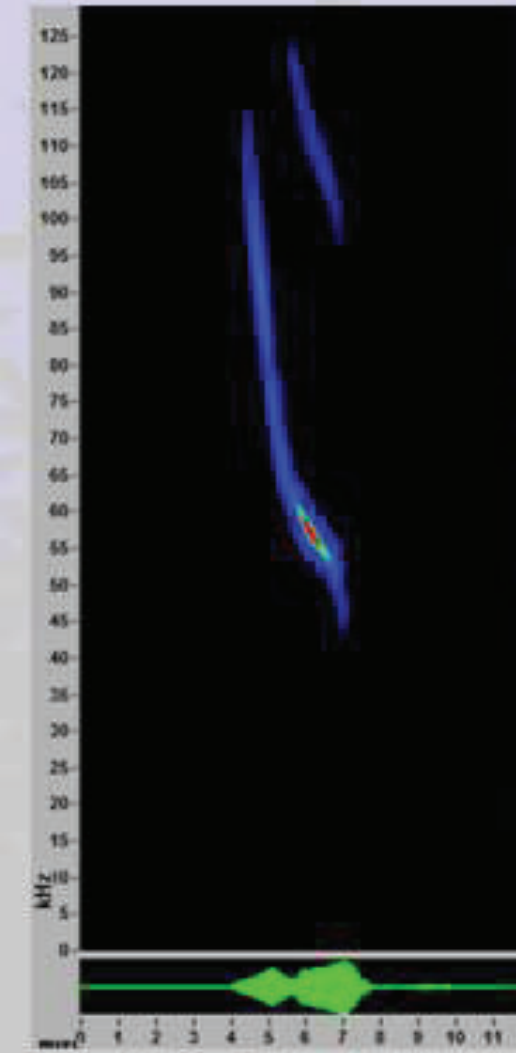


- FM sweep a smooth curve, beginning steeply and then increasing in curvature
- Often with a prominent downward tail
- Some calls have inflection, but smooth variant is diagnostic

***Red scale bars are set at 50 kHz.**

Figure 87. Call shapes of the California Myotis (*Myotis californicus*, MYCA)

MYCA Definitive Characteristics



- FM sweep a smooth curve
- Sometimes a lower inflection, or "ledge," before f_c
- Often a well-defined downward tail
- Peak power persists for at least 1 ms
- $f_c > 48$ diagnostic when within MYCI geographical range

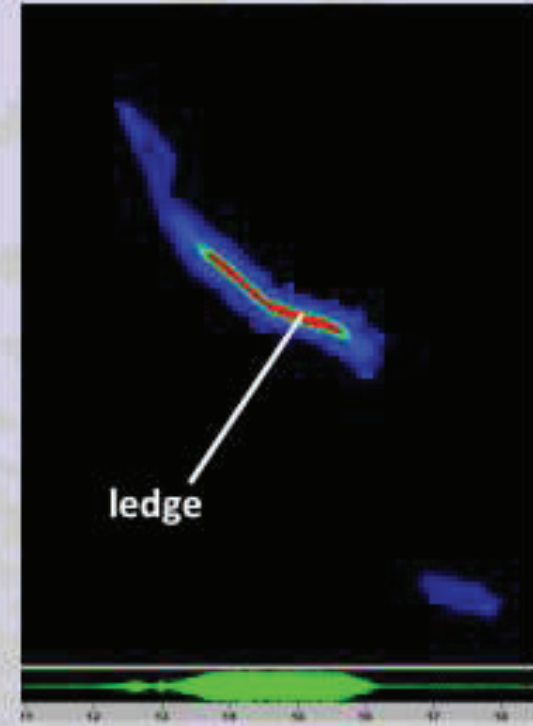
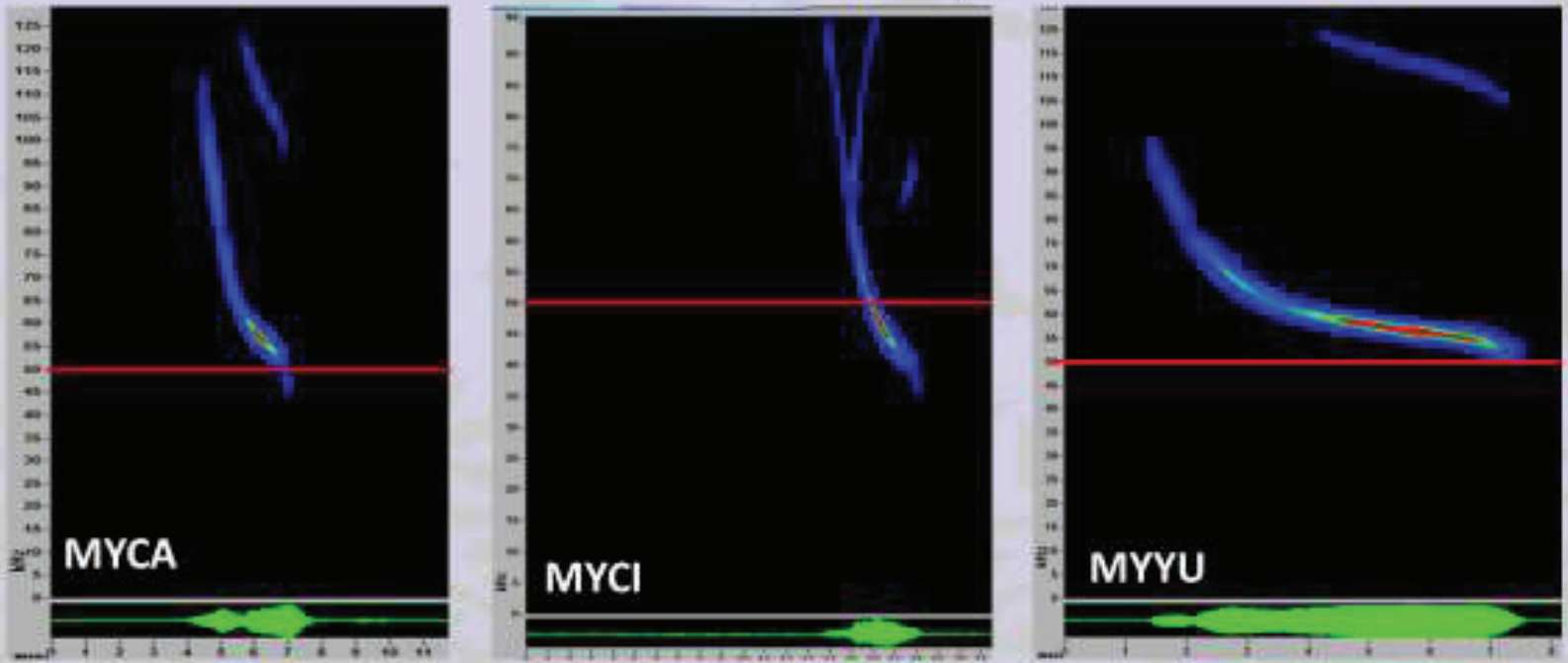


Figure 88. Definitive characteristics of call sequence for the California Myotis (*Myotis californicus*, MYCA)

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.

***Red scale bars are set at 50 kHz.**

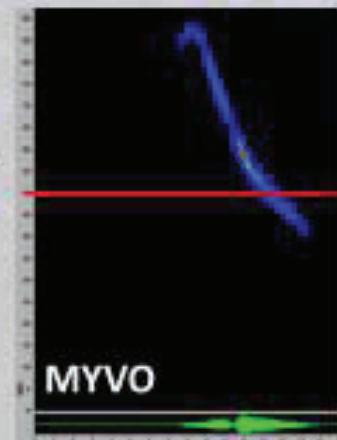


Figure 89. Calls sequences produced by other species that may be confused with the California Myotis (*Myotis californicus*, MYCA)