**Montana Bat and White-Nose Syndrome Surveillance Plan and Protocols
2012 -2016**

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Purpose

This document outlines objectives and tasks to be completed by state, federal, tribal, and private partners in order to address information needs associated with Montana's bat populations and conservation threats such as White-nose Syndrome (WNS), mortalities at wind turbine facilities, and disturbances at winter roost sites. This information will provide biologists and resource managers with a better understanding of the natural history, ecology, year-round spatial and temporal distribution, habitat use, and conservation status of bat populations, allowing them to better respond to threats faced by Montana's bat species.

Introduction

Montana's bat populations face a wide array of conservation issues, including loss of roosting sites, elimination of prey species, collision or drowning hazards at sites where they forage, drink, and mate, and a lack of baseline information on distribution and habitat use that is available to resource managers. In recent years, concerns have focused on fatalities at wind turbine facilities and those resulting from WNS (Table 1). The large increases in mortality posed by these threats are especially significant to bat populations because bats are long-lived and have only 1 or 2 young per year (Barclay and Harder 2003).

Of North America's 45 documented bat species, mortalities from wind turbines have been documented in 11 and 7 of them occur in Montana for at least a portion of the year (Table 1; Kunz et al. 2007, Arnett et al. 2008). Of these species, mortality rates have been highest ($\geq 75\%$) in tree roosting migratory species such as the Silver-haired Bat (*Lasionycteris noctivagans*), Eastern Red Bat (*Lasiurus borealis*), and Hoary Bat (*Lasiurus cinereus*) (Kunz et al. 2007, Arnett et al. 2008 and 2011, Cryan 2008). However, resident bats may also be impacted and impacts may occur even during the winter. For example, data from Canada suggests that non-migratory overwintering bats may remain active to some degree during the winter when temperatures go down to as low as -6 or -7 °C (21 to 19 °F) (Lausen and Barclay 2006).

Since 2006, White-Nose Syndrome, resulting from the cold adapted fungus *Pseudogymnoascus destructans*, has killed an estimated 5.7 to 6.7 million bats in eastern North America (Blehert et al. 2008, Lorch et al. 2011, USFWS News Release January 17, 2012, Minnis and Lindner 2013). As a result, the extinction of Little Brown Myotis (*Myotis lucifugus*) is predicted in eastern North America by 2026 (Frick et al. 2010), *M. lucifugus*, Northern Myotis (*M. septentrionalis*), and Tri-colored Bat (*Perimyotis subflavus*) were emergency listed as Endangered under Canada's Species at Risk Act (COSEWIC 2012), *M. lucifugus* has been petitioned for emergency listing under the United States Endangered Species Act (Kunz and Reichard 2010), and *M. septentrionalis* has been listed as Threatened under the United States Endangered Species Act across its range, including portions of eastern Montana (USFWS 2015). *P. destructans* has progressed westward to states along the Mississippi River corridor as well as the Province of Ontario, Canada, has caused WNS in at least three species documented in Montana, has been detected in other species that may serve as local or regional vectors, and seems likely to affect other Montana species due to the close relatedness of species that have been impacted (Table 1, Blehert et al. 2011, Heffernan 2014).

Table 1. Montana bat species, conservation status, and known or potential concerns from WNS and wind turbine facilities.

Species	Conservation Status	Species known to be affected by White-Nose Syndrome / <i>P. destructans</i>	Species known to be subject to mortality at wind turbines*
Pallid Bat (<i>Antrozous pallidus</i>) = ANPA	G5 S3, MT SOC, BLM Sensitive, USFS Sensitive	No connection known at this time.	No mortalities documented in literature.
Townsend's Big-eared Bat (<i>Corynorhinus townsendii</i>) = COTO	G34 S3, MT SOC, BLM Sensitive, USFS Sensitive	Detected, but no diagnostic sign of WNS (USFWS 2014). Potential winter roost vector.	No mortalities documented in literature.
Big Brown Bat (<i>Eptesicus fuscus</i>) = EPFU	G5 S4	Blehert et al. 2008, Langwig et al. 2012, 2014, Frank et al. 2014.	Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011.
Spotted Bat (<i>Euderma maculatum</i>) = EUMA	G4 S3, MT SOC, BLM Sensitive, USFS Sensitive	No connection known at this time.	No mortalities documented in literature.
Silver-haired Bat (<i>Lasionycteris noctivagans</i>) = LANO	G5 S4, Potential MT SOC	Detected, but no diagnostic sign of WNS (Bernard et al. 2015, USFWS 2014). Potential regional migratory vector.	Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011; Baerwald et al. 2009; Poulton and Erickson 2010.
Eastern Red Bat (<i>Lasiurus borealis</i>) = LABO	G5 SU, Potential MT PSOC	Detected, but no diagnostic sign of WNS (Bernard et al. 2015, USFWS 2014). Potential regional migratory vector.	Kunz et al. 2007; Arnett et al. 2008, 2011.
Hoary Bat (<i>Lasiurus cinereus</i>) = LACI	G5 S3, MT SOC	No connection known at this time.	Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011; Baerwald et al. 2009; Poulton and Erickson 2010.
California Myotis (<i>Myotis californicus</i>) = MYCA	G5 S4	Close relatedness to <i>M. leibii</i> indicates possible susceptibility (Agnarsson et al. 2011, Langwig et al. 2012)	No mortalities documented in literature.
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>) = MYCI	G5 S4	Relatively close relatedness to <i>M. lucifugus</i> indicates possible susceptibility (Frick et al. 2010, Agnarsson et al. 2011)	No mortalities documented in literature.
Long-eared Myotis (<i>Myotis evotis</i>) = MYEV	G5 S4 BLM Sensitive	Close relatedness to <i>M. sodalis</i> indicates possible susceptibility (Agnarsson et al. 2011, Langwig et al. 2012)	Kunz et al. 2007
Little Brown Myotis (<i>Myotis lucifugus</i>) = MYLU	G3 S3, MT SOC	Blehert et al. 2008, Frick et al. 2010, Lorch et al. 2011, Warnecke et al. 2012, Johnson et al. 2014, Langwig et al. 2012, 2014.	Johnson et al. 2004; Kunz et al. 2007; Arnett et al. 2008, 2011.
Northern Myotis (<i>Myotis septentrionalis</i>) = MYSE	G1G3 SU, BLM Special Status, USFS Threatened, USFWS Listed Threatened	Blehert et al. 2008, Langwig et al. 2012, 2014, USFWS 2015.	Kunz et al. 2007; Arnett et al. 2008
Fringed Myotis (<i>Myotis thysanodes</i>) = MYTH	G4 S3, MT SOC, BLM Sensitive	Relatively close relatedness to <i>M. lucifugus</i> indicates possible susceptibility (Frick et al. 2010, Agnarsson et al. 2011)	No mortalities documented in literature.
Long-legged Myotis (<i>Myotis volans</i>) = MYVO	G5 S4 BLM Sensitive	Close relatedness to <i>M. sodalis</i> indicates possible susceptibility (Agnarsson et al. 2011, Langwig et al. 2012)	No mortalities documented in literature.
Yuma Myotis (<i>Myotis yumanensis</i>) = MYYU	G5 S3S4, Potential MT SOC	Relatively close relatedness to <i>M. grisescens</i> indicates possible susceptibility (Agnarsson et al. 2011, USFWS 2014)	No mortalities documented in literature.

*Unidentified Myotis species mortalities have also been reported at the Judith Gap Wind Farm (Poulton and Erickson 2010).

Objectives

The overarching objectives of bat and WNS surveillance efforts in Montana are to:

1. Gain a better understanding of Montana's bats, including their year-round distribution, roost use, and activity levels in various habitats.
2. Gain a better understanding of Montana's cave environments and their likelihood of supporting *P. destructans*, including initiation of baseline surveys to detect the presence of *P. destructans*.
3. Develop risk criteria for WNS invasion of winter bat roosts (e.g., bat use, temperature, humidity, and human visitation rates) and rank the relative risks of WNS in cave and mine sites used, or potentially used, as winter hibernacula by Montana's bats in order to inform response plans.
4. Centralize information on Montana bat roosts and bat distribution and activity levels, as well as broader research on bats and the threats they face, and make it readily available to natural resource managers for mitigating the impacts of WNS, wind turbines, and other threats to bat populations.

Collaborators have agreed to accomplish these overarching objectives through a common set of roost and acoustic surveillance goals and protocols detailed below.

Surveillance of Montana Bat Roosts: Collaborative Assessment of Year-Round Roost Distribution, Roost Characteristics, and Risk of WNS Invasion

Background

The threat of WNS led to an initially contentious meeting between stake holders in the fall of 2010 that has since evolved into a strong collaborative partnership between caving groups and federal, state, tribal, and nongovernmental organizations centered around the goal of addressing information needs that will allow WNS to be detected in a timely manner and provide the best opportunities for impacts from WNS and other threats to be mitigated. Central to this collaboration is a consensus that the collective knowledge and unique skillsets of caving groups are essential to gaining a better understanding of Montana's cave resources and their use by bats. While cavers and caving groups have been the primary method of gathering information on Montana's caves and their use by bats and humans, a variety of other collaborators are contributing information on summer bat roosts in Montana. To-date collaborators have included, ABR Inc., Big Fork Caving Club, the Montana/Dakotas office of the Bureau of Land Management, Confederated Salish and Kootenai Tribes, Fort Peck Tribal Office of Environmental Protection, Montana Department of Environmental Quality, Montana Department of Fish, Wildlife, and Parks, Montana Natural Heritage Program, MPG Ranch, National Bison Range, National Park Service, Northern Rocky Mountain Grotto, Plum Creek Timber Company, University of Montana, U.S. Fish and Wildlife Service, and Region 1 of the U.S. Forest Service.

Goals

While individual goals may vary across collaborators depending on funding availability and local information needs, collaborators have agreed on the following common roost surveillance goals for an initial 4-5 year (2011-2016) collaborative statewide effort:

1. Conduct winter (November to early April) surveys of caves and mines (see decontamination protocols in Appendix 1 and example survey report and datasheets in Appendix 2) to document:
  - a. presence and body condition of bats with identification of species through morphological measurement of a limited number of individuals (Appendix 3) and, if necessary, wing punches and subsequent genetic testing for species not able to be confidently identified to species in hand (e.g., *M. septentrionalis* and *M. yumanensis*)
  - b. numbers of bats including cluster sizes of bats roosting in direct contact with one another, and within a 1 foot of other bats, through direct counts or post survey counts of digital photos taken during the survey
  - c. roost features used (e.g. cracks, crevices, walls, ceilings)
  - d. period of bat occupancy documented through multiple surveys or deployment of a low power acoustic roost logger (e.g., Anabat Roost Logger, Titley Scientific)
  - e. roost surface and/or bat temperatures remotely measured with an infrared thermometer
  - f. air temperatures and relative humidities throughout caves and mines, including areas near bats, measured at the time of the survey with hand held thermometers as well as across one or more years measured with data loggers (e.g., Hobo Pro v2 U23-001 or U23-002 or DS 1923 Hygrochron iButton)
  - g. lesions resulting from WNS by UV fluorescence of bats (Turner et al. 2014)
  - h. presence of *P. destructans* by swabbing bats and substrates (Muller et al. 2013, Shuey et al. 2014).
  - i. presence of *P. destructans* by soil sample collection (Lorch et al. 2012, 2013)

2. Conduct active season (late April through late October) surveys of bridges, buildings, caves, mines, rock crevices, tree snags, and other habitats potentially supporting maternity (highest priority), day, and night roosts (see cave and mine decontamination protocols in Appendix 1 and example survey report and cave and bridge survey datasheets in Appendices 2 and 4) to inform resource managers and provide additional bat surveillance opportunities for determining the potential impacts of WNS by documenting:
  - a. period of bat occupancy documented through multiple surveys or electronic surveillance (e.g., videography)
  - b. presence and body condition of bats with identification of species through morphological measurement of a limited number of individuals (Appendix 3) and, if necessary, wing punches and subsequent genetic testing for species not able to be confidently identified to species in hand (e.g., *M. septentrionalis* and *M. yumanensis*)
  - c. numbers of bats and clustering behavior through direct counts or post survey counts of digital photos taken during the survey
  - d. roost features used (e.g. cracks, crevices, walls, ceilings)
  - e. roost surface and/or bat temperatures remotely measured with an infrared thermometer at the time of survey
  - f. air temperatures and relative humidities of roost crevices measured throughout the summer roosting period with data loggers (e.g., Hobo Pro v2 U23-001 or U23-002 or DS 1923 Hygrochron iButton)
3. Document human visitation rates at Montana caves, with an emphasis on those used by bats, and particular emphasis on those that are ungated and known to support significant aggregations of winter roosting bats (e.g., Lick Creek Cave, Ophir Cave, Old Dry Wolf Station Cave, Whitaker Sink, and Little Ice Cave) by:
  - a. getting estimates of annual visitation rates and timing of visitation events from local cavers
  - b. installing water proof cave registers at/near the entrance and the terminal room or end of larger caves
  - c. installing game cameras to document human activity at cave entrances (e.g., Moultrie Game Spy M-990i Gen 2 10.0 MP)
  - d. installing infrared beam counters or pressure sensitive plate counters (e.g., TRAFx G3 counters) to document human activity inside caves
  - e. deploying low power acoustic roost logger to record bat activity and correlate timing of bat activity with timing of human activity (e.g., Anabat Roost Logger, Titley Scientific)
4. Develop risk criteria and rank the relative risks of WNS in cave and mine sites used or potentially used as winter hibernacula by Montana's bats in order to prioritize future surveillance efforts and inform managers of high risk sites. To-date, risk criteria have included the following variables with risk values listed from low to high for each criteria:
  - a. numbers of roosting bats at potential winter roosts with various levels of bat activity documented (no bat sign documented, bat droppings detected, <20 bats detected, 20-100 bats detected, >100 bats detected)
  - b. temperature (<5°C, unknown temperature in small cave/mine, unknown temperature in large cave/mine, 5-17°C)

- c. humidity (e.g., <90% relative humidity, unknown humidity level in small cave/mine, unknown humidity level in large cave/mine, >90% relative humidity)
  - d. estimated number of human visitors per year (<5, 6-20, 21-200, >200)
- 5. Centralize information on what is known about active and winter season bat roosts in Montana as well as across the known range of Montana's bat species, including period of roost occupancy, temperature, humidity, and physical nature of roosts, and make it readily available to natural resource managers so that it can be used to inform a variety of management decisions, prevent the spread of WNS and/or mitigate impacts of WNS and other threats to bat populations (see Appendix 5 for the latest overview of roost site, travel distance, and home range information for Montana bat species).
- 6. Identify non-cave/mine roost habitat features that are providing the dominant winter roosting habitat for Montana bats (e.g., rock crevices, talus slopes, root wads, and other nonfreezing microhabitats) and determine their likelihood of supporting *P. destructans* by:
  - a. conducting radio telemetry studies of bats in winter and summer
  - b. filming likely landscape features (e.g., talus slopes and rock outcrops) with infrared videography to document emergence and immergence locations (e.g., Sony HDR SR12 Camera on nightshot infrared light setting with illumination provided by a dual IRLamp6 array)
  - c. documenting air temperatures and relative humidities of roost features that are detected with data loggers (e.g., DS 1923 Hygrochron iButton)

Equipment/Supplies Needed for Roost Surveys

Internet Purchases

1. Cason 380 pistol grip infrared thermometer for remote measurement of roost surface temperatures http://www.amazon.com/Non-contact-Infrared-Digital-Thermometer-Measurement/dp/B00DRTESDQ/ref=sr_1_1?ie=UTF8&qid=1423081674&sr=8-1&keywords=Cason+380+thermometer
2. Taylor 6094N dial bi-therm (-40 to + 50 C) Thermometer (rugged and inexpensive for air temps) http://www.amazon.com/Taylor-Bi-Therm-Standard-Instant-Thermometer/dp/B0062PCP7S/ref=sr_1_fkmr1_2?ie=UTF8&qid=1423081874&sr=8-2-fkmr1&keywords=Taylor+6094N+dial+bi-therm+%28-40+to+%2B+50+C%29+Thermometer
3. UV Flashlight 51-LED 385 or 395nm for florescence of WNS presence/damage to bats http://shop.ledwholesalers.com/index.php?route=product/product&product_id=176
4. UV Protection Safety Glasses for use with UV Flashlight http://shop.ledwholesalers.com/index.php?route=product/product&path=41&product_id=263
5. Hobo Pro v2 temperature and relative humidity data logger U23-001 or U23-002 <http://www.onsetcomp.com/products/data-loggers/pro-v2-temp-rh-data-loggers-outdoor>
6. DS 1923 Hygrochron iButton temperature and humidity data logger <http://www.ibuttonlink.com/products/ds1923>
<https://store.thermodata.us/content/ds1923-hygrochron>
<http://www.embeddeddatasystems.com>
<http://www.mouser.com/>
7. DeWalt DCT411S1 9mm inspection camera http://www.amazon.com/DEWALT-DCT411S1-12V-Inspection-Camera/dp/B005LUKE0U/ref=sr_1_1?ie=UTF8&qid=1431641651&sr=8-1&keywords=Dewalt+DCT+9mm+Inspection+Camera
8. Anabat Roost Logger (Anabat RL1) <http://www.titley-scientific.com/us/index.php/anabat-roost-logger>
9. Pesola 50 gram spring scale <http://www.pesola.com/e/>
10. 150 mm 0.1mm scale dial caliper e.g., <http://www.amazon.com/Wiha-Metric-Dial-Max-Caliper-Resolution/dp/B001CTUCGA>
11. Three millimeter Militec Biopsy Punch <http://www.militec.com/prodinfo/surgical/biopsypunches.aspx>
12. Game camera, e.g., http://www.amazon.com/Moultrie-M-990i-Camera-MossyTreestand/dp/B00SSGUHVA/ref=dp_ob_title_sports
13. TRAFx G3 counters <http://www.trafx.net/products.htm>
14. Sony HDR SR12 Camera in nightshot mode http://www.amazon.com/gp/offer-listing/B00123WDR2/ref=olp_tab_all
15. Dual IRLamp6 array <http://www.batmanagement.com/Ordering/irlight/irlight.html>

Other Supplies

1. Clear ruler with millimeter scale for measuring ear, tragus, and toe lengths
2. Nitrile gloves for sterile handling of individual bats
3. Lysol Wipes for decontamination of measurement gear, headlamps, headlamps, pencils, etc.
4. Ziplock bags for sterile management of supplies and samples and disposal of smaller waste items
5. Garbage bags for containing gear from cave to decontamination area to prevent spread of WNS
6. Swabs for swabbing bats for PCR
7. Microcentrifuge boxes and tubes with buffer for swabs or tissue biopsies for detection of *P. destructans* or bat species identification (best to get from genetics collaborator)
8. Compass for orientation
9. GPS for documenting longitude and latitude of site location

**Passive Acoustic Surveillance of Montana Bats:
Assessing Year-Round Distribution and Activity Levels with Songmeter Ultrasonic Detectors**

Background

Starting in the fall of 2011, various federal, state, and tribal partners began deploying SM2Bat and SM2Bat+ ultrasonic detectors to gather year-round baseline information on bat activity in various localities across Montana. During 2012, individual efforts began to coalesce into a statewide array of detectors to address most bat species known to occur in Montana (Figure 1, Table 2, Appendices 6 and 7). Most of the recordings from this array are being analyzed by the Montana Natural Heritage Program and stored in the Montana Bat Call Library. The library of Montana bat calls is housed on a series of 15-20 Terabyte Drobo 5D and 5N storage arrays at the Montana State Library as well as a secondary offsite location to protect against catastrophic loss.

Goals

While individual goals may vary across collaborators depending on funding availability and local information needs, the following common baseline information goals emerged for an initial 2-3 year (2012-2015) collaborative statewide effort focused on the species that are readily detected by the SM2Bat, SM2Bat+, and SM3 detector/recorder systems (Figure 1, Table 2, Appendices 6 and 7).

1. Summaries of year-round monthly and nightly bat activity levels, as measured by the number of bat passes detected, regardless of species
2. Summaries of year-round nightly activity levels of individual bat species based on automated Sonobat 3.0 call identification analyses in order to identify annual timing of emergence to and emergence from hibernacula by resident bat species and timing of spring and fall migrations by migratory bat species
3. Summaries of timing of nightly activity patterns of individual bat species based on automated Sonobat 3.0 call identification analyses
4. Correlations of overall bat activity and activity of individual species with temperature and, where possible, wind speed and barometric pressure
5. Confirmation of both monthly species presence and minimum temperatures of activity through hand analyses given that Sonobat 3.0 automated call identification analyses are not always reliable
6. Summaries of information gathered on individual ultrasonic acoustic monitoring devices will be compiled in site specific powerpoint presentations that can be readily shared with local partners and the general public
7. Collective summaries of information gathered on all ultrasonic acoustic monitoring devices deployed across the state in order to identify landscape characteristics that are associated with different levels of bat activity throughout the year and in order to identify timing, and potentially pathways, of migratory events.

Considerations for Selecting Passive Acoustic Monitoring Locations

Sites selected for deployment of acoustic monitoring devices have been determined by the following considerations:

1. Does location fill gap in statewide acoustic monitoring scheme?
2. Does location provide information to inform local management decisions?

- Figure 1. SM2Bat and SM2Bat+ Detector/Recorder Deployment Status as of October 2015**

Table 2. Acoustic Monitoring Comments for Montana Bat Species

Common Name	Scientific Name	4 Letter Code	Conservation Status	Acoustic Monitoring Comments (see Montana Bat Acoustic Key and Call Identification Training Materials in Appendices 6 and 7 for more details)
Pallid Bat	<i>Antrozous pallidus</i>	ANPA	G5 S3, MT SOC, BLM Sensitive, USFS Sensitive	Probably only able to differentiate via social calls.
Townsend's Big-eared Bat	<i>Corynorhinus townsendii</i>	COTO	G34 S3, MT SOC, BLM Sensitive, USFS Sensitive	Quiet bat. Poor rates of detection by most detectors. Partial calls overlap with Fringed Myotis. Need good recordings with harmonics for differentiation. Surveys of known roosts likely to remain an important component of monitoring species.
Big Brown Bat	<i>Eptesicus fuscus</i>	EPFU	G5 S4	Calls often overlap, and are confused with, calls of Silver-haired Bat and, more rarely, Hoary Bat.
Spotted Bat	<i>Euderma maculatum</i>	EUMA	G4 S3, MT SOC, BLM Sensitive, USFS Sensitive	Poor rate of detection with Long-term SM2 detectors. Standard call processing (16 KHz lower cutoff) does not allow for detection of this species. Processing to filter calls with a 3-8 ms duration at 7-10 KHz has successfully pulled out call sequences for this species as well as social calls for other species. Species needs focal acoustic surveys in high elevation meadows above big cliff habitats.
Silver-haired Bat	<i>Lasionycteris noctivagans</i>	LANO	G5 S4, Potential MT SOC	Calls often overlap, and are confused with, calls of Big Brown Bat and, more rarely Hoary Bat.
Eastern Red Bat	<i>Lasiurus borealis</i>	LABO	G5 SU, Potential MT PSOC	Call sequences for this species are easily differentiated by finding sequences with variable frequencies and characteristic call shapes. Sonobat 3.0 often mistakes MYLU call sequences for this species.
Hoary Bat	<i>Lasiurus cinereus</i>	LACI	G5 S3, MT SOC	Call sequences for this species are easily differentiated by finding sequences with variable frequencies and characteristic call shapes.
California Myotis	<i>Myotis californicus</i>	MYCA	G5 S4	Calls overlap to some extent with the calls of Yuma Myotis.
Western Small-footed Myotis	<i>Myotis ciliolabrum</i>	MYCI	G5 S4	Reasonably well differentiated call with good recordings that contain harmonics.
Long-eared Myotis	<i>Myotis evotis</i>	MYEV	G5 S4 BLM Sensitive	Reasonably well differentiated call using characteristic frequency cutoff for good recordings that contain harmonics.
Little Brown Myotis	<i>Myotis lucifugus</i>	MYLU	G3 S3, MT SOC	Calls overlap to some extent with Eastern Red Bat and Plains version of Sonobat 3.0 often mistakes this species for Eastern Red Bat calls.
Northern Myotis	<i>Myotis septentrionalis</i>	MYSE	G1G3 SU, Potential MT SOC, BLM Sensitive	Only a single record in Montana.
Fringed Myotis	<i>Myotis thysanodes</i>	MYTH	G4 S3, MT SOC, BLM Sensitive	Reasonably well differentiated call using characteristic frequency cutoff for good recordings that contain harmonics.
Long-legged Myotis	<i>Myotis volans</i>	MYVO	G5 S4 BLM Sensitive	Very difficult to differentiate from other Myotis species unless a rarely observed upswEEP into calls is recorded.
Yuma Myotis	<i>Myotis yumanensis</i>	MYYU	G5 S3S4, Potential MT SOC	Calls overlap to some extent with the calls of California Myotis.

Equipment/Supplies Needed for Each Detector/Recorder Installation

(see Figure 2 photos below for examples of SM2 mounting setups)

Parts from Wildlife Acoustics <http://www.wildlifeacoustics.com/>

- SM2Bat+ ultrasonic detector/recorder
- 10-meter or 50-meter SM2 microphone cable
- SM2 6/12 volt power adapters
- SMX-US ultrasonic omnidirectional microphone
- Ultrasonic calibrator
- Extra windscreens for the microphones
- Extra cover fasteners
- Ultrasonic microphone calibrator/tester

Other Internet Purchases

- Optima YellowTop 12-volt dual purpose starting and deep cycle battery (8071-167 D51)
- Instapark 30-watt mono-crystalline solar panel and 12-volt charge controller
- Kingston 32 gigabyte class 10 flash memory cards (SD10G2/32gb) x 5 per detector
- AA Energizer industrial strength batteries x 2 changed approximately annually for powering internal clock

Parts from Local Hardware Store

- 4 x 6 ft metal picket fence posts to mount the detector, microphone, and solar panel
- 10 ft of electrical conduit for mounting microphone (could also use a wooden dowel)
- Bent ¾ inch PVC pipe to hold microphone
- Duct tape for initially holding conduit on fence post and PVC pipe on conduit
- Bailing or other malleable wire to attach solar panel on fence post, and detector on fence post
- 4 x hose clamps to attach conduit on fence post and PVC pipe on conduit
- 9 inch x 9 inch piece of plywood to mount the detector/recorder to with wood screws. Drill holes in the plywood to wire it to a fence post or screw it to a tree etc.
- Plastic tub (ammo container may be better in bear country) for the battery and extra cable
- Zip ties (9 or 11 inch) to hold the cables down to the fence post and conduit
- Small amount of fencing and a few fence posts if detector is at risk of cattle rubbing on the detector or microphone

Other Supplies for Installing and/or Checking Detector/Recorder

- Phillips screw driver to open detector/recorder cover
- Multimeter for checking battery voltage
- Compass to orient direction (south) and angle (~60 degrees) of solar panel
- GPS for setting latitude and longitude and setting and checking time
- Fence post pounder
- Fencing pliers
- Retaining ring pliers for replacing microphone covers
- Drobo 20 TB 5-drive array for data storage with redundancy to protect against drive failure

Figure 2. Examples of SM2 Deployment Locations and Setups

Figure 2 Continued. Examples of SM2 Deployment Locations and Setups

Settings for SM2Bat and SM2Bat+ Detector/Recorders with SMX-US Microphones

Basic settings are below, but see Powerpoint overview with images at:

http://mtnhp.org/animal/presentations/20130101_SM2_Deployment_Settings.pdf

Note: We do not recommend using the SM2Bat detector when recording high frequency/bandwidth bats (e.g., *M. evotis*, *M. thysanodes*, *M. volans*, *M. septentrionalis*) because the maximum frequency of sampling and maximum frequency recorded are too low at 192 kHz and 96 kHz, respectively, to record the full frequency bandwidth of these species.

Switches (SM2Bat+)

- Power – set to external when on external 12-volt battery
- Switches 1 and 7 set to on and all others set to off

Jumpers (SM2Bat)

- Power – set to external when on external 12-volt battery
- Left and right high pass filter set to 1,000 Hz (i.e. top two jumpers set to the far right)
- Left and right gain both set to 48 dB (i.e. for both right and left microphone, both of the bottom two jumpers will be at 24 dB in order to add up to 48 dB bottom). This results in a staggered appearance so that the bottom is to the far right and second to the bottom is one pin to the left.

Schedule Settings

Set Schedule Settings to the Advanced option with the following lines of code

```
01 At SSET-00:00:00
02 DO
03 RECORD 00:30:00
04 GOTO LINE 03 0X
05 UNTSRIS+00:00:00
06 GOTO LINE 01 0X
```

Time and Date Settings

- Set at Standard Mountain Time (do not use Daylight Savings Time) so that a consistent time setting is used year-round. During the summer this will result in a displayed time that is one hour earlier than Daylight Savings Time.

Location Settings

- Prefix = Enter abbreviated location name
- Location = Enter Longitude North and Latitude West decimal degree coordinates
- Time Zone = set at UTC -7:00

Audio Settings

- Sample Rate = 192,000
- Channels = Mono-R, Mono-L, or Stereo depending on microphone(s) deployed
- Compression = WACO
- Gain Left and Right = leave at 0.0 dB. These are only set with jumpers/switches
- Advanced Settings
  - o Dig HPF Left and Right = Off if not in use and fs/24 if in use ($192/24 = 8$ kHz as minimum frequency in order to filter out sounds below Spotted Bats)
  - o Dig LPF Left and Right = Off since we don't want to remove highest frequencies
  - o Trg Lvl Left and Right = Off if not in use and 18SNR if in use (SNR = signal-to-noise ratio)
  - o Trg Win Left and Right = 2.0s so that call sequences won't be recorded within 2 seconds of one another
  - o Trig Max Length = 0s
  - o Div Ratio = 16
  - o Nap Trg Lv1 = off

Upgrading Firmware

1. Download the new firmware (V 3.3.9 or later) from the Wildlife Acoustics website <http://www.wildlifeacoustics.com/wa-php/downloads.php> onto an SD card
2. Insert the SD card into Slot A of the detector
3. Hold the Up button down as you hit and release the Reset button (SM2Bat) or turn the power switch off and back on (SM2Bat+) until you see the boot message
4. Your SM2 file will show up on the screen and use the Up/Down and Select to select it
5. Press Reset (SM2Bat) or turn the power switch off and back on (SM2Bat+) to reboot and the screen will tell you it is "Upgrading" and "Complete"

Utility Settings

1. Use "Save A:SONGMETR.SET" to save the current recording settings into a configuration file. This can be handy for diagnosing problems with recording settings.
2. Use "Erase all cards" to erase all cards in the unit. This is handy for quickly eliminating 0 Kb files that sometimes get recorded. Cards can also be reformatted using SDFormatter V3.1 or later software https://www.sdcard.org/downloads/formatter_3/

Restarting Recording After the Start of a Scheduled Recording Session

If power is not provided to the detector/recorder until after the beginning of a scheduled recording session or if you are making changes in the settings menu during the beginning of a scheduled recording session, the detector will not record that night and will instead start recording the next evening. If this happens, you can hold the Wake/Exit button down to force recording to initiate. The display will read "Backing up..." and then "Recording...."

Settings for SM2Bat+ Detector/Recorders with SMX-U1 Microphones

*See Upgrading Firmware, Utility Settings, and Restarting Recording After the Start of Scheduled Recording Session above.

Switches

- Power – set to external when on external 12-volt battery
- Switches 1, 6 and 9 set to on and all others set to off. This sets the unit to recording in kilohertz and the microphone gain to 12 dB.

Schedule Settings

Set Schedule Settings to the Advanced option with the following lines of code

```
01 At SSET-00:00:00
02 DO
03 RECORD 00:30:00
04 GOTO LINE 03 0X
05 UNTSRIS+00:00:00
06 GOTO LINE 01 0X
```

Time and Date Settings

- Set at Standard Mountain Time (do not use Daylight Savings Time) so that a consistent time setting is used year-round. During the summer this will result in a displayed time that is one hour earlier than Daylight Savings Time.

Location Settings

- Prefix = Enter abbreviated location name
- Location = Enter Longitude North and Latitude West decimal degree coordinates
- Time Zone = set at UTC -7:00

Audio Settings

- Sample Rate = 384,000
- Channels = Mono-R, Mono-L, or Stereo depending on microphone(s) deployed
- Compression = WACO
- Gain Left and Right = leave at 0.0 dB. These are only set with jumpers/switches
- Advanced Settings
  - o Dig HPF Left and Right = Off if not in use and fs/48 if in use ($384/48 = 8$ kHz as minimum frequency in order to filter out sounds below Spotted Bats)
  - o Dig LPF Left and Right = Off since we don't want to remove highest frequencies
  - o Trg Lvl Left and Right = Off if not in use and 18SNR if in use (SNR = signal-to-noise ratio)
  - o Trg Win Left and Right = 2.0s so that call sequences won't be recorded within 2 seconds of one another
  - o Trig Max Length = 0s
  - o Div Ratio = 16
  - o Nap Trg Lv1 = off

Checklist for Checking SM2Bat and SM2Bat+ Detectors

Tools Needed

- Phillips Screw Driver for opening detector
- Multimeter for checking voltage
- Rag for cleaning solar panel

Checklist

1. Check microphone to make sure it is oriented slightly downward so that precipitation drains away from the microphone and the microphone cover to make sure it is intact (i.e. no bird damage). The cover will turn orange, but still provides protection to the microphone if intact and not brittle. If damaged, the cover needs to be replaced in order to ensure the microphone is protected from precipitation damage. Replacing the SMX-US microphone covers is recommended every 6 months.
2. Check that the microphone cable is connected at the detector.
3. Clean solar panel to make sure it is free of dust, bird feces, etc.
4. Check power cable connections on detector, voltage regulators, and battery to make sure everything is connected.
5. Check voltage of battery with the multimeter. Hopefully it is in the range of 12-13.5 volts. If it is below 11 volts there is a problem.
6. Check that “charging” (red) and “power out” (green) lights on charge controller are on; sometimes hard to see in direct sunlight so cup your hands over them. If the voltage is 12-13 volts then this isn’t a big deal, but if voltage is below that, the power and charging lights provide important information to diagnose problems with battery charging issues.
7. Take the cover off the detector recorder with the Phillips Screw Driver and do the following:
  - a. If the screen doesn’t power up when you take the cover off, push the Wake/Exit button in the upper left.
  - b. Record the % full reading for each card.
  - c. Remove cards that are full or partially full.
  - d. Shift empty cards on the right to the left (i.e. towards slot A) and add empty cards in at the right so that 4 cards are in the detector from May through September and at least 2-3 cards are in the detector from October through April. If you are using 64GB cards make sure that they are formatted to FAT32 format with the SmartDisk_Fat32_Tool program at:
http://www.verbatim.com/includes/binary_details.php3?show=1&id=840
  - e. Make sure cards are reading in their new slots. If they aren’t, push the Wake/Exit button to put the unit to sleep and then wake it up again.
  - f. If interested, or if there have been recent problems with the detector, check that the detector recorder settings match those suggested above
  - g. Check that microphone is working properly with a Wildlife Acoustics Microphone Calibrator using the protocol at the Wildlife Acoustics website
<http://www.wildlifeacoustics.com/images/documentation/Ultrasonic-Calibrator.pdf>
A quick check of microphone performance can also be made by plugging headphones into the detector, putting it in recording mode by holding the up and down buttons down, turning on the headphone sound by pressing the select button, and turning on the “chirp” mode of the calibrator while placing it in the vicinity of the microphone.
  - h. Put the detector to sleep by pushing the Wake/Exit button and take note of the time when the detector says it is going to sleep until. The time should correspond with the standard time for sunset; i.e. one hour before sunset while we are on daylight savings time between March 10 and

November 3 and at sunset once we are back on standard time between November 4 and March

9. If necessary, update the time using your GPS unit or a watch with accurate time.
  - i. If for any reason the screen freezes during your visit, turn off the power using the external/internal power switch/jumper in the middle of the right side of the unit.
8. See instructions above for Upgrading Firmware, Utility Settings, and Restarting Recording After the Start of a Scheduled Recording Session.
9. If there are problems during your visit and you have cell phone coverage you can call Bryce Maxell for immediate feedback at: (406)-444-3989 (office) or (406) 461-1279 (cell).

Settings and Checklist for SM3Bat Detector/Recorders with SMM-U1 or SM3-U1 Microphones

SM3 Bat Detector Settings

Use the SM3 Configurator Software from Wildlife Acoustics to load the following settings into a .PGM file that you can load onto the detector using the program update instructions below.

Prefix = prefix you want to use for all files at the deployment location

Timezone = UTC-07 for Montana

Position = enter latitude and longitude coordinates of the detector

Solar mode = sunrise/sunset

Deployment scenario = SM3BAT with cards of the size you have

Mic 0 = SMM-U1 microphone

Mic 1 = internal

01	HPF	1,000	Off	
02	Gain	12.0 dB	Auto	
03	FS	WAC	0	256k
04	ZC	Off	8	
05	Frqmin	7,000	Off	
06	Frqmax	128,000	Off	
07	Dmin	Off	Off	
08	Dmax	Off	Off	
09	Trglvl	+18	Off	
10	Trgwin	2.0	0.1	
11	Trgmax	Off	Off	
12	Nap	Off		
13	Repeat			
14	At SSet	+00:00:00		
15	Repeat			
16	Record	00:30:00		
17	UntSris	+00:00:00		
18	UntCount	Forever = Inf		

*Save the file with the desired name onto an SDHC or SDXC card

To load a program update

1. Save the .pgm file on an SDHC or SDXC memory card
2. Load the card into slot A of the SM3
3. Press the Check Status button
4. As soon as you see something come up on the screen, push the Program Stop button
5. With the cursor flashing on the Program line, press the Enter/Menu button
6. Toggle down to the Import Program option and press the Enter/Menu button
7. It will take a few seconds to pop up, but you should see the XXXX.pgm filename pop up. Select it and hit the Enter/Menu button
8. Press the left arrow
9. Press the Program Start Button

To update the firmware

1. Download the latest firmware from the Wildlife Acoustics website and store it on an SDHC or SDXC memory card
2. Load the card into slot A of the SM3
3. Press the Check Status button
4. As soon as you see something come up on the screen, push the Program Stop button
5. Enter the Utilities menu and select Firmware Update
6. Select the Sys-XXXXX.SM3 file corresponding to the firmware version and press the Enter/Menu button
7. Confirm that it has updated to the latest firmware version on the screen message
8. Press the Program Start Button

Checklist for checking SM3 detectors

1. Check microphone to make sure it is free of spider webs and not damaged. Remove spider webs if needed and let Bryce know if there appears to be any damage.
2. Check that the microphone cable is connected to the detector
3. Clean solar panel to make sure it is free of dust, bird feces, etc.
4. Check that the power cable is connected to the detector and to the battery via the wire loops.
5. Check voltage of battery with the multimeter. Hopefully it is in the range of 12-15.5 volts. If it is below 11 volts there is a problem.
6. Press the Check Status button on the left side of the front of the detector....as soon as you see something come up on the screen, push the Program Stop button on the lower right side of the front of the detector
7. Press the Check Status button and note how full cards A, B, C, and D are.
8. Remove any cards that have data and send them in and move remaining cards from the D to A direction (note card indications stamped onto outside of card cover piece). Put new cards in so that unit has 4 empty cards.
9. Press the Check Status button and make sure that cards A, B, C, and D are being read by the detector. If not, power down with switch inside the card bays and power back up and recheck.
10. Press the Program Start button and make sure the unit says it is going to sleep at the approximate time of sunset (1 hour earlier than sunset during daylight savings time since the unit is set at standard time year round).

Work Flow for Data Management and Analysis for SM2 Detectors with SMX-US Microphones

*see Figure 3 below.

1. Remove card(s) from detector and use card reader to copy .wac files to computer. Archive original .wac files for potential reanalysis in the future.
2. Convert .wac files to .wav files using Wildlife Acoustics WAC to WAV Conversion Utility using the following settings: Split Triggers checked, Skip Noise checked, Sonobat checked, Max duration = 86400, Gain Adj = 0, Min signal = 0.002, Min freq = 16000, Min spacing = 5, filter = SMX-US Comp, Max freq = 125000
3. Compensate for SMX-US weatherproof ultrasonic microphone using Sonobat Batch Compensator Utility with default settings
4. Eliminate nonbat noise files using Sonobat Batch Scrubber
5. Batch attribute files using Sonobat Batch Attributer
6. Batch analyze files using Batch Analysis Utility in one of the three versions of Sonobat 3.0. Given our current understanding of species distributions, it is advisable to generally use the "Mountains" version for mountainous areas of western Montana, the "South" version for eastern Montana Great Plains habitats south of the Missouri River and the "Plains" version for eastern Montana Great Plains habitats north of the Missouri River.
7. Import Sonobat 3.0 Batch Analysis output files and temperature log files into a Microsoft Access database for long term management, hand analyses, and data summaries.
8. Hand check files identified to species by Sonobat 3.0 Batch Analysis Utility against the Montana Bat Acoustic Key and Montana Bat Call Identification training materials (see Appendices 6 and 7, respectively). Hand analyzed calls are classified as DEFINITIVE if the call sequence meets definitive characteristics, PROBABLE if the call sequence meets some, but not all, of the definitive characteristics, and NOT CONFIDENT if the call sequence as identified by automated analysis lacks characteristics of a particular species that allow it to be even tentatively identified as a particular species, or NO if the call sequence is clearly not the species identified by the automated analysis such as when the software reads overlapping calls, a harmonic, or background noise.
Hand analyses will focus on the following priorities:
  - a. Check calls identified to species by Sonobat 3.0 or later batch analyses within each month until each species has either been definitively identified as present during that month or until all calls have been reviewed by hand.
  - b. Check all call sequences associated with temperatures below 0 degrees Celsius to verify that they are bats and, if possible, what their species identity is.
  - c. Check other calls of interest as needed (e.g. to identify migration date range within a month or establish new low temperatures of activity for a species).
10. Summarize call data within worksheets of an Excel Workbook and in site specific Powerpoint presentations or reports using pivot tables to generate graphical summaries.

**Work Flow for Data Management and Analysis for SM2BAT+ Detectors with SMX-U1
Microphones and SM3 Detectors with SMM-U1 or SM3-U1 Microphones**

*see Figure 3 below.

1. for all Montana bat species with the exception of Spotted Bat (*Euderma maculatum*), convert WAC to WAV files with Kaleidoscope Pro 3.0 or later using the following settings: Time expansion factor = 1, Split to max duration seconds = 5, Filter noise files = checked, Keep noise files = unchecked, Signal of interest = 16-128 kHz, 2-500 ms, Minimum number of calls = 2, Advanced signal enhancement = checked
2. for *E. maculatum*, convert WAC to WAV files with Kaleidoscope Pro 3.0 or later using the following settings: Time expansion factor = 1, Split to max duration seconds = 5, Filter noise files = checked, Keep noise files = unchecked, Signal of interest = 7-10 kHz and 3-8 ms, Minimum number of calls = 2, Advanced signal enhancement = checked
3. Eliminate nonbat noise files using Sonobat Batch Scrubber
4. Conduct automated species identification analyses with Sonobat 4.0 using the standard recommended settings for mountains and plains and Kaleidoscope Pro 3.0 using both the Accurate and Sensitive Classifier settings; Kaleidoscope analysis for *E. maculatum* files is only analyzed with the Sensitive Classifier.
5. Import Sonobat 4.0 Batch Analysis output files and temperature log files into a Microsoft Access database for long term management, hand analyses, and data summaries.
6. Hand check files identified to species by Sonobat 3.0 Batch Analysis Utility against the Montana Bat Acoustic Key and Montana Bat Call Identification training materials (see Appendices 6 and 7, respectively). Hand analyzed calls are classified as DEFINITIVE if the call sequence meets definitive characteristics, PROBABLE if the call sequence meets some, but not all, of the definitive characteristics, and NOT CONFIDENT if the call sequence as identified by automated analysis lacks characteristics of a particular species that allow it to be even tentatively identified as a particular species, or NO if the call sequence is clearly not the species identified by the automated analysis such as when the software reads overlapping calls, a harmonic, or background noise.
Hand analyses will focus on the following priorities:
  - a. Check calls identified to species by Sonobat 3.0 or later batch analyses within each month until each species has either been definitively identified as present during that month or until all calls have been reviewed by hand.
  - b. Check all call sequences associated with temperatures below 0 degrees Celsius to verify that they are bats and, if possible, what their species identity is.
  - c. Check other calls of interest as needed (e.g. to identify migration date range within a month or establish new low temperatures of activity for a species).
7. Summarize call data within worksheets of an Excel Workbook and in site specific Powerpoint presentations, using pivot tables to generate graphical summaries.

Figure 3. Data processing flow chart.

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Appendix 1.

Decontamination Protocols for Bat Surveys (WNS, Chytrid, and other Pathogens)

Goal

The major goal of decontamination protocols is to greatly reduce the likelihood of pathogen transfer by human researchers. Bats are likely the major vector for WNS so minimizing bat contact with people and reused gear will minimize decontamination requirements. Using disposable gloves between handling individual bats will reduce likelihood of pathogen transmission. Wearing disposable gloves over leather or nitrile gloves will reduce the need to decontaminate those gloves between bats while protecting the researcher from bites.

When to Decontaminate

- Between any site separated by more than 10 miles, a major change in watersheds (e.g., crossing Continental Divide).
- After any site where an ill or potentially infected animals are encountered.
- Anytime a gear item has been in direct or indirect contact (e.g., handling a bat and then touching your hat or headlamp) with a bat and the above situations apply.

Decontamination Protocols for Washable Gear

Gear examples:

Mistnets, clothes, net bags, bat bags, nitrile gloves, guy lines

Protocol:

1. Heat water to a minimum sustainable temperature of 50C or 122F. This can be done by turning up the temperature on hot water heaters or using a large pot on a stove or using a turkey fryer in more back country situations.
2. Fully immerse items to be decontaminated for a minimum of 20 minutes, monitoring temperature throughout.
3. Air or tumble dry gear.

Decontamination of Large Non-washable Gear

Gear examples:

Net poles, rebar, rubber boots, waders, gear tubs

Protocol:

1. Wash off all mud, vegetation, and other debris before leaving a site and before beginning decontamination.
2. Mix a 10% bleach mixture by using 1 part household bleach (sodium hypochlorite) and 9 parts tap water in a 1 gallon pump action pressurized weed sprayer. Mixing is facilitated by marking the sides of the container.
3. Lay out gear to be sprayed on a road surface or other unvegetated area
4. Pressurize the container and spray gear until entire surface is thoroughly wetted; be sure to turn gear over to wet all surfaces.
5. Let gear air dry for as long as possible. If immediate transport is necessary then place gear in tubs or rinse in tap water after at least 10 minutes of saturation with bleach.

Decontamination of Small Non-washable Gear

Gear examples:

Headlamps, calipers, scales, cutting boards, rulers, tables, tweezers, forceps, naked hands

Protocol:

1. Use Lysol Wipes (also possible to use Formula 409) to wipe down all surfaces of all minor gear items.
2. Wipe down all gear coming into contact with bats between processing of individual bats.

Appendix 2

Example Cave Survey Report and Cave Survey Datasheets

Site Name: Cave X Lat: XXXXXXX Long: XXXXX
 Town: TRS County: Lewis and Clark State: Montana Date: 8 March 2014
 Surveyors: Bryce Maxell, James Cummins, Ellen Whittle, Ian Chechet, Haendel Zepeda
 Contact email: bmaxell@mt.gov
 Site type (**circle one**): Cave mine Time in: 13:30 Time out: 17:00
 Specify type (e.g. fractured cave, limestone mine): Limestone Cave at entrance elevation of 6411 ft.
 WNS present (circle one): Unknown Suspect/Confirmed Pd positive
 WNS 1st Year of Detection: _____ Bat Mortality: Y/N _____ %
 Site map: See attached.
 Please include a site map or draw a rough sketch here. (See example on back.)
 See attached.

Site description (describe features – standing water, rappel in, multiple entrances, crawling, etc):
 See attached.

Approximate physical size of hibernaculum:

- ☐ **Very small:** blunt, dead end passage < 10m in length
☐ **Small:** one to two short passages > 10 – 100 m in length, may have a single room
☒ **Medium:** multiple rooms connected by 2 or more passages, or passages > 100 m in length
☐ **Large:** many rooms, passages, and levels; total area is >1 km², but < 5 km²
☐ **Very large:** many rooms, passages, and levels, extensive passages; > 5 km²

Complete survey: (**circle one**): (Y) N

If **NO**: Please briefly list the areas surveyed, and with a description of sections that were skipped.

Percent of **site area** (e.g. number of chambers or levels used) occupied by bats:

<10% ☐ 10-25% ☐ 25%-50% ☐ 50-75% ☒ >75% ☐

Percent of **occupied areas** (e.g. within used areas, amount of wall) covered by bats:

<10% ☒ 10-25% ☐ 25%-50% ☐ 50-75% ☐ >75% ☐

Species present and final counts of each:

Circle:	MYCI	Unidentified Myotis							
Total #	2	42							

If other species present, please specify and include count by species:

Section ID and Description (Start/End Time)	Tally of bats by species in each cluster Numbers represent # of bats in each cluster (defined as bats in physical contact); indicate number of bats with visible signs of WNS in parenthesis (see example below)	# Bats Swabbed (swab IDs)
Entrance Room (mostly on cave right wall and ceiling) (ca. 13:30-14:00)	Unidentified Myotis Species: 1	0
Right Passage off Entrance Room (ca. 14:00-14:45)	Unidentified Myotis Species: 1-1-1	0
Small Room rigging for drop into bottom room (ca. 15:15-15:45)	Unidentified Myotis Species: 1	0
Lower Level (ca. 16:00-17:00)	MYCI: 1-1 Unidentified Myotis Species: 1-1-1-2-1-1-1-1-1-1-8-10-8	0
Total Count Summary	MYCI = 2 Unidentified Myotis = 42 Total Bats = 44	

Upper Level

Lower Level

Cave X 8 March 2014 Survey Photos in Order of Survey

Haendel Zepeda in snow shoot leading to entrance

Entrance looking out through excavated snow drift

Entrance chamber looking at cave right wall with overwintering Cave Moths (*Triphosa haesitata*). James Cummins (dark jacket), Ian Chechet (green jacket), Ellen Whittle (reflectors on jacket). Unidentified *Myotis* species on ceiling.

Shaft at cave left at bottom of entrance chamber

3 Unidentified Myotis species in cave right room with entrance at bottom right edge of entrance chamber

Unidentified Myotis species roosting singly in lower level chamber.

Unidentified Myotis species roosting in clusters in lower level chamber

Haendel Zepeda on upper wall of terminal end of lower level

Looking back toward Ellen Whittle at middle of lower level from base of wall at terminal end

Cave register near bottom of rope line into lower level
Paper is basically a consistency of paste.

Ellen Whittle ascending rope from lower level to upper level.

Temperature and Relative Humidity Data

Cave X Hobo Data Logger = 10130202

An Onset Hobo V2 U23-002 temperature and relative humidity data logger was deployed near the bottom of the drop into the lower level on cave right under a large rock on a large shelf about 8 feet from the access to the shelf itself. Between the initial deployment at 20:30 on 21 May 2012 and the download at 16:19 on 8 March 2014 temperature averaged 4.65 degrees C (range 4.5 to 4.8) and relative humidity was at 100% with the possibility that the sensor just became saturated very near the time of deployment.

Site Name: _____ Lat: _____ Long: _____

Town: _____ County: _____ State: _____ Date: _____

Surveyors: _____ Contact email: _____

Site type (**circle one**): cave/mine Time in: _____ Time out: _____

Specify type (e.g. fractured cave, limestone mine): _____

WNS present (circle one): Unknown/Suspect/Confirmed Pd positive

WNS 1st Year of Detection: _____ Bat Mortality: Y/N _____ %

Site map:

Please include a site map or draw a rough sketch here. (See example on back.)

Site description (describe features – standing water, rappel in, multiple entrances, crawling, etc):

Approximate physical size of hibernaculum:

___ **Very small**: blunt, dead end passage < 10m in length

___ **Small**: one to two short passages > 10 – 100 m in length, may have a single room

___ **Medium**: multiple rooms connected by 2 or more passages, or passages > 100 m in length

___ **Large**: many rooms, passages, and levels; total area is >1 km², but < 5 km²

___ **Very large**: many rooms, passages, and levels, extensive passages; > 5 km²

Complete survey: (**circle one**: Y/N)

If **NO**: Please briefly list the areas surveyed, and with a description of sections that were skipped.

Percent of **site area** (e.g. number of chambers or levels used) occupied by bats:

<10% _____ 10-25% _____ 25%-50% _____ 50-75% _____ >75% _____

Percent of **occupied areas** (e.g. within used areas, amount of wall) covered by bats:

<10% _____ 10-25% _____ 25%-50% _____ 50-75% _____ >75% _____

Species present and final counts of each:

Circle:	MYLU	MYSO	MYLE	MYSE	MYGR	MYVE	PESU	EPFU	COTO	COTOVI
Total #										

If other species present, please specify and include count by species:

Example:

Section ID and Description (Start/End Time)	Tally of bats by species in each cluster Numbers represent # of bats in each cluster (defined as bats in physical contact); indicate number of bats with visible signs of WNS in parenthesis (see example below)	# Bats Swabbed (swab IDs)
Section 1: Entry Hall to beginning of big room (9:00-9:15)	MYLU: 3-2-1-1-2(1WNS+)-4-8(2 WNS+)-1 MYSO: 50-10(3WNS+)-5-100(5WNS+) Mixed: 3(2 MYLU, 1 MYSE) – 8 (7 MYSO(3WNS+), 1 MYLU)	2 NY00023 NY00024

Swab Instructions: Moisten swab in dipping tube, rub moistened swab on closed right forearm 5X, then muzzle 5X, break into storage tube and label with ID tag.

Section ID (as on map)	Swab ID	Bat Spp	Cluster Size	# bats within 1ft	# bats touching focal bat	Is Pd visible? (Circle one)	Substrate sample ID	Sex (M/F)	Other (Notes, Band #, Photo #, etc)
1 – Entrance Hall	WF14NY001	MYLU	5 MYLU 5 MYSO	10 MYLU 5 MYSO	3MYLU	No/Wings/Face	WF14NY002	M	
						No/Wings/Face			
						No/Wings/Face			
						No/Wings/Face			
						No/Wings/Face			
						No/Wings/Face			
						No/Wings/Face			
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						No/Wings/Face			
						No/Wings/Face			
						No/Wings/Face			
						No/Wings/Face			

Section ID: Indicate section ID or description within hibernacula using same ID/naming system corresponding to cave map and count data. **Swab ID:** Unique identifier provided - label should be placed on tube. **Bat species:** First two letters of genus and species (ex: MYLU). **Cluster size:** Total number of bats in the cluster where focal bat is located; cluster is defined as group of bats that have physical contact, if mixed spp cluster use: (Tot: 10, MYLU:5, MYSO:5) **# of bats within 1 ft:** Indicate the cumulative total number of bats of each species within 1 ft/30 cm of sampled bat, including bats that were counted in the cluster (ex: MYLU:20, MYSO:5; if cluster had 10 bats (5 MYLU, 5 MYSO) and 15 more MYLU present within 1 ft **# bats touching focal bat:** Number of individuals touching focal (sampled) bat. **Where is fungus visible on bat on wall/in hand?** If visible, circle where fungus is visible (Wings/Face), otherwise circle "No". **Substrate sample:** Write ID (ex: WF13NY002) if you swab the wall underneath where bat was roosting.. **Sex:** M/F. **Other:** Record any helpful notes, including band number and origin (if known), corresponding photo #, etc.

Appendix 3

Morphological Key for Montana Bat Species

Abbreviated Summary of Characteristics for Identification of Montana Bat Species (see detailed key below for details)

Species	Forearm (mm)	Keeled Calcar	Characteristic Frequency (KHz)	Other Key Identifying Features
Larger Easily Identified Bats (arranged from largest to smallest forearm lengths)				
ANPA	48-60	N	26-30	Muzzle like pit bull terrier. Musky odor. Cream or pale yellow in color.
LACI	46-58	Y (narrowly)	13-30	Grizzled dorsal fur edged with black and contrasting with yellowish/orangish collar and white wing patches
EUMA	48-51	N	7-10	Black with 3 conspicuous dorsal white patches
EPFU	43-52	Y	26-32	Orangish brown, rounded dark muzzle.
COTO	39-48	N	18-27	Very large ears joined on forehead. Two prominent lumps on nose.
LABO	37-45	Y	38-50	Reddish orange with whitish tips. Relatively long uropatagium.
LANO	37-44	N	26-28	Light color at base of small rounded black ears. Black fur with silver highlights.
Myotis Species (Use calcar keel, forearm length, and then other key features listed. Brackets identify species pairs most difficult to distinguish or features difficult to distinguish)				
MYVO	34-43	Y	40-46	Fur extending to elbow. Usually dark chocolate.
MYCI	29-35	Y	37-43	Bare snout length 1.5 times distance between nostrils. Thumb >4.2mm. Usually lighter color.
MYCA	29-35	Y	47-55	Bare snout length same length as distance between nostrils. Thumb <4.2 mm. Usually reddish.
MYSE	36-41	N	41-45	Ear extends <5mm beyond nose tip. Only a single record in NE Montana.
MYEV	36-41	N	33-38	Ear >16mm and extending beyond tip of nose by >5mm.
MYTH	39-46	N	15-32	Conspicuous fringe of hairs extending backward from edge of tail membrane.
MYLU	>36(34-40)	N	37-43	See last page, but best to have genetics to definitively distinguish from MYYU.
MYYU	<36(32-38)	N	47-55	See last page, but best to have genetics to definitively distinguish from MYLU.

Key to Idaho, Montana, & South Dakota Bats 2005*

---

1. a) About half of the tail projecting beyond the uropatagium (Fig. 1); forearm length 36-46 mm → ***Tadarida brasiliensis***, [TABR], (Family Molossidae), mexican free-tailed bat. *This species is typically associated with temperate climates at more southerly latitudes than this region.*
-

Free tail

Enclosed tail

Fig. 1 Free tail vs enclosed tail

- b) Tail enclosed in uropatagium (Fig. 1), with no more than a few mm projecting free (Family Vespertilionidae) → 2
2. a) Ears very large (Fig 2), over 26 mm from notch to tip (Fig. 3) → 3
- b) Ears less than 26 mm from notch to tip (Fig. 2&3) → 4

Fig. 2 Ear and tragus measures

Nagorsen and Brigham 1995

3. a) Fur black, with 3 conspicuous white patches on back; forearm length 48-51 mm → ***Euderma maculatum***, [EUMA], spotted bat

Very large ears

Fig. 3 large ears and glands

- b) Dorsal fur darkest at base, gray to brown; ears joined across forehead; 2 prominent lumps on nose; naked uropatagium; forearm length 39-48 mm → ***Corynorhinus townsendii***, [Coto], Townsend's big-eared bat; lump-nosed bat
- c) Dorsal fur lightest at base, colored cream or pale yellowish; simple muzzle; ears not joined; wings and ears pale; often has a distinct musky odor; forearm length 48-60 mm → ***Antrozous pallidus***, [ANPA], pallid bat
- 4. a) Color of fur black, occasionally dark brown, and may or may not be silver-tipped; dorsal surface of uropatagium lightly furred; round ears with light patch at base of leading edge, blunt tragus; forearm length 37-44 mm → ***Lasionycteris noctivagans***, [LANO], silver-haired bat
- b) Color other than the above → 5
- 5. a) Uropatagium densely furred across entire dorsal surface; distinct patches of fur on wrists → 6
- b) Uropatagium unfurred for at least posterior half → 7
- 6. a) Fur color black with white tips, giving overall frosty or hoary appearance; ears contrastingly edged in black, contrasting yellow collar and yellow and/or white wing patches; forearm length 46-58 mm → ***Lasiurus cinereus***, [LACI], hoary bat
- b) Fur color reddish orange to yellowish brown sometimes with white tips; comparatively long uropatagium; forearm length < 45 mm (M. Kalcounis pers. Comm.) → ***Lasiurus borealis***, [LABO], eastern red bat. *This species has been documented in eastern Montana and in South Dakota. This species has not been documented in Idaho. Lasiurus blossevillei may be more likely to occur in Idaho, although it has not been documented.*
- 7. a) Small bat with ashy-gray to yellowish-gray colored fur with contrasting black mask; individual hairs tri-colored; short and blunt tragus with tip bent forward; forearm length 27-33 mm → ***Pipistrellus hesperus***, [PIHE], western pipistrelle. *Records for this species are limited to west-central and southwestern Idaho in this region(R. Dixon pers. Comm.).*

Similar to above with simple blunt tragus and dorsal surface of forearm reddish in contrast to darker wing membrane; hair on back dark at base and tip, but lighter in the middle. ***Pipistrellus subflavus*** [PISU] eastern pipistrelle. *Records for this species are limited to South Dakota.*

- b) Fur color not as above → 8
- 8. a) Forearm length more than 42 mm; calcar keeled; brown to copper-colored fur; blunt tragus → ***Eptesicus fuscus***, [EPFU], big brown bat
- b) Forearm length less than 42 mm → 9
- 9. a) Conspicuous fringe of hairs projecting backward from posterior edge of uropatagium (**Fig 4**); ears 16-20 mm, may extend beyond nose tip when gently laid forward; dorsal fur usually reddish brown, varying to dark brown; ventral fur comparatively pale; rostrum typically furred; calcar typically not keeled; forearm length 39-46 mm → ***Myotis thysanodes***, [MYTH], fringed myotis; fringed bat

Fig. 4 Stiff hairs (fringe) along tail membrane.

- b) Without a conspicuous fringe of hairs projecting backward from posterior edge of uropatagium → 10
- 10. a) Ear extends more than 5 mm beyond tip of nose when gently laid forward, i.e. ear more than 16 mm; ears and other membranes black; rostrum typically bare; keeled calcar typically lacking or reduced; few hairs on posterior edge of uropatagium, visible with hand lens; forearm length 36-41 mm → ***Myotis evotis***, [MYEV], western long-eared myotis
- b) Ear extends less than 5 mm beyond nose tip when gently laid forward; ears and membranes dark, not black; few hairs on posterior edge of uropatagium, visible with hand lens; dark shoulder patches sometimes noticeable; Tragus sharp and slender (unlike MYLU; T. Dewey pers. Comm.), may have pink flesh around eyes and lower lip that distinguishes them from other long-eared *Myotis* (D. Burles, pers. Comm.); forearm length 36-41 mm ***Myotis septentrionalis***, [MYSE], northern long-eared

myotis. *According to Natureserve, the range for this species includes eastern Montana and South Dakota.*

Ear does not extend beyond tip of nose when gently laid forward, i.e. ear less than 16 mm → 11

Fig. 5 keeled, unkeeled calcar

Szewczak 2002

11.a) Keeled calcar → 12

b) Calcar not keeled → 14

12.a) Well-developed keel on calcar; ventral fur extends outward onto wing to a line from elbow to knee (Fig. 6); anterior quarter of uropatagium dorsal surface furred; Foot greater than 8.5 mm long (Fig 7); forearm usually more than 35 mm → ***Myotis volans*, [MYVO], Hairy-winged myotis, Long-legged myotis**

Fig. 6 furred wing elbow to knee

b) No fur on underside of wing from elbow to knee; foot less than 8.5 mm long (Fig 7), → 13

Nagorsen and Brigham 1995

Fig. 7 Hind foot measure

- 13.a) Well-developed keel on calcar; Forehead rises abruptly; tail does not extend to point beyond interfemoral membrane, or if it does by only one vertebra; dorsal fur dull, not glossy, often brown, but may vary to light brown; brown facial mask, dark brown ears; distance to hairline on snout about equal to width of snout when viewed from above; third metacarpal usually longer than 30.5 mm; forearm length 29-36 mm → ***Myotis californicus***, [MYCA], California myotis
- b) Well-developed keel on calcar; Forehead more flattened; *tail extends to point beyond interfemoral membrane by 2 or 3 vertebrae*; dorsal fur glossy, straw-colored; black facial mask; sharp tragus; distance to hairline on snout about one and a half times the width of snout when viewed from above; third metacarpal usually less than 30.5 mm; forearm length 30-36 mm → ***Myotis ciliolabrum***, [MYCI], Small-footed myotis
- 14.a) Lacking keeled calcar; flat forehead; dorsal fur brown, with a noticeable sheen; ear color typically darker than dorsal fur color; ventral fur lighter; toe hairs may extend past end of toes; forearm length 34-40 mm, typically > 36 mm → ***Myotis lucifugus***, [MYLU], Little brown bat
- b) Lacking keeled calcar; dorsal fur dull brown, in eastern Oregon often very light; forearm length 32-38 mm, typically < 36 mm; a post-calcar lobe may be visible → ***Myotis yumanensis***, [MYYU], Yuma myotis

Fig. 8 Bat anatomy

Fig. 9 Tragus Comparisons

Fig. 10 Adult vs. juvenile phalanges and metacarpal joints

Fig 2. *Myotis californicus* / *Myotis ciliolabrum*: View of nose from above, and of tail

*Sources include: Ormsbee and Risdal, 2002: Oregon Bat Data Base; Szewczak 2002: northern California bat key; Cross: Key to bats of Oregon; BCI: Key to the bats of the eastern U. S.; Anthony, E.L.P.. 1988. Age determination in bats. In Kunz, T.H. (editor) Ecology and behavior methods for the study of bats. Smithsonian Inst. Press., Wash. DC. Pp 533; Nagorsen, D.W., and R.M. Brigham. 1995. Bats of British Columbia. UBC Press, Vancouver, BC, Canada Pp 164; Setter, C. 1991. in Schmidly, D. J. (Editor) Bats of Texas Texas A&M, Univ. Press Pp 188; Barbour, RW, and Davis, W. H. 1969. Bats of America. Univ. Press Kentucky, Lexington, KY.

Differentiating Little Brown Myotis (*Myotis lucifugus*) and Yuma Myotis (*Myotis yumanensis*) with Characteristic Frequency and Forearm Length (from Weller et al. 2007 Acta Chiropterologica 9(1):133-147)

FIG. 4. Forearm length versus characteristic frequency of echolocation calls for *M. lucifugus* ($n = 150$) and *M. yumanensis* ($n = 155$) in the Pacific Northwest, 2002–2004. Values depicted are from training and test datasets. Fc was obtained from the longest duration call for individuals recorded with ANABAT

TABLE 2. Predicted probability (%) with which individual bats may be identified as *Myotis lucifugus* as a function of their forearm length and characteristic frequency (Fc) of their echolocation call. Values in parentheses represent the probability that an individual was *M. yumanensis*. Values in bold represent combinations of the variables that provide > 95% probability of correct assignment to either species

Fc (kHz)	Forearm length (mm)												
	32	32.5	33	33.5	34	34.5	35	35.5	36	36.5	37	37.5	38
41	99.63	99.84	99.93	99.97	99.99	99.99	>99.99	>99.99	>99.99	>99.99	>99.99	>99.99	>99.99
42	97.12	98.74	99.45	99.76	99.90	99.96	99.98	99.99	>99.99	>99.99	>99.99	>99.99	>99.99
43	80.76	90.68	95.76	98.13	99.18	99.65	99.85	99.93	99.97	99.99	99.99	>99.99	>99.99
44	34.34	54.82	73.78	86.72	93.80	97.23	98.79	99.47	99.77	99.90	99.96	99.98	99.99
45	6.12	13.14	25.97	44.86	65.36	81.40	91.03	95.93	98.20	99.22	99.66	99.85	99.94
46	(99.19)	(98.15)	(95.81)	9.21	19.04	35.30	55.86	74.59	87.19	94.05	97.34	98.84	99.50
47	(99.90)	(99.77)	(99.46)	(98.75)	(97.15)	6.37	13.62	26.79	45.91	66.31	82.03	91.37	96.09
48	(99.99)	(99.97)	(99.93)	(99.84)	(99.64)	(99.16)	(98.07)	(95.64)	9.57	19.70	36.27	56.90	75.38
49	(>99.99)	(>99.99)	(99.99)	(99.98)	(99.95)	(99.89)	(99.76)	(99.43)	(98.70)	(97.03)	6.62	14.13	27.62
50	(>99.99)	(>99.99)	(>99.99)	(>99.99)	(99.99)	(99.99)	(99.97)	(99.93)	(99.84)	(99.62)	(99.12)	(97.99)	(95.46)
51	(>99.99)	(>99.99)	(>99.99)	(>99.99)	(>99.99)	(>99.99)	48(>99.99)	(99.99)	(99.98)	(99.95)	(99.89)	(99.75)	(99.41)

Appendix 4

Bridge Information

Bridge ID		Date:	Observer:	Road Type:		Bridge Type:		
				4-lane interstate 2-lane interstate 1-lane paved 2-lane unpaved 1-lane unpaved		culvert decked		
County	Latitude	Longitude	Elevation (ft)	Feature Crossed:		Ideal Crevices?		
				road flowing water standing water railroad other		No Abutment Parallel Central Expansion		
Percentage of Surrounding Habitat (top 4)				Span Material:		Decking Material:		
Conifer forest____ Deciduous Forest____ Agriculture____ Residential____ Riparian____ Grasslands____ Wetland____				Concrete Steel Wood		Concrete Steel Wood		
Start Time:		End Time:	Weather:	Clear	Overcast	Partly Cloudy	Rain	Wind
General Comments:								
Mark for return visit? Yes/No								

Roost Information

Roost #	Roost Type	Roost Feature	# Bats in Roost	Night Roost Classification	Species (Ex. 1 x MYLU @ 17°C)
1	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	
2	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	
3	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	
4	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	
5	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	
6	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	
7	No Night Day Maternity	Crevice Depth < 4" >4" Open Other_____		0 1 2 3 4	

Sketch of Photographed Roost Locations

*Side View

**Bottom View

*Include height of roost (side) and width (bottom) and photo locations. Label sides for orientation between views.

**Shade areas with droppings, circle (with number) locations of bat roosts

# Active Nests	<u>Cliff Swallow</u>				<u>Barn Swallow</u>				<u>Rock Pigeon (Y/N)</u>
	<5	5-10	10-20	>20	<5	5-10	10-20	>20	

Other Notes (e.g., incidental species):

Night Use Index

Rating	Level of Usage Index
0	No sign of droppings or urine stains.
1	Small amount of such signs in only one location.
2	Small urine stains and/or scattered droppings in several locations
3	Large dropping accumulations and/or urine stains obvious and widespread.
4	Dropping accumulations several inches thick in several locations. Roosting evident throughout structure. Fresh urine stains in all optimal locations.

Table 2. The qualification of varying levels of use for night roosts.

Appendix 5.

Overview of Roosting Habitat and Home Range / Foraging Distance Documented for Montana Bats

Bryce A. Maxell, Montana Natural Heritage Program - 24 February 2015

The table, figures, and images below summarize and provide examples of what is known about winter, maternity, and day/night roost habitat use and home range or other travel distance information for Montana bat species in the state and/or elsewhere across their ranges. Protection of these cave, mine, cliff, rock outcrop, ground crevice, large tree, bridge, and building habitats with cracks and crevices ranging from $\frac{1}{3}$ to 1 inch in width and associated temperature and humidity regimes, is essential for protection and conservation of Montana's bats. Artificial bat roosts that provide maternity, night, and day roosts for some species, can be deployed to serve as a surrogate for large diameter tree and other roosts that have been lost and/or to encourage roosting away from buildings where bats would be in close proximity to sleeping humans.

Species / Comments	Winter Roost	Summer Maternity Roost	Summer Day/Night Roost	Home Range/Foraging Distance
Pallid Bat (<i>Antrozous pallidus</i>) Low roost site fidelity with 90% of inter-night movements of 50-600 meters. ³ Highly social, often using day and night roosts in groups of 20 or more guided by social vocalizations and odors. ^{2, 4} Yearling females typically give birth to a single pup, but older females typically give birth to 2 pups. ^{4, 43}	Not documented in Montana, but likely occurs in deep rock crevices if the species is present. ^{1, 4}	Not documented in Montana. Elsewhere in vertical and horizontal rock crevices, under rock slabs, in buildings, and on taller and larger diameter live trees and tree snags with loose bark in mature stands with southerly aspects and lower percentages of overstory. ^{4, 37, 38, 41, 42, 44}	Under rock slabs, in horizontal and vertical rock crevices, and on farm equipment in Montana. ¹ Elsewhere occasionally on buildings, bridges, caves, mines, vertical and horizontal rock crevices that are typically on east or southeast aspects, and taller and larger diameter live trees and tree snags with loose bark in mature stands with southerly aspects and lower percentages of overstory. ^{2, 4, 21, 22, 23, 30, 37, 38, 39, 40, 41, 44}	Lactating females moved an average of 2,450 meters +/- 845 from roost to foraging areas and had an average foraging area size of 1.56 square km +/- 0.88 SE. Post-lactating females moved an average of 210 meters from roost to foraging areas and had an average foraging area size of 5.97 square km +/- 2.69 SE in northern California. ³⁷ Individuals commuted 1 to 4 km between day roosting and foraging areas, 0.5 to 1.5 km between day roosts and night roosts, and switched day roosts often, usually moving <200 meters between roosts (range 25 to 3,660 meters) in eastern Oregon. ^{38, 39} Individuals typically commuted 1-2 km from day roosts to foraging areas, but one male often used different day roosts separated by 10 km in California. ⁴²
Townsend's Big-eared Bat (<i>Corynorhinus townsendii</i>) High fidelity to maternity and hibernacula roosts, lower interseasonal roost site fidelity, and travel up to 24 km from hibernacula to summer foraging areas. ⁷³ Forage and commute adjacent to vegetation. ⁷²	Twilight areas of caves, mines, and unused tunnels in Montana. ^{1, 31, 32, 75, 84} Limestone or lava tube caves and mines are known to be used elsewhere with arousal and movement within or between sites, possibly responding to changing temperature. ^{5, 73, 74, 82}	Caves and mines, often in twilight areas in Montana. ^{1, 75} Reported in caves, mines, buildings, and basal tree hollows elsewhere. ^{2, 5, 72, 73, 81, 82, 83} Females prefer cooler maternity roosts than other vespertilionid bat species. ²	In Montana, usually in caves and mines, often in twilight areas, but more rarely building attics, root cellars, and pocket/daylight caves. ^{1, 21, 31, 32, 75} Reported in caves, mines, buildings and large diameter basal tree hollows elsewhere. ^{2, 5, 72, 81, 82, 83}	Average one-way travel distances between day roosts and foraging areas was 3.2 km +/- 0.5 SD for males and 1.3 km +/- 0.2 SD for females in coastal California; maximum distance traveled from the day roost was 10.5 km. ⁷²

Species / Comments	Winter Roost	Summer Maternity Roost	Summer Day/Night Roost	Home Range/Foraging Distance
Big Brown Bat (<i>Eptesicus fuscus</i>) Males often roost solitarily during summer. Rarely move more than 80 km between summer and winter roosts. ^{2, 6} Roost switching is common at natural roosts, but show high fidelity to man-made roosts. ^{64, 65, 71}	Caves, mines, and some evidence for rock crevices which are probably the most widespread winter roost in Montana. ^{1, 31, 84} Known to use narrow deep rock crevices or erosion holes in steep valley walls on the Canadian prairie and buildings in Ohio. ^{6, 62}	Buildings, bridges, large diameter trees snags with hollows or loose bark in Montana. ^{1, 75} Primarily large diameter tree snag hollows and crevices, but also live aspen hollows, in more sparsely spaced stands, deep rock crevices, and older human structures are known to be used elsewhere. ^{6, 29, 59, 64, 65, 66, 67, 68, 71}	Rock crevices, buildings, bridges, and caves in Montana. ^{1, 22, 31} Larger diameter tree snags with hollows and crevices and preferential selection for older more sparsely spaced stands, older buildings, and rock crevices with good solar exposure are known to be used elsewhere. ^{27, 29, 30, 64, 65, 66, 67, 68, 69, 71} Caves and mines known to be used as night roosts elsewhere. ^{70,}	Average of 1.5 km +/- 0.9 SD (range 0.4 to 1.8 km) from roosts to capture locations with average movement between successive roosts of 1.1 km +/- 0.7 SD (range 0.4 to 2.0 km) in the Black Hills of South Dakota. ²⁹ Average one-way travel distances between day roosts and foraging areas of 1.8 km +/- 0.1 SE) range (0.3 to 4.4 km) in southern British Columbia. ⁶⁴
Spotted Bat (<i>Euderma maculatum</i>) High roost site fidelity with multiple individuals following the same nightly commuting routes up side canyons to foraging areas at speeds of up to 53 km/hr. ^{8, 49} Forage over clearings and along cliff rims. ^{49, 50, 51}	Not documented in Montana. Deep rock cracks and crevices are commonly used elsewhere and caves and human structures are rarely used elsewhere. ^{1, 2, 7, 51}	Not documented in Montana. Rock cracks and crevices in upper portions of tall remote south facing cliffs near perennial waters are used elsewhere. ^{1, 2, 7, 8, 50}	Buildings and other human structures in Montana. ^{1, 47} Rock cracks and crevices in upper portions of tall remote cliffs near perennial waters, and, apparently more rarely, cave entrances and buildings elsewhere. ^{2, 7, 8, 45, 46, 47, 48, 49, 50, 51}	50-60 km round trip flight distances nightly with average home range size of 297 +/- 25 SE (range = 242.5 to 363.8) square km in northern Arizona. ⁸ Nightly round trip commutes of >77 km between day roosts, foraging areas, and night roosts that differed in elevation by ca. 2,000 meters in northern Arizona. ⁴⁹ Nightly round trip foraging flights of 12 to 20 km in British Columbia. ⁵⁰
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	Not documented in Montana. Known to use loose bark, basal tree cavities, cavities under tree roots, and rock crevices on more southerly aspects and in older stands of trees, elsewhere with retreat to more underground sites at lower temperatures. ⁹³ Use of mines is also known. ⁹⁴	Large diameter tree snags with loose bark or cavities in Montana. ^{1, 9, 26} Hollows and crevices in live aspen and large diameter and taller trees or tree snags in older lower canopy closure stands known to be used elsewhere. ^{9, 59, 86, 90, 91, 92, 95, 96}	Large diameter tree snags with loose bark or cavities and a building in Montana. ^{1, 26, 78} Large diameter trees or tree snags in older stands with hollows and crevices are predominant summer roost elsewhere, but rock crevices, buildings, bridges, and other human structures also used. ^{9, 22, 86, 90, 91, 96}	Distance between capture locations and roost snags ranged from 0.1 to 3.4 km (averages for juvenile males, juvenile females, adult males, and adult females were 1.3, 1.5, 1.8, and 0.5 km, respectively) in northeastern Washington. ⁹⁶

Species / Comments	Winter Roost	Summer Maternity Roost	Summer Day/Night Roost	Home Range/Foraging Distance
Eastern Red Bat (<i>Lasiurus borealis</i>) Species is a solitary rooster at heights of 1 to 6 meters from the ground, but forage and migrate in groups. ¹⁰	Not documented in Montana and thought to migrate far to the south where they use tree roosts on warmer days and nights and retreat below leaf litter when temperatures dip below freezing. ^{10, 54}	Maternity roosts or lactating individuals have not been detected in Montana. Elsewhere, known to roost mostly in dense foliage that provides shade and protection from the wind, but also on trunks, of larger diameter mature deciduous and conifer trees, often in riparian areas. ^{10, 52, 53, 55, 56, 57}	Not documented in Montana. Elsewhere, known to roost mostly in denser foliage, but also on trunks, of larger diameter mature deciduous and conifer trees, often in riparian areas. Also more rarely in shrubs, under leaf litter, and on human structures. ^{10, 52, 53, 55, 56, 57}	Maximum distances traveled to foraging areas averaged 1.24 km (range 0.19 to 3.28) and foraging areas averaged 94.4 Ha +/- 20.2 SE with no significant differences between sex and age classes in Mississippi. ⁵² Maximum distances traveled from diurnal roosts to foraging areas ranged from 1.2 to 5.5 km for females and 1.4 to 7.4 km for males with average foraging area size of 334 Ha in Kentucky. ⁵³
Hoary Bat (<i>Lasiurus cinereus</i>) Species is a solitary rooster at heights of 3 to 5 meters from the ground, but forage and migrate in groups. ¹¹	Not documented and thought to migrate far to the south of Montana in the winter. ¹¹	Only a bridge roost documented in Montana. ¹ Known to be a solitary rooster in deciduous and conifer tree foliage that offers shelter from the wind and more southern exposure to the sun elsewhere. ^{11, 85, 86, 87, 88, 89}	A bridge and cottonwood foliage in Montana. ¹ Known to roost in deciduous and conifer tree foliage elsewhere. ^{1, 11, 85, 86, 87}	Females traveled one-way distances up to 20 km from day roosts while on first of up to five nightly foraging bouts in Manitoba Canada. ⁸⁵
California Myotis (<i>Myotis californicus</i>) Roosts alone or in groups. ¹²	Recent acoustic and telemetry data indicates species likely overwinters in rock crevices in Montana. ^{1, Nate Schwab, personal communication} Rock crevices, caves, mines, tunnels, and buildings are used elsewhere. ^{2, 12, 25, 61}	Not documented in Montana. Elsewhere known to roost under loose bark or in holes or cracks in more isolated larger diameter tree snags in areas with lower canopy closure. ^{58, 59} More rarely, known to use buildings elsewhere. ⁶⁰	A house and a cellar in Montana. ³² Elsewhere known to roost under loose bark or in holes or cracks in more isolated larger diameter tree snags in areas with lower canopy closure. ^{58, 59} Also known to use rock crevices, bridges, buildings, and other human structures elsewhere. ^{12, 21, 22, 30, 60}	*No documentation found.
Western Small-footed Myotis (<i>Myotis ciliolabrum</i>) Mostly a solitary rooster, but sometimes aggregates in small groups. Fidelity to roost areas is shown, but roost switching within those areas is frequent ^{13,} ⁶³ Also show a high fidelity to commuting corridors. ⁶³	Caves and mines documented in Montana. ^{1, 76, 84} Known to use lava tube caves, deep cracks in ground, deep rock crevices, tunnels, and drill holes in rock elsewhere. ^{2, 13, 77}	Rock outcrop crevices with good solar exposure in Montana. ¹ Known to rely mostly on vertical and horizontal crevices in cliffs and rock outcrops, but also documented using buildings elsewhere. ^{13, 63}	Rock outcrop crevices, bridges, caves, mines, and buildings in Montana. ^{1, 31, 32} Known to use rock outcrops, cracks in ground, tree hollows, and trees with loose bark elsewhere. ^{13, 63} No bats were detected using night roosts in a north central Oregon study. ⁶³	6 to 24 km round trip travel distances from roosts to foraging areas in north central Oregon. ⁶³

Species / Comments	Winter Roost	Summer Maternity Roost	Summer Day/Night Roost	Home Range/Foraging Distance
Long-eared Myotis (<i>Myotis evotis</i>) Suspected of only traveling short distances between summer and winter roosts. ¹⁴ Have low fidelity to individual roosts, but high fidelity to roost areas. ^{97, 98, 99}	Caves and mines. ^{1, 75, 84} May also use deeper rock crevices. ¹⁴	Caves, cliff and rock outcrop crevices, and large diameter trees in Montana. ^{1, 26, 76} Known to use sheltered erosion cavities on stream banks, crevices in basalt, conifer stumps, conifer snags, buildings, and mine tunnels elsewhere. ^{14, 97, 98, 99}	Large diameter trees, rock outcrops, buildings, and caves in Montana. ^{1, 26, 31, 79} Known to use buildings, trees/snags with loose bark, trestle bridges, mines, rock crevices, stream bank cavities, and sink holes elsewhere. ^{14, 21, 27, 97, 98, 99}	Traveled an average of 970 meters (range 35-5,154 meters) between roosts in western Montana. ²⁶ Moved 1 to 812 meters between day roosts and had roosting home ranges that ranged from 0.08 to 1.93 ha in Alberta. ⁹⁷ Traveled 620 meters from capture sites to day roosts in western Oregon. ⁹⁸ Traveled an average distance between day roosts of 148.9 m in northeastern Washington. ⁹⁹
Little Brown Myotis (<i>Myotis lucifugus</i>) Show high fidelity to summer colonies and hibernacula across years, but some individuals relocated between years a median distance of 315 km between hibernacula (range 6 to 563 km) and 431 km between summer roosts (range 25 to 464 km). ¹⁰⁰ Males and nonreproductive females occupy cooler roosts than pregnant or lactating females. ¹⁵	Caves and mines with high humidities and temperatures above freezing in Montana and elsewhere. ^{1, 31, 36, 75, 84} May also use deeper rock crevices. ¹⁵ Predominantly documented using caves elsewhere. ¹⁰⁰	Attics and roofs of buildings, bridges, and bat houses in Montana. ¹ Known to use cracks or hollows in larger diameter tree snags in older stands, rock crevices, and buildings elsewhere. ^{2, 15, 35, 90, 101, 102, 103}	Large diameter tree, rock crevices, buildings, bridges, caves, and bat houses in Montana. ^{1, 26, 31, 80} Known to use cracks or hollows in larger diameter tree snags in older stands, wood piles, and rock crevices elsewhere. ^{15, 35, 90} Caves and mines known to be used as night roosts elsewhere. ⁷⁰	Average 970 meters (range 35-5,154 meters) between roosts in western Montana. ²⁶ Traveled 10 to 647 km from hibernacula to summer colonies in Manitoba and northwestern Ontario, Canada. ¹⁰⁰ Female home range averaged 30.1 ha +/- 15.0 SD during pregnancy and 17.6 ha +/- 9.1 SD during lactation in Quebec, Canada. ¹⁰¹ Males moved and average of 275 m +/- 406 SD between successive roosts, had mean minimum roosting areas of 3.9 ha +/- 7.9 SD, mean minimum foraging areas of 52.0 ha +/- 57.4 SD, mean distance between roosting and foraging areas of 254 m +/- 254.2 SD, and mean distances between capture sites and first roosts of 761 m +/- 623 SD in New Brunswick. ¹⁰² Mean home range area was 143 ha +/- 71.0 SE in New York. ¹⁰³

Species / Comments	Winter Roost	Summer Maternity Roost	Summer Day/Night Roost	Home Range/Foraging Distance
Northern Myotis (<i>Myotis septentrionalis</i>) Low roost site fidelity, but often stay in same general area within a season. May travel up to 56 km between summer and winter roosts. ¹⁶	Only known from a single abandoned coal mine in Montana. ^{1, 75} Known from caves, with a preference to cluster in deep crevices and possibly move between caves within a winter elsewhere. ¹⁶	Not documented in Montana. Known to use bark and hollows of larger diameter trees, usually in decay, and building crevices and bat houses elsewhere. ^{16, 29, 35, 69, 102}	Not documented in Montana. Known to use bark and hollows of larger diameter trees, usually in decay, and building crevices and bat houses elsewhere. ^{16, 29, 35, 69} Caves and mines known to be used as night roosts elsewhere. ^{70,}	Average of 2.2 km +/- 1.4 SD (range 0.1 to 5.9 km) from roosts to capture locations with average movement between successive roosts of 0.6 km +/- 0.5 SD (range 0.1 to 1.5 km) in the Black Hills of South Dakota. ²⁹ Females/males moved and average of 457/158 m +/- 329/127 SD between successive roosts, had mean minimum roosting areas of 8.6/1.4 ha +/- 9.2/1.4 SD, mean minimum foraging areas of 46.2/13.5 ha +/- 44.4/8.3 SD, mean distance between roosting and foraging areas of 584.6/293.0 m +/- 405.8/282.8 SD, and mean distances between capture sites and first roosts of 1001/402 m +/- 693/452 SD in New Brunswick. ¹⁰²
Fringed Myotis (<i>Myotis thysanodes</i>) Very sensitive to roost site disturbance. ¹⁷ Maintain at least some level of group integrity when switching roosts. ²⁹	Not documented in Montana and presumed to migrate south of Montana. ¹	Caves. ¹ Known to use cracks and hollows of larger diameter trees, usually in decay, rock crevices on south-facing slopes, and buildings elsewhere. ^{17, 29}	Caves in Montana. ^{1, 32} Known to use cracks and hollows of larger diameter trees, usually in decay, rock crevices on south-facing slopes, mines, buildings, and bridges elsewhere. ^{17, 21, 22, 29}	Average of 1.0 km +/- 0.6 SD (range 0.1 to 2.0 km) from roosts to capture locations with average movement between successive roosts of 0.5 km +/- 0.6 SD (range 0.1 to 2.0 km) in the Black Hills of South Dakota. ²⁹
Long-legged Myotis (<i>Myotis volans</i>)	Caves and mines in Montana and elsewhere. ^{1, 19, 31, 36, 75, 84}	Large diameter trees in Montana. ^{1, 26} Elsewhere in taller, but random to normal diameter tree snags with loose bark or cracks, especially in areas with less habitat fragmentation, greater snag density but with greater tree spacing. ^{28, 33, 34, 35} Also in rock crevices, cracks in the ground, and buildings are known to be used elsewhere with south-facing roosts preferred. ^{2, 29}	Buildings, mines, caves and large diameter trees in Montana. ^{1, 26, 31, 32, 78, 79} Elsewhere in taller but random to larger diameter tree snags with loose bark or cracks, especially in areas with less habitat fragmentation, greater snag density but with greater tree spacing, are known to be used elsewhere with south-facing roosts preferred. ^{27, 28, 29, 30, 33, 34, 35} Also in buildings, cracks in the ground, rock crevices, and caves. ^{19, 36}	Average of 2.0 km +/- 0.1 SE from roosts to capture locations with average movement between successive roosts of 1.4 km +/- 0.1 SE across four study areas in Washington and Oregon. ²⁸ Average of 1.9 km +/- 1.6 SD (range 0.4 to 3.7 km) from roosts to capture locations with average movement between successive roosts of 0.7 km +/- 0.5 SD (range 0.2 to 1.6 km) in the Black Hills of South Dakota. ²⁹ Average home range size of 647 ha +/- 354 SE (range 16.5 to 3,029 ha) for males, 448 ha +/- 78.7 SE for pregnant females, and 304 ha +/- 53.8 SE for lactating females in Idaho. ³³

Species / Comments	Winter Roost	Summer Maternity Roost	Summer Day/Night Roost	Home Range/Foraging Distance
Yuma Myotis (<i>Myotis yumanensis</i>) Sensitive to roost site disturbance. ²	Not documented in Montana, but acoustic evidence indicates overwintering in rock crevices in cliffs. ¹	Building, bridges, and bat houses in Montana. ¹ Buildings, bridges, caves, mines, and abandoned cliff swallow nests are known elsewhere. ^{2, 20, 21, 22, 25}	Buildings, bridges, and bat houses in Montana. ^{1, 79} Large diameter trees, buildings, rock/cliff crevices and abandoned cliff swallow nests elsewhere. ^{2, 21, 22, 23, 24, 25, 30}	Average of 2 km (range 0.59-3.5 km) from roosts to capture locations in California. ²⁴ 4 km from maternity roost to foraging areas in British Columbia. ²⁵

¹ supported by observations in Montana's statewide point observation database.

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Overview of Known Bat Roosts in Montana

Pallid Bat Roost Use Type Overview

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	0	
Hibernacula	0	
Day and Night Roost	3	2 Rock Outcrops, 1 Tractor
Night Roost	0	

Spotted Bat Roost Use Type Overview

*Cliffs and rock crevices are primary roosts in other states

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	0	
Hibernacula	0	
Day and Night Roost	3	1 House, 1 Parking Garage, 1 Electric Meter
Night Roost	0	

Big Brown Bat Roost Use Type Overview

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	12	1 Bridge, 5 Buildings
Hibernacula	6	3 Caves, 2 Mines
Day and Night Roost	44	9 Bridges, 9 Buildings, 5 Rock Outcrops
Night Roost	0	

Townsend's Big-eared Bat Roost Use Type Overview

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	13	2 Caves, 1 Mine
Hibernacula	69	18 Caves, 20 Mines, 1 Tunnel
Day and Night Roost	33	6 Buildings, 7 Caves, 7 Mines
Night Roost	0	

Silver-haired Bat Roost Use Type Overview

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

*Trees (cavities, bark crevices) are primary roosts in other areas

Roost Type on Survey	No. Records	Notes on Roost Structures
Bachelor Roost	0	
Maternity Roost	1	1 Ponderosa Pine snag
Hibernacula	0	
Day and Night Roost	1	Inside animal hide
Night Roost	0	

*No roost information is available for Eastern Red Bat in Montana, but the species is known to roost in deciduous tree foliage in other states and most acoustic or mist netting records in Montana are from areas adjacent to floodplains with cottonwood gallery forests.

Hoary Bat Roost Use Type Overview

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

*Deciduous tree foliage is primary roost habitat in other areas

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	1	1 Bridge (Hendricks 2005)
Hibernacula	0	
Day and Night Roost	1	1 recent cottonwood tree roost
Night Roost	0	

*Recent radio telemetry data indicates California Myotis likely use tree and rock crevice roosts in the summer and rock crevice roosts in the winter in Montana (Nate Schwab, personal communication). The species is known to roost in rock crevices, trees, caves, and mines in other states.

Western Small-footed Myotis Roost Use Type Overview

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	1	1 Rock Outcrops
Hibernacula	11	2 Caves, 6 Mines
Day and Night Roost	24	16 Rock Outcrops, 2 Bridges, 2 Buildings, 3 Mines
Night Roost	0	

Long-eared Myotis Roost Use Type Overview

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	5	1 Cave, 1 Tree, 2 Rock Outcrops
Hibernacula	3	1 Cave, 2 Mines
Day and Night Roost	28	25 Rock Outcrops, 2 Buildings, 1 Cave
Night Roost	0	

Little Brown Bat Roost Use Type Overview

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	16	1 Bridge, 7 Buildings
Hibernacula	12	6 Caves, 1 Mine
Day and Night Roost	36	1 Bat House, 5 Bridges, 10 Buildings, 1 Cave
Night Roost	1	1 Building

*Trees are also a likely primary roost, but are not well documented.

Northern Myotis Roost Use Type Overview

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	
Maternity Roost	0	
Hibernacula	1	1 Mine
Day and Night Roost	0	
Night Roost	0	

Fringed Myotis Roost Use Type Overview

*Known to roost in trees, rock crevices, and buildings in other areas

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	1 Cave
Maternity Roost	1	
Hibernacula	0	
Day and Night Roost	0	
Night Roost	0	

Long-legged Myotis Roost Use Type Overview

*Also known to use trees and rock crevices in other areas

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	2 Caves, 1 Mine 1 Building, 1 Mine
Maternity Roost	0	
Hibernacula	6	
Day and Night Roost	2	
Night Roost	0	

Yuma Myotis Roost Use Type Overview

*Call data strongly supports this, but genetic confirmation is needed.

- Bachelor Roost
- Maternity Roost
- Hibernacula
- Day and Night Roost
- Night Roost

Roost Type on Survey	No. + Surveys	No. Roost Structures
Bachelor Roost	0	1 Building
Maternity Roost	1*	
Hibernacula	0	
Day and Night Roost	0	
Night Roost	0	

Examples of Winter Roosts for Montana Bats

Townsend's Big-eared Bats in cave – James Cummins

Cluster of Little Brown Myotis in cave – Ronan Donovan

Bats roosting on wall of large cave room – Ronan Donovan, James Cummins

Little Brown Myotis among cave speleotherms – Ronan Donovan

Mine adit supporting Townsend's Big-eared Bat overwintering – Bryce Maxell

Big Brown Bat in dynamite drill hole – Bryce Maxell

Western Small-footed Myotis in cave – Bryce Maxell

Townsend's Big-eared Bat in cave – Ronan Donovan

Big Brown Bat in crevice in cave hibernaculum – Bryce Maxell

Western Small-footed Myotis in crevice in cave hibernaculum – Bryce Maxell

Western Small-footed Myotis in cave – Bryce Maxell

Long-eared Myotis in crevice in cave hibernaculum – Bryce Maxell

Unidentified *Myotis* (notice frost on fur) – Alex Jensen

Townsend's Big-eared Bat in cave – Bryce Maxell

Cluster of unidentified *Myotis* in cave hibernaculum – Bryce Maxell

Unidentified *Myotis* (notice damp fur) – Bryce Maxell

Examples of Summer Maternity Roosts for Montana Bats

Interior/exterior views of unidentified Myotis maternity colony (notice staining at wall/ceiling junction - Kristi DuBois

Unidentified Myotis maternity roost behind south facing sign on brick wall – Bryce Maxell

Townsend's Big-eared Bat maternity colony in twilight zone of cave - Kristi DuBois

Little Brown Myotis maternity colony in barn - Kristi DuBois

Stump and rounds of large diameter Ponderosa Pine that was a maternity roost for Big Brown Bat and Little Brown Myotis, and a day roost for Silver-haired Bat – Bryce Maxell

Long-eared Myotis
maternity roost
Nate Schwab

Silver-haired Bat
maternity roost
Nate Schwab

Long-legged Myotis
Maternity Roost

Kristi DuBois

Little Brown Myotis maternity colony in cook house attic. Bat house is not used. – Kristi DuBois

Yuma Myotis maternity colony - Kristi DuBois

Little Brown Myotis maternity colony - Kristi DuBois

Big Brown Bat maternity colony in house attic – Bryce Maxell

Unidentified Myotis maternity colony in interstate highway bridge expansion joint – Bryce Maxell

Entry point for unidentified Myotis maternity colony in garage eaves – Bryce Maxell

Droppings from Little Brown Myotis maternity colony – Kristi DuBois

Eave entry points for Little Brown Myotis maternity colony – Kristi DuBois

Big Brown Bat maternity colony on metal barn rafters – Adam Messer

Examples of Summer Night and Day Roosts for Montana Bats

Fringed Myotis in vertical rock crevice – Bryce Maxell

Pallid Bat under slab rock – Keaton Wilson

Pallid Bat in vertical rock crevice – Bryce Maxell

Townsend's Big-eared Bat in small cavern in sandstone – Alexis McEwan

Long-eared Myotis roost in horizontal crevice – Bryce Maxell

Long-eared Myotis in horizontal rock crevice – Ayla Doubleday

Western Small-footed Myotis under slab rock – Bryce Maxell

Big Brown Bat in horizontal rock crevice – Alexis McEwan

Hoary Bat on tree trunk – Kristi DuBois

Hoary Bat on tree trunk - Kristi DuBois

Big Brown Bat emerging from tree bark – Kristi DuBois

Little Brown Myotis on tree night roost
Bryce Maxell

Fringed Myotis on tree trunk
Kristi DuBois

Hoary Bat roosting in cottonwood foliage – Nathan Cooper

Spotted Bat on brick wall of Billings parking garage – Dick Dede

Townsend's Big-eared Bat on underside of cellar roof – Kristi DuBois

Hoary Bat at atypical (typically in tree foliage) concrete roost – Matt Bell

Bat droppings from night roost under highway bridge – Amie Shovlain

Western Small-footed Myotis on brick wall with good solar exposure – Bryce Maxell

Big Brown Bat in highway expansion joint crevice – Bryce Maxell

Little Brown Myotis pup in crack of log cabin – Kristi DuBois

Droppings under bridge. Sometimes large volumes of droppings result only from night roosting near foraging areas – Ellen Whittle

Examples of Artificial Summer Roosts (Bat Houses)

Bat houses on 4 x 4 inch posts with good solar exposure – Lewis Young

Bat houses mounted back to back – Lewis Young

Crevices in bat house that supports a Little Brown Myotis maternity colony – Lewis Young

Bat house on old power pole with good solar exposure – Bryce Maxell

Bat house on brick chimney with good solar exposure – Bryce Maxell

Rocket box bat house on eve with good solar exposure – Bryce Maxell

Bat houses on brick wall with good solar exposure – Bryce Maxell

Appendix 6 Echolocation Call Characteristics of Montana Bats¹													
	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	NHP Notes ³	Search Phase call intervals ³
50	<i>Myotis yumanensis</i> Yuma Myotis	49.2	45.6	90.0	55.2	5.5	16.6	4.4	8.1	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).	f_c > 50 kHz dur > 6 ms	Date range: Year round	90-175 ms
	<i>Myotis californicus</i> California Myotis	49.1	45.3	99.6	52.8	3.8	28.0	7.4	15.1	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.	f_c > 50 kHz dur < 5 ms	<i>D calls should have:</i> f_c > 48 kHz uppr slp >20 total slp > 10 dur < 4 ms tail > 3 kHz Date range: Year round	75-125 ms (occ. >175 ms)
40	<i>Myotis ciliolabrum</i> Western Small-footed Myotis	44.3	40.6	95.1	49.1	3.2	33.5	9.6	16.9	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 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.	f_c > 42 kHz dur < 5 ms Kaleido Accurate	<i>D calls should have :</i> f_c > 42 kHz uppr slp >25 total slp > 12 tail > 3 kHz Date range: Year round	75-125 ms
	<i>Myotis septentrionalis</i> Northern Long-eared Myotis	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 <i>Myotis</i> spp. Presence in Montana uncertain - 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 <i>Myotis</i> by confirming consistent search phase call intervals across the sequence.	unknown
	<i>Myotis volans</i> Long-legged Myotis	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?
	<i>Myotis lucifugus</i> Little Brown Bat	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 <i>Myotis</i> . Dur >7 ms (95% CI for MYVO) and lwrSlp <3 diagnostic among 40 kHz <i>Myotis</i> ; f_c <44 kHz diagnostic 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.	dur > 6 ms	Date range: Year round	100-200 ms
	<i>Lasiurus borealis</i> Eastern Red Bat	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 15	100-250 ms (occ. >300 ms)
30	<i>Myotis evotis</i> Long-eared Myotis	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
	<i>Eptesicus fuscus</i> Big Brown Bat	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)
	<i>Antrozous pallidus</i> Pallid Bat	28.0	26.2	54.5	31.0	6.8	8.1	2.7	4.3	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 <i>Myotis</i> -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 5 - Oct 1	150-300 ms?
20	<i>Lasionycteris noctivagans</i> Silver-haired Bat	26.5	25.4	41.5	28.8	9.2	5.2	1.3	2.5	Some call variants can be confused with EPFU. Flat calls with f_c ≥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> Fringed Myotis	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 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.	f_c < 24 kHz, dur 3-5 ms, and/or Kaleido Accurate	Date range: Apr 3 - Oct 31	100-160 ms
	<i>Corynorhinus townsendii</i> Townsend's Big-eared Bat	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)
	<i>Lasiurus cinereus</i> Hoary Bat	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: May 1 - Oct 31	250-400 ms (occ. >500 ms)
10	<i>Euderma maculatum</i> Spotted Bat	10	9.6	14.5	12.5	3.2	2.2	1.5	1.7	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”	200-500 ms
												Date range: Apr 19 - Nov 12	

¹ data from Humbolt 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 January 2015.

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 Humbolt 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.

OBSERVATIONS AND SEASONAL RANGES OF MONTANA BAT SPECIES

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*)

Fringed Myotis (*Myotis thysanodes*)

Long-legged Myotis (*Myotis volans*)

Yuma Myotis (*Myotis yumanensis*)

Acoustic Survey Sites

Mistnet Survey Sites

Northern Myotis (*Myotis septentrionalis*)

Montana Bat Call Identification

Montana Natural Heritage Program

Bryce Maxell, Shannon Hilty, Braden Burkholder, and Scott Blum

*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

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*)

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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

MONTANA
Natural Heritage
Program

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

Michael Dunham/Minden Pictures/Bat Conservation International

Montana Fish,
Wildlife & Parks

The University of
Montana

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	<i>Antrozous pallidus</i>	ANPA	17
Townsend's Big-eared Bat	<i>Corynorhinus townsendii</i>	COTO	281
Big Brown Bat	<i>Eptesicus fuscus</i>	EPFU	1,090
Spotted Bat	<i>Euderma maculatum</i>	EUMA	108
Silver-haired Bat	<i>Lasionycteris noctivagans</i>	LANO	1,381
Eastern Red Bat	<i>Lasiurus borealis</i>	LABO	65
Hoary Bat	<i>Lasiurus cinereus</i>	LACI	1,041
California Myotis	<i>Myotis californicus</i>	MYCA	189
Western Small-footed Myotis	<i>Myotis ciliolabrum</i>	MYCI	917
Long-eared Myotis	<i>Myotis evotis</i>	MYEV	1,085
Little Brown Myotis	<i>Myotis lucifugus</i>	MYLU	1,468
Northern Myotis	<i>Myotis septentrionalis</i>	MYSE	1
Fringed Myotis	<i>Myotis thysanodes</i>	MYTH	130
Long-legged Myotis	<i>Myotis volans</i>	MYVO	252
Yuma Myotis	<i>Myotis yumanensis</i>	MYYU	34

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.

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

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

bandwidth: 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

call interval: duration between calls when viewed in “real time”; useful for identifying search, approach, and feeding buzz calls

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

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, shorter, and have tighter call intervals 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.

The background of the slide is a light purple color with a repeating pattern of small, dark purple bat silhouettes in flight. The bats are scattered across the entire page, creating a textured, thematic background.

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 “std 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

The diagram illustrates a network of entities represented by circles. The entities are: EUMA, LACI, COTO, MYSE, MYVO, ANPA, MYEV, EPFU, MYTH, LANO, MYLU, LABO, MYCA, and MYCI. The connections are as follows:

- Highlighted Nodes:** COTO (red border), MYVO (red border), ANPA (red border), and MYSE (yellow border).
- Connections:**
  - Double-headed arrows connect LACI to COTO, COTO to MYTH, MYEV to MYTH, MYEV to EPFU, MYTH to LANO, LANO to MYLU, MYLU to LABO, MYLU to MYCA, and MYCA to MYCI.
  - Curved arrows point from LACI to MYSE and from MYSE to MYCA.

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

Difficult to
record
definitive
characters

Easy to
record
definitive
characters

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 call 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.

The background of the slide is a light purple color with a repeating pattern of small, stylized bat silhouettes in a slightly darker shade of purple. The bats are scattered across the entire page, some appearing larger and more prominent than others, creating a sense of a large colony in flight.

Overview of Call Characteristics for Montana's Bats

Spotted Bat (*Euderma maculatum*) = EUMA

EUMA_real_time

EUMA_time_expanded

Bat Observation Type

- x MISTNET/HAND CAPTURE/OTHER
- o SM2 ACOUSTIC
- PETERSSON ACOUSTIC
- ANABAT ACOUSTIC

Range Type

- Year-round
- Summer

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

EUMA Definitive Characteristics

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

Hoary Bat (*Lasiurus cinereus*) = LACI

LACI_time_expanded

Bat Observation Type		Range Type	
x	MISTNET/HAND CAPTURE/OTHER	Year-round	Summer
•	SM2 ACOUSTIC		
•	PETERSSON ACOUSTIC		
•	ANABAT ACOUSTIC		

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.

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.

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.

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

LANO_time_expanded

Bat Observation Type

- × MISTNET/HAND CAPTURE/OTHER
- SM2 ACOUSTIC
- PETERSSON ACOUSTIC
- ANABAT ACOUSTIC

Range Type

- Year-round
- Summer

LANO Call Shapes

*Red scale bars are
set at 26 kHz.

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

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

Bat Observation Type		Range Type	
×	MISTNET/HAND CAPTURE/OTHER	Year-round	Summer
●	SM2 ACOUSTIC		
●	PETTERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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

Bat Observation Type		Range Type	
×	MISTNET/HAND CAPTURE/OTHER	■	Year-round
●	SM2 ACOUSTIC	■	Summer
●	PETTERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

ANPA Call Shapes

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

ANPA Definitive Characteristics

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

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.

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

= COTO

COTO_time_expanded

Bat Observation Type		Range Type	
x	MISTNET/HAND CAPTURE/OTHER		Year-round
●	SM2 ACOUSTIC		Summer
●	PETERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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

Bat Observation Type		Range Type	
x	MISTNET/HAND CAPTURE/OTHER		Year-round
●	SM2 ACOUSTIC		Summer
●	PETERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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 $f < 24$ kHz
- $f_c < 28$ kHz, total slope >10 , and low $f < 24$ kHz diagnostic IF harmonics converge toward primary call component

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*Red scale bar is set at 28 kHz.

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

Bat Observation Type

- × MISTNET/HAND CAPTURE/OTHER
- SM2 ACOUSTIC
- PETERSSON ACOUSTIC
- ANABAT ACOUSTIC

Range Type

- Year-round
- Summer

MYEV Call Shapes

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

MYEV Definitive Characteristics

- Converging harmonics
- f_c : 32-36 kHz

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 upswing 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.

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

MYVO_time_expanded

Bat Observation Type		Range Type	
×	MISTNET/HAND CAPTURE/OTHER	Year-round	Summer
●	SM2 ACOUSTIC		
●	PETTERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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

*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.

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Northern Myotis (*Myotis septentrionalis*) =MYSE

Bat Observation Type		Range Type	
×	MISTNET/HAND CAPTURE/OTHER	■	Year-round
●	SM2 ACOUSTIC	■	Summer
●	PETTERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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

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.

MYSE Similar Species

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

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.

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. Call intervals are very tight (40-50 ms) as well, indicating that these are approach phase.

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 there are two bats in the sequence. While both bats appear to be in search phase (over 100 ms call intervals), it is difficult to tell whether or not the calls are altered due to interactions between the two.

MYSE Definitive Sequences

Joe Szewczak emphasizes that in order to definitively identify call sequences as MYSE you need to: (1) examine whether there are steady intervals across the call sequence to ensure that they are search-phase calls instead of inspection/approach-phase calls of other *Myotis* species; (2) then examine Fc and other call features to see if they match MYSE.

Sequence from Joe Szewczak and the Humboldt State University Bat Lab

MYSE Definitive Sequences

Calls have steady intervals and are likely search phase calls throughout sequence.

Sequence from Joe Szewczak and the Humboldt State University Bat Lab

Little Brown Myotis (*Myotis lucifugus*) = MYLU

MYLU_time_expanded

Bat Observation Type

- × MISTNET/HAND CAPTURE/OTHER
- SM2 ACOUSTIC
- PETERSSON ACOUSTIC
- ANABAT ACOUSTIC

Range Type

- Year-round
- Summer

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*

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.

*Red scale bars are set at 40 kHz.

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

*Red scale bars are set at 35 kHz.

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 *fc* 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 *fc*.

Yuma Myotis (*Myotis yumanensis*) = MYYU

MYYU_time_expanded

Bat Observation Type

- × MISTNET/HAND CAPTURE/OTHER
- SM2 ACOUSTIC
- PETERSSON ACOUSTIC
- ANABAT ACOUSTIC

Range Type

- Year-round
- Summer

MYYU Call Shapes

- Power focused around f_c ; 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.

*Red scale bars are set at 50 kHz.

Western Small-footed Myotis (*Myotis ciliolabrum*)

= MYCI

MYCI_time_expanded

Bat Observation Type		Range Type	
×	MISTNET/HAND CAPTURE/OTHER	Year-round	Summer
●	SM2 ACOUSTIC		
●	PETTERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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

Bat Observation Type		Range Type	
×	MISTNET/HAND CAPTURE/OTHER	Year-round	Summer
●	SM2 ACOUSTIC		
●	PETTERSSON ACOUSTIC		
●	ANABAT ACOUSTIC		

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.

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

MYCA Similar Species

MYCA vs. MYCI: Calls are similar in appearance and characteristics. When the two overlap geographically, $fc > 48$ 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.

Appendix 8
Montana Bat Acoustic Monitoring Database – SQL Server 2008

Structure, Creation Code, and Query Code

Authorship/Contact:

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Table structure in SQL Server Database

Table_Name	Column_Name	Data_Type	Max_Length
Bat_Species_Data	ID	int	4
Bat_Species_Data	ELCODE	nvarchar	20
Bat_Species_Data	S_Sci_Name	nvarchar	500
Bat_Species_Data	S_Com_Name	nvarchar	400
Bat_Species_Data	Four_Code	nvarchar	12
Bat_Species_Data	Min_Month_Day	datetime	8
Bat_Species_Data	Max_Month_Day	datetime	8
Bat_Species_Data	Min_Month_Typical	int	4
Bat_Species_Data	Max_Month_Typical	int	4
Lunar_Calculations	ID	int	4
Lunar_Calculations	SiteID	int	4
Lunar_Calculations	SampleNight	datetime2	6
Lunar_Calculations	LastRise	datetime2	6
Lunar_Calculations	LastSet	datetime2	6
Lunar_Calculations	NextRise	datetime2	6
Lunar_Calculations	NextSet	datetime2	6
Lunar_Calculations	midNightIllum	float	8
MT_Acoustic_Monitoring_Stations	SiteID	int	4
MT_Acoustic_Monitoring_Stations	Location	nvarchar	510
MT_Acoustic_Monitoring_Stations	Latitude	float	8
MT_Acoustic_Monitoring_Stations	Longitude	float	8
MT_Acoustic_Monitoring_Stations	Contact	nvarchar	510
MT_Acoustic_Monitoring_Stations	Comments	nvarchar	-1
MT_Acoustic_Monitoring_Stations	Installation_Date	datetime2	6
MT_Acoustic_Monitoring_Stations	Decommission_Date	datetime2	6
MT_Acoustic_Monitoring_Stations	Ownership	nvarchar	510
MT_Acoustic_Monitoring_Stations	Detector_Survey_Type	nvarchar	510
MT_Acoustic_Monitoring_Stations	Status	nvarchar	510
MT_Acoustic_Monitoring_Stations	Funder	nvarchar	510
MT_Acoustic_Monitoring_Stations	SiteNameShort	nvarchar	30
MT_Acoustic_Monitoring_Stations	AnalysisGroup	nvarchar	30
MT_Acoustic_Monitoring_Stations	TimeStamp	timestamp	8
MT_Acoustic_Monitoring_Stations	State	nvarchar	4
MT_Acoustic_Monitoring_Stations	FolderName	nvarchar	510
MT_Acoustic_Monitoring_Stations	WxStnID_Wind	varchar	5
MT_Acoustic_Monitoring_Stations	WxStnID_Wind2	varchar	5
MT_Acoustic_Monitoring_Stations	WxStnID_Temp	varchar	5
MT_Acoustic_Monitoring_Stations	WxStnID_Press	varchar	5
MT_Acoustic_Monitoring_Stations	WxStnID_Humid	varchar	5

Table_Name	Column_Name	Data_Type	Max_Length
MT_Acoustic_Monitoring_Stations	WxStnID_Solar	varchar	5
MT_Acoustic_Monitoring_Stations	WxStnID_Precp	varchar	5
MT_Acoustic_Monitoring_Stations	SiteElev_m	float	8
MT_Acoustic_Monitoring_Stations	POINT	geometry	-1
MT_Acoustic_Monitoring_Stations	DistWxStn_Wind_km	float	8
MT_Acoustic_Monitoring_Stations	DistWxStn_Wind2_km	float	8
MT_Acoustic_Monitoring_Stations	DistWxStn_Temp_km	float	8
MT_Acoustic_Monitoring_Stations	DistWxStn_Press_km	float	8
MT_Acoustic_Monitoring_Stations	DistWxStn_Humid_km	float	8
MT_Acoustic_Monitoring_Stations	DistWxStn_Solar_km	float	8
MT_Acoustic_Monitoring_Stations	DistWxStn_Precp_km	float	8
Solar_Calculations	ID	int	4
Solar_Calculations	SiteID	int	4
Solar_Calculations	Date	datetime2	6
Solar_Calculations	Sunrise	datetime2	6
Solar_Calculations	Sunset	datetime2	6
Solar_Calculations	Daylength_M	float	8
Temp_Logger_Master	ID	int	4
Temp_Logger_Master	SiteID	int	4
Temp_Logger_Master	Date	datetime2	6
Temp_Logger_Master	Time	datetime2	6
Temp_Logger_Master	Temp_C	float	8
Temp_Logger_Master	Sensor	float	8
Temp_Logger_Master	Date_Time	datetime2	6
Temp_Logger_Master	Date_Time_Round	datetime2	6
Temp_Logger_Master	TimeStamp	timestamp	8
TemperatureLU	ID	int	4
TemperatureLU	SiteID	int	4
TemperatureLU	Date_Time	datetime2	6
TemperatureLU	tDate_Time	datetime2	6
TemperatureLU	Temp_C	float	8
TemperatureLU	Temp_Time_Diff_M	float	8
TemperatureLU	TimeStamp	timestamp	8
WAV_Master	ID	int	4
WAV_Master	SiteID	int	4
WAV_Master	Filename	nvarchar	510
WAV_Master	M_Sonobat_Class	nvarchar	510
WAV_Master	M_DiscrProb	nvarchar	510
WAV_Master	S_Sonobat_Class	nvarchar	510
WAV_Master	S_DiscrProb	nvarchar	510

Table_Name	Column_Name	Data_Type	Max_Length
WAV_Master	P_Sonobat_Class	nvarchar	510
WAV_Master	P_DiscrProb	nvarchar	510
WAV_Master	Master_Class	nvarchar	510
WAV_Master	Hand_Class	nvarchar	510
WAV_Master	Comments	nvarchar	510
WAV_Master	MultiSpp	smallint	2
WAV_Master	Reviewer	nvarchar	510
WAV_Master	Location	nvarchar	510
WAV_Master	Download_Date	nvarchar	510
WAV_Master	Channel	nvarchar	510
WAV_Master	Year	smallint	2
WAV_Master	Month	smallint	2
WAV_Master	Day	smallint	2
WAV_Master	Date	datetime2	6
WAV_Master	Sample_Night	datetime2	6
WAV_Master	Hour	datetime2	6
WAV_Master	HHMMSS	datetime2	6
WAV_Master	Date_Time	datetime2	6
WAV_Master	Date_Time_Round	datetime2	6
WAV_Master	tDate_Time	datetime2	6
WAV_Master	tDate_Time_Round	datetime2	6
WAV_Master	Temp_C	float	8
WAV_Master	Temp_Time_Diff_M	float	8
WAV_Master	Temp_toLU	int	4
WAV_Master	Sunrise	datetime2	6
WAV_Master	Sunset	datetime2	6
WAV_Master	Time_After_Sunset	datetime2	6
WAV_Master	Hour_After_Sunset	datetime2	6
WAV_Master	Daylength_M	float	8
WAV_Master	NightLength_M	float	8
WAV_Master	M_Class_Group	nvarchar	510
WAV_Master	M_Class_Group_DiscrProb	nvarchar	510
WAV_Master	M_FcMean	nvarchar	510
WAV_Master	M_FcStdDev	nvarchar	510
WAV_Master	M_DurMean	nvarchar	510
WAV_Master	M_DurStdDev	nvarchar	510
WAV_Master	M_Mean_Calls_Sec	nvarchar	510
WAV_Master	M_SpeciesRank1	nvarchar	510
WAV_Master	M_SpeciesRank2	nvarchar	510
WAV_Master	M_SpeciesRank3	nvarchar	510

Table_Name	Column_Name	Data_Type	Max_Length
WAV_Master	M_SpeciesRank4	nvarchar	510
WAV_Master	M_SpeciesRank5	nvarchar	510
WAV_Master	M_SpeciesRank6	nvarchar	510
WAV_Master	S_Class_Group	nvarchar	510
WAV_Master	S_Class_Group_DiscrProb	nvarchar	510
WAV_Master	S_FcMean	nvarchar	510
WAV_Master	S_FcStdDev	nvarchar	510
WAV_Master	S_DurMean	nvarchar	510
WAV_Master	S_DurStdDev	nvarchar	510
WAV_Master	S_Mean_Calls_Sec	nvarchar	510
WAV_Master	S_SpeciesRank1	nvarchar	510
WAV_Master	S_SpeciesRank2	nvarchar	510
WAV_Master	S_SpeciesRank3	nvarchar	510
WAV_Master	S_SpeciesRank4	nvarchar	510
WAV_Master	S_SpeciesRank5	nvarchar	510
WAV_Master	S_SpeciesRank6	nvarchar	510
WAV_Master	P_Class_Group	nvarchar	510
WAV_Master	P_Class_Group_DiscrProb	nvarchar	510
WAV_Master	P_FcMean	nvarchar	510
WAV_Master	P_FcStdDev	nvarchar	510
WAV_Master	P_DurMean	nvarchar	510
WAV_Master	P_DurStdDev	nvarchar	510
WAV_Master	P_Mean_Calls_Sec	nvarchar	510
WAV_Master	P_SpeciesRank1	nvarchar	510
WAV_Master	P_SpeciesRank2	nvarchar	510
WAV_Master	P_SpeciesRank3	nvarchar	510
WAV_Master	P_SpeciesRank4	nvarchar	510
WAV_Master	P_SpeciesRank5	nvarchar	510
WAV_Master	P_SpeciesRank6	nvarchar	510
WAV_Master	KA_Class	nvarchar	510
WAV_Master	KA_Pulse	smallint	2
WAV_Master	KA_Match	smallint	2
WAV_Master	KA_Margin	float	8
WAV_Master	KB_Class	nvarchar	510
WAV_Master	KB_Pulse	smallint	2
WAV_Master	KB_Match	smallint	2
WAV_Master	KB_Margin	float	8
WAV_Master	KS_Class	nvarchar	510
WAV_Master	KS_Pulse	smallint	2
WAV_Master	KS_Match	smallint	2

Table_Name	Column_Name	Data_Type	Max_Length
WAV_Master	KS_Margin	float	8
WAV_Master	TimeStamp	timestamp	8
WAV_Master	DateTime_RoundHour	datetime2	6
WAV_Master	Wind_m_s	float	8
WAV_Master	Pressure_mb	float	8
WAV_Master	Last_Updated	datetime2	6
WAV_Master	Wind2_m_s	float	8
WAV_Master	TempWx_C	float	8
WAV_Master	PressChng_mb	float	8
WAV_Master	Precip_mm_hr	float	8
WAV_Master	RHumid_pcnt	float	8
WAV_Master	MoonUp	int	4
WAV_Master	MoonIllum	float	8
Weather_Data	WeatherDataID	int	4
Weather_Data	STID	varchar	5
Weather_Data	Station_Date	datetime	8
Weather_Data	Air_Temp	real	4
Weather_Data	Relative_Humidity	real	4
Weather_Data	Wind_Speed	real	4
Weather_Data	Wind_Direction	real	4
Weather_Data	Solar_Radiation	real	4
Weather_Data	Altimeter	real	4
Weather_Data	Precip_Accum	real	4
Weather_Data	DateTimeMST_RoundHour	datetime2	6
Weather_Data	BaroPrss_Adj_mb	float	8
Weather_Stations	WeatherStationsID	int	4
Weather_Stations	State	char	3
Weather_Stations	County	varchar	20
Weather_Stations	STID	varchar	5
Weather_Stations	Station_Name	varchar	80
Weather_Stations	Site_ID	int	4
Weather_Stations	Latitude	numeric	5
Weather_Stations	Longitude	numeric	5
Weather_Stations	Elev_Ft	int	4
Weather_Stations	Max_Date	datetime	8
Weather_Stations	Last_Run_Date	datetime	8
Weather_Stations	Rec_Count	int	4
Weather_Stations	Active	bit	1
Weather_Stations	POINT	geometry	-1

Creation Code for replicating Table structure above in a SQL Server Database
Change highlighted text as needed.

```
USE [NHPBat]
GO
/***** Object: Table [dbo].[Bat_Species_Data] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[Bat_Species_Data](
    [ID] [int] IDENTITY(1,1) NOT NULL,
    [ELCODE] [nvarchar](10) NULL,
    [S_Sci_Name] [nvarchar](250) NULL,
    [S_Com_Name] [nvarchar](200) NULL,
    [Four_Code] [nvarchar](6) NULL,
    [Min_Month_Day] [datetime] NULL,
    [Max_Month_Day] [datetime] NULL,
    [Min_Month_Typical] [int] NULL,
    [Max_Month_Typical] [int] NULL,
    CONSTRAINT [PK_Bat_Species_Data] PRIMARY KEY CLUSTERED
(
    [ID] ASC
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]

GO
/***** Object: Table [dbo].[Lunar_Calculations] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[Lunar_Calculations](
    [ID] [int] IDENTITY(1,1) NOT NULL,
    [SiteID] [int] NULL,
    [SampleNight] [datetime2](0) NULL,
    [LastRise] [datetime2](0) NULL,
    [LastSet] [datetime2](0) NULL,
    [NextRise] [datetime2](0) NULL,
    [NextSet] [datetime2](0) NULL,
    [midNightIllum] [float] NULL,
    CONSTRAINT [PK_Lunar_Calculations] PRIMARY KEY CLUSTERED
(
    [ID] ASC
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]

GO
```

```

/***** Object: Table [dbo].[MT_Acoustic_Monitoring_Stations] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
SET ANSI_PADDING ON
GO
CREATE TABLE [dbo].[MT_Acoustic_Monitoring_Stations](
    [SiteID] [int] IDENTITY(1,1) NOT NULL,
    [Location] [nvarchar](255) NULL,
    [Latitude] [float] NULL,
    [Longitude] [float] NULL,
    [Contact] [nvarchar](255) NULL,
    [Comments] [nvarchar](max) NULL,
    [Installation_Date] [datetime2](0) NULL,
    [Decommission_Date] [datetime2](0) NULL,
    [Ownership] [nvarchar](255) NULL,
    [Detector_Survey_Type] [nvarchar](255) NULL,
    [Status] [nvarchar](255) NULL,
    [Funder] [nvarchar](255) NULL,
    [SiteNameShort] [nvarchar](15) NULL,
    [AnalysisGroup] [nvarchar](15) NULL,
    [TimeStamp] [timestamp] NOT NULL,
    [State] [nvarchar](2) NULL,
    [FolderName] [nvarchar](255) NULL,
    [WxStnID_Wind] [varchar](5) NULL,
    [WxStnID_Wind2] [varchar](5) NULL,
    [WxStnID_Temp] [varchar](5) NULL,
    [WxStnID_Press] [varchar](5) NULL,
    [WxStnID_Humid] [varchar](5) NULL,
    [WxStnID_Solar] [varchar](5) NULL,
    [WxStnID_Precp] [varchar](5) NULL,
    [SiteElev_m] [float] NULL,
    [POINT] AS
    ([geometry]::STGeomFromText(((( 'POINT(' + CONVERT([varchar](20),[Longitude],0)) + '
    ')+CONVERT([varchar](20),[Latitude],0))+' '), (4326))),
    [DistWxStn_Wind_km] [float] NULL,
    [DistWxStn_Wind2_km] [float] NULL,
    [DistWxStn_Temp_km] [float] NULL,
    [DistWxStn_Press_km] [float] NULL,
    [DistWxStn_Humid_km] [float] NULL,
    [DistWxStn_Solar_km] [float] NULL,
    [DistWxStn_Precp_km] [float] NULL,
    CONSTRAINT [MT_Acoustic_Monitoring_Stations$PrimaryKey] PRIMARY KEY CLUSTERED
    (
        [SiteID] ASC
    )WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
    ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
    ) ON [PRIMARY] TEXTIMAGE_ON [PRIMARY]

GO
SET ANSI_PADDING OFF
GO

```



```

/***** Object: Table [dbo].[Solar_Calculations] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[Solar_Calculations](
    [ID] [int] IDENTITY(1,1) NOT NULL,
    [SiteID] [int] NULL,
    [Date] [datetime2](0) NULL,
    [Sunrise] [datetime2](0) NULL,
    [Sunset] [datetime2](0) NULL,
    [Daylength_M] [float] NULL,
    CONSTRAINT [PK_Solar_Calculations] PRIMARY KEY NONCLUSTERED
    (
        [ID] ASC
    )WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
    ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]
GO
/***** Object: Table [dbo].[Temp_Logger_Master] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[Temp_Logger_Master](
    [ID] [int] IDENTITY(1,1) NOT NULL,
    [SiteID] [int] NULL,
    [Date] [datetime2](0) NULL,
    [Time] [datetime2](0) NULL,
    [Temp_C] [float] NULL,
    [Sensor] [float] NULL,
    [Date_Time] [datetime2](0) NULL,
    [Date_Time_Round] [datetime2](0) NULL,
    [TimeStamp] [timestamp] NOT NULL,
    CONSTRAINT [PK_Temp_Logger_Master] PRIMARY KEY CLUSTERED
    (
        [ID] ASC
    )WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
    ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]
GO
/***** Object: Table [dbo].[TemperatureLU] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[TemperatureLU](
    [ID] [int] IDENTITY(1,1) NOT NULL,
    [SiteID] [int] NULL,
    [Date_Time] [datetime2](0) NULL,
    [tDate_Time] [datetime2](0) NULL,
    [Temp_C] [float] NULL,
    [Temp_Time_Diff_M] [float] NULL,
    [TimeStamp] [timestamp] NOT NULL,
    CONSTRAINT [PK_TemperatureLU] PRIMARY KEY NONCLUSTERED
    (
        [ID] ASC
    )WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
    ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]
GO

```

```

/***** Object: Table [dbo].[WAV_Master] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
CREATE TABLE [dbo].[WAV_Master](
    [ID] [int] IDENTITY(1,1) NOT NULL,
    [SiteID] [int] NULL,
    [Filename] [nvarchar](255) NULL,
    [M_Sonobat_Class] [nvarchar](255) NULL,
    [M_DiscrProb] [nvarchar](255) NULL,
    [S_Sonobat_Class] [nvarchar](255) NULL,
    [S_DiscrProb] [nvarchar](255) NULL,
    [P_Sonobat_Class] [nvarchar](255) NULL,
    [P_DiscrProb] [nvarchar](255) NULL,
    [Master_Class] [nvarchar](255) NULL,
    [Hand_Class] [nvarchar](255) NULL,
    [Comments] [nvarchar](255) NULL,
    [MultiSp] [smallint] NULL,
    [Reviewer] [nvarchar](255) NULL,
    [Location] [nvarchar](255) NULL,
    [Download_Date] [nvarchar](255) NULL,
    [Channel] [nvarchar](255) NULL,
    [Year] [smallint] NULL,
    [Month] [smallint] NULL,
    [Day] [smallint] NULL,
    [Date] [datetime2](0) NULL,
    [Sample_Night] [datetime2](0) NULL,
    [Hour] [datetime2](0) NULL,
    [HHMMSS] [datetime2](0) NULL,
    [Date_Time] [datetime2](0) NULL,
    [Date_Time_Round] [datetime2](0) NULL,
    [tDate_Time] [datetime2](0) NULL,
    [tDate_Time_Round] [datetime2](0) NULL,
    [Temp_C] [float] NULL,
    [Temp_Time_Diff_M] [float] NULL,
    [Temp_toLU] [int] NULL,
    [Sunrise] [datetime2](0) NULL,
    [Sunset] [datetime2](0) NULL,
    [Time_After_Sunset] [datetime2](0) NULL,
    [Hour_After_Sunset] [datetime2](0) NULL,
    [Daylength_M] [float] NULL,
    [NightLength_M] [float] NULL,
    [M_Class_Group] [nvarchar](255) NULL,
    [M_Class_Group_DiscrProb] [nvarchar](255) NULL,
    [M_FcMean] [nvarchar](255) NULL,
    [M_FcStdDev] [nvarchar](255) NULL,
    [M_DurMean] [nvarchar](255) NULL,
    [M_DurStdDev] [nvarchar](255) NULL,
    [M_Mean_Calls_Sec] [nvarchar](255) NULL,
    [M_SpeciesRank1] [nvarchar](255) NULL,
    [M_SpeciesRank2] [nvarchar](255) NULL,
    [M_SpeciesRank3] [nvarchar](255) NULL,
    [M_SpeciesRank4] [nvarchar](255) NULL,
    [M_SpeciesRank5] [nvarchar](255) NULL,
    [M_SpeciesRank6] [nvarchar](255) NULL,
    [S_Class_Group] [nvarchar](255) NULL,
    [S_Class_Group_DiscrProb] [nvarchar](255) NULL,

```

```

[S_FcMean] [nvarchar](255) NULL,
[S_FcStdDev] [nvarchar](255) NULL,
[S_DurMean] [nvarchar](255) NULL,
[S_DurStdDev] [nvarchar](255) NULL,
[S_Mean_Calls_Sec] [nvarchar](255) NULL,
[S_SpeciesRank1] [nvarchar](255) NULL,
[S_SpeciesRank2] [nvarchar](255) NULL,
[S_SpeciesRank3] [nvarchar](255) NULL,
[S_SpeciesRank4] [nvarchar](255) NULL,
[S_SpeciesRank5] [nvarchar](255) NULL,
[S_SpeciesRank6] [nvarchar](255) NULL,
[P_Class_Group] [nvarchar](255) NULL,
[P_Class_Group_DiscrProb] [nvarchar](255) NULL,
[P_FcMean] [nvarchar](255) NULL,
[P_FcStdDev] [nvarchar](255) NULL,
[P_DurMean] [nvarchar](255) NULL,
[P_DurStdDev] [nvarchar](255) NULL,
[P_Mean_Calls_Sec] [nvarchar](255) NULL,
[P_SpeciesRank1] [nvarchar](255) NULL,
[P_SpeciesRank2] [nvarchar](255) NULL,
[P_SpeciesRank3] [nvarchar](255) NULL,
[P_SpeciesRank4] [nvarchar](255) NULL,
[P_SpeciesRank5] [nvarchar](255) NULL,
[P_SpeciesRank6] [nvarchar](255) NULL,
[KA_Class] [nvarchar](255) NULL,
[KA_Pulse] [smallint] NULL,
[KA_Match] [smallint] NULL,
[KA_Margin] [float] NULL,
[KB_Class] [nvarchar](255) NULL,
[KB_Pulse] [smallint] NULL,
[KB_Match] [smallint] NULL,
[KB_Margin] [float] NULL,
[KS_Class] [nvarchar](255) NULL,
[KS_Pulse] [smallint] NULL,
[KS_Match] [smallint] NULL,
[KS_Margin] [float] NULL,
[TimeStamp] [timestamp] NOT NULL,
[DateTime_RoundHour] [datetime2](0) NULL,
[Wind_m_s] [float] NULL,
[Pressure_mb] [float] NULL,
[Last_Updated] [datetime2](0) NULL,
[Wind2_m_s] [float] NULL,
[TempWx_C] [float] NULL,
[PressChng_mb] [float] NULL,
[Precip_mm_hr] [float] NULL,
[RHumid_pcmt] [float] NULL,
[MoonUp] [int] NULL,
[MoonIllum] [float] NULL,
CONSTRAINT [PK_WAV_Master2] PRIMARY KEY CLUSTERED
(
    [ID] ASC
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON) ON [PRIMARY]
) ON [PRIMARY]

GO

```

```

/***** Object: Table [dbo].[Weather_Data] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
SET ANSI_PADDING ON
GO
CREATE TABLE [dbo].[Weather_Data](
    [WeatherDataID] [int] IDENTITY(1,1) NOT NULL,
    [STID] [varchar](5) NOT NULL,
    [Station_Date] [datetime] NOT NULL,
    [Air_Temp] [real] NULL,
    [Relative_Humidity] [real] NULL,
    [Wind_Speed] [real] NULL,
    [Wind_Direction] [real] NULL,
    [Solar_Radiation] [real] NULL,
    [Altimeter] [real] NULL,
    [Precip_Accum] [real] NULL,
    [DateTimeMST_RoundHour] [datetime2](0) NULL,
    [BaroPrss_Adj_mb] [float] NULL,
    CONSTRAINT [PK_Weather_Data] PRIMARY KEY CLUSTERED
    (
        [WeatherDataID] ASC
    )
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]
GO
SET ANSI_PADDING OFF
GO
/***** Object: Table [dbo].[Weather_Stations] *****/
SET ANSI_NULLS ON
GO
SET QUOTED_IDENTIFIER ON
GO
SET ANSI_PADDING ON
GO
CREATE TABLE [dbo].[Weather_Stations](
    [WeatherStationsID] [int] IDENTITY(1,1) NOT NULL,
    [State] [char](3) NULL,
    [County] [varchar](20) NULL,
    [STID] [varchar](5) NULL,
    [Station_Name] [varchar](80) NULL,
    [Site_ID] [int] NULL,
    [Latitude] [numeric](9, 5) NULL,
    [Longitude] [numeric](9, 5) NULL,
    [Elev_Ft] [int] NULL,
    [Max_Date] [datetime] NULL,
    [Last_Run_Date] [datetime] NULL,
    [Rec_Count] [int] NULL,
    [Active] [bit] NULL,
    [POINT] AS
    ([geometry]::STGeomFromText((((('POINT('+CONVERT([varchar](20),[Longitude],(0))+'
')+CONVERT([varchar](20),[Latitude],(0))+'')',(4326))),
    CONSTRAINT [PK_Weather_Stations] PRIMARY KEY CLUSTERED
    (
        [WeatherStationsID] ASC
    )
)WITH (PAD_INDEX = OFF, STATISTICS_NORECOMPUTE = OFF, IGNORE_DUP_KEY = OFF,
ALLOW_ROW_LOCKS = ON, ALLOW_PAGE_LOCKS = ON, FILLFACTOR = 75) ON [PRIMARY]
) ON [PRIMARY]

```



```

GO
SET ANSI_PADDING OFF
GO

ALTER TABLE [dbo].[WAV_Master] ADD CONSTRAINT [DF__WAV_Master__Temp] DEFAULT ((0)) FOR
[Temp_toLU]
GO
ALTER TABLE [dbo].[Lunar_Calculations] WITH CHECK ADD CONSTRAINT
[FK_Lunar_Calculations_MT_Acoustic_Monitoring_Stations] FOREIGN KEY([SiteID])
REFERENCES [dbo].[MT_Acoustic_Monitoring_Stations] ([SiteID])
GO
ALTER TABLE [dbo].[Lunar_Calculations] CHECK CONSTRAINT
[FK_Lunar_Calculations_MT_Acoustic_Monitoring_Stations]
GO
ALTER TABLE [dbo].[Solar_Calculations] WITH CHECK ADD CONSTRAINT
[FK_Solar_Calculations_MT_Acoustic_Monitoring_Stations] FOREIGN KEY([SiteID])
REFERENCES [dbo].[MT_Acoustic_Monitoring_Stations] ([SiteID])
GO
ALTER TABLE [dbo].[Solar_Calculations] CHECK CONSTRAINT
[FK_Solar_Calculations_MT_Acoustic_Monitoring_Stations]
GO
ALTER TABLE [dbo].[Temp_Logger_Master] WITH CHECK ADD CONSTRAINT
[FK_Temp_Logger_Master_MT_Acoustic_Monitoring_Stations] FOREIGN KEY([SiteID])
REFERENCES [dbo].[MT_Acoustic_Monitoring_Stations] ([SiteID])
GO
ALTER TABLE [dbo].[Temp_Logger_Master] CHECK CONSTRAINT
[FK_Temp_Logger_Master_MT_Acoustic_Monitoring_Stations]
GO
ALTER TABLE [dbo].[TemperatureLU] WITH CHECK ADD CONSTRAINT
[FK_TemperatureLU_MT_Acoustic_Monitoring_Stations] FOREIGN KEY([SiteID])
REFERENCES [dbo].[MT_Acoustic_Monitoring_Stations] ([SiteID])
GO
ALTER TABLE [dbo].[TemperatureLU] CHECK CONSTRAINT
[FK_TemperatureLU_MT_Acoustic_Monitoring_Stations]
GO
ALTER TABLE [dbo].[WAV_Master] WITH CHECK ADD CONSTRAINT
[FK_WAV_Master2_MT_Acoustic_Monitoring_Stations] FOREIGN KEY([SiteID])
REFERENCES [dbo].[MT_Acoustic_Monitoring_Stations] ([SiteID])
GO
ALTER TABLE [dbo].[WAV_Master] CHECK CONSTRAINT
[FK_WAV_Master2_MT_Acoustic_Monitoring_Stations]
GO

```

Query Code for filling in supplementary fields in a SQL Server Database
Change highlighted text as needed.

```

/***** These queries match bat call batch data output from Sonobat to *****/
/***** temperature logger, solar, lunar, and weather data within a SQL server *****/
/***** environment. If these data are not present, some queries will not *****/
/***** update any records. If queries require a SiteID, change as needed. *****/

/***** After data from a Site is Downloaded and Imported: *****/
/***** CHECK APPEND COUNTS *****/
SELECT COUNT(*)
FROM NHPBat.dbo.WAV_Master WAV
WHERE ((WAV.SiteID) Is Null);

SELECT COUNT(*)
FROM NHPBat.dbo.PlainsAppend Plns
WHERE ((Plns.SiteID) Is Null);

SELECT COUNT(*)
FROM NHPBat.dbo.Temp_Logger_Master TEMP
WHERE ((TEMP.SiteID) Is Null);

/***** ENTER VARIABLES *****/
--Site to assign
DECLARE @site_id INT = SiteID;
--Download Date to assign
DECLARE @ddate INT = 20150101;

/***** ASSIGN SiteID *****/
UPDATE WAV
SET WAV.SiteID = @site_id
FROM NHPBat.dbo.WAV_Master WAV
WHERE ((WAV.SiteID) Is Null);

UPDATE Plns
SET Plns.SiteID = @site_id
FROM NHPBat.dbo.PlainsAppend Plns
WHERE ((Plns.SiteID) Is Null);

UPDATE TEMP
SET TEMP.SiteID = @site_id
FROM NHPBat.dbo.Temp_Logger_Master TEMP
WHERE ((TEMP.SiteID) Is Null);

/***** APPEND PLAINS *****/
UPDATE WAV SET [P_Class_Group] = Plns.P_Class_Group
, [P_Class_Group_DiscrProb] = Plns.P_Class_Group_DiscrProb
, [P_FcMean] = Plns.P_FcMean
, [P_FcStdDev] = Plns.P_FcStdDev
, [P_DurMean] = Plns.P_DurMean
, [P_DurStdDev] = Plns.P_DurStdDev
, [P_Mean_Calls_Sec] = Plns.P_Mean_Calls_Sec
, [P_SpeciesRank1] = Plns.P_SpeciesRank1
, [P_SpeciesRank2] = Plns.P_SpeciesRank2
```

```

        ,[P_SpeciesRank3] = Plns.P_SpeciesRank3
        ,[P_SpeciesRank4] = Plns.P_SpeciesRank4
        ,[P_SpeciesRank5] = Plns.P_SpeciesRank5
        ,[P_SpeciesRank6] = Plns.P_SpeciesRank6
FROM NHPBat.dbo.WAV_Master WAV JOIN NHPBat.dbo.PlainsAppend Plns ON WAV.[Filename] =
Plns.[Filename]
WHERE (((WAV.P_Mean_Calls_Sec) Is Null)) AND WAV.SiteID = @site_id;

/***** FILENAME SPLITTING *****/
-- Variables for different Filename structures
DECLARE @offset INT;
DECLARE @offset2 INT;
SET @offset = (SELECT DISTINCT (CASE
WHEN [Filename] LIKE '%|_|_0|_|_0|_20%' ESCAPE '|' THEN 4
WHEN [Filename] LIKE '%|_|_0|_|_20%' ESCAPE '|' THEN 1
WHEN [Filename] LIKE '%|_0|_20%' ESCAPE '|' THEN 0
WHEN [Filename] LIKE '%|_20%' ESCAPE '|' THEN -2 END)
FROM NHPBat.dbo.WAV_Master WHERE (Date Is Null AND SiteID = @site_id));
SET @offset2 = (SELECT DISTINCT (CASE
WHEN [Filename] LIKE '%|_|_0|_|_0|_20%' ESCAPE '|' THEN 4
WHEN [Filename] LIKE '%|_|_0|_|_20%' ESCAPE '|' THEN 1
WHEN [Filename] LIKE '%|_0|_20%' ESCAPE '|' THEN 0
WHEN [Filename] LIKE '%|_20%' ESCAPE '|' THEN 0 END)
FROM NHPBat.dbo.WAV_Master WHERE (Date Is Null AND SiteID = @site_id));

-- Apply variables and extract data
UPDATE WAV
SET WAV.Location = Left((WAV.[Filename]),(Len(STN.SiteNameShort))),
WAV.Channel = Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset2+2),1),
WAV.Year = Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+4),4),
WAV.Month = Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+8),2),
WAV.Day = Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+10),2),
WAV.Hour =
convert(datetime,Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+13),2)+'':00:0
0',114),
WAV.HHMMSS =
convert(datetime,Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+13),2)+'':'+
Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+15),2)+'':'+Substring((WAV.[Fil
ename]),(Len(STN.SiteNameShort)+@offset+17),2),114),
WAV.Date =
convert(datetime,Substring((WAV.[Filename]),(Len(STN.SiteNameShort)+@offset+4),8), 112)
FROM NHPBat.dbo.WAV_Master WAV JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations STN ON
WAV.SiteID = STN.SiteID
WHERE (((WAV.Location) Is Null) AND (WAV.SiteID = @site_id));

/***** INITIAL Master_Class VALUES *****/
UPDATE WAV SET
WAV.Master_Class = CASE
WHEN WAV.Master_Class IS NULL AND WAV.M_Sonobat_Class IS NOT NULL THEN
WAV.M_Sonobat_Class
WHEN WAV.Master_Class IS NULL AND WAV.S_Sonobat_Class IS NOT NULL THEN
WAV.S_Sonobat_Class
WHEN WAV.Master_Class IS NULL AND WAV.S_Sonobat_Class IS NULL AND WAV.P_Sonobat_Class IS
NOT NULL THEN WAV.P_Sonobat_Class
WHEN WAV.Master_Class = 'Undetermined' AND WAV.S_Sonobat_Class IS NULL AND
WAV.P_Sonobat_Class IS NOT NULL THEN WAV.P_Sonobat_Class

```

```

WHEN WAV.Master_Class IS NULL AND WAV.M_Sonobat_Class IS NULL AND WAV.S_Sonobat_Class IS
NULL AND WAV.P_Sonobat_Class IS NULL THEN 'Undetermined'
END
FROM NHPBat.dbo.WAV_Master WAV
WHERE ((WAV.Master_Class IS NULL) AND (WAV.SiteID = @site_id));

/***** DATE AND TIME *****/
UPDATE NHPBat.dbo.WAV_Master
SET Date_Time = DT.Date_Time,
    Sample_Night = DATEADD(dd, DATEDIFF(dd, 0, DATEADD(hh,-12,DT.Date_Time)), 0),
    Date_Time_Round = DATEADD(mi, DATEDIFF(mi,0,DATEADD(s,150,DT.Date_Time)) / 5 * 5,
0),
    DateTime_RoundHour = DATEADD(hh, DATEDIFF(hh, 0, DATEADD(mi, 30, DT.Date_Time)),
0),
    Temp_toLU = 0
FROM(
SELECT WAV.ID, CAST(CAST(WAV.[Date] AS DATE) AS DATETIME) + CAST(WAV.HHMMSS AS TIME) AS
Date_Time
FROM NHPBat.dbo.WAV_Master WAV
WHERE ((WAV.Date_Time Is Null) AND (SiteID = @site_id))
) DT INNER JOIN NHPBat.dbo.WAV_Master ON NHPBat.dbo.WAV_Master.ID = DT.ID;

/***** ASSIGN DOWNLOAD DATE *****/
UPDATE WAV
SET WAV.Download_Date = @ddate
FROM NHPBat.dbo.WAV_Master WAV
WHERE (((WAV.Download_Date) Is Null) AND ((WAV.SiteID)=@site_id)
AND
((DateDiff("n", (WAV.[Date_Time]), DateAdd(hh,12,convert(datetime,str(@ddate),112))))>0));

/***** SOLAR DATA *****/
UPDATE NHPBat.dbo.WAV_Master
SET Sunrise = ST.Sunrise,
    Sunset = ST.Sunset,
    Daylength_M = ST.Daylength_M,
    NightLength_M = ST.NightLength_M,
    Time_After_Sunset = CONVERT(datetime,CONVERT(varchar(8), DATEADD(s,
DATEDIFF(ss,ST.Sunset, ST.Date_Time), 0), 114),114),
    Hour_After_Sunset = CONVERT(datetime,CONVERT(varchar(8), DATEADD(hh,
(DATEDIFF(ss,ST.Sunset, ST.Date_Time)/3600), 0), 114),114)
FROM(
SELECT WAV.ID, WAV.Date_Time,
    SOLAR.[Sunrise] AS Sunrise,
    SOLAR.[Sunset] AS Sunset,
    SOLAR.[Daylength_M] AS Daylength_M,
    (1440-SOLAR.[Daylength_M]) AS NightLength_M
FROM NHPBat.dbo.WAV_Master WAV JOIN NHPBat.dbo.Solar_Calculations SOLAR ON WAV.SiteID =
SOLAR.SiteID AND WAV.[Date] = SOLAR.[Date]
WHERE (((WAV.Sunrise) Is Null) AND (WAV.SiteID = @site_id))
) ST INNER JOIN NHPBat.dbo.WAV_Master ON NHPBat.dbo.WAV_Master.ID = ST.ID;

/***** LUNAR DATA *****/
UPDATE NHPBat.dbo.WAV_Master
SET MoonUp = MoonData.Moon,

```



```

        MoonIllum = MoonData.midNightIllum
FROM (
SELECT MoonTbl.ID, MoonTbl.midNightIllum,
(CASE WHEN ([Before_LastRise]+[Before_LastSet]+[After_NextRise]+[After_NextSet] = 0)
THEN CASE WHEN RiseFirst=1 THEN 0 ELSE 1 END
ELSE CASE WHEN ([Before_LastRise]+[Before_LastSet]+[After_NextRise]+[After_NextSet] = 1)
THEN CASE WHEN [Before_LastRise]=1 THEN 0
            WHEN [Before_LastSet]=1 THEN 1
            WHEN [After_NextRise]=1 THEN 1
            WHEN [After_NextSet]=1 THEN 0
ELSE NULL END END END) AS Moon
FROM (
SELECT WAV_Master.ID, Lunar_Calculations.LastRise, Lunar_Calculations.LastSet,
Lunar_Calculations.NextRise, Lunar_Calculations.NextSet,
Lunar_Calculations.midNightIllum,
(CASE WHEN ([Date_Time]<[LastRise]) THEN 1 ELSE 0 END) AS Before_LastRise,
(CASE WHEN ([Date_Time]<[LastSet]) THEN 1 ELSE 0 END) AS Before_LastSet,
(CASE WHEN ([Date_Time]>[NextRise]) THEN 1 ELSE 0 END) AS After_NextRise,
(CASE WHEN ([Date_Time]>[NextSet]) THEN 1 ELSE 0 END) AS After_NextSet,
(CASE WHEN ([LastRise]<[LastSet]) THEN 1 ELSE 0 END) AS RiseFirst
FROM NHPBat.dbo.WAV_Master INNER JOIN NHPBat.dbo.Lunar_Calculations
ON (NHPBat.dbo.WAV_Master.SiteID = NHPBat.dbo.Lunar_Calculations.SiteID) AND
(NHPBat.dbo.WAV_Master.Sample_Night = NHPBat.dbo.Lunar_Calculations.SampleNight)
WHERE ((NHPBat.dbo.WAV_Master.SiteID)=@site_id AND (NHPBat.dbo.WAV_Master.MoonUp IS
NULL))) AS MoonTbl
) AS MoonData INNER JOIN NHPBat.dbo.WAV_Master ON NHPBat.dbo.WAV_Master.ID =
MoonData.ID;

```

```

/***** TEMPERATURE LOGGER DATE AND TIME *****/
UPDATE TEMP
SET TEMP.Date_Time = CAST(CAST(TEMP.[Date] AS DATE) AS DATETIME) + CAST(TEMP.[TIME] AS
TIME),
TEMP.Date_Time_Round = DATEADD(mi, DATEDIFF(mi,0,DATEADD(s,150,(CAST(CAST(TEMP.[Date] AS
DATE) AS DATETIME) + CAST(TEMP.[TIME] AS TIME)))) / 5 * 5, 0)
FROM NHPBat.dbo.Temp_Logger_Master TEMP
WHERE (((TEMP.Date_Time_Round) Is Null) AND TEMP.SiteID = @site_id);

```

```

/***** APPEND TEMP LOGGER DATA *****/
UPDATE WAV
SET WAV.tDate_Time = TEMP.[Date_Time],
WAV.tDate_Time_Round = TEMP.[Date_Time_Round],
WAV.Temp_C = TEMP.[Temp_C],
WAV.Temp_Time_Diff_M = abs(DATEDIFF(mi,WAV.[Date_Time],TEMP.[Date_Time])),
WAV.Temp_toLU = 1
FROM NHPBat.dbo.WAV_Master WAV INNER JOIN NHPBat.dbo.Temp_Logger_Master TEMP
ON (WAV.SiteID = TEMP.SiteID) AND (WAV.Date_Time_Round = TEMP.Date_Time_Round)
WHERE ((WAV.tDate_Time IS NULL) AND (WAV.SiteID = @site_id));

```

```

/***** APPEND WEATHER DATA *****/
-- Append average Temperature for the current hour
UPDATE NHPBat.dbo.WAV_Master
SET TempWx_C = dataStnWxHr.AvgTemp
FROM NHPBat.dbo.WAV_Master WAV
INNER JOIN (
SELECT dataStn.SiteID, dataStn.ID, WxHr.AvgTemp

```

```

FROM (
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Temp
FROM (
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBat.dbo.WAV_Master
WHERE ((TempWx_C IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, Round(Avg(Air_Temp),2) AS AvgTemp
FROM NHPBat.dbo.Ratz_Weather_Data
GROUP BY STID, DateTimeMST_RoundHour
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Temp AND WxHr.DateTimeMST_RoundHour =
dataStn.DateTime_RoundHour
) AS dataStnWxHr ON dataStnWxHr.SiteID = WAV.SiteID AND dataStnWxHr.ID = WAV.ID;

-- Append average Wind Speed for the current hour
UPDATE NHPBat.dbo.WAV_Master
SET Wind_m_s = dataStnWxHr.AvgWind
FROM NHPBat.dbo.WAV_Master WAV
INNER JOIN (
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour,
WxHr.DateTimeMST_RoundHour, WxHr.AvgWind
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Wind
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBat.dbo.WAV_Master
WHERE ((Wind_m_s IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, Round(Avg(Wind_Speed),2) AS AvgWind
FROM NHPBat.dbo.Ratz_Weather_Data
GROUP BY STID, DateTimeMST_RoundHour
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Wind AND WxHr.DateTimeMST_RoundHour =
dataStn.DateTime_RoundHour
) AS dataStnWxHr ON dataStnWxHr.SiteID = WAV.SiteID AND dataStnWxHr.ID = WAV.ID;

-- Append SECONDARY average Wind Speed for the current hour
UPDATE NHPBat.dbo.WAV_Master
SET Wind2_m_s = dataStnWxHr.AvgWind
FROM NHPBat.dbo.WAV_Master WAV
INNER JOIN (
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour,
WxHr.DateTimeMST_RoundHour, WxHr.AvgWind
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Wind2
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBat.dbo.WAV_Master
WHERE ((Wind2_m_s IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN

```

```

(SELECT STID, DateTimeMST_RoundHour, Round(Avg(Wind_Speed),2) AS AvgWind
FROM NHPBat.dbo.Ratz_Weather_Data
GROUP BY STID, DateTimeMST_RoundHour
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Wind2 AND WxHr.DateTimeMST_RoundHour =
dataStn.DateTime_RoundHour
) AS dataStnWxHr ON dataStnWxHr.SiteID = WAV.SiteID AND dataStnWxHr.ID = WAV.ID;

--Append average Humidity for the current hour
UPDATE NHPBat.dbo.WAV_Master
SET RHumid_pcmt = dataStnWxHr.AvgHumid
FROM NHPBat.dbo.WAV_Master WAV
INNER JOIN (
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour,
WxHr.DateTimeMST_RoundHour, WxHr.AvgHumid
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Humid
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBAT.dbo.WAV_Master
WHERE ((RHumid_pcmt IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, Round(Avg(Relative_Humidity),2) AS AvgHumid
FROM NHPBat.dbo.Ratz_Weather_Data
GROUP BY STID, DateTimeMST_RoundHour
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Humid AND WxHr.DateTimeMST_RoundHour =
dataStn.DateTime_RoundHour
) AS dataStnWxHr ON dataStnWxHr.SiteID = WAV.SiteID AND dataStnWxHr.ID = WAV.ID;

-- Append Avg mb Pressure for current hour, mb_change and direction (+ -) over the
previous 2 hours
-- temp tables
CREATE TABLE #Prss0 (
SiteID int,
ID int,
RndHour Datetime2(0),
AvgPress float,
MinPress0 float,
MaxPress0 float)
CREATE TABLE #Prss1 (
SiteID int,
ID int,
RndHour Datetime2(0),
MinPress1 float,
MaxPress1 float)
-- first part is Pressure during hour of call
INSERT INTO #Prss0 (SiteID, ID, RndHour, AvgPress, MinPress0, MaxPress0)
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour, Avg(WxHr.BaroPrss_Adj_mb)
AS AvgPress, Min(WxHr.BaroPrss_Adj_mb) AS MinPress, Max(WxHr.BaroPrss_Adj_mb) AS MaxPress
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Press
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBAT.dbo.WAV_Master
WHERE ((PressChng_mb IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data

```

```

INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, BaroPrss_Adj_mb
FROM NHPBat.dbo.Ratz_Weather_Data
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Press AND WxHr.DateTimeMST_RoundHour =
dataStn.DateTime_RoundHour
GROUP BY dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour
-- second part is Pressure during hour prior to call
INSERT INTO #Prss1 (SiteID, ID, RndHour, MinPress1, MaxPress1)
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour, Min(WxHr.BaroPrss_Adj_mb)
AS MinPress1, Max(WxHr.BaroPrss_Adj_mb) AS MaxPress1
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Press
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBAT.dbo.WAV_Master
WHERE ((PressChng_mb IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, BaroPrss_Adj_mb
FROM NHPBat.dbo.Ratz_Weather_Data
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Press AND
dateadd(hh,1,WxHr.DateTimeMST_RoundHour) = dataStn.DateTime_RoundHour
GROUP BY dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour
UPDATE NHPBat.dbo.WAV_Master
SET PressChng_mb = Pressure.PressChng_mb,
Pressure_mb = Pressure.Pressure_mb
FROM NHPBat.dbo.WAV_Master WAV
INNER JOIN
(SELECT Data0.SiteID, Data0.ID, ROUND(CASE WHEN (Data0.MaxPress0-
Data1.MinPress1)>(Data1.MaxPress1-Data0.MinPress0) THEN (Data0.MaxPress0-Data1.MinPress1)
ELSE
CASE WHEN (Data0.MaxPress0-Data1.MinPress1)=(Data1.MaxPress1-Data0.MinPress0) THEN 0
ELSE(Data0.MinPress0-Data1.MaxPress1) END END, 3) AS PressChng_mb, ROUND(Data0.AvgPress,
3) AS Pressure_mb
FROM #Prss0 AS Data0
LEFT JOIN
#Prss1 AS Data1 ON Data1.SiteID = Data0.SiteID AND Data1.ID = Data0.ID AND Data1.RndHour
= Data1.RndHour
) AS Pressure
ON Pressure.SiteID = WAV.SiteID AND Pressure.ID = WAV.ID;
DROP TABLE #Prss0
DROP TABLE #Prss1

--Append Precip mm_change over the previous 2 hours
-- temp tables
CREATE TABLE #Precip0 (
SiteID int,
ID int,
RndHour Datetime2(0),
MaxPrecip0 float)
CREATE TABLE #Precip1 (
SiteID int,
ID int,
RndHour Datetime2(0),

```



```

MinPrecip1 float)
-- first part is Precip during hour of call
INSERT INTO #Precip0 (SiteID, ID, RndHour, MaxPrecip0)
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour, Max(WxHr.Precip_Accum) AS
MaxPrecip0
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Precp
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBAT.dbo.WAV_Master
WHERE ((Precip_mm_hr IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, Precip_Accum
FROM NHPBat.dbo.Ratz_Weather_Data
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Precp AND WxHr.DateTimeMST_RoundHour =
dataStn.DateTime_RoundHour
GROUP BY dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour
-- second part is Precip during hour prior to call
INSERT INTO #Precip1 (SiteID, ID, RndHour, MinPrecip1)
SELECT dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour, Min(WxHr.Precip_Accum) AS
MinPrecip1
FROM(
SELECT data.SiteID, data.ID, data.DateTime_RoundHour, Stn.WxStnID_Precp
FROM(
SELECT SiteID, ID, Date_Time, DateTime_RoundHour
FROM NHPBAT.dbo.WAV_Master
WHERE ((Precip_mm_hr IS NULL) AND (Download_Date = @ddate) AND (SiteID = @site_id))
) AS data
INNER JOIN NHPBat.dbo.MT_Acoustic_Monitoring_Stations AS Stn ON Stn.SiteID = data.SiteID
) AS dataStn
LEFT JOIN
(SELECT STID, DateTimeMST_RoundHour, Precip_Accum
FROM NHPBat.dbo.Ratz_Weather_Data
) AS WxHr ON WxHr.STID = dataStn.WxStnID_Precp AND
dateadd(hh,1,WxHr.DateTimeMST_RoundHour) = dataStn.DateTime_RoundHour
GROUP BY dataStn.SiteID, dataStn.ID, dataStn.DateTime_RoundHour
UPDATE NHPBat.dbo.WAV_Master
SET Precip_mm_hr = Precip.Precip_hr_mm
FROM NHPBat.dbo.WAV_Master WAV
INNER JOIN
(SELECT Data0.SiteID, Data0.ID, Data0.RndHour, (CASE
WHEN MaxPrecip0 IS NULL THEN NULL
WHEN MinPrecip1 IS NULL THEN NULL
WHEN (MaxPrecip0 < MinPrecip1) THEN NULL
ELSE Round(MaxPrecip0-MinPrecip1, 3) END) AS Precip_hr_mm
-- first part is MaxPrecip during hour of call
FROM #Precip0 AS Data0
INNER JOIN
-- second part is MinPrecip during hour prior to call
#Precip1 AS Data1 ON Data1.SiteID = Data0.SiteID AND Data1.ID = Data0.ID AND
Data1.RndHour = Data1.RndHour
) AS Precip
ON Precip.SiteID = WAV.SiteID AND Precip.ID = WAV.ID;
DROP TABLE #Precip0
DROP TABLE #Precip1

```

Appendix 9

Downloading Weather Station Data from Mesowest

Braden Burkholder bburkholder@mt.gov, Dave Ratz, and Bryce Maxell
Montana Natural Heritage Program
1515 East, 6th Avenue, Helena, Montana 59620

The Data Request Code below can be used to download data from a single weather station from the nationwide network of weather stations represented on the Mesowest Application Programming Interface <http://mesowest.utah.edu/>. Just plug in the STID (station id...e.g., E5549) for the site of interest as listed on the Mesowest website, and the start (e.g., 7/23/2014 as 20140723) and end (e.g., 3/1/2015 as 20150301) dates of interest into the red font sections in the URL code below and paste the resulting text string into a web browser to get a text file of weather data back. We have also developed code that can be used to download weather station data for multiple sites at once. Please contact us if that is of interest, but you would need to get your own token from Mesowest in order to do this.

http://api.mesowest.net/v2/stations/timeseries?stid=E5549&start=201407230000&end=201503010000&vars=air_temp,relative_humidity,wind_speed,wind_direction,solar_radiation,altimeter,precip_accum&token=cf05237b2fe34b6bb744a6dd1a482c69&output=csv

*Please note that the default time output in the resulting text file is in Coordinated Universal Time (UTC) so you will need to adjust this to match your local time zone and whether you want it represented in daylight savings or standard time http://www.worldtimeserver.com/current_time_in.UTC.aspx

** refer to the API documentation (<http://mesowest.org/api/v2/docs/>) for changing this or other variables in the URL query string (e.g. additional sensors may be present at your site of interest).

Appendix 10
Montana Bat Acoustic Solar and Lunar Data

Python (v. 2.7.8) Code

with packages:
ephem (3.7.6.0)
pyodbc (3.0.7)

Authorship/Contact:

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Solar Data - code for computation and database storage
Change highlighted text as needed.

```
###
```

```
import datetime, pyodbc, ephem
```

```
MST=-7.0/24.0 # UTC correction factor
```

```
serverName = 'Server_Name'
```

```
batDatabase = 'BatDBName'
```

```
sites = ()
```

```
# generate valid site list
```

```
cnxn = pyodbc.connect(driver='{SQL
```

```
Server}',server=serverName,database=batDatabase,trusted_connection=True)
```

```
cursor = cnxn.cursor()
```

```
siteQry = cursor.execute("SELECT SiteID \n\nFROM MT_Acoustic_Monitoring_Stations\n\nWHERE Status IN ('Installed','Decommissioned')")
```

```
for site in siteQry:
```

```
    sites+=(site[0],)
```

```
cursor.close()
```

```
cnxn.close()
```

```
# iterate for all sites
```

```
for SiteID in sites:
```

```
    # get site data
```

```
    cnxn = pyodbc.connect(driver='{SQL
```

```
Server}',server=serverName,database=batDatabase,trusted_connection=True)
```

```
    cursor = cnxn.cursor()
```

```
    cursor.execute("SELECT SiteID, Latitude, Longitude, Installation_Date, Decommission_Date, Status \n\nFROM MT_Acoustic_Monitoring_Stations\n\nWHERE SiteID="+ str(SiteID))
```

```
    SiteInfo=list(cursor.fetchone())
```

```
    SiteInfo=list(cursor.fetchone())
```

```
    cursor.close()
```

```
    cnxn.close()
```

```
# format dates, default end date if NULL
```

```
startDate = datetime.datetime.strptime(str(SiteInfo[3]),'%Y-%m-%d %H:%M:%S')
```

```
if SiteInfo[4] == None:
```

```
    endDate = datetime.datetime(2017, 12, 31, 0, 0)
```

```
else:
```

```
    endDate = datetime.datetime.strptime(str(SiteInfo[4]),'%Y-%m-%d %H:%M:%S')
```



```

# buffer dates to months deployed
startMonth = datetime.datetime(startDate.timetuple()[0],startDate.timetuple()[1],1)
endMonth =
datetime.datetime((endDate+datetime.timedelta(days=31)).timetuple()[0],(endDate+datetime.timedelt
a(days=31)).timetuple()[1],1)
AprxDays = (endMonth - startMonth)

# adjust to noon MST
startMonth += datetime.timedelta(hours=19)

# sun viewing site parameters
site = ephem.Observer()
site.pressure = 0
site.horizon = '-0:34'
site.lat, site.long = str(SiteInfo[1]),str(SiteInfo[2])

# create date list for range provided above
date_list = [startMonth + datetime.timedelta(days=x) for x in range(0, AprxDays.days)]

cnxn = pyodbc.connect(driver='{SQL
Server}',server=serverName,database=batDatabase,trusted_connection=True)
cursor = cnxn.cursor()

# iterate for all dates
for date in date_list:
    site.date = date
    # sun object created
    sun = ephem.Sun()
    #check if data already exist for site and date
    cursor.execute("SELECT SiteID FROM Solar_Calculations WHERE SiteID = "+\
        str(SiteInfo[0]) +" AND Date = '"+str(ephem.date(site.date-0.5))+"'")
    if cursor.rowcount == 0:
        # write new record if not present
        delta = ephem.date(site.next_setting(sun)+MST)-ephem.date(site.previous_rising(sun)+MST)
        cursor.execute("INSERT INTO Solar_Calculations "\
            "VALUES (" + str(SiteInfo[0]) + "," + "\
            str(ephem.date(site.date+MST-0.5))+"," + "\
            str(ephem.date(site.previous_rising(sun)+MST))+"," + "\
            str(ephem.date(site.next_setting(sun)+MST))+"," + "\
            str(round(delta*1440))+")")
        cnxn.commit()
    else:
        pass
cursor.close()
cnxn.close()

```

Lunar Data - code for computation and database storage
Change highlighted text as needed.

```
###
```

```
import datetime, pyodbc, ephem
```

```
MST=-7.0/24.0 # UTC correction factor
```

```
serverName = 'Server_Name'
```

```
batDatabase = 'BatDBName'
```

```
sites = ()
```

```
# generate valid site list
```

```
cnxn = pyodbc.connect(driver='{SQL
```

```
Server}',server=serverName,database=batDatabase,trusted_connection=True)
```

```
cursor = cnxn.cursor()
```

```
siteQry = cursor.execute("SELECT SiteID \n\nFROM MT_Acoustic_Monitoring_Stations\n\nWHERE Status IN ('Installed','Decommissioned')")
```

```
for site in siteQry:
```

```
    sites+=(site[0],)
```

```
cursor.close()
```

```
cnxn.close()
```

```
# iterate for all sites
```

```
for SiteID in sites:
```

```
    # get site data
```

```
    cnxn = pyodbc.connect(driver='{SQL
```

```
Server}',server=serverName,database=batDatabase,trusted_connection=True)
```

```
    cursor = cnxn.cursor()
```

```
    cursor.execute("SELECT SiteID, Latitude, Longitude, Installation_Date, Decommission_Date, Status \n\nFROM MT_Acoustic_Monitoring_Stations\n\nWHERE SiteID="+ str(SiteID))
```

```
    SiteInfo=list(cursor.fetchone())
```

```
    SiteInfo=list(cursor.fetchone())
```

```
    cursor.close()
```

```
    cnxn.close()
```

```
# format dates, default end date if NULL
```

```
startDate = datetime.datetime.strptime(str(SiteInfo[3]),'%Y-%m-%d %H:%M:%S')
```

```
if SiteInfo[4] == None:
```

```
    endDate = datetime.datetime(2017, 12, 31, 0, 0)
```

```
else:
```

```
    endDate = datetime.datetime.strptime(str(SiteInfo[4]),'%Y-%m-%d %H:%M:%S')
```

```

# buffer dates to months deployed
startMonth = datetime.datetime(startDate.timetuple()[0],startDate.timetuple()[1],1)
endMonth =
datetime.datetime((endDate+datetime.timedelta(days=31)).timetuple()[0],(endDate+datetime.timedelt
a(days=31)).timetuple()[1],1)
AprxDays = (endMonth - startMonth)

# adjust to midnight MST
startMonth += datetime.timedelta(hours=7)

# moon viewing site parameters
site = ephem.Observer()
site.pressure = 0
site.horizon = '-0:34'
site.lat, site.long = str(SiteInfo[1]),str(SiteInfo[2])

# create date list for range provided above
date_list = [startMonth + datetime.timedelta(days=x) for x in range(1, AprxDays.days+1)]

cnxn = pyodbc.connect(driver='{SQL
Server}',server=serverName,database=batDatabase,trusted_connection=True)
cursor = cnxn.cursor()

# iterate for all dates
for date in date_list:
    site.date = date
    # moon objects created
    moon = ephem.Moon()
    moonPhs = ephem.Moon(site.date)

#check if data already exist for site and sample night
cursor.execute("SELECT SiteID FROM Lunar_Calculations WHERE SiteID = "+\
    str(SiteInfo[0]) +" AND SampleNight = '"+str(ephem.date(site.date+MST-1))+"'")
if cursor.rowcount == 0:
    # write new record if not present
    cursor.execute("INSERT INTO Lunar_Calculations "\
        "VALUES (" + str(SiteInfo[0]) + "," + "\
        str(ephem.date(site.date+MST-1))+"," + "\
        str(ephem.date(site.previous_rising(moon)+MST))+"," + "\
        str(ephem.date(site.previous_setting(moon)+MST))+"," + "\
        str(ephem.date(site.next_rising(moon)+MST))+"," + "\
        str(ephem.date(site.next_setting(moon)+MST))+"," + "\
        str(round(moonPhs.moon_phase, 3))+")")
    cnxn.commit()
else:
    pass
cursor.close()
cnxn.close()

```