Report 2020: Study of Seasonal Altitudinal Migrations, Overwintering Activity Patterns, and Continued Surveys for Bats on Boulder County Open Space

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SECTION 1, <u>Abstract</u>

We continued our study of bat abundance, distribution, and species richness of Heil Valley Ranch, Hall Ranch, Walden Ponds, Twin Lakes, Cardinal Mill, Blue Jay Mine, Platt-Rogers Memorial Park, and Rocky Mountain Mammoth. We also continue study of seasonal elevational migrations in St. Vrain Canyon at locations that correspond with BOCO Open Space properties (Hall Ranch, Adams-Cowger, and Randolf-Pratt). In 2019, we began fall/winter sonar surveys for bats and have found activity in every month from November 2019-May 2020 at Ingersol Quarry indicating over-wintering bats at that site. We continued sonar surveys on Geer and Plumley canyons and also at a thinned area near Ingersol Quarry that we have monitored over the years to better understand how forest thinning affects bat foraging patterns.

Hypotheses

We hypothesize that surveyed areas of Heil Valley Ranch will continue to show significant bat diversity. We also hypothesize that tricolored and red bats will be found to be reproducing in eastern BOCO properties. In addition, we hypothesize that seasonal migration patterns in hibernating species of bats will show significant movements of species through St. Vrain Canyon. Based on preliminary data, winter activity and local hibernacula will be found to be persistent at Ingersol Quarry.

Summary of published literature

Although previously there had been only two individuals of the tricolor bat (*Perimyotis subflavus*) found in Boulder County, Colorado over the years (Armstrong et al. 2006, RA Adams personal observation 2013) with no evidence of reproductive individuals, in 2017 a female with two pups was found along South Boulder Creek. The tricolored bat has been devastated by white-nose syndrome in the eastern US and a petition has been submitted for listing this species as endangered. This provides the first evidence that this species now has reproductive populations in the state (Adams et al. 2018). In addition, Boulder County bats are showing apparent changes in population numbers and seasonal elevational migration (Adams 2018, Adams and Hayes 2020) and in sex-ratios (Adams and Hayes 2018) and these patterns align with climate change. Winter activity in areas with below freezing winter temperatures is poorly studied, but activity over water during winter in arid regions of western North America has been documented in New Mexico (Geluso 2007) and Utah (Ruffner 1979). Almost nothing is known about seasonal migrations over elevations from hibernacula to lowlands in the spring and pattern reversal in the fall. In addition, monitoring over elevational gradients may give valuable information on how bat activity and distribution patterns may change in light of climate warming (Adams 2018).

Methods

Captures: No mist netting was done in 2020 due to COVID19.

Sonar Surveys: Sonar surveys give much resolution into bat assemblage structure and are noninvasive, thus providing unobstructed insight into bat behavior and ecology. We conducted acoustic surveys using SM2+ and SM4 sonar detectors (Wildlife Acoustics, Inc.) with call analysis using SonoBat 4.1 species identification programs (SonoBat, Inc., Arcata, CA). In some cases, detectors were deployed over a 4-night regimen to discern species presence, whereas in other cases continuous monitoring was conducted to discern seasonal activity patterns.

Results

Winter/Spring Activity at Ingersol Quarry: I conducted overwinter sonar surveys using an SM4 with an SMM-U2 microphone place in a stationary location at the NW end of Ingersol Quarry (Fig. 1) from 14 September 2019 till 13 May 2020. The general trend was decreasing activity from autumn into



Figure 1. Positioning of SM4 at Ingersol Quarry for fall, winter, spring surveys.

winter, but activity from some bat species persisted throughout winter, with increasing activity and species richness into spring (Fig. 2). There was a curious dip in activity between 7 and 25 March 2020 with a large rebound by the end of March and into May. Snow precluded access at times during winter and fall 2020 which is represented by gaps in data collection.



Figure 2. Totals (all species combined) of bat activity (defined as total number of bat sequences, i.e. passes) recorded at Ingersol Quarry from 17 October 2019 to 13 May 2020.

The fact that bats were active at Ingersol Quarry throughout the winter months is clear indication that some individuals of some species are persisting and hibernating at the site. Boyles et al. (2016) reviewed the literature and found Townsend's big-eared bat, Corynorhinus townsendii, moved between caves during winter in central California (Pearson et al. 1952) as well as several studies concerning winter activity of big brown bats, E. fuscus. Little brown myotis (M. lucifugus) have been found active in winter in some parts of their range and eastern pipistrelles (now known as tricolored bats, Perimyotis subflavus) were rarely active in winter in Indiana (Whitaker and Rissler 1992). Lausen and Barclay (2006) reported *E. fuscus* flying during winter at air temperatures as low as -7.9C in Alberta, Canada. As for migratory species, one hoary bat (L. cinereus) was found active in January in Indiana (Whitaker 1967) with evidence it had been feeding and this species has been observed active in February in Pennsylvania (Doutt et al. 1966). GPS tags on several L. cinereus in northern California, Oregon, and western Nevada, showed that *L. cinereus* was capable of hibernation in these areas (Weller et al. 2016). As for silver-haired bats (Lasionycteris noctivagans), Falxa (2007) found winter activity for this species in Olympia, Washington that experiences a maritime climate. As far back as 1962, Pearson observed L. noctivagans hibernating in silica mines in southern Illinois (Pearson 1962). This species has also been observed hibernating in building on Lake Michigan (Kurta et al. 2018). Brigham (1995) found a silverhaired bat hibernating in a building in Saskatchewan. It was an emaciated juvenile and died two days later. Bonewell et al. (2017) found a total of five (1-2 individuals in any survey) L. noctivagans hibernating in an abandoned mine in southwestern Colorado from 2004-2008.

Bat Activity in Relation to Ambient Temperatures: Temperatures measured at Ingersol Quarry were measured from 25 January to 13 May (Fig. 3) and showed fluctuations across days and months . Some discrepancies in higher temperatures were noted. Temperatures in the 30s are likely a response to microhabitat conditions. For example, high temperature for Boulder on 2 February was 21C whereas the SM4 measured 31.2C. Heating of rocks by sunlight at the quarry may cause a microenvironment that facilitates higher temperatures. This would make melted ice more reliable for drinking and any resident bat roosts may stay above freezing for most of the winter. These unique conditions may be the reasons that bats can persist at Ingersol Quarry year-round and even be active on any nights where daytime temperatures exceeded freezing. It should be noted that no bat activity was recorded along the stream in St. Vrain Canyon during the winter.



Figure 3. Temperature patterns based on 83,533 data points recorded at Ingersol Quarry from 25 January to 13 May 2020.

Bat activity at Ingersol Quarry during the winter (25 Jan – 7 February) was significant and appeared to be related to temperature (Fig. 4). When temperatures were warmer, activity increased, and bats were also active at night and early morning hours. When temperatures were cooler, activity only occurred in early evening hours. Winter activity of bats during winter is thought to be from individuals that are not using traditional underground caverns as hibernacula, but instead using nontraditional roosts such as scree slopes, rock crevices and rock piles or possibly underground burrows for hibernation. In dry climates, individuals over-wintering in these types of hibernacula lose water through evaporative water loss and therefore must replenish those losses. When diurnal temperatures are higher and sunlight melts ice, bats leave these hibernacula to find drinking water (Speakman and Racey 1989).



Figure 4. Relationship between temperature and bat activity at Ingersol Quarry from 25 January to 07 February 2020. Temperature data line is composed from 19,464 data points taken over the 14 days.

Species Richness Dynamics at Ingersol Quarry Autumn to Spring: In September 2019, 10 species were recorded at Ingersol (Fig. 5). Of the myotis, *M. evotis* was the recorded in highest relative numbers, followed by *M. ciliolabrum*, and then *M. thysanodes*. Ingersol remains an important resource for these species. Outside of myotis species, there was a high relative incidence of big brown bats (*E. fuscus*) followed by hoary bats (*L. cinereus*). In late October, all 10 species were still present, but the ensemble was dominated by *M. ciliolabrum*, *E. fuscus*, *L. cinereus*, and silver-haired bats (*Lasionycteris noctivagans*).



Figure 5. Frequency of Occurrence of 10 bat species active at Ingersol Quarry from September to December 2019. MYCI = *Myotis ciliolabrum*, MYEV = *M. volans*, MYLU = *M. lucifugus*, MYTH = *M. thysanodes*, MYVO = *M. volans*, EPFU = *Eptesicus fuscus*, COTO = *Corynorhinus townsendii*, LACI – *Lasiurus cinereus*, LANO = *Lasionycteris noctivagans*, and PESU = *Perimyotis subflavus*.

In November, species richness had dropped to four, with only *M. ciliolabrum* present for the myotis species and *E. fuscus* and *L. cinereus* being most active. In mid- to late-December, *M. ciliolabrum* persisted at the site, with a few calls of the long-eared myotis (*M. evotis*) and fringed myotis (*M. thysanodes*). *Eptesicus fuscus* continued to be present, and surprising, migratory species *L. cinereus* and *L. noctivagans* continued to be active, showing clear evidence of over-wintering activity. Curiously, Passes per Night (PPN) increased with decreasing temperatures, but these calls are across fewer species of bats.

In 2020, bat activity was monitored at Ingersol from January to May. In late January and early February (Fig 6A), migratory species *L. cinereus* and *L. noctivagans* persisted in relatively high numbers of passes, again supporting local over-wintering. All myotis species had disappeared except for *M. ciliolabrum*, which clearly is overwintering at the site as well. In early March, a few tricolored (*Perimyotis subflavus*) and fringed myotis (*M. thysanodes*) calls were recorded with *L. cinereus*, *L. noctivagans* and *E. fuscus* also present (Fig. 6B). In late March and early April, representatives of all 10 species were recorded, and this included Townsend's big eared bat (*Corynorhinus townsendii*). In early to mid-May, numbers increased. Passes per Night (PPN) generally increased from January to May but took a dip in early March. By mid-May PPN had reached over 480 passes per night. Species accumulation curve shows all 10 species back after hibernation by 4 May 2020 (Fig 7). As species



Figure 6. Frequency of Occurrence of 10 bat species active at Ingersol Quarry from January to May 2020.

accumulated at Ingersol from January to May, presence/absence varied by species at any given time as did frequency of occurrence between 31 March and 12 April (Fig. 8A). However, from May 4th onward, all 10 species were consistently present (Fig. 8B). These data support the high importance of Ingersol Quarry to bats, not only during the breeding season, but also as an overwintering site, especially for small-footed myotis (*M. ciliolabrum*) which are likely hibernating in the rocks or rock piles



Figure 7. Species Accumulation Curve from Ingersol Quarry sonar data gathered in March into May 2020.

proximate to the quarry. As to where hoary bats (*L. cinereus*) and silver-haired bats (*L. noctivagans*) are actually roosting during the winter months, this very much remains a mystery as they are typically migratory. It would appear that the unique thermal microclimates provided by the landscape around Ingersol Quarry is allowing for overwintering of these migratory species as well as big brown bats (*E. fuscus*) and *M. ciliolabrum*.





Figure 8. Presence/Absence and activity of species over time at Ingersol Quarry **A**) March to April, **B**) April to May 2020.

Ingersol Trail Camera Data: I placed a trail camera at Ingersol Quarry in attempts to film bats drinking at the melted water's edge. Unfortunately, no bats were filmed, but other animals were. The edges of the quarry were commonly ice free during the winter. The trail-cam recorded many birds (Fig. 9A) visiting the site during daylight hours as well as skunks (Fig. 9B) and possibly a mink (Fig. 10) at night.



Figure 9. A) Frame shots from trail camera video showing birds using the edge of Ingersol Quarry to bath and drink in February. **B**) Resident striped skunks (*Mephitis mephitis*).



Figure 10. Frame shots from trail camera showing what appears to be a mink (Neovison vison) in February.

Heil Valley Ranch and Calwood Fire. On 17 October 2020, the Calwood fire started and reached Heil Valley Ranch burning through much of the property. SM4 bat detectors were in position in Geer Canyon and Ingersol Quarry. The unit in Geer Canyon was burned and melted (Fig. 11) but was later found to still be operational. It did not record any data due to burning of the microphone cord.





At Ingersol Quarry, the SM4 unit did survive the burn untouched (Fig. 12). Thus, the unit recorded before, throughout, and during the burn. Temperature sensor in the unit showed ambient temperatures at the detector ranged from daytime highs of about 35C to nighttime lows of -13C.



Figure 12. Temperatures (°C) recorded by the SM4BAT detector at Ingersol Quarry from 16 October – 2 November 2020.

Focusing on the temperature profile at Ingersol in relation to fire behavior indicates that the burn was closest to the quarry at about 1908h on 17 Octobers. The SM4 temperature sensor began to rise at about 1626h and continued to climb to 22.75C at 1908h and began to drop below 20C at 2011h (Fig. 13). At 0200h the temperature had dropped to 6C with a low of 1.5C reached at 0928h the morning of 18 October.



Figure 13. Temperature recording from the SM4BAT sensor from morning 17 October to evening 18 October. Increase in temperature late-afternoon into Friday night indicates when fire was most proximate to the detector, just a few meters away.

Bat activity at Ingersol during the fire was relatively high and persistent throughout the Calwood fire incident (Fig. 14). It is unclear if bats were fleeing the area as the fire moved through. Most activity was from 19-22 October 2020, there temperature data shows that heat from the fire had dissipated, although most likely smoke had not. Lower activity was recorded between 22-28 October, with an uptick and persistent activity thereafter

Adams, RA Report 2020



Figure 14. Bat activity (i.e. raw numbers of bat passes recorded) from 16 October to 2 November. Bat activity persisted during the Calwood Fire with most activity recorded on 21-22 October 2020.

The lull in bat activity appears to be linked more to ambient temperature than effects from the fire (Fig. 15). However, that bats left the area and then returned could not be ruled out. What ever the case, bats were active at the site as of early November. The SM4BAT was serviced on 8 December 2020, and thus we will be able to ascertain the state of affairs and monitor the quarry throughout the winter months to compare with December 2019 and January 2020 data.



Figure 15. bat activity at Ingersol Quarry in relation to temperature data gathered by the SM4BAT sonar detector.

Heil Valley Ranch Prairie Dog Colony: To test if bats, specifically small-footed myotis (M.

ciliolabrum) might be using Heil black-tailed prairie dog (*Cynomys ludovicianus*) burrows to overwinter in, I place an SM2 in the prairie dog colony in March. I also placed an SM2 there in early June to see what bats activity was present. From 7-16 March, only eight sonar passes were recorded with identification of two passes, one little brown myotis (*M. lucifugus*) and one silver-haired bat (*L. noctivagans*), not supporting burrow hibernation. Much more activity was recorded from 4-6 June 2020 with 209 sonar passes (PPN = 104.5). Of these 149 were identified to species with 36% of those calls being *M. ciliolabrum* further indicating preferences for this bat species to forage and perhaps roost in *C. ludovicianus* colonies (Fig. 16). Curiously, fringed myotis (*M. thysanodes*) were also prevalent foraging in the prairie dog colony when they are typically considered forest bats.



Figure 16. Frequency of Occurrence of 10 bat species foraging in the Heil Valley Ranch prairie dog colony in March 2020.

Plumely Canyon: This canyon continues to be a very active for bats at Heil Valley Ranch. Total number of calls recorded in 2020 was 9,746. July sampling in this canyon over 11 nights showed mean activity (Passes per Night-PPN) to be 659 whereas sampling over seven nights in August indicated a PPN of 499 (Fig. 17).



Figure 17. Activity patterns of bats foraging in Plumely Canyon in July and August 2020.

Ten species were recorded using the canyon in July and August (Fig. 18). During both sampling periods, the fringed myotis (*M. thysanodes*) was the most abundant. In July, big brown bats (*E. fuscus*) were secondly most common, whereas in August little brown myotis (*M. lucifugus*) were second most occurring. Of interest is that Townsend's big-eared bat (*Corynorhinus townsendii*), a species of high conservation concern, was present in both months. In addition, tricolored bats (*Perimyotis subflavus*), an eastern species that has recently been found reproducing in Boulder County, appeared to be using this area as well even though this species tends to prefer deciduous trees along rivers for roost sites. However, *P. subflavus* is known to be generalist in roosting selection, using buildings (Jones & Pagels, 1968; Winchell et al., 1996), foliage of overstory trees (Carter et al., 1999), Spanish moss of understory



trees (Menzel et al., 1999; Veilleux et al. 2003), and rock crevices (Lacki & Hutchinson, 1999).

Figure 18. Frequency of occurrence of 10 bat species recorded foraging in Plumely Canyon in July and August 2020.

Geer Canyon: A detector failure in June caused no data collection in that month. Sonar survey data from Geer Canyon in July and August 2020 showed much higher activity in July as opposed to August, similar to Plumley Canyon. Average number of passes per night (PPN) in July was 751 in July compared to 108.5 in August (Figure 19).

Ten species were recorded in Geer Canyon in 2020. In terms of species composition, in both months, fringe myotis (*Myotis thysanodes*), occurred in highest frequency in both sampling periods. In July, silver-haired bat (*L. noctivagans*) occurred in second highest frequency, followed by hoary bats (*L. cinereus*), big brown bats (*E. fuscus*), and small-footed myotis (*M. ciliolabrum*). In August, most species



Figure 19. Activity patterns of bats foraging in Geer Canyon in July and August 2020.

with the exception of *M. thysanodes* and *M. ciliolabrum*, had declined notably in Geer Canyon (Fig. 20). This is close to the timing of increased bat activity at mid- and high-elevation sites along the South St. Vrain canyon corridor. Thus hypothetically, bats were moving upslope in July and August due to record setting consecutive >32°C at lower elevations. This is also the time when females would likely be weening their young and therefore are able to move away from their maternity roost sites to other areas.

Adams, RA Report 2020



Figure 20. Frequency of occurrence of 10 bat species recorded foraging in Geer Canyon in July and August 2020.

Myotis evotis thinned site: This site (Fig.21) has been monitored over the years both before and after



Figure 21. Location of MYEV_Thinned Site (yellow pin) downslope from Ingersol Quarry.

thinning occurred in overwinter 2016. Compared to the previous years of 2016 and 2017, 2019 and 2020 showed activity that dropped off precipitously (Fig. 22). The site was not sampled in 2018. Species

activity (raw number of calls recorded per species) composition at the site has also changed dramatically, with only a few small-footed myotis (*M* . *ciliolabrum*) using the site in 2020 (Figure 23, Table 1).



Figure 22. PPN (number of raw bats passes recorded divided by survey nights) in each year shows dramatic change in usage of this area by bats in 2019 and 2020.



Figure 23. Activity of species recorded in the *M. evotis* thinned site from 2016-2020. The site was not sampled in 2018.

Table	1. Raw	numbers	of pass	es by	each	species	recorded	in <i>M</i> .	evotis	thinned	site,	gra	phed	in I	Fig.	18
			1	2		1						ω			ω	

	2016	2017	2019	2020
MYCI	140	480		8
MYEV	97	751		1
MYLU	56	615		
MYTH	4	49	4	
MYVO		17		
EPFU	22	615	2	1
СОТО		12	2	
LACI	2	45	3	
LANO	6	83		
PESU				
Totals	327	2667	11	10

St. Vrain Canyon Elevational Transect: In 2019 we began placing three SM2 sonar detectors across an elevational gradient in St. Vrain Canyon. Positions of the detectors were Site 1 (Hall Ranch, 40.12.622, 105.17.211, 1664m,), Site 2 (adjacent to Adams-Cowger, 40.10.075, 105.24.740, 2360m), and adjacent to Rudolf-Pratt (40.08.520, 105.28.198, 2602m) (Fig. 24). In 2020, a total of 13,286 bat sonar sequences was recorded from 2 January to 9 October 2020 across the three detectors.



Figure 24. South St. Vrain Canyon elevational transect showing positioning of SM2 detectors.

Bat Activity Along South St. Vrain Canyon Elevational Transect: The SM2 placed at lowest elevation (Hall Ranch) was the first to pick up any spring bat activity which began in March 2020 (Fig. 25A). Activity increased at this site into early July, peaking the last week in July and declining thereafter. At middle and higher elevations, detectors did not pick up any bat before 2 July 2020. Thus, the detectors did not measure downslope migrations from hibernacula and therefore this pattern remains

elusive. In addition, no bats registered on detectors at middle and upper elevations until a sudden burst at both sites the first week of July with over 2,000 passes at each location (Fig. 25B, C).



Figure 25. Activity of bats at detectors positioned along South St. Vrain Canyon elevational transect March to October 2020.

Overall activity at Hall Ranch was diminished in 2020 compared to 2019 (Fig. 26). Reasons for this are unclear, but Boulder did set a record for days over 32°C in 2020. It is possible that bats sought higher elevation roost sites and foraging areas when lower elevations became too warm.



Figure 26. Comparison of bat activity at Hall Ranch lower elevation transect site in 2019 (left) and 2020 (right). Unfortunately, the detector at the Ranch in 2019 failed in July, August, and September, so only comparison between June and October is available. PPN refers to passe per night which is calculated by dividing total pass numbers by number of survey night for standardization.

Comparisons of activity between 2019 and 2020 at the mid-elevation site (Adams-Cowger)

shows different activity patterns in June, August, and September with 2019 having highest activity in

August and 2020 having highest activity in July (Fig. 27). This may have been due to consistently high

temperatures and drought at lower elevations in 2020. This may also indicate how bats may react to

climate warming in general.



Figure 27. Comparison of bat activity at Adams-Cowger (mid-elevation site) in 2019 (left) and 2020 (right). PPN measures bat activity adjusted by sampling nights for standardization. Detector malfunctioned in in July 2019, so no data were recorded



At Randolf-Pratt, the highest elevation site in the transect, passes per night (PPN) was highest in 2019 in August, but was highest in 2020 in early July and persisted longer at this elevation (Fig. 28).

Figure 28. Bat activity at Rudolf-Pratt (highest elevation site) in 2019 (left) and 2020 (right). PPN measures bat activity adjusted by sampling nights for standardization.

Species Richness Through Time along Elevational Transect: Hall Ranch: At Hall Ranch, in early May (Fig. 29A) only a single identified recording from a long-legged myotis (*M. volans*) was recorded. In midMay (Fig. 29B), similarly only one call sequence was identified to species and that was a small-footed myotis (*M. ciliolabrum*). In lateMay to early June, no sonar calls were recorded at this site (Fig. 29C). Multiple species recordings were taken in midJune (Fig. 29D) showing the presence of *M. ciliolabrum* making up about 65% of recorded passes, followed by big brown bats (*E. fuscus*, 20%), the silver-haired bat (*L. noctivagans*) and lastly fringed myotis (*M. thysanodes*). Species recorded at Hall Ranch varied between 2 July (Fig 30E) and 3 September (Fig 30H) with the exception of *M. ciliolabrum* which was consistently present and contributed the most activity.



Figure 29. Distribution of species activity at Hall Ranch lowest elevation site in South St. Vrain Canyon elevational transect.

From early July through the first few days of September (Fig 25E-H), *M. ciliolabrum* continued to be the species with highest activity, however *E. fuscus* activity was recorded throughout all session.



Figure 30. Distribution of species activity at Hall Ranch lowest elevation site in South St. Vrain Canyon elevational transect.

From 4-14 September, fringed myotis (*M. thysanodes*) activity increased at the Hall ranch site (Fig 31I) and although their activity eventually declined, this species was still present from 16-26 September (Fig. 31J). From 1-9 October and also 9-18 October 2020 (Fig. 26K), only *M. ciliolabrum* was present, and their activity was very low with only two passes recorded during each survey period (31K, H).



Figure 31. Distribution of species activity at Hall Ranch lowest elevation site in South St. Vrain Canyon elevational transect.

Adams-Cowger: This is the middle elevational survey site in South St. Vrain Canyon. Bats were not recorded at this site until 2 July 2020 when over 1,111 species-identifiable passes were recorded (Fig 32A). Most of those calls were from hoary bats (*Lasiurus cinereus*) followed by silver-haired bats (*Lasionycteris noctivagans*). In August (Fig. 32C) all 10 species were present and there was greater evenness among them. This started to decline in September (Fig 32D) with hoary (*L. cinereus*) and silver-haired bats (*L. noctivagans*) making up the highest proportional presence. This pattern continued through October (Fig. 32E-G). The autumn pattern is what would be expected for locally hibernating

species moving to higher elevation towards hibernacula. The sustained activity of what were assumed migratory species (*L. cinereus* and *L. noctivagans*) is corroborated by the recordings of these species at Ingersol Quarry throughout the winter indicating a clear pattern of locally hibernating individuals for these species. A previously undocumented part of their natural history in Colorado.



Caption after next Figure (cont.)



Figure 32. Species frequency of occurrence at mid-elevation site (Adams-Cowger) from July into October 2020. There were no bats recorded from January to July 2020 at this site. N = sample size of calls identified to species. Ambient noises including wind, rain, or auto traffic may affect call quality and therefore N may not represent activity at the site, but instead simply number of identifiable recording. Be advised axes are not standardized, so percentages of occurrence vary.

Rudolf-Pratt: This site is the highest elevation site in the South St. Vrain Canyon elevational transect. The pattern recorded here was similar to what was found at the mid-elevation site (Adams-Cowger) in that no bats were recorded until early July. However, there are differences to point out. Relatively speaking, myotis species were not a major component of occurrences throughout the summer and autumn. Instead, this site was dominated by hoary (*L. cinereus*) and silver-haired bats (*L. noctivagans*) through the summer and fall. In addition, tricolored bats (*Perimyotis subflavus*) were not recorded at this elevation at all but were present in August at the mid-elevation site. Of the myotis species, the longlegged myotis (*M. volans*) a higher elevation specialist was most commonly occurring relative to other myotis species (Fig. 33A-G). Again, late residents of hoary bats (*L. cinereus*) and silver-haired bats (*L. noctivagans*) indicates the possibility of over-wintering in Boulder County, possible at higher elevations.



Caption after next Figure (cont.)



Figure 33. (A-G) Species frequency of occurrence at highest elevation site (Rudolf-Pratt) from July into October 2020. There were no bats recorded from January to July. N = sample size of calls identified to species. Ambient noises including wing, rain, or auto traffic may affect call quality and therefore N may not represent activity at the site, but instead simply number of identifiable recording. Be advised axes are not standardized, so percentages of occurrence vary.

Transect Activity: Thus far it appears that when bat emerge from hibernation, they move very quickly to lower elevation sites when weather conditions and insect availability are more fitful. The middle and high sites did not record activity until July whereas activity was detected at Hall Ranch in March. However, in any case, they do not appear to be moving along the South St. Vrain drainage during downslope migration.

Other High Elevation Sites: There were four sites above 2,000m that were surveyed in 2020, not including the elevational transect. Three of the sites were near Nederland, CO and the other was near Jamestown, CO (Fig 34).



Figure 34. Locations of four sites above 2,000m that were surveyed in 2020.

Rocky Mountain Mammoth: (39° 58.984', 105° 23.842', 2,541m) An SM4 sonar detector was deployed at RMM on 27 July 20 and stopped recording on 2 August. A total of 3,163 call sequences were recorded resulting in approximately 452 call sequences recorded per night (PPN). Of these, 1,891 call sequences were identified to species (Table 2). By far the most calls recorded was for long-legged

Number

myotis (*M. volans*). This likely indicates that RMR is a maternity roost for this species. Second most commonly recorded were little brown myotis (*M. lucifugus*) with 186 calls followed closely by small-footed myotis (*M. ciliolabrum*). Therefore, it is also possible that RMR houses maternity or bachelor colonies of these species as well. Also present at the site were long-eared myotis (*M. evotis*), fringed myotis (*M. thysanodes*), big brown bats (*E. fuscus*), silver-haired bats (*L. noctivagans*), and also a small number of tricolored bats (*Perimyotis subflavus*) (Table 1, Fig. 35) that may be roosting in the structure.

Table 2. Number	of calls	sequen	ces iden	tified to	species	at Rocl	cy Mou	ntain N	Mammo	th.	
Species	MYCI	MYEV	MYLU	MYTH	MYVO	EPFU	СОТО	LACI	LANO	PESU	Total

Species	MYCI	MYEV	MYLU	MYTH	MYVO	EPFU	СОТО	LACI	LANO	PESU	Total
Number	154	62	186	31	1352	24	5	51	19	7	1891



Figure 35. Histogram of number of sonar call sequences (i.e. activity) by species at Rocky Mountain Mammoth. N = total number of identified bats calls recorded.

Reynolds Ranch: (39° 57.108',105° 27.484', 2607m) An SM4 was positioned in an aspen grove facing south into a meadow (Fig. 36) from 23-27 July 2020. Highest number of sonar recording were from long-legged myotis (*M. volans*), followed by little brown myotis (*M. lucifugus*) and small-footed myotis (*M. ciliolabrum*). In addition, a relatively large number of hoary bat (*L. cinereus*) call sequences were recorded (Table 3, Fig. 37).



Figure 36. Photograph of meadow at Reynolds Ranch surveyed in July 2020.

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 Table 3. Number of calls sequences identified to species at Reynolds Ranch over four nights in July 2020.

 Species
 MYCI
 MYEV
 MYLU
 MYTH
 MYVO
 EPFU
 COTO
 LACI
 LANO
 PESU
 Totals

Blue Jay Mine: (40° 6.319', 105° 23.047', 2196m) This site was surveyed from 27 September to 7 October using an SM2 sonar detector. A single call sequence over the survey period was recorded on the night of 29 September and was identified as a small-footed myotis (*M. ciliolabrum*). Unfortunately, it was likely too late in the year to know if and how bats may be using this site. I suggest resampling in summer 2021.

Figure 37. Histogram of number of sonar call sequences (i.e. activity) by species at Reynolds Ranch over four nights in July 2020.

Cardinal Mill: (39° 57.994', 105° 32.954', 2688m) Activity at Cardinal Mill appears to have decreased substantially in 2020. In 2018, 194.7 passes per night (PPN) were recorded. In 2019, 411.2 PPN were recorded. In 2020, only 3.7 PPN were recorded at the site (Fig. 38).



Figure 38. Comparisons of passes per night (PPN) from 2018, 2019. 2020 which showed a major decline in activity.

It is unclear what could have caused this precipitous decline of a major long-legged myotis (*M. volans*) maternity colony as well as potential maternity colonies of small-footed myotis (*M. ciliolabrum*) and little brown myotis (*M. lucifugus*). It is possible that the SM2 detector was faulty, however in June the detector recorded 186 passes over 13 nights (PPN = 14.3) with no signs of faultiness. In 2019, from 4-18 July, the SM2 recorded 3,098 passes (PPN = 205.9). In 2020, late July into early August recordings dropped from 0.57 PPN to zero sonar passes recorded (Fig. 39). There were no sonar passes recorded in

August or September 2020. By comparison, in 2019, 1,134 passes were recorded in September. Replacement of windows in the structure (Susan Spaulding, pers comm.) may be responsible for deterring bat usage.



Figure 39. Activity (defined as total number of sonar passes by bats) showed a steep decline from 186 passes to 8 to 0 for unknown reasons. By comparison, in 2019, 1,134 passes were recorded in September.

Walden Ponds: Two sites were surveyed at Walden Ponds in 2020 (Fig. 40). **Site 1**. Surveys from Site 1 located in a group of cottonwood trees adjacent to South Boulder Creek from 14-18 June 2020 captured only two bat passes, both identified to small-footed myotis (*M. ciliolabrum*). No sonar calls were recorded from 22-25 June 2020 and from 28 June to 3 July 2020 only 11 passes were recorded and

of these only one was identifiable as small-footed myotis, *M. ciliolabrum*. Reasons why this site was not as active as in 2018, 2019 remain unclear. The 2020 sampling was done a little earlier in the season than in those years, but by only a matter of weeks.



Figure 40. Location of sites surveyed at Walden Ponds in 2020.

Walden Ponds Site 3: From 13-19 July 2020, Site 3 was very active with 7, 415 sonar passes recorded. Of those sonar passes, 2,133 were identifiable to species with 90% confidence. Highest species occurrences recorded was for little brown myotis (*M. lucifugus*), followed by tricolored bats (*Perimyotis subflavus*) and then small-footed myotis (*M. ciliolabrum*) (Fig. 41). Curiously, in 2018 and 2019, big brown bats (*E.fuscus*) was the most active at this site, whereas in 2020, their occurrence was very low. Also, in 2020, tricolored bats were more active at this site than in the last two years. This could mean an increasing population size.



Figure 41. Relative Occurrence of bat species recorded at Walden Pond, Site 3.

Tricolored Bats at Walden Ponds: Tricolored bats (*Perimyotis subflavus*) showed a large increase in activity at Walden Ponds in 2020 (Fig. 42). This increase could be due to high survivorship of young and low over-winter mortality and thus increasing population sizes. Another possibility is that more tricolored bats are moving into this area.



Figure 42. Passes per night (PPN) at Walden Ponds of tricolored bats (*P. subflavus*) from 2018 to 2020. In 2020, there was a large increase in activity at this site.

Twin Lakes: Two sites were surveyed at East Twin Lake in 2020. Surveys focused on two active bat foraging corridors (Fig. 43). Site 1 was positioned in a north-south flight path along the eastern border over proximate wetlands of East Lake, whereas Site 2 was located along Left-Hand Ditch and trail that forms an flight corridor in an otherwise heavily vegetated habitat of cottonwood trees, ash trees, and various species of bushy vegetation. Site 2 was more active than Site 1, but generally both areas averaged more than 125 bat passes per night (PPN, Fig. 44).



Figure 43. Sites surveyed at Twin Lakes in 2020. Sonar surveys focused on two active flight corridors.



Figure 44. Comparison of bat activity (calculated as average passes per night, PPN) at Site 1 and 2 at Twin Lakes.

Although Sites 1 and 2 had the same species richness (N = 7), frequency of occurrence of species varied per site (Fig. 45). Site 1, which was open habitat located above a wetlands area, had a higher frequency of open aerial foragers such as hoary bats (*L. cinereus*) and silver-haired bats (*L. noctivagans*). Site 2 was used by more maneuverable species such as small-footed myotis (*M. ciliolabrum*) and tricolored bats (*P. subflavus*).



Figure 45. Frequency of Occurrence of seven species of bats recorded at two sites from Twin Lakes in 2020.

Tricolored Bat Population at Twin Lakes: Tricolored bat activity adjusted for sampling nights (PPN) at Twin Lakes was about six times greater at Site 2 in the Left Hand Ditch flyway than at Site 1 over the wetlands (Fig. 46). This is likely because this species forages on water-emergent insects and typically is associated with streams and riparian corridors. Therefore, this area at Twin Lakes provides for critical habitat for this species and should be managed appropriately as this species uses diurnal roosting sites, in the open, on the branches of riparian vegetation.



Figure 46. Activity patterns (PPN = Passes per Night) of tricolored bats at Twin Lakes. Site 1 is over wetlands that border the East Lake, whereas Site 2 is along the Lefthand Ditch riparian corridor.

Tricolored bats appear to have increased in numbers at Twin Lakes along the Left Hand Ditch corridor. In 2018, eight calls were recorded over three nights (PPN = 2.7). In 2019, numbers appeared to drop with only six calls recorded over five nights (PPN = 1.2). However, in 2020, 125 calls were recorded over eight nights (PPN = 15.6) (Fig. 47). This large increase in activity of tricolored bats observed at Twin Lakes is consistent with the pattern observed at Walden Ponds in 2020 (see Fig. 42) and may indicate increasing population size.



Figure 47. Passes per Night (PPN) of tricolored bats at Twin Lakes from 2018-2020. In 2020, a large increase in activity was noted.

Conclusions & Recommendations

Ingersol Quarry. *Conclusions*: This site appears to be highly important for wildlife, not only in the spring, summer, and autumn months, but also in winter. This site is unique predominately because of its rocky landscape and ability to hold heat. Ice at the quarry commonly melts around the edges in winter providing drinking and bathing opportunities for wildlife. In terms of bats, the rocks and scree slopes of loose rocks apparently provide hibernations sites for several species, especially small-footed myotis (*M. ciliolabrum*) persistent throughout the winter months. Although warm rock crevices that offer a microclimate that does not go below 0°C provide potential hibernations sites, in Colorado, the biggest

threat to hibernating bats is dehydration due to the low humidity environment. Thus, ordinarily bats could not overwinter under these conditions and must seek humid underground caverns for hibernation. However, because the edges of the quarry melt whenever air temperatures exceed freezing, bats can leave their hibernaculum to drink water, thereby replenishing their daily losses. In addition, sonar overwinter sonar recording from Ingersol captured feeding buzzes from bats indicating winter insect activity that could replenish and lost energy due to arousal from torpor. We have yet to find other sites where this may be occurring even though we have run detectors overwinter in the South St. Vrain Canyon with no bat calls recorded. However, finding these microhabitat areas is challenging and our placement was clearly not in accordance with any hibernation sites. Neubaum et al. (2006) found prehibernation roost sites of big brown bats (*E. fuscus*) along the Poudre River watershed in Larimer County, CO, some of which appears to be overwintering sites. In addition, biologists with Boulder OSMP ran detectors in Ber Creek Canyon after hearing of the Ingersol Quarry data and found similar activity from bats overwintering there (pers comm, Will Keeley). Thus, it is likely that there are other rock crevice hibernation sites used by bats along streams and drainages.

However, what remains unique to the natural history of Boulder County bats is the overwinter persistence of long-thought migratory species, hoary (*L cinereus*) and silver-haired (*L. noctivagans*) bats. These species were active during every winter months at Ingersol Quarry. *Recommendations*: Ingersol Quarry should be a highly protected site from human disturbances especially in the form of forest disruptions and prescribed burns, particularly during the hibernation season from November to April. Overwinter monitoring should continue.

Plumely and Geer Canyons. *Conclusions*: These two canyons continue to be very active sites during the spring, summer, and autumn months. We have not as yet checked these sites for winter activity. In most years Plumely Canyon appears to go completely dry and thus would not predictably provide water sources for overwintering bats. Geer Canyon retains water and in some reaches the flow is over bare rocks which may provide the same microenvironment as Ingersol Quarry wherein melting of pools occurs in areas of direct winter sunlight. If that is the case, one would predict overwintering bats in Geer Canyon. *Recommendations:* Both Plumely and Geer canyons should be of high priority for protection with limited human disturbance allows in the areas. Overwinter monitoring in Geer Canyon is highly recommended.

Twin Lakes and Walden Ponds. *Conclusions*: These two properties showed exponential growth in tricolored bats (*P. subflavus*). It appears that their populations are growing, most likely due reproductive output and survivorship, but perhaps also due to new immigrants coming into Boulder County from eastern Colorado along the South Platt River drainage that runs from Nebraska into eastern Colorado and into Boulder County. Increases in sonar detections were abut 5-6 times that of 2018 and 2019 at these sites. **Recommendations**: Both Twin Lakes and Walden ponds should be managed to protect tricolored bats, in particular, the Left Hand Ditch corridor. These bats use deciduous, and in some cases conifer, trees for diurnal and nocturnal roost sites. They roost individually, and females give birth and raise their young far out on the extremities of branches to limit predation. Twinning is common. Therefore, care should be taken in terms of any tree trimming or removal at these sites, especially along the edges of streams and ponds. Continue summer monitoring.

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High Elevations Sites. *Conclusions*: Cardinal Mill which provided a major maternity site for longlegged myotis (*M. volans*), one of the only species in Boulder County that reproduces more readily at higher than at lower elevations, and little brown myotis (*M. lucifugus*), a generalist species that reproduces more readily at lower elevations. For some reason, activity at Cardinal Mill crashed in 2020. *Recommendations:* Hopefully, the site has not been abandoned by these species due to disturbance. It is possible that the detector used at CM malfunctioned, so further bat survey work should be done at this site in 2021.

Rocky Mountain Mammoth. *Conclusions*: This site is a major nursery site for long-legged myotis (*M. volans*). Smaller colonies of small-footed myotis (*M. ciliolabrum*) and little brown myotis (*M. lucifugus*) appear to be using the structure. Whether these are maternity or bachelor roosts is not known. *Recommendations*: This site should be protected from human disturbance and monitored for any changes in bats using the site.

Reynolds Ranch. *Conclusions*: This site was very activity with foraging bats. *Recommendations*: This site should be further monitored for bats but is not high priority as not known roosting sites are present.

Blue Jay Mine, Jamestown. *Conclusions*: Unfortunately, this site was not surveyed until October when any resident bats would have likely moved off to breeding and hibernations sites: *Recommendation*: Resurvey site in summer 2021.

South St. Vrain Elevational Transect. *Conclusions*: The elevational transect is giving new insights into how bats may move among elevations depending on ambient conditions. As yet we have not been able to record any bats descending from hibernation sites in spring, but we could track patterns of arrival at lower elevations, particularly at Ingersol Quarry and Hall Ranch to give an idea when bats have

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moved to lower elevations in the spring. *Recommendations*: Continue to monitor bats across elevations. Extend transect to higher elevations to better uncover seasonal migrations.

Other Patterns: Some areas appear to have dropped in activity for bats for unknown reasons. The Hall Ranch location for the low-mark of the elevational transect was very low in activity in 2020, unlike previous years. Also, the MYEV_Thinned Site at Heil Valley Ranch near Ingersol Quarry has little to no activity in 2019 and 2020 even though it was a highly active site in previous years. These sites should continue to me monitored for changes. No conclusions can be drawn at this time, but a hypothesis may be that after thinning these sites eventually became very dry and therefore insect reproduction and activity decreased. In addition, prescribed burns in the area may have reduced insect availability (Susan Spaulding, pers. comm.).

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