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Cover Photograph: Trail camera image of an American Marten (*Martes americana*) approaching a Little Brown Bat (*Myotis lucifugus*) flying from a central Manitoba limestone cave. Photograph © Malcolm Reimer.

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Mustelid Predators Catch Little Brown Bats (*Myotis lucifugus*) during Spring Emergence from a Cave Hibernaculum

Malcolm H. R. Reimer[1,*] and Craig K. R. Willis[1]

Abstract - We report the first direct observations of 2 mustelids, *Neogale frenata* (Long-tailed Weasel) and *Martes americana* (American Marten), capturing *Myotis lucifugus* (Little Brown Myotis) in flight, as the bats emerged from a cave in Manitoba, Canada. These predators also regularly entered the cave over 3 months in late winter and spring. The number of bats in this hibernaculum has declined dramatically due to white-nose syndrome. Our observations suggest that predation represents an additional risk to population recovery at this site and highlight the need to consider predation at hibernacula among the many threats faced by endangered North American bats.

Resumen - Reportamos las primeras observaciones directas de dos especies de mustélidos, *Neogale frenata* (Comadreja Cola Larga) y *Martes americana* (Marta Americana) capturando *Myotis lucifugus* (Myotis Marrón Pequeño) mientras los murciélagos emergían de una cueva en Manitoba, Canadá. También estos depredadores entraban en la cueva durante 3 meses a finales de invierno y primavera. La cantidad de murciélagos en este hibernáculo ha disminuido drásticamente debido al síndrome de la nariz blanca. Nuestras observaciones sugieren que la depredación podría representar un riesgo para la recuperación de la población en este sitio, y subrayan la necesidad de considerar la depredación en los hibernáculos como una de las amenazas que enfrentan los murciélagos norteamericanos en peligro de extinción.

Bats, especially species that hibernate communally in caves, are thought to experience low predation risk during hibernation. Bats in caves may be difficult for predators to access, while aggregation may dilute individual predation risk and improve the chances of predator detection (Lima and O'Keefe 2013, Wilkinson and South 2002). The prevalence and impacts of predation on North American bats during hibernation are not well understood, but anecdotal reports from North America and Europe suggest varying degrees of reliance on hibernating bats by avian and mammalian predators. *Peromyscus maniculatus* (Wagner) (Deer Mice) consume dislodged *Myotis lucifugus* (Le Conte) (Little Brown Myotis) from the floor of a mine in Ontario (Trevor-Deutsch 1973). *Parus major* Linnaeus (Great Tits) systematically forage for hibernating *Pipistrellus pipistrellus* (Schreber) (Common Pipistrelles) in a Hungarian cave and are attracted to the calls of arousing bats, suggesting the birds may use hibernacula as long-term food sources (Estók et al. 2010). *Apodemus sylvaticus* (Linnaeus) (Field Mice) actively seek out and eat torpid *Myotis* in human-made hibernacula, with mouse predation contributing an estimated 1.8% to average annual mortality across more than 1500 study sites in the Netherlands (Haarsma and Kaal 2016).

Evidence of mustelid predation on bats has been reported at some hibernacula. Scat from *Martes foina* (Erxleben) (Stone Marten) containing bat remains was present in underground pits in the Netherlands (Bekker 1988, Slim and Stumpel 1986). In Kentucky, the stomachs of 2 *Mustela vison* (Schreber) (American Mink) contained remains of *Myotis*, which may have comprised virtually the entire winter diet for these individuals (Goodpaster and Hoffmeister 1950). Zhigalin (2019) estimated that *Mustela sibirica* Pallas (Siberian Weasels)

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consumed 2.1 kg of bats per year, based on scat contents at a hibernaculum; these scats contained no other prey, suggesting some individual-level specialization on bats by these predators. Here we report 4 instances of bat predation by mustelids at a cave hibernaculum, before and during spring emergence, including the first direct observation of *Martes americana* (Turton) (American Marten) as a bat predator and the first direct observations of mustelids capturing bats in flight.

All observations occurred in the Lake St. George Caves Ecological Reserve, located about 12 km south of Lake St. George in central Manitoba, Canada (51°41'55.32'' N, 97°26'49.2'' W). The reserve sits within a lowland boreal forest and contains 8 limestone caves, the largest of which is used by Little Brown Myotis as a hibernaculum. This cave is 48-m long and has 1 narrow vertical entrance into a small chamber, which slopes downward into a tall main chamber, about 12 m below the entrance (Fig. 1; see McRitchie and Monson 2000 for details). Prior to the detection of white-nose syndrome (WNS), the invasive fungal disease that has devastated populations of multiple bat species in North America, we counted between 7000 and 9000 individuals hibernating at this site each year. WNS was detected at the cave in 2017, and the average winter count between 2018 and 2024 was 2600, with 1924 bats hibernating in March 2024.

As part of a study on hibernation physiology, we attached radio transmitters to 40 bats from this cave on 14 March 2024. Surprisingly, on 24 March, we detected a radio signal from 1 of these transmitters outside the hibernaculum, over a month before we expected bats to emerge. We could not find the transmitter in deep snow during March or April, but on 3 May we tracked the signal to a spot about 650 m north of the cave. We discovered the transmitter, with a patch of bat skin still attached, by a cluster of birch (*Betula*) trees under which several small burrows were dug into the soil, suggesting that the tagged bat was taken from the cave by a predator and consumed at its den.

On 14 March 2024, we placed 9 infrared trail cameras (Dark Ops HD Max, Browning Trail Cameras, Birmingham, AL) inside the cave and aimed at the ceiling to capture images of clustering bats, and a tenth camera outside and facing the cave entrance from above (Fig. 1).

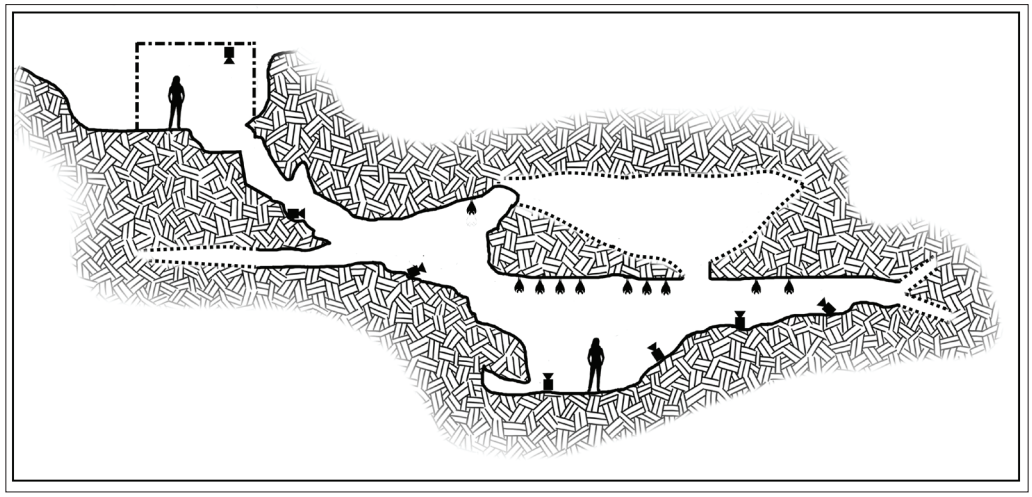

Figure 1. A profile view of Lake St. George Bat Cave. Dotted lines represent areas of the cave extending forward or backward in the image, and the box of dashed lines represents the protective cage around the entrance. Camera icons show the locations of some infrared trail cameras, and bat icons show the roosting locations of most bats. Human figures are added for approximate scale.

We set the internal cameras to capture photos every hour and when triggered by motion, with a 1-h delay between motion-triggered photos. We set the entrance camera to record up to 20 sec of video after detecting motion. Recordings from the entrance camera mainly consisted of bats exiting the cave, but after closely reviewing the videos, we discovered multiple instances of an American Marten and a *Neogale frenata* (Lichtenstein) (Long-tailed Weasel) visiting the cave entrance and capturing bats.

On 2 April 2024, at 02:37 h the entrance camera recorded a Long-tailed Weasel chasing and catching a bat on the ground at the cave entrance (see Supplemental File 1, available online at https://eaglehill.us/nabronline/suppl-files/nabr-023-Reimer-s1.AVI). On 10 May, at 08:58 h, video showed an American Marten catching a bat mid-flight as it emerged from the cave (see Supplemental File 2, available online at https://eaglehill.us/nabronline/suppl-files/nabr-023-Reimer-s2.AVI). On 11 May, at 02:06 h, the camera documented a Long-tailed Weasel capturing a bat on the ground and bringing its prey into the cave entrance (see Supplemental File 3, available online at https://eaglehill.us/nabronline/suppl-files/nabr-023-Reimer-s3.AVI).

Our internal motion-triggered cameras captured photos of American Marten (Fig. 2) or Long-tailed Weasel (Fig. 3) inside the cave on 46 of the 102 days we recorded. All these visits occurred during the evening and night, between 17:00 and 05:00. What appeared to be the same individual of each species usually visited multiple times per day and appeared on several cameras each time, suggesting that these predators were actively searching the cave for accessible bats. Most of the cameras were positioned to record clusters of bats roosting high on the ceiling of the cave, so we would have been unlikely to record predation occurring inside the cave. However, our tracking observation and videos confirm that 4 bats were killed by these predators between 14 March and 26 May 2024.

American Martens have been observed ambushing prey (Spencer and Zielinski 1983), and birds are a regular component of their diet (Raine 1987). Consequently, catching flying bats from a known emergence point could be a feasible hunting strategy for these predators. While

Figure 2. *Martes americana* (Turton) (American Marten) inside the Lake St. George hibernaculum. Photograph © Malcolm Reimer.

weasels are generally crepuscular (Zielinski 2000), American Martens switch from nocturnal activity in winter to diurnal in summer (Zielinski et al. 1983), so spring emergence at a hibernaculum likely represents 1 of the few occasions when these mustelids might interact with bats. All videos of American Martens were recorded during the day. Both weasels and martens locate their prey visually (Murphy 1985, Gillingham 1986), so highly visible bat activity, such as during fall swarming, may attract these predators to the cave. In addition, we recorded bats flying out of and into the cave as early as 29 March, several weeks before most bats began emerging, and such flights may also alert mustelids. Few data on hearing are available for the 2 predators we observed, but *Mustela nivalis* Linnaeus (Least Weasel) can hear tones up to 60.5 kHz (Heffner and Heffner 1985), which exceeds the frequency of highest energy in the echolocation calls of Little Brown Myotis (45–47 kHz, Fenton and Bell 1979). Thus, weasels in the area may hear bat-produced ultrasound, although there have been no studies investigating the response of mustelids to bat calls.

It would be impossible for a mustelid to reach torpid bats on the high cave ceiling, where the majority of bats at Lake St. George roost, although some bats hibernate in crevices closer to the ground. However, repeated searches by mustelids inside the cave could disturb bats, causing them to arouse and fly into a narrow bottleneck at the cave entrance, where they would be more easily captured. Even if mustelids fail to capture the bats, repeated disturbance could cause premature fat depletion and starvation (Boyles and Willis 2010). Little Brown Myotis have high site fidelity to hibernacula (Norquay et al. 2013) and could return to a cave despite the presence of predators. Driessens and Siemers (2010) showed that *Myotis myotis* (Borkhausen) (Greater Mouse-eared Bats) do not avoid or show a fear response to certain mustelid scent compounds. These factors suggest that hibernating *Myotis* may be especially vulnerable to these predators.

Small population sizes or densities can leave species more vulnerable to extirpation and extinction. Demographic Allee effects (reductions in the per capita rate of population growth at low densities) increase extinction risk (Courchamp et al. 2008) and present

Figure 3. *Neogale frenata* (Lichtenstein) (Long-tailed Weasel) inside the Lake St. George hibernaculum. Photograph © Malcolm Reimer.

conservation challenges for endangered prey species (Sinclair et al. 1998). Allee effects can arise due to predation alone in 2-species systems (Kramer and Drake 2010), but bats are likely not the primary prey of either Long-tailed Weasels or American Martens, so these predators are unlikely to be primary drivers of population declines for Little Brown Myotis. However, hibernating groups of Little Brown Myotis have become much smaller after the introduction of WNS, with average population declines of over 90% (Hoyt et al. 2021) and the disappearance of nearly all large (>10,000 individuals) winter colonies (Cheng et al. 2021). An Allee effect could occur as individual risk of predation becomes greater in a smaller population, despite the frequency of predator interactions remaining the same (McLellan et al. 2010).

Although bat numbers appear to be stabilizing at the Lake St. George Bat Cave and improving in many hibernacula after the initial population crash from WNS (e.g., Langwig et al. 2017, Maslo et al. 2015), population growth rates of bats are slow (COSEWIC 2013, Frick et al. 2010). Thus, even a low rate of predation during hibernation could have meaningful impacts on population recovery. Although predation is obviously a natural phenomenon, management plans for endangered species often consider and attempt to mitigate impacts of predation (Engeman et al. 2009). Removal or exclusion of native or introduced predators has been highly effective in reducing mortality rates of several species, from fish to birds to mammals (Cavallo et al. 2013, Courchamp et al. 2008, Jaatinen et al. 2022, Smith et al. 2010, Zimmerman and Ward 1999). In the case of Lake St. George Bat Cave, if bat numbers fail to recover or continue to decline, and mustelid predators continue to capture or potentially disturb hibernating bats, managers should consider predator removal or exclusion to help preserve and recover the population that relies on this hibernaculum.

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