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Chiropterophagy by the Siberian weasel (*Mustela sibirica*): the first record in the Russian Far East

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Abstract: Chiropterophagy is a widespread phenomenon, but only one case of bat consumption by sable has been documented in the Russian Far East. This study presents the first recorded instance of chiropterophagy by the Siberian weasel (*Mustela sibirica*) in the southern Russian Far East, based on excrement collected from the Solyanik Cave in the southern Sikhote-Alin Mountains in 2007. The excrement included bones from three bat species (*Murina hilgendorfi*, *Myotis bombinus*, *Plecotus ognevi*) and one vole species (*Myodes rutilus*). Our findings suggest that the Siberian weasel visits caves during the cold season, although not annually. These visits appear to be correlated with food shortages rather than adverse weather conditions. Additionally, we propose the term "chiropterocapy" to describe a specific foraging strategy where predators consume bats at rest.

Keywords: chiropterophagy, Siberian weasel, *Mustela sibirica*, Sikhote-Alin Mountains, ecology

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INTRODUCTION

Chiropterophagy, the consumption of bats, is a widespread phenomenon, particularly in tropical regions. The term was first coined by Schätti (1984) in his work "*Bats as food for snakes*", where it referred to bat consumption by snakes. In subsequent studies, the term has been mentioned occasionally but lacks a formal definition. It is generally understood to refer to bat consumption by any animal (Hammer & Arlettaz, 1998; Nuffer & Kno, 2013; Mikula, 2015; Amal et al., 2022). Chiropterophagy has been observed in a variety of species, including giant scolopendra (Molinari et al., 2005), free-living and web-building spiders (Das et al., 2012; Nyffeler & Knörnschild, 2013), birds (Fenton & Fleming, 1976; Bauer, 1988; McCune, 2016; Mallick et al., 2021; Amal et al., 2022), snakes (Schätti, 1984; Aya-Cuero et al., 2019; Mallick et al., 2021), amphibians, fish (Mikula, 2015), and various mammals (Dwyer, 1964; Gillette & Kimbrough, 1970; Gabór, 1981; Urbanczyk, 1981; Wroe & Wroe, 1982; Tiunov & Yudin, 1986; Bekker, 1988; Sparks et al., 2000, 2003; Black et al., 2001; Khritankov & Shishikin, 2001; Zhigalin, 2019; Mallick et al., 2021).

Chiropterophagy in caves is relatively common among mustelids, with cases documented for the common marten (Gabor, 1981; Urbanczyk, 1981; Bekker, 1988), sable, steppe polecat, and Siberian weasel (Khritankov & Shishikin, 2001; Zhigalin, 2019). In the Russian Far East, there is evidence of sables feeding on bats in wintering sites based on excrement collected in the caves of Priiskovaya in the Primorsky krai and Stary Medved in the Khabarovsky krai (Tiunov & Yudin, 1986) (Fig. 1: 3, 4).

In 2007, Siberian weasel excrement containing primarily bat remains was discovered in the Solyanik Cave in the southern Sikhote-Alin Mountains (Fig. 1: 1). This marks the first documented case of Siberian weasel chiropterophagy in the Russian Far East and the third such case reported in the literature (Khritankov & Shishikin, 2001; Zhigalin, 2019). Due to the limited data on Siberian weasel visits to caves, it remains unclear what triggers these visits. It is not known whether the weasels enter caves with a specific goal—such as seeking food or shelter—or if this behavior results from an "exploratory instinct" (Ovodov, 1979).

Presumably, predators may detect the presence of bats in the cave vestibule by smell or sound. However, no studies have been conducted on how predators become aware of bats deeper within caves, where there is no natural light, and temperatures remain constant throughout the year. Existing literature only speculates on how other mustelids detect bats in caves. For example, it has been suggested that the sable may initially enter caves out of curiosity or to hunt prey like pikas or pigeons in the caves of Central

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Siberia (Zhenevskaya, Ledyanaya, Tunnelnaya, Cossack Zastava, Pandora's Box, Syyskaya, Berloga, Archeologicheskaya, etc.). Afterward, it may detect and eat a bat and then return to the cave to feed on bats specifically (Khritankov & Shishikin, 2001). Similarly, the entry of the marten into the Baradla Cave (Hungary) has been linked to shelter-seeking behavior and human activity. While in the cave, the marten could notice and eat a bat, and only later return to the cave for the purpose of chiropterophagy (Gabor, 1981). In both cases, it is proposed that the predator enters the cave for an external reason and, after encountering bats, returns specifically to feed on them.

Since the Siberian weasel did not visit the cave en masse all the time but only during one winter, and since the cave conditions (temperature, humidity, passage configuration, accessibility, presence of hibernating bats) remain unchanged, we assumed that some external factors, most likely weather conditions or food availability, influenced the Siberian weasel's entry into the cave.

Previous literature indicates that the Siberian weasel may remain in shelter during periods of cold temperatures (Aristov & Baryshnikov, 2001). For the Russian Far East, Bromley (1960) notes that in late December, the Siberian weasel "lies down in burrows" for 15–30 days. Caves could provide favorable shelter, as many long caves in the southern Far East maintain a constant temperature of approximately +4°C in their darkened parts (Bersenev, 1989). For instance, in Siberia, where winter conditions are harsher, the Siberian weasel was observed entering the Barsukovskaya Cave (Fig. 1: 2) each winter over a three-year period (Zhigalin, 2019). Although weather conditions are milder in the southern Far East, they can vary significantly from year to year, which may cause the Siberian weasel to enter caves only during the harshest years.

Rodents are the primary food source for the Siberian weasel, with plant material, invertebrates, amphibians, reptiles, and birds also being consumed in the summer (Aristov & Baryshnikov, 2001). In winter, carrion becomes a significant part of its diet (Aristov & Baryshnikov, 2001), likely due to food scarcity. This may explain the Siberian weasel's search for new food sources in caves, such as wintering bats.

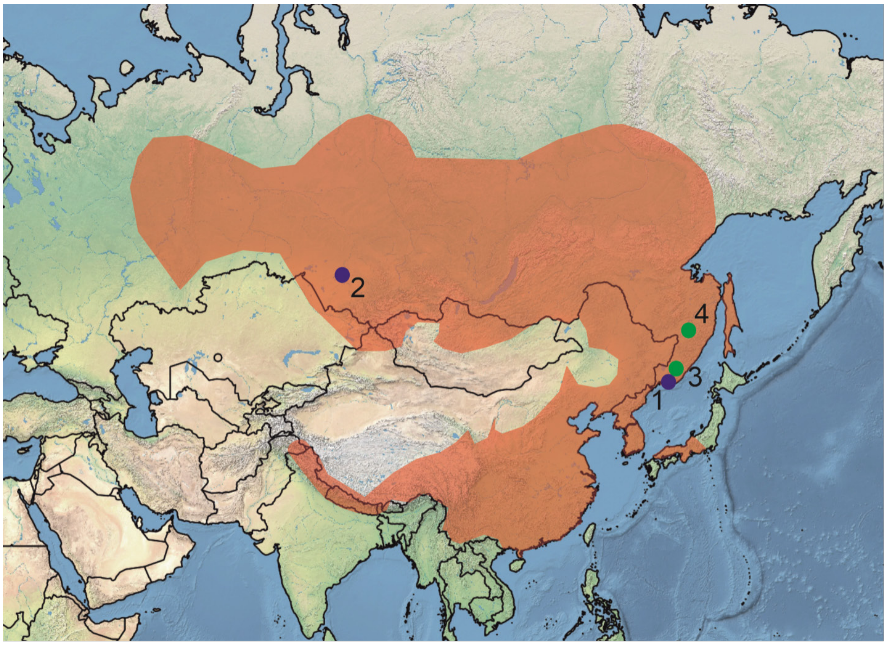

Fig. 1. The distribution area of the Siberian weasel (orange area). Blue dots – finds of the Siberian weasel excrement in caves. 1: Solyanik Cave, 2: Barsukovskaya Cave; green dots – finds of the sable excrement in caves of the Far East: 3: Priiskovaya Cave, 4: Starogo Medvedya (Old Bear) Cave.

Before exploring the reasons for the Siberian weasel's active entry into caves, it is necessary to determine when and for how long the weasel visited the Solyanik Cave and deposited the numerous excrements found. While the excrement was collected on 15–16 December, it remains unclear how long it had been present before this or whether it accumulated over the preceding autumn and early winter months, or even earlier.

The aim of this study is to investigate the characteristics of Siberian weasel chiropterophagy in the southern Russian Far East, based on material obtained from the Solyanik Cave. Specifically, we aim to identify the species of prey, determine the timing of Siberian weasel visits to the cave, and explore the possible reasons for the weasel's mass visits in particular years.

CHARACTERISTICS OF THE SOLYANIK CAVE

The Solyanik Cave is located on the upper section of the steep western slope of the Lozovyy Range in the southern part of the Sikhote-Alin Mountains. The entrance is situated at an altitude of 660 m a.s.l., with a relative height of 440 m above the Novorudnaya River valley. The entrance is tall and narrow, measuring 3.3 m in height and 0.5 to 1.5 m in width. The cave is divided into two systems of passages: the Old System and the New System (the Kashlev Passage). The total length of the cave passages is 425 m, with a depth of 125 m, an area of 365 m², and a volume of 3,800 m³ (Shelepin, 2019).

In narrower sections, occasional airflows are noticed, with their direction and intensity varying according to the season. Several temporary small water bodies are present within the cave, including one at the cave's bottom and one other on a stone shelf in the Old System. Dripping water is continuously observed from a depth of approximately 20 m, occasionally forming small streams due to the intensity of the dripping. Ice is found only in the entrance area in the form of sublimation crystals, which are seasonal, occurring from December to April.

MATERIAL AND METHODS

Siberian weasel excrement

Excrement of the Siberian weasel was collected from the Old System of the Solyanik Cave by V.E. Omelko on 15–16 December 2007. The excrement was found throughout almost the entire passage of the Old System, from Chaynikov Hall (end of the Big Shkurodyor) to Start Hall (beginning of the Semedisyatnik Well) (Fig. 2, beige area). Both individual excrements and clusters of several dozen excrements were encountered along the passage. It appears that the accumulation of excrement resulted from the activities of multiple Siberian weasel individuals. Fresher and older excrements, some covered in mold, could be visually distinguished. For this study, the cluster of excrement collected were closest to the exit in Chaynikov Hall, near the end of the Big Shkurodyor, approximately 40 m from the cave entrance (Fig. 2, red dot).

During a follow-up visit to the cave on 24–25 May 2008, it was observed (V.O.) that almost no excrement remained in the area where it had been found in December. The excrement had not been replenished, and the existing remains were significantly washed away by water.

Bone remains

The excrement primarily contains bone remains from all parts of the skeleton and fur of bats. One of the authors (Tiunov), identified the species of the lower and upper jaw fragments (a total of 130 specimens) using the comparative collection at the Laboratory of Theriology, Federal Scientific Center of the East Asia Terrestrial Biodiversity of the Far Eastern Branch of the Russian Academy of Sciences.

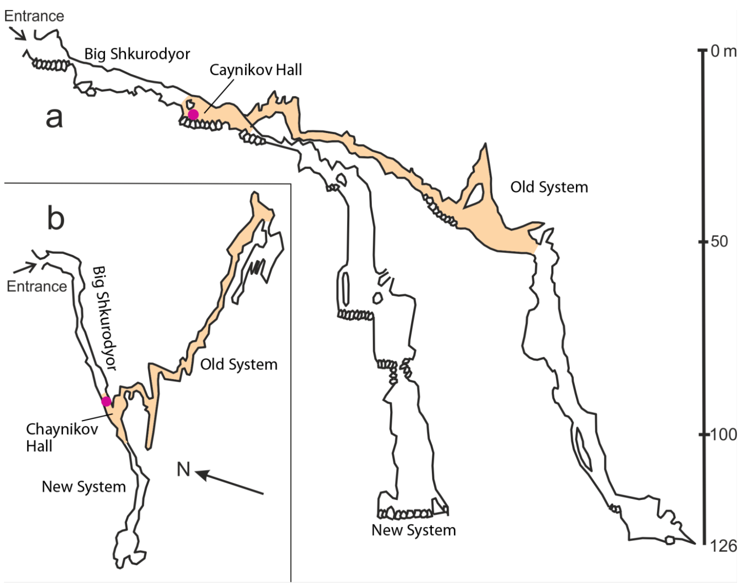

Fig. 2. Cross-section (a) and plan (b) of the Solyanik Cave (archival materials of the Vladivostok Speleology Club; surveying by Bersenev, 1973, Shkurygin & Minaev, 1986). The beige area represents the tunnel where Siberian weasel excrement was observed. The red dot indicates the location where Siberian weasel excrement was collected for this study.

RESULTS

Prey of the Siberian weasel

Bone remains from three species of bats and one species of vole were identified in the Siberian weasel excrement collected from the Solyanik Cave (Table 1). The rodent remains were represented by three cranial elements, most likely from a single vole. The excrement predominantly contained remains of Murina hilgendorfi, based on the number of skull fragments and lower jaws. Remains of Myotis bombinus were found in second place, and Plecotus ognevi remains were found in third.

Season of active visits of the Siberian weasel to the Solyanik Cave

The timing of excrement accumulation corresponds to the period when the Siberian weasel was actively visiting the cave. It is very difficult to determine how long the excrement had been in the cave before it was found, as decomposition in caves is much slower than on the surface. The presence of mold on the excrement cannot be used to estimate its age, as troglobiont fungi, adapted to low temperatures, can appear within days, weeks, or even months.

Table 1. Number of bones remains of different prey species in the Siberian weasel excrement from the Solyanik Cave.

Taxa	Lower jaw	Upper jaw
Murina hilgendorfi	64	42
Plecotus ognevi	3	2
Myotis bombinus	11	3
Myotis sp.	5	0
Myodes rutilus	1	0
Rodentia	1	1
Total	**85**	**48**

The proportion of remains from different bat species in mustelid excrement aligns with the relative abundance of those species in bat colonies (Tiunov & Yudin, 1986; Zhigalin, 2019). Since the species composition of bats, their numbers, and the ratio of species in colonies fluctuate throughout the year in caves (Tiunov, 1997), these parameters can be used to estimate the time of excrement deposition.

The predominance of *Murina hilgendorfi* remains in the Siberian weasel excrement corresponds to the peak of this species' numbers in bat colonies, which occurs from February to April (Table 2). Therefore, it is likely that the Siberian weasel visited the Solyanik Cave, fed on bats, and left excrement during these months, in the cold period of 2006–2007, prior to the collection of excrement in December 2007. The excrement likely remained in the cave during the warmer months of 2007, from April to December, a period of at least seven months, before being collected on 15–16 December 2007.

Table 2. Proportion (%) of bat species identified in Siberian weasel excrement (numerator: lower jaw; denominator: upper jaw) compared to their occurrence in caves of the southern Russian Far East across different months, based on long-term observations from 1981 to 1991 (Tiunov, 1997). Maximum values are shown in bold; s: single individuals.

Locations and seasons	***Murina hilgendorfi***	***Myotis bombinus***	***Plecotus ognevi***	**All species of *Myotis***	**Other species of bats**
Siberian weasel excrement in the Solyanik Cave	**75.3/87.5**	12.9/6.3	3.5/4.2	–	–
In the colonies from February to April	**73.9–88.8**	0.6–2.6	5.5–13.8	5.1–2.8	
In the caves in summer	s	s	s	s	
In the colonies in autumn	~5	-	s	**~95**	s
In the colonies in December	~10	-	~40	**~50**	s

Factors determining cave visitation by the Siberian weasel

To investigate whether weather conditions influence the Siberian weasel's decision to enter the cave, we compared the weather conditions during two winters: the first winter when the Siberian weasel visited the cave (2006–2007) and the second winter when it did not (2007–2008). At the beginning of both cold periods, the average monthly temperatures and precipitation were nearly identical (Fig. 3). However, starting in January, the average monthly temperatures in the second winter (2007–2008) were consistently lower. These data contradict the hypothesis that weather conditions are the determining factor for the Siberian weasel's visits to caves in the southern Russian Far East.

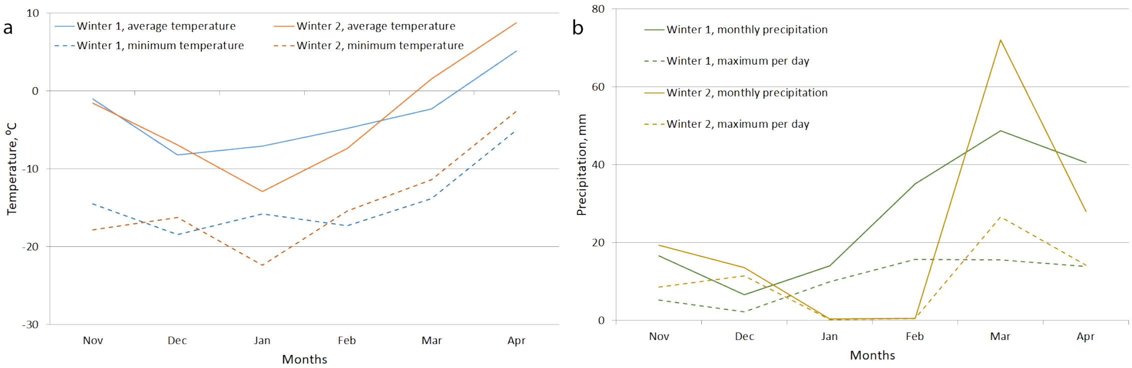

Fig. 3. Weather data from the Partisansk meteorological station nearest to the Solyanik Cave. (a) the average monthly and minimum temperatures, and (b) the monthly total and maximum daily precipitation.

To test the hypothesis that the mass visits of the Siberian weasel to the Solyanik Cave are linked to a shortage of winter food, we analyzed rodent trapping data from the Lozovyy Ridge. In the summer of 2006 (before the first winter when the Siberian weasel actively visited the Solyanik Cave), rodent numbers were extremely low, and we did not capture any rodents. In contrast, in the summer of 2007 (before the second winter when the Siberian weasel did not enter the cave), rodent numbers increased significantly, with a capture rate of 12.9 individuals per 100 trap-days. These facts suggest a strong correlation between the abundance of rodents and the Siberian weasel's cave visitation.

DISCUSSION

The main interest of this study lies in the fact that, despite many years of observation (the author (V.O.) visited the cave 1-2 times per year from 2000 to 2007), such a massive accumulation of Siberian weasel excrement in Solyanik Cave was observed only once. Despite the limited data, two hypotheses were tested. The first suggests that Siberian weasels are attracted and use the caves as shelters during adverse weather conditions. This hypothesis seemed plausible initially, particularly since Siberian weasels were observed visiting caves annually during harsher conditions in Siberia (Zhigalin, 2019). However, this hypothesis is not supported by our data.

The second hypothesis suggests that the Siberian weasel entered the cave for chiropterophagy during periods of food scarcity. This hypothesis was confirmed. When rodent numbers decline, the Siberian weasel likely seeks alternative food sources, such as carrion or wintering bat colonies. This is consistent with studies on the feeding habits of great tits (*Parus major*) in the Hungarian Istállós-köi Cave, where a food shortage in winter led to chiropterophagy. When extra food was provided to the great tits, they ceased feeding on bats (Estók et al., 2009).

The feeding on bats by the Siberian weasel in Solyanik Cave could be considered extreme due to the vertical shafts (Fig. 2). This likely makes the cave unpopular with Siberian weasels during "normal" winters.

During winter hibernation, bats—especially when forming large colonies—are an easily accessible food source for predators, as they do not fly away or resist. Literature on bat consumption by predators often uses terms like "predation" (e.g., Estók et al., 2009) or "consumption" (e.g., Amal et al., 2022). Sparks and co-authors (2000) referred to this as "scavenging," contrasting it with hunting, although they acknowledged that it is sometimes difficult to draw the line between these concepts. We propose naming the method of obtaining food from resting bats (during hibernation, daily rest, or roosting) "chiropterocapy" (from Latin “chiroptera” - bats, and “capio” - to take). Chiropterocapy is an advantageous feeding strategy for predators due to the low energy cost of searching for and capturing high-calorie, typically abundant food. In the case of the Siberian weasel in Solyanik Cave, chiropterocapy serves as a productive substitute for its usual rodent hunting, especially when rodent numbers are low.

Observations of great tits feeding on bats in the Istállós-köi Cave over a decade have led to questions about whether cultural transmission plays a role in the spread of this feeding behavior (Estók et al., 2009). This question is relevant for the Siberian weasel and other mustelids. These animals likely exchange information about cave visitation within a single season, leaving traces like excrement and scent marks that may alert other individuals—and even other species—to the presence of food. When considering this question over several years, one must take into account the lifespan and sedentary or active nature of the animals. The lifespan of the Siberian weasel is relatively short, ranging from 2 to 4 years, compared to 6 to 8 years for the sable. Additionally, the phenomenon of "migratory movement" («миграционный ход») (Aristov & Baryshnikov, 2001) or "motion of the Siberian weasel" («ходовой колонок») (Bromley, 1960) indicates that the Siberian weasel moves en masse to follow its prey, sometimes traveling 8-10 km/day, such as during the mass reproduction of voles. The seasonal variation in cave visitation intensity is another factor to consider. It is unlikely that the Siberian weasel visited the Solyanik Cave during the warm season, because at this time, the temperature inside the cave is relatively low, not exceeding +7°C in the entrance part and even lower in the deeper sections (Dyomin et al., 1980), and the scarcity of bats, if any. Thus, due to the short lifespan and high migration activity, it can be assumed that the same individuals of the Siberian weasel will most likely not return to the cave the following winter.

CONCLUSION

While chiropterophagy is a common phenomenon among animals in various climatic zones, this study reports it for the first time in the Siberian weasel in the Russian Far East. It has been established that the Siberian weasel in Solyanik Cave consumed three bat species: *Murina hilgendorfi*, *Myotis bombinus*, and *Plecotus ognevi*. The Siberian weasel’s mass visits to caves in the southern Far East occur primarily during the cold season, though they do not happen every year. The likely reason for the Siberian weasel’s visit to Solyanik Cave in the winter of 2006–2007 was a food shortage, driven by a significant decline in rodent numbers during the preceding warm period of 2006. Adverse weather conditions (low temperatures and heavy precipitation) do not appear to influence the Siberian weasel's decision to enter caves.

Given the limited data and observations in this study, these conclusions should be considered preliminary. Future research should aim to expand on these findings by collecting additional data from other caves in the Far East, across different seasons, and using diverse methods of data collection.

Several important questions remain unanswered: Are the Siberian weasel’s visits to caves intentional or accidental? How is information about "feeding" caves transmitted between individuals within the same season? Do Siberian weasels return to the same cave in subsequent years, and is this behavior passed down across generations? How do Siberian weasels discover the presence of bats in the deeper areas of caves?

Other aspects of Siberian weasel behavior, such as the number of individuals entering the cave (considering their solitary lifestyle), how they navigate in complete darkness (especially during their first entry, when there are no scent marks in the form of excrement), and how the cave’s configuration and microclimate influence visitation by Siberian weasels and other animals, also remain unexplored.

The introduction of the term of chiropterocapy contributes to the understanding of the unique behaviors of predators in cave environments. However, further research is necessary to examine how the chiropterocapy of Siberian weasels impacts bat population dynamics, including fluctuations in bat numbers, recovery rates, sex-age composition, and other ecological aspects.

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Authorship statement: VEO collection of material and observations, conceptualization and designed the study, analyzed the data, wrote the paper, MPT identification of bone remains, discussion of research results and the manuscript.

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