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Sciurus alleni and *Otospermophilus variegatus* winter activity in Nuevo León, México

Actividad invernal de *Sciurus alleni* y *Otospermophilus variegatus* en Nuevo León, México

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Water and food availability during winter is essential for the survival of non-hibernating squirrels in temperate forests; tree and ground squirrels have different survival strategies during winter. This note reviews the winter activity and behavior of *Sciurus alleni* and *Otospermophilus variegatus* at ground level. Using camera traps, in a water spring and in a natural wildlife crossing, within a walnut forest (*Juglans mollis*), the activity and behavior of both squirrels was recorded; furthermore, by direct observation, the search, storage and dispersion of nuts was analyzed. The winter activity pattern of *S. alleni* is long bimodal in both sites and for *O. variegatus* it depends on the habitat of the site ranging from short unimodal to multimodal. *Sciurus alleni* stores nuts on a scattered pattern. The type of behavior is situational depending on the site of observation, drinking water at the water spring, and travelling at the wildlife crossing. The presence of a chipmunk *Neotamias solivagus* was also recorded confirming its activity during winter. *Sciurus alleni* is active during the whole winter even on sub-zero temperatures and at twilight, differing from *O. variegatus* which displayed short periods of activity, showing that both squirrels have different strategies to avoid overlapping their niche. The results of this study revealed the importance of water sources and walnut trees for the survival of *S. alleni* and *O. variegatus* in the cold and dry winter season in the forests of Cumbres de Monterrey National Park.

Key words: Behavior; camera trap; hot spots; nut dispersion; squirrels.

La disponibilidad de agua y alimento durante el invierno es esencial para la supervivencia de ardillas no hibernantes en bosques templados; las ardillas arbóreas y terrestres tienen diferentes estrategias para sobrevivir en invierno. Esta nota reporta la actividad y comportamiento de *Sciurus alleni* y *Otospermophilus variegatus* a nivel del suelo durante el invierno. Usando cámaras trampa, en un ojo de agua y en un paso de fauna, en un bosque de nogal encarcelado (*Juglans mollis*), la actividad y comportamiento de ambas ardillas fue registrada; además, por observación directa se analizó la búsqueda, almacenaje y dispersión de nueces. El patrón de actividad invernal de *S. alleni* es bimodal largo en ambos sitios y para *O. variegatus* es según el hábitat del sitio de unimodal corto a multimodal. *Sciurus alleni* almacena nueces en forma dispersa. El tipo de comportamiento es situacional según el sitio de observación, bebiendo en el ojo de agua o tránsito en el paso de fauna. La presencia del chichimoco *Neotamias solivagus* también fue registrada confirmando su actividad durante el invierno. *Sciurus alleni* es activa todo el invierno aún en temperaturas congelantes y en el crepúsculo, a diferencia de *O. variegatus* que presentó cortos períodos de actividad, mostrando que ambas ardillas tienen diferentes estrategias para evitar traslape de nicho. Estos resultados revelan la importancia de las fuentes de agua y los nogales silvestres para la supervivencia de *S. alleni* y *O. variegatus* en la temporada fría y seca de invierno en bosques del Parque Nacional Cumbres de Monterrey.

Palabras clave: Ardillas; cámaras trampa; comportamiento; dispersión de nueces; sitios de interés.

The survival of small mammals that do not hibernate during winter is strongly determined by weather conditions and the availability of food and water for thermogenesis (Merrit and Zegers 2002; Kilpatrick 2003). Maintaining body temperature in low temperature environments consumes a high amount of energy and water, which can produce a negative energy balance with a high possibility of death (Feist and White 1989; Olson *et al.* 2017). For these reasons, during the winter or the dry season mammals must develop efficient strategies and activity patterns to survive (Halle and Stenseth 2000). The Sciuridae family has members that may or may not hibernate, or with short periods of torpor, and with different energy storage strategies, some with body fat and others with food storage spaces (Thorington *et al.* 2012). Tree squirrels *Sciurus* spp. and ground squirrels *Otospermophilus* spp. are of interest due to the different strategies they use to survive during cold or dry weather seasons (Ortega 1991; Halle and Stenseth 2000). Non-territorial tree squirrels (*Sciurus* spp.) may store food using scatter-hoarding methods and have little ability to protect the food source (Stapanian and Smith 1978), while *Otospermophilus variegatus* do not store food and instead accumulate body fat and may be a facultative hibernator depending on weather conditions (Oaks *et al.* 1987; Waterman 1996). Furthermore, acorns and walnut trees nuts (*Juglans* spp.) are an important source of energy for

squirrels (Smith and Follmer 1972; Sundaram *et al.* 2017) since they have a low rate of degradation and thus a long storage life (Vander-Wall 2001; Sutton *et al.* 2016).

The north of México, due to its latitude and orography, presents regions with cold and dry winters, such is the case of the mountains in the state of Nuevo León, where long periods of low rainfalls are common between the months of October and May in addition to temperatures below the freezing point for several consecutive days (García 2004).

In Llanitos community (25° 32´ 48" N; 100° 31´ 28" W, 2,210 m), Santa Catarina, Nuevo León, within Cumbres de Monterrey National Park, in mixed forests including pines (*Pinus* spp.), oaks (*Quercus* spp.), walnut (*Juglans mollis*), madrone (*Arbutus xalapensis*), black cherry (*Prunus serotina*), cedars (*Juniperus* spp.) and hawthorn (*Crataegus mexicana*; Mercado-Morales 2020), there is presence of the tree squirrel *Sciurus alleni*, and the ground squirrel *Otospermophilus variegatus*, both species with important winter activity at ground level to feed of walnuts and acorns (Mercado-Morales 1985; Oaks *et al.* 1987; Best 1995a). Due to walnut trees availability and water sources, this site allows high activity of both squirrels at ground level, and thus allows the study of their activity patterns and behavior on the ground during the coldest and driest months, even with limited tools (one camera trap per site).

As a result of 3 years of observation, 2 sites were located close to Llanitos community where both squirrels displayed activity during winter. The first one 650 m north of Llanitos, at 2,380 m, in a ravine with a water spring of less than 2 m^2 of water surface, location named Ojo de Agua (ODEA); 11 people live in Llanitos and use this water spring with a hose. The second location, at 750 m southeast of Llanitos, 2,170 m, between 2 forest patches of walnut (*J. mollis*) with few oaks, flanked by a small mountain creek and a rock wall creating a funnel for wildlife transit, location named Nogalillos (NOGA), the creek had very little water flowing during the study. Both sites are considered interesting for the observation of winter activity at ground level for both species of squirrels due to the water and food availability. From December 27, 2020, to March 20, 2021, a camera trap Neewer 1015 was placed in NOGA (45 cm from the ground in a walnut tree) and a camera trap MixMart HC-800A was placed in ODEA (at a distance of 7 m and a height of 2 m, due to the slope of the place, directed at an angle of 45° towards the water spring), both recorded the time of day (GMT-6) and temperature in degrees Celsius; they were programmed to capture 3 consecutive pictures and a 10 second video which allows to confirm the observation and the behavior of the mammals; a break of 1 minute between pictures. Nine different types of behaviors were analyzed depending on each photographic record and sustained by the videos, according to Shuttleworth (2000) and Koprowski and Corse (2005): drink, eat, grooming, interspecific and intraspecific interactions, rest, searching, travelling and vigilance. For the analysis, only the individual records of each species with a timeframe greater than 5 minutes between pictures were accounted (time considered adequate for the type of behavior of constant traveling when they are on the ground and they don't stay more than a minute drinking or resting in the ground), except when it was possible to identify different individuals (by coloration, tail length, body volume or scrotal testes) or when 2 or more individuals appear in the same image.

Furthermore, to understand the behavior of searching, storage, or dispersion of nuts by both squirrels, from January 6 to 8, 2021, a small experiment was carried out. In a walnut forest 500 m SE from Llanitos in a visibly delimited area of 25 m^2, on January 6, 2021, in the morning all nuts in the ground were removed by hand to leave the site 24 hr without nuts. On January 7, 2021, before sunrise, 30 new *J. mollis* nuts were placed, these were obtained randomly from a nearby area. For 2 consecutive days, from sunrise to sunset, observations were conducted from a vantage point 30 m away from the site with binoculars, taking notes of the activity of the squirrels and their interaction with the 30 placed nuts.

In the study area, the last rainfall (48 mm) was registered on September 18, 2020; there was no recorded rain during the study and the temperatures oscillated between -8 °C and 32 °C. On December 27, 2020, the sunrise was at 7:24 hr and the sunset was at 17:58 hr with 10:33 hr of daylight and on March 21, 2021, the sunrise was at 6:45 hr and the sunset was at 18:55 hr for a total of 12:08 hr of daylight, a difference of 1:35 hr of sunlight between the start and the end of the study. We need to consider that due to the geographical location of the study area sunlight appears 2 hr after the sunrise and sunlight vanishes 2 hr earlier than the sunset due to orographic shadow, which in turn affects the environmental temperature in both sites (ODEA and NOGA). The photographs and videos for this study were archived in the photographic collection of the Mammals Collection of the Facultad de Ciencias Biológicas of the Universidad Autónoma de Nuevo León (UANL).

From both camera traps in 156 effective days, 9,447 images and 3,149 videos were obtained between 6:00 hr and 19:00 hr, 743 records were from tree squirrels *S. alleni,* 70 % in ODEA and 30 % in NOGA; for ground squirrel *O. variegatus* 78 records were obtained, 47 % in ODEA and 53 % in NOGA. At least 4 different *S. alleni* individuals were identified and 2 *O. variegatus* in NOGA and at least 7 different *S. alleni* individuals and 4 *O. variegatus* in ODEA. There were no records of juvenile individuals. In 150 camera trap-days (96 % of total that the cameras were active) there was a record of *S. alleni* and only in one third of the camera trap-days there were records of *O. variegatus* due to several three-to-six-day lapses without presence on the spot.

The activity of *S. alleni* was long bimodal (active during 100 % of daylight) in both locations doubling the activity during the morning. The activity of *O. variegatus* was short unimodal (less than 35 % of time with daylight) at noon in NOGA and multimodal in ODEA (Figure 1a). For the ground squirrel, 13 records of ODEA were obtained between 15:00

hr and 18:00 hr (31 % in ODEA, 17 % in both sites) and its activity started on the morning after 10:00 hr when the sunlight hits directly; in ODEA the activity is extended during sunset specially for drinking water. For *S. alleni,* 19 records were before the sunrise and 7 after the sunset thus 4 % of the records are with crepuscular activity, double at sunrise than in sunset. Integrating records from both locations (Figure 1b), *S. alleni* is long bimodal pattern with a high peak activity 2 hr after sunrise and a low peak 2 hr before sunset, with a short resting phase (25 % of day), and for *O. variegatus* a unimodal pattern at noon with little noticeable activity in the afternoon. In relation to the activity and the environmental temperature, for *S. alleni* 48 records (6.5 %) in 14 different days were at freezing temperatures between -8 °C and -1 °C (Table 1; Figure 2 a, b); 88.5 % of all records were at temperatures below 20 °C. For *O. variegatus* 5 records (6.5 %) in 3 different days were at temperatures between 0 °C and 9 °C, with 43.5 % of the records in temperatures above 20 °C.

In the site for observation of dispersion and storage of nuts, *S. alleni* on the first day located 18 nuts of the 30 placed, 3 were rejected, 6 were buried beneath the leaves of the same area, 4 were eaten after climbing a tree and 5 were taken more than 30 m away from the observation area. On the second day, 7 nuts were found, 2 of them were

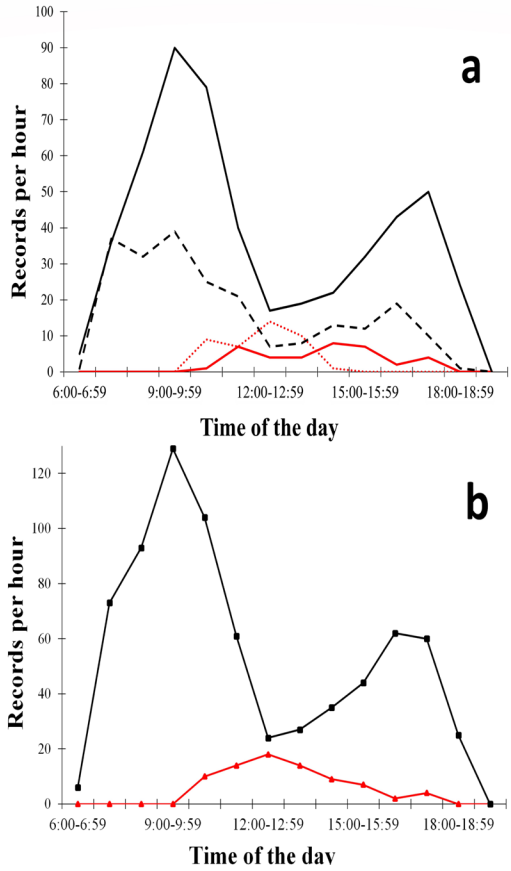

Figure 1. Squirrels recorded by camera trap by hour per day in Llanitos, Santa Catarina, Nuevo León from December 27, 2020, to March 21, 2021. a) *Sciurus alleni* in ODEA (continuous black line) and NOGA (dashed black line) and *Otospermophilus variegatus* in ODEA (continuous red line) and NOGA (dotted red line). b) Winter activity pattern in both locations (ODEA and NOGA) for *Sciurus alleni* (black line) and *Otospermophilus variegatus* (red line).

Table 1. Activity records by environmental temperature range in percent of *Sciurus alleni* and *Otospermophilus variegatus* by camera trap. *n* = quantity of records for each species in the sites ODEA and NOGA together in winter season from Nuevo León, México.

Environmental temperature	*Sciurus alleni*	*Otospermophilus variegatus*
	n = 743	*n* = 78
-8 °C to -1 °C	6.5	-
0 °C to 9 °C	36.0	6.5
10 °C to 19 °C	46.0	50.0
20 °C to 32 °C	11.5	43.5

rejected, 4 were eaten on top of a tree, 1 was taken away. Furthermore, from the 6 buried ones the day before, 4 were retrieved and were taken away. The time taken to open and eat each nut was between 9 and 18 minutes (average 15.6 minutes), 26.6 % were eaten immediately after found, 33.3 % ware taken away to distant places. The rejected nuts were vain nuts, it took less than 2 seconds for the squirrels to detect it and reject them. No ground squirrel was seeing on those 2 days.

Regarding the observed behavior in the 821 images and 426 videos (71 minutes) with record of activity for both squirrels (Table 2), in ODEA, for *S. alleni* in 49.4 % of the records they are drinking water (Figure 2c) and in 25 % they are travelling. For *O. variegatus*, in 62 % of the records they are drinking and vigilance (Figure 2d). In NOGA, for *S. alleni* in most of the records they are travelling and searching; for *O. variegatus* in 78 % they are travelling and watching. Thirty intraspecific encounters were recorded of 2 individuals of *S. alleni* and 4 encounters of 3 individuals; 7 intraspecific encounters of 2 individuals of *O. variegatus* were recorded (Figure 2e). In 4 occasions interspecific encounters between both species were recorded (Figure 2f). All encounters intra and interspecific were non agonistic, even in the presence of *S. alleni* male with scrotal testes.

The chipmunk *Neotamias solivagus* was recorded in 5 different days in ODEA between 9:00 hr and 12:00 hr with temperature between 4 °C and 13 °C (Figure 2g, h, i). Two times *N. solivagus* was recorded with *S. alleni* with no sign of aggression. Other recorded species during the day were black bear (*Ursus americanus*; Figure 2j), puma (*Puma concolor*; Figure 2k) and white tail deer (*Odocoileus virginianus*). Cacomixtle (*Bassariscus astutus)* and gray fox (*Urocyon cinereoargenteus*) were active during the sunrise or sunset when *S. alleni* was active too.

The long bimodal activity pattern of *S. alleni* is as the one reported by Mercado-Morales (1985) for all the year in a warmer and more humid zone of Nuevo León. The long bimodal patterns are related to species that live in habitats with warm winters and high energy attainment (Halle and Stenseth 2000). With higher ambient temperature and sun light (insolation) during mid-day, the activity of *S. alleni* is reduced and the activity of *O. variegatus* starts, this allows them to avoid competition for resources in a location where tree squirrels are more abundant and active than ground squirrels.

Table 2. Behaviors recorded by camera trap in percentage of *Sciurus alleni* and *Otospermophilus variegatus* in each site of observation (ODEA and NOGA). *n* = quantity of records for each species in each site in winter season from Nuevo León, México.

Behaviors recorded	*Sciurus alleni*		*Otospermophilus variegatus*	
	ODEA	**NOGA**	**ODEA**	**NOGA**
	n = 518	*n* = 225	*n* = 37	*n* = 41
Travelling	25.10	58.67	10.81	65.85
Drinking	49.42	0.00	43.24	0.00
Searching	9.85	25.78	8.11	7.32
Vigilance	10.23	7.56	18.92	12.20
Intraspecific interactions	4.44	3.11	8.11	7.32
Interspecific interactions	0.77	0.00	10.81	0.00
Resting	0.00	2.22	0.00	7.32
Eating	0.19	2.22	0.00	0.00
Grooming	0.00	0.44	0.00	0.00

Differing from *S. alleni* long bimodal activity pattern, other tree squirrels in temperate forests in winter such as *S. niger, S. carolinensis, S. arizonensis, S. nayaritensis* and *S. vulgaris* their activity pattern is unimodal (Thompson 1977; Tonkin 1983; Koprowski 1994; Halle and Stenseth 2000; Koprowski and Corse 2005; Wassmer and Refinetti 2016; Steen and Barmoen 2017; Ciurej *et al.* 2019). Wassmer and Refinetti (2019), document with telemetry that in winter some individuals of *S. niger* are unimodal and some other bimodal, this can even vary day by day for everyone, remaining in the nest up to 77 % of the time, considering important the climatic factors, social interactions, and the personality of each individual in the description of the activity patterns. For Mexican neotropical squirrels, Ramos-Lara and López-González (2017), report that *S. aureogaster* is unimodal and *S. oculatus* is multimodal where they coexist; but where only *S. aureogaster* is present it is bimodal (Mora-Ascencio *et al.* 2010; Ramos-Lara and Cervantes 2011). *Sciurus deppei*, a tropical squirrel from the east and south of México, is bimodal and spends up to 60 % of the time in the ground (Best 1995b). *Sciurus colliaei,* a tropical squirrel from western México is bimodal, but in cloudy days can be active all day (Best 1995c). The tropical tree squirrel *S. ingrami* in Brazil is bimodal the whole year (Bordignon and Monteiro-Filho 2000). It is possible that bimodal winter activity pattern of *S. alleni* differs from other squirrels in tempered and cold forests because in Nuevo León even in winter days with over 20 °C are common at noon and this squirrel rests at the time of highest temperature; furthermore, this rest at noon is important for digestion (Koprowski and Corse 2005). Kilpatrick (2003) mentions the importance of using solar radiation to reduce the thermoregulation costs in *S. carolinensis* during winter by spending time feeding in the sun, which is not detected in *S. alleni* as it is highly active from the sunrise even at subzero temperatures for a couple of hours without sunshine due to the orographic shadow in both study locations.

The short unimodal activity pattern that is displayed by *O. variegatus* in NOGA is similar to the other reported for the species in sites where there is no hibernation and the multimodal pattern that was displayed in ODEA while drinking water after 15:00 hr (30 % of records) is not known for the species (Oaks *et al.* 1987). This shows the importance of drinking water for the squirrel in cold and dry conditions, possibly because there is not enough water in the food.

The span of consecutive days with no record for *O. variegatus* are related to the days with minimum temperatures below freezing point and maximum temperatures lower than 10 °C, our data suggests that *O. variegatus* may entered a state of torpor due to the low temperatures for up to 6 consecutive days in 3 different occasions (Oaks *et al.* 1987; Ortega 1991; Waterman 1996).

The time taken to open and eat each nut for *S. alleni* is similar as the one reported by Smith and Follmer (1972). The nuts were eaten immediately after finding them, similar to what was reported by Tamura *et al.* (1999) where 32.6 % of the nuts are eaten immediately during all seasons of the year; the nuts were taken away to distant places, possibly safer to protect themselves from cold and predators (Preston and Jacobs 2009). The scatter-hoarding behavior of *S. alleni* (Figure 2l) is common in the tree squirrels of tempered forests (Preston and Jacobs 2009; Zong *et al.* 2014; Sundaram 2017), differing from more neotropical squirrels in México and Central America that do not store food (Best 1995d; Ramos-Lara and Cervantes 2011; Sutton *et al.* 2016). As an exception of squirrels that do not store or burry nuts regularly in tempered forests, is *S. nayaritensis,* in the Sierra Madre Occidental, which is very active on the ground all year (Best 1995e) and also *S. arizonensis*, from tempered deciduous forests in Arizona and north Sonora (Best 1995f). The results suggested that *S. alleni* has an influence on the walnut seed dispersion by selecting viable nuts to store on the ground, when these nuts are forgotten it favors their germination (Stapanian and Smith 1984; Tamura *et al.* 1999; Vander-Wall 2001; Steele *et al.* 2011). The absence of *O. variegatus* during the observations of walnut dispersion, may be because the ambient temperature was below 15 °C with sub-zero temperatures in the sunrise, but it is common to see this species feed from nuts when the weather conditions are appropriate; however, in 3 years of observations in Llanitos, the ground squirrel was never observed burying nuts.

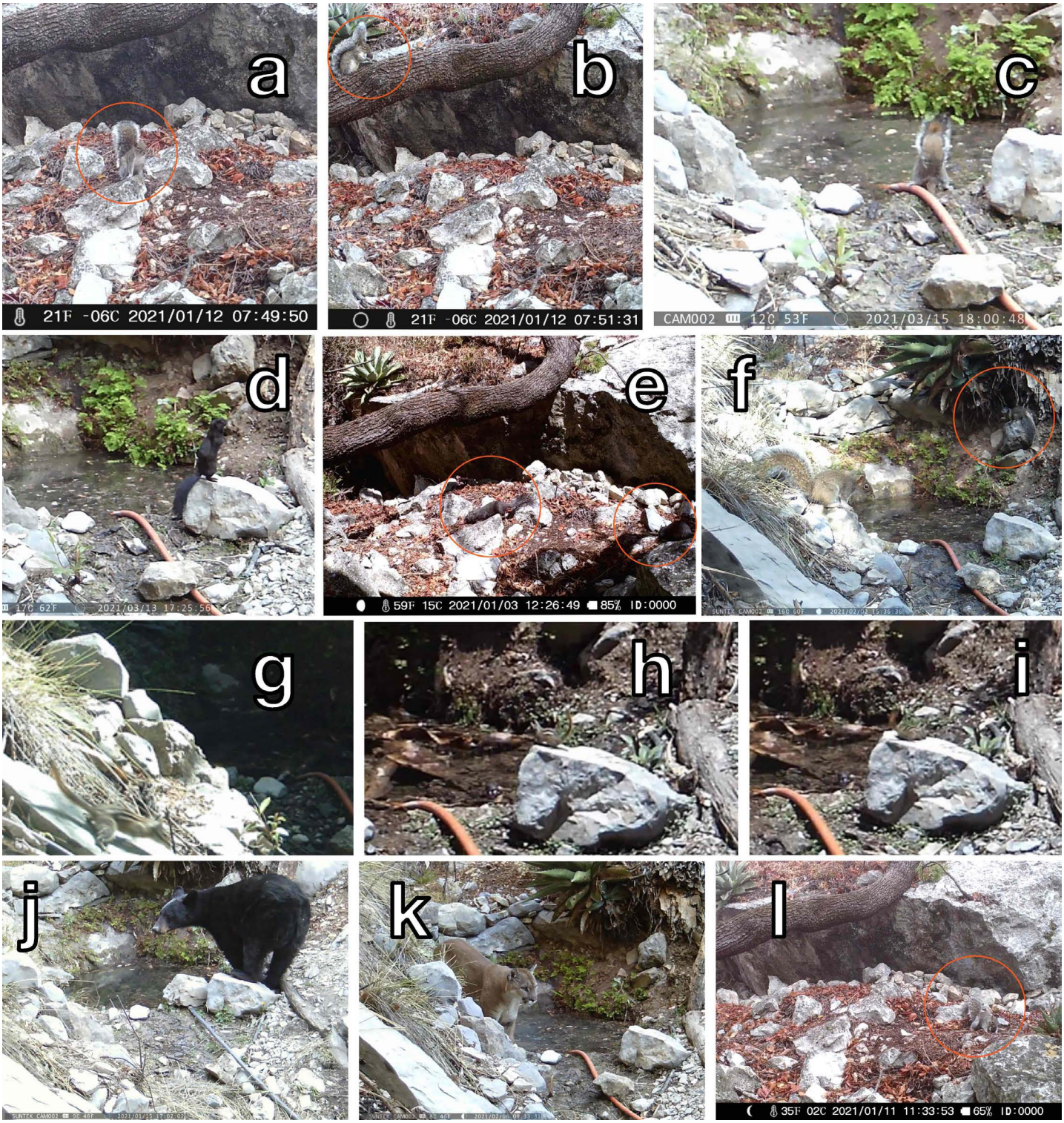

Figure 2. a) *Sciurus alleni* travelling on the ground and b) feeding on a tree branch at -6 °C environmental temperature (NOGA). c) *Sciurus alleni* drinking water at the water spring (ODEA). d) *Otospermophilus variegatus* showing a vigilance behavior (ODEA). e) Non agonistic intraspecific encounter of two *Otospermohilus variegatus* displaying a searching behavior (NOGA). f) Interspecific encounter between *Sciurus alleni* and *Otospermophilus variegatus* at the water spring (ODEA). g, h and i) *Neotamias solivagus* in ODEA. j) *Ursus americanus* and k) *Puma concolor* in ODEA. l) *Sciurus alleni* burying a nut of walnut *Juglans mollis* (NOGA).

The high percentage of records drinking and travelling in ODEA, as well as travelling in NOGA, are in line with the situational characteristic of the site. With low percentage of records searching primarily vigilance to be looking for predators, others risk, or social situations are complementary behaviors of their daily activity (McAdam and Kramer 1998; Shuttleworth 2000). Behaviors of rest and eat have very low number of records because both locations are at ground level and not well suited to these behaviors that are more likely to be seen on trees and safer locations (Wauters *et al.* 1992). Oaks *et al.* (1987) mentioned that *O. variegatus* is tolerant to water deprivation of more than 100 days in captivity, what differs from the obtained data where they arrive at the location to drink water regularly in the wild,

and considering the water is important for thermoregulation (Feist and White 1989), this confirms why both squirrels spend time drinking water during the winter in this dry and cold forest. Mercado-Morales (1985) mentions that in some places *S. alleni* is abundant and in others it is not present, it is possible that the abundance of squirrels could be related to the proximity of water sources, at least in the dry and cold season, since in places with more than 1 km away from water sources it is rare to observe *S. alleni*.

The *Neotamias solivagus* record in ODEA is 2.4 km north from the recent record of the species for Nuevo León (Mercado-Morales 2020) confirming its winter activity; with only 5 records it is not possible to determine if this chipmunk is an occasional visitor to ODEA or could come out of some seasonal lethargy or torpor, it is important to mention that this chipmunk is too small for the camera trap to record all its activity.

In relation to the intra and interspecific encounters between the 3 species of squirrels, perhaps agonistic behavior is not displayed during winter as no females are in estrus (Best 1995a; Oaks *et al.* 1987); furthermore, this confirmed that the 3 species are non-territorial in winter to defend water and food source areas. The other mammals recorded during the day could be considered predators and/or competitors.

The results of this study revealed the importance of water sources and walnut trees for the survival of *S. alleni* and *O. variegatus* in the cold and dry winter season and demonstrate that both squirrels have different strategies to avoid overlapping of niche. It is confirmed that *S. alleni* stores nuts in a scattered pattern. This knowledge is important for the conservation of squirrels, the integral management of forests and to carry out subsequent studies even with few material resources (camera traps) to carry them out when hot spots of wildlife activity are located.

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