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Short Communication

Daily activity pattern in spring of *Liolaemus nigroviridis* (Squamata: Liolaemidae), a sky island lizard of the Andes mountains

Patrón de actividad diaria en primavera de *Liolaemus nigroviridis* (Squamata: Liolaemidae), un lagarto que habita las islas del cielo de la cordillera de los Andes

Jorge Mella[1], Jorge Mella-Romero[2,3,*] & Juan Luis Allendes[4]

[1]Consultora Cristian Muñoz Villouta, Marchant Pereira 2950, Santiago, Chile.
[2]Laboratorio de Conservación Biológica y Laboratorio de Ecología y Genética, Facultad de Ciencias, Universidad de Chile, Santiago, Chile.
[3]One Health Institute, Faculty of Life Sciences, Universidad Andrés Bello, Santiago, Chile.
[4]Programa para la Conservación de los Murciélagos de Chile (PCMCh), Santiago, Chile.
*Corresponding author: jorgemella@ug.uchile.cl

ABSTRACT

This work presents the daily activity pattern in spring of *Liolaemus nigroviridis* Müller & Hellmich, 1932, a sky island lizard of the Andes. Behavioral data were recorded and analyzed for *L. nigroviridis* in Farellones (central Chile) during the spring season. The pattern for adult lizards was unimodal, with a higher concentration of specimens observed between 13:00 and 14:00 pm. Juveniles presented a relatively constant activity during the day. The results may be explained by seasonality and the thermoregulatory behavior of the species.

Keywords: Andean, behavior, reptiles, saxicolous, seasonality.

RESUMEN

Este trabajo presenta el patrón de actividad diaria en primavera de *Liolaemus nigroviridis* Müller & Hellmich, 1932, un lagarto Andino. Se registraron y analizaron datos conductuales de *L. nigroviridis* en Farellones (Chile central) durante la estación de primavera. El patrón para lagartos adultos fue unimodal, observándose una mayor concentración de ejemplares entre las 13:00 y las 14:00 hrs. En los juveniles se observó una actividad relativamente constante durante el día. Los resultados se explican por la estacionalidad y el comportamiento termorregulador de la especie.

Palabras clave: andino, comportamiento, estacionalidad, reptiles, saxícola.

The activity of an animal is a broad concept, however, in herpetological studies it is associated with movements to escape predators and to search for food, reproductive mates or sites to regulate its temperature (Gibbons & Semlitsch 1987). The daily activity patterns of lizards vary according to environmental thermal conditions (Labra *et al.* 2008; Caicedo-Portilla *et al.* 2010), since the thermal resource is one of the main limiting factors in the activity of ectothermic organisms (Martori *et al.* 1998).

One of the most diverse groups of lizards in South America is the genus *Liolaemus* Wiegmann, 1834 (Moya *et al.* 2025; Uetz *et al.* 2024). In the case of *Liolaemus* from the northern highlands, such as *L. alticolor* and *L. jamesi*, their activity is concentrated at midday, when there is greater availability of thermal resources, determining a unimodal pattern (Marquet *et al.* 1989). In central Chile, the valley species (at low altitudes), such as *L. fuscus*, *L. lemniscatus*, and *L. tenuis*, also tend to present a unimodal activity pattern, with greater

activity between 12:00 and 14:00 pm (Labra & Bozinovic 2002). On the other hand, Núñez (1996) found that two sympatric species of *Liolaemus* which inhabit the hills of the O'Higgins Region, in central Chile (at high altitudes) vary in their activity pattern, with *L. curis* showing bimodal activity (with decreased activity at midday, when it is warmer) and *L. curicensis* showing unimodal activity. In the case of three saxicolous *Liolaemus* species inhabiting the central Andean range (*L. belli*, *L. leopardinus*, and *L. nigroviridis*), Carothers *et al.* (1998) found that they show a greater use of rocks in the afternoon than in the morning, which would suggest a bimodal activity pattern. Recently, Mella (2020) showed that two species of lizards from the mountain range of the Maule Region, in south-central Chile (*L. carlosgarini*, *L. buergueri*) present a bimodal activity pattern. However, all the mentioned studies determined the activity pattern in summer, without giving further details on the likely changes in other seasons of the year.

Liolaemus nigroviridis Müller & Hellmich, 1932 is a Chilean endemic lizard with saxicolous habits (Donoso-Barros 1966; Mella *et al.* 2024; Moya *et al.* 2024) that inhabits the sky islands (i.e., patches in elevated zones that differ from patches in intermediate valleys; Shepard & Burbrink 2008; Mella-Romero *et al.* 2024) of the Andean and Coastal mountain ranges. *Liolaemus nigroviridis* is distributed from Quebrada Manque (Coquimbo Region) to Cerro Poqui (O'Higgins Region), between 816 and 3940 m a.s.l. (Castro-Pastene *et al.* 2018; Mella-Romero *et al.* 2023). Although there are some antecedents to suggest eventual bimodal activity in this species (Fuentes 1976; Carothers *et al.* 1998), this has not been studied, nor is it known whether activity patterns are similar for juveniles and adults. The only information previously available was that juveniles are more active in the morning and adults in the afternoon (Carothers *et al.* 1998). Within this framework, the goal of this study was to evaluate the daily activity pattern of *L. nigroviridis* in spring, and to compare whether this pattern vary along ontogenetic stage (comparing juveniles and adults).

A herpetological survey was conducted in the locality of Farellones (Andean mountain range, Metropolitan Region, central Chile), specifically in the Casa de Piedra sector (33°21'33" S, 70°17'44" W; 2365 m a.s.l.), between November 4th and 5th (austral spring season) with the participation of three specialists. The daily activity pattern of *L. nigroviridis* was quantified using a transect 600 m long and 10 m wide, covering an area of 0.6 ha. This transect was walked at one-hour intervals, between 08:30 am and 19:30 pm. (totaling 12 walks, five in the morning and seven in the afternoon), counting each specimen observed (Mella 2020). No lizards were active before 9:00 am. Our sampling effort follows that proposed by other studies evaluating activity patterns in lizards of South America (e.g., see Carothers *et al.* 1998; Filogonio *et al.* 2010; Llanqui *et al.* 2022). We have evaluated the number of records, independent of the number of specimens observed, even if these were observed more than once, in a similar area, following Mella & Marambio-Alfaro (2023). The transect was always traveled in the same direction, and passive sampling was carried out (without approaching the specimens and without removing rocks or vegetation, minimizing the disturbance of the individuals). We consider the sampling effort (concentrated over two days) to be representative for the following reasons: (i) it involved systematic sampling conducted repeatedly every hour throughout the entire activity period, minimizing potential biases such as sampling at different times on different days (e.g., Carothers *et al.* 1998; Marquet *et al.* 1989); (ii) it allowed us to obtain a high number of records (245 in total), in contrast to other studies where the total number of observations is lower (e.g. Marquet *et al.* 1989).

The age of the specimens was based on body size (visually estimated), in two categories: juveniles (including subadults, less than 14 cm total length), and adults (more than 14 cm) (Mella 2017). In addition, the coloration pattern was used as a complement to differentiate juveniles and adults: the former, with grayish-brown coloration, with discontinuous vertebral line, and adults, with conspicuous greenish-black coloration, and without vertebral line (Mella 2017; Fig. 1). Since this study does not involve capture or handling of animals and was conducted in an open access area, permission from the environmental authority (Servicio Agrícola y Ganadero; SAG) was not required.

Thermal changes in the air temperature (T*air*; between 10 to 15 cm from the ground) and in the temperature of rocks (T*sub*), the substrate most used by this saxicolous species (Mella *et al.* 2024), were measured using a multimeter (Stanley, model STHT77364) with a thermocouple (Labra *et al.* 2008). Temperature measurements were taken every 15 minutes, between 08:30 am and 19:30 pm, indicating the average (from four values) in each hour.

With a total of 245 recorded observations, the daily activity pattern of *L. nigroviridis* in spring was found to be unimodal, with the highest concentration of records observed between 13:00 and 14:00 pm: a maximum of 39 records in an area of 0.6 ha (Fig. 2A). Individuals appeared after 09:00 am (there is no record of any specimens between 08:00 and 09:00 am) and their activity decreased markedly at 19:30 pm, with only seven individuals recorded (Fig. 2A). After 19:30 pm, no lizards were observed.

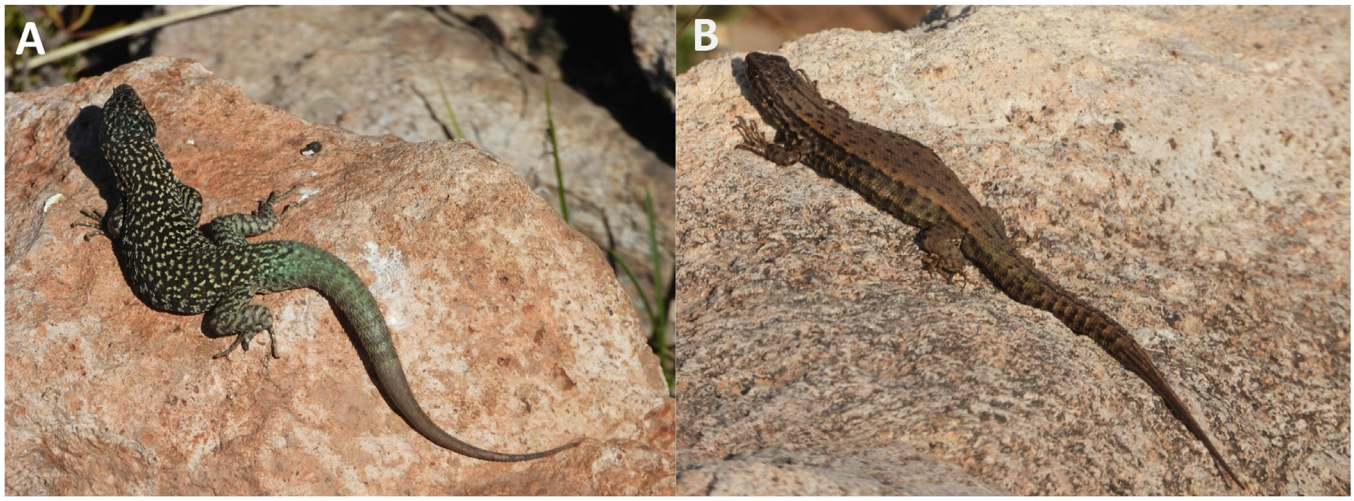

Figure 1. Adult (A) and juvenile (B) specimens of *Liolaemus nigroviridis* in Farellones, Chile. Photograhps by Jorge Mella. / Ejemplar adulto (A) y juvenil (B) de *Liolaemus nigroviridis* en Farellones, Chile. Fotografías de Jorge Mella.

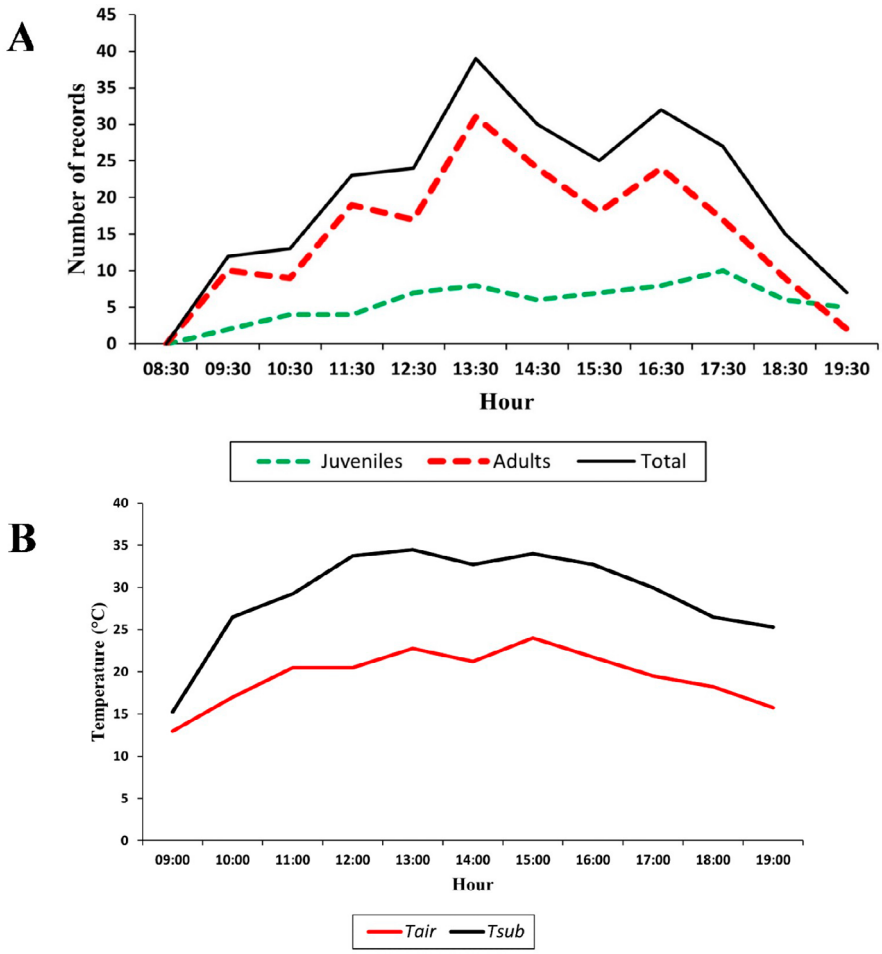

Figure 2. (A) Daily activity pattern of *L. nigroviridis* in Farellones (spring season), Chile. (B) Daily record of air temperature (T*air*) and rock temperature (T*sub*), Farellones (spring season). / (A) Patrón de actividad diaria de *L. nigroviridis* en Farellones (estación primaveral), Chile. (B) Registro diario de la temperatura del aire (T*air*) y de la roca (T*sub*), Farellones (estación primaveral).

Adults dominated numerically in almost the entire period (explaining the observed unimodal pattern) except at 19:30 pm (the last hour of sampling) where more juveniles than adults were observed (Fig. 2A). Juveniles represented a low proportion of the total specimens observed, and displayed an homogeneous activity throughout the day, with maximum values of six to 10 specimens per hour (Fig. 2A).The adult/juvenile ratio was highest in the early morning (adult/juvenile = 5 at 09:30 pm), oscillated until 13:30 pm, and then gradually decreased to a minimum in the afternoon, with an adult/juvenile ratio of 0.4 (Fig. 3).

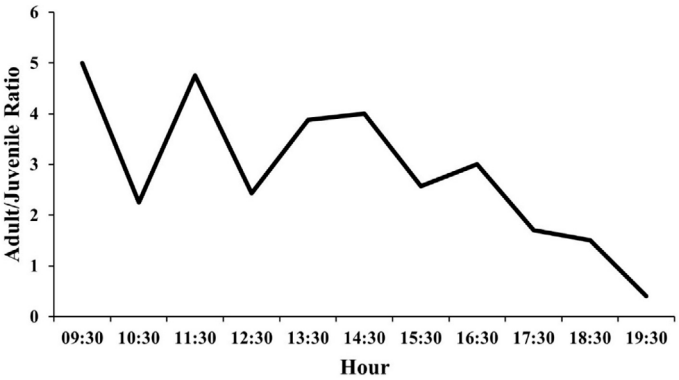

Figure 3. Adult/juvenile ratio of *L. nigroviridis* throughout the day, Farellones (spring season). / Proporción adulto/juvenil de *L. nigroviridis* a lo largo del día, Farellones (estación primaveral).

Air temperature oscillated between a minimum of 13 °C at 09:00 am, gradually increasing to a maximum of 24°C at 15:00 pm, and gradually decreasing to 15.75 °C at 19:00 pm (Fig. 2B). In contrast, rock temperature, while presenting a daily curve similar to the air temperature, always presents higher values, with a minimum of 15.25 °C at 09:00 am, rising rapidly to 26.5 °C at 10:00 am, and rising to a maximum of 32.75 °C - 34.5 °C between 12:00 and 16:00 pm, gradually decreasing to 25.3 °C at 19:00 pm (Fig. 2B).

The daily activity pattern of adults of *L. nigroviridis* in Farellones during spring tends to be unimodal. The absence of specimens before 09:00 am can be explained by that there was still shade in the sector at that time. Although the total curve (245 observations; Fig. 2A) shows a second-highest value at 16:30 pm, this does not represent a second modal value, since there is no decrease in activity at midday, which is characteristic of bimodal patterns. The comparison between ages shows that the unimodal pattern is basically explained by the adults, while the juveniles presented a homogeneous activity, with a slight gradual increase in juvenile activity during the day (until 17:30 pm), decreasing at sunset.

The adult/juvenile ratio was highest in the early morning, and then gradually decreased to a minimum in the afternoon. This ratio is opposite to that observed by Carothers *et al.* (1998) for several species inhabiting central Chile (including *L. nigroviridis*). These authors observed that in general, the adult/juvenile ratio for *L. nigroviridis* was always higher in the late afternoon (after 18:00 pm) than in the early morning (before 10:00 am), meaning that juveniles would be more active in the morning and adults more active in the afternoon. This correlates with thermal inertia associated with ectotherm body size, as smaller lizards warm up faster and larger lizards cool down more slowly (Porter *et al.* 1973). Unlike the Carothers *et al.* (1998) study, which was carried out in summer, the pattern observed in our study was conducted in spring, with a maximum air temperature of 24°C. These climatic conditions could be influencing the activity pattern of *L. nigroviridis*, compared to summer conditions, a period in which such a pattern could resemble bimodality (e.g., Mella 2020).

It is likely that different thermoregulatory mechanisms may partly explain what was observed, with an eventual change of heat absorption by radiation in the early morning (several adult specimens perched on rocks, which were at a low temperature; 15 °C) and by tigmothermia in the afternoon (when the rocks temperature was higher than 32 °C). Given the latter, it would be interesting to compare the seasonal activity pattern for adults and juveniles, incorporating surveys in summer and autumn (since in winter the area is covered with snow and lizards are inactive), as well as the thermal changes of the rocky substrate. Carothers *et al.* (1998) determined the body temperature of several species of *Liolaemus* (including *L. nigroviridis*) and proposed that this could determine a differential activity pattern between adults and juveniles. This is due to their different thermoregulatory capacities, determined by their cooling and heating rates (by thermal inertia).

The unimodal activity pattern observed in *L. nigroviridis* does not agree with the antecedents reported by Carothers *et al.* (1998) in Farellones, Lagunillas and El Volcán (all these localities are located in central Chile), who document that the adults show greater use of rocks in the afternoon (after 18:00 pm), with 85.1 % of the records, compared to the early morning (before 10:00 am), with 66.7 %; from which a bimodal activity could be deduced. For the same periods analyzed by Carothers *et al.* (1998), complementary data of microhabitat use recorded by us in both periods of the day (Mella *et al.* 2024) indicate that in the early morning, adults

present 68.2 % of rock use, while in the afternoon this value is 87.5 %, which agrees with Carothers *et al.* (1998). However, the present study shows that in the early morning there is low activity (10 adult specimens), like the afternoon (nine specimens) and both values are clearly lower than the maximum of 31 adults (at 13:30 pm). Regarding the latter, the daily microhabitat use does not necessarily relate to the daily activity pattern of the species, so caution is required in extrapolations.

On the other hand, Carothers *et al.* (1998) document neither the activity nor the use of microhabitats during the rest of the day, nor do they indicate in which season of the year the study was carried out (although it was probably summer). It is likely that in midsummer, with higher midday temperatures, the bimodal pattern is more clearly expressed, with greater activity of the species in mid-morning and mid-afternoon and decreasing activity at midday. In autumn, with lower temperatures, it would expect a more evident unimodal pattern than in spring. In some species, it has indeed been shown that the activity pattern changes from bimodal in summer to unimodal in the more temperate periods, as in the Argentinian species *L. wiegmannii* and *L. darwini* (Videla & Puig 1994; Martori *et al.* 1998).

The unimodal activity pattern described here for *L. nigroviridis* also does not agree with that observed for two other mountain species of *Liolaemus* from central Chile, such as *L. carlosgarini* and *L. buergueri*, for which a bimodal pattern has been described (Mella 2020). The latter may be due to seasonality, since in Mella (2020), the data were taken in summer and early autumn, where temperatures are higher than in spring. Interestingly, the unimodal pattern observed for *L. nigroviridis* (a sky island lizard) does agree with that recorded for other *Liolaemus* species inhabiting the Chilean central valley at low altitudes (*L. fuscus*, *L. lemniscatus*, and *L. tenuis*), with greater activity concentrated between 12:00 and 14:00 pm (Labra & Bozinovic 2002). To clarify the latter and fill the information gaps, we suggest describing quantitatively the activity pattern of other *Liolaemus* species, considering spatial, temporal (seasonal) and ontogenetic variations.

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