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Characterization and selection of microhabitat of *Microcavia australis* (Rodentia: Caviidae): first data in a rocky habitat in the hyperarid Monte Desert of Argentina

Abstract: A rocky habitat, in its broadest sense, may be described as any locality that contains boulders, rocks, scree, pebbles, outcrops, cliffs, or caves. In these habitats, mammals find shelter sites that they use as nesting sites or dens to raise their young in a stable microclimate that is relatively secure from predators. The aim of this study was to characterize and evaluate the microhabitat selection by the southern mountain cavy (*Microcavia australis* Geoffroy and d'Orbigny) in a rocky habitat. This rodent selected the highest and deepest crevices, which provided them with a more stable microenvironment than outside. The present study is the first to report a southern mountain cavy population associated with a rocky habitat, suggesting a strong plasticity to inhabit a variety of habitats, as indicated by its wide distribution.

Keywords: crevices; *Microcavia australis*; microhabitat characterization; Monte Desert; rock outcrops.

Dedicated to: This article is dedicated to the memory of our deceased colleague Verónica Lahoz.

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Introduction

Habitat structure has a strong influence on several aspects of the life history of species in their environments, affecting population dynamics (Seamon and Adler 1996, Williams et al. 2001, Tabeni and Ojeda 2005), food search activities (Covich 1976, Thompson 1987, Ojeda 1989, Schradin and Pillay 2006), thermoregulation (Lagos et al. 1995a, Bronikowski and Altmann 1996, Taraborelli et al. 2009), search of shelter to avoid predators (Kotler 1984), search of nesting sites (Lott 1991, Lagos et al. 1995a,b, Beck and Watts 1997, Brashares and Arcese 2002), and social organization (Taraborelli 2009, Andino et al. 2011), among other factors.

Most rodents use burrows (Reichman and Smith 1990, Turner 2000, Shenbrot et al. 2002, Taraborelli et al. 2009), which can provide them with several benefits, like places for food storage (Arends and McNab 2001), offspring protection, and refuge from predators during surface activity (Reichman and Smith 1990, Lagos et al. 1995a, Shenbrot et al. 2002, Burda et al. 2007). In addition, because the microenvironment inside the burrow is thermally buffered with respect to the external environment (Contreras and McNab 1990, Šumbera et al. 2004, Burda et al. 2007), burrows can provide a relatively stable microclimate. Indeed, these burrows protect small animals from extreme surface temperatures and external aridity (Reichman and Smith 1990, Kinlaw 1999, Shenbrot et al. 2002, Burda et al. 2007, Taraborelli et al. 2009). However, burrows can be very complex and challenging, and the occupants have to face high energy expenditure involved in digging, among other constraints (Šumbera et al. 2004). As a result, burrowing mammals have to assign a high proportion of their energy and time budget to the construction and maintenance of their burrows (Luna and Antinuchi 2006, 2007, Perissinotti et al. 2009). Those costs restrict burrowing animals to habitats where excavation is energetically feasible, which is probably related to soil characteristics and associated vegetation as well as the animal's burrowing ability (Calede et al. 2011).

In deserts, due to their pronounced daily and seasonal temperature fluctuations, and low availability of resources, rocky habitats can be important sites for rodents. Despite this, knowledge on habitat requirements by mammal species living in this environment is scarce. Rocky habitats may offer shelter sites because they contain caves and crevices, among other elements (boulders, rocks, scree, pebbles, outcrops, cliffs) (Nutt 2007). In these habitats, rodents may use caves and crevices as nesting sites or dens to raise their young in a stable microclimate that is relatively secure from predators (Mares 1997, Nutt 2007).

There are several hypotheses that attempt to explain why many rodents live in rocky habitats (see review in Nutt 2007). One of them addresses the insulating effect of rocks in moderating temperature fluctuations, which can help rodents to properly thermoregulate (see review in Nutt 2007). Temperatures inside crevices are generally much more stable than external temperatures, which can undergo pronounced fluctuations in desert environments (Mares 1997, Nutt 2007). Another hypothesis considers the high predation risk of desert areas and postulates that rocky substrate might enhance the ability of rodents to protect from predation using rocks as lookout posts to detect predators (see review in Nutt 2007). It has been also proposed that the complex topography of rocky habitats, including the presence of water catchment sites, can generate unique microenvironments throughout the rocky substrate with increased richness of plant species that remain green for long periods due to increased water availability afforded by the rocks (Mares 1997, Nutt 2007).

The southern mountain cavy (*Microcavia australis* Geoffroy and d'Orbigny) is a hystricognath rodent that inhabits arid and semiarid lowlands and valleys; it occurs in riparian habitats, forested areas, or sandy forested flats (Rood 1970, Redford and Eisenberg 1992). It is one of the smallest caviomorph rodents (250 g) (Tognelli et al. 2001), exhibits diurnal habits, and lives in social groups (Andino et al. 2011). Its breeding season occurs during approximately 8–10 months (Rood 1970, Vélez et al. 2010, Andino unpublished data). In the central Monte Desert of Argentina, burrow systems of this cavy reach their highest density in a mesquite community, under *Prosopis chilensis* Molina and/or *Prosopis flexuosa* DC trees, whose branches are arched and touch the ground (Tognelli et al. 1995). Knowledge of the life history of the southern mountain cavy is based on field studies in the ecotone between Espinal and Monte ecoregions (Rood 1970). More recently, several studies in the Monte Desert have focused on a population that inhabits mesquite communities (Contreras and Roig 1978, Tognelli et al. 1999, Taraborelli et al. 2009, Sassi et al.

2011) and in the creosote bush communities (Taraborelli et al. 2009, Sassi et al. 2011, Andino et al. 2011). Although the southern mountain cavy has a wide distribution that includes several habitats (Tognelli et al. 2001), no studies have addressed ecological requirements of populations associated with rocky habitats. Furthermore, there are no studies describing the attributes of used crevices and identifying variables that increase crevice suitability for the southern mountain cavy use in this habitat type. In this study, we hypothesized that the southern mountain cavy would use crevices with particular characteristics. Accordingly, the objectives were to 1) measure the dimensions of used and available crevices to determine the structural characteristics that influence crevice selection; 2) describe the thermal microhabitat used by the southern mountain cavy and analyze the variables that affect mean temperature and temperature range inside crevices.

Materials and methods

Study site

The study was conducted in 2011 (January, February, March, and December) and 2012 (January) in the locality of La Laja (31°19′S, 68°41′W; Figure 1), 27 km north of San Juan city (San Juan province, Argentina). The site belongs to the Monte of mountains and closed basins in the Monte Desert ecoregion. The vegetation is mainly xerophic, psamophilic, and halophytic (Cabrera 1994). According to the classification of Köppen, the climate of this region is BWw type, which is very arid with scarce and torrential rains during the summer and cold temperatures during the winter. The average annual precipitation never exceeds 80 mm and is concentrated in summer months, from November to March, with dry winters from April to October (Suvires 2004). The mean temperature in summer is 24.3°C, with an absolute maximum of 45°C. The mean temperature in winter is 8.5°C, with an absolute minimum of -10°C (Poblete and Minetti 1999).

Geologically, the study site is located in the "Lomas de Las Tapias" formation, which is composed of sandstones, claystones, siltstones, and stratified conglomerates, and the "Torrecitas" formation, composed of tuffs and outcrops of travertine deposits (Contreras et al. 1999). Suffossion or piping processes occur in La Laja, i.e., natural holes (pipes) are formed and further developed in the soil or other unconsolidated deposits by eluviation or subsurface differential erosion processes (Gutiérrez Elorza and Rodriguez Vidal 1984), resulting in a release of travertine

Figure 1　Photograph of rocky habitat used by the southern mountain cavy in La Laja, San Juan, Argentina.

material (Yacante et al. 1997) and slabs, carbonate rocks with several plant impressions. These processes occurring in La Laja may be induced by the arid climate, heavy precipitations, and sparse vegetation (Yacante et al. 1997).

Habitat characterization

We analyzed the characteristics and use of burrows by the southern mountain cavy at two levels: rock outcrops and burrows (as defined below). At the former level, we identified five disconnected rock outcrops with the presence of southern mountain cavy individuals. We obtained the dimensions of each rock outcrop by measuring their height every 7 m from the bottom to the top, therefore, recording the total length (m). Furthermore, in each rock outcrop, we laid out 27-m-long transects. We distributed four quadrats (9 m² each) at 3-m intervals along each transect to record cover of plant, bard soil, rock, and crevices, by applying the design of use-availability proposed Johnson et al. (2006).

We defined two types of burrows based on the depth of the crevices: nesting and refuge crevices (Figure 2A, B). We assumed that the nesting crevices are the deepest (>20 cm) ones, which offer greatest protection against predators and climate. Refuge crevices (<20 cm) would provide easy escape from predators and would not be occupied permanently by the cavies.

We considered that crevices were either used by the southern mountain cavy or available to them. The used crevices were identified by the presence of signs of use such as feces, footprints, and caches of plant material, whereas available crevices had no signs. In each one of the used and available crevices, we recorded the depth, height, width (cm), and orientation (Figure 2A, B). The depth was measured as the distance from the entrance to the rock bottom; the height was measured at the entrance, from the ground to the rock ceiling; the width of crevice was the maximum length of crevice entrance, and the orientation to magnetic north was the orientation of the entrance to the crevice and was assigned to four quadrants (north, east, west and south), following the method
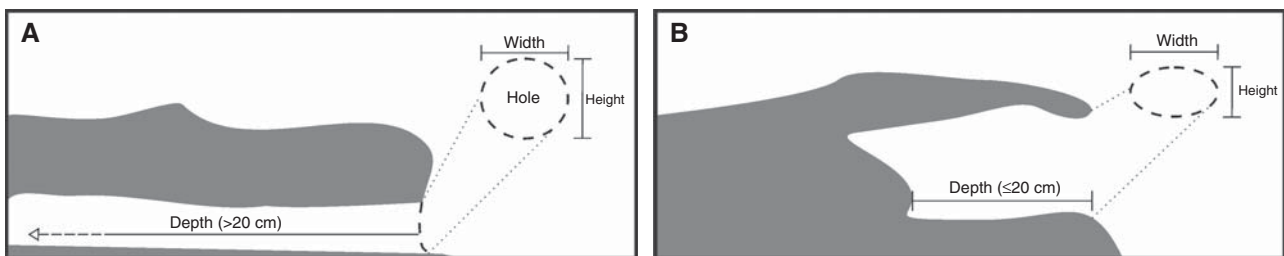

Figure 2　Registering of width, height, depth, and orientation in nesting crevices (A) and refuge crevices (B) used and available by the southern mountain cavy.

proposed by Torres et al. (2003). We recorded soil hardness (kg/cm^2) by randomly taking five measurements with a penetrometer (S-170 Pocket Penetrometer, Brainard-Kilman, Longyear U.S. Products Group, Stone Mountain, GA, USA) located at the crevice entrances.

Finally, to characterize the thermal microhabitat, we recorded environmental temperature at 1.5 m above the soil, soil temperature at the entrance of nesting crevices, and soil temperature inside these nesting crevices, at 30 cm in depth in 18 used nesting crevices, oriented to the north, east, south, and west. Temperature values were recorded every 2 h for 1 week from December 2011 to January in 2012 using DS1922L and DS1921H I-button model data loggers (I-Buttons® Maxim products, Cold-Chain TD Started Kit CTSK, Fairbridge Technologies, USA).

Statistical analyses

We used descriptive statistics to characterize the rock outcrops. To evaluate differences in structural characteristics of nesting crevices and refuge crevices, we performed a Mann-Whitney U-test because the data did not show normality. To evaluate differences in orientation of used and available crevices, we performed Fisher' exact (2×4) test using package "exact" (Calhoud 2013).

We used the generalized linear model (GLM) to model the data of use of habitat and the generalized linear mixed models (GLMMs) to analyze the thermal microhabitat used by the southern mountain cavy. The information theoretic approach, Akaike's information criterion corrected for small sample size (AIC$_c$), was calculated to evaluate the models that best fitted the data (Burnham and Anderson 2002). The difference between the lowest AIC$_c$ value and the AIC$_c$ from all the other models (ΔAIC$_c$) was calculated to rank the potential models (Burnham and Anderson 2002). The AIC$_c$ weight of a model (w$_i$) was calculated based on all candidate models according to Burnham and Anderson (2002), representing the likelihood that a particular model is the best model, given the data and the candidate models considered. Complementarily, we evaluated the support for predictor variables by summing w$_i$ across all models that contained the considered parameters. Predictor variables with good support presented high parameter-likelihood values (w$_i$ near 1). Parameter estimates were calculated using model-averaged parameter estimates based on w$_i$ for all candidate models.

For the analyses of use and availability of habitat, we built models that provided an estimate of the odds of the southern mountain cavy selecting a crevice based on their structural characteristics. The response variable (used: 1,

available: 0 crevices) fitted to a binomial distribution (link=logit) and the type of crevices (nesting and refuge crevices), depth, height, width, and crevice entrance orientation were the fixed factors (predictor variables) evaluated to test their effect on crevice selection. Models with all possible combinations of explanatory variables for used/available crevices were considered.

Temperatures as well as breadth of temperature range are key habitat environmental variables because both affect the physiological and behavioral functions of individuals. Owing to their importance and for a better understanding of thermal characteristics of microhabitats used by the species, we assessed the mean and range of soil temperature in nesting crevices and built models to analyze the variables that affect their values inside crevices. Although mean temperature is a good predictor of the microhabitat temperature, we also used the temperature range because extreme temperatures are important in deserts, where the species is subjected to thermal stress. We built 10 GLMMs and used as predictor variables environmental temperature, the crevice orientation (factor with four levels: north, east, south, west), and time of day when temperature is read. We included crevice identity as random effect. We considered all possible combinations of predictor variables as well as the interaction between time of the day and environmental temperature. Temperature values are expressed in degree Celsius (°C).

In all cases, for each candidate model, we evaluated the relative importance (RI) of each predictor variable (Burnham and Anderson 2002) and the percentage of the total variance explained using library "rms" for data binomial distribution (Harrel 2014) and R^2 for GLMMs (Nakagawa and Schielzeth 2013).

All statistical analyses were performed using R Core Team (2014) version 3.1.1.

Results

In the study site, the southern mountain cavy was present in five rock outcrops. The mean height of rock outcrops was 3.37±1.00 m, with a maximum of 5.8 m and a minimum of 1.2 m, whereas the mean length was 63.6±16.78 m, with a maximum of 75 m and a minimum of 30 m. The coefficient of variation of height and length evidences a high heterogeneity in rock outcrop dimensions (CV=29.72 and CV=26.40, respectively).

Rock outcrops were characterized by a high rock cover, reaching nearly 60% of the substrate (57±4.9%, range: 10–100%), and a low cover of bare soil (29.8±5.6%, range: 5–100%); the latter was present only in three of

the five studied rock outcrops. Vegetation cover was low and distributed only at the base of the rock outcrops (22.9±3.2%), being represented only by shrub (21.0±3.6%, range: 2–100%) and herb (2.8±1.1%, range: 1.3–40%) layers. Litter cover was very low and was only recorded in one of the rock outcrops sampled (litter mean cover: 4.37±9.64%, range: 0–30%).

Structural characteristics of crevices

We recorded and characterized 108 crevices: 86 nesting crevices and 22 refuge crevices. The crevice types show statistical differences in entrance height (Mann-Whitney U=571.00, n=108, p=0.004) and crevice depth (Mann-Whitney U=8.00, n=108, p<0.0001) but not in width (Mann-Whitney U=817.00, n=108, p=0.35). The nesting crevices were higher and deeper than refuge crevices and similar in width (Table 1). Substrate hardness of nesting sites and refuge crevices at the entrance of crevices exhibited similar values (Mann-Whitney U=660.50, n=108, p=0.40), with a mean of 3.90±0.26 and 4.22±0.19 kg/cm², respectively.

Both nesting crevices and refuge crevices were non-randomly oriented (Fisher's exact test, p=0.03). The used crevices were oriented to the east quadrants (percentage deviation=44%), and crevices oriented to the south quadrant were not selected (percentage deviation=-29%).

Use and availability of crevices

To analyze the use and availability of crevices, we built 16 models. The best models were those that presented a ΔAICc <2, which resulted in three best models (Table 2). Of this set of three models, the one that included the additive effect between depth and height was the best model selected with w_i of 0.31 (Table 2). This model differed by 0.16 U from each of the other two models (Table 2). The total deviance explained by the best model was 90%, and

Table 1 Dimensions (cm) of nesting sites and refuge crevices.

	Variable	N	Mean (±SD)	CV	Min	Max
Nesting crevices	Height	86	19.18±8.54	44.52	7.00	55.00
	Width	86	19.90±8.19	41.15	7.00	36.40
	Depth	86	56.57±39.16	69.22	25.00	220.00
Refuge crevices	Height	22	13.71±4.31	31.43	6.50	21.00
	Width	22	18.28±7.96	43.54	9.00	35.60
	Depth	22	13.81±4.00	28.96	5.50	20.00

Table 2 The three best models of crevices selection by the southern mountain cavy.

Models	K	AICc	ΔAICc	w_i	R²
Height+depth	3	143.25	0.00	0.31	90.05
Height	2	144.54	1.28	0.16	60.1
Depth	2	144.55	1.30	0.14	58.3

AICc values for each candidate model; differences between the model with the lowest AICc value and each candidate model (ΔAICc) from best to worst; number of estimated parameters (k), Akaike weight (w_i), and R². The fixed factors included in these models were depth, height of crevices.

the RI of height (RI: 0.70) and depth (RI: 0.68) was high compared to the other predictor variables: width (RI: 0.28) and orientation (RI: 0.07). The logistic regression equation of the selected model was:

$$Y=-0.66+0.055\,(\text{height})+0.011\,(\text{depth})$$

Considering this model, the odds of selection increased by exp (0.055) or 56.9% for every 1 cm increase in crevice height. Additionally, the odds of selection increased by exp (0.011) or 11.4% for every 1 cm increase in depth of crevice.

Thermal characterization of crevices

Mean environmental temperature varied throughout the day (Figure 3). The mean maximum environmental temperature (41.15°C) was recorded at 18:00, whereas the minimum value (12.8°C) was recorded at 6:00 (Figure 3). Inside nesting crevices, the mean substrate temperature was higher in crevices with north orientation and lower in crevices with south and east orientation (Figure 4). Outside nesting crevices, the highest mean substrate temperature was recorded in crevices with north orientation, and the lowest one was recorded in east-oriented crevices (Figure 4). The absolute maximum and minimum substrate temperatures (63.72°C) outside crevices were recorded at 10:00 in nesting sites with north orientation and at 4:00 (16.52°C) in nesting sites with east orientation. Inside nesting crevices, the absolute maximum and minimum substrate temperatures were recorded at 12:00 (49.56°C) in nesting sites with north orientation and at 4:00 a.m. (19.5°C) in nesting sites oriented to east, respectively.

The range of substrate temperature was highest outside than inside of nesting crevices (mean=8.57±0.10°C and 6.47±0.10°C, respectively) (Figure 5). Nesting crevices with east orientation showed the greatest temperature
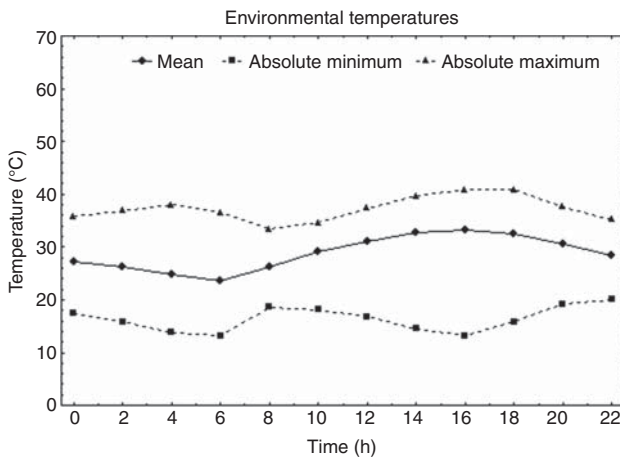
Figure 3 Profile of environmental temperature recorded every 2 h from December 2011 to January 2012. Mean temperature, mean maximum, and mean minimum temperatures are shown.
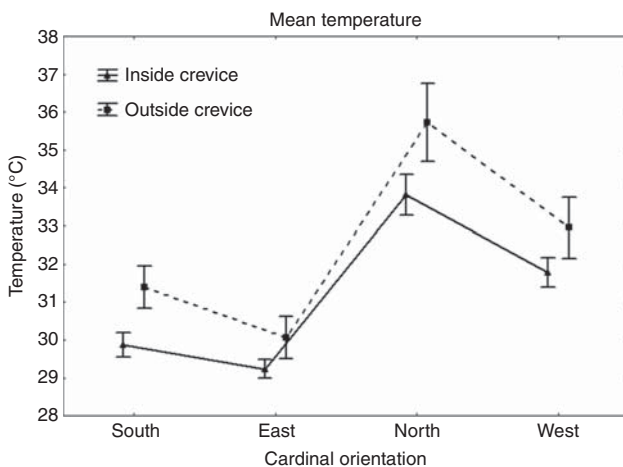

Figure 4 Mean temperature of substrate inside and outside nesting crevices in the four cardinal orientations.
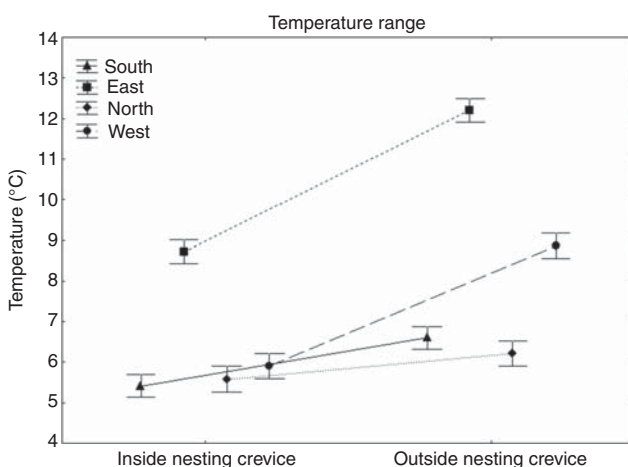

Figure 5 Range of substrate temperature inside and outside nesting crevices in the four cardinal orientations.

range (mean=10.46±0.11°C), and nesting crevices with north orientation exhibited the smallest substrate temperature range (5.89±0.12°C) (Figure 5).

The best model that explained the mean temperature inside nesting crevices was the additive effect between the time of day of temperature reading and orientation (Table 3). Temperature variability (78.94%) was explained by this model and the RI of these predictor variables was higher (orientation: 0.99, time of the day of temperature reading: 0.90) than that of environmental temperature (RI: 0.06) and the interaction between time of the day and orientation (RI: 0.04). The mean temperature inside nesting crevices changed significantly according to crevice orientation (Table 4). The highest temperatures were recorded in nesting crevices with north and west orientation (33.81±0.19°C and 31.77°C±0.19°C). East- and south-oriented nesting crevices showed the lowest temperatures

Table 3 Summary of model-selection results for generalized mixed linear models explaining variation in mean temperature and range of temperature inside nesting crevices used by the southern mountain cavy in relation to cardinal orientation (O) of nesting site, time (H) of day when temperature is read, and environmental temperature (T_{env}).

Response variable: mean temperature inside of nesting crevices

Candidate model	AICc	ΔAICc	w_i	% of total deviance explained
O+H	2896.33	0.00	0.94	78.94
O+H+T_{env}	2901.85	5.52	0.06	78.01
H	2918.40	22.07	0.00	49.61
H+T_{env}	2923.85	27.53	0.00	49.78
O*H	2954.85	58.52	0.00	78.67
O*H+Tenv	2964.36	68.04	0.00	78.66
T_{env}+O	3720.38	824.05	0.00	48.78
T_{env}	3741.59	845.26	0.00	27.77
O	4164.12	1267.80	0.00	28.58
Null model	4186.92	1290.59	0.00	–

Response variable: range of temperature inside of nesting crevices

Candidate model	AICc	ΔAICc	w_i	% of total deviance explained
O*H	3517.48	0.00	0.91	68.90
O*H+T_{env}	3522.16	4.68	0.09	68.56
O+H+Tenv	3959.08	441.60	0.00	54.69
O+H	3963.04	445.56	0.00	54.08
H+T_{env}	3986.55	469.07	0.00	13.59
H	3989.73	472.25	0.00	13.29
T_{env}+O	4168.70	651.22	0.00	42.24
O	4179.46	661.98	0.00	41.55
T_{env}	4195.17	677.69	0.00	1.18
Null model	4206.87	689.39	0.00	–

The best model exhibited maximum Akaike weight; % of the total deviance explained by the best model. We used identity of crevice as a random effect. Models are listed in decreasing order of importance.

Table 4 Generalized linear mixed model of the best models for (A)- mean temperature and (B)- range of temperature.

Model:		
(A)- Mean temperature~orientation+hour		
Effect		
Fixed	F value	p-Value
Orientation	$F_{3,864}$=22.53	<0.0001
Hour	$F_{47,864}$=6.84	<0.0001
Random	Variance ($\pm$SD)	LRT[a]
Nesting crevice	1.48$\pm$1.01	χ^2=133, p<0.0001
Residual	5.27$\pm$1.18	
(B)- Range~orientation∗hour		
Effect		
Fixed	F-value	p-Value
Orientation	$F_{3,864}$=22.53	<0.0001
Hour	$F_{47,864}$=12.55	<0.0001
Orientation∗hour	$F_{141,864}$=4.73	<0.0001
Random	Variance ($\pm$SD)	LRT[a]
Nesting crevice	1.52$\pm$1.23	χ^2=282, p<0.0001
Residual	3.17$\pm$1.78	

Random effect: nesting crevice.

[a]Significances of random effects were tested with likelihood-ratio test (LRT).

(29.22$\pm$0.12°C and 29.86$\pm$0.16, respectively). The time of day of temperature reading also had a significant effect on the temperature inside the nesting crevice (Table 4). The highest temperature was recorded at 15:00 (34.43$\pm$0.84°C), and the lowest temperature was recorded at 7:00 (26.40$\pm$0.65°C). We found a significant random effect (Table 4).

The interaction between the time of the day of temperature reading and orientation explained the temperature range inside nesting crevices (Table 3). This model explained 68.90% of the variability of the temperature range. The highest relative importance was the interaction between the time of the day of temperature reading and orientation (RI: 0.99), followed by the time of the day (RI: 0.92) and orientation (RI: 0.90). Environmental temperature presented a low RI (0.09). Orientation of nesting crevice, time of the day of temperature reading, and their interaction significantly affected the temperature range (Table 4). The greatest temperature range was 11.7°C at 19:30 in nesting crevices with west orientation, and the lowest range (2.6°C) was recorded at 15:30 in nesting crevices with the same orientation. We also found a significant random effect (Table 4).

Discussion and conclusion

The southern mountain cavy has a wide distribution; it inhabits arid and semiarid lowlands and valleys, with occurrences reported in riparian habitats, forested areas and sandy forested flats (Redford and Eisenberg 1992), associated with shrubs and trees (Rood 1970, Tognelli et al. 1995, Taraborelli et al. 2009, Andino et al. 2011). Nevertheless, to our knowledge, this study represents the first report of the species living in a rocky habitat.

Previous studies in the Monte Desert showed that southern mountain cavies live in burrows that they dig actively on highly compact to soft soils with high organic content under the cover of trees, such as *Prosopis chilensis* and *Prosopis flexuosa* trees, which have arched branches touching the soil (Rood 1967, Tognelli et al. 1995, Campos 1997), or under shrubs of *Larrea nitida* Cav. (Taraborelli et al. 2009, Andino et al. 2011) and *Larrea cuneifolia* Cav. (Campos et al. 2006). The study site has rock outcrops composed of travertine, a deposit of undetermined shape where piping processes are frequent (Gutiérrez Elorza and Rodriguez Vidal 1984) and which form several crevices used by the southern mountain cavies. The crevices provide a suitable microclimate where these rodents can nest and find shade and protection against predators, as indicated for other desert mammal species (Ghobrial and Nour 1975, Trainor et al. 2000, Sundell and Ylönen 2004, Nutt 2007, Campos et al. 2013).

We found that the crevices were located on the sides of rock outcrops that had a high proportion of rock, far from the vegetation cover, as plants were only distributed at the base of rock outcrops. These results do not agree with the reported relationship between this mammal species and vegetation in other populations. In previous studies, the presence of this species was associated with vegetation that they used for feeding and finding refuge from predators and harsh climate (e.g., Rood 1967, Tognelli et al. 1995, Campos 1997, Taraborelli et al. 2009, Andino et al. 2011). The southern mountain cavy consumes mostly dicots and behaves as a facultative specialist (Sassi et al. 2011) according to the categories of specialization proposed by Shipley et al. (2009). The diet reported for the southern mountain cavy includes eight of the 14 plant species present in the study area (Sassi et al. 2011). However, a specific study of its feeding behavior is necessary to enhance the knowledge of the ecology of this southern mountain cavy population occurring in a rocky habitat.

We found that the orientation of both nesting and refuge crevices was not randomly distributed. Indeed, we found that the observed frequency of the used crevices was higher in the crevices oriented to the east that in those oriented to the south. These results suggest that the southern mountain cavy would make a differential use of crevices in response to environmental factors, such as sunlight and prevalent wind direction (Poblete and

Minetti 1999), as found for another desert species (Torres et al. 2003, Taraborelli et al. 2009).

Nesting site and refuge crevices were of different dimensions, with the former being almost four times deeper than the latter. Previous studies conducted in other environments showed that the southern mountain cavy builds two types of burrows: main and satellite burrows (Taraborelli et al. 2009, Andino et al. 2011), which differ in dimensions, holes number, and functions. The main burrows have several holes close to one another, connected by active trails and are used for sleeping at night, napping during the day, giving birth, and rearing litter, nesting in group (social thermoregulation) and avoiding inclement weather (Ebensperger et al. 2006, Taraborelli and Moreno 2009). Hence, this rodent spends most of the activity in the main burrows. By contrast, satellite burrows, which are not permanently occupied by the southern mountain cavy, have few entrances, are close to the foraging area, and provide shelter from threats (Armitage 1988, Branch et al. 1994, Taraborelli et al. 2009). Even though we were not able to discriminate between main and satellite burrows in our study site, we consider that nesting crevices may function as main burrows, and refuge crevices, as satellite ones; however, further studies are needed to assert this similarity between burrows and crevices.

In our study site, habitat suitability for the southern mountain cavy appeared to be related to certain characteristics of crevices. We found a positive association between species presence and depth and height of crevices. Our results are consistent with previous studies in other species, which were found to select physical attributes of crevices to establish in rocky habitats (Rossell et al. 2009, Campos et al. 2013). In a hyper-arid sector of the Monte Desert, Campos et al. (2013) found that crevice selection by *Octomys mimax* Thomas (Octodontidae) was related to crevice depth, but not to width, because the authors found a negative relationship between presence of species and crevice width. Studies performed in the Appalachian Mountains showed that *Neotoma magister* Baird and *Neotoma floridana haematoreia* Howell selected crevices of large dimensions (height, width, and depth) (Rossell et al. 2009). A greater depth in the used shelters is probably related to a higher thermal stability, which would help reduce the cost of thermoregulation and increase protection from predators (Sundell and Ylönen 2004, Nutt 2007).

Regarding height, we cannot determine an advantage of selecting highest crevices. Further studies should be conducted in the sampling to be able to compare them with other rocky sites with the presence of the southern

mountain cavy in order to understand the selection found in our site study.

One of the most important factors affecting the spatial distribution of small endotherms is environmental temperature (Lagos et al. 1995a). In deserts, the combination of lack of water with seasonal periods of high temperatures poses a profound challenge for small mammals (Walsberg 2000). Regarding thermal properties of crevices, our results show that, in the study period (summer), the temperature inside crevices was lower than outside, indicating that the southern mountain cavy would be able to avoid extreme temperatures by using rock crevices as shelters. This fact was also reported for other rodents, both fossorial and semifossorial, such as *Cratogeomys castanops* Baird, *Octodon degus* Molina, *Meriones crassus* Sundevall, *Tympanoctomys barrerae* Lawrence, and *Octoymys mimax*, which would use burrows and crevices to avoid extreme temperatures and protect from predators (Hickman 1977, Ebensperger and Bozinovic 2000, Ebensperger 2001, Shenbrot et al. 2002, Torres et al. 2003, Campos et al. 2013).

We found that environmental temperature did not affect the temperature inside crevices, unlike records reported in other studies, in which burrow and soil temperatures are affected by fluctuations in environmental temperature (Kennerly 1964, Hall and Myers 1978, Kay and Whitford 1978, Altuna 1985, Rezende et al. 2003). In the study site, the temperature inside crevices was lower than that of the outside. Although we did not study the internal structure of crevices, based on the long distance between crevices (nearly 2.5 m, Andino per. obs.), we assume that crevices structure would not allow air flow, generating a stable microclimate inside crevices that is not affected by environmental temperature fluctuations.

We found that temperature inside crevices was influenced by the orientation of crevices and time of day of temperature recording. The north-oriented crevices have the highest mean temperature, probably because these crevices receive incident sunlight for more hours than the others. The low temperature recorded in south-oriented crevices can be the effect of the entrance of cool moist winds from the south, reducing high temperatures inside crevices, as reported by Taraborelli et al. (2009) for this species in other sites of the Monte Desert and by Torres et al. (2003) for *T. barrerae*.

Several rock-dwelling species exhibit similar characteristics and high specialization for saxicolous life such as *Abrocoma bennetti* Waterhouse, *A. schistacea* Thomas, *A.* uspallata Braun & Mares, *A. vaccarum* Thomas, *Chinchilla brevicaudatus* Waterhouse, *Chinchilla lanigera* Molina, *Ctenodactylus gundi* Rothmann, *Heterohyrax brucei* Gray,

Kerodon rupestres Cuvier, *Lagidium peruanum* Meyen, *L. viscacia* Molina, *L. wolffsohni* Thomas, *Neotoma cinerea* Ord, *N. magister* Baird, some *O.* species as *Ochotona collaris* Nelson and *O. princeps* Richardson, *Petromus typicus*, Smith and *Petromyscus collinus* Thomas & Hinton, *Procavia capensis* Pallas (Hoeck 1982), *Pronolagus rupestris* Smith, *Thrichomys apereoides* Lund (MacDonald and Jones 1987, Mares and Lacher 1987, Chapman and Flux 1991, Nutt 2007). There are also other species strongly associated with rocky habitat but which do not exhibit a high specialization for saxicolous life such as voles genus Chionomys (Wilson and Reeder 2005), *Akodon andinus* Philippi, *Phyllotis xantophygus* Waterhouse (Mares 1997).

Nevertheless, we do not know any species similar to the southern mountain cavy in terms of the extent of flexibility in habitat requirements (i.e., occurring in very different habitats and having a wide distribution) (Redford and Eisenberg 1992), which do not exhibit highly specialized characteristics for saxicolous life.

Our study provides evidence of the importance of rocky habitat for the southern mountain cavy because it allows them to face hard climatic conditions of desert areas. We also highlight that despite the variable habitat use indicated for this species, this is the first record of rocky habitat use by this species.

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