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Seasonal behaviour and habitat ecological features of *Pristidactylus valeriae* in the Mediterranean ecosystem of central Chile

H. Díaz[a], D. Estay-Olea[a], M. González[b], M. Salvo-Sierralta[c], C. Hidalgo[d], N. Sallaberry-Pincheira[e], C. Botto-Mahan[c] and G. Rojo[a]

[a]Instituto de Ciencias Agroalimentarias, Animales y Ambientales (ICA3), Universidad de O'Higgins, San Fernando, Chile; [b]Departamento de Administración, Santuario de la Naturaleza Cerro Poqui, Chile; [c]Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Santiago, Chile; [d]Núcleo de Investigación en One Health (NIOH), Facultad de Medicina Veterinaria y Agronomía, Universidad de las Américas, Santiago Centro, Chile; [e]Unidad de Rehabilitación de Fauna Silvestre, Escuela de Medicina Veterinaria, Facultad de Ciencias de la Vida, Universidad Andres Bello, Santiago, Chile

ABSTRACT

This study focuses on the ecological characteristics and seasonal behaviour of *Pristidactylus valeriae*, an endemic lizard of Chile inhabiting the O'Higgins Region. This species used to be a common sighting, and in the last 30 years its population has been declining. The primary objective was to explore the species' habitat ecology across different seasons, including microhabitat availability and the associated flora and fauna. The research was conducted from March 2022 to March 2023 in the Cantillana Mountain Range, using direct observation and camera traps to monitor *P. valeriae* activity. Our findings reveal that *P. valeriae* is active in spring and summer, with no activity recorded during autumn and winter. The study also sheds light on the lizard's preferences for rock substrates. Variations in substrate temperature across seasons were also recorded. Camera traps did not provide a meaningful method of observation, with direct sightings as the only effective method of detection. Exotic species, such as cats and rats, were found co-habiting with *P. valeriae*, which raises concerns regarding conservation efforts for this species. These insights are crucial for understanding the ecology of *P. valeriae*, particularly considering the species' endangered status and growing environmental threats in its habitat. The study emphasizes the need to consider seasonal variations and human impacts in conservation strategies for this species.

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Introduction

The thermoregulatory behaviour and thermal relationships that lizards establish with their environment, such as microhabitat selection, are determinants in almost all aspects of their life history since they affect their body temperature (Ibargüengoytía et al. 2008), and this, in turn, affects their physiological and behavioural traits (Angilletta et al. 2002), including physiological rates of metabolism and digestion (Beaupre 1995, Naya et al. 2010, Naya et al. 2011), growth (Piantoni et al. 2006), diet (Espinoza et al. 2004), type of reproduction (Shine 2004; Sears 2005), reproductive cycle (Zug et al. 2001; Labra & Bozinovic 2002), survival (Huey 1982), and locomotion (Hertz et al. 1983).

In temperate climates with large daily thermal oscillations, lizards start the day sheltered and inactive, given the minimum nocturnal environmental temperatures under the temperature of activation (Doucette et al. 2023). As the day progresses, environmental temperatures begin to rise, increasing the lizards' body temperature in their shelter until ambient conditions allow them to reach a body temperature suitable for locomotion, at which point they emerge and begin a period of sunlight exposure and heating at different rates through an external heat source, such as solar radiation (Clark & Kroll 1974; Paulissen 1999). This body temperature, called "activity body temperature" (Pough & Gans 1982), is maintained throughout the active period by behavioural adaptations and, less conspicuously, by physiological control (Carrascal et al. 1992), ensuring optimal conditions for food intake, digestive efficiency, reproduction, and growth (Ibargüengoytía 2005). Thus, in ectothermic organisms, the study of their thermal biology is relevant in understanding key

CONTACT G. Rojo gemma.rojo@uoh.cl Instituto de Ciencias Agroalimentarias, Animales y Ambientales (ICA3), Universidad de O'Higgins, Carretera I50, KM 3, Región de O'Higgins, San Fernando, Chile

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aspects of their behaviour, diet, reproduction, use of space, and activity patterns (Angilletta et al. 2002; Muraro et al. 2022).

The genus *Pristidactylus* encompasses only 10 species worldwide, restricted exclusively to the southern cone of South America (Morando et al. 2015): four in Chile and six in Argentina (Etheridge & Williams 1991; Cei et al. 2001; Avila et al. 2003; Morando et al. 2015). They are part of the family Leiosauridae, being lizards of medium to large size (between 80 and 90 mm in snout–cloaca length) characterized by a peculiar comb of smooth subdigital scales, from which is derived the name of the taxon (meaning "serrated fingers"), a conspicuous fold and melanic collar on the neck, and the ability to emit vocalizations for help through the violent expulsion of air when captured, which is why some species are commonly known as grunters ("Gruñidores") (Donoso-Barros 1966; Díaz & Labra 2023).

In Chile, all four species of grunters are endemic: *Pristidactylus volcanensis* Lamborot and Díaz, 1987, *Pristidactylus torquatus* Philippi, 1861, *Pristidactylus alvaroi* Donoso-Barros, 1966, and *Pristidactylus valeriae* Donoso-Barros, 1966 (Philippi 1861; Donoso-Barros 1966; Donoso Barros 1974). These last three species are characterized by an association with *Nothofagus* forests. *Pristidactylus valeriae* is distributed in the Mediterranean forests, woodlands, and scrub of central Chile, specifically along the Coastal Range from the sclerophyllous forests of the Cantillana mountain range, to the montane ecosystems of the Roblería del Cobre de Loncha National Reserve (Donoso-Barros 1966; Etheridge & Williams 1985; Mella 2005; Núñez & Torres-Mura 2007). The species' distribution has recently been extended 22 km to the south in the foothills of Cerro Curamahuí (Castro & Tobar-González 2014), within the Mediterranean ecoregion, becoming the *Pristidactylus* species with the second largest range of distribution in the country after *P. torquatus*, which extends from the montane forests near San Fernando to the temperate rainforests of Chiloé Island (Donoso-Barros 1966; Etheridge & Williams 1985; Mella 2005; Núñez & Torres-Mura 2007).

Pristidactylus valeriae is described as a species of saxicolous habits inhabiting *Nothofagus* forests and *Chusquea quila* formations. It is listed as endangered (Mella 2005; Núñez & Torres-Mura 2007), with little information on its behaviour, ecology, and distribution (De Gamboa 2020). Furthermore, the International Union for Conservation of Nature (IUCN) Red List, which lists *P. valeriae* as endangered, states that research into the distribution, habitat status, and impact of threats on the population to this rare species should be implemented (Avilés et al. 2017; IUCN 2024). The last available research effort in this area was performed more than 30 years ago (Sufán-Catalán & Núñez 1993). Since then, sightings of this species have become scarcer (Park rangers, personal observation). Moreover, recognizing the threat to their survival, the Ministry of Environment enacted the plan RECOGE0011, which is aimed at recovering *Pristidactylus* spp. populations between the years 2022 and 2032, promoting protection from wildfires, as well as monitoring and research (MMA 2025). Therefore, our main purpose was to investigate, through a rigorous and replicable methodology, the species' abundance in areas where it has been commonly sighted, in order to generate data that could help to understand why a species that used to be commonly observed has become so rare. To achieve this, we aimed to investigate the presence of *P. valeriae* during the four seasons of the year in three sites of the Cordón de Cantillana in the Libertador General Bernando O'Higgins Region (33.9667°S, 70.9658°W), characterizing the main ecological qualities of their habitat, behaviour, and availability of microhabitat (substrate where the specimen is found) following the methodology of the last published research effort (Sufán-Catalán & Núñez 1993). We also assessed the community of accompanying flora and fauna, which previous research efforts have not reported. Our results provide useful data regarding factors involved in the decline of *P. valeriae* populations.

Materials and methods

Study area

The study area consisted of three sampling zones; the first site corresponded to the "Roblería del Cobre de Loncha" National Reserve (RNRCL) located in the commune of Alhué, Metropolitan Region, bordering the O'Higgins Region (34°08′36″S, 70°58′38″W), where sampling was carried out in the "Quebrada del Chivato" (34°09′56.3″S, 70°57′21.7″W), with predominant areas of sclerophyllous forest and forests of *Nothofagus macrocarpa* and *N. glauca* (Sufán-Catalán & Núñez 1993). The second sampling site corresponded to a sector of Lo Miranda in the Doñihue commune, O'Higgins Region. This point is adjacent to

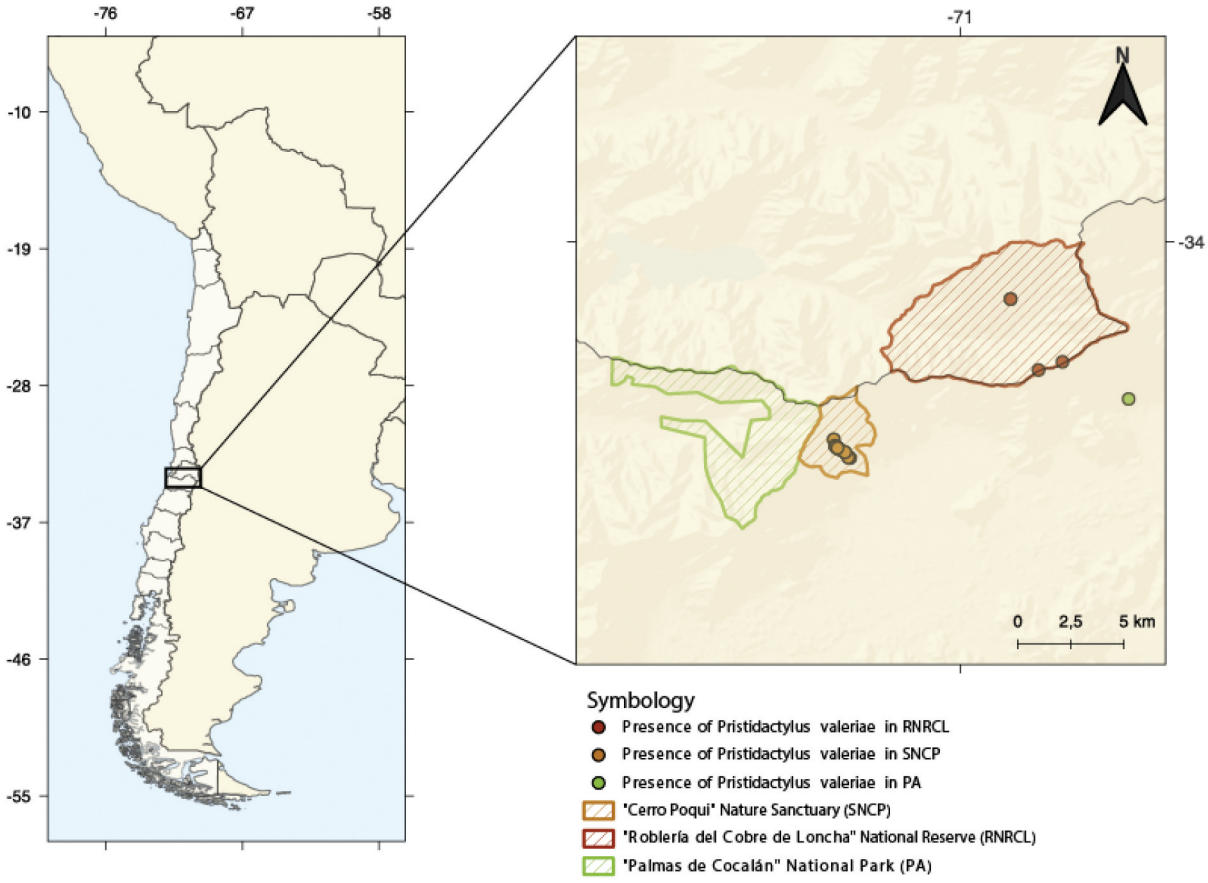

Figure 1. Geographical location of all *Pristidactylus valeriae* individuals registered between March 2022 and March 2023 for the three sectors studied: "Roblería del Cobre de Loncha" National Reserve (RNRCL) with red spots, "Cerro Poqui" Nature Sanctuary (SNCP) with orange spots, and a sector adjacent to "Parque en el Aire" (PA) in green.

a recreational centre called "Parque en el Aire" (PA), which has a sclerophyllous forest where the presence of *P. valeriae* has been recorded (34.1866°S, 70.9130°W). Finally, the third site was the "Cerro Poqui" Nature Sanctuary (SNCP) in the "Quebrada Los Calabozos" and "Quebrada Pozas Negras" located in the commune of Coltauco, O'Higgins Region (34.2192°S, 71.0476°W), with forests of *N. glauca*, sclerophyllous forest, with permanent water courses, where several records of the species of interest have been reported. The study area is shown in Figure 1.

Sampling methodology and activity period

For the campaigns, the following activities were conducted: registration of activity period (time of the day that the specimen was observed), microhabitat availability and use, substrate temperature, perch height, critical escape distance, seasonal hygrothermal evolution of microhabitats, and accompanying flora and fauna. The campaigns were carried out in summer (March 2022), autumn (June 2022), winter (August 2022), and spring (December 2022), and each lasted 3 consecutive days. Sampling was carried out under a variety of weather conditions, such as sunny days in summer and heavy snow in winter.

In each site, the observers walked along the park trails. Due to the complex geomorphology of the study sites, straight 100 m transects were not feasible, as there are steep cliffs. Routes were determined considering past sightings by park rangers, as well as the availability of potential refuge elements, such as caves, tree trunks or rocks. All sightings were carried out by two investigators (HD, DE-O, or MG) who have experience in herpetology and identification of *Pristidactylus* spp. specimens. The investigators walked slowly, at a pace of 2–3 km/h, from 09:00 h to 18:00 h, stopping for 30 min for lunch. The same trails were walked twice each day. For each individual sighted, time and date

were recorded, in addition to their stage of development: juvenile or adult. The same transects were walked at each site across all seasons. All procedures were carried out following the Chilean manual of wildlife sampling (de la Maza Musalem & Bonacic Salas 2013).

Microhabitat availability and use

The classification and use of the microhabitats were determined as previously described (Sufán-Catalán & Núñez 1993). Briefly, where *P. valeriae* specimens were sighted, a 50 m measuring tape was placed in the ground. The different types of microhabitats available in the environment were recorded: oak, shrub, rock, leaf litter, tree, fallen trunk, bare soil, oak second-growth forest, and herbage. The type of substrate on which each of the individuals were sighted perched was recorded. In addition, the differences in availability of different microhabitats per site sampled in each of the stations was evaluated.

Substrate temperature

Measurement of the surface temperature of the substrate used as a perch by each individual was recorded by means of a digital infrared thermometer (UT301A+ UNI-T®). The temperature of the substrate was measured immediately after the individuals fled from the observers.

Perch height

Measurement of the height from the exact point of the individual sighted to the ground was recorded using a digital distance meter (Laser Sndway Sw-g4s 40mts) (Sufán-Catalán & Núñez 1993).

Critical escape distance

Measurement of the straight-line length from the height of the investigator's eyes to the exact point where the individual flees, after an approach of the researcher directed towards them, was recorded using a digital distance meter.

Seasonal hygrothermal change of microhabitats

Data loggers (RC-4HC Elitech®) were located in places where *P. valeriae* were previously sighted. The same site was selected across all seasons. They were set up for 24 h of continuous recording with a frequency of 5 min for 3 consecutive days. Temperature and relative surface humidity of two substrates was assessed: Rock (surface of a rock with a minimum length of 50 cm) and trunk (tree bark native to the sclerophyllous forest at a height of 1.5 m). Finally, the surface temperature was periodically recorded on the substrate: leaf litter (soil covered with fallen leaves). Since data-loggers could malfunction due to adverse weather conditions, the data shown corresponds to 24 h of uninterrupted recordings within the 3 days of sampling.

Accompanying flora and fauna

To evaluate syntopic species, accompanying flora was identified while determining microhabitat availability and use, using the 50 m measuring tape. A flora baseline was determined, considering the environmental supply. Fauna was registered by means of two trail cameras (24 MP, Bushnell) per sampling site. These cameras are infrared, and movement-activated. They were placed following two criteria: the first camera was placed pointing to the site of a previous *P. valeriae* sighting (following data-logger placement criteria), and the other was placed pointing to potential sites where *P. valeriae* could be found considering the environmental conditions (i.e. rock refuge). Distance between cameras was not considered. Trail cameras were deployed for 3 days in the same places across all seasons, with 24-h photographs.

Data analysis

A partial likelihood ratio test (G-test) was performed to determine microhabitat availability and use. T-test and Mann-Whitney tests were performed to determine differences between substrate temperature, perch height, and critical escape distance; comparisons were made between seasons for each *P. valeriae* stage (i.e. differences in substrate temperature in juveniles between summer and spring) or between *P. valeriae* stage in each season (i.e. differences in substrate temperature in spring between juveniles and adults). Activity patterns were estimated using kernel density functions following the procedure of published methodology for camera trap observations (Ridout & Linkie 2009). To determine differences in the activity period between summer and spring, a Watson-Wheeler test was performed (Jammalamadaka & Sengupta 2001). Data analysis was performed using R with the "ggplot2" package (R Core Team, R 2013) and GraphPad Prism version 10.0.0 for Windows (GraphPad Software, Boston, Massachusetts USA, www.graphpad.com).

Results

A total of 27 records of *P. valeriae* (Figures 2 and 3) were obtained at the sampling sites in the spring and summer seasons; there were no records in autumn or winter. Total distance covered is available in Table 1.

Activity period

Of the total number of *P. valeriae* individuals, 12 were recorded in spring, four corresponding to juveniles and eight adults, with an hourly range between 10:18 and 19:10 h. For the summer, 15 records were obtained in total, seven juveniles and eight adults, with an hourly range between 11:12 and 18:46 h (Figure 4).

Figure 2. Adult individuals of *Pristidactylus valeriae* observed at study sites. (a) and (b) correspond to sightings in "Cerro Poqui" Nature sanctuary (SNCP); (c) and (d) correspond to sightings in "Roblería del Cobre de Loncha" National Reserve (RNRCL).

Figure 3. An infant individual of *Pristidactylus valeriae* with rhombus design and ante humeral collar observed in the sector adjacent to "Parque en el Aire" (PA).

Table 1. Total distance covered by the observers during the search effort. Data is shown as the average distance travelled by the observers in each sampling site across all seasons.

	RNRCL	SNCP	PA
Average distance (average time)	4.01 km (4 h)	5.2 km (5 h)	4.4 km (6 h)

RNRCL: Roblería del Cobre de Loncha National Reserve; SNCP: Cerro Poqui Nature Sanctuary; PA: Parque en el Aire.

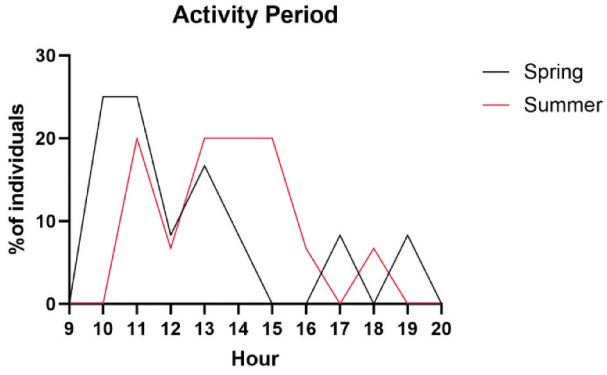

Figure 4. Seasonal activity period of *P. valeriae*. Frequency polygon showing the percentages of individuals seen (accumulated) in 1 h of observations in spring (red line) and summer (black line).

The daily activity of *P. valeriae* observed in the study sites had two peak hours of activity in both seasons; in spring, a maximum number of individuals was observed between 10:00–11:00 h with a second peak at 13:00. On the other hand, in summer, the greatest activity was concentrated at 11:00 h and later between 13:00–15:00 h. Nonetheless, *P. valeriae* daily activity is not significantly different between summer and spring ($W = 2.24$, $df = 2$, $p = 0.3264$) (Figure 5).

Microhabitat availability and use

Different types of substrates were evaluated, where the substrate with the highest representation during the spring and summer seasons was leaf litter, at 28.33% and 60.73%, respectively (Figure 6). The substrate with the highest use by *P. valeriae* in both spring and summer was rock, with 16.67% for juveniles and 41.67% for adults during the spring and 26.67% and 33.33% for juveniles and adults, respectively, during the summer (Table 2). Habitat preference by *P. valeriae* was detected for rock in both spring ($G = 180.62$, $p < 0.05$) and summer ($G = 149.63$, $p < 0.05$).

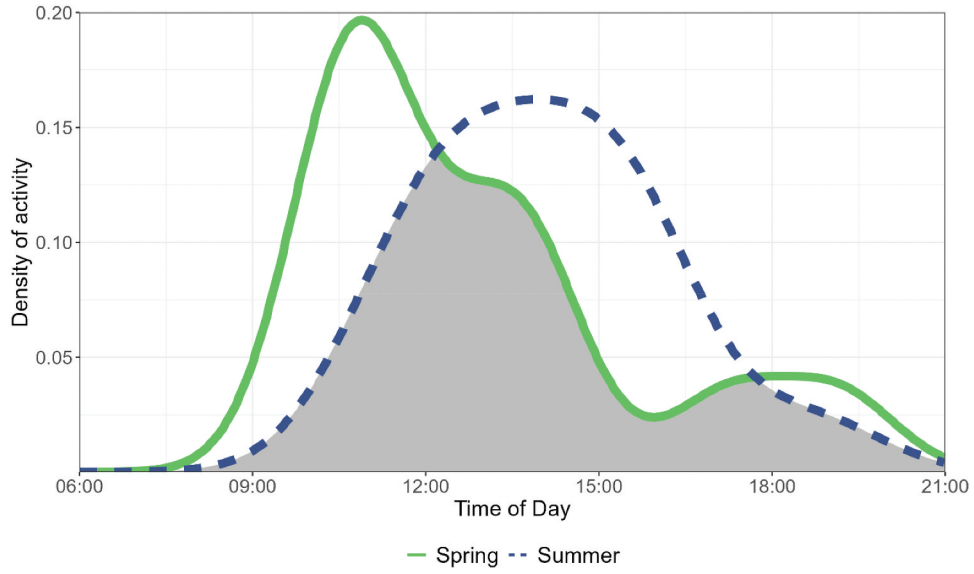

Figure 5. Comparison of the daily activity of *P. valeriae* between spring (solid green) and summer (dotted blue). The grey area shows the overlap of activity between spring and summer, which is not statistically different. Watson-Wheeler test ($W = 2.24$, $df = 2$, $p = 0.3264$).

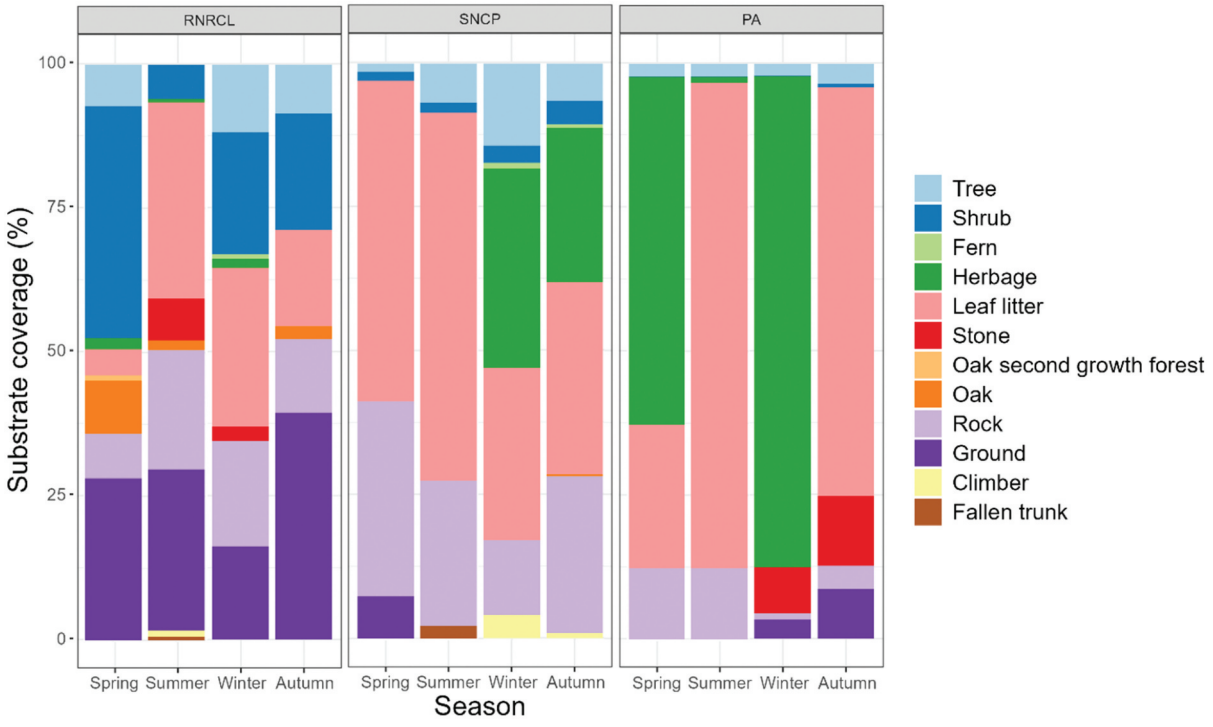

Figure 6. Substrate percentage coverage by stations in each of the sampling sites. RNRCL: "Roblería del Cobre de Loncha" National Reserve; SNCP: "Cerro Poqui" Nature Sanctuary; and PA: the sector adjacent to "Parque en el Aire". Both the oak and oak second growth forest substrates corresponded to *Nothofagus glauca*.

Substrate temperature

The substrate temperatures (rock, leaf litter, tree, fallen trunk and oak) at which *P. valeriae* individuals were found are shown in Figure 7.

The average substrate temperatures in summer were similar between adults and juveniles, at 22.14 and 22.37°C (Mann-Whitney test, $U = 27.50$, $p = 0.9790$), respectively. In spring, adults registered 27.55°C and

Table 2. Availability and seasonal use of microhabitat by juveniles and adults of *Pristidactylus valeriae* during their activity period.

	Spring			Summer		
Microhabitat	Availability (%)	Juveniles	Adults	Availability (%)	Juveniles	Adults
Oak	3.07	0	1	0.57	0	1
Shrub	14.00	0	0	2.67	0	0
Rock	18.00	2	5	19.40	4	5
Leaf litter	28.33	1	0	60.73	1	2
Tree	3.70	1	1	3.07	2	0
Fallen trunk	0	0	1	0.93	0	0
Bare soil	11.80	0	0	11.73	0	0
Oak second growth forest	0.30	0	0	0	0	0
Herbage	20.80	0	0	0.90	0	0

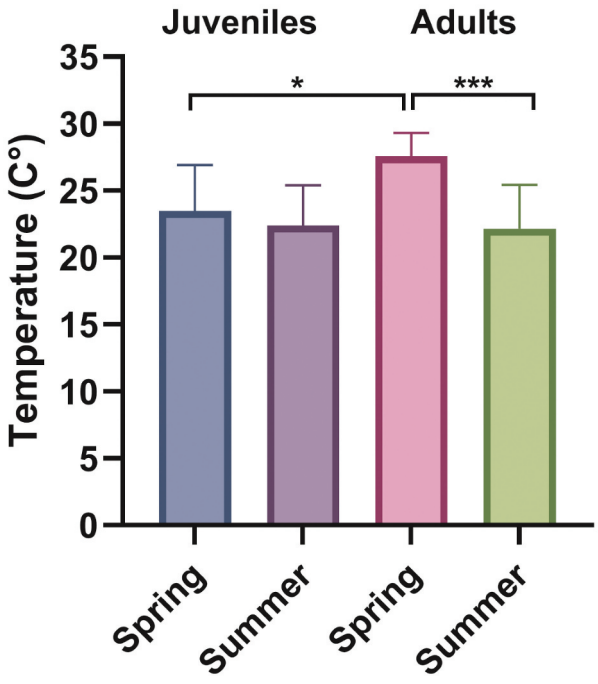

Figure 7. Temperature of the seasonal substrate used by juveniles and adults of *Pristidactylus valeriae*. Average (±2 standard errors) substrate temperature for juveniles and adults in spring and summer. The maximum average was obtained in adults and in spring. *: $p = 0.0485$; ***: $p = 0.0005$, Mann-Whitney test.

juveniles 23.48°C, which was statistically higher for the adult specimens (Mann-Whitney test, U = 4, $p = 0.0485$), and higher than the temperature measured in summer (Mann-Whitney test, U = 1.5, $p = 0.0005$). The maximum substrate temperature measured was 30.3°C for an adult on a rock in spring, followed by 29.6°C for an adult on a trunk. In summer, the maximum temperature was 26.3°C on the trunk substrate of a juvenile, followed by an adult on the rock at 25.8°C. In contrast, the minimum temperatures recorded for both seasons were in juvenile individuals, with 18.1°C on leaf litter in summer and 19.6°C on rock in spring. The minimum temperature of the adults was all on rock substrate, in summer at 18.2°C and in spring at 25.6°C. All measurements were performed in the shade and in indirect sunlight.

Perch height

This variable was evaluated between juveniles and adults in the spring and summer seasons, considering each of the five substrates chosen by the individuals (Figure 8).

The average perch height of adults was higher than that of juveniles in both seasons; however, these differences were not statistically significant, in spring (Mann-Whitney test, U = 7.5, $p = 0.1657$) or in summer (Mann-Whitney test, U = 21, $p = 0.4601$). In spring, they reached an average height of 42 cm for adults versus

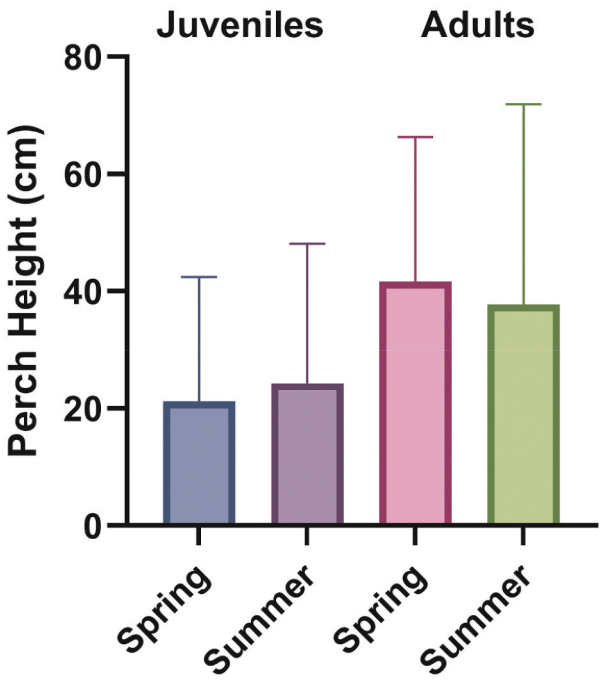

Figure 8. Perch height per activity season in juveniles and adults of *Pristidactylus valeriae*. Average (±2 standard errors) perch height in centimetres for juveniles and adults recorded in spring and summer.

21 cm for juveniles, and in summer, an average height of 38 cm for adults and 24 cm for juveniles. The maximum height in both seasons was also recorded in adult individuals but on different substrates: 104 cm on a rock in summer and 96 cm on a trunk in spring. Two juveniles were observed in leaf litter substrate at ground level (0 cm), one in summer and the other in spring.

Critical escape distance

The average values of the distance to which the individuals fled were higher in spring, with 175 cm in adults and 180 cm in juveniles (Mann-Whitney test, U = 15, $p = 0.9333$), while in summer, the values were 148 cm and 125 cm (Mann-Whitney test, U = 24, $p = 0.6943$), respectively. The minimum critical escape distance was recorded in summer and was 18 cm for an adult on rock, while in spring, it was 50 cm for a juvenile on a trunk. The maximum values were obtained for adults on a rock, with 583 cm in summer and 443 cm in spring (Figure 9).

Seasonal hygrothermal evolution of microhabitats

To evaluate the variation of temperature and humidity of the potential microhabitats to be used by *P. valeriae*, the four seasons of the year in each of the chosen sites were considered (Table 3, Figure 10). In autumn (Wilcoxon test, W = 49770, $p < 0.0001$), winter (Wilcoxon test, W = 67528, $p < 0.0001$), and spring (Wilcoxon test, W = 351, $p < 0.0001$), higher temperatures were recorded on rock, followed by the tree trunk and then by leaf litter. In summer, higher temperatures were recorded on rock, followed by leaf litter and then by trunk (Wilcoxon test, W = 67528, $p < 0.0001$). Regarding relative humidity, the trunk had a higher relative humidity than rock in autumn (Mann-Whitney test, U = 252405, $p < 0.0001$), spring (Mann-Whitney test, U = 82067, $p < 0.0001$), and summer (Mann-Whitney test, U = 163623, $p < 0.0001$), while there were no statistical differences in winter (Mann-Whitney test, U = 163623, $p = 0.5469$).

Accompanying fauna and flora

Accompanying fauna species were captured with trail cameras and are summarized in Table 4. The trail cameras captured four records of endemic, three of native, and five of exotic species (Figure 11).

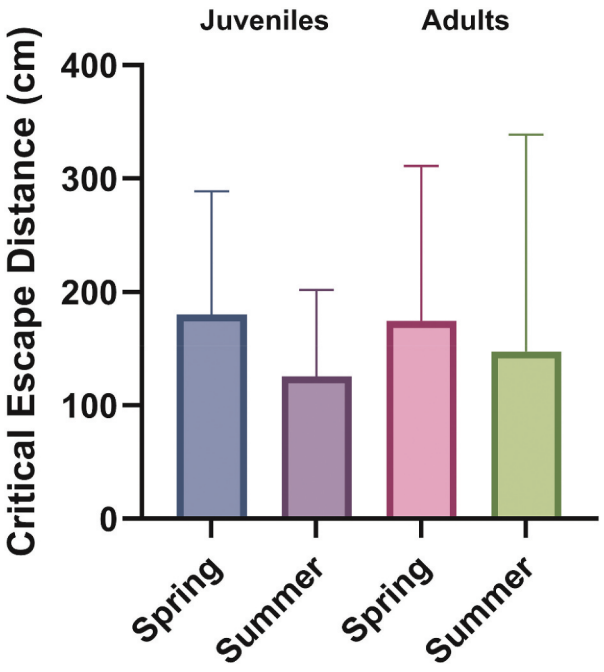

Figure 9. Critical escape distance, by season, in juveniles and adults of *Pristidactylus valeriae*. Average (±2 standard errors) of critical escape distance in metres for juveniles and adults were recorded in spring and summer.

At RNRCL, the flora species include a variety of ferns, including *Adiantum chilense*. The herbs encompass various types, including annual herbs such as *Loasa triloba*, perennial herbs, and geophytic herbs like *Chusquea cumingii* and *Alstroemeria ligtu*. The trees and shrubs feature species from the sclerophyllous forest and scrub, such as *Cryptocarya alba*, *Lithrea caustica*, *Peumus boldus*, *Baccharis linearis*, *Baccharis vernalis*, and *Nothofagus glauca* from the deciduous forest. At SNCP, there is a notable presence of ferns including *A. chilense*, *Adiantum excisum*, and *Blechnum hastatum*. The herbs show a diversity of annual, perennial, and geophytic types like *Loasa triloba*, *Chusquea cumingii*, and *Solenomelus pedunculatus*, along with climbers such as *Dioscorea humilis*. The trees and shrubs include sclerophyllous forest species such as *Cryptocarya alba*, *L. caustica*, *P. boldus*, *Aristotelia chilensis*, and *Myrceugenia obtusa*, as well as *N. glauca* from the deciduous forests. Invasive plants like *Lactuca* sp., *Galium aparine*, and *Rubus ulmifolius* were also present. At PA, there is a significant abundance of ferns, particularly *A. chilense*. The herbs include introduced annuals such as *Anthriscus caucalis* and *Stellaria media*, alongside perennial and geophyte herbs like *L. triloba* and *A. ligtu*. Trees and shrubs noted at PA include *C. alba*, *P. boldus*, and *M. obtusa*. These results are summarized in Table 5. No species of accompanying fauna were observed during the foot transects.

Discussion

Of a total of 27 individuals registered, 11 corresponded to juvenile stages and 16 to adults. The latter were registered equally between spring and summer, while only four juveniles were observed in spring and seven in summer.

The period of activity in the summer season covered from 10:18 to 19:10 h, while in spring, it was between 11:12 and 18:46 h. These results increased by more than an hour the time range in which individuals of *P. valeriae* were active, compared with that previously reported (Sufán-Catalán & Núñez 1993). Those authors proposed that the activity period in summer for individuals was between 12:00 and 18:00 h. However, considering the latest record of activity for the species (Castro-Pastene & Salazar 2016), which reported a sighting at 21:00 h in summer, we propose that the period of summer activity of *P. valeriae* comprises a range of 10 h from 11:00 to 21:00 h. Finally, for the spring season, the total activity of the species covered 9 h.

Table 3. Surface temperature and relative humidity of seasonal air of microhabitats. Measurements were made in three consecutive days. Some temperature and humidity measurements of trunk and rock substrates are incomplete due to malfunctions of data loggers. The same occurred with some temperature measurements of the leaf litter substrate. RNRCL = "Roblería del Cobre de Loncha" National Reserve; SNCP = "Cerro Poqui" Nature Sanctuary; PA = sector adjacent to "Parque en el Aire".

			RNRCL			SNCP			PA		
			Rock	Trunk	Leaf litter	Rock	Trunk	Leaf litter	Rock	Trunk	Leaf litter
Spring	Temperature (°C)	Average	21.8	20.0	20.2	23.6	23.5	22.4	24.2	23.5	23.5
		Max	35.4	33.4	36.6	33.9	42.0	30.5	35.3	47.9	51.5
		Min	15.2	12.0	12.7	15.6	16.6	17.0	15.9	12.1	12.7
		Diff	20.2	21.4	23.9	18.3	25.4	13.5	19.4	35.8	38.8
	Relative humidity (%)	Average	40.2	39.9	–	44.0	47.9	–	40.2	43.6	–
		Max	51.8	50.1	–	61.5	67.4	–	48.9	65.1	–
		Min	18.8	19.6	–	23.0	26.4	–	30.1	16.0	–
		Diff	33.0	30.5	–	38.5	41.0	–	18.8	49.1	–
Summer	Temperature (°C)	Average	20.0	18.8	18.7	23.5	20.0	19.3	22.0	21.3	21.7
		Max	32.2	33.1	32.1	32.9	33.6	24.6	34.3	34.9	46.1
		Min	14.9	13.0	13.6	17.5	14.2	15.2	14.7	13.0	14.7
		Diff	17.3	20.1	18.5	15.4	19.4	9.4	19.6	21.9	31.4
	Relative humidity (%)	Average	58.6	62.1	–	33.6	42.9	–	57.7	56.6	–
		Max	76.4	81.5	–	45.7	60.2	–	73.1	78.2	–
		Min	37.0	39.2	–	24.6	22.5	–	41.7	30.2	–
		Diff	39.4	42.3	–	21.1	37.7	–	31.4	48.0	–
Autumn	Temperature (°C)	Average	9.0	9.4	8.9	–	5.8	6.7	7.3	6.4	6.4
		Max	11.7	12.5	13.5	–	7.9	8.9	9.5	11.8	12.1
		Min	7.5	6.4	6.1	–	4.3	5.4	6.3	3.5	3.5
		Diff	4.2	6.1	7.4	–	3.6	3.5	3.2	8.3	8.6
	Relative humidity (%)	Average	35.8	35.9	–	–	90.4	–	86.9	79.2	–
		Max	44.7	45.5	–	–	94.4	–	90.6	88.0	–
		Min	28.0	25.5	–	–	81.0	–	82.0	64.4	–
		Diff	16.7	20.0	–	–	13.4	–	8.6	23.6	–
Winter	Temperature (°C)	Average	10.1	9.4	–	11.2	8.4	8.4	9.8	9.5	9.0
		Max	18.9	12.5	–	24.8	14.9	13.2	12.9	17.0	12.0
		Min	6.4	6.4	–	4.6	4.6	5.0	8.2	5.2	6.5
		Diff	12.5	6.1	–	20.2	10.3	8.2	4.7	11.8	5.5
	Relative humidity (%)	Average	52.7	–	–	–	86.2	–	94.2	77.3	–
		Max	83.3	–	–	–	94.1	–	97.6	90.7	–
		Min	34.0	–	–	–	73.6	–	91.0	55.3	–
		Diff	49.3	–	–	–	20.5	–	6.6	35.4	–

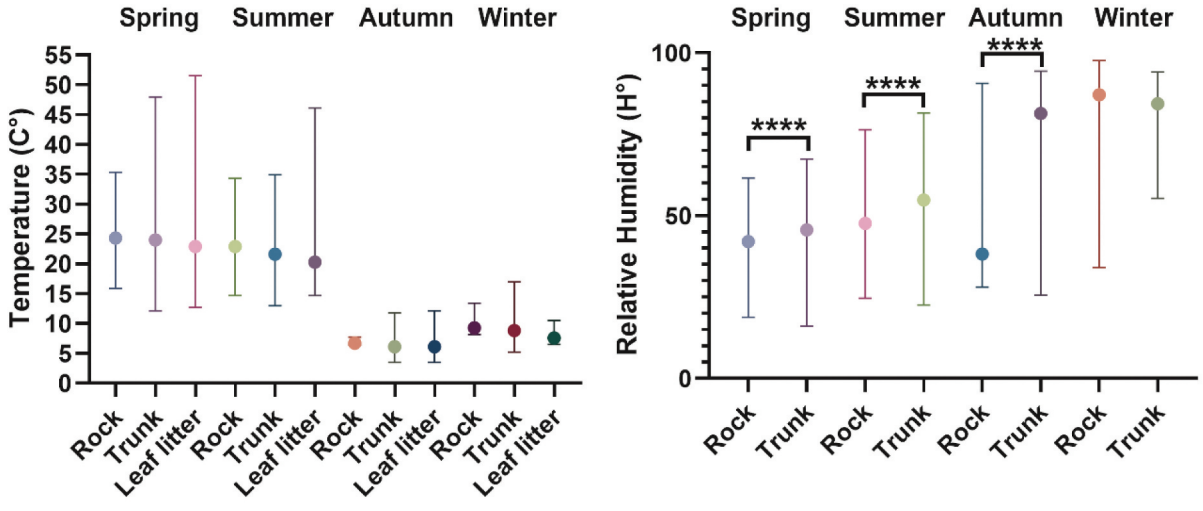

Figure 10. Seasonal hygrothermal change of microhabitats. Seasonal record of surface temperatures and relative humidity records of three microhabitats used by *Pristidactylus valeriae* (rock, trunk, and leaf litter) in the three sampling sites. Data is shown as the median with the range. **** = $P < 0.0001$, Mann-Whitney test.

Table 4. Species in trail cameras and their classification. RNRCL: "Roblería del Cobre de Loncha" National Reserve; SNCP: "Cerro Poqui" Nature Sanctuary; and PA: sector adjacent to "Parque en el Aire". Conservation status is omitted for exotic species.

Study site	Species	Common name	Conservation status	Native, endemic, or exotic species	Season
RNRCL	*Phylottis darwini*	Darwin's leaf-eared mouse	LC	Native	Spring
RNRCL	*Octodon lunatus*	Moon-toothed degu	NT	Endemic	Spring
RNRCL	*Sephanoides sephaniodes*	Green-backed firecrown	LC	Native	Autumn
SNCP	*Rattus rattus*	Black rat	–	Exotic	Spring
SNCP	*Pristidactylus valeriae*	Valeria's grunter	EN	Endemic	Spring
SNCP	*Liolaemus tenuis*	Jewel lizard	LC	Endemic	Summer
SNCP	*Rattus rattus*	Black rat	–	Exotic	Summer
SNCP	*Callipepla californica*	California quail	–	Exotic	Summer
SNCP	*Rattus rattus*	Black rat	–	Exotic	Autumn
SNCP	*Tordus falcklandii*	Austral thrush	LC	Native	Autumn
SNCP	*Octodon lunatus*	Moon-toothed degu	NT	Endemic	Autumn
SNCP	*Octodon lunatus*	Moon-toothed degu	NT	Endemic	Winter
SNCP	*Rattus rattus*	Black rat	LC	Exotic	Winter
PA	*Liolaemus tenuis*	Jewel lizard	LC	Endemic	Spring
PA	*Liolaemus tenuis*	Jewel lizard	LC	Endemic	Summer
PA	*Thylamys elegans*	Elegant fat-tailed mouse opossum	NT	Endemic	Summer
PA	*Felis silvestris catus*	Cat	–	Exotic	Summer
PA	*Tordus falcklandii*	Austral thrush	LC	Native	Autumn
PA	*Bos taurus*	Cattle	–	Exotic	Autumn
PA	*Oryctolagus cuniculus*	Rabbit	–	Exotic	Autumn
PA	*Thylamys elegans*	Elegant fat-tailed mouse opossum	NT	Endemic	Winter
PA	*Phylottis darwini*	Darwin's leaf-eared mouse	LC	Native	Winter
PA	*Turdus falcklandii*	Austral thrush	LC	Native	Winter
PA	*Oryctolagus cuniculus*	Rabbit	–	Exotic	Winter

Currently, climate change scenarios affect the geographical distribution and appropriate environment size of species belonging to the genus *Pristidactylus* (Minoli & Avila 2017). Data on habitat use represent a solid framework for achieving successful actions for the conservation of *Pristidactylus* sp. in the medium and long term – even more so in a scenario of accelerated changes.

Rocks were the preferred substrate, which had been previously reported (Sufán-Catalán & Núñez 1993), regardless of whether the highest percentage of availability corresponds to a different substrate, as in the case of this study, where leaf litter availability was over 60% during the summer.

When comparing the average temperatures of the substrate previously measured in summer (Sufán-Catalán & Núñez 1993), the values obtained in this work for the same season were lower; however, the average substrate temperature measured for the spring season was higher. Also, there could have been differences in the particular temperature of the year of sampling. If we consider the minimum temperature of substrates used by *P. valeriae*, this corresponds to 18.1 and 18.2°C for a juvenile and an adult in summer, respectively. No substrate reaches this temperature in the autumn season for any of the study sites, and in winter, only the rock substrate in SNCP registered temperatures of 18.1°C or higher between 10:00 and 15:55 h. This result allows us to explain the absence of records of *P. valeriae* in activity during both autumn and winter, given the very limited thermal resources offered by the different microhabitats. Regarding the seasonal hygrothermal change of microhabitats, these are the first published records of temperature and humidity for specific substrates used by *P. valeriae*, and although there were statistically significant differences in humidity between trunk and rocks in both autumn and spring, we are unable to assess its effect on *P. valeriae* ecology. This is of particular interest for determining *P. valeriae* health status, as thermal stress is proven to cause damage to developing reptiles (Sanger et al. 2021); further research efforts should be made to measure temperature ranges in probable nesting sites to fully understand the impact of rising temperatures.

The average perch height previously reported is not considerably different from those obtained in the present study for both the summer and spring seasons. The average perch height of adult individuals was higher than that of juveniles, which is also concordant with previous studies (Sufán-Catalán & Núñez 1993).

The average critical escape distance previously reported was 1 m higher than those obtained in the present study for both summer and spring; this could be due to an increase in the human presence in

Figure 11. Native species captured by trail cameras. (a) Green-backed firecrown (*Sephanoides sephaniodes*), (b) moon-toothed degu (*Octodon lunatus*), (c) elegant fat-tailed mouse opossum (*Thylamys elegans*), (d) Darwin's leaf-eared mouse (*Phylottis darwini*), (e) Valeria's grunter (*Pristidactylus valeriae*), and (f) jewel lizard (*Liolaemus tenuis*).

these sites in the last 30 years, as SNCP attracts many tourists during the summer and spring seasons (Sufán-Catalán & Núñez 1993). Capture of *P. valeriae* individuals is considered one of the 10 risks that this species faces in Chile, according to the RECOGE0011 plan from the Ministry of Environment (MMA 2025). Likewise, muleteers are known to capture and sell specimens as pets (Veloso et al. 1995), so a reduction in the escape distance could be involved in a diminishing of the population, as lizards are fleeing from a shorter distance from humans, probably making them easier to capture (McGowan et al. 2014).

Regarding accompanying flora species, our recordings agree with previous reports, describing that *P. valeriae* is associated with relictual *Nothofagus* formations, although their habitats are not exclusively arboreal (Cei et al. 2004). As for accompanying fauna, the biggest threats to *P. valeriae* are cats, rats, and dogs that come with cattle herds that are brought for grazing; these animals stay and graze for several days, which increases the risk of dog attacks on local fauna. Although trail cameras were placed to observe *P. valeriae* specimens, we only captured one image at SNCP, demonstrating that this resource is not suitable to observe this species as compared with our sampling methodology.

Currently, this represents the largest research effort carried out to understand the ecology and behaviour of *P. valeriae*; with a total of 36 days of sampling (3 consecutive days, three sampling sites, four seasons), which is longer than previous reports (Sufán-Catalán & Núñez 1993; Castro & Tobar-González 2014; Castro-Pastene & Salazar 2016). Still, our data represents a limited view of the ecological conditions of *P. valeriae*, and future research efforts should consider longer campaigns. One of the main issues that prevented longer campaigns was the presence of illegal activities in the sampling areas (i.e. drug trafficking), which represents

Table 5. Composition of scrub and sclerophyllous forest and deciduous forest accompanying *Pristidactylus valeriae*. LF = life form; PO = phytogeographic origin; N = native; E = exotic; I = introduced; X = present; RNRCL = "Roblería del Cobre de Loncha" National Reserve; SNCP = "Cerro Poqui" Nature Sanctuary; PA = sector adjacent to "Parque en el Aire".

Family	LF	PO	Species	RNRCL	SNCP	PA
Pteridaceae	Fern	E	*Adiantum chilense*	X	X	X
Pteridaceae	Fern	E	*Adiantum excisum*		X	
Aextoxicaceae	Tree	N	*Aextoxicon punctatum*		X	
Asteraceae	Bush	N	*Ageratina glechonophylla*		X	
Alstroemeriaceae	Geophyte	N	*Alstroemeria ligtu*	X	X	X
Apiaceae	Annual herb	I	*Anthriscus caucalis*	X	X	
Elaeocarpaceae	Tree	N	*Aristotelia chilensis*		X	X
Asteraceae	Bush	N	*Baccharis linearis*			X
Asteraceae	Bush	E	*Baccharis vernalis*			X
Blechnaceae	Fern	N	*Blechnum hastatum*		X	
Alstroemeriaceae	Geophyte	E	*Bomarea salsilla*		X	
Montiaceae	Annual herb	N	*Calandrinia compressa*	X		
Brassicaceae	Annual herb	I	*Capsella bursa pastoris*	X		
Brassicaceae	Perennial herb	I	*Cardamine sp.*		X	
Poaceae	Perennial herb	N	*Chusquea cumingii*		X	X
Orchidaceae	Perennial herb	N	*Chloraea sp.*	X		
Vitaceae	Vine	N	*Cissus striata*		X	
Cardiopteridaceae	Tree	E	*Citronella mucronata*		X	
Onagraceae	Annual herb	N	*Clarkia tenella*	X	X	
Rhamnaceae	Bush	E	*Colletia ulicina*		X	
Euphorbiaceae	Bush	E	*Colliguaja odorifera*	X		
Tecophilaeaceae	Geophyte	E	*Conanthera bifolia*	X		
Tecophilaeaceae	Geophyte	E	*Conanthera sp.*	X	X	
Lauraceae	Tree	E	*Cryptocarya alba*	X	X	X
Dioscoreaceae	Climber	E	*Dioscorea humilis*	X	X	
Dioscoreaceae	Climber	E	*Dioscorea humifusa*	X		
Apocynaceae	Climber	E	*Diplolepis menziesii*		X	
Euphorbiaceae	Annual herb	I	*Euphorbia helioscopia*	X		
Euphorbiaceae	Annual herb	I	*Euphorbia peplus*	X	X	
Rubiaceae	Annual herb	I	*Galium aparine*	X	X	
Amaryllidaceae	Geophyte	E	*Gilliesia isopetala*		X	
Asteraceae	Bush	E	*Gochnatia foliolosa*			X
Rosaceae	Tree	E	*Kageneckia oblonga*			X
Asteraceae	Annual herb	I	*Lactuca sp.*		X	
Lardizabalaceae	Vine	E	*Lardizabala biternata*		X	
Anacardiaceae	Tree	E	*Lithrea caustica*	X	X	X
Loasaceae	Annual herb	E	*Loasa triloba*	X	X	X
Asteraceae	Annual herb	N	*Madia sp.*	X	X	
Celastrales	Tree	N	*Maytenus boaria*		X	
Amaryllidaceae	Geophyte	E	*Miersia chilensis*		X	
Asteraceae	Climber	N	*Mutisia* sp.		X	X
Myrtaceae	Bush	E	*Myrceugenia obtusa*	X	X	
Nothofagaceae	Tree	N	*Nothofagus glauca*		X	X
Iridaceae	Geophyte	N	*Olsynium junceum*	X	X	
Oxalidaceae	Perennial herb	N	*Oxalis perdicaria*	X	X	
Asparagaceae	Geophyte	E	*Oziroe arida*	X	X	
Monimiaceae	Tree	E	*Peumus boldus*	X	X	X
Asteraceae	Vine	E	*Proustia pyrifolia*		X	
Bromeliaceae	Perennial herb	E	*Puya coerulea*			X
Quillajaceae	Tree	E	*Quillaja saponaria*	X		
Rhamnaceae	Bush	E	*Retanilla ephedra*			X
Rhamnaceae	Bush	E	*Retanilla trinervia*		X	
Rosaceae	Bush	I	*Rubus ulmifolius*		X	
Apiaceae	Perennial herb	I	*Sanicula crassicaulis*		X	
Apiaceae	Perennial herb	I	*Sanicula graveolens*		X	
Anacardiaceae	Bush	N	*Schinus polygamus*			X
Iridaceae	Geophyte	E	*Solenomelus pedunculatus*	X	X	
Asteraceae	Annual herb	I	*Sonchus* sp.	X		
Fabaceae	Bush	E	*Sophora macrocarpa*		X	
Caryophyllaceae	Perennial herb	N	*Stellaria arvensis*	X	X	
Asteraceae	Perennial herb	I	*Taraxacum* sp.	X	X	
Loranthaceae	Parasite bush	N	*Tristerix corymbosus*			X

a life-threatening condition to the researchers, as reported in other countries in the Americas (Davalos & Bejarano 2008; Dudley et al. 2013; Devine et al. 2020, 2021).

The results of this study enhance our understanding of the ecology and behaviour of *P. valeriae*, providing valuable information for its conservation. The identification of activity in spring and summer, along with the

absence of records in autumn and winter, suggests that any monitoring strategy should account for seasonal variations to optimize detection efforts. Additionally, the species' preference for rocky substrates and its association with *Nothofagus* forests reinforce the need to preserve these microhabitats, which have been declining in the past two decades (Bustamante & Castor 1998).

Given the limited information on the population size and structure of *P. valeriae*, future research should focus on estimating population densities and assessing sex ratios, key aspects for understanding the long-term viability of its populations. Furthermore, the presence of invasive species such as *Felis catus* and *Rattus rattus* in the study area highlights the need to evaluate their impact on the species, considering their potential role in juvenile predation (Woods et al. 2003) and resource competition (Delaugerre et al. 2019). Studies on the reproductive success of *P. valeriae*, including nesting rates and juvenile survival, would also provide crucial insights for its management and protection. It is important to note that during this study, an infant individual was found in PA, which was the only such record during all the campaigns. This finding could indicate that the individuals that inhabit this area are reproducing, an important record since it is an area outside the protected areas of the Cordón de Cantillana, with great human intervention and the presence of exotic species. Conserving *Nothofagus* remnants and mitigating anthropogenic impacts emerge as fundamental actions to ensure the species' persistence within its distribution range.

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ORCID

D. Estay-Olea http://orcid.org/0009-0001-0248-6097
M. Salvo-Sierralta http://orcid.org/0009-0009-4803-9709
C. Hidalgo http://orcid.org/0000-0002-0780-6969
N. Sallaberry-Pincheira http://orcid.org/0000-0002-5142-2460
C. Botto-Mahan http://orcid.org/0000-0002-2726-2188
G. Rojo http://orcid.org/0000-0001-5012-419X

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